WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Flood Risk Management Report

St Marys Flood Risk Management Study

Break O'Day Council

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1 INTRODUCTION AND BACKGROUND

Break O'Day Council (BODC) engaged Water Technology to undertake the St Marys Flood Risk Management Study. This has involved the preparation of two key reports:

- An Interim Flood Investigation Report (previously submitted) which documents the current level of flood risk at St Marys across a range of design events. The report details the development and calibration of the hydrological and hydraulic models and documents key flood intelligence across the range of modelled design events
- A Flood Risk Management Report (this document) which has investigated a range of options to improve flood risk at St Marys. This has included consideration for flood warning, flood response and structural flood mitigation options.

The first key objective of the overall study is to provide flood mapping and flood intelligence for St Marys' major waterways based on best practice modelling and utilising knowledge from recent flood events. Mapping will be used to update flood intelligence for emergency response, and to guide future development of the township.

The second key objective of the study is to assess and determine floodplain management options for St Marys which can be implemented as part of a Flood Risk Management Plan for the town.

St Marys is a small rural town located near the eastern coastline of Tasmania. St Marys Rivulet flows through the township as do two small tributaries – Newmans Creek and St Patricks Creek. The catchment upstream of St Marys is predominately farmland and bushland with some areas of rural and low density residential properties within and around the township. The township was subject to three significant flood events in 2016 with the January 2016 event being the largest and two smaller events occurring in June and November.

This document forms the final report for the St Marys Flood Risk Management Study and consists of the following three sections all of which aim to improve flood risk for the town:

- Flood warning
- Flood Response
- Flood Mitigation; and
- Summary and Recommendations

2 FLOOD WARNING

A flood warning system does not currently exist for St Marys and an investigation of such a system is not within the scope of the current project. However, there have been a number of key findings made in the study which should be considered by Council and other key stakeholders in the context of improved flood warning for St Marys.

The key findings include:

- The St Marys Rivulet upstream of St Marys has a relatively short response time during rainfall and flood events. Depending on catchment antecedent conditions, the period between the onset of rainfall and the peak of a flood event could be as short as 4-6 hours (and therefore considered flash flooding) or as long as 18-24 hours. Given the small upstream catchment area and potential for short warning times it is likely a warning system would need to be rainfall-based as opposed to relying on streamflow gauging alone.
- While there is a good density of daily rainfall gauges in and around the catchment upstream of St Marys there are few sub-daily gauges or pluviograph stations in the region which record the temporal pattern or timing of rainfall. The nearest active sub-daily is at Fingal and the flood study modelling has shown that rainfall at Fingal is not representative of rainfall patterns across the catchment upstream of St Marys. A sub-daily gauge previously existed at Upper Scamander and provided rainfall data more representative of rainfall at St Marys, but this gauge has been inactive since August 2016. It is not expected that this gauge will be become active again in the short-term.
- Relationships have been developed which relate rainfall to runoff from the catchment upstream of St Marys and these can be a useful tool for understanding flood conditions that could occur at St Marys based on recorded rainfall depths and duration. This has allowed the development of a flash flood early warning tool shown in Figure 2-1 below. It should be noted that the tool is indicative in nature and runoff will also be highly dependent on a range of antecedent conditions in the catchment such as whether the catchment is wet or dry at the start of the rainfall event.

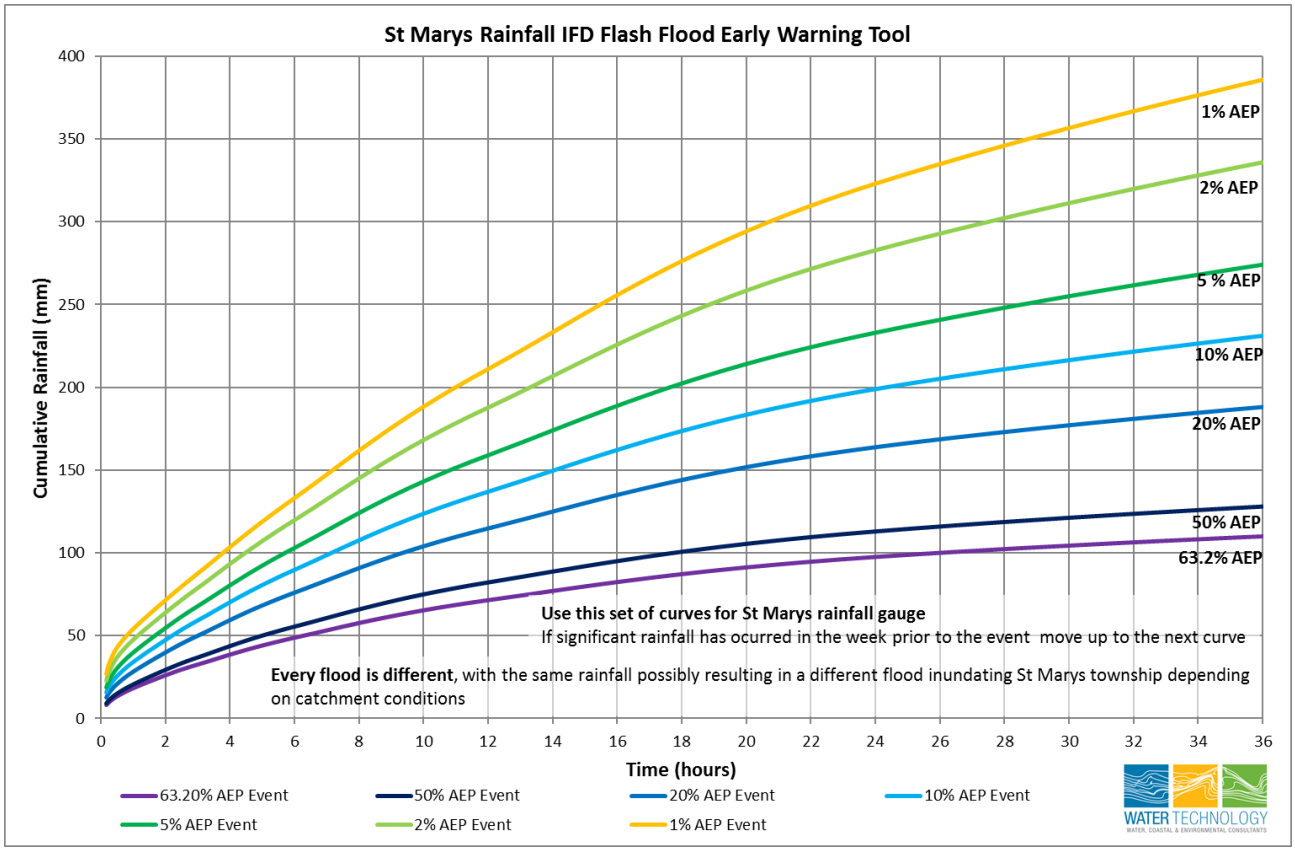

FIGURE 2-1 ST MARYS EARLY FLASH FLOOD WARNING TOOL

The total flood warning system concept includes many elements, including; flood prediction, interpretation of the flood impacts, messaging and communication of the flood risk, generating a timely response from the community, and reviewing the system. Given that the St Marys catchment is relatively small, the major flood risk is relatively short duration storm events and flash flooding. There are no streamflow gauges in the upper catchment or immediately downstream, so the flood prediction element of the total flood warning system relies on rainfall forecasts and rainfall observations.

Based on the above the following are features that could be considered as part of a flood warning system for St Marys:

- The installation of sub-daily rainfall gauge/s in the catchments upstream of St Marys could be considered. Multiple gauges located in the south and the north of the catchment could be considered given the localised rainfall patterns that are known to occur in this region. There are a number of standalone, commercial rainfall gauge options that could be considered which can alert Council staff once a certain threshold is reached in terms of recorded rainfall over a particular period of time (as shown in Figure 2-1).
- Radar rainfall could also be considered as part of an early warning system. The effectiveness of such a system will be dependent on the quality of radar rainfall and it is recommended that be discussed further between Council, SES and BOM. The forecast rainfall, made available via the BoM and the above mentioned sub-daily rainfall gauges and gridded radar rainfall could be used in combination with an early flood prediction tool to predict possible flash flooding.

  Water Technology suggests that the following flood prediction procedure could be considered:

  - Use the BoM Severe Weather Warning and Flood Watch alerts as a trigger to begin monitoring the situation.

- Use a gridded rainfall forecast model such as ACCESS, GFS, ECMWF, ADFD, NOWCAST, etc. to provide a more localised forecast for St Marys. The ADFD product can be accessed through the BoM MetEye page. Compare the forecast rainfall depths over various durations and plot on the flash flood early warning tool provided in Figure 2-1.
- As the storm event begins across St Marys, monitor the sub-daily rainfall gauges as well as radar rainfall. Compare the observed rainfall depths over various durations and plot on the flash flood early warning tool provided in Figure 2-1. Alternatively, this early flash flood warning tool can be built into flood warning systems to automate this process.
- By plotting the rainfall depth and storm duration on the flash flood early warning tool provided in Figure 2-1, an indication of the likely AEP of the storm event is provided. Take the maximum AEP for the various rainfall depth/duration observations and use that flood map and associated consequences to plan and respond to the flash flood event.
- Alert appropriate people regarding the likely flood consequences, including agencies, community members and businesses which may be impacted.

If Break O'Day Council want to establish an automated system to monitor, analyse and alert for flash flood warnings, Water Technology can provide further assistance in this regard.

The Intensity-Frequency-Duration (IFD) design rainfall data used to develop the hydrology used in the St Marys Flood Mapping Project, can be utilised along with forecast and observed rainfall data as an early warning tool. This can be used to identify the likely magnitude of flooding and possible consequences. Figure 2-1is the representation of the cumulative rainfall and durations that lead to flooding events. The user can monitor the rainfall depths over different durations and plot it on Figure 2-1. Whichever curve it intersects (or is closest to), is the likely AEP of flooding. It is likely that when plotting various rainfall depth/duration combinations, the AEP will differ. The user should use the maximum AEP for planning purposes to be conservative. It should be noted that in short duration rainfall bursts it is possible that the rainfall observed may indicate a rare event, but the storm may not have enough volume to produce flooding of that magnitude, particularly at the lower end of the catchment.

For example, if the 150 mm of rainfall over a period of 8 hours was observed, the flash flood early warning tool predicts a 2% AEP event occurring and contact houses within the affected areas. Although this is a helpful method in the prediction of flood events no flood is the same, flooding will be dependent of catchment conditions.

It is recommended that the findings of this study and key points described above be considered by Council, SES, BOM and other key stakeholders as part of any future flood warning system for St Marys.

3 FLOOD RESPONSE

As outlined in Section 5: Flood Intelligence in the Interim Flood Report, flood mapping was produced to identify the consequences of flooding for the various design flood events. Table 3-1 describes the key flooding consequences across the study area for each design event.

The consequences in the tables have been described in terms of depth of inundation, using the following key depth thresholds:

- Depths of 0.5 to 1 m, generally unsafe for vehicles, children and elderly
- Depths of 0.3 to 0.5 m, unsafe for small vehicles
- Depths below 0.3 m, generally safe for vehicles, people and buildings

The reasoning behind these specific depths relates to Australian Rainfall and Runoff Book 6 Chapter 7: Safety Design Criteria, as shown in Figure 3-1 below.

The criteria for the hazard mapping provided in Appendix C is also based on the flood hazard curves shown in Figure 3-1.

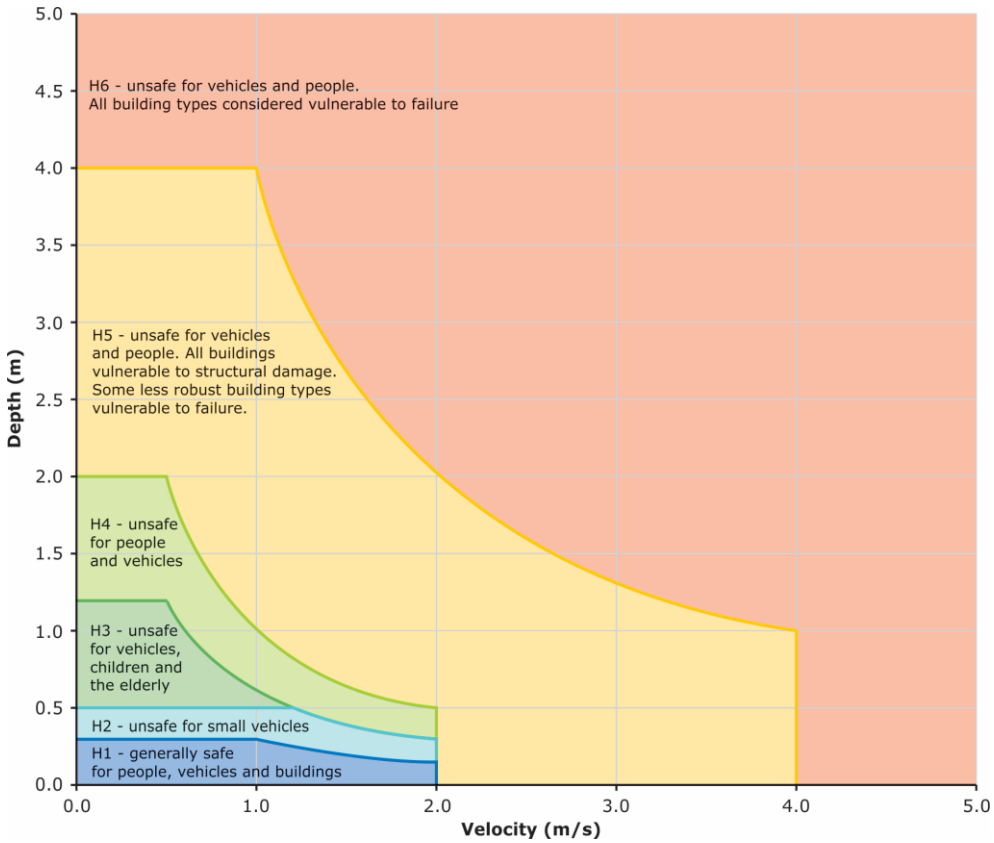

FIGURE 3-1 FLOOD HAZARD CURVES (SMITH ET AL, 2014)

TABLE 3-1 SUMMARY OF FLOODING CONSEQUENCES - ST MARYS

Flooding Event	Flood Consequences / Impacts	Key roadways inundated – Access and Egress	Possible/Suggested Response
20% AEP (5-year ARI) **Peak Flow: 51 m^3/s**	■ Flooding largely remaining within banks of inflow tributaries ■ Minor breakouts along St Marys Rivulet, located upstream of The Flat and downstream of Main Street and Story Street ■ Minor flooding for properties along Main Street, Aulichs Lane, and Groom Street ■ Minor ponding at the end of Groom Street ■ Minor flooding in paddocks and rural residential properties, particularly downstream of Story St.	■ No roadways inundated	■ Monitor rainfall and water levels ■ Preparation of implementation of evacuation plan ■ Issue minor flooding alert pertaining to driving through flood waters and property inundation ■ Prepare deployment of signage for remaining roads traversing St Marys Rivulet, Newmans Creek and Margisons Creek and consider closing roads depending on rainfall and water levels

Flooding Event	Flood Consequences / Impacts	Key roadways inundated – Access and Egress	Possible/Suggested Response

10% AEP (10-year ARI)
 	
Peak Flow: 66 m^3/s
	■ Impacts as described in 20% AEP event and:
	■ Floodwaters backup behind Esk Main Road
	■ Breakouts occurring onto the lower areas of several properties along Main Street but houses not impacted
	■ Floodwaters overtop The Flat Bridge on St Marys Rivulet. Some shallow inundation of Main Street near The Flat intersection.
	■ Large breakouts across paddocks downstream of St Marys township
	■ Further inundation of properties along Aulichs Lane
	■ Limited access to property at PO Box 20, St Marys
		■ 0.3 to 0.5 metres inundation depth
		  ■ The Flat (near St Marys Rivulet bridge)
		■ Below 0.3 metres inundation depth
		  ■ Main Street (near intersection with The Flat)
			■ Monitor rainfall and water levels
			■ Preparation of implementation of evacuation plan
			■ Issue minor flooding alert pertaining to driving through flood waters and property inundation
			■ Place “Road Closed” sign for The Flat
			■ Place “Water over road” signs for Main Street
			■ Prepare deployment of signage for remaining roads traversing St Marys Rivulet, Newmans Creek and Margisons Creek and consider closing roads depending on rainfall and water levels

