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Bowen Water Hazards Assessment Stage 2:
Coincident Event Modelling Basis Report & Mapping

January 2018

Whitsunday Regional Council

Document Control Sheet

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Executive Summary

A pre-screening analysis to assess the potential impact to peak water level due to the coincidence of coastal inundation (storm tide) and catchment flooding across the Bowen local area has been completed. The analysis follows the two-stage approach described in the Australian Rainfall and Runoff 2016 Guidelines (ARR2016), Book 6, Chapter 5 (Westra et al. 2016). In accordance with State Planning Policy (SPP) for assessing natural hazards, both current climate and future climate assessments were completed.

With regard to catchment flooding statistics, the analysis adopted the outcomes of previous assessments described in AECOM (2014), AECOM (2015a) and AECOM (2015b). The storm tide water level statistics were taken from the recently completed Bowen Water Hazards Assessment Stage 1: Storm Tide Modelling Basis (BMT WBM & SEA 2017).

The pre-screening analysis estimated the extent of the 1% AEP ‘joint probability zone’ and magnitude of impact due to storm tide coinciding with catchment flooding. The overall extent of the joint probability zone is relatively large; however, the magnitude of the impact is considered small and typically within the 0.3 m freeboard allowance adopted for planning purposes throughout the WRC local government area.

The overall impact extent, and magnitude in some areas, increases between the current climate and future climate scenarios due to the assumed increase to rainfall intensity, change to TC climatology and associated storm tide response, and increase to mean sea-level. The relative contribution of each future climate assumption has not been established; however, the sea-level rise assumption (combined with the storm tide condition) is expected to be the dominant influence. Sea-level rise is likely to impact the performance of drainage infrastructure at the coastline.

Considering the relatively small impact to water level surfaces associated with the coincidence of storm tide and catchment flooding across the Bowen local area, a more complex joint probability assessment is not considered necessary. Under this scenario and following ARR2016, ‘complete dependence’ can be assumed and the ‘dependence case’ scenario, combining storm tide and catchment processes at the AEPs of interest, is considered an appropriate estimate of flood levels across the study area.

Prior to assessing the relevant dependence case scenarios in detail, it is recommended that the Bowen local catchment flood hazard statistics are updated in accordance with ARR2016. In the interim, planning throughout the Bowen local catchment should consider both the independent storm tide and catchment flood levels. In areas exposed to both flood hazards, the higher water level should be adopted. Within the defined joint probability zones, WRC may wish to consider increasing the additional freeboard allowance from 0.3 m to 0.5 m to account for the potential influence of coastal processes on catchment flood levels.

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1 Introduction

1.1 Project Background

The Whitsunday Regional Council (WRC) has identified potential risks to the Bowen region associated with inundation hazards, namely:

(1) Inundation of coastal areas due to storm tide; and

(2) The coincidence of coastal inundation and catchment flooding.

Throughout north Queensland these hazards are often associated with severe Tropical Cyclone (TC) weather systems.

This report focuses on technical assessments to better understand the potential hazard associated with coincident coastal inundation (storm tide) and catchment flooding. The work flow for this analysis is summarised in Figure 1-1 and builds on the Bowen Water Hazards Assessment Stage 1: Storm Tide Modelling Basis (BMT WBM & SEA 2017) and a number of previous Don River and Bowen local catchment flood studies, namely:

- Don River Flood Risk and Mitigation Study (AECOM 2014)
- Bowen Local Catchment Flood Study (AECOM 2015a)
- Don River and Bowen Local Catchment Coincident Flood Study (AECOM 2015b)

The approach to the assessments described in this report generally follows the Australian Rainfall and Runoff 2016 Guidelines (ARR2016), Book 6, Chapter 5 (Westra et al. 2016). This involved determining a 'joint probability zone' which is defined in ARR2016 as being a *'region in which the dependence between riverine and ocean processes has the potential to influence the design flood level'*. This approach is described further in Section 1.2.

Current & future climate considerations for the Bowen region

↓

Development of recommeded storm tide design water levels (i.e. Bowen Water Hazards Assessment Study Stage 1)

↓

Detailed modelling of conincident coastal inundation and catchment flooding events

↓

Analysis to determine the joint probability (coincident event) zone and its significance

Figure 1-1 Coincident inundation event hazard assessment work flow

1.2 Coincident Event Assessment Approach

The concept of the so-called joint probability zone is illustrated in Figure 1-2 and is determined through a comparison of peak level results from a complete independent scenario (lower curve) with a complete dependent scenario (upper curve).

In the case of the present study, an independent event refers to either:

- A Don River breakout and/or a local catchment rainfall event occurring during normal tide conditions; or
- A storm tide event occurring in the absence of significant rainfall.

The 'complete independence' scenario is derived by combining the peak water level surfaces from the individual events listed above. The resulting 'peak water level envelope' represents both catchment flooding and coastal inundation that occur independently.

A 'complete dependence' event refers to the resulting peak water level from a Don River breakout and/or local catchment flooding event perfectly coinciding with the peak of a storm tide event.

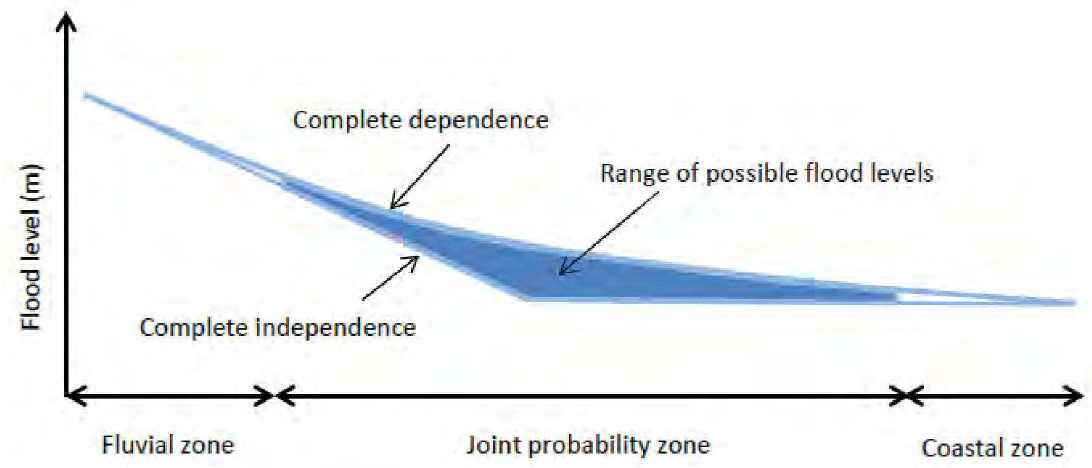


Figure 1-2 Illustration of Joint Probability Zone (Source: Book 6, ARR2016)

The ‘fluvial zone’ shown in Figure 1-2 is defined as the area upstream from the joint probability zone where catchment flood mechanisms dominate and is generally unaffected by the coastal water level. That is, the resulting peak water levels within the fluvial zone from a 100 year ARI (1% AEP) catchment event would be similar regardless of whether normal tide conditions or 100 year ARI storm tide conditions existed at the coastline.

Similarly, the ‘coastal zone’ is downstream of the joint probability zone and peak flood levels are generally determined by the storm tide water level with little influence from catchment flows.

If the joint probability zone is of limited spatial extent and/or the maximum difference in flood levels within the joint probability zone is small then a full treatment of joint probability using the design variable method (or other more complex joint probability approach) described in ARR2016 is generally not warranted (Westra et al. 2016). Therefore, assessing the joint probability of catchment flooding coinciding with storm tide conditions is considered a two-stage process:

- Stage 1: A pre-screening analysis in which the maximum peak level difference within the joint probability zone is determined and assessed against an adopted tolerance. If the difference is less than the tolerance, then further assessment is not warranted.
- Stage 2: If peak level differences in Stage 1 are greater than the adopted tolerance, then proceed to full treatment of joint probability using the design variable method (or other more complex joint probability approach) as detailed in ARR2016.

The analyses applied in the present study focuses on the Stage 1 pre-screening described above. This allows the extent and magnitude of the potential coincident flood hazard to be better understood and determine whether a Stage 2 analysis is of value to Council and the Bowen region.

2 Modelling of Coincident Events

2.1 Modelling Approach

A suite of numerical models described in AECOM (2015b) have been used to simulate both independent and dependent flood scenarios as part of the coincident event pre-screening analysis. The MIKE 21 Bowen Local Model configuration is illustrated in Figure 2-1 and includes:

- Direct rainfall inputs (XP-RAFTS and rain-on-grid)
- Representation of hydraulic structures (MIKE 11)
- Representation of the drainage network (MIKE URBAN)
- Tidal boundary at the downstream model extent
- A number of potential locations for Don River breakout flows

The breakout flow rates are informed by output from a separate Don River MIKE 21 Flexible Mesh model. The Don River flood hazard assessments and model development is described in AECOM (2014).

The 100 year ARI (1% AEP) was used as the basis for coincident event pre-screening and determining whether the additional complexity of a joint probability analysis would be warranted. The current and future climate model inputs and assumptions are discussed throughout this Chapter.

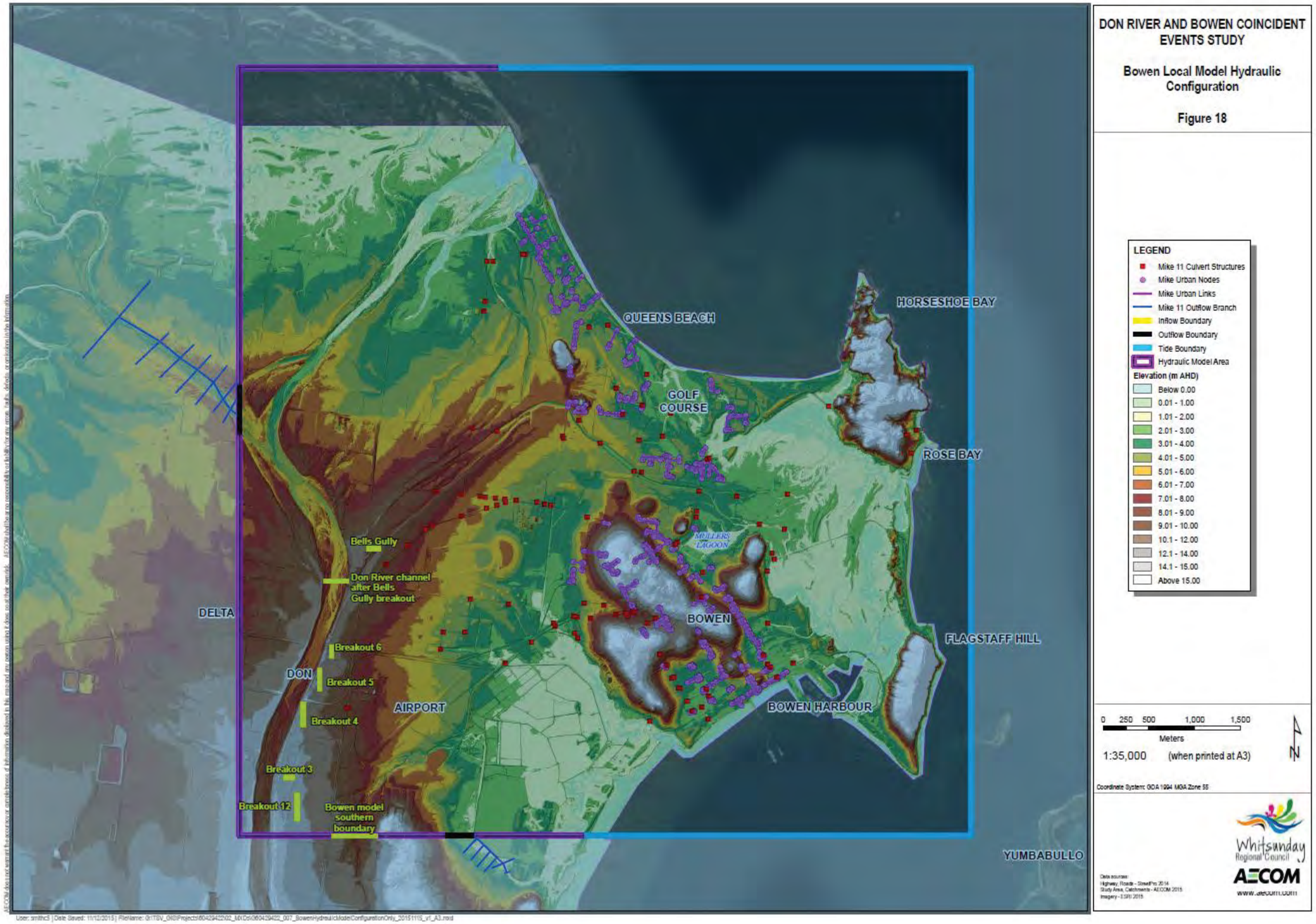


Figure 2-1 Bowen Local Model configuration (from AECOM 2015b)

2.1.1 Current Climate Scenarios

The current climate scenario model inputs are summarised in Table 2-1.

