# ADDITIONAL CROSSING OF THE CLARENCE RIVER AT GRAFTON

## Appendix E – Technical Paper: Flooding and hydrology assessment

**AUGUST 2014**

# Executive summary

BMT WBM Pty Ltd was commissioned by Arup to undertake the flood risk hydrologic and hydraulic components of the Environmental Assessment phase of the Grafton Bridge project. This assessment has been undertaken on route 'Option C' which was confirmed as the preferred option in April 2013.

The study area for this assessment encompasses the portion of the Clarence River floodplain adjacent to Grafton/South Grafton. Grafton and South Grafton have a long history of flooding, and are currently protected by a series of levees that, in addition to natural high ground along with the elevated railway and Pacific Highway embankment, surround the town.

A baseline assessment of existing flood risk was hydraulically modelled focusing on design flood events ranging from the 20 year average recurrence interval (ARI) event to the Probable Maximum Flood. The assessment showed that during major flood events, in excess of the 20 year ARI, significant and extensive overtopping of the levee system occurs. The 100 year ARI flood depths are of the order of 2.5m and 2.7m for Grafton and South Grafton respectively.

The four mitigation options assessed consisted of raising lengths of the existing levee and raising a section of the Gwydir Highway. Following hydraulic modelling, two of the mitigation options were identified as successfully reducing the impacts from the proposed project in Grafton and South Grafton:

- Mitigation Option 2: Raising 3.7km of levee on the north bank and 7km of levee on the south bank of the Clarence River by 0.2m.
- Mitigation Option 4: Raising 3.7km of levee on the north bank, 4.7km of levee on the south bank, and raising a 550m length of the Gwydir Highway to an elevation of 7mAHD (current existing elevations are between 5 and 6.5mAHD).

With mitigation the proposed project would have residual impact in terms of increased water levels remaining for up to 58 rural properties outside of the zone of protection afforded by the levees. Typically these increases are less than 0.1m in the 100 year ARI event. It is recommended that further investigations to quantify this risk and identify additional mitigation measures (if possible) be completed during detailed design. This would include a habitable floor level survey and comparison to existing and predicted flood levels, followed by consideration of additional mitigation options for these properties.

The proposed mitigation measures also include a detention basin and pumping arrangement to provide a flood free approach road to Grafton during a 20 year ARI event.

The communities of Grafton and South Grafton are vulnerable to the potential impacts of a changing future climate. The proposed scheme would not significantly alter this increase in future risk. It is recommended that future stages of this project ensure consistency with any future climate adaptation strategies adopted by Clarence Valley Council. Existing flood evacuation arrangements within Grafton will generally benefit from the proposed project which will improve access to higher ground in South Grafton, subject to the existing constraints of traffic congestion within the business district of Grafton.

# Contents


**Executive summary** i

**1 Introduction** 1

1.1 Project description 1

1.2 Report purpose 2

1.3 Assessment tool 3

**2 Existing flood risk** 5

2.1 Background 5

2.2 Existing studies 5

2.2.1 Flood studies 5

2.2.2 Floodplain management plans 7

2.3 Existing conditions 7

**3 Bridge design and impact assessment criteria** 21

3.1 Proposed design 21

3.2 Bridge design criteria 21

3.3 Impact assessment criteria 21

**4 Flood impact assessment** 23

4.1 Introduction 23

4.2 Existing and future receivers 23

4.3 Unmitigated flood impacts 24

**5 Mitigation options assessment** 35

5.1 Introduction 35

5.2 Potential mitigation measures for Grafton / South Grafton 35

5.2.1 Potential flood modification measures 36

5.2.2 Potential property modification measures 37

5.2.3 Summary of potential mitigation measures 37

5.3 Mitigation Option 1 37

5.4 Mitigation Option 2 40

5.5 Mitigation Option 3 51

5.6 Mitigation Option 4 53

5.7 Flood impact assessment conclusions 65

**6 Residual flood risk** 66

6.1 Introduction 66

6.2 Additional mitigation 66

6.2.1 Summary of additional mitigation 67
**7 Climate change considerations 69**
7.1 Introduction 69
7.2 Results 69
7.2.1 Change to baseline conditions 69
7.2.2 Impacts of the proposed project under a future climate 75
7.3 Climate change results summary 86
7.3.1 Effect of climate change scenario with Mitigation Option 2 86
7.3.2 Additional bridge with Mitigation Option 4 86
7.4 Climate change assessment conclusions 87
**8 Other considerations 88**
8.1 Local drainage 88
8.2 Emergency response and evacuation 89
**9 Conclusions 92**
**10 References 94**
**Appendix A Flood model inputs A-1**
**Appendix B Extended Flood Impact Maps B-1**
**Appendix C Local Drainage Assessment C-1**

# List of Figures

Figure 1-1 Route alignment 4
Figure 2-1 Existing case peak flood level: 20 year ARI event 9
Figure 2-2 Existing case peak flood level: 50 year ARI event 10
Figure 2-3 Existing case peak flood level: 100 year ARI event 11
Figure 2-4 Existing case peak flood level: PMF event 12
Figure 2-5 Existing case peak flood depth: 20 year ARI event 13
Figure 2-6 Existing case peak flood depth: 50 year ARI event 14
Figure 2-7 Existing case peak flood depth: 100 year ARI event 15
Figure 2-8 Existing case peak flood depth: PMF event 16
Figure 2-9 Existing case peak flood velocity: 20 year ARI event 17
Figure 2-10 Existing case peak flood velocity: 50 year ARI event 18
Figure 2-11 Existing case peak flood velocity: 100 year ARI event 19
Figure 2-12 Existing case peak flood velocity: PMF event 20
Figure 4-1 Peak flood depth – Grafton (Intersection of Pound Street and Prince Street) 26
Figure 4-2 Peak flood depth – South Grafton (Intersection of Abbott and Vere Streets) 27

| | | |
|---|---|---|
| Figure 4-3 | North Grafton levee overtopping flow, unmitigated case (50 year ARI) | 27 |
| Figure 4-4 | South Grafton levee overtopping flow, unmitigated case (50 year ARI) | 28 |
| Figure 4-5 | North Grafton levee overtopping flow, unmitigated case (100 year ARI) | 28 |
| Figure 4-6 | South Grafton levee overtopping flow, unmitigated case (100 year ARI) | 29 |
| Figure 4-7 | Peak flood level impacts (Unmitigated): 20 year ARI event | 30 |
| Figure 4-8 | Peak flood level impacts (Unmitigated): 50 year ARI event | 31 |
| Figure 4-9 | Peak flood level impacts (Unmitigated): 100 year ARI event | 32 |
| Figure 4-10 | Peak flood level impacts (Unmitigated): PMF event | 33 |
| Figure 4-11 | Peak flood velocity impacts (Unmitigated): 100 year ARI event | 34 |
| Figure 5-1 | Mitigation Option 1: 100 year ARI peak flood level impacts | 39 |
| Figure 5-2 | North Grafton levee overtopping flow, Option 2 (50 year ARI) | 42 |
| Figure 5-3 | South Grafton levee overtopping flow, Option 2 (50 year ARI) | 42 |
| Figure 5-4 | North Grafton levee overtopping flow, Option 2 (100 year ARI) | 43 |
| Figure 5-5 | South Grafton levee overtopping flow, Option 2 (100 year ARI) | 43 |
| Figure 5-6 | Pound Street, North Grafton, design flood elevations, Option 2 | 44 |
| Figure 5-7 | Alumy Creek (Fry St), North Grafton, design flood elevations, Option 2 | 44 |
| Figure 5-8 | Near Wharf St, South Grafton, design flood elevations, Option 2 | 45 |
| Figure 5-9 | Iolanthe St, South Grafton, design flood elevations, Option 2[5] | 45 |
| Figure 5-10 | Mitigation Option 2: 20 year ARI peak flood level impacts | 46 |
| Figure 5-11 | Mitigation Option 2: 50 year ARI peak flood level impacts | 47 |
| Figure 5-12 | Mitigation Option 2: 100 Year ARI peak flood level impacts | 48 |
| Figure 5-13 | Mitigation Option 2: PMF peak flood level impacts | 49 |
| Figure 5-14 | Mitigation Option 2: 100 year ARI peak flood velocity impacts | 50 |
| Figure 5-15 | Mitigation Option 3: 100 year ARI peak flood level impacts | 52 |
| Figure 5-16 | North Grafton levee overtopping flow (50 year ARI) | 56 |
| Figure 5-17 | South Grafton levee overtopping flow (50 year ARI) | 56 |
| Figure 5-18 | North Grafton levee overtopping flow (100 year ARI) | 57 |
| Figure 5-19 | South Grafton levee overtopping flow (100 year ARI) | 57 |
| Figure 5-20 | Pound Street, North Grafton, design flood elevations, Option 4 | 58 |
| Figure 5-21 | Alumy Creek (Fry St), North Grafton, design flood elevations, Option 4 | 58 |
| Figure 5-22 | Near Wharf St, South Grafton, design flood elevations, Option 4 | 59 |
| Figure 5-23 | Iolanthe St, South Grafton, design flood elevations, Option 4[6] | 59 |
| Figure 5-24 | Mitigation Option 4: 20 year ARI peak flood level impacts | 60 |
| Figure 5-25 | Mitigation Option 4: 50 year ARI peak flood level impacts | 61 |
| Figure 5-26 | Mitigation Option 4: 100 year ARI peak flood level impacts | 62 |

| | | |
|---|---|---|
| Figure 5-27 | Mitigation Option 4: PMF peak flood level impacts | 63 |
| Figure 5-28 | Mitigation Option 4: 100 Year ARI peak flood velocity impacts | 64 |
| Figure 6-1 | Properties potentially affected by residual impacts | 68 |
| Figure 7-1 | Change in peak baseline levels (20 year ARI 2050 climate) | 71 |
| Figure 7-2 | Change in peak baseline levels (20 year ARI 2100 climate) | 72 |
| Figure 7-3 | Change in peak baseline levels (100 year ARI 2050 climate) | 73 |
| Figure 7-4 | Change in peak baseline levels (100 year ARI 2100 climate) | 74 |
| Figure 7-5 | Peak flood level impacts: Mitigation Option 2 (20 year ARI 2050 climate) | 78 |
| Figure 7-6 | Peak flood level impacts: Mitigation Option 2 (20 year ARI 2100 climate) | 79 |
| Figure 7-7 | Peak flood level impacts: Mitigation Option 2 (100 year ARI 2050 climate) | 80 |
| Figure 7-8 | Peak flood level impacts: Mitigation Option 2 (100 year ARI 2100 climate) | 81 |
| Figure 7-9 | Peak flood level impacts: Mitigation Option 4 (20 year ARI 2050 climate) | 82 |
| Figure 7-10 | Peak flood level impacts: Mitigation Option 4 (20 year ARI 2100 climate) | 83 |
| Figure 7-11 | Peak flood level impacts: Mitigation Option 4 (100 year ARI 2050 climate) | 84 |
| Figure 7-12 | Peak flood level impacts: Mitigation Option 4 (100 year ARI 2100 climate) | 85 |
| Figure 8-1 | Grafton evacuation strategy (SES, 2012) | 91 |
| Figure A-1 | Lower Clarence River hydraulic model extent | A-2 |
| Figure A-2 | Clarence River historical rating curve | A-4 |
| Figure A-3 | Flood frequency curve using GEV (Annual Maxima series from 1839 to 2000) | A-5 |
| Figure A-4 | Lower Clarence flood model design tidal boundaries | A-7 |
| Figure A-5 | Storm tide / catchment flooding response time (Harwood) | A-8 |
| Figure B-1 | Peak flood level impacts (unmitigated) 20 year ARI event (extended model) | B-2 |
| Figure B-2 | Peak flood level impacts (Mitigation Option 2) 20 year ARI event (extended model) | B-3 |
| Figure B-3 | Peak flood level impacts (Mitigation Option 2) 50 year ARI event (extended model) | B-4 |
| Figure B-4 | Peak flood level impacts (Mitigation Option 2) 100 year ARI event (extended model) | B-5 |
| Figure B-5 | Peak flood level impacts (Mitigation Option 4) 20 year ARI event (extended model) | B-6 |
| Figure C-1 | Grafton local drainage model layout | C-2 |
| Figure C-2 | Grafton local drainage model – 2009 boundary conditions | C-4 |
| Figure C-3 | Grafton local drainage model – 3 hour, 20 year ARI boundary conditions | C-4 |
| Figure C-4 | Grafton local drainage model – 72 hour, 20 year ARI boundary conditions | C-5 |
| Figure C-5 | Grafton local drainage model validation 2009 event results | C-6 |
| Figure C-6 | Existing case Grafton local drainage model 3 hour, 20 year ARI event results | C-7 |

Figure C-7 Existing case Grafton local drainage model 72 hour, 20 year ARI event results C-8
Figure C-8 Mitigated case Grafton local drainage model 3 hour, 20 year ARI event results C-10
Figure C-9 Mitigated case Grafton local drainage model 72 hour, 20 year ARI event results C-11

## List of Tables

Table 2-1 Existing design peak flood levels 7
Table 2-2 Existing design peak flood depths 7
Table 3-1 DGR requirements – Hydrology (flood risk) 22
Table 4-1 Existing and significant planned infrastructure 23
Table 4-2 Peak unmitigated flood level impacts summary 24
Table 4-3 Unmitigated overtopping volumes – North Grafton 24
Table 4-4 Unmitigated overtopping volumes – South Grafton 25
Table 5-1 Summary of potential mitigation measures 37
Table 5-2 Peak flood level impact (Mitigation Option 2) 40
Table 5-3 Option 2 overtopping volumes – North Grafton 40
Table 5-4 Option 2 overtopping volumes – South Grafton 41
Table 5-5 Peak flood level impact (Mitigation Option 4) 53
Table 5-6 Option 4 overtopping volumes – North Grafton 53
Table 5-7 Option 4 overtopping volumes – South Grafton 54
Table 6-1 Number of properties potentially affected by residual impacts in events up to the 100 year ARI 66
Table 7-1 Change in 20 Year peak flood levels due to climate change (existing case) 70
Table 7-2 Change in 100 year peak flood levels due to climate change (existing case) 70
Table 7-3 Change in 20 year peak flood levels due to development (Mitigation Option 2) under a future 2050 climate 75
Table 7-4 Change in 20 Year peak flood levels due to development (Mitigation Option 2) under a future 2100 climate 75
Table 7-5 Change in 100 year peak flood levels due to development (Mitigation Option 2) under a future 2050 climate 76
Table 7-6 Change in 100 year peak flood levels due to development (Mitigation Option 2) under a future 2100 climate 76
Table 7-7 Change in 20 year peak flood levels due to development (Mitigation Option 4) under a future 2050 climate 76
Table 7-8 Change in 20 year peak flood levels due to development (Mitigation Option 4) under a future 2100 climate 77

| | | |
|---|---|---|
| Table 7-9 | Change in 100 year peak flood levels due to development (Mitigation Option 4) under a future 2050 climate | 77 |
| Table 7-10 | Change in 100 Year peak flood levels due to development (Mitigation Option 4) under a future 2100 climate | 77 |
| Table A-1 | Lower Clarence flood model landuse categories | A-3 |
| Table A-2 | Lower Clarence flood model peak design flood inflows | A-4 |
| Table A-3 | Flood model calibration Events | A-9 |
| Table A-4 | Flood model calibration results (Prince St Gauge, Grafton) | A-9 |
| Table C-1 | Grafton local drainage model event scenarios | C-3 |
| Table C-2 | Mitigated peak flood levels at Grafton approach road | C-9 |

# 1 Introduction

The Grafton Bridge project is being undertaken by Roads and Maritime Services (Roads and Maritime). Roads and Maritime commissioned Arup to undertake the conceptual development for the study. Part of this conceptual development involves producing an environmental impact statement.

BMT WBM Pty Ltd was commissioned by Arup to undertake the flood risk hydrologic and hydraulic components of the project. This report outlines the flooding assessment results for the Environmental Assessment phase of the project.

## 1.1 Project description

A description of the project is provided in Chapter 5 and Chapter 6 of the environmental impact statement. This section provides a summary of the project.

The main components of the Grafton Bridge project are:

- Construction of a new bridge over the Clarence River about 70 metres downstream (east) of the existing road and rail bridge, comprising two traffic lanes;
- Construction of a new road to link the new bridge with Iolanthe Street in South Grafton;
- Construction of a new road to link the new bridge with Pound Street in Grafton;
- An approach viaduct, about 58 metres long, on the South Grafton side of the Clarence River and 29 metres long on the Grafton side;
- Upgrades to the road network in South Grafton to connect the new bridge to the existing road network, including:
    - Widening Iolanthe Street to four lanes;
    - Widening the Gwydir Highway to four lanes between Bent Street and the Pacific Highway;
    - Realigning the existing Pacific Highway to join Iolanthe Street near Through Street;
    - Providing a new roundabout at the intersection of the Pacific Highway and Gwydir Highway;
    - Providing a new roundabout at the intersection of Through Street and Iolanthe Street;
    - Limiting Spring Street and the Old Pacific Highway to left in and left out only where they meet Iolanthe Street; and
    - Realigning Butters Lane.
- Upgrades to the road network in Grafton to connect the new bridge to the existing road network, including:
    - Widening Pound Street to four lanes between Villiers Street and the approach to the new bridge;
    - Providing traffic signals at the intersection at Pound Street and Clarence Street;
    - Closing Kent Street where it is crossed by the bridge approach road;

- Realigning and lowering Greaves Street beneath the new bridge;
- Realigning Bridge Street to join directly to the southern part of Pound Street (east of the new bridge approach). There would be no direct connection between Pound Street south and the new bridge approach;
- Widening Clarence Street to provide formal car park spaces; and
- Minor modifications to the existing Dobie Street and Villiers Street roundabout.

- Replacement of the existing three span concrete arch rail viaduct which crosses Pound Street in Grafton with a single span steel truss bridge;
- Construction of a pedestrian and cycle path to provide connectivity between Grafton, South Grafton and the new bridge;
- Provision of two signalised pedestrian crossings in South Grafton to improve safety for pedestrians crossing Iolanthe Street and Gwydir Highway;
- Construction of new pedestrian links to connect the new bridge with the existing bridge;
- Provision of designated car park spaces in Pound Street and Clarence Street, including some off street parking, to maintain a similar number of existing car park spaces currently available in those two street;
- Flood mitigation works, which include raising the height of sections of the existing levee upstream from the new bridge in Grafton and South Grafton;
- Construction of a stormwater detention basin and pump station in Grafton to manage local flooding;
- Public utilities adjustment; and
- Ancillary facilities required for the construction of the project, including some or all of the following: site compounds, concrete batching plant, pre-cast facilities, and stockpile areas for materials and temporary storage of spoil and mulch.

The main elements of the project are shown in Figure 1-1, including the construction footprint of the project.

## 1.2 Report purpose

This report documents the flood impact assessment undertaken to support the environmental impact assessment phase of the design. The aims of this flooding assessment are as follows:

(1) Establish the existing flood risk ‘the baseline’ from the Clarence River in the Grafton area.

(2) Identify the potential for hydraulic impacts resulting from the additional crossing on peak flood levels, depths, velocities and durations across a full range of design flood magnitudes.

(3) If hydraulic impacts are identified then the assessment identifies mitigation solutions designed to offset impacts identified in (2).

(4) Quantify any residual impacts that may remain after mitigation.

The results of this flooding assessment contribute towards the environmental impact assessment. Further investigations will be undertaken as part of the design refinement process during the detailed design phase.

## 1.3 Assessment tool

Definition of the existing flood behaviour in the Grafton region is required to define the baseline for the flooding component of the Environmental Assessment. For this purpose, the Environmental Assessment has been completed using the lower Clarence River flood model, originally developed and calibrated as part of the Lower Clarence River Flood Study Review (WBM, 2004) and subsequently updated for Clarence Valley Council by BMT WBM in 2013 (BMT WBM, 2013).

The updated flood model incorporates a number of changes from that used in the *Route Options Development Report* (Roads and Maritime, 2012) in order to provide a more detailed assessment of the potential flooding impacts of the project. Updates to the lower Clarence River flood model included:

- A more detailed model grid was used to define the existing topography in the flood plain. A combination of a 30 metre grid on the flood plain and a 10 metre grid in the vicinity of Grafton was used. This results in a more detailed representation of flooding in the Clarence River and less averaging of flood depths when compared with the flood model used during the route selection stage of the project (which used a 60 metre grid to define the existing topography).
- More accurate survey data for the flood plain including updated LiDAR[1] data and ground survey of the existing levee system was incorporated into the flood model.
- The model uses the latest version of the TUFLOW modelling software.

These updates were made to improve the resolution of the flood model and to provide a more detailed assessment of flood impacts as a result of the project. As a result of the more detailed flood model and survey data, there are some minor differences in the flood extents and changes in peak flood levels (an additional two centimetres at the existing bridge in a 1 in 20 year flood event) as a result of the project, when compared with the flood model used during the route selection stage of the project

The updated model is considered to represent the latest model and terrain data. The model has been used in consultation and with the approval of Clarence Valley Council. A summary of the lower Clarence River flood model inputs is provided in Appendix A.

The updated lower Clarence River flood model is considered appropriate for use in the Environmental Assessment.

[1] LiDAR is a detection system which works on the principle of radar but uses light from a lasar.




Title:

# Route Alignment

Figure: 1-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 200 400m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_077_140610_Route_Alignment.wor"

# 2 Existing flood risk

## 2.1 Background

The Clarence River is a major coastal river in New South Wales with lower floodplain areas subject to frequent and extensive flood inundation. The catchment of the Clarence River covers approximately 20,000km$^2$ upstream of Grafton and at times of major flooding a floodplain of some 500km$^2$ downstream of Grafton may become inundated.

Although minor tributaries within the lower floodplain of the Clarence River do have the potential to cause flooding issues, the flooding behaviour of the lower Clarence is dominated by runoff generated in the large catchment area upstream of Grafton. The catchment upstream from Grafton/Mountain View typically contributes 80% to 90% of the total volume of floodwater that enters the lower floodplains during main river flood events. Clarence River floods typically occur from low rainfall intensity events that last several days or even weeks.

The study area for this assessment encompasses the portion of the Clarence River floodplain adjacent to Grafton/South Grafton. Grafton and South Grafton have a long history of flooding, and are currently protected by a series of levees that, in addition to natural high ground along with the elevated railway and Pacific Highway embankment, surround the town.

Overtopping of the current Grafton and South Grafton levees commences when flood levels are at, or close to 8.0m on the Prince Street gauge (See Figure 2-1 for gauge location). Based on flood modelling results defined using the lower Clarence River flood model, there is approximately a 5% annual exceedance probability (AEP) that overtopping of the current levees may occur in a given year. This AEP translates to approximately a 20 year average recurrence interval (ARI) flood event.

Significant overtopping of the Grafton and South Grafton levees occurs during events greater than the 20 year ARI event. Following overtopping, large areas of Grafton and South Grafton are inundated by floodwater. No overtopping is predicted to occur for events with a magnitude less than the 20 year ARI event. For this reason the 20 year ARI event is the lowest magnitude event considered in this assessment.

The existing flooding behaviour of the Grafton area has been defined using the lower Clarence River flood model, originally developed and calibrated as part of the Lower Clarence River Flood Study Review (WBM, 2004) and subsequently updated for Clarence Valley Council (BMT WBM, 2013). A summary of the lower Clarence River flood model inputs and historic event calibration results is provided in Appendix A.

## 2.2 Existing studies

### 2.2.1 Flood studies

**Lower Clarence Flood Study (1988)**

WBM Oceanics Australia (now BMT WBM) completed the Lower Clarence River Flood Study (PWD, 1988) for the Public Works Department in December, 1988. This study developed a one-dimensional (1D) dynamic flood model of the entire floodplain downstream of Grafton. Hydrological

models of the tributary catchments of the floodplain (e.g. Sportsmans Creek, Glenugie Creek, Coldstream River) were also created.

**Lower Clarence Flood Study Review (2004)**

The 1D model created for the lower Clarence Flood Study was updated to a two-dimensional (2D) dynamic flood model with a 60m grid resolution. The upstream boundary of the 1988 flood study model was revised and the model was extended upstream of Grafton to Mountain View, including the township of Grafton in the flood study review.

The flood study review examined and defined the flood behaviour of the lower Clarence River from Mountain View (approximately 10km upstream of Grafton) to the ocean outlet at Yamba. The primary objective of the study was to define flood behaviour in the lower Clarence River floodplain for a full range of flood events under existing catchment floodplain conditions. The events included the 5 year, 20 year, 100 year, 500 year ARI and an extreme flood event.

**Grafton and Maclean Flood Levee Overtopping: Hydraulic Assessment (2011)**

The Grafton and Maclean Flood Levee Overtopping study refined the 2D flood model developed during the Lower Clarence Flood Study Review (WBM 2004). The model was refined such that it included multiple domains, increasing the model resolution within and surrounding the urban areas of Grafton, South Grafton and Maclean. This model was used to assess the flood behaviour in Grafton and Maclean when the levee systems surrounding these towns are overtopped.

The urban areas of Grafton, South Grafton and Maclean were modelled using a 10m grid resolution. This degree of resolution was required within the respective urban areas to represent the complex urban flow patterns after levee overtopping has occurred.

The Clarence River adjacent to the subject areas of Grafton and South Grafton, extending upstream to Mountain View utilised a 30m grid resolution. In this location, compared with a coarser 60m grid, the 30m grid resolution improves representation of the levee and overtopping regime in Grafton and South Grafton. The remaining sections of the Clarence River floodplain downstream of Grafton were represented using a 60m grid resolution.

Using the refined flood model, the levee overtopping analysis aimed to identify locations along levees where overtopping occurs, and to approximate the frequency of overtopping. The 2011 study was not released publically as it was determined that more accurate survey data was required.

**Lower Clarence Flood Model Update (2013)**

The flood model update was undertaken by BMT WBM and refined the model developed for the overtopping assessment with updated topography data. This data principally consisted of 2010 topographic LiDAR data and 2012 ground level survey of the levees.

Re-calibration of the updated model was undertaken for eight historical events, including the January 2013 event. The model was demonstrated to perform well, offering an improved calibration over previous models. This model is therefore the best and latest model available and has been used to prepare this assessment.

### 2.2.2 Floodplain management plans

A Grafton and Lower Clarence Floodplain Risk Management Plan was issued by Clarence Valley Council in June 2007 (Bewsher Consulting, 2007). The plan recognises the existing flood risk to Grafton and South Grafton and identifies mitigation works for these communities which are generally focussed on the maintenance and augmentation of levees. The plan notes that any works to increase the levee height have the potential to increase the inundation to areas not protected by the levees.

## 2.3 Existing conditions

Figure 2-1 to Figure 2-12 present maps showing peak design flood levels, depths and velocities for the 20, 50, 100 year ARI and Probable Maximum Flood (PMF)[2] events under existing conditions.

Peak flood levels for the Prince Street gauge, existing Grafton Bridge, Grafton and South Grafton are provided in Table 2-1. Table 2-2 presents peak flood depth at locations in Grafton and South Grafton. Reporting locations are shown on Figure 2-1.

**Table 2-1 Existing design peak flood levels**

| Design Flood Event | Peak Flood Level (mAHD) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton[1] | South Grafton[2] |
| 20 year | 7.95 | 7.60 | No Flooding | No Flooding |
| 50 year | 8.27 | 7.90 | 6.40 | 3.83 |
| 100 year | 8.35 | 7.96 | 7.05 | 5.86 |
| PMF | 9.78 | 9.29 | 9.27 | 10.01 |

1 Intersection of Pound Street and Prince Street

2 Intersection of Abbott Street and Vere Street

**Table 2-2 Existing design peak flood depths**

| | Grafton[1] | South Grafton[2] |
|---|---|---|
| 20 year | No Flooding | No Flooding |
| 50 year | 1.00 | 0.56 |
| 100 year | 1.65 | 2.59 |
| PMF | 3.87 | 6.74 |

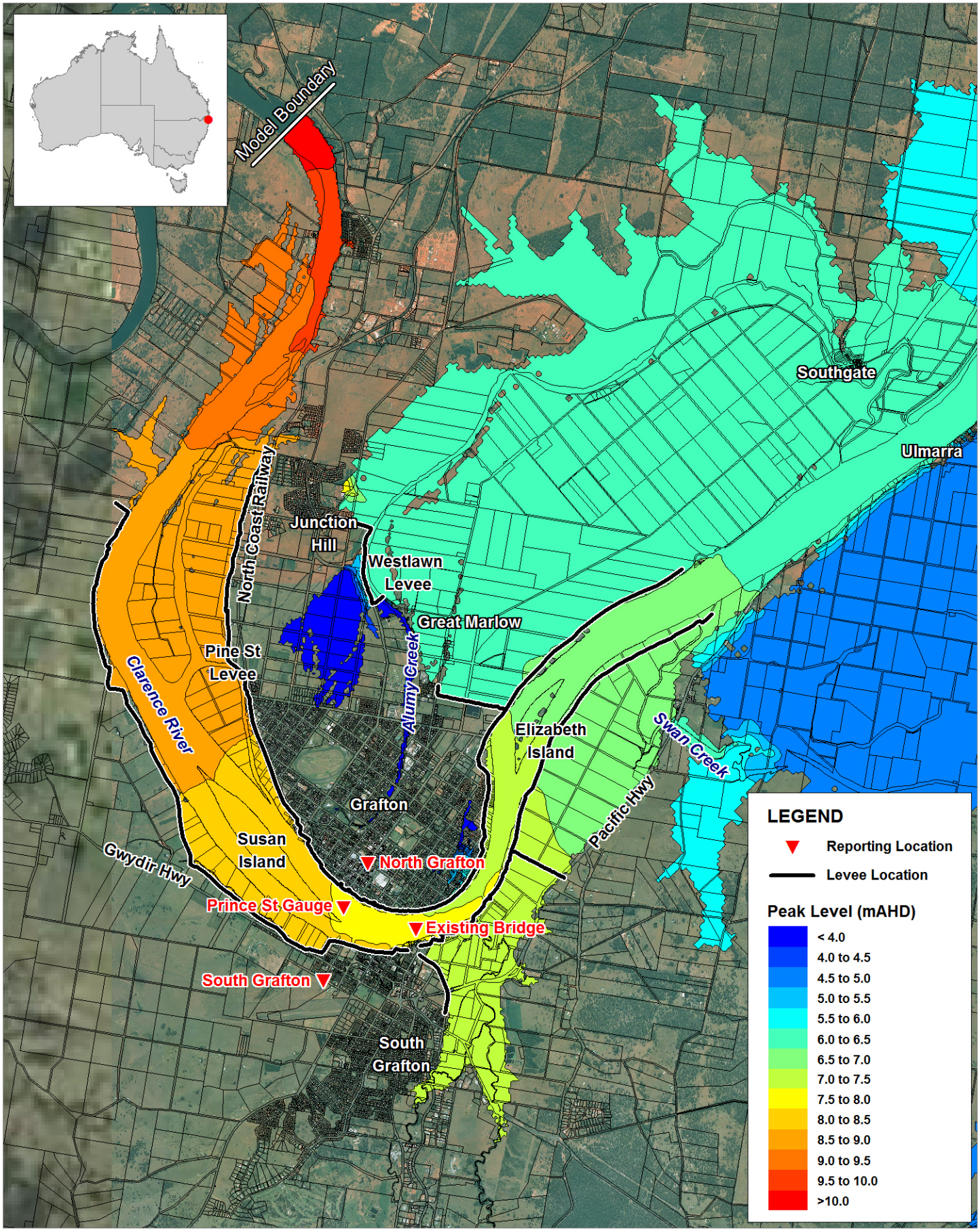
1 Intersection of Pound Street and Prince Street

2 Intersection of Abbott Street and Vere Street

It can be seen from Figure 2-1 to Figure 2-12 and Table 2-1 and Table 2-2 that during major flood events, in excess of the 20 year ARI, significant overtopping of the existing levee system occurs[3].

[2] The PMF event applied for the Clarence River in Councils adopted model is a scaled up version of the 100 year ARI event.
[3] Minor overtopping of levees occurs in the 20 year ARI event affecting small extents within Grafton.

The impact associated with flood inundation for the areas inside levees can be significant. Inundation of individual properties would potentially result in damage to houses and belongings, as well as the physical and mental health impacts associated with flood inundation (e.g. injury during and after floods, sickness, emotional losses, fear of future flooding). Furthermore, local businesses would suffer hardship during and after flood events due to a loss of trade and income. To some extent, these impacts are compounded in communities with levees, as flood inundation and its associated impacts become less frequent and less expected.




Title:

# Existing Case Peak Flood Level 20 Year ARI Event

Figure: **2-1**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

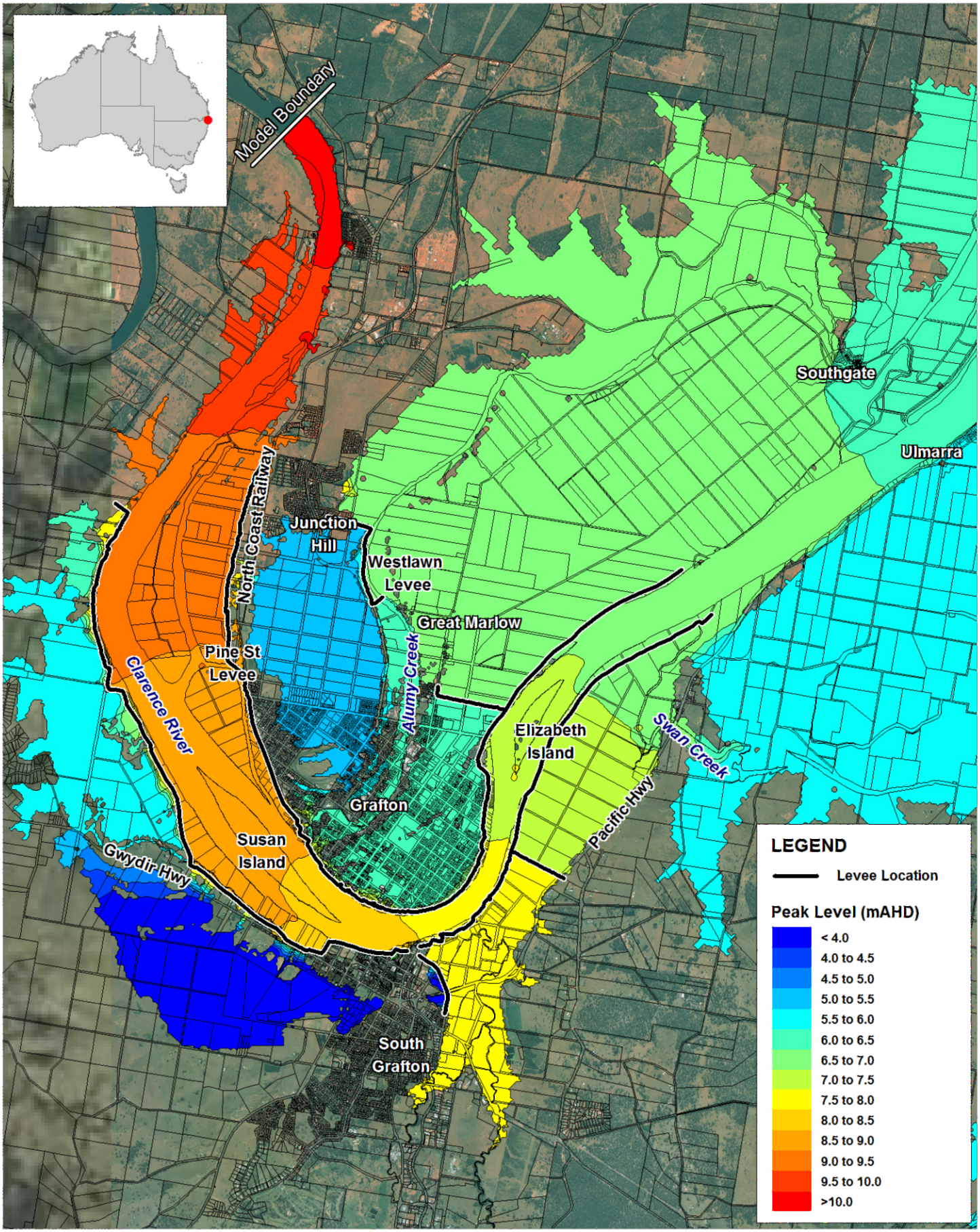
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17815_I_Summerland_Way\DRG\EIS\FLD_006_140122_Q020_Exg_hmax.wor




Title:

# Existing Case Peak Flood Level 50 Year ARI Event

Figure: 2-2

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

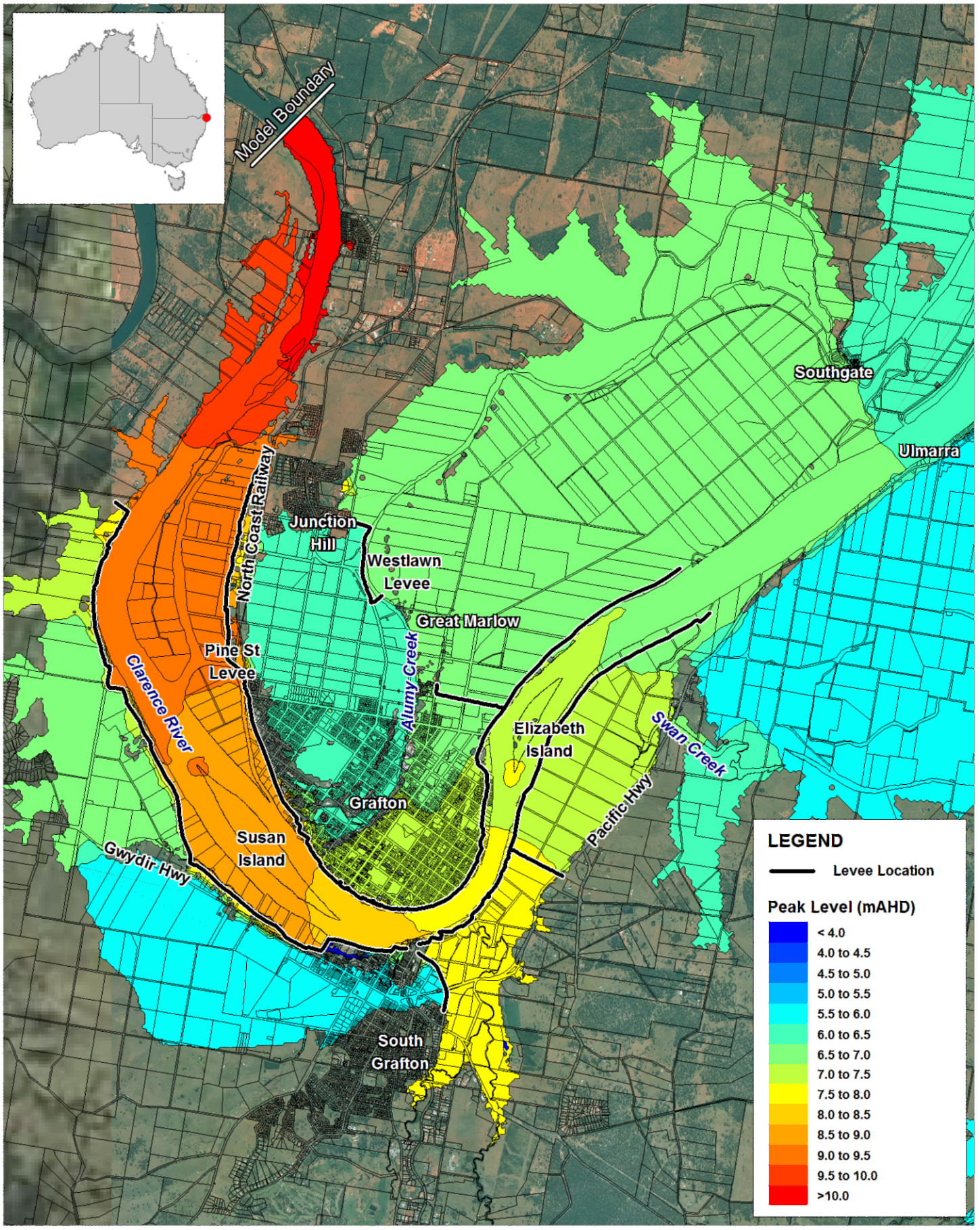
N

0km 1.5 3

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17815_I_Summerland_Way\DRG\EIS\FLD_007_140122_Q050_Exg_hmax.wor




Title:

# Existing Case Peak Flood Level 100 Year ARI Event

Figure: 2-3

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

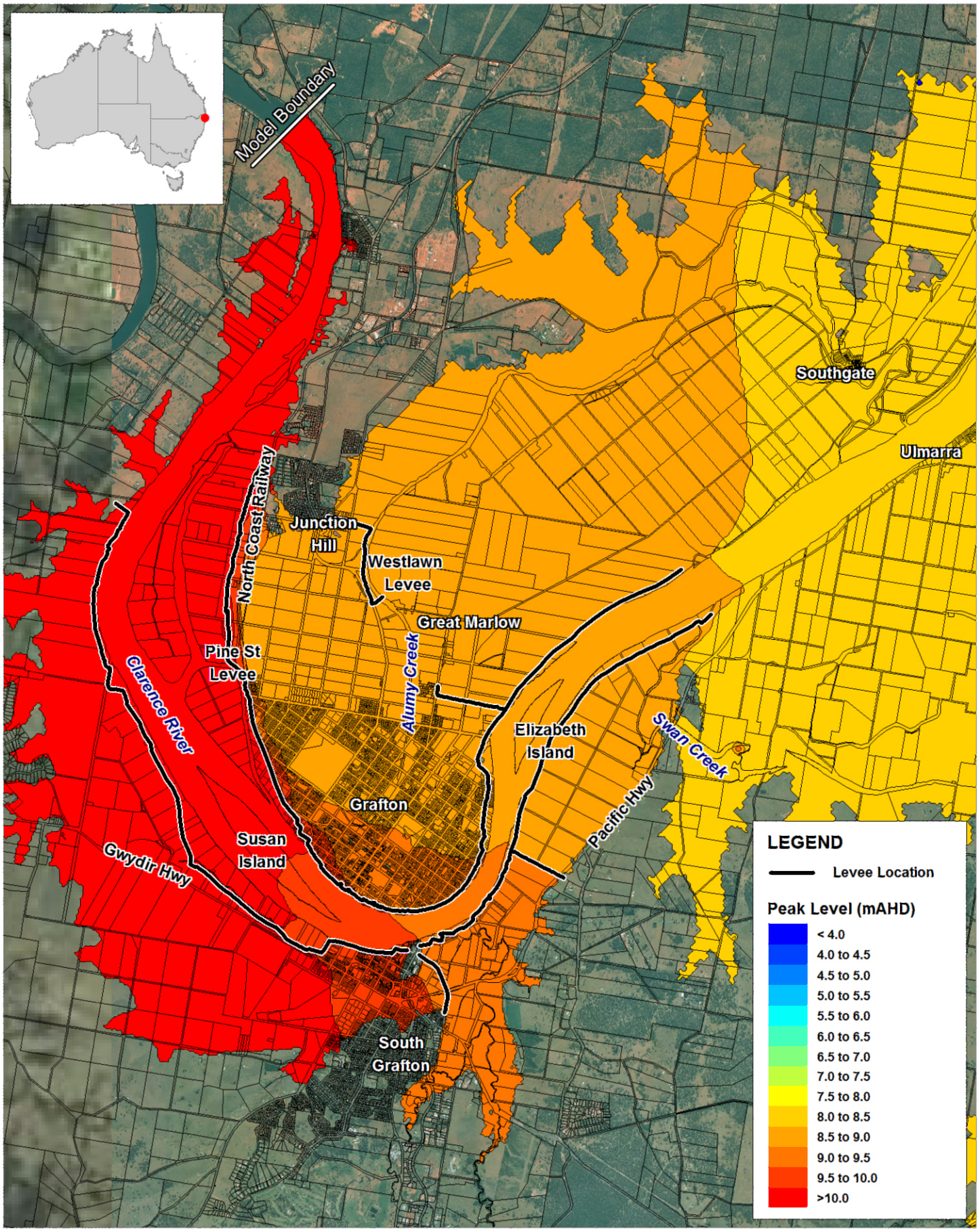
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17815_I_Summerland_Way\DRG\EIS\FLD_008_140122_Q100_Exg_hmax.wor




Title:

# Existing Case Peak Flood Level PMF Event

Figure: **2-4**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

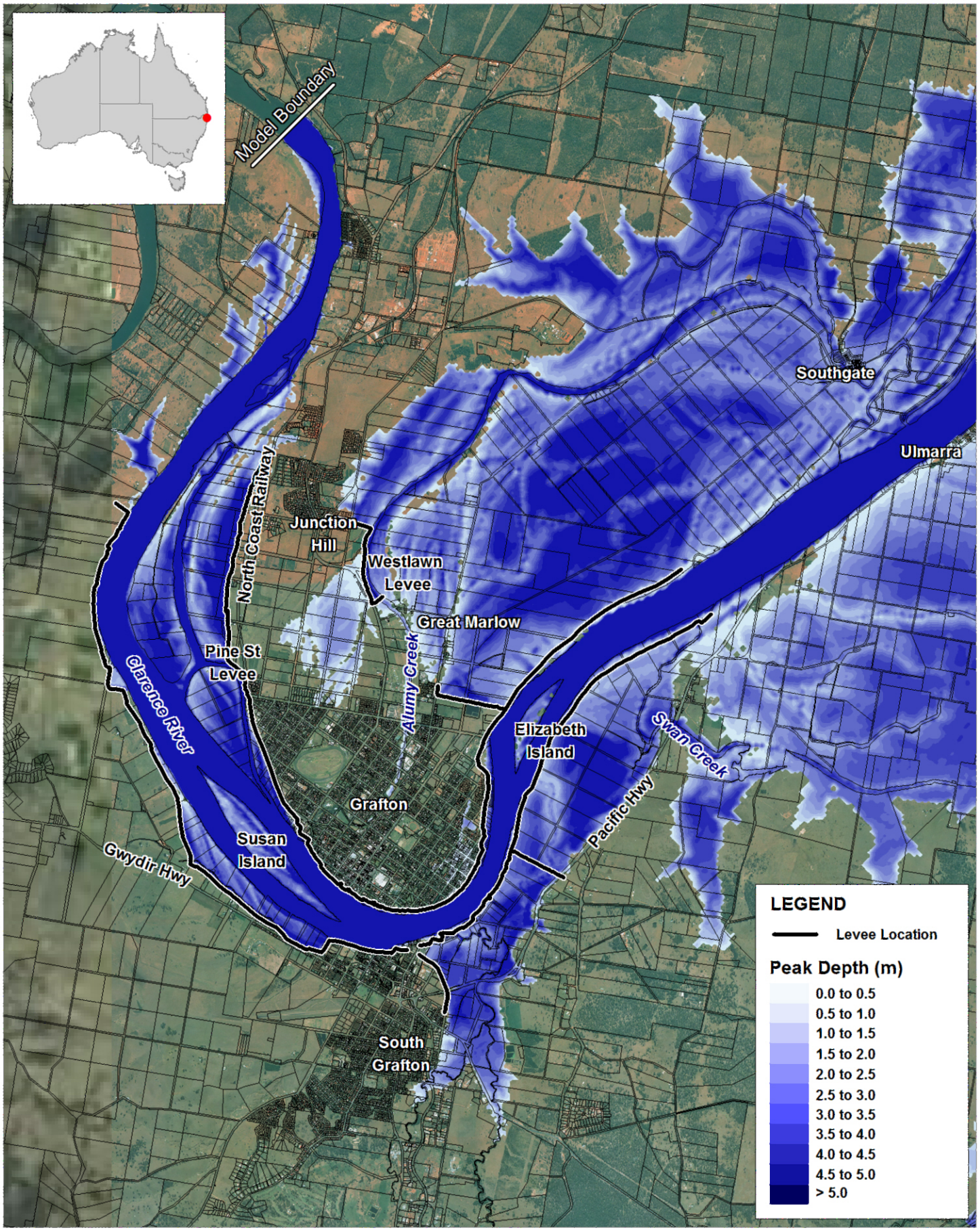
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_009_140122_QPMF_Exg_hmax.wor"




