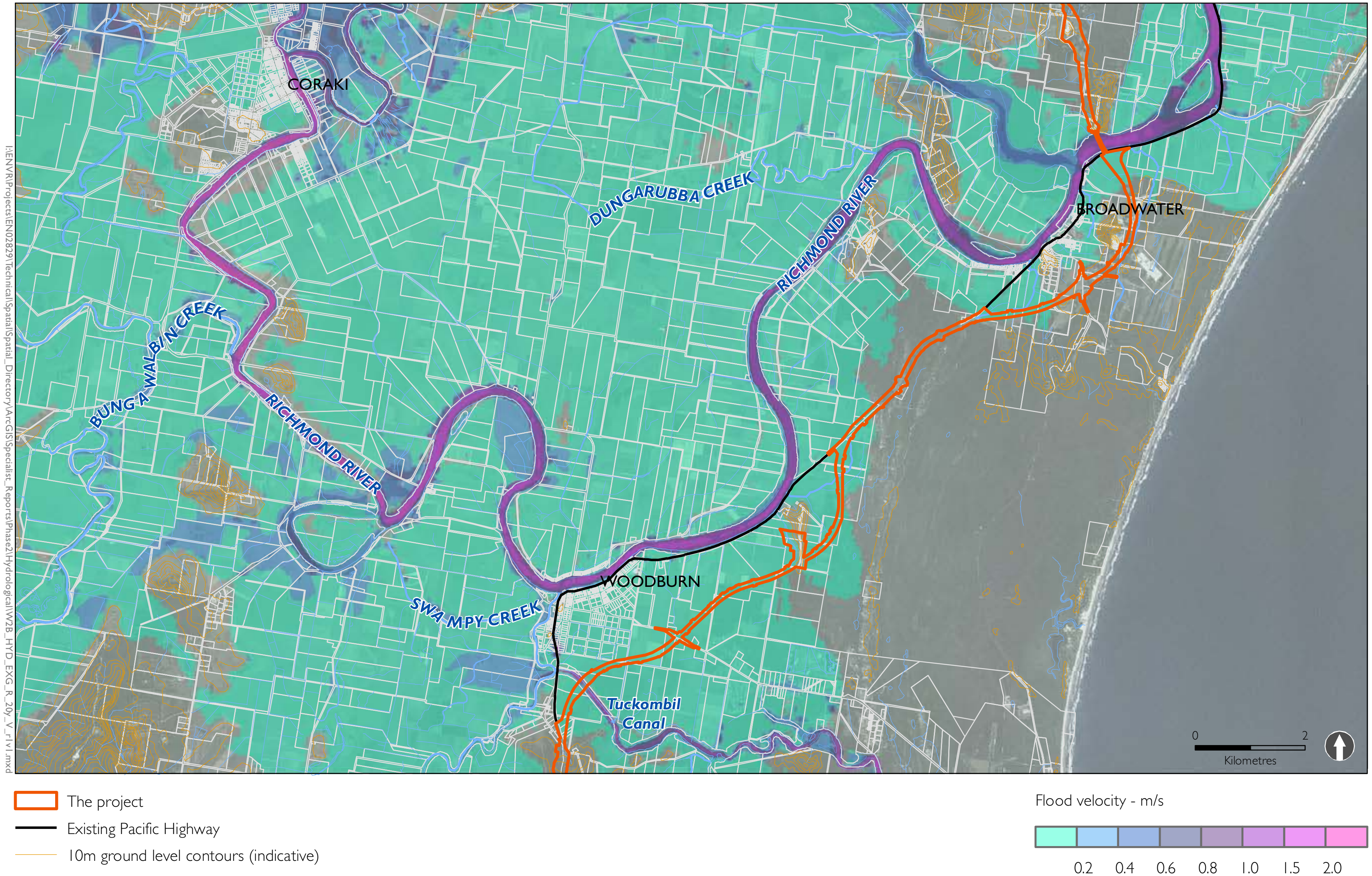
Figure 4-38 Peak 20y ARI flood velocities: Mid Richmond River



8. Mitigation and management

8.1. Pre-construction measures

Some targeted approaches or specific measures as part of the design process are presented in more detail below to identify and/or mitigate impacts which may arise through detailed design of the project.

8.1.1. Adherence of design objectives for flood management

As discussed in Section 2.1.1, the design process is undertaken iteratively to achieve a design that would meet all stated flood design objectives. This includes both maintaining design immunity of the road (bridges and embankments) and flood management objectives; ie, that which would, at minimum, reduce impacts to a level that is tolerable for the land use conditions of any given impacted area.

Therefore, continued application of the design objectives detailed in this study would be required throughout the detailed design phase to provide ongoing identification and mitigation of flood impacts as a result of the project. This would apply to road immunity, flood levels, flood velocity and direction, duration of inundation, rate of flood rise, flood warning, evacuation and access, including navigability of rivers during flood events.

Flood management objectives in general should not change; however, it is possible that the flood management objectives at a particular location may change as a result of modified or newly identified conditions (eg construction of a residence or a change in land use).

Modifications to design

It has been identified that as a result of changing circumstances in a small number of locations, there are structures and stretches of road that no longer meet the road immunity or flood management objectives for that area. Consequently, mitigation measures in Table 8-1 are proposed for the detailed design phase to maintain achievement of the flood management objectives.