Storm tide water level statistics have been recently derived for the Bowen region as part of the Bowen Water Hazards Assessment Stage 1: Storm Tide Modelling Basis (BMT WBM & SEA 2017). The current climate 'sustained peak' storm tide level has been used to define the downstream model boundary for the coincident event pre-screening analysis. A static water level, as opposed to a tidally varying water level timeseries, was adopted at the downstream boundary. This represents the peak storm tide level coinciding with the peak rainfall event and is likely to be a conservative assumption (that is, the peak ocean water level precisely coinciding with the peak rainfall is expected to be a rare event).

Existing Don River and Bowen local catchment flood statistics and coincident event scenarios have been used as the basis for the coincident event pre-screening analysis. Full details of the previous flood assessments, and the basis for Don River and Bowen local catchment flood scenario definitions, are provided in AECOM 2014, AECOM 2015a and AECOM 2015b[1].

Table 2-1 Summary of current climate scenario model inputs

Parameter	Current Climate	Units
1% AEP sustained peak storm tide level[1]	2.3	mAHD
1% AEP peak rainfall intensity (6-hour duration)[2]	39.1	mm/hr
1% AEP Don River breakout peak flow (6-hour duration)[2]:		m^3/s
-breakout locations 1,2	25.7	
-breakout location 3	6.8	
-breakout location 4	19.3	
-breakout location 5	128.0	
-breakout location 6	42.1	
-Bowen model southern boundary	1,399	
-Bells Gully	10.9	
-Don River Channel (after Bells Gully breakout)	3,328	

[1]*Defined by Bowen Water Hazards Assessment Stage 1: Storm Tide Modelling Basis (BMT WBM & SEA 2017)*

[2]*Defined by previous AECOM assessments (AECOM 2014; AECOM 2015a; AECOM 2015b)*

2.1.2 Climate Change Considerations

In accordance with the SPP, future climate scenarios should be considered in natural hazard risk assessment and planning in Queensland. In the context of the present study, the principal assumptions associated with defining a future climate scenario are related to increases to mean sea level, changes to TC climatology and increases to rainfall intensity. These primary future climate considerations are briefly discussed below.

[1] Updates to the existing catchment-scale assessments are beyond the scope of the present study and the previously developed tools and statistics have been assumed suitable for the coincident event pre-screening analysis. It is noted that some of the assumptions underpinning the previous studies have been superseded by ARR2016.

2.1.2.1 Tropical Cyclones & Storm Tide

Following the Engineers Australia Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering (Harper 2012, 2017), key considerations for the present study that are deemed relevant to the Bowen region include:

- Sea-Level Rise
- Tropical Cyclones (tracks, intensity, frequency, rainfall)

The future climate assumptions relating to sea-level rise and tropical cyclone climatology are summarised in Table 2-2. This information was used to inform parametric modelling of TC events and detailed numerical modelling of storm tide inundation for selected TC events. Further details regarding these assumptions are provided BMT WBM & SEA (2017). It is noted that the design water levels reported in BMT WBM & SEA (2017) and adopted in the present study also included consideration of the non-cyclonic storm tide statistics.

Table 2-2 Year 2050 and 2100 coastal processes climate change parameters

Parameter	2050	2100	Units
MSL Increase	0.4	0.8	m
TC Maximum Potential Energy (MPI) Increase	5%	10%	m/s
	10%	20%	hPa
TC Frequency Change	0%	0%	-

2.1.2.2 Rainfall Intensity

The ARR Data Hub provides 'Interim Climate Change Factors' for the Whitsunday region, including average increases to temperature and associated percentage increases to rainfall intensity for a set of forecast years and Representative Concentration Pathway (RCP) gas emission scenarios up to the year 2090. The RCP scenarios follow the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC 2014) and CSIRO & BOM (2015). The ARR Data Hub percentage increases to rainfall relevant to the Whitsunday region are summarised in Table 2-3.

Table 2-3 ARR Interim Climate Change Factors: rainfall intensity increase

Planning Horizon	RCP 4.5	RCP 6.5	RCP 8.5	Units
2030	3.6%	3.3%	4.0%	mm/hr
2040	4.6%	4.2%	5.5%	mm/hr
2050	5.5%	5.2%	7.3%	mm/hr
2060	6.3%	6.3%	9.3%	mm/hr
2070	7.0%	7.4%	11.4%	mm/hr
2080	7.5%	8.6%	13.5%	mm/hr
2090	7.6%	9.7%	15.6%	mm/hr

In addition to the ARR Interim Climate Change Factors provided in Table 2-3, consideration was also given to the rainfall intensity increases adopted as part of the recently completed Town of Whitsunday Drainage Study (BMT WBM 2017). This study defined 2050 and 2100 rainfall intensity increases considering both the ARR Data Hub values and climate change factors incorporated to the URBS rainfall runoff routing software package (hydrologic model). Table 2-4 summarises the rainfall intensity increases adopted by BMT WBM (2017) and the present study.

Table 2-4 Year 2050 and 2100 rainfall intensity increase climate change parameters

Parameter	2050	2100	Units
Rainfall Intensity Increase	5.2%	11.0%	mm/hr

2.1.3 Future Climate Scenarios

The future climate scenario model inputs adopted for the coincident event pre-screening analysis are summarised in Table 2-5 and incorporate the climate change considerations described in Section 2.1.2. With regard to peak rainfall intensity and breakout peak flows, the equivalent current climate values (refer Table 2-1) were increased by 5.2% and 11.0% for the 2050 and 2100 planning horizons respectively (refer Section 2.1.2.2). It is noted that the adopted percentage increases to breakout peak flows does not account for rainfall loses typically applied to rural areas and are therefore likely to be conservatively high.

Table 2-5 Summary of future climate scenario model inputs

Parameter	2050	2100	Units
1% AEP sustained peak storm tide level[1]	2.6	3.1	mAHD
1% AEP peak rainfall intensity (6-hour duration)[2]	41.1	43.4	mm/hr
1% AEP Don River breakout peak flow (6-hour duration)[2]:			m^3/s
-breakout locations 1,2	27.0	28.5	
-breakout location 3	7.2	7.5	
-breakout location 4	20.3	21.4	
-breakout location 5	134.7	142.1	
-breakout location 6	44.3	46.7	
-Bowen model southern boundary	1471.7	1552.9	
-Bells Gully	11.5	12.1	
-Don River Channel (after Bells Gully breakout)	3,501	3,694	

[1]*Defined by Bowen Water Hazards Assessment Stage 1: Storm Tide Modelling Basis (BMT WBM & SEA 2017)*

[2]*Scaled on equivalent parameter summarised in Table 2-1*

2.2 Selected Events for Detailed Modelling

Following the approach described in Section 1.2, the pre-screening analysis calculates the outer envelope of flood level estimates, which are the upper and lower limits illustrated in Figure 1-2. These limits represent the full independence and dependence cases as follows:

- The complete independence case is represented by the combined peak water level surfaces due to:
    - A Don River breakout and/or a local catchment rainfall event occurring during normal tide conditions; and
    - A storm tide event occurring in the absence of significant rainfall.
- The complete dependence case where both catchment flooding and storm tide inundation occur simultaneously.

Table 2-7 summarises the model runs needed to support the pre-screening analysis. For each simulation, the peak water level surface and peak depth was determined at every MIKE 21 Bowen Local Model grid point. This so-called 'statistical maximum' summary is the primary model output required for the pre-screening analysis (results are described in Chapter 3). The coincident event scenarios are listed Table 2-7, including the independence case and dependence case definitions (with reference to the Run ID in Table 2-7).

Table 2-6 Coincident event detailed modelling summary

Run ID	Climate scenario	Bowen Local Catchment	Don River Breakout	Coastal Water Level	Event Description
1.1	Current	NA	NA	1% AEP, sustained peak[2]	Independent storm tide
1.2	Current	1%AEP, 6 hour[1]	NA	MSL	Independent Bowen local catchment
1.3	Current	1%AEP, 6 hour[1]	1%AEP, 6 hour[1]	MSL	Independent Bowen local catchment + Don River breakout
1.4	Current	1%AEP, 6 hour[1]	NA	1% AEP, sustained peak[2]	Dependent Bowen local catchment + storm tide
1.5	Current	1%AEP, 6 hour[1]	1%AEP, 6 hour[1]	1% AEP, sustained peak[2]	Dependent Bowen local catchment + Don River breakout + storm tide
2.1	2050	NA	NA	2050 1% AEP, sustained peak[2]	2050 Independent storm tide
2.2	2050	2050 1%AEP, 6 hour[3]	NA	MSL + 0.4 m	2050 Independent Bowen local catchment
2.3	2050	2050 1%AEP, 6 hour[3]	2050 1%AEP, 6 hour[3]	MSL + 0.4 m	2050 Independent Bowen local catchment + Don River breakout
2.4	2050	2050 1%AEP, 6 hour[3]	NA	2050 1% AEP, sustained peak[2]	2050 Dependent Bowen local catchment + storm tide
2.5	2050	2050 1%AEP, 6 hour[3]	2050 1%AEP, 6 hour[3]	2050 1% AEP, sustained peak[2]	2050 Dependent Bowen local catchment + Don River breakout + storm tide
3.1	2100	NA	NA	2100 1% AEP, sustained peak[2]	2100 Independent storm tide
3.2	2100	2100 1%AEP, 6 hour[4]	NA	MSL + 0.8 m	2100 Independent Bowen local catchment
3.3	2100	2100 1%AEP, 6 hour[4]	2100 1%AEP, 6 hour[4]	MSL + 0.8 m	2100 Independent Bowen local catchment + Don River breakout
3.4	2100	2100 1%AEP, 6 hour[4]	NA	2100 1% AEP, sustained peak[2]	2100 Dependent Bowen local catchment + storm tide
3.5	2100	2100 1%AEP, 6 hour[4]	2100 1%AEP, 6 hour[4]	2100 1% AEP, sustained peak[2]	2100 Dependent Bowen local catchment + Don River breakout + storm tide

[1] Defined by previous AECOM assessments (AECOM 2014; AECOM 2015a; AECOM 2015b)

[2] Defined by Bowen Water Hazards Assessment Stage 1: Storm Tide Modelling Basis (BMT WBM & SEA 2017)

[3] Current climate 1% AEP rainfall intensity and flow inputs increased by 5.2%

[4] Current climate 1% AEP rainfall intensity and flow inputs increased by 11.0%

Table 2-7 Pre-screening Assessment Summary (with reference to Run ID in Table 2-6)

Scenario	Description	Independence Case (peak water level surface envelope)	Dependence Case (peak water level surface)
A	Current climate Bowen local catchment + storm tide	Run ID 1.1 + Run ID 1.2	Run ID 1.4
B	Current climate Bowen local catchment + Don River breakout + storm tide	Run ID 1.1 + Run ID 1.3	Run ID 1.5
C	2050 Bowen local catchment + storm tide	Run ID 2.1 + Run ID 2.2	Run ID 2.4
D	2050 Bowen local catchment + Don River breakout + storm tide	Run ID 2.1 + Run ID 2.3	Run ID 2.5
E	2100 Bowen local catchment + storm tide	Run ID 3.1 + Run ID 3.2	Run ID 3.4
F	2100 Bowen local catchment + Don River breakout + storm tide	Run ID 3.1 + Run ID 3.3	Run ID 3.5

3 Coincident Event Pre-screening Analysis Results

3.1 Results Presentation

The coincident event pre-screening analysis results are presented in Appendix A. The spatially mapped results for each scenario defined in Table 2-7 are presented in a single figure template with the following format:

(1) Independence case peak water level envelope (left panel)

(2) Dependence case peak water level (middle panel)

(3) Joint probability zone impact determined by calculating the difference between (1) and (2) (right panel)

To assist interpretation and discussion of the results presented in Appendix A the following generic joint probability impact areas have been defined:

- Don River Mouth South (DRMS): area to south of the Don River mouth at the northern extent of Queens Beach
- Bowen Golf Course (BGC): golf course and adjacent areas towards the southern extent of Queens Beach
- Denison Park and Wetlands (DPW): area to the west of Kings Beach comprising State land, reserve and freehold land (generally open space and rural areas)
- Mullers Lagoon (ML): area adjacent to Mullers Lagoon
- Port Denison Waterfront North (PDWN): area to the northeast of the Bowen Jetty
- Port Denison Waterfront South (PDWS): area to the southwest of the Bowen Jetty
- Salt Evaporator (SE): salt fields and evaporation ponds
- Boundary Road (BR): area adjacent to Boundary Road (immediately north of the Salt Evaporator area)

In addition to the above, independence and dependence case water level and joint probability zone impact at road crossings along Bells Gully are also reported (similar point locations to those reported by AECOM 2015b).