Title:

# Existing Case Peak Flood Depth 20 Year ARI Event

Figure: 2-5

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

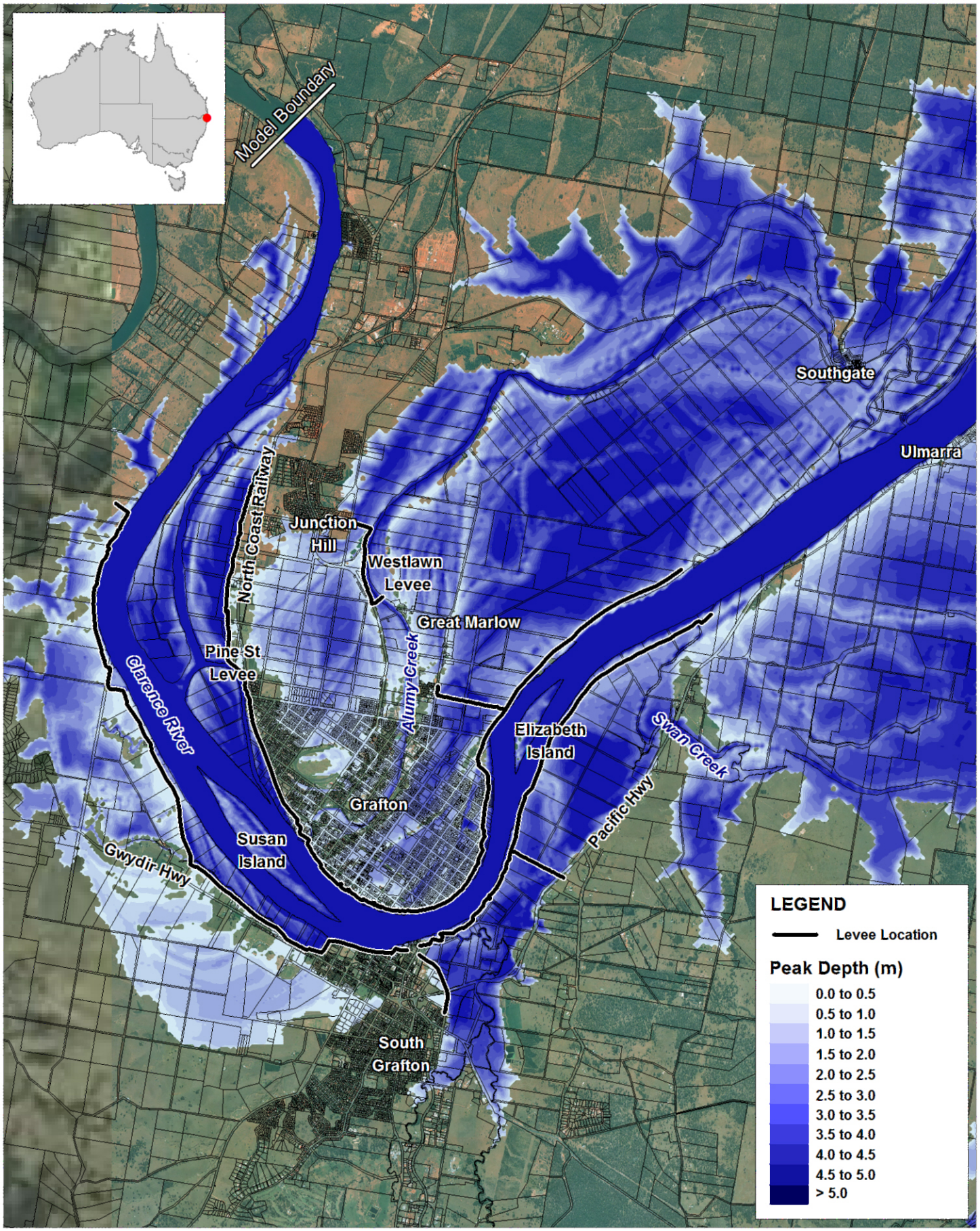
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_012_140122_Q020_Exg_dmax.wor"




Title:

# Existing Case Peak Flood Depth 50 Year ARI Event

Figure: 2-6

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

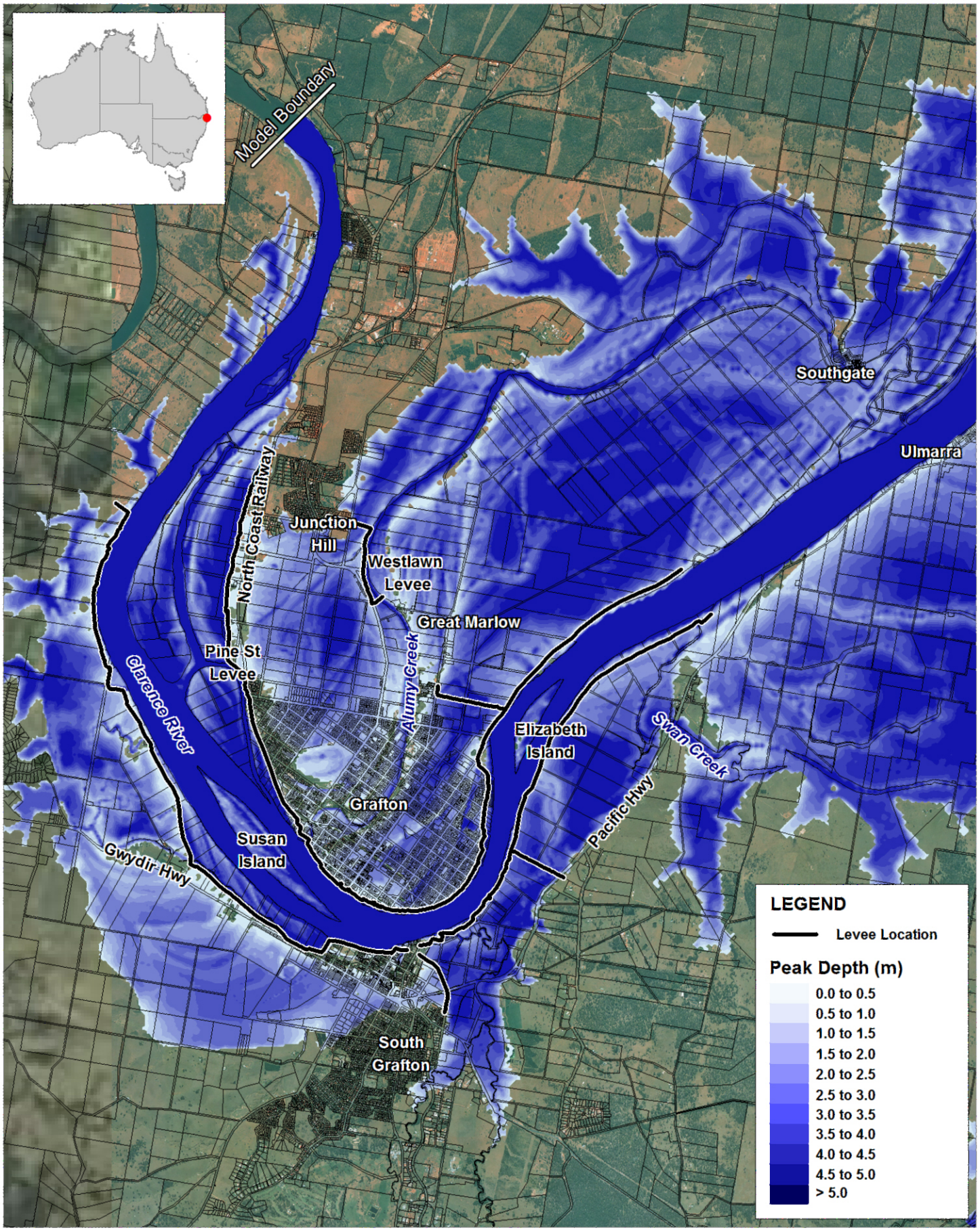
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_013_140122_Q050_Exg_dmax.wor"




Title:

# Existing Case Peak Flood Depth 100 Year ARI Event

Figure: 2-7

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

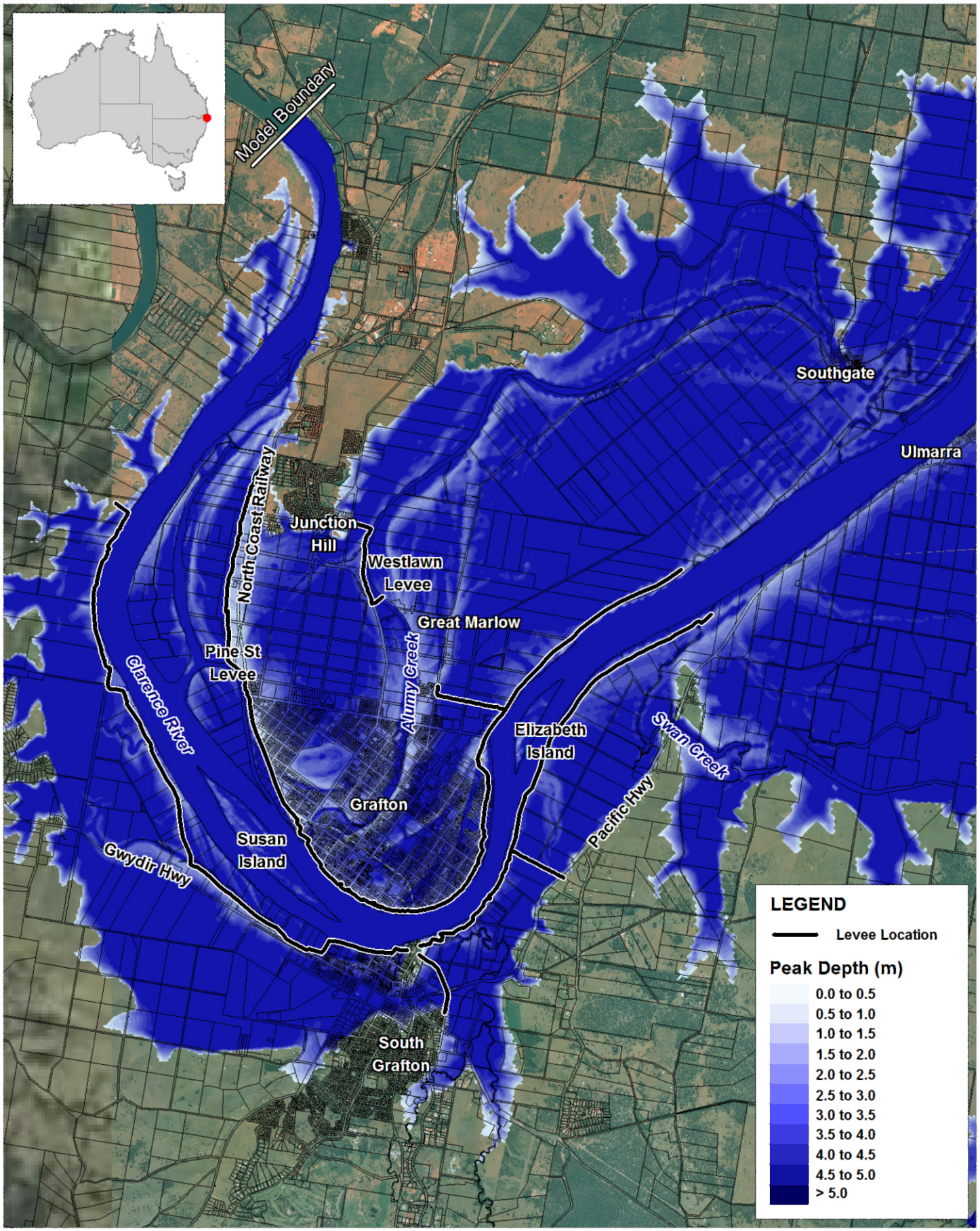
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_014_140122_Q100_Exg_dmax.wor"




Title:

# Existing Case Peak Flood Depth PMF Event

Figure: **2-8**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

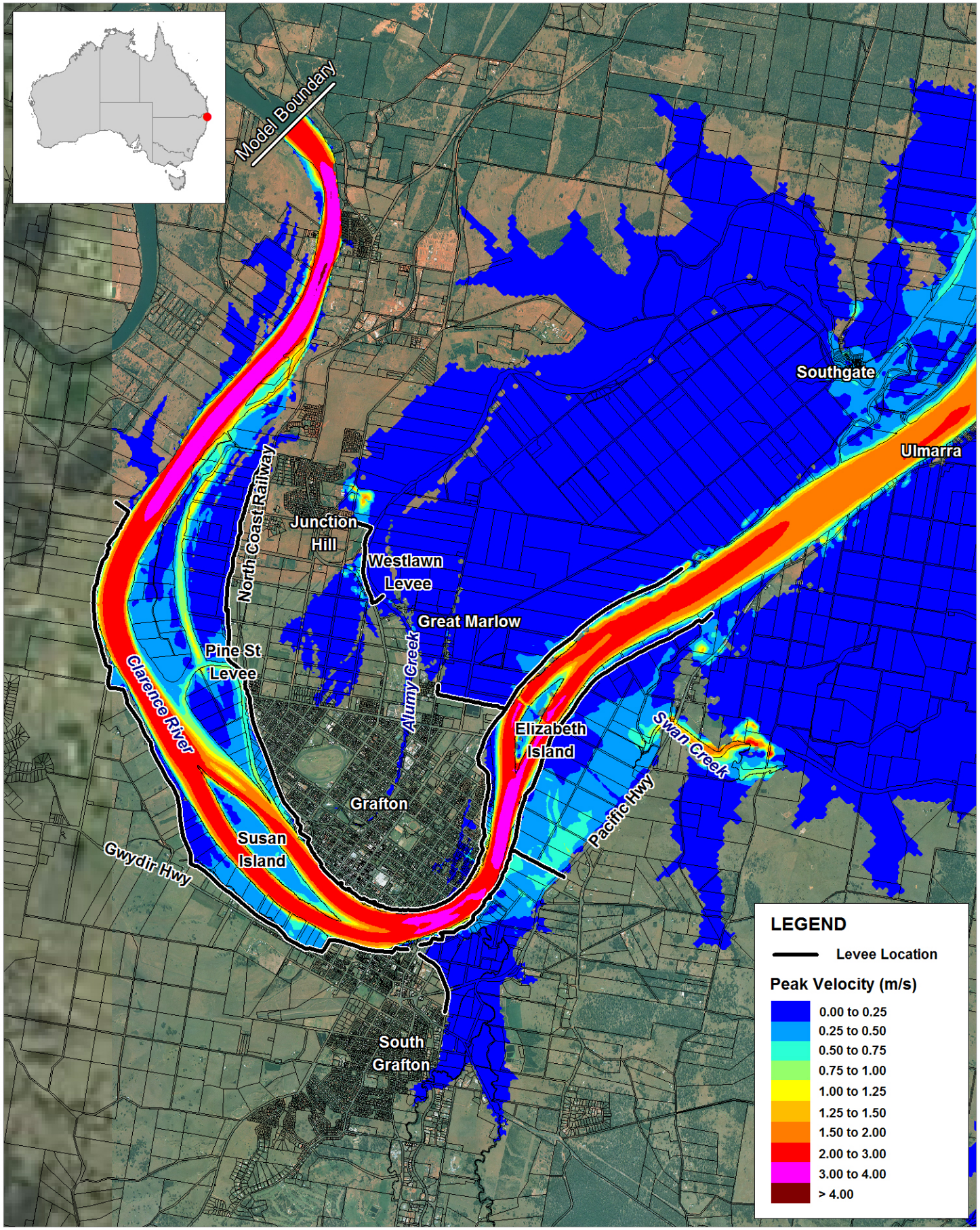
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_017_140122_QPMF_Exg_dmax.wor"




Title:

# Existing Case Peak Flood Velocity 20 Year ARI Event

Figure: **2-9**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

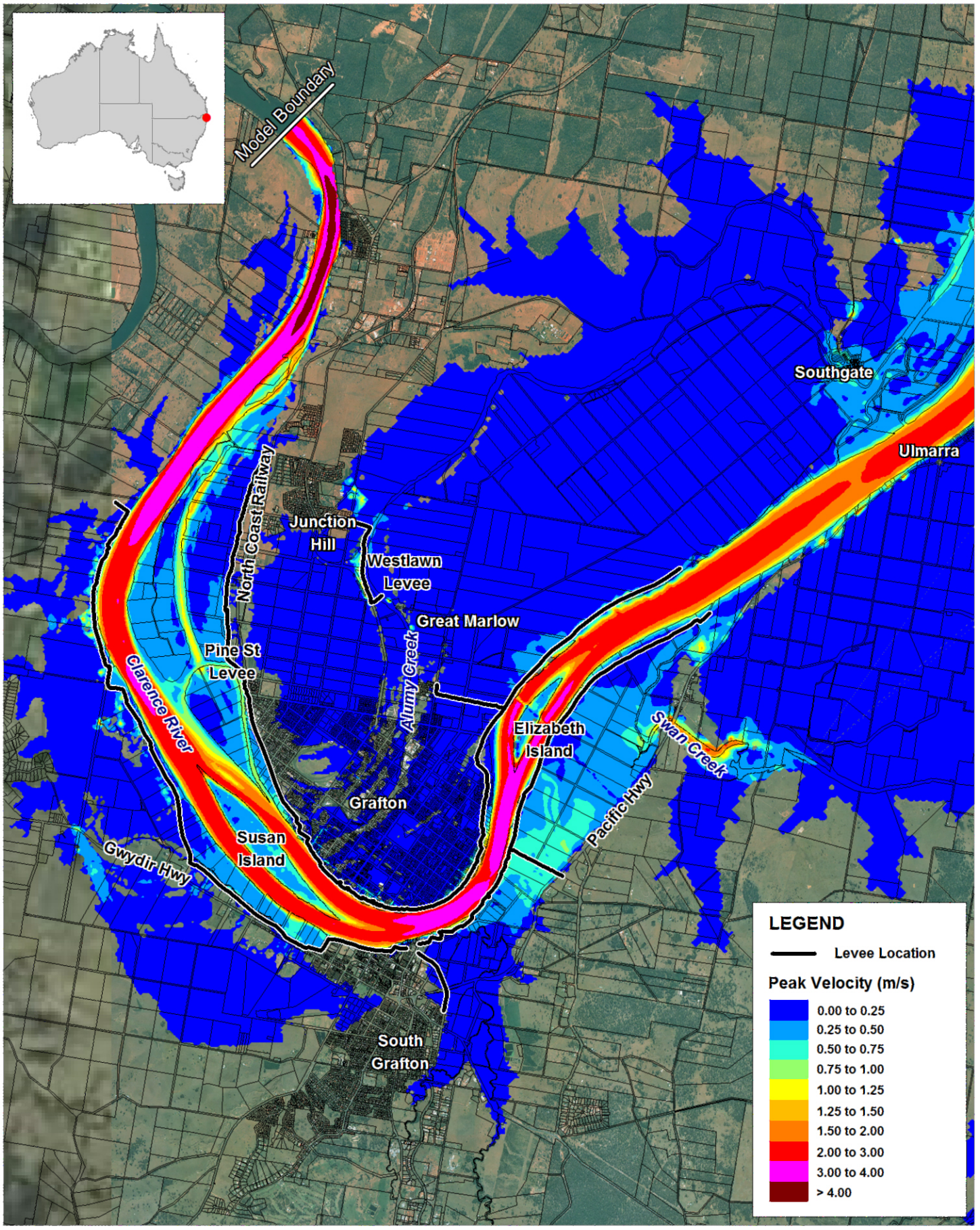
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_019_140122_Q020_Exg_Vmax.wor"




Title:

# Existing Case Peak Flood Velocity 50 Year ARI Event

Figure: 2-10

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

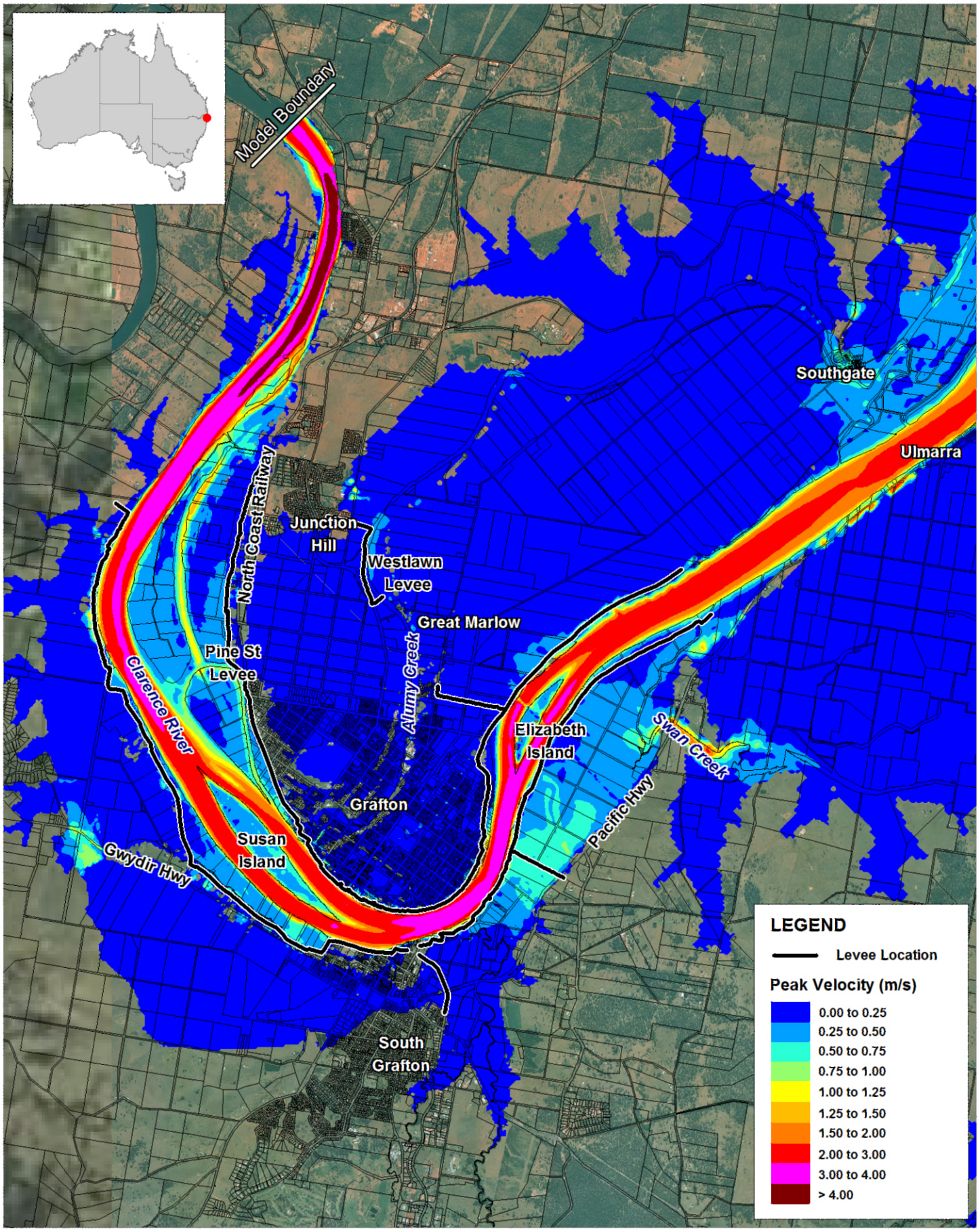
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_020_140122_Q050_Exg_Vmax.wor"




Title:

# Existing Case Peak Flood Velocity 100 Year ARI Event

Figure: 2-11

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

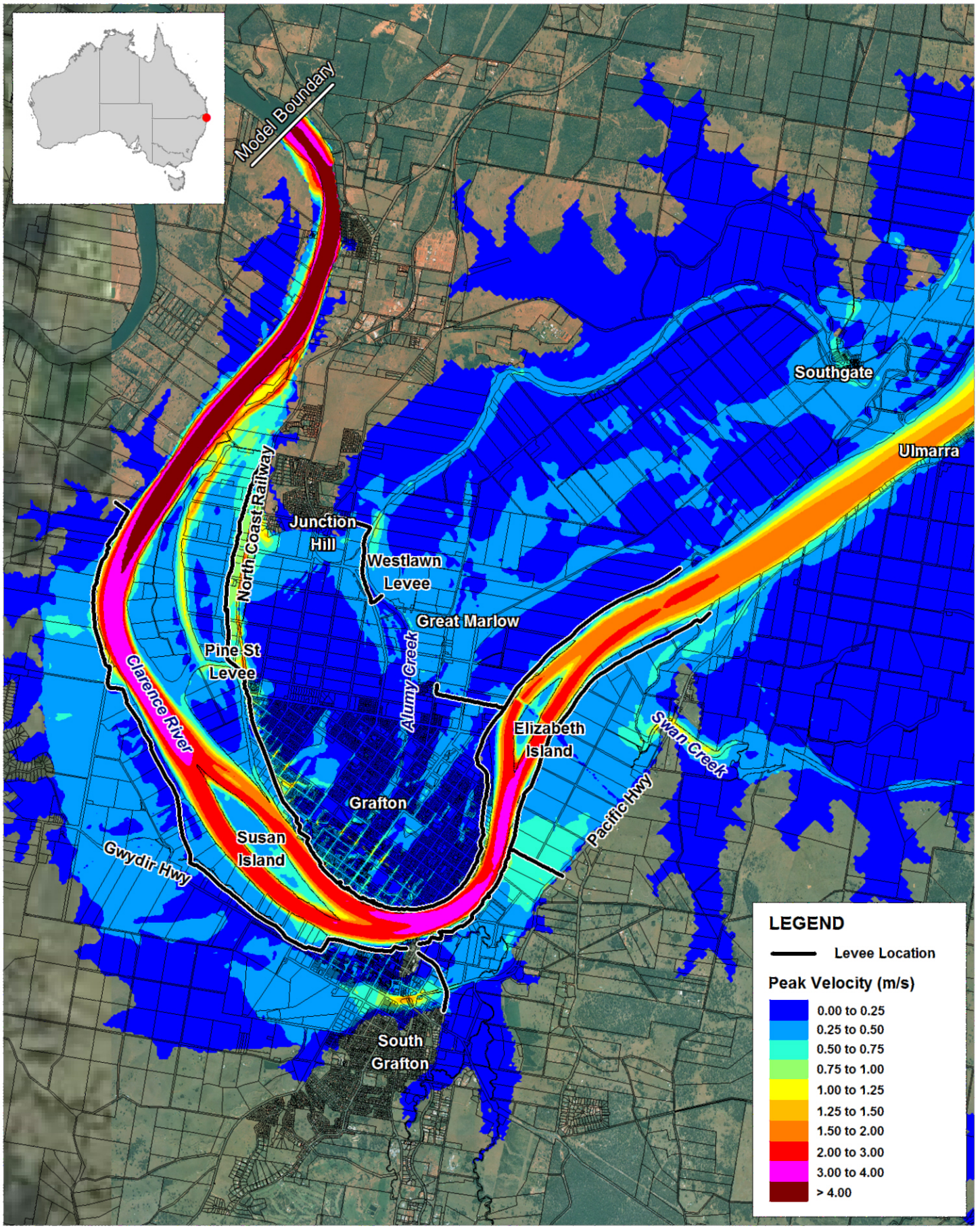
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_021_140122_Q100_Exg_Vmax.wor"




Title:

# Existing Case Peak Flood Velocity PMF Event

Figure: 2-12

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_022_140122_QPMF_Exg_Vmax.wor"

# 3 Bridge design and impact assessment criteria

## 3.1 Proposed design

The proposed crossing would be located approximately 70m downstream of the existing Grafton Bridge and would connect Grafton to South Grafton via Pound Street and Iolanthe Street (See Figure 1-1). The bridge includes 10 piers, 5 of which are partially submerged by the mean low water surface. There is a maximum span of 74m between the piers and each pier is approximately 3m wide in the direction perpendicular to the main flow. The minimum soffit elevation is 9.1mAHD to comply with navigation requirements. This is significantly above the 100 year ARI peak flood level at the location of the proposed crossing of 8.0mAHD.

In total, the modelled bridge and viaducts representing the proposed project span a total length of 580m.

Refer to the *Additional crossing of the Clarence River at Grafton Environmental Impact Statement: Main Report* for additional details of the proposed project.

## 3.2 Bridge design criteria

A number of engineering design criteria have been developed to guide the design of the bridge during previous stages of the project. The criteria that relate to flooding include:

- Waterway structures outside of the Grafton levee banks, including the main bridge and viaducts, must be of sufficient height to maintain a freeboard during a 100 year average recurrence interval (ARI) design flood event.
- Bridges within the Grafton levees (Alumy Creek and minor drainage) must be flood immune during a 20 year ARI design flood event.
- The main approach roads to the new bridge must be flood immune during a 20 year ARI design flood event.

As well as design standards, a number of minimum requirements have been proposed to minimise any impacts of the additional bridge crossing on the environment and local community.

The criteria that relate to flooding include:

- Proposed options should not adversely impact the flood immunity in Grafton and South Grafton. Where impacts are identified, design mitigation measures must be implemented to maintain the current level of flood immunity; and
- No adverse impacts on flood evacuation of Grafton.

## 3.3 Impact assessment criteria

In addition to the bridge design criteria set out in Section 3.2, a number of organisations were consulted as part of the EIS process. Their responses were compiled to form the Director Generals Requirements (DGRs). With regard to hydrology (flood risk) the DG assessment requirements are for an assessment to be in accordance with the Floodplain Development Manual (Department of Natural Resources 2005) and to address the items listed in Table 3-1.

**Table 3-1 DGR requirements – Hydrology (flood risk)**

| DGR assessment requirement | Report section where addressed |
|---|---|
| Changes to existing flood regimes (including riverine, overland and internal levee ponding) in Grafton and South Grafton, with reference to modelling for a range of flood events (including the 1, 2 and 5 % AEP events[4] and the Probable Maximum Flood (PMF) and across a range of flood characteristics (including changes in depth, velocity, direction, hazard, frequency or duration of inundation). | 4,5 |
| Consistency with relevant floodplain risk management plans. | 5 |
| Impacts to existing receivers and infrastructure, the future development potential of affected land (including areas outside of the existing levee system) and planned infrastructure (including the project). | 4,5,6 |
| Identifying the potential impacts on flow velocities and directions, and impacts on the bed and bank stability, as a result of construction of a new bridge. | 4,5 |
| Details of any proposed mitigation measures, including, where required, upgrade of the Grafton, South Grafton and other rural levee systems, evacuation routes, riverbank protection assets and drainage assets. | 5,8 |
| An assessment of the effects of sea level rise as a result of climate change on the project. | 7 |

[4] Advice from the Department of Planning and Environment states that reference to the 1, 2 and 5 year ARI in the DGRs is actually the 1%, 2% and 5% AEP events which corresponds to the 100, 50 and 20 year ARI events respectively.

# 4 Flood impact assessment

## 4.1 Introduction

The flood impact assessment identifies the potential for hydraulic impacts resulting from the proposed project to existing and potential future receivers. The bridge and approaches have been represented in the hydraulic model of the Clarence River and the model has been simulated for the 20, 50 and 100 year average recurrence interval (ARI) and probable maximum flood (PMF) events. Peak results for flood level, velocity and duration were then compared to the baseline (existing) scenario. The resulting differences between the two scenarios have been mapped to produce impact maps.

Due to the extensive length of the Grafton and South Grafton levees, small changes in flood level within the main Clarence River (even as little as 0.01m) have the potential to significantly alter the volume of water overtopping the levee. Increases in the overtopping volume can potentially result in significant variations in ponded flood levels behind the levee systems as seen by the range of depths in Table 2-2. The remainder of Section 4 details the impacts of the project on Grafton and South Grafton without mitigation.

To reduce the potential adverse flood impacts on adjacent urban areas resulting from the construction of an additional bridge across the Clarence River at Grafton, mitigation measures aimed at maintaining the current level of flood immunity within Grafton and South Grafton have been assessed. The identified mitigation measures are outlined in Section 5 of this report.

## 4.2 Existing and future receivers

For the purposes of this assessment, existing receivers is taken as being existing property and infrastructure. Future receivers are significant planned infrastructure. Existing and significant planned infrastructure is summarised in Table 4-1.

**Table 4-1 Existing and significant planned infrastructure**

| Infrastructure description | Status |
|---|---|
| Pacific Highway Upgrade – Woolgoolga to Ballina<br>Highway upgrade which will bypass South Grafton | NSW Planning approval received |
| Pacific Highway Upgrade – Iluka Road to Woodburn (Devils Pulpit Section) | Recently opened to traffic |
| Proposed Service Station, fast food restaurant and café – intersection of Spring Street and Iolanthe Street, South Grafton | Application being determined by Clarence Valley Council |
| Proposed Homemaker Centre at intersection of Through Street and Iolanthe Street, South Grafton | Approval has lapsed and development may change in the future |

## 4.3 Unmitigated flood impacts

Unmitigated flood impacts are presented as follows:

- Table 4-2 summarises the peak (unmitigated) flood level impacts.
- Table 4-3 and Table 4-4 summarise the total volume of water overtopping the levees along with the associated change in overtopping volume from the baseline.
- Figure 4-1 and Figure 4-2 present graphically the expected increases in flood depth from the additional crossing with no mitigation for Grafton and South Grafton respectively.
- Figure 4-3 to Figure 4-6 show hydrographs of the flow entering Grafton and South Grafton during the 50 and 100 year ARI events via overtopping of the levees for the baseline and unmitigated scenarios. Due to only minor localised overtopping in the 20 year ARI event this event has not been included.
- Figure 4-7 to Figure 4-10 map the unmitigated flood level (afflux) impacts for the 20, 50 and 100 year ARI and PMF events. These are the changes in flood depth predicted to occur if the crossing was constructed and no further mitigation works, such as raising the levee, were undertaken.
- Figure 4-11 shows the unmitigated flood velocity impacts for the 100 year ARI event.

**Table 4-2 Peak unmitigated flood level impacts summary**

| Design flood event | Change in peak flood level (m) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton[1] | South Grafton[2] |
| 20 year | 0.07 | 0.07 | 0.00 | 0.00 |
| 50 year | 0.04 | 0.06 | 0.08 | 0.67 |
| 100 year | 0.04 | 0.06 | 0.01 | 0.43 |
| PMF | 0.05 | 0.08 | 0.04 | 0.04 |

1 Intersection of Pound Street and Prince Street

2 Intersection of Abbott Street and Vere Street

**Table 4-3 Unmitigated overtopping volumes – North Grafton**

| Design flood event | Overtopping volume (Megalitres) | | | |
|---|---|---|---|---|
| | Baseline | Unmitigated | Change | % Change |
| 50 year | 8,304 | 9,053 | 749 | 9% |
| 100 year | 17,951 | 18,941 | 990 | 6% |

**Table 4-4 Unmitigated overtopping volumes – South Grafton**

| Design flood event | Overtopping volume (Megalitres) | | | |
|---|---|---|---|---|
| | Baseline | Unmitigated | Change | % Change |
| 50 year | 12,215 | 16,074 | 3,858 | 32% |
| 100 year | 30,148 | 36,015 | 5,867 | 19% |

Areas highlighted on Figure 4-7 to Figure 4-10 as 'was wet now dry' of 'was dry now wet' show changes in flood extent. It can be seen that there are no significant changes in extent and inspection of the results shows no predicted changes in flow direction following construction of the additional crossing. Changes in direction are limited to minor increases in flood extent around the periphery of areas subject to existing flooding.

It can be seen from Figure 4-11 that no impacts in terms of increased or decreased flow velocity is predicted to occur as a result of the additional crossing. This finding is the same for all modelled events.

The following observations are summarised for the unmitigated flood impacts:

- The additional bridge crossing results in increased levels within the Clarence River upstream of the crossing for all modelled events. No impacts are predicted downstream of the crossing.
- No impacts to flood velocity or notable changes in flow direction are predicted.
- Increases within the Clarence River range from 0.06m to 0.08m near the proposed crossing and from 0.04m to 0.07m at the Prince Street gauge.
- The increased river water levels result in increases in volume overtopping the levee in Grafton and significant increases in volume overtopping the levee in South Grafton for the 50 and 100 year ARI and PMF events. The South Grafton increase is more pronounced for the 50 year ARI event.
- South Grafton is subject to the greatest increase in flood risk with peak levels increased by up to 0.7m in the 50 year ARI event. However the extent of this increase is generally limited to areas near the periphery of the town and beyond. Significant increases in the order of 0.4m affect South Grafton in the 100 year ARI event. This has a notable impact on the flood extent, more so than for the 50 year ARI event, affecting a greater number of properties within the town.
- Grafton, which experiences significant depths of inundation for events greater than the 20 year ARI, is impacted by the additional bridge crossing with peak flood levels increasing by up to 0.08m.
- The PMF event results in extreme depths of inundation within Grafton and South Grafton. Minor increases in this peak depth are expected to occur due to the additional bridge crossing.
- The planned Pacific Highway Upgrade is not impacted by the additional crossing in any assessed event.

- Other planned infrastructure listed in Table 4-1 and located in South Grafton is predicted to be unaffected by flooding for events up to an including the 50 year ARI event. In the 100 year ARI event the two sites are negatively impacted with peak water level increases of approximately 0.4m.

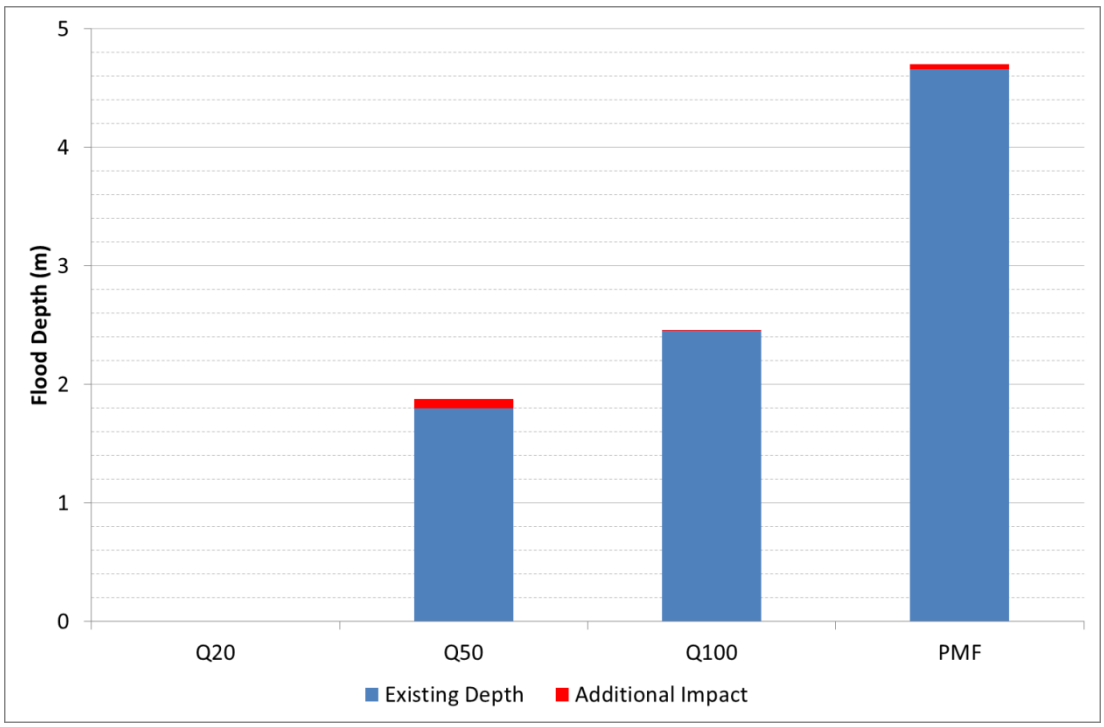



**Figure 4-1 Peak flood depth – Grafton (Intersection of Pound Street and Prince Street)**

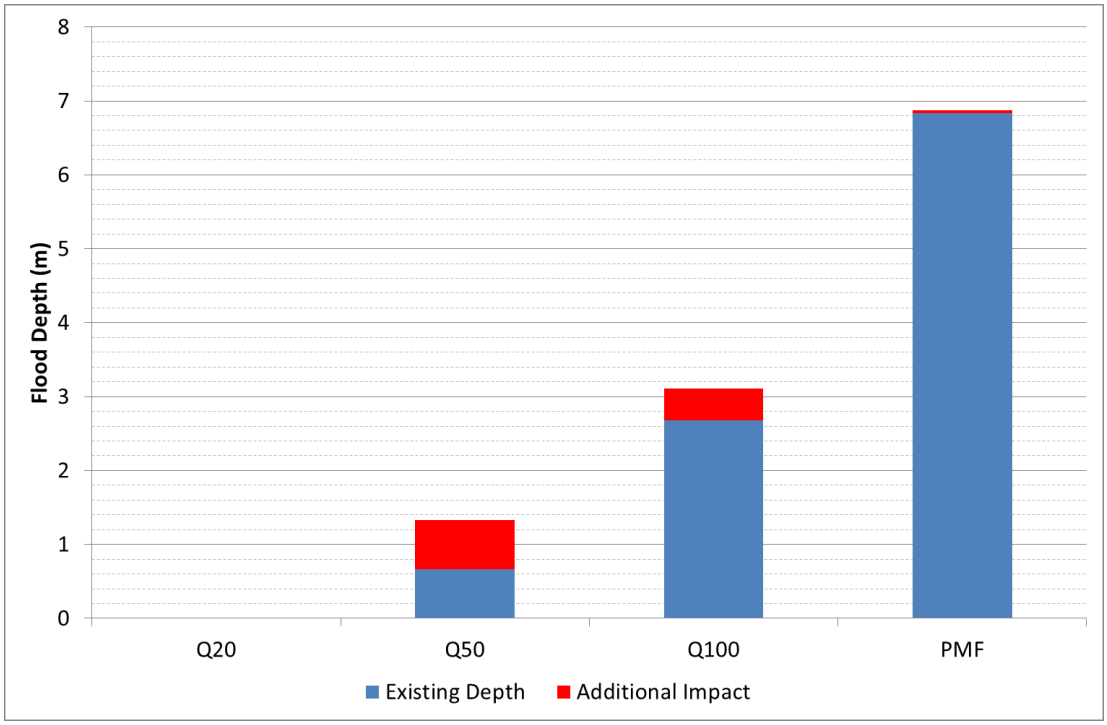



**Figure 4-2 Peak flood depth – South Grafton (Intersection of Abbott and Vere Streets)**

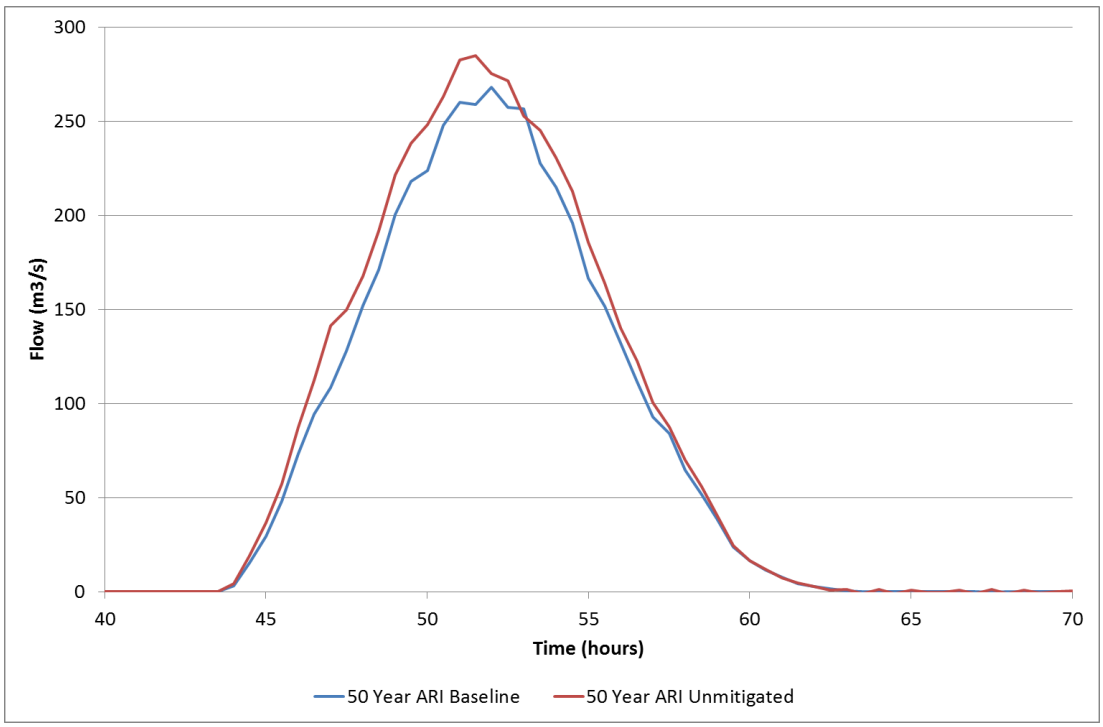



**Figure 4-3 North Grafton levee overtopping flow, unmitigated case (50 year ARI)**

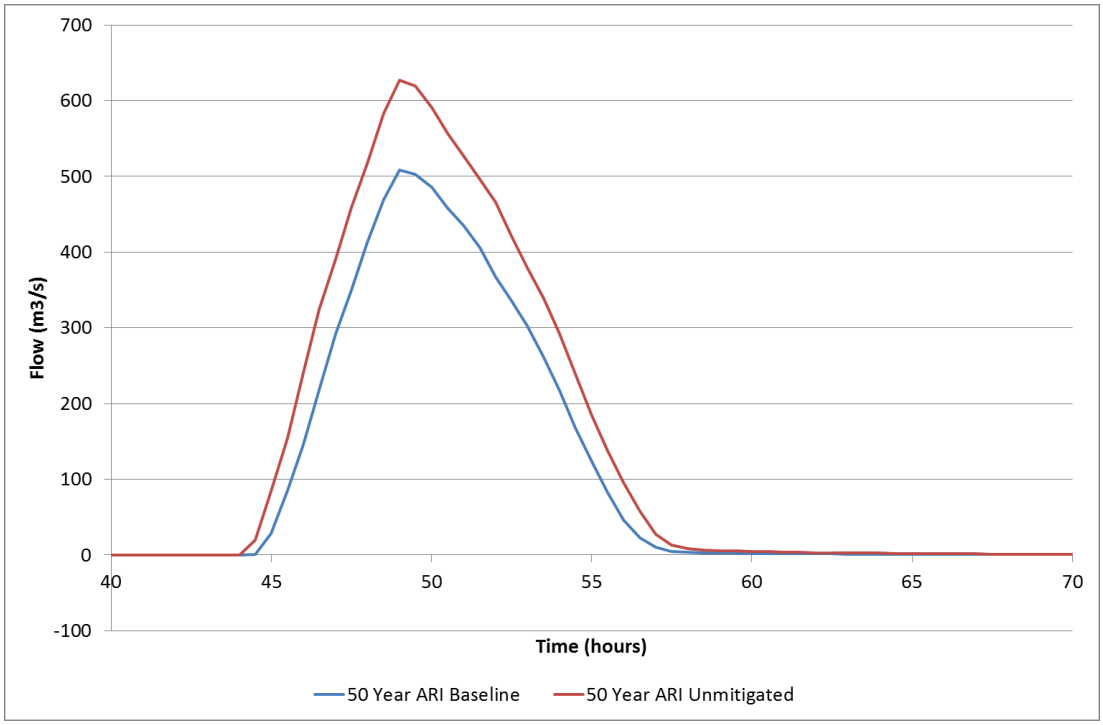



**Figure 4-4 South Grafton levee overtopping flow, unmitigated case (50 year ARI)[5]**

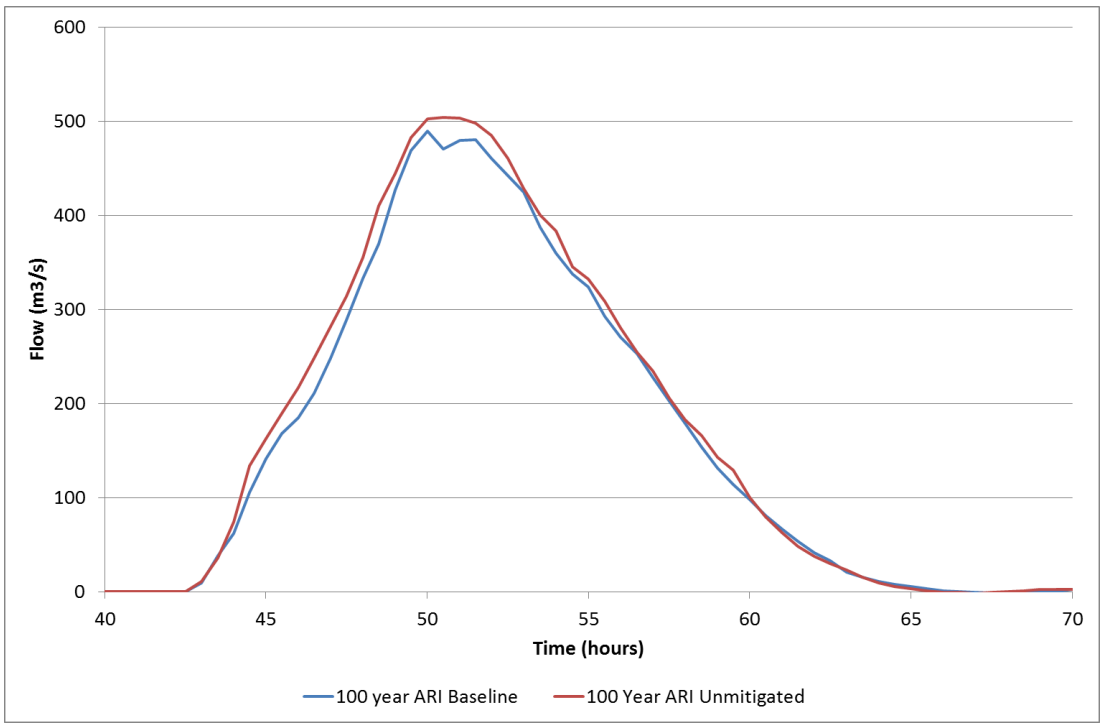



**Figure 4-5 North Grafton levee overtopping flow, unmitigated case (100 year ARI)**

[5] The south Grafton flows are the combined flows of floodwater spilling over the south Grafton levee adjacent to the town and flow entering from the north across the Gwydir Highway. It is this latter component that dominates in terms of its contribution to the overall inflow volume.