Flooding Event	Flood Consequences / Impacts	Key roadways inundated – Access and Egress	Possible/Suggested Response

5% AEP (20-year ARI)
 	
Peak Flow: 78 m^3/s
	■ Impacts as described in 10% AEP event and:
	■ Floodwater breakout along St Patricks Creek flowing parallel with St Marys Rivulet traversing Grey Road and Harefield Road
	■ Large breakouts downstream of Story Road through paddocks
	■ Properties inundated along Groom Street and Franks Street to shallow depths
	■ Further property inundation along Main Street, Aulichs Lane, and Groom Street
	■ Further inundation across Main Street near The Flat intersection
	■ Minor flooding breakouts along Newmans Creek
	■ Access to rural properties along Harefield Road becomes inundated
		■ 0.5 to 1 metre inundation depth
		  ■ No roads inundated to this depth
		■ 0.3 to 0.5 metres inundation depth
		  ■ Main Street (near intersection with The Flat)
		■ Below 0.3 metres depth
		  ■ Groom Street
		  ■ Grey Road
		  ■ Harefield Road
			■ Continue to monitor rainfall and water levels
			■ Preparation of implementation of evacuation plan
			■ Prepare evacuation of properties along Aulichs Lane and intersection with Main Street.
			■ Prepare evacuation of properties located within Newmans Creek and St Marys Rivulet boundaries
			■ Issue medium flooding alert pertaining to driving through flood waters, property inundation and housing inundation
			■ Place “Water over road” signs for Groom Street, Grey Road and Harefield Road
			■ Place “Road Closed” sign for Main Street
			■ Prepare deployment of signage for remaining roads traversing St Marys Rivulet, Newmans Creek and Margisons Creek and consider closing roads depending on rainfall and water levels

Flooding Event	Flood Consequences / Impacts	Key roadways inundated – Access and Egress	Possible/Suggested Response

2% AEP (50-year ARI)
 	
Peak Flow: 100 m^3/s
	■ Impacts as described in 5% AEP event and:
	■ Flood backwater at Esk Main Road traversing St Marys Rivulet
	■ Breakouts along Newmans Creek inundating properties located in the Newmans Creek/St Marys Rivulet wedge. Generally shallow depth. Above floor flooding unlikely.
	■ Properties and houses along Main Street subject to inundation (below floor level)
	■ Deepening floodwater around end of Groom Street
		■ 0.5 to 1 metre inundation depth
		  ■ The Flat
		  ■ Main Street (near intersection with The Flat)
		■ 0.3 to 0.5 metres inundation depth
		  ■ Grey Road
		  ■ Harefield Road
		■ Below 0.3 metres depth
		  ■ Esk Highway (near Irish Town Road
			■ Continue to monitor rainfall and water levels
			■ Mobilise sandbagging operation
			■ Action evacuation plan, removal of furniture etc from properties in Newmans Creek/St Marys Rivulet wedge
			■ Prepare evacuation of Groom Street
			■ Place “Water over road” signs for Story Street

Flooding Event	Flood Consequences / Impacts	Key roadways inundated – Access and Egress	Possible/Suggested Response

1% AEP (100-year ARI)
 	
Peak Flow: 114 m^3/s
	■ Impacts as described in 2% AEP event and:
	■ Increased depths of flooding throughout the town
	■ Additional breakout through properties on Groom Street, shallow depths
		■ 0.5 to 1 metre inundation depth
		  ■ Esk Highway (near Irish Town Road)
		■ 0.3 to 0.5 metres inundation depth
		  ■ No further roads inundated
		■ Below 0.3 metres depth
		  ■ No further roads inundated
			■ Continue to monitor rainfall and water levels
			■ Mobilise sandbagging operation
			■ Action evacuation plan, removal of furniture etc from properties in Newmans Creek/St Marys Rivulet wedge
			■ Issue flooding alert pertaining to sandbagging and removal of furniture
			■ Issue larger area flood alert for remaining property inundation and driving risks through floodwaters

Flooding Event	Flood Consequences / Impacts	Key roadways inundated – Access and Egress	Possible/Suggested Response

0.5% AEP
 	
Peak Flow:
138 m^3/s
	■ Impacts as described in 1% AEP event and:
	■ Houses along Main street, Groom Street and Aulichs Lane inundated to depths above 0.5 metres
	■ Numerous, large breakouts along St Marys Rivulet
	■ No access to hospital facilities for properties east of Main Road Bridge
	■ Restricted access to the township from properties east of Main Road bridge and south of Storey Street bridge
		■ 0.5 to 1 metre inundation depth
		  ■ Grey Road
		  ■ Harefield Road
		■ 0.3 to 0.5 metres inundation depth
		  ■ No further roads inundated
		■ Below 0.3 metres depth
		  ■ No further roads inundated
			■ Continue to monitor rainfall and water levels
			■ Mobilise sandbagging operation
			■ Action evacuation plan, removal of furniture etc from properties along Main street, Groom Street, Aulichs Lane and Storey Road
			■ Issue flooding alert pertaining to sandbagging and removal of furniture
			■ Issue extensive area flood alert for remaining property inundation and driving risks through floodwaters

Flooding Event	Flood Consequences / Impacts	Key roadways inundated – Access and Egress	Possible/Suggested Response
PMF **Peak Flow:** **330 m^3/s**	■ Increased depths throughout inundated areas. Main breakout through Groom Street area increases in depth and extent, ■ All downstream areas from Story Road inundated ■ No safe access along Main Street or Esk Highway to the east or Story Street to the south	■ No further roads inundated ■ No access to the township from the east or south due to inundation across Esk Highway, Main Street and Story Street.	■ Evacuate remaining properties within 0.5% AEP event extent

4 FLOOD MITIGATION OPTIONS

4.1 Overview

Flood mitigation infrastructure is aimed at reducing flood risk to a region located on a floodplain. Mitigation options can be in the form of structural options (levees, bridges, culverts, and creek diversion etc.) or non-structural (flood warnings, rezoning, relocating residents, and resilience etc.) processes. This section focuses on structural mitigation options and has assessed a range of options suggested by the community and key stakeholders.

The key focus for the selection of mitigation options was driven by community consultation sessions that were conducted throughout December 2017 and February 2018. There were a number of suggestions raised by the local St Marys community, these were refined through reference group meetings and adhered to specific criteria, primarily; hydraulic effectiveness, practicality, cost, community support and environmental impacts.

Eight mitigation options were considered for the abovementioned criteria, modelled and assessed for two different design events. The proposed options represented 20 model scenarios (including each design event) from Option A through to Option G.

The tested of options included various forms of:

- Vegetation removal;
- Levee and embankments; and
- Modifying or replacing existing drainage infrastructure;

Each option was modelled in the TUFLOW hydraulic model by modifying relevant parameters such as Manning's' 'n' roughness or the topography. Full detail regarding the hydraulic model development is provided in the separate St Marys Interim Flood Report.

The pre-existing models for the 10%, 5%, 1% AEP events and the January 2017 event were manipulated in order to best represent the proposed options. TUFLOW has five main inputs:

- Topography and drainage infrastructure data;
- Inflow data (based on catchment hydrology);
- Roughness; and,
- Boundary conditions.

The mitigation modelling described in this section has taken into account all the main inputs and adjusted the model to replicate the proposed options.

4.2 Option A – Vegetation Removal

4.2.1 Option Overview

A soft-engineering approach was considered as Option A in improving flood risk. This would be achieved by reducing the amount of vegetation present along the banks and across the floodplain around the confluence of St Patrick's Creek and St Marys Rivulet and along Newmans Creek. These are areas known to be very densely vegetated and suggested by the community as key areas to focus on. In practise, this option would likely involve the removal of exotic Willows and other species throughout the area and replacement with more appropriate, less dense, native species.

This option was tested in the model by replacing identified areas of denser vegetation which had a higher roughness in the model (generally 0.09) with moderately dense vegetation (value of 0.06). This would streamline flow through these areas resulting in reduced water levels locally and less backing up of water levels upstream.

The 1% and 10% AEP events were modelled with this option. The areas of dense vegetation which were modified are marked in Figure 4-1 below.

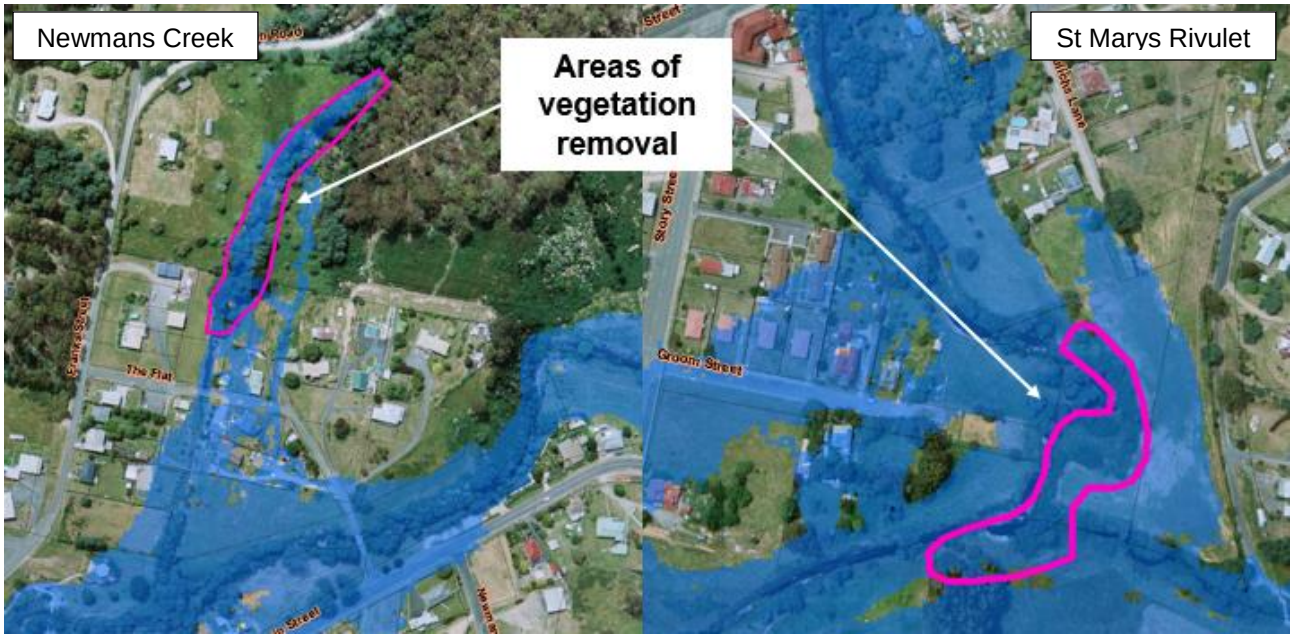

FIGURE 4-1 LOCATIONS OF MODELLED VEGETATION REMOVAL

4.2.2 Results Summary

A summary of the model results for this option is presented in Table 4-1 below.

TABLE 4-1 OPTION A BENEFITS AND ADVERSE IMPACTS

Option A	
1% AEP Benefits to Flood Risk:	Reduction in flood depth by 50 – 150 mm at the eastern end of Groom Street along St Marys Rivulet. Flood levels in the vicinity of the works are less than 50 mm lower than the original 1% AEP flood levels. Minimal benefit along Newmans Creek.

Option A	
10% AEP Benefits to Flood Risk:	Reduction in flood depth by 50 – 150 mm at the eastern end of Groom Street along St Marys Rivulet. Flood levels in the vicinity of the works are less than 50 mm lower than the original 1% AEP flood levels. Minimal benefit along Newmans Creek.
1% AEP Adverse Impacts:	No adverse impacts, however, it does not provide a significant improvement to flood risk to people or property.
10% AEP Adverse Impacts:	No adverse impact, however, it does not provide a significant improvement to flood risk to people or property
Summary:	Achieves a small and localised reduction in flood risk along the watercourse, however only slightly reduces flooding extents/depths. Minimal benefit on Newmans Creek. The reinstatement of vegetation may cause erosional activities along the watercourse if not undertaken carefully and with consideration for appropriate species. The mechanisms for ongoing maintenance would also need to be considered. Considered an environmental sensitive model, reinstating a more natural aesthetic for the watercourse and would result in more appropriate vegetation species.

Difference plots for the Option A modelled events are provided in Figure 4-2 through to Figure 4-5.

