NSW GOVERNMENT | Transport Roads & Maritime Services

Foxground and Berry bypass

Princes Highway upgrade

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Technical paper: Surface water, groundwater and flooding

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Princes Highway upgrade

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Executive summary

The Roads and Maritime Services (RMS) is seeking approval under Part 3A of the *Environmental Planning and Assessment Act 1979* for the upgrade of 11.6 kilometres of the Princes Highway, to achieve a four lane divided highway (two lanes in each direction) with median separation between Toolijooa Road north of Foxground and Schofields Lane, south of Berry (the project). The project would include bypasses of Foxground and Berry. The key features of the project are shown in **Figure 1-1**.

The project is one of a series of upgrades to sections of the Princes Highway which aims to provide a four lane divided highway between Waterfall and Jervis Bay Road, Falls Creek. This would improve road safety and traffic efficiency, including for freight, on the NSW south coast.

This report discusses surface water, groundwater and flooding issues associated with the project.

Surface water

Existing environment

The project would begin at Toolijooa Road, pass through a large cutting and onto the Broughton Creek floodplain. It would then cross Broughton Creek three times before joining the existing Princes Highway alignment, following a ridgeline east of Berry. The project alignment would cross the confluence of Broughton Mill Creek, Connollys and Bundewallah Creek via the proposed bridge at Berry. It would then pass north of the Berry township, crossing a number of smaller catchments from the surrounding foothills, before finishing south of Schofields Lane. The project would also include the diversion of Town Creek to the north of the upgrade into Bundewallah Creek upstream of its confluence with Connollys Creek.

Water quality studies (refer to the *Aquatic Ecology and Water Quality Management Technical Paper* (Cardno, 2012) at Appendix G to this environmental assessment) determined that most waterways in the study area were considered typical of aquatic ecosystems that have been impacted due to agricultural and grazing practices, and that the existing pollution levels exceed those considered to be sustainable for maintaining ecosystem integrity. The values of total phosphorus within the Crooked River and Broughton Creek catchments are regularly above the Australia and New Zealand Environment Conservation Council (ANZECC) guidelines due to runoff containing manure and fertilisers from neighbouring pasture lands. In addition, the existing highway does not have any water quality controls and is likely to be contributing pollutant loads especially at or near creek crossing locations.

Broughton Creek is a Class 1 waterway providing major fish habitat. Broughton Mill Creek and Bundewallah Creek are Class 2 waterways providing moderate fish habitat and Connollys Creek is a Class 3 waterway with minimal fish habitat. Most of the higher elevation tributaries are ephemeral and are unlikely to provide fish habitat.

Downstream of the project, Town Creek is a relatively degraded stream having been cleared, urbanised and is thick with introduced vegetation. The vegetation creates the potential for blockage at a number of small culverts within Berry. These reaches are unlikely to provide fish habitat, have few standing pools and are largely disturbed.

No areas along the alignment have been identified as having high risk of containing acid sulfate soils.

Potential impacts

The primary risk to the surface waters during construction would be the increased potential for sediment release and transportation through runoff during clearing, cut and fill operations.

The primary risks to surface waters during operation would be an increase in surface runoff due to an increase in impervious surfaces and concentration of road runoff through drainage infrastructure, and the pollutants associated with road runoff, including sediments, oil and grease, heavy metals, chemicals and nutrients.

The proposal would include the diversion of Town Creek from its current alignment through Berry, to a new alignment that joins Bundewallah Creek to the east of Berry. This would increase flows in Bundewallah Creek, potentially increasing scour and erosion at the new confluence of Town and Bundewallah Creeks.

The proposed earthworks and associated changes to drainage would change the natural flow of water into some existing farm dams and potentially affect their yield.

Proposed mitigation measures

During the construction phase of the project, the overall erosion and sediment control strategy would be to first reduce erosion then capture sediment as close to the source as possible. Sediment basins are proposed to be utilised in a number of locations, however these would form only one part of the overall strategy. The sequencing of construction works would also form a key component of the erosion and sediment control strategy.

For the operational phase of the project, the strategy for the treatment of runoff includes using either swales and/or water quality basins designed to satisfy the target reduction in phosphorous and sediment pollutant loadings. Additional runoff treatment measures for outlets discharging directly to Broughton Creek, Broughton Mill Creek and Bundewallah Creek in the form of bioretention systems would be considered, space and grade permitting, to reduce nitrogen loads prior to discharge to sensitive receiving environments.

Bank stabilisation works, to mitigate scour would be incorporated at the new confluence of Town and Bundewallah Creeks.

Groundwater

Existing environment

There are two main aquifer systems present along the project alignment including unconsolidated and unconfined alluvial/colluvial aquifers, and Shoalhaven Group sediments.

Deep aquifers are accessed by the majority of licensed bores in the area extracting groundwater from depths between 30 and 50 metres below ground level. Groundwater quality data is limited. Groundwater level monitoring indicated the watertable naturally oscillates in response to climatic variation and topography.

A review of water bores registered with the NSW Office of Water (NOW) indicates there are 16 registered bores within 0.5 kilometres of the study area. Groundwater in this area is used for stock, domestic and agricultural purposes to supplement surface water supplies collected in dams and pumped from creeks.

Riparian vegetation associated with Broughton Creek is likely to be dependent upon groundwater to some extent. Groundwater discharge via springs, seeps or spring fed dams may also sustain local small communities.

Potential impacts

Potential impacts to groundwater due to the proposed construction works include the risk of hydrocarbon contamination via fuel spills, and potential changes in groundwater pH levels associated with the disturbance of acid sulfate soils. In addition, changes to groundwater flow patterns, recharge and discharge characteristics may be altered due to the intersection of the aquifer by artificial barriers such as road cuts and localised dewatering. It is not expected that groundwater extraction for water supply would be required during construction. If this need is identified during detailed design, further investigation would be undertaken.

Impacts occurring during the operational phase include road cuttings intercepting groundwater and locally lowering the water table, and the possibility that pollutants in road runoff may infiltrate to groundwater. There is a potential risk that groundwater dependent ecosystems (GDEs) may be impacted due to the development.

Proposed mitigation measures

Groundwater impacts during the construction phase would be managed through construction design and by management measures contained in a construction environmental management plan (CEMP) which includes a groundwater management plan for addressing issues during and after construction. Management measures would include:

- Minimising the depth of excavations in areas of alluvium.
- Limiting the need to dewater during construction.
- Limiting the need to excavate in areas if acid sulfate soils are identified.
- Using water treatment devices to treat runoff water quality before it has the opportunity to infiltrate to the water table.

Dewatering may be required during the excavation and construction of the Toolijooa Ridge cut and other deep cuts where the watertable would be intersected, and during the construction of infrastructure such as piles within the floodplain alluvium east of Berry. Discharge of the extracted groundwater would be to creeks or temporary storage in water quality basins to reduce turbidity prior to discharge.

During the operational phase potential on-going impacts to groundwater levels and groundwater quality would be addressed. Groundwater seepage into deep road cuts would be directed towards spoon drains that would flow by gravity into the road drainage system. Groundwater monitoring would be required to monitor potential impacts to groundwater quality. Included in the groundwater management plan would be emergency response plans to address spillages as a result of accidents that may impact on groundwater quality.

Flooding

Existing environment

The project traverses the Broughton Creek floodplain in the north, crosses a number of local ephemeral drainage lines through the hills between Tomlins Road and Tindalls Lane, then crosses the floodplain a second time near the confluence of Bundewallah, Connollys and Broughton Mill Creeks. It passes to the north of Berry before crossing a series of ephemeral creek lines between Berry and Jaspers Brush.

Named creeks and tributaries in the vicinity of the project include (from east to west):

- Broughton Creek.
- Broughton Mill Creek.
- Connollys Creek.
- Bundewallah Creek.
- Town Creek.
- Hitchcocks Lane Creek.

Connollys Creek, Bundewallah Creek, Broughton Mill Creek and Town Creek are the main sources of flooding in Berry. Town Creek in particular presents a flood risk to a significant number of properties within Berry. Cardno (2012) indicates the existing Princes Highway is overtopped during 100 year ARI event at the crossings of Broughton Mill Creek, Town Creek, Hitchcocks Lane Creek and Hitchcocks Lane Tributary.

Potential impacts

Where the alignment crosses the Broughton Creek floodplain there would be some localised increase in peak flood levels during the 100 year ARI event. This is due to changes in the overbank flow distribution patterns, particularly at Broughton Creek Bridge 2 where the proposed embankment has the potential to split flows along the east and west side of the embankment. These impacts would generally be limited to agricultural land use areas and would not impact structures or access, except for the existing Princes Highway crossing over Broughton Creek at Broughton Village.

The embankment between Broughton Creek bridge 2 and Broughton Creek bridge 3 may be subject to floodwaters flowing parallel to the alignment, along the toe of the embankment. This would increase the risk of scour of the embankment.

The project would cross the confluence of Connollys, Broughton Mill and Bundewallah Creeks at the bridge at Berry. While the bridge deck is located above the 100 year ARI flood level, the southern abutment extends out, into the existing 100 year ARI flood extent.

As a result of the highway works across the floodplain at Berry (including the embankment, piers and water quality basins) the available waterway area would be reduced and the 100 year ARI flood levels upstream of bridge at Berry would be affected. Areas downstream of the bridge would also experience increases in flood levels in the 100 year ARI event as a result of a combination of flows diverted from Town Creek together with a greater concentration of flow through the constricted bridge opening. There would be minimal flood level impacts along the Town Creek diversion route

Floor level survey has been used to undertake a review of those properties within Berry that may experience adverse flood impacts as a result of the proposed highway upgrade as well as those that will be better off.

Eleven properties near the bridge at Berry would be affected by changes in flood level as a result of the highway upgrade. For the three properties upstream of the bridge at Berry, the increase in 100 year ARI flood level would correspond to a reduction in freeboard as the properties do not currently experience flooding above floor level. One of the properties downstream of the bridge is far above the existing and proposed design flood levels and therefore not affected. The remainder of the properties currently experience flooding during the 100 year ARI event and the increase in flood levels at these properties is considered relatively minor in the context of the existing level of above floor inundation.

The proposed diversion of Town Creek would provide a significant benefit to properties within Berry township that currently experience flooding during large events. The existing portion of Town Creek flowing through the town of Berry (south of the proposed highway) will experience a lowering of 100 year ARI flood levels. Floor survey has been provided for 113 properties in the area around Town Creek, south of the proposed highway. Flood levels at these 113 properties would be reduced by a minimum of 0.01 metres to a maximum of 1.04 metres. Twelve houses currently have floor levels below the 100 year ARI flood level. Of these, nine would no longer experience above floor inundation. None of the properties in Berry would experience an increase in flood levels from Town Creek.

Climate change is expected to have adverse impacts on sea levels and rainfall intensities, both of which may have a significant influence on flood behaviour. Provision has been made in the design of the drainage structures for an increase in rainfall intensities of six per cent. Should rainfall intensities increase by more than six per cent there is the potential risk that the flood immunity of the highway would be reduced, that the capacity of drainage infrastructure would be exceeded and that flood extents would increase. An adaptive management approach to climate change is being taken by the RMS to manage these uncertainties.

Proposed mitigation measures

The alignment would be designed to be immune for flood events up to the 100 year ARI.

To minimise impacts on flow culverts would be located and sized to adequately convey the 100 year ARI runoff event (if on the main alignment) and designed to meet the design velocity criteria.

Bridge configurations would be designed to maintain existing flow patterns as far as possible to minimise increases in flood levels and velocities around the bridge structures. Upgraded highway levels would be set to provide the required 100 year ARI flood immunity with adequate freeboard to the underside of the bridge structure. Appropriate scour protection would be provided to the bridge abutments and piers where velocities have the potential to cause scour. Suitable batter treatment along the toe of the embankment between Broughton Creek bridges 2 and 3 would be designed to minimise damage or failure of the embankment due to scour.

Various options are available to reduce the impact of the on flood levels upstream and downstream of the bridge at Berry, including:

- Removal of the water quality basins that are located in the floodplain beneath the bridge at Berry.
- Modification of the retaining wall at the east abutment of the bridge to maintain the existing flowpath from the billabong at property 3.
- Creation of an opening at the western abutment of the bridge.

In addition to the above arrangements, all basins in the floodplain should be constructed at or close to ground level or replaced with bunded swales.

Provision would be made for adequate scour protection where velocities are high at the culvert outlets, in the Town Creek diversion channel and at the confluence of the Town Creek diversion channel and Bundewallah Creek.

Other mitigation options include local measures at individual properties such as diversion swales, local bunding or flood proofing.

The development of the proposed has been planned with an awareness of the potential for climate change impacts. The recommended measures to manage potential impacts would involve:

- The provision of an appropriate freeboard of around 0.5 metres minimum for major bridge waterway crossings on Broughton Creek and Berry.
- The provision of a six per cent allowance for increased rainfall intensities. For minor waterway crossing culverts, additional impacts could feasibly be accommodated (if required) through future local adaptive measures such as culvert amplification and/or lifting the level of the highway.

Further detailed modelling would be carried out as part of the detailed design process to confirm and minimise any flood level impacts.

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Glossary of terms and abbreviations

Term	Meaning
A	
Acid sulfate soils	Waterlogged soils that are rich in iron sulphides (primarily pyrite). If the sediments are exposed to air, the pyrite could be oxidised and generate sulfuric acid.
Afflux	The increase in upstream flood levels due to the restriction of flows.
ANZECC	The Australian and New Zealand Environment Conservation Council.
Aquifer	An underground waterlogged layer of permeable rock.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand.
ASSMP	An acid sulfate soil management plan.
Attenuation	Reduction of flows by providing flood storage.
Australian Height Datum (AHD)	A national standard level at approximately mean sea level.
Average Recurrence Interval (ARI)	A statistically derived estimate of the average time between rainfall and/or flooding events.
AWBM	The Australian Water Balance Model, which is a catchment scale rainfall/runoff numerical model.
AWS	Automatic weather station.
B	
Batter	A controlled sloping surface.
Bund	A small embankment designed to retain water.
C	
Catchment	A specific area where rainfall collects and drains to a known outlet.
CEMP	Construction environmental management plan.
Conveyance	The transportation of flow through a river or creek.
Critical storm	A storm that occurs for a precise time over a catchment of specific size to produce the greatest runoff and flow.
Culvert	A round or rectangular pipe that transports flow under a road or an embankment.
Cut	Excavation of the existing terrain to accommodate for new road levels.
Confluence	Joining of rivers or creeks.
Colluvial soils	Soils that have been formed by the deposition of particles due to gravity.
D	
DECCW	NSW Department of Environment, Climate Change and Water. Now part of the Office of Environment and Heritage.

Term	Meaning
DGRs	Director-General's requirements. Requirements and specifications for an environmental assessment prepared by the Director-General of the Department of Planning under section 75F of the *Environmental Planning & Assessment Act 1979*.
Discharge	Also known as flow which is the volume of water moving per time. Often measured in litres per second or cubic metres per second.
DLWC	The former NSW Department of Land and Water Conservation.
DNR	The former NSW Department of Natural Resources.
DSEWPAC	The Commonwealth Department of Sustainability, Environment, Water, Population and Communities.
DTIRIS	The NSW Department of Trade and Investment, Regional Infrastructure and Services
E	
EMC	Event mean concentration. A method for characterising pollutant concentrations in receiving water from a runoff event.
EPBC	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).
EPL	Environment Protection Licence.
EPA	NSW Environment Protection Authority.
ESCP	Erosion and sediment control plan.
F	
Fill	Addition of selected material to the existing terrain to accommodate for new road levels.
Flood	When flows in a creek or river are large enough to overtop the side banks.
Flood Frequency Analysis	The use of statistics to determine how large floods would be at specific periods in time.
Flood fringe	Remaining area of flood prone land after floodway and flood storage have been identified.
Flood storage	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodplain	An area of low lying land adjacent to a river or creek that becomes inundated when the creek floods.
Flow diversions	Intentionally redirecting water flow from its natural path.
FM Act	NSW *Fisheries Management Act 1994*.
Fraction impervious	The percentage area of catchment that consists of an impermeable surface such as roads or houses.
Freeboard	The vertical distance from the top water level of a flood or creek to a specific location such as a road surface level or a ground level of a house.

Term	Meaning
G	
GDE	Groundwater Dependent Ecosystems.
Groundwater	Water that passes underground through seams of rock and/or soil.
H	
HEC-RAS	Hydraulic Engineering Centre River Analysis System, developed by the US Army Corps of Engineers. Models the hydraulics of water flow through natural channels.
HRC	The Healthy Rivers Commission.
Hydraulic	The broad name used in defining characteristics of flow that travels through rivers, channels or pipes.
Hydrograph	A graph showing the seasonal variation in the level of a body of water, from which its velocity and discharge can be calculated.
Hydrology (hydrologic)	The broad name used in defining the characteristics of flow that develop from rainfall.
I	
Impervious	Not permeable or penetrable. Often refers to a surface that does not allow for water to be absorbed, like a road or a roof.
Inlet control	Where the flow through a pipe is controlled by the geometric characteristics of the upstream end of the pipe.
J	
-	-
K	
-	-
L	
-	-
M	
Manning’s ‘n’	Parameter relating to surface roughness.
MHRDC	Calculation of the Maximum Harvestable Right Dam Capacity. Dams used for erosion and sedimentation control are exempt from MHRDC.
MUSIC	The model for urban stormwater improvement conceptualisation (MUSIC) - developed by the Co-operative Research Centre for Catchment Hydrology to predict the effectiveness of various stormwater treatment techniques. Used to simulate the impact of a change in land use, by an estimate of the performance of a stormwater treatment train put in place to retain pollutants. Best used as a comparative assessment tool, ie to compare predevelopment with post development or to measure the effectiveness of treatment measures.
N	
NOW	NSW Office of Water.

Term	Meaning
NWQMS	The National Water Quality Management Strategy, a joint initiative of the Federal and State Governments.
O	
OEH	NSW Office of Environment and Heritage.
P	
PASS	Potential acid sulfate soil.
Peak flow	The maximum flow that results from a specific rainfall event.
Pervious	Permeable. Often refers to a surface that allows for water to be absorbed like a grassed field.
Pluviograph	An automated instrument that measures rainfall.
POEO	NSW *Protection of the Environment Operations Act 1997.*
Probable maximum flood	The PMF is the largest flood that could conceivably occur at a particular location.
Probabilistic rational method	A method defined in the *Australian Rainfall and Runoff* that estimates the peak flow in a catchment under a certain storm.
Pavement drainage	The broad term used to define flow and its corresponding structures that travel along a road. This is generally referred to a dirty flow as is contains many vehicular pollutants.
Q	
-	-
R	
Rainfall intensity	The amount of rainfall that fall per time usually measured in millimetres per hour.
RCP	Reinforced concrete pipe.
Receiving environment	A river, ocean, stream or other watercourse into which treated water is discharged.
Runoff	Rainfall that eventually converges to make flow often in a creek or river.
Riparian vegetation	Plants that grow on the fringe of land and rivers.
S	
SAQP	A Sampling Analysis and Quality Plan, which would be prepared for the purposes of groundwater monitoring.
Scuppers	Designed orifices or holes in a bridge deck that allow for drainage.
Sediment basin	A pond like structure that captures runoff and promotes sediment particles to drop out of the flow thus improving water quality.
Sensitive receiving environment	Receiving environment with high conservation value or supporting human uses of water that are sensitive to degradation.
SEPP	A State Environmental Planning Policy.

Term	Meaning
Sheet flow	Runoff that has not yet converged in a low point. It has uniform depth due to the relatively even planar surface it flows over. Flow over a smooth road is said to be sheet flow before it collects into a gutter or kerb.
SO gutter	An RMS standard “vee” shaped kerb type.
SPM	Suspended particulate matter.
Storm duration	The time that a storm produces rainfall. These are often recorded in specific standardised intervals which aid continuity in design.
STP	Sewage treatment plant
Suspended solids	Small particles that remain mixed in flow due to the motion and turbulence of the water.
Swale	Type of flow channel that is heavily vegetated to promote water quality.
SWMP	A soil and water management plan.
T	
TN	Total Nitrogen.
TP	Total Phosphorus.
Transverse drainage	The broad term used to define flow and its corresponding structures that travel under a road or an embankment. This is generally referred to a clean flow as is does not contain many vehicular pollutants.
TSS	Total Suspended Solids.

U	
-	-
V	
-	-
W	
Water quality basins	A pond like structure that captures runoff and promotes water quality through the use of plants and micro-organisms.
Weir	Structure used to regulate flow in a river or stream.
WM Act	The *NSW Water Management Act 2000*.
WQO	Water Quality Objectives (WQO), adopted by the NSW Government for local waterways as part of the *Drinking Water Catchments Regional Environment Plan No. 1.*
X, Y, Z	
-	-

1 Introduction

1.1 The project

Roads and Maritime Services (RMS) propose to upgrade 11.6 kilometres of the Princes Highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry, in New South Wales (NSW) (the project), to achieve a four lane divided highway (two lanes in each direction) with median separation. The project includes bypasses of Foxground and Berry.

The project comprises the following key features:

- Construction of a four lane divided highway (two lanes in each direction) with median separation (wire rope barriers or concrete barriers where space is constrained, such as at bridge locations).
- Bypasses of the Foxground bends and the Berry township.
- Construction of around 6.6 kilometres of new highway where the project deviates from the existing highway alignment at Toolijooa Ridge, the Foxground bends and the Berry township.
- Provision for the possible widening of the highway (if required in the future) to six lanes within the road corridor and, in some areas, construction of the road formation to accommodate future additional lanes where safety considerations, traffic disruption and sub-optimal construction practices are to be avoided.
- Grade-separated interchanges at:
  - Toolijooa Road.
  - Austral Park Road.
  - Tindalls Lane.
  - East of Berry at the existing Princes Highway, referred to as the northern interchange for Berry.
  - West of Berry at Kangaroo Valley Road, referred to as the southern interchange for Berry.
- A major cutting at Toolijooa Ridge (around 900 metres long and up to 26 metres deep).
- Six lanes (two lanes plus a climbing lane in each direction) through the cutting at Toolijooa Ridge for a distance of 1.5 kilometres.
- Four new highway bridges:
  - Broughton Creek bridge 1, a four span concrete structure around 170 metres in length and nine metres in height.
  - Broughton Creek bridge 2, a three span concrete structure around 75 metres in length and eight metres in height.
  - Broughton Creek bridge 3, a six span concrete structure around 190 metres long and 13 metres in height.
  - A bridge at Berry, an 18 span concrete structure around 600 metres long and up to 12 metres in height.

- Three highway overbridges:
  - Austral Park Road interchange, providing southbound access to the highway.
  - Tindalls Lane interchange, providing southbound access to and from the highway.
  - Southern interchange for Berry, providing connectivity over the highway for Kangaroo Valley Road along its existing alignment.

Eight underpasses including roads, drainage structures and fauna underpasses:

  - Toolijooa Road interchange, linking Toolijooa Road to the existing highway and providing northbound access to the upgrade.
  - Property access and fauna underpass in the vicinity of Toolijooa Ridge at chainage 8400.
  - Dedicated fauna underpass in the vicinity of Toolijooa Ridge at chainage 8450.
  - Property access underpass between Toolijooa Ridge and Broughton Creek at chainage 9475.
  - Combined drainage and fauna underpass in the vicinity of Austral Park Road at chainage 12770.
  - Combined drainage and fauna underpass in the vicinity of Tindalls Lane at chainage 13320.
  - Dedicated fauna underpass in the vicinity of Tindalls Lane at chainage 13700.
  - Property access underpass between the Tindalls Lane interchange and the northern interchange for Berry in the vicinity of at chainage 15100.

- Modifications to local roads, including Toolijooa Road, Austral Park Road, Gembrook Road, Tindalls Lane, North Street, Queen Street, Kangaroo Valley Road, Hitchcocks Lane and Schofields Lane
- Diversion of Town Creek into Bundewallah Creek upstream of its confluence with Connollys Creek and to the north of the project at Berry.
- Modification to about 47 existing property accesses.
- Provision of a bus stop at Toolijooa Road and retention of the existing bus stop at Tindalls Lane.
- Dedicated u-turn facilities at Mullers Lane, the existing highway at the Austral Park Road interchange, the extension to Austral Park Road and Rawlings Lane.
- Roundabouts at the southern interchange for Berry and the Woodhill Mountain Road junction with the exiting Princes Highway.
- Two culs-de-sac on North Street and the western end of Victoria Street in Berry.
- Tie-in with the existing highway about 75 metres north of Toolijooa Road and about 440 metres south of Schofields Lane.
- Left in/left out only provisions for direct property accesses to the upgraded highway.
- Dedicated public space with shared pedestrian/cycle facilities along the southern side of the upgraded highway from the playing fields on North Street to Kangaroo Valley Road.
- Ancillary operational facilities, including permanent detention basins, stormwater treatment facilities and a permanent stockpiling site for general road maintenance.

During detailed design, refinements could be made to the design features and construction methods (refer to Chapter 4 of the environmental assessment).

This report provides an assessment of the key surface, groundwater and flooding related issues for the project as nominated by the Director-General's requirements (DGRs) as set out in **Table 1-1**.

For each key issue, the existing environment is described, the potential impacts (both direct and indirect) during construction and operation are assessed, the influence of relevant planning matters are considered and proposed management and mitigation measures are described. The proposed management measures have influenced the development of the draft Statement of Commitments in Chapter 11 of the environmental assessment.

1.2 Agency consultation

In relation to surface, groundwater and flooding management, this document addresses the relevant DGRs as indicated in **Table 1-1**.

Agency letters accompany and inform part of the DGRs. These originate from Shoalhaven City Council, the Department of Environment and Climate Change and Water (DECCW) now known as the Office of Environment and Heritage (OEH), the Department of Industry and Investment now known as the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) and the NSW Office of Water (NOW). Relevant agency issues are outlined in **Table 1-2**.

Table 1-1: Director-General's requirements for surface, groundwater and flooding

Director-General's requirements	Section reference
Water quality taking into account impacts from both accidents and runoff and considering relevant environmental water quality criteria specified in the 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000'. The assessment must describe measures to control erosion and sedimentation during construction activities and measures to capture and treat runoff from the site during the operational phase.	Sections 1.3.1, 2.1.2, 2.2.1, 2.2.3 and 2.3
Identify potential risks of the project on groundwater resources including: characterising existing local and regional hydrology; potential risks of drawdown; impacts to groundwater quality; discharge requirements; and implications for groundwater-dependent surface flows (including springs and drinking water catchments), groundwater-dependent ecological communities, and groundwater users.	Section 3
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 4
Waterways to be modified as a result of the project, including ecological, hydrological and geomorphic impacts (as relevant) and measures to rehabilitate the waterways to pre-construction conditions or better.	Sections 2.1, 2.3, 3.2, 3.3, 4.2 and 4.3 Appendix G of the environmental assessment

Director-General's requirements	Section reference
An assessment of the key issues, including an assessment of the worst case and representative impact for each issue for all aspects of the project (including the proposed locations of and/or options for the ancillary facilities) with the following aspects addressed for each key issue (where relevant):	Sections 2.2.6, 3.3.3 and 4.2.9
• Describe the existing environment.	Sections 2.1, 3.2 and 4.1
• Assess the potential impacts of the project at both construction and operation stages, in accordance with relevant policies and guidelines. Both direct and indirect impacts must be considered including potential interactions with the existing Princes Highway (as relevant).	Sections 2.2, 3.3 and 4.2
• Identify how relevant planning, land use and development matters, (including relevant strategic and statutory matters), have been considered in the impact assessment and/or in developing management/mitigation measures.	Sections 2.3, 3.4 and 4.3
• Describe measures to be implemented to avoid, minimise, manage, mitigate, offset and/or monitor the impacts of the project and the residual impacts.	Sections 2.3, 3.4 and 4.3

Table 1-2: Surface, groundwater and flooding issues raised by local and State Government agencies

Agency issues	Section reference
Office of Environment and Heritage (OEH)	
The environmental outcomes for the project in relation to water should be: • No pollution of waters (including surface and groundwater) during construction or occupation of the site by the final users. • Acceptable in terms of the achievement or protection of the River Flow Objectives and Water Quality Objectives. The EA should document the measures that would achieve the above outcomes.	Sections 2.2 and 2.3
The source of water for dust control is a major issue for this project. The RMS should clearly demonstrate where the water would be sourced and quantities required for dust control and other activities.	Section 2.3.1
Other water issues include erosion and sediment control during construction activities including pipelines, stormwater runoff control and chemical storage during operation.	Section 2.3.1
If an offsite discharge is proposed for any or all wastewater streams, then the EA must address potential impacts and demonstrate that the discharges would not prejudice attainment of water quality objectives for the receiving water course. The NSW government has adopted Water Quality Objectives (WQO) for local waterways as part of the *Drinking Water Catchments Regional Environment Plan No. 1* and its supporting policies and guidelines, as a guide for the assessment of environmental impacts on aquatic ecosystems. These WQOs were developed from community consultation and the Healthy Rivers Commission (HRC) Inquiry into the Hawkesbury Nepean River System.	Sections 1.3 and 2.3

Agency issues	Section reference
Describe measures for dealing with the following water pollution issues: • Measures to control erosion and sedimentation during construction activities. Further guidance is available in the guideline 'Managing Urban Stormwater - Soils and Construction' (Landcom, 2004). • Measures to capture and treat runoff from the site during the operational phase. • Sealing areas of the site to prevent soil erosion. • Spillage controls and bunding for materials used onsite. • The environmental assessment should specify and assess all monitoring programs for measuring noise, air quality and water quality monitoring during the construction phase and on-going operation of the facility. These monitoring programs should be capable of assessing whether or not the development achieves a satisfactory level of environmental performance. The evaluation should include a detailed description of the monitoring strategies, sample analysis methods and the level of reporting proposed.	Sections 2.3.1 and 2.3.2
The key issues of concern to DTIRIS in relation to development are: • Direct impacts on aquatic environments and key fish habitat (including riparian vegetation, instream aquatic vegetation and large woody debris) from road construction. • Impacts on water quality during all road construction activities and from stormwater runoff and road drainage during the ongoing use of the upgraded highway. • Impacts on recreational fishing access and opportunities in Broughton Creek, Broughton Mill Creek and Bundewallah Creek.	Sections 2.3.1 and 2.3.2 Appendix G of the environmental assessment
Proposed measures to mitigate, rehabilitate or compensate for such impacts are to be detailed in accordance with the Department's Policy and Guidelines to ensure that there is 'no net loss' of aquatic habitats. Consider and provide information on the following specific issues: • Description of aquatic and riparian environments in the vicinity of the development - particularly extent and condition of riparian vegetation and instream aquatic vegetation, water depth, and permanence of water flow and snags (large woody debris) within the footprint of the project. • Analysis of any interactions of the proposed roadworks with aquatic and riparian environments and predictions of any impacts upon aquatic and riparian environments (including fish and aquatic and riparian vegetation) from the roadworks (both temporary and permanent). This should include assessment of both direct impacts (removal, disturbance, smothering) and indirect impacts (eg shading, permanent loss of habitat). • Description of proposed environmental compensation measures to offset the permanent loss of riparian habitats in Broughton Creek, Broughton Mill Creek and Bundewallah Creek (eg funding for aquatic rehabilitation works, such as removal of fish passage barriers, elsewhere in the catchment as recommended by DTIRIS). • Description of potential impediments to fish passage as a result of the works (eg temporary coffer dams, instream bunds or work platforms) and possible mitigation measures to be employed to negate these impacts.	Sections 2.1, 2.2, 2.3 and section 7.3 of the environmental assessment Appendix G of the environmental assessment

Agency issues	Section reference
• Predictions of impacts upon water quality of the proposed road development, including in Broughton Creek, Broughton Mill Creek and Bundewallah Creek, both during the construction and operational phases. • Safeguards to mitigate any impacts upon aquatic species and environments and water quality during construction and operation of the highway upgrade. In particular, provide details on proposed revegetation of riparian areas, projects for erosion and sediment control (to be incorporated into a construction environmental management plan (CEMP)) and proposed stormwater and road drainage management measures (eg sediment basins). Water quality management for the highway upgrade should be designed to achieve no nett increase in pollutant runoff to Broughton Creek, Broughton Mill Creek and Bundewallah Creek. • An assessment of any impacts of the proposed development and construction works on recreational fishing in the area, especially in relation to fishing access arrangements (foreshore and boat based).	
Office of Water (NOW)	
The EA needs to provide sufficient details for the NOW to assess any water licensing requirements under the *Water Act 1912*, including: • Water supply source(s) for the proposal. • Any proposed surface water extraction, including purpose, location of any existing and proposed pumps or storage ponds/ dams. • Any proposed groundwater extraction. • Volumes of water to be used. • The function and location of all existing and proposed storages/ponds for the project. If the proposal includes water management structures/dams, the EA needs to provide details on the following: • Any existing structures (date of construction, location, purpose, size and capacity, the legal status/approval for existing structures). • Any proposal to change the purpose of existing structure/s. • If any remedial work is required to maintain the integrity of the existing structure/s. • The purpose, location and design specifications for any proposed structure/s. • Size and storage capacity of the structure/s. • Calculation of the Maximum Harvestable Right Dam Capacity (MHRDC). • If the structure/s is affected by flood flows. • Any proposal for shared use, rights and entitlement of the structure/s. • If the proposed development has the potential to bisect the structure/s. The proposal needs to demonstrate that it is consistent with NSW State groundwater policy, does not impact on groundwater quality or the health of groundwater dependent ecosystems (GDEs).	Sections 2.1, 2.2, 2.3 and section 7.3 of the environmental assessment

Agency issues	Section reference
The EA should consider and provide the following details: • The predicted highest groundwater table at the site. • Any works likely to intercept, connect with or infiltrate the groundwater sources. • Any proposed groundwater extraction, including purpose, location and construction details of all proposed bores and expected annual extraction volumes. • A description of the flow directions and rates and physical and chemical characteristics of the groundwater source. • The predicted impacts of any final landform on the groundwater regime. • The existing groundwater users within the area (including the environment), any potential impacts on these users and safeguard measures to mitigate impacts. • An assessment of the quality of the groundwater for the local groundwater catchment. • How the proposed development would not potentially diminish the current quality of groundwater, both in the short and long-term. • Measures for preventing groundwater pollution so that remediation is not required. • Protective measures for any groundwater dependent ecosystems (GDEs). • Proposed methods for the disposal of waste water and requirement for approval from the relevant authority. • The results of any models or predictive tools used. Where potential impact/s are identified the EA would need to identify limits to the level of impact and contingency measures that would remediate, reduce or manage potential impacts to the existing groundwater resource and any dependent groundwater environment or water users, including information on: • Any proposed monitoring programs, including water levels and quality data. • Reporting procedures for any monitoring program including mechanism for transfer of information. • An assessment of any groundwater source/aquifer that may be sterilised from future use as a water supply as a consequence of the proposal. • Identification of any nominal thresholds as to the level of impact beyond which remedial measures or contingency plans would be initiated (this may entail water level triggers or a beneficial use category). • Description of the remedial measures or contingency plans proposed. Any funding assurances covering the anticipated post development maintenance cost, for example on-going groundwater monitoring for the nominated period.	

