7.5 Flooding

This chapter provides an assessment of flooding, which was nominated in the DGRs as a key environmental issue for the project. It represents a summary of the *Surface Water, Groundwater and Flooding Technical Paper* (AECOM, 2012), which was prepared for the project to address the DGRs.

The technical paper is provided at **Appendix H**. The relevant extract from the DGRs is presented below.

Director-General's requirements	Where addressed
Flooding *- including but not limited to:*	
Identifying potential impacts of the project on existing flood regimes, consistent with the Floodplain Development Manual (Department of Natural Resources 2005), including impacts to existing receivers and infrastructure and the future development potential of affected land, demonstrating consideration of the changes to rainfall frequency and/or intensity as a result of climate change on the project. The assessment shall demonstrate due consideration of flood risks in the project design.	Section 7.5 Appendix H – Technical paper: Surface water, groundwater and flooding.

7.5.1 Methodology

The general approach and methodology adopted for this assessment includes:

- Compilation and review of available information, such as previous reports, 1:25,000 topographical maps, aerial photogrammetric survey and detailed field survey (where available), and hydraulic structure information. This included consideration of studies conducted by Cardno and SMEC Australia Pty Ltd on behalf of Shoalhaven City Council for floodplain management.
- Development of performance criteria based on the *NSW Floodplain Development Manual* (DIPNR, 2005) and specifications and technical criteria of the RMS.
- Estimation of peak flows for each catchment and for each major drainage infrastructure located along the project alignment based on the Probabilistic Rational Method (PRM) in accordance with *Australian Rainfall and Runoff* (Institution of Engineers, Australia, 1987).
- Provision for potential climate changes within the peak flow estimates to assess the impacts of a six per cent increase in rainfall intensity, in accordance with the Office of Environment and Heritage (OEH) guideline *Practical Consideration of Climate Change – Floodplain Risk Management Guideline* (Department of Environment and Conservation (DEC), 2007).
- Use of XP RAFTS and TUFLOW models developed for the Broughton Creek Floodplain Risk Management Strategy and Plan (Cardno, 2012) to assess major crossings of the project at Broughton Mill Creek, Bundewallah Creek and Connollys Creek floodplain immediately north of Berry. The TUFLOW two-dimensional model, developed by Cardno, covers an area of around nine square kilometres that corresponds to Berry and its immediate surrounds.
- Use of the HEC-RACs one-dimensional model and culvert hydraulic calculations to assess other water crossings at Broughton Creek, as well as Hitchcocks Lane Creek and Hitchcocks Lane Tributary.
- Each model considered the one, two, five, 10, 50 and 100 year flood event for the existing catchment (without the project) and the project.
- Assessment of other culvert crossings using either the Bentley Culvert master or HY-8 culvert hydraulic software packages.

In assessing the performance and/or impacts of the project, the following three scenarios have been considered:

- A representative scenario, which corresponds to the proposed drainage infrastructure (including culverts and bridges) perform as designed.
- A worst case scenario, which represents when all proposed drainage infrastructure becomes blocked during a flood event. The worst case scenario would be ameliorated by the implementation of appropriate mitigation measures, as outlined at **section 7.5.4**.
- The probable maximum flood (PMF) event, which has been assessed for emergency planning purposes only. The PMF is the largest flood that could conceivably occur at a particular location.

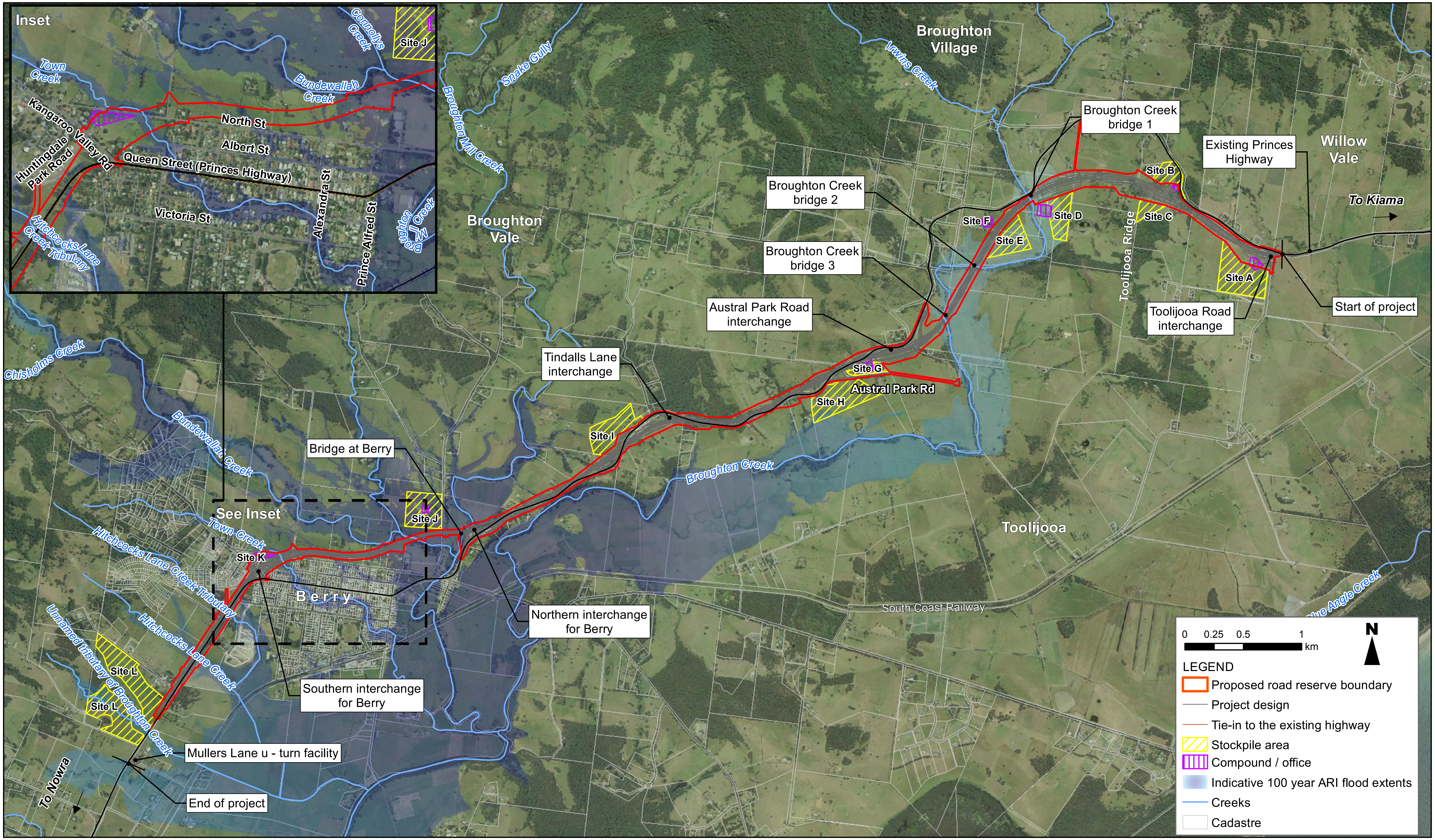
7.5.2 Existing environment

A full description of the waterbodies present in the project area is provided in **Section 7.4** of this environmental assessment. This section focuses on flooding matters.