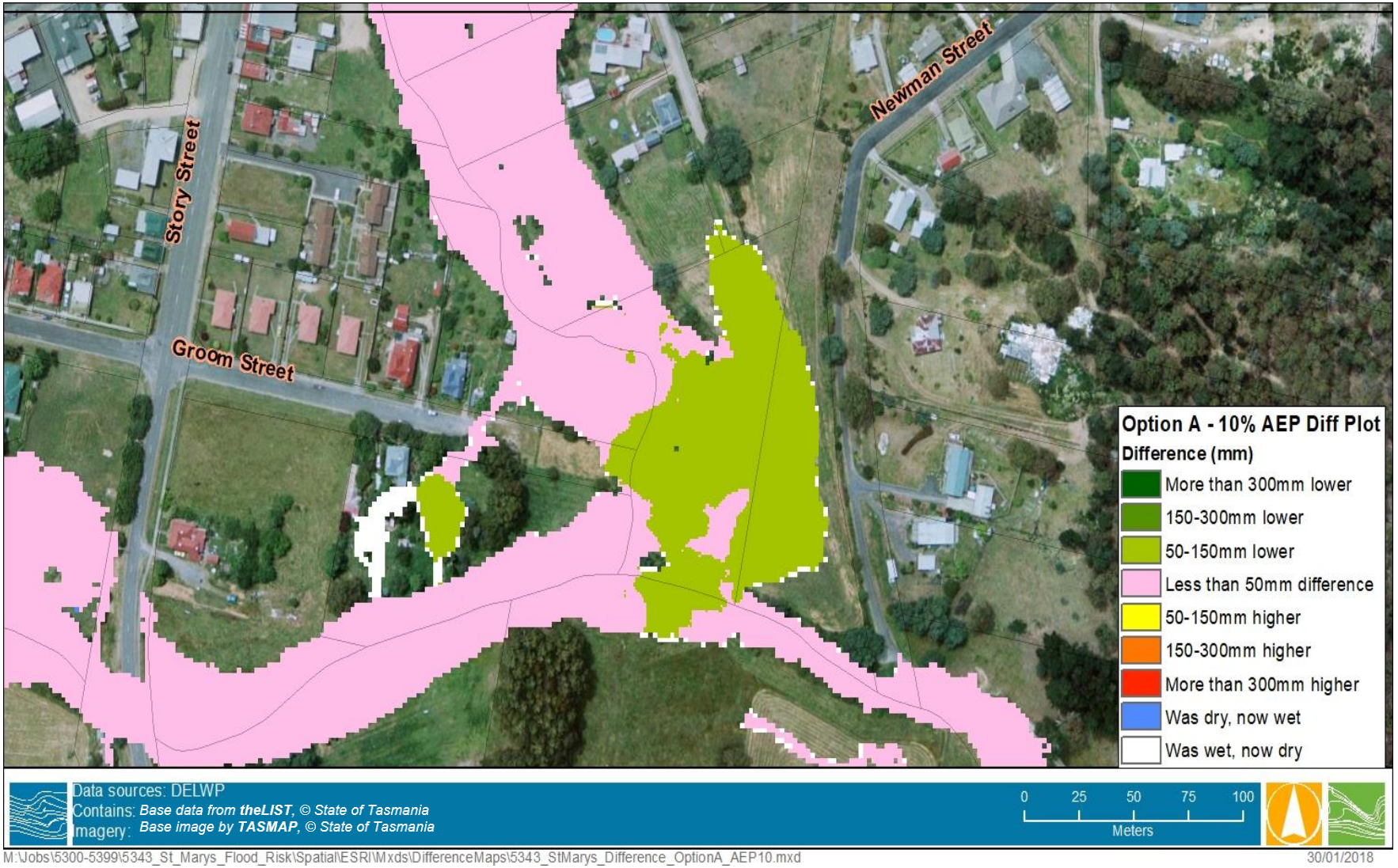

FIGURE 4-2 OPTION A – 10% AEP DESIGN EVENT FLOOD EXTENT NEAR ST MARYS RIVULET AND PATRICKS CREEK CONFLUENCE

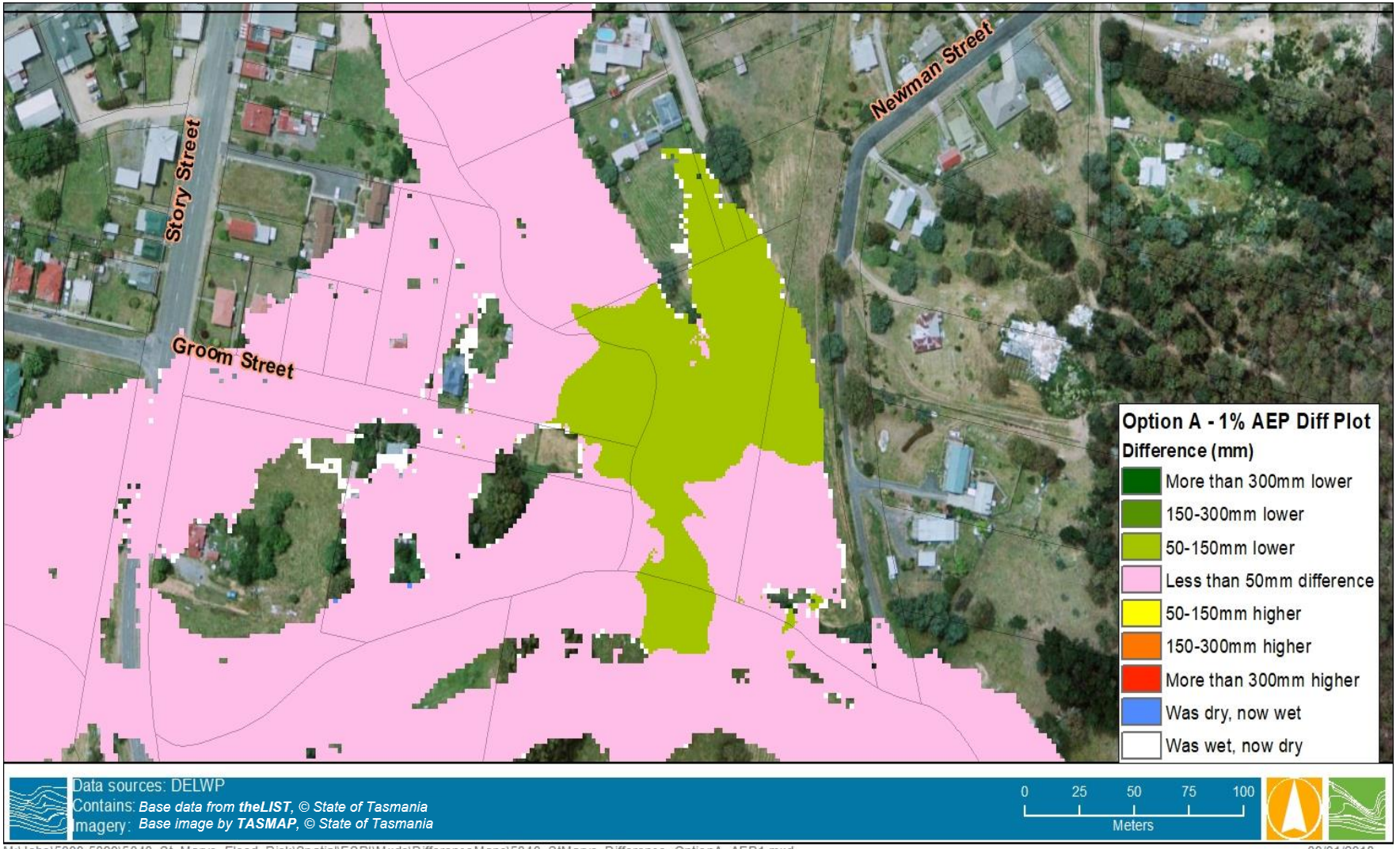

FIGURE 4-3 OPTION A – 1% AEP DESIGN EVENT FLOOD EXTENT NEAR ST MARYS RIVULET AND PATRICKS CREEK CONFLUENCE

FIGURE 4-4 OPTION A – 10% AEP DESIGN EVENT FLOOD EXTENT ALONG NEWMANS CREEK

FIGURE 4-5 OPTION A – 1% AEP DESIGN EVENT FLOOD EXTENT ALONG NEWMANS CREEK

4.3 Option B – Groom Street Levees

4.3.1 Option Overview

Low level levees were considered for Option B in improving flood risk. The option consisted of construction of low levees along the St Marys Rivulet watercourse to prevent out of bank breakouts over properties in the vicinity of Groom Street and Story Street.

Three different levee alignments were modelled for the 1% AEP events and 10% AEP events:

- Option B1 involved a long levee which extended from the pub to Groom Street along the western bank of the rivulet
- Option B2 involving a short levee near Groom Street which aimed to prevent the breakout which occurs in that area in the 1% AEP event
- Option B3 a medium length levee which aimed to provide more benefit than the short levee (B2) but without the adverse impacts found to occur with the long levee (B1). This was tested following the last round of community consultation.

The levees were modelled in TUFLOW by raising the topography along the levee alignment (using a Z shape).

The modelled levees consisted of:

- B1 (Long levee) – 280 metres long, would need to be an average of 500 mm high to achieve 300mm freeboard in the 1% AEP event
- B2 (Short levee) – 80 metres long, would need to be an average of 400 mm high to achieve 300mm freeboard in the 1% AEP event
- B3 (Medium levee) – 160 metres long, would need to be an average of 400 mm high to achieve 300mm freeboard in the 1% AEP event

The 1% AEP event and January 2016 event for the levees options were tested. The three levee alignments are shown in Figure 4-6 below.

FIGURE 4-6 OPTION B LEVEE ALIGNMENTS

4.3.2 Results Summary

A summary of the model results for the three levee alignment options is presented in Figure 4-2 below.

TABLE 4-2 OPTION B1(LONG LEVEE) BENEFITS AND ADVERSE IMPACTS

Option B1 (Long Levee)	
1% AEP Benefits to Flood Risk (Long levee)	A number of blocks become flood free along Groom Street with a less than 50 mm flood depth difference for the watercourse. Directly downstream of the long levee properties experience a reduction of 50 to above 300 mm flooding depth. Story Street breakouts limited to those occurring along St Marys Rivulet and not across Groom Street.
Jan 2016 Benefits to Flood Risk (Long levee)	A number of properties along Groom Street and Story Street become flood free, with a number of property flooding depths reducing by more than 300mm.
1% AEP Adverse Impacts (Long Levee):	Increased flood depths of up to 300 mm directly upstream of the levee and slightly increased flood extents along the watercourse. The adverse impacts extent only a short distance and do not impact dwellings.

Option B1 (Long Levee)	
Jan 2016 Adverse Impacts (Long Levee):	Increased flood extents and depths along the watercourse and levee by 100 - 300 mm. The impacts extend to just upstream of the Main Street bridge. The areas impacted are generally not developed however there are three properties with dwellings that would be adversely impacted.
Summary:	The long levee generated very positive benefits reducing and, in some cases, removing flooding for properties along Groom street, however, the larger flooding extents and increased depths elsewhere in the region limit the positive impacts. The long levee would be the costliest levee option given its greater length and there would also likely be additional expense where it passes by and through the property where the pub is located.

TABLE 4-3 OPTION B2 (SHORT LEVEE) BENEFITS AND ADVERSE IMPACTS

Option B2 (Short Levee)	
1% AEP Benefits to Flood Risk (Short levee)	Some blocks along Groom street become flood free, and a reduction of depths traversing Groom street by 50 – 150 mm.
Jan 2016 Benefits to Flood Risk (Short levee)	Reduction in flooding depths by more than 300 mm directly behind the levee for properties along Groom street.
1% AEP Adverse Impacts (Short Levee):	No adverse impacts.
Jan 2016 Adverse Impacts (Short Levee):	Flooding extents and depths increase throughout the region. Directly opposite to the proposed levee there is an increase instream depth of more than 300mm and on nearby properties along Auliches Lane increase flooding depths by 150 – 300 mm.
Summary:	The short levee provides good benefits in the 1% AEP event with significant reduction in flood depths and extents, whilst the adverse impacts are largely negated or minimal. The benefits in rarer events of the magnitude of the January 2016 event are small with only a small pocket that experiences reduced flood levels. The medium level would be a relatively inexpensive option given its length and height.

TABLE 4-4 OPTION B3 (MEDIUM LEVEE) BENEFITS AND ADVERSE IMPACTS

Option B3 (Medium Levee)	
1% AEP Benefits to Flood Risk (Medium levee)	A number of blocks become flood free along Groom Street with a less than 50 mm flood depth difference for the watercourse. Directly downstream of the long levee properties experience a reduction of 50 to above 300 mm in flood depths. Additional protection near the end of Groom Street is provided compared to the short levee. Story Street breakouts limited to those occurring along St Marys Rivulet and not across Groom Street.
Jan 2016 Benefits to Flood Risk (Medium levee)	A number of properties along Groom Street and Story Street become flood free, with a number of property flooding depths reducing by more than 300mm.
1% AEP Adverse Impacts (Medium Levee):	Increased flood depths of up to 300 mm directly upstream of the levee and slightly increased flood extents along the watercourse. The adverse impacts extend only a short distance and do not impact dwellings.
Jan 2016 Adverse Impacts (Medium Levee):	Increased flood extents and depths along the watercourse on the upstream side of the levee by 100 - 300 mm. The impacts extend upstream but not as far as they do with the long levee. The areas impacted are generally not developed however there are three properties with dwellings that would be adversely impacted. The impacts are slightly less than the long levee.
Summary:	The medium levee generated very positive benefits reducing and, in some cases, removing flooding for properties along Groom street, however, it does result in larger flooding extents and increased depths elsewhere upstream of the levee in extreme events of the magnitude of the January 2016 event. The adverse impacts are not as severe as the long levee but still significant. The medium level would be a relatively inexpensive option given its length and height.

Difference plots for the Option B modelled events are provided in Figure 4-7 through to Figure 4-12.