Agency issues	Section reference
Shoalhaven City Council	
No relevant issues relating to ground and surface water.	N/A
Kiama Municipal Council	
No relevant issues relating to ground and surface water.	N/A

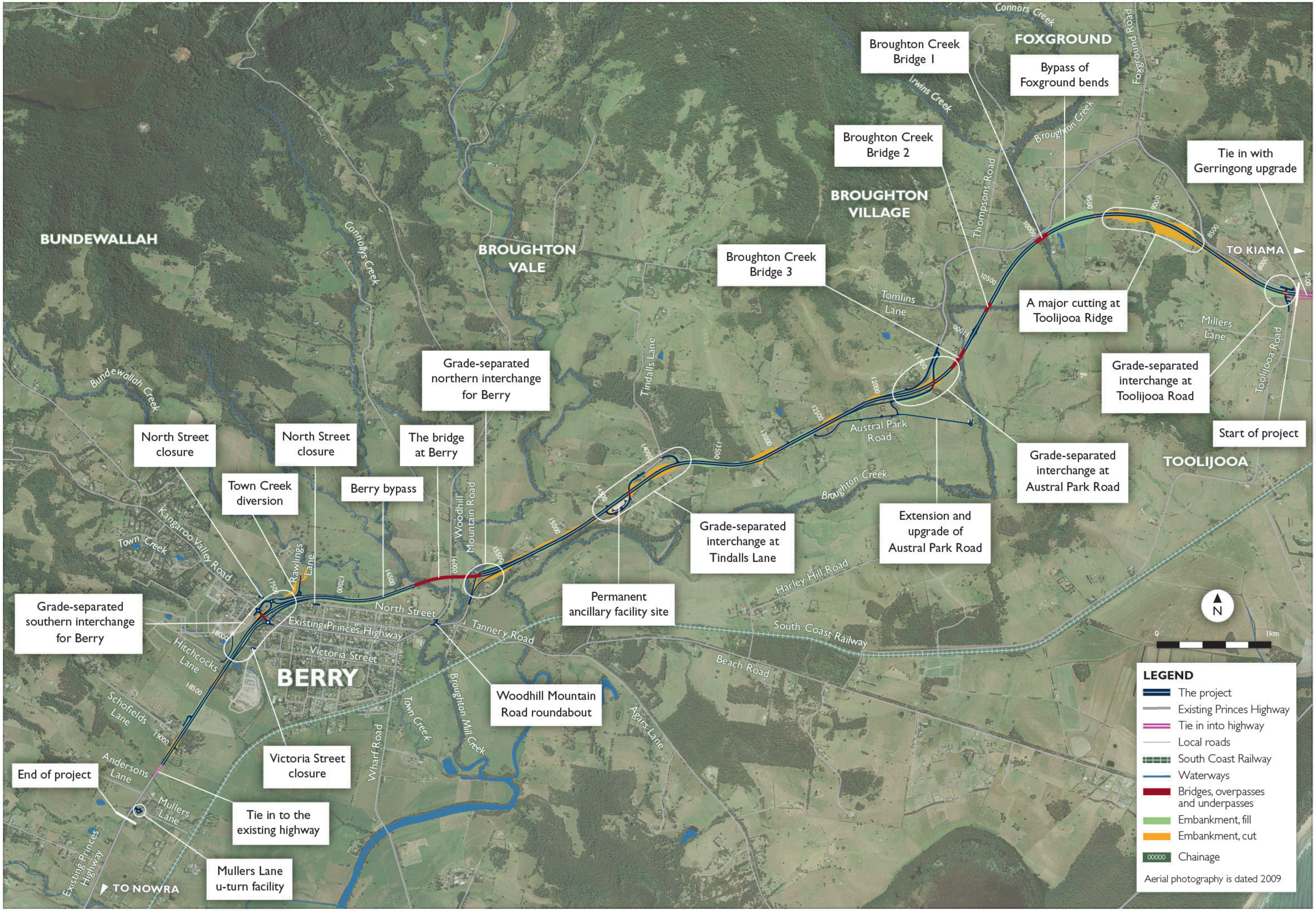

Figure 1-1: Foxground and Berry bypass project area

1.3 Policy context and legislative framework

A brief summary of the strategic policy and guidelines that have been considered as part of this assessment is provided below.

1.3.1 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000), (referred to as the ANZECC water quality guidelines) form part of the National Water Quality Management Strategy and list a range of environmental values for water bodies. Different water quality criteria are set for the water bodies based on environmental values assigned to that water body. These values include consideration as to whether the water is to be used for drinking, recreation or according to ecological values. The ANZECC water quality guidelines provide water quality criteria (scientifically-based benchmark values) for a wide range of parameters for each of these values. The ANZECC guidelines state that "The Guidelines should not be used as mandatory standards because there is significant uncertainty associated with the derivation and application of water quality guidelines" (ANZECC, 2000, Chapter 1 Introduction). However the guidelines provide a useful measure of risks to aquatic ecosystem health.

ANZECC guidelines are ambient water quality guidelines, appropriate for the monitoring of baseflows or water bodies and have therefore been used in the assessment of the existing water quality of creeks in proximity to the project as discussed in **Section 2**. ANZECC criteria would also be used in future monitoring of ambient conditions (base flow) of the downstream waterways to assess the impacts of the proposal on these ecosystems.

It is not appropriate to use the guidelines for the assessment of stormwater runoff from urbanised or natural catchments, since the concentrations of pollutants in runoff may at times exceed the guidelines recommended for ambient water quality in both natural and urbanised catchments. There are guidelines specifically derived for the management of stormwater runoff such as Managing Urban Stormwater: Council Handbook (Environment Protection Authority (EPA), 1998a) as discussed below.

ANZECC guidelines are also applicable to groundwater quality and have been used in the groundwater quality assessment detailed in **Section 3** of this report.

1.3.2 National Water Quality Management Strategy

The National Water Quality Management Strategy (NWQMS) is a joint initiative of the Federal and State Governments. The policy objective of the strategy is "to achieve sustainable use of the nation's water resources by protecting and enhancing their quality whilst maintaining economic and social development" (Department of Sustainability, Environment, Water, Population and Communities (DSEWPC), 1994).

1.3.3 NSW Water Quality and River Flow Objectives

The NSW Water Quality and River Flow Objectives are consistent with the agreed national framework and are primarily aimed at maintaining and improving water quality, thereby supporting aquatic ecosystems, recreation and where applicable water supply and the production of aquatic foods suitable for consumption and aquaculture activities (DECCW, 2006).

NSW Water Quality and River Flow Objectives have been developed for most river catchments in the state, though not for the Shoalhaven River catchment. The catchments immediately upstream and downstream of the Shoalhaven catchment are the Illawarra catchment and the Clyde River and Jervis Bay catchment. The water quality and river flow objectives that were determined for these catchments which could be applied to the

Shoalhaven catchment are shown in **Table 1-3** along with cross references to sections of this report where discussion relating to each objective is located.

Table 1-3: NSW water quality and river flow objectives

Objective	Section reference
Water quality objectives:	
Protect aquatic ecosystems.	Sections 2.1, 2.2, 2.3
Protect livestock water supply.	Section 2.2.5
Protect irrigation water supply.	Section 2.2.5
River flow objectives:	
Protect natural low flows.	Sections 2.2.3, and 4
Protect pools in dry times.	Sections 2.2.3, and 4
Protect important rises in water levels.	Section 4
Maintain wetland and floodplain inundation.	Section 4
Mimic natural drying in temporary waterways.	Section 4
Maintain natural flow variability.	Section 4
Maintain natural rates of change in water levels.	Section 4
Manage groundwater for ecosystems.	Section 3
Minimise effects of weirs and other structures.	Section 4

1.3.4 Managing Urban Stormwater: Council Handbook, Draft (EPA, 1998a)

The Managing Urban Stormwater: Council Handbook (EPA, 1998a) is part of a package of documents addressing the management of urban stormwater published by NSW Government agencies. The aim of this document is to provide guidance on the preparation and meeting of requirements of catchment-based stormwater management plans.

These guidelines have been developed for urban catchments and as such are not strictly applicable to the rural environment along the project route. However, the recommended treatment objectives have been used as a basis for developing appropriate design criteria for water quality treatment for this project. The development of these design criteria is discussed in **Section 2.3**.

1.3.5 Protection of the Environment Operations Act 1997

Clause 48 of the *Protection of the Environment Operations Act 1997* (POEO Act) applies to scheduled activities where Schedule 1 indicates that a licence is required for premises at which the activity is carried on.

Clause 35 of Schedule 1 states that:

"(2) The activity to which this clause applies is declared to be a scheduled activity if it results in the existence of 4 or more traffic lanes (other than bicycle lanes or lanes used for entry or exit) for at least:

(b) where the road is classified, or proposed to be classified, as a main road (but not a freeway or tollway) under the Roads Act 1993:

(i) 3 kilometres of their length in the metropolitan area, or
(ii) 5 kilometres of their length in any other area."

As the proposed road would be classified as a main road with four traffic lanes, is located outside the metropolitan area and is greater than five kilometres is length, an Environmental Protection Licence (EPL) would be required to be obtained for the construction of the project.

Section 120 of the POEO Act prohibits the pollution of any waters. Standard conditions of the EPL would require compliance with the POEO Act and this has been taken into consideration in the design of the project. Mitigation measures would be implemented to prevent pollution of waters as discussed in **Section 2.3** and **Section 2.4**.

1.3.6 Other policies and guidelines

The following guidelines were also considered in the assessment:

- Managing Urban Stormwater - Soils and Construction, Volume 1 (Landcom, 2004); Volume 2D – Main Road Construction (NSW DECCW, 2008) colloquially known as the Blue Book).
- RMS Road Design Guideline: Section 8 Erosion and Sedimentation (Roads and Traffic Authority (RTA), 2003).
- RMS Guideline for Construction Phase Water Quality Monitoring (RTA, n.d.).
- RMS Erosion and Sedimentation Management Procedure (RTA, 2009).
- Procedures for Selecting Treatment Strategies to Control Road Runoff (RTA, 2003a).
- RMS Code of Practice for Water Management (RTA, 1999).
- RMS Water Policy (RTA, 1997).
- Road Runoff and Drainage: Environmental Impacts and Management Options, AP-R180 (Austroads, 2001).
- Guidelines for Treatment of Stormwater Runoff from Road Infrastructure, AP-R232 (Austroads, 2003).
- Floodplain Development Manual (Department of Natural Resources (DNR), 2005).
- RMS Technical Guideline: Environmental Management of Construction Site Dewatering (RTA, 2011).
- Coastal Lakes: Independent Inquiry into Coastal Lakes and Statement of Joint Intent (Healthy Rivers Commission of NSW, 2002)
- The relevant targets within the State Water Management Outcomes Plan (NOW, 2003).
- Managing Urban Stormwater: Council Handbook (EPA, 1998a).
- Managing Urban Stormwater: Source Control (EPA, 1998b).
- Managing Urban Stormwater: Treatment Techniques (EPA, 1998c).
- State Groundwater Policy Framework Document (Department of Land and Water Conservation (DLWC), 1997).
- The NSW State Groundwater Quality Protection Policy (DLWC, 1998).
- (Draft) NSW State Groundwater Quantity Management Policy (DLWC, n.d.).
- NSW State Groundwater Dependent Ecosystems Policy (DLWC, 2002).
- National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and ANZECC, 1995).

2 Surface water

2.1 Existing environment

2.1.1 Overview

A brief description of the project alignment is provided below (refer also to **Figure 1-1**):

- The project would begin at Toolijooa Road, and pass through a large cutting and onto the Broughton Creek floodplain.
- It would cross Broughton Creek three times before moving out of the floodplain and through the foothills north of Broughton Creek.
- It would then join the existing Princes Highway alignment, following a ridgeline east of Berry.
- It would cross the confluence of Broughton Mill Creek, Connollys Creek and Bundewallah Creek at the bridge at Berry.
- It would then pass north of the Berry township, crossing a number of smaller catchments from the surrounding foothills, before finishing south of Schofields Lane.

The project would also include the diversion of Town Creek into Bundewallah Creek to the north of the project (upstream of its confluence with Connollys Creek).

Broughton Creek (upstream of Berry) traverses the proposed route in a southerly then westerly direction before meandering south again and finally flowing into the Shoalhaven River approximately five kilometres west of Shoalhaven Heads. The Broughton Creek catchment (refer **Figure 4-2**) consists predominately of rural pastures below steeper forested hillsides.

Bundewallah Creek, located to the north of Berry, flows eastwards under a bridge at Woodhill Mountain Road to join Broughton Mill Creek. From the confluence with Bundewallah Creek, Broughton Mill Creek flows southwards under an existing bridge at the Princes Highway, then under a second bridge at the South Coast Railway Line before flowing to the south of Berry. Broughton Mill Creek then flows into Broughton Creek downstream and to the east of Berry,

Connollys Creek enters Bundewallah Creek upstream of the confluence with Broughton Mill Creek. Two unnamed creeks flow through Berry before joining Broughton Mill Creek.

Town Creek (or Princess Creek) is a small ephemeral watercourse that passes directly through the Berry township. It has a catchment area of 70 hectares upstream of Berry. Town Creek meanders southeast through the Berry town centre, adjacent to Princess Street, before joining Broughton Mill Creek near its confluence with Broughton Creek. The reach of Town Creek through Berry is in poor condition.

Broughton Creek, Broughton Mill Creek, Bundewallah Creek and Connollys Creek are considered sensitive receiving environments in the study area.

2.1.2 Water quality studies

A number of water quality studies have been undertaken as part of the route selection process for the project. These included field investigations, sampling and testing undertaken by Cardno Ecology Lab in June 2011, April 2009 and January/February 2007.

Water quality analyses were undertaken at a range of waterway locations associated with the project including potential crossing locations. This information was used to assess water quality within the study area in terms of health of aquatic ecosystems by comparison with ANZECC (2000) guidelines for low-land and estuarine watercourses (as appropriate) in south–eastern Australia (The Ecology Lab, 2007).

In-situ water testing determined that most waterways had pH, salinity levels and to a lesser extent, turbidity within acceptable limits and all sites had levels of organochlorine pesticides and trace elements that were below ANZECC thresholds.

Values of total phosphorus generally exceeded the ANZECC guidelines. As nearly all creeks lie adjacent to land cleared for agricultural purposes, the application of fertilisers and manure from stock are the likely sources of the high nutrient levels. Dissolved oxygen values were almost universally less than the ANZECC lower threshold for the protection of ecosystems.

Overall the water quality results were considered typical of aquatic ecosystems that have been impacted by agricultural and grazing practices. The study found that the long-term agricultural land use in the region has ultimately resulted in significant pollution that exceeds levels considered to be sustainable for maintaining ecosystem integrity.

In addition, the existing highway does not have any water quality controls and is likely to be contributing pollutant loads especially at or near creek crossing locations.

2.1.3 Biodiversity

The maintenance of water quality to the receiving waterways is important, in order to support downstream ecosystems. As flora and fauna all depend on water quality, an understanding of the existing habitats for flora and fauna in the study area is central to understanding potential impacts the project may have.

Existing aquatic habitats

Broughton Creek is a Class 1 waterway providing major fish habitat, Broughton Mill Creek and Bundewallah Creek are Class 2 waterways providing moderate fish habitat and Connollys Creek is a Class 3 waterway with minimal fish habitat (Cardno Ecology Lab, 2012).

The above creeks are considered sensitive receiving environments with respect to this project.

Town Creek is a Class 4 waterway unlikely to provide fish habitat. The waterway is ephemeral at the proposed route crossing and much of the watercourse channel is undefined and has been colonised by pasture grasses and annual weeds (Cardno Ecology Lab, 2012).

The patches of vegetation present within the urbanised reaches of Town Creek were characterised as disturbed riparian open woodland. South of the urban centre, Town Creek flows through pasture land with riparian vegetation consisting of closed grassland. It then flows through a constructed wetland adjacent to the Berry Sewage Treatment Works (STP) and subsequently through disturbed riparian open woodland habitat before its confluence with Broughton Mill Creek (Cardno Ecology Lab, 2012).

Downstream of the project at the confluence of Broughton Creek and the Shoalhaven River there are a variety of important estuarine wetland habitats such as seagrass beds, tidal flats, saltmarsh and mangroves which are important for seabirds and migratory waders. There are a number of State Environmental Planning Policy No.14 Coastal Wetlands (SEPP 14 wetlands) in this locality, including the Comerong Island Nature Reserve, which are sensitive receiving environments.

Coomonderry Swamp, to the southeast of the study area near the coast, is a freshwater coastal wetland and sensitive receiving environment that is also protected under SEPP14 and represents one third of all semi-permanent coastal freshwater wetland habitat in NSW (NPWS, 1998). It provides habitat for a diverse array of flora and fauna, including many threatened species such as the Green and Golden Bell Frog, *Litoria aurea*.

For further information on wetland habitats in the locality of the study area refer to the *Aquatic Ecology and Water Quality Management Assessment* (Cardno Ecology Lab, 2012) which is provided at Appendix G to the environmental assessment.

Aquatic fauna

A previous study undertaken to inform route selection (The Ecology Lab, 2007) identified 36 fish species that could potentially exist within the study area, of which 33 are native. Of these, the Macquarie Perch, *Macquarie australasica* is listed as endangered and vulnerable (*Fisheries Management Act 1994* (FM Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) respectively) and the Australian Grayling, *Prototroctes maraena* is listed as vulnerable (EPBC Act). However, the study noted that given the relatively small size and low elevation of the drainage systems and the degraded nature of the habitat, it is unlikely that viable populations of either Macquarie Perch or Australian Grayling are present within the study area (The Ecology Lab, 2007).

Further the Aquatic Ecology and Water Quality Management Assessment (Cardno Ecology Lab, 2011) for the project noted that it is probable that not all 36 species occur within the study area. The Broughton Creek catchment supports an estuarine floodplain and freshwater reach, but the catchment is still relatively small and most of the higher elevation tributaries are ephemeral and are unlikely to provide fish habitat. It is possible that some species, particularly the larger and more sensitive, may not be present (Cardno Ecology Lab, 2011).

Aquatic flora

The reach of Broughton Creek upstream of Berry is surrounded by cleared agricultural land although there are significant sections with relatively intact native riparian vegetation dominated by river oak (*Casuarina cunninghamiana* subsp. *Cunninghamiana* and *Eucalyptus* spp.) (Cardno Ecology Lab, 2011).

The land surrounding Broughton Mill Creek has largely been cleared for agricultural use, with existing riparian vegetation containing a mixture of native and exotic trees and shrubs. Similarly, the land surrounding Bundewallah Creek had been cleared for agricultural use and recreation. Riparian vegetation is relatively continuous and composed of native trees (river oak) and exotic shrubs, climbers and annuals (Cardno Ecology Lab, 2011).

Broughton Creek, Broughton Mill Creek and Bundewallah Creek were all classed as Category 1 Riparian Habitats (Environmental Corridor), this classification representing the objective to provide biodiversity linkages by maintaining connectivity for the movement of aquatic species along the riparian corridor and between key destinations (for example, the bottom and the top of the catchment) (Cardno Ecology Lab, 2011).

2.1.4 Acid sulfate soils

Acid sulfate soil (ASS) is a naturally occurring soil and sediment containing iron sulphides which when exposed to oxygen can generate sulphuric acid. ASS generally occurs in marine or estuarine sediments of recent geological age (holocene), within soil horizons typically less than five metres above Australian Height Datum (AHD) (Coffey, 2007).

The study area is covered by three acid sulfate risk maps - Kiama, Burrier / Berry and Gerroa (DLWC, 1997a-c). Reference to these risk maps indicate that no areas along the alignment have been identified as being at risk. Geotechnical investigations for the project (Coffey, 2010) included field and laboratory investigations to identify ASS. No soils were identified as being of potential ASS (PASS) risk within the study area. ASS may still be present in the floodplain sediments around Berry and Broughton Creek although the risk is considered low.

2.2 Assessment of potential surface water impacts

A water quality impact assessment has been undertaken to identify potential impacts and provide appropriate management controls within the project (refer Section 2.3 for a discussion on environmental management measures).

Surface water impacts have been considered in terms of the NSW Water Quality and Flow Objectives as listed in Section 1.3.3.

Further assessment of impacts to water quality is presented in the *Aquatic Ecology and Water Quality Management Technical Paper* at Appendix G of the environmental assessment.

2.2.1 Construction potential impacts

The primary risk to surface water quality during construction would be the increased potential for sediment release and transportation through runoff during and following clearing and cut and fill operations, as bare soil would be exposed to erosion during the construction works. Transportation of sediment could also occur through vehicular movements such as tracking onto roads. Increased sedimentation of watercourses can smother aquatic habitats and organisms, and can increase levels of nutrients, metals and other potential toxicants that attach to sediment particles.

Turbidity and suspended particulate matter (SPM) are positively correlated with suspended sediment loads (Cardno Ecology Lab, 2012). Therefore without appropriate management controls the potential construction impact of sediment release may increase turbidity levels within waterways associated with the project.

Noting previous water studies indicate several of these waterway's turbidity levels are narrowly outside the ANZECC lower thresholds (Cardno Ecology Lab, 2012) an increase could place additional physical stress on aquatic biota.

Other potential risks to surface water during the construction phase include:

- Sediment release from stockpile sites and earthmoving activities.
- Increased surface runoff due to an increase in cleared and impervious surfaces.
- Exposure of ASS resulting in acidic runoff that could have environmental impacts on the water quality of receiving creeks.
- Oil/fuel leakage from construction equipment.
- Contaminated runoff or spills (for example caused by accidental chemical spills, or damage to chemical storage areas) that could pollute receiving waterbodies.
- General waste generation from construction materials and activities that could enter waterbodies.
- Dust generation during excavation that could settle in waterbodies.
- Changes to existing farm dam catchments and therefore a disruption of water supply for livestock and irrigation, resulting from the diversion of existing runoff due to cut or fill (see discussion in Section 2.2.5 below).
- Damage to ancillary facilities, such as stockpile sites and chemical storages that could result in an export of pollutants to receiving water bodies.
- Flood damage to chemical storage or stockpile areas.
- Tannins leachate from vegetation stockpiles.
- Riparian vegetation removal resulting in increased sedimentation and erosion into waterbodies.
- Hydrologic and water quality impacts as a result of the proposed Town Creek diversion channel.
- Decreased health of aquatic ecosystems due to increased sediment and contaminants in waterbodies.

2.2.2 Operational potential impacts

The primary risk to surface waters during operation would be an increase in surface runoff due to the increase in impervious surfaces potentially resulting in an:

- Increase in pollutant loads reaching waterways.
- Increase in the volume, frequency and velocity of flows in receiving waterways, leading to or exacerbating erosion and the mobilisation of sediments.

With respect to the ANZECC guidelines the pollutants of interest associated with road runoff are primarily sediments (as noted in the potential construction impacts increased sediments are likely to impact on turbidity levels) nutrients (namely nitrogen and phosphorus), heavy metals, hydrocarbons and organics.

Studies undertaken in the Broughton Creek catchment generally show that turbidity levels are narrowly outside the ANZECC lower thresholds and values of total phosphorus generally exceeded the ANZECC guidelines (Cardno Ecology Lab, 2012).

Without appropriate management controls the potential operational impacts may place further stress on waterways associated with the project.

The proposed design would require two piers within Bundewallah Creek. Typical bankfull average flow velocities are in the order of 1 to 3m/s. The piers would typically slow average velocities immediately upstream by 0.1 to 0.2m/s. As the flow passes around the piers there would be an increase in the velocities close to the piers, however this increase would not typically extend across the entire flow width at this cross section.

Other potential risks to surface water during the operational phase include:

- Sediment from the paved surface entering waterbodies.
- Heavy metals, attached to particles washed off the paved surfaces, entering waterbodies.
- Oil, grease and other hydrocarbon products from general vehicular use of the road reducing runoff water quality and entering water bodies.
- Anthropogenic litter entering waterways and reducing water quality.
- Permanent changes to existing catchments (primarily due to cuttings to create the alignment) that may result in reduced runoff to farm dams and therefore a disruption to water supply for livestock and irrigation.
- Chemical spills, resulting from road traffic crashes, entering waterbodies.
- Nutrients (nitrogen and phosphorus) found in road runoff due to atmospheric deposition entering waterbodies.
- Contaminants from erosion of roadway or road shoulder entering waterbodies.
- Flow regime and water quality impacts as a result of the proposed Town Creek diversion channel.
- Decreased health of aquatic ecosystems due to increased sediment and contaminants in waterbodies.

2.2.3 Town Creek diversion channel – Hydrologic and water quality impacts

As part of the proposed highway upgrade, runoff from the Town Creek catchment (approximately 70 hectares) to the north of the highway upgrade would be rerouted by a diversion channel passing under Rawlings Lane into Bundewallah Creek upstream of its confluence with Connollys Creek. It would then flow into Broughton Creek.

The diversion of Town Creek would alter flow regimes in parts of Bundewallah Creek, Connollys Creek, Broughton Mill Creek and Town Creek within Berry. Generally, Town Creek south of the alignment would receive less flow while Bundewallah, Connollys and Broughton Mill Creeks would receive higher flows.

The reduced flow regime for reaches downstream of the proposed diversion channel is not expected to have a significant impact as these reaches are typically colonised by pasture grasses with undefined flow paths, and are heavily urbanised or constructed. The impacts resulting from the stemming of flow from the upstream catchment (due to the proposed diversion channel) are considered negligible as these largely disturbed reaches are unlikely to provide fish habitat (Class 4 waterway) and have few standing pools. Refer to the *Aquatic Ecology and Water Quality Management Assessment* (Cardno Ecology Lab, 2012) provided at Appendix G of the environmental assessment for additional information.

Impacts on flow regime were assessed for the five river reaches shown in **Figure 2-1**.

The flow regimes would be affected by changes in the size of the catchments feeding into each creek. Bundewallah Creek, Connollys Creek, upstream Broughton Mill Creek, and downstream Broughton Mill Creek (B, C, D and F) would have less than five per cent change in catchment area due to the proposed development. The reach of Town Creek flowing through Berry would experience changes in catchment area of -100 per cent at the upstream end (A) and -47 per cent at the downstream end (E).

Table 2-1 indicates the changes in catchment areas as a result of the diversion.

Table 2-1: Catchment area changes as a result of the Town Creek diversion

River	Map location	Existing upstream catchment area (km^{2*})	Proposed upstream catchment area (km^2)	% change in catchment area
Town Creek- north end of Berry	A	0.7	0	-100
Bundewallah Creek - below diversion of Town Creek	B	14.1	14.8	5
Bundewallah Creek - below confluence with Connollys Creek	C	21.6	22.3	3
Broughton Mill Creek upstream	D	43.2	43.9	2
Town Creek- south end of Berry	E	1.5	0.80	-47
Broughton Mill Creek downstream	F	45.5	45.5	0

**Existing upstream catchment areas are shown in Figure 2-1*

An Australian Water Balance Model (AWBM) was created for the existing and proposed catchment areas. AWBM is a catchment scale rainfall/runoff numerical model that allows estimates of streamflow to be derived from rainfall by quantifying the volume and duration of rainfall storage prior to its discharge as runoff. The model was calibrated using daily streamflow data from the flow gauging station at Broughton Mill Creek, combined with daily rainfall data from Berry Masonic Village and monthly evapotranspiration (ET) data from Port Kembla.

A set of parameters were determined that could be used to approximate rainfall/runoff relationships throughout the ungauged catchments of Town, Bundewallah and Connollys Creeks.

The model was run for the existing and proposed catchment areas with results reported at the six locations (A-F) on the river reaches that would be affected by the diversion of Town Creek. The existing and proposed flow duration curves for each site are presented in **Figure 2-2**.

The flow duration curves represent the percentage of time that a given flowrate is equalled or exceeded at each of the assessed locations. ‘0 per cent time exceeded’ corresponds to the highest possible flow, and ‘100 per cent time exceeded’ corresponds to the lowest possible flow. If the portion of the curve above 80 per cent is relatively steep this indicates a low input from natural sources such as groundwater. Conversely, if this portion of the curve has a gentler slope, this indicates a significant baseflow in the waterway.

The results of the modelling indicate that as Bundewallah Creek, Connollys Creek, upstream Broughton Mill Creek, and downstream Broughton Mill Creek (B, C, D and F) would experience a minimal change in catchment areas due to the proposed development, the resulting impact on flow volumes in these reaches is negligible.

As Town Creek would be completely diverted upstream of the highway, there would be no flow at the upstream end of the reach through Berry (A), and the flow volume would be reduced to approximately one third of the existing flow at the downstream end of the reach through Berry (E). The diversion could lead to sediment accumulating in Town Creek downstream of the diversion as a result of reduced flushing efficiency.

There are potential water quality impacts (primarily erosion) associated with the creation of the diversion channel through excavation works but this will be dependent on the rehabilitation landscape works. In a worst case scenario this could lead to excess sediment loads into Bundewallah Creek resulting in mortality and decreased growth of aquatic species, degradation of habitat and reduced water quality.

There are also potential operational water quality impacts including the accumulation of sediment as a result of reduced flushing efficiency and erosion at the confluence of the diversion channel and Bundewallah Creek due to eddying.

The final diversion channel concept (which would be determined in consultation with directly impacted landowners, EPA/OEH and NOW) would include design measures to maintain flushing efficiency and mitigate potential erosive forces at the diversion’s discharge location. Construction would be undertaken in a staged manner in conjunction with erosion control landscaping measures to reduce exposure of soils.