Broughton Creek is a tributary of the Shoalhaven River which drains across the northern side of the Shoalhaven floodplain. Agriculture is the major land use in the vicinity of the project, with extensive areas utilised for dairy and cattle grazing. Downstream of the Berry township, the terrain is flat, swampy and generally below the level of the Broughton Creek levees. Tidal influence extends around 12 kilometres upstream of the point where Broughton Creek and the Shoalhaven River merge, to the vicinity of the Coolangatta Road bridge.

Floods inundate areas of rural land adjacent to Broughton Creek (refer to **Figure 7-15**). There are minimal structures located within the floodplain (1 in 100 year), with the majority of land utilised for agricultural purposes. During large flood events, the banks of the upper Broughton Creek are overtopped with flood waters taking the shorter routes across the floodplains and returning to Broughton Creek some distance downstream.

Berry and its immediate surrounds are also prone to flooding, with Broughton Mill Creek, Connollys Creek, Bundewallah Creek and Town Creek being the main sources of flood waters (SMEC Australia Pty Ltd, 2008). Town Creek presents a particular flood risk to a significant number of properties within Berry, which are impacted by the 100 year flood event.



Path: \\ausyd1fp001\Projects\60021933_G2B\4_Tech_work_area\4.7_GIS\Maps_20120925_CaitlinBennett\Fig 7-15_G022_Indicative100yearARI_120803.mxd 26/09/2012

Figure 7-15 Indicative 100 year flood extents along the project alignment

Source: AECOM (2012), Cardno (2011), LPMA (2011)

The existing Princes Highway at Berry is also impacted during major flood events. At the highway crossing at Broughton Mill Creek and Hitchcocks Lane Creek, the highway is overtopped in a 1 in 2 year flood event. The highway is also overtopped as a result of flooding of Town Creek and Hitchcocks Lane Tributary during the 1 in 20 year flood event and 1 in 100 year flood event respectively. Overtopping of the highway during flood events can eliminate access for north and south bound highway traffic. Rural/residential areas near Hitchcocks Lane tributary can also be flooded during the 100 year flood event.

7.5.3 Assessment of potential impacts

Construction

A number of ancillary construction sites would be provided along the project alignment. Some of these sites would be located within the floodplain, including those that would be located near Broughton Creek and would be inundated during the 1 in 100 year flood event (refer to **Figure 7-15**). This includes stockpiling sites adjacent to Broughton Creek, the site located adjacent to Woodhill Mountain Road and the site located south of Schofields Lane. If inundated during a flood, material, fuel, chemicals and equipment stored in stockpile and compound sites could wash away. This could impact the surrounding environment, particularly adjacent waterbodies. Compounds and stockpiles could also affect flood flow paths, if inappropriately located.

Operation

Broughton Creek, Connollys Creek, Broughton Mill Creek, Bundewallah Creek, Town Creek and Hitchcocks Lane Creek have the potential to be impacted by the project. Culverts, bridges and embankments proposed as part of the project would potentially impact the existing flooding regime by:

- Reducing the capacity of the floodplain to store flood water due to the road being constructed on floodplains and taking up area previously available for water storage. This could lead to increases in the extent and level of flooding.
- Affecting the existing flood conveyance due to the restriction of waterways by bridges or culvert crossings. This could lead to increases in flood levels and velocities.
- Affecting flood behaviour through interfering with existing flow patterns, leading to the re-distribution of flows that could impact on flood levels, overland flow paths and flow velocities. This includes the piers of the bridge at Berry at Bundewallah Creek and the diversion of Town Creek flows to Bundewallah Creek, upstream of Connollys Creek.

These potential impacts to the existing flooding regime could provide negative or beneficial impacts to structures, roads and stock access due to increases or reductions in flood levels and flood extents.

High flow velocities resulting from flooding would also potentially lead to bed and bank scour and erosion both at and downstream of culvert outlets and bridge crossings. Such erosion could potentially lead to structural failure of infrastructure components and could lower water quality of nearby waterways.

The main objectives for the drainage design for the project are to provide the required flood immunity for the project and to minimise changes to the existing flood behaviour. The proposed road level, bridges and culverts have been designed to achieve the following:

- Flood immunity for the project during the 1 in 100 year flood event, with adequate freeboard.
- Flood immunity for local roads during the 1 in 20 year flood event.
- Cross drainage structures, such as culverts, to convey a 1 in 100 year flood event where surcharge is undesirable, or the 1 in 50 year flood event where surcharge is allowable.

The design of the project has taken into consideration the requirement to minimise potential flooding impacts on upstream and downstream properties. The design has also factored in an increase in rainfall intensity of six per cent to take into account the effect of climate change.

Details of each proposed bridge or culvert is provided in **Table 7-56**. **Figure 7-16** illustrates the catchments corresponding to **Table 7-56**.

The impacts of the project on flooding, and the performance of the proposed drainage were considered for both the representative scenario and the worst case scenario. The worst case scenario would be ameliorated by the implementation of appropriate mitigation measures, as outlined at **Section 7.5.4**.

During the representative scenario, flood water levels would be no higher than the existing situation between Broughton Creek bridge 3 and Tindalls Lane. However, changes in flood levels to varying degrees have been predicted at all the proposed major bridge structures at Broughton Creek, and north of Berry. Changes to flood patterns would also occur as a result of the proposed diversion of Town Creek. These impacts are considered individually in detail further in this section.

In terms of regional impacts resulting from the loss of flood storage capacity on the floodplain and/or in the flood fringe area, the project is not considered to have any significant effect on flooding in the Shoalhaven River. This is because the footprint of the proposed project is relatively small when considered against the total flood storage of the Broughton Creek floodplain. As identified earlier, localised flooding impacts would occur as a result of the project.

