6.12. Mororo Creek

6.12.1. Flood management objectives

Land use within the catchment is a mixture of rural, agricultural and forest. There are no houses within the of 100 year ARI flood extent within the area that would be affected by the project. The flood management objectives of relevance to this catchment are:

- On grazing, forested and other rural areas, generally less than 250 millimetres increase with localised increases of up to 400 millimetres for short duration/ local catchment flooding acceptable over small areas (nominally less than five hectares) up to the 100 year ARI event
- No more than ten per cent increase in the flood duration in recognition on grazing, forested and other rural lands
- Velocities to remain below one metre per second on grazing, forested and other rural lands where currently below these figures. An increase of not more than 20 per cent where existing velocity is above these figures
- No change to the direction of watercourses or the direction of flood flows except for constriction into and expansion out of discrete openings (culverts and bridges) and constructed diversions.

These objectives are detailed in Section 2.1.

6.12.2. Design

Section 6 of the project passes along the eastern side of the Mororo Creek floodplain and does not cross Mororo Creek itself. The project would cross several tributary flow paths on the eastern side of the creek.

The project would use the existing highway as the south-bound carriageway with a new north-bound carriageway to be constructed to the west of the existing highway. The flows from four individual local sub-catchment flow paths crossing the project are currently conveyed via four existing sets of box culverts. As part of the project, these culverts would be extended and augmented with additional culverts, as summarised in Table 6-20, to provide the flow capacity required to meet the flood objectives.

Table 6-20 Extended and additional culverts at Mororo Creek

Station (km)	Proposed structures[1]
95.97	2 x 1.5 m x 0.6 m box culverts (extension of existing culverts)
96.21	6 x 1.5 m x 0.6 m box culverts (4 new culverts and extension of 2 existing culverts)

Station (km)	Proposed structures[1]
96.68	2 x 1.8m x 0.9m (extension of existing culvert)
96.99	2 x 2.1m x 1.5 m (1 new culvert and extension of existing culvert)

1. Subject to review during the subsequent stages of the project.
2. No additional culvert cells required but existing culverts lengthened through new embankment.

6.12.3. Flood impacts

Flood level impacts

The impacts to peak flood levels in the 100 year ARI flood event are presented in Figure 6-34. Approximate flood impact levels at a number of locations are presented in Table 6-21.

Downstream of the culvert at station 96.21, impacts of up to 80 millimetres would be experienced during the 100 year ARI flood event. This area is cane land and the area with impacts more than 50mm (the flood management objective for this land use) would be about 0.6 hectares. While these impacts exceed the flood management objective for this land use, this would occur in a short duration flood event with shallow depths of flooding (less than 0.3 metres). The flood management objectives for cane lands were developed with a focus on long duration flood events on large floodplains. In these types of flood events, increased flood depths and durations of inundation can reduce cane crop health. In short duration flood events, it is highly unlikely that small increases in flood depths on shallow base depths would result in any damage to cane crop health.

No residences will be subject to flood level impacts in this area.

Table 6-21 Flood level impacts in Mororo Creek

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Upstream of culvert at stn 95.97	40 mm	190 mm	130 mm	100 mm
Upstream of culvert at stn 96.21	0 mm	40 mm	0 mm	0 mm
Upstream of culvert at stn 96.68	0 mm	0 mm	0 mm	0 mm
Upstream of culvert at stn 96.99	220 mm	220 mm	- 70 mm	-140 mm

Flood inundation duration impacts

While there would be some minor increase in the period of inundation downstream of the culvert at station 96.1 and 96.2, this would not impact on the productivity of the land at that location.

Where peak flood levels are reduced, a reduction in inundation duration would also occur.

Flood velocity and direction impacts

Velocity impacts upstream and downstream of structures are considered representative of greatest velocity impacts that would be experienced outside the property boundary. Changes in velocities upstream and downstream of structures through this catchment are included in Appendix F.

The overall location of culvert would not change, resulting in negligible changes in velocity and flow direction. Velocities are less than one metre per second upstream and downstream of all structures in the 100 year ARI event.

No areas that are currently flood free would be inundated as a result of the project.

Rate of flood rise and warning time impacts

Based on the plots of flood level over time upstream of the project in the Mororo Creek catchment, the project would have a similar rate of rise as the existing case for most locations. Flood level plots and locations are provided in Appendix G.

Upstream and downstream of the culverts near station 97.0 there would be a reduction in warning time of around 12 minutes and six minutes respectively. As the land use around and immediately upstream of this location is agricultural, this is not expected to have any impact on flood warning time for residents.

Flood evacuation and flood access impacts

As this section of the project would be a duplication of the existing highway, no known evacuation routes would be severed by the project. Therefore, there is not expected to be any impact to the potential for evacuation in this area. The increased immunity of the highway would in most cases provide greater ability to evacuate during large flood events.

Flood hazard impacts

In regard to a broad consideration of flood hazard parameters (depth, velocity, velocity-depth product, duration of flooding, rate of rise, warning times, evacuation and flood access), it is considered that the overall level of flood hazard would not be increased by the project.

Bed and bank stability impacts

The project does not include any bridges in this section. All watercourses are proposed to be crossed by extension or augmentation of existing culvert crossings. Appropriate scour protection would be provided upstream of, through and downstream of culvert structures.

Sensitivity to culvert and bridge blockage on floodplains

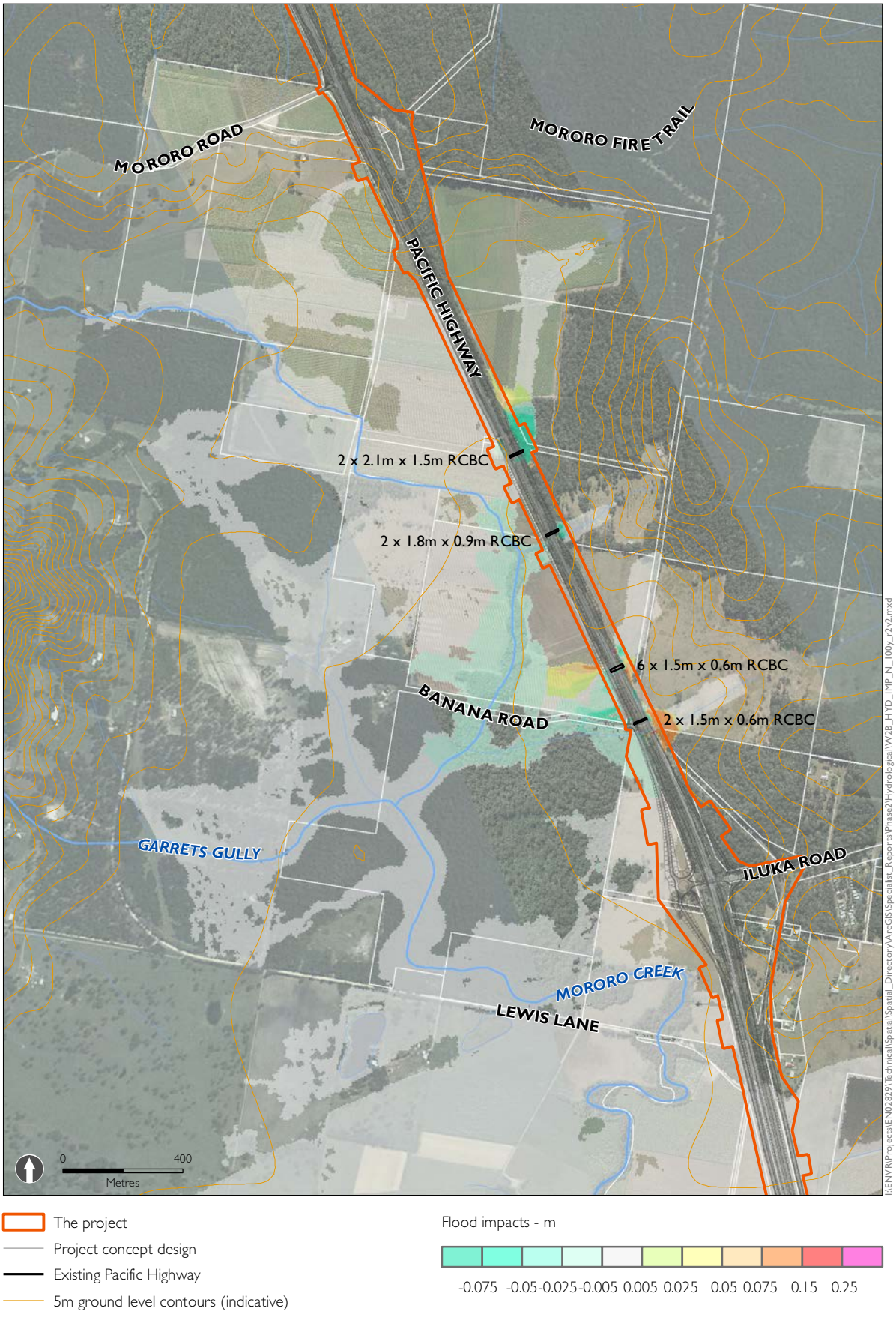
An analysis was carried out to determine the sensitivity of the flood impacts to assumptions of culvert and bridge blockage during the 100 year ARI flood event. The analysis was based on a 10 per cent blockage of culverts with diagonal span over six metres. Culverts with a diagonal span up to one metre were simulated with a 25 per cent blockage. For culverts with a diagonal span between one and six metres, linear interpolation was used to determine the fraction of blockage.

No increase in impact occurs across the floodplain, apart from the area upstream of the two 1.5 metre wide by 0.6 metre high box culverts north of Iluka Road. Here, an increase in impact of five millimetres occurs.

6.12.4. Flood impact summary

The project would meet the stated flood management objectives for this area.

Figure 6-34 Flood impacts 100 year ARI event: Clarence River North Arm and Mororo Creek



6.13. Tabbimoble Creek

6.13.1. Flood management objectives

Land use within the catchment is a mixture of rural, agricultural and forest. A few houses near the intersection of Tullymorgan-Jackybulbin Road and the Pacific Highway are within the 100 year ARI flood extent. The flood management objectives of relevance to this catchment are:

- Less than 50 millimetres increase in flood heights at houses for any assessed flood event less than and equal to 100 year ARI event
- On grazing, forested and other rural areas, generally less than 250 millimetres increase with localised increases of up to 400 millimetres for short duration/ local catchment flooding acceptable over small areas (nominally less than five hectares) up to the 100 year ARI event
- No more than five per cent increase in the flood duration where there are houses
- No more than ten per cent increase in the flood duration in recognition on grazing, forested and other rural lands
- Velocities to remain below one metre per second on grazing, forested and other rural lands where currently below these figures. An increase of not more than 20 per cent where existing velocity is above these figures
- Velocity-depth products for houses, commercial premises and urban areas remain in low hazard category (for children)
- No change to the direction of watercourses or the direction of flood flows except for constriction into and expansion out of discrete openings (culverts and bridges) and constructed diversions.