Table 8-1 Design mitigation measures to adhere to flood management objectives

Station (km)	Mitigation measure
4.01	Bridge over Corindi River floodplain revised to reduce impacts upstream to within flood management objectives.
4.7	Bridge over Cassons Creek (north of Corindi River) raised to meet immunity requirements and debris clearance.
20.72	Hydraulic relationship between bridge over Halfway Creek and service road bridge requires consideration at detailed design phase to minimise stream velocity impacts.
46.45	Re-design of toe of northern abutment of bridge over Pillar Valley Creek to avoid impacts on bank formation.

Station (km)	Mitigation measure
43.12 – 43.91	Redesign of bridge crossings over Coldstream River to meet flood level impact objectives.
78.4 – 80.6	Bridge over Edwards Creek raised by 80 millimetres to meet immunity requirements and debris clearance.
85.4	Construction of a multi-cell culvert about 50 metres long with a bund on the eastern side to reduce impacts in small flood by closely replicating the existing flood behaviour.
87.50	Extension of 46 x 3.0 m x 2.1 m box culverts to 56 x 3.0 m x 2.1 m.
90.0 – 90.75	Design of 750 m of the proposed service road to the same level as the existing highway to serve as a low levee to impede back-up flow and reduce impacts in small flood events. This would not impede flow for larger flood events.
162.68	Consideration of a bund on the western side of the highway to a level equivalent to the exiting highway to serve as a low levee to impede flow and reduce impacts in small flood events. This would not impede flow for larger flood events.
163.60	Consideration of a bund on the western side of the highway to a level equivalent to the exiting highway to serve as a low levee to impede flow and reduce impacts in small flood events. This would not impede flow for larger flood events.
163.84	Consideration of a bund on the western side of the highway to a level equivalent to the existing highway to serve as a low levee to impede flow r and educe impacts in small flood events. This would not impede flow for larger flood events.

In addition, the design of drainage structures across Chatsworth Island would be further reviewed during detailed design to enable the most appropriate and cost-effective structures to be installed.

Interaction with other disciplines

Other disciplinary studies as part of the project present measures and/or design principles to guide design of measures. These measures or principles may interact with the design objectives for flood management presented in this paper. Potential areas for conflict which would require consideration at the detailed design phase are presented in Table 8-2.

Table 8-2 Measures requiring further consideration for hydrology and flooding

Discipline	Discipline measure / design principle	Consideration for hydrology and flooding
Biodiversity	Habitat within a culvert is to be as natural as possible (eg allow rocks and bed materials to infill the culvert base) without compromising the hydraulic function of the culvert	Culvert sizes would need to be increased to account for the reduction in roughness and cross-sectional area as a result of rock and bed material infilling.
Biodiversity	[Fauna] fencing must be integrated with crossing structures by guiding animals towards the crossing structure and preventing access to the road. ... In general fencing is to extend at least 200 metres either side of the structure ... Fence height must prevent animals from jumping over (eg at least 1.8 metres for kangaroos, 40-60 centimetres for amphibians)	Fauna fencing would need to be designed to avoid further impacts during flood events or flood impacts of fencing would need to be modelled at the detailed design phase to maintain achievement of flood management objectives.

8.1.2. Upgrade of flood models and on-going modelling

Ongoing modelling of the flood investigation areas would be required during detailed design to maintain recency of data, including floor survey, and also to monitor flood impacts in line with changes to the project design. This would involve ongoing consultation with residents through the detailed design phase.

In mid 2012, the NSW government made survey data available for the major floodplains along the project route. The flood models for these major floodplains along the project (ie Clarence, mid Richmond and lower Richmond rivers) would be upgraded with the use of this data. This may require re-calibration of the flood models to flood records of historical flood events. Further, the bathymetrical data on which the Clarence River flood model is based would be updated to reflect the current status of the river and the important tributaries along the route (ie Coldstream River, Shark Creek and Serpentine Channel).

As part of this upgrade and ongoing continuous improvement processes, it may be practical to rebuild some models to achieve a consistent modelling platform across all catchments. This will reduce inefficiencies arising out of the use of several modelling packages.

8.1.3. Scour protection and geomorphological issues

A detailed geomorphological assessment would be undertaken at the detailed design phase for all waterways with an aim to minimise changes to natural stream flow and velocity. This assessment would consider impacts on stream geomorphology dictated by regular stream flows, as a result of increased flow velocities, changed direction of flow and instream bridge piers. NSW Office of Water guidelines would need to be considered at the detailed design phase regarding consider instream works, outlet structures, riparian corridors, watercourse crossings and Vegetation Management Plans.

This assessment would include an investigation of scour protection at all waterway crossings, particularly banks adjacent to bridges and inlets and outlets of culverts. The requirements for erosion protection measures upstream and downstream of the highway, such as rock armouring or increasing culvert or bridge size, would be considered to ensure minimal soil erosion occurs as a result of the project. This comment is particularly pertinent on sugar cane floodplains where fallow paddocks are highly susceptible to soil erosion.

Several bridges and culverts have been specifically flagged as having the potential to cause scour or bed and bank stability issues during flooding. These structures are detailed in Table 8-3.