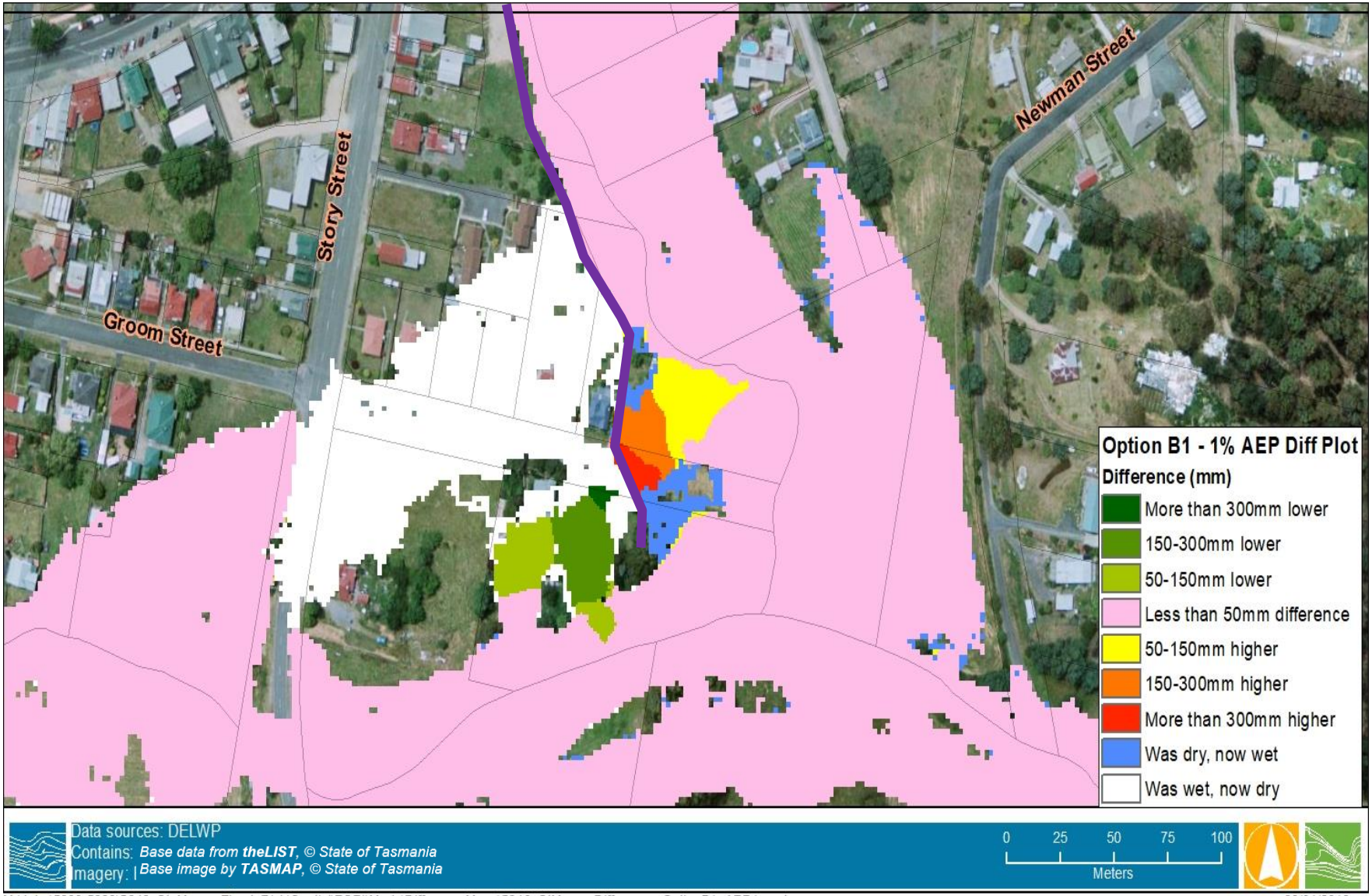

FIGURE 4-7 OPTION B1 (LONG LEVEE) – 1% AEP DESIGN EVENT FLOOD EXTENT

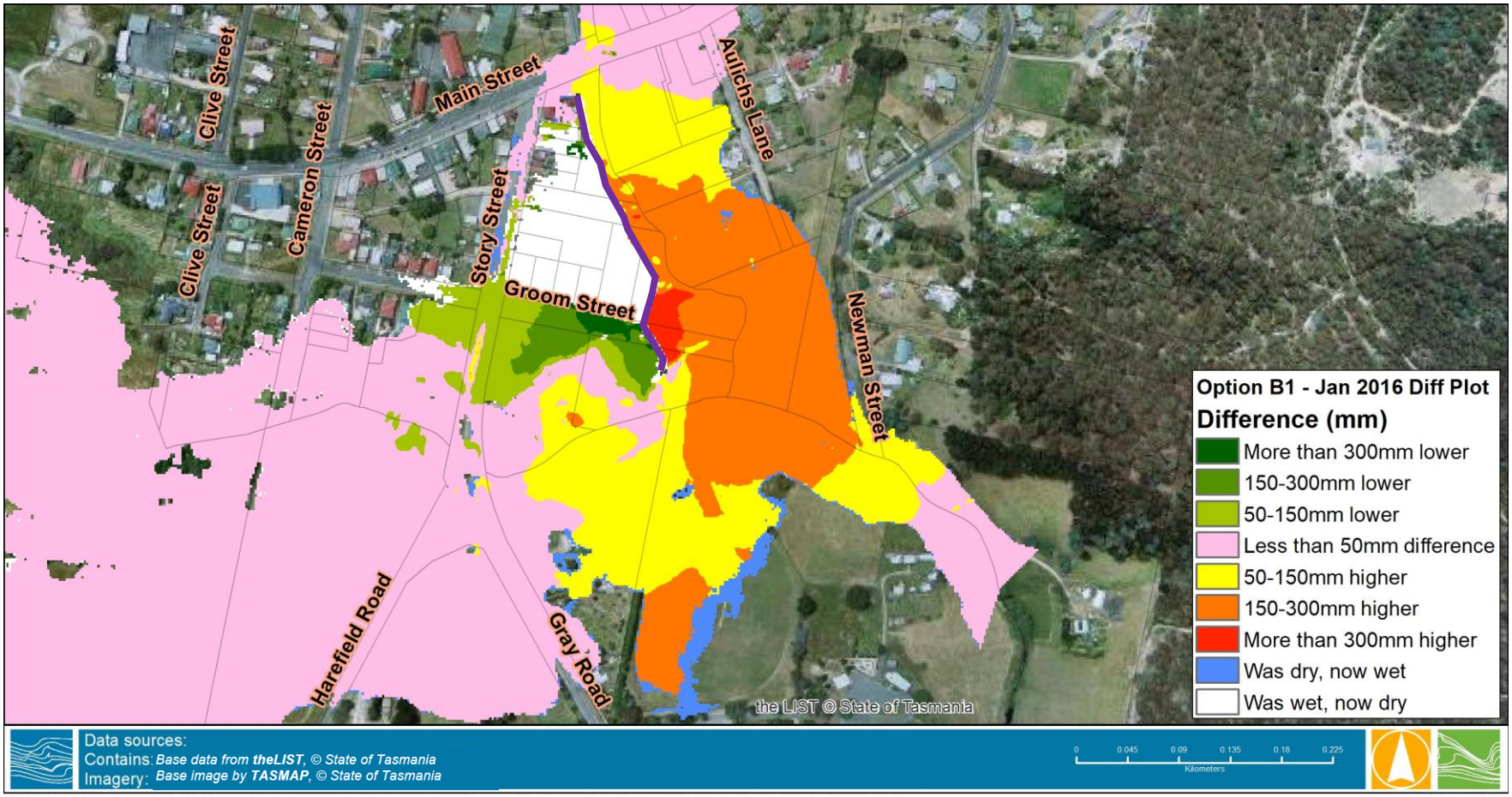

FIGURE 4-8 OPTION B1 (LONG LEVEE) – JANUARY 2016 FLOOD EXTENT

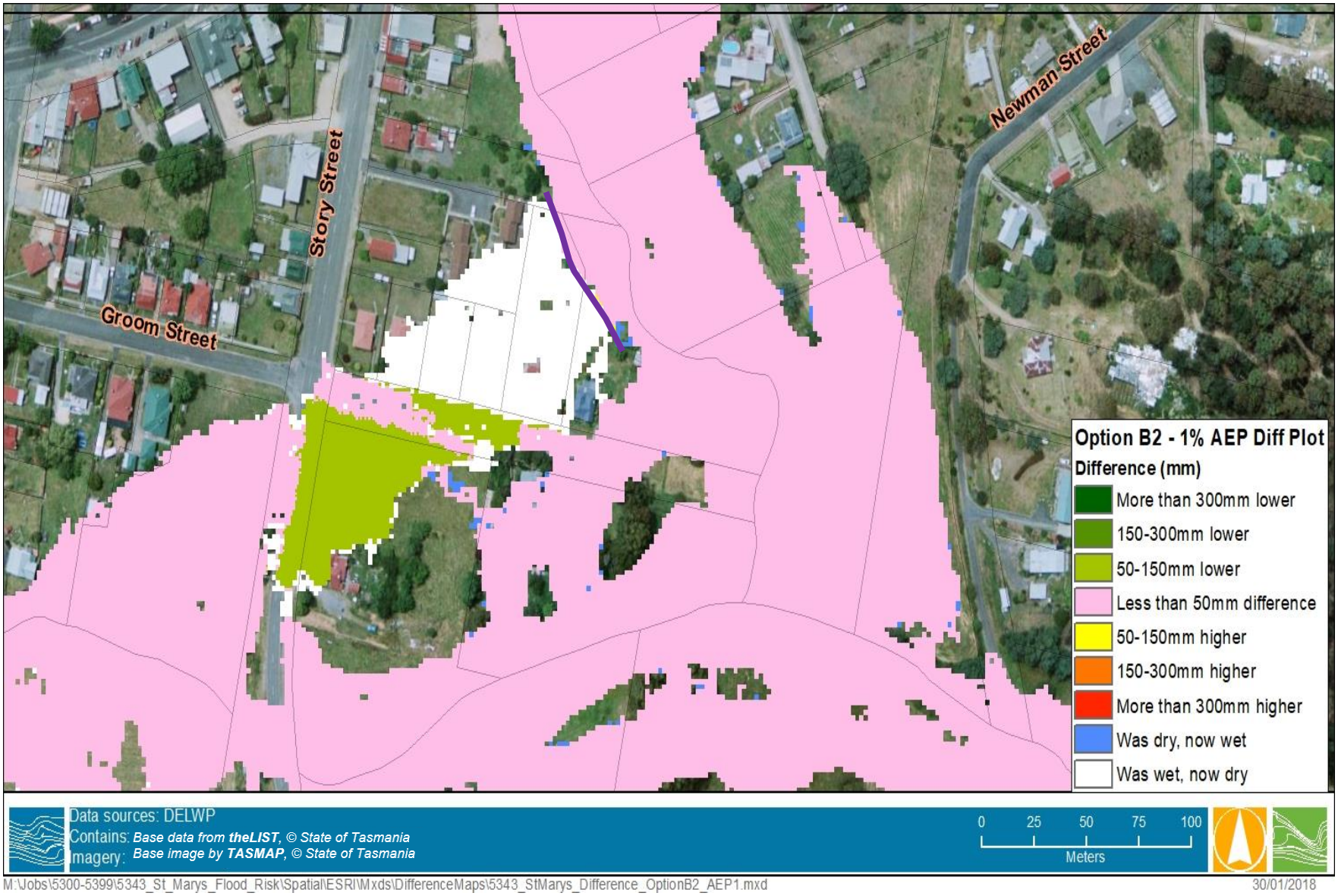

FIGURE 4-9 OPTION B2 (SHORT LEVEE) – 1% AEP DESIGN EVENT FLOOD EXTENT

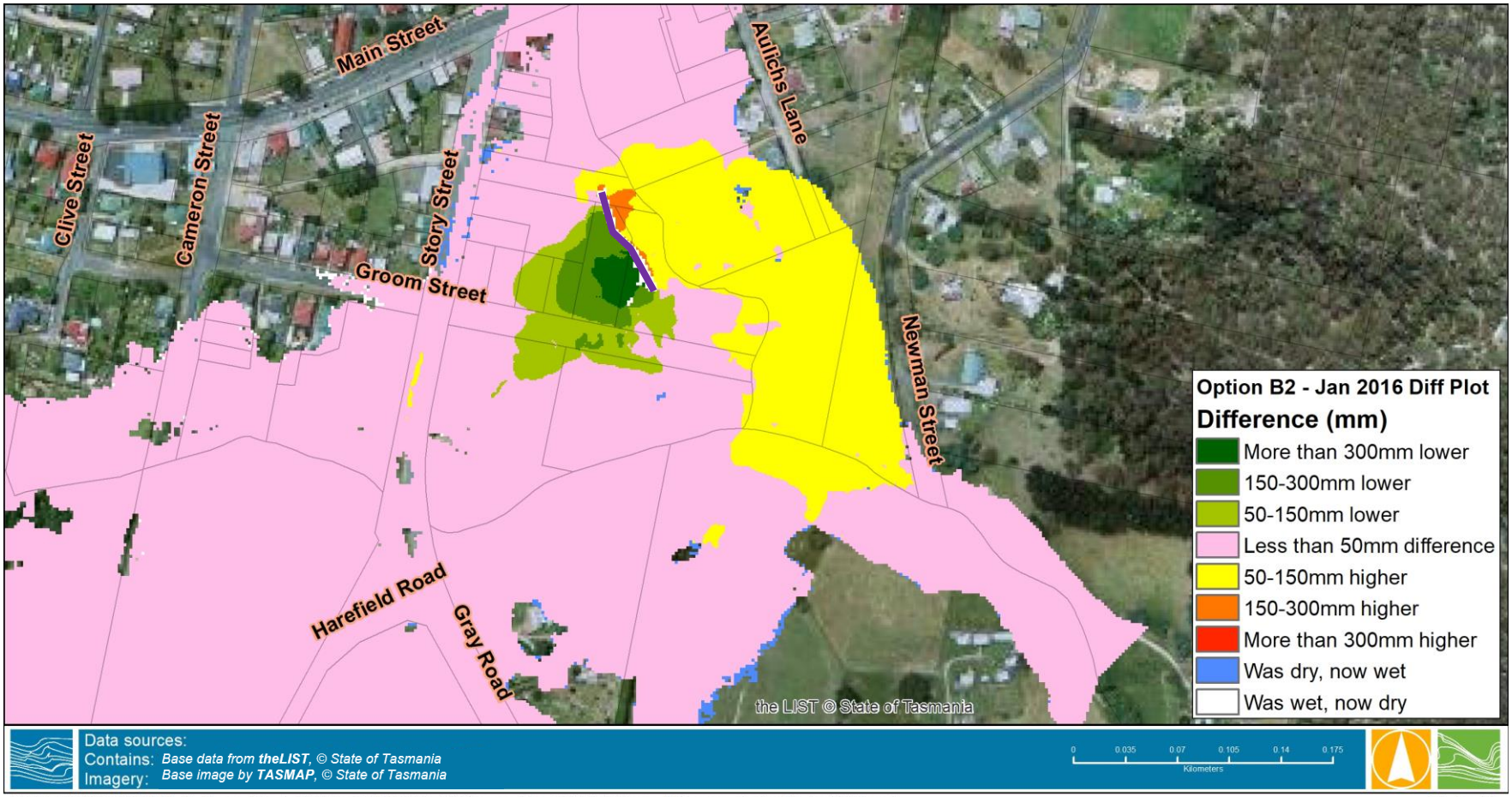

FIGURE 4-10 OPTION B2 (SHORT LEVEE) – JANUARY 2016 FLOOD EXTENT

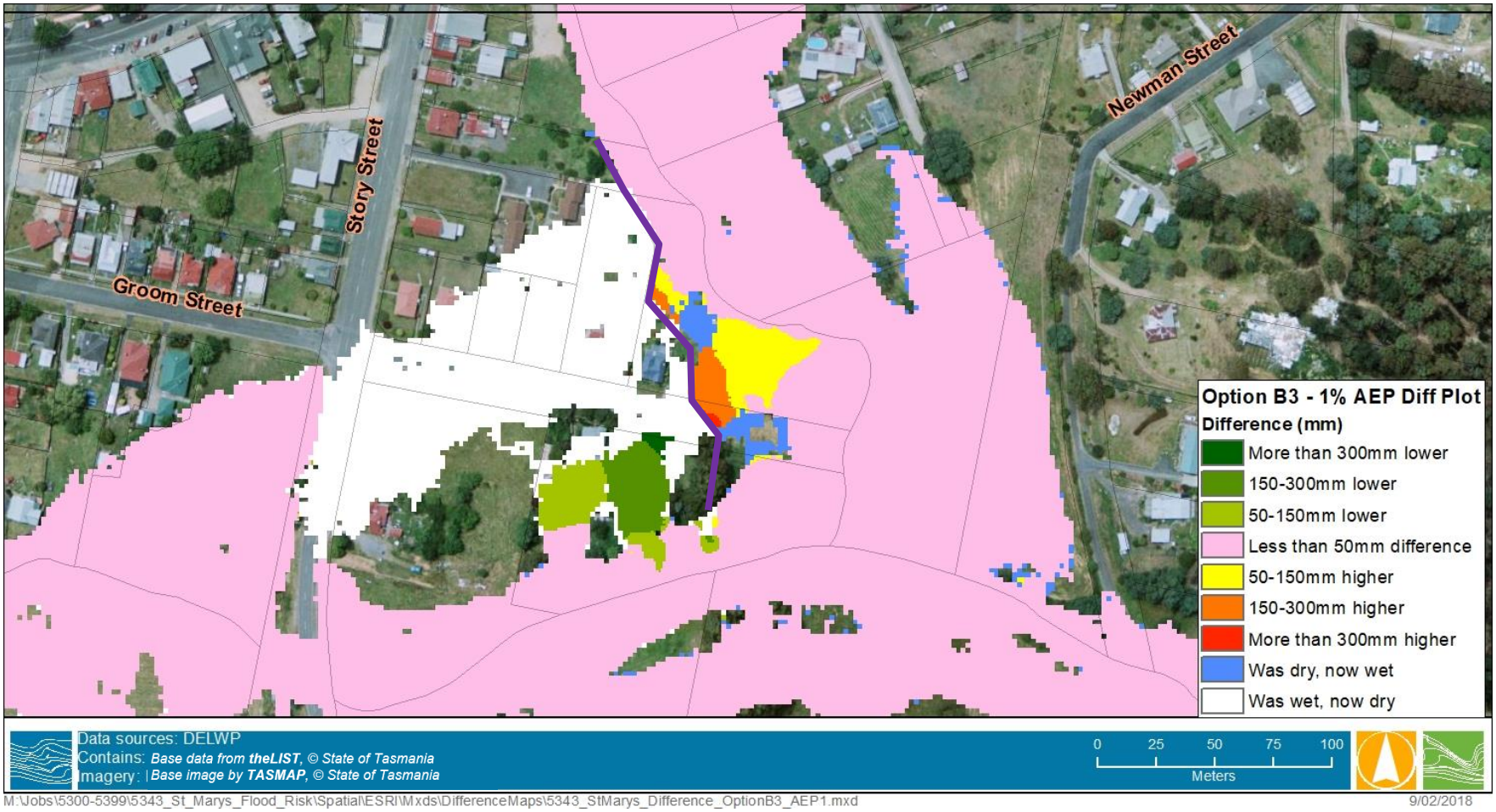

FIGURE 4-11 OPTION B3 (MEDIUM LEVEE) – 1% AEP DESIGN EVENT FLOOD EXTENT

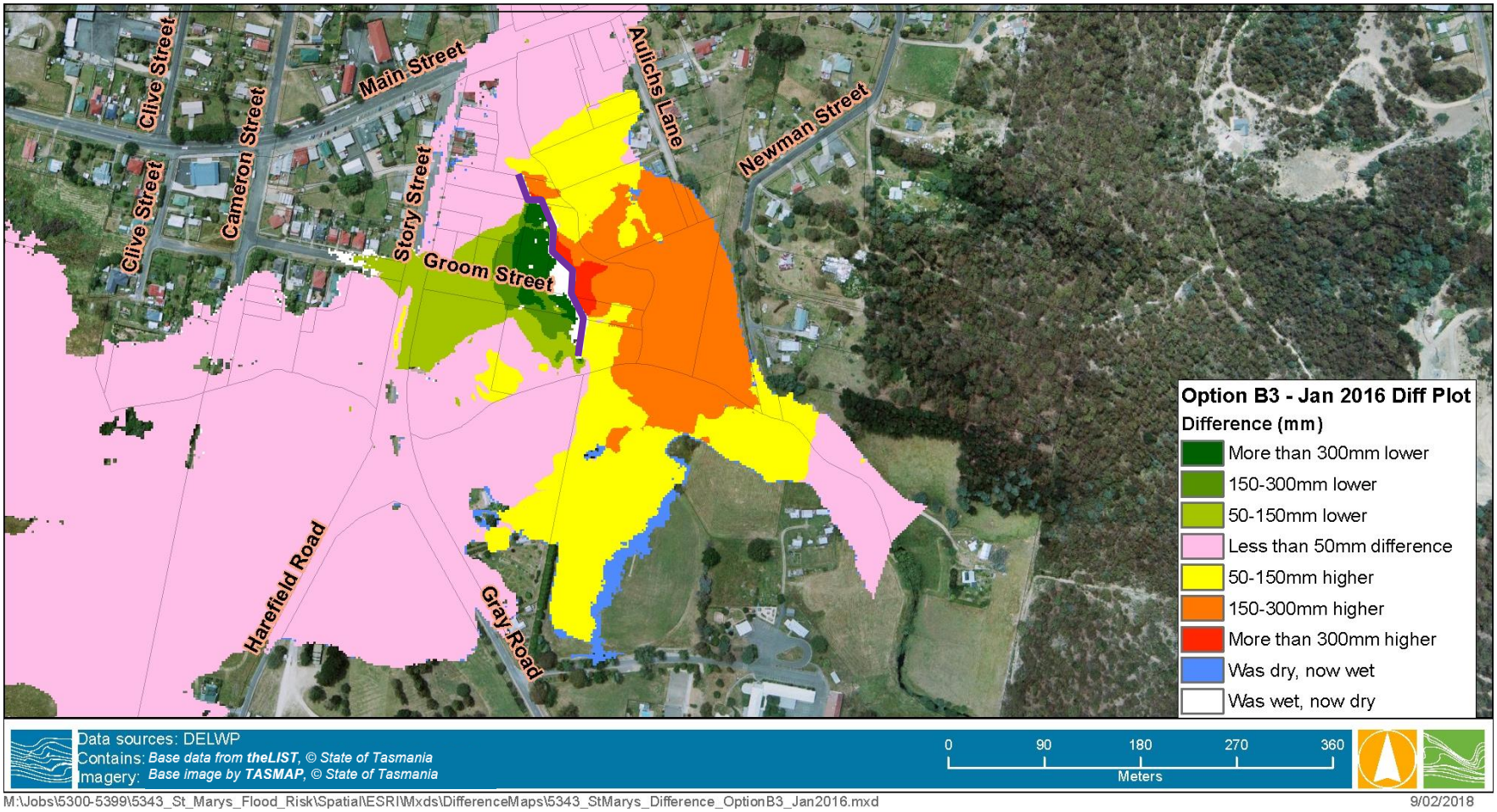

FIGURE 4-12 OPTION B3 (MEDIUM LEVEE) – JANUARY 2016 FLOOD EXTENT

4.4 Option C – Main Street Levee

4.4.1 Option Overview

Option C involves the construction of a levee running parallel to Main Street near the intersection with The Flat. The levee would primarily prevent flows overtopping Main Street and inundating nearby properties. The levee would stretch approximately 280 metres and have an average height of 500 mm which would provide 300 mm of freeboard. Similar benefit could also achieved by raising the road crest by 300 – 700 mm along this stretch. Raising the road would need to be combined with a short section of levee at the western end running north towards the rivulet as consistent with the levee alignment shown in Figure 4-6.

The 1% and 5% AEP events were tested with this option. The modelled levee alignment is shown below in Figure 4-6.

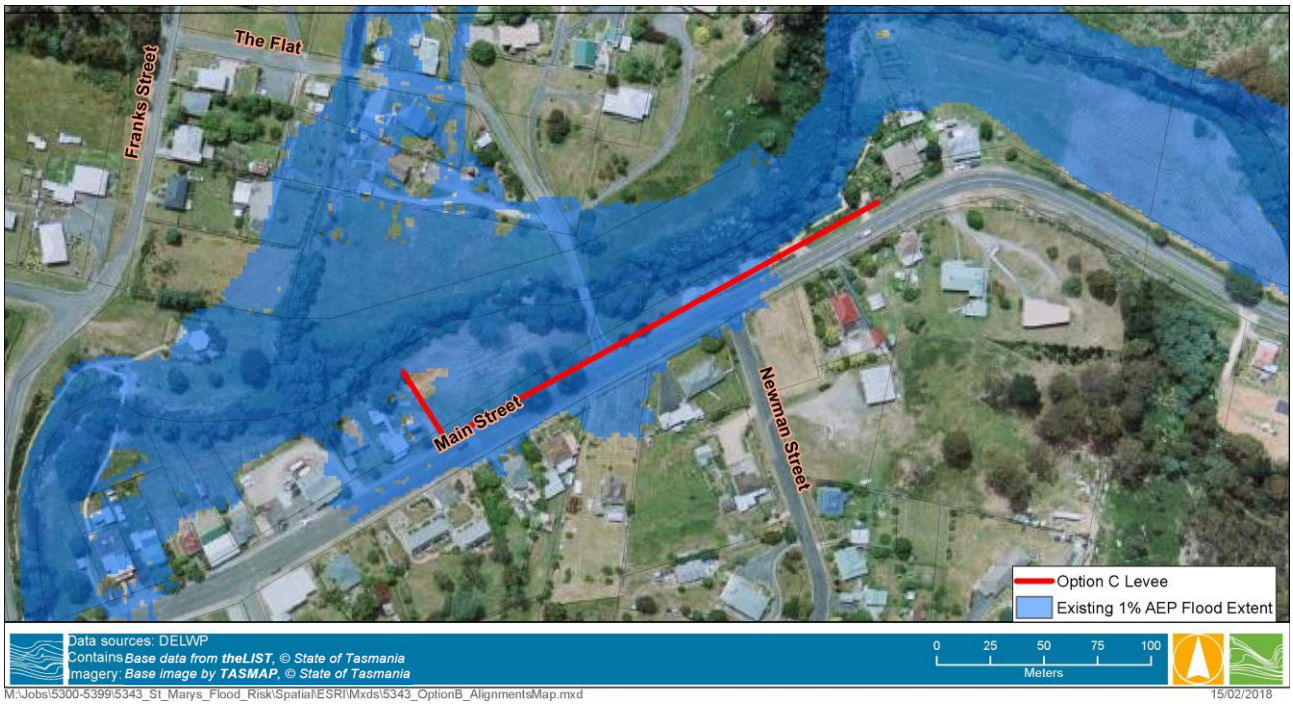

FIGURE 4-13 OPTION C LEVEE ALIGNMENT

4.4.2 Results Summary

A summary of the model results for this option is presented in Table 4-5 below.

TABLE 4-5 OPTION C BENEFITS AND ADVERSE IMPACTS

Option C	
1% AEP Benefits to Flood Risk	Main Street no longer overtops and several properties along Main Street become flood-free. .
5% AEP Benefits to Flood Risk:	Main Street no longer overtops and shallow inundation along the front of a couple of properties along Main Street is prevented.

Option C	