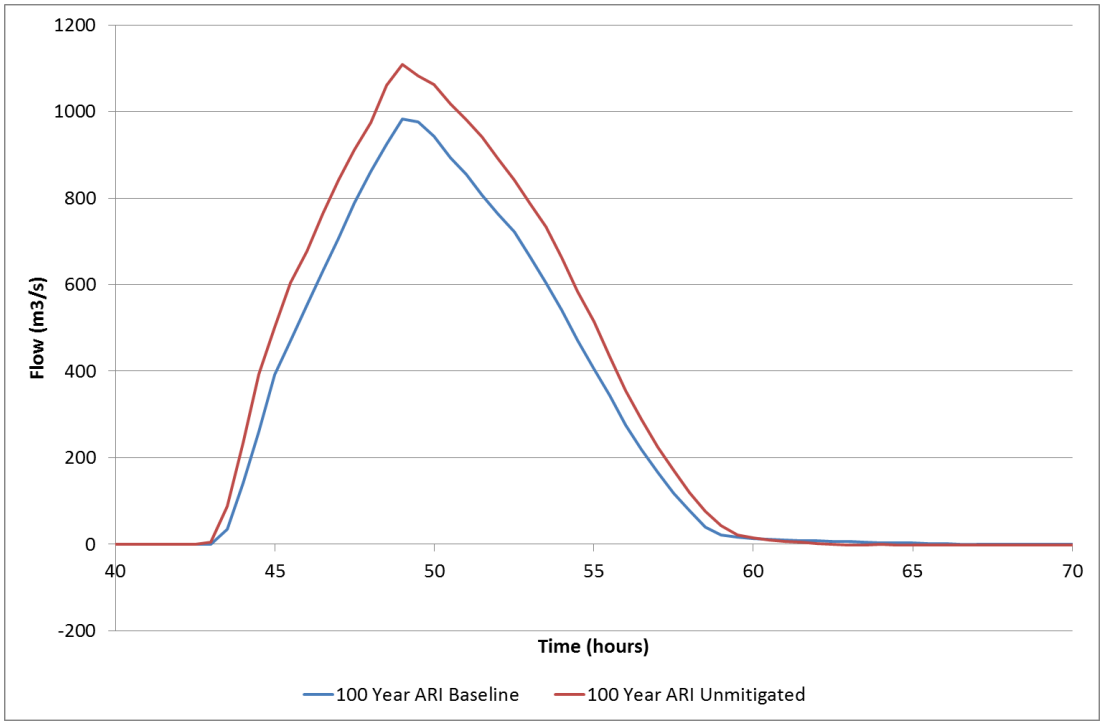
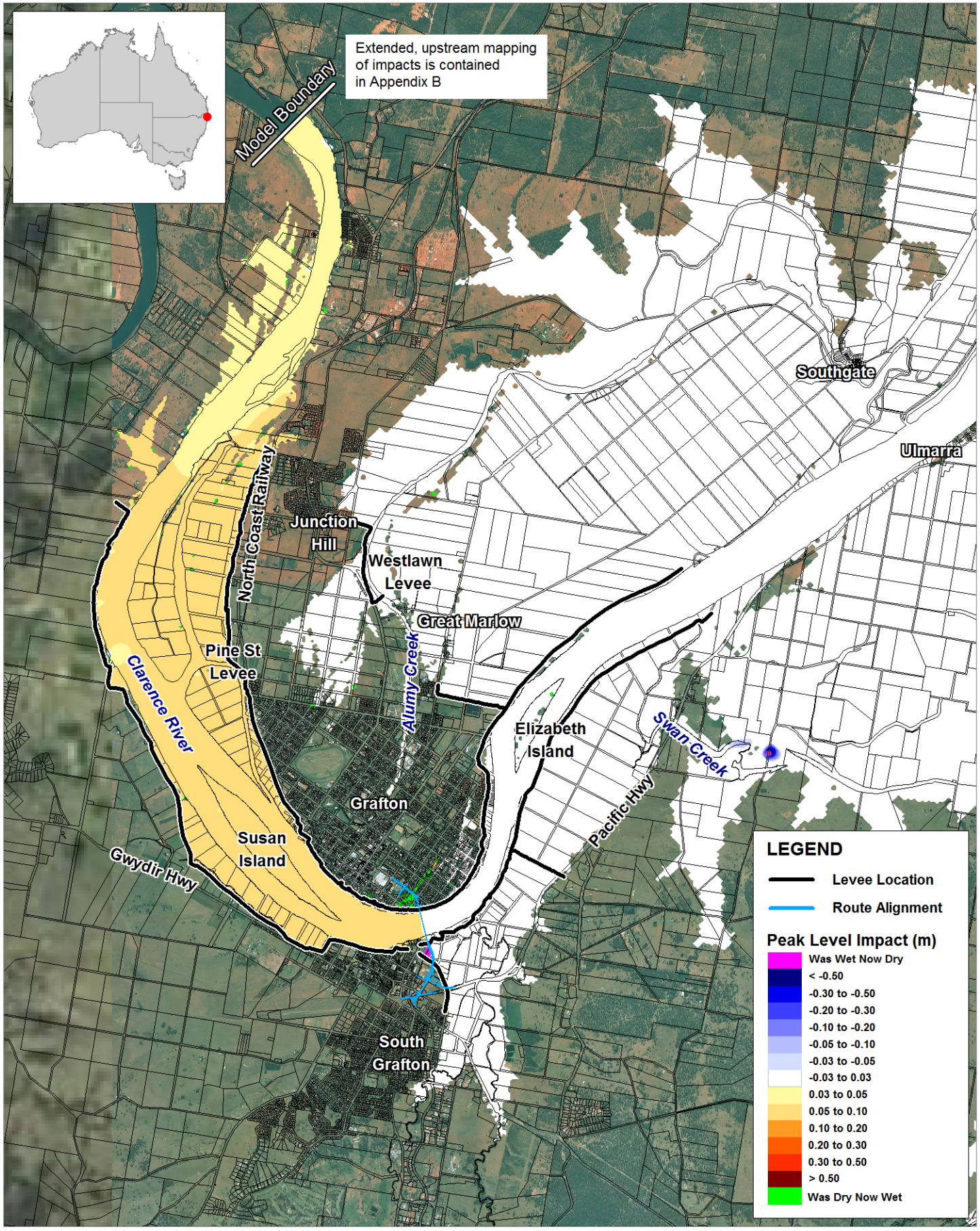



**Figure 4-6 South Grafton levee overtopping flow, unmitigated case (100 year ARI)**




Title:

# Peak Flood Level Impacts (Unmitigated) 20 Year ARI Event

Figure: 4-7

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

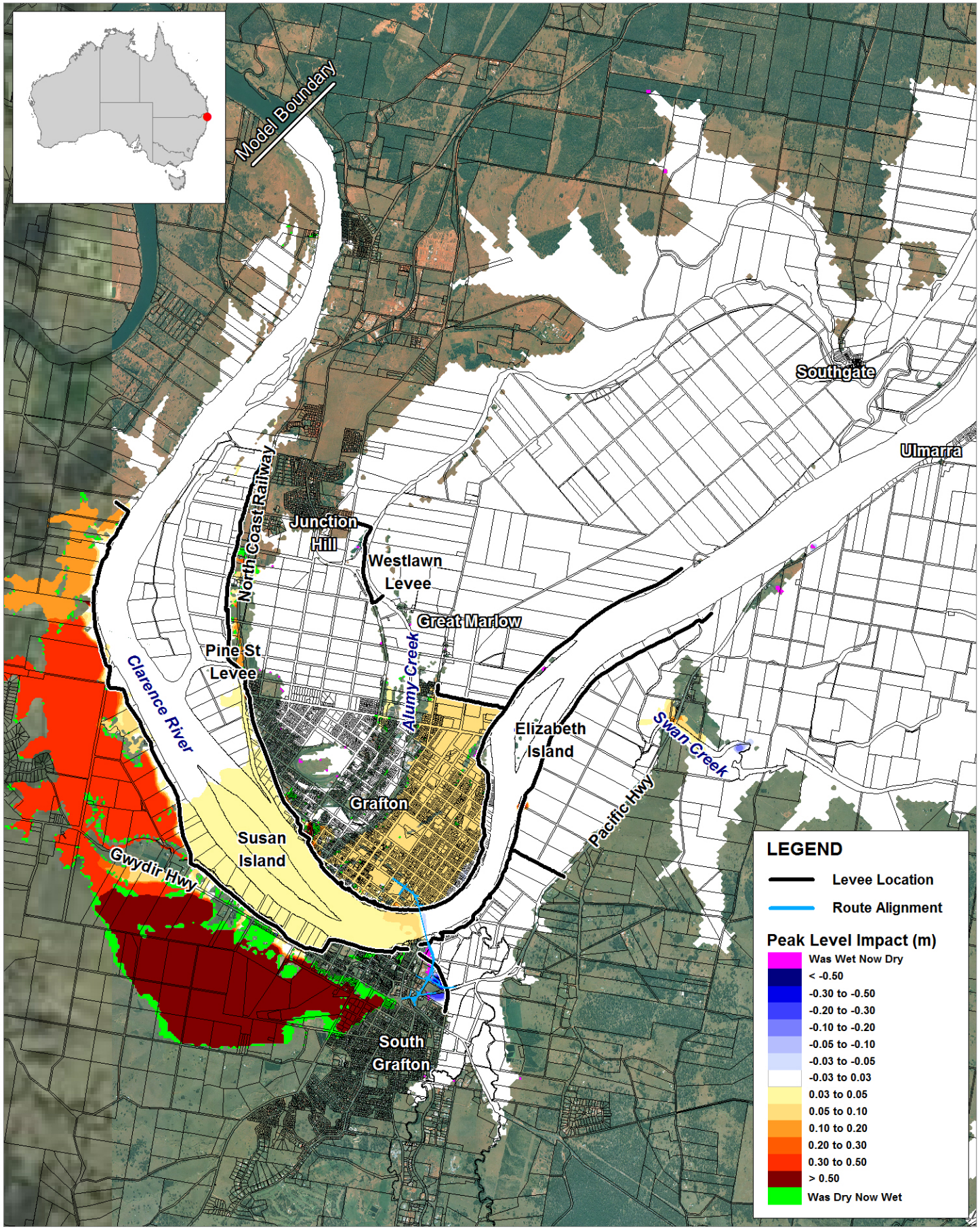
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_023_140122_Q020_NoMit_Hdiff.wor"




Title:

# Peak Flood Level Impacts (Unmitigated) 50 Year ARI Event

Figure: **4-8**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

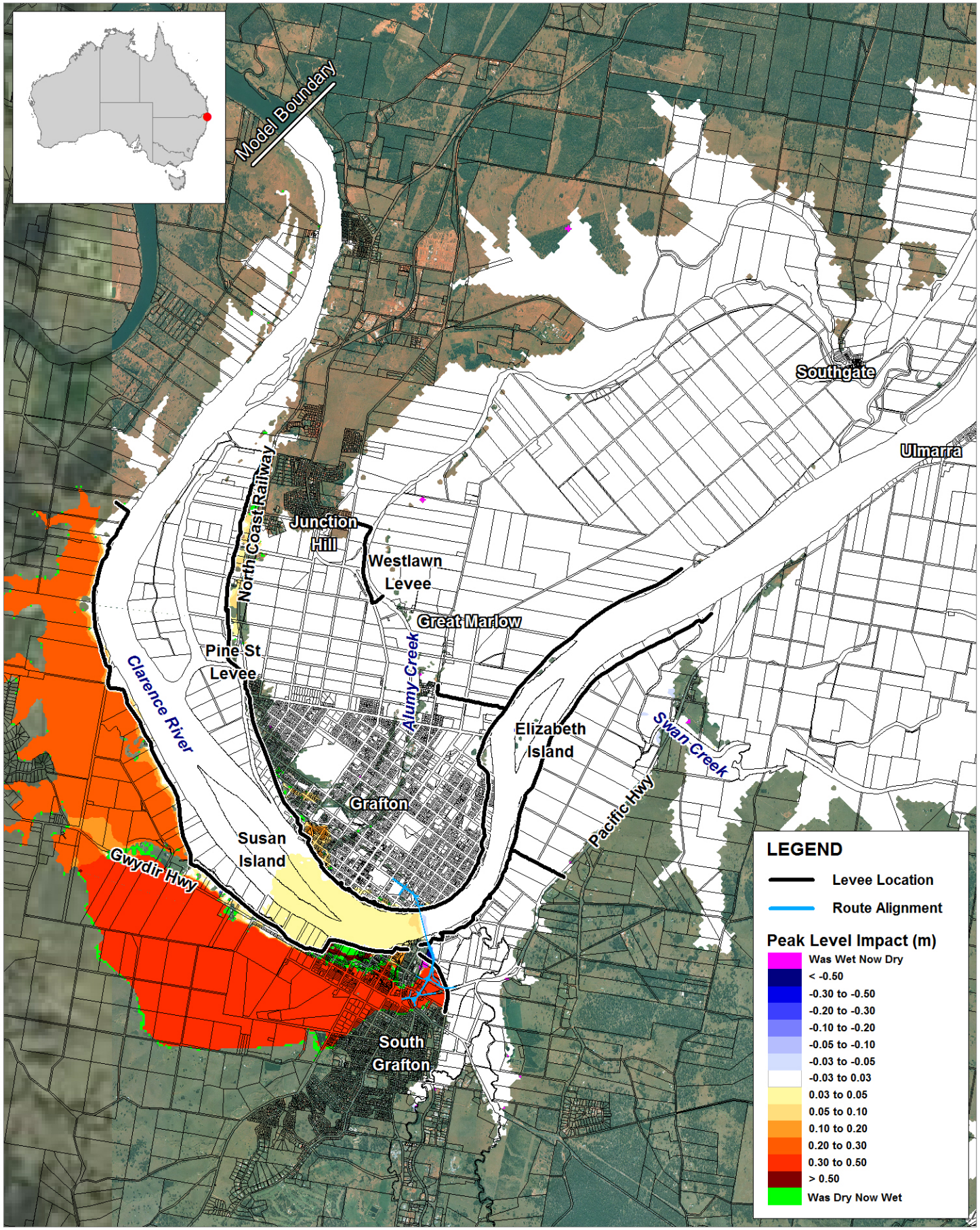
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_024_140122_Q050_NoMit_Hdiff.wor"




Title:

# Peak Flood Level Impacts (Unmitigated) 100 Year ARI Event

Figure: **4-9**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

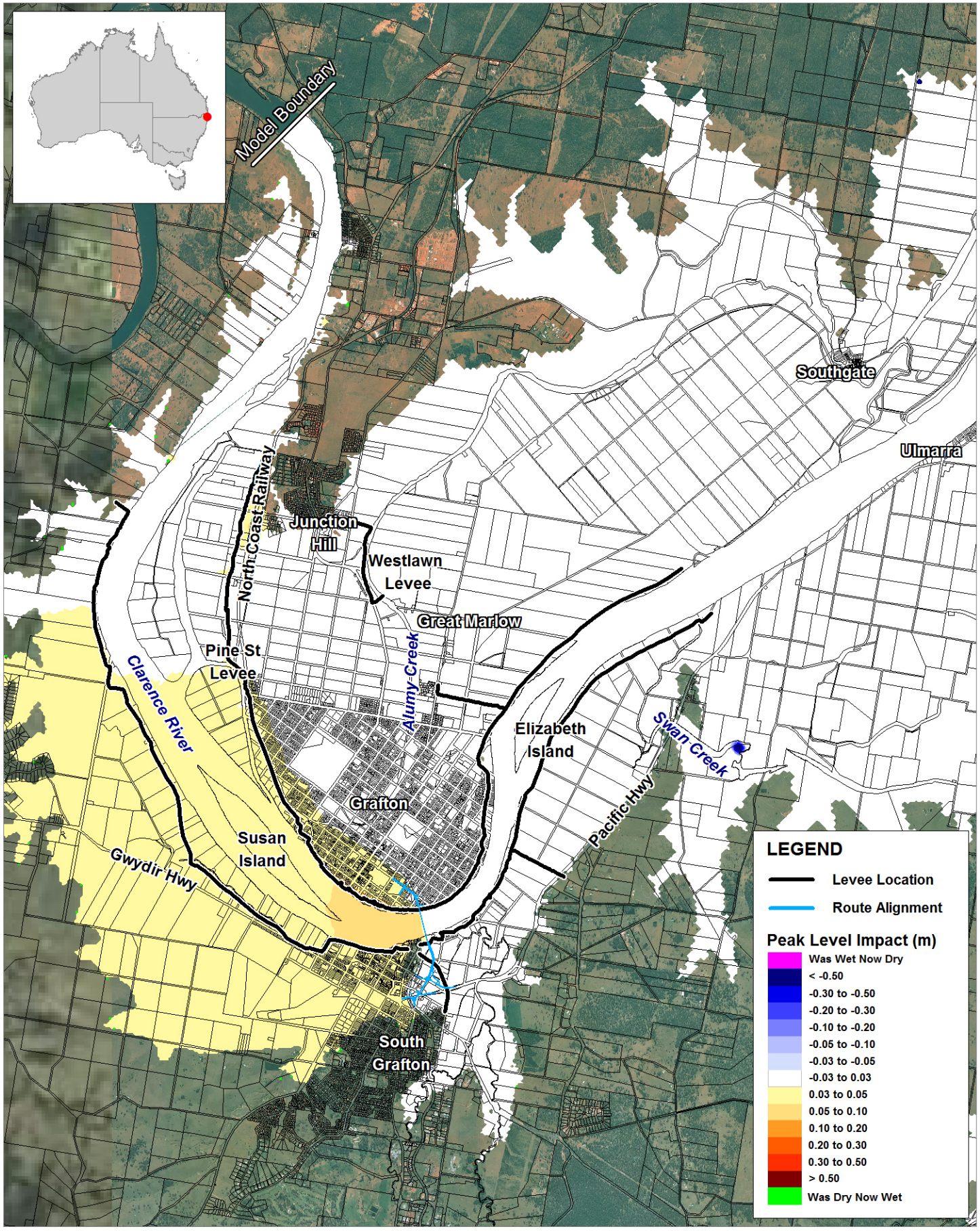
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_025_140122_Q100_NoMit_Hdiff.wor"




Title:

# Peak Flood Level Impacts (Unmitigated) PMF Event

Figure: **4-10**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

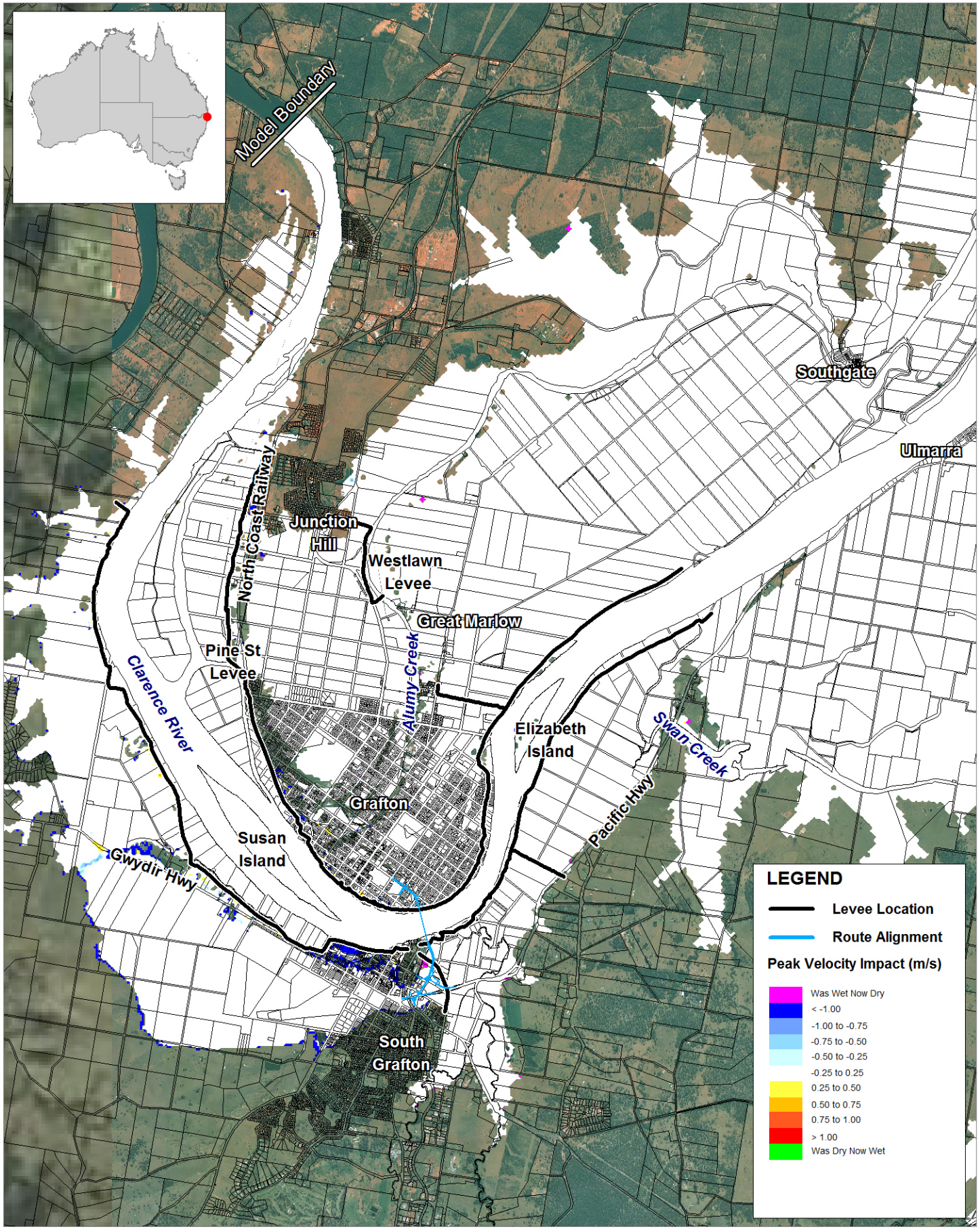
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_026_140122_QPMF_NoMit_Hdiff.wor"




Title:

# Peak Flood Velocity Impacts (Unmitigated) 100 Year ARI Event

Figure: 4-11

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_026_140122_QPMF_NoMit_Hdiff.wor"

# 5 Mitigation options assessment

## 5.1 Introduction

The flood impact assessment predicted that without mitigation the additional bridge crossing will result in increases in peak flood level upstream of the crossing during significant flood events. These predicted impacts are particularly significant in South Grafton.

Mitigation of impacts provides an opportunity to not only reduce the impacts but to provide a net reduction (an improvement) in flood risk for the communities of Grafton and South Grafton.

Flood mitigation measures can be classified into three general categories:

- Flood modification – measures to modify the behaviour of floodwater by either reducing flood depths and/or velocities or by excluding floodwater from certain areas. Examples include levees and floodways;
- Response modification – changing or improving a community's response to flooding such as through flood warning or education; and
- Property modification - increasing the resilience of existing property to flooding and implementing appropriate planning controls ensure new property is compatible with the level of flood risk.

Flood risk management typically consists of a suite of measures drawn from all three general categories listed above. For the mitigation of impacts from a development, typically the measures will consist of either flood modification measures to 'offset' or mitigate against the flood modification caused by that development or property modification measures to reduce the consequences of the impacts. Combinations of these measures may also be used.

## 5.2 Potential mitigation measures for Grafton / South Grafton

Within Grafton and South Grafton the predicted flood impacts resulting from the additional crossing are triggered by relatively minor increases of water level in the Clarence River.

Potential flood modification measures for mitigating such impacts include:

- Dredging the river with the aim of lowering flood levels;
- Implementing a floodway with associated inlet and outlet control structures to reduce downstream flood levels;
- Containing flood level increases through the use of levees; or
- Creating or enhancing zones of storage within the floodplain to temporarily detain or slow the floodwater and reduce the peak levels.

These potential options and their applicability to Grafton and South Grafton are summarised below.

### 5.2.1 Potential flood modification measures

**Dredging**

Dredging would involve increasing the depth and conveyance capability of the Clarence River channel through the removal of silt from the river bed. It is not a sustainable solution as dredging operations would need to be repeated within a few years as the river naturally replaces the silt which was previously removed. Dredging itself can also lead to impacts with uncertain outcomes such as increasing the erosive potential of the river which may in turn impact on existing structures crossing the river or the stability of river banks. For these reasons dredging is not considered a viable option for the project.

**Floodway**

To mitigate the impacts of the additional crossing a floodway would need to be located upstream of the bridge. Existing levees protecting Grafton and South Grafton are located in areas of dense urban development and so there are no feasible locations for a floodway. An opportunity for a floodway bypass exists further upstream in the area to the north of Grafton and to the south of Junction Hill. It would convey a controlled volume of floodwater from the eastern Clarence River floodplain out into the western Clarence floodplain bypassing Grafton.

A floodway would extend for approximately 2km and would require inlet and outlet structures to the Clarence River. Existing viaducts under the North Coast Railway line will require widening to accommodate a floodway. An embankment along the southern side of the floodway may also be required to prevent flow passing south into Grafton.

The likely costs of this measure are likely to be prohibitive when compared to alternative measures and it is therefore not considered further in this assessment.

**Construction/Augmentation of Levees**

Levees are currently used to manage flood risk in Grafton and South Grafton. Mitigating the increased flood levels from the additional crossing would involve increasing the heights of the existing levees and potentially extending the levees upstream. The Grafton and Lower Clarence Floodplain Risk Management Plan identifies mitigation works for Grafton and South Grafton which are generally focussed on the maintenance and augmentation of levees.

By containing or partially containing floodwater within the channel, levees will raise in-bank flood levels and this in turn will impact on areas outside of the levee's zone of protection. These areas potentially include Carrs Island and Carrs Peninsula, isolated properties within Grafton and South Grafton and areas of upstream floodplain. This residual risk will need to be established and quantified. Further residual risk remains through the risk of levee failure (breach of overtopping) and evacuation plans should account for this risk.

Levees are considered as a potential option for mitigating the impacts of flooding from the additional crossing. They have been assessed further within sections 5.3 to 5.6.

**Floodplain Storage**

The creation of dams within the upper Clarence River catchment to detain floodwater and reduce the peak river levels will entail prohibitive costs and would require many further investigations to

assess the feasibility and impacts of such measures. The scale of the flood flows (17,700m$^3$/s in the 100 year ARI event) means that local flood storage measures around Grafton will be of very limited effect against such significant flows.

Floodplain storage options do have the potential when considered alongside other measures such as levees. One potential flood storage measure for South Grafton is to raise the Gywdir Highway to prevent or reduce floodplain flows entering South Grafton from the north. This measure has been considered further in Section 5.5 and 5.6.

### 5.2.2 Potential property modification measures

Property modification measures can potentially be used with flood modification measures or as standalone measures to mitigate the impacts from the additional crossing.

For Grafton and South Grafton, property modification measures would need to offset the impacts of increased flood levels. The most appropriate measure to achieve this is house raising with the aim of raising dwellings by a height which is greater than the height increases to the flood.

For this project this measure will typically be applied for dwellings located outside of areas mitigated by flood modification measures. Property modification measures are considered further in Section 6.

### 5.2.3 Summary of potential mitigation measures

Table 5-1 presents a summary of potential mitigation measures highlighting the ones which have been taken forward for further consideration.

**Table 5-1 Summary of potential mitigation measures**

| Measure | Type of measure | Assessed further? | Reason/s for no further assessment |
|---|---|---|---|
| Dredging of Clarence River | Flood Modification | No | Not sustainable<br>Uncertain impacts |
| Floodway | Flood Modification | No | Prohibitive costs |
| Levee Options | Flood Modification | Yes | |
| Floodplain Storage | Flood Modification | Yes | |
| House Raising | Property Modification | Yes | |

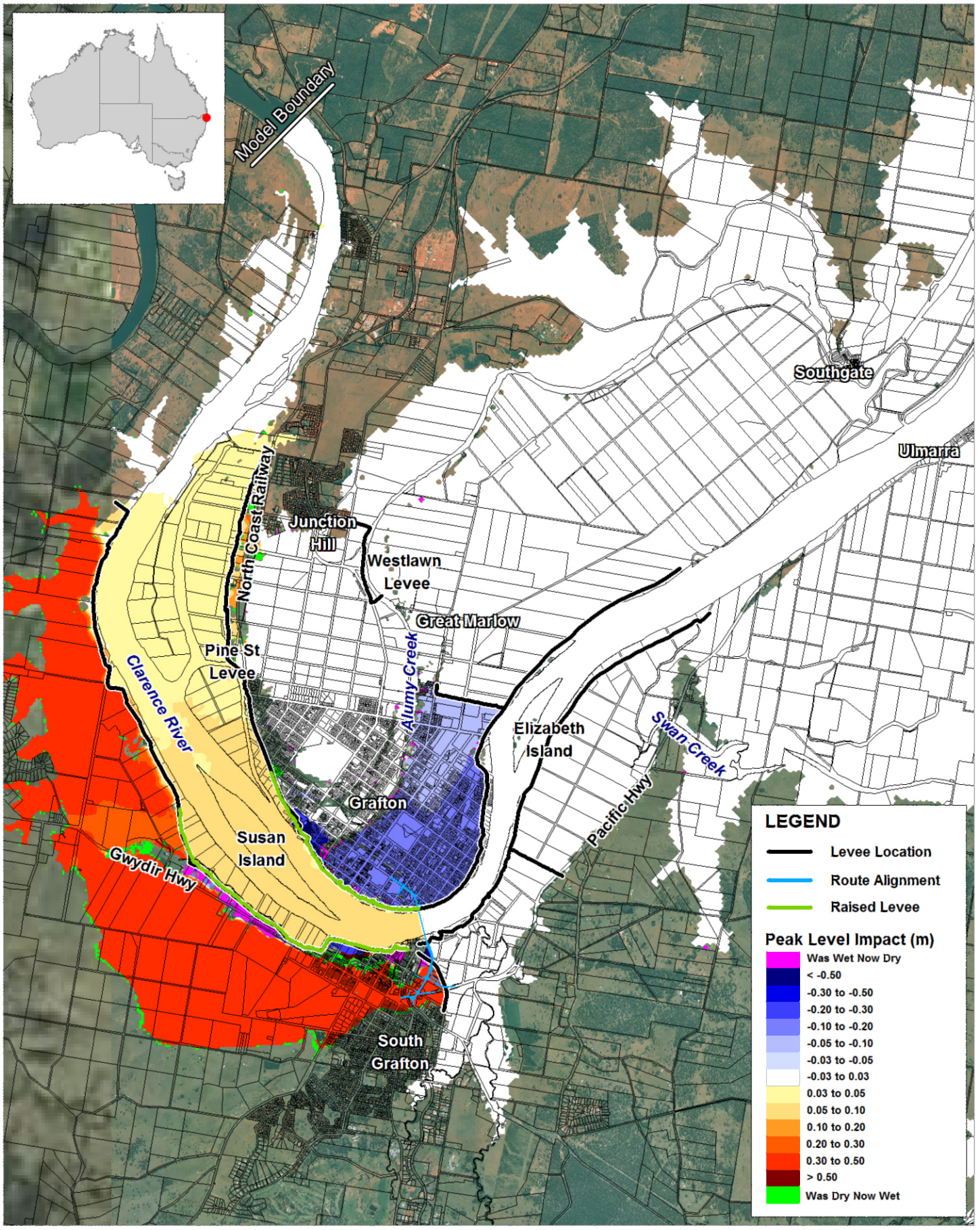
Mitigation measures are further considered in the remainder of this Section 5 with house raising considered in Section 6.

## 5.3 Mitigation Option 1

Option 1 consists of raising 3.7km of levee on the northern side of the Clarence River by 0.2m and a further 4.7km of levee on the southern side by 0.2m.

Option 1, along with the 100 year average recurrence interval (ARI) modelled impacts are shown in Figure 5-1. Peak levels in Grafton are reduced by 0.13m but an impact of 0.42m remains in South Grafton. Whilst the volume of water overtopping the raised levee into South Grafton is reduced, there remains significant overtopping into the floodplain to the north which then flows into South

Grafton. Option 1 was therefore not considered further in this assessment and no events other than the 100 year ARI were modelled.




Title:

# Peak Flood Level Impact 100 Year ARI Event Additional Crossing (Mitigation Option 1)

Figure: **5-1**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_027_140122_Q100_Mit01_Hdiff.wor"

## 5.4 Mitigation Option 2

Option 2 raises the same length of levee on the northern side of the Clarence River as Option 1 (3.7km) but extends the length of levee raised on the southern side to 7km. Both levees are raised by 0.2m.

Figure 5-2 to Figure 5-5 show hydrographs of the flow entering Grafton and South Grafton during the 50 and 100 year ARI events via overtopping of the levees for the baseline and Mitigation Option 2 scenarios. Due to only minor localised overtopping in the 20 year ARI event this event has not been included.

Figure 5-6 to Figure 5-9 plot design flood levels over time at urban locations in Grafton and South Grafton. Much of the urban area of South Grafton remains flood free during the 50 year ARI event. As such only the 100 year levels were plotted.

Figure 5-10 to Figure 5-13 show mitigation Option 2 along with the predicted flood level impacts for the 20, 50 and 100 year ARI and the PMF events. Figure 5-14 show Option 2 with the predicted flood velocity impacts for the 100 year ARI event.

Table 5-2 summarises the changes in peak flood level for locations in Grafton and South Grafton. Table 5-3 and Table 5-4 summarise the levee overtopping volumes.

**Table 5-2 Peak flood level impact (Mitigation Option 2)**

| | Prince St Gauge | Existing Grafton Bridge | Grafton[1] | South Grafton[2] |
|---|---|---|---|---|
| 20 year | 0.06 | 0.07 | 0.00 | 0.00 |
| 50 year | 0.08 | 0.08 | -0.27 | 0.05 |
| 100 year | 0.09 | 0.09 | -0.07 | -0.11 |
| PMF | 0.05 | 0.07 | 0.02 | 0.05 |

1 Intersection of Pound Street and Prince Street

2 Intersection of Abbott Street and Vere Street

**Table 5-3 Option 2 overtopping volumes – North Grafton**

| Design flood event | Overtopping volume (Megalitres) | | | |
|---|---|---|---|---|
| | Baseline | Unmitigated | Change | % Change |
| 50 year | 8,304 | 7,193 | -1,111 | -13% |
| 100 year | 17,951 | 16,539 | -1,412 | -8% |

**Table 5-4 Option 2 overtopping volumes – South Grafton**

| Design flood event | Overtopping volume (Megalitres) | | | |
|---|---|---|---|---|
| | Baseline | Unmitigated | Change | % Change |
| 50 year | 12,215 | 12,617 | 402 | 3% |
| 100 year | 30,148 | 28,979 | -1,169 | -4% |

Option 2 significantly reduces the impact resulting from the additional bridge crossing but a minor predicted increase of 0.05m remains in South Grafton for the 50 year ARI event. Whilst the peak levee overtopping flow has reduced (see Figure 5-3), the overall overtopping volume has marginally increased by around 3%. Much of the existing urban extent of South Grafton remains flood free during the 50 year ARI event and the resulting increase in flood level is therefore limited to the periphery of South Grafton. It does impact on the South Grafton Airport and three residential properties on Skinner Street. The reduction in flood levels in South Grafton in the 100 year ARI event benefits existing property.

A predicted net reduction in peak flood levels in Grafton occurs for the 50 and 100 year ARI events along with a very slight reduction in flood duration due to a delayed onset of flooding.

Very minor increases in flood level are predicted for a PMF event. It is not considered necessary to offset this minor impact for an event of such rarity, especially when the baseline flood depths are such that they would most likely result in properties being so badly damaged that they would need to be replaced.

Properties that lie outside of the levee banks such as those on Carrs Island would be affected by increased levels in the Clarence River from both the additional crossing and the Option 2 levee augmentation. The increases in flood levels at Carrs Island are typically between 0.05m and 0.10m for all modelled events. Under Option 2 it may be necessary to compensate or raise any houses that fall within this zone of residual impacts. This is covered further in Section 6.

No notable impacts were observed for changes in peak flood velocity under Option 2. Minor increases in flood hazard will result where the depth has increased but as discussed above the impacts are of limited spatial extent. There are no predicted increases in duration or frequency of flooding and Grafton will experience a slight reduction in the predicted frequency of levee overtopping.

No impacts have been identified on planned infrastructure listed in Table 4-2. The proposed Pacific Highway upgrade is a significant distance downstream from the crossing and no downstream impacts have been predicted for any assessed event. The two planned developments in South Grafton are located outside the extent of the 50 year ARI flood but are potentially affected in the 100 year ARI event. However, the assessment has shown that the mitigation measures included in Option 2 result in lower flood levels at the locations of these developments for this event.