The pre-screening analysis results for each scenario are briefly discussed in the Section below.

3.2 Results Summary

Scenario A: Current climate Bowen local catchment + storm tide (Figure A-1)

The joint probability zone is generally restricted to the Bowen Golf Course (BGC), Denison Park and Wetlands (DPW), Port Denison Waterfront (PDWN and PDWS) and Salt Evaporator (SE). Within these general impact areas, the coincidence of peak rainfall and storm tide processes increases the water level surface by up to 0.05 m. Impacts greater than 0.05 m are generally limited to coastal creeks and stormwater outlets.

Scenario A independence and dependence case water level and joint probability zone impact at road crossings along Bells Gully are listed in Table 3-1. The Avoca Road and Kings Beach Road point locations are within the joint probability zone with minor impact between 0.02 and 0.08 m. The water levels at other locations are not influenced by the coincident storm tide condition.

Table 3-1 Scenario A water level and coincident event impact along Bells Gully

Road Crossing	Independence Case (mAHD)	Dependence Case (mAHD)	Impact (m)
Chilli Lane*	7.14	7.14	0.00
Mt Nutt Road	5.57	5.57	0.00
Jilletts Road	4.86	4.86	0.00
Argyle Park Road	3.99	3.99	0.00
Soldiers Road	3.60	3.59	0.00
Queens Road	2.84	2.84	0.00
Avoca Road	2.53	2.54	0.02
Kings Beach Road	2.33	2.41	0.08

**not shown in Figure A-1*

Scenario B: Current climate Don River Breakout + Bowen local catchment + storm tide (Figure A-2)

The joint probability zone is generally restricted to the Don River Mouth (DRM), Bowen Golf Course (BGC), Denison Park and Wetlands (DPW), Port Denison Waterfront (PDWN and PDWS) and Boundary Road (BR). Within these general impact areas, the coincidence of peak riverine, rainfall and storm tide processes increases the water level surface by up to 0.05 m. Impacts greater than 0.05 m are generally limited to coastal creeks and stormwater outlets.

Scenario B independence and dependence case water level and joint probability zone impact at road crossings along Bells Gully are listed in Table 3-2. Avoca Road and Kings Beach Road point locations are within the joint probability zone with minor impact between 0.01 and 0.07 m. The water levels at other locations are not influenced by the coincident storm tide condition.

Table 3-2 Scenario B water level and coincident event impact along Bells Gully

Road Crossing	Independence Case (mAHD)	Dependence Case (mAHD)	Impact (m)
Chilli Lane*	7.33	7.33	0.00
Mt Nutt Road	5.48	5.48	0.00
Jilletts Road	4.87	4.87	0.00
Argyle Park Road	3.86	3.87	0.00
Soldiers Road	3.63	3.63	0.00
Queens Road	2.81	2.81	0.00
Avoca Road	2.54	2.56	0.01
Kings Beach Road	2.33	2.40	0.07

**not shown in Figure A-2*

Scenario C: 2050 climate Bowen local catchment + storm tide (Figure A-3)

The joint probability zone covers all the general impact areas listed in Section 3.1. Within the Bowen Golf Course (BGC), Denison Park and Wetlands (DPW), Mullers Lagoon (ML) and Boundary Road (BR) areas, the coincidence of peak rainfall and storm tide processes increases the water level surface by up to 0.05 m. Water level impact exceeding 0.1 m occurs within the Port Denison Waterfront (PDWN and PDWS) areas. The magnitude of the joint probability zone impact is approximately twice the equivalent current climate scenario (Scenario A).

Scenario C independence and dependence case water level and joint probability zone impact at road crossings along Bells Gully are listed in Table 3-3. Queens Road, Avoca Road and Kings Beach Road point locations are within the joint probability zone with minor impact between 0.02 and 0.04 m. The water levels at other locations are not influenced by the coincident storm tide condition.

Table 3-3 Scenario C water level and coincident event impact along Bells Gully

Road Crossing	Independence Case (mAHD)	Dependence Case (mAHD)	Impact (m)
Chilli Lane*	7.15	7.15	0.00
Mt Nutt Road	5.60	5.60	0.00
Jilletts Road	4.88	4.88	0.00
Argyle Park Road	4.03	4.03	0.00
Soldiers Road	3.61	3.61	0.00
Queens Road	2.86	2.87	0.02
Avoca Road	2.64	2.68	0.04
Kings Beach Road	2.64	2.67	0.03

**not shown in Figure A-3*

Scenario D: 2050 climate Don River Breakout + Bowen local catchment + storm tide (Figure A-4)

The joint probability zone covers all the general impact areas listed in Section 3.1. Within the Don River Mouth (DRM), Bowen Golf Course (BGC), and Port Denison Waterfront South (PDWS) areas the coincidence of peak riverine, rainfall and storm tide processes increases the water level surface by up to 0.07 m. With the exception of the coastline, the impact in other areas is generally less than 0.05 m.

Scenario D independence and dependence case water level and joint probability zone impact at road crossings along Bells Gully are listed in Table 3-4. Queens Road, Avoca Road and Kings Beach Road point locations are within the joint probability zone with minor impact between 0.02 and 0.04 m. The water levels at other locations are not influenced by the coincident storm tide condition.

Table 3-4 Scenario D water level and coincident event impact along Bells Gully

Road Crossing	Independence Case (mAHD)	Dependence Case (mAHD)	Impact (m)
Chilli Lane*	7.34	7.34	0.00
Mt Nutt Road	5.50	5.50	0.00
Jilletts Road	4.88	4.88	0.00
Argyle Park Road	3.88	3.88	0.00
Soldiers Road	3.63	3.64	0.00
Queens Road	2.82	2.84	0.02
Avoca Road	2.64	2.68	0.04
Kings Beach Road	2.64	2.67	0.03

**not shown in Figure A-4*

Scenario E: 2100 climate Bowen local catchment + storm tide (Figure A-5)

The coincidence of peak rainfall and storm tide processes increases the water level surface between 0.1 to 0.2 m within the Port Denison Waterfront (PDWN and PDWS) area. This is approximately four times greater than the equivalent current climate impact (Scenario A). The water level impact in other areas including the Bowen Golf Course (BGC), Denison Park and Wetlands (DPW), Mullers Lagoon (ML), Salt Evaporator (SE) and Boundary Road (BR) are generally less than 0.1 m.

Scenario E independence and dependence case water level and joint probability zone impact at road crossings along Bells Gully are listed in Table 3-4. Argyle Park Road, Soldiers Road, Queens Road, Avoca Road and Kings Beach Road point locations are within the joint probability zone with minor impact between 0.01 and 0.03 m. The water levels at other locations are not influenced by the coincident storm tide condition.

Table 3-5 Scenario E water level and coincident event impact along Bells Gully

Road Crossing	Independence Case (mAHD)	Dependence Case (mAHD)	Impact (m)
Chilli Lane*	7.16	7.16	0.00
Mt Nutt Road	5.64	5.64	0.00
Jilletts Road	4.90	4.90	0.00
Argyle Park Road	4.06	4.07	0.01
Soldiers Road	3.63	3.64	0.01
Queens Road	3.12	3.15	0.03
Avoca Road	3.12	3.15	0.03
Kings Beach Road	3.12	3.15	0.03

**not shown in Figure A-5*

Scenario F: 2100 climate Don River Breakout + Bowen local catchment + storm tide (Figure A-6)

The coincidence of peak riverine, rainfall and storm tide processes increases the water level surface between 0.1 to 0.2 m within the Don River Mouth (DRM), Port Denison Waterfront (PDWN and PDWS) and Mullers Lagoon (ML) areas. The impact in other areas including the Bowen Golf Course (BGC), Denison Park and Wetlands (DPW), Salt Evaporator (SE) and Boundary Road (BR) are generally less than 0.07 m. The magnitude of the joint probability zone impact is approximately three times the equivalent current climate scenario (Scenario B).

Scenario E independence and dependence case water level and joint probability zone impact at road crossings along Bells Gully are listed in Table 3-4. Queens Road, Avoca Road and Kings Beach Road point locations are within the joint probability zone with minor impact of 0.02 m. The water levels at other locations are not influenced by the coincident storm tide condition.

Table 3-6 Scenario F water level and coincident event impact along Bells Gully

Road Crossing	Independence Case (mAHD)	Dependence Case (mAHD)	Impact (m)
Chilli Lane*	7.35	7.35	0.00
Mt Nutt Road	5.53	5.53	0.00
Jilletts Road	4.89	4.89	0.00
Argyle Park Road	3.91	3.91	0.00
Soldiers Road	3.65	3.65	0.00
Queens Road	3.12	3.15	0.02
Avoca Road	3.12	3.14	0.02
Kings Beach Road	3.12	3.14	0.02

**not shown in Figure A-6*

3.3 Results Discussion

The coincident event pre-screening analysis has estimated the extent of the 1% AEP joint probability zone and magnitude of the impact to water surface levels across the Bowen local catchment. The analysis has considered the current, 2050 and 2100 climate scenarios and focussed on storm tide conditions interacting with catchment flooding. While the overall extent of the joint probability zone is relatively large, the magnitude of the impact is considered small and typically within the 0.3 m freeboard allowance adopted for planning purposes throughout the WRC local government area.

The overall impact extent, and magnitude in some areas, increases between the current climate and future climate scenarios due to the assumed increase to rainfall intensity, change to TC climatology and associated storm tide response, and increase to mean sea-level. The relative contribution of each future climate assumption has not been established; however, the sea-level rise assumption (combined with the future climate storm tide level) is expected to be the dominant influence. Sea-level rise is likely to impact the performance of existing drainage infrastructure at the coastline.

Considering the relatively small impact to water level surfaces associated with the coincidence of storm tide and catchment flooding across the Bowen local are (including Don River breakout flooding), a more complex joint probability assessment is not considered necessary. Under this scenario and following ARR2016, ‘complete dependence’ can be assumed and the ‘dependence case’ scenario is considered an appropriate estimate of flood levels across the study area and can be used for planning purposes[2]. Suitably defined dependence case scenarios, combining the storm tide level and catchment processes at AEPs of interest, can therefore be used to define design water levels across the Bowen local area. This is discussed further in Chapter 4.

[2] It is noted that the current pre-screening analysis has only considered the 1% AEP and could be repeated if other AEPs are of interest.

4 Recommendation & Conclusion

4.1 Recommendations

The storm tide and catchment flooding coincident event pre-screening analysis has shown that the peak water level difference within the 1% AEP joint probability zone is generally within an acceptable tolerance[3] across the Bowen local catchment. Under this scenario, full treatment of joint probability using the design variable method (or other more complex joint probability approach) as detailed in ARR2016 is not warranted (refer Section 1.2).