Table 7-56 Description of project structures

Catchment*	Infrastructure description	Waterway	Design flow (m^3/s)	Number of cells or piers	Span or diameter (m)	Length of bridges (m)	Comments
LB	Culvert drop structure	Unnamed ephemeral	2.7	1	1.5		Existing structure.
K	Bridge	Broughton Creek	646	6 piers	4	122	Broughton Creek bridge 1.
KA	Pipe	Broughton Creek	32	4	1.8		Pipe culvert at northern embankment of Broughton Creek bridge 1.
LA	Box culvert	Unnamed ephemeral	n/a	1	4.6h x 3.0w		Oversized to provide access therefore would not create upstream impacts.
L	Bridge	Broughton Creek	661	4 piers	3	76	Broughton Creek bridge 2.
M	Bridge	Broughton Creek	715	10 piers	6	200	Broughton Creek bridge 3.
N	Pipe culvert	Unnamed ephemeral	4.8	2	1.5		To provide drainage under the main carriageway and secondary roads on each side of the project.
O	Pipe culvert	Unnamed ephemeral	4.8	2	1.5		
P	Pipe culvert	Unnamed ephemeral	4.1	3	1.5		
Q	Box culvert	Unnamed ephemeral	48	7	1.8		A minimal water level impact is desirable due to existing upstream property. Dual use fauna underpass.
R	Box culvert	Unnamed ephemeral	9.0	1	1.5		Dual use fauna underpass.
S	Pipe culvert	Unnamed ephemeral	12.1	1	1.5		
TC	Pipe culvert	Unnamed ephemeral	0.6	1	1.5		
TA	Pipe culvert	Unnamed ephemeral	2.6	1	1.5		

Catchment*	Infrastructure description	Waterway	Design flow (m^3/s)	Number of cells or piers	Span or diameter (m)	Length of bridges (m)	Comments
TB	Pipe culvert	Unnamed ephemeral	0.7	1	1.5		
T	Bridge	Broughton Mill Creek/ Bundewallah Creek/Connollys Creek	896	54 piers	54	600	The bridge at Berry. Some piers may be located within Bundewallah Creek as a visual impact mitigation measure.
WA	Box culvert	Town Creek diversion under Rawlings Lane	33.9	5	2.4h x 2.1w		Designed to carry the 1 in 100 flood event with appropriate freeboard.
XA	Pipe culvert	Duck pond ephemeral	3.23	1	1.5		Culvert would provide flows to existing duck pond (Mark Radium Park).
X	Pipe culvert	Tributary to Hitchcocks Lane Creek	36.0	1	1.8		
Y	Pipe culvert	Hitchcocks Lane Creek	33.1	1	1.8		
Z	Pipe culvert	Unnamed ephemeral	2.0	1	1.5		Designed for the 1 in 5 year flood event. A lower design year has been proposed as it is a temporary structure that would be replaced as part of the Berry to Bomaderry upgrade proposal.

** Refer to **Figure 7-16** for the location of the catchments and Surface Water, Groundwater and Flooding Technical Paper* (AECOM, 2012) found at **Appendix H**. *Catchment TB has not been shown on **Figure 7-16** .*

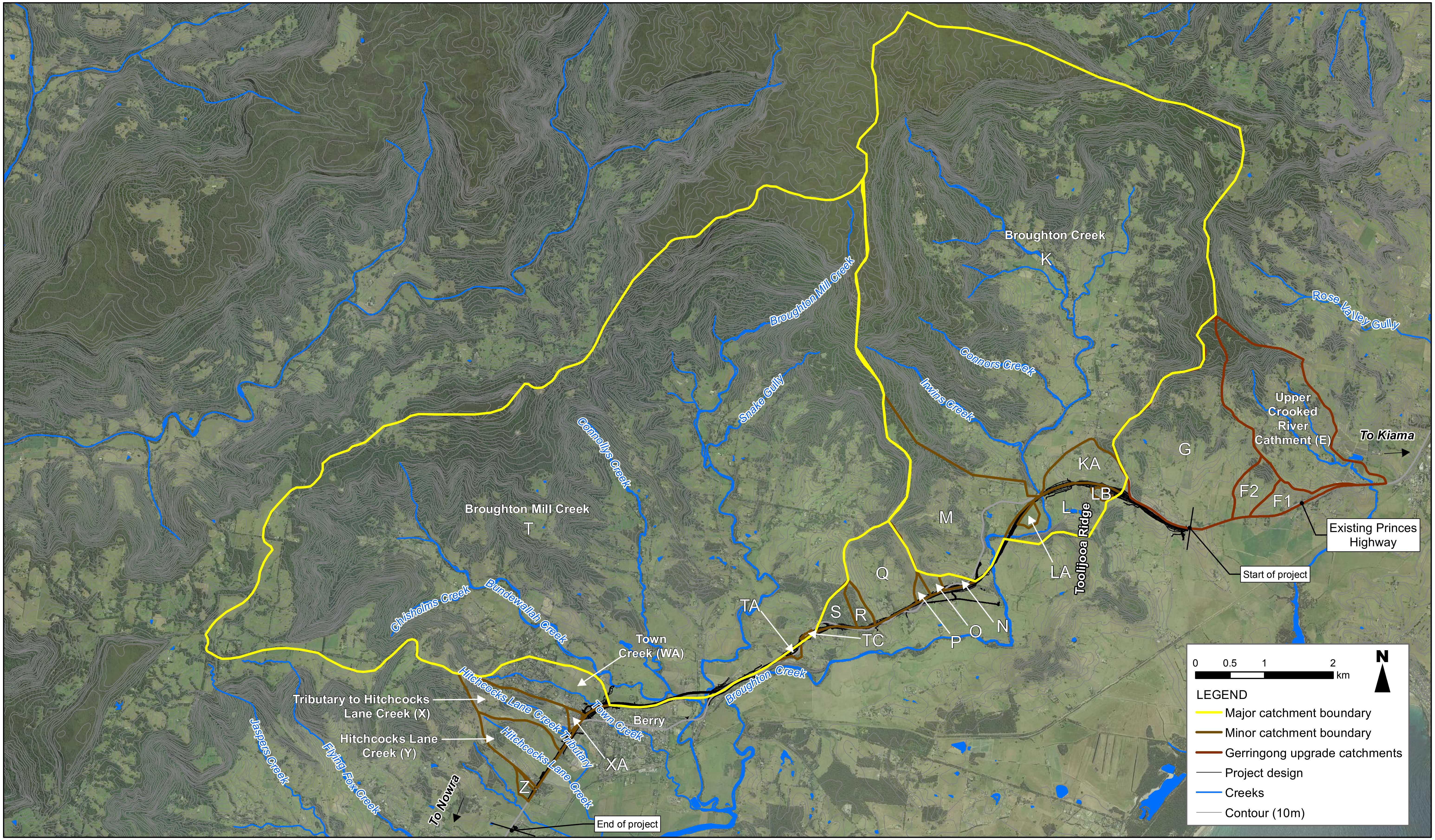


Figure 7-16 Catchment map (catchment lettering corresponds to Table 7-54)