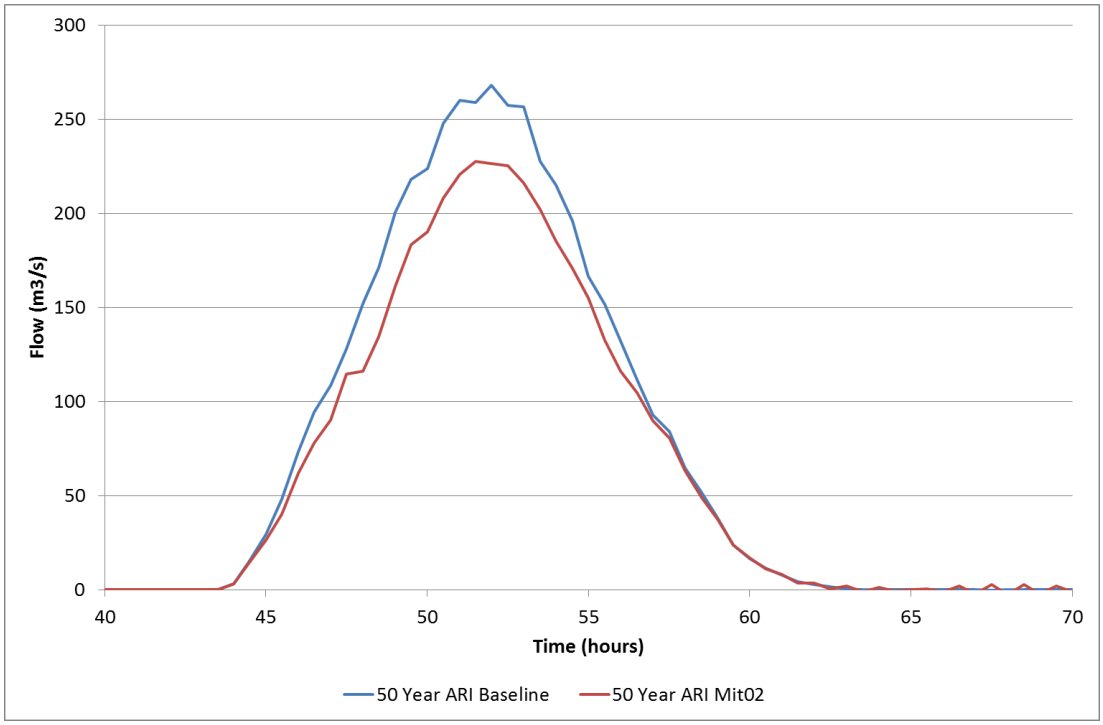



**Figure 5-2 North Grafton levee overtopping flow, Option 2 (50 year ARI)**

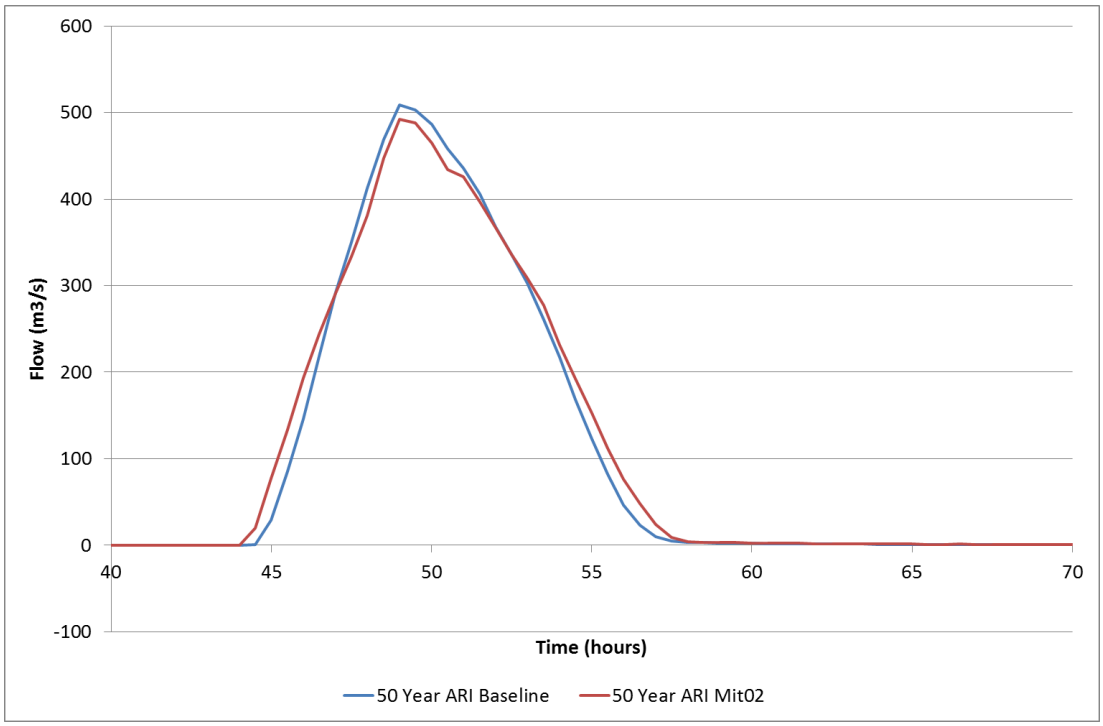



**Figure 5-3 South Grafton levee overtopping flow, Option 2 (50 year ARI)**

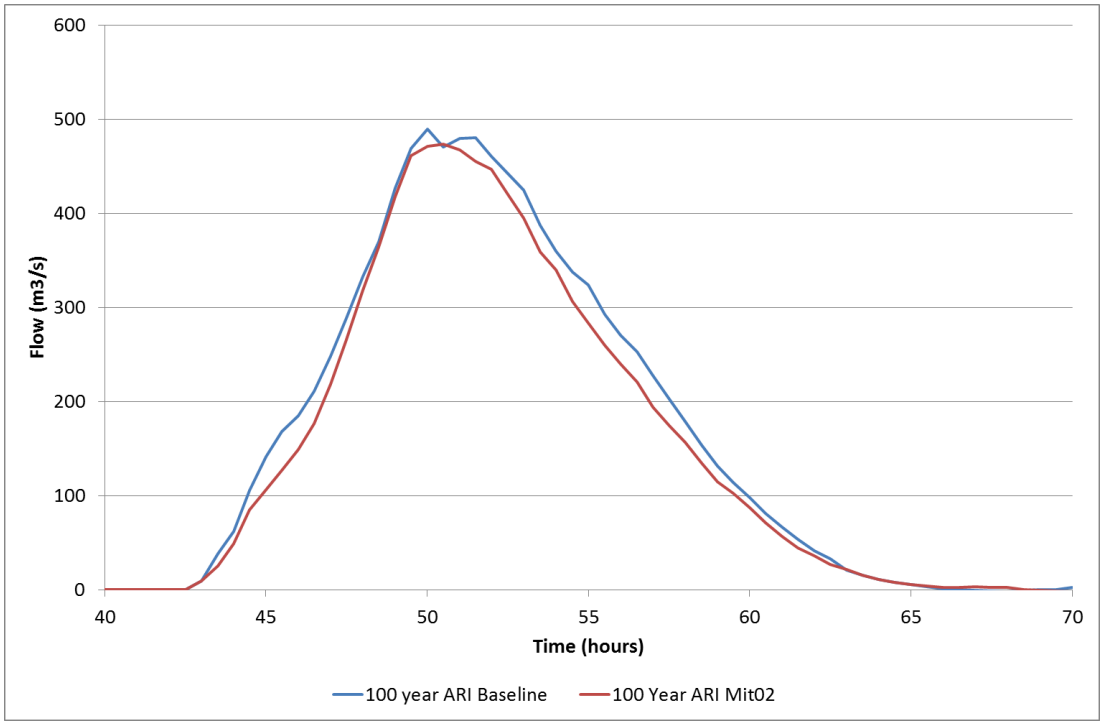



**Figure 5-4 North Grafton levee overtopping flow, Option 2 (100 year ARI)**

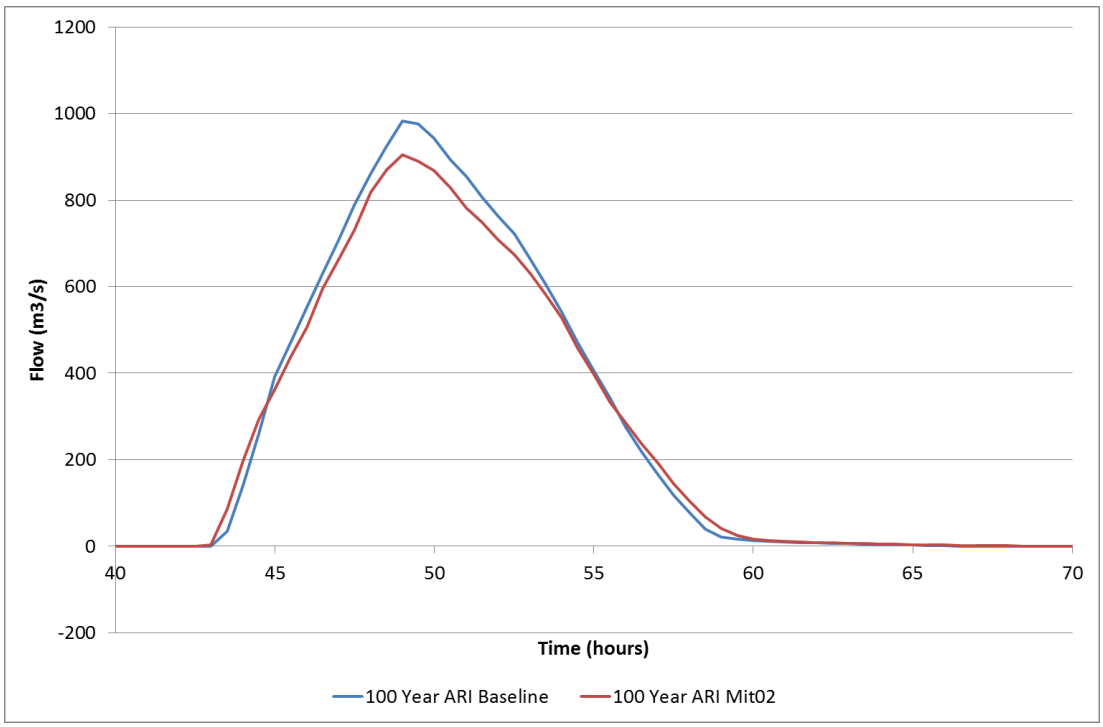



**Figure 5-5 South Grafton levee overtopping flow, Option 2 (100 year ARI)**

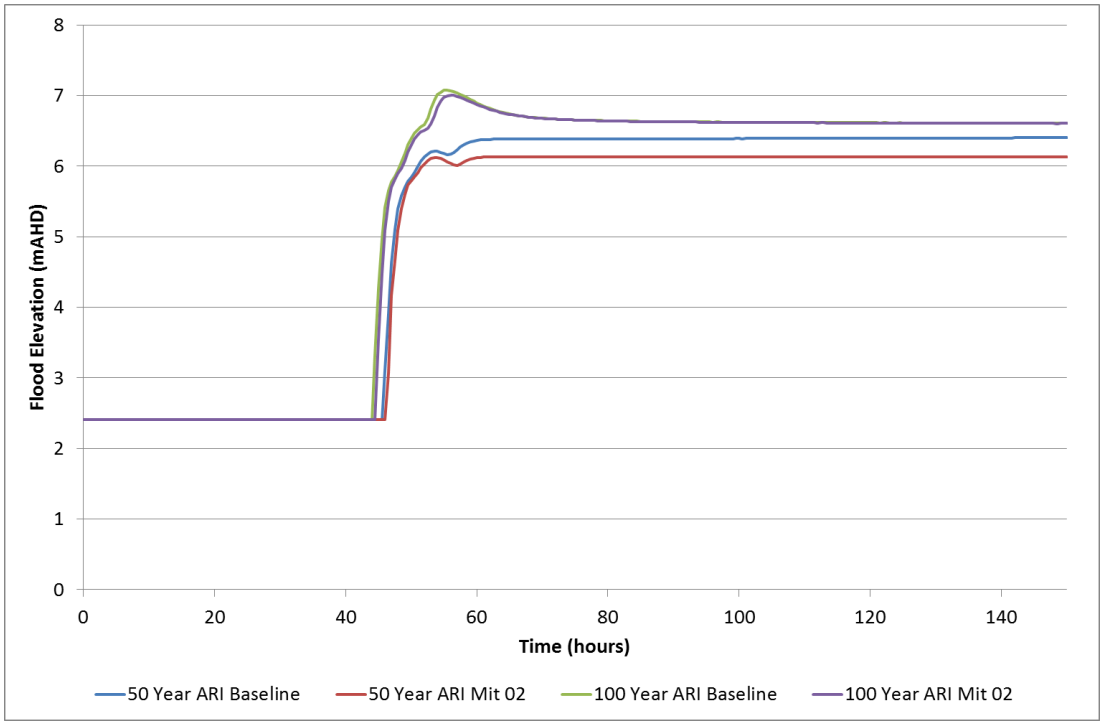



**Figure 5-6 Pound Street, North Grafton, design flood elevations, Option 2**

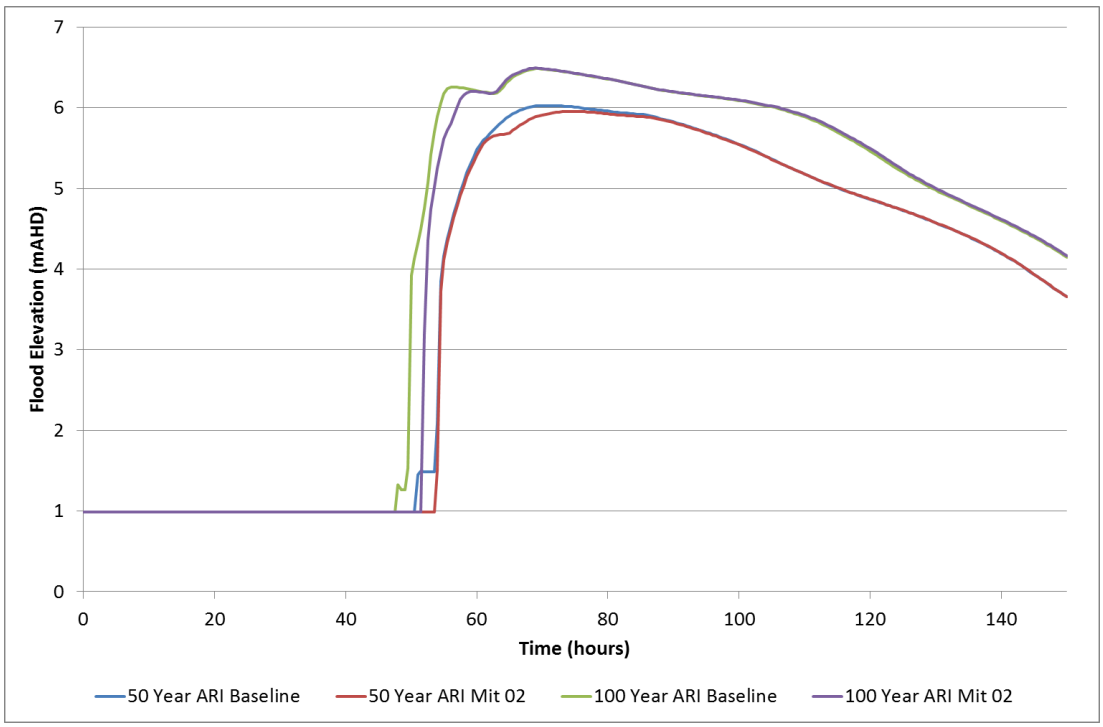



**Figure 5-7 Alumy Creek (Fry St), North Grafton, design flood elevations, Option 2**

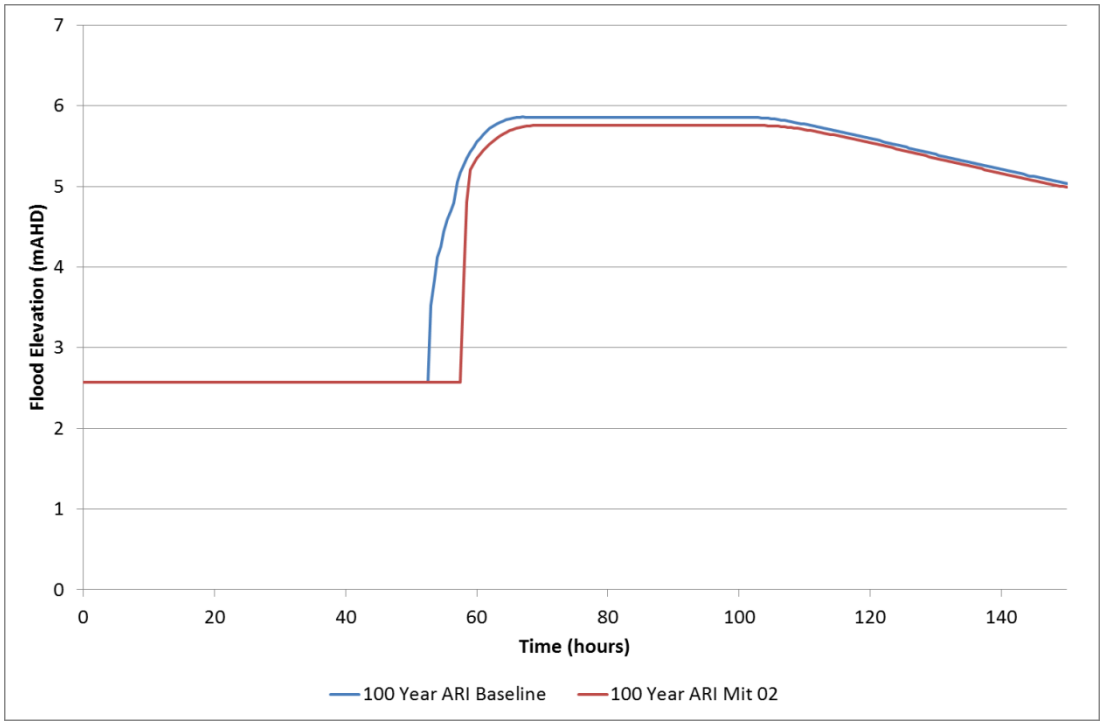



**Figure 5-8 Near Wharf St, South Grafton, design flood elevations, Option 2[6]**

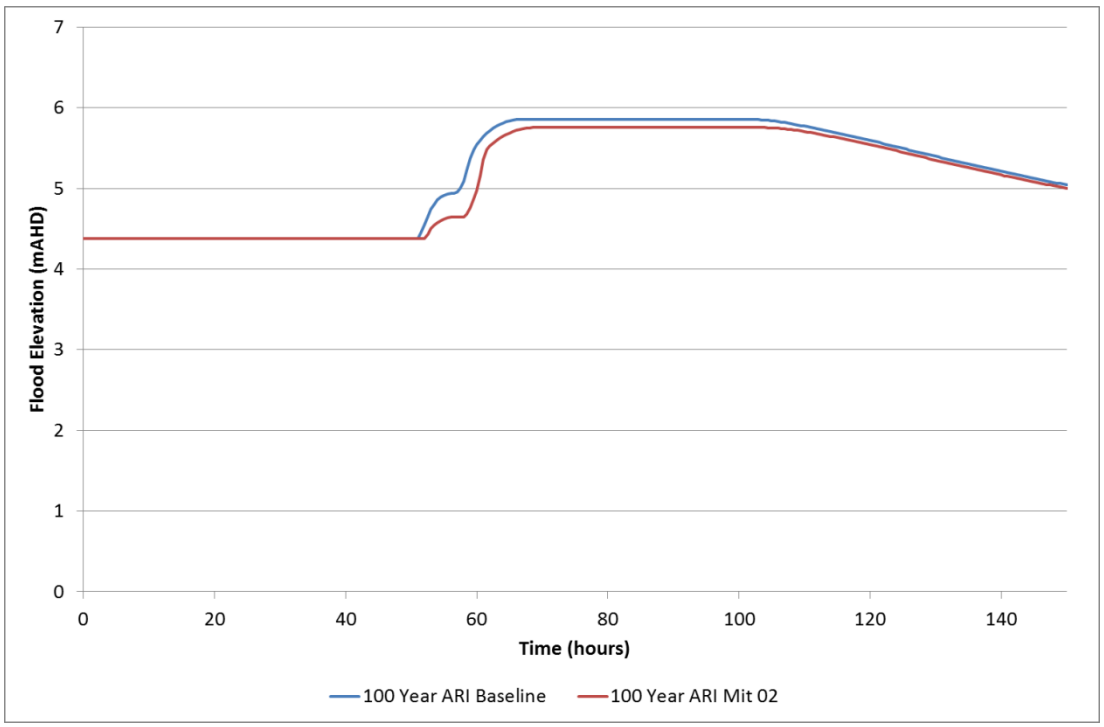
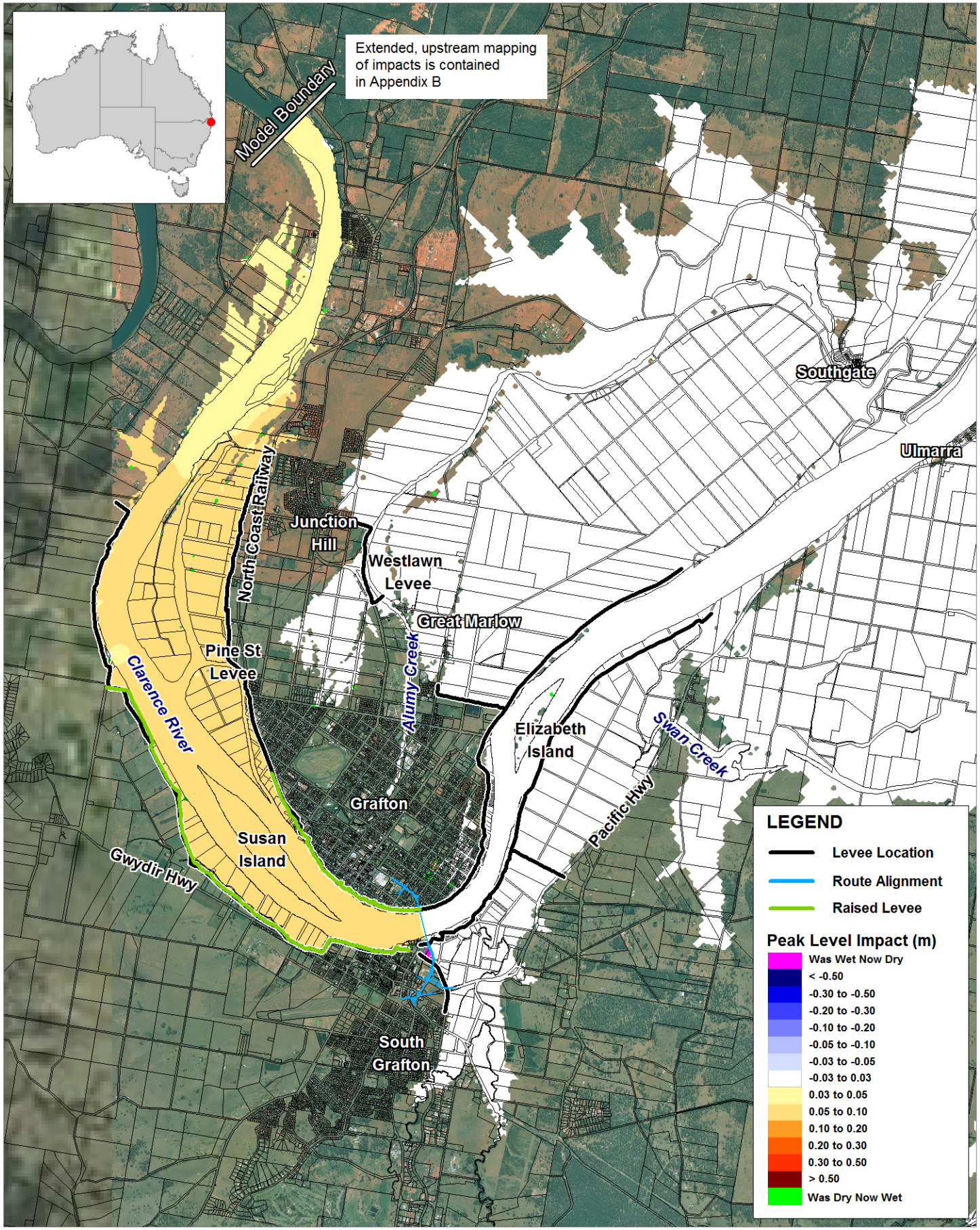



**Figure 5-9 Iolanthe St, South Grafton, design flood elevations, Option 2[5]**

[6] No flooding at this location in the 50 year ARI event




Title:

# Peak Flood Level Impact 20 Year ARI Event Additional Crossing (Mitigation Option 2)

Figure: **5-10**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

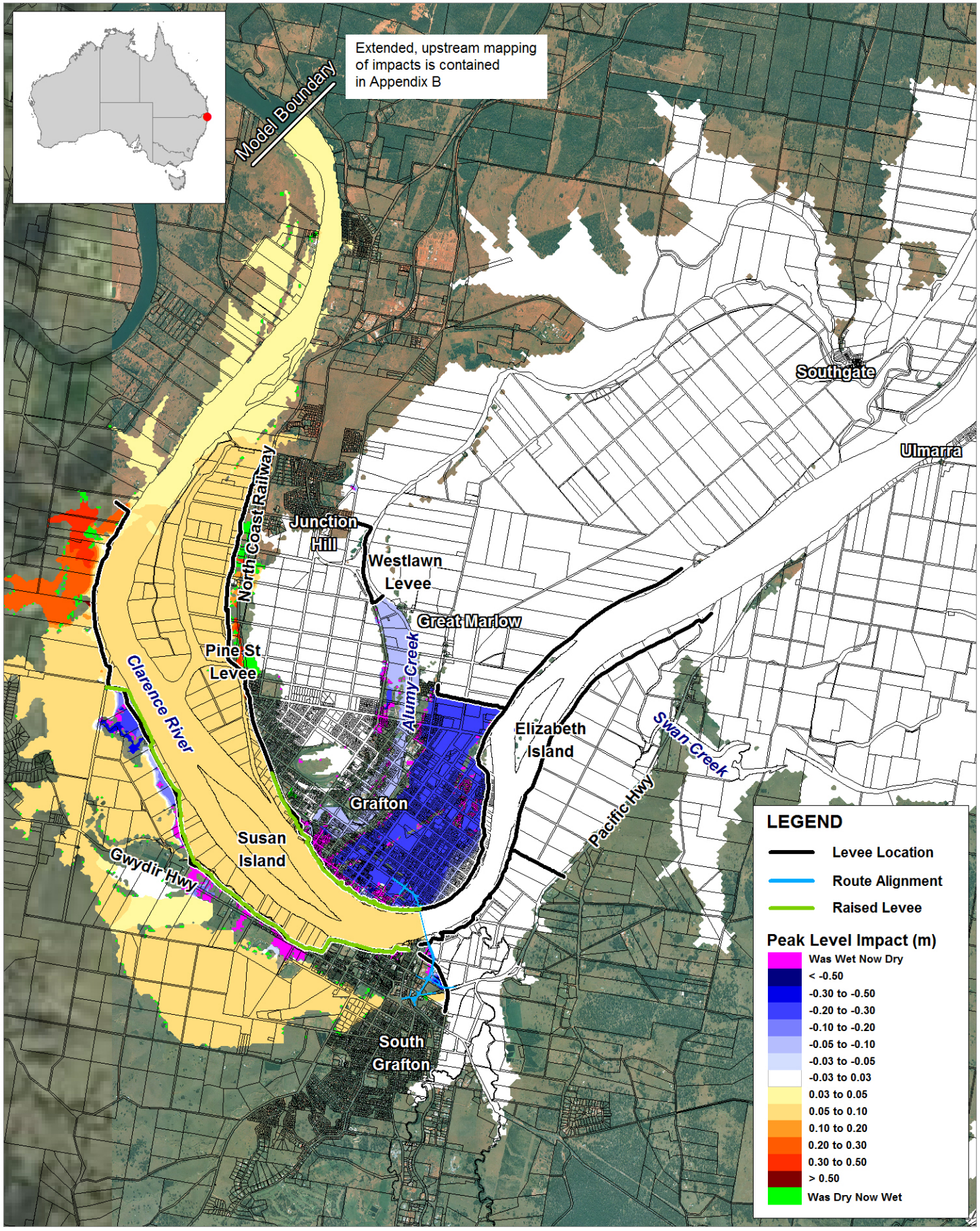
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_028_140122_Q020_Mit02_Hdiff.wor"




Title:

# Peak Flood Level Impact 50 Year ARI Event Additional Crossing (Mitigation Option 2)

Figure: **5-11**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

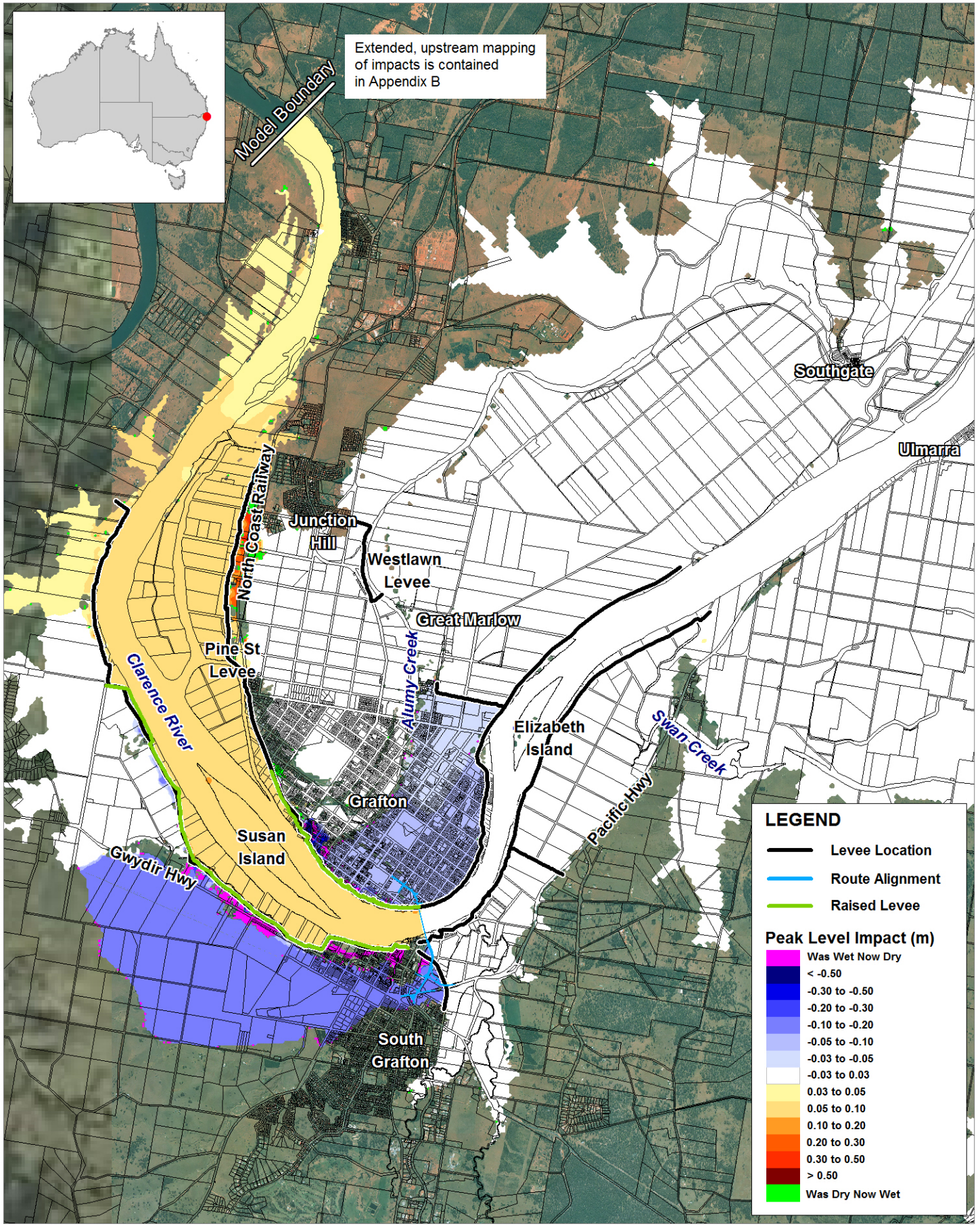
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_029_140122_Q050_Mit02_Hdiff.wor"




Title:

# Peak Flood Level Impact 100 Year ARI Event Additional Crossing (Mitigation Option 2)

Figure: **5-12**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

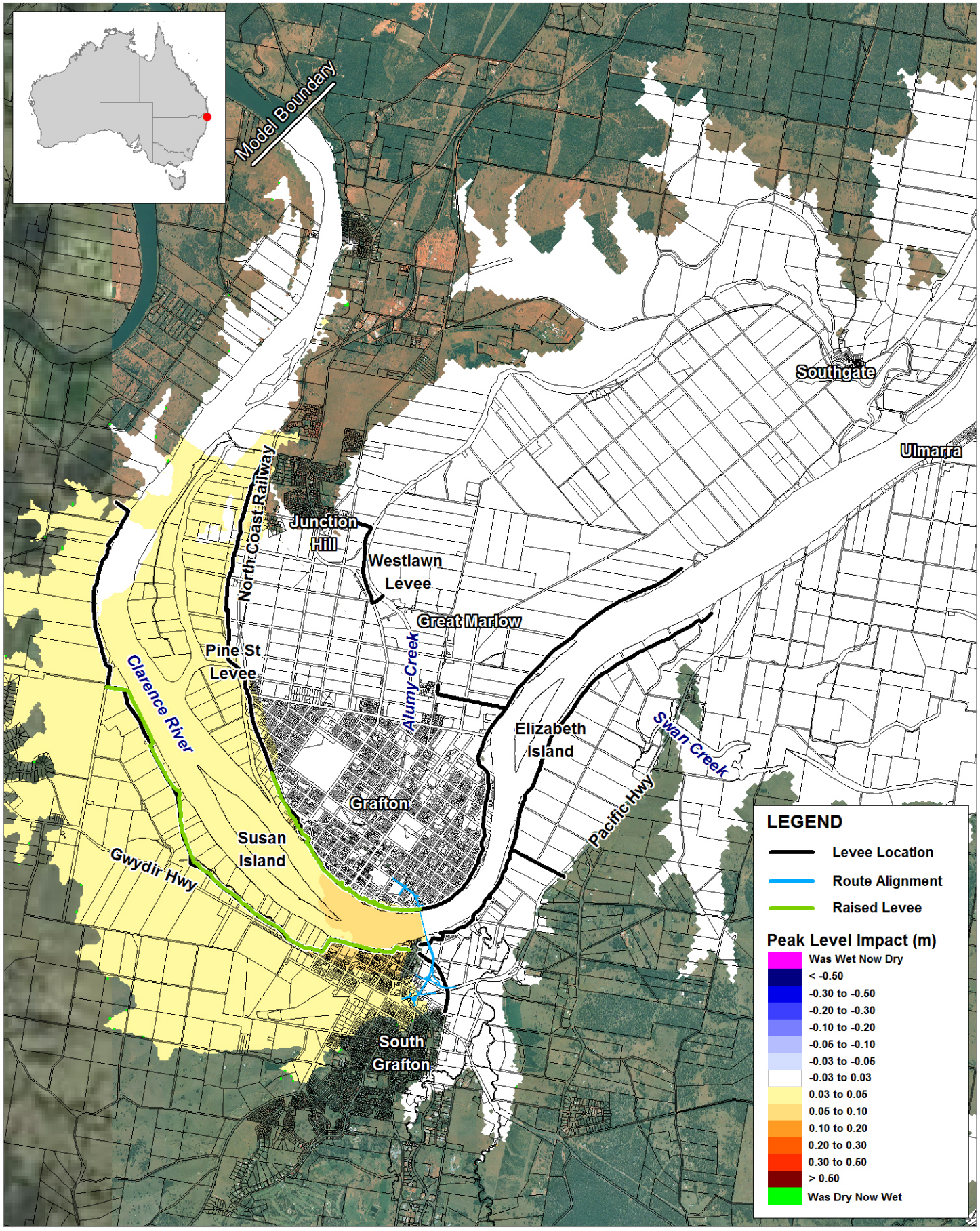
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_030_140122_Q100_Mit02_Hdiff.wor"




Title:

# Peak Flood Level Impact PMF Event Additional Crossing (Mitigation Option 2)

Figure: 5-13

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

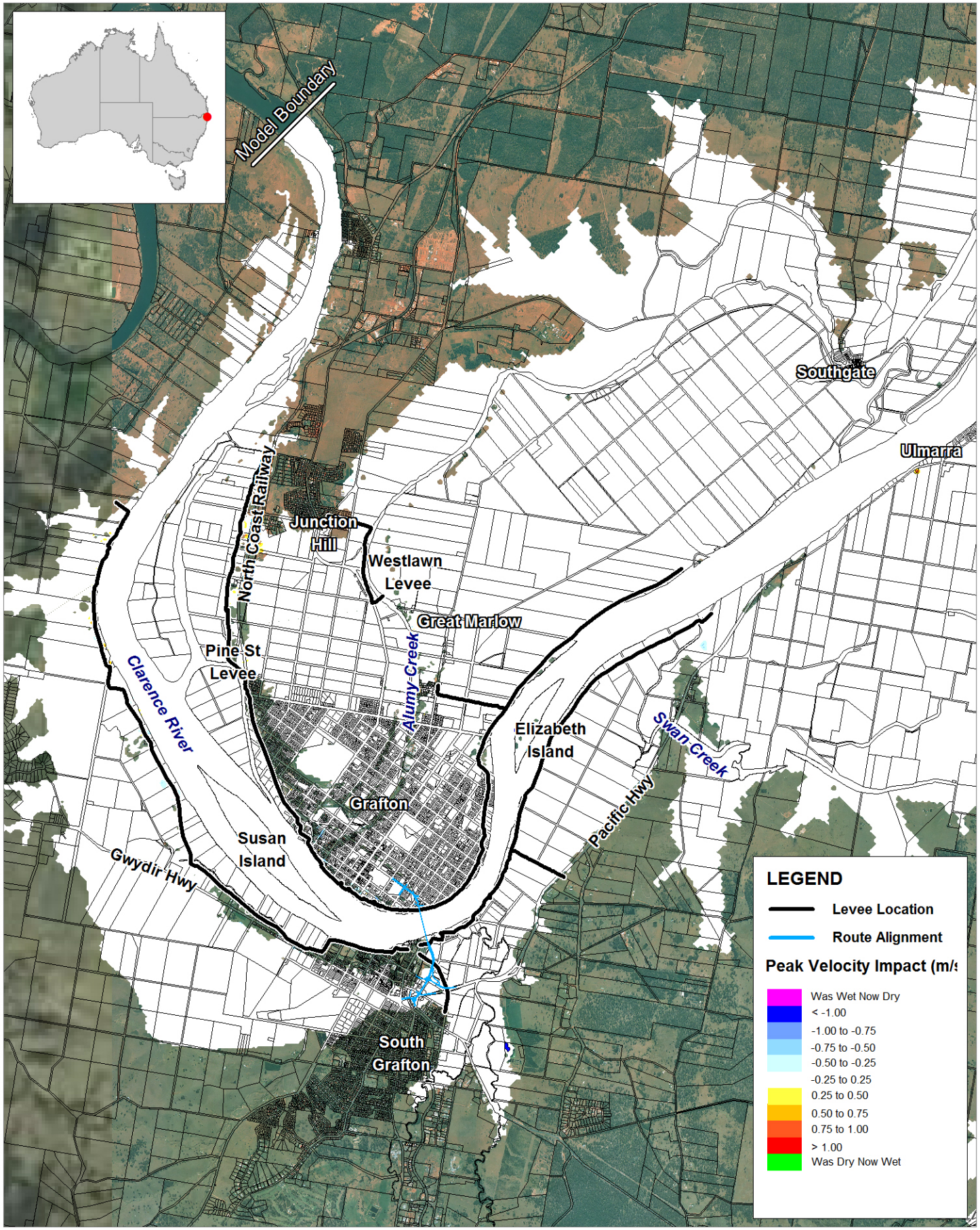
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_031_140122_QPMF_Mit02_Hdiff.wor"




Title:

# Peak Flood Velocity Impact 100 Year ARI Event Additional Crossing (Mitigation Option 2)

Figure: 5-14

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_059_140310_Q100_Mit02_Vdiff.wor"

## 5.5 Mitigation Option 3

Option 3 reduces the length of levee raising required compared to Option 2 by utilising and modifying a natural constriction in the floodplain terrain near South Grafton. The aim is to reduce the floodplain flow which is conveyed behind the levee bank into South Grafton.

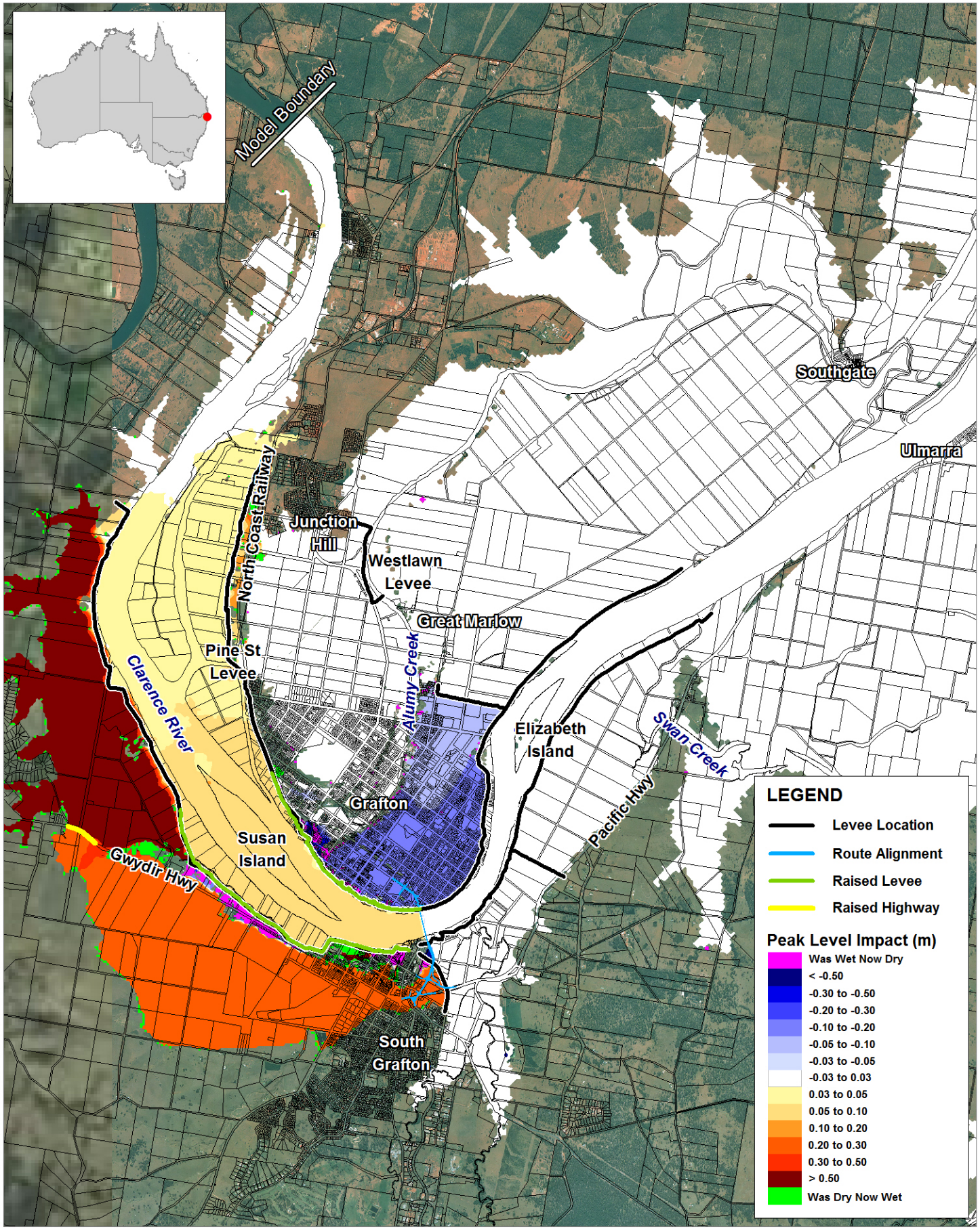
The proposed levee raising extents are the same as Option 1 with 3.7km and 4.7km of levee raised by 0.2m on the northern and southern sides of the Clarence River respectively.

The constriction in the South Grafton floodplain is located along the Gwydir Highway near its intersection with Friars Lane. Mitigation Option 3 would require raising the minimum road elevation of the Gwydir Highway to 6.5mAHD. This represents a total length of 425m of the highway. Current road elevations along this length of highway range between 5mAHD and 6.5mAHD resulting in a maximum raising height of 1.5m. An existing small watercourse, Saltwater Creek, drains the South Grafton Commons floodplain in this area and passes under the Gwydir Highway in a northerly direction. Floodgates would need to be installed under the highway to allow local runoff to drain when the Clarence River is not in flood, which can close and prevent backflow when floodwater flows towards South Grafton from the north.

Figure 5-15 shows the scheme along with the predicted 100 year ARI peak level impacts.

Under Option 3 the peak 100 year ARI flood level in Grafton is reduced by 0.13m. Peak 100 year ARI flood levels in South Grafton are reduced from the unmitigated case but remain 0.24m higher than the baseline peak flood level (before the additional bridge crossing is constructed). This increase affects existing property and is considered unacceptable and therefore no events other than the 100 year ARI were modelled.

Option 3 has not been taken forward for further assessment.




Title:

# Peak Flood Level Impact 100 Year ARI Event Additional Crossing (Mitigation Option 3)

Figure: **5-15**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_032_140122_Q100_Mit03_Hdiff.wor"

## 5.6 Mitigation Option 4

Option 4 is similar to Option 3 but with the Gwydir Highway raised to a minimum elevation of 7.0mAHD (0.5m higher than for Option 3). This requires the raising of approximately 550m of road by a maximum height of 2m. As for Option 3, flood gates would be required under the highway to allow Saltwater Creek to drain to the north.

Figure 5-16 to Figure 5-19 show hydrographs of the flow entering Grafton and South Grafton during the 50 and 100 year ARI events via overtopping of the levees for the baseline and Mitigation Option 2 scenarios. Due to only minor localised overtopping in the 20 year ARI event this event has not been included

Figure 5-20 to Figure 5-23 plot design flood levels over time at urban locations in Grafton and South Grafton. Much of the urban area of South Grafton remains flood free during the 50 year ARI event. As such only the 100 year levels were plotted.

Figure 5-24 to Figure 5-27 show mitigation Option 4 along with the predicted impacts for the 20, 50 and 100 year ARI and the PMF events. Figure 5-28 shows the predicted impacts for the 100 year ARI peak flood velocity.

Table 5-5 summarises the changes in peak flood level for two locations in Grafton and South Grafton. Table 5-6 and Table 5-7 summarise the levee overtopping volumes.

**Table 5-5 Peak flood level impact (Mitigation Option 4)**

| | Prince St Gauge | Existing Grafton Bridge | Grafton[1] | South Grafton[2] |
|---|---|---|---|---|
| 20 year | 0.06 | 0.07 | 0.00 | 0.00 |
| 50 year | 0.06 | 0.06 | -0.41 | -0.56 |
| 100 year | 0.07 | 0.07 | -0.13 | -0.07 |
| PMF | 0.05 | 0.07 | 0.02 | 0.05 |

1 Intersection of Pound Street and Prince Street

2 Intersection of Abbott Street and Vere Street

**Table 5-6 Option 4 overtopping volumes – North Grafton**

| Design Flood Event | Overtopping Volume (Megalitres) | | | |
|---|---|---|---|---|
| | Baseline | Unmitigated | Change | % Change |
| 50 year | 8,304 | 6,537 | -1,767 | -21% |
| 100 year | 17,951 | 14,009 | -3,942 | -22% |

**Table 5-7 Option 4 overtopping volumes – South Grafton**

| Design Flood Event | Overtopping Volume (Megalitres) | | | |
|---|---|---|---|---|
| | Baseline | Unmitigated | Change | % Change |
| 50 year | 12,215 | 16,034 | 3,819 | 31% |
| 100 year | 30,148 | 36,106 | 5,958 | 20% |

Raising the Gwydir Highway creates additional storage in the floodplain upstream of South Grafton. Therefore, whilst levee overtopping volumes have notably increased, the peak flood levels in South Grafton have reduced. The reduced length of levee raising, in comparison with Option 2, means that peak river levels are lower than for Option 2. At Carrs Island there is still a residual impact in the form of increased flood levels with the largest increases predicted at 0.06m in the 20 year ARI event and increases of 0.05m in the 100 year ARI event.

Mitigation Option 4 offers significant benefits to Grafton and South Grafton, over and above the mitigation of the impacts from the additional bridge crossing.

Peak levels are reduced in Grafton in the 50 year ARI by up to 0.41m. In South Grafton the raised levee and highway prevent floodwater inundating the town in the 50 year ARI. This compares to flood depths of up to 0.56m in the baseline (existing) conditions.

Ponding to the north of the raised highway increases the 50 and 100 year ARI peak water levels in the floodplain near Waterview Heights by 0.93m and 0.76m respectively with corresponding peak flood elevations of 6.6mAHD and 7.7mAHD. Development in Waterview Heights is typically above an elevation of 10mAHD and so is not predicted to be affected by the increase in flood level. Highly localised increases in velocity are predicted as water overtops the raised road. Energy dissipation measures such as riprap should be considered as part of the road raising to manage the increases in velocity.

For both Grafton and South Grafton minor increases in flood level are predicted for a PMF event. Minor increases of less than 0.05m are predicted near Waterview Heights in the PMF event. It is not considered necessary to offset this minor impact for an event of such rarity, especially when the baseline flood depths would most likely result in properties being so badly damaged that they would need to be replaced.

Minor increases in flood hazard will result where the depth has increased, particularly for the area to the north of the raised highway. No increases in flood hazard are predicted for the urban areas of Grafton and South Grafton. In both Grafton and South Grafton, the duration of flooding is marginally reduced following the implementation of Option 4 and the frequency of flooding will similarly be marginally reduced.

No impacts have been identified on planned infrastructure listed in Table 4-2. The proposed Pacific Highway upgrade is a significant distance downstream from the crossing and no downstream impacts have been predicted for any assessed event. The two planned developments in South Grafton are located outside the extent of the 50 year ARI flood but are potentially affected in the

100 year ARI event. However, the assessment has shown that the mitigation measures included in Option 4 result in lower flood levels at the locations of these developments for this event.