Table 8-3 Drainage structures at risk of scour and bed and bank stability issues

Station (km)	Structure
4.69	56 m bridge over Cassons Creek floodway
5.70	1 x 2.4 m wide x 1.7 m high box culverts
20.65	4 x 3.0 m wide x 2.4 m high box culverts (extension of existing)
20.72	Twin 50 m length highway bridges over Halfway Creek
42.54	120 m span bridge over western tributary

Station (km)	Structure
43.91	160 m span bridge over unnamed creek to the east of the Coldstream River
47.7	60 m long bridge over Pillar Valley Creek northern tributary
57.03	80 m bridge over Champions Creek

Concept design of large waterway crossings considers minimising impact to natural waterway features. For smaller gullies and ephemeral streams, it would be important in the detailed design phase to undertake a thorough assessment of each waterway to ensure the stability of these streams and to prevent any adverse ecological impacts. To achieve this, the following process would be undertaken:

- The overall stability of specific crossings will be assessed, to determine the risk of deepening upstream through the culvert, or for sediment from upstream blocking the crossing. If the risk is high, grade control or sediment stabilisation may be required
- The overall layout of each culvert will be reviewed to ensure a waterway has not been shortened, which might increase the risk of channel deepening. Similarly there may be some risk if a channel is increased in length that sedimentation might occur.

8.1.4. Waterway diversions

A detailed geomorphological assessment is specifically required for the diversion of Eversons Creek, east of Broadwater, in the Mid Richmond River floodplain. Although only a short length of the creek is diverted (around 200 metres), a detailed geomorphologic assessment is required to direct appropriate design at the detailed design phase, which may incorporate measures for mitigating scour and other downstream geomorphological impacts. These measures may include lengthening the diversion to match the existing stream length or inclusion of energy dissipating structures to restrict stream velocities and/or rock armouring and re-vegetation.

Waterway diversions would be designed so that the final diversion mimics, to the greatest extent possible, the characteristics of the waterway that is being diverted. Characteristics include flow regime, flow velocity, base material, vegetation and habitat for aquatic fauna.

A geomorphological assessment of the Picaninny Creek diversion has already been undertaken. Mitigation measures for operation of the diversion arising from this assessment have been documented in Section 8.1.5 and are incorporated into the current design.

8.1.5. Picaninny Creek diversion

As a result of potential geomorphological impacts as a result of the diversion at Picaninny Creek, a geomorphological assessment was undertaken for this section of the project. The diversion design has adopted several features to mitigate impacts as a result of modified fluvial conditions. These include rock armouring, channel re-vegetation and energy dissipating structures such as a plunge pool and rock chute.

Any modifications to the diversion design would be undertaken in a manner that ensures the final diversion mimics, to the greatest extent possible, the characteristics of the waterway that is being diverted.

Energy-dissipating structures

The first structure is to be located at running distance[7] 580 (upstream end) of the diversion route. A plunge pool was chosen as a rock chute to achieve the same objective, would prove to be unviable. The properties of the plunge pool are described further in Table C-19 and Figure C-2 in Appendix C.4.

The second energy dissipating structure is a rock chute located immediately downstream of the proposed culverts under the on-ramp. The rock chute is located at running distance 326 and encompasses the entire 52-metre right-hand bend downstream of the culverts. The properties of the rock chute are described further in Table C-20 and Figure C-3 in Appendix C.4.

Rock armouring

Rock armouring would be placed in areas where scour erosion is most susceptible. These locations include:

- About 30 metres upstream and downstream of the Eight Mile Lane overhead crossing along the entire height of the batters, on both sides. (Volume = 670 cubic metres, assuming d50[8] = 400 millimetres and depth is twice d50)
- Around 15 metres upstream from the on-ramp culverts along both sides and the entire height of the batters. (Volume = 190 cubic metres, d50 = 400 millimetres)
- About 50 metres downstream of the on-ramp culverts along both sides (bordering the rock chute) along both sides, starting from half-way up the batter and tapering down to 2 metres up the batter. (Volume = 450 cubic metres, d50 = 400 millimetres)
- About 800 square metres for the exit chute, existing bank armouring and apron. (Volume = 650 cubic metres, d50 = 400 millimetres).

Re-vegetation

Early establishment of vegetation and erosion protection prior to the diversion receiving flows would be particularly important to the success of the diversion. This in conjunction with other scour and erosion measures would help to maintain the integrity of the diversion banks and bed. Jutemat (fine), a hessian woven matting product, which is 100 per cent biodegradable is often used to aid the establishment of grasses in soils which are susceptible to erosion by wind and water. The bed and banks should also be planted out with endemic native species which can tolerate the potentially fast flowing environment in which it would be placed.

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[7] Location in metres from downstream extent of diversion.
[8] Sediment size for which 50% by weight of the particles are smaller; similarly d65, d85, d90 represent sizes for which 65%, 85% and 90% of the particles are smaller.

Additional measures

A number of issues were highlighted during the design of the Picaninny Creek diversion which require further consideration during final design of the interchange at Eight Mile Lane and associated drainage infrastructure.

- There is limited room for the diversion at the confluence of the diversion with Picaninny Creek – it is restricted at this point by both the location of the Pheasant creek meander and also the construction boundary
- Batter stability issues – should be assessed due to the potential close vicinity of the drainage pond and also the highway batter slopes to the creek diversion. Sufficient room either side of the diversion route should be allowed for maintenance access and to meet stability requirements
- High results – for the velocity, shear stress and stream power at the entrance to the Eight Mile Lane culvert and confluence at Pheasant Creek can be addressed to limit bed scour at this point through rock armour applied to the bed and banks. The locations, volumes and size of rock should be confirmed during detailed design
- Vegetation – specification of species, location and numbers to re-vegetate the diversion channel should not only address local vegetation requirements, but also species that would be able to tolerate the physical conditions within the diversion channel. The planting of endemic species which existing on the bed and banks of Picaninny and Pheasant Creeks should be considered.