The pre-screening analysis suggests that the 'dependence case' scenario, combining storm tide and catchment processes at the AEPs of interest, is an appropriate method for modelling and assessing coincident flood levels across the Bowen local catchment. This requires both the catchment and storm tide statistics to be established. In the case of Bowen, the 'catchment statistics' could refer to either a local catchment event or a Don River breakout event coinciding with a local catchment event.

Table 4-1 provides an example of dependence case scenario definitions to define the coincident flood hazard and support planning throughout the Bowen local catchment. The sustained peak coastal water levels were derived as part of the Bowen Water Hazards Assessment Stage 1: Storm Tide Modelling Basis (BMT WBM & SEA 2017). These scenarios would be considered complementary to an updated catchment assessment for Bowen. It is noted that some of the assumptions underpinning the previous studies (i.e. AECOM 2014; AECOM 2015a; AECOM 2015b) and inputs to this analysis have been superseded by guidance contained in ARR2016. Updating the catchment flood hazard statistics in accordance with ARR2016 is likely to be a priority for the Bowen local catchment and is considered necessary work prior to assessing the dependence case scenarios proposed in Table 4-1.

In the interim and prior to completing the updates and assessments described above, planning throughout the Bowen region should consider both the independent storm tide and catchment flood levels. In areas exposed to both flood hazards, the higher water level should be adopted. Within the joint probability zones defined by the analysis described in this report, WRC may wish to consider increasing the additional freeboard allowance from 0.3 m to 0.5 m to account for the potential influence of coastal processes on catchment flood levels.

[3] Case studies presented in Book 6, Chapter 5 of Australian Rainfall and Runoff 2016 adopt a threshold of 0.1m to define sufficient difference between complete dependent and independent events.

Table 4-1 Proposed storm tide and catchment event dependence case scenarios to be considered as part of future Bowen local catchment assessments

Scenario	Bowen Local Catchment[1]	Don River Breakout[2]	Sustained Peak Coastal Water Level[3] (mAHD)
1	20% AEP	NA	1.9
2	20% AEP	20% AEP	1.9
3	10% AEP	NA	2.0
4	10% AEP	10% AEP	2.0
5	2% AEP	NA	2.1
6	2% AEP	2% AEP	2.1
7	1% AEP	NA	2.3
8	1% AEP	1% AEP	2.3
9	2050 1% AEP	NA	2.6*
10	2050 1% AEP	2050 1% AEP	2.6*
11	2100 1% AEP	NA	3.1**
12	2100 1% AEP	2100 1% AEP	3.1**

[1]Consideration of multiple critical storm durations may be required

[2]Consideration of multiple breakout scenarios may be required

[3] Derived by BMT WBM & SEA (2017)

** Includes 0.4 m increase to mean sea level*

*** Includes 0.8 m increase to mean sea level*

4.2 Study Limitations

The coincident event pre-screening analysis has relied upon datasets and existing tools provided by Council, including previously completed Don River and Bowen local catchment flood studies models (AECOM 2014; AECOM 2015a; AECOM 2015b). The accuracy of the assessments described in this report is therefore limited to the accuracy and completeness of this previous work.

The MIKE FLOOD model used is of 'local catchment scale' and suitable for a flood hazard and/or drainage study. The model is limited in its ability to represent fine scale features smaller than the resolution of the model grid (5 m) which in turn limits the resolution of the results.

BMT WBM & SEA (2017) also includes a number of qualifications specifically related to the storm tide hazard assessment and modelling relevant to this study.

5 References

AECOM (2014). Don River Flood Risk and Mitigation Study, Stage 1 – Flood Risk Assessment, prepared on behalf of Whitsunday Regional Council.

AECOM (2015a). Bowen Local Drainage Study, prepared on behalf of Whitsunday Regional Council.

AECOM (2015b). Storm Surge, Don River and Bowen Local Catchment Coincident Events, prepared on behalf of Whitsunday Regional Council.

BMT WBM & SEA (2017). Bowen Water Hazards Assessment Stage 1: Storm Tide Modelling Basis, prepared on behalf of Whitsunday Regional Council.

Harper B.A. (2012). Guidelines for responding to the effects of climate change in coastal and ocean engineering – 3rd Edition May 2012. Engineers Australia, National Committee on Coastal and Ocean Engineering, EA Books, 74pp. Revised June 2013. https://www.engineersaustralia.org.au/sites/default/files/shado/Learned%20Groups/National%20Committees%20and%20Panels/Coastal%20and%20Ocean%20Engineering/vol_1_web.pdf

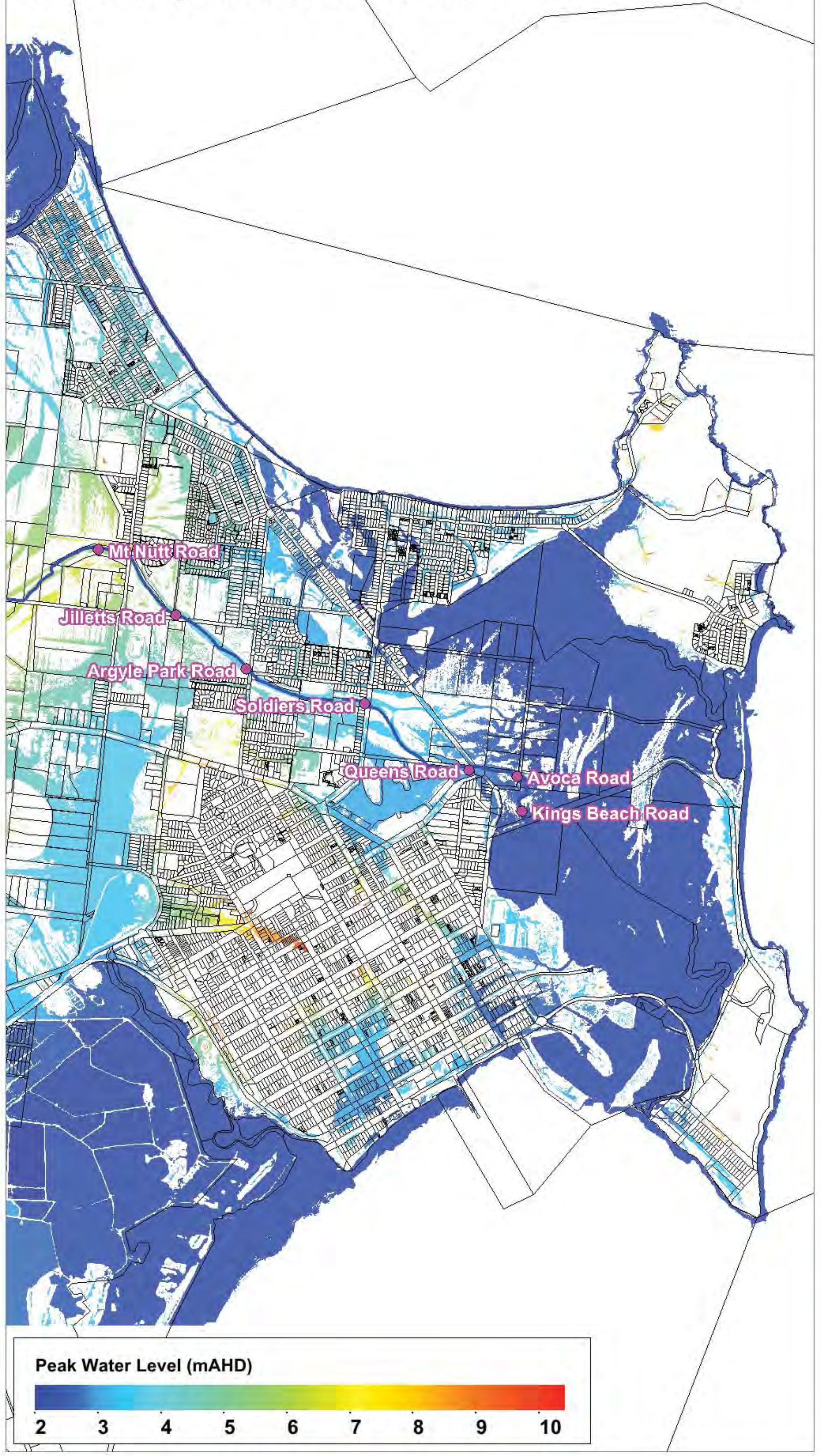
Harper B.A. (2017). Guidelines for responding to the effects of climate change in coastal and ocean engineering – 4th Edition (in prep). Engineers Australia, National Committee on Coastal and Ocean Engineering.

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. https://www.ipcc.ch/report/ar5/

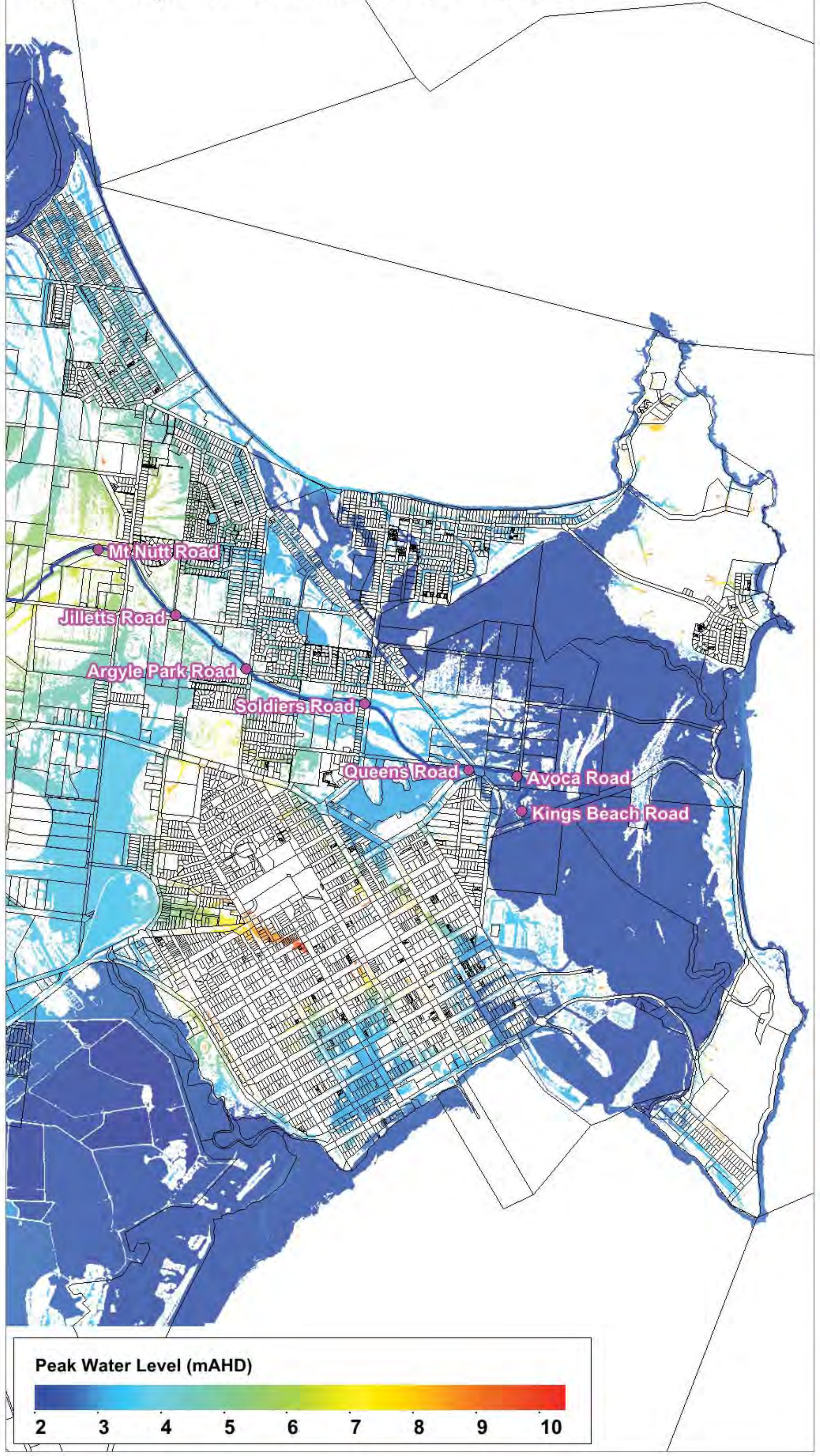
Westra S., Leonard M. and Zheng F. (2016). Interaction of Coastal and Catchment Flooding, Book 6, Chapter 5 in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia. http://arr.ga.gov.au/arr-guideline