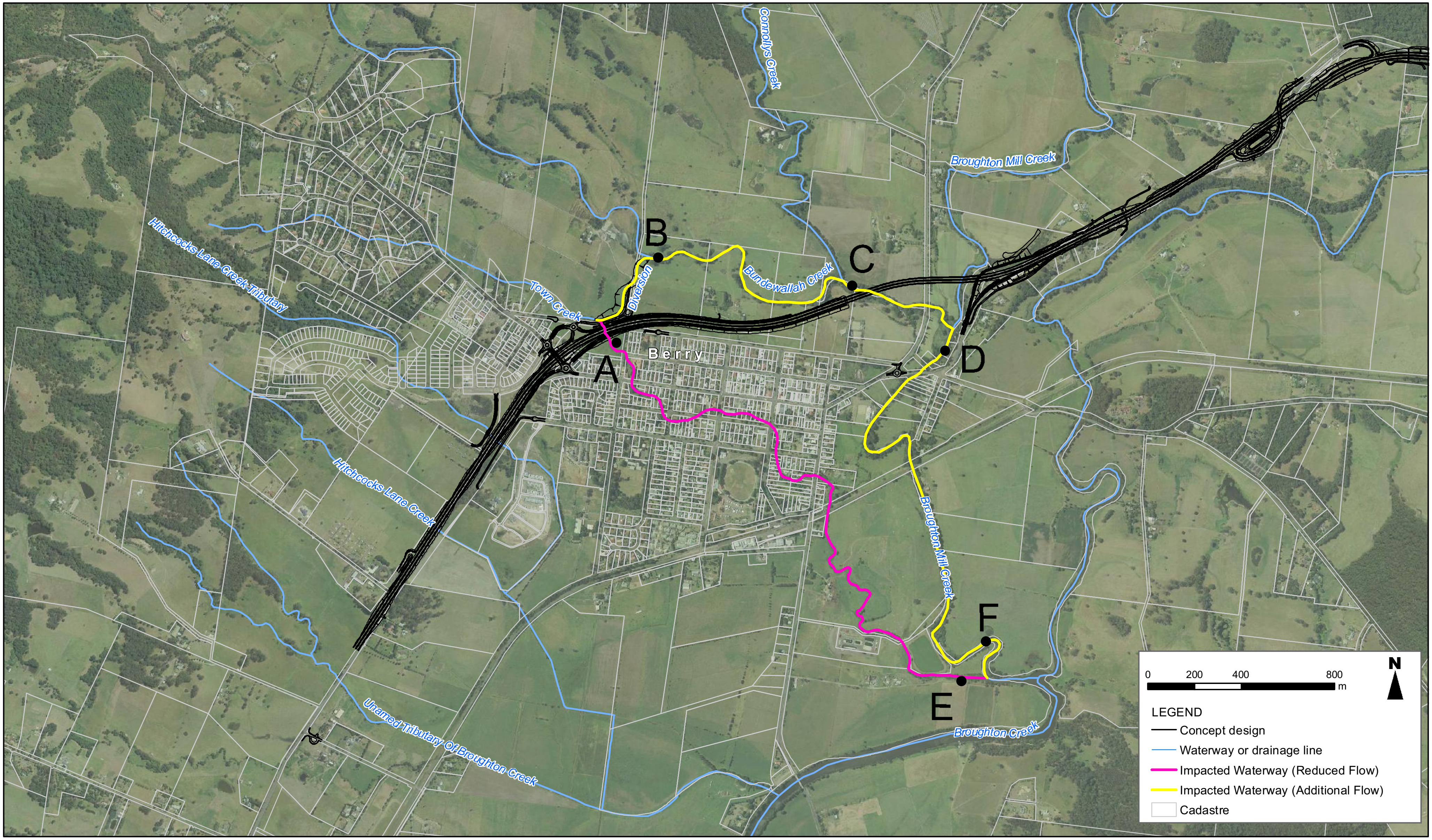

Figure 2-1 Town Creek Diversion - Impacted streamlines and flow reporting locations

Source: AECOM (2012), LPMA (2011)

Note 1: Letters identify flow reporting locations. Refer to Table 2.1

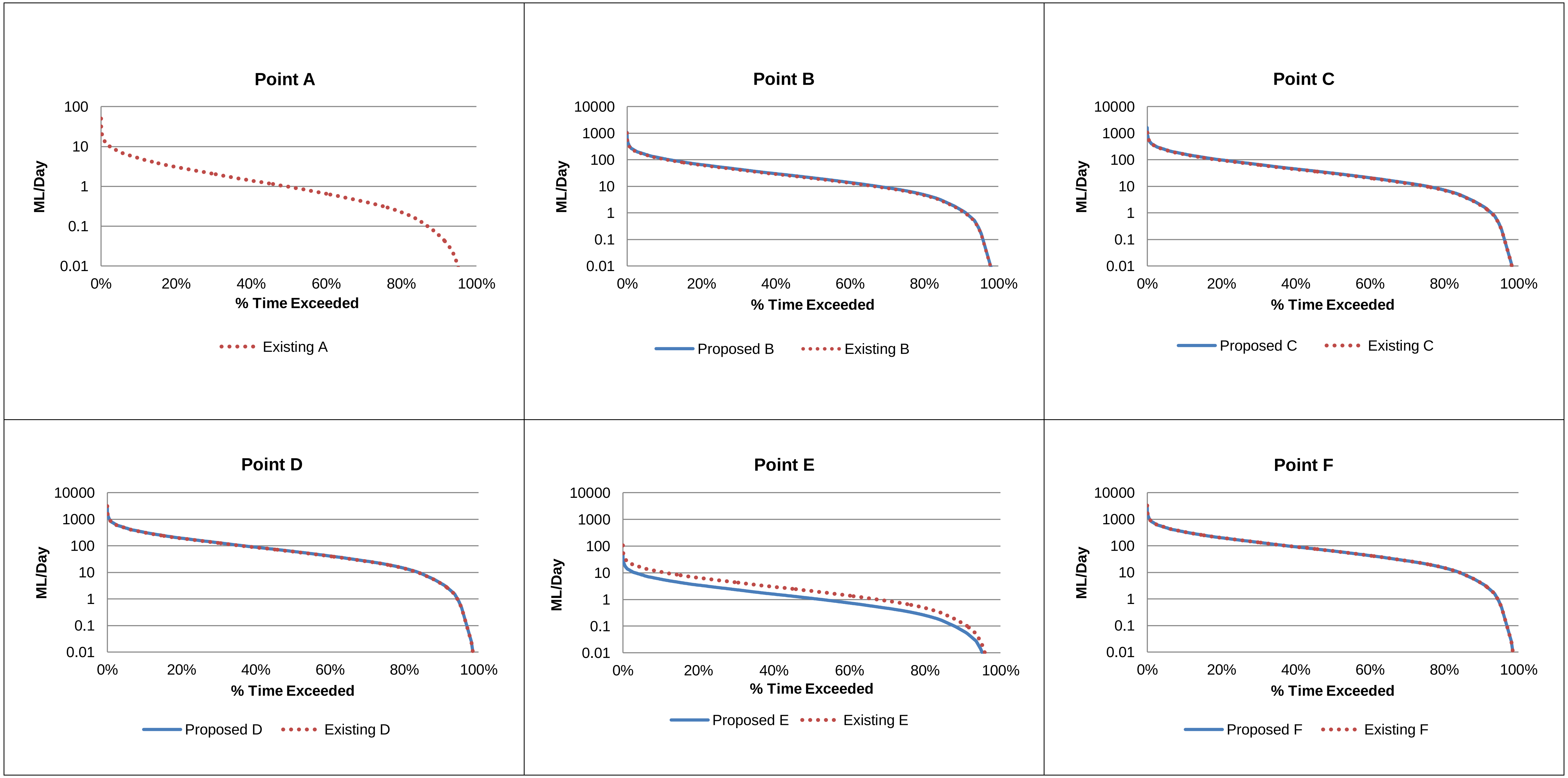

Figure2-2: Flow duration curves – existing and proposed conditions at reaches affected by the Town Creek diversion

2.2.4 Water quality impact assessment

In order to assess the impacts on the surface water quality for the operation phase, existing and proposed runoff was modelled in the MUSIC (Model for Urban Stormwater Improvement Conceptualisation) water quality modelling package (MUSIC Version 4).

The aim of this assessment was to ascertain and compare loads of pollutants generated from the existing environment (current highway) and the project (highway upgrade).

Further analysis was undertaken to test and refine mitigation measures in order to minimise surface water quality impacts of the project on receiving waterways, refer Section 2.3.2.

Rainfall from the Nowra RAN Air Station (number 068072) was adopted for the modelling as it was one of few pluviographs (providing six minute interval data) within close proximity to the project with a consecutive data set and relatively high annual rainfall. Data from 1969 to 1976 was used providing an annual mean rainfall of 1230 millimetres for the modelled period. These dates were used because they cover a period with minimal data gaps from a geographically relevant pluviograph and that is neither particularly wet or dry. The long-term mean annual rainfall for this station is 1133 millimetres.

Typical one hectare catchments were analysed for “pre-existing” (rural land only), “existing” (existing Princes Highway) and “proposed” (the project) pollutant loadings. Event Mean Concentrations (EMCs) for Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) were adopted based on typical pollutant load generation for rural and road catchments (Fletcher *et al.* 2004).

The “pre-existing” catchment was modelled as a single one hectare rural node.

In order to determine pollutant loadings of road runoff on a per hectare basis for the “proposed” catchment, the following assumptions were made with regards to road geometry:

- Three metre wide impervious outside shoulder.
- Two 3.5 metre impervious traffic lanes (pavement).
- One metre wide impervious inside shoulder.
- Five metre wide pervious central median.
- Twenty metre wide pervious batter on each side draining to the pavement.

The typical one hectare catchment breakdown modelled for the proposed catchment is illustrated in **Figure 2-3**.

The “existing” catchment was based on the same assumptions as the “proposed” catchment model, with the exception of a reduced pavement width to reflect the existing traffic lane area. This included a road and median node (41 per cent impervious) and a batter/fill node (zero per cent impervious). The “existing” catchment model did not include any water quality treatment measures.

The “proposed” catchment model was set up with two source nodes; a road and median node (82 per cent impervious) and a cut/fill batter node (zero per cent impervious).

In order to establish a baseline for comparison, the three one hectare catchments were analysed for generated pollutant loadings (kilogram per year), as summarised in **Table 2-2**.

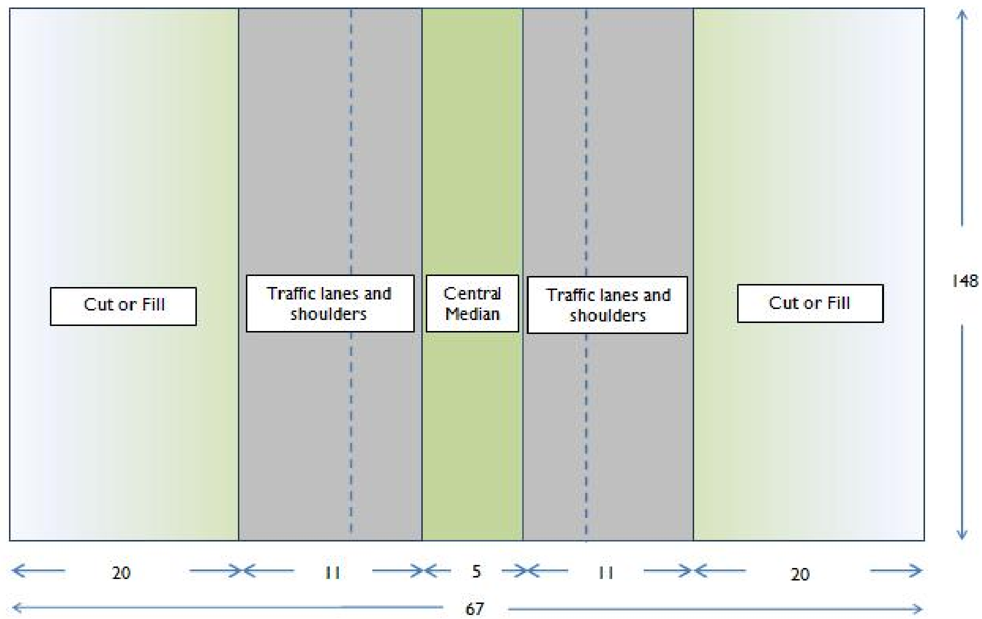

Figure 2-3: Typical 1 hectare of proposed highway upgrade (not to scale, distance in metres)

Table 2-2: MUSIC model residual pollutant loads (no treatment)

	TSS (kg/year)	TP (kg/year)	TN (kg/year)
Pre-existing	235	0.62	6.36
Existing	1260	2.31	10.8
Proposed	1980	3.64	16.6

TSS – Total suspended solids, TP –Total phosphorous, TN – Total nitrogen.

Table 2-2 shows there is an increased pollutant generation from the existing highway compared to a pre-developed rural state. Modelling also shows the project is likely to generate loads in excess of the existing highway as the impervious areas (primarily pavement widths) would increase.

2.2.5 Farm drains/dam yield and downstream ecosystems

An assessment of farm dam catchments was undertaken to determine the likely impact of the construction and operation of the project on the yield of farm dams.

The road development and associated changes to drainage patterns would prevent the natural flow of water into some existing farm dams and potentially affect their yield. During construction and in some cases during operation (refer **Table 2-3**) surface water runoff that, under pre-development conditions, would have flowed downhill to farm dams may in some circumstances be diverted around road cuttings via catch drains and other drainage infrastructure. The water would then be conveyed via a culvert or catch drain, to discharge to a natural waterway.

Farm dams likely to be impacted by the project have been identified and their catchment areas determined. The assessment identified 29 farm dam catchments that are likely to be affected by the proposal. The pre- and post-construction catchment areas were compared to determine the likely impact for each affected farm dam. The changes in catchment area are presented in **Table 2-3**. The farm dam numbers correspond to the labels shown on **Figure 2–4**. Consultation with affected landowners would be carried out during detailed design.

Table 2-3: Changes in farm dam catchment area

Dam No.	Dam location		Pre development area (m^2)	Post development area (m^2)	Area lost / gained (m^2)	Change as % of original
	DP	Lot				
1	615284	6	143,590	141,551	-2040	-1%
2	615284	5	39,426	39,426	Nil	0%
3	1040653	8	16,926	13,615	-3311	-20%
4	563651	2	28,443	32,950	4508	16%
5	563651	2	39,368	39,368	-	0%
6	840646	31	60,628	60,628	-	0%
7	801177	1	58,591	43,227	15,364	-26%
8	1098617	11	204,129	206,156	2027	1%
9	1098617	13	100,100	91,836	-8264	-8%
10	1098617	13	2,900	2490	-411	-14%
11	620014	4	41,848	41,848	-	0%
12	801512	4	7636	7636	Nil	0%
13	628132	2	148,836	141,843	-6992	-5%
14	Unknown	Unknown	42,642	34,716	-7925	-19%
15	628132	3	73,624	71,297	-2327	-3%
16	628132	4	430,286	402,572	27,715	-6%
17	628132	2	716,027	711,489	-4537	-1%
18	653306	69	61,409	35,412	25,997	-42%
19	653306	69	15,803	7299	-8504	-54%
20	377518	A	248,846	248,846	Nil	0%
21	224377	2	13,358	13,470	112	1%
22	701647	22	334,290	304,700	29,591	-9%
23	607155	11	183,977	187,226	3250	2%
24	224377	2	14,271	1894	12,377	-87%
25	224377	2	70,511	48,841	21,669	-31%
26	224377	2	92,035	64,632	27,403	-30%
27	621894	151	99,655	81,688	17,967	-18%
28	255171	1	126,165	134,063	7898	6%
29	1014800	1	27,689	27,521	-168	-1%

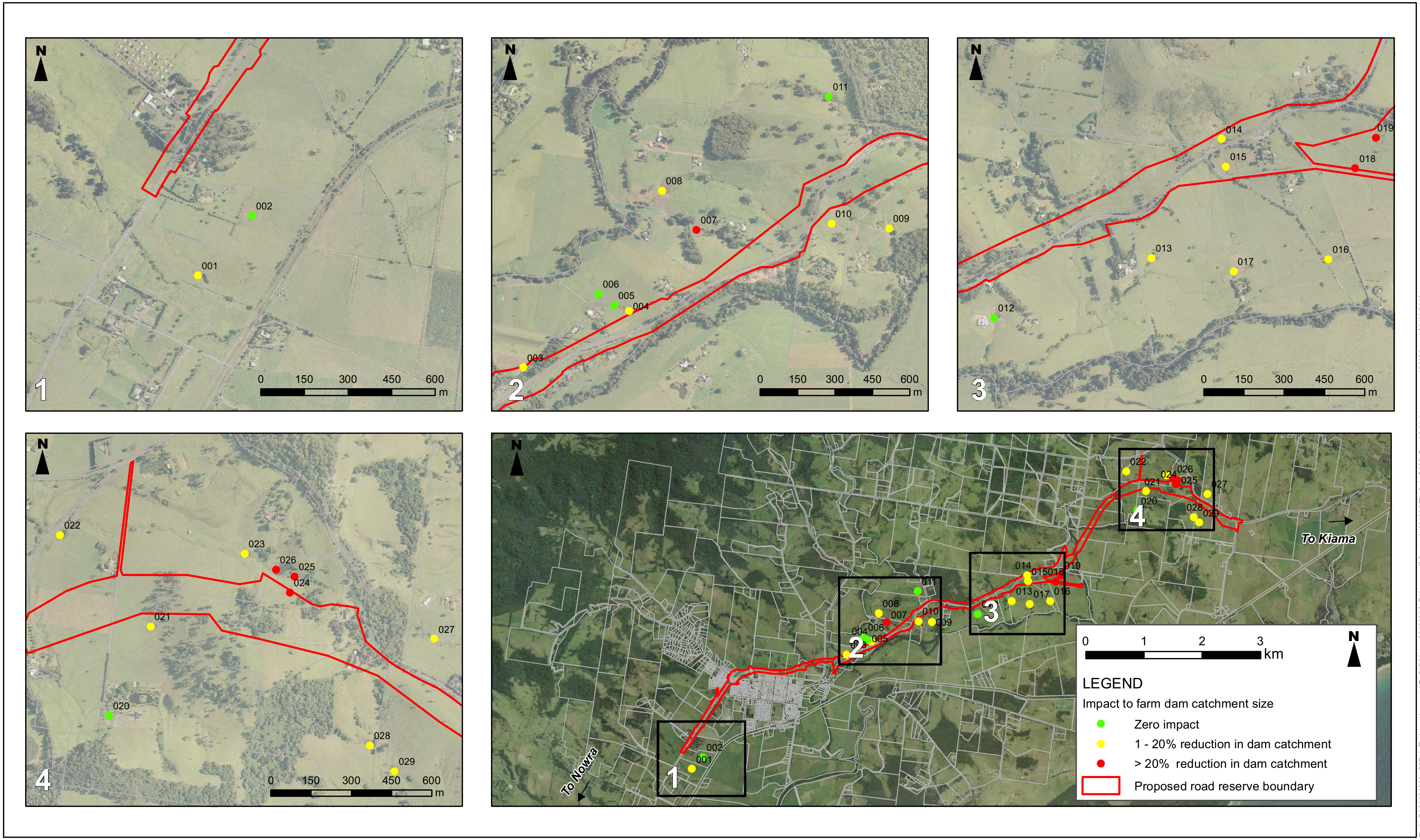

Figure 2-4 Location and impacts on farm dams in the project area

Source: LPMA (2011)

Path: P:\60021933_G2B4_Tech_work_area\4.7_GIS\Maps_20120806_DKennewell\Centred_121030\Fig 2-4_G032_DamYieldsAssessment_121030.mxd 30/10/2012

2.2.6 "Worst case" surface water impacts

The DGRs for the project require that the "worst case" impacts be described. For the purpose of surface water impact assessment, this has been interpreted to represent a situation where no mitigation measures are incorporated in the design, or the mitigation measures have failed. Discussion has been provided below to improve understanding of issues that may arise if this case was realised.

Untreated runoff has hydrologic and water quality impacts. Hydrologically, impervious areas, such as road pavement, deliver an increased volume of water flowing at a faster rate. This could result in the receiving streams potentially eroding over say one to two decades (depending on the rainfall) to a new equilibrium. The new stream form would be wider and deeper than the existing stream and the geomorphic diversity of the stream could be impacted. Consequently, the biodiversity of the flora and fauna that has evolved to the stream geomorphology could be reduced.

These impacts can be mitigated if treatment is provided as part of the project or shortly after construction. The longer the stormwater runoff remains untreated, the less effective mitigation measures would be.

Untreated stormwater runoff can lead to an accumulation of pollutants in waterways over time. This creates ongoing pressures on the ecology of these waterways, leading to lower biodiversity. These water quality impacts would be difficult to remediate as it would take a considerable amount of time to remove pollutants and allow the ecosystems to recover.

2.3 Environmental management measures

2.3.1 Construction management measures

Appropriate management measures are to be implemented during construction to effectively reduce the generation of pollutants and minimise impacts on receiving waters.

Erosion and sediment controls

A soil and water management plan (SWMP) documenting the controls for capturing and removing sediment from runoff prior to reuse or discharge to receiving waters would be developed for the construction phase. Additionally, site specific erosion and sediment control plans (ESCP) would be developed to document the specific controls in place at that time for each area of the site. These would typically be a progressive series of plans to reflect changes to sediment and erosion controls implemented as construction progresses. The erosion and sediment controls across the site would be planned and implemented in accordance with Managing Urban Stormwater-Soils and Construction, Volume 2D (Landcom 2004), and the conditions of the EPL required for the project.

The overall erosion and sediment control strategy for the project would be to first prevent or reduce erosion then capture sediment as close to the source as possible using multiple small control devices rather than solely relying on large sediment basins downstream of construction works. Sediment basins are proposed to be utilised in a number of locations, however these would form only one part of the overall strategy. The sequencing of construction works would also form a key component of the erosion and sediment control strategy.

A proactive and committed approach to erosion control would minimise the sediment generated from the site and lessen the chance of offsite impacts on water quality. Erosion control strategies that would be considered and implemented include:

- Diverting non-site water around and/or through the construction site and the establishment of temporary cross drainage so that up gradient stormwater is not mixed with site stormwater.
- Minimising the extent of disturbed areas and rehabilitating disturbed areas as soon as practicable.
- Reducing the length of slopes through the use of temporary diversion drains to reduce water velocity, and therefore erosion potential, over exposed surfaces.
- Limiting the volume of water movement within the site by removing water from the site at regular intervals though multiple small scale sediment capture devices.
- Construction of operational drainage measures prior to construction, where possible, for use during the construction stage.

Sediment capture strategies

As stated above, sediment capture would be secondary to erosion control and would utilise multiple small capture devices such as check dams and construction sediment basins.

Sediment capture would be undertaken in accordance with Managing Urban Stormwater - Soils and Construction, Volume 2D (Landcom, 2004).

In some areas of the alignment, water quality swales are proposed to convey stormwater as part of the overall water quality management process during the operational phase. During construction in these locations, an increased focus would be placed on at-source erosion control with the footprint of the proposed operational swales utilised as a location to provide multiple water storage areas. This would be achieved by providing rock or sandbag check dams (or similar) along the footprint of the operational swale drain, or other methods in accordance with Managing Urban Stormwater - Soils and Construction, Volume 2D (Landcom, 2004). This construction footprint could also be over excavated if additional water storage volume is required, though a dewatering method statement would be required for each location.

Construction sediment basins

Preliminary basin sizing has been undertaken based on the concept design in order to provide an indication of how erosion and sediment control may be achieved.

Detailed sediment basin sizing would be undertaken by the construction contractor during the construction planning stage of the project. Basin volumes would be calculated for estimated catchment areas at both the clearing stage of the project and at the final earthworks levels, and would be based on the sensitivity of the receiving environments as per Managing Urban Stormwater - Soils and Construction, Volume 2D (Landcom, 2004). Basin volumes for all other stages of construction would be expected to be within this range. Cut batters have been included in the catchment area when sizing sediment basins as earthworks reach the final levels. Fill batters may be excluded as they can be progressively stabilised as they are constructed or can be managed as separate catchment areas.

The construction sediment basins have been sized using the required design criteria for Type D or F (dispersible and fine-grained) soils specified in Managing Urban Stormwater - Soils and Construction, Volume 2D (Landcom, 2004) and shown in **Figure 2-5**.

The sediment basins that do not drain directly to water bodies would be designed to capture and treat the 80th percentile five day rainfall event.

The sediment basins that would directly discharge to sensitive receiving environments such as Broughton Creek, Broughton Mill Creek and Bundewallah Creek would have a higher capacity and capture all runoff from the 85th percentile five day rainfall event.

Typically, operational water quality basins would be constructed during the clearing stage, and utilised during construction to control sediment. A preliminary analysis of the project identified three locations where temporary sediment basins may be required for the construction period only (refer **Figure 2-5**). These basins have been indicatively sized based on the catchment required during the clearing stage. As earthworks progress, these basins would become redundant as construction water is directed to the operational basin locations.

The locations of these indicative temporary basins have been determined based on the concept design and would be subject to change during the detailed design phase. During construction planning, the construction contractor may also determine that more or less temporary construction basins are necessary. The final location of any temporary construction basins would take into account other site factors such as ecological constraints and the availability of land and the basins would not extend beyond the approved construction footprint without further assessment.

A number of locations exist along the alignment where operational basins are not proposed and temporary construction basins are not feasible due to topographical constraints or small catchment areas. These locations have been identified as high residual risk erosion and sedimentation areas (refer **Figure 2-6**) based on the RMS's Erosion and Sedimentation Management Procedure (RTA, 2009).

Generally, the areas identified as high risk are the major cuttings and areas close to the creek as they represent the largest disturbance, steepest slopes and closest proximity to the receiving environment. However these areas can be effectively managed by employing at-source erosion controls to limit the potential for erosion as well as multiple small scale sediment capture structures to trap sediment prior to water leaving the construction site.

As portions of the site have been identified as posing a high risk for erosion and sedimentation a soil conservationist would be engaged to provide advice throughout the construction period.

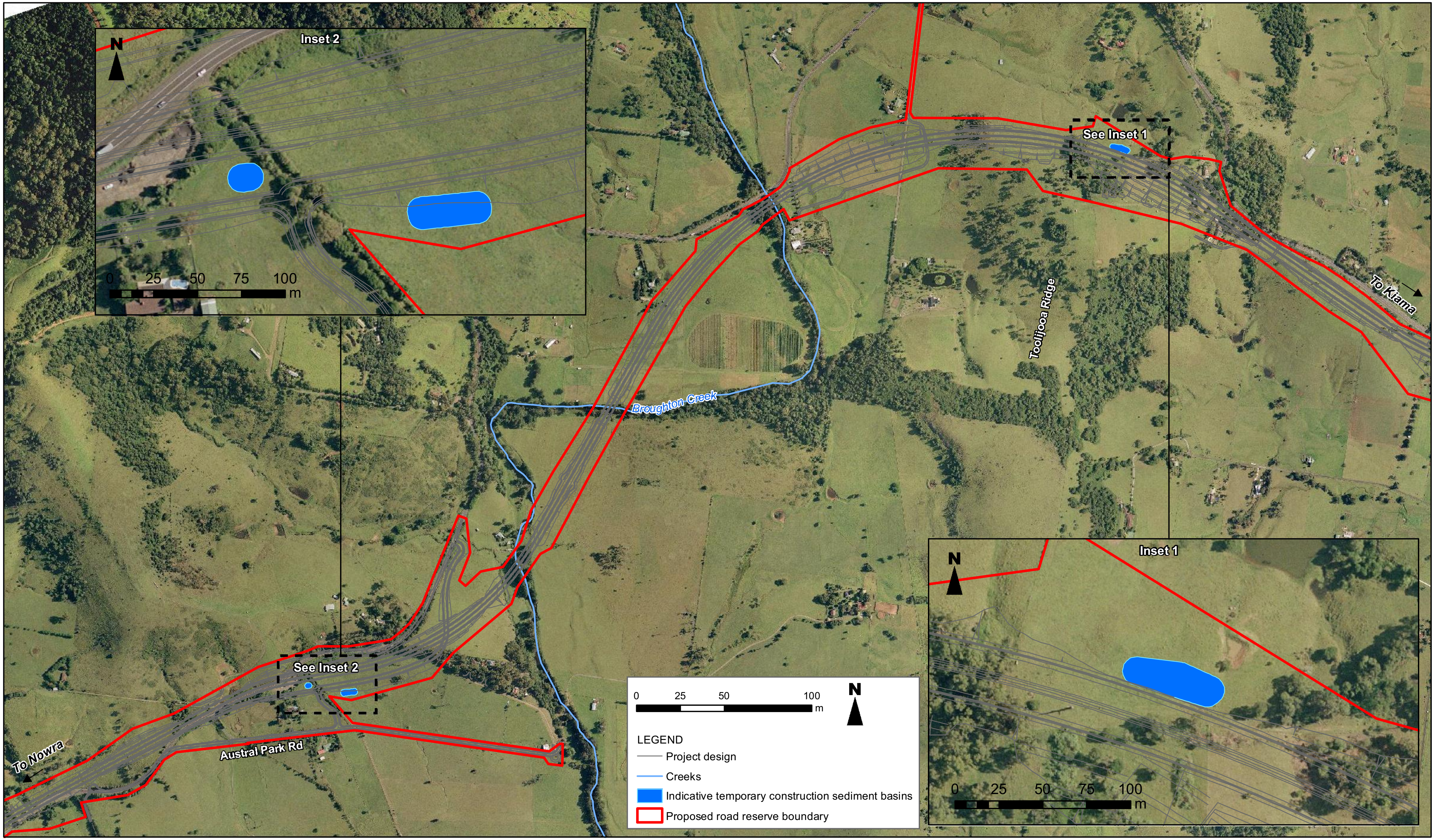

Figure 2-5 Location of indicative temporary construction sediment basins

Source: AECOM (2012), LPMA (2011)

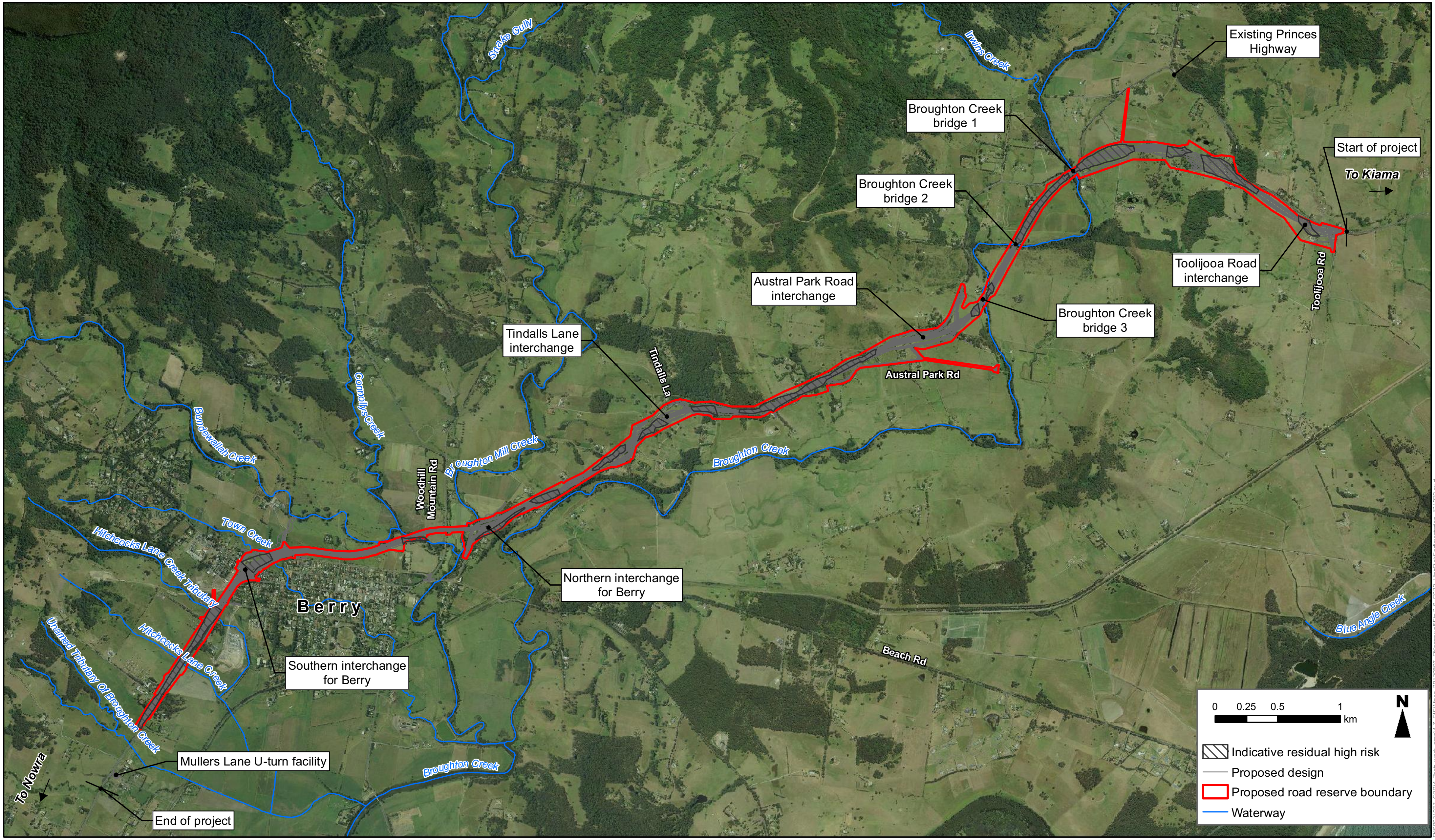

Figure 2-6 Residual high risk erosion and sedimentation area

Source: AECOM (2012), LPMA (2011)

Construction sequencing

Construction sequencing can play a significant role in the erosion and sediment control strategy. When planning construction sequencing, consideration would be made of the following:

- Detailed design and construction staging would be informed by the use of a qualified soil conservation specialist
- Construction works would be planned to minimise the extent of disturbed areas and to rehabilitate disturbed areas as soon as practicable after construction.
- Permanent clean water diversion and top of cut drains would be constructed at the commencement of construction to limit the volume of water on the construction site.
- Where possible, permanent transverse drainage would be installed early in the construction program to allow offsite water conveyance through the construction site. Where this is not possible, temporary drainage structures may be required.
- Sediment basins (both operational and temporary/construction) would be constructed prior to or concurrently with clearing activities.
- Where practical, the proposed operational water quality swales would be constructed prior to or concurrently with clearing activities to enable their use during the construction period.
- Fill batters would be stabilised progressively as they are constructed to limit the areas of disturbed land.
- The proposed diversion of Town Creek (refer to Section 4 for a discussion of the proposed Town Creek diversion) would largely be constructed off line until new beds and banks were stabilised before diverting flows from the upper Town Creek catchment.