1% AEP Adverse Impacts:	Flood extents and depths increase around the levee on the rivulet side with increases of up to 150 mm, Similar increases in depths occur downstream of the levee on the upstream side of the Main Street Bridge. This results in additional flooding across Main Street in the vicinity of the bakery and the library.
5% AEP Adverse Impacts:	No adverse impacts
Summary:	This option has good benefits in that it prevents Main Street from overtopping up to the 1% AEP flood event and protects several properties from inundation. The adverse impacts which occur in the 1% AEP event downstream around the Main Street bridge are significant and would need to be addressed if this option was further considered The levee would be associated with significant cost, particularly if it involved raising the roadway. The interaction with The Flat would also need to be considered in any design to ensure it remained trafficable whilst providing flood protection. This would increase the levee cost.

Difference plots for the Option C modelled events are provided in Figure 4-14 and Figure 4-15.

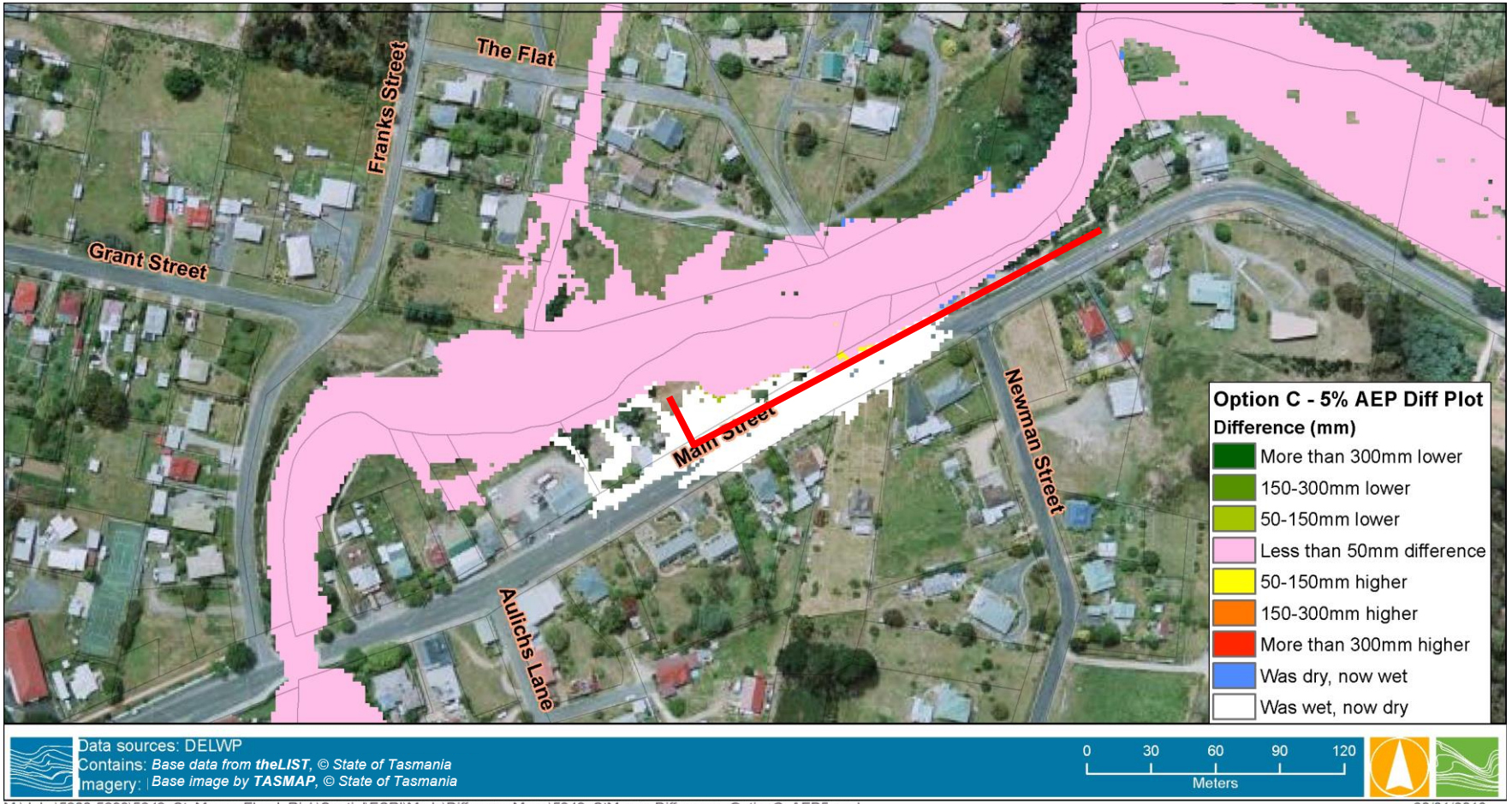

FIGURE 4-14 OPTION C – 5% AEP DESIGN EVENT FLOOD EXTENT

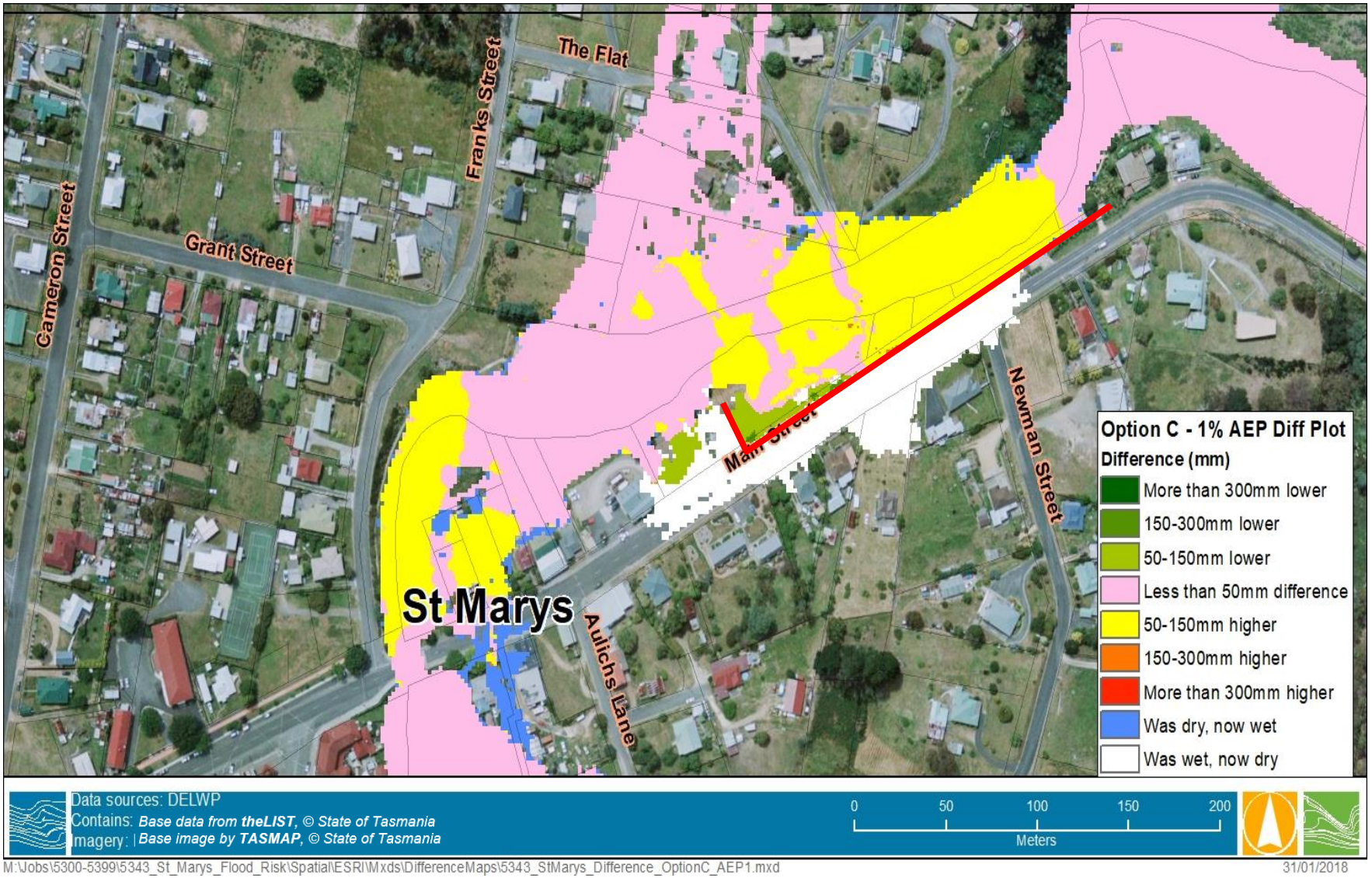

FIGURE 4-15 OPTION C – 1% AEP DESIGN EVENT FLOOD EXTENT

4.5 Option D – The Flat Bridge Ford Replacement

4.5.1 Option Overview

A ford structure was trialled to replace the existing The Flat road bridge across St Marys Rivulet. This ford is designed to reduce the constriction created by the bridge which is perceived by many local residents to contribute to flooding in this area. A ford is a shallow crossing were the roadway is dropped to the waterway bed with slowing raising wings on each side.

The ford structure would be impassable during high rainfall events, and the impacts on nearby residents would need to be considered. This was modelled by using the topographic information and a steady-slope gradient to the waterway bed level.

The 1% and 10% AEP events were modelled with this option.

