6. Operational impact assessment

6.1. Overview

The following sections discuss the operational flood impacts predicted along the project. The impacts are generally assessed:

- On a catchment-specific basis, with respect to:
- Flood management objectives
- Bridge, culvert and embankment design
- Flood levels, including impacts to:
- Residences
- Farm structures
- Flood inundation duration
- Flood velocities and direction
- Flood hazard
- Culvert blockage
- Bed and bank stability
- With respect to hydrological considerations, including:
- Small, frequent events (ie hydrological regime)
- Probable Maximum Flood (PMF)
- With respect to land use and infrastructure, such as impacts to:
- Farm dams
- Cane drainage network
- Future land use potential.

References to flood impacts in millimetres in this chapter relate to the change in flood levels or flood depths as a result of the project, and not to the absolute depth of flooding. Changes to flood depths are also presented in the form of impact maps (increases or decreases to flood levels and depths).

6.2. Corindi River

6.2.1. Flood management objectives

Land use within the flatter sections of the catchment consists predominantly of agricultural and rural residential use. There are some forested areas on the higher ground and vegetation along the Corindi River. There is no cane farm land within the flood extent that would be impacted by the project. There are no residences but a shed exists in about 100 metres from the Corindi River upstream of the project. The flood management objectives for 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 10 per cent increase in the flood duration on grazing, forested and other rural lands
- Velocities to remain below one metre per second near houses and 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.

6.2.2. Design

Section 1 of the project crosses the Corindi River floodplain about 800 metres upstream of the existing highway via a bridge. The project would also cross the upper reach of Cassons Creek. The total width of the floodplain in this location is 1.4 kilometres.

The project crosses the floodplain on an embankment that is above the 100 year ARI flood level. Bridge structures and several banks of culverts convey flood flows under the embankment, as detailed from south to north in Table 6-1.

Table 6-1 Proposed project structures across Corindi River and floodplain

Station (km)	Proposed structures[1]
Continuous except for the structures listed below	Embankment
3.55	85 m bridge over Corindi River main channel
3.89	6 x 2.7 m x 1.2 m box culverts
4.01	280m bridge over Corindi floodway
4.37	3 x 2.7 m x 1.2 m box culverts
4.69	56 m bridge over Cassons Creek floodway
4.89	2 x 3.0 m x 0.9 m box culverts
4.95	10 x 3.0 m x 0.9 m box culverts

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

6.2.3. Flood impacts

The reduction in flow area associated with embankment construction across much of the floodplain would cause water to back up behind the embankment. Downstream of the embankment, flow would be concentrated at culvert and bridge outlets, causing increased velocities and peak levels at these locations.

Flood level impacts

Changes to peak flood levels in the 100 year ARI event are presented in Figure 6-1. Approximate flood impact levels event are presented in Table 6-2. Upstream of the Corindi River crossing, the project would cause peak 100 year ARI levels within the creek to increase by up to 150 millimetres (and 125 millimetres in the 20 year ARI flood event).

In a small area less than 15 metres upstream of the project along the floodplain between the Corindi River and Cassons Creek, flood levels increase by more than 400 millimetres. Impacts are up to 430 millimetres in the 100 year ARI event (and 350 millimetres in the 20 year ARI flood event) and reduce to less than 250 millimetres within 150 metres upstream of the project. The area of land outside the project with impacts exceeding 250 millimetres is 2.3 hectares. These impacts do not meet the flood management objectives for this catchment as impacts exceed 400 millimetres. The waterway crossings at this location would be revised as part of the detailed design phase to meet the flood management objectives. This issue has been further documented in Section 8.1.1.

Downstream of the 300 metre bridge, peak levels are increased due to the concentration of flow through this structure through the new embankment.

The areas adversely impacted by flooding are predominantly used for grazing. Due to the relatively steep gradient of the Corindi River floodplain, areas that have flood levels increased by more than 250 millimetres are confined to within 80 metres of the project boundary in all assessed flood events.

The constriction caused by the embankment at Cassons Creek would result in a peak 100 year ARI flood level increase of up to 170 millimetres upstream of the project boundary (and 110 millimetres in the 20 year ARI flood event). This area is a mixture of wooded and cleared grazing land. About 350 metres upstream of the project on Cassons Creek, flooding impacts would be as low as 50 millimetres in the 100 year ARI flood event (and 25 millimetres in the 20 year ARI flood event).

Since the original design of the bridge over Cassons Creek, the flood model of this area has been revised and improved. Based on revised flood levels, the bridge design at this location no longer has 100 year ARI immunity. The bridge over Cassons Creek would be raised as part of the detailed design phase to maintain 100 year ARI flood immunity. This issue has been further documented in Section 8.1.1.

A shed is located on the floodplain upstream of the project and the predicted impact at this shed in about 20 millimetres in the 20 year and 100 year ARI flood event. No other buildings would be impacted by the project.

Downstream of the project, levels in the Corindi River would decrease in all assessed ARI events.

The increased levels on agricultural and forested land described above are unlikely to affect farming operations, as stock and machinery are unlikely to be within the floodway at the peak of the flood. To reduce the maximum flood impacts on agricultural land to less than 250 millimetres increase, substantially larger bridges and culverts would be required. The additional cost of these bridges is considered to outweigh the benefit of impact reduction.

The steeper gradient of the floodplain also limits the lateral width of the floodplain, so that the flood extent resulting from the project is not much larger than that under existing conditions.

Table 6-2 Flood level impacts across Corindi River and floodplain

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Upstream of the Corindi River crossing	Up to 75 mm	Up to 125 mm	Up to 150 mm	Up to 160 mm
Along the floodplain between the Corindi River and Cassons Creek	220 mm	370 mm	430 mm	445 mm
Upstream of embankment at Cassons Creek	5 mm	110 mm	170 mm	180 mm
350 metres upstream of the project on Cassons Creek	0 mm	25 mm	50 mm	55 mm
Shed located on the floodplain upstream of Corindi River	Less than 5 mm	20 mm	20 mm	Less than 25 mm

Flood inundation duration impacts

The duration of increased flood levels on agricultural land would be relatively short (in the order of a few hours) due to the relatively short duration of flood events in the Corindi River and Cassons Creek. Impacts to agricultural operations due to increased inundation periods would therefore be negligible. No residences will be affected by increased flood inundation periods.

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 6-2.

Velocities at the project boundary downstream of the 85 metre bridge over Corindi River are up to 1.6 metres per second in the 100 year ARI flood event, which is an increase of about five per cent from the existing scenario. These impacts dissipate downstream to close to zero per cent within about 100 metres of the project boundary.

Velocities downstream of the 280 metre floodplain bridge would be around 1.4 metres per second in the 100 year ARI flood event, which is an increase of 20 per cent compared to the existing scenario. The area downstream of the bridge is open grassland, and is not expected to experience increased scour as a result of the greater velocities.

Velocities downstream of the 56 metre bridge over Cassons Creek are up to 1.5 metres per second in the 100 year ARI flood event, which is an increase of 20 per cent compared to the existing scenario. These increased velocities are contained within Cassons Creek, and decrease to less than one metre per second within 125 metres of the project boundary.

The potential for scour at these locations as a result of the project would need to be confirmed at the detailed design phase through a geomorphologic assessment with suitable mitigation measures identified and incorporated into the final design (eg rock armouring or increasing the bridge span). This issue has been further discussed below with respect to bed and bank stability.

A shed is located on the floodplain upstream of the project; velocities are below one metre per second at this location.

The proposed location of culverts and bridges would minimise changes in flow direction and flood behaviour. Minimal areas that are currently flood free would be inundated as a result of the project. Some constriction and expansion of flow into and out of waterway structures would also occur.

Rate of flood rise and warning time impacts

Based on the plots of flood level over time immediately upstream of the project boundary, the project would have similar rate of floodwater rise as the existing case. North of Corindi River there is a small reduction in the warning time of around 10 minutes, which is less than the five per cent of the overall time of inundation. Flood level plots and locations are provided in Appendix G.

There are no houses or commercial premises impacted by the project in this area. Hence, the flood warning time for residents would be unaffected.

Flood evacuation and flood access impacts

There are no known evacuation routes that would be severed by the project.

Due to the similar rate of floodwater rise as the existing case, there would not be any change to the potential for evacuation in this area.

There is a potential for stock access in times of flood to be affected as the project would separate flooded land from higher ground at station 4.6. This potential would need to be confirmed with affected land owners at the detailed design phase and suitable mitigation measures identified and incorporated into the final design (eg raised stock access tracks).

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.

Agricultural land immediately upstream of the project would experience a faster rise of flood level. However, this would not increase the level of flood hazard for people, stock or property.

Therefore, 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 Corindi River and Cassons 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 Corindi River 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.

It is predicted that peak velocities on the left bank of Corindi River 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.

For Cassons Creek, the velocity plots in Appendix H indicate that the project would not result in any changes to the peak bed and bank velocities in the common flood events (two year ARI). For the rarer 20 year and 100 year ARI flood events, peak velocities on the bed and banks would increase by about 20 per cent due to the project. While this is a moderate percentage increase, it is on a low base velocity of between 0.5 metres per second to about 1.2 metres per second.

Based on the flood level plots provided in Appendix G, the rate of recession in Cassons Creek would also be increased by around 25 per cent. Increased rate of recession has the potential to increase the risk of erosion through bank slumping. It is likely that the well vegetated channel banks could accommodate both the increases in peak velocity and rate of recession without increased risk of erosion. However, this would need to be confirmed at the detailed design phase through a detailed geomorphological assessment.

The concept design includes bridge piers located on or near the bed and banks of both Corindi River and Cassons 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.

Redbank Creek is a small watercourse north of Cassons Creek. Due to its small size, detailed flood modelling was not carried out as part of this assessment. As a result, there is currently no assessment of predicted changes in velocity at this crossing. The condition of the waterway at the location of the project crossing is not known. However, due to clear evidence of bed and bank scour at the existing Pacific Highway crossing, this waterway may have increased risk of erosion as a result of the project. This waterway would require a geomorphological assessment at the detailed design phase to identify and mitigate project impacts. This is further documented in Section 8.1.3.

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 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.

Along the floodplain between the Corindi River and Cassons Creek, flood levels upstream of the project embankment would experience an increase in impact of less than 25 millimetres. This increase in impact is contained within an area of around 8.4 hectares.

Upstream of the Cassons Creek crossing, flood levels would experience an increase in impact of less than 20 millimetres. Upstream of the Corindi River crossing, increases in impact are less than 10 millimetres. This decreases to zero impact within 125 metres of the project boundary.

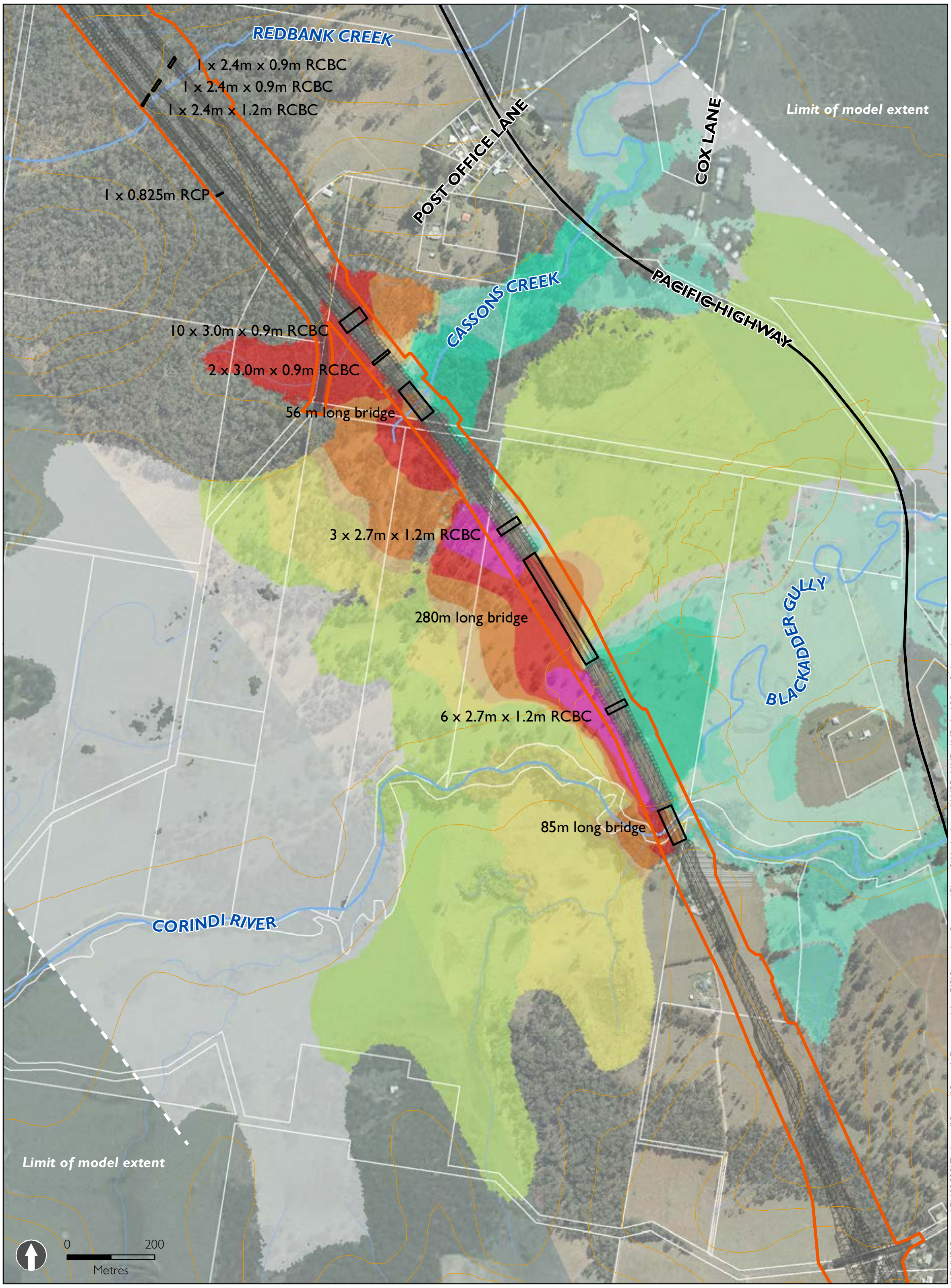
6.2.4. Flood impact summary

The project would result in some localised level increases of greater than 400 millimetres within 15 metres upstream of the project boundary, dissipating to less than 250 millimetres within 150 metres and to 50 millimetres within 250 metres upstream of the project boundary. There would also be some localised increases of up to 150 millimetres downstream of project bridges. Revision of the bridge design at this location would likely be required to achieve the flood management objectives for this catchment.