Dewatering

Construction site dewatering would be managed through a work method statement prepared in accordance with the RMS technical guidelines for the Environmental Management of Construction Site Dewatering (RTA, 2011).

Acid sulfate soils

Although there is a low risk of ASS (refer Section 2.1.4), appropriate management measures would be implemented during construction to reduce the risk associated with disturbing ASS. Such measures would include an acid sulfate soil management plan (ASSMP) outlining the strategies to manage potential ASS (PASS) impacts. During the initial works onsite, further testing for ASS or PASS across the floodplains would be undertaken to quantify the risk of disturbing ASS, with a particular focus on any excavations. The ASSMP would be developed in accordance with the RMS Guidelines for the Management of Acid Sulfate materials: Acid Sulfate Soils, Acid Sulfate Rock and Monosulphidic Black Ooze (RMS, 2005).

The ASSMP would outline the following:

- How excavated material would be temporarily stored, treated and used.
- Specific leachate control procedures.
- Protocol measures should unexpected ASS related incidents occur.

To minimise PASS impacts where possible, construction should be planned to reduce the amount of deep trenching or soil replacement. Designers should also account for the potential acidic nature of the estuarine soils and the impact on engineered structures. Where ASS are found, soil specialists should be consulted to determine soil treatment requirements.

Mitigation measures may include the following:

- Avoidance of ASS.
- Minimising the disturbance of ASS.
- Avoiding activities that could lower the water table.
- Undertaking water quality monitoring downstream of ASS risk areas.
- Neutralising acidic runoff.
- Covering ASS with clean fill to prevent further disturbance.

Contaminated runoff and spills

Areas would be allocated for the storage of fuels, chemicals and other hazardous materials. These facilities would be secured and bunded. Any spills or contaminated runoff would be captured and disposed of at a licensed facility.

Activities such as refuelling, washdown and preparation of construction materials would be undertaken in bunded areas to mitigate risks in relation to spills or leaks of fuels/oils or other hazardous onsite construction material.

The application of good practice in the storage and handling of dangerous and hazardous goods would provide appropriate practical responses to manage impacts on occupational health and safety and minimise the risk of a spill occurring.

In addition, potential discharges from construction sites such as accidental construction spills or leaks would be managed through the installation of basins (primarily designed for sediment capture but with capacity to contain a significant spill volume) constructed in accordance with Managing Urban Stormwater - Soils and Construction, Volume 2D (Landcom, 2004). Captured contaminants resulting from spills or leaks would be treated and disposed of at a licensed facility.

Water required for dust control

Impacts from dust entering waterbodies would be managed using dust suppression techniques such as water spraying. The amount of water required would depend on a number of factors including rainfall, wind direction and intensity, soil type and area of ground disturbance at any one time.

It is estimated that approximately 12 litres/m^2 of water would be required for dust suppression daily. This is dependent on weather and surface exposure and would be variable over the course of the project.

Water for construction purposes including dust control would be sourced, where reasonable, from the following locations in order of preference:

- Recycled effluent from the Gerringong Gerroa Sewerage Scheme and the Berry Sewage Treatment Plant (in accordance with RMS policy and guidance for the use of reclaimed water)
- Surface water (sediment basin captured runoff).
- Surface water (watercourses).
- Potable water.
- Groundwater.

Farm dams

The assessment of existing farm dam catchments (refer Section 2.2.5) showed that for the majority of farm dams the loss of catchment area would be less than 20 per cent of the original catchment. The farm dams with the greatest proportion of catchment loss are those smaller dams which are located at higher elevations and have relatively small catchments. Several of these highly impacted dams are located on properties already acquired by RMS for the project. Residual impacts would be managed through consultation with individual stakeholders.

Water quality monitoring

An independent surface water quality monitoring program would be incorporated into the ESCP in accordance with the recommendations of the *Aquatic Ecology and Water Quality Management Assessment* (Cardno Ecology Lab, 2012), which is provided at Appendix G to the environmental assessment.

This program would use ANZECC trigger values for the protection of aquatic ecosystems as a starting point to develop locally appropriate thresholds that would trigger mitigating management responses. This would include monitoring parameters such as Turbidity (positively correlated with suspended sediment loads) and pH (to monitor ASS).

2.3.2 Operational management measures

The assessment of water quality has sought to identify potential impacts and provide appropriate management controls within the design (see Section 2.2.2). The water quality treatment system selected for the project aims to improve the quality of runoff compared to the existing highway and therefore have a net benefit to receiving waterways. This approach would protect sensitive receiving environments, in particular creeks of ecological importance including moderate and major fish habitat waterways.

The design of crossings over creeks and drainage lines has considered the sensitivity of these receiving environments and appropriate measures would be applied, including suitably spanned bridges to protect the riparian environments.

Town Creek diversion

The diversion channel would include the appropriate use of energy dissipators and/or batter treatment to ensure the diversion of flows from Town Creek into Bundewallah Creek does not cause scour and erosion.

The design of the diversion channel would include a revegetation component to stabilise banks and therefore mitigate erosion. Whilst enhancing the structural integrity of the channel, subsequent benefits of revegetation would include:

- Increased protection to the adjacent landowners land.
- Increased channel roughness thereby reducing velocities and erosive flows.
- Increased channel shear strength and soil binding.
- Provision of habitat, habitat corridor, nutrient assimilation and increased biodiversity.

The design and revegetation of the diversion channel would ensure there is no detrimental impact on water quality within the channel and therefore for flows into Bundewallah Creek.

Operational water quality basins and swales

In order to inform and develop an efficient water quality strategy for the operation phase, pavement runoff was modelled using the MUSIC model developed for the water quality impact assessment (see Section 2.2.2). A range of water quality treatment measures (Scenario 1 through to Scenario 4c) were included in the model. A description of each scenario is provided in **Table 2-4**.

The modelling included the treatment of runoff from a batter of five metres width on both sides of the roads. These "treated batter' nodes have EMC values for sediment loads based on typical agricultural catchments (as per Fletcher *et al.* 2004) as soils for the lower portion of total batter area may be incompletely protected by vegetation. For nutrients the "treated batter" nodes have rural catchment values rather than agricultural values as the fertilisers normally associated with agricultural practices would not be used.

The remaining batter areas (in excess of the five metres assumed draining to the pavement) were modelled as "untreated batter" nodes with typical rural EMC values to represent the vegetated state of the operational phase, allowing little mobilisation of pollutants. These "untreated batter" nodes would generally be diverted around treatment measures and therefore bypass treatment nodes in the MUSIC model.

Table 2-4: Operational pollutant reduction strategies – swales and basins

Scenario	Size (per hectare)	Description of water quality treatment
1	140 m^3 basin	Operational water quality basins include the following assumptions: • 2.5 m deep (including 0.5 m freeboard, 1.4 m extended detention and permanent pool depth of 0.6m). • 2H:1V internal batters. • 3H:1V external batters. • Notional detention time of six hours. • Energy dissipaters or scour protection methods would also be used to prevent erosion at outlets.
2	220 m^3 basin	
2a	300 m^3 basin	
3a	60 m x 1.0 m swale	Swales design would include the following assumptions: • 1% longitudinal grade. • 2H:1V batters. • Exfiltration set to zero. • Depth of 0.3 m. • 0.25 m vegetation height.
3b	100 m x 1.0 m swale	
3c	140 m x 1.0 m swale	
4a	60 m x 2.0 m swale	Swales design would include the following assumptions: • 1% longitudinal grade. • 2H:1V batters. • Exfiltration set to zero. • Depth of 0.3 m. • 0.25 m vegetation height.
4b	100 m x 2.0 m swale	
4c	140 m x 2.0 m swale	

In order to establish a baseline for comparison, the three one hectare catchments were analysed for generated pollutant loadings (kg/year) and the results are summarised in **Table 2-5**.

Table 2-5: Residual pollutant loads – swales and basins

No treatment	TSS (kg/year)	TP (kg/year)	TN (kg/year)
Pre-existing	235	0.62	6.36
Existing	1260	2.31	10.8
Proposed	1980	3.64	16.6
Design with treatment			
Scenario 1	530	1.69	15.4
Scenario 2	433	1.53	14.9
Scenario 2a	376	1.44	14.5
Scenario 3a	413	1.60	16.0
Scenario 3b	298	1.41	15.4
Scenario 3c	240	1.31	15.0
Scenario 4a	316	1.44	15.5
Scenario 4b	226	1.29	14.8
Scenario 4c	184	1.22	14.4

Note: No pre-treatment “buffering” (sheet flow of water over grassed medians or batters) is accounted for in the above scenarios.
TSS – Total suspended solids, TP –Total phosphorous, TN – Total nitrogen.

It should be noted that modelling did not allow for any pavement water ingress through the swale base and sides. It is likely that some runoff would be exfiltrated therefore reducing pollutant loads further than stated in the above results. Similarly pollutant reduction percentages would increase where exfiltration occurs.

As shown in **Table 2-5**, incorporating treatment measures such as swales and permanent operational water quality basins can reduce pollutant loads to receiving environments below existing conditions for TSS and TP. The proportion of pollutant reduction attributable to different treatment devices is shown in **Table 2-6**.

Table 2-6: Pollutant reduction percentages – swales and basins

Water quality basins	TSS (% reduction)	TP (% reduction)	TN (% reduction)
Scenario 1	73.2	53.5	7.6
Scenario 2	78.1	57.8	10.1
Scenario 2a	81.0	60.4	12.8
Swales 1 m wide			
Scenario 3a	79.1	56.0	3.9
Scenario 3b	84.9	61.3	7.3
Scenario 3c	87.9	64.0	10.0
Swales 2 m wide			
Scenario 4a	84.0	60.3	6.9
Scenario 4b	88.6	64.5	10.8
Scenario 4c	90.7	66.5	13.6

The modelling suggests a water quality basin with 300 cubic metres of extended detention storage per hectare (Scenario 2a) can provide up to an 81 per cent average removal of TSS generated under proposed design conditions. A similar level of TSS removal could be provided with a vegetated swale of one metre base width and 60 metres length per hectare (Scenario 3a). However wider and longer swales per hectare are required to achieve TP and TN removal similar to sedimentation basins. Scenario 4c (Two metre base width and 140 metres length) is the swale that matches the basin in Scenario 2a most closely for TN reduction.

It is recommended that the water quality strategy includes a combination of swales and water quality basins to treat road runoff and protect downstream receiving environments, in accordance with the following:

- Swales: A range of swales of varying length are proposed both in the median and along outer road edges to convey and treat runoff. As a minimum these swale sizes would meet the total area requirements of Scenario 4c (ie 140 metres long by two metres wide, per hectare of upstream catchment).
- Basins: Proposed sizes for water quality basins along the upgrade are summarised in **Table 2-7** (based on Scenario 2A). Access in the form of a three metre wide access track would be incorporated in the basin berm for maintenance.

Based on the current concept design, **Table 2-7** indicates that water from the operational roadway would be treated in one of up to 18 operational water quality basins prior to discharging into the environment. An initial assessment of the positioning of the proposed operational water quality basins (refer **Figure 2-7**) indicated that the majority of these basins would also be suitable for use during the construction period. Water quality basins 12A and 13A were determined not to be suitable for use as they are designed to capture water from a bridge structure and the amount of earthworks in the vicinity of these basins would be minimal. The preliminary sizing indicates that one operational basin (3A) would be below the design criteria during the clearing stage and five operational basins (2A, 4A, 6A, 9B and 9C) would be below the design criteria at final construction levels (note: basins 3A and 6A discharge to sensitive receiving environments). The latter five basins were all associated with areas of cut. In these areas, other measures would be implemented during construction to compensate for this shortfall in the basin volume (such as staging of works, at-source erosion control and small sediment capture devices throughout the catchment).

Additionally, the cut batters could be managed as separate catchments with multiple small sediment capture devices to reduce reliance on the end of line sediment basin. It should be noted that the actual operational water quality requirements, including number and location of basins, would be refined and finalised during detailed design.

Table 2-7: Potential size requirements for operational water quality basins based on the Concept Design

Basin name	Catchment area (m^2)	Indicative volume required (m^3)
1A	8480	254
2A	38,661	1160
3A	12,990	390
4A	27,579	827
5A	16,850	505
6A	17,839	535
7A	19,165	575
8A	56,289	1689
8B	13,792	414
9A	6644	199
9B	19,040	571
9C	11,610	348
10A	19,033	571
11A	24,155	725
12A	5280	158
13A	4296	129
14A	36,738	1102
15A	24,465	734

Note: see ***Figure 2-7*** *for basin locations. Number of basins and volumes are subject to change during detail design*

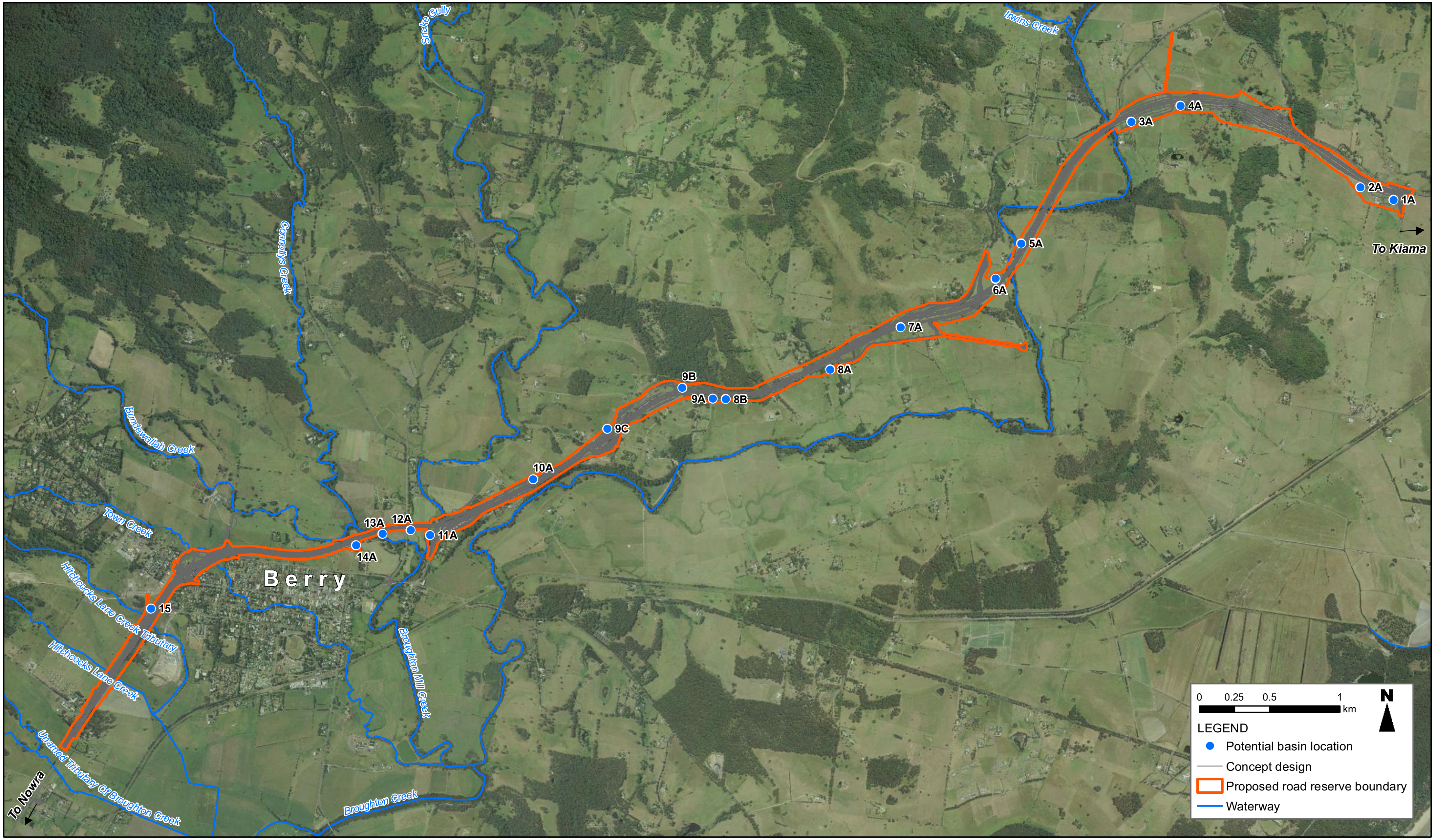

Figure 2-7 Potential operational water quality basin locations

Source: LPMA (2011)

Path: P:\60021933_G2B\4_Tech_work_area\4.7_GIS\Maps_20120906_DKennawell\Central_121030\Fig 2-7_G029_WaterQualityBasins_121030.mxd 30/10/2012

Capture and spills

The upgraded highway alignment would likely provide for safer transportation of vehicles compared with the existing alignment. This would reduce the total number of accidents along the upgraded section and therefore the potential of a spill of hazardous substances would also reduce.

Any spills that do occur would be directed to the permanent water quality basins and swales, all of which would have the capacity to receive a spill with a volume corresponding to that of a typical transport truck.

Both water quality basins and swales have potential for spillage control or containment. These water quality treatment measures provide capacity to treat first flush from the pavement surface and reduce the risk of spills discharging onto adjacent land or watercourses. The potential for spillage control or containment would be based on the hydrologic conditions prevailing at the time of the spill.

Additional treatment measures for sensitive receiving environments

Basins capturing runoff from pavements that drain to sensitive receiving environments would be designed with special outlet configurations to reduce the likelihood of overflow into the sensitive environment. For example:

- Water quality basins would have a permanent pool which a volume of spill would have to displace before passing through the entire basin.
- Bioretention systems would have extended detention depths that would have to be breached before overflowing into the downstream environment.

These simple yet effective arrangements would be incorporated into the design of water treatment systems as mentioned above with capacity to accommodate a typical transport truck.

In addition to swales and water quality basins, other treatment measures would be considered to further reduce nutrient loads from road runoff (primarily targeting nitrogen).

With regard to the runoff pollutants TSS, TP and TN, the latter is usually the most difficult pollutant to remove. This is because TSS and a large fraction of TP are associated with particulates, which are readily trapped by basins or swales. Only a small fraction of TN is particulate, the remainder being dissolved forms of nitrogen that can only be removed by biological processes such as a bioretention swale or trench (as shown in **Figure 2-8** and **Figure 2-9**).

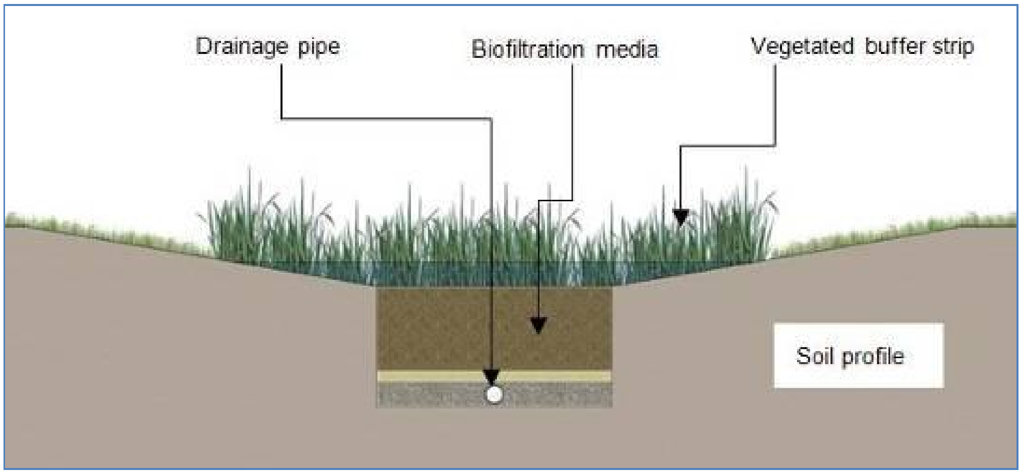

Figure 2-8: **Typical cross section of a bioretention swale (note saturated zone not shown on this section)**

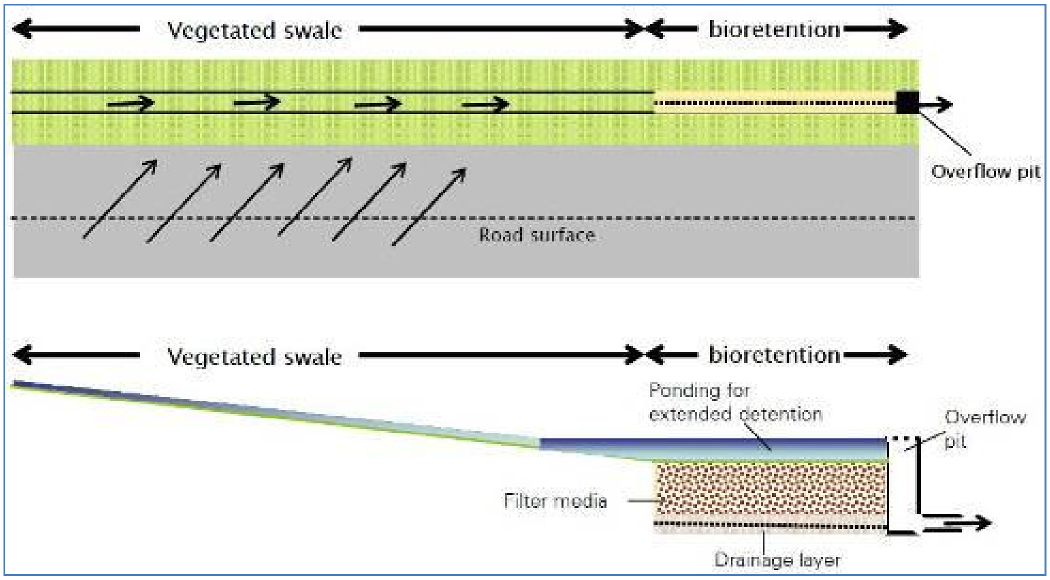

Figure 2-9: **Conceptual layout for bioretention swale (WSUD Technical Design Guidelines, 2006)**

Bioretention systems effectively remove fine suspended sediments, dissolved nutrients and heavy metals. Treatment of runoff occurs both on the surface of the bioretention system and within the filter media. When large storm inflows cause temporary ponding on the surface of the system (provided flat grades are achieved or check dams are installed to detain flows) pollutants are removed from the runoff through sedimentation and particulate adhesion onto the stems and leaves of the vegetation.

As stormwater percolates through the filter media, fine particulates and some soluble pollutants are removed through processes such as adhesion onto the surface of the filter media particles, biological transformation of pollutants by biofilms growing on the surface of the filter media particles, and biomass uptake of nutrients and metals through the root systems of the vegetation. The agitation of the surface layer of the soil caused by movement of the vegetation and the growth and death of roots helps maintain the permeability of the filter media.

Recent developments in bioretention system design have aimed to enhance the removal of dissolved nitrogen by enhancing anaerobic nitrogen removal processes such as denitrification. This has been done by modifying bioretention system designs to accommodate a submerged anoxic zone within the filter media and the addition of a carbon source to promote the denitrification bacterial activity. Studies of submerged zone bioretention systems have reported very high dissolved nitrogen removal from these adapted systems (Zinger *et al,* 2007).

Bioretention systems are typically planted with select species that are well adapted to the bioretention hydrology, are indigenous to the area, are hardy and would provide complementary habitat to the waterways into which they would drain. Dense and diverse plantings of such an ecological community provide excellent pollutant removal and require very little maintenance after establishment.

Effective removal of nitrogen requires that the footprint of the bioretention system be large enough to treat a sufficient volume of water from most storms (up to one year average recurrence interval (ARI)).

Targeted catchments

The catchments where additional nutrient removal treatment measures would be most effective are those that discharge directly to permanent waterways such as Broughton Mill Creek, Connollys Creek, Bundewallah Creek or Broughton Creek.

Bioretention construction involves trenching (up to one metre deep to accommodate filter depths and submerged zones) and it is possible that ASS (if present) may be exposed during this process. Bioretention also requires effective hydraulic operation to allow sub-surface collection drains to discharge downstream. This may be prohibitive for some areas within these floodplains.

Investigations would be undertaken to determine the presence of ASS at locations immediately upstream of road runoff discharge points to Broughton Mill Creek, Bundewallah Creek or Broughton Creek where bioretention would be most beneficial.

Where it is found that site conditions are suitable for bioretention, including an available area that does not contain ASS and where levels allow suitable hydraulic function, bioretention systems would be considered for implementation as part of the road runoff treatment.

Bioretention sizing

In order to determine suitable sizes for bioretention systems a range of scenarios were modelled using MUSIC. Modelling was undertaken as per the source catchment descriptions and EMC pollutant loads outlined above. A description of each scenario is provided in **Table 2-8**. Scenarios include swales as a pre-treatment to bioretention or a water quality basin preceded by a bioretention system. Note the scenarios described in **Table 2-8** could replace standalone swales and water quality basins, provided site conditions are suitable for bioretention.

The MUSIC modelling results outlined in **Table 2-9** and **Table 2-10** show a substantial reduction in TSS, TP and TN pollutant loads for all scenarios.

Table 2-8: Additional bioretention treatment measures for sensitive receiving environments (based on one hectare of road corridor)

Scenario	Description	Description of water quality treatment
5a	Swale and bioretention: 140 m swale + 60 m^2 bioretention system (ie 30 linear metres of bioretention swale)	Swales design would include the following assumptions: • 1 % longitudinal grade. • 2 m wide base. • 2H:1V batters. • Exfiltration set to zero. • 0.3 m depth. • 0.25 m vegetation height. Bioretention design would include the following assumptions: • 0.5 m deep filter depth. • 0.3 m extended detention depth. • 150 mm/h saturated hydraulic conductivity • 0.3 m submerged zone with carbon source.
5b	Swale and bioretention: 140 m swale + 70 m^2 bioretention system (ie 35 linear metres of bioretention swale)	
5c	Swale and bioretention: 140 m swale + 80 m^2 bioretention system (ie 40 linear metres of bioretention swale)	
6a	Sediment basin and bioretention: 25 m^3 sediment basin + 75 m^2 bioretention system	Sediment Basin design would include the following assumptions: • 2.0 m deep (including 0.5 m freeboard, 0.5 m extended detention and permanent pool depth of 1.0 m). • 2H:1V internal batters. • 3H:1V external batters. • Energy dissipaters or scour protection methods would also be used to prevent erosion at outlets. Bioretention design would include the following assumptions: • 0.5 m deep filter depth. • 0.3 m extended detention depth. • 150 mm/h saturated hydraulic conductivity • 0.3 m deep submerged zone with carbon source.
6b	Sediment basin and bioretention: 30 m^3 basin + 85 m^2 bioretention system	
6c	Sediment basin and bioretention: 35 m^3 basin + 95 m^2 bioretention system)	

Table 2-9: Residual pollutant residual loads - additional bioretention measures

No treatment	TSS (kg/year)	TP (kg/year)	TN (kg/year)
Existing Princes Highway	1260	2.31	10.8
Design Princes Highway	1980	3.64	16.6
Design with treatment			
Scenario 5a	119	0.811	9.6
Scenario 5b	112	0.78	9.2
Scenario 5c	107	0.76	8.9
Scenario 6a	347	1.18	10
Scenario 6b	279	1.03	9.09
Scenario 6c	249	0.97	8.7

Table 2-10: Pollutant reduction percentages - additional bioretention measures

Scenario	TSS (% reduction)	TP (% reduction)	TN (% reduction)
Scenario 5a	94.0	77.7	42.3
Scenario 5b	94.3	78.5	44.4
Scenario 5c	94.6	79.1	46.3
Scenario 6a	82.4	67.7	39.8
Scenario 6b	85.9	71.6	45.3
Scenario 6c	87.4	73.3	47.6

Suitable bioretention scenarios for catchments that discharge directly to Broughton Mill Creek, Bundewallah Creek or Broughton Creek would include for example:

- Scenario 5c: 140 metre swale plus 80 square metres of bioretention (ie 40 linear metres of two metre wide bioretention swale).
- Scenario 6b: 30 cubic metres of water quality basin plus 85 square metres of bioretention.

These meet a 45[1] per cent TN reduction target as per the EPA guidelines (Managing Urban Stormwater: Council Handbook (refer **Table 2-10**).

[1] This indicates compliance is possible, under a "typical" section of highway, if these scenarios were adopted. The purpose of this analysis is to confirm a solution is possible, but maintain flexibility to provide site-specific solutions during detail design. The actual solution implemented would depend on factors such as the availability of engineered soils, the suitability of existing topsoils and the season/time of year during which revegetation would occur.

Maintenance

The typical maintenance requirements of the proposed stormwater treatment elements are described in **Table 2-11**.

Table 2-11: Maintenance requirements for typical stormwater treatment element

Treatment element	Typical maintenance requirements
Swales	• Check that vegetation is at suitable height to allow design flow capacity. • Clear obstructions or debris. • Check for erosion, weeds, plant condition, oil spills and the build-up of litter and sediment.
Sediment basins	• Check that pits, pipes, weirs and other structures are clear of any obstructions or debris. • Check for erosion, weeds, plant condition, oil spills and the build-up of litter and sediment. • Desilt approximately once every five years (or when half of the sediment storage capacity is full).
Bioretention systems	• Check that pits, pipes, weirs and other structures are clear of any obstructions or debris. • Check for erosion, weeds, plant condition, compaction of filter media, oil spills and the build-up of litter and sediment.

Generally, inspection of stormwater treatment devices is recommended every three months until the system has become established. After this time inspection is recommended after large storm events (minimum of one inspection per year). Additional maintenance is then only required if a problem is evident during the inspection. Maintenance requirements can be further reduced through appropriate considerations and provisions in the detailed design phase, for example:

- Adopting a bush regeneration approach (using native species) for the water treatment features of the landscape. This would reduce the frequency of maintenance compared to an exotic species based formal landscape. As the vegetation community in a native species based landscape establishes, it becomes increasingly self-sustaining or self-regenerating.
- By specifying very high and diverse planting densities in planting plans to make aquatic features resistant to weed establishment, for example, six to 12 plants per square metre, depending on the situation. Effective weed management would then be achieved through regular monitoring and the early removal of weed propagules during the establishment phase.

Water quality basins generally require cleaning out about every five years depending on the sizing of inlet ponds, while bioretention systems may need resetting every 25 years (MUSIC by eWater (2010)).

Management measures summary

In order to mitigate the impact on receiving waterways from runoff generated from the project, appropriate water quality treatment mechanisms would be adopted. This would include as a minimum swales and/or permanent water quality basins to target sediment and nutrient capture.

Suggested water quality treatment targets for the project are:

- An 80 per cent reduction in TSS load.
- A 60 per cent reduction in TP load.