Appendix A Coincident Event Pre-Screening Analysis Results

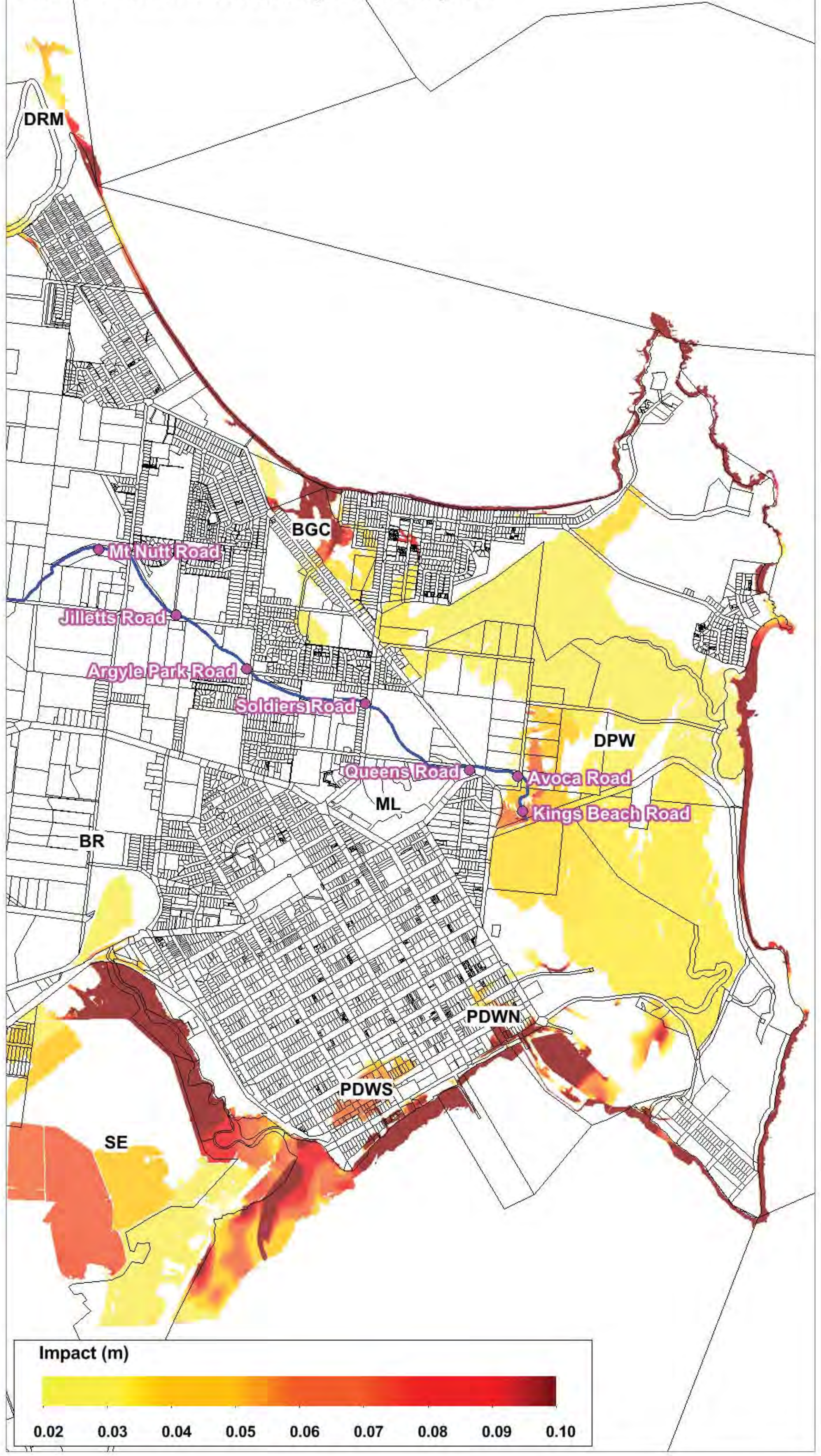
1% AEP Independent Scenario Peak Water Level Envelope



1% AEP Dependent Scenario Peak Water Level



1% AEP Joint Probability Zone Impact



LEGEND

Bells Gully

Bells Gully Road Crossing Reporting Point

Title:

Scenario A Analysis Results: Current Climate 1% AEP Bowen Local Catchment & Storm Tide

Figure: **A-1**

Rev: **A**

N

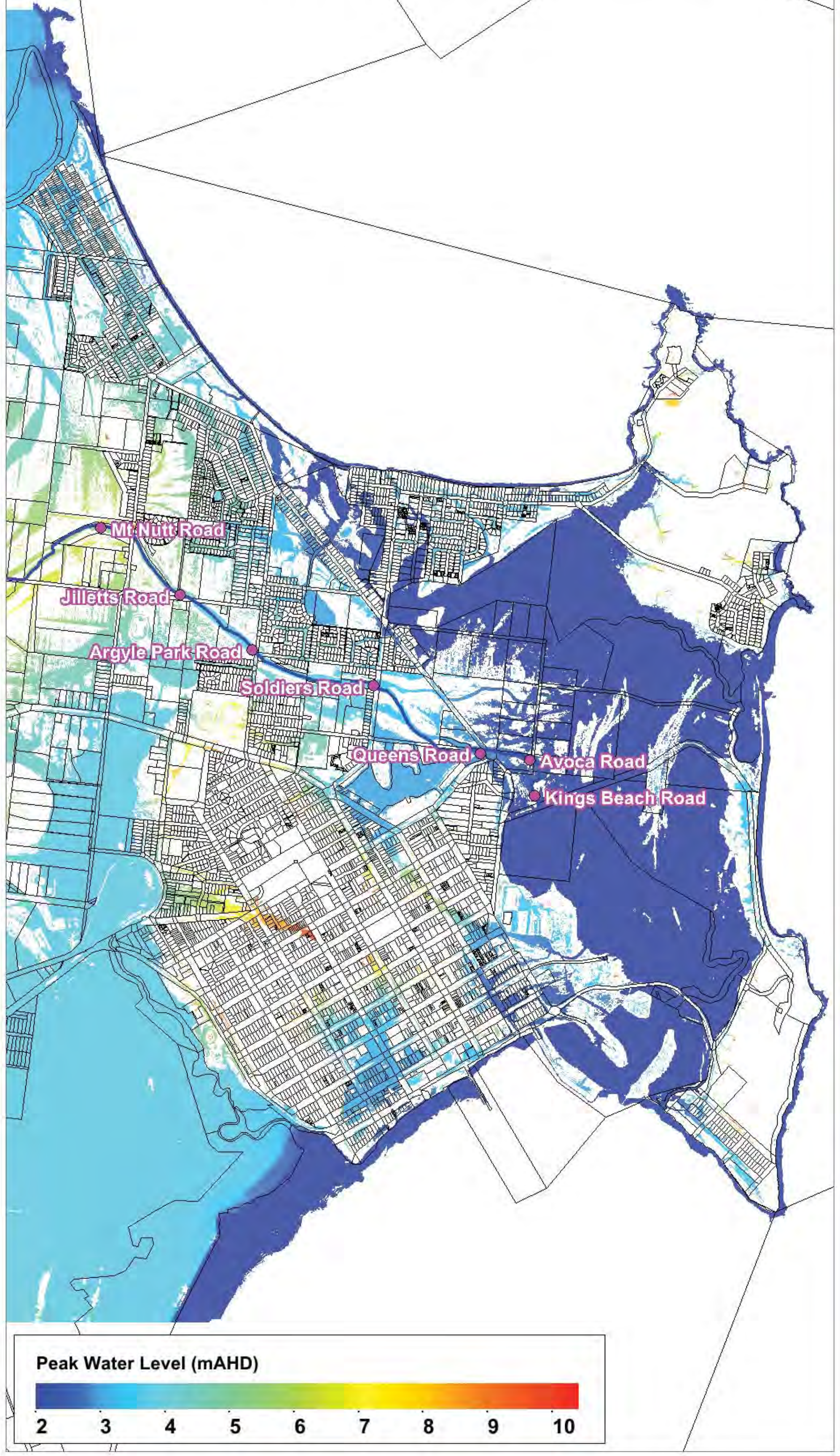
0 0.75 1.5km

Approx. Scale

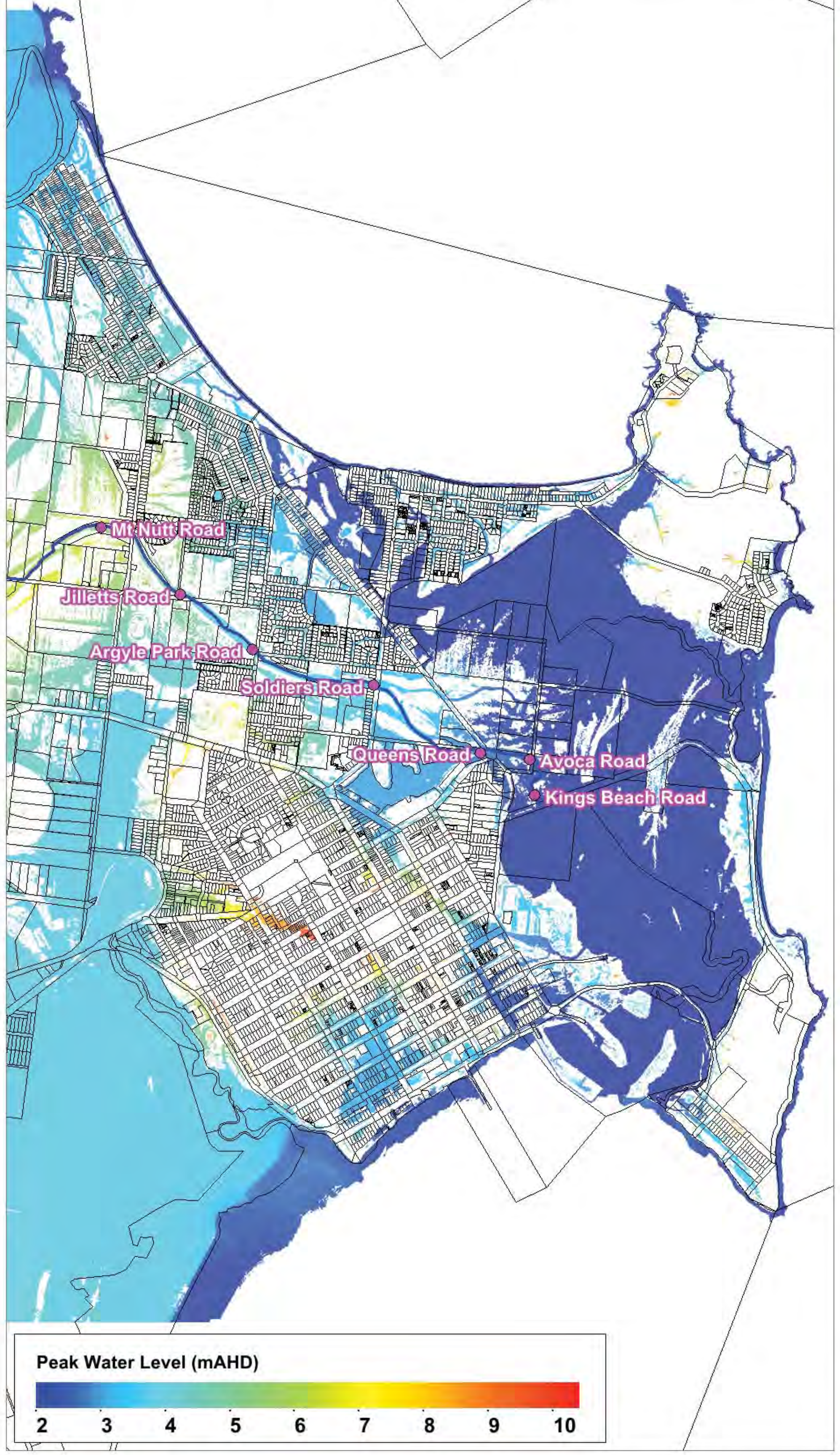
www.bmt.org

Filepath: I:\B22589_I_JLB Bowen Water Hazards Study MB\DRG\COA_065_Bowen_2017_BL_ST_coincident.wor