8.1.6. Cane drainage

All cane drains crossed by the project are incorporated into the existing concept design through the co-location of culverts along the project length. In some instances where several cane drains cross the project in close proximity, drains would be diverted and combined upstream to allow them to be directed under the project via one large culvert instead of several small culverts. This approach allows for a more cost-effective design and is not expected to create further impacts.

As with mitigation of impacts to cane drainages during construction, consultation would be undertaken with the relevant drainage unions and impacted landowners during the detailed design phase to ensure cane drainage is adequately allowed for in individual locations. This approach would also capture opportunities to simplify cane drainage for farmers through basic modification of current drains already requiring diversion.

There are three main areas where major cane drainage diversions will occur along the project: the Shark Creek floodplain (Section 4), immediately north of Tuckombil Canal (Section 8) and cane land to the west of Wardell (Section 10). Mitigation measures for these areas are further discussed in the following subsections.

Shark Creek floodplain - Section 4

The issue of cane drain diversion is of most relevance for the Shark Creek floodplain, which has large areas of cane farmland. Further, major waterway structures on the floodplain would also be coordinated with these smaller drainage structures to provide adequate cross-drainage for both smaller and larger events during the detailed design phase. Identified diversions (greater than 50 metres) along the project in the Shark Creek floodplain are detailed in Table 8-4 and presented in Figure 8-1.

Table 8-4 Cane drainage diversions in Shark Creek basin (Section 4)

Station (km)	Mitigation measure
70.0 - 70.5	Existing drain runs parallel to the project – diversion of southern and northern drainage along project to drain at Stn 70.5.
71.7 – 72.4	Existing drain crosses project at Stn 72.4 and drains south-west along edge of cane land – diversion of northern cane land drainage along northern edge of project to pass underneath project at Stn 71.7.
73.4 – 74.7	Existing drain crosses project at Stn 74.7 and is pumped over high ground at several locations to join with major drain crossing back underneath project at Stn 73.4 – diversion of this drain along western edge of project to join up with major drain. Also picks up diversion of another minor drain crossing west-east under project at Stn 73.6.

North of Tuckombil Canal - Section 8

A large tract of cane land exists along the project immediately to the north of Tuckombil Canal, including some very low-lying land. Identified diversions (greater than 50 metres) in this section of the project are detailed in Table 8-5 and presented in Figure 8-2.

Table 8-5 Cane drainage diversion north of Tuckombil Canal (Section 8)

Station (km)	Mitigation measure
131.1 – 131.8	Existing major drain crosses project north-south at Stn 131.1 and two minor drains cross project north-south at Stn 131.4 and Stn 131.8 and run east-west to converge with major drain at project at Stn 131.1 – diversion of drains at Stn 131.4 and Stn 131.8 along northern edge of project to combine with major drain and pass underneath bridge at Stn 131.1. Small diversion of east-west running drain to converge with major drain immediately downstream of the project.
133.5 – 134.3	Existing minor drain crosses project east-west around Stn 134.2 – diversion of drain south-west along project about 300 m and then south to join with minor drain which would cross project at Stn 133.55.

West of Wardell - Section 10

A smaller region of cane land exists to the west of Wardell, with some drainage diversion being required along the project to combine cane drains through culvert structures. These diversions are detailed in Table 8-6 and presented in Figure 8-3.

Table 8-6 Cane drainage diversion west of Wardell (Section 10)

Station (km)	Mitigation measure
153.0 – 153.2	Existing drains cross project west-east at Stn 153.05 and Stn 153.2 – diversion of drain at Stn 153.2 south along western edge of project to join with drain at Stn 153.105 and pass west through culverts underneath project.
153.4 – 153.6	Existing drains cross project west-east near Stn 153.5 and at Stn 153.6 – diversion of drain near Stn 153.5 north along western edge of project to join with drain at Stn 153.6 and pass west through culverts underneath project.
154.0 – 154.1	Five existing drains converge at project at around Stn 154.05 – four drains are diverted to be combined upstream (north-west) of the project with the remaining drain diverted around 100 m downstream (south-east) of the project to combine with new drain at culvert outlet.
154.6 – 154.8	Existing drain crosses project at around Stn 154.75 – drain diverted west to pass through culverts underneath project at around Stn 154.65.

Figure 8-1 Proposed cane drainage diversions in Shark Creek basin (Section 4)

Figure 8-2 Proposed cane drainage diversions north of Tuckombil Canal (Section 8)