Source: AECOM (2012), LPMA (2011)

Note: Catchment TB has not been shown on the figure for clarity reasons

Broughton Creek

At Broughton Creek bridge 1, the project increases peak flood levels by 0.4 meters upstream of the bridge due to the bridge abutments extending into the existing 1 in 100 year flood extents. This would impact the flood immunity of the existing highway bridge, located 20 metres upstream at this location, with the potential for some localised overtopping of the existing highway bridge during the 1 in 100 year flood event. However, the project would provide the alternative flood immune access in this area. Otherwise, the impacts would generally be limited to agricultural land and due to the steep slopes at the edge of the floodplain, it would not result in any significant increase in the extent of the 1 in 100 year flood. Structures and accesses (other than the existing highway bridge) would not be impacted.

In the vicinity of the proposed Broughton Creek bridges 1 and 2, events above the 1 in 5 year flood event currently lead to the Broughton Creek banks being overtopped with flood waters flowing across the floodplain. The general flow paths for these events without the project are shown in **Figure 7-17**.

The proposed construction of the embankment linking Broughton Creek bridges 2 and 3 would split this overbank flow at Broughton Creek into two paths on the eastern and western side of the alignment, as shown in **Figure 7-18**. This change would impact flood levels by the following three mechanisms:

- The separated flow would produce turbulence and energy loss that would increase flood levels upstream.
- The placement of fill within the floodplain would potentially reduce the storage and capacity of the floodplain. However, this is deemed relatively insignificant due to the large width of the floodplain.
- The overland flow distribution across the floodplain would be altered with more flow along the eastern side of the alignment. This could increase flood levels upstream of Broughton Creek bridge 2 and along the eastern side of the embankment between bridges 2 and 3.

The area where there would be an increase in upstream flood levels, due to these mechanisms is shown in **Figure 7-18**. The change in flood levels during peak flood events has been estimated at 0.3 metres in the 1 in 100 year flood event. The impacts of the increase would be limited to agricultural land and would not impact on any structures or accesses. The impacts would also not result in any significant increases in the 1 in 100 year flood extents due to the steep slopes at the edge of the floodplain.

On the western side of the embankment upstream of Broughton Creek bridge 3, flood level impacts are expected to be minimal due to the diversion of more flood flows along the eastern side of the embankment. However, the embankment would change flow paths and could have localised impacts to rural pastures of properties along Broughton Creek where flows are redistributed.

A small tributary flows across a property immediately upstream of Broughton Creek bridge 3 and joins Broughton Creek around 200 metres downstream of the bridge. The Austral Park Road interchange with the existing Princes Highway could affect the flow patterns of this tributary and depending on the distribution of flows on either side of the embankment between bridge 2 and 3 could cause localised flood impacts to the property immediately upstream of bridge 3. The maximum impact immediately upstream of the bridge is around 0.1 metres. However, the impact at the residence itself is likely to be less.

Floodwaters flowing parallel to the embankment between bridges 2 and 3 also pose a risk to the structural integrity of the embankment due to scouring.

The construction of the embankments and bridges would also isolate an area of private land, which could pose a risk to stock and/or humans if there isn't the provision of stock refuge or evacuation routes. This is discussed further in **Section 7.5.4**.

At Broughton Creek bridge 3, the bridge abutments are on the fringe of the 1 in 100 year flood extents and therefore have minimal impacts on flood levels. No infrastructure or buildings would be impacted.