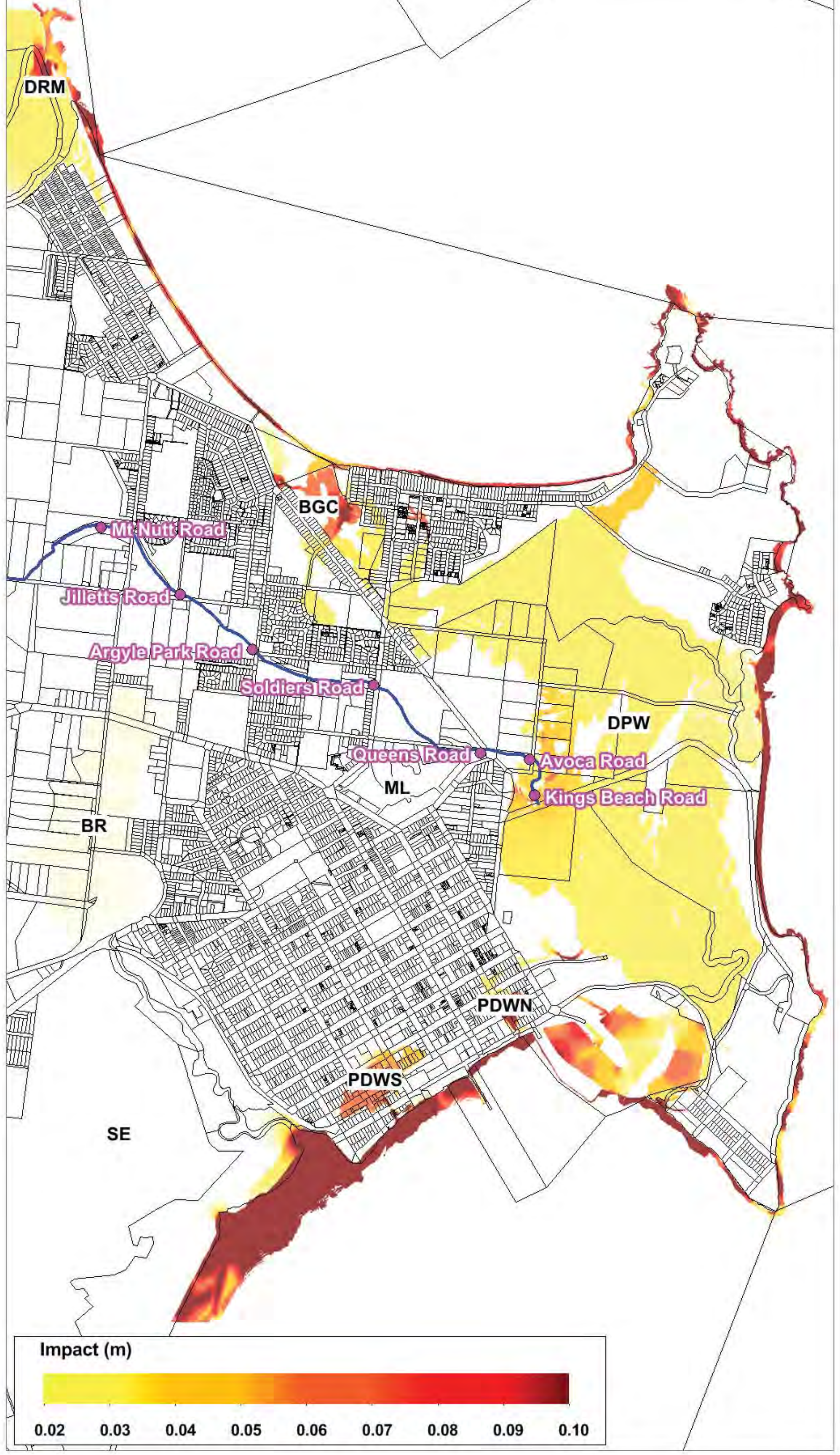
1% AEP Independent Scenario Peak Water Level Envelope



1% AEP Dependent Scenario Peak Water Level



1% AEP Joint Probability Zone Impact



LEGEND

Bells Gully

Bells Gully Road Crossing Reporting Point

Title:

Scenario B Analysis Results: Current Climate 1% AEP Don River Breakout, Bowen Local Catchment & Storm Tide

Figure: A-2

Rev: A

N

0 0.75 1.5km
Approx. Scale

BMT
www.bmt.org

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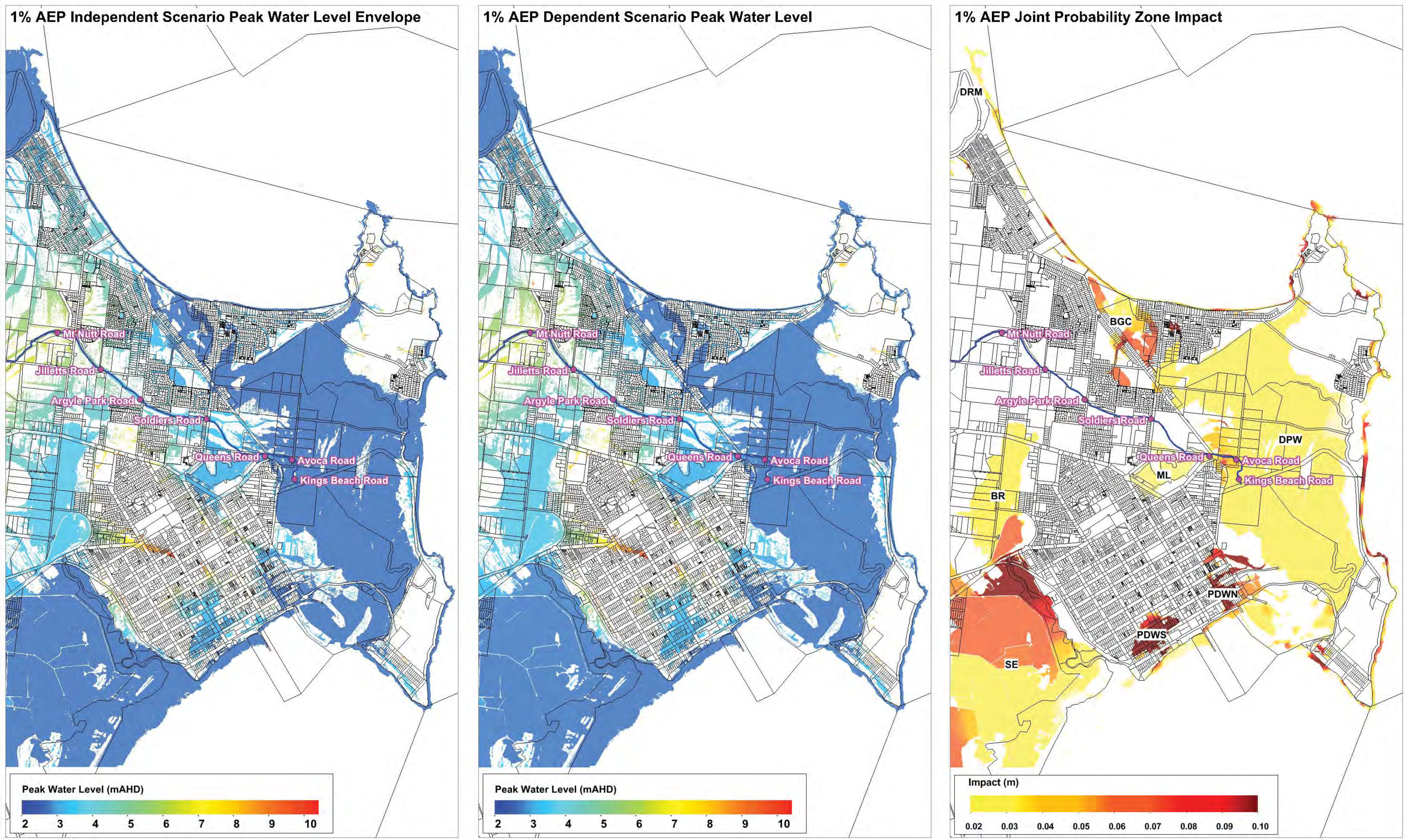

LEGEND

Bells Gully

Bells Gully Road Crossing Reporting Point

Title:

Scenario C Analysis Results: 2050 Climate 1% AEP Bowen Local Catchment & Storm Tide