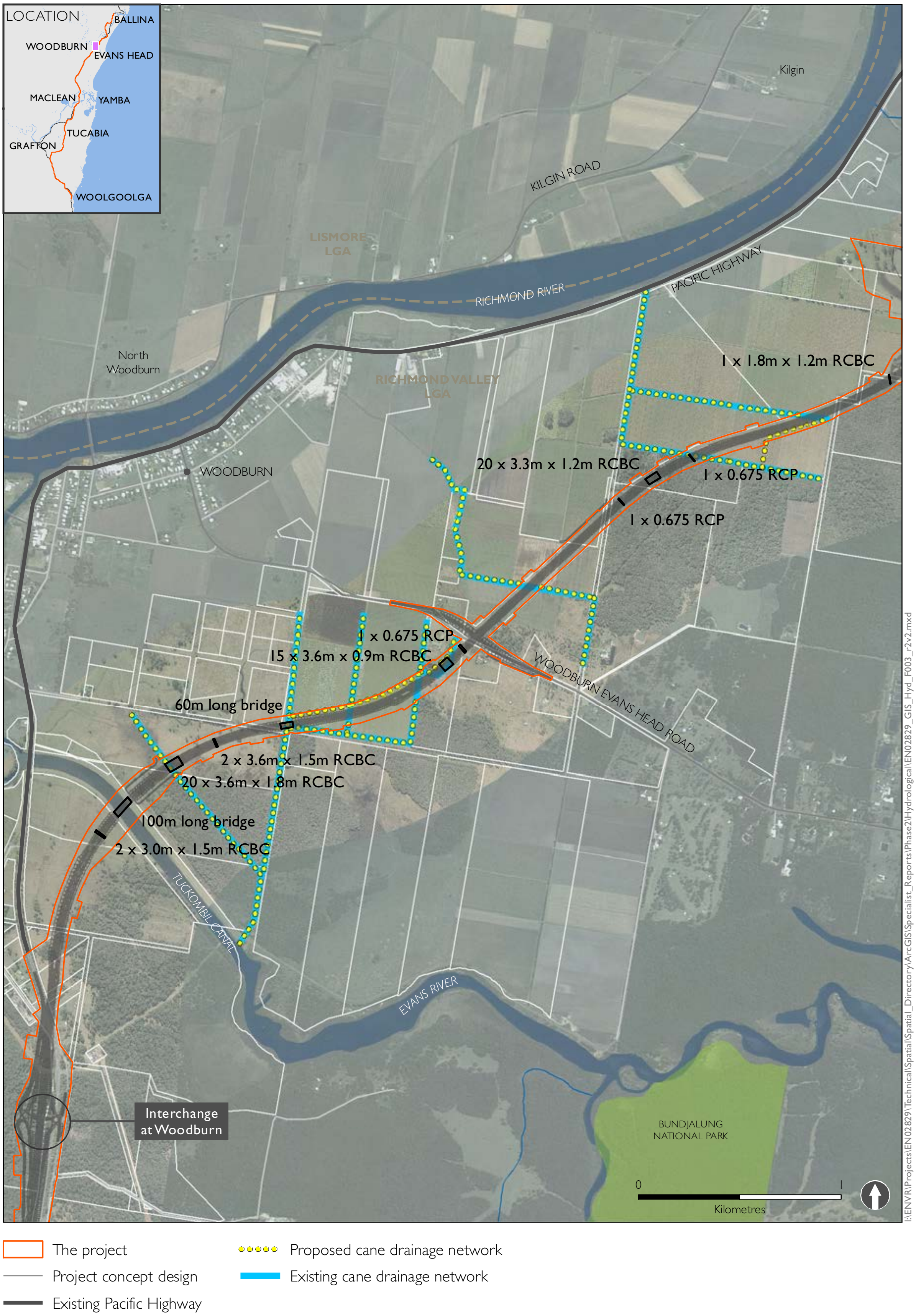
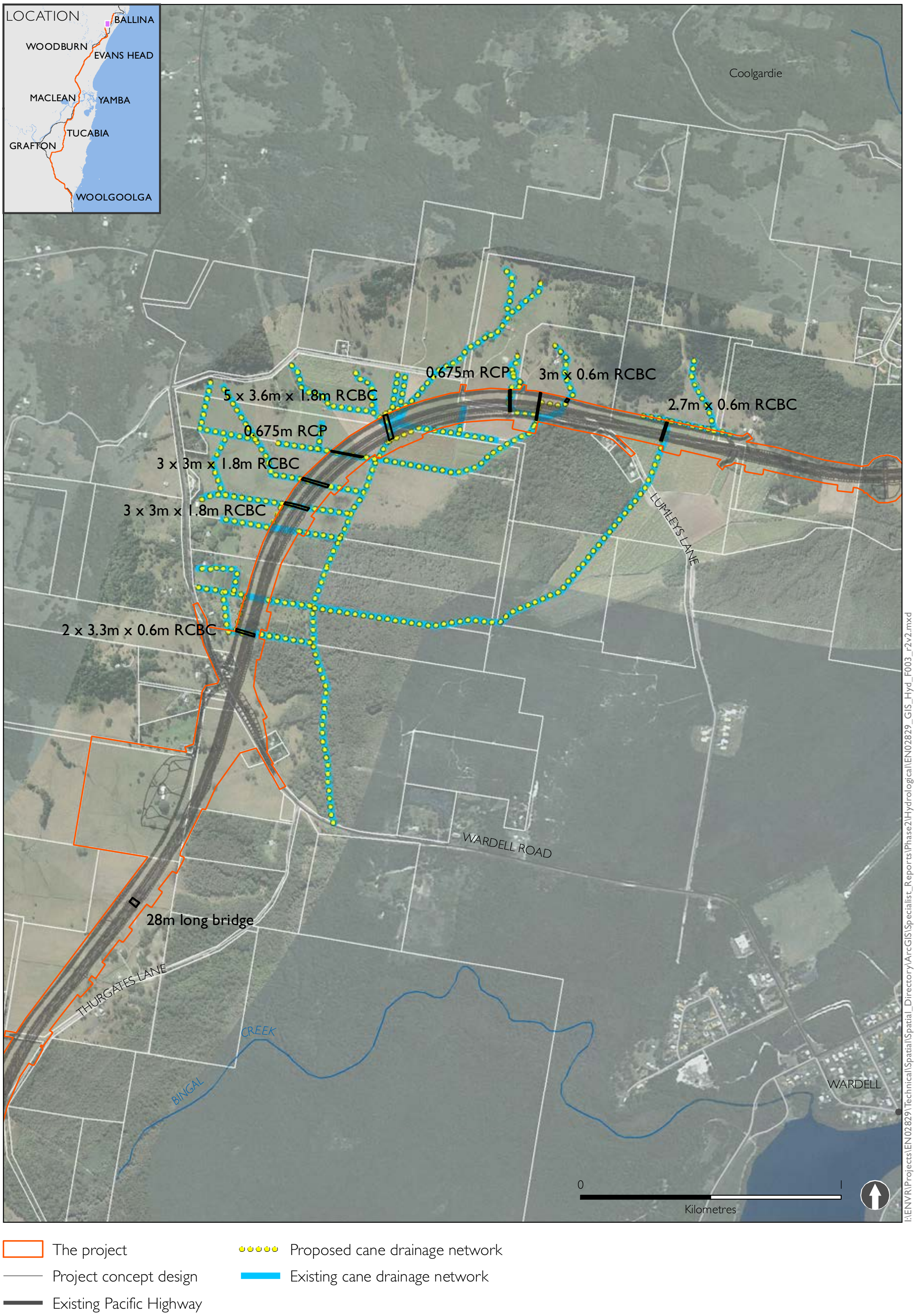