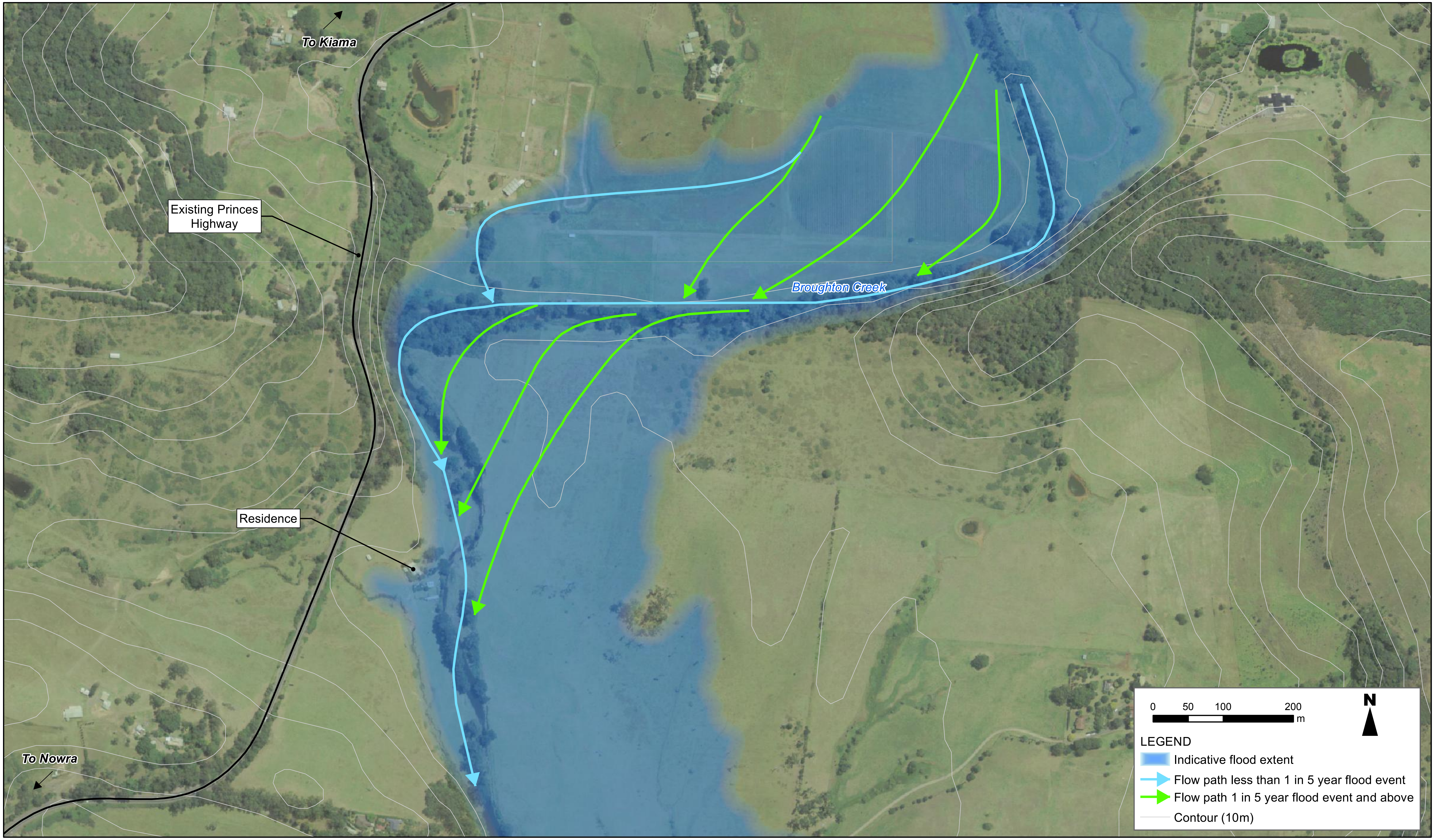


Figure 7-17 Broughton Creek overbank flowpaths without the project

Source: AECOM (2007), LPMA (2011)

Path: \\ausyd1fp001\Projects\60021933_G2B\4_Tech_work_area\4.7_GIS\Maps_20120806_DKennewell\Centred_121030\Fig 4-7_G024_Overland Flow Paths Map1_121030.mxd 6/11/2012

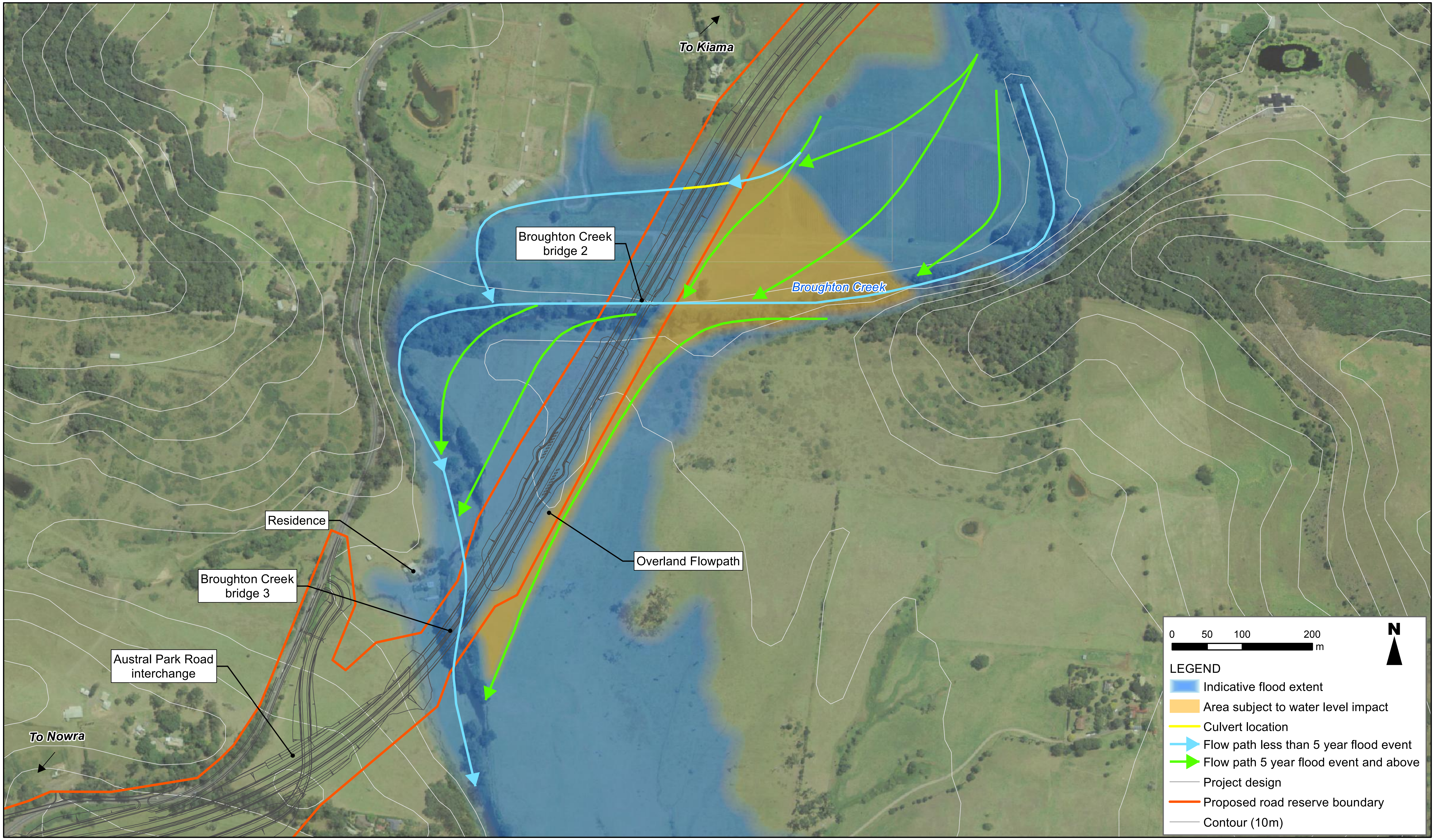


Figure 7-18 Broughton Creek overbank flowpaths with the project

Source: AECOM (2007), LPMA (2011)

Path: \\ausyd1fp001\Projects\60021933_G2B4_Tech_work_area\4.7_GIS\Maps_20121010_Updated_from_20120925\Fig 7-18_G025_OverlandFlowPathsMap2_121024.mxd 6/11/2012

Broughton Mill Creek, Bundewallah Creek and Connollys Creek

The bridge at Berry crosses the point where Connollys Creek, Broughton Mill Creek and Bundewallah Creek merge. The height of the bridge is constrained by the height of the ridge to the north of Berry and the requirement to provide adequate clearance for Woodhill Mountain Road. As such, the bridge itself would be considerably higher than the peak flood level of the 1 in 100 year event.