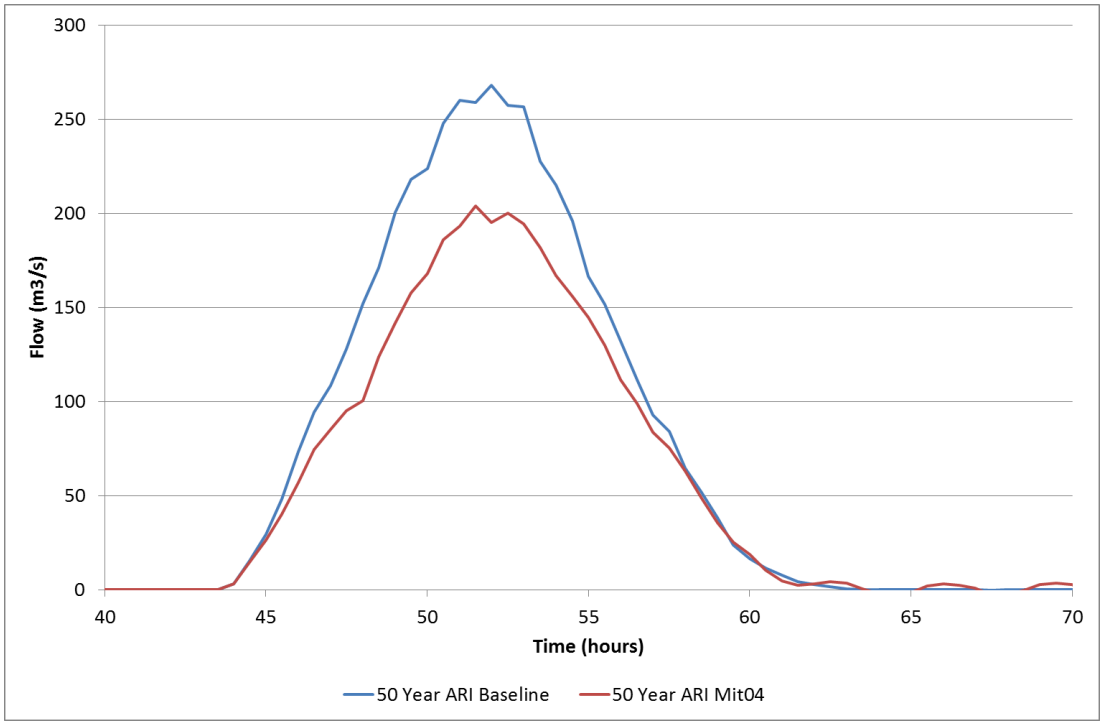



**Figure 5-16 North Grafton levee overtopping flow (50 year ARI)**

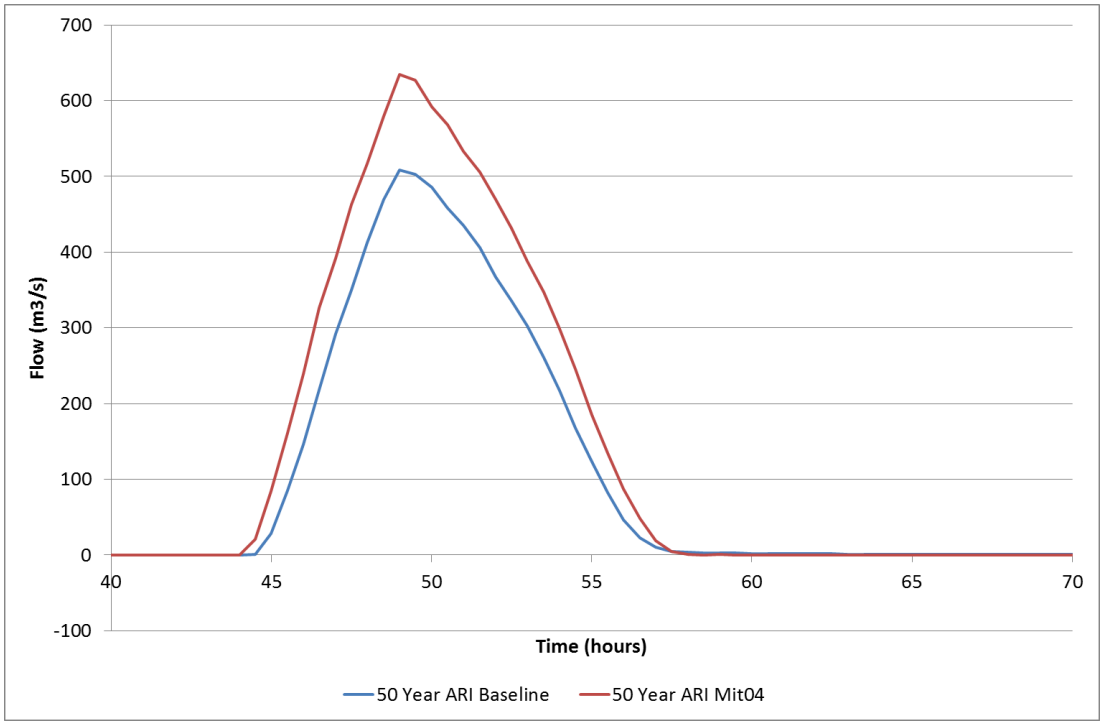



**Figure 5-17 South Grafton levee overtopping flow (50 year ARI)**

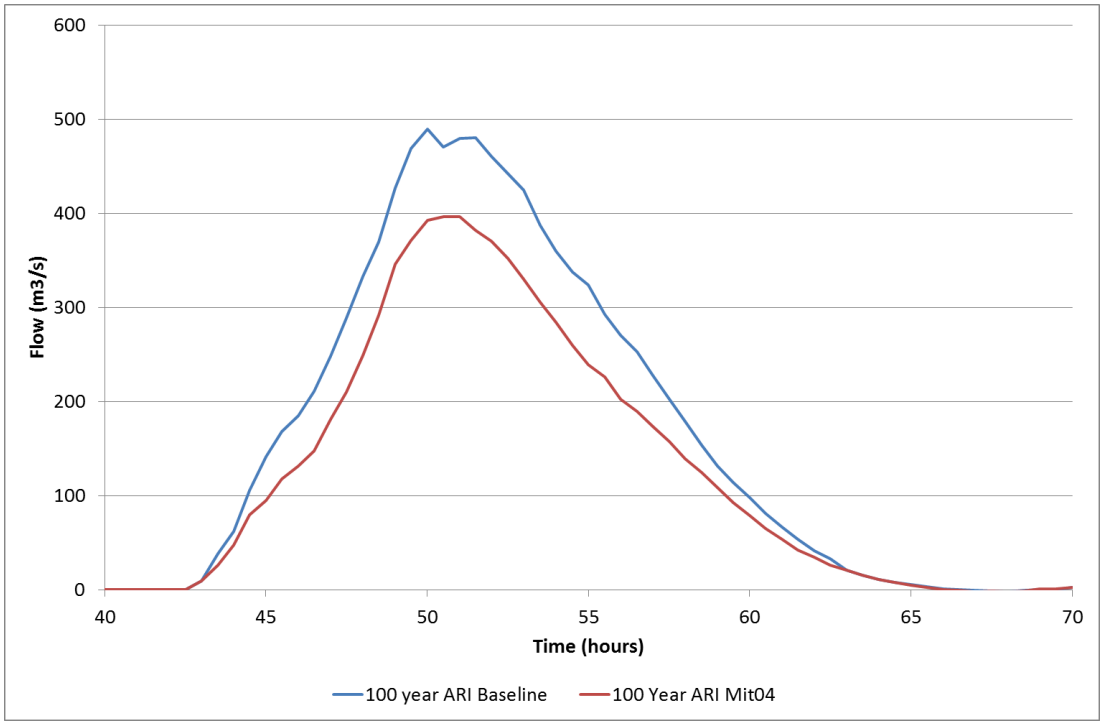



**Figure 5-18 North Grafton levee overtopping flow (100 year ARI)**

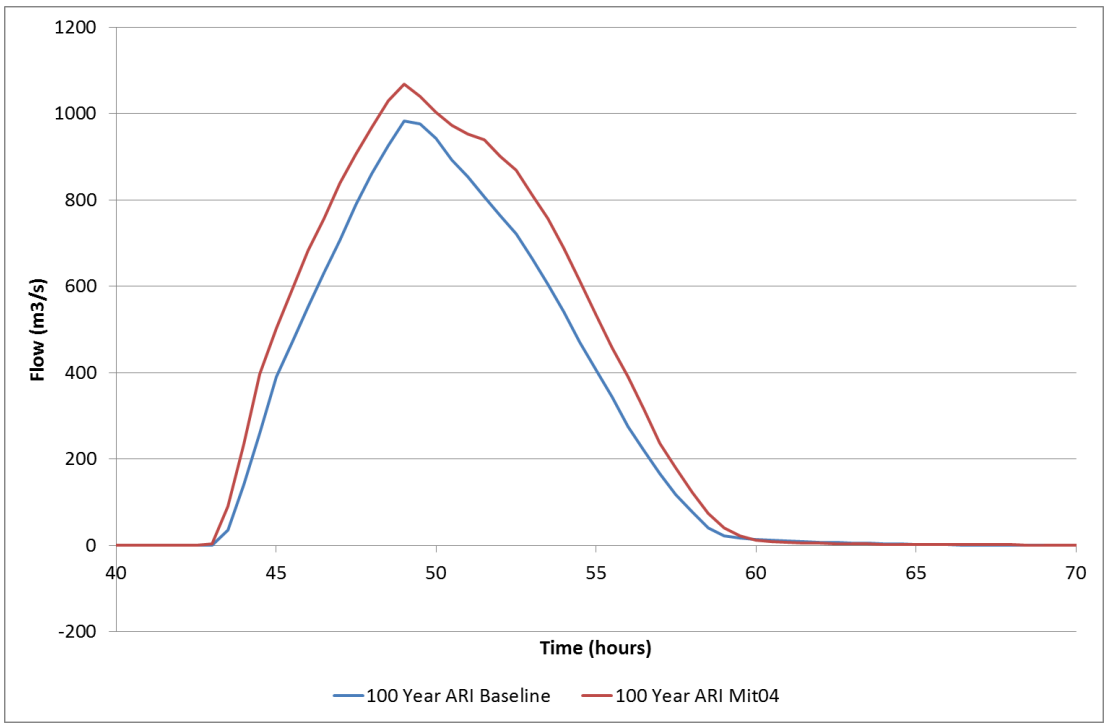



**Figure 5-19 South Grafton levee overtopping flow (100 year ARI)**

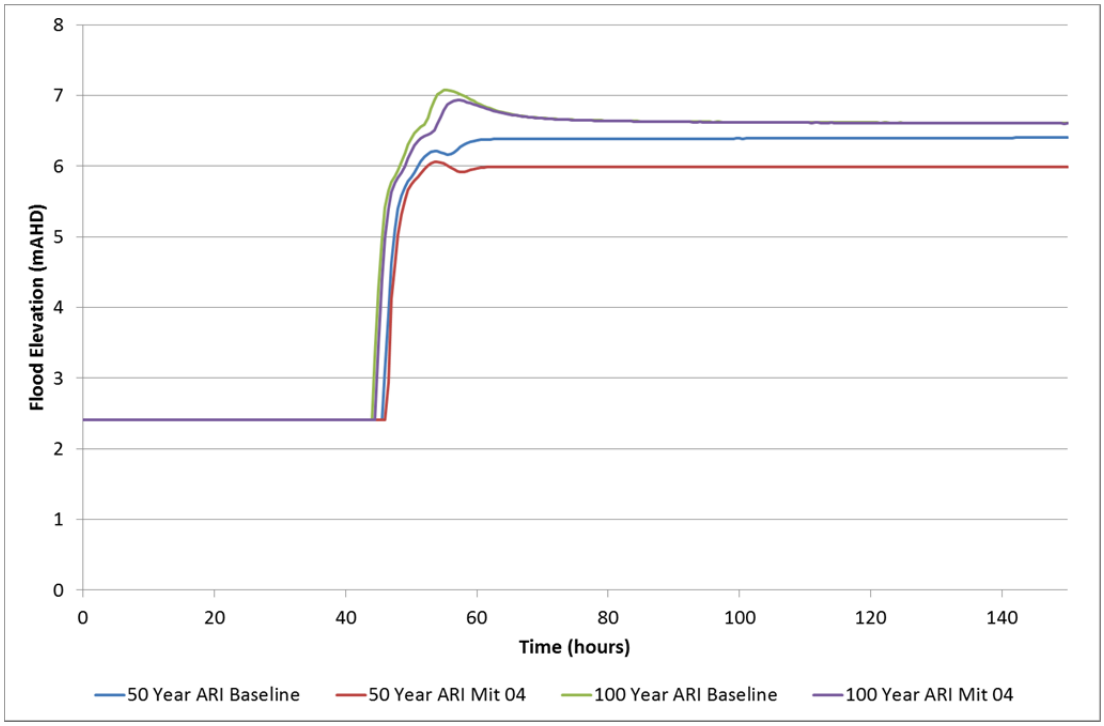



**Figure 5-20 Pound Street, North Grafton, design flood elevations, Option 4**

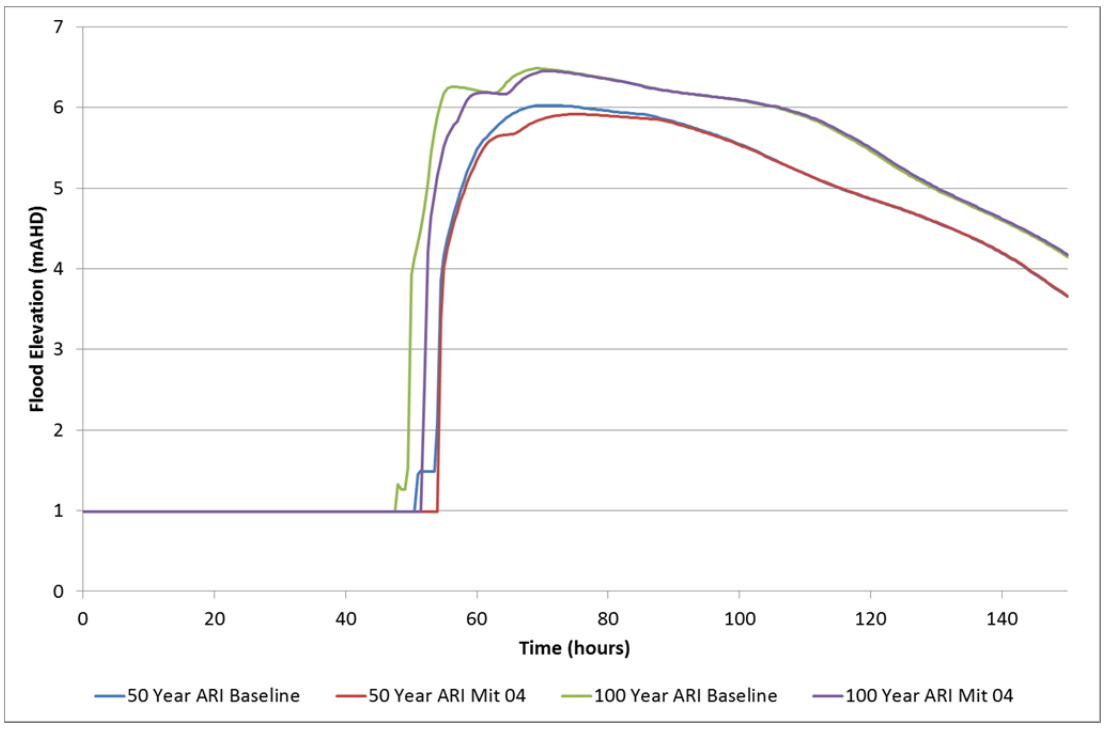



**Figure 5-21 Alumy Creek (Fry St), North Grafton, design flood elevations, Option 4**

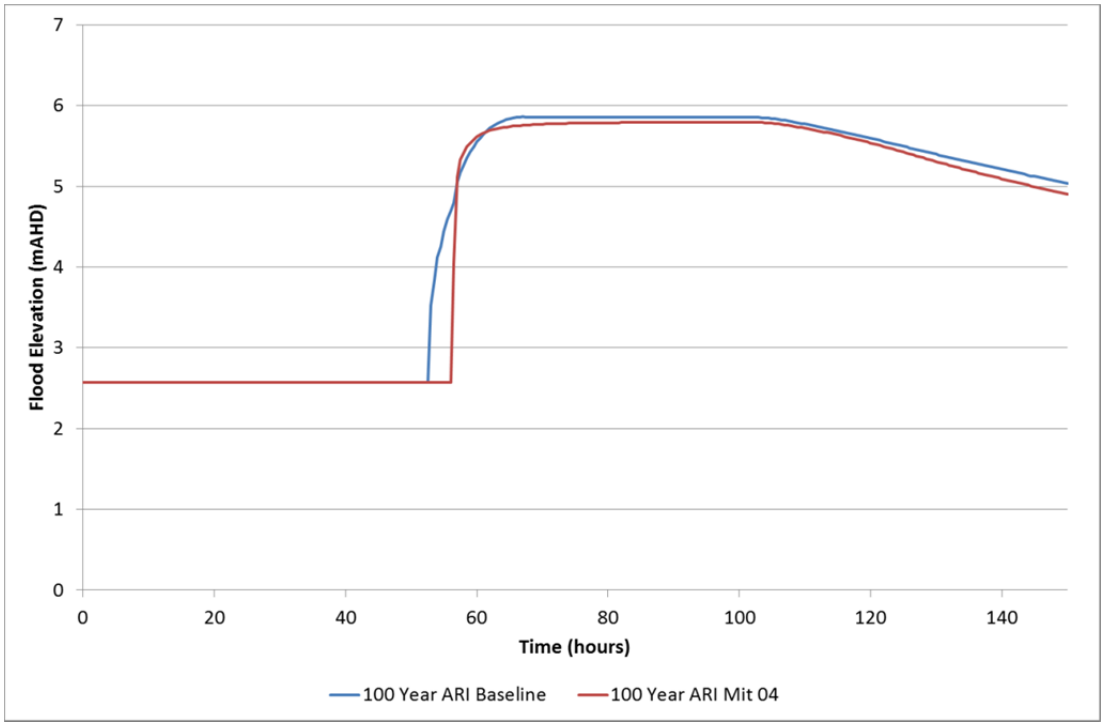



**Figure 5-22 Near Wharf St, South Grafton, design flood elevations, Option 4[7]**

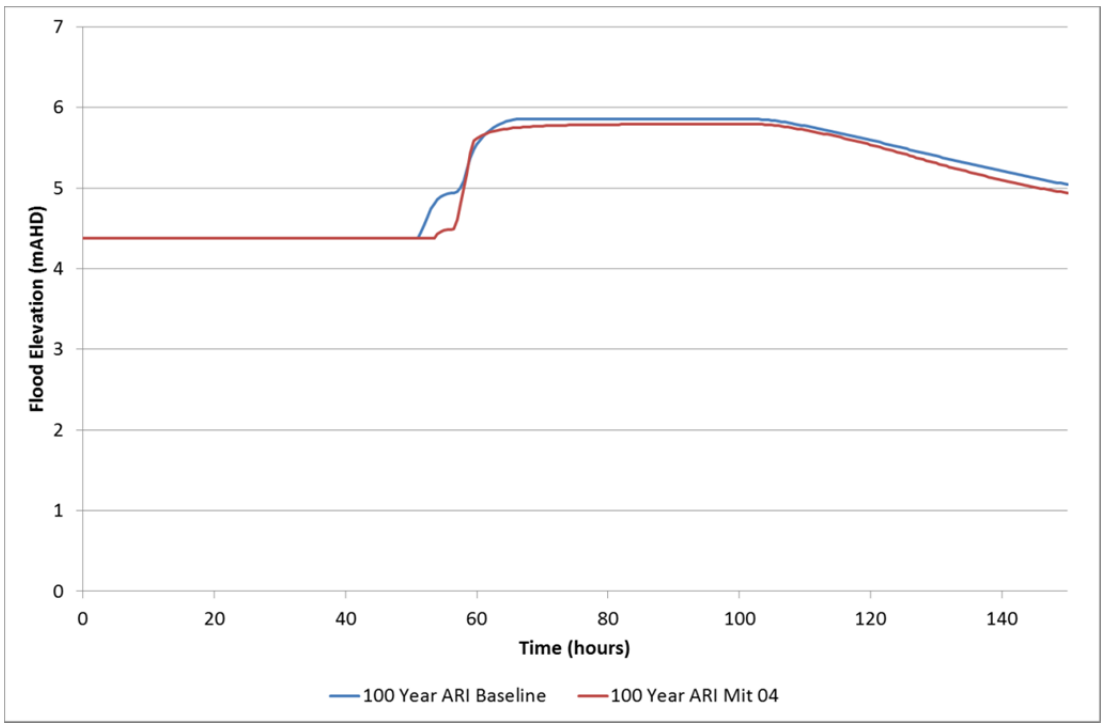
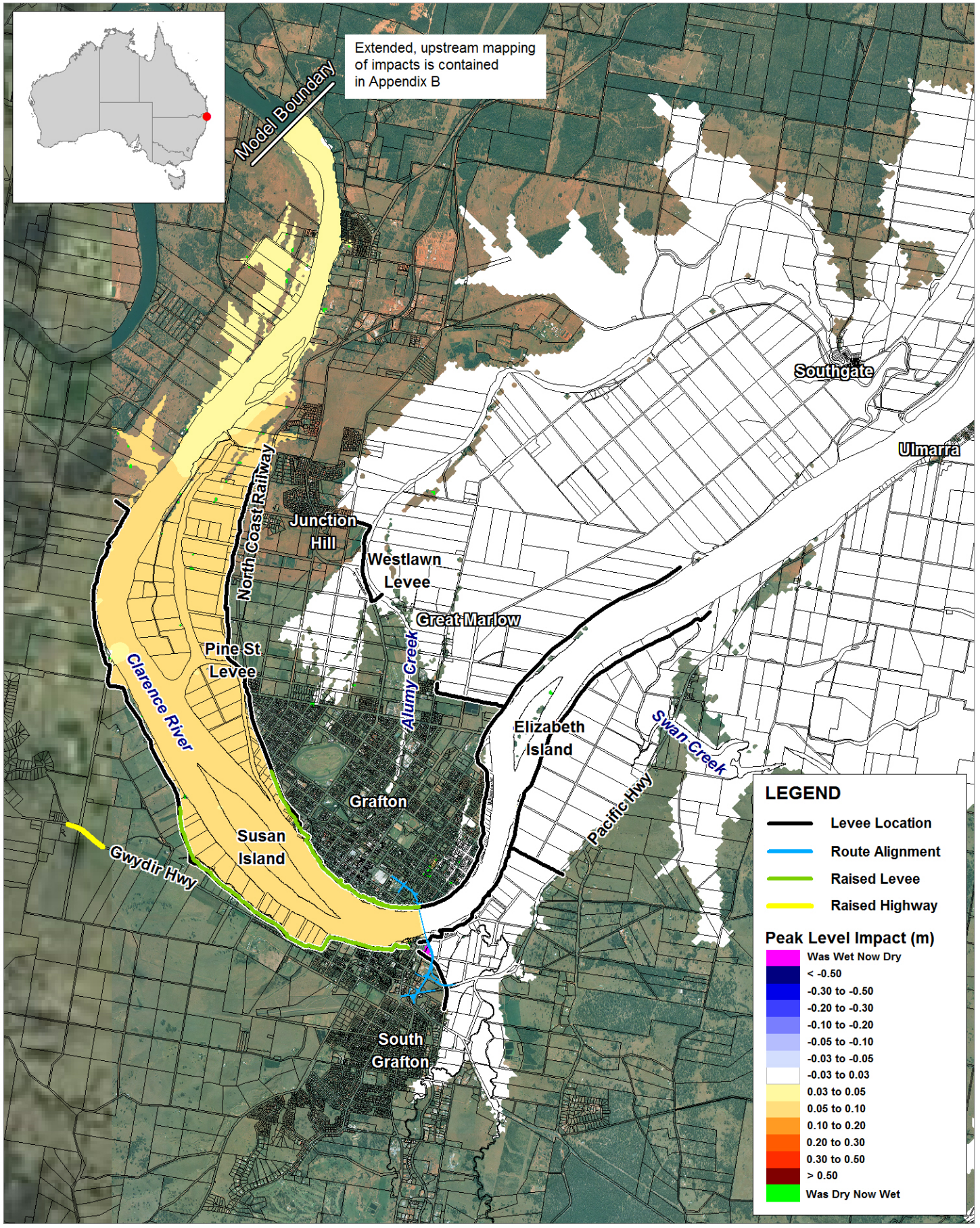



**Figure 5-23 Iolanthe St, South Grafton, design flood elevations, Option 4[6]**

[7] No flooding at this location in the 50 year ARI event




Title:

# Peak Flood Level Impact 20 Year ARI Event Additional Crossing (Mitigation Option 4)

Figure: **5-24**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

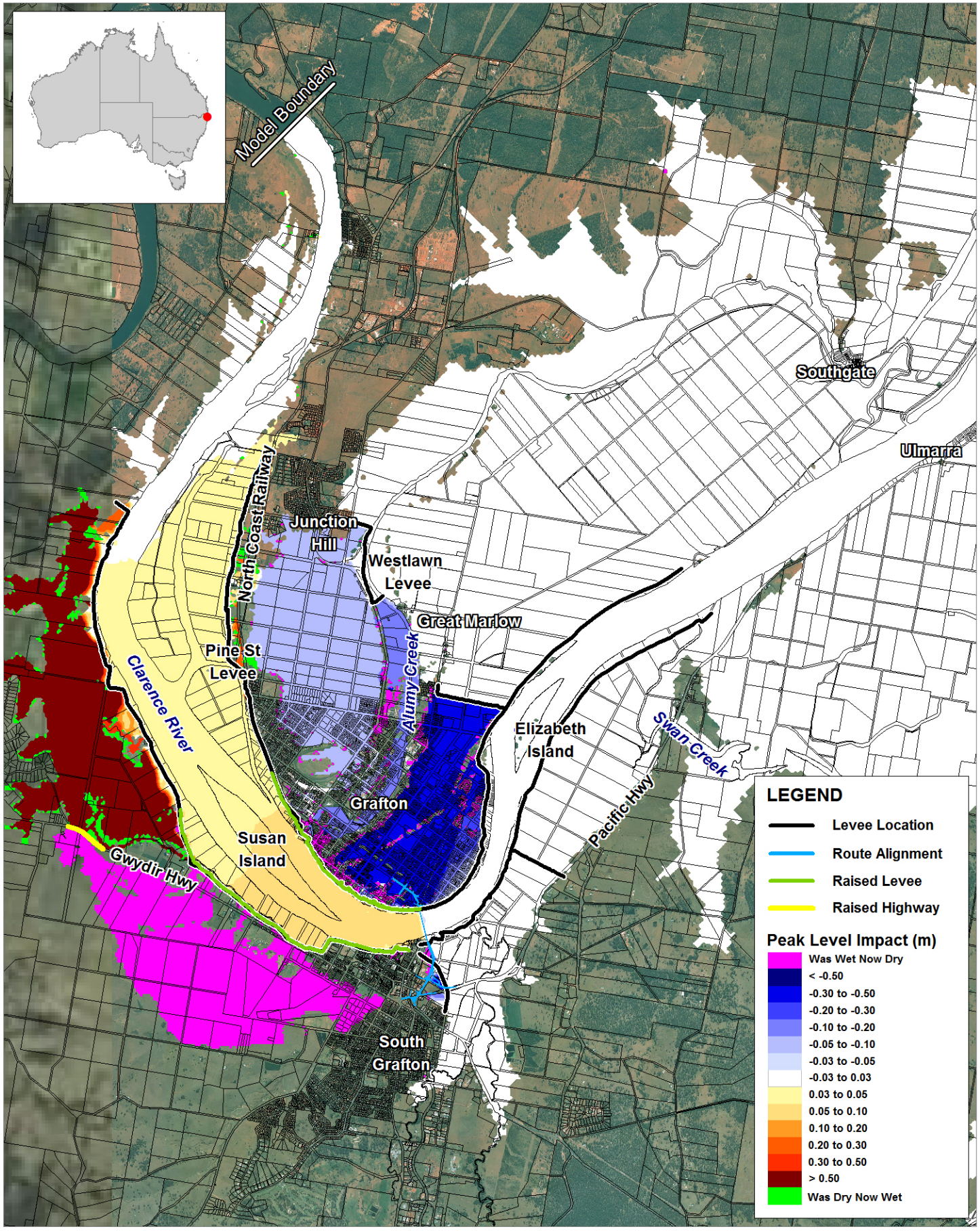
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_033_140122_Q020_Mit04_Hdiff.wor"




Title:

# Peak Flood Level Impact 50 Year ARI Event Additional Crossing (Mitigation Option 4)

Figure: **5-25**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

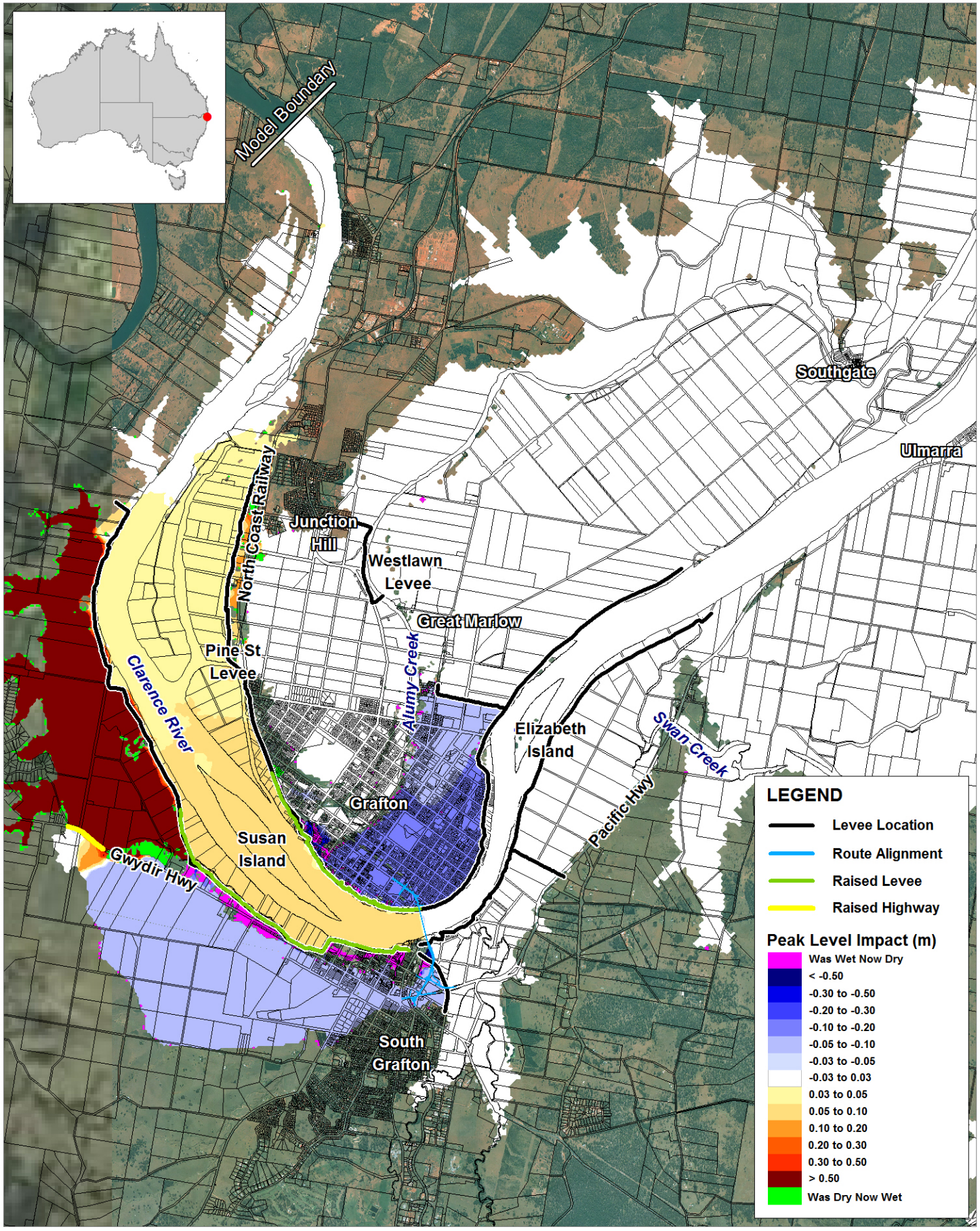
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_034_140122_Q050_Mit04_Hdiff.wor"




Title:

# Peak Flood Level Impact 100 Year ARI Event Additional Crossing (Mitigation Option 4)

Figure: **5-26**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

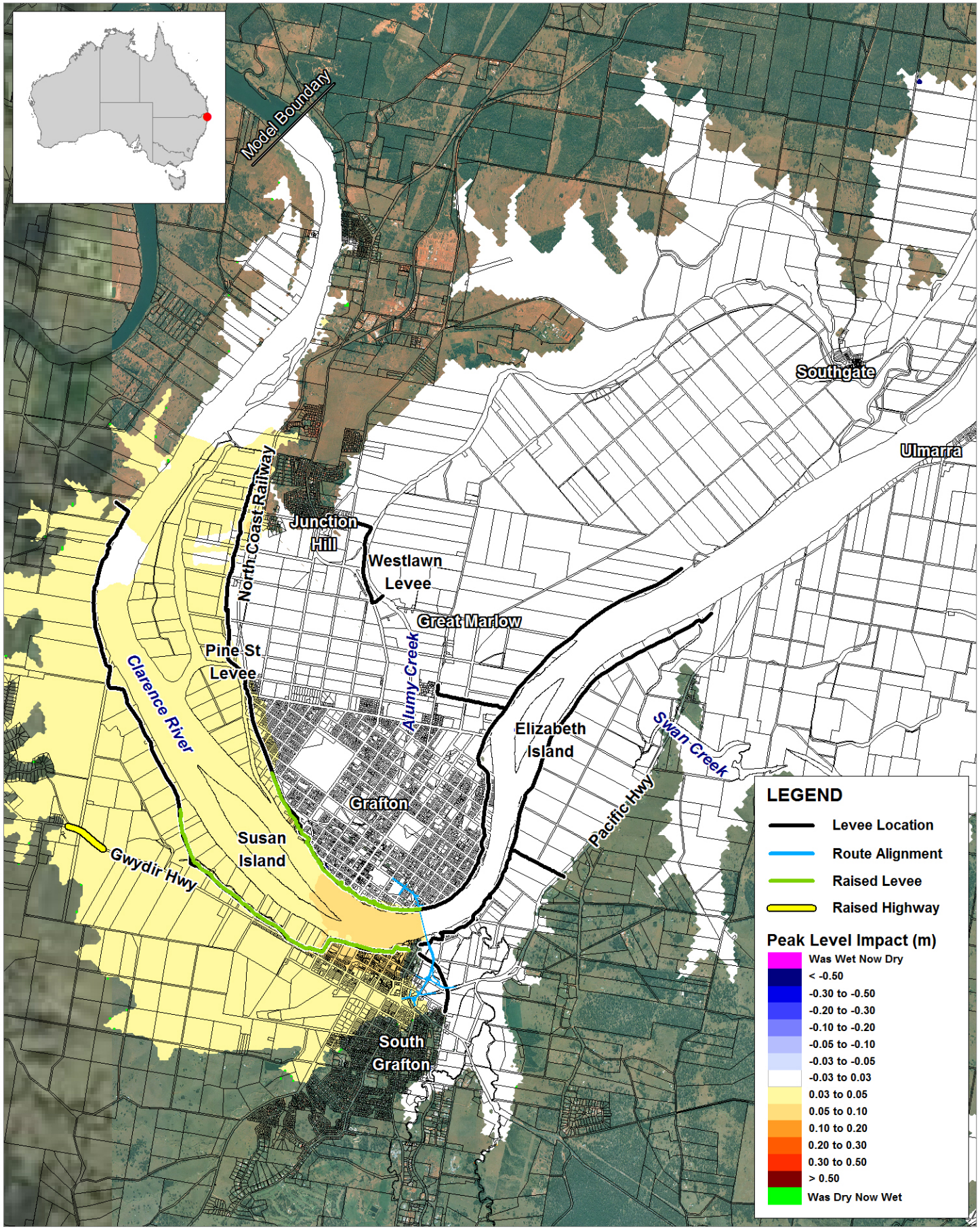
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_035_140122_Q100_Mit04_Hdiff.wor"




Title:

# Peak Flood Level Impact PMF Event Additional Crossing (Mitigation Option 4)

Figure: **5-27**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

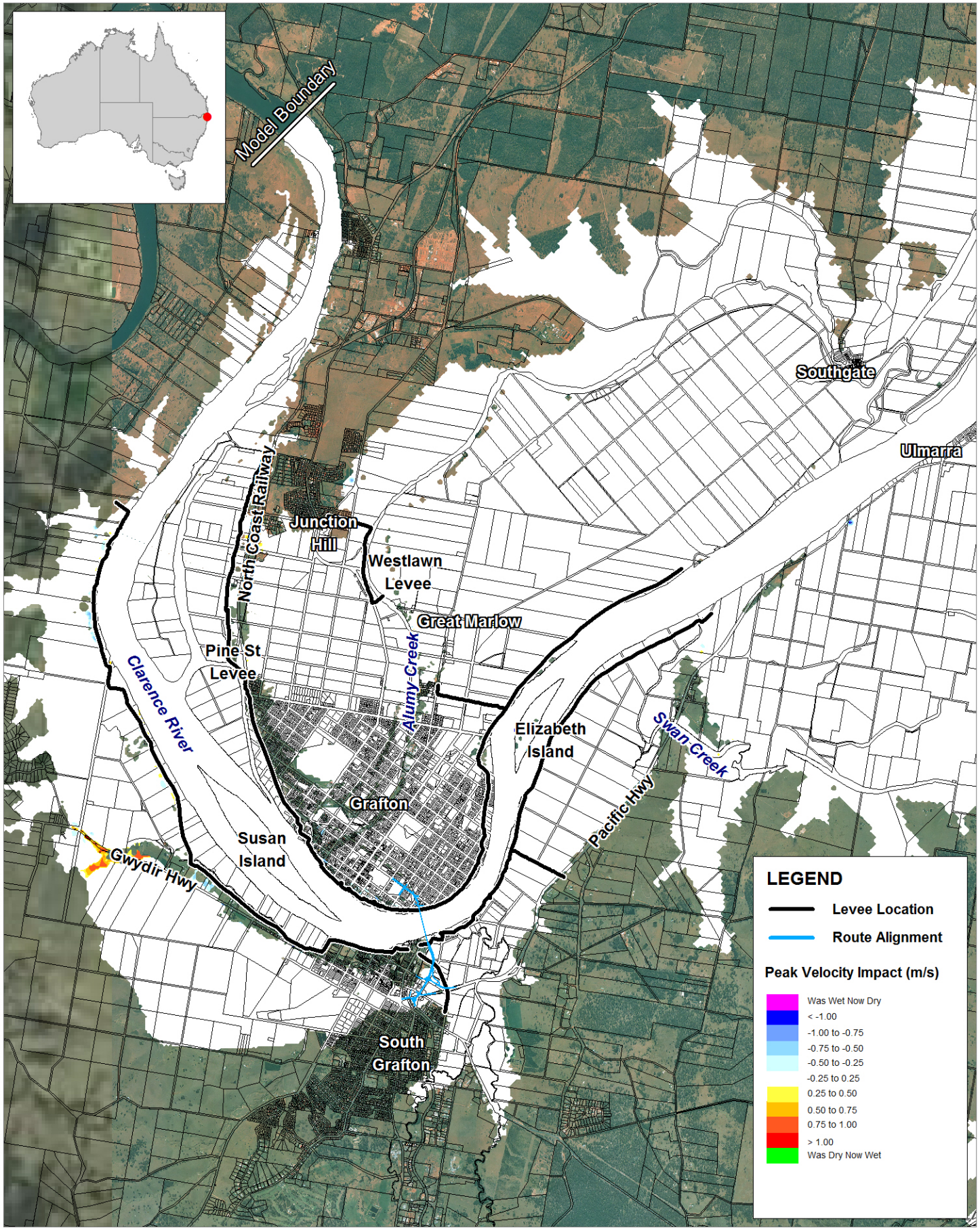
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_036_140122_QPMF_Mit04_Hdiff.wor"




Title:

# Peak Flood Velocity Impact 100 Year ARI Event Additional Crossing (Mitigation Option 4)

Figure: **5-28**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_060_140310_Q100_Mit04_Vdiff.wor"

## 5.7 Flood impact assessment conclusions

Two mitigation options, Option 2 and Option 4, were shown to mitigate the majority of the flood impact resulting from the additional crossing to Grafton and South Grafton. In both options residual impacts remain to properties located outside the zone of protection afforded by the levees. The majority of these properties are located on Carrs Island.

Section 6 further considers the risk and additional mitigation measures for properties in locations of remaining residual risk.

# 6 Residual flood risk

## 6.1 Introduction

Residual flood risk is considered to be the remaining flood risk after a scheme or measure has been put in place. This may consist of risk to properties outside of the schemes influence, risk of an event occurring larger than that for which the scheme was designed, or flood risk as a result of scheme infrastructure failing.

Mitigation measures considered in this report are designed to offset any predicted flood impacts associated with the additional crossing, rather than any whole scale mitigation scheme to improve the flood risk to Grafton and South Grafton. An assessment of the structural failure of the levee is therefore beyond the scope of this assessment. The (residual) risk of the levee overtopping has been assessed in Section 5.

The remainder of this section assesses the increase in residual flood risk to properties located outside of the zone influence of the respective mitigation option as a result of the additional crossing.

## 6.2 Additional mitigation

For the majority of flood events Mitigation Options 2 and 4 both decrease the overall level of flood risk in Grafton and South Grafton. However residual impacts remain to properties located in areas outside of the levees and for events in excess of the 20 year ARI event. Estimated numbers of affected properties are summarised in Table 6-1.

**Table 6-1 Number of properties potentially affected by residual impacts in events up to the 100 year ARI**

| Mitigation Option | Number of Properties with Remaining Impacts | Comments |
|---|---|---|
| 2 | 45 | Majority located on Carrs Island/Peninsula<br>Four properties within the levee potentially affected in the 50 year ARI |
| 4 | 58 | Majority located on Carrs Island/Peninsula<br>Thirteen properties potentially affected on land north of raised Gwydir Highway |

Figure 6-1 shows the locations of properties potentially affected by residual impacts (i.e. those impacts which remain after the main mitigation measures are implemented).

It can be seen from Figure 6-1 that the majority of properties potentially subject to residual impacts are located on Carrs Island/Peninsula. The properties identified are expected to incur increases in flood levels following the construction of the additional bridge crossing (and Mitigation Option 2 or 4). From the impact maps contained in Section 5 it can be seen that the predicted impacts

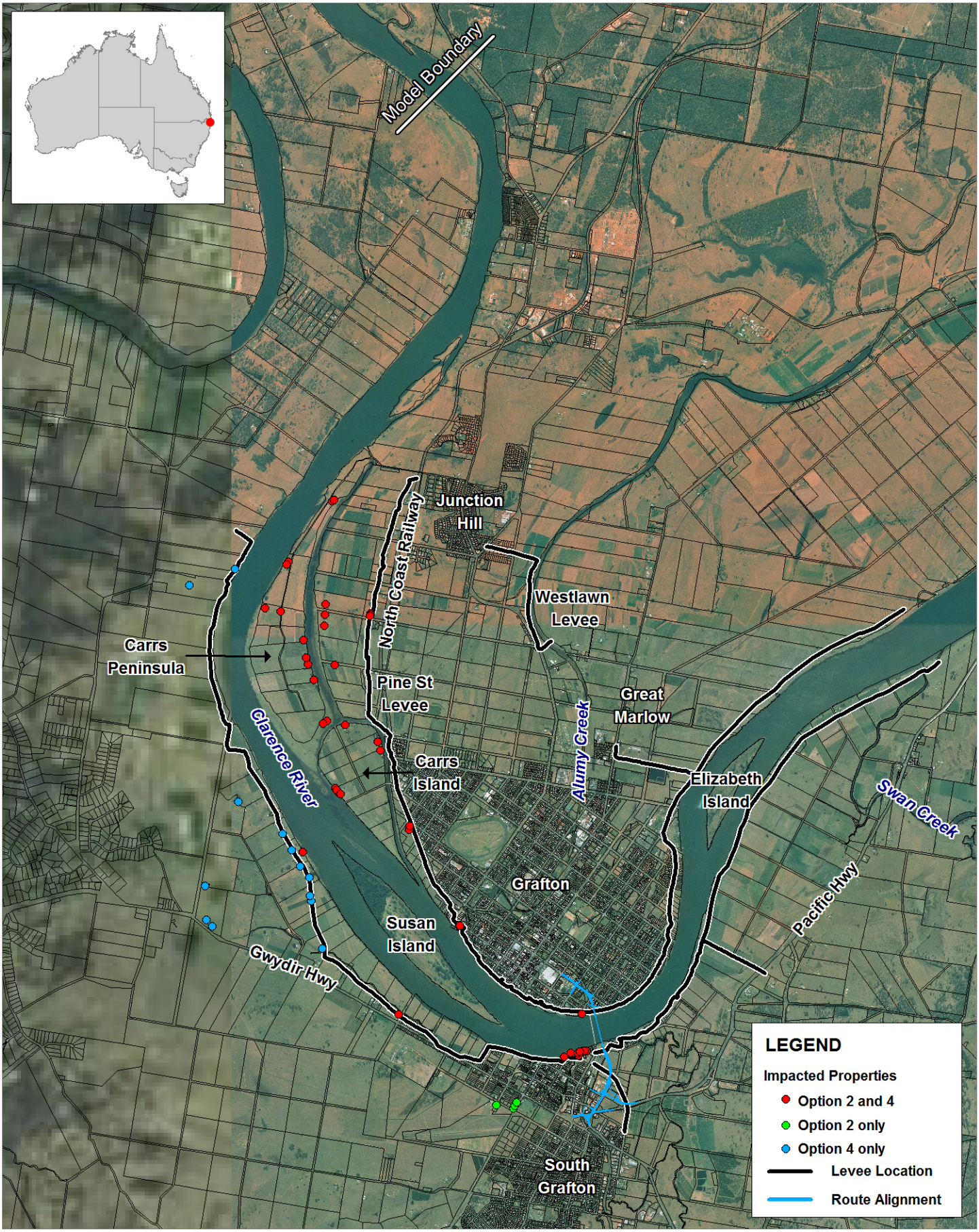
(increases in flood levels) at Carrs Island / Peninsula typically range between 0.03m and 0.10m for all modelled events.

It is recommended that a floor level survey is undertaken of the identified properties shown in Figure 6-1 to establish the relative impact to each property. This will allow the property specific risk to be better understood and can form the basis of any discussion regarding further mitigation options for the property with the property owner.

### 6.2.1 Summary of additional mitigation

Mitigation Option 2 which involves augmenting and extending the lengths of levees within Grafton and South Grafton would also require consultation with an estimated 45 property owners to determine further mitigation options for residual impacts from the increased flood levels.

Mitigation Option 4 which involves augmenting and extending the lengths of levees within Grafton and South Grafton along with raising the Gwydir Highway would require consultation with an estimated 58 property owners to determine further mitigation options for residual impacts from the increased flood levels.




Title:

# Properties potentially affected by residual impacts Mitigation Options 2 and 4

Figure: 6-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_061_140312_Residual_Impacts.wor"

# 7 Climate change considerations

## 7.1 Introduction

Future climate change can potentially affect flood behaviour through:

- Increased sea levels; and
- Increased severity of storms and other weather systems.

The NSW Government announced its Stage One Coastal Management Reforms on 8 September 2012. As part of these reforms the NSW Government no longer recommends state-wide sea level rise benchmarks for use by local councils. Previously the NSW sea level rise planning benchmarks were an increase above 1990 mean sea levels of 40cm by 2050 and 90cm by 2100. The reforms allow councils to have the flexibility to consider local conditions when determining local future hazards. Due to the levees, Grafton and South Grafton are particularly sensitive to any factors which may result in changes to the baseline water levels within the Clarence River. Future sea level rise is one such factor which has the potential to increase the rate and frequency of inundation within the towns. Sea level rise has therefore been modelled as a sensitivity check on predicted flood levels. Both the 2050 and 2100 scenarios have been assessed (ocean boundary increases of 0.4m and 0.9m respectively).

Climate change also has the potential to impact on rainfall. Evidence to date suggests that whilst mean annual rainfall over Australia is likely to reduce, the intensity of extreme daily rainfall could increase. The CSIRO predicts the effects of climate change to result in increases in rainfall of up to 12% by 2070 (CSIRO, February 2007).

As part of this study, a sensitivity assessment was also undertaken on the potential impact of 10% and 20% increases in rainfall intensity combined with the sea level rise, as suggested in a letter from the Office of Environment and Heritage responding to the DGRs. In summary two future climate scenarios have been modelled:

- 2050 Climate: 0.4m rise in sea level and 10% increase in rainfall intensity; and
- 2100 Climate: 0.9m rise in sea level and 20% increase in rainfall intensity.

The 20 and 100 year average recurrence interval (ARI) events were used as the basis of the sensitivity assessment with levels compared for a future baseline and developed case (with mitigation) scenarios.

## 7.2 Results

### 7.2.1 Change to baseline conditions

Under a 2050 climate scenario, baseline peak water levels in the Clarence River at Grafton for a 20 year ARI event increase by between 0.2m and 0.3m compared with an existing climate scenario. During a 100 year ARI event the change is less pronounced, but the 100 year ARI peak levels still increase by between 0.1m and 0.15m. The increases result in a significant additional overtopping of the levees into Grafton and South Grafton leading to increased flooding within the towns. In Grafton, this is most notable for the 20 year ARI event, in which floodwaters under an existing

climate are largely excluded from urban areas by the levees but which are overtopped under a future climate.

Peak river levels at Grafton increase further still under a 2100 future climate with increases typically between 0.4m and 0.5m for both the 20 and 100 year ARI events.

Figure 7-1 and Figure 7-2 map the differences in peak flood levels between an existing climate scenario and the 2050 and 2100 climate scenarios respectively for a 20 year ARI event. Figure 7-3 and Figure 7-4 present the differences in peak flood levels for the 100 year ARI event. The differences are obtained by deriving the increase in peak level from an existing, present climate. Summary tables of the impacts are presented in Table 7-2 and Table 7-2 for the 20 and 100 year ARI events respectively. It should be noted that these impacts are all derived from a baseline (pre-development) stage.