Figure 8-3 Proposed cane drainage diversions west of Wardell (Section 10)



8.1.7. Farm dams

Farm dams which are located inside the project boundary would be acquired as part of the project land acquisition process. Consequently, there are no mitigation measures identified for these dams, although landowners would be compensated accordingly.

In areas where loss of catchment area is a result of the project cutting into elevated catchment terrain, it may be possible for rainfall run-off to be re-diverted back into the farm dam catchment through appropriate drainage routes (subject to land acquisition agreements and environmental assessment). This would be adopted at the detailed design phase wherever possible.

Alternative mitigation measures would be investigated on a case-by-case basis where re-diversion of stormwater is not an option. In most cases it may not be possible to adopt an alternative mitigation measure; in this instance, compensation of landowners would be considered in conjunction in line with other property acquisition processes.

8.1.8. Evacuation and access

During consultation for the project, concerns were raised by some owners of farming properties about potential impacts on the movement of cattle and farm machinery between paddocks due to the location of the highway. In particular, issues were raised about restrictions on the movement of cattle during flood events and general connectivity between agricultural land parcels.

Currently, most owners of farming properties have evacuation procedures specific to their individual circumstances. These may include arrangements between neighbouring farmers or family members which are not formalised or documented, or they may include use of local flood refuges established on Crown land by the NSW Government. Evacuation routes to flood refuges on Crown land in the Pillar Valley and Tyndale have been assessed in Sections 6.7.3 and 6.9.3 respectively.

Concerns were also raised by some owners of private land regarding impacts to flood evacuation procedures and access for residents. Instances of impacts to current evacuation and access procedures have already been identified for some residents. However, it is possible that some private property owners may have individual circumstances for evacuation which may be impacted by the project which may not yet be identified.

The RMS is continuing to consult with property owners directly impacted by the project about potential property impacts and opportunities to minimise impacts on future development and the use and functioning of rural properties. However, the informal nature of other flood refuge locations or farmers' or residents' individual evacuation procedures means that it is not practicable for a comprehensive assessment to be undertaken during concept design.

Consequently, contact with individual farmers and residents would continue to be undertaken as part of consultation during the detailed design phase. Farmers and residents would be able to voice concerns relating to potential impacts to stock refuges or evacuation routes as part of this process, which would allow the most current practices to be understood. Any potential impacts identified would be assessed against the most current design and flood modelling results and individualised measures would be developed in consultation with property owners to mitigate any identified impacts. These would be developed on a case-by-case basis and may include measures such as extending bridges to incorporate an underpass or raising access tracks or roads.

Currently, several mitigation measures have been proposed or incorporated into design to manage impacts identified to-date. These are summarised in Table 8-7.

Table 8-7 Flood evacuation and access mitigation measures

Station (km)	Mitigation measure
Approximately 3.0	The level of flood immunity of Eggins Drive into Corindi would be further reviewed in consultation with Coffs Harbour City Council
4.6	Consultation with land owners at detailed design to confirm or disregard potential stock access impacts and determine suitable management measures if required.
43.1	Construction of an access track under the eastern abutment of the bridge over the Coldstream River to assist in the movement of stock during times of flood. This access track would need to be constructed above 2.1 m AHD and tie into the ground adjacent to the project boundary at 2.1 m AHD.
48.8 – 49.1	Access to flood refuge on Mitchell Hill maintained via the Mitchell Road underpass.
52.0	Appropriate flood evacuation and stock refuges for a property at approximate station 52.0 near Chaffin Creek would be further considered.
57.2	Access to a property during local flooding in the Champions Creek catchment may experience prolonged closure as a result of the project. Mitigation may involve either longer or additional bridging over Champions Creek to reduce flood impacts or raising Somervale Road by about 0.5 m over a length of about 120 m. This approach would also require minor (200 millimetres) raising of the private road on the northern bank of Champions Creek.
64.7 – 65.9	Access to Tyndale flood refuge maintained via new road and overpass which connects to Coldstream Road to the west of the project.
71.2	Residents on Byrons Lane currently use a small boat to gain access to the existing highway once flood levels prevent access by vehicle. The project will make it very difficult if not impossible to access the existing highway by boat. Consultation between the RMS and the property owner is ongoing as no cost effective measure has yet been identified to directly mitigate this impact.
121.2 – 122.1	Consultation with a property owner at Oakey Creek at detailed design to confirm or disregard potential restrictions to stock movement during peak flooding and determine suitable management measures if required.

