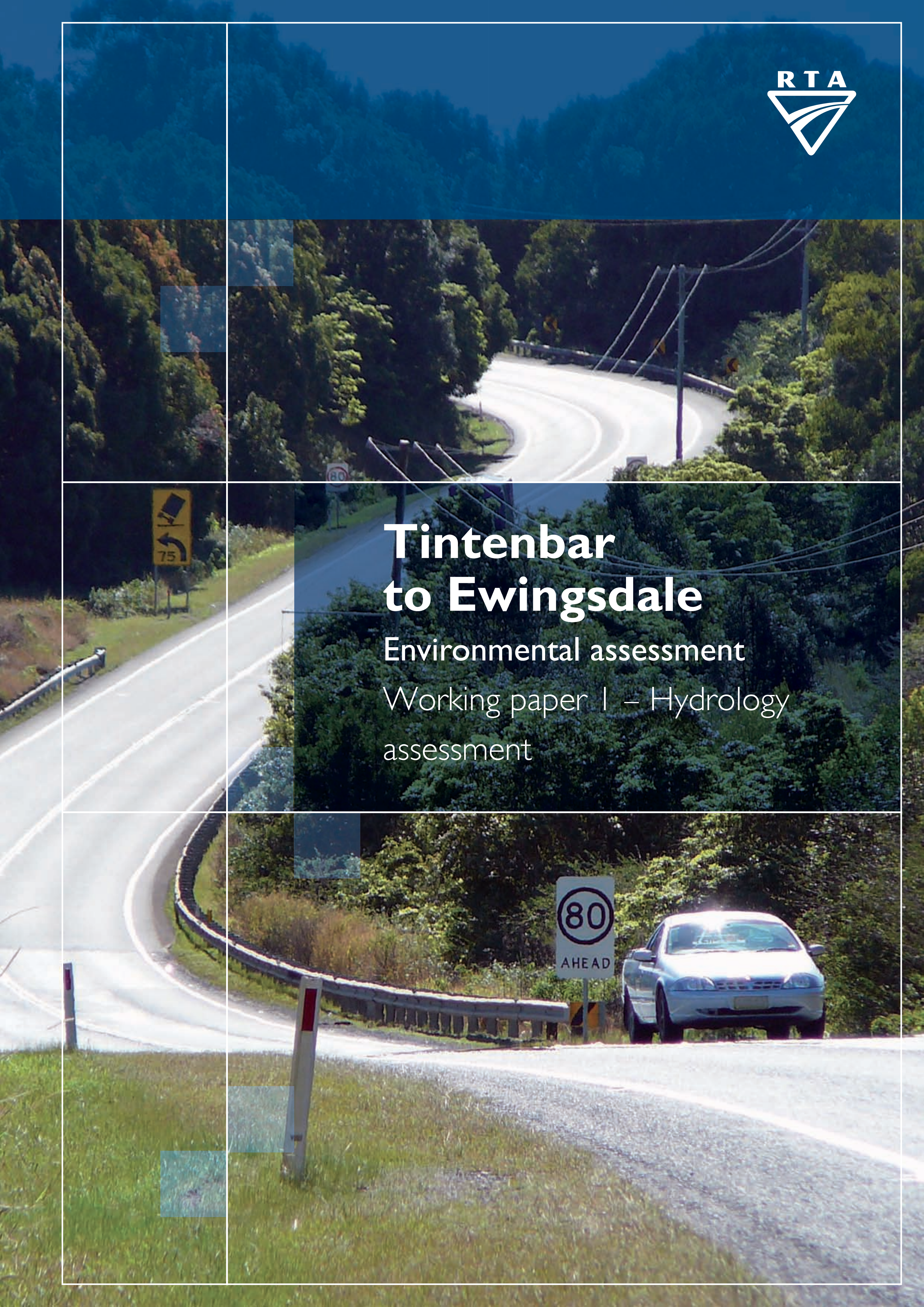
RTA

Tintenbar to Ewingsdale

Environmental assessment

Working paper 1 – Hydrology assessment



Roads and Traffic Authority

Tintenbar to Ewingsdale Pacific Highway Upgrade

Working Paper 01 - Hydrology Assessment

June 2008

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Contents

Tables

Figures

Executive Summary

On behalf of the Roads and Traffic Authority, Arup have undertaken a hydraulic/hydrologic assessment for the proposed Pacific Highway upgrade between Tintenbar and Ewingsdale. This hydrology working paper provides an overview of baseline hydrological conditions, assessment of the impacts of the proposed upgrade on flood behaviour, and assessment of the impact of changes to surface water flows as a result of the proposed upgrade, including modifications to waterways and local overland flow paths.

An initial map of hydraulic constraints was assembled based on desk study of available topographic data and aerial photography, review of historical reporting and data, and discussions with Ballina Shire Council, Byron Shire Council and the Richmond River County Council. Input from the community and stakeholders received during Community Information Sessions and Planning Focus Workshops was reviewed and incorporated into the initial assessment of baseline conditions.

Hydrologic and one-dimensional hydraulic modelling was subsequently undertaken for the four named creeks: Tinderbox, Byron, Skinners and Emigrant creeks. The 1% Average Exceedance Probability (AEP) floodplain extent was mapped from modelled results. For unnamed creeks, 1% AEP flows were determined using the Rational Method.

A preliminary assessment of required waterway opening structures required beneath the proposed upgrade has been undertaken. For named creeks, waterway structures have been designed based on modelled 1% AEP flood extents. For unnamed creeks, waterway opening sizes have been determined using standard culvert capacity calculations. Waterway openings would be designed with sufficient capacity to convey the 1% AEP peak flow with:

- No flow on at least one carriageway of the proposed upgrade
- Minimal increase to water levels upstream of the structure
- Minimal disruption to the natural hydrological regime through the diversion of flow onto adjoining catchments
- Minimal increase in flow velocities with appropriate scour protection where increased velocities have the potential to cause scour.

Hydrological impacts have been minimised through the incorporation of sufficient transverse drainage infrastructure to maintain existing surface water flow regimes. Waterways would only be diverted from their existing alignment where it is not feasible to provide a culvert on the current alignment, for example when the proposed upgrade is in a significant cutting, or where it is necessary to direct clean water around a water quality sediment basin. Preliminary waterway diversions have been determined and allowance has been made in the definition of property acquisition boundaries for the construction of watercourse diversions.

In addition, impacts will be managed through:

- Provision of appropriate scour protection on the upstream and downstream ends of all drainage structures where increased velocities have the potential to cause scour.
- Further modelling combined with refinement of bridges, abutments and sediment basin layouts as part of the detail design process, to achieve minimal increase in flood level behind structures and minimal change to existing inundation periods and flow velocities.

1 Introduction

On behalf of the Roads and Traffic Authority, Arup has been commissioned to undertake a hydraulic/hydrologic assessment for the proposed Pacific Highway upgrade between Tintenbar and Ewingsdale. This hydrology working paper provides:

- an overview of baseline hydrological conditions
- assessment of the impacts of the proposed upgrade on flood behaviour
- assessment of the impact of changes to surface water flows as a result of the proposed upgrade, including modifications to waterways and local overland flow paths.

2 Description of the proposed upgrade

A description of the proposed upgrade is provided in Part B, Chapter 6 of the Environmental Assessment report. This section provides a summary of the proposed upgrade of the Pacific Highway.

The length of the proposed upgrade would be approximately 17 km starting at Ross Lane in Tintenbar and extending to the north to the existing Ewingsdale interchange, near the settlement of Ewingsdale. At Ross Lane, the proposed upgrade would connect to the north end of the Ballina bypass. Generally the proposed upgrade would be in close proximity to existing highway corridor from Ross Lane to the Bangalow bypass. The existing highway would be maintained for local and regional traffic.

From Bangalow, the proposed upgrade would diverge away from the Bangalow bypass to the northeast through Tinderbox Creek valley. From there, the proposed upgrade would avoid the steep grades of St Helena Hill by way of a tunnel approximately 340 m long and 45 m below the ridge line. North of the tunnel, the proposed upgrade alignment is located immediately to the east of the existing highway before tying into the Ewingsdale interchange.

The general features of the proposed upgrade would be:

- Four-lane divided carriageways, with a wide median allowing for the future addition of a third lane in each direction.
- Class M standard over the full length of the proposed upgrade. In accordance with the RTA's Pacific Highway Design Guidelines, 'Class M' projects are designed to 110 km/h (posted speed) freeway standard. This means a controlled access road with divided carriageways, no access for traffic between interchanges, grade separation at all intersections and alternative routes available for local traffic through the provision of service roads or local arterial road networks.
- Modifications to the Ross Lane interchange. This interchange will be constructed as part of the Ballina bypass project.
- Modifications to the existing Ewingsdale interchange to provide full access between the modified local and regional road network and the highway.
- A half interchange at Ivy Lane. North-facing ramps would provide access between the local road network and the proposed upgraded highway to the north.
- A half interchange at Bangalow. South-facing ramps would provide access between the local road network, including to Bangalow and Lismore, and the proposed upgrade to the south. This arrangement would replicate the arrangement with the existing Bangalow bypass which also has south-facing ramps only.

- Six twin bridges and four underpasses allowing roads and creeks to pass underneath the proposed upgrade. These would include twin bridges above Byron Creek and the existing Casino-Murwillumbah railway on the north side of Byron Creek.
- Two bridges carrying local roads over the proposed upgrade, one for Broken Head Road and one about 500 m north of Lawlers Lane providing access to several properties east of the upgrade. Protection screens would be provided on both bridges.
- Emergency u-turn and median crossovers at about 2.5 km intervals. These facilities incorporate lay-bys where vehicles could safely pull off the upgraded highway.
- Sedimentation basins to intercept run-off for treatment before discharging into the natural watercourses.
- Medians and outer verges, including safety barriers where required.
- Signage providing clear directions for traffic at the Ross Lane, Ivy Lane, Bangalow and Ewingsdale interchanges.
- Relatively flat gradients compared to the existing highway, with the maximum grade just south of Bangalow being approximately 5.4% over 1300 metres. There would also be a 4.4% grade over almost 2 km on the north side of the tunnel. An additional southbound climbing lane would be provided in both sections so that slow moving trucks would not be a significant safety hazard to other vehicles.
- The existing highway would be retained as a continuous road for local and regional traffic. It is further anticipated that between Ross Lane and Bangalow the existing highway would be handed over to the councils. Between Bangalow and Ewingsdale the existing highway would continue to function as a regional link between Lismore/Bangalow and the north and would be retained by RTA.
- Two significant diversions of the existing highway are proposed to retain it as a continuous local road. The first is just north of Emigrant Creek where the existing highway would be diverted underneath the bridge taking the proposed upgrade over Emigrant Creek. The other diversion is where the existing highway south of the Ewingsdale interchange is being diverted to a roundabout on the western side of the interchange.
- Additional local roads and property access would be provided including:

  safe access to all properties affected by the proposed upgrade, either directly to the existing highway or indirectly via a new local access road.

  new local roads as required to link the proposed interchanges with the existing highway and other local access roads
- The proposed upgrade would incorporate twin parallel tunnels under St Helena ridge. The tunnels would each be about 340 m long and about 45 m below St Helena Road. One tunnel would be provided for each carriageway, separated by a rock pillar. The northbound tunnel would be 11.5 m wide between barriers, providing sufficient width for linemarking as 3 lanes in each direction if required in the future. The southbound tunnel would be 12.5 m wide to incorporate the southbound climbing lane while still allowing 1 m wide shoulders on each side. In view of the additional southbound lane proposed initially, there is no provision for adding an additional lane to the southbound carriageway through the tunnel. The precise dimensions of the tunnel may be modified slightly during detailed design.

3 Policy context and legislative framework

3.1 State

Floodplain Development Manual and Flood Prone Land Policy

The NSW State Government's Flood Prone Land Policy is contained in the *NSW Floodplain Development Manual* (Department of Natural Resources, 2005). This document builds on and replaces the 2001 Floodplain Management Manual.

The objective of the policy is to reduce the impact of flooding and flood liability on landowners and occupiers. The manual requires local Councils to consider all development proposals in flood prone land, taking into account social, economic and ecological issues as well as flooding issues.