Example treatment systems to meet this target would include:

- Swales 140 metres by two metres per hectare of road catchment (based on **Figure 2-3**).
- Water quality basins providing 300 cubic metres of working volume per hectare of road catchment (based on **Figure 2-3**).

These treatments would meet stormwater quality targets for TSS and TP and also reduce loads for these parameters below existing conditions.

Suggested water quality treatment targets for catchments that discharge directly to the more sensitive receiving environments of Broughton Mill Creek, Connollys Creek, Bundewallah Creek or Broughton Creek are:

- An 85 per cent reduction in TSS load.
- A 60 per cent reduction in TP load.
- A 40 per cent reduction in TN load.

Additional water quality treatment measures for outlets directly discharging to sensitive receivers would be considered in order to increase nitrogen removal. This requires the addition of bioretention systems to the treatment train. This would include swales and bioretention and/or water quality basins and bioretention in place of standalone swales or water quality basins. Example treatment systems to meet this target would include:

- 140 metre swale plus 80 square metres of bioretention per hectare of road catchment (based on **Figure 2-3**).
- 30 cubic metres of water quality basin plus 85 square metres of bioretention per hectare of road catchment (based on **Figure 2-3**).

In addition to meeting targets for TSS and TP, these treatments would meet stormwater quality targets for TN to reduce loads for nitrogen below existing conditions.

Note site conditions would be assessed at the detailed design phase to ensure bioretention is suitable. Site conditions such as the presence of PASS and minimum grades may prevent bioretention being feasible. In this case swales and/or water quality basins would be adopted to treat runoff.

In situations where it would not be possible to meet the nitrogen reduction target without compromising the hydraulic capacity of the system, or exposing PASS, the nitrogen reduction target would be waived in preference to hydraulic capacity and TSS removal.

Water quality monitoring

The water quality treatment system selected for the project aims to improve the quality of runoff compared to the existing highway and therefore have a net benefit to receiving waterways. Monitoring of surface waters upstream and downstream of site would be required In order to assess the performance of the system.

An independent surface water quality monitoring program is described in *Aquatic Ecology and Water Quality Management Assessment* (Cardno Ecology Lab, 2012) which is provided at Appendix G to the environmental assessment.

This program would use ANZECC trigger values for the protection of aquatic ecosystems as a starting point to develop locally appropriate thresholds that would trigger operational mitigating management responses. This would include monitoring parameters such as Turbidity (positively correlated with suspended sediment loads), pH (to monitor ASS), Nutrients (TP and TN), Metals (Aluminium, Cadmium, Copper, Lead, Zinc) and Total Petroleum Hydrocarbons.

3 Groundwater

This chapter describes the existing groundwater features in the locality of the project and assesses the potential impacts of the construction and operation of the project. It also outlines measures to mitigate these potential impacts. The chapter is based on the DGRs for the project and consideration of comments from the NOW (2011). Site specific groundwater information is derived from a geotechnical investigation (Coffey, 2010), in which 20 monitoring wells were constructed. Groundwater was encountered in all these monitoring wells along the route and groundwater levels were measured. However no groundwater quality data is available. The shallowest groundwater (0.96 metres below ground level) intersected along the route was within sandstone adjacent to Broughton Creek.

Groundwater management strategies outlined in this chapter have been compiled in accordance with NSW State policy as outlined by the OEH and NOW.

3.1 Groundwater regulation and management

Groundwater and surface water within the Sydney Basin is managed by NOW. The access, extraction and use of groundwater in NSW is currently managed and implemented under two key pieces of legislation - the *Water Management Act 2000* (WM Act) and the *Water Act 1912* (Water Act). The WM Act is gradually replacing the planning and management frameworks in the Water Act, although some provisions of the Water Act are still in force. The WM Act regulates water use for rivers and aquifers where Water Sharing Plans have commenced, while the Water Act continues to operate in the remaining areas of the State. The project area is located within the Sydney Basin Southern management zone of the Greater Metropolitan Region Water Sharing Plan which commenced on 1 July 2011 (NOW, 2011a).

The objective of the WM Act is the sustainable and integrated management of the State's water for the benefit of both present and future generations. The Act requires approvals for activities that impact the aquifer(s) present. The approval is for activities that intersect groundwater other than water supply bores and may be issued for up to ten years. In accordance with Part 3A of the EP&A Act water use approval under Section 89, and a water management work approval under Section 90 or an activity approval under Section 91 of the WM Act is not required.

The NSW State Groundwater Policy Framework Document was adopted in 1997 and aims to manage the State's groundwater resources to sustain their environmental, social and economic uses (DLWC, 1997). The policy has three component parts:

- The NSW State Groundwater Quality Protection Policy (DLWC, 1998).
- The (Draft) NSW State Groundwater Quantity Management Policy (largely replaced by Water Sharing Plans) (DLWC, no date).
- The NSW State Groundwater Dependent Ecosystems Policy (DLWC, 2002).

While these policies set the principles and overarching goals for groundwater management, the Water Sharing Plans are legislated sets of rules for specific groundwater sources, placing volumetric limits on different categories of extractive use, and identifying minimum environmental water needs. Interference to environmental water requirements is governed by strict rules regarding the long-term average annual recharge. Thus construction activities would need to manage impacts within the prescribed limits.

The protection of groundwater from contamination is primarily governed by the POEO Act which makes it an offence to pollute waters, including groundwater. In accordance with Part 3A of the EP&A Act, under section 75v(1) an application for an EPL under the POEO Act cannot be refused if necessary for the carrying out of an approved project.

3.1.1 Groundwater quality

The NSW Groundwater Quality Protection Policy (DLWC, 1998) states that the objectives of the policy would be achieved by applying the management principals listed below:

- All groundwater systems should be managed so that the most sensitive identified beneficial use (or environmental value) is maintained.
- Town water supplies should be afforded special protection against contamination.
- Groundwater pollution should be prevented so that future remediation is not required.
- For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the resource.
- A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwaters that are incompatible with soil, vegetation or receiving waters.
- Groundwater dependent ecosystems would be afforded protection.
- Groundwater quality protection should be integrated with the management of groundwater quantity.
- The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource.
- Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.

3.1.2 Groundwater dependent ecosystems

The NSW State Groundwater Dependent Ecosystems Policy (DLWC, 2002) is specifically designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations. The policy defines GDEs, as “communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater.” A GDE may either be entirely dependent on groundwater for survival or it may use groundwater opportunistically or for a supplementary source of water (Hatton and Evans, 1998). GDEs often occur in low lying areas with shallow groundwater close to the surface, however they are also associated with perched swamps, springs, karsts and base-flow to creeks and estuaries.

Five management principles establish a framework by which groundwater is managed in ways that ensure, whenever possible, that ecological processes in dependent ecosystems are maintained or restored. A summary of the principles are as follows:

- GDEs have important values. Threats should be identified and action taken to protect them.
- Groundwater extractions should be managed within the sustainable yield of aquifers.
- Priority should be given to ensure that sufficient groundwater is available at all time to identified GDEs.
- Where scientific knowledge is lacking, the precautionary principle should be applied to protect GDEs.
- Planning, approval and management of developments should aim to minimise adverse effects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater systems.

3.1.3 Groundwater quantity protection

The objectives of managing groundwater quantity in NSW are:

- To achieve the efficient, equitable and sustainable use of the State's groundwater.
- To prevent, halt and reverse degradation of the State's groundwater and/or its dependent ecosystems.
- To provide opportunities for development which generates the most cultural, social and economic benefits to the community, region, state and nation, within the context of environmental sustainability.
- To involve the community in the management of groundwater resources.

The policy for managing access to groundwater sources and relevant links with the Water Sharing Plan process and licensing conditions are outlined in NOW (2011b).

3.2 Existing environment

3.2.1 Aquifer characteristics

There are two main aquifer systems present along the project alignment including:

- Unconsolidated and unconfined alluvial/colluvial aquifers.
- Shoalhaven Group sediments.

The alluvial aquifer occurs as sand, silt clay and gravel flanking the creek systems and as more widespread floodplain deposits. Groundwater flow within the alluvial aquifer is via intergranular flow where sand and gravel lenses are interconnected providing preferential pathways of higher permeability. Within the flood plain sediments localised perched groundwater is expected above interbedded clay horizons. Little information is available within the NOW database for the alluvial aquifers suggesting the groundwater available for abstraction within the alluvial aquifer is limited and there are other water supply options available for local land holders. Groundwater movement within the alluvial aquifer and flood plain sediments is expected to flow towards low lying topographical features discharging into local creek systems or as springs.

Groundwater within the Shoalhaven Group sediments within the study area is present within the volcanoclastic Broughton Sandstone as well as within latite and underlying Berry Siltstone. Groundwater within the Shoalhaven Group sediments occurs in perched horizons within the weathered sandstone, siltstone and latite and within the deeper regional aquifer. Groundwater flow within the generally shallow perched horizon is limited and dominated by intergranular flow in the weathered sedimentary rocks. In contrast groundwater flow within the deeper aquifers is along both primary features, such as less well cemented zones within the rocks and secondary structural features such as joints, shear zones, faults and bedding plane partings. Groundwater flow within the tuff, basalt and latite of the Gerringong Volcanics is dominated by fracture flow but is also by interconnected vesicular zones.

Data obtained from the NOW database indicates that bores constructed in the Shoalhaven Group sediments in the area have variable yields. These deep aquifers are accessed by the majority of licensed bores in the area extracting groundwater from depths typically between 30 and 50 metres below ground level.

3.2.2 Groundwater levels

The depth of groundwater along the route is influenced by positioning in the landscape and proximity to discharge features. Typically the watertable is a subdued reflection of the topographic expression being deepest beneath hills and shallowest adjacent to creeks and wetlands. Shallow groundwater has been identified within the Broughton Creek floodplain immediately north of Berry where a number of water courses converge. Groundwater monitoring conducted between November 2009 and January 2010 confirms these general trends (Coffey, 2010).

Groundwater level monitoring (Coffey, 2010) also confirmed that groundwater along the route was shallow and typically less than ten metres below ground level for all lithologies. The elevation of groundwater was variable ranging from six metres AHD in low lying silts and gravels up to 100 metres AHD within latite in topographically elevated areas.

Time series groundwater level monitoring (Coffey, 2010) indicated the watertable naturally oscillates in response to climatic variation. As expected groundwater levels increased following significant rainfall and declined following periods of low rainfall. The amplitude of the groundwater response was variable and dependent upon landscape position and aquifer type. Low to moderate groundwater fluctuations of less than one metre were recorded in the siltstone and sandstone aquifers whereas larger fluctuations (between three and four metres) were typically measured in the sandstone and latite aquifers.

3.2.3 Groundwater quality

Groundwater quality data throughout the proposed route is limited. Some groundwater quality data has been obtained from the NOW groundwater database however the data is often incomplete. Background groundwater quality data in the existing groundwater monitoring network has yet to be collected, although this is likely to be undertaken in the early stages of the project.

Groundwater quality within the unconsolidated and unconfined alluvial/colluvial aquifers is expected to be of low salinity given low residence times and neutral pH. The high groundwater quality is due to local recharge via infiltration of rain and local runoff and low residence times within the predominately quartzose aquifers. In fact groundwater from these aquifers is often potable with appropriate water quality treatment.

In contrast groundwater quality within the Shoalhaven Group sediments is variable depending on the lithology intersected. Within shale lenses, groundwater quality is typically poor and saline due to connate salts within the marine shale units and low formation permeability. Groundwater within the sandstone and siltstone units is variable but typically of better quality than the shale units due to a high quartz content and higher groundwater flow, flushing the unit. Groundwater from the latite (Broughton Sandstone) is expected to be of better quality than groundwater derived from the Berry Siltstone due to poor quality groundwater within shale lenses leaking into the Berry Siltstone aquifer.

3.2.4 Groundwater users

A review of water bores registered with NOW indicates there are 16 registered bores within 0.5 kilometres of the project. Although the data within the database are limited, analysis indicates that groundwater along the alignment is a valuable resource used for stock, domestic and agricultural purposes to supplement surface water supplies collected in dams and pumped from creeks. Groundwater is extracted from a variety of aquifers including latite, gravels, sandstone, shale and fractured rock. The groundwater yield is variable but typically less than two litres per second.

There are no drinking water catchments in the project area. Groundwater has low use within the region because the area receives a relatively high rainfall and Shoalhaven Water provides a reticulated water supply to Berry. North of Berry water users are more reliant on tank water and groundwater.

3.2.5 Groundwater dependent ecosystems

See Section 3.1.2 for a definition of GDEs.

Groundwater from the alluvial aquifer systems associated with the Broughton Creek floodplain discharges into Broughton Creek. Riparian vegetation associated with Broughton Creek is likely to be dependent upon groundwater in some capacity. Local shallow groundwater flow systems also exist within elevated parts of the catchment within the Berry Sandstone and latite. Groundwater discharge via springs, seeps or spring fed dams may also sustain local small communities.

Coomonderry Swamp and Foys Swamp are coastal freshwater wetlands, located east of Broughton Creek. The Sydney Basin Southern management zone of the Greater Metropolitan Region Water Sharing Plan for the project area identifies Coomonderry Swamp as a high priority GDE in Schedule 4 of the Plan (NOW, 2011a). Coomonderry Swamp is a large (429 hectare) semi-permanent freshwater swamp, northeast of Nowra that is listed on the register of the National Estate. Foys Swamp is not listed in the Water Sharing Plan.

Floodplain swamp forest is a low, dense forest tolerant of brackish groundwater that was identified along Toolijooa Road and the railway line between Berry and Gerringong (Maunsell, 2007). This community may grade into estuarine fringe forest with increasing groundwater salinity.

Further information on GDEs can be found in the Aquatic Ecology and Water Quality Management Assessment Report (Cardno Ecology Lab, 2011). Water management plans that are to be prepared for this project are expected to minimise any impacts to GDEs.

3.3 Assessment of potential groundwater impacts

Several potential impacts to groundwater due to the proposed project have been identified. Impacts may occur during the construction phase or long-term operations phase.

3.3.1 Construction potential impacts and groundwater drawdown

Construction impacts may include potential changes to groundwater quality and groundwater levels. Potential groundwater quality risks include spills and accidents throughout construction. These risks consist of hydrocarbon contamination via fuel spills, and potential changes in groundwater pH levels associated with the disturbance of ASS, if present. In addition changes to groundwater flow patterns, recharge and discharge characteristics may be altered due to the intersection of the aquifer by artificial barriers such as road cuts and/or localised dewatering.

Deep excavations and cuttings may require temporary localised dewatering during the construction phase. Within the alluvial gravels identified north of Berry the groundwater is shallow and the foundations for cased bored piles associated with bridges or other major structures may have to be dewatered. Localised dewatering would temporarily alter groundwater flow conditions but after dewatering is completed original groundwater flows would be re-established.

It is not expected that groundwater extraction for water supply would be required during construction. If this need is identified during detailed design, further investigation would be undertaken.

Reduced groundwater recharge

The construction of access roads, tracks and the isolation of areas for stockpiling of construction materials can alter groundwater recharge and introduce pollutants. Compaction of shallow soils due to construction works may be caused in areas of unconsolidated alluvial sediments which can also result in reduced groundwater recharge.

Excavation of road cuttings beneath the watertable or intersecting perched groundwater causes groundwater to drain into culverts, creeks or rivers, locally reducing groundwater recharge and lowering the watertable.

Groundwater drawdown construction impacts

Temporary dewatering may be required during construction to artificially lower the watertable to maintain dry working conditions within excavations. Dewatering may be required in the cases of construction of bridge footings or road cuttings. Temporary dewatering is likely to draw down local groundwater levels in the immediate vicinity of the excavation. Should dewatering of the alluvial aquifer be required during the construction of bridge footings, groundwater drawdown will be limited to the base of the footing, and the zone of influence or induced cone of depression is expected to be limited due to the highly transmissive nature of an alluvial aquifer. Should dewatering be required during the construction of road cuttings, the impacts will depend on the local hydraulic conductivity of the aquifer matrix and secondary water bearing structural features.

In the event of temporary dewatering being required, modelling would be undertaken to assist in quantifying the amount of groundwater drawdown and any potential impacts. This would be included as a requirement in groundwater management plans for the project.

Groundwater quality impacts

Potential exists for fuel and chemical spills including petrol, diesel, hydraulic fluids, lubricants, and explosives residue to contaminate groundwater and GDEs, particularly if a leak or spill occurs on highly permeable sandy strata. Spills as a result of accidents can occur during construction activities, refuelling operations or from storage areas. Runoff from unpaved areas may be highly turbid. Accession of suspended solids to the groundwater however is likely to be retarded by filtering through the unsaturated zone, reducing the significance of impact.

There is a low risk that ASS may be present along the alignment. Should the watertable be lowered where ASS are present or during excavation works, ASS may become exposed and oxidation of sulphide minerals could result. This process generates sulphuric acid and increases metal concentrations in solution, which can lead to the degradation of the groundwater. Rainfall runoff could cause acidic water to migrate within the shallow groundwater system and discharge into surface water systems and groundwater receptors.

Impacts to groundwater dependent ecosystems

The potential risk that GDEs may be impacted due to construction activities is low. Local GDEs that may be associated with shallow groundwater flow systems are within elevated parts of the catchment and would continue to be sustained via discharge from springs or seeps following high rainfall events.

The risk of impacts to downstream GDEs in Broughton Creek is low. Groundwater flow volumes in Broughton Creek would remain virtually unchanged and surface water discharged to the creek from sedimentation basins would be treated in accordance with best practice.

3.3.2 Operational potential impacts

On-going impacts may also occur during the long-term operations phase of the project. Road runoff may be impacted by fuels and oils and permanent barriers to groundwater flow may remain following the upgrade.

Interception of groundwater and groundwater drawdown

The capacity of water extraction bores in the vicinity of the deep road cuttings may likely be reduced due to the lowering of the watertable. Similarly farm dams or GDEs recharged by springs which intersect groundwater down hydraulic gradient of the road cuts may also be affected by reduced spring flow due to altered groundwater flow conditions.

The deepest road cutting is up to 27 metres below ground surface through the Toolijooa Ridge cut, bypassing Broughton Village. Preliminary assessments indicate that groundwater would seep into the cutting from the latite and Kiama Sandstone. The predicted drawdown in the vicinity of the Toolijooa Ridge cut is not expected to impact any current users as registered groundwater bores are at a sufficient distance from the cutting so as not to be adversely affected. No GDEs have been identified in the vicinity. Potential future groundwater use in this area has not been identified at this stage.

Other cuts along the alignment are no deeper than 13 metres and may also be subject to groundwater inflows. Inflow to the cuttings may reduce groundwater recharge (as throughflow), lower the local watertable and alter groundwater flow paths. Cuttings in fractured rock may intersect water bearing fractures which are likely to seep.

Groundwater modelling may be required to be undertaken at some locations to quantify the amount of groundwater drawdown during a range of scenarios. The results of the groundwater modelling will be used to develop trigger points within groundwater management plans. The groundwater modelling program, if required would be undertaken in consultation with NOW.

Groundwater quality and recharge

Road runoff can contain pollutants associated with vehicular movement and normal use due to leaks, spills and accidents. The contaminants can include hydrocarbons (petrol, diesel and oils), metals, suspended solids and other compounds. Operational water quality basins and roadside swales are to be established to remove suspended solids to meet surface water quality criteria (refer Section 2.3.2).

Increasing the hard surface road area would increase runoff and decrease groundwater recharge. However recharge decrease would be minor given the small road surface compared to the remainder of the catchment. The risk of impacts to GDEs is slight as flows in Broughton Creek would remain virtually unchanged and surface water discharged to the creek from water quality basins would be treated in accordance with best practice.

3.3.3 Worst case

The worst case scenario adopted for the project assumes that all environmental management measures are ineffective. Groundwater contamination, should it occur, can be difficult, expensive and in some cases impossible to remediate. The severity of contamination would be determined by the type and volume of the pollutant, the nature and scale of the groundwater system, and where in the groundwater system the contamination has occurred. Whilst groundwater in some systems moves quite slowly and over short distances, in some alluvial or fractured rock systems water can travel considerable distances relatively quickly. The severity of the impacts is also dependent on the proximity to active groundwater users including town water supply, stock and domestic bores, and irrigation bores. Environmental impacts may occur in connected GDEs such as wetlands, springs and to surface water systems fed by groundwater base-flow.

Depending on the nature of the interference with a groundwater system, reductions in groundwater levels may be anything from short-term, to long-term or even permanent. Localised impacts from dewatering or additional extraction would generally disappear upon cessation of the activity, and could be mitigated with localised re-injection to ensure continuity of supply. Where an activity significantly alters a groundwater recharge zone or flow-path, or removes whole sections of an aquifer, the resultant impacts are more likely to be permanent.

A key aspect of the DGRs for this project is the provision of appropriate environmental management measures and design standards to minimise the potential risk of groundwater impacts. It is considered highly unlikely that all the management measures nominated for the project would operate ineffectively, and as such there is a very low risk of the worst case impacts occurring.

3.4 Environmental management measures

3.4.1 Construction management measures

Management of groundwater impacts during the construction phase is dependent upon the implementation of various measures which would be included in a CEMP that addresses potential groundwater impacts and details site practices. A separate groundwater management plan would be complied to address groundwater issues during and after construction. Potential impacts to groundwater during construction would be managed by:

- Minimising the depth of excavations in areas of alluvium.
- Limiting the need to dewater during construction.
- Using water treatment devices to treat runoff water quality before it has the opportunity to infiltrate to the water table.

During the construction phase, communications procedures must be in place to educate the project team on groundwater issues. Potential impacts to groundwater would be addressed directly in the groundwater management plan, which would:

- Identify strategies to minimise disturbance and control runoff from construction areas.
- Install bunding around fuel depots and stockpile areas to minimise the risks of contaminants reaching the watertable.
- Detail response plans to address fuel leaks and spills at machinery compounds or during refuelling. It is recommended that a hazardous materials plan (and spill emergency procedure) be implemented as part of the groundwater management plan.
- Detail the establishment of a groundwater monitoring network along the route to adequately characterise groundwater quality and establish background water quality within the alluvial/colluvial aquifers and Shoalhaven Group Sediments, including the Broughton Sandstone and latite... Monitoring wells would also be required adjacent to major cuts to monitor the effect on groundwater levels, where groundwater is encountered. The baseline water quality data would be used for comparison with groundwater quality data collected throughout the construction program.
- Identify strategies to remove or reduce the risks associated with the excavation of ASS or generating acidic groundwater.
- Assess the performance of groundwater mitigation measures.

Road cuttings

Dewatering may be required during the excavation and construction of the Toolijooa Ridge cut and possibly other deep cuts where the watertable is intersected. The dewatering program/s would involve construction of extraction bores, gravity drainage systems and/or pumping. Discharge of the extracted groundwater would depend on the groundwater quality but options include:

- Supplementing farm dams supply (subject to water quality testing and negotiations with farm dam owners)
- Discharge to creeks or temporary storage in water quality basins to reduce turbidity prior to discharge.

Discharge quality would be required to comply with the ANZECC (2000) water quality guidelines. Licensing to extract and discharge may be required through NOW. Dewatering may also be required during the construction of infrastructure such as piles within the floodplain alluvium east of Berry.

Groundwater monitoring

Groundwater monitoring would be required to monitor potential impacts to groundwater quality and levels during and after construction. A detailed sampling, analysis and quality plan outlining the groundwater monitoring programs would be compiled in consultation with the OEH and NOW in accordance with the *Guidelines for the Assessment and Management of Groundwater Contamination* (NSW DEC, 2007). The results of, and any recommendations from the monitoring would be reported to these agencies. The timing of sampling would be more frequent during the construction phase due to the higher risk of contamination to the local aquifers.

The monitoring program would be required to monitor groundwater level fluctuations and groundwater quality parameters within the existing groundwater monitoring network. During the field program the following field parameters and laboratory analyses would be collected from a minimum of four monitoring wells.

- pH, dissolved oxygen, redox, electrical conductivity and temperature (field parameters).
- Total petroleum hydrocarbons/benzene, toluene, ethylbenzene, xylene (TPH/BTEX), PAH, heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn).
- Installation of dataloggers in four key monitoring wells to monitor groundwater levels on a daily schedule.

Groundwater sampling protocols would be defined in the Sampling Analysis and Quality Plan (SAQP) however in summary all monitoring wells would be purged a minimum of three well volumes prior to sampling and metals are to be field filtered. Field meters would be calibrated daily and water samples collected for metals analysis would be field filtered prior to transportation to a NATA accredited laboratory in a chilled cooler.

The ANZECC 2000 Fresh and Marine Water Guidelines are considered the appropriate groundwater investigation levels for the protection of aquatic systems. The 95 per cent level of protection is considered the most appropriate in this sensitive fresh water ecosystem.

Groundwater monitoring should be undertaken and reported on a three monthly basis during construction.

3.4.2 Operational management measures

Following the construction of the project, strategies would be required to address potential on-going impacts to groundwater levels and groundwater quality.

Groundwater is likely to seep into deep road cuts where the watertable is intersected. Seepage from these sections would be directed towards spoon drains that flow by gravity into the road drainage system. At road cuts where large sections of the watertable are intersected a network of vertical drains may be installed into the road cut to allow groundwater to flow to the drainage network relieving hydraulic pressures within the road cut. The slotted connection drains may be lined with geotextile fabric to restrict the migration of fine particles minimising sediment blockages within the drainage system.

Groundwater monitoring

Section 3.4.1 sets out the approach to be taken to groundwater monitoring for the project. During operation groundwater monitoring would be carried out every six months with a review after two years to assess data trends and assess if further monitoring is warranted. The framework for monitoring would be set out in the SAQP. The objectives of the groundwater monitoring program would be established in consultation with NOW and the EPA as appropriate and would likely include an assessment of groundwater level data trends and comparison with rainfall data, and an assessment of water quality trends and exceedences, if any.

4 Flooding

This chapter addresses the DGRs for the assessment of flooding impacts relating to the project. The DGRs and the section in which they are addressed are presented in **Table 1-1**.

4.1 Existing environment

4.1.1 Overview

The project traverses the Broughton Creek floodplain in the north, crosses a number of local ephemeral drainage lines through the hills between Tomlins Road and Tindalls Lane, then crosses the floodplain a second time near the confluence of Bundewallah, Connollys and Broughton Mill Creeks. It passes to the north of Berry before crossing a series of ephemeral creek lines between Berry and Jaspers Brush.

Named creeks and tributaries in the vicinity of the project area are shown on **Figure 1-1** and include (from east to west):

- Broughton Creek.
- Broughton Mill Creek.
- Connollys Creek.
- Bundewallah Creek.
- Town Creek.
- Hitchcocks Lane Creek.

These creeks and tributaries are described in the following sections. There are also 14 minor unnamed waterway crossings that are traversed by the project that have been assessed as part of the project.

4.1.2 Broughton Creek

Broughton Creek and its tributaries drain the hills of the Cambewarra Range that lie north of the township of Berry as well as the broad flat floodplain that lies to the south of Berry. Broughton Creek flows south from Berry for approximately 8km before joining the Shoalhaven River.

The catchment area of Broughton Creek at Coolangatta Road (south of Berry) is approximately 104 square kilometres (SMEC, 2008). Natural forest and cleared pasture are typical of the catchment, with varying levels of development around the townships of Berry, Bundewallah, Foxground, Broughton, Broughton Vale and Broughton Village.

Broughton Creek drains across the northern side of the Shoalhaven floodplain. Agriculture is the major land use, with extensive areas utilised for dairy and cattle grazing. Downstream of the Berry Township, the terrain is flat and swampy. Tidal influence extends about 12 kilometres upstream from the Broughton Creek and Shoalhaven River confluence to the vicinity of the Coolangatta Road Bridge.

The upper reach of Broughton Creek meanders across the northern section of the project in a southerly then westerly direction then south again before flowing south of Berry and into the Shoalhaven River approximately five kilometres west of Shoalhaven Heads.

During larger flood events the banks of the upper Broughton Creek are overtopped with flood waters taking the shorter routes across the floodplains, returning to Broughton Creek some distance downstream.

The existing Princes Highway traverses the upper reach of Broughton Creek near Broughton Village. The project would pass just south of this location.

4.1.3 Berry township

Named creeks traversed by the project in the vicinity of Berry are shown on **Figure 1-1**.

Bundewallah Creek is located to the north of Berry and flows eastwards under a bridge at Woodhill Mountain Road to join Broughton Mill Creek. Broughton Mill Creek flows southwards from the confluence with Bundewallah Creek, under an existing bridge at the Princes Highway, then under a second bridge at the South Coast Railway Line. Downstream and to the east of Berry, Broughton Mill Creek flows into Broughton Creek.

Connollys Creek enters Bundewallah Creek upstream of the confluence with Broughton Mill Creek.

Town Creek (also referred to as Princess Creek) meanders eastwards through the Berry town centre, adjacent to Princess Street, before joining Broughton Mill Creek.

Connollys Creek, Bundewallah Creek, Broughton Mill Creek and Town Creek are the main sources of flooding in Berry. Town Creek in particular presents a flood risk to a significant number of properties within Berry.

According to Cardno (2012) the existing Princes Highway is overtopped at the locations listed in **Table 4-1** during the ARI events indicated. During the 100 year ARI event, the crossings at Broughton Mill Creek, Town Creek and Hitchcocks Lane Creek and Tributary all experience overtopping.

Table 4-1: Existing overtopping of Princes Highway

	ARI event			
Waterway	2 year	5 year	20 year	100 year
Broughton Mill Creek	Overtops	Overtops	Overtops	Overtops
Town Creek			Overtops	Overtops
Hitchcocks Lane Creek	Overtops	Overtops	Overtops	Overtops
Hitchcocks Lane Tributary				Overtops

4.1.4 Available data

Previous flood studies

A number of studies have been carried out for the Broughton Creek and wider Shoalhaven River catchments. These studies provide useful background information to understanding the nature of flooding across the study area and include:

- Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012).
- Lower Shoalhaven River Floodplain Management Study & Plan: Climate Change Assessment (WMAwater, 2011).
- Broughton Creek Flood Study (SMEC Australia Pty Ltd, 2008).
- Lower Shoalhaven River Floodplain Risk Management Study and Plan (Webb McKeown & Associates, 2008).
- Lower Shoalhaven River Flood Study (Public Works Department, 1990).

As part of the route selection process for the Gerringong to Bomaderry Princes Highway Upgrade, Maunsell (now AECOM) produced indicative 100 year ARI flood extents as shown in **Figure 4-1** (Maunsell, 2008). The upgrade falls within the indicative 100 year ARI flood extent in a number of places.

Property survey

As part of the Broughton Creek Floodplain Risk Management Study (Cardno, 2012), a floor level survey was conducted in 2010 on properties in Berry that were identified as being affected by the Probable Maximum Flood (PMF). This survey data has been used to assess the potential impacts of the project on properties within Berry.