Velocities downstream of bridges would exceed an increase of 20 per cent from existing conditions in the 100 year ARI flood and would be investigated for scour potential at the detailed design phase.

The project would meet all other flood management objectives for this area. The project would not result in any increased risk to life, stock or property associated with changes to flood hazard.

Figure 6-1 Flood impacts 100 year ARI event: Corindi River

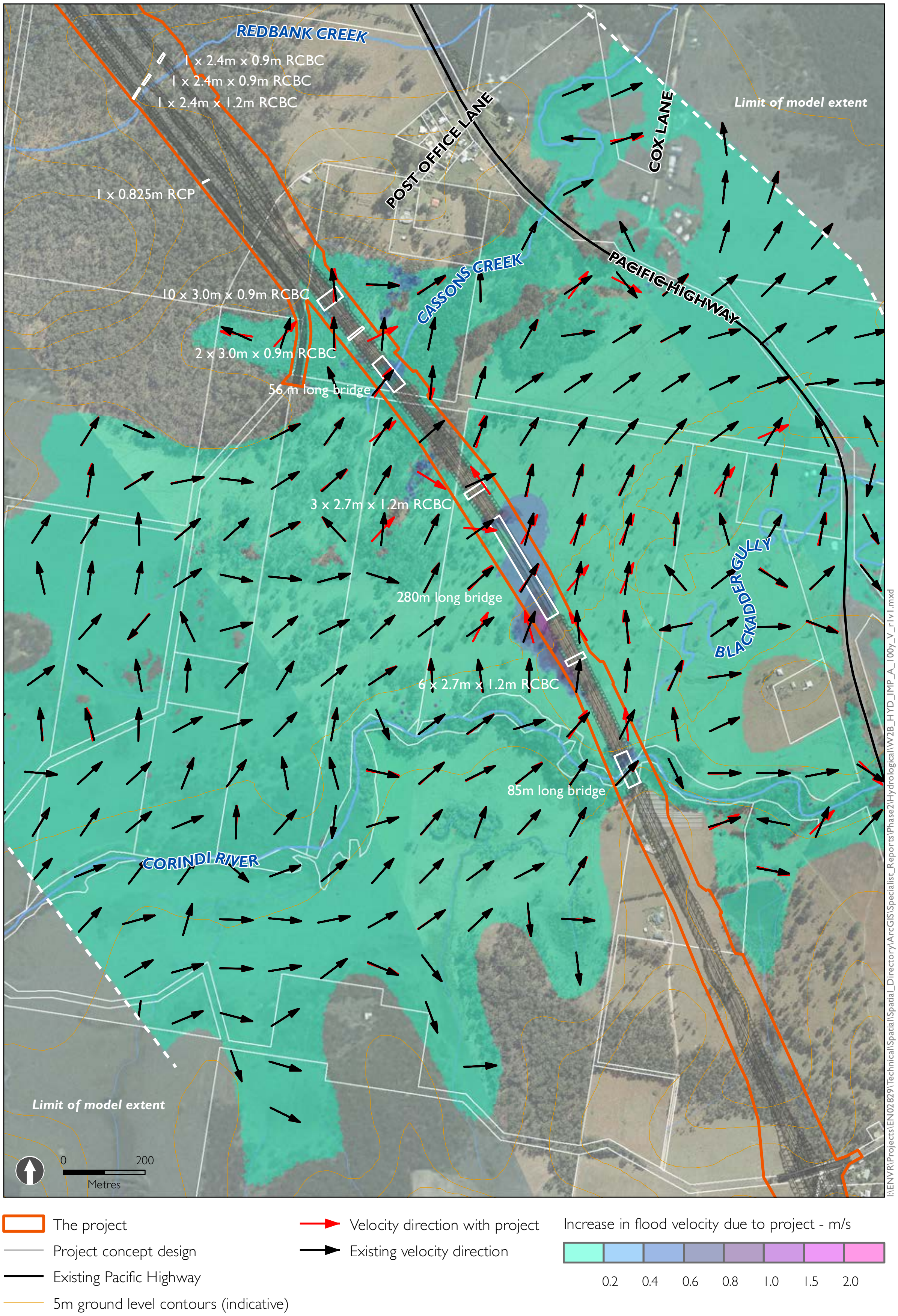


The project
Project concept design
Existing Pacific Highway
5m ground level contours (indicative)

Flood impacts - m

-0.075 -0.05 -0.025 -0.005 0.005 0.025 0.05 0.075 0.15 0.25

Figure 6-2 Velocity impacts 100 year ARI event: Corindi River



6.3. Halfway Creek

6.3.1. Flood management objectives

Land use within the catchment is predominantly forest, with some cleared agricultural areas, mostly downstream (west) of the existing highway. A residence at station 20.5 kilometres is inundated in existing 100 year ARI flood event. This residence and a shed (most likely a packing shed) on the same property are within the property boundary. Therefore, there would be no houses outside of the project boundary that would be within the flood extent for this section of the creek.

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 5 hectares) up to the 100 year ARI event
- No more than ten per cent increase in the flood duration 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.

6.3.2. Design

South of Halfway Creek crossing, Section 2 of the project deviates slightly to the west of the existing highway alignment.

The project consists of the construction of twin 50 metre span highway bridges, a 32 metre span bridge for the service road just downstream (west) of the highway as shown in Table 6-3. The existing four 3.0 metre by 2.4 metre box culverts to the south of the existing bridge will also be augmented.

Table 6-3 Proposed project structures across Halfway Creek floodplain

Station (km)	Proposed structures[1]
Continuous except for the structures listed below	Embankment
20.65	4 x 3.0 m x 2.4 m box culverts (extension of existing)

Station (km)	Proposed structures[1]
20.72	Twin 50 m length highway bridges over Halfway Creek
20.72	32 m length service road bridge over Halfway Creek

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

The proposed alignment of the twin 50 metre span bridges would be skewed by a small angle from the existing bridge due to the slight deviation in road alignment. The new bridges would be located about five metres downstream of the existing bridge (to be demolished).

The augmented box culverts would discharge into a formed channel in the corridor between the proposed highway upgrade embankment and the service road embankment, which would need to be lined with appropriate scour protection. Flows would then be discharged into the main creek channel at the bridge crossing.

This design differs to the design of the previous project development phase because of the upgraded hydraulic modelling methodology used for this study. This has allowed more accurate prediction of losses through the structures. Therefore, all bridges are 50 metres long as per the existing span, as compared to 60 metres in the previous project development phase. The proposed extension of the culvert under the local road also differs from the previous project development phase.

6.3.3. Flood impacts

Flood level impacts

Impacts on peak flood levels in the 100 year ARI event are shown in Figure 6-3. Approximate flood impact levels event are presented in Table 6-4.

The enhanced hydraulic capacity of the proposed highway bridges over Halfway Creek would reduce peak 100 year ARI levels upstream by an average of 120 millimetres (and 450 millimetres in the 20 year ARI flood event).

A small area of agricultural land to the west of the proposed bridge over Halfway Creek would experience increased peak 100 year ARI levels up to 350 millimetres (and 150 millimetres in the 20 year ARI flood event) due to the altered flow regime as a result of the project.

No residences would experience flood level impacts in this floodplain.

Increased flood levels between the highway and local access road result from the increased upstream bridge capacity and downstream bridge constriction. These are within the project boundary.

Table 6-4 Flood level impacts across Halfway Creek floodplain

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Upstream of proposed highway bridges over Halfway Creek	Up to -450 mm	Up to -450 mm	Up to -120 mm	Up to -685 mm

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Agricultural land to the west of the proposed bridges	150 mm	150 mm	350 mm	220 mm

Flood inundation duration impacts

The period of inundation would reduce across all areas outside of the project boundary where a reduction in peak flood level would occur. Again, the area of permanent planting would benefit from a shorter period of inundation.

The small area to the west of the service road bridge that would experience increased flood levels would also experience a minor increase in inundation duration. This will have negligible impact on agricultural activities at this location.

No residences would be affected by increased flood inundation periods.

Flood velocity and direction impacts

The constriction and expansion patterns for the Halfway Creek catchment would be very similar to existing due to the proposed embankment and structures being in a similar location to existing. 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.

Downstream of the culverts, velocities decrease by 44 per cent in the 100 year ARI flood event. Velocities are less than one metre per second upstream of the culverts.

Downstream of the highway bridge, velocities increase by up to 60 per cent, with velocities up to two metres per second in the 100 year ARI flood event. This is a result of the increased flow through the bridge over Halfway Creek and constriction of flow through the service road bridge. Further consideration would be required at the detailed design phase to improve the balance between the hydraulic relationship of the service road bridge and the bridge over Halfway Creek.

The land is currently forested. Velocities decreases to less than one metre per second within 100 metres of the project boundary. This change is not expected to have impact on people, stock or property.

The potential for scour at these locations as a result of the project would need to be confirmed at the detailed design phase through a geomorphologic assessment with suitable mitigation measures identified and incorporated into the final design (eg rock armouring or increasing the bridge span).

Rate of flood rise and warning time impacts

There are no houses or commercial premises 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. Ability to evacuate is likely to be enhanced by the increase in flood immunity of the road.

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.

Agricultural land immediately upstream of the project would experience a faster rise of flood level. However, this would not increase the level of flood hazard for people, stock or property.

Therefore, 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 Halfway 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 would decrease velocities on the right bank and bed of Halfway Creek for common floods (two year ARI) through to rare floods (100 year ARI) due to the removal of the existing highway bridge.

It is predicted that peak velocities on the left bank of Halfway Creek at the project crossing will increase by about 150 per cent in common two year ARI flood events and about 20 per cent in rarer 20 year and 100 year ARI flood events. While this is a large percentage increase for the two year ARI flood event, it is on a very low base velocity of between 0.3 metres per second increasing to about 0.8 metres per second.

However, as a result of the constriction of flow through the service road bridge around 30 metres downstream of the bridge over Halfway Creek, velocities increase by up to 60 per cent from around 2.0 to around 3.0 metres per second. These velocity changes are likely to change erosion potential in this channel. The hydraulic relationship between the service road bridge and the bridge over Halfway Creek would require further consideration at the detailed design phase to further minimise changes in existing stream flow and velocity.

The concept design includes bridge piers located on or near the bed and banks of Halfway 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