Figure: **A-3**

Rev: **A**

N

0 0.75 1.5km

Approx. Scale

www.bmt.org

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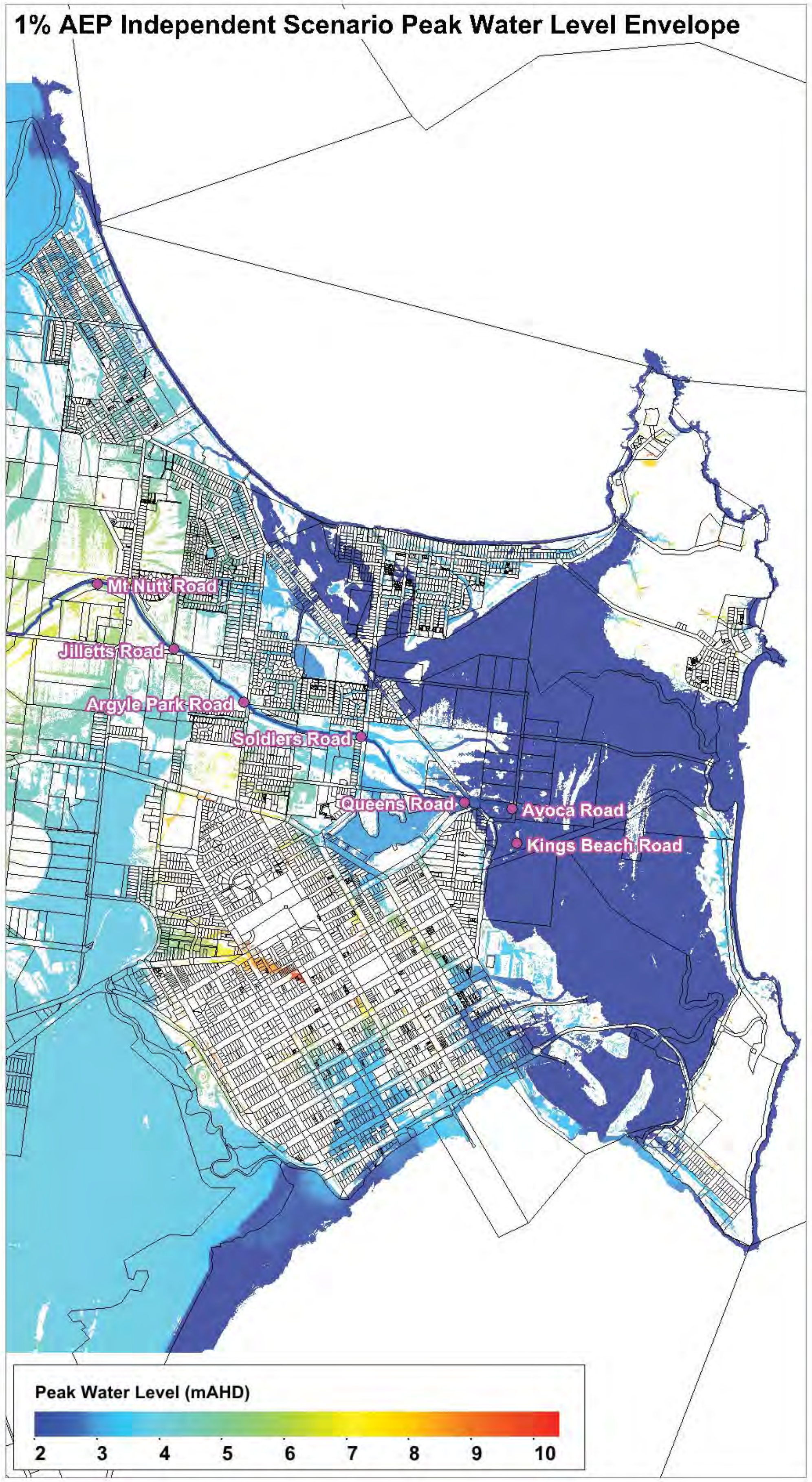
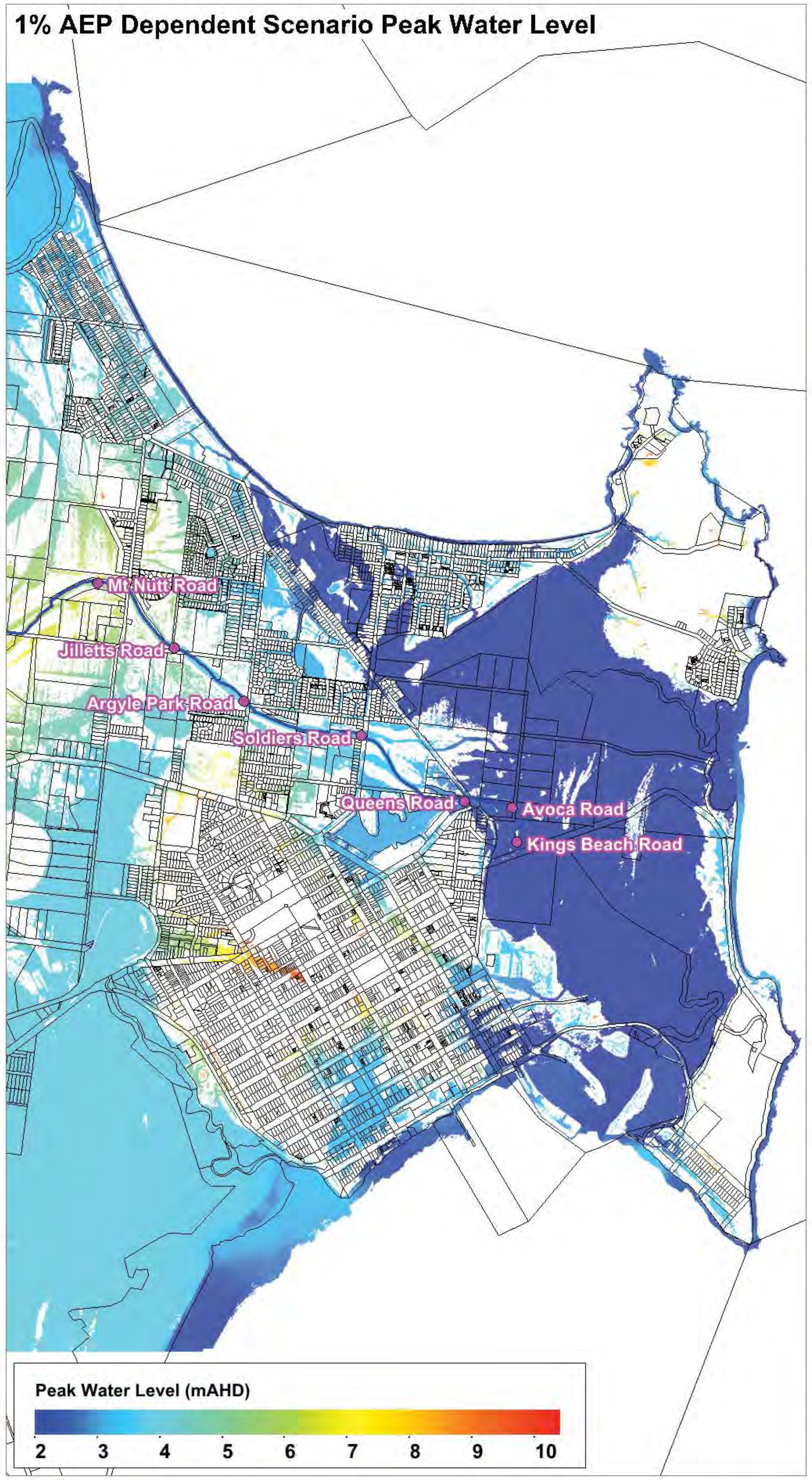
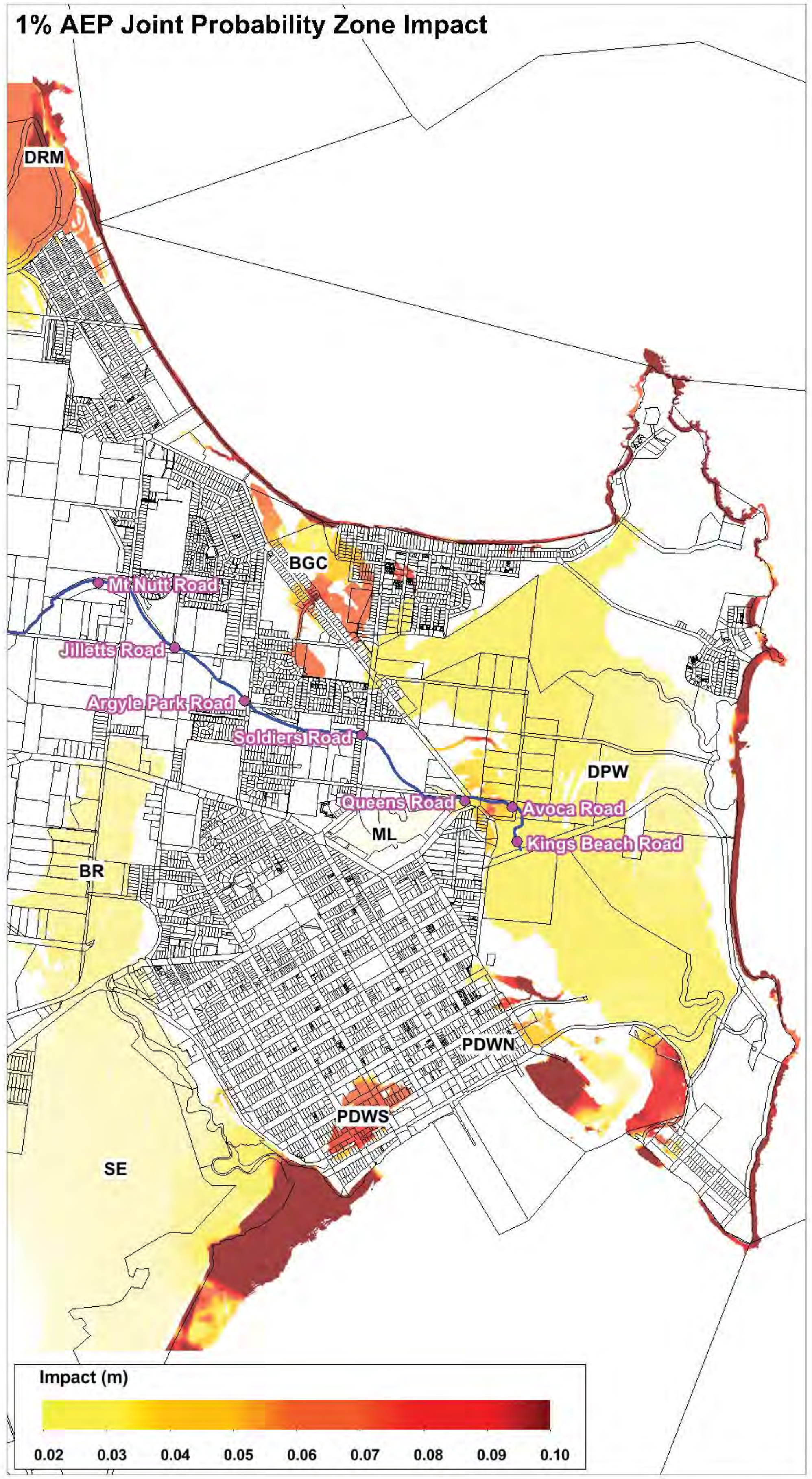






LEGEND

Bells Gully

Bells Gully Road Crossing Reporting Point

Title:

Scenario D Analysis Results: 2050 Climate 1% AEP Don River Breakout, Bowen Local Catchment & Storm Tide