These objectives are detailed in Section 2.1.

6.13.2. Design

Section 6 of the project includes duplication of the existing Pacific Highway in the Tabbimoble Creek catchment. The road embankment would be widened to accommodate the dual carriageway.

The existing Pacific Highway includes a bridge over Tabbimoble Creek (100 metres long) and a bridge over Tabbimoble Overflow (55 metres long). These bridges would be duplicated in the project to provide twin bridges for the dual carriageways.

In addition to the bridges there are a number of existing culverts summarised in Table 6-22. These culverts would be extended under the widened road embankment. Additionally, two new sets of box culverts are proposed, as shown in Table 6-22, to provide the capacity required to achieve the flood levels that are within the flood management objectives.

Table 6-22 Extended and additional culverts at Tabbimoble Creek

Station (km)	Proposed structures[1]
99.10	2 x 2 m x1.5 m box culverts (extension of existing culverts)
101.54	100 m bridge over Tabbimoble Creek
102.85	55 m bridge over creek north of the Tullymorgan-Jackybulbin Road / Pacific Highway intersection
103.77	4 x 1.2 m concrete pipe (extension of existing culverts)
103.79	4 x 1.2 m x 1.2 m box culverts
103.93	3 x 1.2 m RCP (extension of existing culverts)
103.95	3 x 1.2 m x 1.2 m box culverts
104.49	2 x 0.75 m concrete pipe (extension of existing culverts)
104.59	3 x 1.05 m concrete pipe (extension of existing culverts)

1. Subject to review during the subsequent stages of the project.
2. No additional culvert cells required but existing culverts lengthened through new embankment.

6.13.3. Flood impacts

Flood level impacts

The impacts to peak flood levels in the 100 year ARI flood event are presented in Figure 6-35. Very similar impacts were observed during an event with an ARI of 200 years. Approximate flood impact levels are presented in Table 6-23.

The area upstream of the project boundary is expected to experience increases typically less than 50 millimetres during all modelled flood events. Some slightly larger impacts are observed downstream of the project at the northern end of this section, with up to 275 millimetres impact experienced in the 100 year event (slightly less in other modelled events). This decreases to less than 50 millimetres impact within 190 metres of the project boundary.

Upstream of the project at the southern end of this section, up to 70 millimetres impact is expected during 20 and 100 year ARI floods as a result of altered culvert arrangements. Larger impacts of up to 90 millimetres are expected during a 200 year event. Flood level impacts during a two year event are around 25 millimetres. All impacts decrease to less than 10 millimetres impact within 200 metres of the project boundary.

Impacts to the north of the Tullymorgan-Jackybulbin Road / Pacific Highway intersection result from the additional carriageway being spatially separated from the existing motorway. Water levels are increased in the 20, 100 and 200 year ARI events by up to 100 millimetres. Level increases of up to 125 millimetres are observed during a two year event. Overall, the impacts are slightly higher during the more frequent events (two year and 20 year ARI) than the rare events (100 and 200 year ARI).

One residency and one shed near the Tullymorgan-Jackybulbin Road / Pacific Highway intersection are impacted by the 100 year ARI flood event. Flood level increases would be less than 10 millimetres for both house and shed during all modelled floods.

The above impacts and those on other agricultural or rural land are within the flood management objectives.

Table 6-23 Flood level impacts in Tabbimoble Creek

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Tullymorgan-Jackybulbin Road / Pacific Highway intersection	125 mm	100 mm	100 mm	100 mm
Residency near Tullymorgan-Jackybulbin Road / Pacific Highway intersection	10 mm	10 mm	Less than 5 mm	5 mm
Shed near Tullymorgan-Jackybulbin Road / Pacific Highway intersection	10 mm	10 mm	Less than 5 mm	5 mm
Upstream of project boundary at southern tributary crossing	90 mm	70 mm	70 mm	25 mm
Downstream of project boundary at Tabimoble Creek and northern tributary crossings	210 mm	275 mm	180 mm	105 mm

Flood inundation duration impacts

While there would be some increase in the period of inundation at the houses near the Tullymorgan-Jackybulbin Road / Pacific Highway, this would be less than the five per cent objective.

Any increase in the period of inundation on grazing, forested and other rural lands resulting from the project would not affect the productivity of the land.

Flood velocity and direction impacts

Velocity impacts upstream and downstream of structures are considered representative of greatest velocity impacts that would be experienced outside the property boundary. Velocities are less than one metre per second upstream and downstream of all structures in the 100 year ARI event. Changes in velocities upstream and downstream of structures through this catchment are included in Appendix F.

A slight change to the direction of flow would occur where the second carriageway deviates from the route of the existing carriageway to the north of the Tullymorgan-Jackybulbin Road / Pacific Highway intersection. These changes are within flood management objectives and the flood behaviour would remain intuitive and easy to predict.

No areas that are currently flood free would be inundated as a result of the project.

Rate of flood rise and warning time impacts

Based on the plots of flood level over time upstream of the project in the Tabbimoble Creek catchment, the project would have a similar rate of rise as the existing case for most locations. Flood level plots and locations are provided in Appendix G.

The project in this area duplicates the existing highway and bridges over Tabbimoble Creek and adjacent tributary. As a result, there would not be any impact to the flood warning time at these locations.

Flood evacuation and flood access impacts

As this section of the project would be a duplication of the existing highway, no known evacuation routes would be severed by the project. Therefore, there is not expected to be any impact to the potential for evacuation in this area. The increased immunity of the highway would in most cases provide greater ability to evacuate during large flood events.

Flood hazard impacts

In regard to a broad consideration of flood hazard parameters (depth, velocity, velocity-depth product, duration of flooding, rate of rise, warning times, evacuation and flood access), it is considered that the overall level of flood hazard would not be increased by the project.

Bed and bank stability impacts

The peak flood velocities for a range of flood events in Tabbimoble Creek are shown in Appendix H for the existing case and that predicted with the project. These velocity profiles are taken underneath bridges where generally the greatest changes in velocity are expected as a result of constriction of flow through the structure.

These plots show that the project will increase velocities on the right bank and bed of Tabbimoble Creek by about 10 per cent for common floods (two year ARI) through to rare floods (100 year ARI). Similar increases are predicted on the left bank in common flood events. These changes are unlikely to result in changes to bed form of the channel erosion. The creek is relatively stable and likely to be stabilised by rock bars and valley margins.

It is predicted that peak velocities on the left bank of Tabbimoble Creek will increase by about 50 per cent in rarer 20 year and 100 year ARI flood events. While this is a large percentage increase, it is on a low base velocity of about 0.8 metres per second increasing to about 1.2 metres per second. It is likely that the well vegetated channel banks could accommodate these increases in peak velocity without increased risk of erosion as the resulting velocities would be well below the threshold of two metres per second for scour on well vegetated banks. Velocities would reduce to less than one metre per second at the project boundary upstream and downstream of this crossing.

For the creek crossing at station 102.85, north of Tabbimoble Creek, the project would duplicate the existing bridge and result in similar velocities to the existing case with risk of bank erosion unlikely.

The concept design includes bridge piers located on or near the bed and banks of Tabbimoble Creek. These piers would have the potential to result in localised erosion of the bed and bank without appropriate design. The final location of these piers would be determined in the detailed design phase with a more detailed consideration of the bridge spans. The design of these piers in waterways would be in accordance with the NSW Office of Water guidelines for instream works and watercourse crossings to minimise the impacts to the stability and hydrology of the watercourse.

Sensitivity to culvert and bridge blockage on floodplains

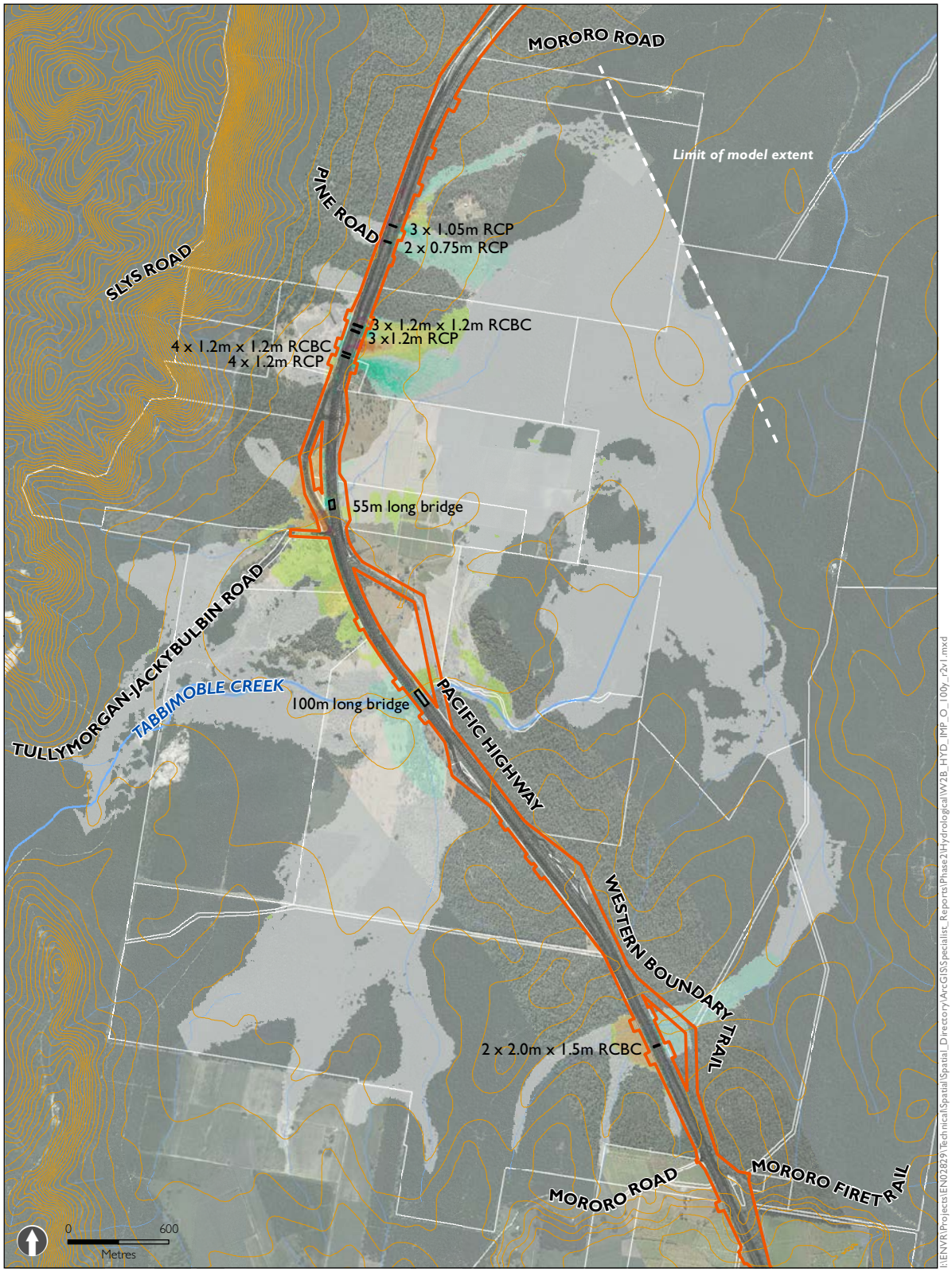
An analysis was carried out to determine the sensitivity of the flood impacts to assumptions of culvert and bridge blockage during the 100 year ARI flood event. The analysis was based on a 10 per cent blockage of culverts with diagonal span over six metres. Culverts with a diagonal span up to one metre were simulated with a 25 per cent blockage. For culverts with a diagonal span between one and six metres, linear interpolation was used to determine the fraction of blockage.