8.1.9. Permanent road fencing

The project may require permanent border fencing or fauna fencing along the project to restrict access. At the detailed design phase, design of any permanent fencing at culvert and bridge crossings would need to consider the potential for blockage and be designed and operated in a manner that would not result in impacts to flooding.

8.1.1. Waterway ecology

Changes in hydrological and flooding conditions as a result of the project have the potential to impact aquatic ecosystems. The potential impacts identified with respect to changed hydrological response and/or flooding behaviour are generally related to the habitats and potential habitats of threatened fish species (Oxleyan Pygmy Perch and Purple-spotted Gudgeon) near the project. During detailed design, the design of project structures would be further considered to further assess velocity impacts to Oxleyan Pygmy Perch in consultation with relevant government agencies.

8.1.2. Ongoing consultation

Continual consultation with the NSW Office of Water and relevant councils would be required during detailed design regarding flooding impacts on residents and properties during construction and operation. This would also involve ongoing consultation with residents through the detailed design phase which would assist in the identification of changed or changing conditions such as landholding and/or land use.

8.2. Construction measures

The management of flood impacts is incorporated into the project design as discussed throughout Section 6.1. Further discussion on measures to mitigate flood impacts due to ancillary facilities and impacts of the project on cane drainage are presented in the following subsections. Construction will need to be managed at the detailed design phase in accordance with the NSW Office of Water guidelines which consider instream works, outlet structures, riparian corridors, watercourse crossings and Vegetation Management Plans.

8.2.1. Ancillary facilities

Several construction sites are identified with the potential to cause impact to existing flooding conditions, generally due to their location. Table 8-8 summarises the measures proposed to mitigate potential flood impacts for these ancillary facilities identified in Section 5.2.

Table 8-8 Ancillary facilities flood mitigation measures

Section No.	Site No.	Mitigation Measure
3	2	Ensure adequate drainage through site. May require small diversion around southern end of site.
3	5	Would need to allow adequate room for flow corridor. Recommend moving south to clear main channel and bridge.
4	2	Would require cane drainage through or diversion around the site, or reshaping of the construction site to avoid crossing cane drains.
4	6	Recommend reshaping to a longer and narrower site to keep site away from main channel.
4	7a	Recommend reshaping of site boundary by 30m from the south to allow greater passage of backwater drainage.
4	7b	Recommend reshaping of site boundary by 30m from the south to allow greater passage of backwater drainage.
5	2a	Recommend moving site south if possible, or reshaping to move site away from areas of high conveyance.
5	2b	Recommend contracting site south if possible or reshaping to move site away from areas of high conveyance.
5	2d	Recommend contracting site south to clear current bridge underpass, or reshaping to move site away from areas of high conveyance.
5	3a	Recommend contracting site north to clear current bridge underpass, or reshaping to move site away from areas of high conveyance.
5	3b	Site would require relocation away from bridge or splitting of site to ensure unobstructed flow across site.
5	4a	Recommend moving site if possible, or relocating the culverts. Given large size of site and constraint of project boundary may be considered an acceptable risk in consideration of comparable impacts imposed in this area during project operation and the probability of a large flood during construction. Measures adopted for this site should be considered in conjunction with Section 5 – Site 4b.
5	4b	Due to small size, recommend moving site north or south to clear multicell culvert. Measures adopted for this site should be considered in conjunction with Section 5 – Site 4b.
5	5a	Site requires relocation or reshaping to ensure bridge remains unobstructed during construction.
5	6	Site requires adequate drainage or diversion around the site to accommodate flows for floods of up to 100 year ARI.
6	3a	Recommend contracting site at the northern boundary around 100 m south to ensure clear flow through culverts.
6	3b	Recommend contracting site at the southern boundary north around 120 m.
8	1	Site may require consideration of flow around or across site during large flood events.
8	2a	Recommend moving site to the north of the Woodburn overpass.
8	2b	Recommend moving site to the north of the Woodburn overpass.
8	2c	Site would need to accommodate culvert under Woodburn overpass.
9	1	Site may require consideration of flow around or across site during large flood events.
10	1a	Recommend moving site south around 150 m to be clear of Richmond River Bridge

Section No.	Site No.	Mitigation Measure
		underpass and the bridge to the south at station 145.5.
11	2	Recommend moving this site around 650 m south on the western edge of the project boundary.

8.2.2. Soft soil sites

The project requires construction of sections of embankment in advance of the road construction to accelerate the settlement of soft soils. These works are referred to as 'soft soil sites' in the project. The source of fill for the construction of these sections of road embankments would come from nearby sections of cut for the project. For the soft soil treatment sites, as discussed in Section 5.3, the following mitigation measures have been proposed.

To ensure cane drains remain operational throughout the duration of construction, temporary drainage culverts under the soft soil treatment sites would be used. These temporary culverts would convey local runoff towards the flood-gated culverts and the Clarence River. These temporary drainage culverts would be sized during detailed design.

In the early stages of a Clarence River flood, the Goodwood Street underpass is the first (and for some time only) flowpath into the Chaselings Basin area. While soft soils sites are present, a conduit with an equivalent capacity of the current Goodwood Street underpass must be maintained during all flood seasons for the entire period of construction, as detailed in Section 8.2.4.

At Chatsworth Island, a gap of 180 metres would need to be included in the soft soil treatment site embankment to reduce the impact it would otherwise have on the surrounding flood levels.