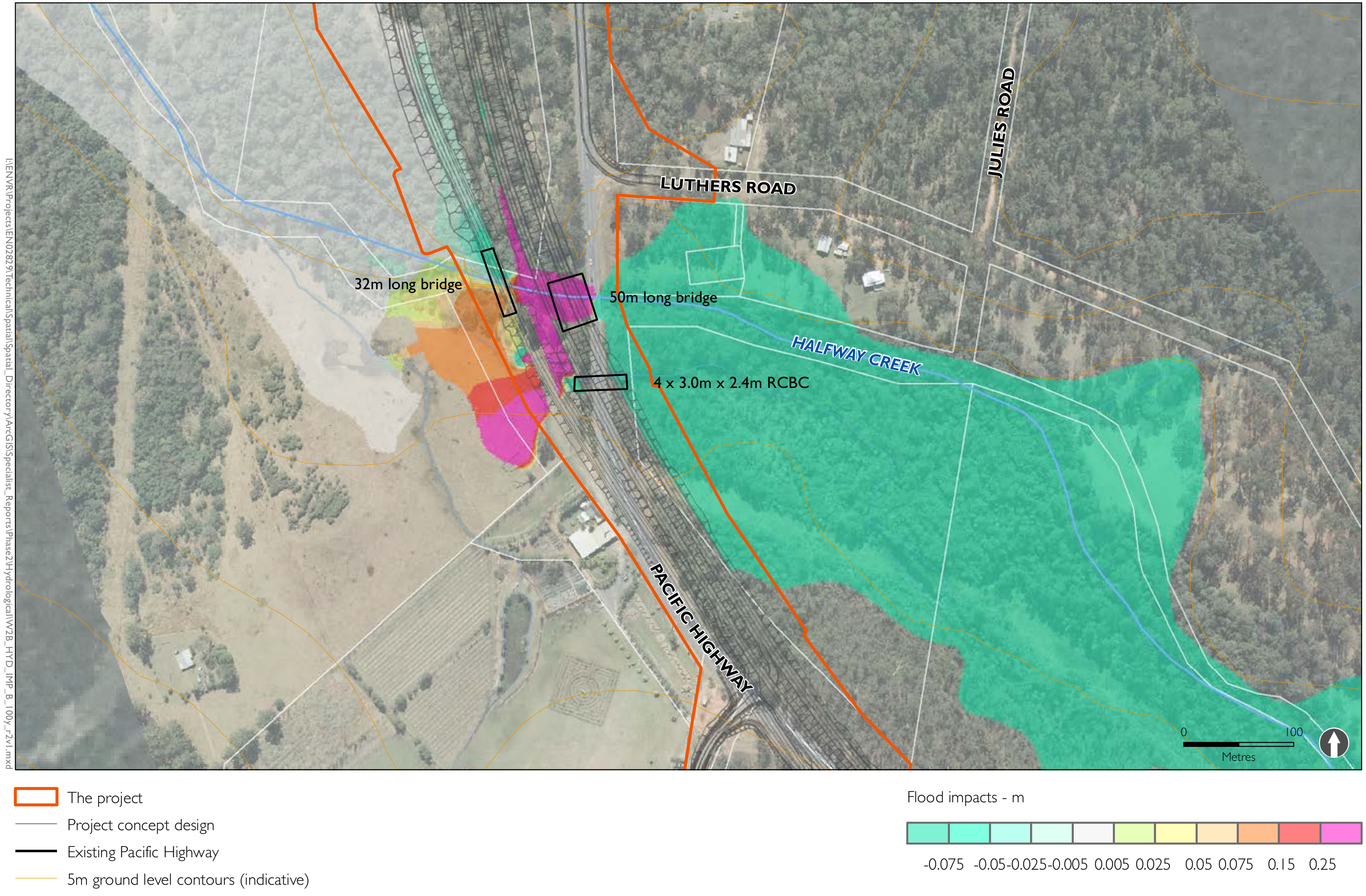
An analysis was carried out to determine the sensitivity of the flood impacts to assumptions of culvert and bridge blockage during the 100 year ARI flood event. The analysis was based on a 10 per cent blockage of bridges and culverts with diagonal span over 6 metres. Culverts with a diagonal span up to one metre were simulated with a 25 per cent blockage. For culverts with a diagonal span between one and 6 metres, linear interpolation was used to determine the fraction of blockage

Culvert blockages cause less than 10 millimetres increase in impact upstream of the Halfway Creek crossing. This decreases to less than five millimetres within 650 metres upstream of the project boundary. Small increases in impacts occur downstream of the project boundary; less than five millimetres.

6.3.4. Flood impact summary

Flood characteristics would improve at all locations except one small area to the west of the service road bridge. Velocities downstream of the highway bridge would exceed an increase of 20 per cent from existing conditions in the 100 year ARI flood and would be further investigated for scour potential at the detailed design phase. The project would meet all other flood management objectives for this area.

Figure 6-3 Flood impacts 100 year ARI event: Halfway Creek



6.4. Pheasant Creek

6.4.1. Flood management objectives

Land use within the area surrounding the project is mostly forest, with some of the downstream (northern) areas of cleared for agricultural use. There are no houses or cane farm land within the flood extent that would be influenced 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 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.

6.4.2. Design

Section 3 of the project crosses Pheasant Creek about 450 metres (stream length) downstream of the current Eight Mile Lane crossing of Pheasant Creek. An interchange at the junction of Eight Mile Lane and the upgraded Pacific Highway would sit just to the west of the confluence of Pheasant Creek and Picanniny Creek. The Eight Mile Lane embankment would cross the creeks at a perpendicular angle to the direction of flood flows, and the upgraded Pacific Highway embankment would be at an oblique angle. All embankments and the interchange would be above the 100 year ARI flood level.

As the location of the project lies over the junction of Picaninny Creek with Pheasant Creek, it is proposed to divert Picaninny Creek along the downstream (western) embankment of the project. This is preferable to flows from Picaninny Creek crossing under the project from west to east, and then joining Pheasant Creek and crossing again from east to west. This diversion substantially reduces the size and cost of the structure required on Pheasant Creek.

Picaninny Creek would discharge into Pheasant Creek immediately downstream of the project embankments and about 250 metres further downstream than the current creek confluence.

As this diversion would significantly modify the existing natural geography of the watercourse, a detailed geomorphological assessment and diversion design has been undertaken. This is discussed in detail later in this section.

Details of the size of these structures and the flood impact are presented in Table 6-5.

Table 6-5 Proposed structures on Pheasant and Picaninny creeks

Station (km)	Proposed structures[1]
Continuous except for the structures listed below	Embankment
36.00	Overpass, with creek to pass under Span 2
36.10	6 x 2.4 m x 1.8m box culvert – on ramp over Picaninny Creek
36.40	55 m length bridge over Pheasant Creek

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

These waterway openings differ from the design of the previous development project as a result of changes to the Eight Mile Lane interchange configuration and rerouting of Picanniny Creek. A backspan and a set of box culverts over Picaninny Creek are proposed in place of two bridges of 130 metres and 80 metres span. The proposed 55 metre bridge over Picanniny Creek is larger than the 36 metres presented in the design of the previous project development phase to accommodate flow that would no longer break out of the main channel and pass through the 80 metre span bridge.

Picaninny Creek diversion design

Picaninny Creek would be diverted over a length of 580 metres (existing channel length is 507 metres) and enter Pheasant Creek downstream of the interchange at Glenugie. Based on site constraints and design guidelines, the diversion design has adopted three main criteria upon which diversion features have been developed.

1) **Alignment –** has been notionally set by the conceptual locations of highway culvert and drainage design and also confined by the project boundaries. Due to these constraints, there is limited opportunity to implement the same natural meandering pattern of Picaninny Creek. The diversion alignment has identified a channelized diversion to meet the above constraints. It would reconstruct the creek to a wider, shallower stream and floodplain

2) **Bed grade –** based upon a theoretical stable bed grade taken from Figure C-1, and an estimated flow for the two year ARI event in this reach of Picaninny Creek being in the order of 10 cubic metres per second, a stable bed grade is 0.003 or 0.3 per cent

3) **Diversion profile** – has been based upon a base width of at least six metres, which is an average width of the original Picaninny Creek, and batters as flat as the footprint allows. The diversion channel footprint is restricted by the highway footprint and batters, proposed drainage assets (eg ponds) and also the construction boundaries.

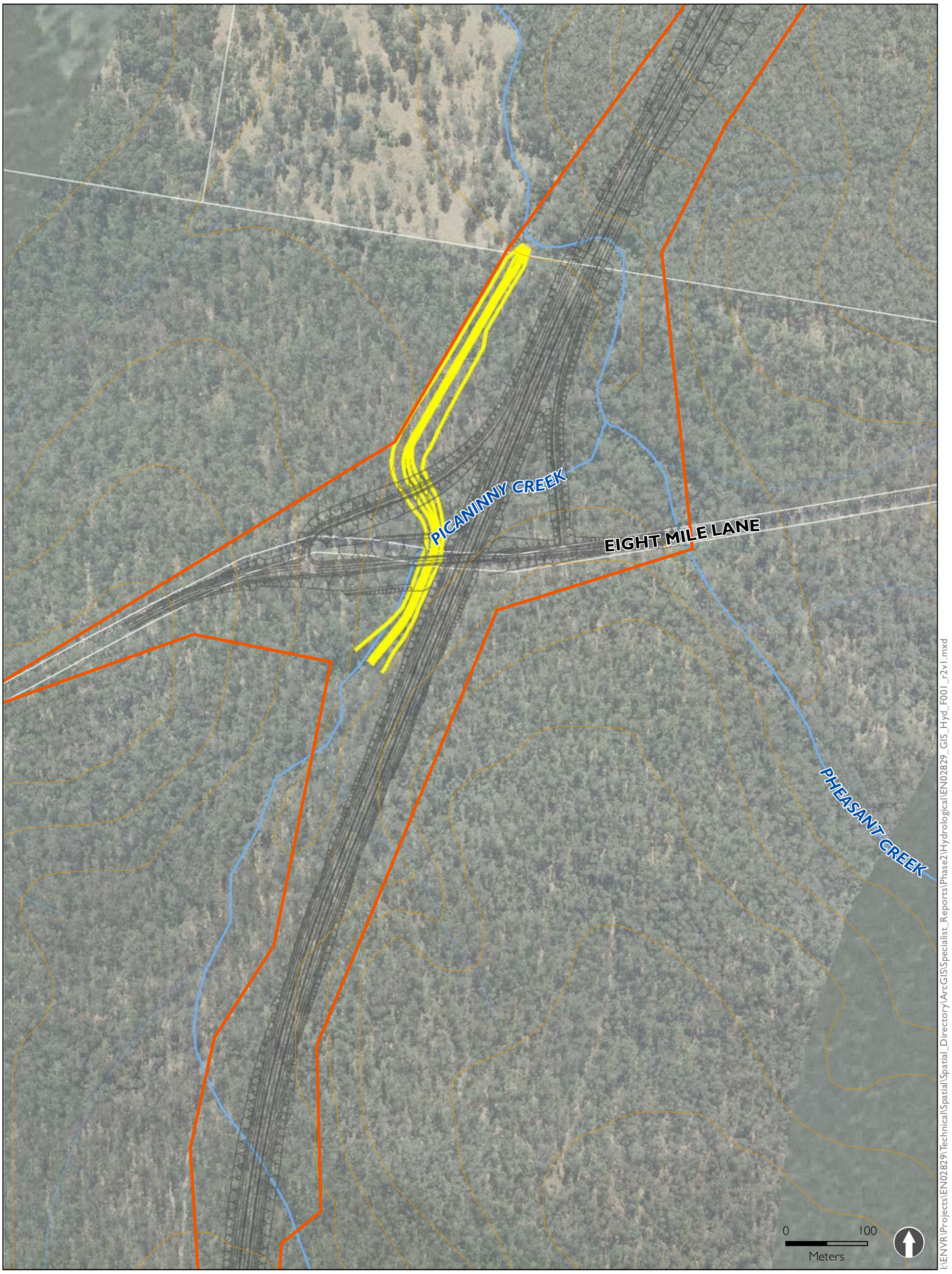
The proposed alignment of the diversion is presented in Figure 6-4. More detail on the diversion route is included in Appendix C.3.

The following features to manage potential impacts have been incorporated into the diversion design:

- In order for the required bed grade to be applied to the diversion alignment, two energy-dissipating structures to assist with grade control (ie the head and velocity in the channel to achieve a stable bed gradient) along the route
- Rock armouring at several locations to reduce susceptibility of channel to scour erosion
- Early establishment of vegetation, particularly endemic native species, using techniques such as the installation of fine jutemat.

More detail on mitigation measures implemented into the diversion design is provided in Section 8.1.5.

Figure 6-4 Picaninny Creek diversion



The project
Project concept design
Existing Pacific Highway
5m ground level contours (indicative)
Picanniny Creek diversion route

6.4.3. Flood impacts

Flood level impacts

Figure 6-5 shows the impacts on flood levels in the 100 year ARI flood event. Approximate flood impact levels event are presented in Table 6-6.

Downstream of the project, impact to peak 100 year ARI flood levels in Pheasant Creek would be 20 to 25 millimetres for a distance of approximately 250 metres (and 60 millimetres in the 20 year ARI flood event for around 300 metres). This decreases to zero millimetres in the 100 year ARI within 350 metres (and to less than five millimetres for the 20 year ARI flood). Upstream of the Eight Mile Lane crossing over Pheasant Creek, peak 100 and 20 year ARI flood levels would increase by approximately 25 millimetres due to the project.

No residences would experience flood level impacts in this floodplain.

Table 6-6 Flood level impacts in Pheasant and Picaninny creeks

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
A distance of approximately 250 metres downstream of the project	-10 to -15 mm	60 mm	20 to 25 mm	15 to 25 mm
Approximately 350 metres downstream of the project	-10 mm	5 mm	Less than 5 mm	30 mm
Upstream of the Eight Mile Lane crossing over Pheasant Creek	15 mm	25 mm	25 mm	25 mm

Flood inundation duration impacts

Increases in the period of inundation would be negligible in all areas and would not impact on land use, people or property.

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.

Velocities upstream and downstream of the 55 metre bridge over Pheasant Creek in the 100 year ARI event are greater than one metre per second, but within the 20 per cent increase flood management objective. This change is not expected to have impact on people, stock or property.

Velocity in the Picaninny Creek diversion channel would be much higher than currently exists at this location due to the altered flow path. Flow directions would also be affected. However, these changes would be contained within the project boundary, and would be clear with the constructed diversion channel signifying a defined flow path. The cost saving in constructing the diversion far outweighs the changes to flow regime considering the land use and that there are no residences or agricultural land uses in the area.

Rate of flood rise and warning time impacts

Based on the plots of flood level over time immediately upstream and downstream of the project on Pheasant Creek and upstream of the project on Picaninny Creek, the project would have similar rate of floodwater rise as the existing case. Flood level plots and locations are provided in Appendix G.

There are no houses or commercial premises impacted by the project in this area. Hence, the flood warning time for residents would be unaffected.

Flood evacuation and flood access impacts

There are no known evacuation routes that would be severed by the project.

Due to the similar rate of floodwater rise as the existing case, there would not be any change to the potential for evacuation in this area.

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.