The floodplain was found to be insensitive to blockages, with increase in impact near zero millimetres.

6.13.4. Flood impact summary

The project would meet the stated flood management objectives for this area.

Figure 6-35 Flood impacts 100 year ARI event: Tabbimoble Creek



6.14. Tabbimoble Floodway No. 1

6.14.1. Flood management objectives

The entire Tabbimoble Floodway No.1 catchment is forested. As such, the flood management objectives of relevance to this catchment are:

- On grazing, forested and other rural areas, generally less than 250 millimetres increase with localised increases of up to 400 millimetres for short duration/ local catchment flooding acceptable over small areas (nominally less than five hectares) up to the 100 year ARI event
- No more than ten per cent increase in the flood duration in recognition on grazing, forested and other rural lands
- Velocities to remain below one metre per second on grazing, forested and other rural lands where currently below these figures. An increase of not more than 20 per cent where existing velocity is above these figures
- No change to the direction of watercourses or the direction of flood flows except for constriction into and expansion out of discrete openings (culverts and bridges) and constructed diversions.

These objectives are detailed in Section 2.1.

6.14.2. Design

Section 7 of the project would include duplication of the existing Pacific Highway embankment in the Tabbimoble Floodway 1 catchment.

The existing Pacific Highway includes a 65 metre length bridge over Tabbimoble Floodway 1. The project would include the construction of an additional dual carriageway upstream of the existing dual carriageway.

In addition to the bridges are two sets of existing culverts, summarised in Table 6-24. It is proposed to augment the existing three by 0.9 metre circular culverts with an additional culvert.

Table 6-24 Extended and additional culverts at Tabbimoble Floodway 1

Station (km)	Proposed structures[1]
114.81	4 x 0.9 m concrete pipe (three existing pipes and one additional culvert)
115.27	65 m bridge
115.61	1 x 0.9m RCP (existing culvert)

1. Subject to review during the subsequent stages of the project.
2. No additional culvert cells required but existing culverts lengthened through new embankment.

6.14.3. Flood impacts

Flood level impacts

The impacts to peak flood levels in the 100 year ARI flood event are presented in Figure 6-36. Approximate flood impact levels are presented in Table 6-25.

The increases in flood levels caused by the upgrade along the project boundary are less than 80 millimetres during all modelled flood events. No residences are expected to experience flood level impacts in this floodplain.

Flood levels are not increased downstream of the project boundary.

Table 6-25 Flood level impacts in Tabbimoble Floodway No. 1 catchment

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Along upstream project boundary	50 mm	15 mm	70 mm	75 mm

Flood inundation duration impacts

Any increase to inundation period as a result of the backup behind the embankment would be minor and would not adversely affect the utility of the forested area.

Flood velocity and direction impacts

Velocity impacts upstream and downstream of structures are considered representative of greatest velocity impacts that would be experienced outside the property boundary. Velocities are less than one metre per second upstream and downstream of all structures in the 100 year ARI event. Thus, flow velocity would be below one metre per second on land outside of the project boundary. Changes in velocities upstream and downstream of structures through this catchment are included in Appendix F.

There would be no changes to the direction or behaviour of flooding other than the permissible contraction and expansion adjacent to waterway structures.

Rate of flood rise and warning time impacts

Based on the plots of flood level over time upstream of the project in the Tabbimoble Floodway catchment, the project would have a similar rate of rise as the existing case. Flood level plots and locations are provided in Appendix G.

There would be a reduction of warning time of up to 12 minutes downstream of the culverts around station 115.0. There are no houses impacted by the project in this area. Hence, the flood warning time for residents would be unaffected.

Flood evacuation and flood access impacts

As this section of the project would be a duplication of the existing highway, no known evacuation routes would be severed by the project. Therefore, there is not expected to be any impact to the potential for evacuation in this area. The increased immunity of the highway would in most cases provide greater ability to evacuate during large flood events.

Flood hazard impacts

In regard to a broad consideration of flood hazard parameters (depth, velocity, velocity-depth product, duration of flooding, rate of rise, warning times, evacuation and flood access), it is considered that the overall level of flood hazard would not be increased by the project.

Bed and bank stability impacts

For the creek crossing at station 115.27 at Tabbimoble Floodway number 1, the project would duplicate the existing bridge and result in similar velocities to the existing case with risk of bank erosion unlikely.

Sensitivity to culvert and bridge blockage on floodplains

An analysis was carried out to determine the sensitivity of the flood impacts to assumptions of culvert and bridge blockage during the 100 year ARI flood event. The analysis was based on a 10 per cent blockage of culverts with diagonal span over six metres. Culverts with a diagonal span up to one metre were simulated with a 25 per cent blockage. For culverts with a diagonal span between one and six metres, linear interpolation was used to determine the fraction of blockage.

The floodplain was found to be insensitive to blockages, with increase in impact near zero millimetres.

6.14.4. Flood impact summary

The project would meet all flood management objectives for this area.

Figure 6-36 Flood impacts 100 year ARI event: Tabbimoble Floodway No. 1

6.15. Oakey Creek

6.15.1. Flood management objectives

The predominant land use in the Oakey Creek catchment is forest, with small clearings comprising rural residential areas. The flood management objectives of relevance to this catchment are:

- Less than 50 millimetres increase in flood heights at houses for any assessed flood event less than and equal to 100 year ARI event
- On grazing, forested and other rural areas, generally less than 250 millimetres increase with localised increases of up to 400 millimetres for short duration/ local catchment flooding acceptable over small areas (nominally less than five hectares) up to the 100 year ARI event
- No more than five per cent increase in the flood duration where there are houses
- No more than ten per cent increase in the flood duration in recognition on grazing, forested and other rural lands
- Velocities to remain below one metre per second on grazing, forested and other rural lands where currently below these figures. An increase of not more than 20 per cent where existing velocity is above these figures
- Velocity-depth products for houses, commercial premises and urban areas remain in low hazard category (for children)
- No change to the direction of watercourses or the direction of flood flows except for constriction into and expansion out of discrete openings (culverts and bridges) and constructed diversions.

These objectives are detailed in Section 2.1.

6.15.2. Design

Section 7 of the project would include duplication of the existing Pacific Highway in the Oakey Creek catchment. Flows are currently conveyed across the existing Pacific Highway via a number of sets of existing culverts, which are summarised in Table 6-26.

The existing Pacific Highway in the catchment is affected by flooding from local catchment events, in addition to backwater flooding from the Richmond River further downstream. The local catchment events result in relatively high velocity flows in comparison to the very slow backup floodwaters during Richmond River flood events. The waterway requirements for the project were sized to meet the flood management objectives for both events.

The project includes four additional sets of culverts under the new carriageway and the existing carriageway. These are summarised in Table 6-26.

Table 6-26 Existing and additional culverts in Oakey Creek and tributaries

Station (m)	Existing culverts	Additional culverts[1]
124.49		4 x 1.8 m concrete pipes
124.48	2 x 1.8 m x 1.2 m box culverts	2 x 1.8 m x 1.2 m box culverts (extension of existing culverts)
124.01	1 x 0.6 m	1 x 0.6 m (extension of existing culverts)
123.59	2 x 1.5 m x 0.9 m box culverts	4 x 3 m x 2.4 m box culverts (replacing existing culverts)
122.55	3 x 1.5 m x 0.9 m box culverts	3 x 3 m x 2.4 m box culverts (replacing existing culverts)
122.29		3 x 2.7 m concrete pipes
122.28	3 x 3 m x 1.8 m box culverts	2 x 3 m x 1.8 m box culverts (removal of one existing culvert)
122.14	3 x 2.1 m x 1.2 m box culverts	3 x 1.5 m x 0.9 m box culverts (replacing existing culverts)
121.78	3 x 1.5 m x 0.9 m box culverts	2 x 1.5 m x 0.9 m box culverts (replacing existing culverts)
121.59	2 x 1.5 m x 0.6 m box culverts	2 x 1.5 m x 0.9 m box culverts (replacing existing culverts)

1. Subject to review during the subsequent stages of the project.
2. No additional culvert cells required but existing culverts lengthened through new embankment.

6.15.3. Flood impacts

Flood level impacts

The impacts to peak flood levels in the 100 year ARI flood event are presented in Figure 6-37. Approximate flood impact levels are presented in Table 6-27. Peak 100 year flood levels are increased due to the project by up to 310 millimetres along the upstream boundary of the project south of the junction with Turners Road. This is below the design objective of a maximum 400 millimetres increase in flood levels in the 100 year ARI event.

The 200 year ARI results show a maximum increase of around 385 millimetres upstream of the project boundary below Turners Road. The maximum impact during a 20 year ARI event is 140 millimetres. During a two year ARI event, flood levels were shown to decrease by up to 940 millimetres.

Flood levels decrease or remain approximately the same downstream of the project boundary in all modelled events.

The only infrastructure that was shown be affected by the increase in flood levels during events of 20 to 200 year ARI is a set of stock yards upstream of the project. One shed within this area is inundated in the 20 year ARI flood. This shed is expected to experience increases of 125 millimetres in flood level during a 200 year ARI event, with smaller increases in more frequent events. No other residences would experience flood level impacts in this floodplain.

Table 6-27 Flood level impacts in Oakey Creek and tributaries

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Upstream of project south of junction with Turners Road	-940 mm	140 mm	310 mm	385 mm
Shed located 20 metres south east of project boundary	No flooding	65 mm	65 mm	125 mm

Flood inundation duration impacts

Although there is an increase in flood levels upstream of Oakey Creek, flood inundation duration is either similar to the existing case, or decreased. This is likely a result of improvement of drainage through the project in comparison to the existing highway.