The southern bridge abutment would extend approximately 200 metres into the existing 1 in 100 year flood extents. Piers and water quality structures under the bridge would also be within the flood extents. As a result of these structures, an increase of 0.3 metres in flood levels is expected around the upstream side of the southern abutment (refer to **Figure 7-19**).

Immediately downstream of the project there would be an increase in flood levels due to the loss of floodplain storage, the concentration of flows through the structures of the bridge at Berry combined with the additional flows from Town Creek. As a result, 11 properties are potentially affected by changes in flood levels as a result of the project as shown in **Figure 7-19**.

Flood levels would increase by around 0.06 metres at property 1 and 0.08 metres at property 2 and 3 due to the loss of floodplain storage. This would reduce the freeboard at the buildings located at these properties. However, property 1 and 2 would still have a freeboard in excess of 0.5 metres. The freeboard at property 3 would be reduced from 0.18 metres to 0.11 metres. Other areas impacted by the increase in flooding are used for agriculture and are zoned for rural purposes under the Shoalhaven Local Environmental Plan (LEP) 1985. This land is already flood affected as it is within the existing 1 in 100 year flood extents and as such, the project would not be expected to alter the development potential of this land

Property 4 would be impacted by the combination of the diverted flows of Town Creek together within the concentration of flows through the bridge opening. No detailed floor level or ground level data is available for this property. However, the results of the flood model suggest that it experiences significant inundation around the building. Further survey data is required to confirm the susceptibility of the building floor level to flooding and if mitigation would be warranted.

Property 5 is also impacted by the diversion of Town Creek and changes in the flow regime at the bridge at Berry. As the floor level survey of property 5 shows that the building is elevated over three metres above the 1 in 100 year flood event, an increase of around 0.03 metres is not considered significant.

Properties 6, 7, 8, 9 and 11 are predicted to experience an increase of 0.03 metres due to the diversion of Town Creek. This increase is considered minor relative to the existing level of inundation during the 1 in 100 year flood event.

Property 10 is the sports amenity building at the Berry sportsground. Increases at this building based on the current project design are considered negligible or minor.

The impact on properties 1 to 10 needs to be considered in the context of the improvements within Berry that would be achieved through the diversion of Town Creek flows.

Town Creek

Town Creek currently causes flash flooding within Berry. The construction of the proposed highway around the northern side of Berry presents an opportunity to alleviate the existing flash flooding during large events for the residents of Berry and the wider community to the south of the highway, by diverting flows from the northern catchment of Town Creek into Bundewallah Creek. The location of the diversion is shown in **Figure 4-3** and is described in **Chapter 4. Figure 7-19** illustrates the potential change in flood levels as a result of the diversion.

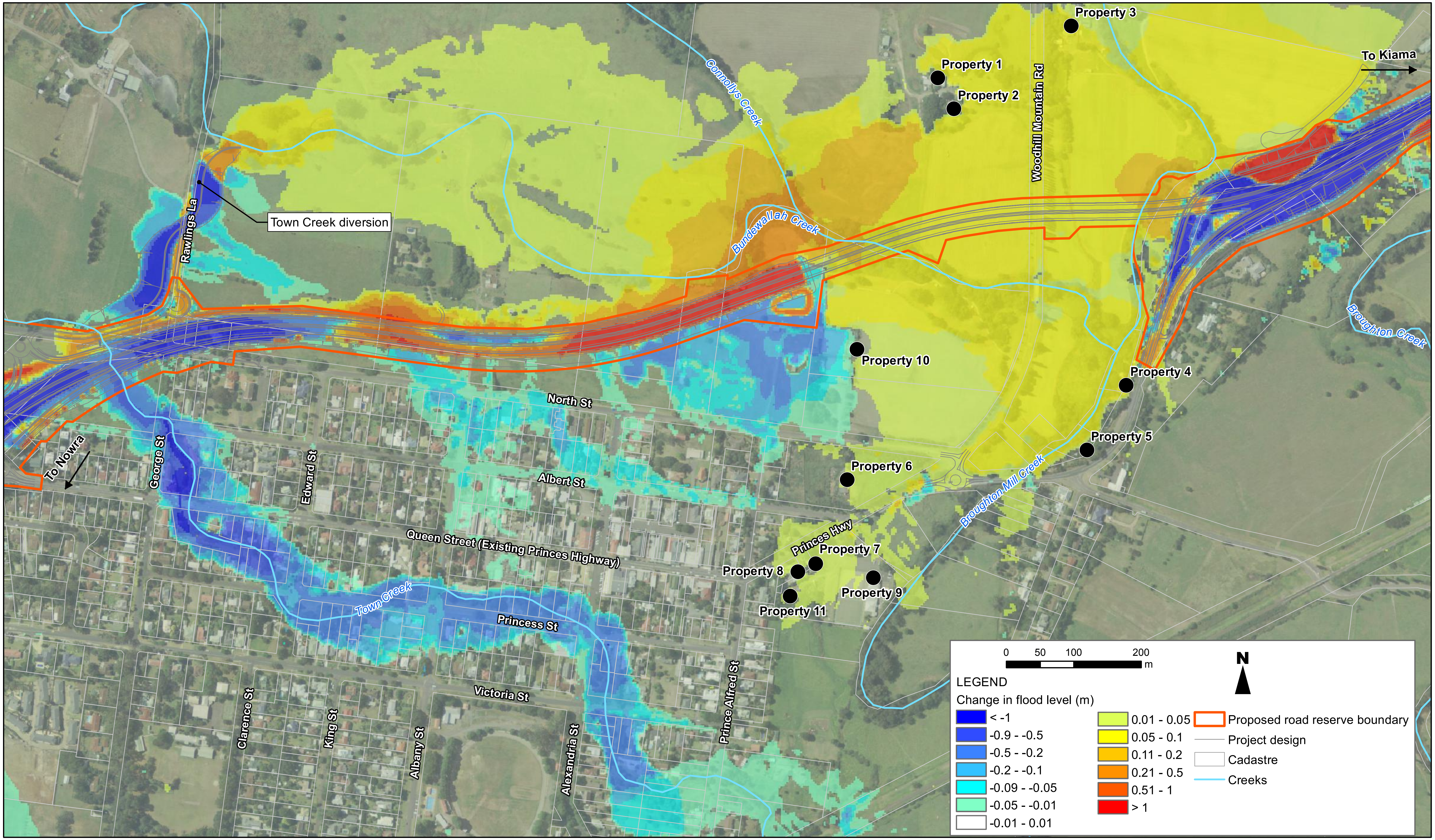


Figure 7-19 Changes in flood levels at Berry in the 1 in 100 year flood event

Source: AECOM (2012), Cardno (2011)