Therefore, 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 Pheasant 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 would decrease velocities on the bed and banks of Pheasant Creek for common floods (two year ARI) through to rare floods (100 year ARI) due to the diversion of Picanniny Creek catchment to downstream of the bridge crossing. Hence, the bed and bank stability of Pheasant Creek is unlikely to be impacted by the project.

The concept design includes bridge piers located on or near the bed and banks of Halfway 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.

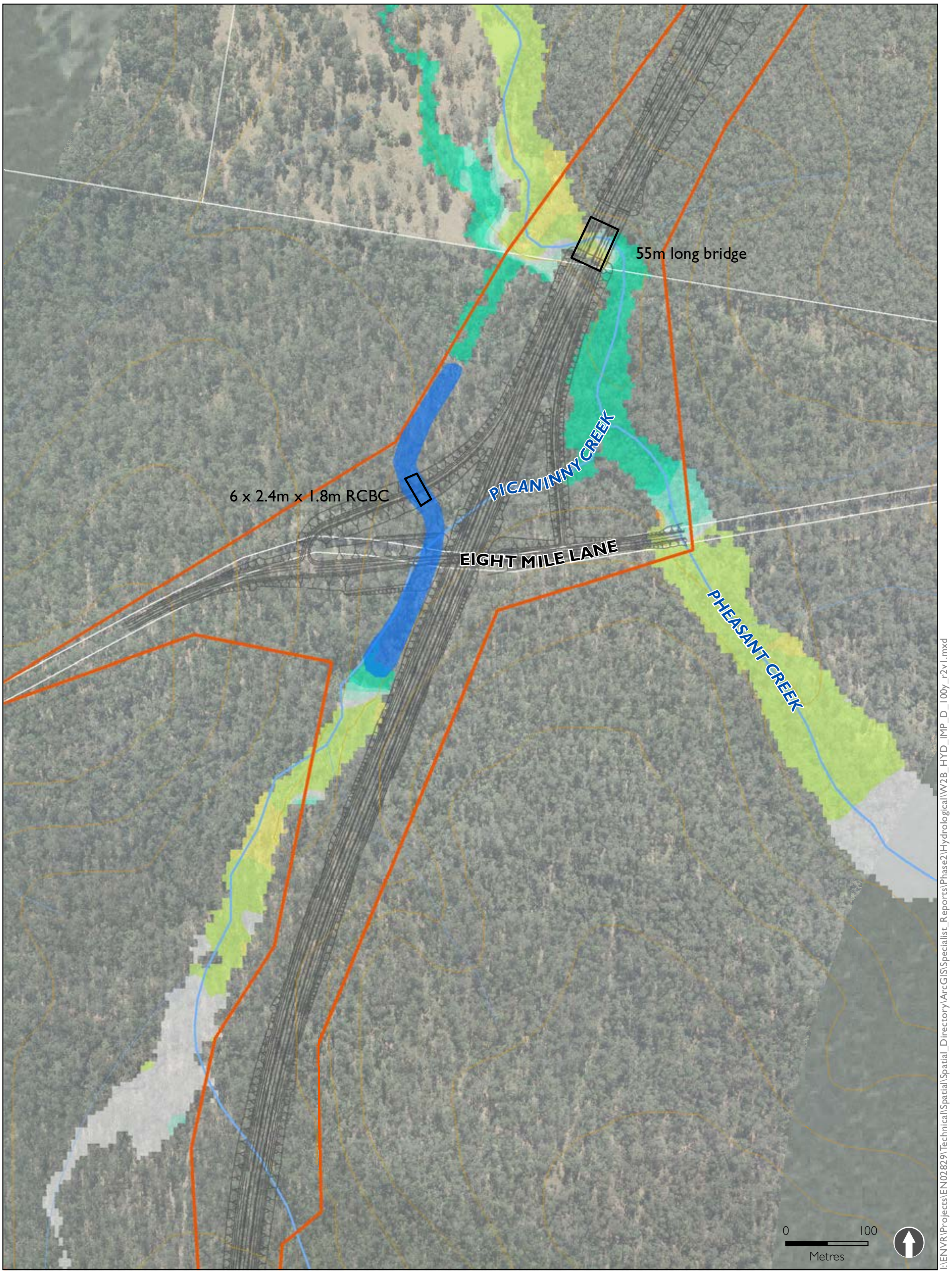
Sensitivity to culvert and bridge blockage on floodplains

An analysis was carried out to determine the sensitivity of the flood impacts to assumptions of 10 per cent culvert and bridge blockage during the 100 year ARI flood event in the Pheasant Creek catchment. Small increases in impact would occur across most of the floodplain. Effects were concentrated upstream of the Pheasant Creek crossing and are contained within the project boundary, with increases in impacts up to 35 millimetres. The remainder of the floodplain is considered insensitive to the blockage, with impacts less than five millimetres.

6.4.4. Flood impact summary

While the diversion of Picanniny Creek would change the flood behaviour of the area, there no change to the flood hazard of the area compared to the existing case (where the same amount of flow occurs just 100 metres to the east). The project would also meet all flood management objectives for this area.

Figure 6-5 Flood impacts 100 year ARI event: Pheasant Creek



The project
Project concept design
Existing Pacific Highway
5m ground level contours (indicative)
Area inundated due to diversion

Flood impacts - m

-0.075 -0.05 -0.025 -0.005 0.005 0.025 0.05 0.075 0.15 0.25

6.5. Coldstream River

6.5.1. Flood management objectives

The upper parts of the catchment are heavily forested and include Yuraygir National Park, Newfoundland State Forest and Glenugie State Forest. Within the area that would be affected by the project, land use is split relatively evenly between forest and farming (predominantly grazing). There are no houses within the 100 year ARI flood extent. However, a small cluster of houses have primary access via Wants Lane, which crosses the western tributary of the Coldstream River about 370 metres upstream of the project. Wants Lane then continues through the Coldstream River floodplain along a length of about 1500 metres until it joins Eight Mile Lane.

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.

6.5.2. Design

Runoff from the Coldstream River catchment results in a wide, relatively fast flowing shallow floodplain. Section 3 of the project crosses the Coldstream River floodplain at a location where the width of 100 year ARI flooding event is about 1800 metres under existing conditions. The main river is highly sinuous with secondary channels in the overbank area. The project also crosses a significant tributary to the west of the main Coldstream River.

The highway embankment is above the Coldstream River 100 year ARI flood level.

Three bridges are proposed across the floodplain: a 120 metre bridge on the western tributary, a 300 metre bridge over the Coldstream River, and a 160 metre bridge on the eastern floodplain. Peak flows and velocities through each of the structures are shown in Table 6-7.

Table 6-7 Proposed structures on Coldstream River and tributaries

Station (km)	Proposed structures[1]
Continuous except for the structures listed below	Embankment
42.54	120 m span bridge over western tributary
43.12	300 m span bridge over Coldstream River
43.91	160 m span bridge over unnamed creek to the east of the Coldstream River

1. Subject to review during future stages of the project.
2. Maximum impact does not occur on the tributary but between the tributary bridge and bridge over Coldstream River.
3. Maximum impact does not occur on the watercourses but between the bridge over Coldstream River and the bridge over unnamed creek to the east of the Coldstream River.

Differences in the waterway openings compared to the design of four bridges in the previous development project include:

- Enlargement of the tributary bridge from 54 metres to 120 metres
- A slight reduction of the bridge over the Coldstream River from 340 metres to 300 metres
- Removal of the easternmost 60 metre bridge.

6.5.3. Flood impacts

The reduction in flow area associated with embankment construction across much of the floodplain would cause water to back up behind the embankment. Downstream of the embankment, flow would be concentrated at culvert and bridge outlets, causing increased velocities and peak levels at these locations, and a reduction in peak levels elsewhere.

Flood level impacts

The impacts of the project on 100 year ARI peak flood levels are shown in Figure 6-6. Approximate flood impact levels event are presented in Table 6-8.

Peak 100 year ARI flood levels upstream of the project would be increased by up to 300 millimetres between the 300 metre and 160 metre bridges (and 260 millimetres in the 20 year ARI flood event). Impacts in the 100 year ARI flood upstream of the 160 metre bridge reduce to less than 250 millimetres within about 200 metres upstream of the project (and less than five millimetres in the 20 year ARI flood). An area of around 5.6 hectares would experience impacts greater than 250 millimetres but less than 400 millimetres. These impacts do not meet the flood management objectives for this catchment.

Near the Wooli Road/Lloyds Road junction, three kilometres (river length) upstream of the project, flood levels for both the 100 year and 20 year ARI reduce to 10 millimetres impact. The area of increase outside of the project boundary is forested and is unlikely to suffer a reduction in productivity as a result of increased flood levels.

Downstream of the project in between the 300 metre long bridge and the 160 metre long bridge, peak 20 and 100 year ARI flood levels would be decreased by over 300 millimetres due to the embankment impeding flow through this area (in 200, 100 and 20 year ARI events).

The floodplain of the western tributary would experience peak 100 year ARI flood level increases generally around 190 millimetres to 210 millimetres (and around 125 millimetres to 140 millimetres in the 20 year ARI flood event). Levels between the 120 metre bridge and 300 metre bridge would be up to 240 millimetres higher than the existing 100 year ARI levels (and 175 millimetres in the 20 year ARI flood event).

Of particular note, levels along Wants Lane would be increased by up to 200 millimetres during the 100 year ARI flood event as a result of the project (and 130 millimetres in the 20 year ARI flood event).

Downstream of each of the three bridges, peak flood levels would increase slightly (less than 55 millimetres at the 120 metre long and 300 metre long bridges, and up to 190 millimetres at the 160 metre long bridge in the 100 and 20yr ARI flood events) due to the concentration of flows through the bridges as a result of the project.

No residences would experience flood level impacts in this floodplain.

Table 6-8 Flood level impacts in Coldstream River and tributaries

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Upstream of the project between the 300 metre and 160 metre bridges	130 mm	260 mm	300 mm	330 mm
200m upstream of the 160 metre bridge	No flooding	5 mm	200 mm	230 mm
Near the Wooli Road/Lloyds Road junction	No flooding	10 mm	10 mm	10 mm
Between the 120 metre bridge and 300 metre bridge on the upstream project boundary	10 mm	130 mm	200 mm	220 mm
Between the 120 metre bridge and 300 metre bridge on the upstream project boundary	40 mm	175 mm	240 mm	260 mm
Along Wants Lane	Less than 5 mm	130 mm	200 mm	220 mm
Downstream 120 metre long and 300 metre long bridges on the project boundary	15 mm	55 mm	55 mm	60 mm
Downstream 160 metre long bridge on the project boundary	No flooding	190 mm	190 mm	195 mm

Flood inundation duration impacts

The period of inundation throughout the floodplain is increased slightly as a result of the constriction of the project embankment. This is unlikely to be of concern throughout the forested and agricultural areas impacted by the project.

Along Wants Lane, flood depths would reach a level that prohibits normal vehicle accessibility slightly earlier, and would stay above this level slightly longer.

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 6-7.

Downstream of the 120 metre span bridge over the western tributary of the Coldstream River, velocities would be around 1.1 metres per second in the 100 year ARI event, representing a 120 per cent increase from existing conditions. This impact is highly localised, with velocities decreasing to less than one metre per second within 50 metres of the project boundary.

Velocities upstream and downstream of the 300 metre bridge over the Coldstream River are up to 1.5 metres per second in the 100 year ARI flood event; however, the increase in velocity from existing conditions is within the 20 per cent flood management objective.

Velocities downstream of the 160 metre span floodplain bridge would be around 1.25 metres per second, about an 80 per cent increase from existing conditions. This increase reduces to the 20 percent flood management objective within 300 metres of the project boundary.

The potential for scour at these locations as a result of the project would need to be confirmed at the detailed design phase through a geomorphologic assessment with suitable mitigation measures identified and incorporated into the final design (eg rock armouring or increasing bridge span).

There would be little change to flood velocity and direction as a result of the project beyond the highlighted effects of constriction and expansion. Velocity changes are not expected to have impact on people, stock or property.

Rate of flood rise and warning time impacts

Based on plots of flood level versus time, the project would have similar rate of floodwater rise as the existing case immediately upstream of the project boundary at the Coldstream River and western tributary bridges and also along Wants Lane. There is a reduction in warning time of 15 to 20 minutes at the bridge over the unnamed creek to the east of the Coldstream River. Flood level plots and locations are provided in Appendix G.

There are some houses which have primary access via Wants Lane. As Wants Lane experiences similar rates of rise as the existing case, the flood warning time for these residents would not be affected.

The area around the bridge over the unnamed creek to the east of the Coldstream River is predominantly forested and there are no residences nearby. As a result, there would be no impact of reduced warning time on residents.

Flood evacuation and flood access impacts

Several residences have primary access via Wants Lane, which is inundated along a length of about 1500 metres in the 100 year ARI flood. Due to the similar rate of floodwater rise as the existing case along this road, there would not be any change to the potential for evacuation in this area.

The plots of flood level rise over the duration of a Coldstream River flood event are presented in Appendix G. It is assumed that the two Wants Lane bridges become non-trafficable (ie more than 0.3 metres over the bridge) when floodwaters reach 2.5 metres AHD as it is assumed the bridges are both at 2.2 metres AHD. The plots of flood levels on the two Wants Lane bridges indicate that the time at which the roads become cut by floodwaters does not change. The duration that the bridges are non-trafficable (ie flood levels above 2.5 metres AHD) does not increase.

There is a reduction in warning time at the main bridge over Coldstream River. There is potential for nearby grazing land in the area to experience a small reduction in warning time which may impact on the ability to evacuate stock. This potential impact would need to be confirmed with affected landholders at the detailed design phase.