3.2 Local

3.2.1 Byron Shire Council

Byron Local Environment Plan

While not directly applicable to this project, the provisions of the Byron Local Environmental Plan (LEP) have been considered in relation to the proposed upgrade.

Clause 24 of the Byron Shire LEP outlines Council's requirements for development in flood prone land. These requirements are further described in the Byron Council Development Control Plan (DCP) Part K and are discussed below,

Development Control Plan Part K: Flood Liable Lands

Part K of the Byron Council Development Control Plan outlines requirements for development of areas classified as "Flood Liable Land", as indicated on a map accompanying the DCP.

The objective of DCP Part K is:

'To ensure that all development and building proposals on flood liable lands are considered by Council, taking into account social, economic and ecological issues, as well as flooding considerations to ensure floodplains are not unnecessarily sterilised and development not unreasonably restricted by virtue of the land being liable to flooding.'

The following criteria provide guidance regarding performance in a 1% Annual Exceedance Probability (AEP) flood event:

- *'Development must not restrict the flow characteristics of flood waters;*
- *Development must not increase the level of flooding on other land in the vicinity;*
- *The structural characteristics of any proposed building or work must be capable of withstanding flooding;*
- *Any building must be adequately flood proofed;*
- *Satisfactory arrangements must be made for access to any building or work during a flood.'*

Development Control Plan Part N: Stormwater Management

Part N of the Byron Shire DCP relates to the design of stormwater systems and on-site detention requirements.

Although highway works are not specifically subject to the DCP, the general principles of the DCP have been considered in relation to the proposed upgrade.

3.2.2 Ballina Shire Council

Local Environment Plan (LEP)

While not directly applicable to this project, the provisions of the Ballina Shire LEP should be considered in relation to the proposed upgrade. Relevant provisions in terms of hydrology will include the provisions for land zoned 7(c) Environmental Protection (Water Catchment) zone.

Development Control Plan 13: Stormwater Management (DCP 13)

The Ballina Shire DCP 13 applies to all new developments within the Ballina Shire. New developments are defined within the DCP as all commercial, industrial or residential development. The general objective of the DCP is that for new urban developments "*there shall be no net increase in the average annual load of key stormwater pollutants and peak discharge flow rates, above that occurring under existing conditions.*"

Although highway works are not specifically subject to the DCP, the general principles of the DCP should be considered in relation to the project, including:

- Implementation of a Stormwater Management Plan and/or Erosion and Sediment Control Plan
- Clear definition of stormwater management objectives and procedures for both the construction and operational phases
- Consideration of stormwater monitoring and environmental auditing.

4 Assessment methodology and assumptions

4.1 Methodology

A desk study of available topographic data and aerial photography was carried out to identify key characteristics of the drainage regime and existing watercourses. This was followed by a site walkover to confirm topography and catchment characteristics, inspect creek lines and existing bridges over watercourses and existing culvert crossings.

Major and minor creeks and water bodies were identified, and using available topographical information, catchments and subcatchments for each creek and its tributaries were determined and mapped.

Byron and Ballina Shire Council LEP's were reviewed for reference to floodable areas and drinking water catchment zones. Meetings were held with both Councils and the Richmond River County Council to discuss and obtain information on historical flooding data, past flood studies and mapping, stormwater design guidelines, and storm intensity, frequency and duration data. Minimum fill level plans were requested from both Councils, to provide a guide to potential 1% AEP event flood levels. Previous hydrologic and hydraulic studies reviewed include the study carried out as part of the *Ballina Bypass Environmental Impact Statement* (Connell Wagner, 1998) and the *Ballina Floodplain Management Study* (WBM, 1998) undertaken on behalf of Ballina Shire Council. Input from the community received during community information sessions was also reviewed and incorporated.

Peak flows were calculated for named creeks at key locations, such us the confluence of major tributaries, using two methods: the Australian Rainfall and Runoff (AR&R) Volume 1 Rural Method and RAFTS (hydrological catchment modelling software). The largest result from the two methods was then conservatively taken forward. Flows were calculated for the 1in 20 year, 1 in 50 year and 1 in 100 year Average Recurrence Interval (ARI) events and the Probable Maximum Flood (PMF). The named creeks were then modelled hydraulically using HEC-RAS (hydraulic modelling software), based on cross sectional profiles taken from a digital terrain model (DTM) and using the flows calculated as described above. The results of the modelling were then used to establish a probable flood extent for the 1% AEP event for each of the named creeks.

This 1% AEP flood extent was then used in conjunction with other constraints such as highway longitudinal grades to determine requirements for bridge spans for the proposed upgrade.

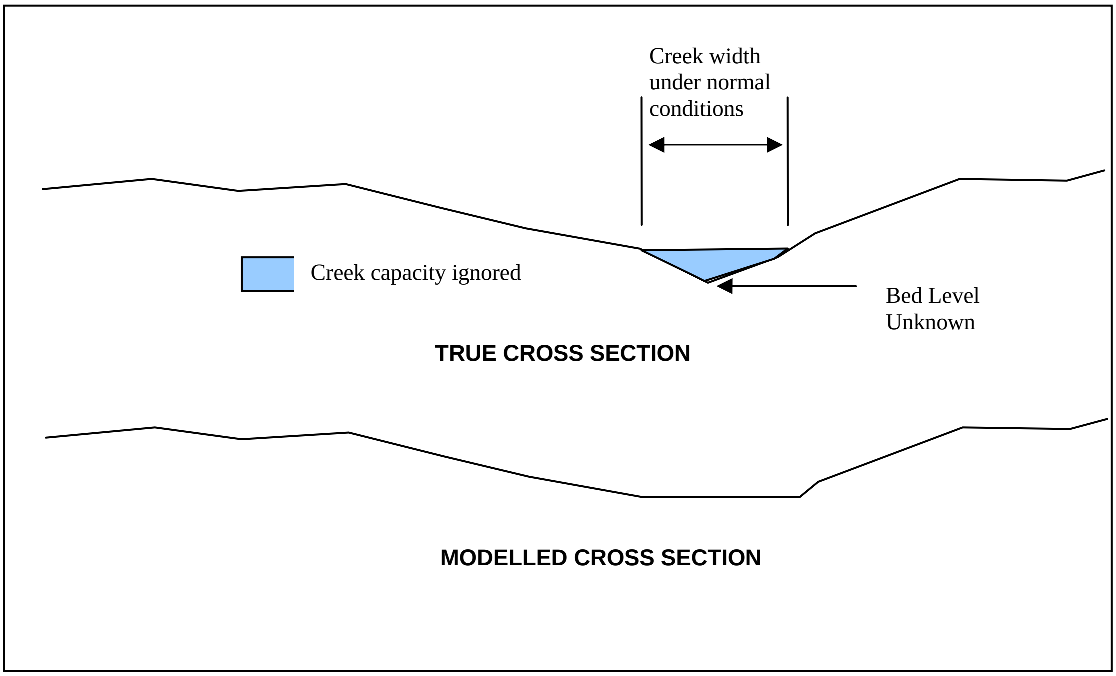
Waterway opening requirements for the unnamed creeks and overland flow paths traversed by the proposed upgrade were assessed using the Rational Method – Eastern New South Wales outlined in Book 4, *Estimation of Peak Flows for Small to Medium Sized Rural Catchments, Australian Rainfall and Runoff* (1997).

4.2 Assumptions

It is noted that the DTM has a number of discontinuities in the contours where dense vegetation occurs. Often this vegetation is in the vicinity of the creek lines. As such the cross sections taken through creek lines, although broadly representative, are of limited accuracy. The creek cross sections were checked prior to hydraulic modelling in order to identify any obvious localised errors or discrepancies, often arising from gaps in the survey data. These were adjusted by inference from other levels. In addition, no bathymetric information is available for the creek bed level. The cross sections used are therefore conservative as they do not include the capacity from normal bank level to bed level (refer **Figure 1**).

Key assumptions used in the modelling are further detailed in Section 5.4.

Figure 1 Assumed Model Cross Sections - 1D Modelling



5 Existing hydrologic environment

5.1 Overview of creek network

The following named creeks are crossed by the proposed upgrade:

- Byron Creek (downstream of the confluence with Tinderbox Creek)
- Skinners Creek
- Emigrant Creek

All four named creeks originate in the highlands west of the Main Coast Range, and flow generally to the southwest. These are described in more detail in the following section.

A number of unnamed creeks are also traversed by the proposed upgrade. These are generally tributaries of the named creeks, and therefore have smaller catchment areas than the named creeks. The larger tributaries traversed by the proposed upgrade are discussed within the sections below.

All creeks within the project area are shown in **Figure 7** of this report. All watercourses have catchment areas of less than 50 km^2, and therefore none are considered to be major creeks.

5.1.1 Tinderbox Creek

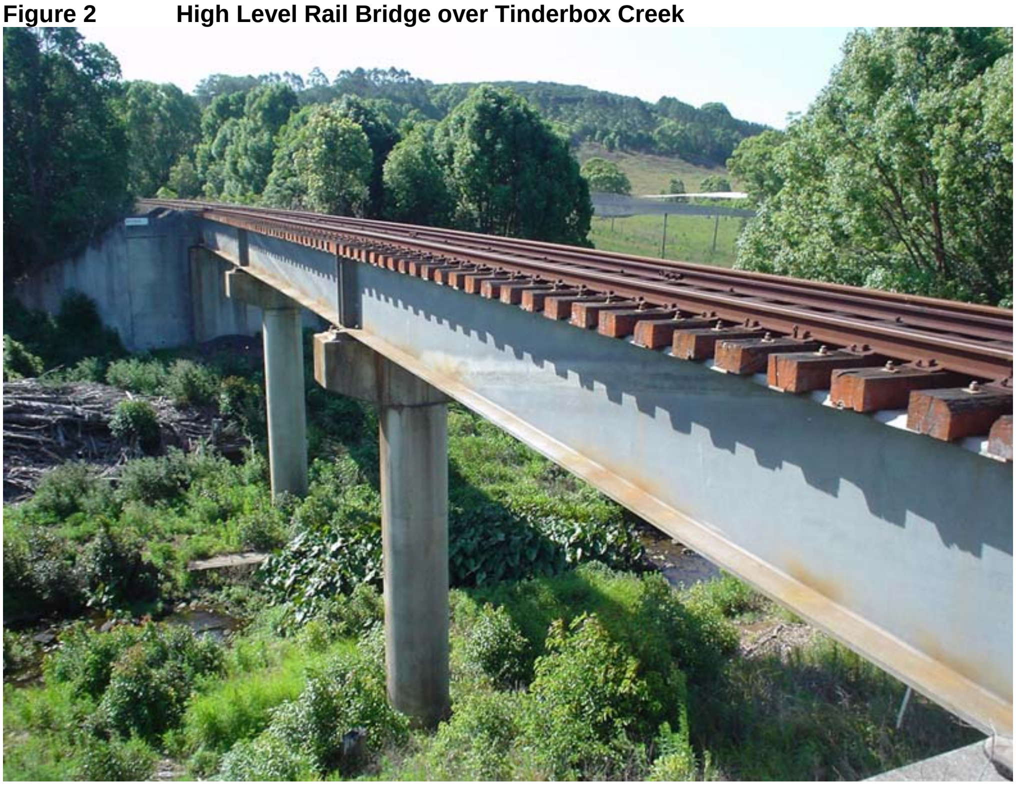
The source of Tinderbox Creek is located in the vicinity of St Helena. It joins Byron Creek approximately 1 km to the northeast of Bangalow, and at this point has a total catchment area of 8.93 km^2. The catchment forms part of the drinking water catchment of the proposed Lismore source, discussed in more detail in **Section 5.5**.

The creek flows predominantly south-west, with steep upper catchments and flatter topography to the west, in particular on the approach to Bangalow.

The proposed upgrade crosses tributaries of Tinderbox Creek a number of times between St Helena Road and the confluence with Byron Creek, with catchments upstream of each of these crossings ranging up to 2.4 km^2 in area. These crossings and associated upstream catchment boundaries are indicated in **Figure 15** and **Figure 16** of this report.