Path: <dyn type="document" property="path"/> <dyn type="date" format="short">

The diversion channel would be sized to fully convey the 1 in 100 year flood flow event (with the required freeboard) from Town Creek into Bundewallah Creek. As such, there would be minimal flood level impacts along the diversion alignment. Further, the culverts constructed under Rawlings Lane, where the diversion would cross under the lane, would also be designed to convey the flows of a 1 in 100 year flood event without overtopping the lane. The diversion would also be designed to prevent high velocities (which can be a hazard during floods) and to limit scour in the diversion swale, at the culvert outlets and where the diversion connects to Bundewallah Creek.

The diversion of Town Creek has the potential for positive flood impacts for Berry, with a reduction in flood levels in a 1 in 100 year flood event through town in excess of one metre (refer to **Figure 7-19**). This would provide a significant benefit to many of the properties within Berry that currently experience flooding. Around 80 residences and structures would receive a flood depth decrease within Berry as a result of the Town Creek diversion and the predicted reductions in flood levels at North Street (in the vicinity of Albany Street). Of the 80 residences, nine properties that currently experience above floor inundation in the 1 in 100 year flood event would become flood free (but with a relatively small freeboard).

The diversion would result in a loss of 47 per cent of the total Town Creek catchment downstream of Berry. However, the loss of flood flows from the north of the highway would have little effect on water quality south of the highway. This is because the waterway is ephemeral and has been extremely degraded by agricultural and residential land uses. Impacts on aquatic ecology and riparian vegetation would also be minor, and are discussed further in **Section 7.3**.

North of Berry

The construction of the bypass north of Berry and the diversion of Town Creek has the potential to change flood levels immediately north, as shown in **Figure 7-19**.

For the agricultural property located immediately north of the project, there would be potential increases in flood levels. This would not impact the dwelling at the property. The area that would be impacted is used for agriculture, is already within the existing 1 in 100 year flood extents and is zoned for rural purposes under the Shoalhaven LEP. As such, the impact of the project would not significantly alter the already limited development potential of this area.

A new access to the property would be provided off Rawlings Lane as the project severs the existing direct access to North Street. This new access would be designed to provide the same level of flood free access to the property as provided by the current access via North Street.

Changes in flood behaviour for more frequent events

The proposed works would impact on flood behaviour during more frequent flooding than the 100 year flood event (such as the five year flood event and the 10 year flood event) through the same mechanisms as described above, namely:

- The narrowing of the floodplain caused by the embankment and abutment works at Berry Bridge.
- The diversion of flows from Town Creek into Bundewallah Creek.

Generally, the impacts experienced during more frequent events would be of a similar or lesser nature than those described for the 100 year flood event. During more frequent flood events the proposed embankment and abutment works associated with the bridge at Berry would encroach into flooded areas to a lesser extent compared to the 100 year flood. Consequently, this would be expected to result in smaller relative impacts on flooding during the more frequent flood events.

The diversion of flows from Town Creek into Bundewallah Creek would result in similar changes in flood behaviour during more frequent flood events as those described for the 100 year flood event. However these impacts would be relative to smaller flood extents and levels associated with these more frequent events

Worst case scenario

The worst case scenario considered involves the complete blockage of drainage infrastructure. There is a very low risk of this scenario occurring, due to the provision of appropriate environmental management measures and design standards. These measures are discussed further in **Section 7.5.3**.

The potential flood impacts, in terms of flood water flow behaviour, would be similar to those expected during a PMF (as discussed later in this section), but with lower flood volumes. During this scenario, flood waters would follow new overland flow paths where possible. There would also be increased scour and erosion due to increased flow velocities at partially blocked culverts or bridge openings. This could affect ecosystems, impact on flood levels and could ultimately affect the structural integrity of the road infrastructure. At certain locations, this could also impact on buildings, as discussed later in this section.

Regional flooding

The PMF is the largest flood that could conceivably occur at a particular location and is a theoretical maximum event.

During the PMF:

- The project would be overtopped by about three metres between Broughton Creek bridges 1 and 2. This would not change flood evacuation routes, as the existing highway is already overtopped during a PMF under existing conditions.
- An increase in flood levels up to two metres above existing levels upstream of Broughton Creek bridge 1 and at Broughton Creek bridge 2 could occur due to the raised road embankment blocking flood flows. No critical infrastructure would be affected, however dwellings on private properties could be affected.
- Drainage crossings, that convey much smaller flows, would have localised impacts during these events but would not affect any critical infrastructure.
- There would be minimal impact on Broughton Creek bridge 3 and the bridge at Berry due to the large bridge waterway openings and the elevation of the bridge above the floodplain.
- North of Berry, the project would reduce the flood risk to Berry as well as some access routes, such as the South Coast railway line.
- An increase in flood levels of around 0.2 to 0.6 metres to the north of the bridge at Berry. Downstream of the bridge, an increase of 0.15 metres is predicted.
- The diversion of Town Creek would provide flood relief to much of the Berry township, with a reduction of up to 0.9 metres at properties within Berry.
- Raised road embankments across the creeks to the west of Berry could result in flood impacts upstream of the project, especially to properties located below the proposed road level.
- At Hitchcocks Lane tributary, impacts would be limited to the area between the project and Huntingdale Park Road. At this location, the project would be three metres above the existing road level and the flood impacts could extend as far as the northern boundary of the property through which the creek runs.

The scope for managing flood impacts on surrounding development includes events up to and including the 1 in 100 year flood event. Events above the 1 in 100 year flood event, such as the PMF, are considered in terms of regional flood behaviour, such as impacts to critical infrastructure and emergency response planning.

It is generally not physically or economically possible to provide complete protection against the PMF. As flood mitigation measures are designed to be effective for events up to the 1 in 100 year flood event, the project would have impacts during the PMF. However, the consequence of flooding during the PMF even without the project will already be significant. Impacts of the project would not affect critical infrastructure and evacuation routes. Further, the project would reduce the flood risk to Berry. As a result, the project should not impact on emergency responses during a PMF.