Peak flood depths would be higher along Wants Lane due to the project. It is not anticipated that access would be attempted during the peak of a 100 year ARI flood event. As discussed above, the trafficability of the road bridges will not be adversely affected. Hence, the project is unlikely to increase the flood hazard of these properties.

The project would impact on the potential for stock movement and evacuation to higher ground at station 43.1 at the eastern edge of a proposed 300 metre bridge across the Coldstream River and floodplain. At this location, the landholder owns land on both sides of the project boundary. In times of flood and especially as floodwaters rise, there is a need to move stock from the northern side of the proposed road to the southern side where there is better access to flood-free land. An access track has been included in the design under this bridge at a level of 2.1 metres AHD to increase the time available for cattle movement from the north to the south of the bridge.

At the Wooli Road/Lloyds Road junction, there would be less than 25 millimetres increase in peak flood depths. Hence, there would be little or no change to the ability to use this road for access during 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.

Agricultural land immediately upstream of the project would experience a faster rise of flood level. However, this would not increase the level of flood hazard for people, stock or property.

Therefore, 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 the Coldstream River and its western tributary 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.

For the western tributary, these plots show that the project will increase velocities on the bed and banks by about 10 per cent for common floods (two year ARI). For the rarer flood events (20 year ARI and 100 year ARI), the project would result in a redistribution of flow on the floodplain which would result in increases of 30 per cent to 50 per cent for the banks of the western tributary. While this is a large percentage increase, it is on a low base velocity of about 0.7 metres per second increasing to about 1.1 metres per second.

However, the vegetation coverage on the banks in this watercourse is poor. This would indicate that the project could result in an increased risk of bank erosion during rare flood events. As previously discussed, velocities also increase by up to 120 per cent from existing conditions downstream of the bridge at this location. Velocities decrease to less than one metre per second within 50 metres of the project boundary.

Based on the flood level plots provided in Appendix G, the rate of recession would also be increased by around 55 per cent at the project crossing and around 40 per cent at Wants Lane upstream. An increased in the rate of flood recession has the potential to increase the risk of erosion through bank slumping.

A larger bridge at this location or at the Coldstream River crossing further east would reduce impacts and subsequent potential for erosion in this channel. This would need to be considered further in detailed design in conjunction with impacts to flood access in the area.

For the Coldstream River, the velocity plots in Appendix H show that the project would not increase velocities on the bed and banks for common floods (two year ARI). For the rarer flood events (20 year ARI and 100 year ARI), the project would result in increases of about 10 per cent for the bed and banks of the Coldstream River. It is likely that the well vegetated channel banks could accommodate these increases in peak velocity without increased risk of erosion.

The concept design includes bridge piers located on or near the bed and banks of both the Coldstream River and its western tributary. 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 10 per cent culvert and bridge blockage during the 100 year ARI flood event within the Coldstream River catchment. Culvert blockages cause an increase in impacts upstream of the project of up to 35 millimetres. Along the western tributary, increases in impact reduce to negligible within 500 metres upstream of the project boundary. Along the Coldstream River upstream of the project, impacts reduce to below five millimetres within one kilometre (river-length) upstream of the project boundary.

Downstream of the project boundary, increases in impact of less than five millimetres would be experienced downstream of the 120 metre bridge. Increases in impact of less than 10 millimetres would be experienced downstream of the 160 metre long bridge.

6.5.4. Flood impact summary

The project would result in some localised flood level increases of up to 300 millimetres between the 300 metre and 160 metre long bridges, dissipating to less than 250 millimetres within about 200 metres upstream of the project boundary. An area of around 5.6 hectares would experience impacts greater than 250 millimetres but less than 400 millimetres. These impacts do not meet the flood management objectives for this catchment.

Velocities downstream of the bridge would exceed an increase of 20 per cent from existing conditions in the 100 year ARI flood and would be further investigated for scour potential at the detailed design phase.

The project would meet all other flood management objectives for this area. The project would not result in any increased risk to life, stock or property associated with changes to flood hazard.

Figure 6-6 Flood impacts 100 year ARI event: Coldstream River

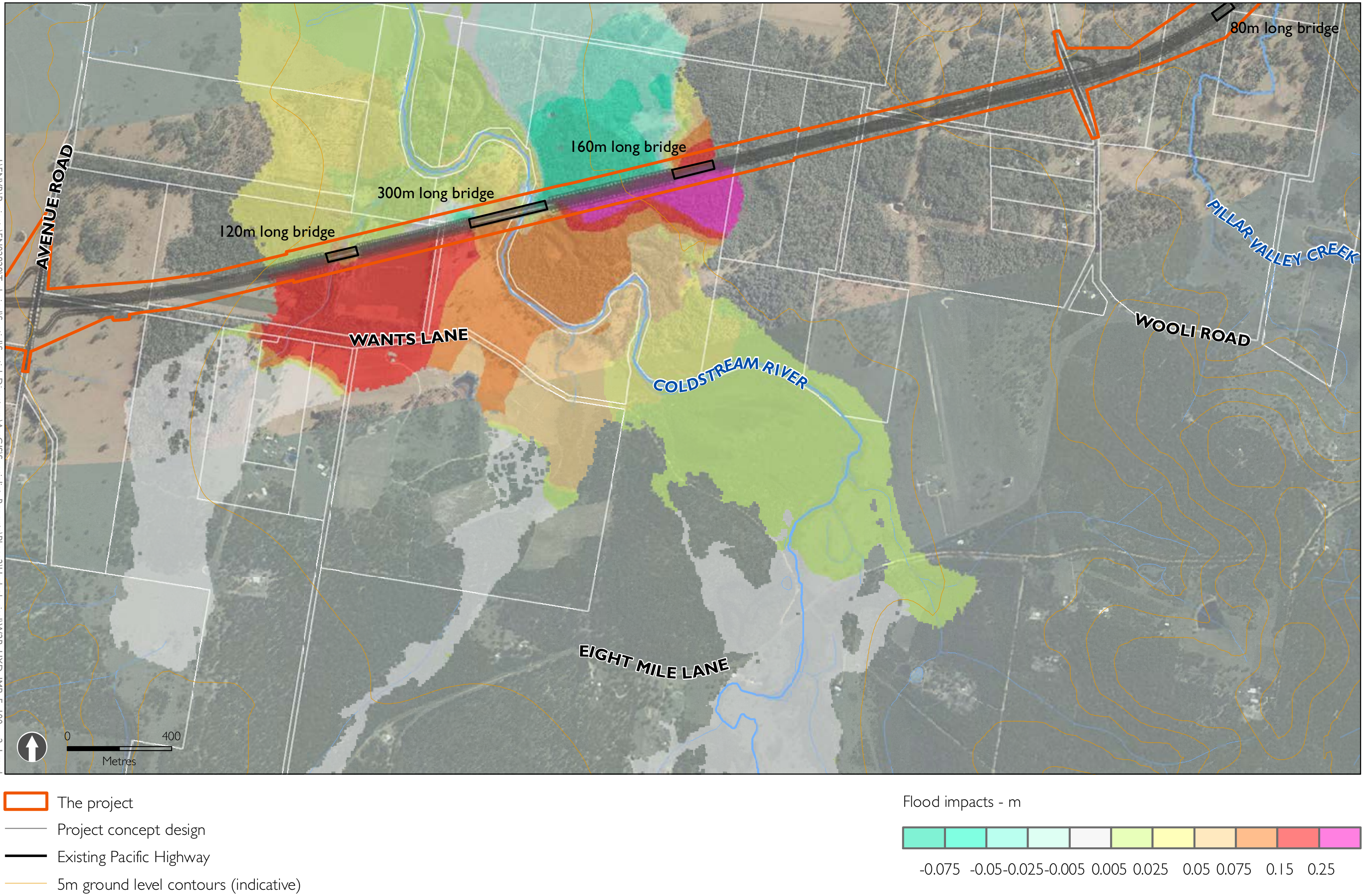
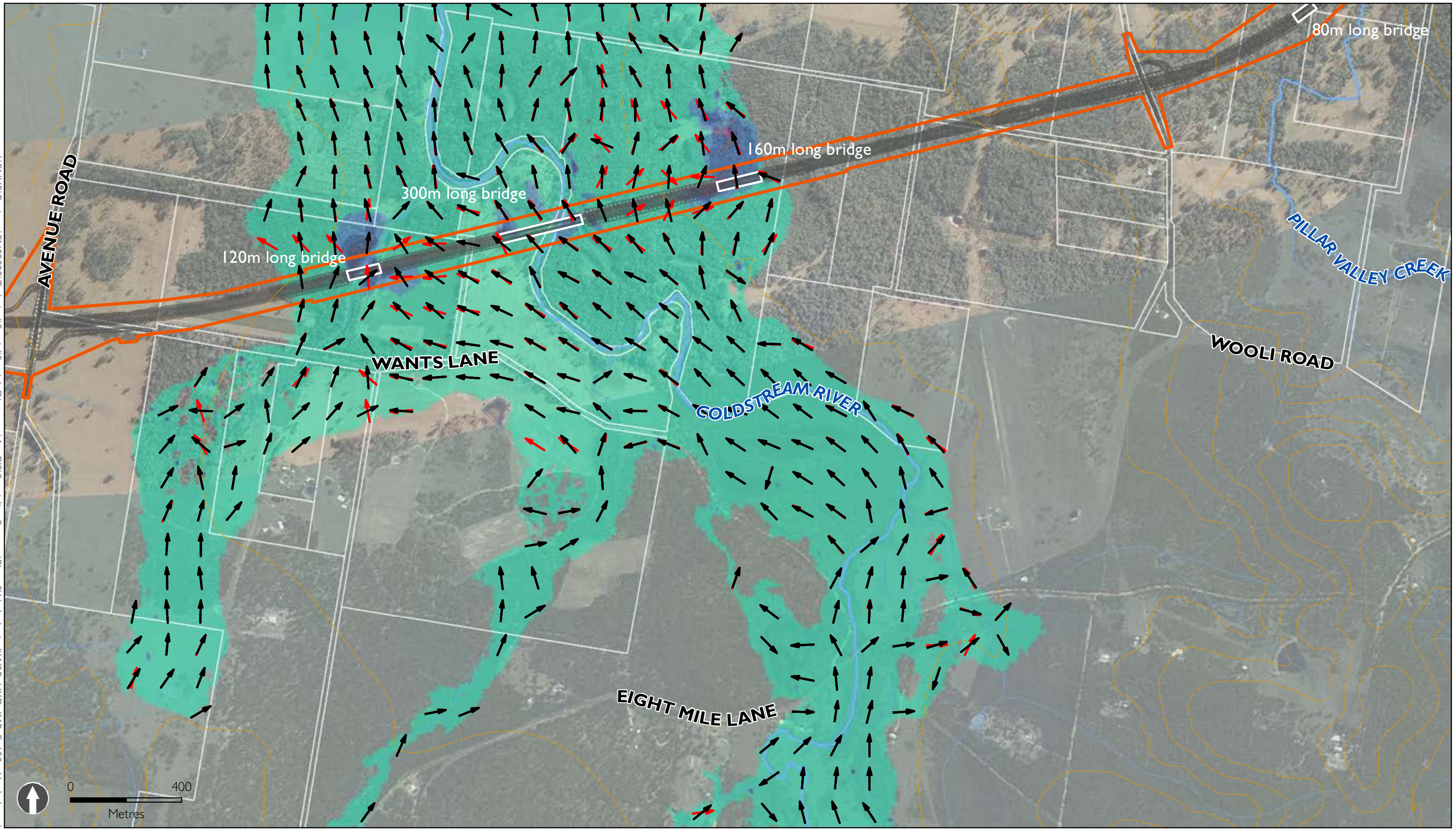


Figure 6-7 Velocity impacts 100 year ARI event: Coldstream River



The project
Project concept design
Existing Pacific Highway
5m ground level contours (indicative)
Velocity direction with project
Existing velocity direction

Increase in flood velocity due to project - m/s

0.2 0.4 0.6 0.8 1.0 1.5 2.0

6.6. Pillar Valley Creek

6.6.1. Flood management objectives

Floodplain areas within the catchment consist largely of grazing land and forested area. 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.

6.6.2. Design

Section 3 of the project would cross Pillar Valley Creek, an anabranch of the creek to the south-west and four tributary channels to the north-east of Pillar Valley Creek. The total length of the embankment across this floodplain would be about 1900 metres, and it would be above the 100 year ARI flood event.

The concept design includes the waterway structures as shown in Table 6-9. Modelled peak flows and velocities through each of these structures are also provided in Appendix F.

Table 6-9 Proposed structures on Pillar Valley Creek, tributaries and nearby unnamed creeks

Station (km)	Proposed structures[1]
Continuous except for the structures listed below	Embankment
46.07	80 m bridge over Pillar Valley Creek anabranch

Station (km)	Proposed structures[1]
46.34	90 m bridge over Pillar Valley Creek
46.67	50 m bridge over Black Snake Creek
47.02	4 x 3.0m x 1.5 m box culverts for Pillar Valley Creek Tributary
47.66	60 m bridge over Pillar Valley Creek Tributary
47.81	40 m twin bridges for Pillar Valley Creek Tributary
49.27	80 m span bridge over Unnamed Creek No. 1 near Mitchell Road
49.45	6 x 3.6 m x 1.5 m box culvert for Unnamed Creek No. 1 near Mitchell Road
50.30	25 m span bridge over Unnamed Creek No. 2 near Mitchell Road

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

These waterway openings differ from the design of the previous development project as a result of consolidating the number of bridges and moving the location of the project to the east through this area.