A high level bridge takes the Casino – Murwillumbah Railway across Tinderbox Creek just before its confluence with Byron Creek (Refer **Figure 2**).

Figure 2 High Level Rail Bridge over Tinderbox Creek



5.1.2 Byron Creek

The source of Byron Creek is approximately 1 km northeast of Coopers Shoot. Byron Creek has a catchment approximately 21.6 km^2 at the point where the proposed upgrade traverses, which includes the Tinderbox Creek catchment since the proposed upgrade crosses downstream of the confluence point. West of the proposed upgrade, Byron Creek joins with the Wilson River, before joining the Richmond River. The catchment forms part of the drinking water catchment of the proposed Lismore source, discussed in more detail in **Section 5.5**.

The existing Pacific Highway crosses Byron Creek approximately 400 m downstream of the crossing for the proposed upgrade, on a bridge that also passes over the adjacent Casino – Murwillumbah Railway.

The proposed upgrade crosses tributaries of Byron Creek a number of times to the south of Bangalow, with catchments upstream of each of these crossings ranging up to 0.97 km^2 in area. These crossings and catchment boundaries are indicated in **Figure 15** of this report.

At the upstream end of the Byron Creek catchment, the topography is relatively steep, interspersed with isolated small areas of flatter grade. Downstream of the confluence with Tinderbox Creek, and in the vicinity of the existing Pacific Highway crossing, Byron Creek widens significantly (refer **Figure 3).**This is potentially the result of a weir located downstream in Bangalow, which appears to have been constructed to provide a swimming facility (refer **Figure 4**). Downstream of the weir, the creek returns to a narrow, natural channel.

Figure 3 Byron Creek Upstream of Bangalow

Figure 4 Bangalow Weir

5.1.3 Skinners Creek

Skinners Creek is the smallest of the named creeks. It has its source near to Piccadilly Hill. Where it is crossed by the proposed upgrade it has a catchment area of 2.3 km^2. Downstream of the crossing, Skinners Creek flows into Pearces Creek, which joins the Wilson River at Booyong. It crosses the existing Pacific Highway approximately 1 km north of Newrybar, where it passes beneath the highway in six 1800 mm circular concrete pipes.

The catchment is less steep than those of Tinderbox and Byron Creeks. Along with Byron and Tinderbox Creeks, this catchment forms part of the drinking water catchment of the proposed Lismore source, discussed in more detail in **Section 5.5**.

The proposed upgrade crosses two minor tributaries of Skinners Creek, with the largest upstream catchment being 0.10 km^2 in area. These crossings and catchment boundaries are indicated in **Figure 14** of this report.

5.1.4 Emigrant Creek

The source of Emigrant Creek is just south of the junction of Piccadilly Hill Road and Broken Head Road. It has a catchment area of 4.1 km^2 where it is crossed by the proposed upgrade, about 6km upstream of the Emigrant Creek Dam. The dam and drinking water catchment is discussed in more detail in **Section 5.5**.

The creek passes beneath the existing highway in four 1800 mm wide by 2000 mm high reinforced concrete box culverts, immediately upstream of the proposed upgrade crossing. Beyond this, Emigrant Creek continues flowing southwards where it outfalls to the Richmond River near West Ballina.

The Emigrant Creek catchment upstream and in the vicinity of the proposed crossing is characterised by gentler sloping hills than the Byron and Tinderbox catchments, with numerous small dams and water bodies, both on the creek and its tributaries, and numerous changes of direction. The approximate tidal limit of Emigrant Creek is near the Tintenbar Road bridge.

The proposed upgrade crosses a number of tributaries of Emigrant Creek, with the largest upstream catchment being 0.83 km^2 in area. These crossings and catchment boundaries are indicated in **Figure 12** through **Figure 14** of this report.

5.2 Rainfall and historic flood records

Rainfall data from the Alstonville Tropical Fruit Research Station is generally used for numerical flood modelling, development planning and stormwater drainage design in the region, in accordance with the requirements of both Ballina and Byron Shire Councils. Alstonville station records an annual average rainfall of 1860.9 mm. Local residents within the study area, in particular the Newrybar Swamp area, have advised that the Newrybar Swamp receives annual average rainfall of closer to 2000 mm, and that in 1999, 3250 mm of rain was recorded.

The design rainfall for the Richmond catchment was revised by the Bureau of Meteorology (BOM) for the Ballina Floodplain Management Study. The Bureau carried out a log-normal frequency analysis of the rainfall records for the Alstonville Tropical Fruit Research Station (No.058131). This analysis resulted in increases of up to 70% to the design rainfall estimates above those derived from Australian Rainfall and Runoff (AR&R) (IEAust, 1987). The two design rainfall distributions for the AEP 50% and AEP 2% are provided in **Table 1.**

Table 1 Revised Design Rainfalls for Alstonville

Duration (hr))	AEP (%)	Revised Rainfall Intensity (mm/hr)	AR&R Rainfall Intensity (mm/hr)	Increase (%)
1	50	51.5	47.5	8
12	50	12.4	10.0	24
72	50	4.0	3.3	21
1	2	95.8	87	10
12	2	34.4	20	72
72	2	10.0	7.4	35

Ballina Shire Council, Byron Shire Council and the Richmond River County Council were queried regarding historical flood data for the study area. Although flooding data is available for the urbanised areas of each Shire, the Councils were not able to provide any peak flood level records for properties within respective local government areas.

In general, the largest flood in recent times was the 1954 flood. This was estimated to be a 1 in 80 year Average Recurrence Interval (ARI) event at Broadwater. Other key historical floods are those of March 1974 and February 1976.

A significant rainfall event occurred during the period 29 June 2005 to 1 July 2005, causing flooding on the Queensland Gold Coast, and New South Wales North Coast. On 30 June 2005, Alstonville Tropical Research Centre had its highest ever daily record (256 mm) in its 41 year recording history.

Figure 5 illustrates rainfall at recording stations in the vicinity of the proposed upgrade for the period 27 June 2005 to 01 July 2005.

Figure 5 Daily Rainfall Records (June 27 to July 1, 2005)

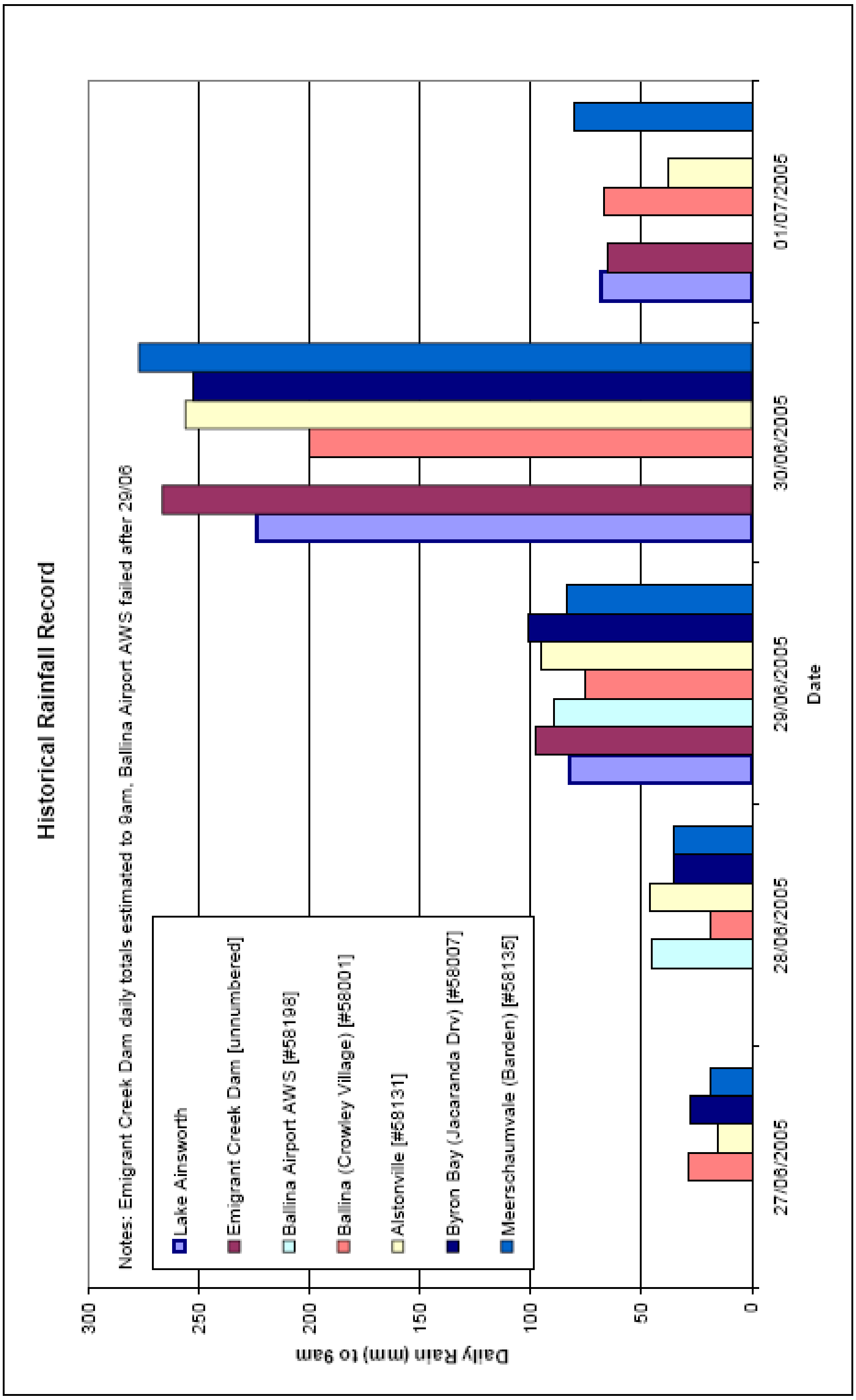


Figure 6 indicates the degree of inundation near the Sandy Flat Road as a result of this storm event in 2005.

Figure 6 June 2005 Flooding – Cumbalum

The Bureau of Meteorology carried out an analysis of the pluviograph records for the period, and have estimated Average Recurrence Intervals (ARI) for each duration event from the peak 5 minute rainfall through to the peak 72 hour rainfall, summarised in **Table 2**.

Table 2 Average Recurrence Interval (ARI) for June Storms (BoM) – Alstonville

Period (min)	Peak Rainfall (mm)	Ending Date	Ending Time	Intensity (mm/hr)	ARI (original AR&R)	ARI (revised BOM analysis)
30	27.6	29 June 2005	20:44	55.2	~1	~1
60	36.5	30 June 2005	9:35	36.5	<1	<1
120	54.5	30 June 2005	10:25	27.3	1 to 2	~1
180	68.9	30 June 2005	10:30	23.0	1 to 2	1 to 2
360	93.5	30 June 2005	10:18	15.6	~2	1 to 2
720	159.7	30 June 2005	10:25	13.3	2 to 5	1 to 2
1440	274.1	30 June 2005	12:07	11.4	10 to 20	~5
2880	362.2	30 June 2005	13:16	7.5	10 to 20	~5
4320	415.5	30 June 2005	12:47	5.8	10 to 20	~5

Based on the revised Alstonville rainfall Intensity Frequency Duration (IFD) data used for generating catchment flows as part of this study, the short duration events (up to 12 hours) were found to be representative of up to a 2 year ARI, whereas the long duration storms were calculated to be representative of a 5 year ARI event.

Transverse drainage beneath the proposed upgrade has been sized for the 1% AEP (100 year ARI) event, a significantly larger event than the June 2005 storm.

5.3 Previous flood studies and flood mapping

5.3.1 Byron Shire Council

Byron Shire Council has not commissioned any flood studies for creeks traversed by the proposed upgrade.

Part K of the Byron Council Development Control Plan outlines requirements for development of areas classified as “Flood Liable Land”, as indicated on a map accompanying the DCP. An area of flood liable land around Byron Creek just upstream of Bangalow is traversed by the proposed upgrade.