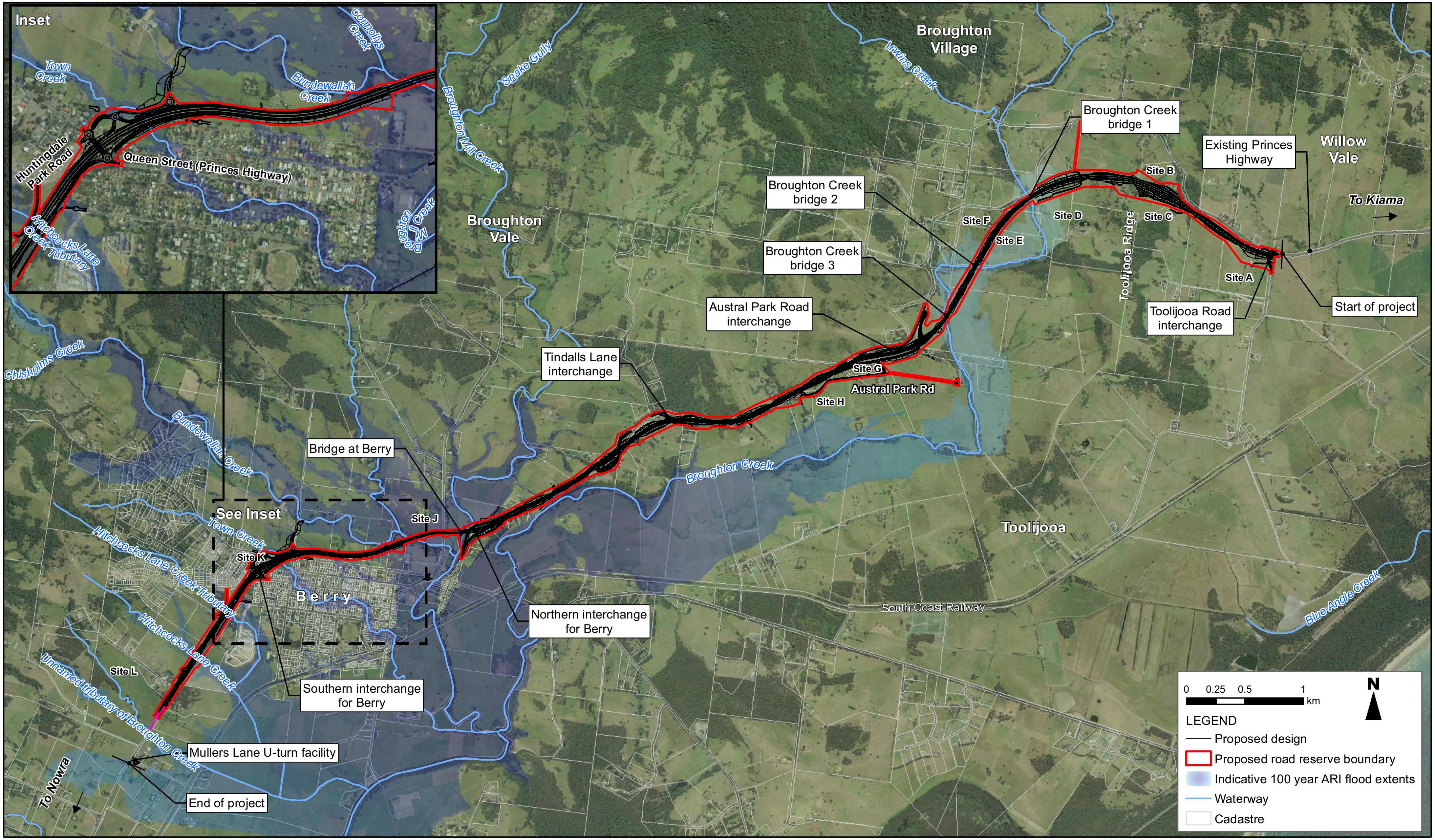

Figure 4-1 Indicative floodplain locations

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

4.2 Assessment of potential flooding impacts

4.2.1 Overview

As nominated by the DGRs, consideration has been given to potential flood impacts on upstream and downstream infrastructure and receivers due to the project. Waterways that could potentially be impacted by the project include:

- Broughton Creek (three crossings).
- Connollys Creek / Bundewallah Creek / Broughton Mill Creek (one crossing at Berry).
- Town Creek.
- Hitchcocks Lane Creek.
- Numerous unnamed tributaries to the above creeks.

The location of the highway with respect to the floodplain is an important consideration in the design and construction of the proposed works. Flooding of the highway can restrict access, cause damage and pose a safety risk. Conversely, any works within the floodplain are likely to change existing flood behaviour with the potential for adverse impacts on the surrounding environment. It has therefore been necessary to carry out an assessment of project related flood impacts. This assessment is outlined in the following sections.

4.2.2 Assessment approach

Hydrologic and hydraulic modelling and assessment has been carried out to better understand the flooding characteristics of the creeks and waterways traversed by the project under both existing and proposed conditions. This information has been used to quantify impacts and thus make informed decisions on managing the flood risks to the project and users as well as impacts on the surrounding environment.

The wider area around the alignment (except around the township of Berry) is generally zoned as rural and/or agricultural according to the Shoalhaven City Council and Kiama Municipal Council Local Environmental Plans. There is no indication at this stage that the existing land use patterns would change significantly in future. The flood impact assessment described in this section has therefore been based on the existing catchment characteristics.

Hydrologic and hydraulic modelling

The flood assessment has involved the development of hydrologic and hydraulic modelling approaches to suit the nature and extent of the waterways traversed by the project.

The assessment of the major crossing of the Broughton Mill Creek / Bundewallah Creek / Connollys Creek floodplain immediately north of Berry was carried out using the XP RAFTS and TUFLOW models developed for the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012). Other waterway crossings were assessed using the Probabilistic Rational Method (PRM) and a combination of HEC-RAS 1D modelling and culvert hydraulic calculations.

Hydrologic modelling

For Broughton Mill Creek, hydrologic modelling was carried out using the XP RAFTS rainfall runoff routing model to derive inflow hydrographs for the TUFLOW hydraulic model. For this purpose the XP RAFTS model constructed and used in the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012) and the Broughton Creek Flood Study (SMEC, 2008) was adopted. The model was used to derive inflows for the 100 year ARI and PMF events.

Flow results obtained from the XP RAFTS/TUFLOW flood models have been compared against PRM estimates and a summary of 100 year ARI flows is provided in **Table 4-2**. The flow result is reported at a location downstream of the project corridor at the convergence of Broughton Mill, Bundewallah and Connollys Creek. The peak flow from the XP RAFTS/TUFLOW model compares reasonably well, with the PRM flow being 11 per cent higher.

Table 4-2: Comparison of TUFLOW and PRM 100 year ARI flows

Waterway	TUFLOW	PRM
Broughton Mill Creek [1]	947	850 [2]

Notes

1. *Approximately 350m downstream of Berry Bridge .*
2. *For comparative purposes PRM estimate presented here is based on no allowance for climate change and is therefore less than the PRM estimate given in* ***Table 4-3****.*

For the remaining waterway crossings PRM was used to estimate peak flows. The PRM is based on data from 308 gauged catchments and is applicable to small to medium rural catchments in eastern NSW. The PRM was therefore considered appropriate for application to the present assessment.

In accordance with design criteria established for the project, provisions for potential future climate changes were made by increasing all rainfall intensities by six per cent (DECC, 2007).

For catchments where the PRM was used the PMF flow was approximated by multiplying the 100 year ARI PRM flow by five.

Catchment areas for each proposed watercourse crossing have been defined using 1:25,000 topographic maps and available survey in the vicinity of the highway. The contours used to define these catchment areas were at minimum 10 metre intervals supplemented where available with aerial photogrammetric survey and detailed field survey.

Catchment layouts and identifiers are as shown in **Figure 4-2** and design flow estimates are listed in **Table 4-3**.

Table 4-3: PRM design flow estimates for major transverse drainage infrastructure

Catch ID	Waterway	Design chainage	Catchment area	1 year ARI	5 year ARI	10 year ARI	50 year ARI	100 year ARI
			(ha)	(m^3/s)				
LB	Unnamed Ephemeral	9000	4	0.5	1.3	1.6	2.3	2.7
KA	Unnamed Ephemeral	9840	66	5.8	15	19	28	32
K	Broughton Creek	9950	2781	106	276	358	557	646
LA	Unnamed Ephemeral	10500	6	0.8	2.1	2.2	3.8	4.3
L	Broughton Creek	10700	2869	108	283	366	570	661
M	Broughton Creek	11200	3197	117	306	396	618	715

Catch ID	Waterway	Design chainage	Catchment area	1 year ARI	5 year ARI	10 year ARI	50 year ARI	100 year ARI
			(ha)	(m^3/s)				
N	Unnamed Ephemeral	11900	7	1.0	2.3	2.9	4.2	4.8
O	Unnamed Ephemeral	12150	7	1.0	2.3	2.9	4.2	4.8
P	Unnamed Ephemeral	12310	6	0.8	1.9	2.4	3.5	4.1
Q	Unnamed Ephemeral	12770	106	8.4	21	27	41	48
R	Unnamed Ephemeral	13320	15	1.7	4.2	5.3	7.8	9.0
S	Unnamed Ephemeral	13580	21	2.3	5.6	7.1	11	12
TC	Unnamed Ephemeral	14150	1	0.12	0.29	0.34	0.51	0.6
TA	Unnamed Ephemeral	14420	3	0.5	1.2	1.6	2.3	2.6
TB*	Unnamed Ephemeral	14500	1	0.15	0.36	0.45	0.64	0.73
T	Broughton Mill/ Connollys Creek	16000	4286	146	383	497	775	896**
W	Town Creek	17450	85	7.0	17.8	22.6	34.2	39.5
XA	Duck Pond ephemeral	17950	4.4	0.6	1.6	1.7	2.8	3.2
X	Tributary to Hitchcocks Lane Creek	18100	75	6.5	16.3	20.7	31.2	36.0
Y	Hitchcocks Lane Creek	18550	68	6.0	15.0	1.1	28.7	33.1
Z	Unnamed Ephemeral	19150	4	0.6	1.5	1.8	2.6	3.0

Catchment TB has not been shown on **Figure 4-2 for clarity reasons*

***TUFLOW 100yr ARI flow of 959m^3/s at Broughton Mill Creek has been used in the hydraulic impact analysis.*

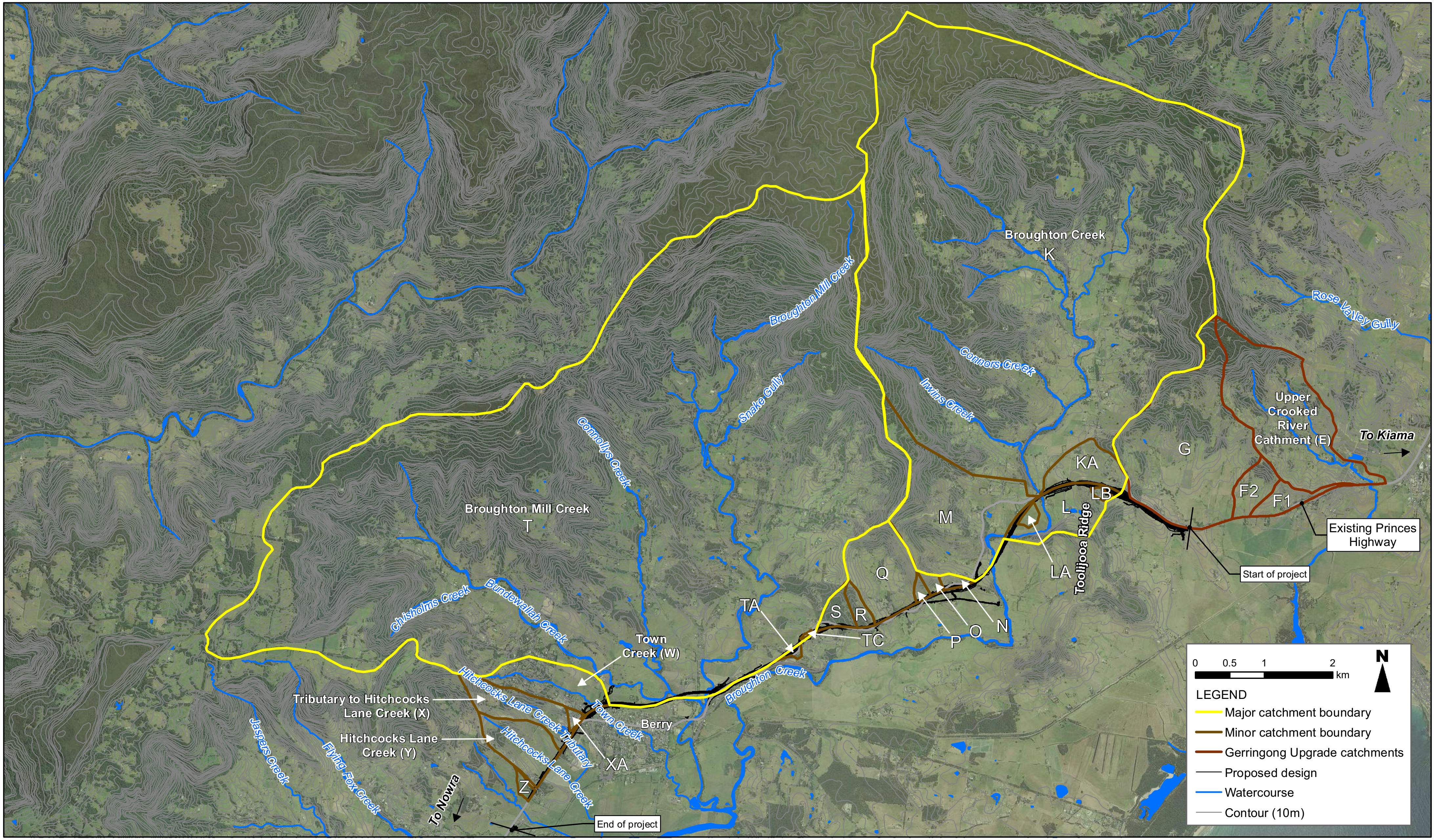

Figure 4-2 Catchment map

Source: AECOM(2012), LPMA (2011)

Note 1: See Table 4.3 for catchment information

Note 2: Gerringong Upgrade Catchments G,E,F2 and F1 Outside Project Area (shown for information only)

Note 3: Catchment TB has not been shown on the figure for clarity reasons

Hydraulic modelling

Flood levels, depths and velocities were determined from a range of detailed hydraulic analyses.

For the Broughton Mill Creek floodplain in the vicinity of Berry (including Bundewallah Creek, Connollys Creek and Town Creek) the TUFLOW 2D model established for the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012) was used as the basis. The Cardno TUFLOW model covers an area of approximately 9 square kilometres covering Berry and its immediate surrounds and is based on a three metres by three metres grid to define the ground topography. The downstream (southern) model limit is approximately 300 metres south of the South Coast railway line.

To assess the impacts of the project on flood behaviour the base model representing existing conditions was modified by adding the road design to the ground definition. For the purposes of concept design, nominal bridge piers were modelled and found to have relatively minor and localised impacts on flood levels and velocities. These impacts would need to be considered in more detail in future investigation or design development stages.

Inflow hydrographs derived from the XP RAFTS hydrologic model were applied to the upstream extents of the TUFLOW model. Rainfall was also applied directly to the 2D grid over the TUFLOW model extent which is consistent with the approach adopted for the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012).

The three bridge crossings of Broughton Creek to the north of the project, as well as Hitchcocks Lane Creek and Tributary were modelled using the HEC RAS 1D model. The remaining waterway crossings were modelled using either Bentley Culvert master or HY-8 culvert hydraulic software packages.

4.2.3 Proposed flood and drainage works summary

Culverts

Culverts along the project have been sized to provide 100 year ARI flood immunity to the highway and to minimise flood level impacts upstream or downstream of the crossings.

The proposed transverse drainage infrastructure for major culvert crossings is summarised in **Table 4-4** and the locations are shown in **Figure 4-3a** to **Figure 4-3b**.

Table 4-4: Proposed culvert summary

Crossing name	Design chainage	Design flow	Type	Size	Comments
	(m)	(m^3/s)		(mm)	
LB	9030	2.7	Pipe	1x1500	Existing culvert drop structure
KA	9840	32	Pipe	4x1800	Goes through northern abutment of Broughton Creek bridge 1
LA	10500	N/A	Box	1x4600x3000	Oversized to provide vehicular access
N	11900	4.8	Pipe	2x1500	Three pipe segments joined by two large drop structures, to provide drainage under main carriageway and secondary roads on each side
O	12150	4.8	Pipe	2x1500	Existing pond at inlet
P	12310	4.1	Pipe	3x1500	Extend existing pipe and install two new pipes
Q	12770	48	Pipe	7x1800	A minimal water level impact is desirable due to upstream property (Existing 3x1500mm RCP)
R	13320	9.0	Pipe	2x1500	
S	13580	12.1	Pipe	2x1500	
TC	14150	0.6	Pipe	1x1500	
TA	14420	2.6	Pipe	1x1500	
TB	14560	0.7	Pipe	1x1500	
XA	17950	3.23	Pipe	1x1500	
X	18100	36.0	Pipe	4x1800	
Y	18550	33.1	Pipe	3x1800	
Z	19150	2.0	Pipe	1x1500	

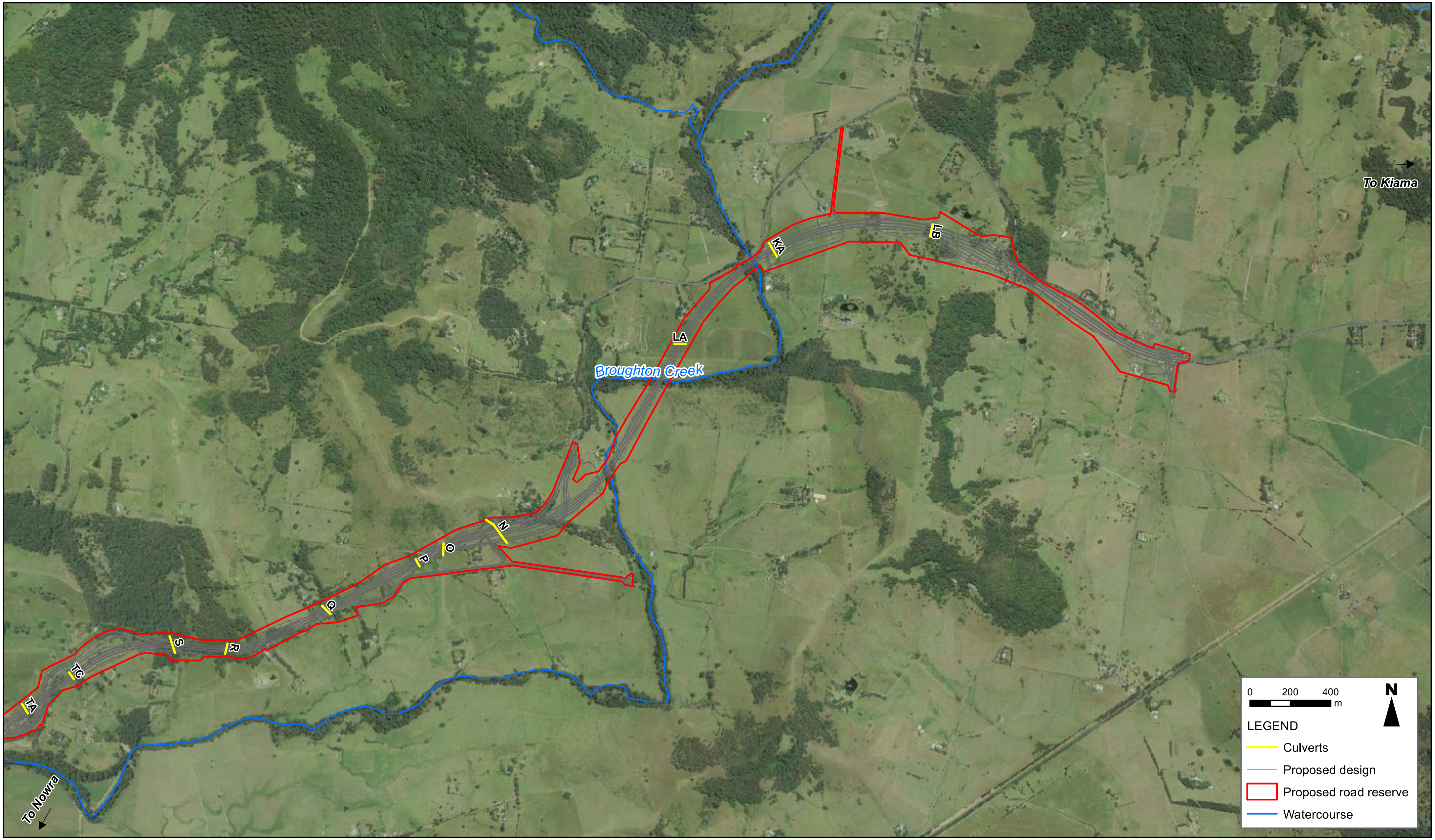

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Figure 4 - 3a : Location of proposed major culverts

Source: AECOM (2012), LPMA (2011)

Figure 4 - 3b : Location of proposed major culverts

Source: AECOM (2012), LPMA (2011)

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Bridges

Three bridge crossings are proposed over Broughton Creek and one bridge over the confluence of Connollys Creek, Bundewallah Creek and Broughton Mill Creek as shown in **Figure 1.1** and in **Table 4-5**. The proposed bridge works have been designed to minimise impacts on the existing flood regime upstream and downstream properties and to provide a suitable level of freeboard to the 100 year ARI flood level.

Table 4-5: Proposed bridge summary

Crossing name	Design Chainage (m)	Design flow (m^3/s)	Indicative Size (m)	Comments
K	9950	646	122m length, 4 spans	Broughton Creek bridge 1
L	10700	661	76m length, 3 spans	Broughton Creek bridge 2
M	11200	715	200m length, 6 spans	Broughton Creek bridge 3
T	16000	896	600m length, 19 spans	Bridge at Berry

At crossing K the project runs just to the south and downstream of the existing Princes Highway. The existing bridge over Broughton Creek would be retained. The proposed new bridge over Broughton Creek at this location (Broughton Creek bridge 1) would consist of four spans with 1.5 metre piers (total bridge span of 122 metres). In order to comply with the vertical alignment road design criteria, the road level at the proposed Broughton Creek bridge 1 has been set significantly higher than 100 year ARI flood levels. The piers would be placed outside the main creek channels.

The second bridge over Broughton Creek (Broughton Creek bridge 2) would be located approximately one kilometre downstream of Broughton Creek bridge 1 (along the main channel centreline). The proposed bridge consists of three spans with 1.5 metre piers (total bridge span 76 metres). The abutments of the bridge would be located to allow for on-grade access tracks to pass underneath on each side of the existing river banks, together with a reasonable allowance for overbank flow under the bridge. The road level at the proposed Broughton Creek bridge 2 has been set to comply with the vertical alignment road design criteria. The piers would be placed outside the main creek channel.

The third bridge over Broughton Creek would be located approximately 600 metres downstream of Broughton Creek bridge 2 (along the main channel centreline). The road level at the proposed Broughton Creek bridge 3 has been set significantly higher than 100 year ARI flood levels in order to comply with vertical alignment road design criteria. The proposed Broughton Creek bridge 3 would consist of six spans with 1.5 metre piers (total bridge span 200 metres). The lowest (underside) edge of the modelled bridge is at the northern abutment.

The bridge at Berry consists of 19 spans with 1.5 metre piers (total bridge span of 600 metres). The lowest (underside) edge of the modelled bridge is at the southern abutment. The road level in the north is set by geometric road design requirements and is considerably higher than the 100 year ARI peak flood level. The road level at the southern end of the bridge is dictated by the 100 year ARI flood level. As a mitigation measure for visual impacts of the bridge, the piers would be spaced to meet aesthetic requirements. This may result in some piers being located within Bundewallah Creek.

Appropriate scour protection would be provided to the bridge abutments and piers where velocities have the potential to cause scour. Further detailed modelling of the bridges would be carried out as part of the detailed design phase of the project.

Diversion of Town Creek

The presence of the proposed alignment around the northern side of Berry presents an opportunity to mitigate the existing flash flooding of Town Creek within Berry. Runoff from the Town Creek catchment (catchment W) north of the highway would be rerouted by a diversion channel passing through culverts under Rawlings Lane into Bundewallah Creek and then into Broughton Creek downstream (see **Figure 2-1** for the diversion channel location).

The diversion channel and culverts under Rawlings Lane would be sized to have adequate capacity to fully convey the 100 year ARI peak flow with appropriate freeboard.

4.2.4 Impacts at Broughton Creek

Flood level impacts along Broughton Creek are summarised in **Table 4-6** and shown in **Figure 4-4, Figure 4-5** and **Figure 4-6**.

Table 4-6: Summary of proposed bridge impacts

Crossing name	Design chainage (m)	Figure reference	Upstream Water Level impact 100 year ARI (m)	Comments
Broughton Creek bridge 1	9950	Figure 4-4	0.4m	Existing Princes Highway flood immunity would be reduced. Flood immune access provided by the project. No other structures affected. Impacts limited to pasture.
Broughton Creek bridge 2	10700	Figure 4-5	0.3m	Impacts are limited to pasture. No structures affected. No change in extent of floodplain due to steep sides of floodplain.
Broughton Creek bridge 3	11200	Figure 4-6	Localised increases due to piers and redistribution of flows. 0.1m	Impacts mitigated by the embankment between bridges 2 and 3 acting to divert flow to Bridge 3

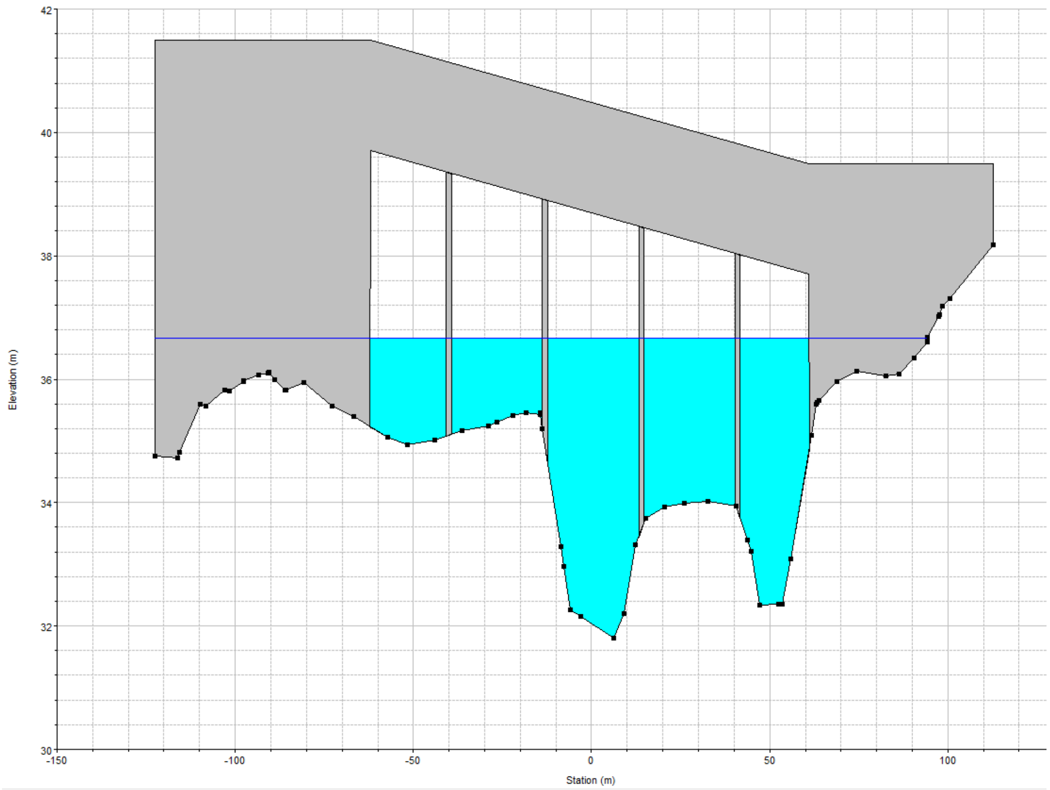


Figure 4-4: 100 year ARI design peak flood level at Broughton Creek bridge 1

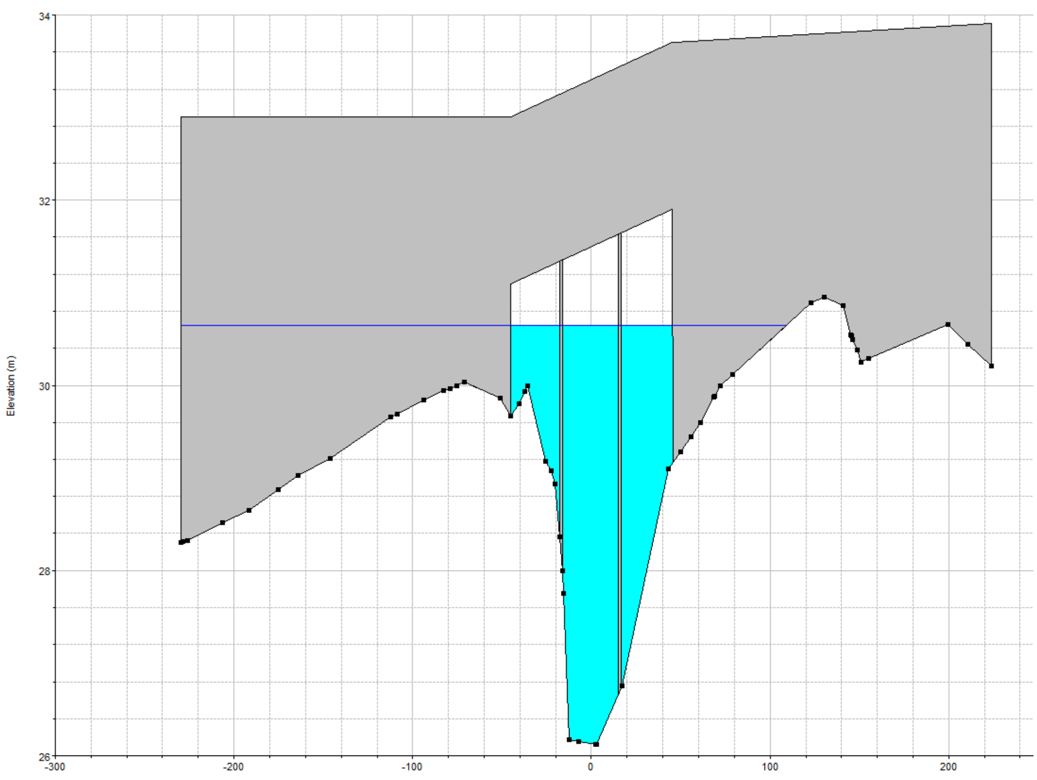


Figure 4-5: 100 year ARI design peak flood level at Broughton Creek bridge 2

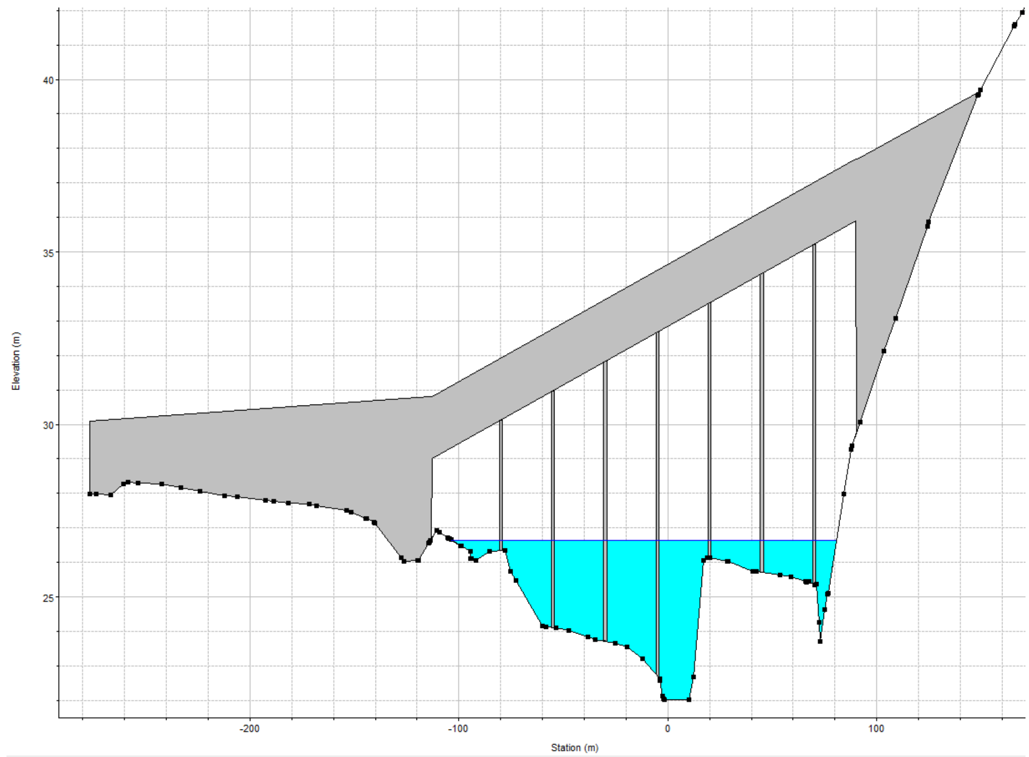


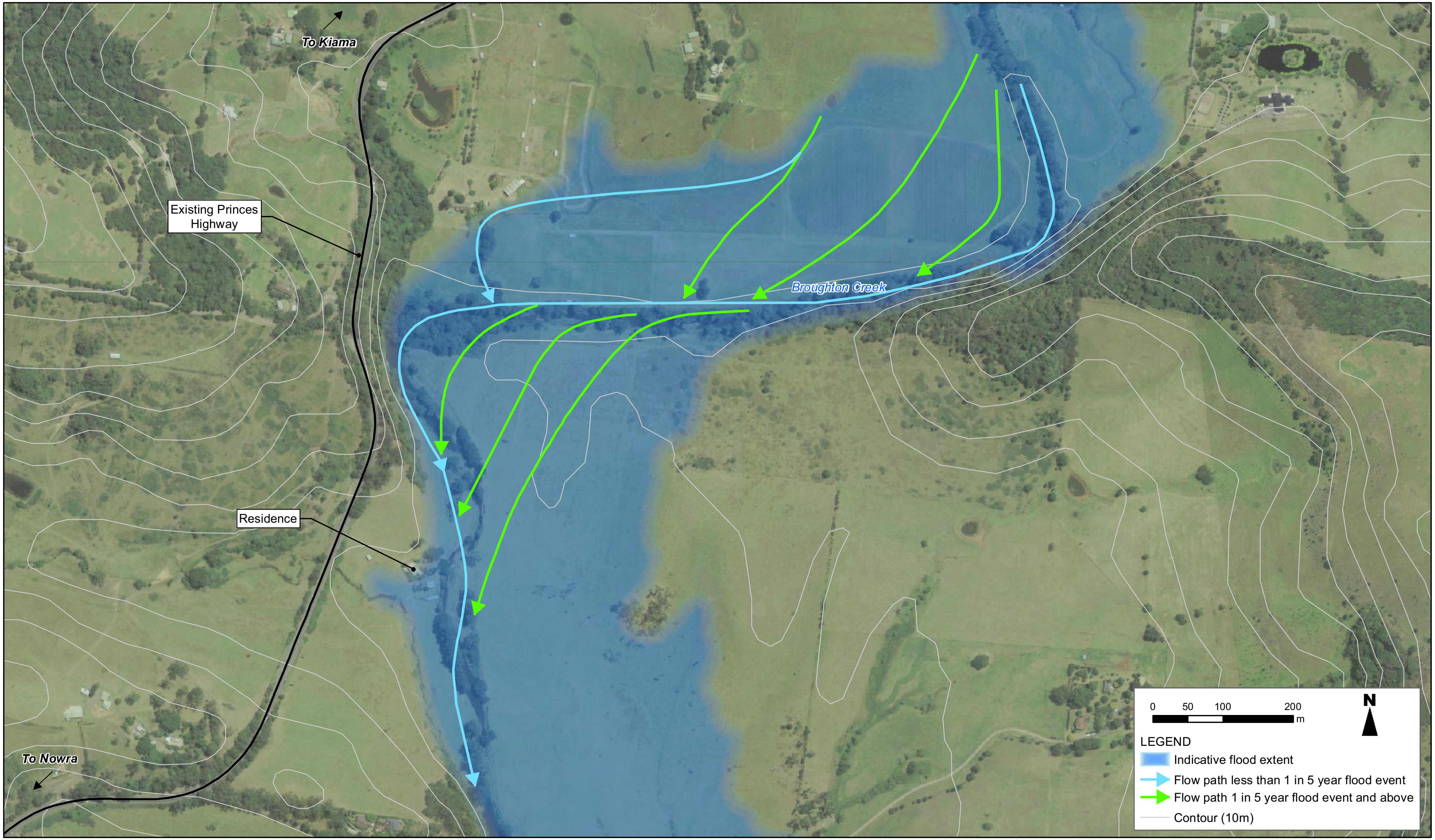
Figure 4-6: 100 year ARI design peak flood level at Broughton Creek bridge 3

Hydraulic modelling indicates that flows would be contained within the Broughton Creek banks for design flood events below the five year ARI. Above the five year ARI flood event, flood waters would overtop the left bank and flow across the floodplain eventually rejoining Broughton Creek further downstream. Under existing conditions the overland flow follows the general flowpaths shown in **Figure 4-7**. The proposed embankment across the floodplain would change the distribution of overland and in channel flows between the three proposed bridges on the upper Broughton Creek.