The design of the previous development project proposed a 50 metre bridge over the Pillar Valley Creek anabranch and a 25 metre bridge between the anabranch and Pillar Valley Creek. These two bridges have been consolidated into a single 80 metre bridge over the anabranch.

Pillar Valley Creek is proposed to have a 90 metre bridge, enlarged from the 70 metre bridge proposed in the design of the previous project development phase.

A levee will be required at station 46.55 measuring about one metre high (crest level at 10.8 metres AHD) and 30 metres long to stop flow from Black Snake Creek heading south into Pillar Valley Creek. The levee would fall entirely within the project boundary.

Two 35 metre bridges and a 60 metre bridge proposed in the design of the previous development project have been consolidated into a single 50 metre bridge over Black Snake Creek at station 46.67 (around 300 metres to the north-west of Pillar Valley Creek) and four 3.0 metre wide by 1.5 metre high box culverts at station 47.02 (around 850 metres north-west from the creek).

Structures on two tributaries north of Balck Snake Creek have changed from the 45 metre and 5 metre bridges proposed in the design of the previous development project to a 60 metre bridge and a 40 metre bridge.

An 80 metre bridge at station 49.27 and six 3.6 metre wide by 1.5 metre high culverts at station 49.45 on the southern-most unnamed creek near Mitchell Road are proposed instead of a 70 metre bridge and 30 metre bridge as per the design of the previous development project.

Further north at station 50.3, the 25 metre bridge that would span a second unnamed creek near Mitchell Road is identical to that proposed in the design of the previous development project.

6.6.3. Flood impacts

Flood level impacts

The impacts of the proposed project on 100 year ARI peak flood levels are shown in Figure 6-8. Approximate flood impact levels event are presented in Table 6-10.

The maximum impact during the 100 year ARI event upstream of the project boundary at the Pillar Valley Creek anabranch would be 220 millimetres increase (and 170 millimetres in the 20 year ARI flood event). This anabranch shares a floodplain with Pillar Valley Creek. Closer to Pillar Valley Creek, the maximum impact would be 160 millimetres increase (and 120 millimetres in the 20 year ARI flood event).

Impacts on flood levels at Black Snake Creek would be less than 10 millimetres increase in all assessed ARI flood events. This impact would be highly localised, dissipating to negligible within 15 metres of the project boundary.

Impacts outside the project boundary at the tributaries north of Black Snake Creek (combined floodplain of two tributaries) would be less than 10 millimetres increase in flood level. These impacts dissipate to zero impact within 30 metres of the project boundary in all assessed ARI flood events.

Peak flood levels increase downstream of the project boundary by less than 30 millimetres at the two unnamed creeks north of Mitchell Road (Figure 6-9). No impact occurs upstream of the first unnamed creek north of Mitchell Road. Upstream of the second creek north of Mitchell Road, a localised impact of up to 220 millimetres occurs in the 100 year ARI flood event (and 160 millimetres in the 20 year ARI flood event). This decreases to less than five millimetres within 45 metres upstream of the project boundary.

No residences would experience flood level impacts in this floodplain.

Table 6-10 Flood level impacts in Pillar Valley Creek, tributaries and nearby unnamed creeks

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Upstream of the project boundary at Pillar Valley Creek crossing	95 mm	165 mm	215 mm	230 mm
Upstream of the second unnamed creek north of Mitchell Road	35 mm	160 mm	220 mm	250 mm

Flood inundation duration impacts

While there would be some increase in the period of inundation upstream of the project, this would be less than the ten per cent flood management objective for grazing, forested and other rural areas.

Flood velocity and direction impacts

The proposed location of culverts and bridges would minimise changes in flow direction and flood behaviour. Some constriction and expansion of flow into and out of waterway structures would occur. The extent of inundation downstream of the northern-most tributary is reduced as a result of the project embankment and culvert configuration. No areas outside of the project boundary that are currently flood free would be inundated as a result of the project.

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.

Velocities upstream and downstream of all structures that are greater than one metre per second in the 100 year ARI flood event are all within the 20 per cent flood management objective. There would be little change to flood velocity and direction as a result of the project beyond the highlighted effects of constriction and expansion.

Rate of flood rise and warning time impacts

Based on the plots of flood level over time immediately upstream of the project boundary, the project would have similar rate of floodwater rise as the existing case. There is an increase in warning time at some locations downstream of the project boundary. Flood level plots and locations are provided in Appendix G.

There are no houses or commercial premises impacted by the project in this area. Hence, the flood warning time for residents would be unaffected.

Flood evacuation and flood access impacts

There are no known evacuation routes that would be severed by the project.

Due to the similar rate of floodwater rise as the existing case, there would not be any change to the potential for evacuation in this area.

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.

Agricultural land immediately upstream of the project would experience a faster rise of flood level. However, this would not increase the level of flood hazard for people, stock or property.

Therefore, 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 Pillar Valley Creek and its unnamed tributaries and Black Snake Creek (also a tributary of Pillar Valley 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.

For the southern tributary (station 46.07), these plots show that the project will increase velocities on the bed and banks by less than 10 per cent for common floods (two year ARI). These changes are unlikely to result in changes to bed form of the channel erosion. For the rarer flood events (20 year ARI and 100 year ARI), the project would result in a redistribution of flow on this tributary floodplain which would result in decreases in bed and bank velocities.

For the Pillar Valley Creek crossing (station 46.34), the velocity plots in Appendix H show that the project would result in increases of about 10 to 20 per cent for the bed and banks for all flood events. 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 two metres per second threshold for scour on well vegetated banks.

The toe of the northern abutment of the bridge over Pillar Valley Creek would be close to the right bank of Pillar Valley Creek. The exact location of this abutment would need to be considered in detailed design to minimise impacts to the bank formation.

For the Black Snake Creek crossing (station 46.67), the velocity plots in Appendix H show that the project would result in increases of less than 10 per cent for the bed and banks for all flood events. These increases to velocities are on a high base of about two to four meters per second due to the relatively steep nature of the floodplain. However, it is likely that the well vegetated and forested channel banks could accommodate these minor increases in peak velocity without increased risk of erosion.

For the northern tributary of Pillar Valley Creek (station 47.66), the velocity plots in Appendix H show that the project would result in increases of less than 10 per cent for the bed and banks for all flood events.

Based on the flood level plots provided in Appendix G, the rate of recession in this creek would also be increased by around 35 per cent. Increased rate of recession has the potential to increase the risk of erosion through bank slumping. It is likely that the well vegetated and forested channel banks could accommodate these minor increases in peak velocity and increases in rate of recession without increased risk of erosion. However, this would need to be confirmed at the detailed design phase through a detailed geomorphological assessment.

The concept design includes bridge piers located on or near the bed and banks of Pillar Valley Creek and its tributaries. 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 10 per cent culvert and bridge blockage during the 100 year ARI flood event within the Pillar Valley Creek catchment. The effects of culvert blockages are mostly contained within the floodplain shared by the Pillar Valley Creek anabranch and Pillar Valley Creek. Here, culvert blockages would cause an increase in impact of up to 40 millimetres. This increase in impact decreases to less than five millimetres within 650 metres upstream of the project boundary.

The effects of culvert blockages upon Black Snake Creek are less than five millimetres upstream of the project boundary, except for a 150 metre section of stream located 850 metres upstream of the project boundary. Here, about 30 millimetres increase in impact would occur.

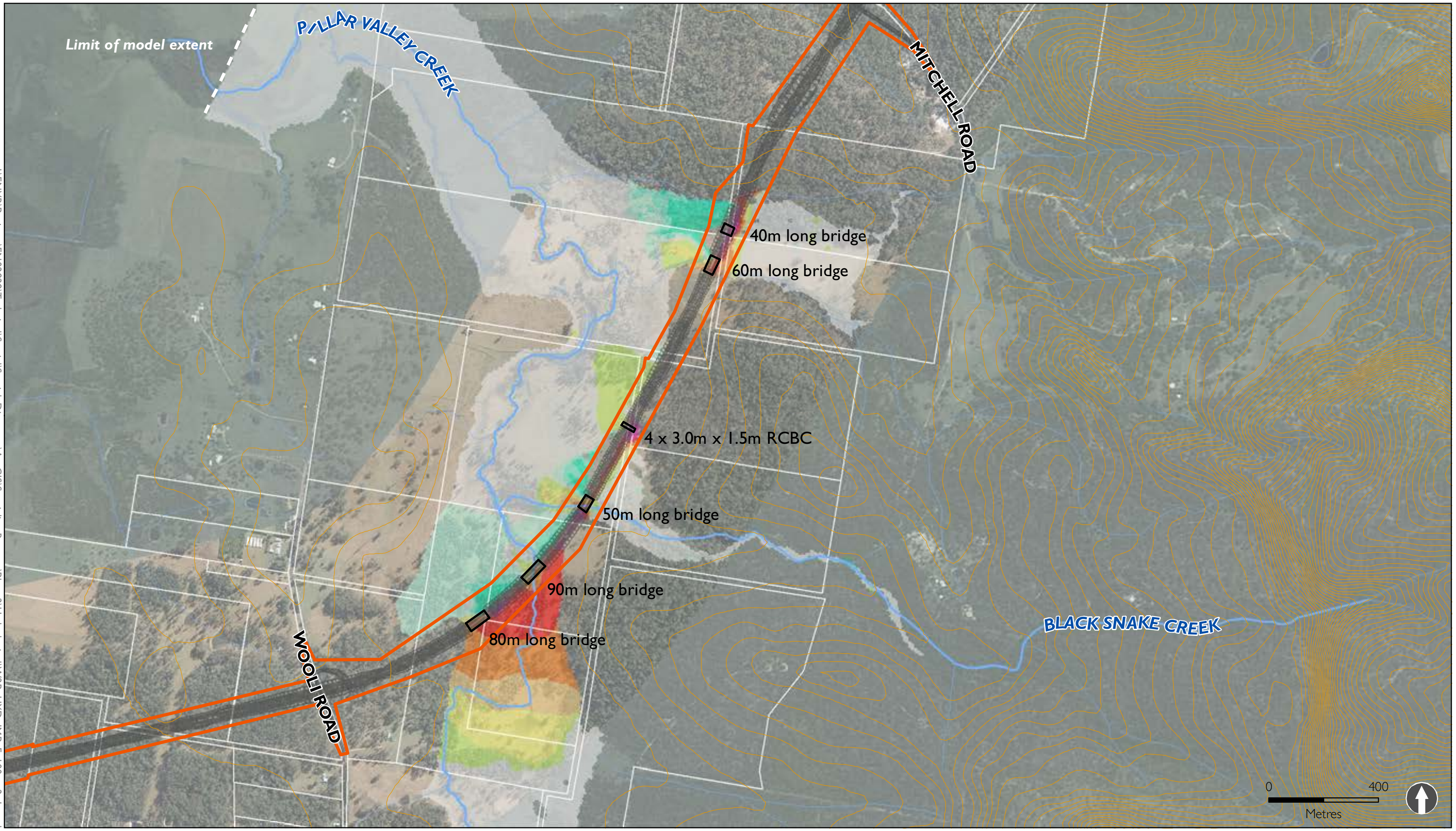
At the second tributary north of Black Snake Creek, around 20 millimetres increase in impact would occur downstream of the project boundary. This reduces to less than five millimetres within 180 metres.

The remainder of the floodplain is considered insensitive to the blockage, with impacts less than five millimetres.