4.5.2 Results Summary

A summary of the model results for this option is presented in Table 4-6 below.

TABLE 4-6 OPTION D BENEFITS AND ADVERSE IMPACTS

Option D	
1% AEP Benefits to Flood Risk	Lowers floodwaters around The Flat intersection with St Marys Rivulet and Main Street, including reducing flood depths across Main Street by up to 300mm. The reduction in flood levels extends for approximately 100 metres upstream.
10% AEP Benefits to Flood Risk:	Lowers floodwaters throughout The Flat area and prevents any floodwaters traversing Main Street and impacting properties. Main Street no longer overtops. The reduction in flood levels extends for approximately 150 metres upstream.
1% AEP Adverse Impacts:	The Flat intersection is impassable as the floodwaters are concentrated through that section of the watercourse alleviating pressures upstream and downstream but preventing access to Main Street.
10% AEP Adverse Impacts:	The Flat intersection is verging on impassable as the floodwaters are increasing by 50 – 300 mm and are deemed unsafe for crossing.
Summary:	As residents along The Flat are able to access Main Street by Franks Street this mitigation option is a sound one. The option reduces floodwater depth and extents throughout this area and improves access along Main Street.

Difference plots for the Option D modelled events are provided in Figure 4-16 and Figure 4-17.

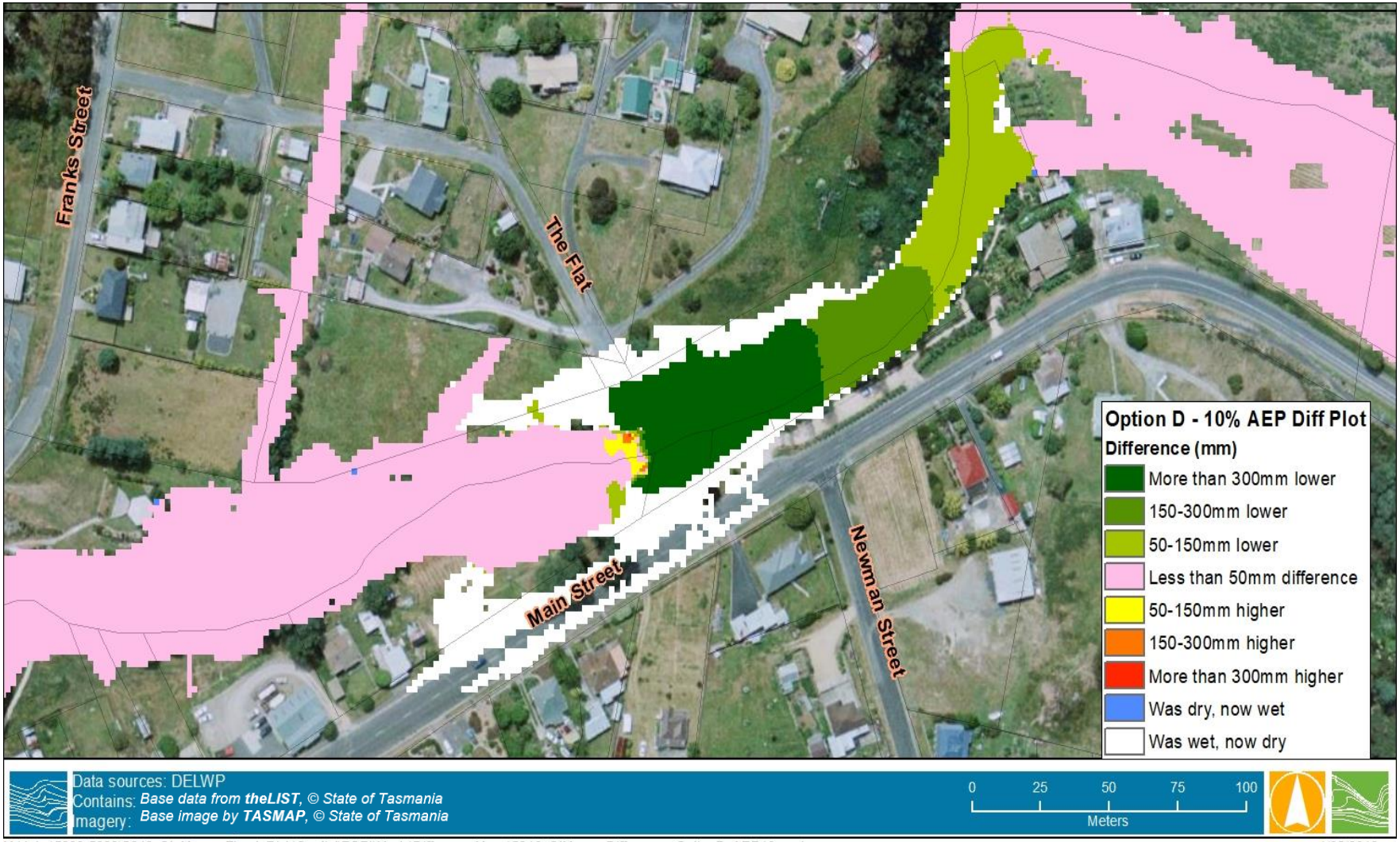

FIGURE 4-16 OPTION D – 10% AEP DESIGN EVENT FLOOD EXTENT

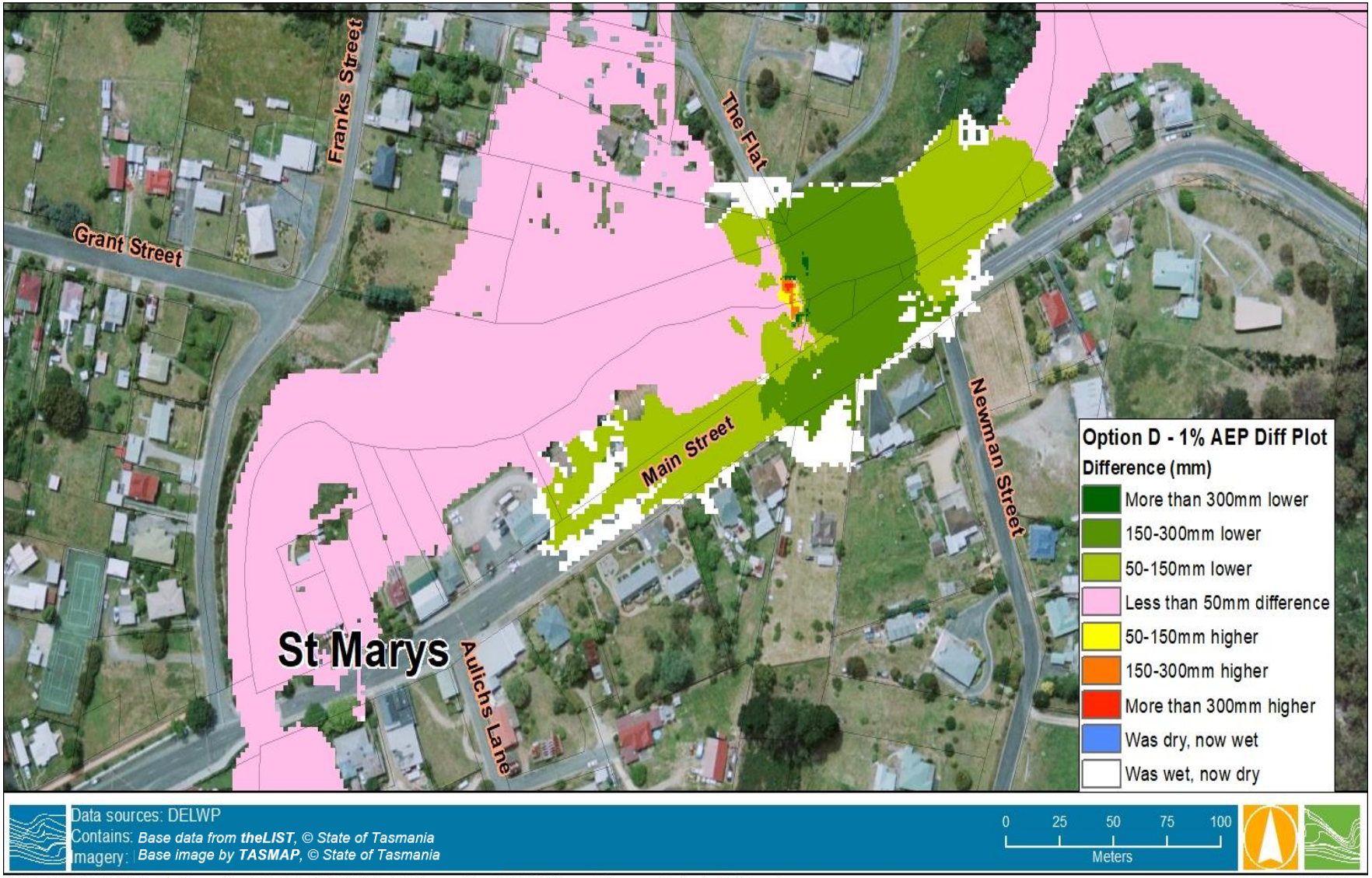

FIGURE 4-17 OPTION D – 1% AEP DESIGN EVENT FLOOD EXTENT

4.6 Option E – Extra Culverts at The Flat Bridge

4.6.1 Option Overview

Option E involved retrofitting the existing The Flat road bridge across St Marys Rivulet with extra culverts to expand capacity. This involved modelling two culverts on either side of the channel and the widening of the banks to ensure flow can get into the culverts. Two 750 mm diameter pipe culverts were trialled.

The 1% and 10% AEP events were tested with this option.

4.6.2 Results Summary

A summary of the model results for this option is presented in Table 4-1 below.

TABLE 4-7 OPTION E BENEFITS AND ADVERSE IMPACTS

Option E	
1% AEP Benefits to Flood Risk	Lowers floodwaters, generally by less than 50 mm, across a very small area within the vicinity of the bridge. Results in less water breaking out and flowing around the bridge. Slight improvement in overtop of Main Street with less flood extent but road still overtops.
10% AEP Benefits to Flood Risk:	Lowers floodwaters, generally by less than 50 mm, across a small area within the vicinity of the bridge. Results in less water breaking out and flowing around the bridge.
1% AEP Adverse Impacts:	None, but does not stop floodwaters overtopping Main Street.
10% AEP Adverse Impacts:	None, but does not stop floodwaters overtopping Main Street
Summary:	Although this option lowers floodwaters locally the overall impact is marginal with flood extents largely remaining the same and floodwater levels only reducing slightly. The impact on flood risk to people and property is minimal. Not recommended for further consideration.

Difference plots for the Option E modelled events are provided in Figure 4-18 and Figure 4-19.