The AEP associated with the “flood liable land” extent shown in DCP Part K is not known, but is thought to be approximately indicative of a 1% AEP flood extent. Flood levels are not provided. It is understood from discussions with Byron Shire Council that no “minimum fill levels” plans have been established to guide floor levels for new developments, and that developments would be assessed on a case-by-case basis. In Bangalow, the point of reference used by Byron Shire Council is generally “Billy Solways Garage” on Byron Street, which has never been flooded. The floor of the garage is at an RL of 45.8 m, and therefore flood planning levels are generally set 0.5 m above this level.

5.3.2 Ballina Shire Council

The Ballina Floodplain Management Study was carried out by WBM on behalf of Ballina Shire Council in 1996-97. As part of the study, numerical models were created for the lower Richmond River. On the Newrybar Plain, the modelling extended as far north as Ross Lane, and for the Emigrant Creek network the model extends to Sandy Flat. This study identified and modelled design floods comprising combinations of the three primary sources of flooding in Ballina Shire:

- Rainfall over the Richmond River Catchment (total catchment area 6900 km^2) causing the river to swell and break its banks.
- Rainfall on the local catchments and floodplains (Maguires Creek, Emigrant Creek, North Creek etc).
- Elevated ocean levels and storm wave conditions. Peak ocean storm tide levels were estimated to reach up to 2.0 m AHD for the 100 year event.

A one-dimensional hydraulic model was developed, from which flood levels for various storm return periods were estimated. The 1% AEP flood levels from this model were used to create the Ballina Minimum Fill Level plan. The fill levels are therefore an approximate representation of the 1% AEP event for the purpose of planning floor levels for new developments. Mapping of fill levels extends as far north as Martins Lane.

It is important to note that the levels shown on the Minimum Fill Levels plan do not represent potential local flood levels associated with localised drainage patterns. In additional, as the modelling was one-dimensional only, the plan provides no assessment of the extent of inundation as a result of the 1% AEP flood.

Key 1% AEP planning levels for the study area are summarised in **Table 3**.

Table 3 1% AEP Flood Planning Levels - Ballina Shire

Location	Approximate 1% AEP level (m AHD)
Martins Lane East	3.2 m
Ross Lane	2.0 m
Deadmans Creek, south of Ross Lane and east of the Ballina Nature Reserve	1.8 m
Confluence of Sandy Flat Creek and Emigrant Creek	4.0 m

WBM have since been commissioned by Ballina Shire Council to carry out two-dimensional modelling for the Richmond River floodplain. This model will have the same extent as the existing one-dimensional model.

5.3.3 Department of Water and Energy

Base floodplain mapping from the Department of Water and Energy (DWE) was obtained. This correlates well with that held by both Councils.

5.3.4 Community observations

Community observations recorded during community information sessions and through submissions on the route options display generally correlated well with floodplain mapping held by Councils and DWE. Observations and submissions related to flooding received from the community were generally in relation to the coastal plain area, which the proposed upgrade does not traverse.

5.4 Hydrologic and hydraulic modelling of named creeks

Hydrologic and hydraulic modelling was carried out for the four named creeks on the plateau, namely Byron Creek, Tinderbox Creek, Skinners Creek and Emigrant Creek. Given the small catchment areas for the unnamed creeks, these have not been hydraulically or hydrologically modelled. Flows and waterway opening requirements for the unnamed creeks have been determined using the Rational Method – Eastern New South Wales outlined in Book 4, *Estimation of Peak Flows for Small to Medium Sized Rural Catchments, Australian Rainfall and Runoff* (1997), and using standard culvert sizing methods based on Manning's equation. For more details, refer to **Section 7** of this report.

5.4.1 Hydrologic modelling

Peak flows were determined using the RAFTS modelling software. A model was created for each creek, and subcatchments identified based on ridge lines. Vectored slopes were calculated for the longest flowpath in each subcatchment and entered into RAFTS as such.

Key assumptions in the derivation of flows are as follows:

- Sub-catchment roughness – the Manning's 'n' value for the catchment was taken as 0.05, which is representative of rural pastures.
- All subcatchments were considered to be 0% impervious as the creeks and surrounds are in relatively undeveloped areas with little or no impermeable surfaces.

- A 'lag' time (time taken for water to travel the course of the creek) between downstream extents of each subcatchment was calculated as an average of 1.5 m/s water velocity over an average distance of 200 m between each subcatchment node, resulting in a lag of 5 minutes. Adopting this relatively short lag time is considered a conservative approach, as it results in higher peak flow values as subcatchment flow peaks are more concurrent.
- Rainfall data for Alstonville was used, which was obtained from Ballina Shire Council, as outlined in section 5.2 above.

The Rational Method – Eastern New South Wales outlined in Book 4, *Estimation of Peak Flows for Small to Medium Sized Rural Catchments, Australian Rainfall and Runoff* (1997) was also used to calculate flows at each subcatchment boundary. These flows were used as a means of comparison to check the results of the RAFTS model. It was found that in general RAFTS model flows were in the order of 10-20% higher than those calculated using the Rural Method, and therefore these flows were adopted for inclusion in the hydraulic model.

Table 4 shows peak flows for 1% AEP event at key locations along each creek as taken from nearest downstream subcatchment node in the RAFTS modelling. The flows calculated through RAFTS and used in further analysis include additional locations between those listed below. The peak storm was found in RAFTS to be the 1% AEP 24 hour duration storm.

Table 4 Flow at key locations in the four major named creeks

Creek	Location	1% AEP (m^3/s)
Byron	Location of existing Pacific Highway crossing creek	532
	Just before Tinderbox/Byron Junction	251
	Just after Tinderbox/Byron Junction (location of proposed upgrade crossing creek)	506
Tinderbox	Location of existing Pacific Highway crossing creek	N/A
	Just before Tinderbox/Byron Junction	246
Skinners	Location of proposed upgrade crossing creek	56
	Location of existing Pacific Highway crossing creek	68
Emigrant	Location of existing Pacific Highway and proposed upgrade crossing creek	146

As noted previously, peak 1% AEP flows for the unnamed creeks have been determined using the Rational Method. Peak flows at each waterway crossing are provided in **Table 7** in **Section 7** of this report.

5.4.2 Hydraulic modelling

One dimensional hydraulic modelling was then carried out for the four named creeks on the plateau. Using the RAFTS model flows as described above and a combination of 12d Model graphical representations of each of the creeks using contours and aerial photographs, a HEC RAS model was generated and manipulated to determine the extent of inundation within the peak 1% AEP flood event.

Using the 12d Model software, each creek previously mapped in GIS from base RTA layers was checked to verify its location in relation to available digital terrain data and high definition orthorectified photography. Some changes to creek centreline and bank locations were required as the GIS defined creek lines strayed from the existing visible creek bed in the aerial photographs. Cross sections through the creeks were generated at regular intervals and additional cross sections added to ensure important areas such as abrupt changes in channel cross section were represented as accurately as possible within the limitations of HEC RAS and the available survey data.

In HEC RAS, the cross sections were first checked for irregularities often arising from gaps in the survey data. Some cross sections required adjustment of the creek bed and location of left and right banks, and in some places the ground levels in the cross section were altered in accordance with inferences made about levels where there were gaps or inconsistencies in the digital terrain model.

Flow data was taken from RAFTS and input at each sub-catchment boundary point along the creek line and the HEC RAS model run in order to obtain water surface levels for the length of each creek.

The models were then examined for irregularities where the model may not have accurately represented the existing conditions and issues resolved to an acceptable level for the development of the concept design of the proposed upgrade.

The resulting water surface profile was overlaid on the digital terrain model to establish the outer limits of the 1% AEP flood event in plan.

Key assumptions in the derivation of flows are outlined below:

- Channel roughness- Manning's n of the channel was taken as a constant 0.025 which is a typical value used for a winding channel with grass and some weeds. The overbank area was assumed to have a Manning's n of 0.05, which incorporates the roughness of long pasture grass. These channel bed characteristics are representative of all creeks within the region, and hence the Manning's n values are relevant for the entire length of all creeks.

- Contraction/Expansion coefficients were taken as 0.1 and 0.3 for gradual transitions in river cross section, which are typical for 1D modeling of natural creek systems.

- Upstream and downstream extents for each creek were determined based on the area of interest, and boundary conditions were assumed to be normal depth, calculated from the existing contours. This data was also used in the RAFTS modelling.

Table 5 Boundary conditions for the four modelled creeks

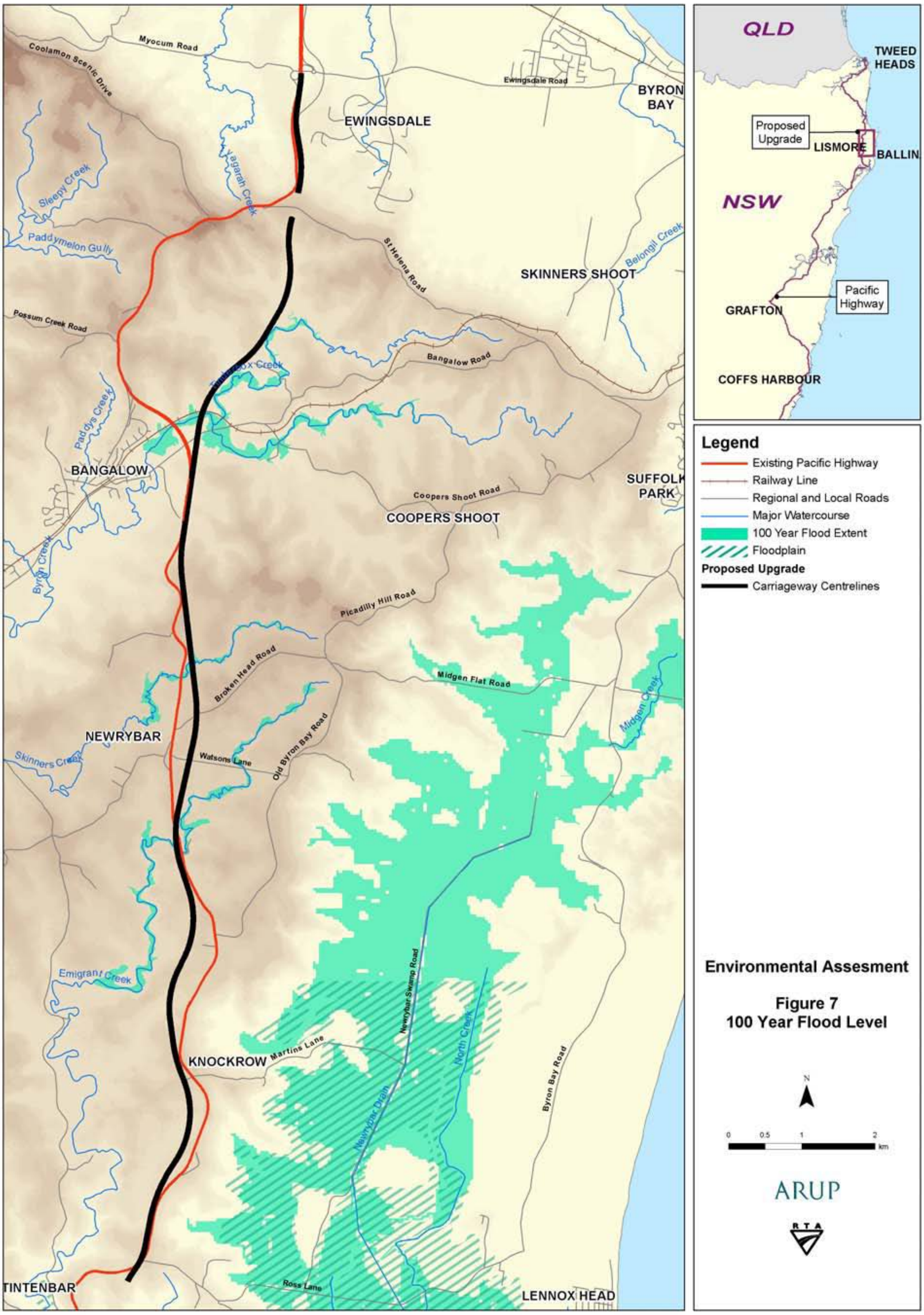
Creek	Upstream Boundary Condition	Downstream Boundary Condition
Byron	Normal Depth, S=0.0055	Normal Depth, S=0.0019
Tinderbox	Normal Depth, S=0.0019	Byron Creek South
Skinners	Normal Depth, S=0.0215	Normal Depth, S=0.0026
Emigrant	Normal Depth, S=0.142	Normal Depth, S=0.0034

Any existing limitations imposed by existing structures have been ignored in establishing the baseline hydraulic model. This avoids capacity issues in the future should existing bridges or culverts be removed or replaced.