**Table 7-1 Change in 20 Year peak flood levels due to climate change (existing case)**

| ARI / Climate Scenario | Change in peak flood level (m) Future climate (Baseline Case) minus existing climate (Baseline Case) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton[1] | South Grafton[2] |
| 20 Year ARI 2050 Climate | 0.27 | 0.25 | 0.45 | 0.00 |
| 20 Year ARI 2100 Climate | 0.42 | 0.38 | 1.68 | 2.95 |

1 Intersection of Pound Street and Prince Street. No flooding in baseline therefore increase in level is from ground level (5.40mAHD)

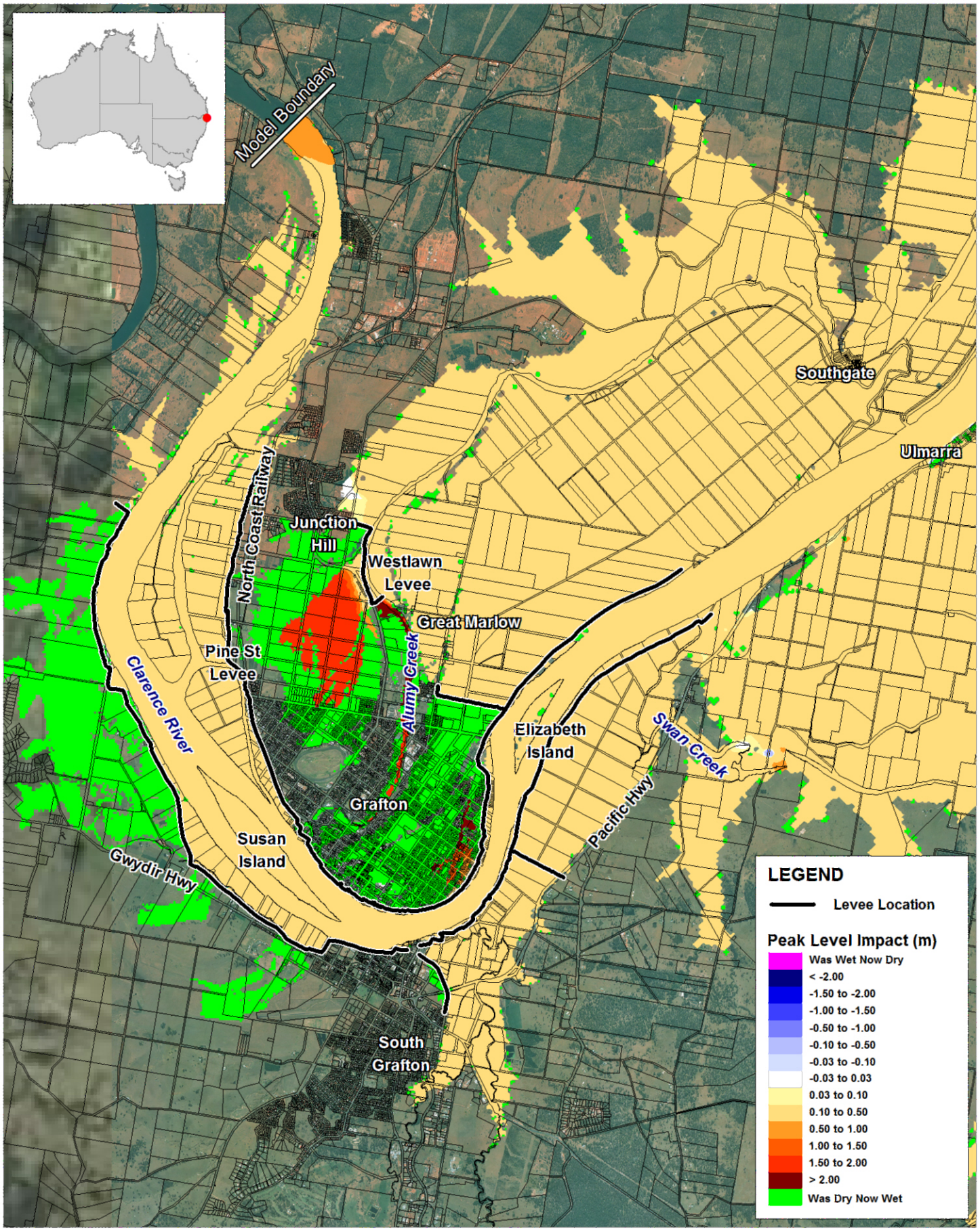
2 Intersection of Abbott Street and Vere Street. No flooding in baseline therefore increase in level is from ground level (3.27mAHD)

**Table 7-2 Change in 100 year peak flood levels due to climate change (existing case)**

| ARI / Climate Scenario | Change in peak flood level (m) Future climate (Baseline Case) minus existing climate (Baseline Case) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton[1] | South Grafton[2] |
| 100 Year ARI 2050 Climate | 0.10 | 0.13 | 0.36 | 2.79 |
| 100 Year ARI 2100 Climate | 0.47 | 0.49 | 0.98 | 3.30 |

1 Intersection of Pound Street and Prince Street

2 Intersection of Abbott Street and Vere Street




Title:

# Change in Peak Baseline Levels
# 20 Year ARI Event (Future Climate 2050)

Figure: **7-1**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

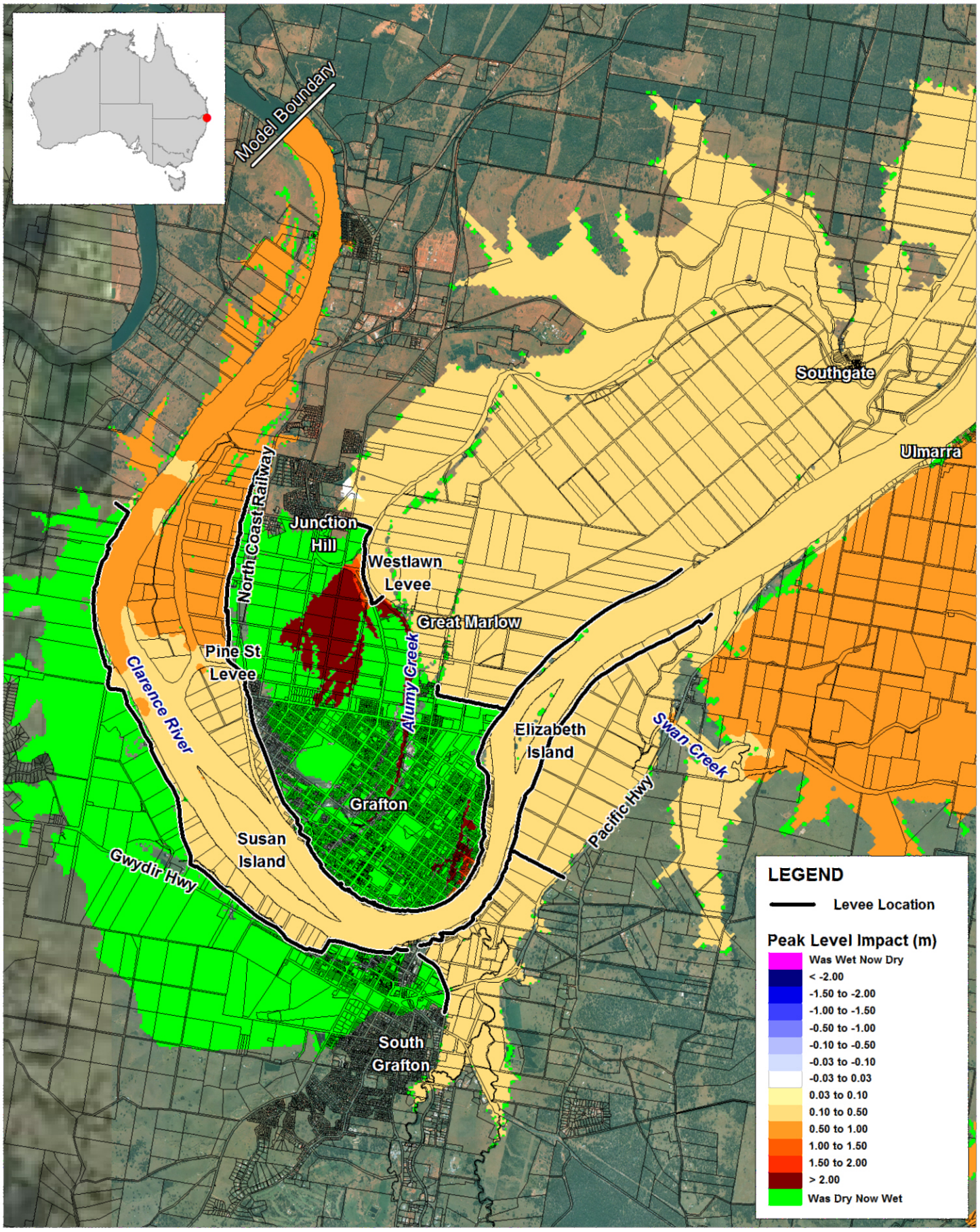
N

0km 1.5 3

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_051_140206_Q20_CC10S40_Base_Base_Hdiff.wor"




Title:

# Change in Peak Baseline Levels
# 20 Year ARI Event (Future Climate 2100)

Figure: 7-2

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

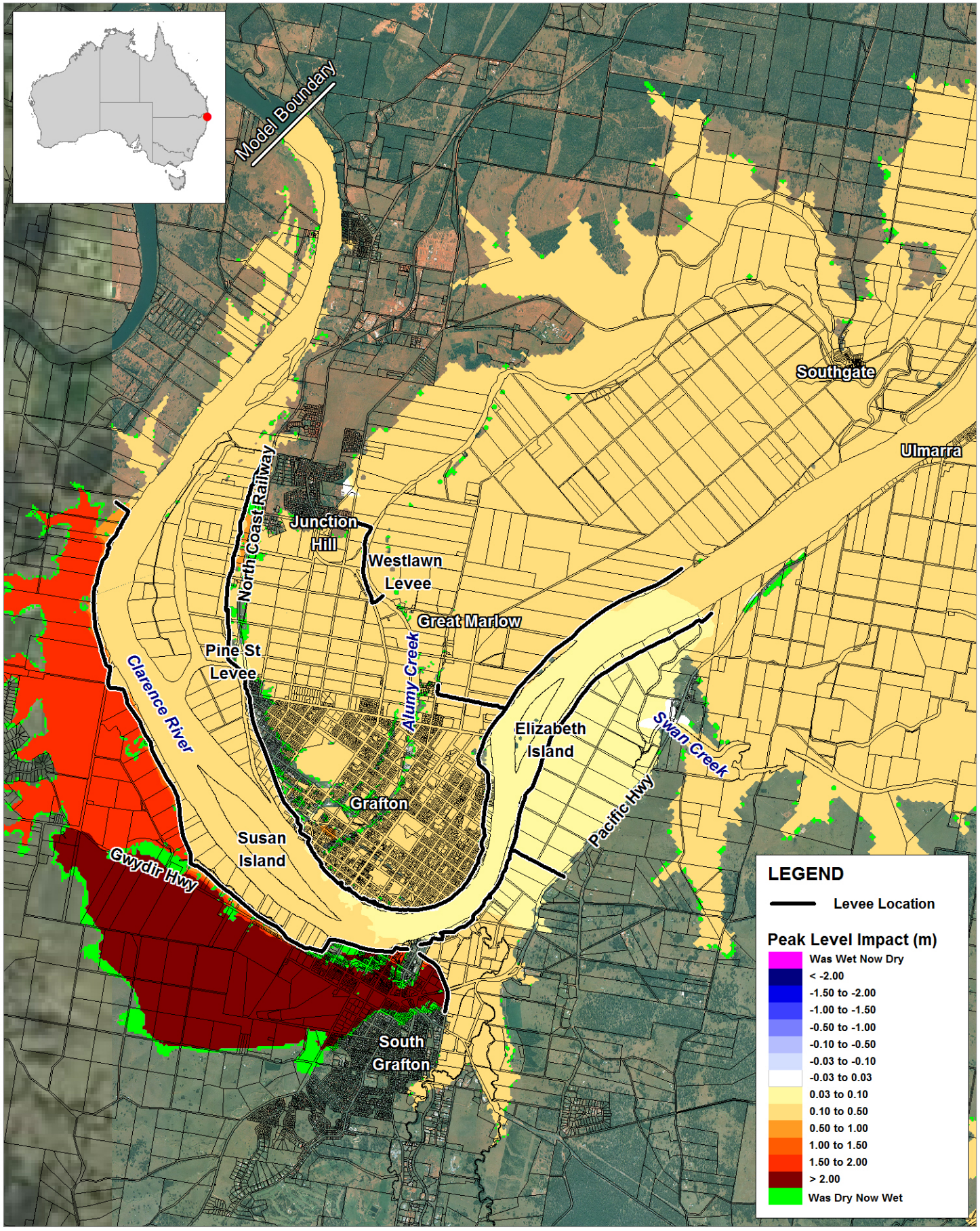
N

0km 1.5 3

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_052_140206_Q20_CC20S90_Base_Base_Hdiff.wor"




Title:

# Change in Peak Baseline Levels
# 100 Year ARI Event (Future Climate 2050)

Figure: **7-3**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

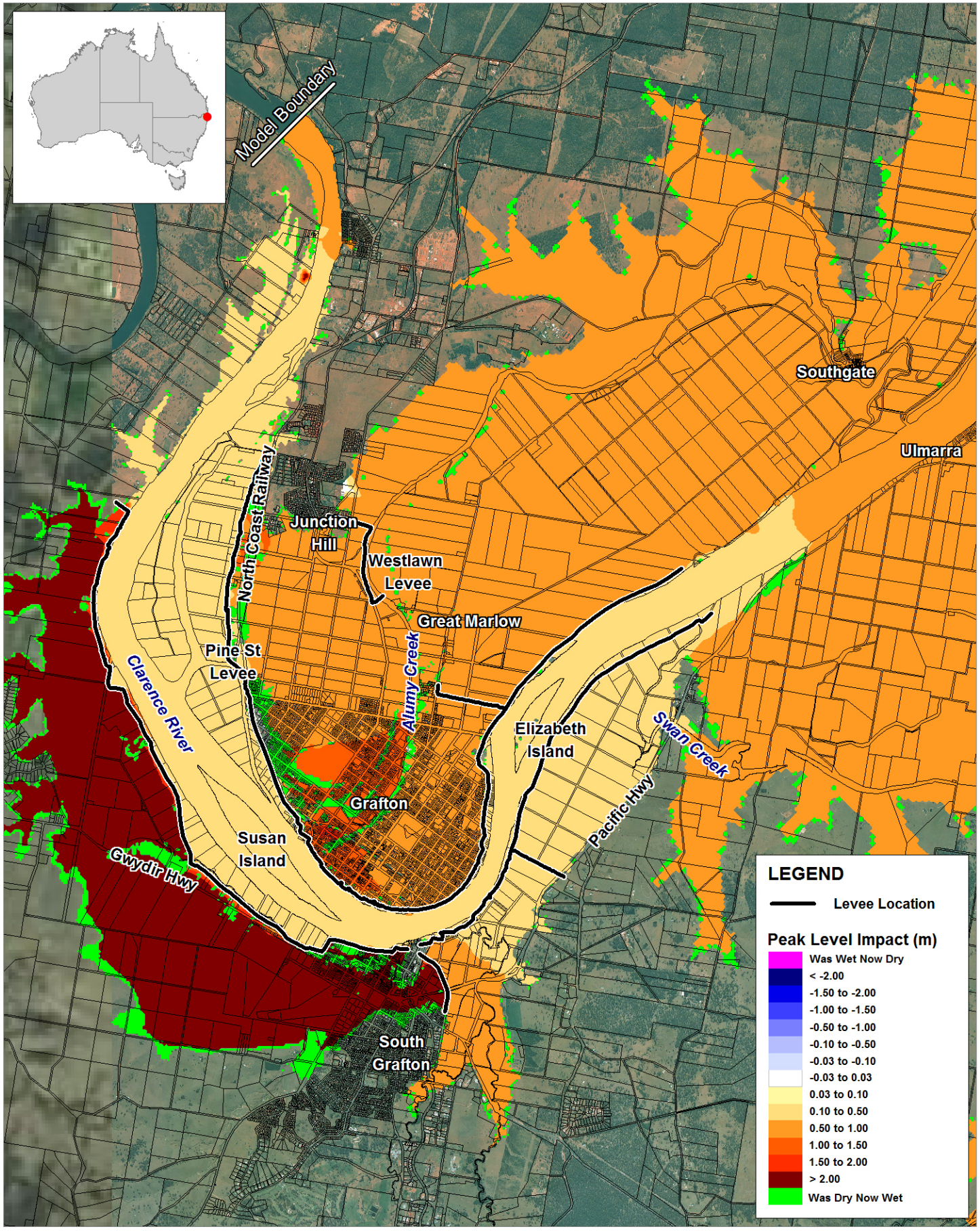
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_037_140122_Q100_CC10S40_Base_Base_Hdiff.wor"




Title:

# Change in Peak Baseline Levels
# 100 Year ARI Event (Future Climate 2100)

Figure: **7-4**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_038_140122_Q100_CC20S90_Base_Base_Hdiff.wor"

### 7.2.2 Impacts of the proposed project under a future climate

The potential changes in flood impacts due to climate change were measured by comparing the change in peak flood levels for the proposed project (with mitigation) under the existing climate with the forecast change in peak flood levels for the proposed project (with mitigation) under the 2050 and 2100 climate scenario. Changes in peak flood levels for each climate scenario are summarised in Table 7-3 to Table 7-10 at the specific reporting locations shown in Figure 2-1. Changes in peak flood levels were determined for both the 20 year and 100 year ARI flood events.

Figure 7-5 to Figure 7-12 present the resulting impact maps for mitigation options 2 and 4 under a 2050 and 2100 climate.

**Table 7-3 Change in 20 year peak flood levels due to development (Mitigation Option 2) under a future 2050 climate**

| Climate scenario | Change in peak flood level (m) Developed Case (future climate) minus Baseline Case (future climate) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton | South Grafton |
| Development Impacts for existing climate | 0.06 | 0.07 | 0.00 | 0.00 |
| Development Impacts for 2050 climate | 0.07 | 0.08 | -0.09 | 0.00 |

**Table 7-4 Change in 20 Year peak flood levels due to development (Mitigation Option 2) under a future 2100 climate**

| Climate scenario | Change in peak flood level (m) Developed Case (future climate) minus Baseline Case (future climate) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton | South Grafton |
| Development Impacts for existing climate | 0.06 | 0.07 | 0.00 | 0.00 |
| Development Impacts for 2100 climate | 0.09 | 0.09 | -0.07 | -0.14 |

**Table 7-5 Change in 100 year peak flood levels due to development (Mitigation Option 2) under a future 2050 climate**

| Climate scenario | Change in peak flood level (m) Developed Case (future climate) minus Baseline Case (future climate) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton | South Grafton |
| Development Impacts for existing climate | 0.09 | 0.09 | -0.07 | -0.11 |
| Development Impacts for 2050 climate | 0.10 | 0.09 | -0.04 | -0.15 |

**Table 7-6 Change in 100 year peak flood levels due to development (Mitigation Option 2) under a future 2100 climate**

| Climate scenario | Change in peak flood level (m) Developed Case (future climate) minus Baseline Case (future climate) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton | South Grafton |
| Development Impacts for existing climate | 0.09 | 0.09 | -0.07 | -0.11 |
| Development Impacts for 2100 climate | 0.05 | 0.06 | -0.07 | 0.06 |

**Table 7-7 Change in 20 year peak flood levels due to development (Mitigation Option 4) under a future 2050 climate**

| Climate scenario | Change in peak flood level (m) Developed Case (future climate) minus Baseline Case (future climate) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton | South Grafton |
| Impacts for existing climate | 0.06 | 0.07 | 0.00 | 0.00 |
| Impacts for 2050 climate | 0.06 | 0.06 | -0.14 | 0.00 |

**Table 7-8 Change in 20 year peak flood levels due to development (Mitigation Option 4) under a future 2100 climate**

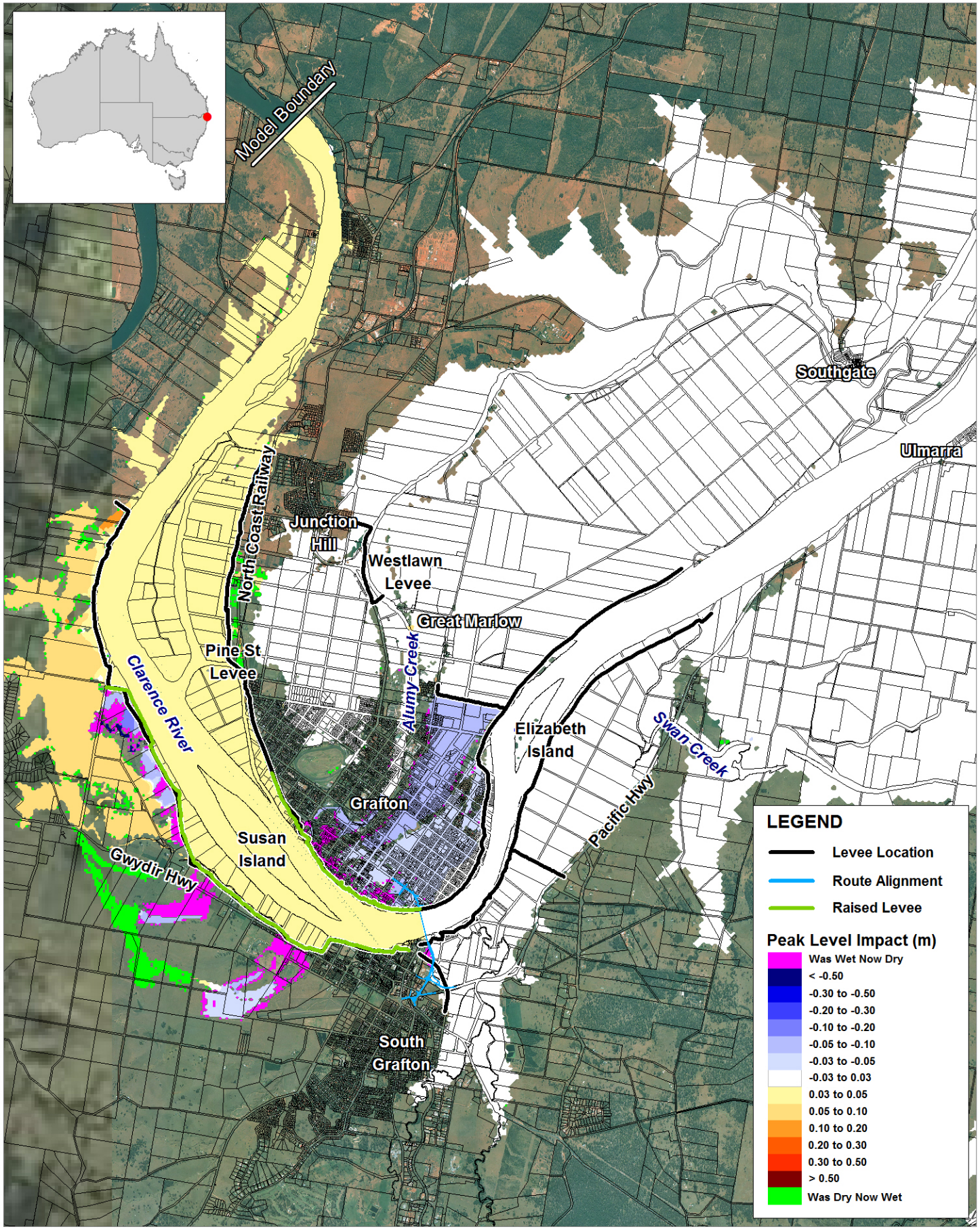
| Climate scenario | Change in peak flood level (m) Developed Case (future climate) minus Baseline Case (future climate) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton | South Grafton |
| Impacts for existing climate | 0.06 | 0.07 | 0.00 | 0.00 |
| Impacts for 2100 climate | 0.07 | 0.08 | -0.14 | 0.14 |

**Table 7-9 Change in 100 year peak flood levels due to development (Mitigation Option 4) under a future 2050 climate**

| Climate scenario | Change in peak flood level (m) Developed Case (future climate) minus Baseline Case (future climate) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton | South Grafton |
| Impacts for existing climate | 0.07 | 0.07 | -0.13 | -0.07 |
| Impacts for 2050 climate | 0.08 | 0.09 | -0.09 | 0.16 |

**Table 7-10 Change in 100 Year peak flood levels due to development (Mitigation Option 4) under a future 2100 climate**

| Climate scenario | Change in peak flood level (m) Developed Case (future climate) minus Baseline Case (future climate) | | | |
|---|---|---|---|---|
| | Prince St Gauge | Existing Grafton Bridge | Grafton | South Grafton |
| Impacts for existing climate | 0.07 | 0.07 | -0.13 | -0.07 |
| Impacts for 2100 climate | 0.07 | 0.08 | -0.04 | 0.08 |




Title:

# Peak Flood Level Impact 20 Year ARI Event Mitigation Option 2; Future Climate 2050

Figure: **7-5**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

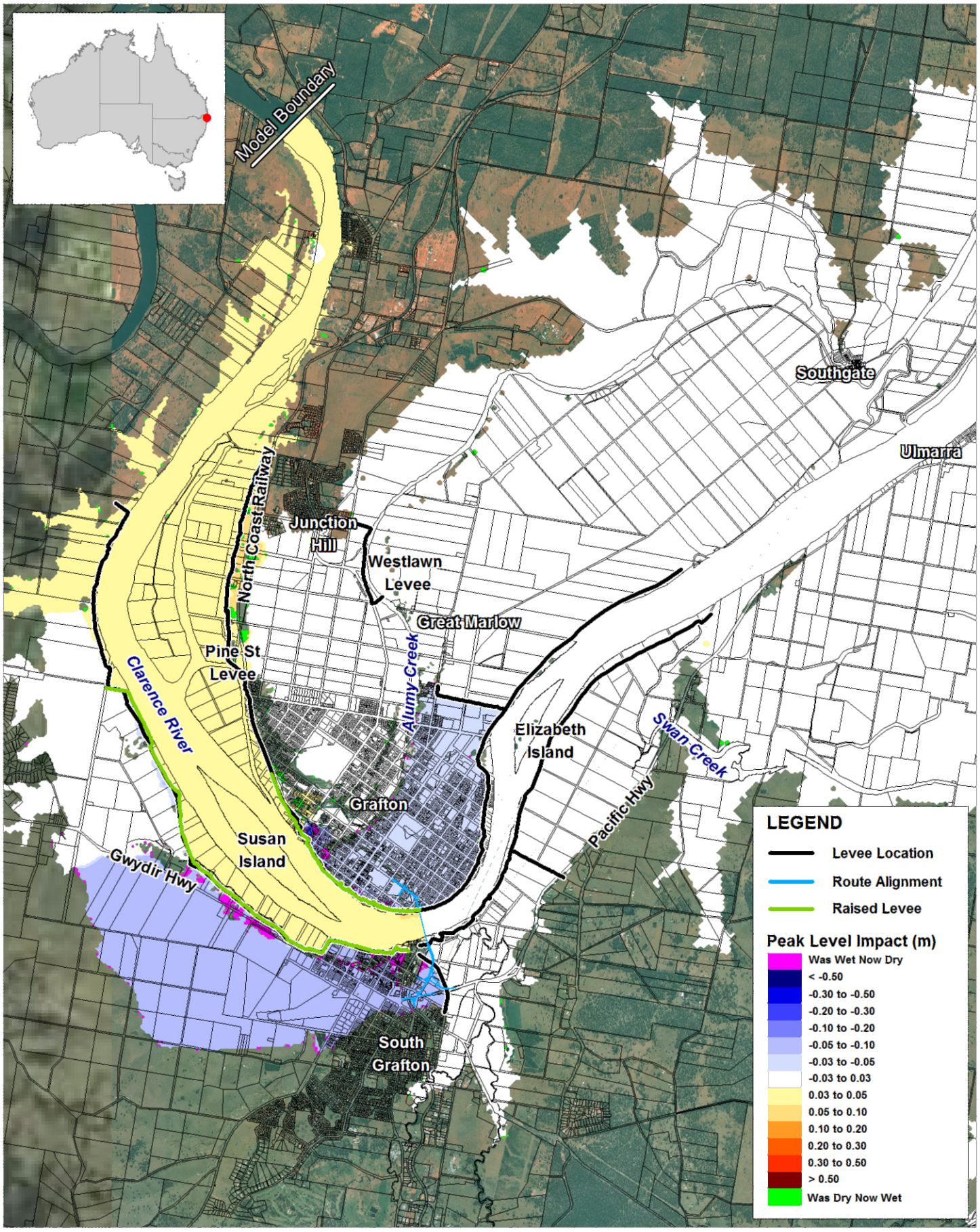
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_053_140306_Q20CC10S40_Mit02_Base_Hdiff.wor"




Title:

# Peak Flood Level Impact 20 Year ARI Event Mitigation Option 2; Future Climate 2100

Figure: 7-6

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

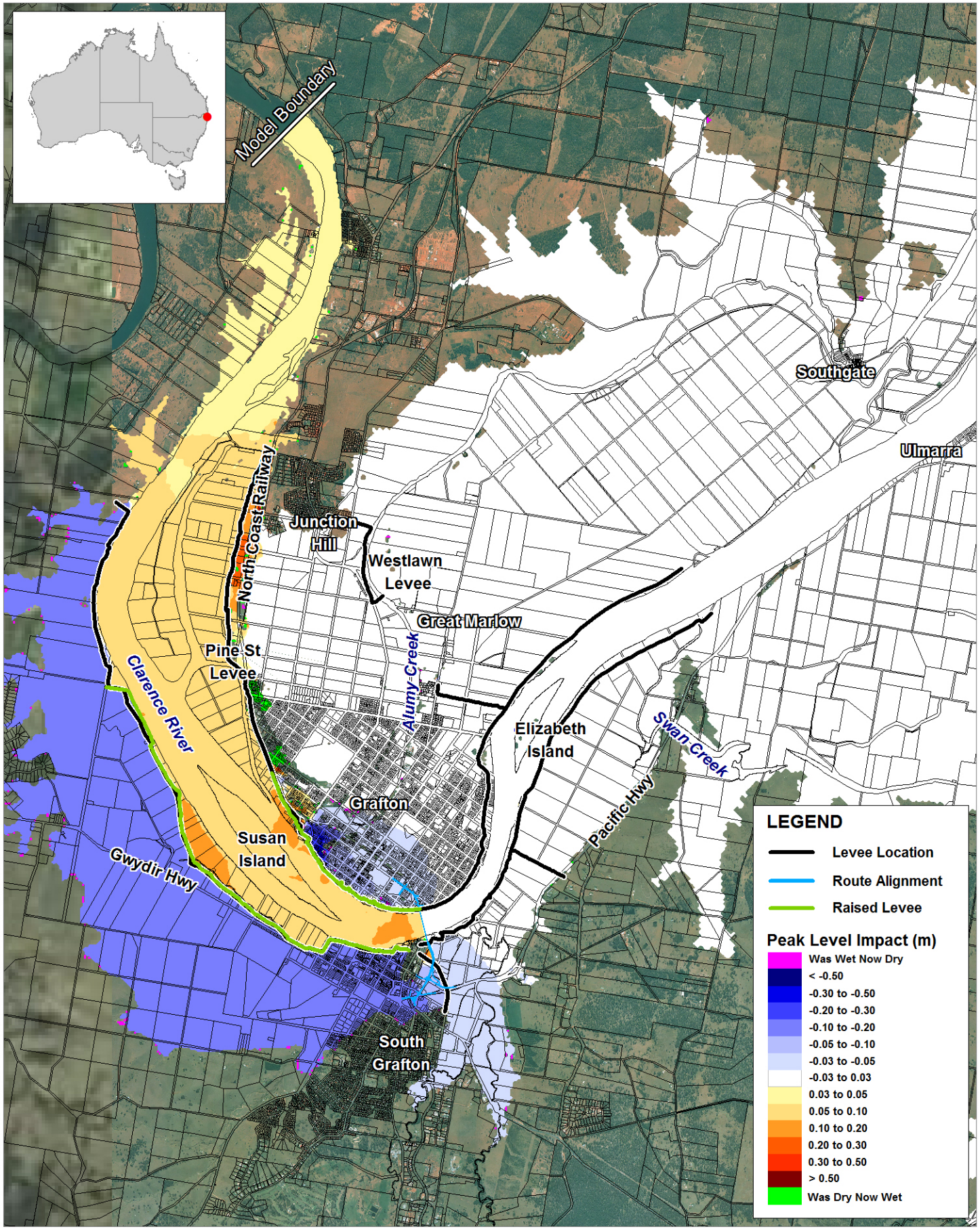
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_054_140306_Q20CC20S90_Mit02_Base_Hdiff.wor"




Title:

# Peak Flood Level Impact 100 Year ARI Event Mitigation Option 2; Future Climate 2050

Figure: 7-7

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

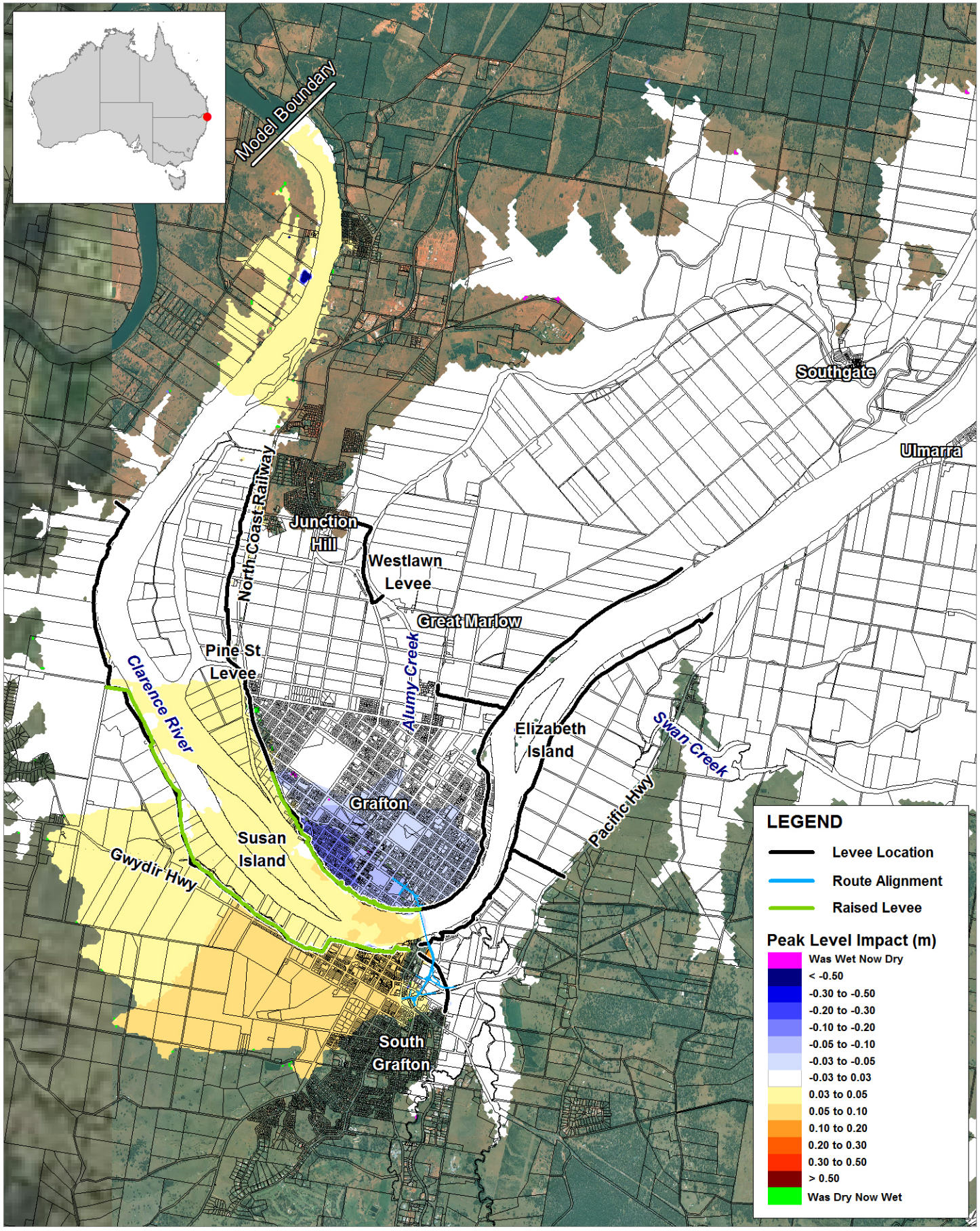
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_039_140122_Q100CC10S40_Mit02_Base_Hdiff.wor"




Title:

# Peak Flood Level Impact 100 Year ARI Event Mitigation Option 2; Future Climate 2100

Figure: **7-8**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

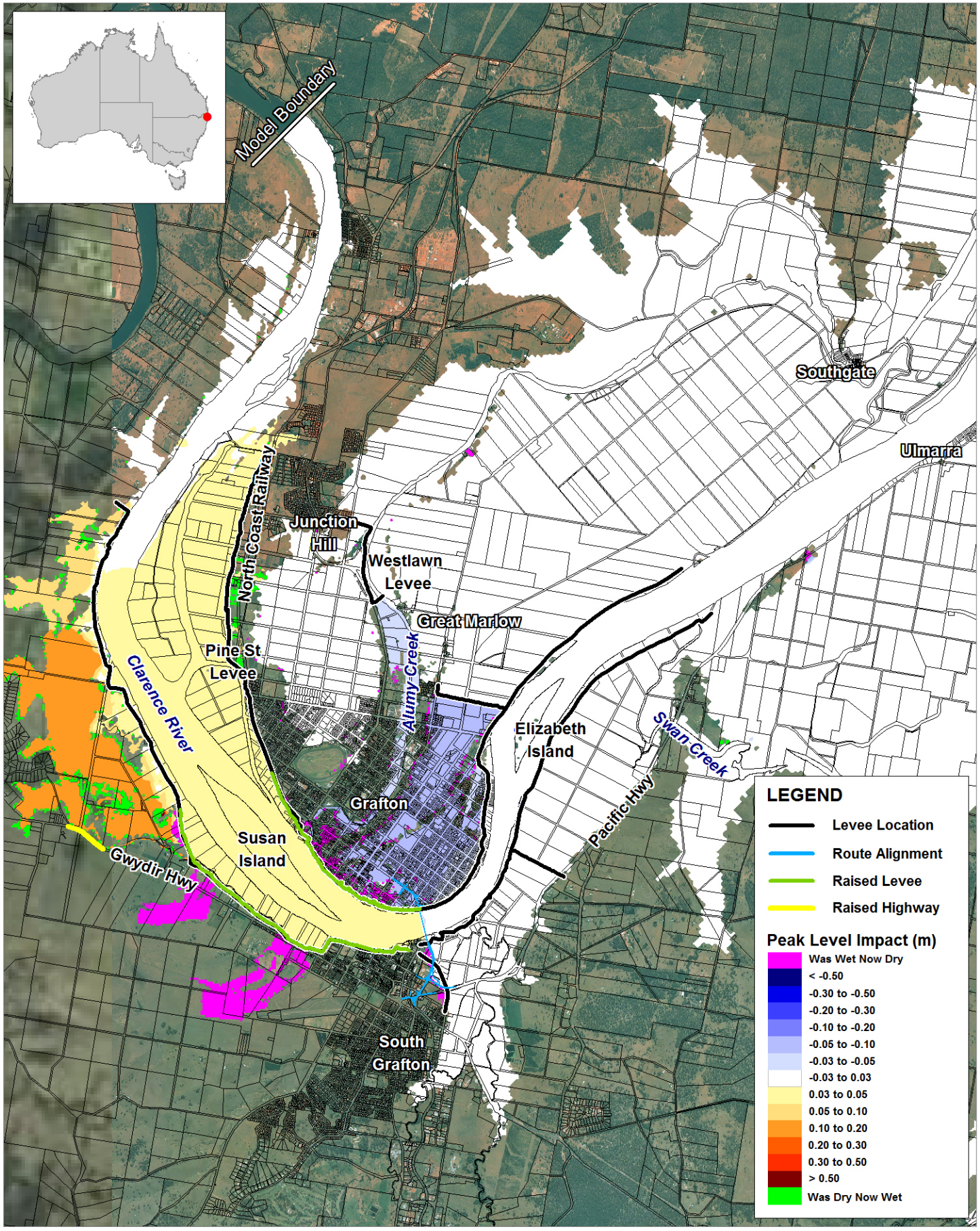
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_040_140122_Q100CC20S90_Mit02_Base_Hdiff.wor"




Title:

# Peak Flood Level Impact 20 Year ARI Event Mitigation Option 4; Future Climate 2050

Figure: **7-9**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

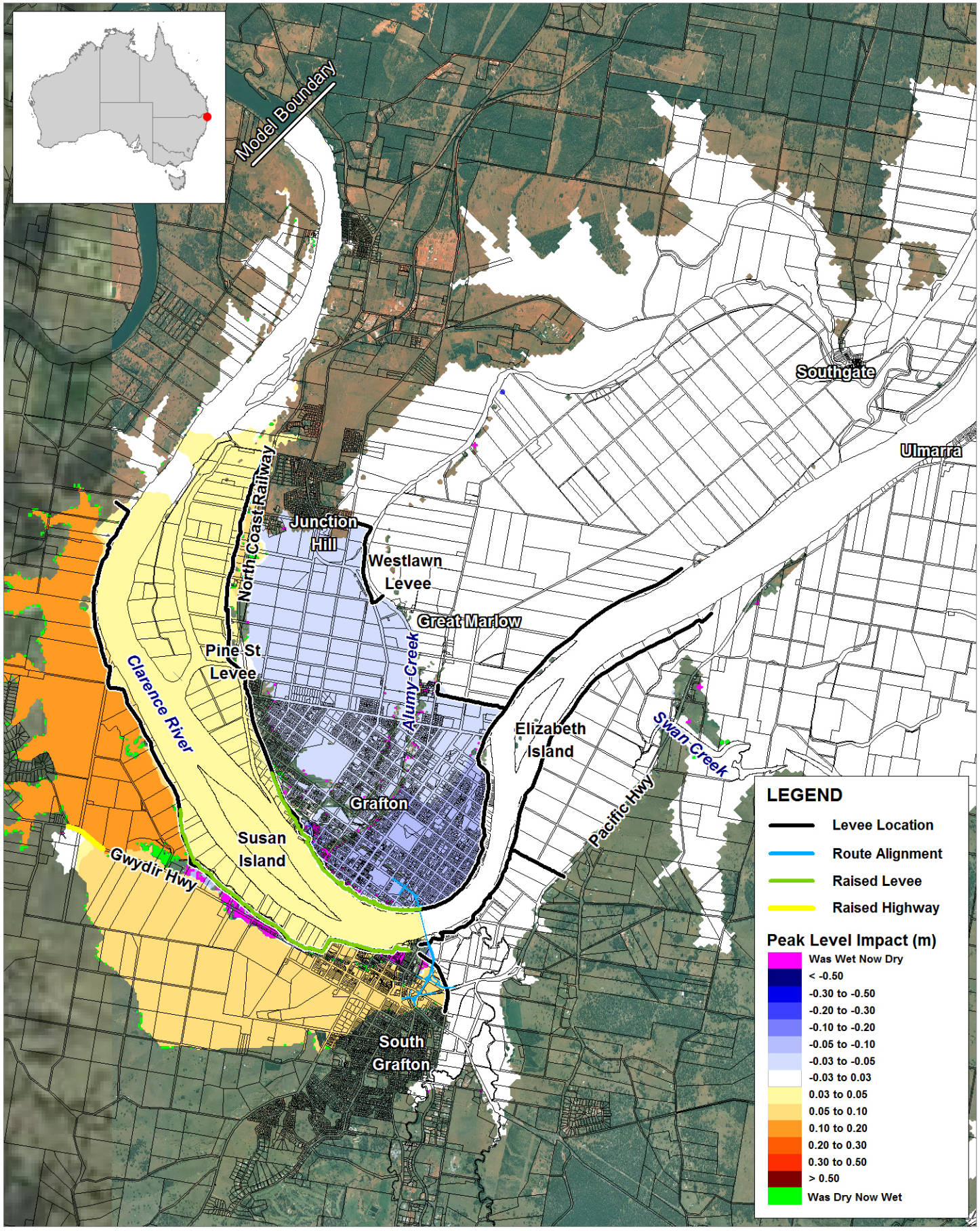
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_055_140306_Q20CC10S40_Mit04_Base_Hdiff.wor"




Title:

# Peak Flood Level Impact 20 Year ARI Event Mitigation Option 4; Future Climate 2100

Figure: **7-10**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

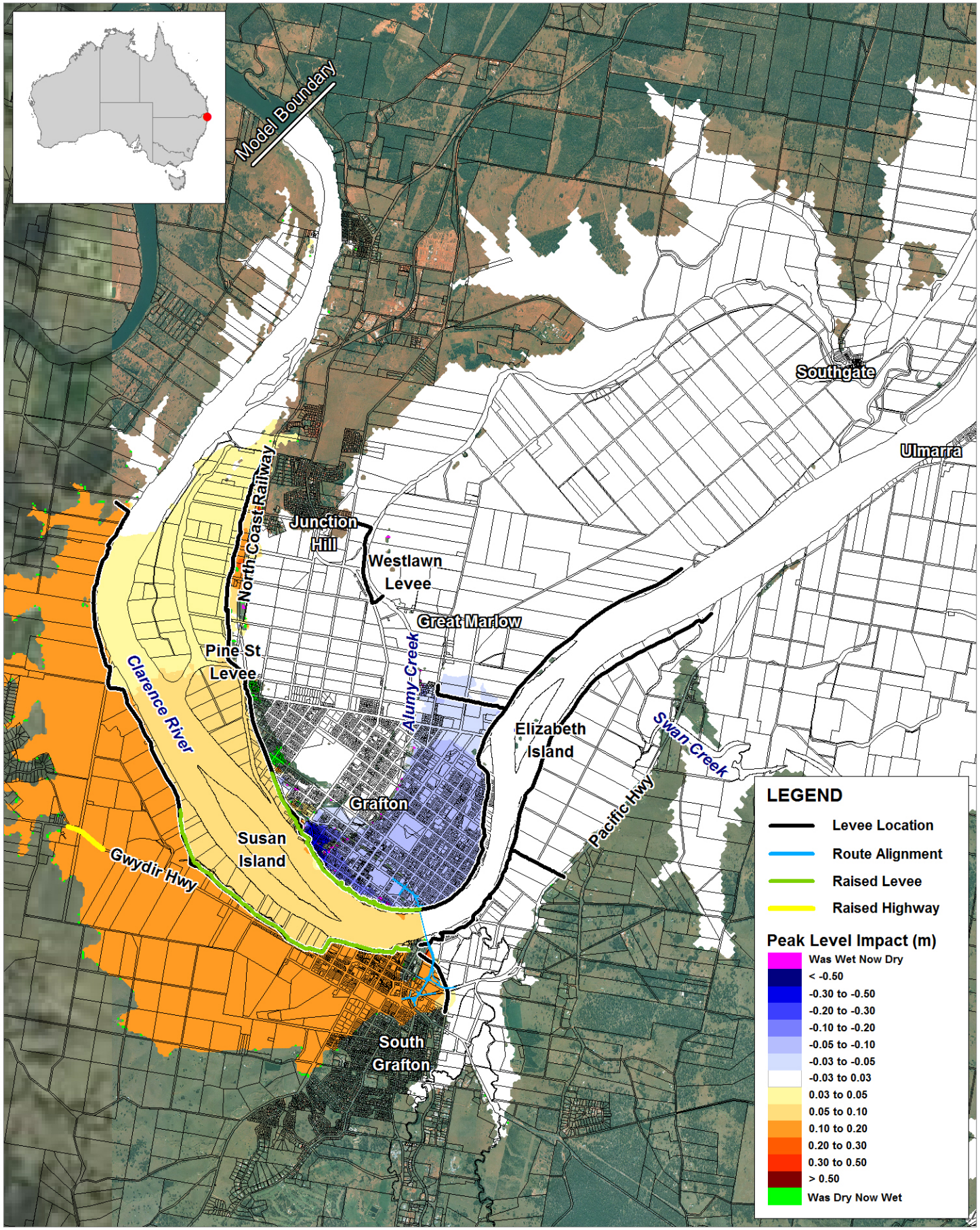
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_056_140306_Q20CC20S90_Mit04_Base_Hdiff.wor"




Title:

# Peak Flood Level Impact 100 Year ARI Event Mitigation Option 4; Future Climate 2050

Figure: **7-11**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

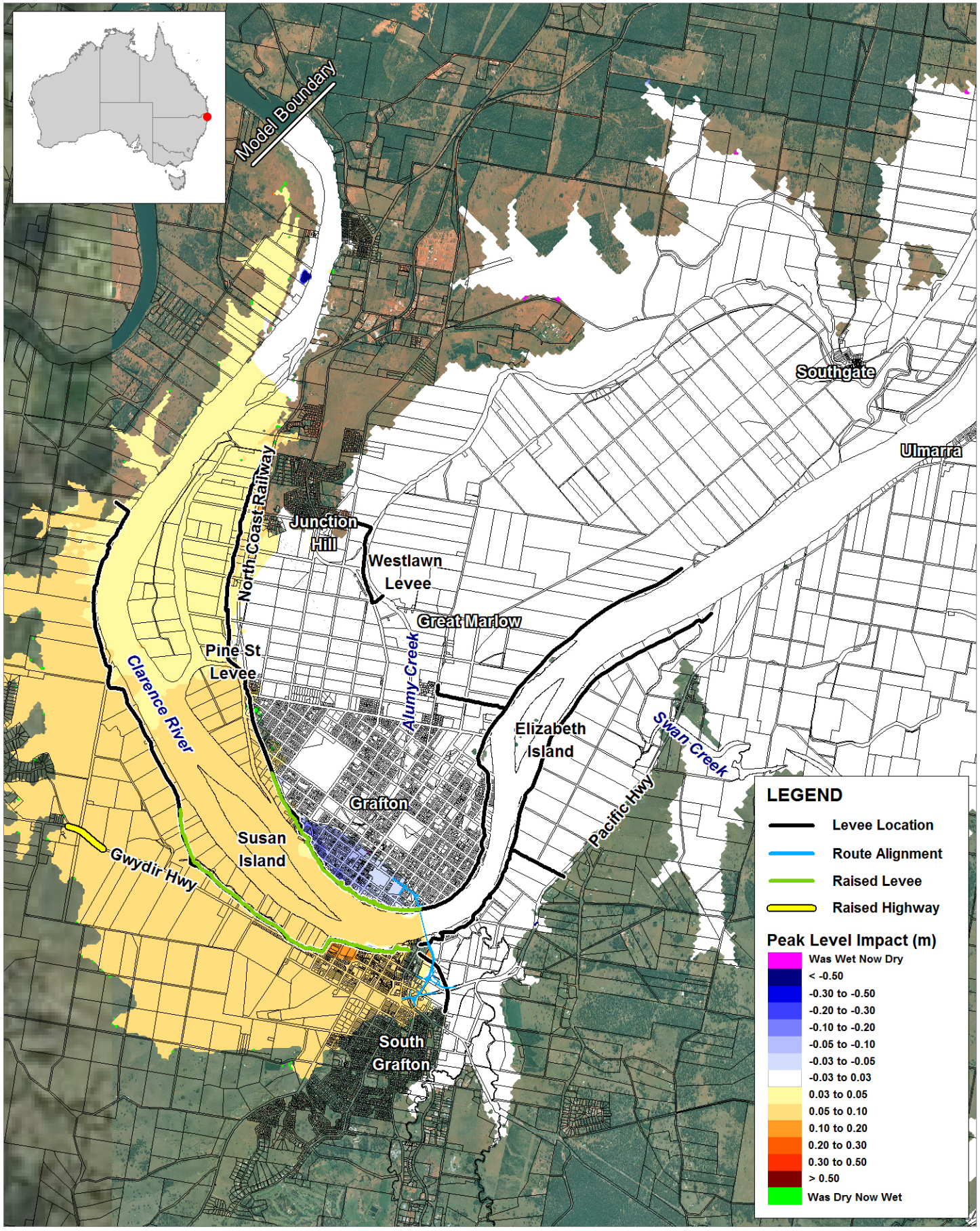
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_041_140122_Q100CC10S40_Mit04_Base_Hdiff.wor"




Title:

# Peak Flood Level Impact 100 Year ARI Event Mitigation Option 4; Future Climate 2100

Figure: 7-12

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_042_140122_Q100CC20S90_Mit04_Base_Hdiff.wor"

## 7.3 Climate change results summary

Under a future climate change scenario there will be potential flood impacts in Grafton and South Grafton. These potential impacts would include increases in peak water levels, which result in additional overtopping of the levees and inundation to greater depths than under the current climate.