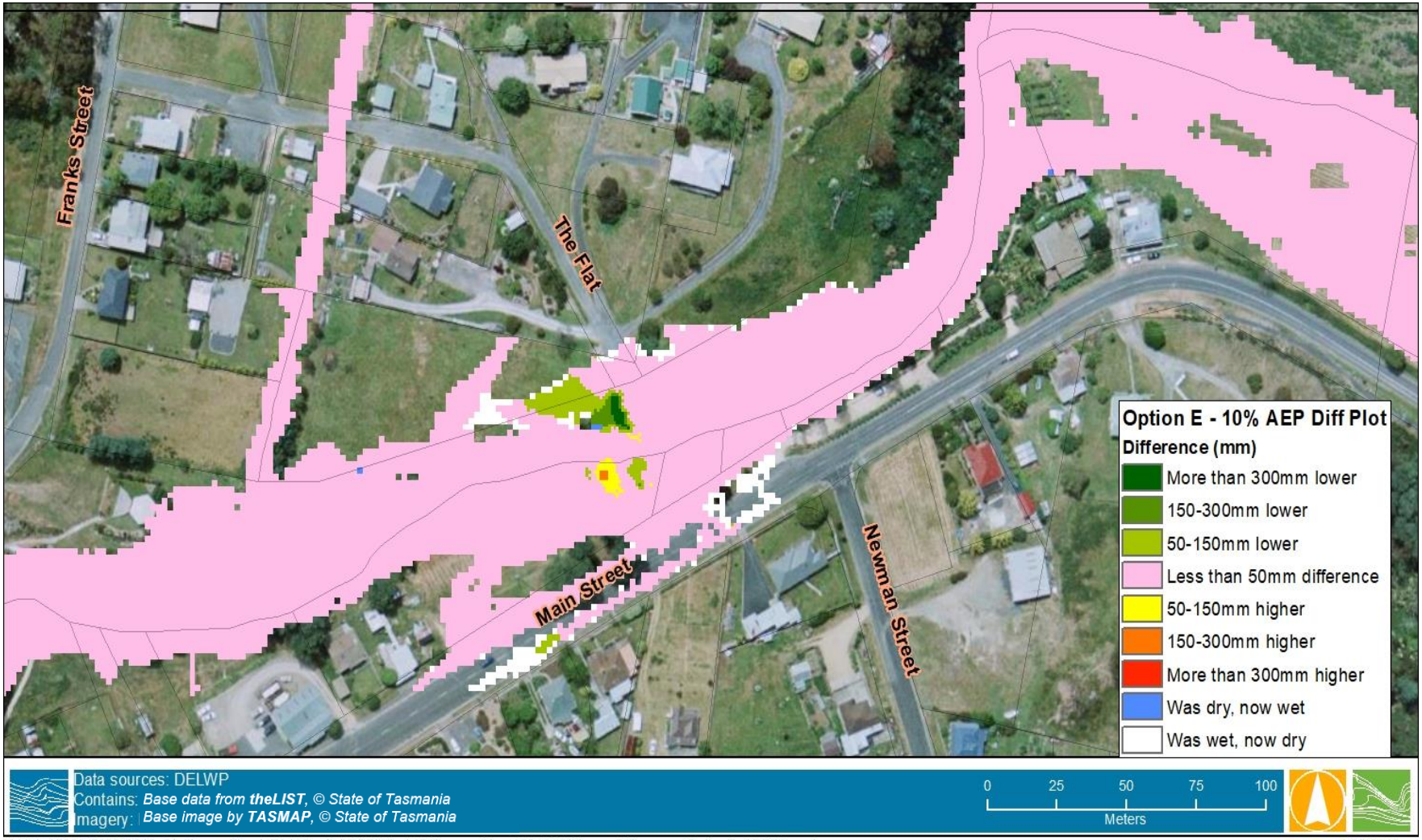

FIGURE 4-18 OPTION E – 10% AEP DESIGN EVENT FLOOD EXTENT

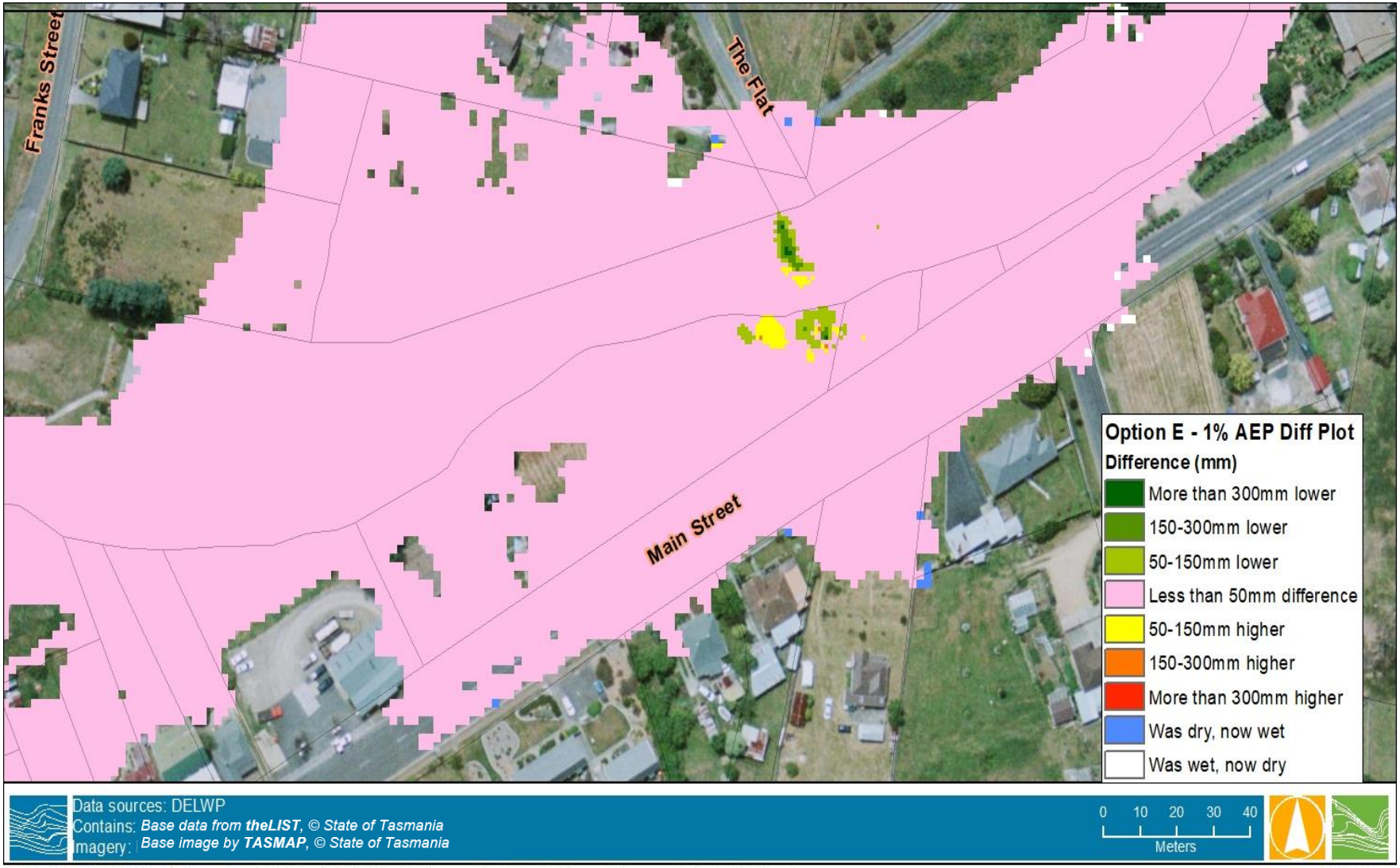

FIGURE 4-19 OPTION E – 1% AEP DESIGN EVENT FLOOD EXTENT

4.7 Option F – Widespread Clearing / Reduction in Vegetation

4.7.1 Option Overview

Option F is a revision of the Option A approach whereby the resistance along the entirety of St Marys Rivulet between Irish Town Road and downstream of Story Street was reduced through removal of all woody debris within the channel and vegetation reduction. This was modelled by a reduction of roughness by 25% through these areas which is deemed to be the largest reduction that could practically be achieved. While this reduction in roughness could physically be achieved, the works would likely result in channel instability, increased erosion processes along the watercourse and impact habitat for aquatic life.

The option was modelled by reducing the in-stream roughness by 25% from bank to bank. Roughness across the floodplain was not modified. The 1% and 10% AEP events were tested with this option.

4.7.2 Results Summary

A summary of the model results for this option is presented in Table 4-8 below.

TABLE 4-8 OPTION F BENEFITS AND ADVERSE IMPACTS

Option A	
1% AEP Benefits to Flood Risk	Reduction in flood depths throughout the township from 50 mm to more than 300 mm however benefits largely confined to waterway corridor. There are limited benefits to areas where dwellings are impacted.
10% AEP Benefits to Flood Risk:	Reduction in flood depths throughout the township from 50 mm to more than 300 mm. Flood extents no longer overtop Main street with breakouts along Groom Street receding. There are limited benefits to areas where dwellings are impacted.
1% AEP Adverse Impacts:	No adverse flood behaviour impacts however there would be significant long-term detrimental impacts to the stream including erosion processes, bank instability and destruction of habitat for aquatic life.
10% AEP Adverse Impacts:	No adverse flood behaviour impacts however there would be significant long-term detrimental impacts to the stream including erosion processes, bank instability and destruction of habitat for aquatic life.
Summary:	Some reduction in flood levels however limited benefit to people and property. Although there are no notable adverse impacts from a flooding perspective the environmental toll for Option F is likely to be considered too high and not supported by many community members and stakeholders. Government funding for such works would also be difficult to obtain. This option is not recommended.

Difference plots for the Option F modelled events are provided in Figure 4-20 and Figure 4-21.

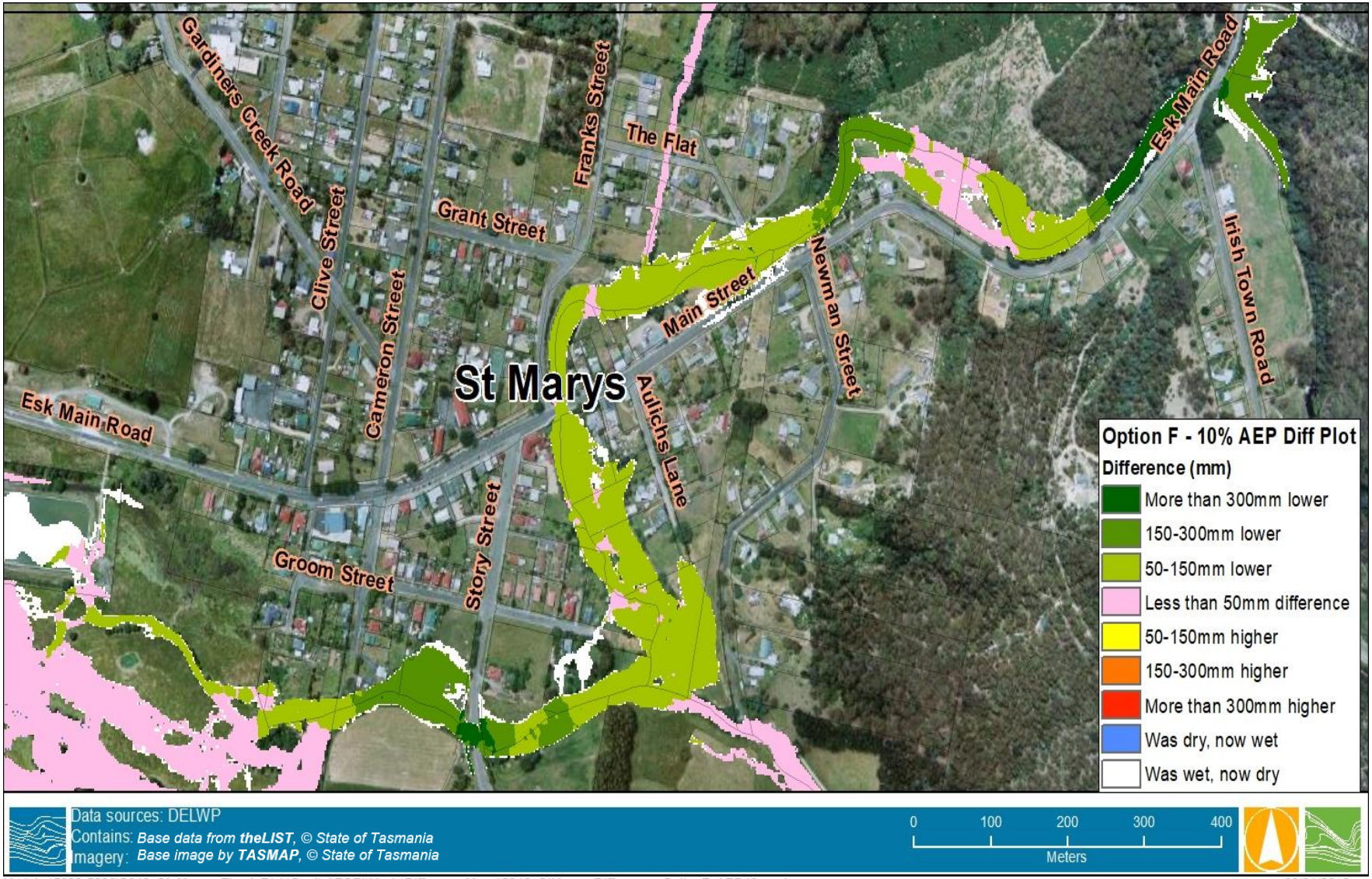

FIGURE 4-20 OPTION F – 10% AEP DESIGN EVENT FLOOD EXTENT

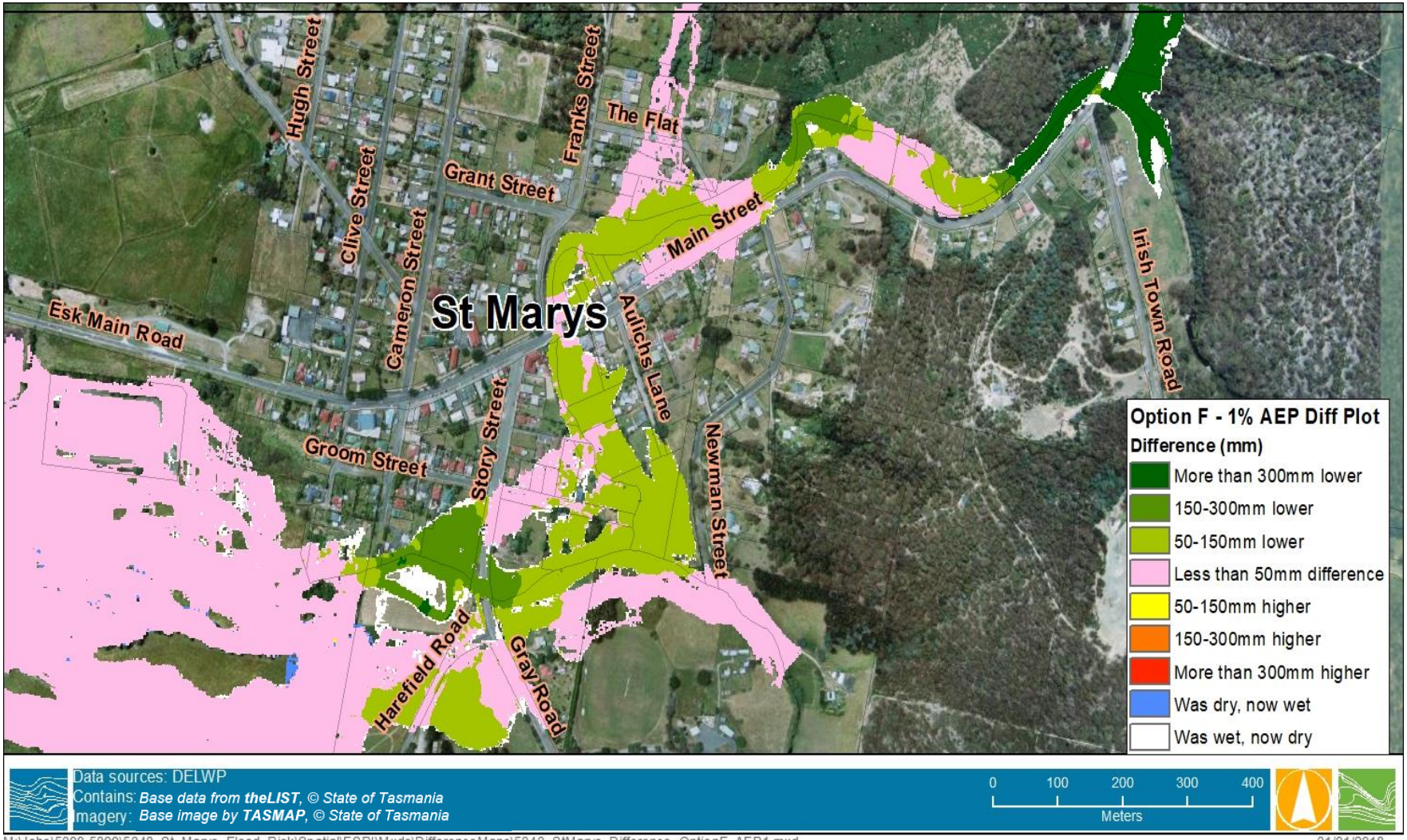

FIGURE 4-21 OPTION F – 1% AEP DESIGN EVENT FLOOD EXTENT

4.8 Option/Scenario G – The Flat Bridge Blockage Sensitivity

4.8.1 Option Overview

The Flat Bridge has been known in past flood events to be subject to blockage and accumulating flood debris. This scenario involved testing the sensitivity of flood behaviour around The Flat bridge to blockage of the bridge.

The scenario was modelled by applying a 25% or 50% blockage to The Flat bridge (below the deck level of the bridge) and modelling both the 1% and 10% AEP flood events.

4.8.2 Results Summary

The following points summarise the findings.

- For the 25% blockage scenarios it can be seen that upstream and downstream flood levels increase significantly in both the 1% and 10% AEP events. Levels increase generally by 50-150 mm in both events for the 25% blockage scenarios. The increase in levels downstream is a result of more water breaking out across and around the bridge with additional flood water across Main Street. In the 1% AEP event it can be seen that the breakout across Main Street increases significantly with additional private property inundated on the southern side of Main Street.
- For the 50% blockage scenarios it can be seen that the increase in upstream and downstream flood levels are very significant with increases of more than 300 mm in the 1% AEP event. In both events the overtop across Main Street is made significantly worse with higher flood levels and much greater flood extents. The results show that blockage of the bridge has the potential to make conditions along Main Street significantly more hazardous for people and vehicles.
- Overall the modelling has shown that flood behaviour in this area is highly sensitivity to blockage of The Flat bridge. Flood conditions are made significantly worse in this area if the bridge is subject to blockage in both rare and more frequent flood events. These findings will need to be considered by Council in the context of ongoing maintenance of the bridge and also for any future upgrades of the bridge.

Difference plots of the modelled scenarios are provided in Figure 4-22 through to Figure 4-25.