Flood extents generated by the modelling are indicated in **Figure 7,** along with the proposed upgrade alignment. The impact of proposed works within proposed land acquisition areas on flooding are discussed in **Section 6.3**.

No verified calibration data was available to validate the modelling. Validation was therefore limited to visual checks of flooding extents and aerial photographs and reasonable assumptions about terrain and existing dwelling floor levels. As stated in Section 5.3.1, a benchmark level that is used by Byron Shire Council is generally “Billy Solways Garage” on Byron Street. The garage, at a level of 45.8 m, is recorded as never having been flooded and therefore Council generally sets flood planning levels 0.5 m above this level. The HEC-RAS model of Byron Creek indicates a flood level of 45.8 m in the vicinity of Byron Street.

Figure 7 Overall 1% AEP Flood Extents



5.5 Drinking water catchments

5.5.1 General

Rous Water currently supplies water to the local government areas of Lismore, Byron, Ballina and Richmond Valley from two sources, Rocky Creek Dam and Emigrant Creek Dam. Rocky Creek Dam is located near Dunoon, 25 kilometres north of Lismore. The proposed upgrade is 800 m from Emigrant Creek Dam at its closest point. In order to meet future water needs, Rous Water proposes to extract water from the Wilson River near to Lismore, which is referred to as the Lismore Source.

Emigrant Creek Dam

Emigrant Creek Dam provides approximately 1,600 ML/year of potable water to Ballina Shire and the wider Northern Rivers area. The drinking water catchment area of 19.1 km^2 includes the village of Newrybar.

The existing Pacific Highway currently traverses part of the drinking water catchment zone.

Emigrant Creek Dam has a full supply volume of 819 ML. Testing of the hydrologic model and of different lake levels showed the dam has no major influence on the calculated flood hydrographs at Tintenbar. The dam was assumed full for all flood events.

Proposed Lismore source

The Lismore source proposal involves a new pump station for the extraction of up to 30 ML/day of water from the tidal pool of the Wilson River at Howard's Grass, located 5 km upstream of Lismore. An Environmental Impact Statement for the project was prepared in 2006. Should the Lismore source project proceed, the catchments of Tinderbox Creek, Byron Creek and Skinners Creek will become drinking water catchment zones, as they form part of the Wilson River catchment upstream of Howard's Grass.

The Pacific Highway currently traverses part of the proposed drinking water catchment.

6 Impact on Flood behaviour

6.1 Overview

The proposed upgrade would pass through steeply undulating topography with well-defined creeks and valleys, and cross creek lines close to their source. As a result, the proposed upgrade would not pass through areas constituting a floodplain, but does traverse creek overbank areas subject to local flooding during large storm events. This includes the three named creeks – Emigrant, Skinners and Byron – as well as a number of smaller unnamed watercourses.

Potential impacts on flood behaviour could include:

- Change in flood levels and extents.
- Change in inundation periods and/or the rate of rise of floodwaters.
- Change in flow velocity.

The criterion for the design of waterway openings, including bridges and culverts, is to:

- Provide adequate capacity to convey the 1% AEP peak flood flow, with:

- No flow on at least one carriageway of the proposed upgrade.
- Minimal increase to water levels upstream of the structure.
- Minimal increase in velocity through the structure
- Minimal disruption to the natural hydrological regime through the diversion of flow onto adjoining catchments.

As described in **Section 5.4**, hydraulic modelling was undertaken to determine potential 1% AEP flood levels and extents under existing conditions. The proposed upgrade crosses Emigrant Creek, Skinners Creek and Byron Creek, and bridges are proposed at each of these crossings, as well as over a tributary of Emigrant Creek and a tributary of Tinderbox Creek.

As a result of the undulating topography, the level of the proposed upgrade at each bridge location has generally been governed by the need to achieve acceptable highway grades rather than provision of flood immunity. **Table 6** illustrates the difference in potential 1% AEP flood level and highway carriageway level at each named creek crossing.

Table 6 Proposed upgrade flood immunity

Creek	Approximate 1% AEP Flood Level (m AHD)	Proposed Upgrade Road Level on Bridge (m AHD)
Emigrant Creek	87.3	97.7
Skinners Creek	103.7	114
Byron Creek	49.8	62.4

For unnamed creeks crossing the proposed upgrade, culverts have been sized to cater for the 1% AEP flood event with predicted headwater levels at the upstream end of the culvert remaining below the level of the proposed upgrade.

Proposed arrangements at the all proposed bridge crossings over creeks and impacts on flood behaviour are discussed in more detail in the **Section 6.3**. Proposed arrangements for all other minor creek crossings are discussed in **Section 7**.

6.2 Hydraulic model limitations

Hydraulic modelling has not been undertaken for the proposed bridge arrangements. As noted previously, no bathymetric data is currently available for the creeks, and a number of discontinuities are present within the survey data in the vicinity of creek lines. Concept bridge arrangements have been assessed based on baseline flood extents, taking into consideration that:

- All creeks traversed by the proposed upgrade are minor, having catchments <50 km^2.
- In each case, bridge abutments have been substantially located outside the potential 1% AEP flood extent determined for the existing baseline conditions. Spill through abutments with 2H:1V batter slopes have been provided for all bridges. Where embankments of the spill through abutments extend into the 1% AEP flood extent, small retaining walls or angled wing walls have been shown to minimise the impact on the hydraulic regime.

During the detailed design period, detailed cross sections upstream and downstream of each of the proposed bridge crossings would be surveyed and hydraulic modelling undertaken to review the impact of bridge arrangements, including abutment earthworks and sediment basins. Modelling with an increased level of detail may enable current conceptual bridge lengths to be reduced during detailed design, with minimal effect on potential water levels and the flooding regime.

6.3 Impacts of changes in flood regime

Generally the bridges over the four main creeks have been designed so that there are no piers within the normal waterway and that the earthworks and abutments are predominantly located outside the baseline 1% AEP flood extent. However, design constraints and the development of an economic bridge layout means that bridge piers and minor earthworks are located in a number of instances within the baseline 1% AEP flood extent.

These locations, described below, affect a relatively small area of the flood plain. As such, minimal increase in flood levels would be anticipated and similarly minimal change to inundation periods and flow velocities would be expected. As described above, a more detailed assessment of existing and proposed flood levels, inundation periods and flow velocities will be carried out as part of the detailed design phase.

6.3.1 Tributary of Emigrant Creek

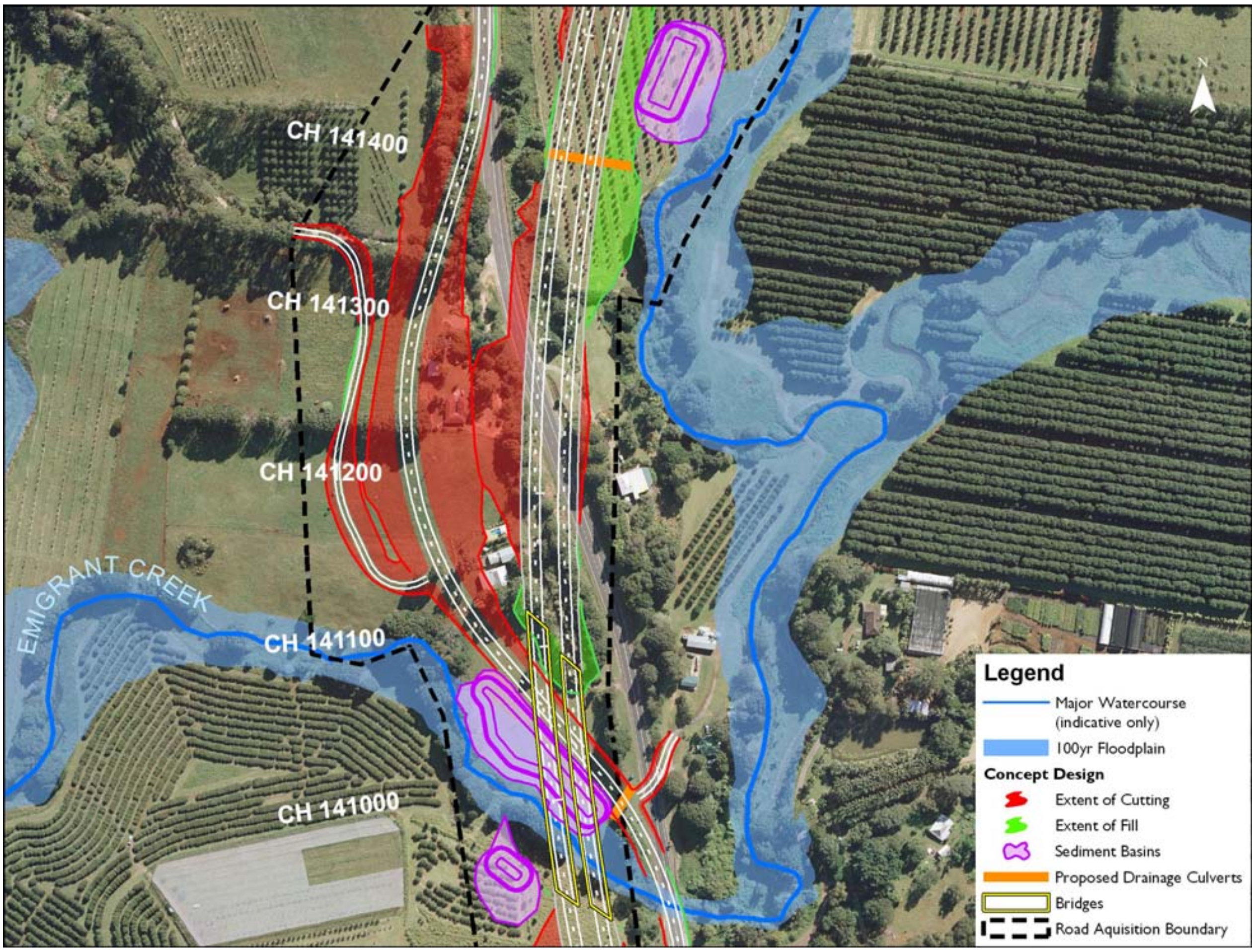
The proposed upgrade crosses an unnamed tributary of Emigrant Creek, approximately 300m south of the crossing of Emigrant Creek. The existing Pacific Highway runs parallel to the proposed upgrade immediately upstream of the new crossing, and the existing waterway opening consists of 2 x 1500 mm diameter pipes. However, despite the relatively minor upstream catchment area, the proposed upgrade incorporates a bridge at this location on the proposed upgrade, in order to span the upstream end of a private dam, and as a result of the steep topography in the area. Given the small catchment area, this creek has not been subject to hydraulic modelling.

6.3.2 Emigrant Creek

Figure 8 indicates conceptual bridge arrangements at the crossing of Emigrant Creek. Bridge abutments on both sides of the creek are located outside the baseline 1% AEP flood extent however the sediment basin on the north side extends partially into the 1% AEP flood extent. The upgrade also runs parallel and to the west of Emigrant Creek for about 800m north of the bridge crossing. The bulk earthworks for the main carriageways are outside the baseline 1% AEP flood extent but the earthworks for sediment basin 24 do extend inside the flood extent. This may result in a minor loss of floodplain storage and minor afflux in flood level. Further modelling combined with refinement of the bridge and sediment basin layout would be carried out as part of the detail design process, including the possible addition of minor retaining walls where required. As such, minimal increase in flood level behind the structure would be anticipated and minimal change to inundation periods and flow velocities. Appropriate scour protection would be required.