However, the local creek 100 year ARI inundation period would still be much lower than the inundation duration associated with 100 year ARI Richmond River flooding.

Flood velocity and direction impacts

Velocity impacts upstream and downstream of structures are considered representative of greatest velocity impacts that would be experienced outside the property boundary. Velocities are less than one metre per second upstream and downstream of all structures in the 100 year ARI event. Thus, flow velocity would be below one metre per second on land outside of the project boundary. Changes in velocities upstream and downstream of structures through this catchment are included in Appendix F.

There would be no changes to the direction or behaviour of flooding other than the permissible contraction and expansion adjacent to waterway structures.

Rate of flood rise and warning time impacts

Based on the plots of flood level over time upstream of the project in the Oakey Creek catchment, the project would have a similar rate of rise as the existing case for most areas. An exception is Norton's Gully to the north, where the rate of rise would be decreased from the existing case (ie floods would rise slower at this location). Flood level plots and locations are provided in Appendix G.

The project would not reduce the flood warning time in any area. Around Norton's Gully the warning time would be increased slightly as a result of slower rates of flood rise.

Flood evacuation and flood access impacts

A flood refuge area exists on the western extent of a property located between Aplins Road, Red Gate Road and the existing Pacific Highway. Oakey Creek runs through this property. The refuge area itself would not be affected by increased flood levels. However, there may be a minor impact on the ability to move cattle across the property upstream of the project during peak flooding, with cattle needing to be taken a small distance upstream to cross Oakey Creek.

Further consultation with the owner of this property is required during the detailed design phase to understand the current procedures taken during large flood events and confirm whether cattle movement would be restricted as a result of the project. Measures, such as raised stock access tracks, would be identified at this stage to adequately manage any project impacts on stock movement during floods.

As this section of the project would be a duplication of the existing highway, no other known evacuation routes would be severed by the project. Therefore, there is not expected to be any impact to the potential for evacuation in this area.

The increased immunity of the highway would in most cases provide greater ability to evacuate during large flood events.

Flood hazard impacts

In regard to a broad consideration of flood hazard parameters (depth, velocity, velocity-depth product, duration of flooding, rate of rise, warning times, evacuation and flood access), it is considered that the overall level of flood hazard would not be increased by the project.

Bed and bank stability impacts

The project does not include any bridges in this section. All watercourses are proposed to be crossed by extension or augmentation of existing culvert crossings. Appropriate scour protection would be provided upstream of, through and downstream of culvert structures.

Sensitivity to culvert and bridge blockage on floodplains

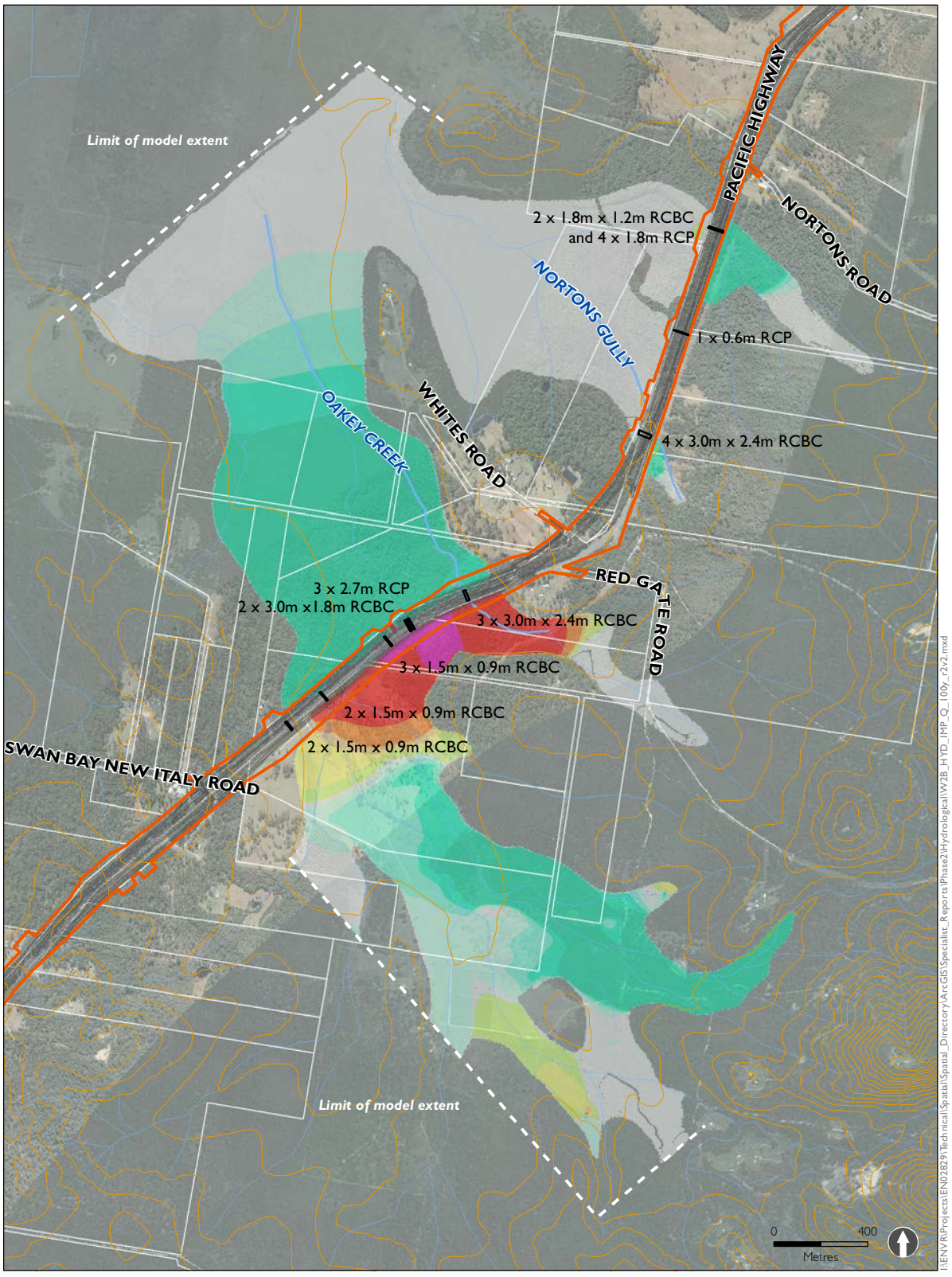
An analysis was carried out to determine the sensitivity of the flood impacts to assumptions of culvert blockage during the 100 year ARI flood event. The analysis was based on a 10 per cent blockage of culverts with diagonal span over six metres. Culverts with a diagonal span up to one metre were simulated with a 25 per cent blockage. For culverts with a diagonal span between one and six metres, linear interpolation was used to determine the fraction of blockage.

Culvert blockages cause some increase in impact for Oakey Creek upstream of the three 1.5 by 0.9 metre culverts and the three 3.0 by 2.4 metre culverts. Here, an area of 0.1 square kilometres experiences an increase in impact of around 95 millimetres. Impact experienced upstream of the project boundary would thus increase from around 300 millimetres to around 400 millimetres. The large increase in impact is due to the nature of the Oakey Creek catchment; unlike in larger floodplains, water in Oakey Creek follows one main flow path that would be affected with blockage of culverts.

6.15.4. Flood impact summary

The project would meet all flood management objectives for this area.

Figure 6-37 Flood impacts 100 year ARI event: Oakey Creek



6.16. Mid Richmond River

6.16.1. Flood management objectives

Land use within the Mid Richmond River floodplain consists of residential, cane farm land, agricultural and forested areas. The flood management objectives of relevance to this catchment are:

- Less than 50 millimetres increase in flood heights at houses for any assessed flood event less than and equal to 100 year ARI event
- Less than 50 millimetres increase in flood heights on cane farm land for any assessed flood event less than and equal to 100 year ARI event
- On grazing, forested and other rural areas, generally less than 250 millimetres increase for any assessed flood event less than and equal to 100 year ARI event
- No more than five per cent increase in the flood duration where there are houses and cane land
- No more than ten per cent increase in the flood duration in recognition on grazing, forested and other rural lands
- Velocities to remain below one metre per second on grazing, forested and other rural lands where currently below these figures. An increase of not more than 20 per cent where existing velocity is above these figures
- Velocity-depth products for houses, commercial premises and urban areas remain in low hazard category (for children)
- No change to the direction of watercourses or the direction of flood flows except for constriction into and expansion out of discrete openings (culverts and bridges) and constructed diversions.

These objectives are detailed in Section 2.1.

6.16.2. Design

The major watercourses crossed by Sections 8 and 9 of the project between Woodburn and Wardell are Tuckombil Canal and the Richmond River. There are also a number of culverts and bridges constructed between these two bridges.

The project also encroaches on a local waterway (Everson Creek) east of Broadwater. The creek runs within the project corridor for about 400 metres and would require a 150 metre diversion to avoid interception with the project embankment. The diversion would be constructed completely within the project corridor.

As the diversion would shorten the existing stream length by less than 50 metres, the potential for significant changes to the stream geomorphology is small. However, to avoid potential downstream impacts, the diversion would require a detailed geomorphologic assessment at the detailed design phase. Measures to mitigate potential downstream impacts may include lengthening the diversion to match the existing stream length or inclusion of energy dissipating structures to restrict stream velocities and/or rock armouring and revegetation to reduce the potential for scour.

The embankment has been designed to have 20 year ARI flood immunity. Along most of the length of the embankment, the 50 year ARI event and the100 year ARI event overtops the roadway. Given the similar flood regimes, the worst impact would therefore be larger the 100 year ARI event.

Details of all structures in this section of the project are detailed in Table 6-28.