Between Broughton Creek bridges 2 and 3 the proposed embankment would effectively split this overbank flow into two paths (see **Figure 4-8**) on the eastern and western side of the alignment respectively. This creates three mechanisms by which the proposed works would impact on flood levels.

Firstly, the separated flow caused by the embankment would produce turbulence and energy loss that would increase flood levels upstream. Secondly, the placement of fill within the floodplain would potentially reduce the floodplain's storage capacity. This second mechanism is deemed relatively insignificant due to the large width of the floodplain. The third is that 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 that could be subjected to water level impacts due to these mechanisms is highlighted in **Figure 4-8**. The impacts are expected to be less than 0.3 metres in a 100 year ARI event and would be limited to agricultural land use areas and would not impact any structures or access. Due to the steep slopes at the edge of the floodplain, the impacts would not result in any significant increase in the 100 year ARI flood extent.



Path: P:\60021933_G2B4_Tech_work_area\4.7_GISMaps_20120806_DKennewell\Centred_121030\Fig 4-7_G024_Overland Flow Paths Map1_121030.mxd 30/10/2012

Figure 4-7 Broughton Creek overbank flowpaths

Source: AECOM (2007), LPMA (2011)

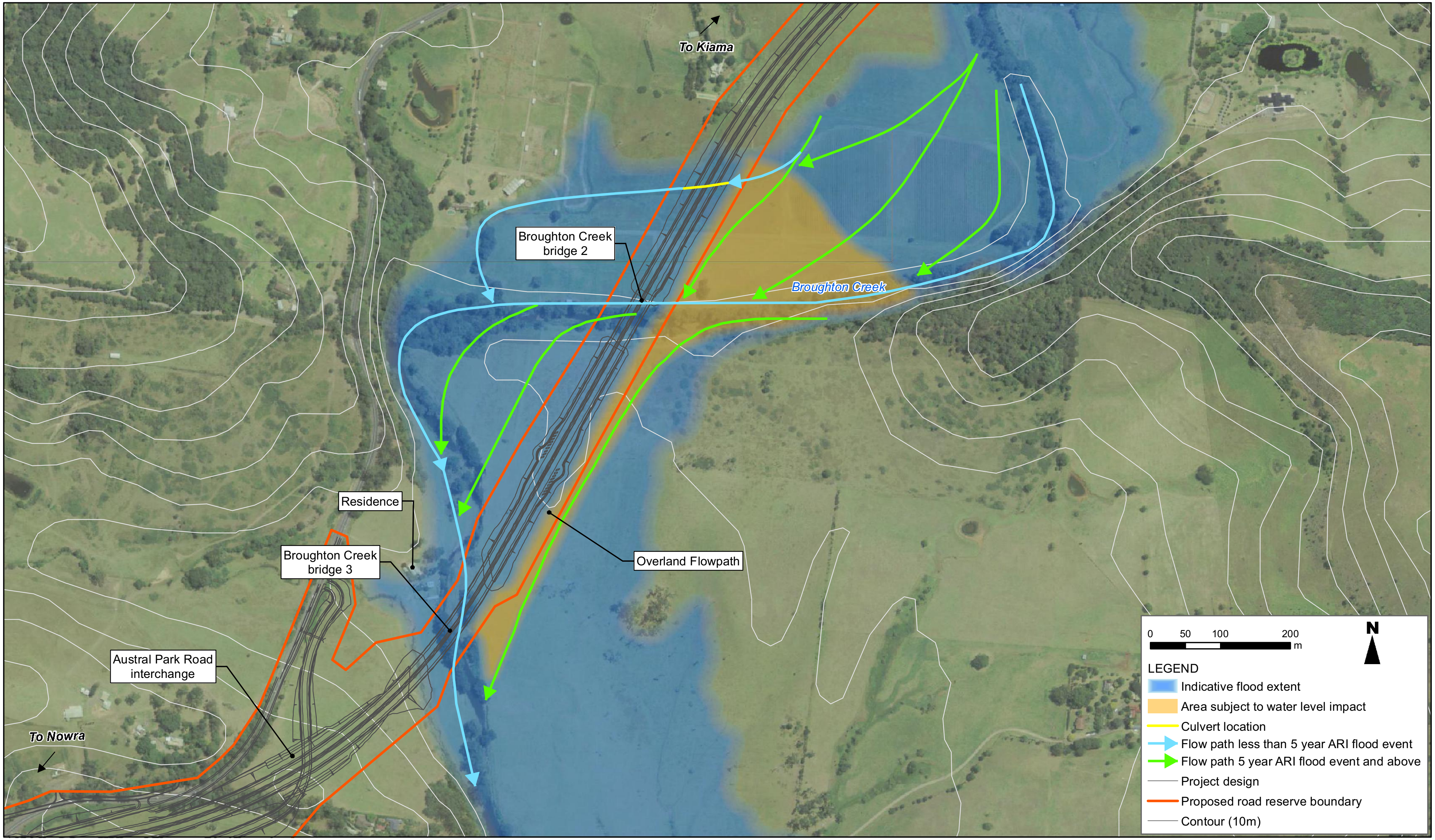


Figure 4-8 Broughton Creek overbank flowpaths

Source: AECOM (2007), LPMA (2011)

Path: P:\60021933_G2B\4_Tech_work_area\4.7_GIS\Maps_20120806_DKennewell\Centred_121030\Fig 4-8_G025_OverlandFlowPathsMap2_121030.mxd 30/10/2012

On the western side of the embankment upstream of Broughton Creek bridge 3, flood level impacts are expected to be minimal because more flow would be diverted along the eastern side of the embankment. However, the proposed road embankment will change the flow paths across the floodplain on the western side of the embankment and could have localised impacts to properties along Broughton Creek where flows are redistributed.

A small tributary flows across the property just upstream of Broughton Creek bridge 3 and joins Broughton Creek approximately 200 metres downstream of the bridge. The works associated with the proposed interchange with the existing Princes Highway could affect the flow patterns of this tributary and, depending on the redistribution of flows either side of the embankment (between Broughton Creek bridges 2 and 3) this could cause localised flood impacts to the property upstream of bridge 3. The maximum impact immediately upstream of the bridge is estimated up to 0.1 metres but the impact at the residence itself is likely to be less.

The suggested modelling approach during the detailed design phase include 2- dimensional modelling of the floodplain to accurately determine the flow split around the southern abutment of Broughton Creek bridge 2 during major flood events. Depending on the amount of flow that would be conveyed along the embankment, appropriate works for a controlled overland flowpath and scour protection would be designed to minimise erosion and flood impacts.

4.2.5 Impacts at Berry Township

The project traverses the broad floodplain at the confluence of Broughton Mill Creek, Bundewallah Creek and Connollys Creek immediately north of Berry. Existing 100 year ARI flood depths and extent for this area are shown in **Figure 4-9**.

The proposed works will involve the diversion of Town Creek along the north of the proposed highway alignment to discharge into Bundewallah Creek, upstream of Connollys Creek. The proposed works will also involve the construction of highway embankment across part of the floodplain. Flood modelling of the proposed works has been used to identify potential impacts on the surrounding environment, set minimum waterway opening requirements and minimum design levels for the highway and associated infrastructure. Flood depths and extent under proposed conditions for the 100 year ARI event are shown in **Figure 4-10**. Corresponding relative changes in flood levels are shown in **Figure 4-11** and described below.

The flood modelling and assessment has shown that there will be an increase in flood levels upstream (north) of the alignment, due largely to a reduction in waterway area from the highway works encroaching across the floodplain as well as the increased in flows associated with the diversion of Town Creek.

From **Figure 4-11** it is evident that at the southern end of the bridge at Berry, where the abutment extends approximately 200 metres into the existing 100 year ARI flood extent, some localised flood impacts up to 0.3 metres would be expected upstream during the 100 year ARI event. Immediately downstream of the southern abutment, including some areas along North Street, flood levels would be reduced.

Immediately downstream of the proposed there would be an increase in flood levels, due to the concentration of flows through the bridge openings combined with the additional flows from Town Creek.

There would be minimal flood level impacts along the Town Creek diversion route as the channel would be sized to convey the 100 year ARI flow. Box culverts would convey the 100 year ARI flow under Rawlings Lane without overtopping.

An assessment has been made of properties that are potentially affected by the proposed works. Floor level survey information has been used to undertake a review of those properties that may experience adverse flood impacts as a result of the proposed highway upgrade as well as those that will be better off.

Potential increases in flood levels

The flood impact summary in **Table 4-7** includes 11 properties that are potentially affected by changes in flood level as a result of the project. Corresponding flood impact mapping is shown in **Figure 4-11**.

Properties 1, 2 and 3

Properties 1, 2 and 3 are located upstream of the project. Increases in flood levels at these properties are predominantly a function of the reduction in available waterway area across the floodplain. The model results show an increase in 100 year ARI flood level at property 1 of 0.06 metres and 0.08 metres at properties 2 and 3. This would result in a reduction in freeboard at these properties. Properties 1 and 2 would still have in excess of 0.5 metre freeboard. However the freeboard at property 3 would be reduced from 0.18 metres (existing) to 0.11 metres (proposed).

Properties 4 and 5

Properties 4 and 5 are located immediately downstream of the project. The properties are impacted by a combination of the diverted flows from Town Creek together with a greater concentration of flow through the constricted bridge opening. It would therefore be difficult to fully offset the impacts on these properties without removing or reducing the diversion of Town Creek.

No detailed floor level or ground level data are available for property 4. The modelled depth of flooding suggests the property experiences significant inundation around the building. Floor level survey is required to confirm the susceptibility of building floor level to flooding.

Floor level survey for property 5 shows the building is elevated over 3 metres above the 100 year ARI flood level. Consequently, the nominal 0.03 metre increase in flood levels is not significant in the context of the impact.

Properties 6, 7, 8, 9 and 11

Properties 6, 7, 8, 9 and 11 are located further downstream of the proposed road alignment. The nominal impacts at these properties (typically 0.03 metres or less) would be primarily due to the diversion of flows from Town Creek. The increase in flood levels at these properties is considered minor relative to the existing level of above floor inundation. Consequently, no additional local flood mitigation measures are expected to be required. This would however be subject to detailed design development.

Property 10

Property 10, the sports amenities building at the Berry sportsground and the Camp Quality Memorial Park, is located immediately downstream of the southern bridge abutment. Relative flood level impacts based on the current concept design are negligible or minor.

Potential reductions in flood levels

The diversion of Town Creek will provide a significant benefit to properties within Berry that currently experience flooding. The existing portion of Town Creek flowing through the town of Berry (south of the project) would experience a lowering of 100 year ARI flood levels of in excess of one metre as indicated on **Figure 4-12**. The property impacts table in **Appendix A** shows the reduction in flood levels affectation and increases in freeboard at these properties. The tabulated results show over 80 properties will have a measurable reduction in flood level. Of these, there are nine properties that experience above floor inundation in a 100 year ARI event under existing conditions that would become flood free under the post highway scenario (albeit with relatively small freeboard).

It is evident from the above assessment that the proposed diversion of Town Creek flows provides a significant benefit in reducing flooding through Berry. This needs to be considered in the context of evaluating any adverse impacts on properties and developing appropriate mitigation measures.

Changes in flood behaviour for more frequent events

The proposed works will impact flood levels during events more frequent than 100 year ARI through the same mechanisms as described above. Generally, the increases and reductions in flood levels will be of a smaller magnitude during more frequent flood events.

The proposed embankment at the southern end of the bridge at Berry would encroach on the flooded area to a lesser extent during more frequent flood events. This would result in relatively smaller impacts due to constriction of the floodplain and, subsequently, more frequent flood events will have a reduced flood impact relative to the 100 year ARI event.

The diversion of flows from Town Creek to Bundewallah Creek would result in changes to the behaviour of more frequent flood events similar to those described in the 100 year ARI assessment, however the impacts would be of a relatively smaller magnitude as a consequence of the smaller flow rates.

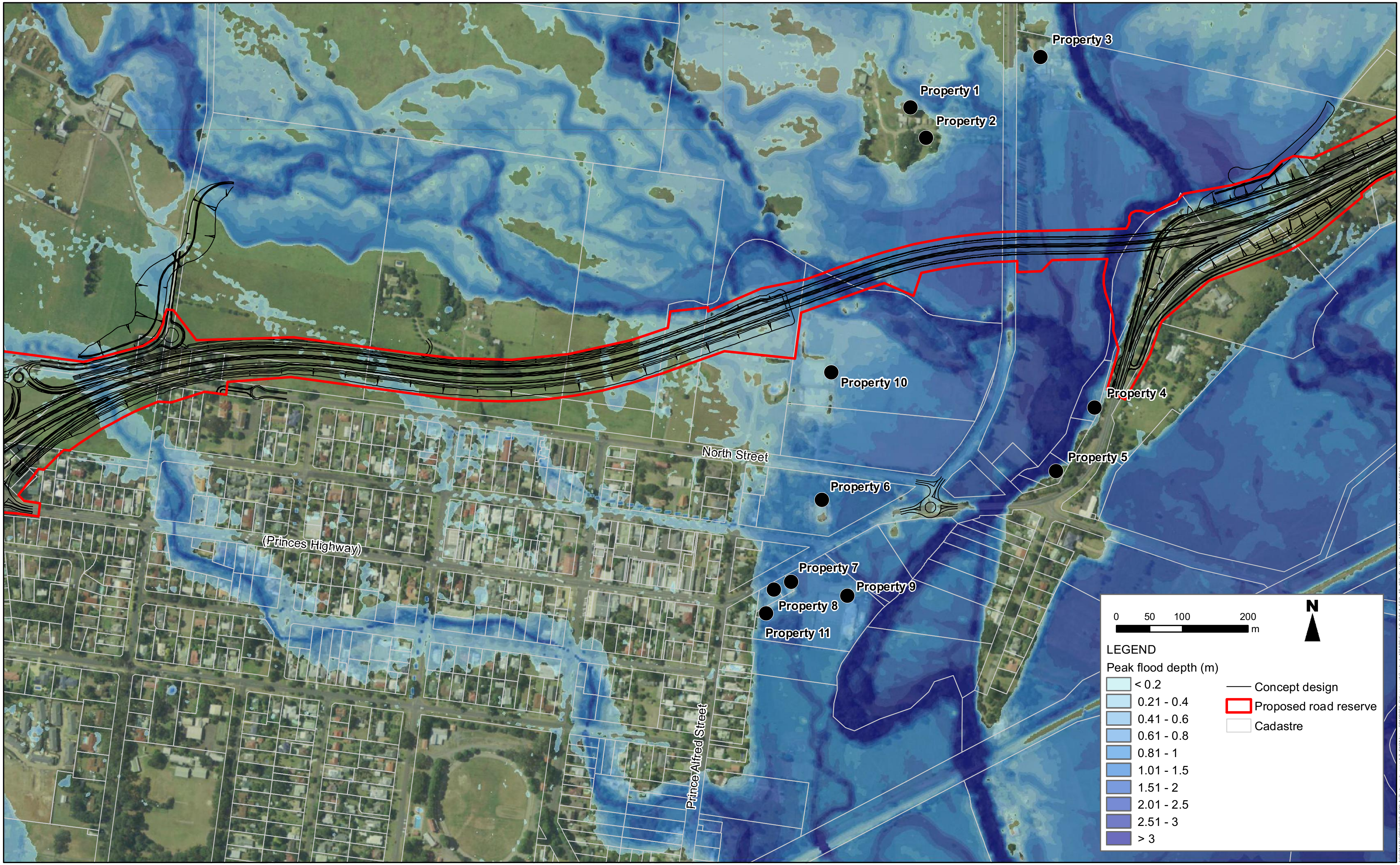


Figure 4-9 Berry Township –100 year ARI peak flood depths – existing conditions

Source: AECOM (2012), Cardno (2011)

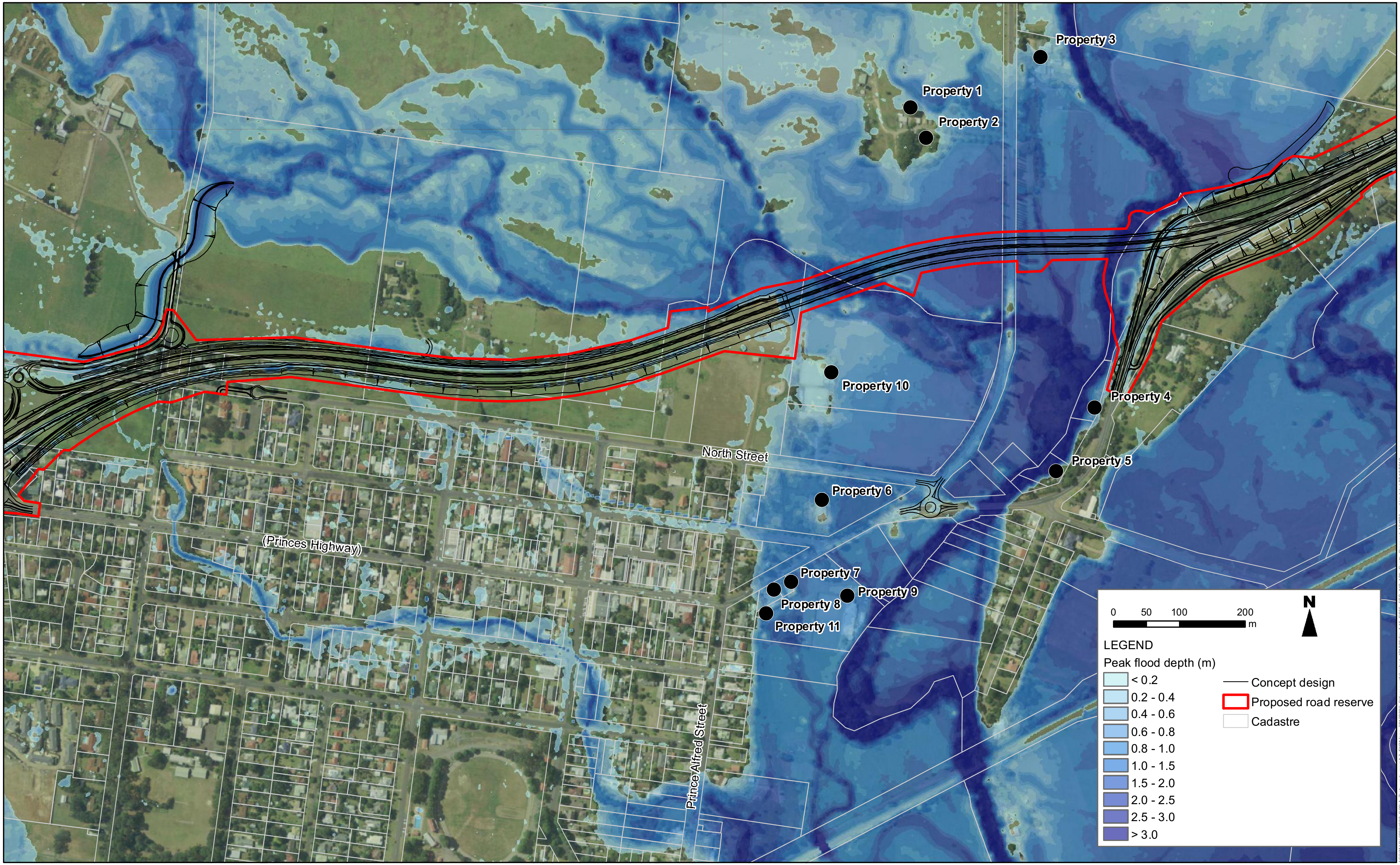


Figure 4-10 Berry Township –100 year ARI peak flood depths – proposed conditions

Source: AECOM (2012), Cardno (2011)

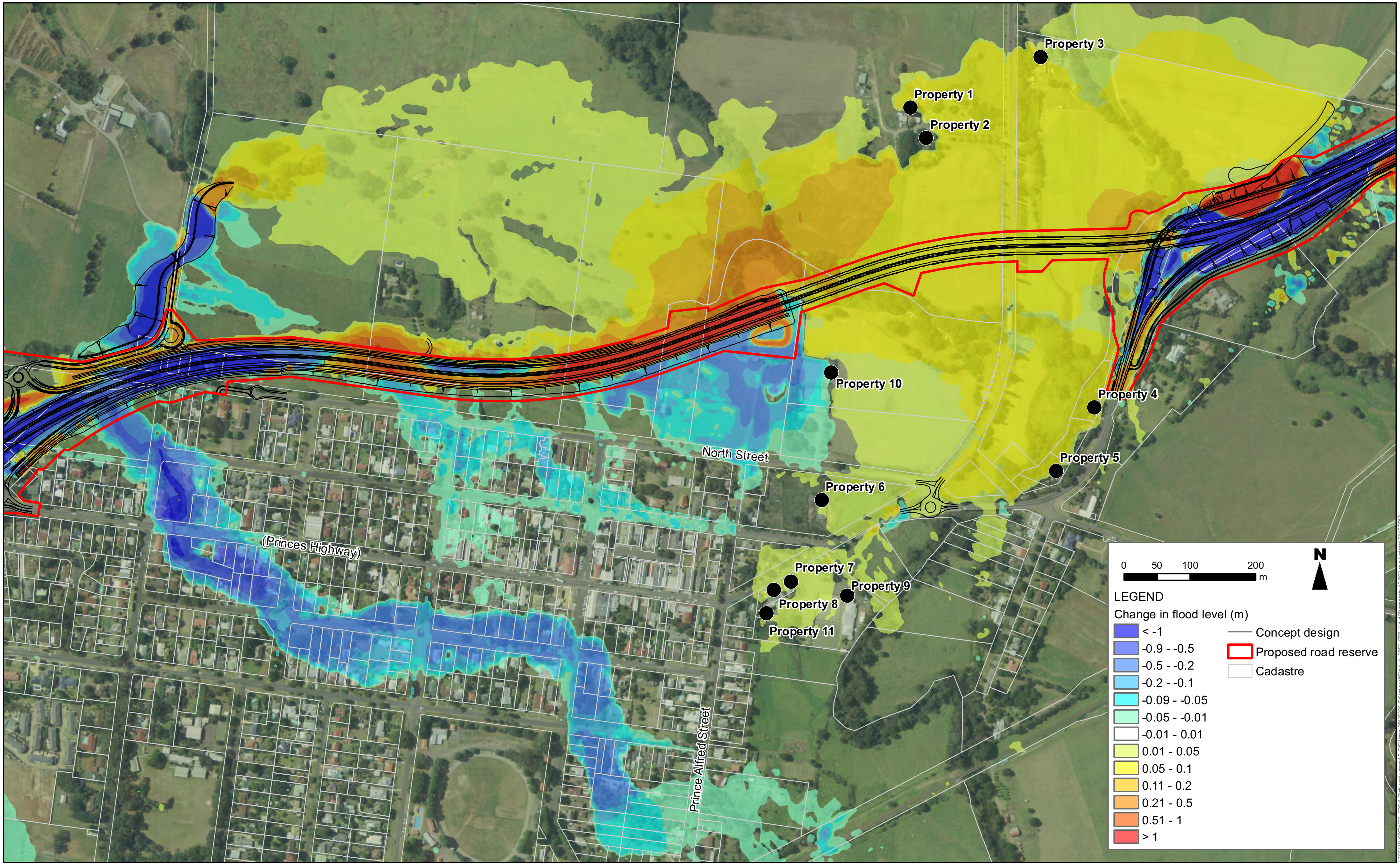


Figure 4-11 Berry Township –100 year ARI change in flood level

Source: AECOM (2012), Cardno (2011)

Notes
- A positive relative impact represents an increase in flood level under proposed conditions relative to existing condtions. A change in flood level of +/- 0.01m is considered to be within the level of accuracy of the model and to have neglible or no impact
- Relative flood level impacts shown along the alignment (within the project corridor) are a function of the direct rainfall on grid hydraulic modelling approach and are a fuction of the relative height between the existing ground and design surface. Impacts indicated in these areas are confined to works within the Proposed Road Corridor.
- The direct rainfall on grid approach can also lead to localised "noise" in flood level results in areas outside the corridor. These isolated pockets of impacts are an artefact of the flood modelling approach rather than a quantifiable impact from the Proposed works.

Table 4-7: Summary of flood levels and relative impacts at property buildings – 100 year ARI event

Property		Survey [Note 1]		Existing Conditions		Concept Design								
#	Address	Floor level (mAHD)	Ground level (mAHD)	100 year ARI flood level at property (mAHD)	Free-board to floor level (m) Note 3	Concept Design 100 yr flood level at property (mAHD)			Change in flood level (m) Note 4			Freeboard to floor level (m)		
						Concept Design	Arrangement 1	Arrangement 2	Concept Design	Arrangement 1	Arrangement 2	Concept Design	Arrangement 1	Arrangement 2
1	59 Woodhill Mountain Rd	11.15	11.06	10.56	0.59	10.62	10.62	10.62	0.06	0.06	0.06	0.53	0.53	0.53
2	59 Woodhill Mountain Rd	11.29	10.90	10.45	0.84	10.53	10.49	10.48	0.08	0.04	0.03	0.76	0.80	0.81
3	76 Woodhill Mountain Rd	10.69	10.85	10.51	0.18	10.58	10.55	10.54	0.08	0.04	0.03	0.11	0.14	0.15
4	29a Princes Hwy	No data	9.8 Note 2	10.12	No data	10.17	10.17	10.16	0.05	0.05	0.03	No data		
5	15 Princes Hwy	13.85	13.56	10.27	3.58	10.30	10.30	10.29	0.03	0.03	0.02	3.55	3.55	3.56
6	152 North St	9.46	8.18	9.09	0.37	9.10	9.11	9.10	0.01	0.02	0.01	0.36	0.35	0.36
7	134 Princes Hwy	7.84	7.02	8.17	-0.33	8.19	8.19	8.18	0.01	0.02	0.01	-0.35	-0.35	-0.34
8	132 Princes Hwy	7.24	7.25	8.18	-0.94	8.20	8.20	8.19	0.01	0.02	0.01	-0.96	-0.96	-0.95
9	140 Princes Hwy (Berry Bowling Club)	7.51	6.55	7.87	-0.36	7.89	7.89	7.89	0.01	0.01	0.02	-0.38	-0.38	-0.38
10	Lot 1 North Street (Camp Quality Park sport amenities)	9.64	9.39	9.83	-0.19	9.82	9.86	9.86	-0.01	0.03	0.03	-0.18	-0.22	-0.22
11	Lot 1 Princes Hwy	7.51	6.92	7.60	-0.09	7.62	7.61	7.61	0.02	0.01	0.01	0.11	0.10	0.10

Notes

1. *Floor and Ground Level survey carried out by Peter Smith & Co for Shoalhaven City Council as part of the Broughton Creek Floodplain Risk Management Study. Except for Properties 1 and 2, which was carried out by RMS.*
2. *No floor level data available for Property 4. Ground levels approximated from flood model DTM.*
3. *A negative freeboard represents the depth of above floor inundation.*
4. *A positive relative impact represents an increase in flood level under proposed conditions relative to existing conditions. A change in flood level of +/-0.01m is considered to be within the level of accuracy of the model and is considered to have negligible or no impact*

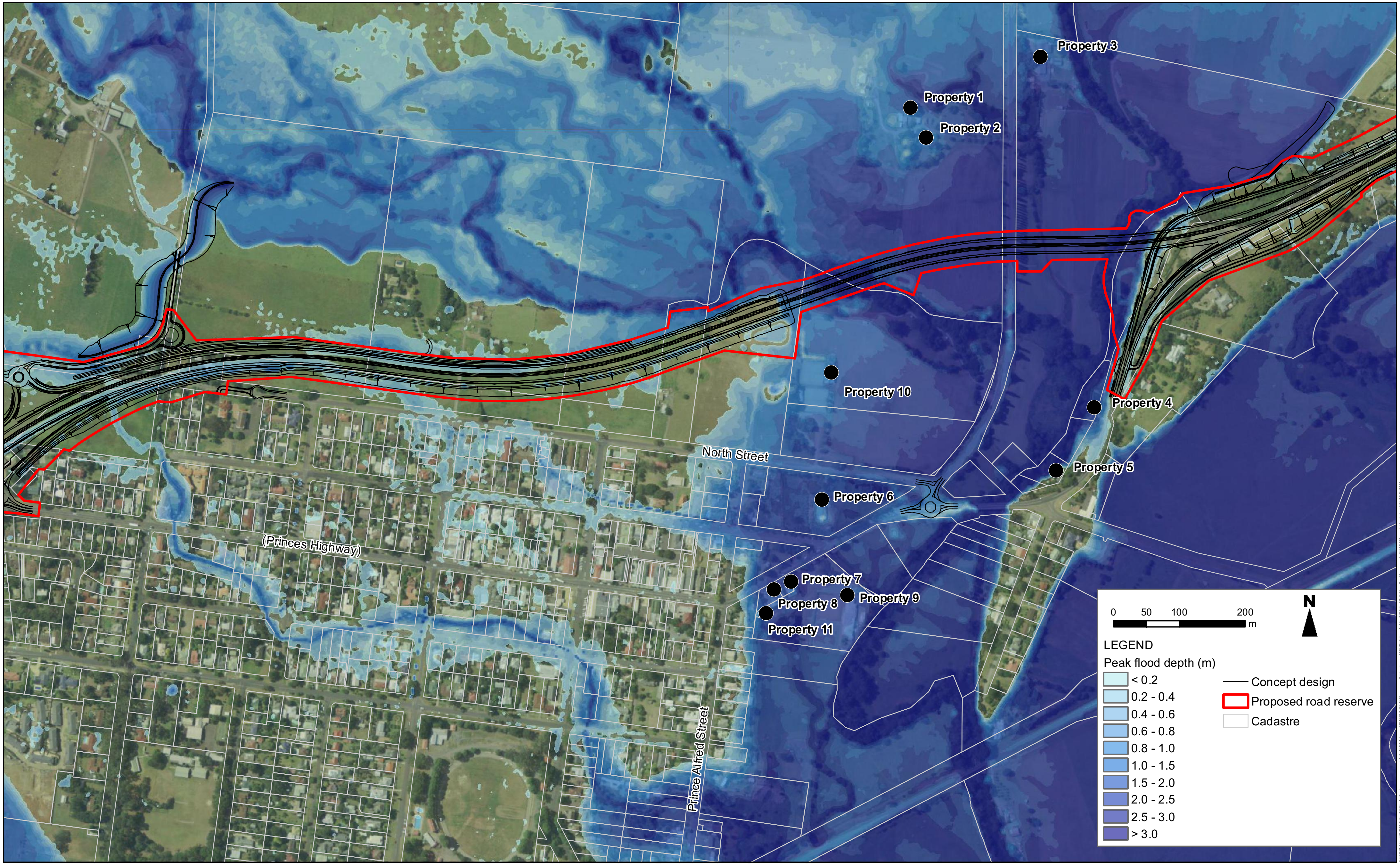


Figure 4-12 Berry Township – PMF peak flood depths – proposed conditions

Source: AECOM (2012), Cardno (2011)

4.2.6 Regional flood impacts during the Probable Maximum Flood

The preceding sections have dealt with local flood impacts around the individual drainage structures. However, flooding on a wider scale has to be considered for emergency planning purposes and impacts on critical infrastructure. The potential flood impacts during the PMF along the proposed route alignment have therefore been investigated. This assessment also serves to identify potential worst case impacts.