The existing Pacific Highway, located upstream of the proposed new crossing, would be retained as an access road, and existing waterway openings (four 1800 mm wide by 2000 mm high reinforced concrete box culverts) retained.

Figure 8 Emigrant Creek Crossing



6.3.3 Skinners Creek

Conceptual bridge arrangements at the crossing of Skinners Creek are indicated in **Figure 9**. Bridge abutments on both the north and south of the crossing are located outside the baseline 1% AEP flood extent and angled bridge abutment wing walls have been introduced to reduce impacts of abutment earthworks on the flood regime. Some abutment earthworks as well as the sediment basin on the north side still extend partially into the 1% AEP flood extent. This may result in a minor loss of floodplain storage and minor afflux in flood level. Further modelling combined with refinement of the bridge, abutment and sediment basin layouts would be carried out as part of the detail design process, including the extension of abutment retaining walls where required. As such, minimal increase in flood level behind the structure would be anticipated and minimal change to inundation periods and flow velocities. Appropriate scour protection would be required.

Figure 9 Skinners Creek Crossing

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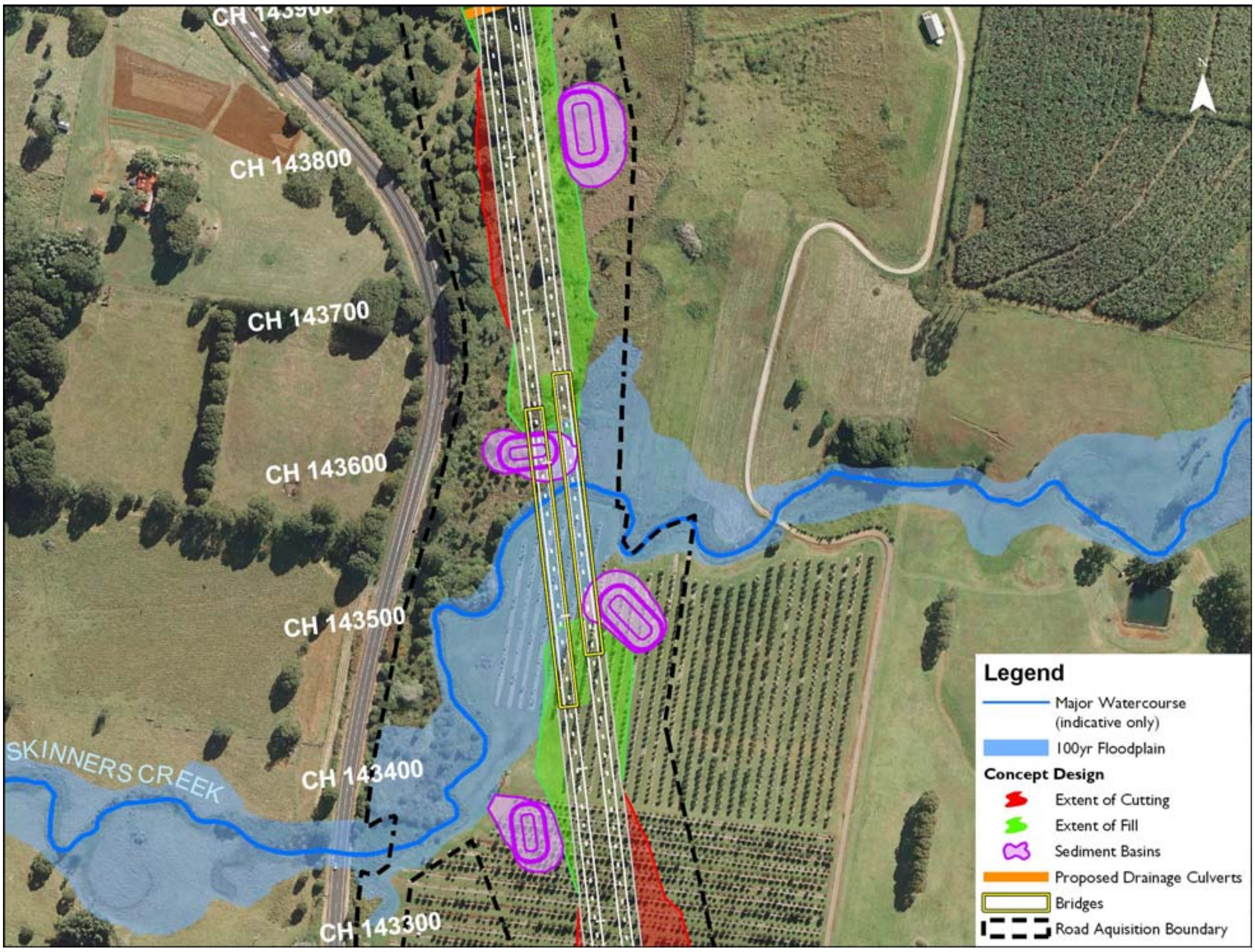
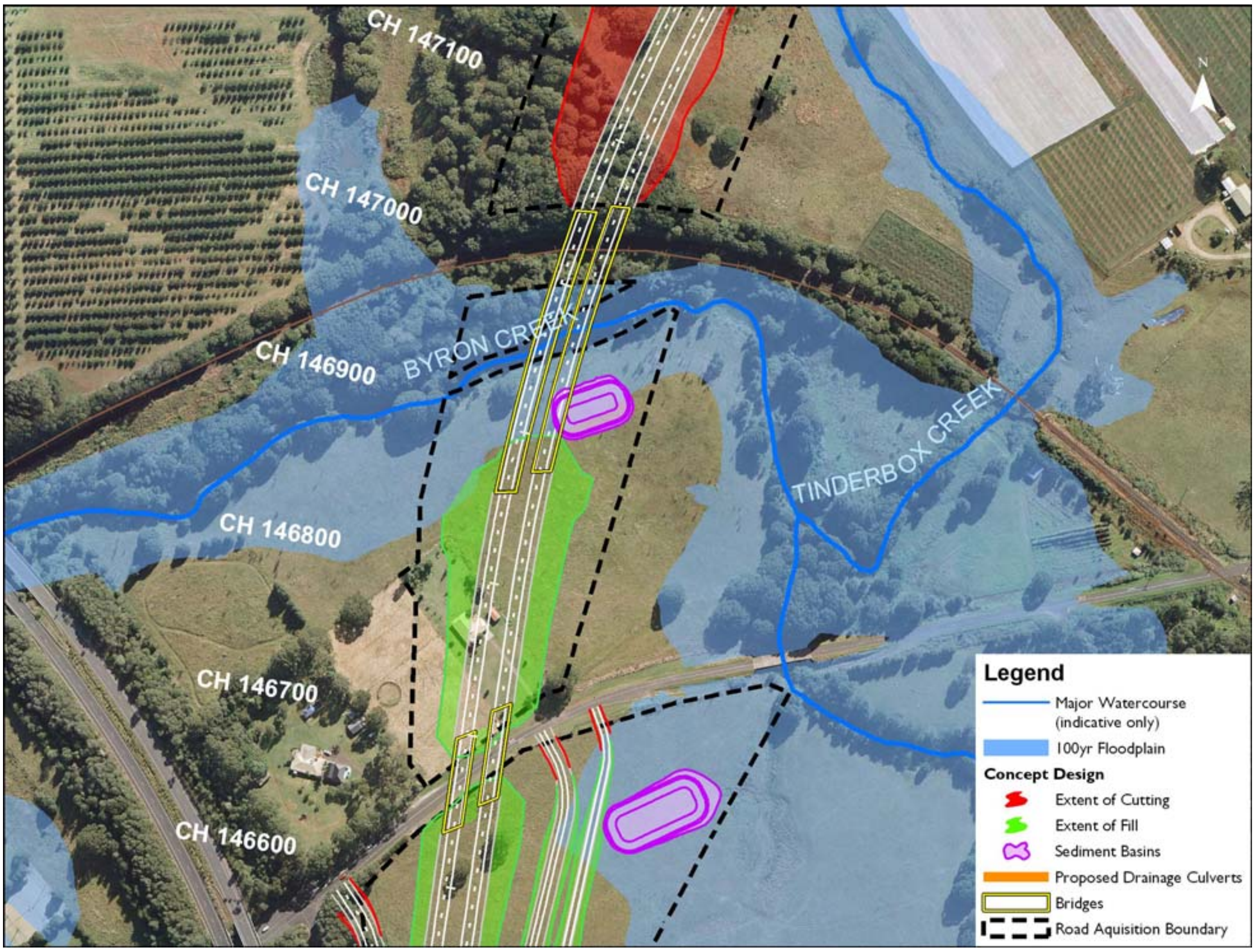


6.3.4 Byron Creek

Conceptual bridge arrangements at the crossing of Byron Creek are indicated in **Figure 10**.

The position of the northern abutments has been driven by the need to clear the Casino-Murwillumbah railway. The railway is above the 1% AEP flood extent, and therefore the abutments are well outside the flood extent. Bridge abutments at the southern end have been angled back where required to reduce impacts of abutment earthworks on the flood regime. Some abutment earthworks, the sediment basin on the south side of the creek, and a sediment basin on the east side of the southbound on-ramp still extend partially into the 1% AEP flood extent. This may result in a minor loss of floodplain storage and minor afflux in flood level. Further modelling combined with refinement of the bridge, abutment and sediment basin layouts would be carried out as part of the detail design process, including the extension of abutment retaining walls where required . As such, minimal increase in flood level behind the upgrade would be anticipated, and minimal change to inundation periods and flow velocities. Appropriate scour protection would be required.

Figure 10 Byron Creek Crossing



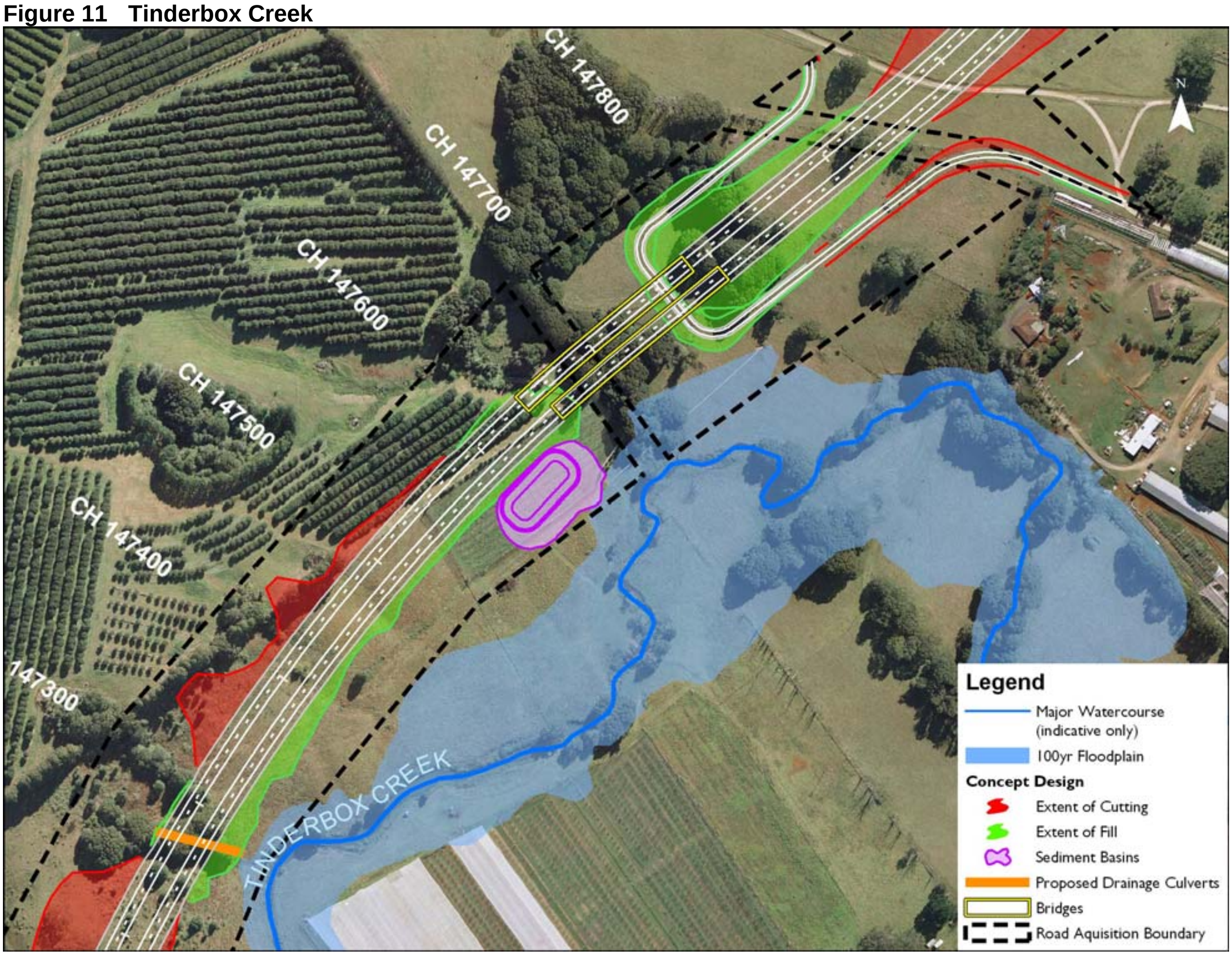
6.3.5 Tinderbox Creek Tributary

The upgrade would not cross Tinderbox Creek but does run beside the creek for a distance of about 1.5 km and would cross a tributary on a bridge structure about 700m north of the rail crossing. The layout in this section is indicated in **Figure 10**.