Table 6-28 Proposed structures on the Mid Richmond River

Station (km)	Proposed structures[1]
Continuous except for the structures listed below	Embankment
130.02	2 x 3.0 m x 1.5 m box culvert
130.11	Additional 100 m span bridge over Tuckombil Canal
130.48	20 x 3.6 m x 1.8 m RCBC
130.74	2 x 3.6m x 1.5 m reinforced concrete box culvert
131.07	60 m span bridge over left floodplain of Tuckombil Canal / Evans River.
131.97	15 x 3.6 m x 0.9 m RCBC
132.14	1 x 0.675m
133.33	20 x 3.3 m x 1.2 m RCBC to convey floodwaters on the left floodplain of Tuckombil Canal / Evans River.
133.14	1 x 0.675 m concrete pipe
133.55	1 x 0.675 m concrete pipe
134.60	1 x 1.8 m x 1.2 m box culvert
135.17	1 x 0.75 m x 0.45 m box culvert
135.28	1 x 0.75 m x 0.45 m box culvert
135.53	1 x 2.4 m x 0.75 m box culvert
135.59	1 x 2.4 m x 0.75 m box culvert
136.54	1 x 0.9 m x 0.6 m box culvert
136.48	1 x 0.9 m x 0.6 m box culvert
136.67	10 m bridge

Station (km)	Proposed structures[1]
137.37	1 x 2.1 m x 0.45 m box culvert
140.82	1 x 2.4 m x 2.7 m box culvert
141.18	3 x 2.1 m x 1.2 m box culverts
141.89	3 x 1.5 m x 1.5 m box culverts
145.11	60 m span bridge to convey floodwaters on the right floodplain of the Richmond River
145.29	Additional 770 m span bridge over the Richmond River

1. Subject to review during future stages of the project.

These structures are different to those proposed in the previous development project due to the refined model that has been used in the project study (as described in Section 4.14.2). The terrain, calibration and representation of flow were improved for the concept design. The bridge over the Richmond River is unchanged from the concept design of the Woodburn to Ballina project. The bridge over the Tuckombil Canal has been shortened from the previous concept design. As well, the structure at station 131.07 has been reduced from the previous design of 200 metres to 60 metres. Further, the structure at station 133.33 has been reduced from the previous design of a 120 metre long bridge to 66 metres of culverts. The other structures are unchanged from the previous design.

6.16.3. Flood impacts

Flood impacts for the Richmond River that have been assessed in the following section include cumulative impacts from culverts, bridges and road embankments.

An assessment of the sensitivity of the culvert and bridges (including the effects of debris on bridge piers) to blockage is included below. Detailed assessments of flood loadings on the proposed bridges will be undertaken during the detailed design phase of this project.

Flood level impacts

The flood level impacts for the 20 year ARI flood event are presented in Figure 6-43. These impacts are less than 25 millimetres increase over the entire floodplain. The 100 year ARI peak flood level impacts are shown in Figure 6-45. Increases are less than 50 millimetres in the 100 year ARI flood event. Approximate flood impact levels are presented in Table 6-29.

Generally, the most significant changes in flood level along the project boundary are expected during a 100 year ARI flood. Houses along the bank of Richmond River near the project boundary experience increases of up to 40 millimetres, while properties east of the project experience reductions of 50 millimetres.

In the area between Woodburn and the project (north of Tuckombil Canal), flood level impacts of around 840 millimetres are expected during a five year ARI event. This impact is due to changes to local flooding within 1.2 kilometres of the project boundary. No houses are affected by these impacts, but a shed experiences an increase in flood level, as well as the backyards of two properties south of Woodburn.

There are no houses that are affected by an increase greater than 50 millimetres in peak flood levels, as required by the flood management objectives.

The utility of cane and other farming land is not expected to be affected by the increases in flood level resulting from the project.

Table 6-29 Flood level impacts in Mid Richmond River catchment

Location	5 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Woodburn	No flooding	15 mm	36 mm	28 mm

Flood impacts to property

The sum total of average annual flood damages is expected to increase around the town of Woodburn by around 0.8 per cent as a result of project flood impacts. Increase in the sum total of average annual flood damages in Broadwater is expected to be around 1.1 per cent. Other residences and commercial properties in this study area, particularly around Coraki, experience a negligible decrease in total flood damages.

The existing mean of average annual flood damages for impacted residences in this area is about $4,400 per property for Woodburn and about $3,700 per property for Broadwater.

Histograms showing the distribution of increased average annual damages and increased flood levels as a result of the project in Woodburn and Broadwater are presented in Figure 6-38 through Figure 6-41.

Although many properties experience an impact in flood levels of 20 to 50 millimetres in these areas, the increase in average annual flood damages per property is mostly below $50. This is due to the greater weighting the damages incurred by more frequent flood events have on the average annual flood damage for a property. In these areas, lower impacts (less than 20 millimetres) occur in more frequent 20 year ARI events while greater impacts (20 to 50 millimetres) occur in the less frequent events (50 and 100 year ARI floods) and are therefore less heavily weighted.

There are no properties which experience greater than 50 millimetres increase in flood levels. Increases of less than 50 millimetres would meet the flood management objectives for the area.

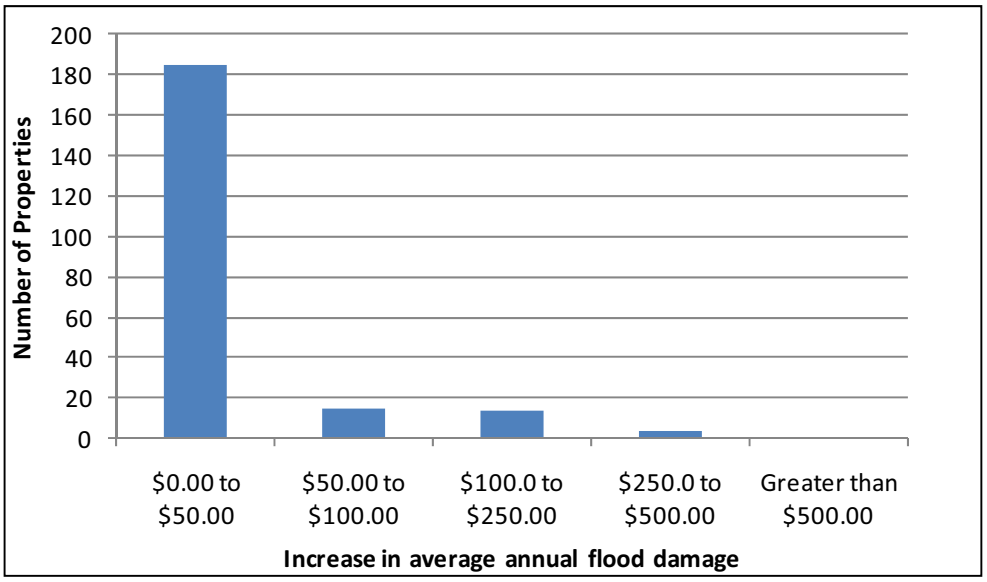


Figure 6-38 Distribution of increase in average annual flood damages in Woodburn

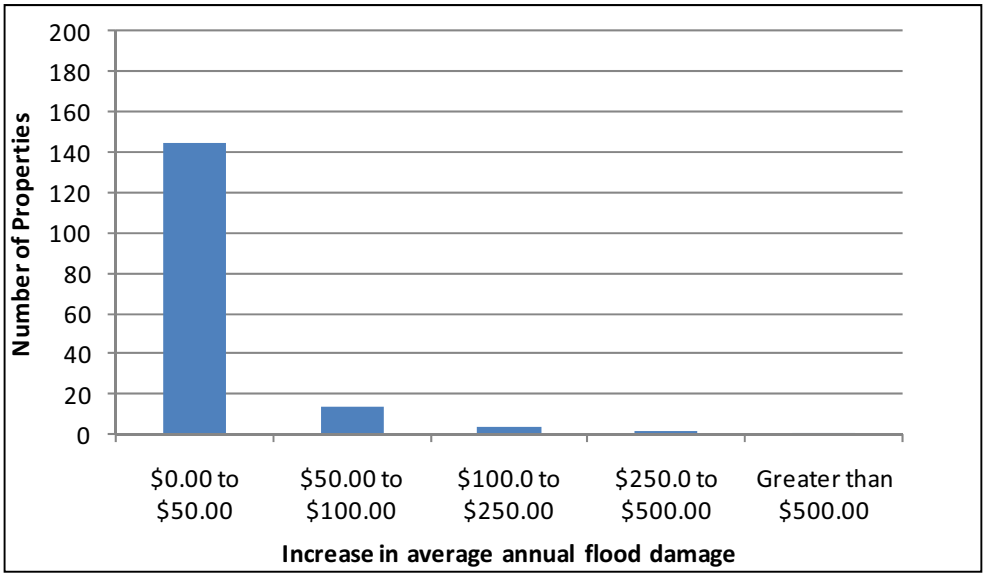


Figure 6-39 Distribution of increase in average annual flood damages in Broadwater

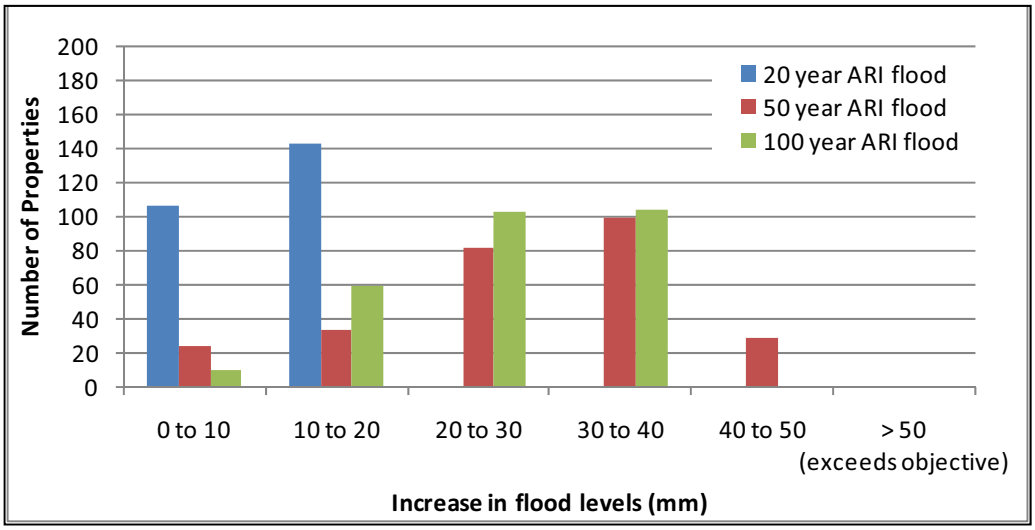


Figure 6-40 Distribution of impact to flood levels in Woodburn

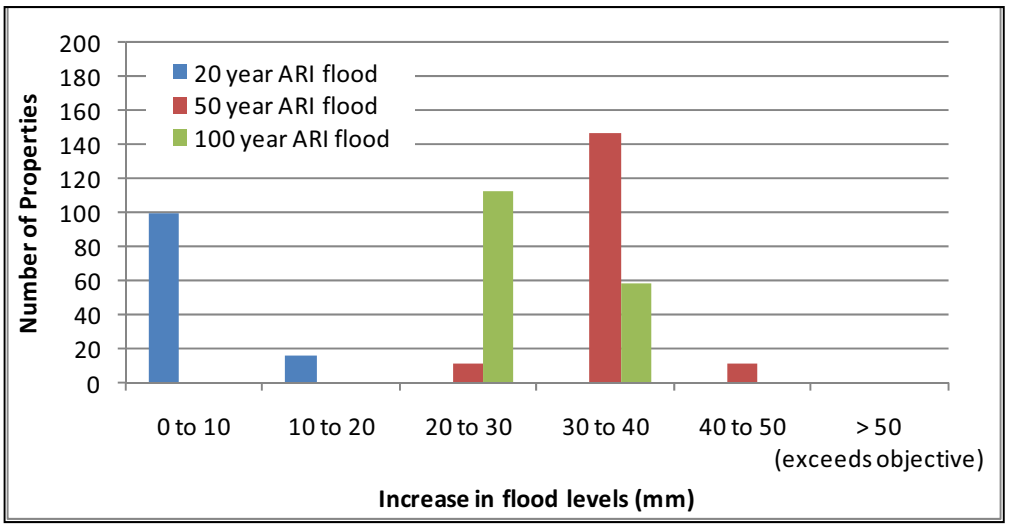


Figure 6-41 Distribution of impact to flood levels in Broadwater

Flood inundation duration impacts

Based on plots of flood level over time for the Mid Richmond River, the overall increase in time of inundation is less than five per cent throughout the floodplain. Flood level plots and locations are provided in Appendix G.