The proposed road embankment has the potential to block flood waters. The road could be overtopped by about three metres between Broughton Creek bridges 1 and 2 during the PMF. The raised road embankment could increase flood levels up to two metres above existing levels during the PMF upstream of Broughton Creek bridge 1, and up to two metres at Broughton Creek bridge 2. While there is no critical infrastructure upstream of these bridges, dwellings on private properties could be affected. The project would not adversely affect evacuation routes as the existing highway in this location is already overtopped during a PMF under existing conditions. Flood impacts at Broughton Creek bridge 3 would be mitigated by the large bridge waterway openings and high elevation of the bridge above the floodplain.

The drainage crossings through the middle reaches between the Broughton Creek crossings and Berry convey much smaller flows and impacts in the PMF would be localised and not affect critical infrastructure.

At Berry, the project would be located north of the current highway. This would reduce the flood risk to the main part of the town of Berry as well as some access routes, such as the South Coast Rail Line. There would be an increase in PMF flood level of approximately 0.2 metres at the north of bridge at Berry. Directly north of the western abutment, the flood level would increase approximately 0.6 metres. Downstream of bridge at Berry, the increase would generally be 0.1 - 0.15 metres. The change in flood levels for the PMF event are shown in **Figure 4-13**.

The diversion channel for Town Creek would provide flood relief to much of the Berry township by diverting water upstream of the upgraded alignment toward Bundewallah Creek. Therefore properties within the town of Berry would experience a reduction in flood level of up to 0.9 metres.

Due to the nature of the terrain at Hitchcocks Lane tributary the flood impacts during the PMF would likely be limited to the area between the highway alignment and Huntingdale Park. The proposed road level at this location is approximately 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 project would have adverse flood impacts during a PMF. However, it would also reduce the flood risk to the township of Berry and critical infrastructure and evacuation routes should not be affected.

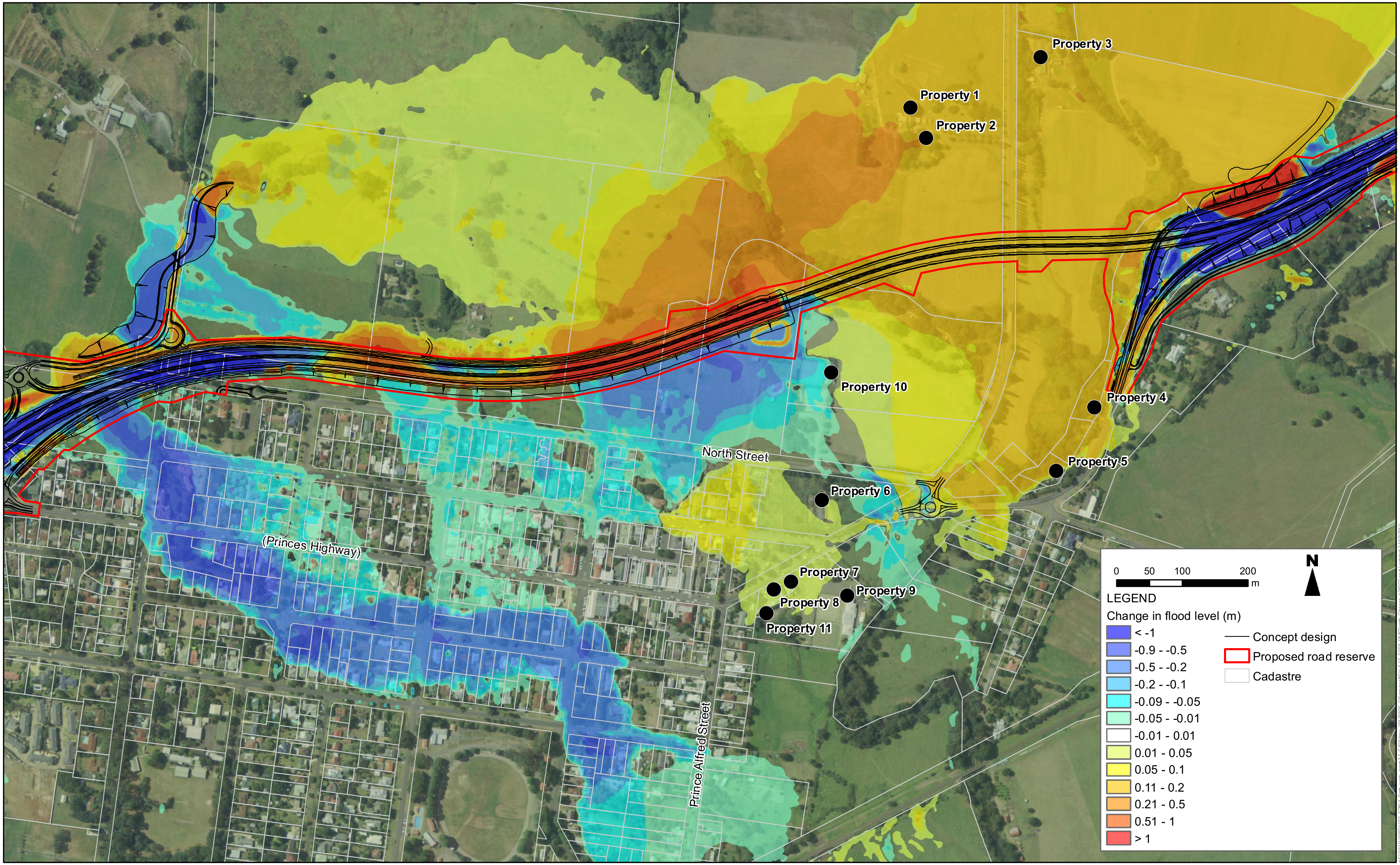


Figure 4-13 Berry Township – PMF change in flood level

Notes

- A positive relative impact represents an increase in flood level under proposed conditions relative to existing condtions. A change in flood level of +/- 0.01m is considered to be within the level of accuracy of the model and to have neglible or no impact
- Relative flood level impacts shown along the alignment (within the project corridor) are a function of the direct rainfall on grid hydraulic modelling approach and are a fuction of the relative height between the existing ground and design surface. Impacts indicated in these areas are confined to works within the Proposed Road Corridor.
- The direct rainfall on grid approach can also lead to localised "noise" in flood level results in areas outside the corridor. These isolated pockets of impacts are an artefact of the flood modelling approach rather than a quantifiable impact from the Proposed works.

Source: AECOM (2012), Cardno (2011)

4.2.7 Site compound and stockpile locations

Site compounds would be used to store plant and equipment and to provide parking and amenities for construction staff. Chemicals and fuels for construction would be stored in appropriately bunded storage areas in the compound site. The compound and stockpile sites would be subject to the site location criteria set out in the Stockpile Site Management Procedures (RTA, 2001).

The exact location of compound and stockpile sites is difficult to determine at this stage of project development and would be subject to change during the detailed design and construction stages. However, potential site compound locations have been identified and are described in **Chapter 4** of the environmental assessment. The site compounds would be located within the project corridor and adjacent lands.

The potential for flood impacts at site compounds and stockpiles would be assessed during the detailed design phase. This assessment would take into consideration factors such as the nature of the sites, the construction sequencing, the duration of operation of these sites and proximity to sensitive waterways.

4.2.8 Stock refuge

The project runs mainly through rural pastures and stock refuges on these rural floodplains are important to protect livestock. Floodwaters can affect livestock in several ways, including injury and drowning or damage to fodder reserves. Stock refuges in the event of flooding on the Broughton Creek floodplain would be maintained by the access road under Broughton Creek bridge 2. This provides a flood evacuation route for stock to walk to higher ground. This outcome could alternatively be achieved by providing mounds of fill within the floodplain, preferably located in fringe areas or at the base of the proposed highway embankment.

4.2.9 Worst case

A key aspect of the DGRs for this project is the provision of appropriate environmental management measures and design standards to minimise the potential risk of flood impacts. For the purposes of determining a worst case scenario in line with the DGRs it has been assumed that all drainage infrastructure (ie culverts, bridges and drains) could experience some form of blockage.

With existing drainage lines blocked, flood waters would follow new overland flowpaths where available, similar to the flood behaviour that might occur during the PMF. Concentrated flows through culverts or bridge openings that are partially blocked could result in increased flow velocities and lead to increased scour and erosion. This could not only affect ecosystems and cause local flood level impacts but could ultimately affect the structural integrity of the road infrastructure.

It is considered highly unlikely that all these measures could fail, and as such there is only a low risk of the worst case impacts occurring.

4.2.10 Climate change potential impacts

Climate change has the potential to alter rainfall and sea level conditions that lead to flooding of the creeks and waterways traversed by the project.

Scientific research into the potential impacts of climate change has been rapidly evolving over recent years. Latest research indicates that climate change is likely to result in more frequent and intense storms, but lower average annual rainfall. This has the potential to increase rainfall intensities for storms leading to increases in the frequency and magnitude of flooding to catchments and waterways in the vicinity of the project.

Research into sea level trends shows that over the period 1870 – 2001 global sea levels rose by 0.2 metres, with the current global rate of increase approximately twice the historical average (DECCW, 2009). Increased sea level rise has the potential to affect Shoalhaven River and Broughton Creek flooding south of Berry. However, the project lies outside the area of Broughton Creek and Shoalhaven River flooding and is therefore not influenced by sea level rise.

The Floodplain Risk Management Guideline Practical Consideration of Climate Change (DECC, 2007) provides estimated changes in rainfall intensities for the 1 in 40 year one day rainfall totals. With regard to the study area the predicted increase in rainfall intensity is plus seven per cent by 2030 and plus five per cent by 2070. On this basis the RMS have established design criteria providing an allowance for six per cent rainfall increase across the overall Gerringong to Bomaderry route alignment (including the project).

While there is general consensus regarding the overall trend of increased rainfall intensities and sea level rise, there is less consensus on the extent of these increases. For this reason the DECC 2007 Guideline recommends assessment of a range of rainfall and sea level scenarios to assess the sensitivity of the catchment to potential increases.

With regard to increase in peak rainfall and storm volume the DECC 2007 guideline recommend consideration of the following:

- Low level rainfall increase 10 per cent
- Medium level rainfall increase 20 per cent
- High level rainfall increase 30 per cent

It should be noted that under the DECC 2007 Guidelines, a high level rainfall increase of 30 per cent is recommended for consideration due to the level of uncertainty in rainfall projections and the implementation of a precautionary approach is recommended. However, on the basis of current research, it is generally acknowledged that a 30 per cent rainfall increase is on the conservative side.

In light of the above, the approach adopted to manage the potential impacts of climate change on flooding has involved:

- Adopting a six per cent increase in design rainfall intensities for design of transverse drainage structures; and
- Undertaking sensitivity analyses for increases in rainfall intensity of 10, 20 and 30 per cent.

Potential increases in rainfall intensities have been assessed as part of the hydrologic and hydraulic modelling of the project. A summary of the implications for 100 year ARI flood levels is provided below.

Potential climate change impacts at the bridge at Berry

Of the total project, the western abutment of the bridge at Berry has the least amount of freeboard provided for in the concept design. As such, flood levels at this location would be most vulnerable to climate change impacts.

Implications for flooding levels due to climate change were assessed for potential increases in rainfall intensity. Variations in rainfall on the local catchment were assessed by factoring the inflows to the TUFLOW model by 10 per cent, 20 per cent and 30 per cent to reflect the respective increases in rainfall intensity. Results of the scenarios assessed are shown in **Table 4-8.**

Table 4-8: Potential impact of climate change on 100 year ARI flood levels at Berry Bridge (metres)

Location	Base case 100yr design flood level (mAHD)	Increase in rainfall intensity		
		10 per cent	20 per cent	30 per cent
Western abutment of the bridge at Berry	11.22	0.05	0.09	0.13

The results show that for a 10 per cent increase in rainfall, the increase in flood level is approximately 0.05 metres. The upper bound of the sensitivity analysis (30 per cent increase in rainfall) would result in an increase in flood level of up to 0.13 metres.

In light of the above, 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. On this basis no additional allowance for climate change is considered necessary.

Potential climate change impacts at Broughton Creek

The potential effects of climate change have been investigated at the three proposed bridges over Broughton Creek and the results are listed in **Table 4.9.**

Table 4-9: Potential impact of climate change on 100 year ARI flood levels at Broughton Creek (metres)

Location	Base case 100yr design flood level (mAHD)	Increase in rainfall intensity		
		10 per cent	20 per cent	30 per cent
Broughton Creek bridge 1	36.66	0.13	0.26	0.38
Broughton Creek bridge 2	30.65	0.14	0.28	0.43
Broughton Creek bridge 3	27.65	0.13	0.26	0.38

The results show that for a 10 per cent increase in rainfall, the increase in flood level is approximately 0.1 metres. For the conservative case of a 30 per cent increase in rainfall, the increase in flood level would be approximately 0.4 metres at the three bridges.

In light of the above, 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. On this basis no additional allowance for climate change is considered necessary.

4.3 Environmental management measures

4.3.1 Waterway crossings

To minimise the project's potential impact on flooding and to minimise the potential impact of the proposed waterway crossings on the environment, appropriate mitigation measures would be implemented to mitigate flooding. The design of drainage structures would allow for the natural flow of floodwaters and existing overland flow paths to be maintained post-construction where possible.

In order to minimise impacts on flow behaviour culverts would be located and, sized to adequately convey the 100 year ARI runoff event (if on the main alignment) and designed to meet the RMS's design velocity criteria. However, it should be noted that the hydrology and hydraulics of the culverts would be refined during detailed design. Climate change would also be taken into account as discussed in Section 4.3.3.

Bridge configurations would be designed to maintain existing flow patterns as far as possible to minimise increases in flood levels and velocities around the bridge structures. Minimising the clearance footprint for embankments and maintaining clear passage of stream channels, would assist in mitigating the construction impacts on the various creeks within the project area. Piers would be placed outside the main creek channels where possible, and would be designed and orientated to minimise the generation of turbulence and subsequent bed and bank erosion. The intrusion of the bridge abutments into the 100 year ARI flood extent would be limited to minimise flood level impacts.

The need for scour protection at any bridge or culvert crossing would be minimised through appropriate design measures. However, some form of scour protection or energy dissipation would be necessary at those waterway crossings with high velocities to prevent excessive erosion and potential damage to structures. Scour protection measures would be installed along the bed and banks upstream and downstream of these waterway crossings where appropriate and in accordance with relevant design guidelines.

These management measures would be further refined during the detailed design stage.

Broughton Creek

The embankment between Broughton Creek bridge 2 and Broughton Creek bridge 3 may be subject to floodwaters flowing parallel to the alignment and, along the toe of the embankment. Suitable batter treatment needs to be designed to prevent failure of the embankment due to scour.

Further detailed modelling, combined with refinement of the bridge configurations would be carried out as part of the detailed design phase to minimise flood and scour impacts.

Bridge at Berry and Town Creek diversion

As a minimum, all water quality basins located on the floodplain should be constructed at or close to ground level or replaced with swales.

Provision would be made for adequate freeboard in the Town Creek diversion channel to prevent overtopping and scour protection provided where velocities are high.

The assessment outlined in Section 4.3.5 of this report has shown that 11 properties are potentially at risk of adverse flood impacts. This assessment is based on the concept design which is subject to change with any optimisation measures introduced during detailed design. During detailed design potential impacts would be confirmed and necessary mitigation measures developed accordingly. The current recommended mitigation approach for each property, based on the concept design, is outlined below (refer **Figure 4-11** for property locations).

Properties 1, 2 and 3

It is recommended that the implications of these impacts and possible local mitigation measures such as diversion swales, local bunding or flood proofing of buildings be discussed with the property owner.

Alternatively, impacts could be offset by increasing the waterway area across the floodplain. To gain an understanding of the extent of works required to offset impacts two additional design scenarios were run and these are also included in **Table 4-7**. These additional scenarios would involve:

- Arrangement 1 - removing the water quality basins that are located in the floodplain; pulling in the retaining wall at the eastern abutment to maintain the existing flowpath from the billabong at property 3; and creating an opening in the western abutment 30 metres long.
- Arrangement 2 – same as Arrangement 1 with an opening in the western abutment 60 metres long; culverts in the southern abutment and additional retaining wall in the northern abutment as per Arrangement 1. In either case, given the sensitive nature of flooding in this area, all basins on the floodplain should be constructed at or close to ground level and/or replaced with bunded swales.

Properties 4 and 5

Local mitigation works should be discussed and agreed with the owner of property 4 and would include consideration of measures such as diversion swales, local bunding or flood proofing of buildings.

Floor level survey for property 5 shows the building is elevated over three metres above the 100 year ARI flood level. Consequently, the nominal increase in flood levels is not significant in the context of the impacts.

However, appropriate property mitigation measures may be warranted to address the impacts (which are 0.05 metres or less) if these are considered to be unacceptable. Local mitigation works should be discussed with the property owner and would include measures such as diversion swales, local bunding or flood proofing of buildings.

Properties 6, 7, 8, 9 and 11

Properties 6, 7, 8, 9 and 11 are located further downstream of the proposed road alignment. The nominal impacts at these properties would be primarily due to the diversion of flows from Town Creek. The increase in flood levels at these properties is considered minor relative to the existing degree of flood potential or inundation. Consequently, no additional local flood mitigation measures are expected to be required. This would however be subject to detailed design development.

Property 10

Property 10, the sports amenities building for the Berry sportsground and Camp Quality Memorial Park, is located immediately downstream of the southern bridge abutment. Relative flood level impacts based on the current concept design are negligible or minor.

4.3.2 Ancillary facilities

To reduce the risk of flood damage (and potential contamination of waterways) ancillary chemical storage facilities would be located above the 100 year ARI flood level.

Stockpile sites and ancillary construction material facilities would be sited above the 100 year ARI flood level where possible, but may be located above the 20 year ARI flood level. Where storage would be required on the floodplain (for activities such as bridgeworks) appropriate mitigation measures would be implemented, such as bunds around materials and equipment would be designed and scour protection applied to mitigate flood impacts.

In addition, the use of automatic weather stations (AWSs) would be considered to gather accurate and timely weather data and to facilitate weather warnings to construction contractors. AWSs are generally solar powered and record rainfall, wind speed and direction, temperature, relative humidity and dew point. The data is transferred to a remote server every 15 minutes over the 3G/4G telephone network. The data is then made available to RMS and contractors via the internet on an easy to navigate website. Information can also be sent to mobile phones by SMS. The AWSs can alert RMS staff and contactors of selected -predetermined weather conditions, such as when a site has received a certain rainfall amount in a day. This system can be used to mitigate potential adverse impacts of weather events.

4.3.3 Rehabilitation of waterways to pre-construction condition

Best practice management measures would be implemented during construction in accordance with applicable RMS QA specifications, Managing Urban Stormwater- Soils and Construction Volume 1 (Landcom, 2004) and Volume 2D – Main Road Construction (DECCW, 2008).

4.3.4 Climate change management measures

On the basis of the preceding assessment, the recommended measures to manage potential impacts due to climate change would involve:

- The provision of an appropriate freeboard of around 0.5 metres minimum for major bridge waterway crossings on Broughton Creek and Berry.
- The provision of a six per cent allowance for increased rainfall intensities. For minor waterway crossing culverts, additional impacts could feasibly be accommodated (if required) through future local adaptive measures such as culvert amplification and/or lifting the level of the highway.

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Appendix A

Assessment of creek property flood impacts - Berry

Assessment of creek property flood impacts - Berry

Property Number	Street	100 year ARI Flood Level Note 1 Existing (mAHD)	Proposed (mAHD)	Change in Flood Level Note 2 (m)	Floor level (mAHD)	Freeboard Existing (m)	Freeboard Proposed (m)	Comment
110	North Street	15.00	14.97	-0.02	15.65	0.65	0.68	
112	North Street	14.92	14.81	-0.12	15.75	0.83	0.94	
114	North Street	14.89	14.77	-0.12	15.84	0.95	1.07	
118	North Street	14.40	14.30	-0.10	14.51	0.11	0.21	
120	North Street	14.04	13.96	-0.08	14.86	0.82	0.90	
122	North Street	13.90	13.83	-0.08	14.53	0.63	0.70	
124	North Street	13.84	13.80	-0.04	13.98	0.14	0.18	
124	North Street	13.86	13.79	-0.07	14.04	0.18	0.25	
124	North Street	13.86	13.82	-0.04	14.06	0.20	0.24	
126	North Street	13.55	13.49	-0.06	13.85	0.30	0.36	
126	North Street	13.55	13.49	-0.06	13.89	0.34	0.40	
126	North Street	13.19	13.17	-0.02	13.82	0.63	0.65	
126	North Street	13.33	13.30	-0.03	13.83	0.50	0.53	
126	North Street	13.45	13.42	-0.03	13.86	0.41	0.44	
130	North Street	13.08	12.95	-0.13	13.30	0.22	0.35	
130	North Street	12.82	12.69	-0.13	13.36	0.54	0.67	
138	North Street	12.13	12.12	-0.02	12.39	0.26	0.27	

Property		100 year ARI Flood Level [Note 1]		Change in Flood Level [Note 2]	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
0	North Street	12.17	12.17	-0.01	9.64	-2.53	-2.53	
150	North Street	11.99	11.87	-0.11	12.61	0.62	0.74	
2	Prince Alfred Street	8.79	8.75	-0.04	9.12	0.33	0.37	
7	Prince Alfred Street	8.99	8.95	-0.04	9.43	0.44	0.48	
67	Albert Street	11.22	11.17	-0.04	11.90	0.68	0.73	
10	Alexandra Street and Albert Street	11.42	11.35	-0.08	12.15	0.73	0.80	
62	Albert Street	11.85	11.81	-0.04	12.12	0.27	0.31	
0	Alexandra Street	11.98	11.96	-0.02	12.37	0.39	0.41	
65	Albert Street	12.12	12.07	-0.05	12.10	-0.02	0.03	Building no longer flooded
7	Alexandra Street	12.18	12.14	-0.04	12.70	0.52	0.56	
4	Alexandra Street	12.08	12.07	-0.02	12.20	0.12	0.13	
6	Alexandra Street	11.89	11.89	-0.01	12.49	0.60	0.60	
63	Albert Street	12.31	12.26	-0.04	12.51	0.20	0.25	
61	Albert Street	12.43	12.36	-0.07	12.82	0.39	0.46	
59	Albert Street	12.56	12.54	-0.02	13.23	0.67	0.69	
51	Albert Street	14.09	14.07	-0.02	14.49	0.40	0.42	
49	Albert Street	14.29	14.28	-0.01	14.78	0.49	0.50	
44	Albert Street	13.89	13.88	-0.01	14.44	0.55	0.56	
42	Albert Street	14.13	14.08	-0.04	14.53	0.40	0.45	

Property		100 year ARI Flood Level Note 1		Change in Flood Level Note 2	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
1	Albany Street	14.70	14.68	-0.01	15.87	1.17	1.19	
3	Albany Street	14.62	14.60	-0.02	15.19	0.57	0.59	
3a	Albany Street	14.57	14.56	-0.01	15.11	0.54	0.55	
18	Albert Street	17.98	17.96	-0.02	18.30	0.32	0.34	
4	Albert Street	17.98	17.96	-0.02	18.30	0.32	0.34	
2	Albert Street	18.11	17.73	-0.38	18.96	0.85	1.23	
2	Albert Street	18.10	17.77	-0.33	18.95	0.85	1.18	
2	Albert Street	18.12	17.98	-0.14	19.02	0.90	1.04	
2	Albert Street	18.13	17.96	-0.17	18.98	0.85	1.02	
2	Albert Street	18.02	17.97	-0.05	19.04	1.02	1.07	
2	Albert Street	17.98	17.94	-0.04	18.99	1.01	1.05	
2	Albert Street	17.99	17.67	-0.32	19.04	1.05	1.37	
2	Albert Street	18.01	17.71	-0.30	19.07	1.06	1.36	
3	Albert Street	18.31	18.30	-0.01	19.05	0.74	0.75	
1	Albert Street	18.23	18.21	-0.02	19.06	0.83	0.85	
64	Princess Street	9.82	9.51	-0.31	9.96	0.14	0.45	
66	Princess Street	9.69	9.59	-0.10	10.35	0.66	0.76	
15	Alexandra Street and Princess Street	10.23	10.11	-0.11	10.96	0.73	0.85	
61	Princess Street	10.50	10.24	-0.26	10.82	0.32	0.58	

Property		100 year ARI Flood Level Note 1		Change in Flood Level Note 2	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
19	Alexandra Street	9.82	9.68	-0.14	10.42	0.60	0.74	
54	Princess Street	9.77	9.69	-0.09	11.78	2.01	2.09	
52	Princess Street	11.03	10.92	-0.11	11.89	0.86	0.97	
50	Princess Street	11.43	11.29	-0.14	12.07	0.64	0.78	
48	Princess Street	11.64	11.41	-0.24	12.04	0.40	0.63	
46	Princess Street	11.70	11.46	-0.24	12.13	0.43	0.67	
44	Princess Street	12.04	11.75	-0.28	12.45	0.41	0.70	
42	Princess Street	12.36	12.05	-0.31	12.26	-0.10	0.21	Building no longer flooded
11	Albany Street	12.48	12.42	-0.07	13.10	0.62	0.68	
13	Albany Street	12.64	12.54	-0.10	13.16	0.52	0.62	
15	Albany Street	12.55	12.52	-0.03	13.40	0.85	0.88	
36	Princess Street	12.96	12.87	-0.09	13.31	0.35	0.44	
34	Princess Street	13.29	13.04	-0.24	14.12	0.83	1.08	
33	Princess Street	13.64	13.62	-0.02	14.27	0.63	0.65	
26	Princess Street	13.65	13.33	-0.32	13.62	-0.03	0.29	Building no longer flooded
31	Princess Street	13.99	13.94	-0.05	14.62	0.63	0.68	
29	Princess Street	14.34	14.31	-0.04	14.59	0.25	0.28	
27	Princess Street	14.76	14.68	-0.08	15.04	0.28	0.36	
37	Edward street and Princess Street	14.88	14.55	-0.34	15.27	0.39	0.72	

Property		100 year ARI Flood Level Note 1		Change in Flood Level Note 2	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
33	Edward Street	15.53	15.11	-0.42	15.56	0.03	0.45	
19	Princess Street	15.92	15.81	-0.11	16.50	0.58	0.69	
17	Princess Street	16.21	16.21	-0.01	16.48	0.27	0.27	
51a	Victoria Street	13.54	13.33	-0.22	14.41	0.87	1.08	
53	Victoria Street	13.45	13.36	-0.08	14.16	0.71	0.80	
22	Alexandra Street and Victoria Street	9.46	9.11	-0.35	9.55	0.09	0.44	
66	Victoria Street	7.37	7.00	-0.37	7.65	0.28	0.65	
68	Victoria Street	8.70	8.42	-0.27	8.78	0.08	0.36	
87	Victoria Street	9.47	9.31	-0.15	9.57	0.10	0.26	
70	Victoria Street	8.98	8.95	-0.03	9.17	0.19	0.22	
35	Prince Alfred Street	6.97	6.95	-0.02	7.44	0.47	0.49	
43	Prince Alfred Street	6.96	6.94	-0.02	6.79	-0.17	-0.15	
45	Prince Alfred Street	6.96	6.94	-0.02	7.26	0.30	0.32	
80	Queen Street	11.30	11.30	-0.01	12.30	1.00	1.00	
46	Queen Street	15.99	15.76	-0.23	16.58	0.59	0.82	
44	Queen Street	16.44	16.34	-0.10	16.38	-0.06	0.04	Building no longer flooded
42	Queen Street	16.51	16.12	-0.39	16.35	-0.16	0.23	Building no longer flooded
40	Queen Street	16.61	16.16	-0.44	16.76	0.15	0.60	
38	Queen Street	16.62	16.17	-0.46	16.59	-0.03	0.42	Building no longer flooded

Property		100 year ARI Flood Level Note 1		Change in Flood Level Note 2	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
36	Queen Street	17.44	17.38	-0.06	17.57	0.13	0.19	
24	Queen Street and George Street	17.93	16.89	-1.04	19.02	1.09	2.13	
24	Queen Street and George Street	17.93	17.21	-0.73	19.02	1.09	1.81	
24	Queen Street and George Street	17.96	17.40	-0.55	18.93	0.97	1.53	
24	Queen Street and George Street	17.96	17.42	-0.54	18.95	0.99	1.53	
35	Queen Street	17.82	17.60	-0.22	17.76	-0.06	0.16	Building no longer flooded
35	Queen Street	17.85	17.71	-0.14	17.77	-0.08	0.06	Building no longer flooded
35	Queen Street	17.87	17.64	-0.23	17.75	-0.12	0.11	Building no longer flooded
37	Queen Street	17.52	17.37	-0.14	17.83	0.31	0.46	
37	Queen Street	17.79	17.58	-0.21	18.07	0.28	0.49	
37	Queen Street	17.82	17.59	-0.23	18.10	0.28	0.51	
39	Queen Street	17.55	17.43	-0.12	17.63	0.08	0.20	
41	Queen Street	17.37	17.34	-0.03	17.49	0.12	0.15	
65	Queen Street	13.58	13.57	-0.01	14.39	0.81	0.82	
65	Queen Street	13.75	13.74	-0.01	14.32	0.57	0.58	
65	Queen Street	13.88	13.86	-0.02	14.25	0.37	0.39	
65	Queen Street	13.95	13.93	-0.03	14.29	0.34	0.36	
65	Queen Street	13.95	13.92	-0.03	14.31	0.36	0.39	
65	Queen Street	13.98	13.96	-0.02	14.30	0.32	0.34	

Property		100 year ARI Flood Level Note 1		Change in Flood Level Note 2	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
69	Queen Street	13.45	13.43	-0.02	13.78	0.33	0.35	
71	Queen Street	13.41	13.40	-0.01	13.89	0.48	0.49	

Notes 1. Flood level has been extracted from flood surface DTM at point location of floor level survey and may therefore be influenced by local features.

A positive relative impact represents an increase in flood level under proposed conditions relative to existing conditions.

2. A change in flood level of +/-0.01m is considered to be within the level of accuracy of the model and have negligible or no impact.

3. A negative freeboard represents the depth of above floor inundation.