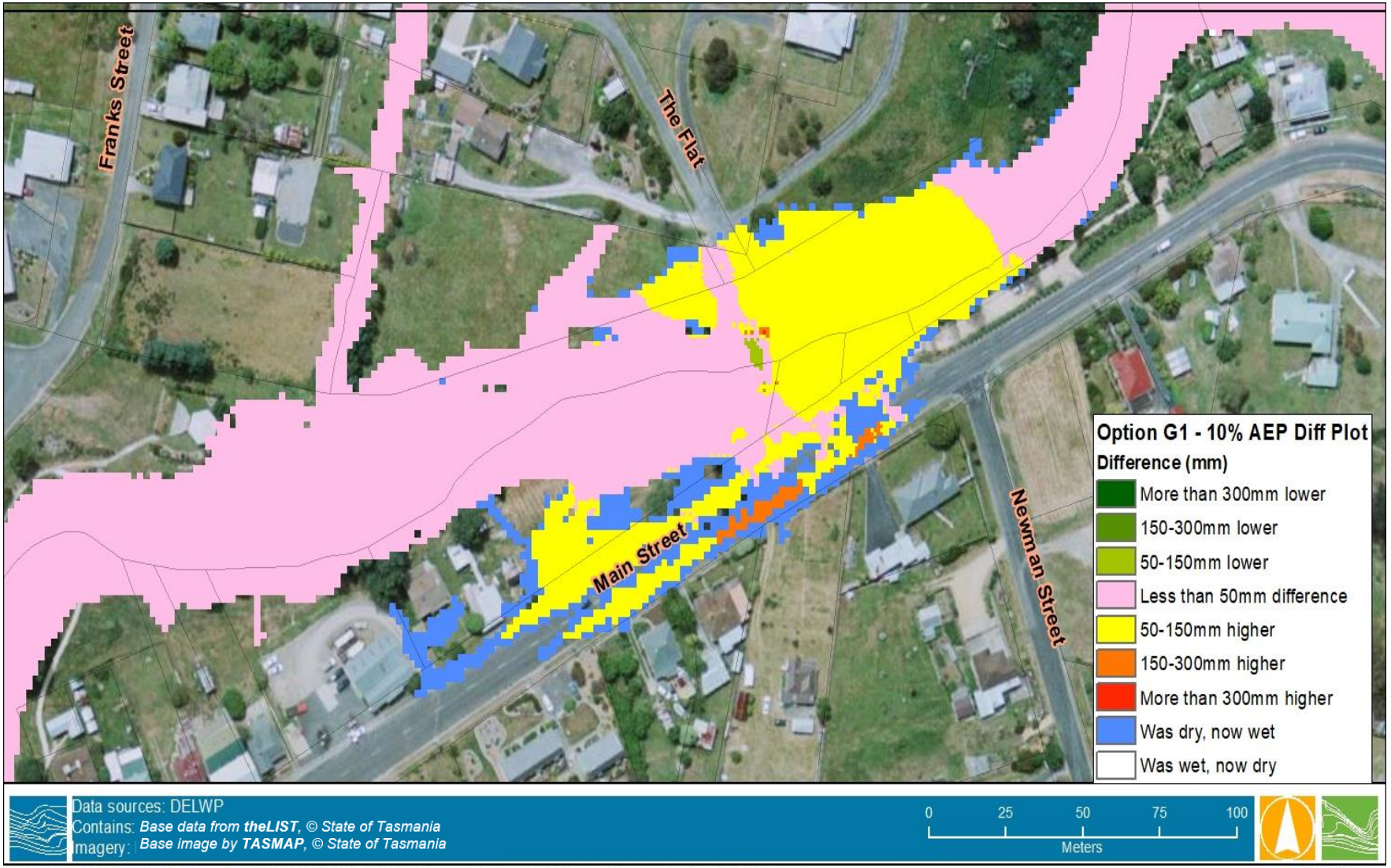

FIGURE 4-22 OPTION/SCENARIO G1 – 10% AEP DESIGN EVENT FLOOD EXTENT WITH 50% BLOCKAGE OF THE FLAT BRIDGE

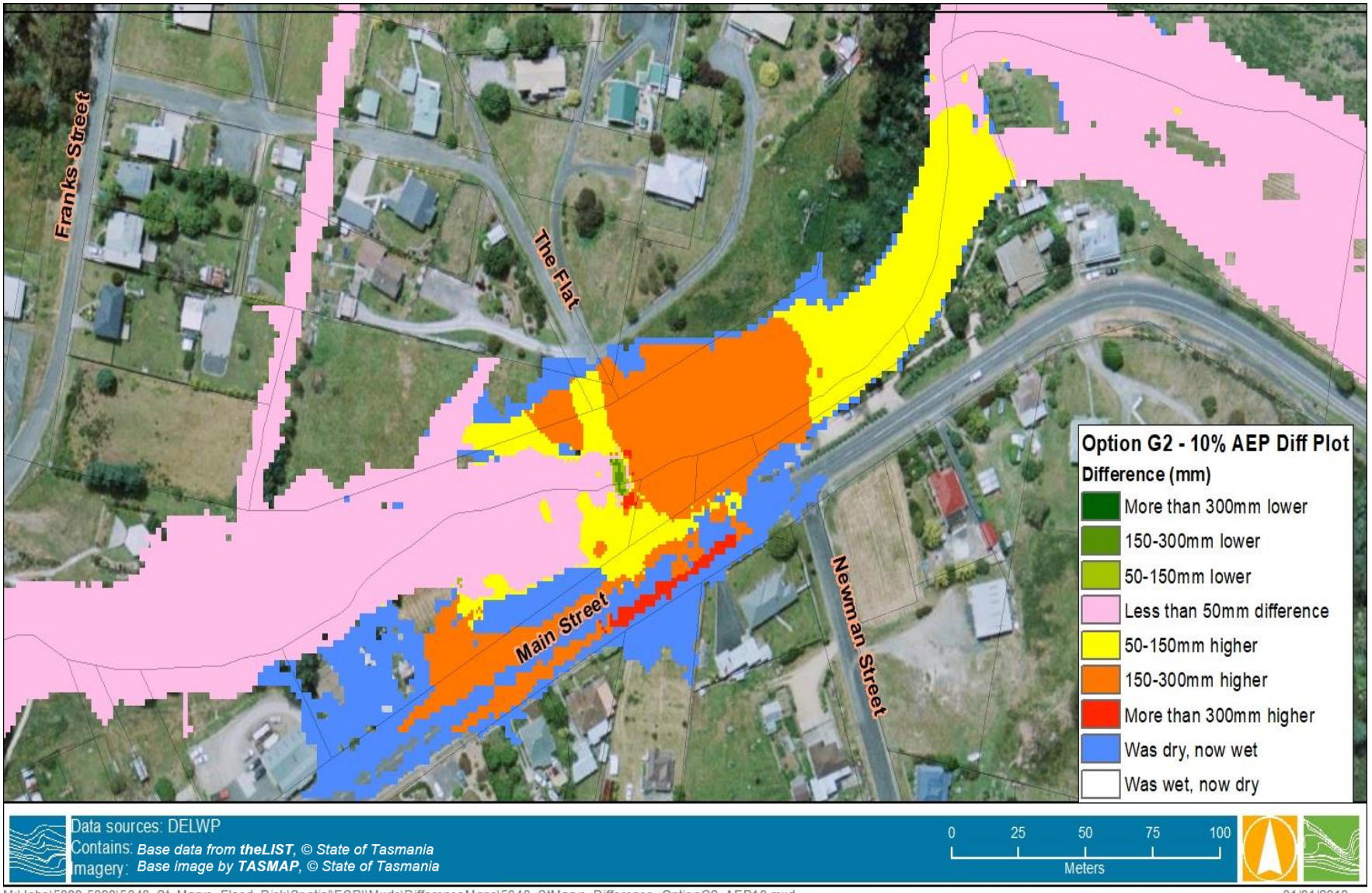

FIGURE 4-23 OPTION/SCENARIO G2 – 10% AEP DESIGN EVENT FLOOD EXTENT WITH 50% BLOCKAGE OF THE FLAT BRIDGE

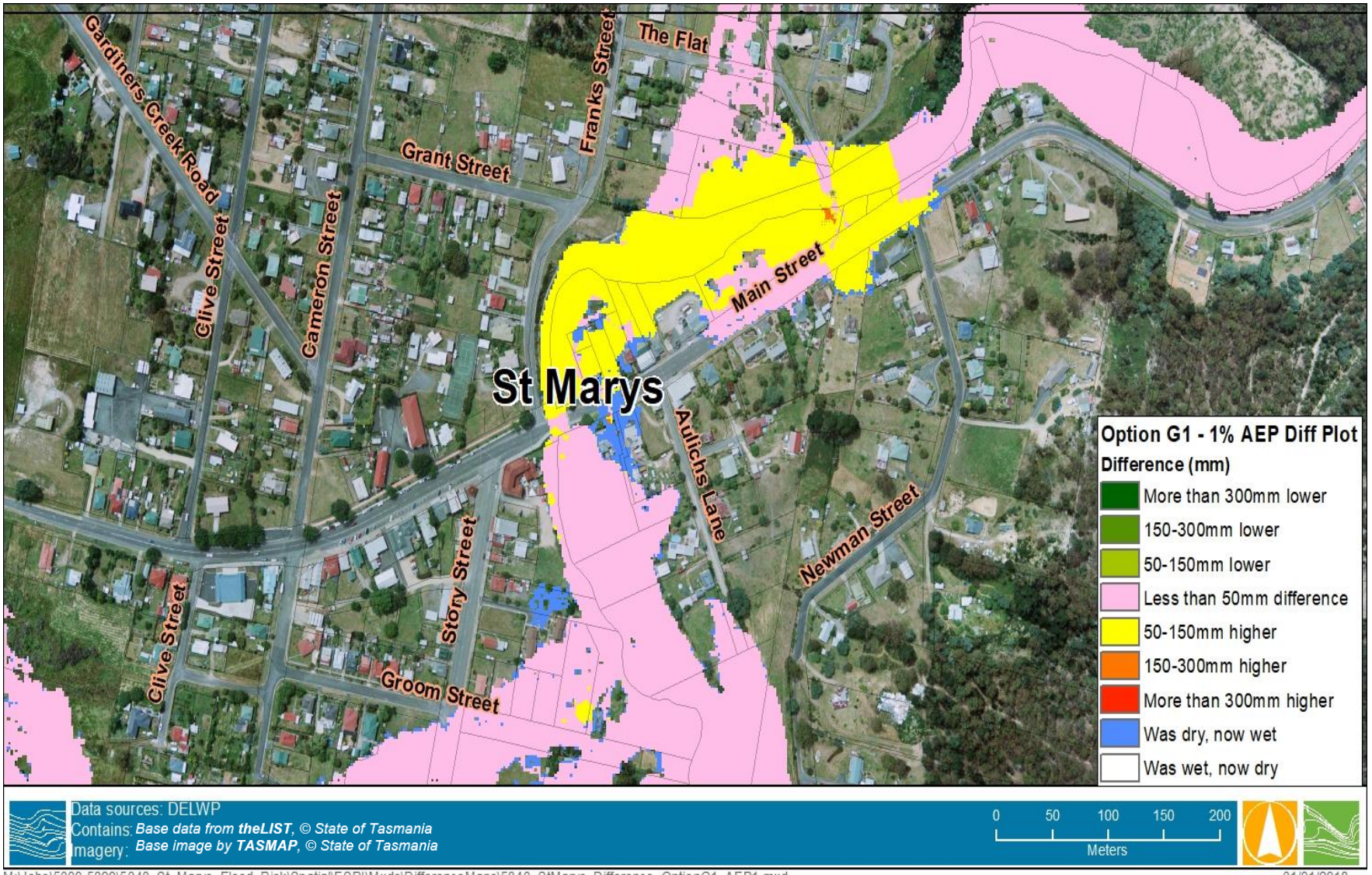

FIGURE 4-24 OPTION/SCENARIO G1 – 1% AEP DESIGN EVENT FLOOD EXTENT WITH 25% BLOCKAGE OF THE FLAT BRIDGE

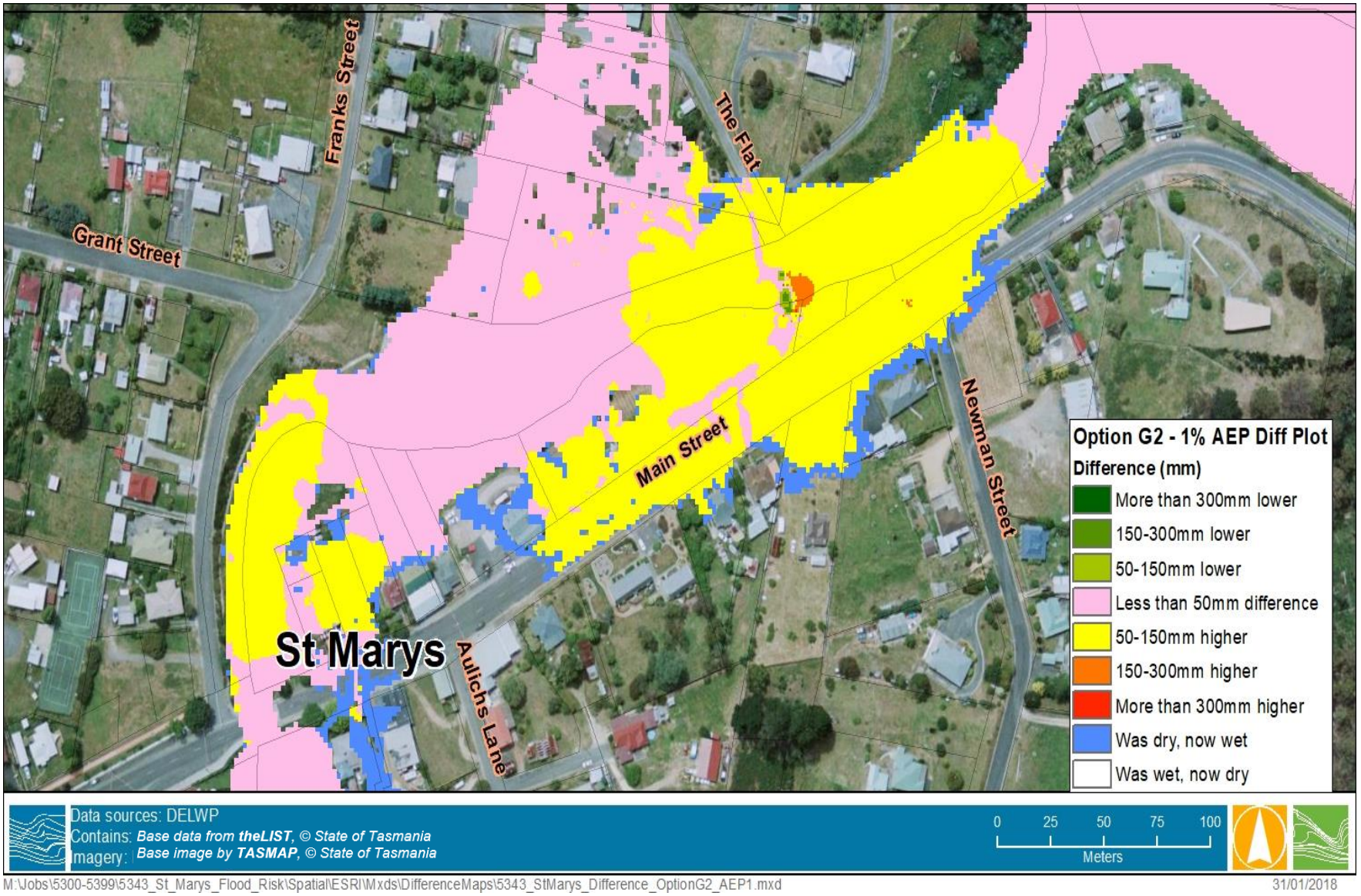

FIGURE 4-25 OPTION/SCENARIO G2 – 1% AEP DESIGN EVENT FLOOD EXTENT WITH 25% BLOCKAGE OF THE FLAT BRIDGE

5 SUMMARY AND RECOMMENDATIONS

The Flood Risk Management Study has investigated a range of measures which will improve flood risk at St Marys. The findings can now be used to develop a flood risk management plan for the township. The study considered three key flood risk management areas:

- **Flood Warning System** – whilst not within the scope of this study a number of findings have been made which will inform and should be considered for any future flood warning system for St Marys. St Marys currently does not have a flood warning system and it is likely that any future system would be rainfall-based (as opposed to being based on streamflows) given the small catchment area and fast response times.
- **Flood Response** - the flood response section provides flood intelligence impact tables that detail the potential impacts likely to occur across a range of design flood events. The tables also included suggested response actions. It is recommended that the tables be incorporated into the municipal flood emergency plan. It is recommended the tables also be used by community members and local business to better understand their own level of flood risk and help develop individual flood plans in conjunction with Council and SES.
- **Flood Mitigation Assessment** - The flood mitigation section outlines an investigation of a range of potential mitigation works for St Marys township which are designed to improve flood risk. The options included vegetation works, levees and replacement or modification of The Flat road bridge. Many of the modelled options showed significant benefit from a flood risk perspective however a number of options also showed significant adverse impacts.

In the last round of consultation that occurred in early February the feedback received was that the following options had the most support of the attendees:

- **Option A** – Vegetation reduction in focused areas and replacement with more appropriate, less dense vegetation. The dense vegetation near the confluence of St Marys Rivulet and St Patricks Creek is seen as the highest priority area.
- **Option B** – Groom Street levee – either short or medium levee.
- **Option D** – Replacement of The Flat road bridge with a ford structure.
- An alternative for Option D could be to raise the existing The Flat road bridge slab to create more capacity under the bridge. Should Council wish to pursue this option it is recommended that thw option first be modelled in isolation to understand it's impacts.

It is recommended that once a final preferred combination of options is selected that these options be modelled together in unison to ensure the full impact of the works are understand across the full range of design events. The results of this modelling should then be presented to the community for comment prior to a flood management plan being adopted for St Marys.

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