With mitigation, the impacts of the proposed bridge would be broadly similar to those predicted under an existing climate scenario. Key points from the climate change assessment are summarised below by mitigation option.

### 7.3.1 Effect of climate change scenario with Mitigation Option 2

20 year ARI event:

- Peak flood level impacts within the river increase by less than 0.01m in the 2050 climate and by up to 0.03m in the 2100 climate.
- Impacts within Grafton and South Graton both decrease under the 2050 and 2100 climates but there are localised increases in impacts by typically 0.3m on largely rural land to the north west of South Grafton. This is due to under an existing climate there being no overtopping in a 20 year ARI event but under a climate change event the raised levee does overtop.

100 Year ARI Event:

- Peak river level impacts generally remain the same under a 2050 climate as for an existing climate. For the 2100 climate the impacts within the river decrease by up to 0.04m.
- Under a 2050 climate minor increases in impact within Graton are predicted within the range of 0.03m to 0.04m. Impacts in South Graton decrease typically by 0.04m. Under a 2100 climate there are no notable changes to impacts within Grafton and increases in impact of up to 0.17m in South Grafton.

### 7.3.2 Additional bridge with Mitigation Option 4

20 Year ARI Event:

- Peak river level impacts show minimal changes between the existing, 2050 and 2100 climates with any changes being less than 0.01m.
- Impacts are predicted to decrease for Grafton under both 2050 and 2100 climates from an existing climate.
- South Grafton has no change in predicted impacts for the 2050 climate but within the 2100 climate the Gwydir highway overtops to a greater degree resulting in increases in impacts within the town of up to 0.14m.
- In both the 2050 and 2100 climates there is increased ponding behind (north) of the raised Gwydir Highway and this is shown as increased impacts when compared to the existing climate.

100 Year ARI Event:

- Peak river level impacts show minor increases for the 2050 and 2100 climates when compared to an existing climate. These increases are up to 0.02m and 0.01m respectively.
- In Grafton increases in impact of 0.04m and 0.09m occur for the 2050 and 2100 climates respectively. It should be noted that in absolute terms the flood levels have decreased from baseline conditions. The decrease is just not as pronounced under the 2050 and 2100 climates as it is under the existing climate.
- In South Grafton the predicted increases in impact are 0.23m and 0.15m under the 2050 and 2100 climates respectively. Typically, predicted decreases in water level following the additional crossing and mitigation under an existing climate become increases in water level under the future climate scenarios.

## 7.4 Climate change assessment conclusions

Both mitigation options 2 and 4 mitigate the predicted flooding impacts from the proposed bridge on the area of Grafton located behind the levees. Residual impacts will remain to properties located outside of the levees. These residual impacts would be marginally increased under a future climate scenario (by an estimated 0.03m). Development of any proposed additional mitigation measures for these properties (identified in Section 6) should also take into account the predicted bridge impacts under a future climate.

Typically the impacts to the river levels remain consistent for all modelled climate scenarios. For Grafton, the predicted decreases in flood levels as a result of the proposed bridge and mitigation are less pronounced under future climates and this is shown as an increase in impact (albeit still a net benefit in terms of reduced flood levels from the baseline).

In South Grafton the maximum change in impact under a climate scenario is 0.23m for the 2050 climate scenario. In this case a decrease in peak level of 0.07m under an existing climate becomes an increase in peak level of 0.16m (difference is 0.23m).

It is beyond the scope of this project to mitigate for the impacts of climate change. It is however recommended that future stages of this project ensure consistency with any future climate adaption strategies adopted by Clarence Valley Council and the NSW Government.

# 8 Other considerations

## 8.1 Local drainage

A requirement of the design criteria is that the main approach roads to the proposed bridge must be flood immune during a 20 year average recurrence interval (ARI) design flood event (See Section 3). Within Grafton the proposed approach alignment runs under the North Coast Railway viaduct at Pound Street. This is an area known to experience existing local drainage issues.

A preliminary assessment of the local drainage flood behaviour was undertaken which included development of a local scale hydraulic model. This was produced to estimate the baseline 20 year ARI flood levels and to determine if any mitigation measures were required to achieve a 20 year ARI flood immunity for the approach road under the viaduct.

Under the proposed design, the arch forming the railway viaduct over Pound Street will be modified to obtain the required clearance for heavy goods vehicles.

When the Clarence River is not in flood, local runoff can drain to the river via gravity drainage. However, when the river is in flood, the raised water levels prevent gravity drainage to the river and runoff needs to be temporarily stored or pumped until the river levels lower.

Under existing conditions a peak 20 year ARI flood level of 4.35mAHD occurs when the water cannot drain to the river. This compares to a proposed road elevation of 3.70mAHD at its lowest point. Therefore mitigation is required to meet the design criteria.

A proposed mitigation option consisting of the following components has been assessed to achieve the design criteria:

- A detention basin with a volume of approximately 1,500$m^3$ located on the southern side of Pound Street;
- A new drainage outlet to the river from the detention basin;
- Pump/s with a combined capacity of up to 2$m^3$/s;
- A series of culverts under Pound Street and the proposed approach road to convey runoff into the detention basin; and
- Diversions of the local piped drainage network into the detention basin.

Following mitigation the peak 20 year ARI flood level is reduced to an elevation of approximately 2.9mAHD. This is approximately 0.5m below the existing road level and 0.8m below the proposed approach road level. As well as meeting the design criteria, the above arrangement reduces the overall flood risk from local flooding in the vicinity of Pound Street compared to the existing situation offering a net benefit to the community.

The volume of water to be pumped into the river is insignificant in the context of the volume of water being conveyed by the river and will have negligible influence on river levels.

Full details of the local drainage assessment including flood impact figures are contained in Appendix C.

## 8.2 Emergency response and evacuation

Grafton is protected by a ring levee system which has an approximate 20 year ARI immunity (i.e. there is a 5% chance that the levee may be overtopped in any given year). In a worst case scenario the entire township of Grafton will be inundated by flooding, as indicated by flood modelling of the Probable Maximum Flood event (see Figure 2-4). Due to these factors, flooding poses a significant risk to the residents in Grafton.

In response to these risks, the State Emergency Services (SES) has developed a flood evacuation plan for Grafton, documented in the Clarence Valley Council Local Flood Plan (SES, 2012).

The Flood Plan defines the following information:

- Evacuation sectors;
- Evacuation trigger levels, defining sector specific evacuation actions relating to a range of flood levels at the Prince Street gauge;
- Vulnerable community groups requiring special consideration/assistance during an evacuation;
- Evacuation routes; and
- Evacuation centres.

Evacuation routes for Grafton and South Grafton are defined by the SES in the Clarence Valley Local Flood Plan (SES, 2012) and are shown in Figure 8-1. The plan defines three main evacuation routes out of Grafton. Two routes north, to Junction Hill, and one route across the existing Grafton Bridge to South Grafton. Overtopping of the Grafton levees during a large flood event results in ponding within the floodplain between Grafton and Junction Hill and cuts the evacuation routes to the north. When this occurs, the only flood free route available for evacuation is via the existing Grafton Bridge to South Grafton. As such, the efficiency of flood evacuation within Grafton is largely constrained by traffic movement across the bridge.

An additional crossing of the Clarence River in the vicinity of the existing bridge may potentially benefit flood evacuation within Grafton. Key factors which influence how the additional crossing will impact evacuation operations include:

- Evacuation Route Contingency – As shown in Figure 8-1, evacuation routes currently converge within the business district of Grafton.
- Evacuation Route Flood Immunity – An evacuation route is compromised if it is inundated by flood water. It is best practice for evacuation routes to be flood free up to and including the Probable Maximum Flood. This criterion is impractical for Grafton, which is affected by flooding in design flood events greater than the 20 year ARI event. Due to this local flood behaviour, where possible, road elevations of flood evacuation routes should be greater than surrounding land and avoid traversing drainage depressions which many prematurely compromise the evacuation route.
- Provision of Services – Flooding within the Lower Clarence Valley can last for prolonged periods (several days to weeks). Due to this flood behaviour, it is important that evacuated residents

have access to services and shelter following evacuation from Grafton. South Grafton represents the primary location of sufficient size to provide these needs.

- Vulnerable Community Groups – SES resourcing needs to accommodate for vulnerable community groups which may require special consideration/assistance during an evacuation.

The proposed bridge will maintain current evacuation routes but will improve the overall efficiency of evacuation.

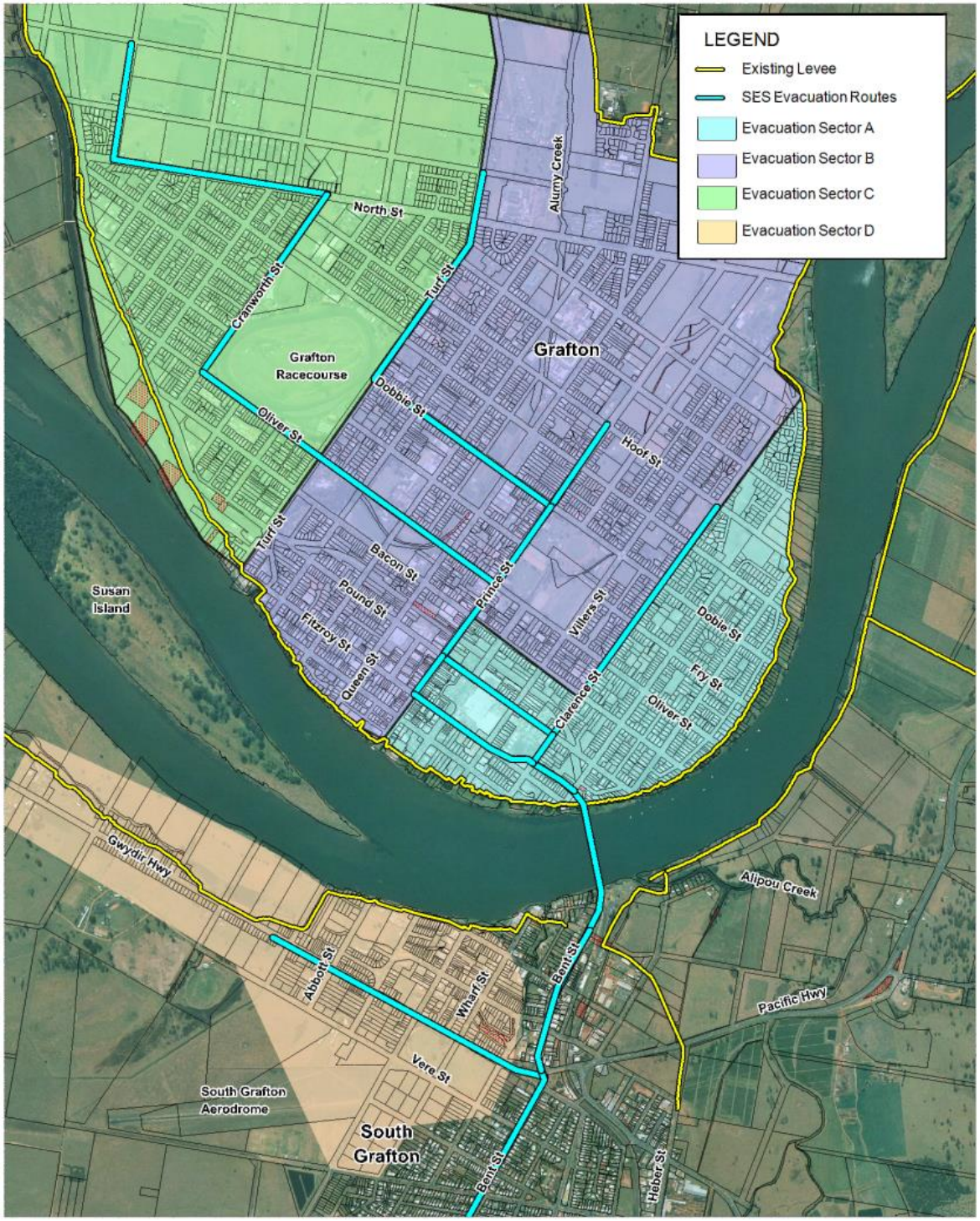



**Figure 8-1 Grafton evacuation strategy (SES, 2012)**

# 9 Conclusions

The flooding component of the Environmental Assessment for the proposed project has found the following:

- In the baseline assessment (existing condition), properties in Grafton are particularly affected during flood events of a 50 year average recurrence interval (ARI) or greater. During a 100 year ARI event the extents and depths of flooding are significant for both Grafton and South Grafton.
- Unmitigated, the additional crossing results in an afflux within the Clarence River of less than 0.1m. Due to the significant length of levees and the duration of overtopping, this afflux in the river results in an increase in the volume of floodwater overtopping the levees for events of a 50 year ARI and greater. Unmitigated this would increase flood levels in Grafton and South Grafton.
- To mitigate this increase, four mitigation options were developed and assessed in a hydraulic model. Of these options, two were found to result in an overall reduction in flood risk to both Grafton and South Grafton:
    - Mitigation Option 2: Raising 3.7km of levee on the north bank and 7km of levee on the south bank of the Clarence River by 0.2m; and
    - Mitigation Option 4: Raising 3.7km of levee on the north bank, 4.7km of levee on the south bank, and raising a 550m length of the Gwydir Highway to an elevation of 7mAHD (current existing elevations are between 5 and 6.5mAHD).
- Both Mitigation Options 2 and 4 generally result in reduced peak flood levels and flood hazard for areas protected by existing levees. Changes to peak velocities and durations of flooding were insignificant except for Mitigation Option 4 where part of the proposed mitigation is to detain floodwater to the north of the Gwydir Highway. As there are no predicted changes to peak velocity then it is reasoned that there will be no predicted hydraulic impacts on bed and bank stability. The mitigation options will generally result in minor decreases in flooding frequency to Grafton and South Grafton.
- The proposed mitigation options are generally consistent with the existing floodplain management plan.
- Under a PMF event minor increases in peak level are predicted following the additional crossing. However the significance of these impacts in the context of the severe flooding during a PMF event is considered minimal.
- After the main mitigation, up to 58 properties, generally located outside of the zone of protection afforded by the levees, will be subject to a residual, typically minor, increase in flood level as a result of the proposed project. House raising is proposed as an additional mitigation measure for these affected properties. The estimated number of properties is indicative and should be further investigated commencing with flood level survey and comparison to existing and predicted flood levels.

- The communities of Grafton and South Grafton are vulnerable to the potential impacts of a changing future climate. This assessment has shown that the changes to sea level rise and increased rainfall intensity will not significantly alter the predicted impacts from the additional crossing under a future climate. It is recommended that future stages of this project ensure consistency with any future climate adaptation strategies adopted by Clarence Valley Council.
- Local drainage issues within Grafton will require flood mitigation works to maintain a flood free approach road during a 20 year ARI event. These mitigation works will consist of a detention basin and pump to temporarily store and discharge local runoff when the Clarence River level is in flood.
- Existing flood evacuation arrangements within Grafton will generally benefit from the additional crossing which will improve access to higher ground in South Grafton, subject to the existing constraints of traffic congestion within the business district of Grafton.

# 10 References

**Bewsher Consulting Pty Ltd (2007)** “Grafton and Lower Clarence Floodplain Risk Management Plan”, Prepared by Bewsher Consulting Pty Ltd for Clarence Valley Council.

**BMT WBM (2010)** “Lower Clarence River May 2009 Flood Event: Event Summary and Model Validation”, Prepared by BMT WBM for the NSW Department of Environment, Climate Change and Water.

**BMT WBM (2013)** “Lower Clarence Flood Study Update, 2013. Prepared by BMT WBM for Clarence Valley Council

**CSIRO (2007)** “Climate Change in the Sydney Metropolitan Catchments. Prepared for the NSW Government.

**Kuczera G and Frank S (2006)** “Australian Rainfall and Runoff, Book IV, Estimation of Peak Discharge-Draft”, Engineers Australia.

**PWD (1988)** “Lower Clarence River Flood Study”, PWD No 86010, December 1986.

**SES (2012)** “Clarence Valley Local Flood Plan”, Prepared by the NSW State Emergency Service.

**WBM (2004)** “Lower Clarence River Flood Study Review”, Prepared by WBM for Clarence Valley Council

# Appendix A Flood model inputs

The hydraulic model used for this assessment was developed and calibrated as part of the *Lower Clarence Flood Study Review* (WBM, 2004) and then subsequently updated for Clarence Valley Council by BMT WBM in 2011 and 2013 to include increased model definition in urban areas and to include updated terrain data. The extent of the Lower Clarence flood model is shown in Figure A-1. The following sections outline the model input used by the flood model.

## A.1 General setup

The Clarence River Hydraulic model uses TUFLOW modelling software. It is a multi-domain model with areas of higher resolution (finer model grid size) attributed to populated areas. Model domains are shown in Figure A-1 and are as follows:

- A 60m grid domain representing the majority of the rural floodplain;
- 10m grid domains for Grafton, South Grafton and Maclean; and
- A 30m domain for the area surrounding Grafton and South Grafton not included in the 10m model domains.

The model runs in TUFLOW version 2012-05.

## A.2 Model geometry

The Lower Clarence flood model uses the latest available topographic data. This data therefore forms the base data used in the current assessment and consists of the following principal datasets:

- 2010 LiDAR data captured in 2010 for Clarence Valley Council;
- In bank bathymetry based on Clarence River hydro-surveys undertaken in 1963, 1978 and 1979; and
- Ground survey data of levee elevations (undertaken in 2012 for CVC) for the Grafton, South Grafton, Heber, Alipou, Clarenza and Ulmarra levees.

Esk River
Chatsworth
North Arm
Chatsworth Island
Goodwood Island
Palmers Island
Harwood Island
Harwood
Iluka
Ocean Levels
Great Estuary Creek
The Broadwater
Maclean
James Creek
Micalo Island
Yamba
Clarence River
INSET 1
Chaselings
Sportsmans Creek
Sportsmans Creek
Lawrence
The Lake
South Pacific Ocean
Woodford Island
South Arm
Shark Creek
Brushgrove
Bultitudes
Crowley Creek
Clarence River
Pacific Highway
Coldstream River
Shark Creek
Ulmarra
Swan Creek
Tucabia
Grafton
South Grafton
INSET 2
Glenurgie Creek
Coldstream River

0 5 10km
Approx. Scale

INSET 1: MACLEAN

0 1 2km
Approx. Scale

INSET 2: GRAFTON/SOUTH GRAFTON

0 1 2km
Approx. Scale

**LEGEND**

- Model Inflows
- 60m model domain
- 30m model domain
- 10m model domain
- Railway
- Pacific Highway
- Levee

-20.0 -10.0 0.0 10.0 25.0 50.0 75.0 100.0 125.0 150.0 175.0 200.0
Sea level
Ground Level : Metres AHD

-2.0 0.0 2.0 4.0 6.0 8.0 10.0
Ground Level Inset

Title:
# Lower Clarence Flood Model Configuration

Figure: A-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_043_140122_Flood_Model_Extent.wor"

## A.3 Hydraulic roughness

Landuse mapping is used by the hydraulic model to represent the various vegetation types and associated hydraulic roughness within the model. The landuse mapping used for this study is consistent with the data used in the *Lower Clarence Flood Study Update* (BMT WBM, 2013).

In total, 11 areas of different landuse type were defined, based on aerial photography. The Manning's 'n' values adopted for the various defined landuses within the hydraulic model are listed in Table A-1. These values were validated as part of the flood model calibration exercise undertaken in the Flood Model Update study.

**Table A-1 Lower Clarence flood model landuse categories**

| Landuse Type | Manning's n Coefficient |
|---|---|
| River Bank | 0.08 |
| River | 0.025 |
| Island Vegetation | 0.08 |
| Minor Tributary | 0.035 |
| Pasture | 0.08 |
| Sugar Cane | 0.15 |
| Crops | 0.1 |
| Forest | 0.2 |
| Urban Blocks | 0.3 |
| Parks | 0.04 |
| Roads (within 10m model domains) | 0.02 |

## A.4 Model boundaries

The Lower Clarence flood model used various input boundary conditions including:

- Flood inflows for the Clarence River at Mountain View;
- Flood inflows for the Clarence River tributaries downstream of Mountain View;
- Lower floodplain rainfall-runoff; and
- Ocean water levels.

Design inflows from the Lower Clarence Flood Study Update model (BMT WBM, 2013) are presented in Table A-2 and are input into the model at the location shown in Figure A-1. These design inflows have been adopted for the current assessment. The derivation and application of each of these inputs during the design event modelling is outlined in the following sections.

**Table A-2 Lower Clarence flood model peak design flood inflows**

| Design Flood Event | Clarence River Inflow ($m^3/s$) | Tributary Inflows ($m^3/s$) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | *Glenugie Creek* | *Coldstream River* | *Shark Creek* | *Sportsmans Creek* | *Great Estuary Creek* | *Cowley Creek* | *Esk River* |
| 5 year ARI | 9,360 | 223 | 486 | 66 | 458 | 192 | 209 | 780 |
| 20 year ARI | 16,280 | 326 | 708 | 96 | 658 | 276 | 300 | 1,110 |
| 50 year ARI | 18,220 | 407 | 877 | 118 | 813 | 341 | 370 | 1,361 |
| 100 year ARI | 19,060 | 445 | 957 | 127 | 884 | 367 | 401 | 1,462 |
| PMF Event | 29,162 | 715 | 1538 | 201 | 1438 | 587 | 641 | 2,330 |

### A.4.1 Derivation of Clarence River inflows

As part of the Lower Clarence River Flood Study Review (WBM, 2004) the inflows used for the Clarence River at Mountain View in the preceding Lower Clarence Flood Study (PWD, 1988) were reviewed. The basis of this review was the development of rating curves for the Clarence River at Grafton to cover the varying catchment states from the start of records in 1839 to the present.

Four “historical” rating curves were derived to represent four distinct floodplain states throughout the gauged history of the river at Grafton. These curves are presented in Figure A-2. These rating curves were then used to produce a revised series of peak flows based on the recorded flood levels at Prince Street Gauge over a period of more than 150 years.

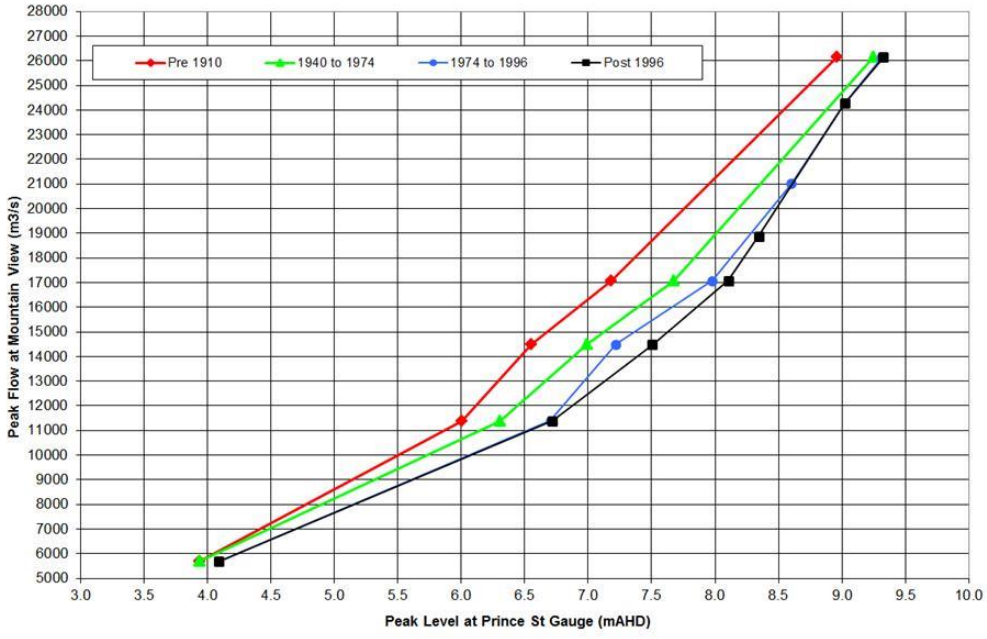



**Figure A-2 Clarence River historical rating curve**

An annual maximum flood frequency analysis of the 162 years of revised peak inflows was completed using the flood frequency analysis program "FLIKE". As part of the flood frequency analysis two distributions were produced. These were the Generalised Extreme Value (GEV) and Log Pearson 3 (LP3) distributions. Comparing the two methods, the GEV distribution was found to provide the best results. For ARI's greater than 5 years the GEV fits the data satisfactorily. Almost all the data fall within the 90% confidence limits. Figure A-3 shows the results of the GEV flood frequency analysis.

Based on the design flows calculated using the flood frequency analysis, the WBM (2004) study scaled Clarence River inflows at Mountain View using a flood hydrograph corresponding to recorded data for a historic 1974 flood event. The 1974 flood event was chosen as the hydrograph input for this purpose as comparisons with other recorded historic events indicated its shape represented a typical stage hydrograph at the Prince Street Gauge.

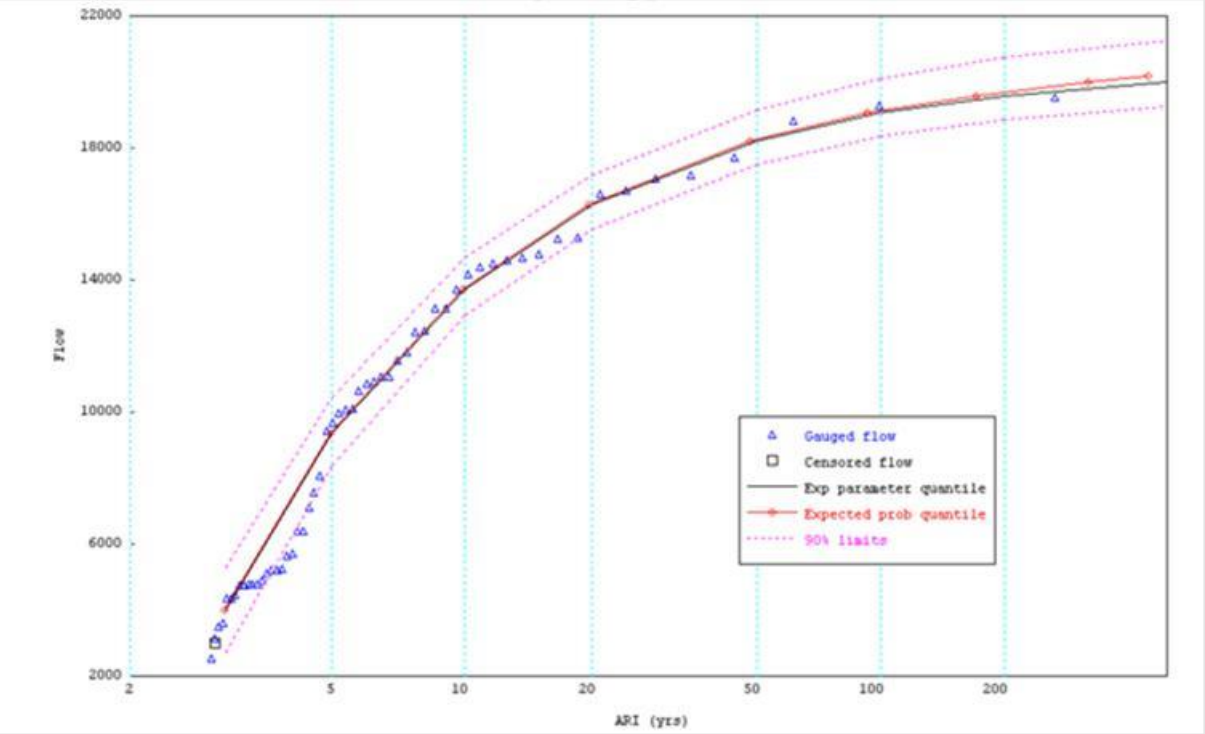



**Figure A-3 Flood frequency curve using GEV (Annual Maxima series from 1839 to 2000)**

The 2004 (WBM) flood frequency analysis adopted a methodology which is consistent with current *recommendations outlined in the draft Australian Rainfall and Runoff update, "Book 4 Estimation of Peak Discharge"* (Kuczera G and Frank S, 2006). The assessment:

(1) Accounts for non-homogeneity within the recorded flood population, including:

(a) Changes in catchment conditions[8] which may have a significant impact on the gauge rating curve; and

(b) Changes in gauge datum – from South Grafton Railway gauge datum to Australian Height datum (mAHD).

[8] For example, the construction of levees containing flow within the river channel.

(2) Uses a sufficient length of record data to reduce uncertainty associated with the extreme value estimates (162 years).

Due to these consistencies with current guidelines, the flood frequency design flows derived during the 2004 (WBM) study have been adopted for this study[9].

### A.4.2 Tributary inflows

The design rainfall and temporal patterns for the tributary catchments for the 72 hour design storm, as recommended in Australian Rainfall and Runoff (1987), were used as input to the hydrologic models of these catchments. The 72 hour design storm was adopted because it represents the longest duration event with defined temporal pattern guidance provided by Australian Rainfall and Runoff. Compared to other temporal patterns, the 72 hour event provides the highest flood levels throughout the catchment. For the initial and continuing rainfall losses, values of 30mm and 2mm/hr were used. These losses are typical of values used for design flood assessments of NSW coastal rivers.

### A.4.3 Floodplain runoff

The rainfall on the floodplain was simulated as runoff to the 2D flood model by simulating ponding of the rainfall immediately on the floodplain without any flood routing. Similar for the above inflows, for the initial and continuing rainfall losses, values of 30mm and 2mm/hr were used.

### A.4.4 Ocean boundary condition

WBM (2004) adopted design flood ocean levels defined by the Lower Clarence River Flood Study (PWD, 1988). These ocean boundaries, shown in Figure A-4, have subsequently been adopted for this study.

[9] It should however be noted that the design flow estimate statistics currently do not include peak flow information associated with the events which have occurred since 2004. As such, it does not include details for the major flood events which occurred in 2009, 2011 and 2013.

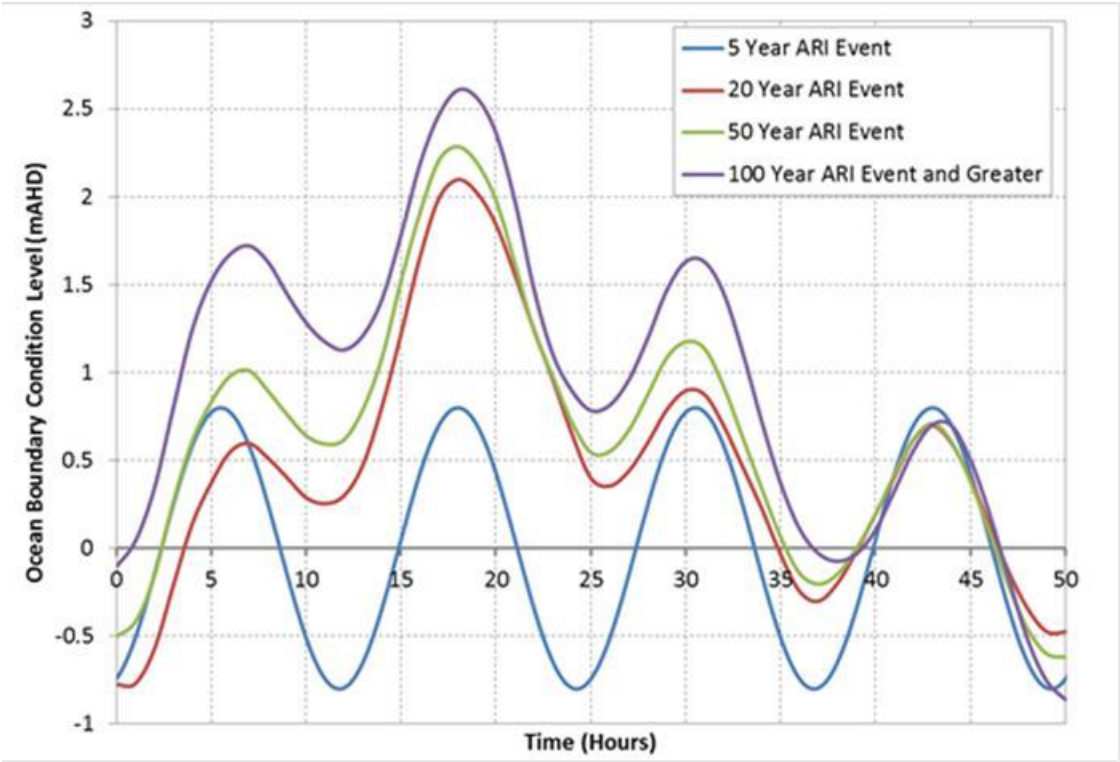



**Figure A-4 Lower Clarence flood model design tidal boundaries**

These peak tidal boundary levels approximate guideline values specified within 'Floodplain Management Guideline No5 Ocean Boundary Conditions' (DIPNR, 2004). The shape of the boundary condition does however vary from the guideline values. This variation reflects site specific tidal conditions at the Clarence River.

This study assumes that peak rainfall on the main and tributary catchments coincides with the storm tide peak, representing a slow moving storm which crosses the coast and moves inland. This boundary configuration results in backwater storm tide inundation prior to the arrival of catchment flooding in the lower catchment, as demonstrated in Figure A-5.

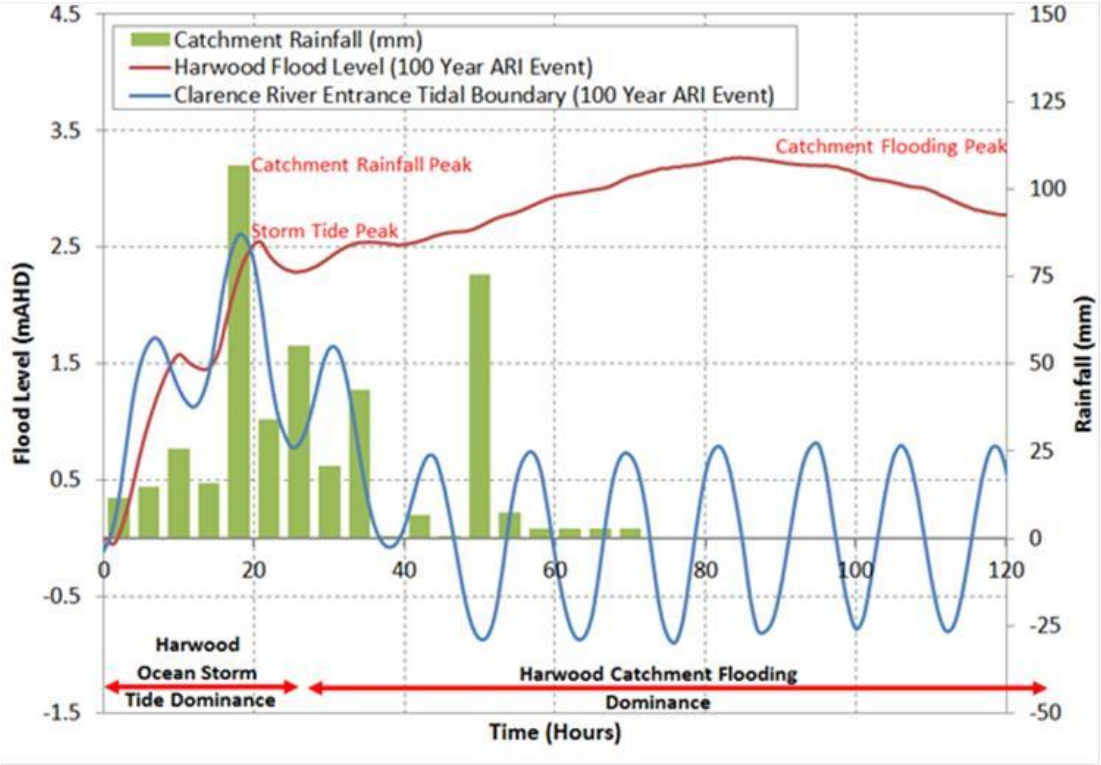



**Figure A-5 Storm tide / catchment flooding response time (Harwood)[10]**

Due to the significant size of the Clarence, and the associated delayed catchment response, coincident timing of equivalent storm tide and catchment flooding peaks at the river entrance has not been assessed as such a scenario is overly conservative.

## A.5 Model calibration

As part of the *Lower Clarence Flood Study Update* (WBM, 2013), calibration of the developed flood model was undertaken for eight historical flood events including the event of January 2013. The calibration events are summarised in Table A-3 and the results for the Prince Street Gauge at Grafton are summarised in Table A-4.

The calibration results summarised in Table A-4 indicate that the model is capable of accurately representing the catchment flood behaviour in Grafton for a range of flood events.

[10] Harwood is located downstream of Maclean on the main branch of the Clarence River

**Table A-3 Flood model calibration Events**

| Historic Flood Event | Prince Street Gauge | | |
|---|---|---|---|
| | ***Peak Flood Level (mAHD)*** | ***Approximate ARI Event Equivalent*** | ***Comment*** |
| June 1967 | 7.55 | 25 year ARI event | Pre 1974 catchment condition rating curve WBM (2004) – refer to Figure A-2 |
| January 1968 | 6.17 | 8 year ARI event | |
| May 1980 | 6.35 | 7 year ARI event | 1974 -1996 catchment condition rating curve WBM (2004) – refer to Figure A-2 |
| April 1988 | 6.73 | 9 year ARI event | |
| May 1996 | 7.03 | 10 year ARI event | |
| March 2001 | 7.70 | 14 year ARI event | Post 1996 catchment condition rating curve WBM (2004) – refer to Figure A-2 |
| May 2009 | 7.33 | 12 year ARI event | |
| January 2013 | 8.09 | 27 year ARI event | |

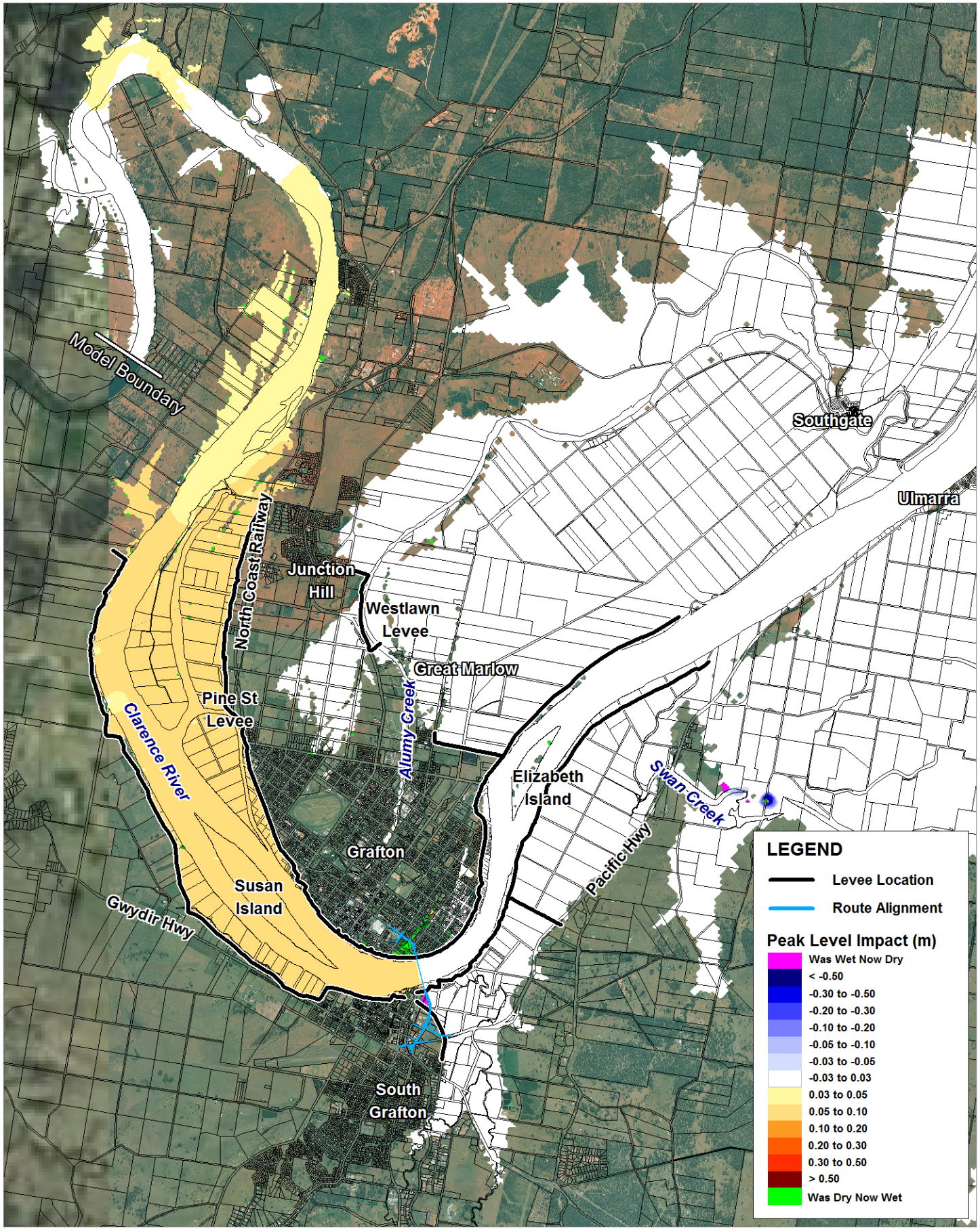
**Table A-4 Flood model calibration results (Prince St Gauge, Grafton)**

| Historic Event | Recorded (mAHD) | Modelled (mAHD) |
|---|---|---|
| June 1967 | 7.6m | 7.5m |
| January 1968 | 6.2m | 6.3m |
| May 1980 | 6.4m | 6.4m |
| April 1988 | 6.8m | 6.8m |
| May 1996 | 7.0m | 7.0m |
| March 2001 | 7.6m | 7.7m |
| May 2009 | 7.3m | 7.5m |
| January 2013 | 8.1m | 8.0m |

# Appendix B Extended Flood Impact Maps

## B.1 Introduction

Appendix B presents supplementary flood impact maps where the impact shown in maps contained in the main body of the report extended to the upstream end of the model boundary. To avoid any doubt as to where the spatial extent of the predicted impacts end, an additional 7km of the Clarence River upstream of Grafton was included in an extended model and the impacts mapped. Appendix B presents these extended model results. Maps have only been presented for modelled scenarios showing impacts extending to the models upstream limit.