Bridge abutments on both the north and south of the tributary crossing are located outside the baseline 1% AEP flood extent and the sediment basins are largely located outside the flood extent.

Further modelling combined with refinement of the bridge, abutment and sediment basin layouts would be carried out as part of the detail design process, including the extension of abutment retaining walls where required . As such, minimal increase in flood level behind the upgrade would be anticipated, and minimal change to inundation periods and flow velocities. Appropriate scour protection would be required.

Figure 11 Tinderbox Creek



6.3.6 Other minor watercourses

As crossings of minor watercourses are designed to convey the 1% AEP flood event with minimal increase in upstream water levels, there would be minimal impact on the existing flood regime. Impacts on surface water flows are discussed in the following sections.

7 Impacts to surface water flows

7.1 Impacts of changes in surface water flows

The local hydrology could be impacted in the following ways:

- Increased flow rate and velocity of surface water runoff due to the increased imperviousness of the footprint area of the proposed upgrade.
- Concentration of flows as a result of waterway diversions and point outflows from water quality basins.
- Changes in flow regimes as a result of waterway diversions.

7.2 Flow estimation

As described in **Section 5.4.1**, flows for named watercourses have been determined using a RAFTS model. Flows for all non-named creeks, local watercourses and overland flow paths in natural depressions have been estimated in accordance with the Rational Method – Eastern New South Wales outlined in Book 4, *Estimation of Peak Flows for Small to Medium Sized Rural Catchments, Australian Rainfall and Runoff* (1997).

Table 7 summarises the catchment areas and predicted 20 yr and 100 yr ARI flows for each watercourse crossed by the proposed upgrade. Refer **Figure 12** through **Figure 16** for the location of each catchment.

Table 7 Watercourse Catchment Areas and Flows

Catchment Number	Area (km^2)	Time of Concentration (min)	5 y ARI Flow (m^3/s)	20 y ARI Flow (m^3/s)	100 y ARI Flow (m^3/s)
1	0.147	22	3.76	5.47	8.10
2	0.227	26	5.30	7.69	11.37
3	0.151	22	3.84	5.59	8.28
4	0.030	12	1.03	1.53	2.31
5	0.053	15	1.66	2.44	3.66
6	0.062	16	1.87	2.76	4.12
7	0.811	42	14.75	21.59	32.14
8	0.079	17	2.29	3.36	5.00
9	0.013	9	0.52	0.77	1.17
9a	0.034	13	1.16	1.72	2.59
9b	0.081	18	2.33	3.41	5.07
10	0.832	43	15.04	22.03	32.81
10a	0.001	5	0.06	0.09	0.13
11 (Emigrant Creek))	4.121	Modelled in RAFTS – Refer Section 5.4.1.			
12	0.005	6	0.23	0.34	0.50
13	0.023	11	0.84	1.25	1.89

Catchment Number	Area (km^2)	Time of Concentration (min)	5 y ARI Flow (m^3/s)	20 y ARI Flow (m^3/s)	100 y ARI Flow (m^3/s)
14	0.019	10	0.71	1.06	1.60
15	0.025	11	0.91	1.35	2.04
16	0.109	20	2.97	4.34	6.44
17	0.054	15	1.68	2.47	3.70
18	0.101	19	2.79	4.07	6.04
19 (Skinners Creek)	2.314	Modelled in RAFTS – Refer Section 5.4.1.			
20	0.091	18	2.56	3.74	5.57
21	0.011	8	0.47	0.70	1.05
22	0.059	16	1.82	2.67	4.00
22a	0.048	14	1.53	2.26	3.39
22b	0.062	16	1.88	2.76	4.12
23	0.064	16	1.93	2.84	4.24
23a	0.193	24	4.00	5.78	8.50
24	0.968	45	16.82	24.68	36.82
25	0.455	34	9.35	13.61	20.16
26 (Byron Creek)	21.563	Modelled in RAFTS – Refer Section 5.4.1.			
27	0.015	9	0.60	0.89	1.36
28	2.084	60	31.05	46.35	70.12
29	0.129	21	3.38	4.92	7.29
30	0.047	14	1.49	2.20	3.30
31	2.395	64	34.95	52.33	79.36
32	0.146	22	3.73	5.43	8.05
33	1.094	47	18.62	27.38	40.92
34	0.314	29	6.86	9.95	14.72
36	0.265	28	6.00	8.70	12.87
37	0.198	25	4.76	6.91	10.22
38	0.200	25	4.79	6.96	10.29
39	0.001	5	0.05	0.08	0.12

7.3 Changes in surface water flows

The design of the proposed upgrade would allow the natural flow regimes and existing overland flow paths to be maintained. Transverse culverts would be provided beneath the proposed upgrade to convey surface water runoff, and would be designed with sufficient capacity to convey the 100 year ARI peak flow with:

- No flow on at least one carriageway of the proposed upgrade.
- Minimal increase to water levels upstream of the structure.
- Minimal disruption to the natural hydrological regime through the diversion of flow onto adjoining catchments.
- Minimal increase in flow velocities with appropriate scour protection on both upstream and downstream ends of all structures where increased velocities have the potential to cause scour.

Transverse culverts beneath highway ramps and access roads would be designed with the capacity to convey the 20 year ARI peak flow, and new property access roads to be constructed as a result of the proposed upgrade would be designed to convey the 1 year ARI peak flow.

A preliminary assessment of required waterway structures beneath the proposed upgrade (including ramps and access roads) is provided in **Table 8** below. The locations of these structures are indicated in **Figure 12** through **Figure 16**. Preliminary sizing is based on culverts flowing full under inlet control. Sizing of new culverts has reflected the desire to limit culvert velocities to 6 m/s where feasible to minimise potential for scour. The steep existing topography in some areas has resulted in velocities above 6 m/s, and appropriate scour protection will be required. Detailed analysis of culvert capacities and outlet velocities should be undertaken in the detailed design stage of the project.

Note that in the table below, RCP refers to a Reinforced Concrete Pipe, and RCBC refers to a Reinforced Concrete Box Culvert. For pipes, sizes provided represent the internal diameter of the pipe, and for culverts, sizes are expressed as number of drainage cells x width of cell x height of cell.

Table 8 Preliminary waterway opening structure requirements

Culvert Number	Design ARI	Design Flow (m^3/s)	Waterway Structure Type	Waterway Structure Size
1	100 Year	8.10	Culvert – Box	1 x 2400 x 1200 RCBC
2	100 Year	11.37	Culvert – Box	1 x 2400 x 1200 RCBC
3	100 Year	8.28	Culvert – Box	1 x 2400 x 1200 RCBC
4	100 Year	2.31	Culvert – Pipe	1 x 900 RCP
5	100 Year	3.66	Culvert – Pipe	1 x 1050 RCP
6	100 Year	4.12	Culvert – Pipe	1 x 1050 RCP
7	100 Year	32.14	Culvert – Box	2 x 2400 x 1200 RCBC
8	20 Year	3.36	Culvert – Pipe	1 x 1200 RCP
9	100 Year	1.17	Culvert – Pipe	1 x 750 RCP
9a	1 Year	0.53	Culvert – Pipe	1 x 450 RCP
9b	1 Year	1.08	Culvert – Pipe	1 x 600 RCP

Culvert Number	Design ARI	Design Flow (m^3/s)	Waterway Structure Type	Waterway Structure Size
10	100 Year	32.81	Bridge – Tributary of Emigrant Creek	Northbound: 126m (3 spans) Southbound: 112m (3 spans)
10a	1 Year	0.03	Culvert – Pipe	1 x 300 RCP
11	100 Year	146	Bridge – Emigrant Creek	Northbound: 182m (5 spans) Southbound: 164m (5 spans)
12	20 Year	0.34	Culvert – Pipe	1 x 450 RCP
13	100 Year	1.89	Culvert – Pipe	1 x 1475 RCP
14	20 Year	1.06	Culvert – Pipe	1 x 750 RCP
15	100 Year	2.04	Culvert – Pipe	1 x 900 RCP
16	100 Year	6.44	Culvert – Box	1 x 1200 x 1200 RCBC
17	100 Year	3.70	Culvert – Pipe	1 x 900 RCP
18	100 Year	6.04	Culvert – Box	1 x 1200 x 1200 RCBC
19	100 Year	56	Bridge – Skinners Creek	Northbound: 195m (5 spans) Southbound: 184m (5 spans)
20	100 Year	5.57	Culvert – Pipe	1 x 1200 x 1200 RCBC
21	100 Year	1.05	Culvert – Pipe	1 x 600 RCP
22	1 Year	0.84	Culvert – Pipe	1 x 600 RCP
22a	10 Year	1.85	Culvert – Pipe	1 x 750 RCP
22b	10 Year	2.28	Culvert – Pipe	1 x 1050 RCP
23	100 Year	4.24	Culvert – Pipe	1 x 1050 RCP
23a	100 Year	8.50	Culvert – Box	1 x 2400 x 1200 RCBC
24	100 Year	36.82	Culvert – Pipe	3 x 2100 x 2100 RCP (Extension of existing culverts)
25	100 Year	20.16	Culvert – Box	3 x 1200 x 1200 RCBC (Extension of existing culverts)
26	100 Year	506	Bridge – Byron Creek	Northbound: 190m (5 spans) Southbound: 180m (5 spans)
27	100 Year	1.36	Culvert – Pipe	1 x 750 RCP

Culvert Number	Design ARI	Design Flow (m^3/s)	Waterway Structure Type	Waterway Structure Size
28	100 Year	70.12	Bridge – Tributary of Tinderbox Creek	Northbound: 144m (3 spans) Southbound: 144m (3 spans)
29	100 Year	7.29	Culvert – Box	1 x 1200 x 1200 RCBC
30	100 Year	3.30	Culvert – Pipe	1 x 1050 RCP
31	100 Year	79.36	Culvert – Box	3 x 2400 x 1200 RCBC
32	100 Year	8.05	Culvert – Box	1 x 1800 x 1200 RCBC
33	100 Year	40.92	Culvert – Box	2 x 3600 x 1200 RCBC
34	100 Year	14.72	Culvert – Box	2 x 1200 x 1200 RCBC
36	20 Year	8.70	Culvert – Pipe	1 x 1200 RCP
37	20 Year	6.91	Culvert – Box	1 x 1200 x 1200 RCBC
38	20 Year	6.96	Culvert – Box	1 x 1800 x 1200 RCBC
39	20 Year	0.08	Culvert – Pipe	1 x 450 RCP

Culverts have in general been designed to follow the existing waterway alignment to minimise potential for bank erosion, which in some cases results in the culverts being set on a skewed alignment to the proposed upgrade.