8.2.3. Cane drainage

Diversions currently proposed to mitigate operational impacts are discussed in Section 8.3.1. However, construction impacts would fluctuate and would need to be resolved at the detailed design phase. This would include a detailed consideration of the crossing of cane drain networks and consultation with the relevant drainage unions.

There are a number of options available at the detailed design phase to incorporate waterway crossing structures. A site-based approach would be the most effective method of ensuring suitable allowances for cane drainage are made during construction. This would involve both consultation with the relevant drainage unions and targeted consultation with impacted landowners.

Targeted consultation would enable access to landowners' in-depth knowledge of the drainage issues affecting their land. This approach would also further capture opportunities to simplify cane drainage for farmers through basic modification of current drains already requiring diversion.

8.2.4. Goodwood Street underpass

As discussed in Section 5.3.4, one of the most important flood elements on the Chaselings Basin area is the Goodwood Street underpass. During Clarence River flood events, floodwaters pass under the existing Pacific Highway via the Goodwood Street underpass and fill the large Chaselings Basin area. In the early stages of a Clarence River flood, this is the first – and for some time, the only – flowpath into the Chaselings Basin area.

At some stage during construction, drainage would convert from the existing underpass to culverts. In order to mitigate impacts from floods occurring during this time, a conduit with capacity equivalent to the existing Goodwood Street underpass needs to be maintained during all flood seasons.

8.2.5. Bridge pier construction

Bridge piers are to be constructed in the Corindi River, Halfway Creek, Pheasant Creek, Coldstream River and tributary, Pillary Valley Creek, Clarence River, Clarence River North Arm, Tabbimoble Creek (and tributary), Tabbimoble Floodway No. 1, Tuckombil Canal, Richmond River and Duck Creek. Any infrastructure associated with the construction of bridges and bridge piers in (but not limited to) the Clarence River, Clarence North Arm, Richmond River and Tuckombil Canal would be removed from the river and floodplain during times of flood to avoid the creation of floating debris and potential blockages.Given the length of flood events of these rivers, there would be ample warning time (several days) to remove and secure infrastructure.

As previously stated, construction would also need to be managed at the detailed design phase in accordance with the NSW Office of Water guidelines for instream works.

8.2.6. Waterway diversions

Revegetation of any diverted waterways and surrounding areas would:

- Be completed prior to the diversion receiving flows, in conjunction with the establishment of other scour and erosion control measures
- Include planting and the establishment of appropriate vegetation communities along the channel bed and banks, using endemic native species that are able to tolerate a potentially fast-flowing environment.

8.2.7. Temporary fencing

Construction of the project may require border fencing along the project. At the detailed design phase, design of fencing at culvert and bridge crossings would need to consider the potential for blockage and be designed and operated in a manner that doesn't result in impacts to flooding. This may either be through temporary fencing that can be easily removed during flood events (ie for regional flooding where ample warning time is provided), or specifically designed so that blockage of structures would not occur.

Where there is a high potential for fencing to capture debris and a low risk of stock crossing the road – for example across sugarcane floodplains – the need for border fencing may be reassessed during detailed design where it may not be suitable.

8.2.8. Ongoing consultation

Continual consultation with the NSW Office of Water and relevant councils would be required during construction regarding flooding impacts on residents and properties. This would also involve ongoing consultation with residents through the construction phase which would assist in the identification of changed or changing conditions such as landholding and/or land use.

8.3. Operational measures

The concept design has been generally developed so potential impacts on flood behaviour have been reduced to a level that would adequately meet the design flood management objectives.

Modifications to bridge and culvert structures to manage flood impacts are incorporated throughout the design process. Due to the large number of structures incorporated into the design throughout the length of the project, these are discussed on a catchment-by-catchment basis throughout Chapter 6.

Some targeted approaches or specific measures are presented in more detail below to address ancillary issues, such as cane drainage, scour erosion, and geomorphological impacts due to the Picaninny Creek diversion.

8.3.1. Drainage structure maintenance

Blockage of drainage structures has the potential to cause upstream impacts during both flooding events and regular streamflow. To reduce the potential for this occurring, regular clearing of drainage structures would be required to maintain the efficacy of structures by keeping culverts and bridges free of debris.

8.3.2. Climate change impact mitigation

A climate change management strategy is proposed for the project and would include the following measures:

- The selection, sizing and design of bridge structures, drainage structures and detention basins would be finalised during detailed design in consideration of climate change factors
- The need for design modifications to address changes in flood behaviour as a result of climate change would be assessed periodically throughout the life of the project

- Should the need for raising the road embankment levels or modifying waterway openings be identified, this would be carried out during periodic pavement rehabilitation works.

This strategy would provide a project with an adaptive approach to developing resilience to climate change.

9. Conclusion

The flooding and hydrology assessments carried out to support this working paper identified a number of key findings. These include:

- The estimation of the minimum road levels required to meet the flood immunity objectives of the project. These levels have been incorporated into the concept design to ensure that the project meets the flood immunity objectives
- The sizing of waterway openings required to meet flood management objectives. These waterway openings have been incorporated into the concept design
- The extent and nature of flood impacts on each of the major watercourses crossed by the project. These impacts have been assessed in a consistent manner across the project in line with the stated methodology
- The predicted changes to long-term average annual flood damages for houses impacted by the project on the Clarence and Richmond river floodplains
- Identification of key watercourses that will require further detailed geomorphological assessments at the detailed design stage to address changes to flood velocities and instream pier construction
- The management measures required to mitigate hydrology and flood impacts during the construction phase
- The measures required to accommodate changes to rainfall intensity and sea levels over the life of the project.

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