Title:

# Peak Flood Level Impacts (Unmitigated) 20 Year ARI Event (Extended Model)

Figure: **B-1**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

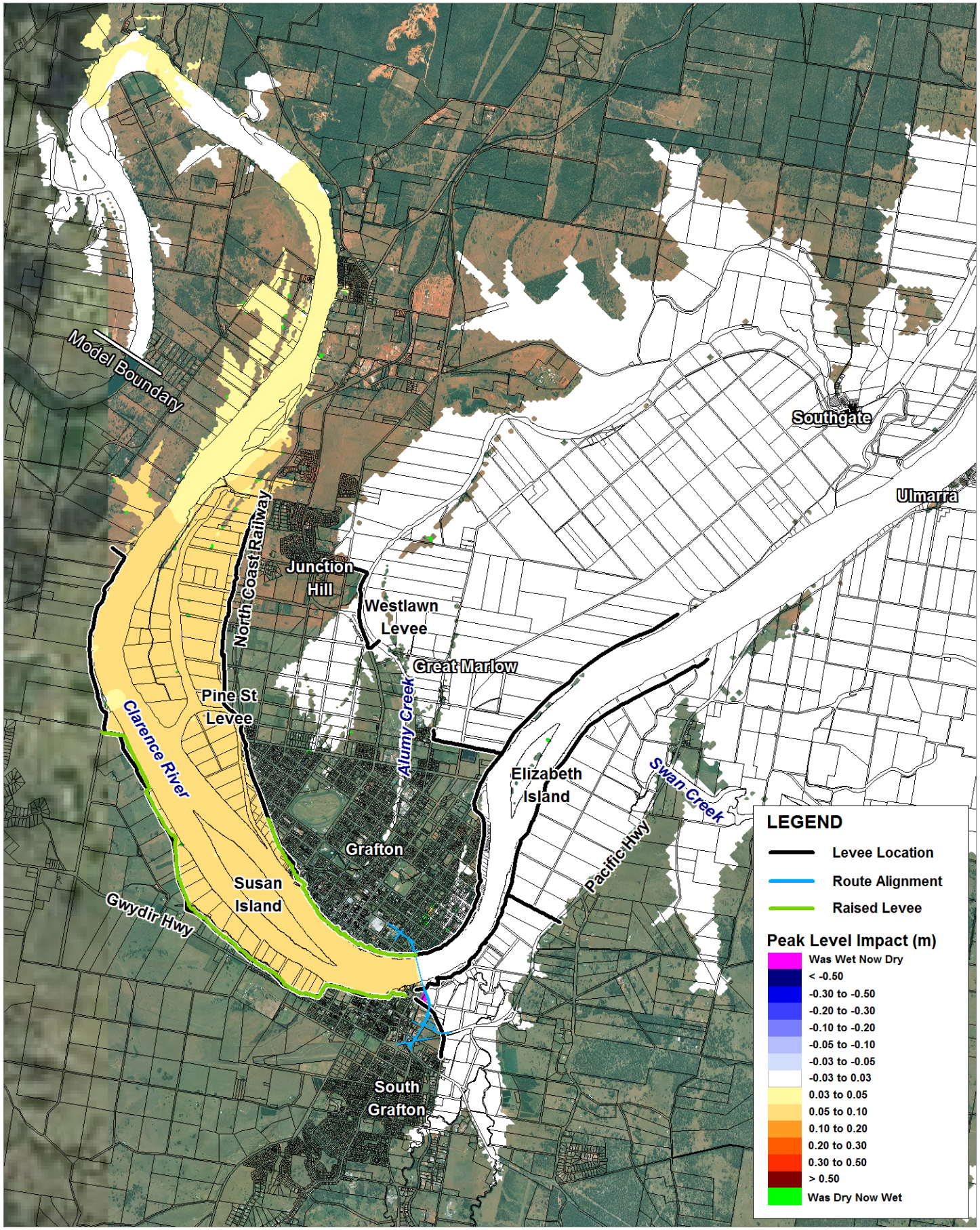
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_072_140428_Q020_NoMit_Hdiff_268.wor"




Title:

# Peak Flood Level Impacts (Mitigation Option 2) 20 Year ARI Event (Extended Model)

Figure: **B-2**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

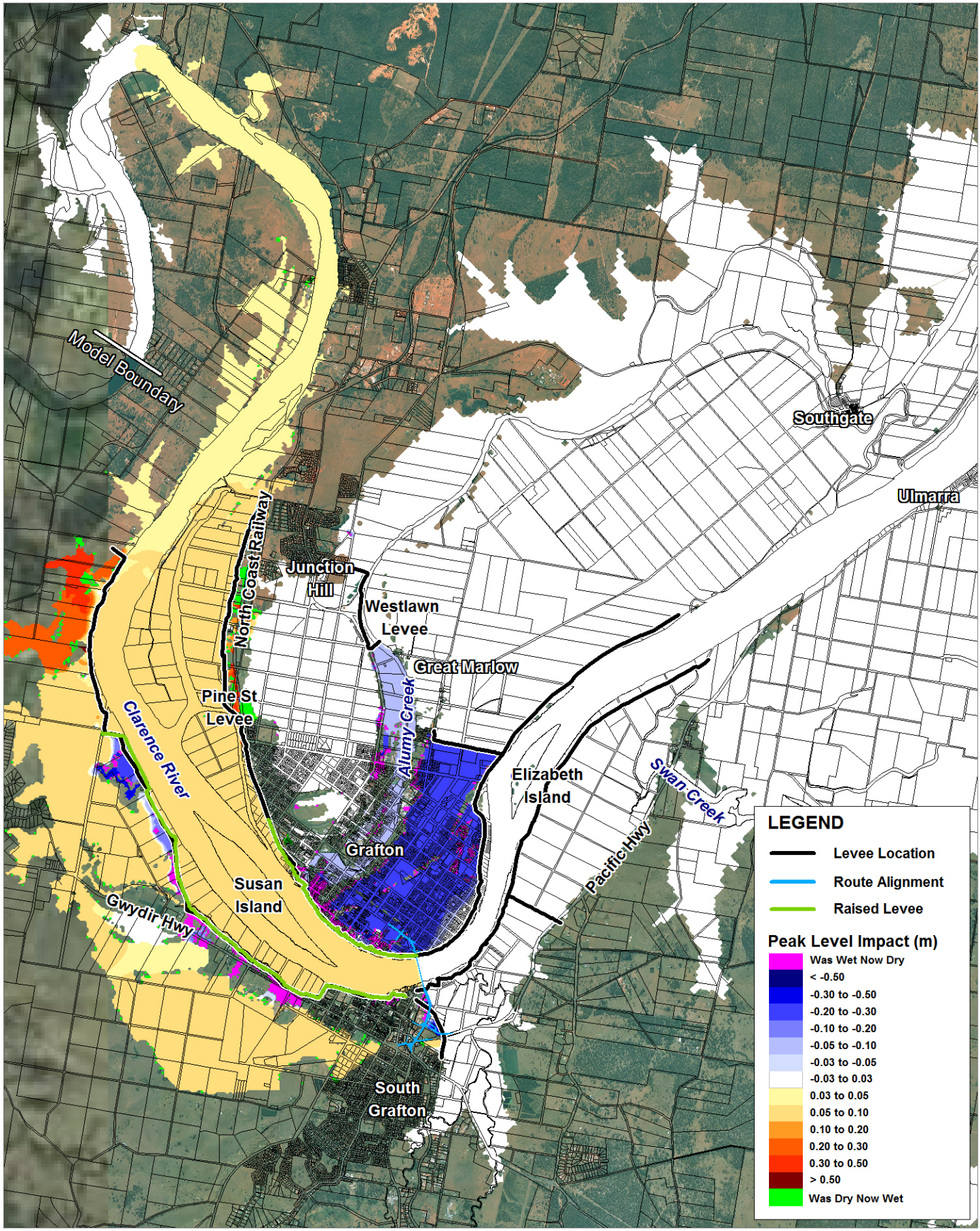
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_073_140428_Q020_Mit02_Hdiff_268.wor"




Title:

# Peak Flood Level Impacts (Mitigation Option 2) 50 Year ARI Event (Extended Model)

Figure: **B-3**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

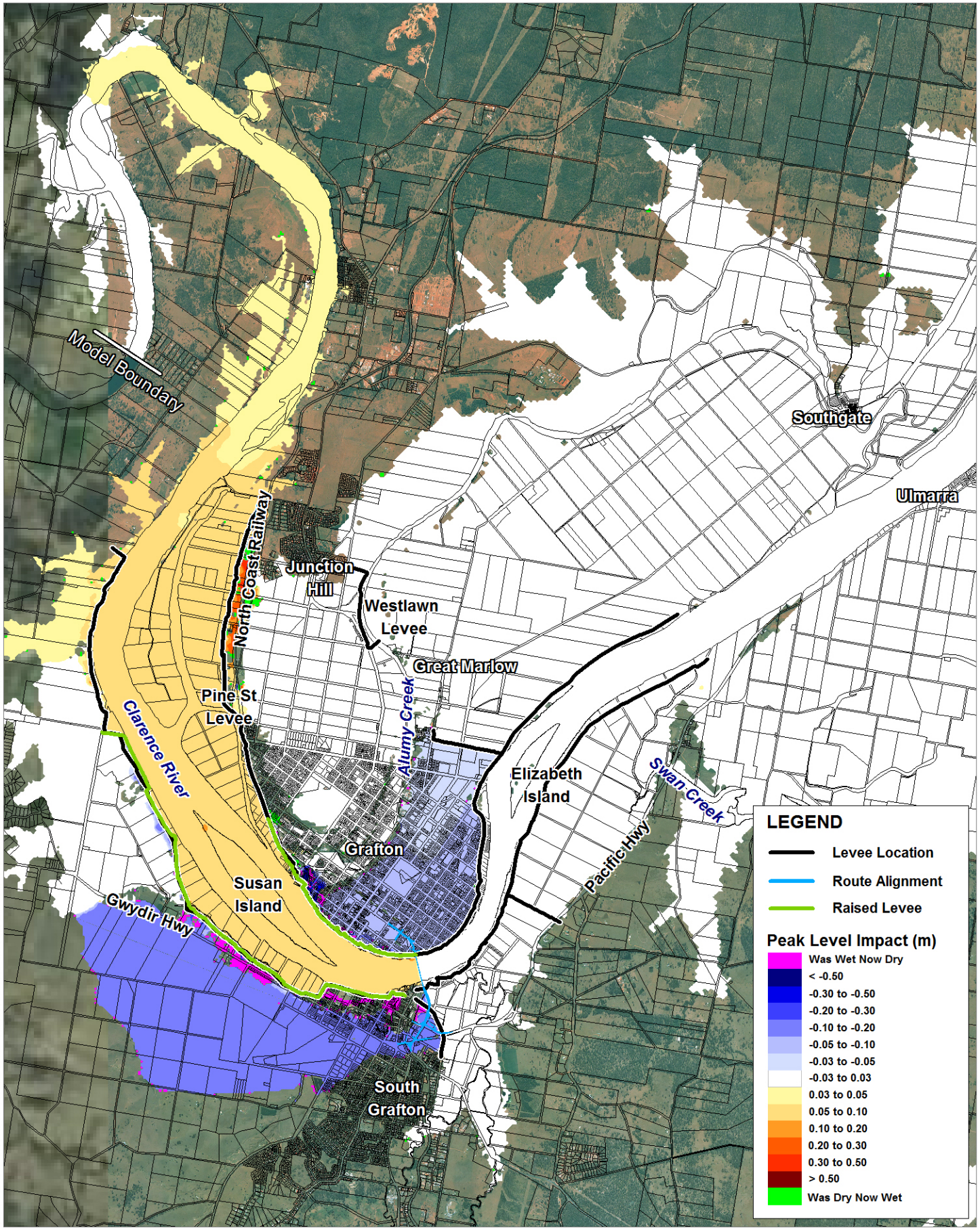
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_074_140428_Q050_Mit02_Hdiff_268.wor"




Title:

# Peak Flood Level Impact (Mitigation Option 2)
# 100 Year ARI Event (Extended Model)

Figure: **B-4**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

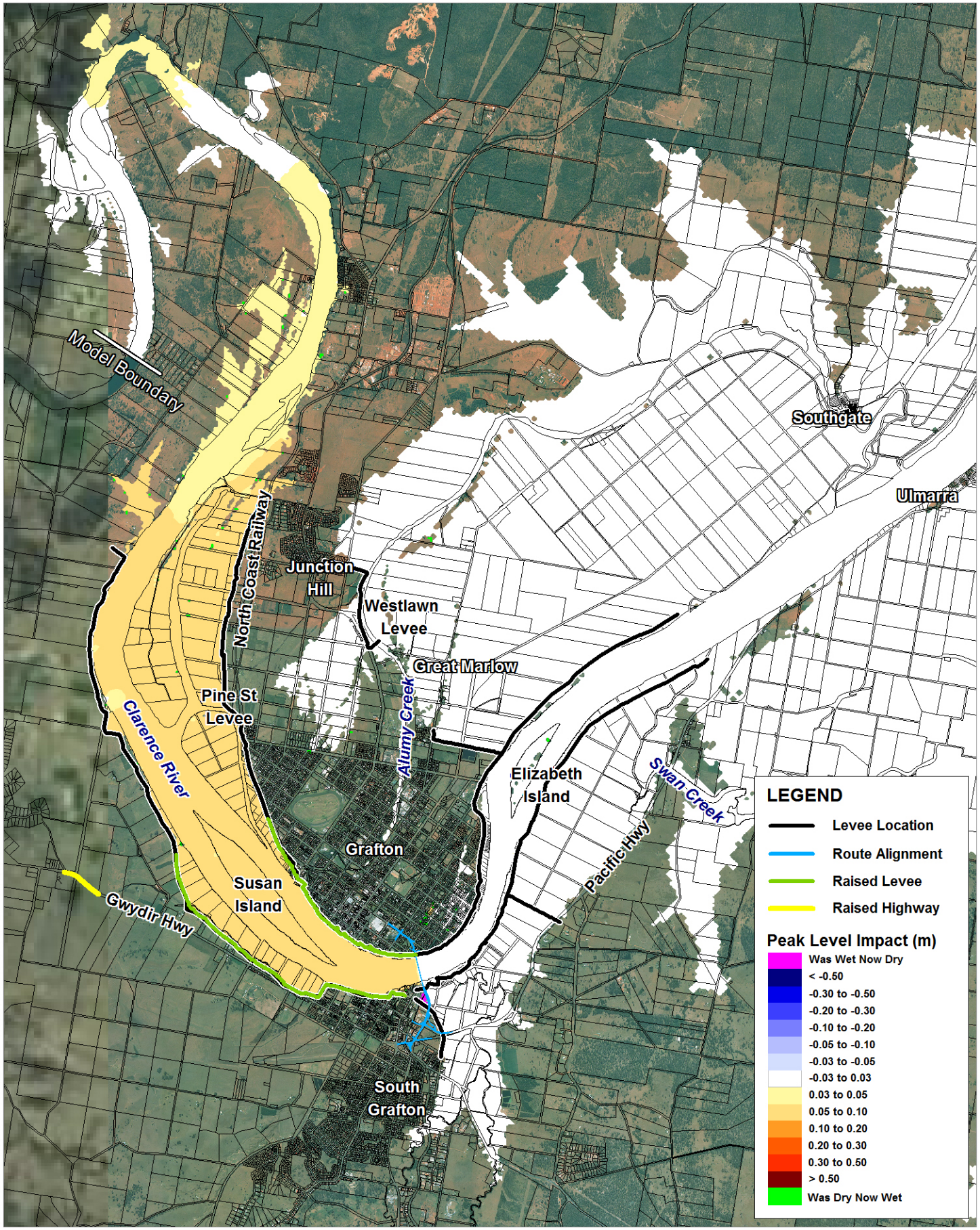
0km 1.5 3

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_075_140428_Q100_Mit02_Hdiff_268.wor"




Title:

# Peak Flood Level Impact (Mitigation Option 4)
# 20 Year ARI Event (Extended Model)

Figure: **B-5**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1.5 3

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_076_140428_Q020_Mit04_Hdiff_268.wor"

# Appendix C Local Drainage Assessment

## C.1 Background

A requirement of the design criteria is that the main approach roads to the new bridge must be flood immune during a 20 year ARI design flood event (see Section 3). Within Grafton the proposed approach alignment runs under the North Coast Railway viaduct at Pound Street. This is an area known to experience existing local drainage issues. The drainage issues in this part of Grafton are predominantly caused by:

(1) Intense short duration storms, resulting in local drainage catchment runoff exceeding the capacity of the stormwater drainage network; and/or

(2) Long duration events resulting in elevated flood levels within the Clarence River, reducing stormwater network outflow.

A preliminary assessment of the local drainage flood behaviour was undertaken which included development of a local scale hydraulic model. This was to establish the baseline 20 year ARI flood levels and to determine if any mitigation measures were required to achieve a 20 year ARI flood immunity design criteria for the approach road under the viaduct.

Under the proposed design, the arch forming the railway viaduct over Pound Street will be modified to obtain the required clearance for heavy goods vehicles.

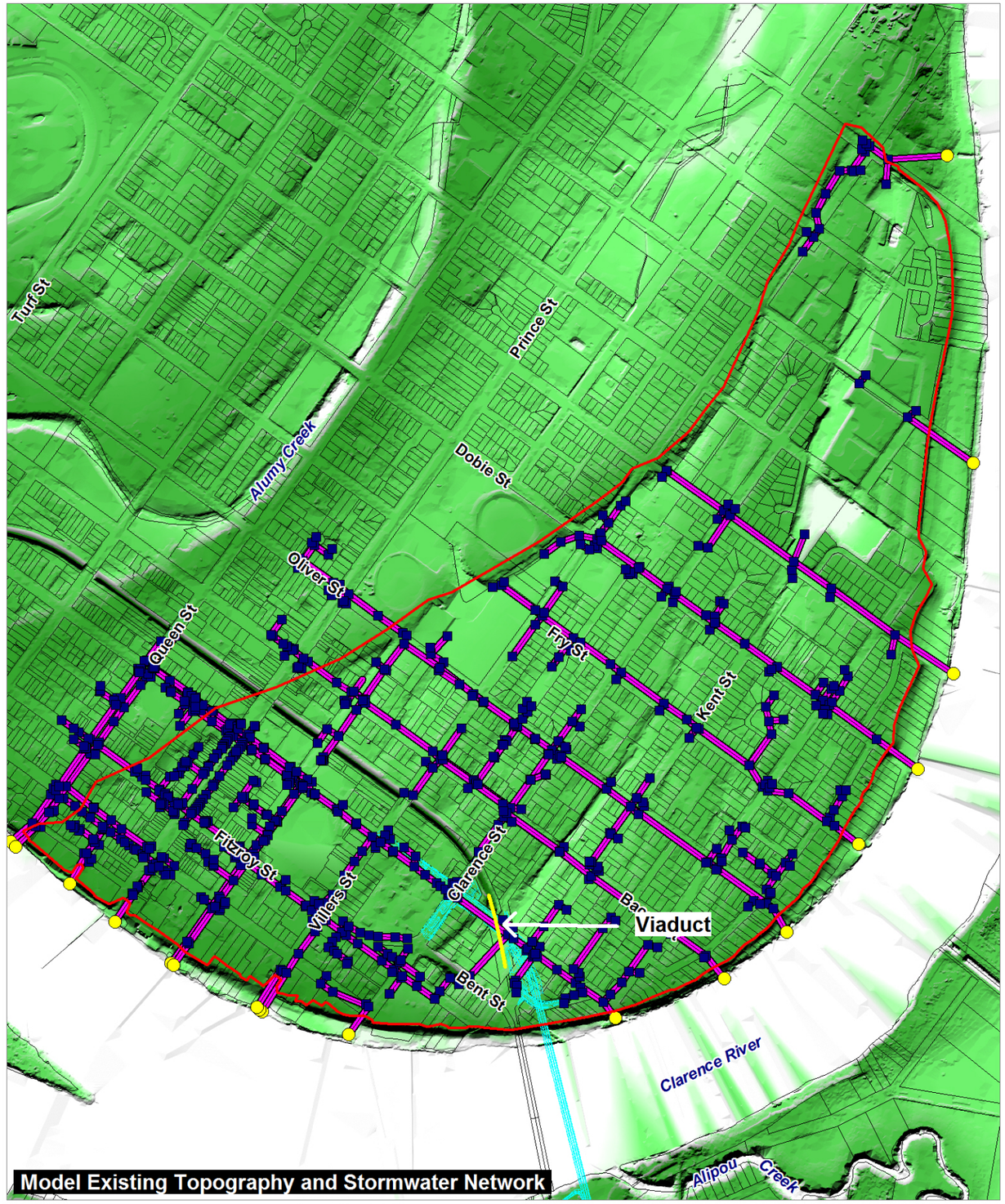
The local drainage model layout is shown in Figure C-1. The model extends beyond the local catchment of the proposed project/railway viaduct crossing. This increased area of assessment was required due to connectivity between neighbouring local drainage catchments via the Grafton stormwater network. A two-dimensional grid resolution of 5m was applied to the entire area, allowing for a detailed representation of the flows within the catchment. One dimensional elements were used to represent the stormwater network within the developed model.

General features represented in the model include:

- The Grafton stormwater pipe network (as supplied by Clarence Valley Council);
- Topographic data obtained from Airborne Laser Survey flown in March of 2010; and
- Refined landuse use mapping digitised from aerial photography, applying Manning's roughness values consistent with the greater Lower Clarence flood model (BMT WBM, 2013).

A 'direct rainfall' approach was used for the inflows to the hydraulic model with a mapping cutoff depth of 50mm. Losses applied to the model are as follows:

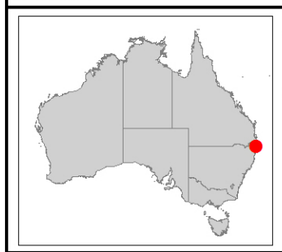
- Initial Rainfall Loss = 0mm;
- Continuing Rainfall Losses, Pervious Areas = 2.5mm/h; and
- Continuing Rainfall Losses, Impervious Areas = 0.0mm/h.




Model Existing Topography and Stormwater Network




Model Landuse Representation



**LEGEND**

- Local Drainage Model Extent
- Stormwater Network
- Stormwater Pit
- Stormwater Outlet
- Route Alignment

**Landuse**

- Urban Blocks
- Roads
- Maintained Grass
- Unmaintained Grass

Title:
# Grafton Local Drainage Model Layout

Figure: C-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0m 300 600

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_045_140122_Local_DR_Model.wor"

## C.2 Boundary conditions

In Grafton, a 3 hour rainfall event is the critical duration event; the duration which ordinarily results in higher flood levels within areas such as Pound Street. However, long duration but less intense rainfall events can cause the Clarence River levels to rise. The increased river levels may, in turn prevent local runoff generated within Grafton from draining to the river.

This assessment has therefore considered the two scenarios of a long duration 20 year ARI rainfall event and a short duration 20 year ARI event. Consideration of both together, i.e. a 20 year ARI river level combined with a 20 year (or greater) ARI short duration storm event would have a combined probability greater than a 20 year ARI event and the assessment of such an event is not required to meet the road design criteria.

A historic rainfall event which occurred in 2009 has been simulated in the existing case model as a verification event to ensure the model is performing adequately.

The three event scenarios modelled as part of this assessment are summarised in Table C-1.

**Table C-1 Grafton local drainage model event scenarios**

| ID | Event Description | Catchment Rainfall Inflow | River Downstream Boundary Condition | Comment |
|---|---|---|---|---|
| 1 | Historic 2009 Flood Event | Rainfall data sourced from BoM from South Grafton gauge | River water level boundaries sourced from 2009 event Lower Clarence flood model calibration simulation (BMT WBM, 2013) | Model verification event |
| 2 | 3 hour 20 Year ARI Event Rainfall combined with a Mean High Water Spring Tide (fixed river boundary) | Rainfall data sourced from BoM Intensity Frequency Duration Program (rainfall volume = 95mm) | Mean high water tide level sourced from Manly Hydraulics | 3hrs = Critical storm event duration when Clarence River is not in flood |
| 3 | 72 hour 20 Year ARI Event Rainfall combined with a 20 Year ARI Clarence River Flood Event (dynamic river boundary) | Rainfall data sourced from BoM Intensity Frequency Duration Program (rainfall volume = 312mm) | River water level boundaries sourced from 20 Year ARI event Lower Clarence flood model | 72hrs = Critical storm event duration when Clarence River is in flood |

Figure C-2 to Figure C-4 show the model boundary conditions for the event scenarios.

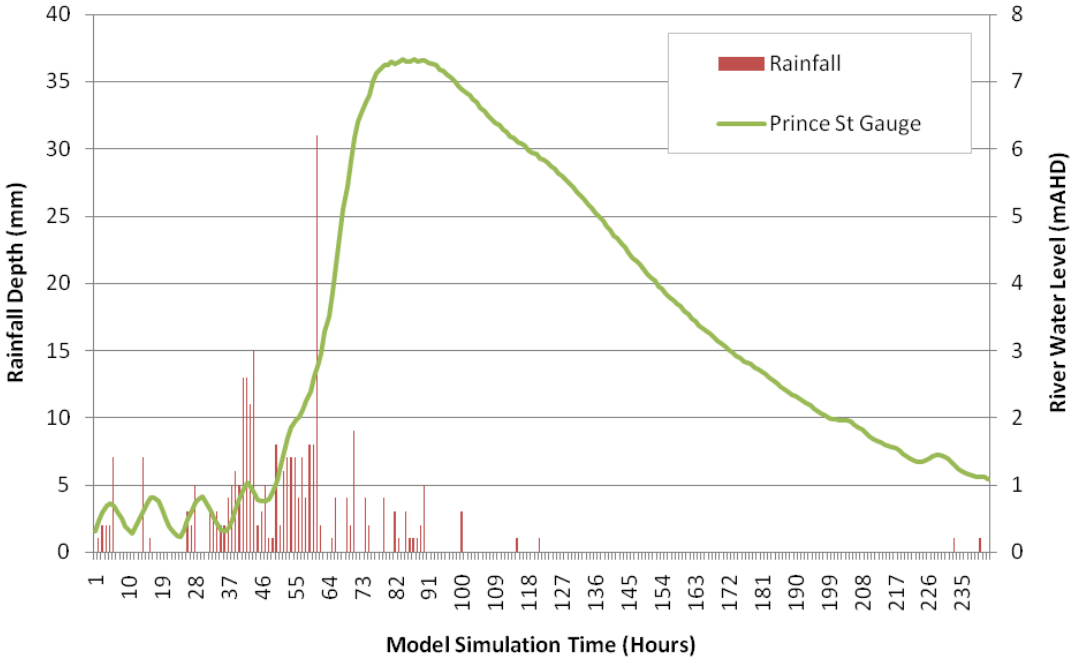



**Figure C-2 Grafton local drainage model – 2009 boundary conditions**

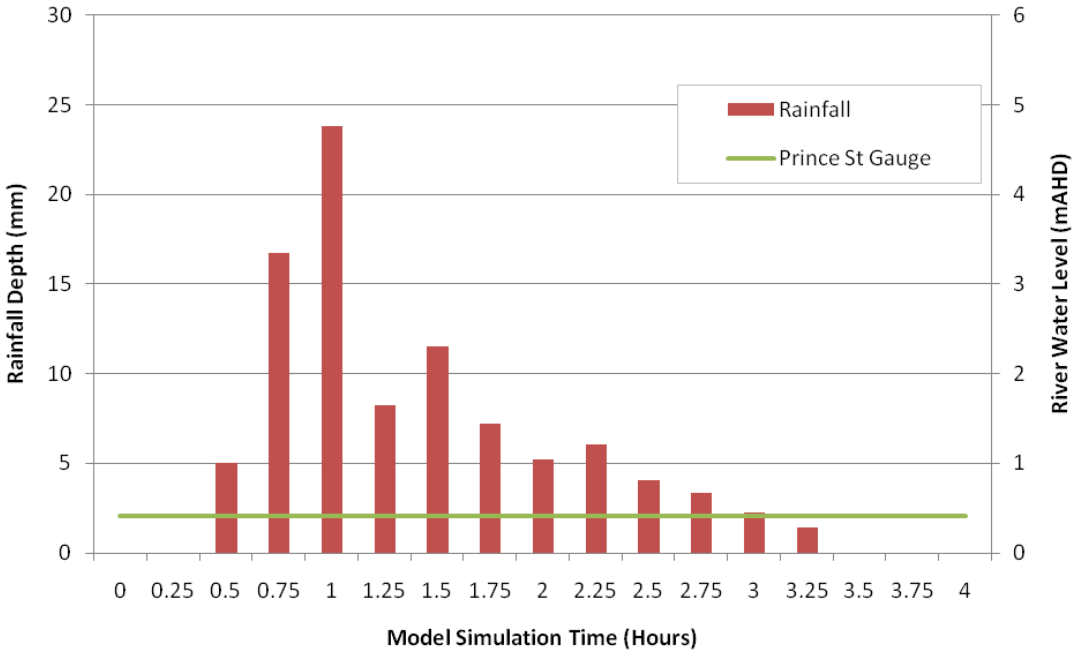



**Figure C-3 Grafton local drainage model – 3 hour, 20 year ARI boundary conditions**

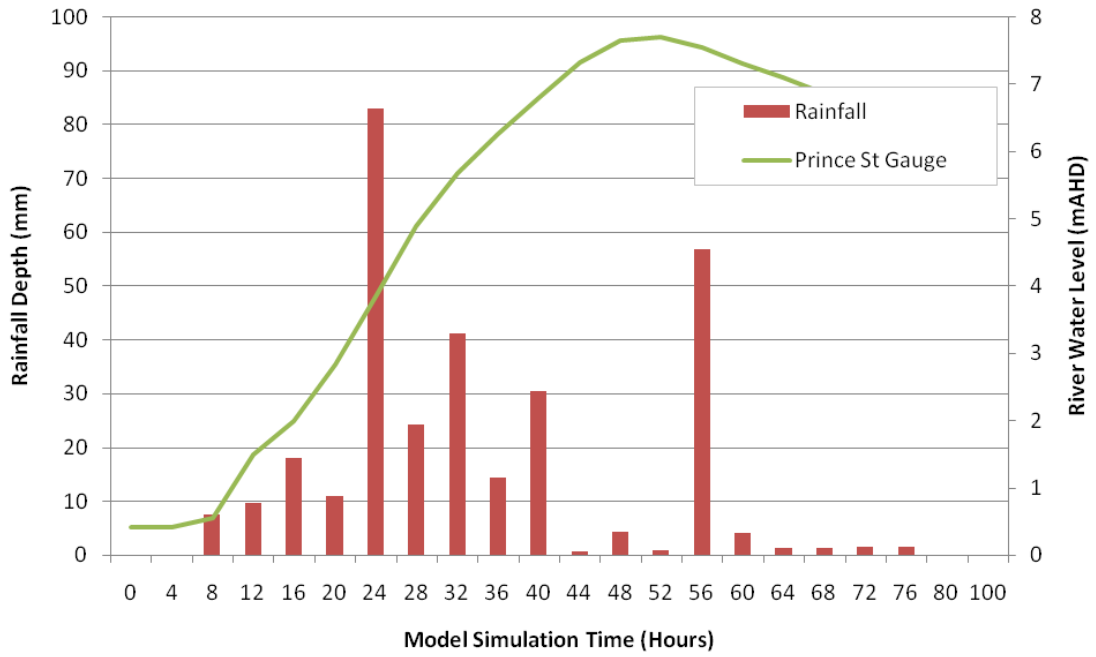



**Figure C-4 Grafton local drainage model – 72 hour, 20 year ARI boundary conditions**

The rainfall of the 2009 event is approximately equivalent to a 10 year ARI event for a 72 hour duration scenario (when the Clarence River would be expected to be in flood).

## C.3 Assessment results

### C.3.1 Existing case

The results for the existing case (pre- additional crossing and associated features) are shown in Figure C-5 to Figure C-7. It can be seen that there is significant inundation in the area of interest where Pound Street passes under the railway viaduct.

Flood levels adjacent to the railway viaduct for the assessed event scenarios are summarised below:

(1) Historic Flood Event: Recorded 3.75mAHD; Modelled 3.52mAHD;

(2) 3 hour, 20 year ARI event rainfall combined with a Mean High Water Spring tide: 3.49mAHD; and

(3) 72 hour, 20 year ARI event rainfall combined with a 20 year ARI flood event within the Clarence River: 4.35mAHD.









**LEGEND**

- Railway Line
- Route Alignment
- 3.52 Modelled Flood Level (mAHD)
- 3.75 Recorded Flood Level (mAHD)
- Cadastral Boundaries

| Peak Level (mAHD) |
|---|
| 1.0 to 2.0 |
| 2.0 to 3.0 |
| 3.0 to 4.0 |
| 4.0 to 5.0 |
| 5.0 to 6.0 |
| 6.0 to 7.0 |
| 7.0 to 8.0 |
| 8.0 to 9.0 |

| Peak Depth (m) |
|---|
| 0.0 to 0.5 |
| 0.5 to 1.0 |
| 1.0 to 1.5 |
| 1.5 to 2.0 |
| 2.0 to 2.5 |
| 2.5 to 3.0 |
| 3.0 to 3.5 |
| 3.5 to 4.0 |
| 4.0 to 4.5 |
| 4.5 to 5.0 |
| > 5.0 |

Title:

# Grafton Local Drainage Model Validation
# 2009 Event Results

Figure: C-5

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0m 100 200

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_046_140122_Local_DR_2009Cal.wor"









**LEGEND**

- Railway Line
- Route Alignment
- Cadastral Boundaries

| Peak Level (mAHD) | Peak Depth (m) |
|---|---|
| 1.0 to 2.0 | 0.0 to 0.5 |
| 2.0 to 3.0 | 0.5 to 1.0 |
| 3.0 to 4.0 | 1.0 to 1.5 |
| 4.0 to 5.0 | 1.5 to 2.0 |
| 5.0 to 6.0 | 2.0 to 2.5 |
| 6.0 to 7.0 | 2.5 to 3.0 |
| 7.0 to 8.0 | 3.0 to 3.5 |
| 8.0 to 9.0 | 3.5 to 4.0 |
| | 4.0 to 4.5 |
| | 4.5 to 5.0 |
| | > 5.0 |

Title:

# Existing Case Grafton Local Drainage Model
# 3 Hour 20 Year ARI Event Results (MHWS River Level)

Figure: C-6

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

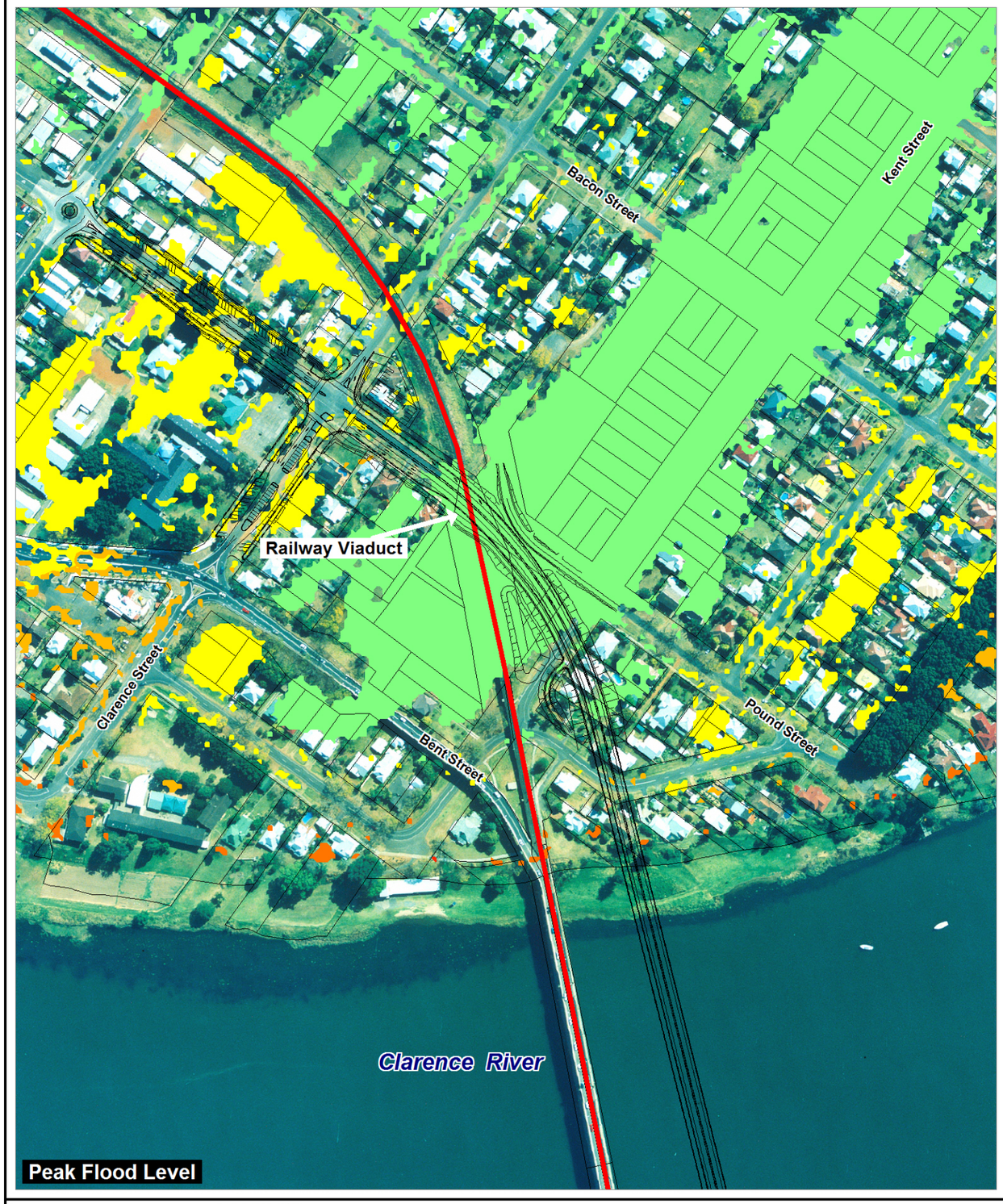
N

0m 100 200

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_047_140122_Local_DR_Q20_3hr.wor"









**LEGEND**

- Railway Line
- Route Alignment
- Cadastral Boundaries

| Peak Level (mAHD) | Peak Depth (m) |
|---|---|
| 1.0 to 2.0 | 0.0 to 0.5 |
| 2.0 to 3.0 | 0.5 to 1.0 |
| 3.0 to 4.0 | 1.0 to 1.5 |
| 4.0 to 5.0 | 1.5 to 2.0 |
| 5.0 to 6.0 | 2.0 to 2.5 |
| 6.0 to 7.0 | 2.5 to 3.0 |
| 7.0 to 8.0 | 3.0 to 3.5 |
| 8.0 to 9.0 | 3.5 to 4.0 |
| | 4.0 to 4.5 |
| | 4.5 to 5.0 |
| | > 5.0 |

Title:

# Existing Case Grafton Local Drainage Model
# 72 Hour 20 Year ARI Event Results (Combined River Flooding)

Figure: C-7

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0m 100 200

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_048_140122_Local_DR_Q20_72hr.wor"

### C.3.2 Developed case

The lowest road elevation along the proposed bridge approach is 3.7mAHD. As a result, with no mitigation, the road would be inundated during the 20 year ARI for the long duration 72 hour event, and be close to being inundated from the short duration 20 year ARI event.

The proposed mitigation aims to create additional storage in the form of a detention basin on the southern side of Pound Street. Flow will be conveyed under Pound Street and the new approach road and into the basin by a series of culverts. Installation of the culverts will intercept the existing piped drainage network under Pound Street. It is proposed to redirect the piped local drainage at this location into the detention basin. The basin also intercepts a local drainage pipe from the west. This will also be diverted into the detention basin. The basin then drains out to the Clarence River via a new outlet pipe with a floodgate.

For short duration (3 hour) events the basin and its associated new outlet will provide sufficient storage/conveyance to significantly lower the 20 year peak flood level to be below the road surface. During these short duration events the water level in the Clarence River will typically be around normal levels and the detained water will drain from the basin via gravity. For long duration (72 hour) events, the Clarence River will most likely be in flood and the basin will detain the water from where it is pumped to the river.

Optimisation of the design has shown that the following arrangement achieves the design criteria:

- A detention basin with a volume of approximately 1,500m$^3$ located on the southern side of Pound Street;
- Pump/s with a combined capacity of up to 2m$^3$/s; and
- A series of culverts under Pound Street with a cross sectional flow area[11] up to 3.75m$^2$.

Table C-2 summarises the resulting peak flood levels following mitigation for the approach road at Pound Street.

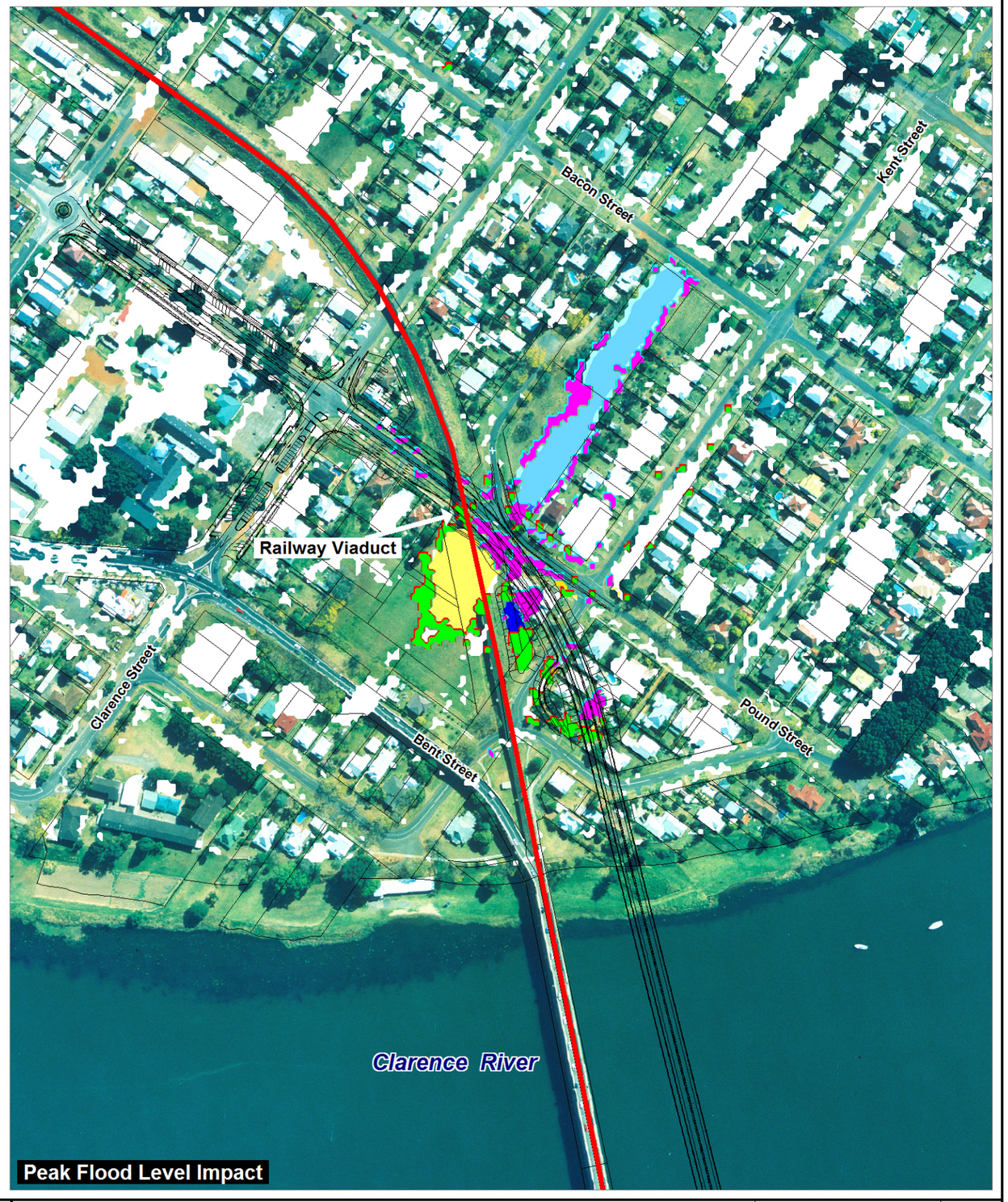
**Table C-2 Mitigated peak flood levels at Grafton approach road**

| 20 year ARI 3 Hour Event | 20 year ARI 72 Hour Event |
|---|---|
| 2.6mAHD | 2.9mAHD |

It should be noted that with further refinement there is scope to reduce the basin size and/or required pumping capacity but the above arrangement demonstrates that a solution can be achieved. Figure C-8 and Figure C-9 present the resulting peak flood levels and change in levels from the existing case for the 20 year ARI 3 hour and 72 hour storm durations respectively.

[11] For hydraulic design purposes a 20% blockage has been assumed by modelling a cross sectional area of 3.0m$^2$.






**LEGEND**

- Railway Line
- Route Alignment
- Cadastral Boundaries

**Peak Level (mAHD)**

- 1.0 to 2.0
- 2.0 to 3.0
- 3.0 to 4.0
- 4.0 to 5.0
- 5.0 to 6.0
- 6.0 to 7.0
- 7.0 to 8.0
- 8.0 to 9.0

**Peak Level Impact (m)**

- Was Wet Now Dry
- < -1.00
- -1.00 to -0.50
- -0.50 to -0.25
- -0.25 to -0.10
- -0.10 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- 0.50 to 1.00
- > 1.00
- Was Dry Now Wet

Title:

# Developed Case Grafton Local Drainage Model
# 3 Hour 20 Year ARI Event Results (MHWS River Level)

Figure: C-8

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

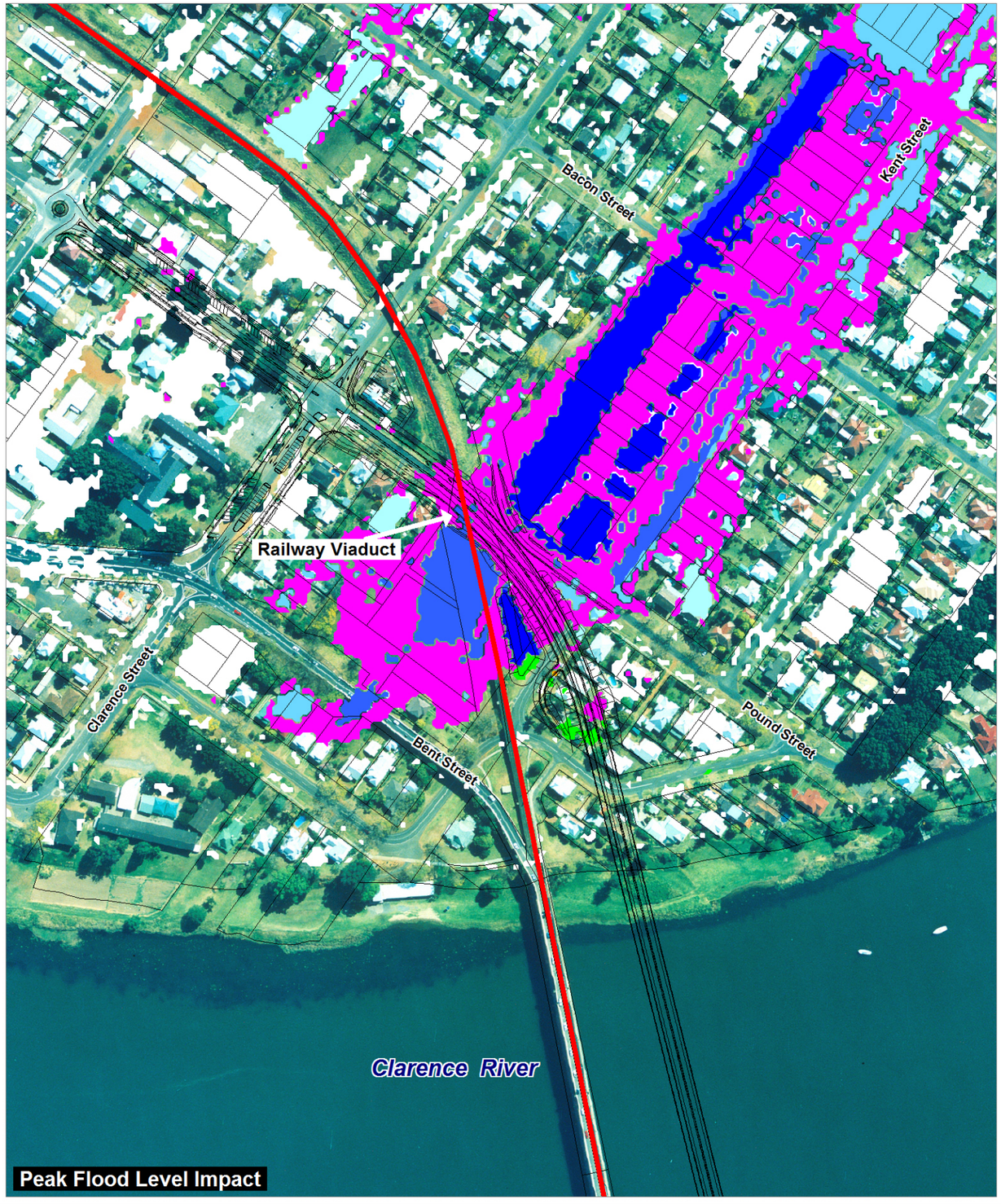
0m 100 200

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_049_140122_Local_DR_Q20_3hr_Impact.wor"






**LEGEND**

- Railway Line
- Route Alignment
- Cadastral Boundaries

| Peak Level (mAHD) | Peak Level Impact (m) |
|---|---|
| 1.0 to 2.0 | Was Wet Now Dry |
| 2.0 to 3.0 | < -1.00 |
| 3.0 to 4.0 | -1.00 to -0.50 |
| 4.0 to 5.0 | -0.50 to -0.25 |
| 5.0 to 6.0 | -0.25 to -0.10 |
| 6.0 to 7.0 | -0.10 to 0.10 |
| 7.0 to 8.0 | 0.10 to 0.25 |
| 8.0 to 9.0 | 0.25 to 0.50 |
| | 0.50 to 1.00 |
| | > 1.00 |
| | Was Dry Now Wet |

Title:

# Option C Grafton Local Drainage Model
# 72 Hour 20 Year ARI Event Results (Combined River Flooding)

Figure: C-9

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0m 100 200

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B17815_I_Summerland_Way\DRG\EIS\FLD_050_140122_Local_DR_Q20_72hr_Impact.wor"








BMT WBM Bangalow
6/20 Byron Street, Bangalow 2479
Tel +61 2 6687 0466 Fax +61 2 66870422
Email bmtwbm@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Brisbane
Level 8, 200 Creek Street, Brisbane 4000
PO Box 203, Spring Hill QLD 4004
Tel +61 7 3831 6744 Fax +61 7 3832 3627
Email bmtwbm@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Denver
8200 S. Akron Street, #B120
Centennial, Denver Colorado 80112 USA
Tel +1 303 792 9814 Fax +1 303 792 9742
Email denver@bmtwbm.com
Web www.bmtwbm.com

BMT WBM London
International House, 1st Floor
St Katharine's Way, London E1W 1AY
Email london@bmtwbm.co.uk
Web www.bmtwbm.com

BMT WBM Mackay
Suite 1, 138 Wood Street, Mackay 4740
PO Box 4447, Mackay QLD 4740
Tel +61 7 4953 5144 Fax +61 7 4953 5132
Email mackay@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Melbourne
Level 5, 99 King Street, Melbourne 3000
PO Box 604, Collins Street West VIC 8007
Tel +61 3 8620 6100 Fax +61 3 8620 6105
Email melbourne@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Newcastle
126 Belford Street, Broadmeadow 2292
PO Box 266, Broadmeadow NSW 2292
Tel +61 2 4940 8882 Fax +61 2 4940 8887
Email newcastle@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Perth
Suite 6, 29 Hood Street, Subiaco 6008
Tel +61 8 9328 2029 Fax +61 8 9486 7588
Email perth@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Sydney
Level 1, 256-258 Norton Street, Leichhardt 2040
PO Box 194, Leichhardt NSW 2040
Tel +61 2 8987 2900 Fax +61 2 8987 2999
Email sydney@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Vancouver
Suite 401, 611 Alexander Street
Vancouver British Columbia V6A 1E1 Canada
Tel +1 604 683 5777 Fax +1 604 608 3232
Email vancouver@bmtwbm.com
Web www.bmtwbm.com