6.6.4. Flood impact summary

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

Figure 6-8 Flood impacts 100 year ARI event: Pillar Valley Creek

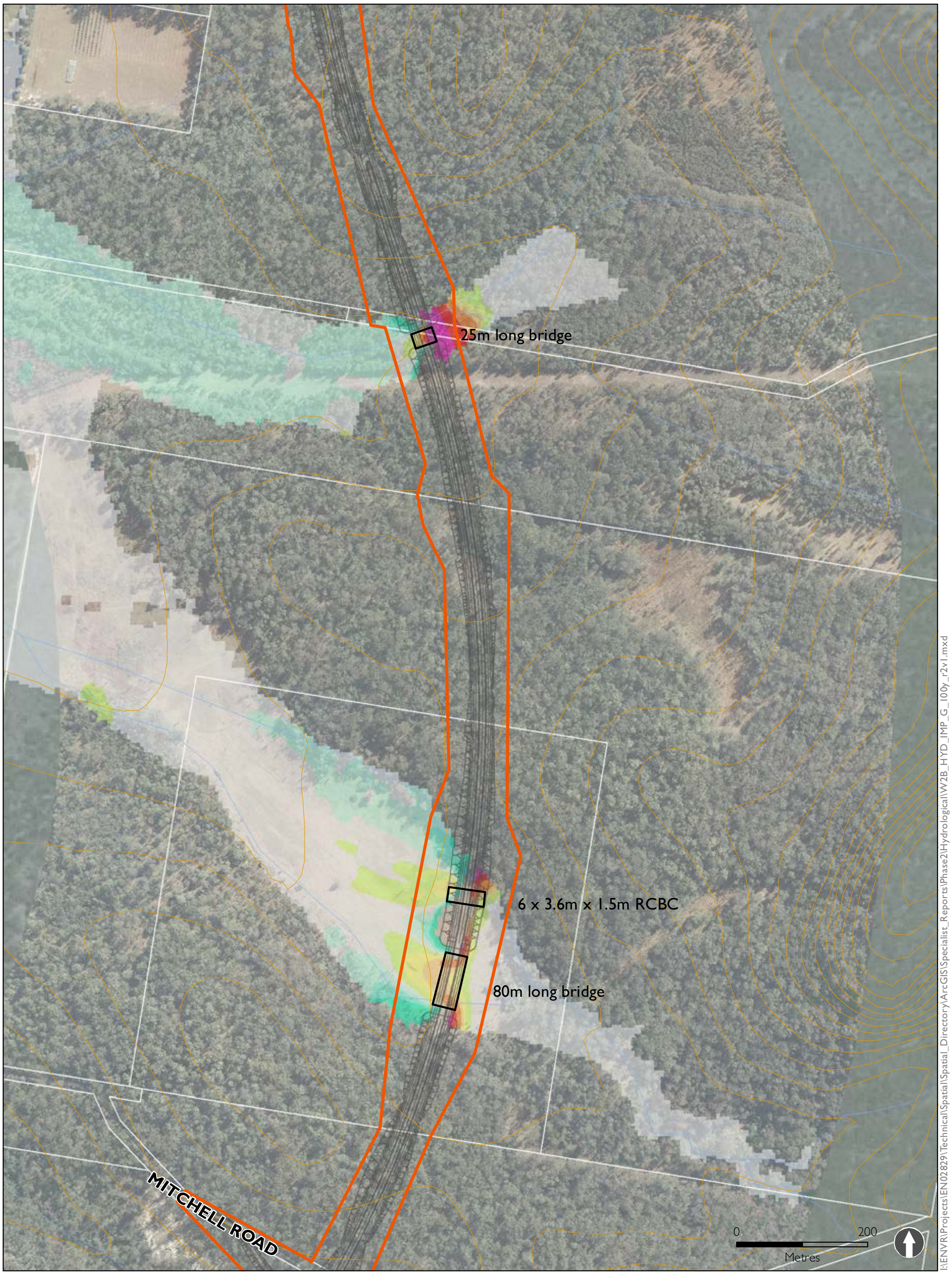


The project
Project concept design
Existing Pacific Highway
5m ground level contours (indicative)

Flood impacts - m

-0.075 -0.05 -0.025 -0.005 0.005 0.025 0.05 0.075 0.15 0.25

Figure 6-9 Flood impacts 100 year ARI event: unnamed creek near Mitchell Road



The project
Project concept design
Existing Pacific Highway
5m ground level contours (indicative)

Flood impacts - m

-0.075 -0.05 -0.025 -0.005 0.005 0.025 0.05 0.075 0.15 0.25

6.7. Chaffin Creek and nearby creeks

6.7.1. Flood management objectives

The land use of the Chaffin Creek catchment is mostly cleared farmland with some areas of medium to dense forest. The project would traverse mostly the forested areas, cutting across small cleared areas. There are two houses on the edge of 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.

6.7.2. Design

Section 3 of the project would cross Chaffin Creek and a number of smaller unnamed creeks in the vicinity. The roadway embankment would be higher than the 100 year ARI flood levels.

The concept design includes the waterway structures as shown in Table 6-11, with locations shown in Figure 6-9 to Figure 6-11. Peak flows and velocities through each of these structures are contained in Appendix F.

Table 6-11 Proposed structures on Chaffin Creek and nearby unnamed creeks

Station (km)	Proposed structures[1]
Continuous except for the structures listed below	Embankment
52.44	60 m span bridge over Chaffin Creek
52.61	6 x 3.6 m x 2.1 m box culvert for Chaffin Creek
54.71	60 m span bridge over Unnamed Creek 3 near Bostock Road
55.06	6 x 1.5 m x 1.5 m box culvert for Unnamed Creek 4 near Bostock Road

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

The waterway areas of these proposed structures are generally the same or smaller than those proposed in the design of the previous development project.

Structures over Chaffin Creek would be a 60 metre bridge and six 3.6 metre wide x 2.1 metre high box culverts compared to two bridges of 60 metres and 50 metres in the design of the previous development project.

The bridge span over Unnamed Creek 3 would be reduced from 90 metres in the design of the previous project development phase to 60 metres.

The 40 metre bridge over Unnamed Creek 4 would be reduced to a multicell culvert of six cells measuring 1.5 metres wide by 1.5 metres high.

6.7.3. Flood impacts

Flood level impacts

The predicted impacts of the project on the peak 100 year ARI flood levels from stations 49.3 to 55.3 are shown in Figure 6-9 to Figure 6-11. Approximate flood impact levels event are presented in Table 6-12. All impacts would be caused by the reduction in flow area associated with embankment construction across much of the floodplain.

The maximum flood level increase outside of the project boundary caused by the project in a 100 year ARI flood event on Chaffin Creek would be less than 290 millimetres (and less than 200 millimetres in a 20 year ARI flood event). Impacts would reduce to an increase of 250 millimetres within 15 metres upstream of the project boundary and to an increase of 50 millimetres within 500 metres upstream of the project boundary for a 100 year ARI flood event.

At a property approximately 500 metres upstream of the project boundary, two sheds are inundated. Impacts experienced at these sheds are approximately 50 millimetres for the 100 year ARI flood level. The house is not inundated during a 20 year ARI flood and unlikely to be inundated during a 100 year ARI flood, but this would need to be confirmed with survey. This house, if inundated, would experience an increase of 50 millimetres in a 100 year ARI flood event. No other residences would experience flood level impacts in this floodplain.

Unnamed Creek 3 near Bostock Road (Figure 6-11) would experience an impact of less than 20 millimetres increase upstream of the project for all assessed ARI events and less than 60 millimetres downstream. At the nearby Unnamed Creek 4 near Bostock Road, the project would have less than five millimetres impact on peak 20 and 100 year ARI flood levels upstream of the project boundary and less than 40 millimetres impact downstream of the project boundary for 100, 20 and five year ARI flood events. In the 200 year event, the impact is less than 75 millimetres.

Table 6-12 Flood level impacts in Chaffin Creek and nearby unnamed creeks

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Upstream of project boundary at Chaffin Creek crossing	50 mm	195 mm	285 mm	320 mm
At a house approximately 500 metres upstream of the project boundary	No flooding	No flooding	52 mm	58 mm

Flood inundation duration impacts

While there would be some increase in the period of inundation at the houses upstream of the Chaffin Creek crossing, this would be less than the five per cent objective.

The period of inundation would not increase by more than ten per cent on grazing, forested and other rural lands.

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.

Velocities upstream and downstream of all structures that are greater than one metre per second in the 100 year ARI flood event are all within the 20 per cent flood management objective.

Flow velocities near the house and sheds upstream of the Chaffin Creek crossing do not vary greatly from the existing scenario and are less than one metre per second.

There would be no changes to the direction or behaviour of flooding other that associated with constriction and expansion near structures.

Rate of flood rise and warning time impacts

Based on plots of flood level versus time, the project would have similar rate of floodwater rise as the existing case immediately upstream and downstream of the project boundary the unnamed creek near Mitchell Road, Chaffin Creek and the unnamed creek near Bostock Road. As a result, there would be no impact of reduced warning time on residents or for stock evacuation. Flood level plots and locations are provided in Appendix G.

Flood evacuation and flood access impacts

Primary access for the residence upstream of the project is Firth Heinz Road to the south of Chaffin Creek. This road would cross the project and join Wooli Road to the west via an overpass. As this access would not be cut by the project and would not experience flood impacts as a result of the project, there would be no change to the potential for evacuation of this area.

A property north of and adjacent to Mitchell road is currently used as a refuge for stock during regional (Clarence River) flooding. This property is cut by the project with the majority of land on the far side of the project. Regardless of whether stock is currently mobilised to the Mitchell Hill refuge via truck or overland, access to the property would be maintained via the Mitchell Road underpass. As this access would not be cut by the project and access would not otherwise experience flood impacts as a result of the project, there would be no change to the potential for flood evacuation of the Clarence River floodplain to the Mitchell Hill flood refuge.

Flood levels would rise more rapidly on Chaffin Creek, particularly adjacent to the upstream boundary of the project property where peak flood level increases are greatest. However, this would not affect the ability of stock or people to evacuate the area safely, and would not affect the operations of the farm to any greater extent than existing conditions.

Of particular note, the houses upstream of Chaffin Creek crossing that would have flood waters adjacent to them at the front of the buildings during the 100 year ARI event would still have dry access at the rear of the house as per current conditions.

There would also be no change in the impact of flooding on evacuation and access routes for people or stock.

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.

Agricultural land immediately upstream of the project would experience a faster rise of flood level. However, this would not increase the level of flood hazard for people, stock or property.

Therefore, 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 Chaffin 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 Chaffin 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 bed form is relatively stable due to the presence of bedrock.

It is predicted that peak velocities on the left bank of Chaffin 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 1.1 metres per second increasing to about 1.6 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. At the property boundary downstream of the structure, velocities increase by less than 20 per cent increase in the 100 year ARI event.

Based on the flood level plots provided in Appendix G, the rate of recession in Chaffin Creek would also be increased by around 25 per cent. Increased rate of recession has the potential to increase the risk of erosion through bank slumping. However, due to the presence of bedrock and well vegetated banks, bank slumping and subsequent increased risk of erosion is unlikely as a result of an increase in the rate of flood recession.

The concept design includes bridge piers located on or near the bed and banks of Chaffin 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

A sensitivity analysis was conducted upon the effects of 10 per cent culvert and bridge blockages on 100 year ARI flood levels within the Chaffin Creek catchment. At the two unnamed creeks north of Mitchell Road, culvert blockages cause zero millimetres increase in impact, bar a localised increase of less than 20 millimetres at the more northern creek. This reduces to zero millimetres within 40 metres of the project boundary.

At Chaffin Creek, increases in impact upstream of the project boundary would be around 70 millimetres. This decreases to less than five millimetres increase in impact in 750m upstream of the project boundary.

At a property approximately 500 metres upstream of the project boundary, two sheds and possibly one house would be inundated in a 100 year ARI flood event. The inundation of the house floor level is unlikely but would need to be confirmed with survey.

Impacts at these sheds and the house would increase due to culvert blockage from 50 to 70 millimetres in the 100y ARI flood event.

Unnamed Creek 3 near Bostock Road would experience a localised increase in impact of less than five millimetres upstream of the project boundary, which reduces to zero within 50 metres. Unnamed Creek 4 would experience zero increase in impact upstream of the project boundary.

The remainder of the floodplain is considered insensitive to the blockage, with impacts less than five millimetres.

6.7.4. Flood impact summary

The area upstream of the Chaffin Creek crossing would experience localised impacts of up to 290 millimetres in the 100 year ARI flood event as a result of the project. This would dissipate to less than 250 millimetres increase within 15 metres upstream of the project boundary and to 50 millimetres impact within 500 metres.