Figure: **A-4**

Rev: **A**

N

0 0.75 1.5km

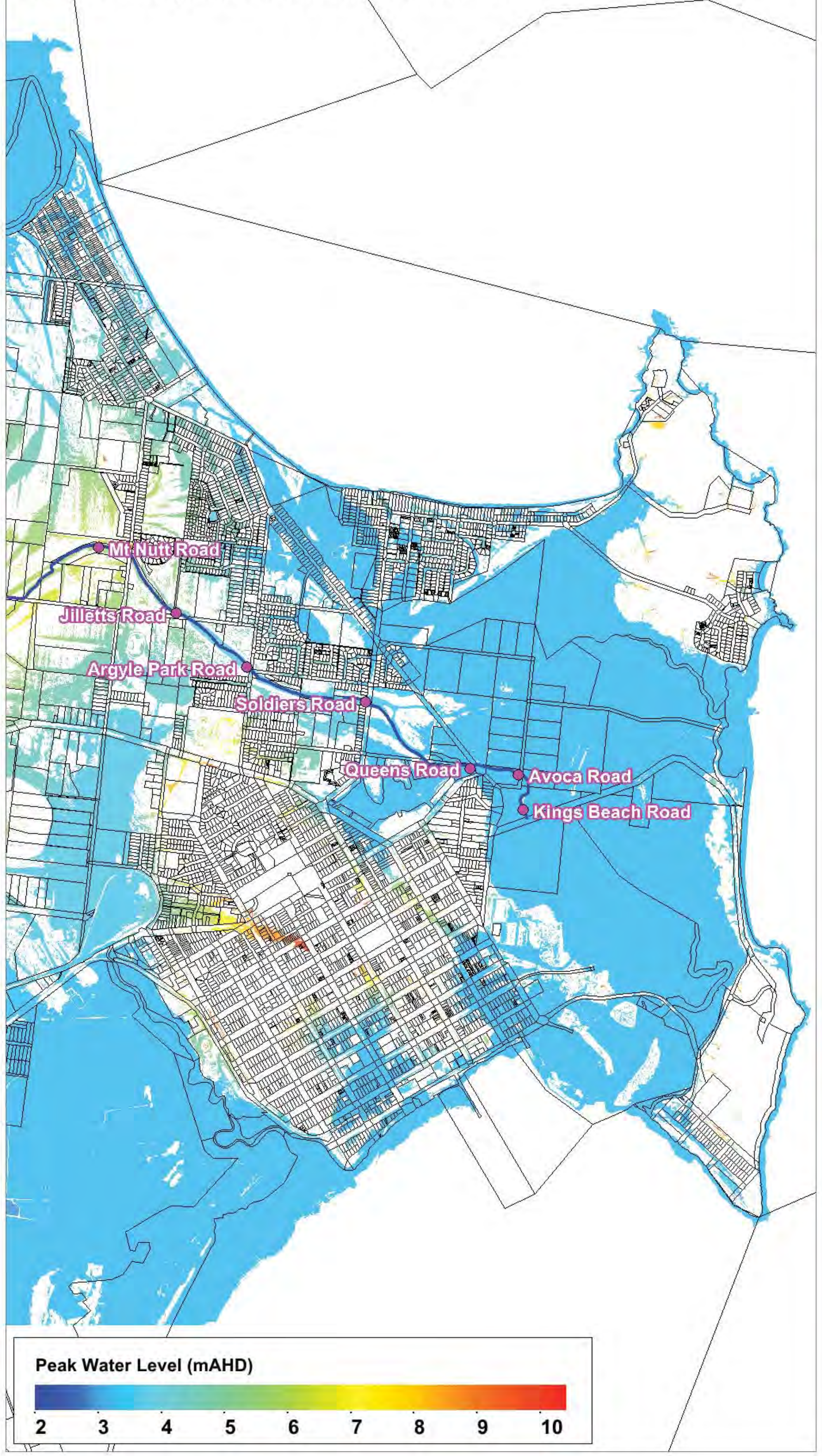
Approx. Scale

BMT

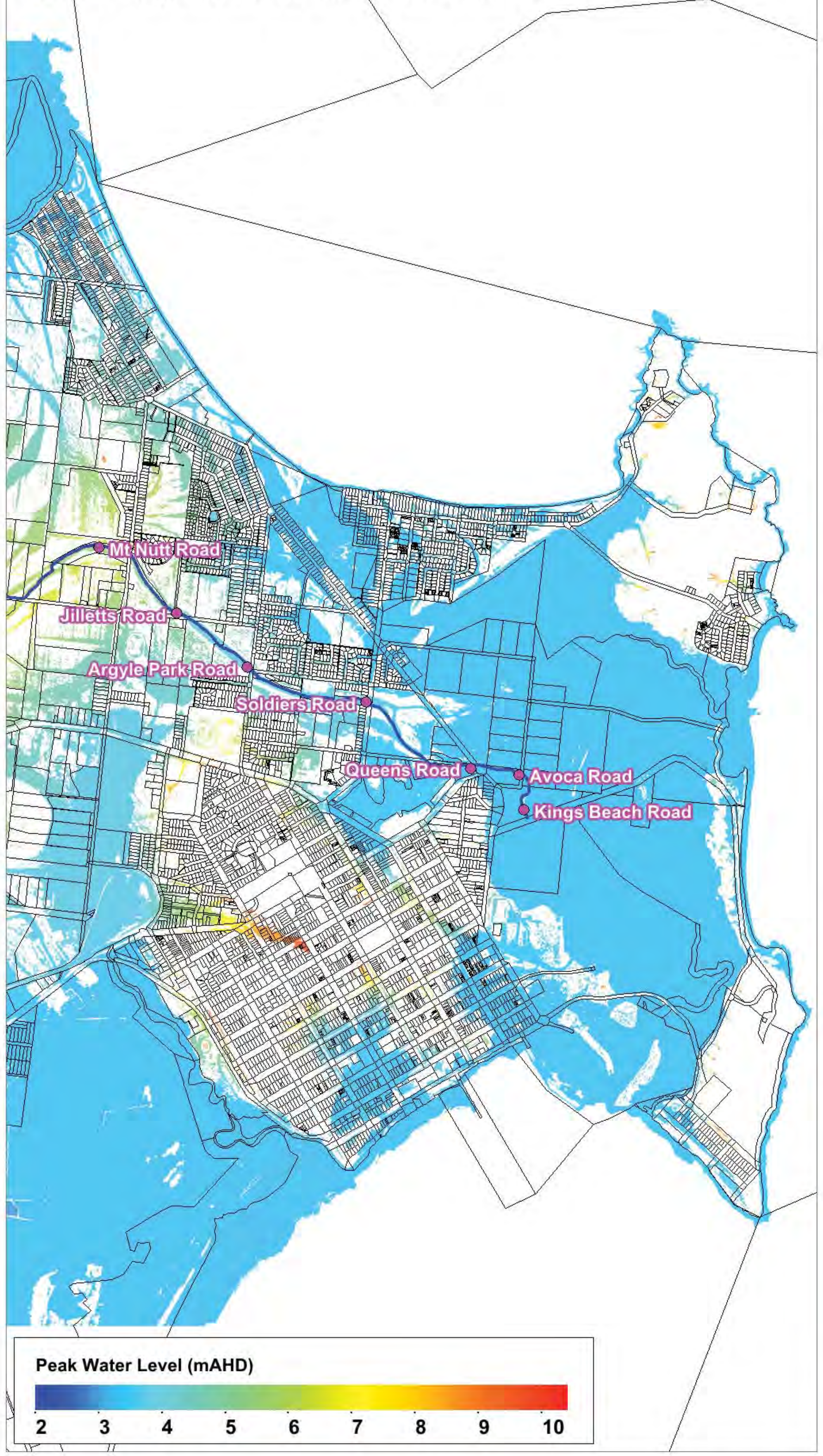
www.bmt.org

Filepath: I:\B22589_I_JLB Bowen Water Hazards Study MB\DRG\COA_063_Bowen_2050_DR_BL_ST_coincident.wor

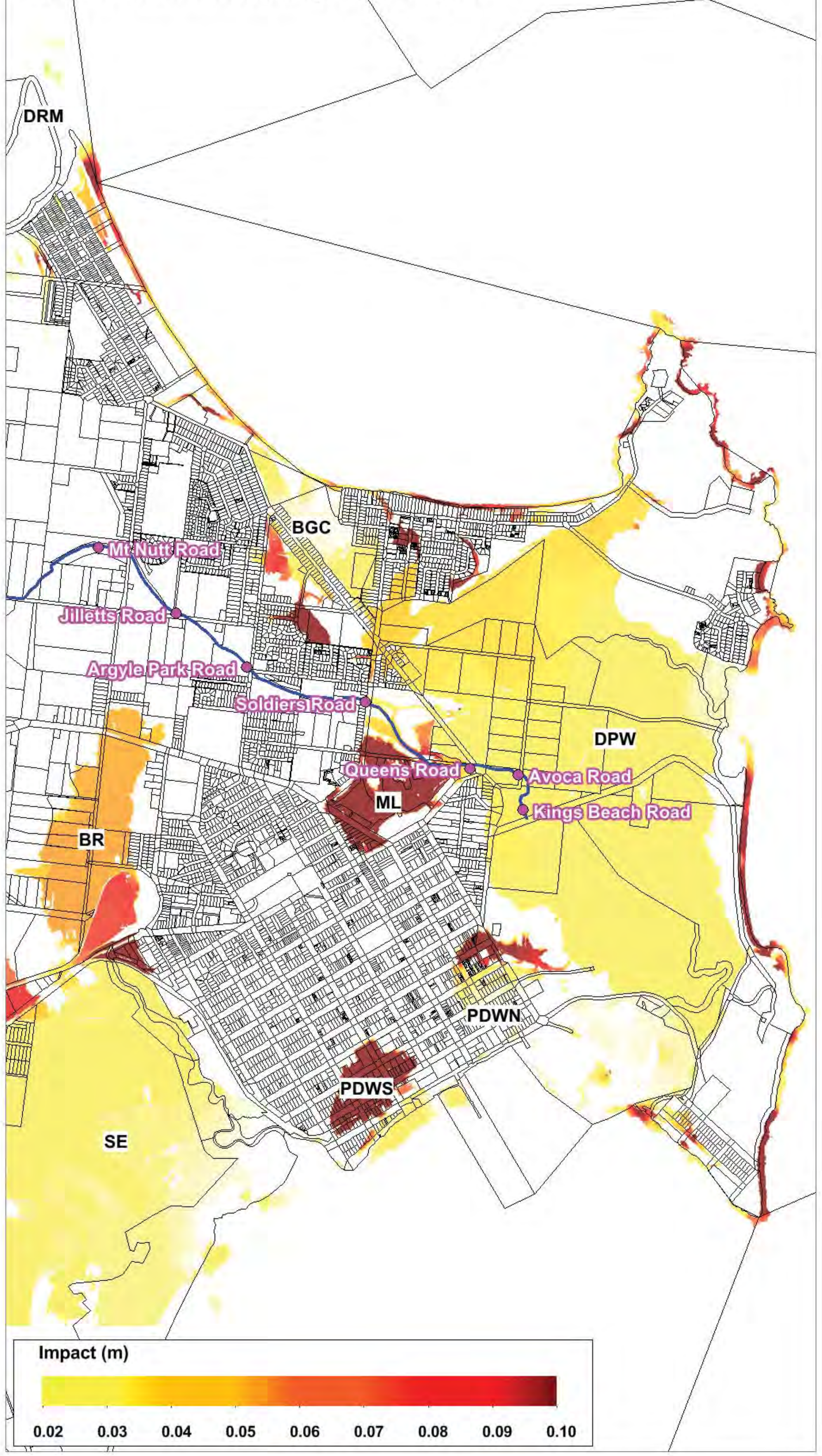
1% AEP Independent Scenario Peak Water Level Envelope



1% AEP Dependent Scenario Peak Water Level



1% AEP Joint Probability Zone Impact



LEGEND

Bells Gully

Bells Gully Road Crossing Reporting Point

Title:

Scenario E Analysis Results: 2100 Climate 1% AEP Bowen Local Catchment & Storm Tide

Figure: **A-5**

Rev: **A**

N

0 0.75 1.5km

Approx. Scale

BMT
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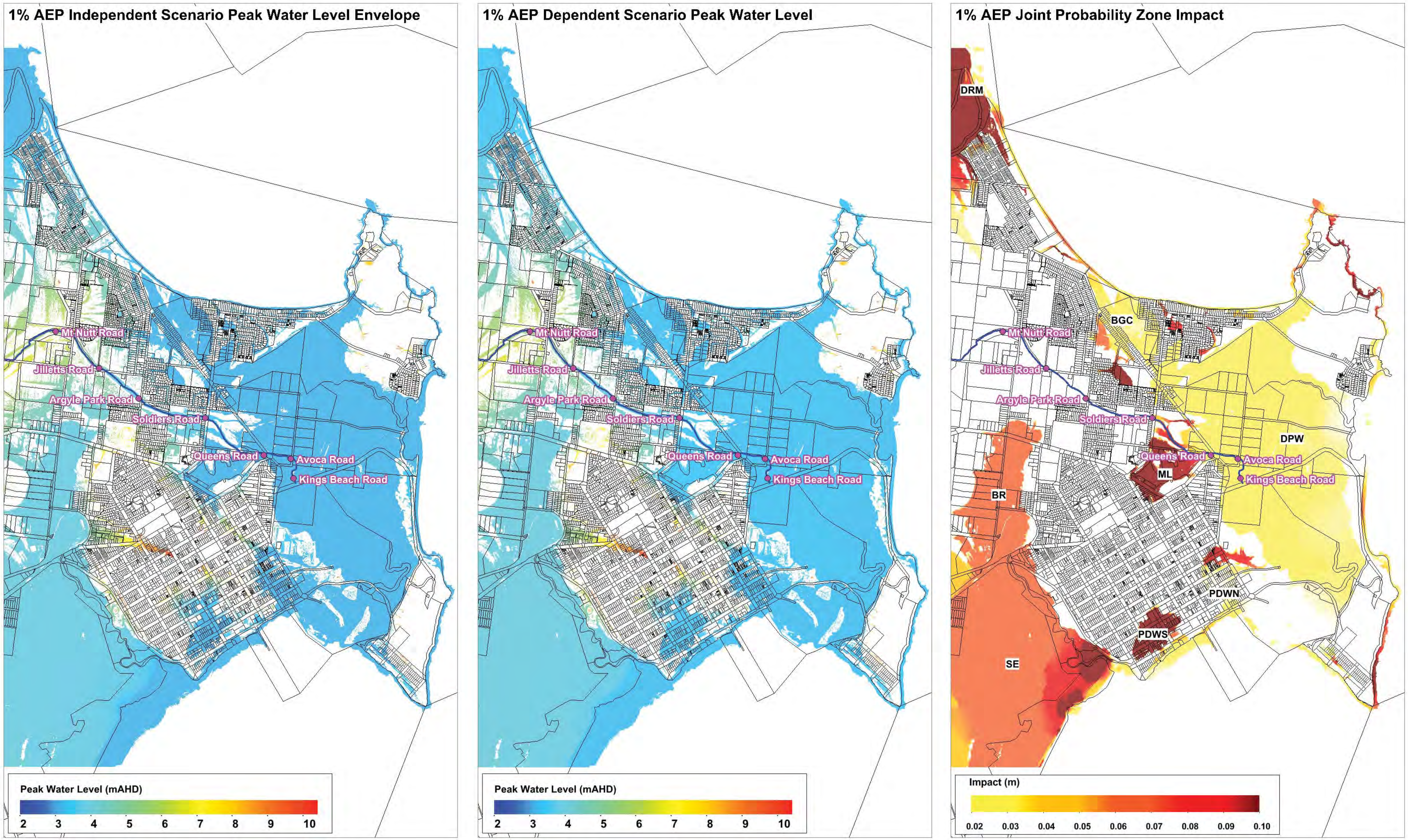

LEGEND

Bells Gully

Bells Gully Road Crossing Reporting Point

Title:

Scenario F Analysis Results: 2100 Climate 1% AEP Don River Breakout, Bowen Local Catchment & Storm Tide

Figure: **A-6**

Rev: **A**

N

0 0.75 1.5km

Approx. Scale

BMT

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