Flood velocity and direction impacts

Velocity impacts upstream and downstream of structures are considered representative of greatest velocity impacts that would be experienced outside the property boundary. Changes in velocities upstream and downstream of structures through this catchment are included in Appendix F.

Peak velocity impacts and changes in direction as a result of the project are presented in Figure 6-46 to Figure 6-48.

Velocities are less than one metre per second upstream and downstream of all structures in the 100 year ARI event, apart from the 100 metre bridge over Tuckombil Canal and the 770 metre bridge over the Richmond River. Here, the change in velocities is within the 20 per cent flood management objective.

The 10-metre bridge across McDonalds Creek was sized to limit the peak flood velocities in commonly occurring flood events to less than one metre per second, with the aim of minimising potential impacts on Oxleyan Pygmy Perch habitat (a critically endangered fish species). A five year ARI flood event was simulated in at this bridge by Hyder Consulting Pty Ltd and is detailed in the Concept Design Report (2008) for Woodburn to Ballina. No change in the concept design has occurred since this time. Based on this modelling, average velocities across the creek would be about 0.7 metres per second with the proposed bridge span of 10 metres.

Two-dimensional modelling would be undertaken at the detailed design phase to provide a better definition of velocity distribution across the channel and confirm peak velocities through the bridge at the project crossing. Modification to the current bridge design may be required to limit peak velocity impacts in consideration of Oxleyan Pygmy Perch requirements.

There would be no further changes to the direction or behaviour of flooding other than contraction and expansion adjacent to waterway structures.

Rate of flood rise and warning time impacts

Based on the plots of flood level over time over the Mid Richmond River floodplain, the project would have a similar rate of rise as the existing case for most of the floodplain. In southern Woodburn, there would be a reduction in warning time of around five hours for land between 1.1 and 1.4 metres AHD. This is not expected to have any impact on residences in Woodburn as the majority of houses are located further north, where flood level plots do not show any impact to rate of flood rise or warning time against the existing case.

Immediately north of Tuckombil Canal, the rate of rise will be temporarily faster than the existing case between around 0.5 metres AHD and 1.5 metres AHD. This would result in a small reduction in warning time of around two to five hours in areas that would usually experience a warning time of at least 20 hours. However, this area is used for agricultural purposes only and therefore would not affect flood warning time for any residents.

Flood level plots and locations are provided in Appendix G.

Flood evacuation and flood access impacts

As discussed in rate of flood rise and flood warning impacts, there would be a reduction in evacuation and access time of around five hours for land between 1.1 to 1.4 metres AHD in Woodburn during the 100 year ARI event. It is possible, but unlikely, that one residence may be affected by this due to roads around the house being cut three to four hours earlier than the existing case. However, given flood warning time in this area for the 100 year ARI flood is at least 24 hours, there would be sufficient warning of an approaching flood to ensure evacuation, and the time until inundation of the house itself would not be affected.

There is not expected to be any impact on the ability to evacuate other towns or residential areas in the Mid Richmond River as a result of the project. The increased immunity of the highway would in most cases provide greater ability to evacuate during large flood events. Meetings with the State Emergency Services in the Richmond River area indicated that there would need to be changes to the emergency plans to accommodate the changes in highway access locations and the improved flood immunity of the highway.

The clearance under the proposed two new Clarence River bridges during the peak of a flood event will be similar or higher to the clearances of the existing bridges (adjacent to the new bridges). Hence, these bridges are unlikely to cause any further impediment to boat movements during flood events associated with disaster management or evacuations.

Flood hazard impacts

There would be some increase in flood hazard in some areas of Woodburn and at other houses throughout the floodplain due to the increase in peak flood levels. However, the slow moving nature of the flooding would mean that the increased levels would pose no additional risk to people as by the time the peak of the flood reached the town, residents would either have evacuated, or be prepared to stay and not enter floodwater for the long duration of the flood.

Plots of flood level versus time in Appendix G show that flood waters in Woodburn would rise earlier as a result of the project between 1.1 and 1.4 metres AHD during the 100 year ARI flood. Within the affected area, there is one house that may have up to four hours less preparation and evacuation time due to access being cut earlier than the existing case.

The flood warning system based on catchment inflows can provide an indication of a significant flood event up to 24 hours in advance of the Richmond River rising at Woodburn. Therefore, there would still be sufficient time to prepare for flooding. In addition, access out of low lying properties would be possible once floodwater reached house floor levels.

The project would have a negligible impact on the times of flood inundation and rates of floodwater rise and recession for the Richmond River. The primary reason for this is that the project would have minimal impact on the rise and fall of the river. Furthermore, the size of the floodplain structures incorporated into the project is more than sufficient to drain the floodplain, recognising the relatively slow rates of floodwater rise and recession in this part of the floodplain.

It is concluded that, because substantial warning is available at Woodburn, any minor changes to flood hazard resulting from the project resulting from higher peak flood levels or flood levels rising earlier would not pose a risk to life, stock or property.

Bed and bank stability impacts

The peak flood velocities for a range of flood events in Tuckombil Canal and the Richmond River are shown in Appendix H for the existing case and that predicted with the project. These velocity profiles are taken underneath bridges where generally the greatest changes in velocity are expected as a result of constriction of flow through the structure.

These plots show that the project would increase velocities in Tuckombil Canal by about 10 per cent for common floods (five year ARI) through to rare floods (100 year ARI). It is likely that the well vegetated channel banks could accommodate these increases in peak velocity without increased risk of erosion as the resulting velocities would be well below the threshold of two metres per second for scour on well vegetated banks.

For the major bridge crossing of the Richmond River, the velocity plots in Appendix H show that the project will increase velocities in Tuckombil Canal by less than five per cent for common floods (two year ARI) through to rare floods (100 year ARI). It is likely that the well vegetated channel banks could accommodate these increases in peak velocity without increased risk of erosion as the resulting velocities would be well below the threshold of two metres per second for scour on well vegetated banks.

The concept design includes bridge piers located on or near the bed and banks of both Tuckombil Canal and the Richmond River. These piers would have the potential to result in localised erosion of the bed and bank without appropriate design. The final location of these piers would be determined in the detailed design phase with a more detailed consideration of the bridge spans. The design of these piers in waterways would be in accordance with the NSW Office of Water guidelines for instream works and watercourse crossings to minimise the impacts to the stability and hydrology of the watercourse.

Tuckombil Canal and Richmond River bridge pier impacts

As discussed, flood impacts for the Mid Richmond River that have been assessed in this section include cumulative impacts from bridges and bridge piers. Detailed assessments of flood loadings on the proposed bridges will be undertaken during the detailed design phase of the project.

In addition, as part of the response to the independent review of flood modelling, a check on bridge losses was undertaken using a one-dimensional hydraulic model (HEC-RAS). This assessment is detailed in Appendix B. The results of the assessment indicate that the current flood model has calculated realistic and conservative afflux from the project bridges. As such, the form losses applied in the current flood model is considered appropriate.

Sensitivity to Tuckombil Canal and Richmond River bridge blockage

An analysis was carried out to determine the sensitivity of flood impacts to assumptions regarding blockage of the proposed bridge over the Richmond River during the 100 year ARI flood event. The analysis was based on doubling the assumed bridge pier area to account for debris wrapped around piers.

With the doubled pier area, impacts upstream of the bridge increased by less than 10 millimetres. As such, the model was found to be insensitive to assumptions regarding blockage.

The existing bridge over the Tuckombil Canal has been identified as particularly susceptible to debris blockage. Plate 6-1 provides an example of debris accumulating around the existing bridge piers and weir.

The project bridge, located about 500 metres downstream, would have spans at least 15 metres longer than the existing bridge. Figure 6-42 shows the difference between bridge piers of the existing (orange) and project (black) bridges. The increase in spans at the project crossing would result in a much lower potential for debris blockage than the existing bridge.

Further, the existing bridge upstream is much more likely to capture the majority of debris, and any debris passing through the smaller (less than 10-metre) spans of the existing bridge are unlikely to be caught in the 25-metre spans of the project bridge.

An assessment to determine sensitivity of the model to floodplain (ie not main channel) bridge and culvert blockage was also undertaken and is further detailed below.

Plate 6-1 Debris blockage at the existing bridge over Tuckombil Canal

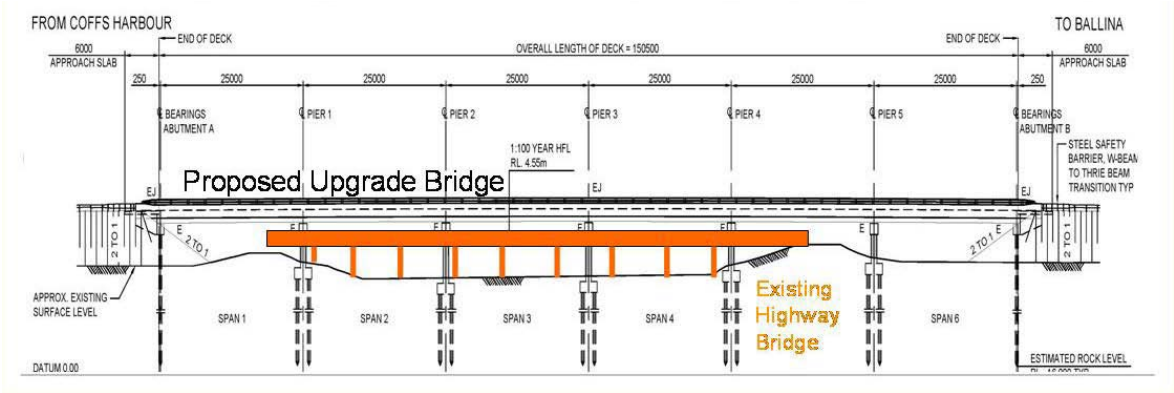


Figure 6-42 Existing versus project bridge piers at Tuckombil Canal (not at same location)

Sensitivity to culvert and bridge blockage on floodplains

An analysis was carried out to determine the sensitivity of the flood impacts to assumptions of culvert and bridge blockage during the 100 year ARI flood event. The analysis was based on a 10 per cent blockage of floodplain bridges (ie not main channel bridges) and culverts with diagonal span over six metres. Culverts with a diagonal span up to one metre were simulated with a 25 per cent blockage. For culverts with a diagonal span between one and six metres, linear interpolation was used to determine the fraction of blockage.