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

Figure 6-10 Flood impacts 100 year ARI event: Chaffin Creek

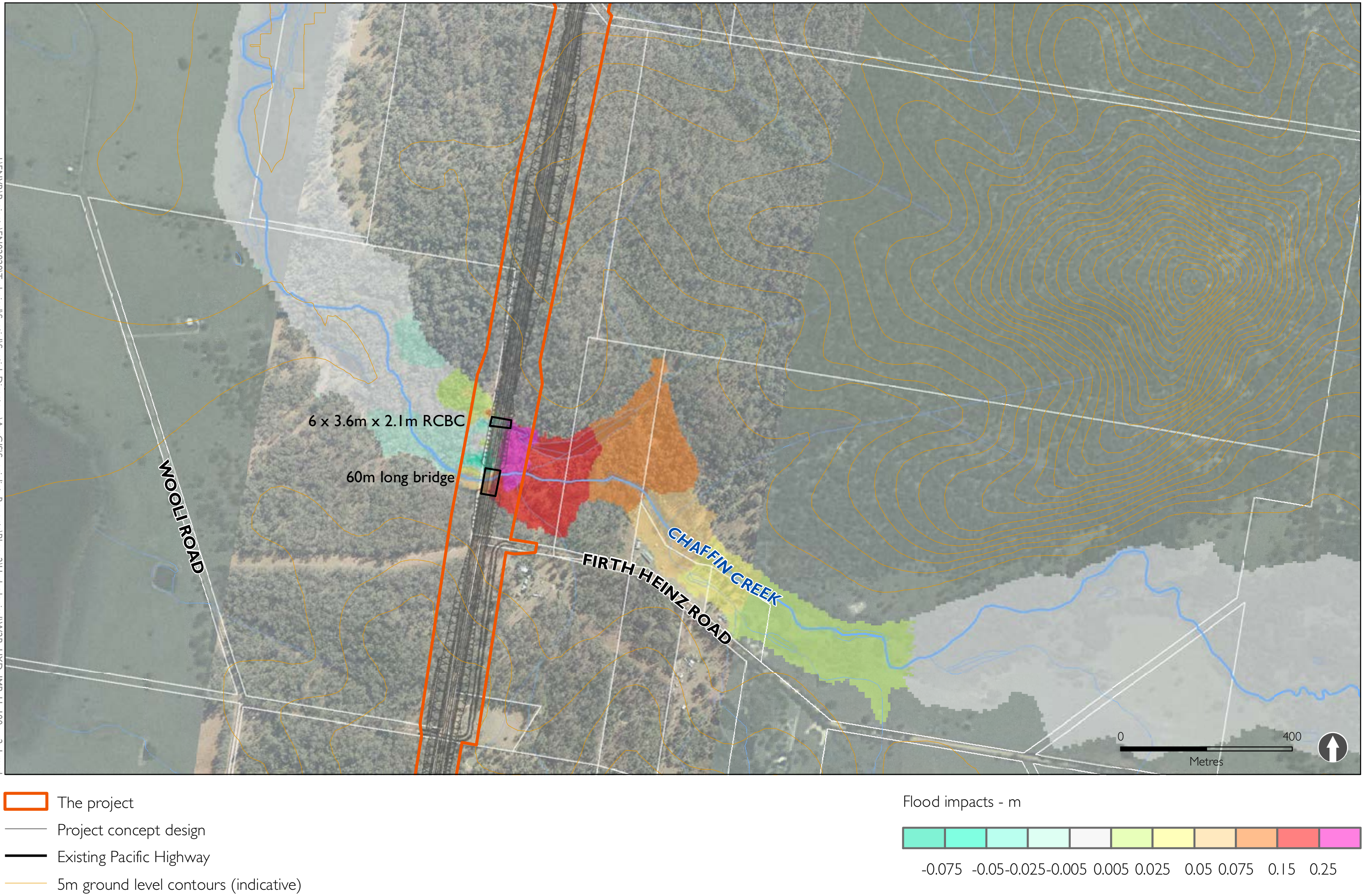
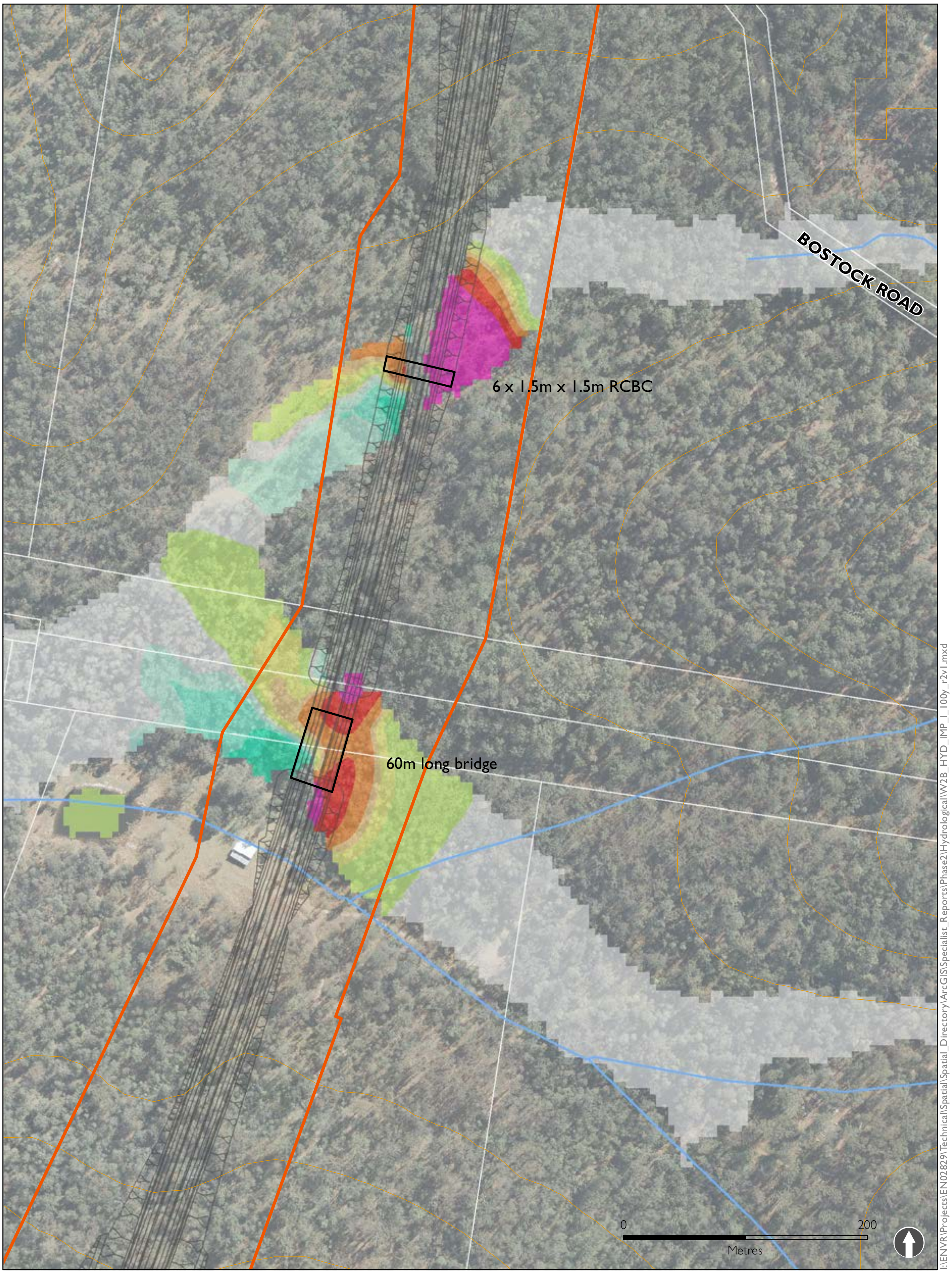


Figure 6-11 Flood impacts 100 year ARI event: unnamed creek near Bostock Road



The project
Project concept design
Existing Pacific Highway
5m ground level contours (indicative)

Flood impacts - m

-0.075 -0.05 -0.025 -0.005 0.005 0.025 0.05 0.075 0.15 0.25

6.8. Champions Creek and nearby creeks

6.8.1. Flood management objectives

The majority of the area that would be impacted by the project is dense forest, with some clearing at the upper extent of the impact. 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.

6.8.2. Design

Section 3 of the project crosses Champions Creek and a number of smaller creeks in the vicinity.

The concept design includes the waterway structures as shown in Table 6-13. Modelled peak flows and velocities through each of these structures are also provided in Appendix F.

Table 6-13 Proposed structures on Champions Creek and nearby unnamed creek

Station (km)	Proposed structures[1]
Continuous except for the structures listed below	Embankment
57.03	80 m bridge over Champions Creek
58.64	50 m over unnamed creek north of Champions Creek

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

The bridge over Champions Creek has been enlarged from the 50 metres proposed in the design of the previous project development phase. The structure on the unnamed creek north of Champions Creek is not detailed explicitly in the design of the previous development project.

6.8.3. Flood impacts

Flood level impacts

The predicted impacts of the project on the peak 100 year ARI flood levels for this section of the project are shown in Figure 6-12. Approximate flood impact levels event are presented in Table 6-14.

The maximum flood level increase in the 100 year ARI event at Champions Creek would be 370 millimetres in the 100 year ARI event (with up to 280 millimetres impact in the 20 year ARI flood event). This would dissipate to less than 250 millimetres impact within 120 metres upstream of the project boundary, and to 150 millimetres impact within 250 metres. The area where Somervale Road crosses Champions Creek, around 460 metres upstream of the project boundary, would experience impacts of about 90 millimetres in the 100 year ARI flood event (and 70 millimetres impact in the 20 year ARI flood event).

A property access track extending along the northern bank of the creek floodplain would experience impacts. This impact is discussed further below in regard to flood access issues. No houses would otherwise experience flood level impacts from the project.

A small area downstream of the project boundary would experience a peak 100 year ARI water level increase of less than 50 millimetres due to the concentration of flow at the culvert outlet.

The impact outside of the project at the unnamed creek north of Champions Creek would be less than five millimetres increase upstream in all ARI events, and less than 20 millimetres downstream.

Table 6-14 Flood level impacts in Champions Creek and nearby unnamed creek

Location	2 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Upstream of Champions Creek crossing at project boundary	140 mm	280 mm	370 mm	400 mm
Somervale Road crossing of Champions Creek	30 mm	70 mm	90 mm	105 mm
Downstream of the project boundary	0 mm	30 mm	45 mm	50 mm

Flood inundation duration impacts

During local flooding, increases in flood inundation duration are only experienced above 2.1 metres AHD immediately upstream of the project boundary. Flood inundation duration is extended by 10 minutes at around 2.3 metres AHD (from about 150 to 160 minutes in inundation duration) up to 20 minutes at 2.5 metres AHD (from about 80 to 100 minutes in inundation duration). However, the duration of inundation is relatively short and there is no inundation of residences at this location.

Little impact is experienced at less than 2.1 metres AHD at this location, and no flood inundation duration impacts are experienced further upstream at the Somervale Road bridge or downstream of the project. Flood level plots and locations are provided in Appendix G.

No flood inundation duration impacts are experienced during regional (Clarence River) flood events.

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. Changes in velocities upstream and downstream of structures through this catchment are included in Appendix F.

For the 80 metre bridge over Champions Creek, velocities at the project boundary upstream and downstream of this bridge are below one metre per second in the 100 year ARI flood event. At the 50 metre bridge, velocities downstream are reduced compared to the existing scenario.

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

Rate of flood rise and warning time impacts

Based on plots of flood level versus time, the project would have similar rate of floodwater rise as the existing case downstream of the project boundary and at the Somervale Road bridge across Champions Creek. There would be a slight reduction in warning time of less than 10 minutes immediately upstream of the project when local flooding reaches about 2.5 metres AHD. A reduction in warning time of up to 10 minutes may therefore be experienced at the driveway access to the property north of the creek.

There would be no impacts to rate of rise or warning time during regional back-up flooding from the Clarence River as a result of the project.

Flood level plots and locations are provided in Appendix G in this catchment for both local and regional flooding.

Flood evacuation and flood access impacts

The primary access for the residence upstream of the project is Somervale Road which crosses Champions Creek upstream of the project. Residents rely upon crossing Somervale Road in local flood events prior to extended periods of inundation in subsequent Clarence River flood events.

The impacts of the project would reduce the time available for access to and from this residence. This reduction in time would affect the ability of the residences to prepare for any subsequent loss of flood access in long duration Clarence River flood events.

As discussed in flood inundation duration impacts, during local flooding immediately upstream of the project boundary there are increases to the time of inundation above 2.3 metres AHD. As a result, there may be implications for where flooding crosses the road easement on the northern bank of Champions Creek depending on the elevation of the road itself. It is estimated that the road in this area would be around 2.3 metres AHD, correlating with the road being cut for a further 10 minutes during an overall inundation period of around 2.5 hours.

Either lengthening of the project bridge over Champions Creek to reduce impacts or raising Somervale Road and the private access track would mitigate this impact.

During regional flooding, where access is likely to be cut for several days, there would be no flood evacuation or access impacts experienced as a result of the project.

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.

Agricultural land immediately upstream of the project would experience a faster rise of flood level. However, this would not increase the level of flood hazard for people, stock or property.

Therefore, 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 Champions 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 at the location of the bridge, the project will increase velocities on the bed and banks of Champions Creek by about 70 per cent for common floods (two year ARI) and up to 120 per cent for the rarer floods (20 year ARI and 100 year ARI). Velocities decrease to less than one metre per second in all events at the project boundary downstream.

These increases in velocity would result in an increased potential for bank erosion as the resulting velocities are between 1.0 and 1.5 metres per second and the banks have poor vegetation coverage. Detailed design would need to consider the need for a larger bridge at this location or changing the culvert crossing 200 metres to the north to a bridge. This change would need to be considered in conjunction with the need to reduce the impacts on Somervale Road inundation discussed above and the costs of embankment construction on the floodplain soils.

Based on the flood level plots provided in Appendix G, the rate of recession in Champions Creek would also be increased by around 25 per cent. Increased rate of recession has the potential to increase the risk of erosion through bank slumping; however, bank slumping is considered to be unlikely in this creek due to the presence of bedrock. Any increased risk in erosion potential as a result of the project would need to be further considered in conjunction with modifications to the project at the detailed design phase.

The concept design includes bridge piers located on or near the bed and banks of Champions 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.

The increases in bed and bank velocities predicted at the tributary north of Champions Creek (station 58.64) are less than 10 per cent and unlikely to result in changes to bed form of the channel erosion.

Sensitivity to culvert and bridge blockage on floodplains

A sensitivity analysis was conducted upon the effects of 10 per cent culvert and bridge blockages on 100 year ARI flood levels within the Champions Creek catchment. At Champions Creek, culvert blockages cause an increase in impact of around 250 millimetres. This increase in impact decreases to less than 50 millimetres within 500 metres upstream of the project boundary, and less than five millimetres increase in impact within 600 metres.

Downstream of Champions Creek crossing, culvert blockages would cause a localised increase in impact of 75 millimetres. This reduces to zero within 150 metres of the project boundary.

At the unnamed creek north of Champions Creek, culvert blockages would cause increases in impact less than five millimetres upstream of the project boundary, and some scattered areas of less than five millimetres and less than 10 millimetres in the downstream floodplain.

6.8.4. Flood impact summary

The area upstream of the Champions Creek crossing would experience localised impacts of up to 370 millimetres in the 100 year ARI flood event. This would dissipate to less than 250 millimetres increase within 120 metres upstream of the project boundary and to 150 millimetres impact within 250 metres.

There may be a reduction in warning time and increase duration of inundation at the property access track on the northern bank of Champions Creek during local flooding. These durations represent a relatively short increase in the duration of the flood at this elevation (about 10 to 20 minutes).

Lengthening of the project bridge over Champions Creek would mitigate these impacts. Raising Somervale Road and the private access track would also mitigate impacts on flood access and evacuation.

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

Figure 6-12 Flood impacts 100 year ARI event: Champions Creek