Climate change

The project has been designed with an awareness of the potential for climate change and the range of potential impacts associated with the project factor in an increase in rainfall intensity of six per cent to take into account the effect of climate change.

The potential increase in rainfall intensities has been assessed as part of the flood modelling assessment (refer to the *Surface Water, Groundwater and Flooding Technical Paper* located at **Appendix H**), and has applied a sensitivity analysis for increases in rainfall intensity of 10, 20 and 30 per cent during a 1 in 100 year flood event.
The assessment focused in two key areas of the project, being the three bridges that cross Broughton Creek and the western abutment of the bridge at Berry (as it has the least amount of freeboard provided in its design). This assessment indicated that:

- For the three bridges at Broughton Creek, a 10 per cent increase in rainfall intensity would increase flood levels by around 0.1 metres and a 30 per cent increase would increase flood levels by 0.4 metres.
- At the western abutment of the bridge at Berry, a 10 per cent increase in rainfall intensity would increase flood levels by around 0.05 metres and a 30 per cent increase would increase flood levels by 0.13 metres.

The potential impacts due to climate change at some point in the future are at worst expected to reduce the freeboard which would normally be available. The changes are within the available freeboard provided at this location and no additional allowance for climate change is considered necessary.

7.5.4 Environmental management measures

Mitigation and management measures would be implemented to minimise or manage impacts to flooding. These mitigation and management measures are identified in **Table 7-57 a**nd have been incorporated in the draft statement of commitments in **Chapter 10**.

Table 7-57 Mitigation and management measures

Potential impacts	Mitigation and management measures
Construction	
Flooding of ancillary sites, stockpiles and hazardous substances	Store chemicals and fuel above the 1 in 100 year flood level where possible. Locate stockpiles and ancillary sites above the 1 in 100 year flood level where possible. If sites cannot be located above the 1 in 100 year flood level, locate them above the 1 in 20 year flood level subject to the implementation of appropriate mitigation measures to reduce flood risk and impacts on the surrounding environment (such as provision of a sufficient freeboard for storage areas). Provide appropriate bunding and scour protection where storage on floodplains is essential, such as in areas where bridge works are required.
Impacts of significant weather events	Implement on the ground environmental controls and response procedures to mitigate the potential impacts of significant weather events. Procedures typically include relocation of equipment or materials to higher ground, the implementation of erosion and sediment control shut down procedures, installation of additional protection measures, such as scour protection controls, and arrangements for the remediation and re-installation of these controls. Consider the use of automatic weather stations to provide a weather response monitoring program if flood prone ancillary sites are used. The Construction Environmental Management Plan would include a requirement to undertake appropriate checks of the Bureau of Meteorology weather bulletins.
Operation	
Increase in flood levels	Design drainage structures to allow for the natural flow of floodwaters and existing overland paths to be maintained post-construction where possible. Locate piers outside the main creek channels where possible, and minimise the intrusion of bridge abutments into the 1 in 100 year flood extent. Design bridges to minimise increases in flood levels and velocities where possible. Design and orient bridge piers to avoid the generation of turbulence and subsequent bed and bank erosion. Undertake rock shielding to protect steepened batters along the bank.

Potential impacts	Mitigation and management measures
	Use scour protection measures or energy dissipation measures along the bed and banks upstream and downstream of any bridge crossing or culvert where high velocities of surface water runoff cannot be minimised by design or by energy dissipaters. This may include flow velocity management measures to minimise erosion and scour in watercourses, or collection and management of runoff waters.
Flood impacts at Broughton Creek bridge 2 and Broughton Creek bridge 3.	Undertake further detailed modelling, and refine the bridge design during the detailed design stage of the project to minimise flood and scour impacts at Broughton Creek bridge 2 and Broughton Creek bridge 3. Provide a stock refuge at Broughton Creek bridge 2 by including access roads under the bridge to provide a flood evacuation route for stock. Alternatively provide mounds within the floodplain located in fringe areas or at the base of the proposed embankment. Stock refuge would be investigated further during the detailed design phase of the project.
Flood impacts at Berry	Confirm potential flooding impacts at Berry during detailed design and develop necessary mitigation measures. Based on project design, the following mitigation options would be considered, and where relevant: • Option 1 – Use of methods such as diversion swales, local bunding, flood proofing of buildings or other agreed solutions at properties 1, 2, 3 and 5 (subject to landowner agreement). Similar mitigation measures would be considered for property 4 should further floor survey data warrant a need for flood mitigation responses following detailed design. • Option2 – Consideration of changes during detailed design to the bridge design at Berry, retaining walls and associated drainage structures as an alternative to mitigation at properties 1, 2 and 3.
Climate change impacts	Provide a freeboard of around 0.5 metres minimum for Broughton Creek bridge 1, 2 and 3, as well as the bridge at Berry. Design the project with additional drainage capacity in order to provide flood immunity on the carriageway for a 1 in 100 year flood event. This would be based on a six per cent allowance for increased rainfall intensities. Use an adaptive approach to the management of the impact of climate change on flood behaviour and the performance of the highway drainage structures. If required, local adaptive measures for minor waterway crossings could include culvert amplification and/or lifting of the level of the highway.

7.5.5 Residual impacts

The potential impacts on property and structures during the 1 in 100 year flood flow event, and mitigation options to minimise the impact have been described in **Section 7.5.3** and **Section 7.5.4**. Specifically, residual flooding impacts would include:

- Reduced floodplain storage and alteration to the overland distribution of flood flows in the region of the Broughton Creek bridge 2 and Broughton Creek bridge 3. This would change flood levels in this region.
- Changes to flood hydrology at Town Creek, Bundewallah Creek and Broughton Creek from installation of transverse drainage structures.
- Increased flood levels at several properties due to the concentration of flows through the structures of the bridge at Berry and the addition of flows to Bundewallah Creek from Town Creek.
- Permanent diversion of Town Creek. The project would cause a residual loss of overall flows and flushing flows from Town Creek, which would potentially increase sedimentation in both Town Creek and Bundewallah Creek. However, the diversion would also have the positive residual impact of reducing flood impacts within Berry.

As part of the detailed design stage of the project, the flood impacts at these locations would be confirmed. This would inform the final mitigation options that could be implemented into the project design to minimise changes in flood levels and velocities, or mitigation options at properties (refer to **Table 7-57**). These mitigation options would be determined during detailed design and in consultation (where relevant) with the affected landowners.