The floodplain was found to be insensitive to culvert blockage, with increases in impact less than five millimetres. The area south of the project near Tuckombil Canal was found to benefit from culvert blockages, with flood impacts from the 100 year ARI flood event decreasing.

6.16.4. Flood impact summary

There are some localised alterations to the timing of the rise of flood levels, mostly upstream (west) of the project around Woodburn. Peak flood levels at this location would also be up to 50 millimetres higher as a result of the project.

The project would meet all flood management objectives for this area.

Figure 6-43 Flood impacts 20 year ARI event: Mid Richmond River

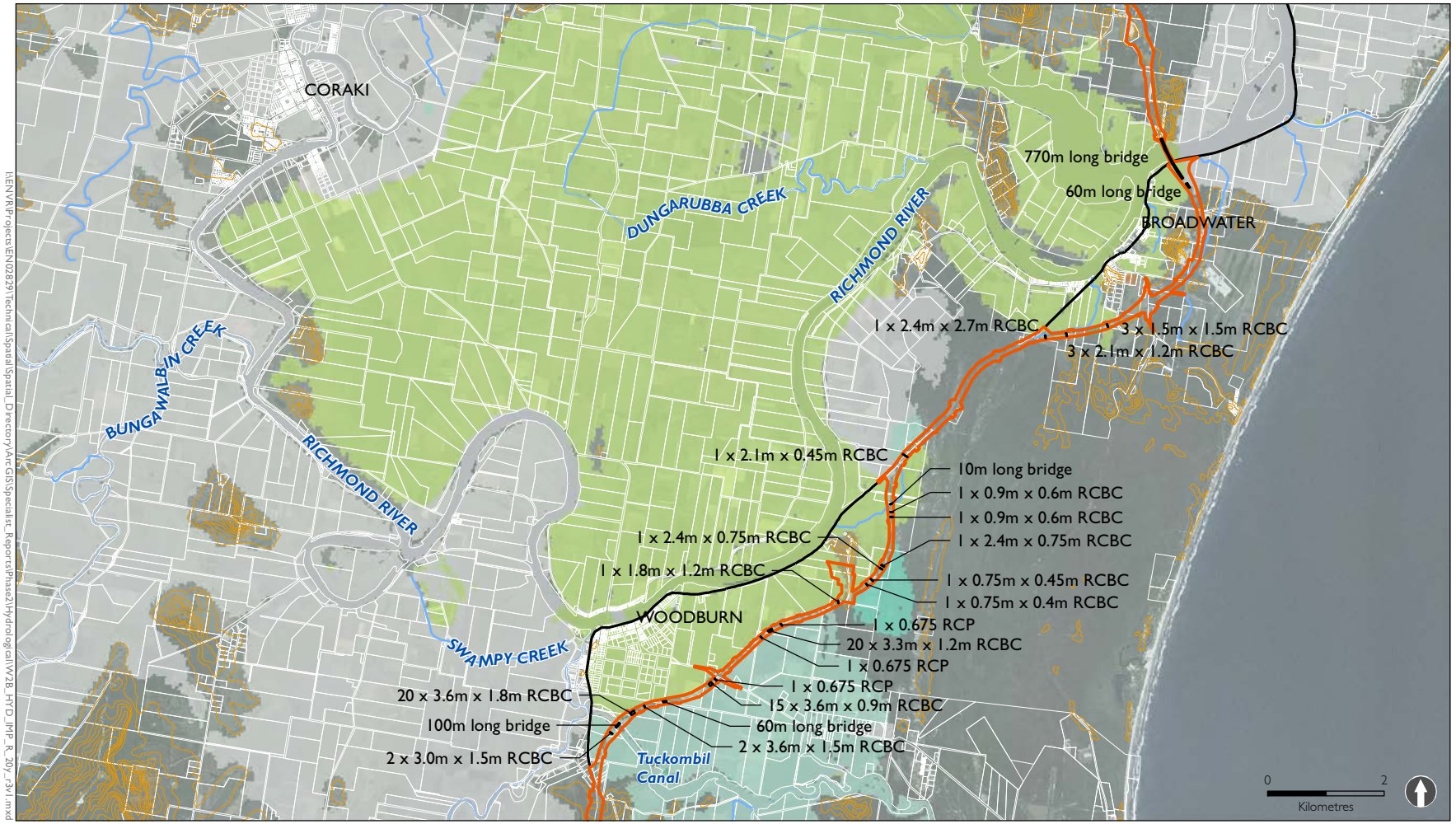


Figure 6-44 Flood impacts 50 year ARI event: Mid Richmond River

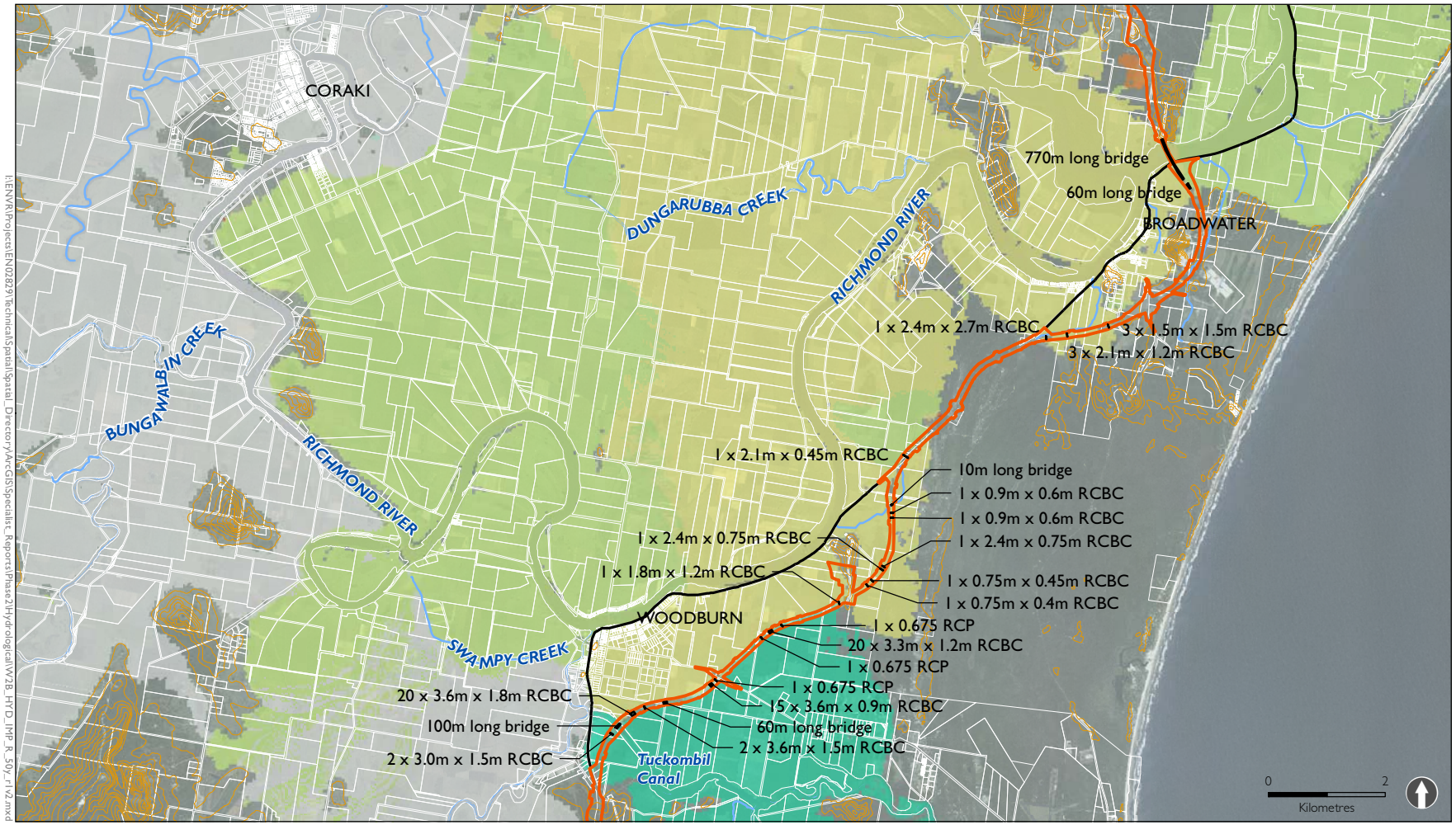
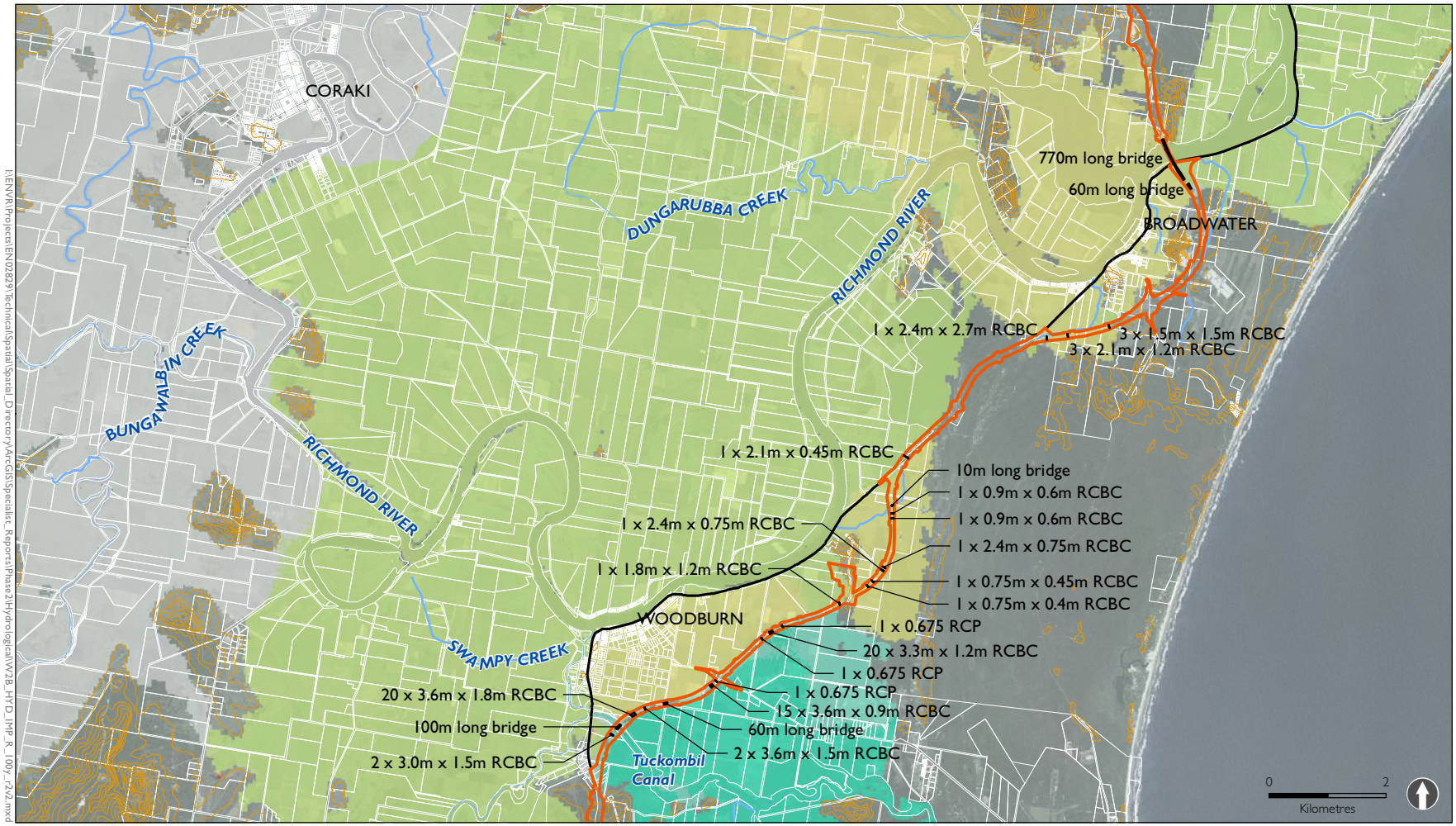


Figure 6-45 Flood impacts 100 year ARI event: Mid Richmond River



The project

Existing Pacific Highway

10m ground level contours (indicative)

Flood impacts - m

-0.075 -0.050 -0.025 -0.005 0.005 0.025 0.050 0.075 0.150

Figure 6-46 Velocity impacts 20 year ARI event: Mid Richmond River at Woodburn

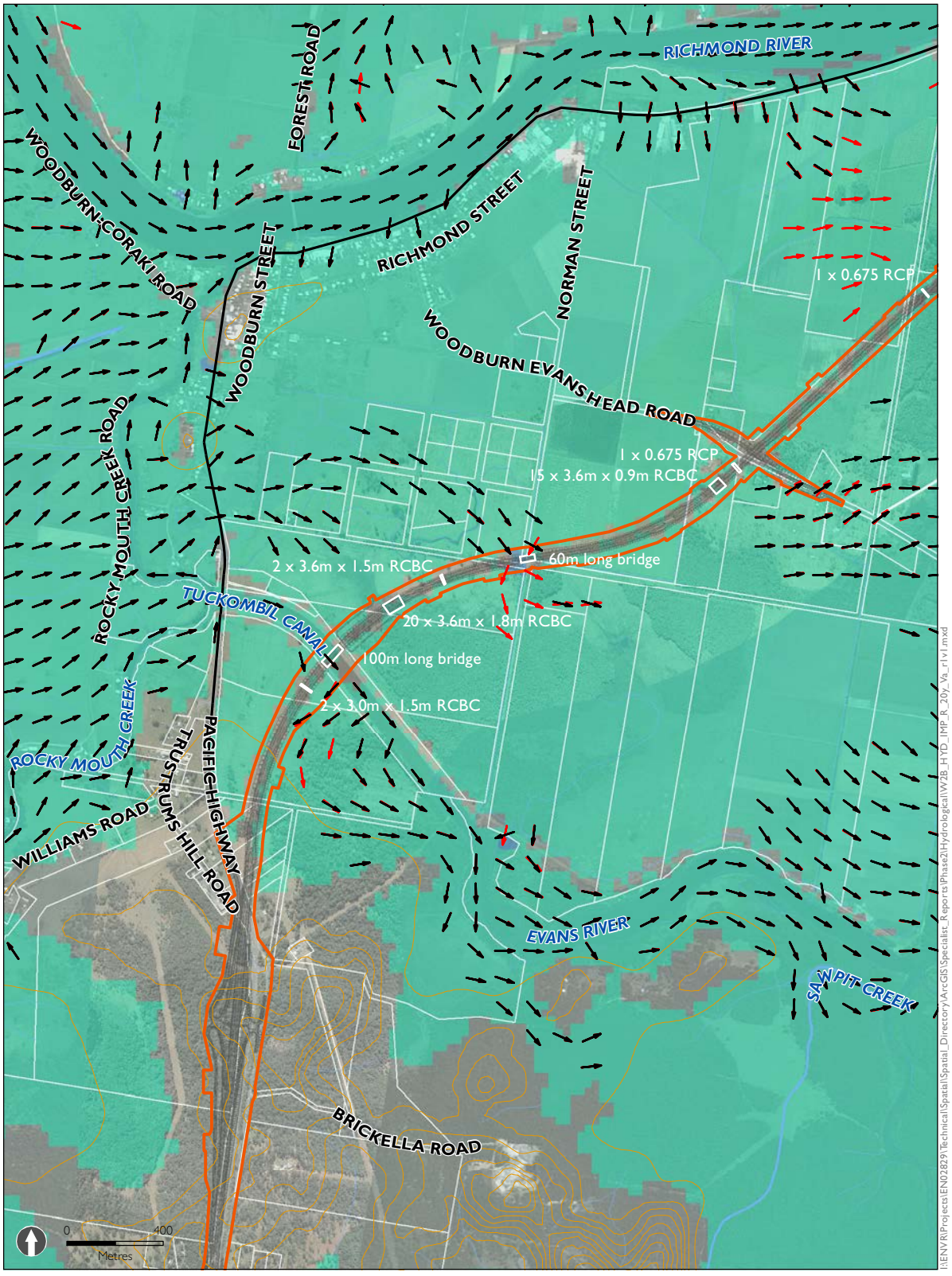


Figure 6-47 Velocity impacts 20 year ARI event: Mid Richmond River at Rileys Hill

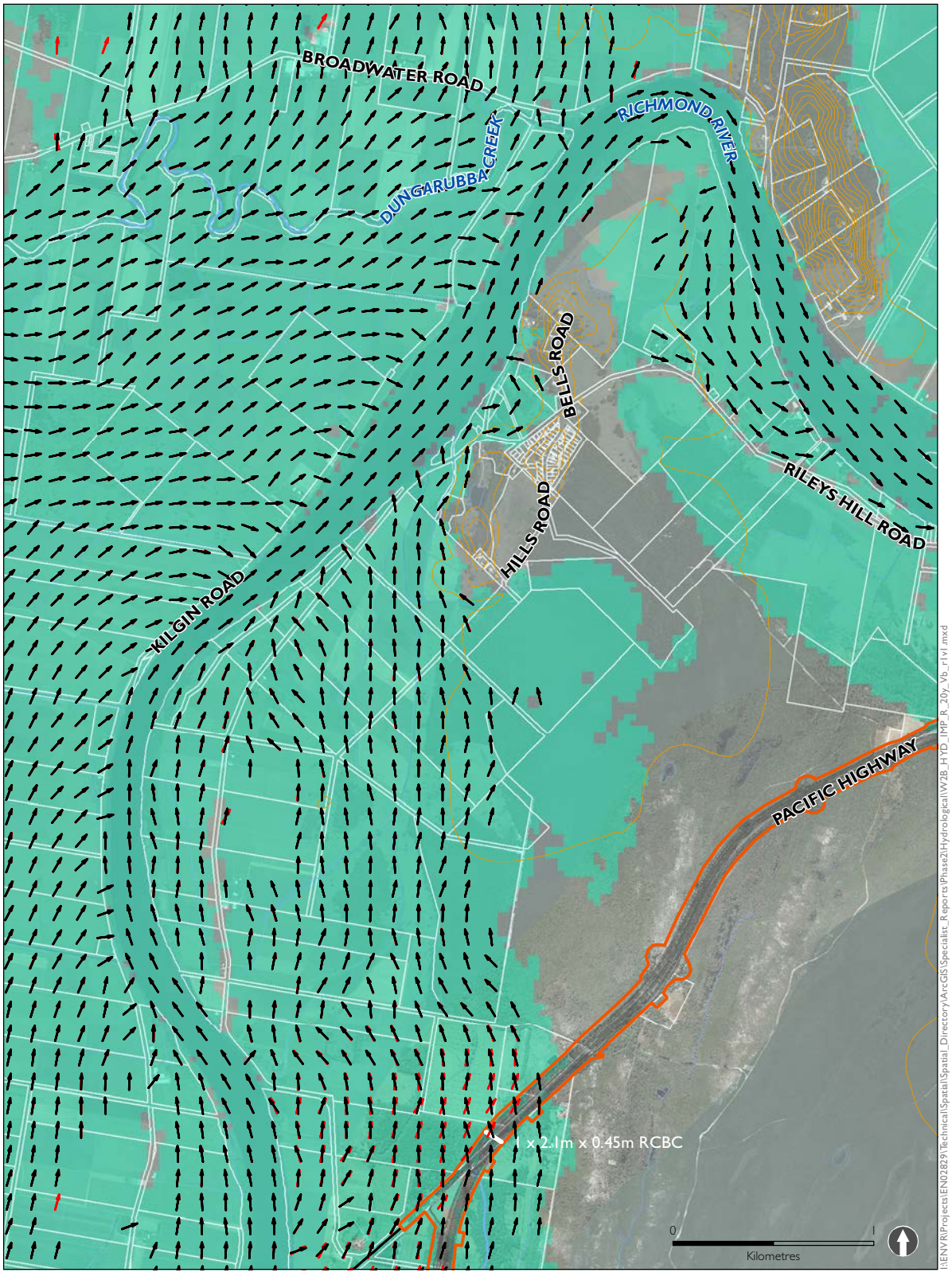


Figure 6-48 Velocity impacts 20 year ARI event: Mid Richmond River at Broadwater