The culvert sizes in **Table 8** represent the minimum opening requirements for surface water drainage. During detailed design, culverts will be reviewed to determine any opportunities for co-location of fauna underpasses, and opening sizes increased where applicable.

Figure 12 Cross Drainage Catchments and Structures, Watercourse Diversions – Map 1 of 5

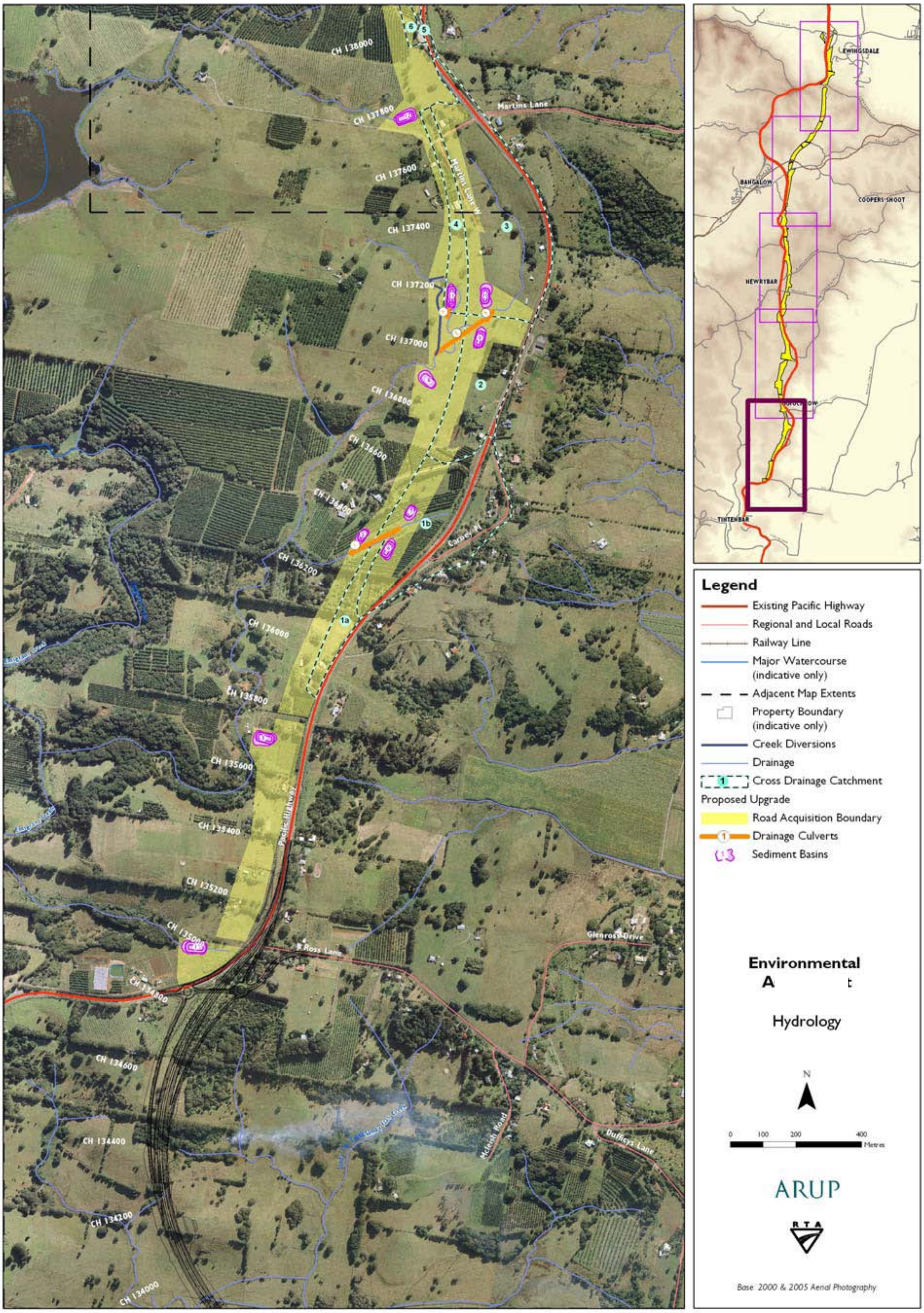


Figure 13 Cross Drainage Catchments and Structures, Watercourse Diversions – Map 2 of 5

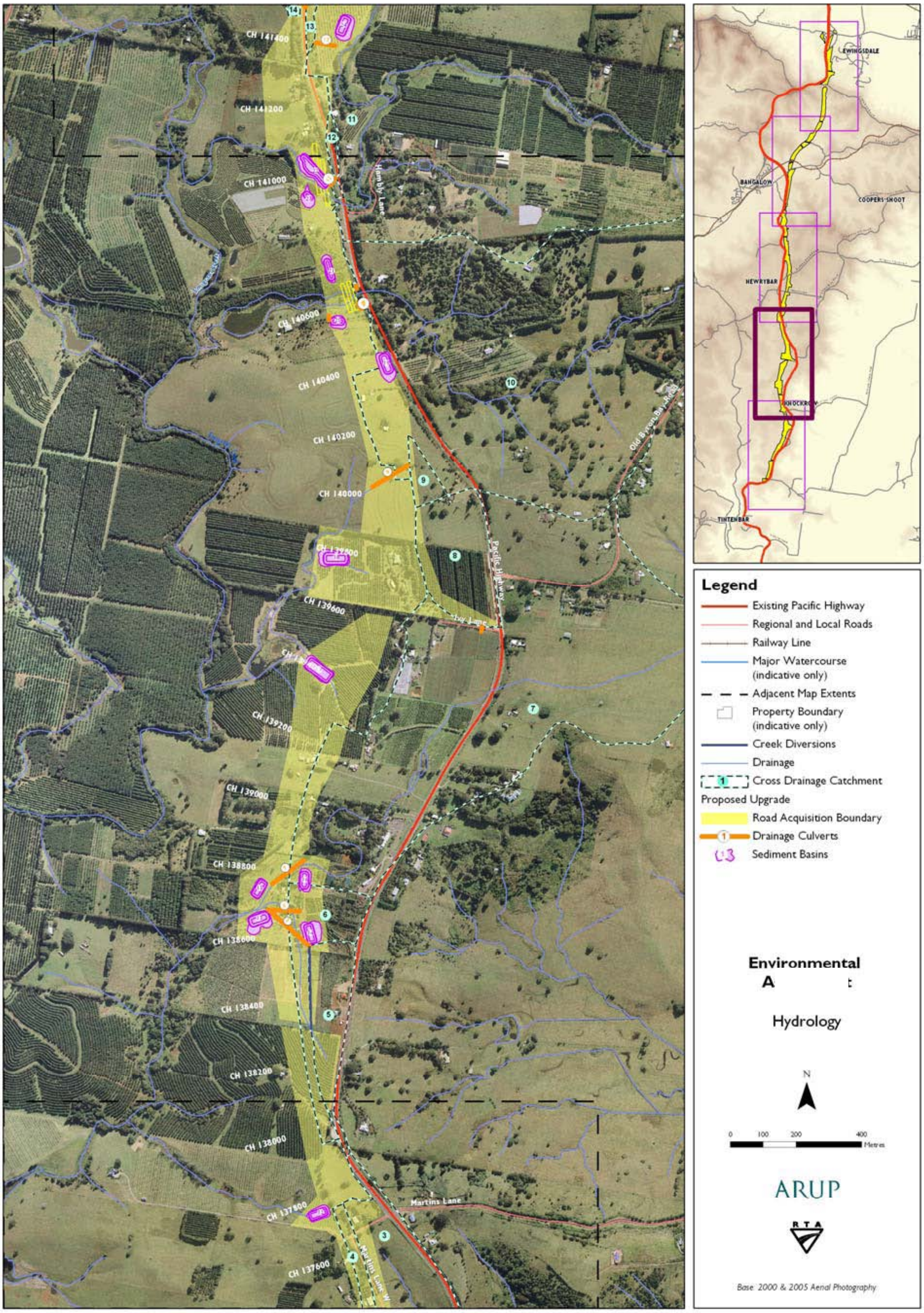


Figure 14 Cross Drainage Catchments and Structures, Watercourse Diversions – Map 3 of 5

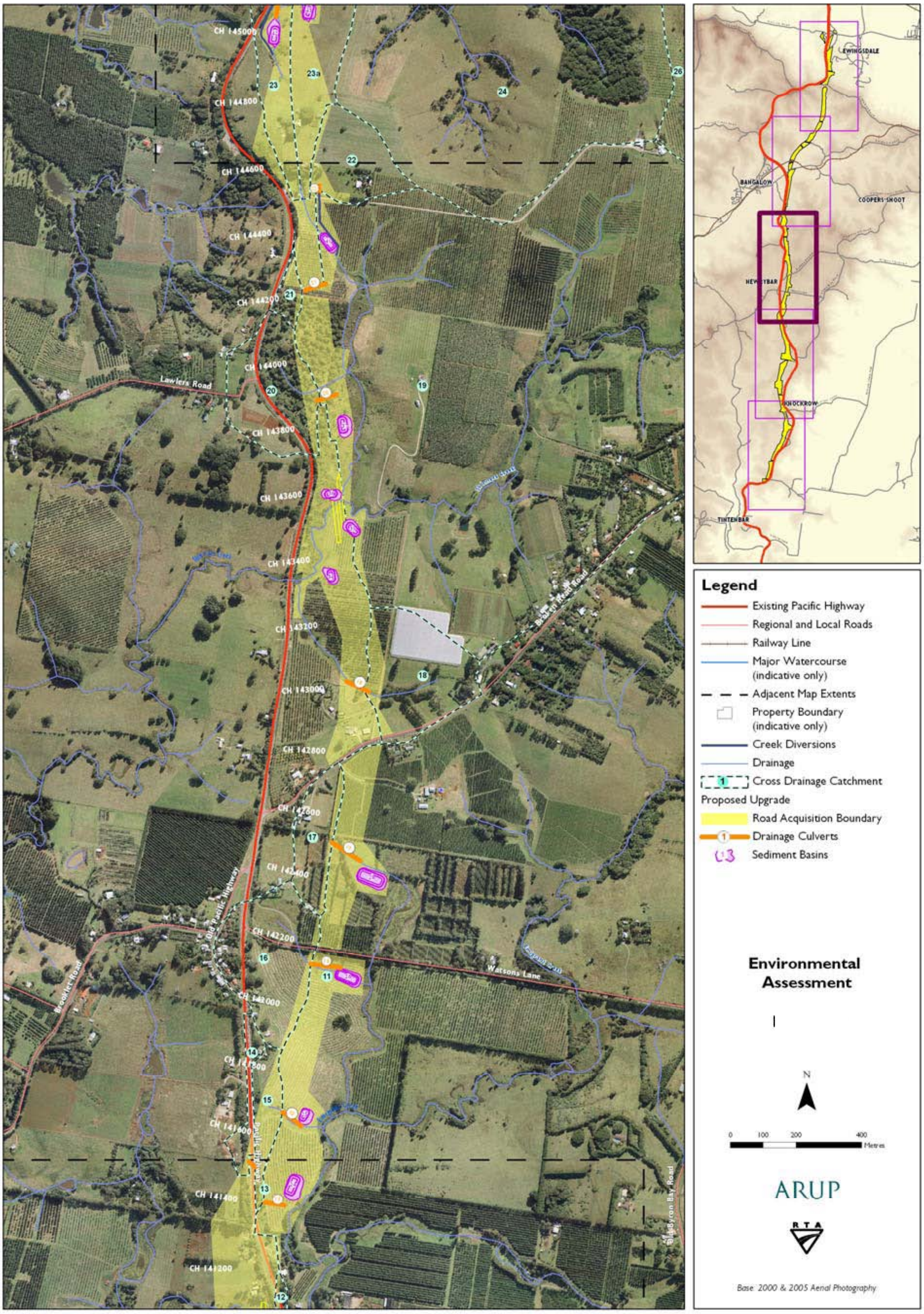


Figure 15 Cross Drainage Catchments and Structures, Watercourse Diversions – Map 4 of 5

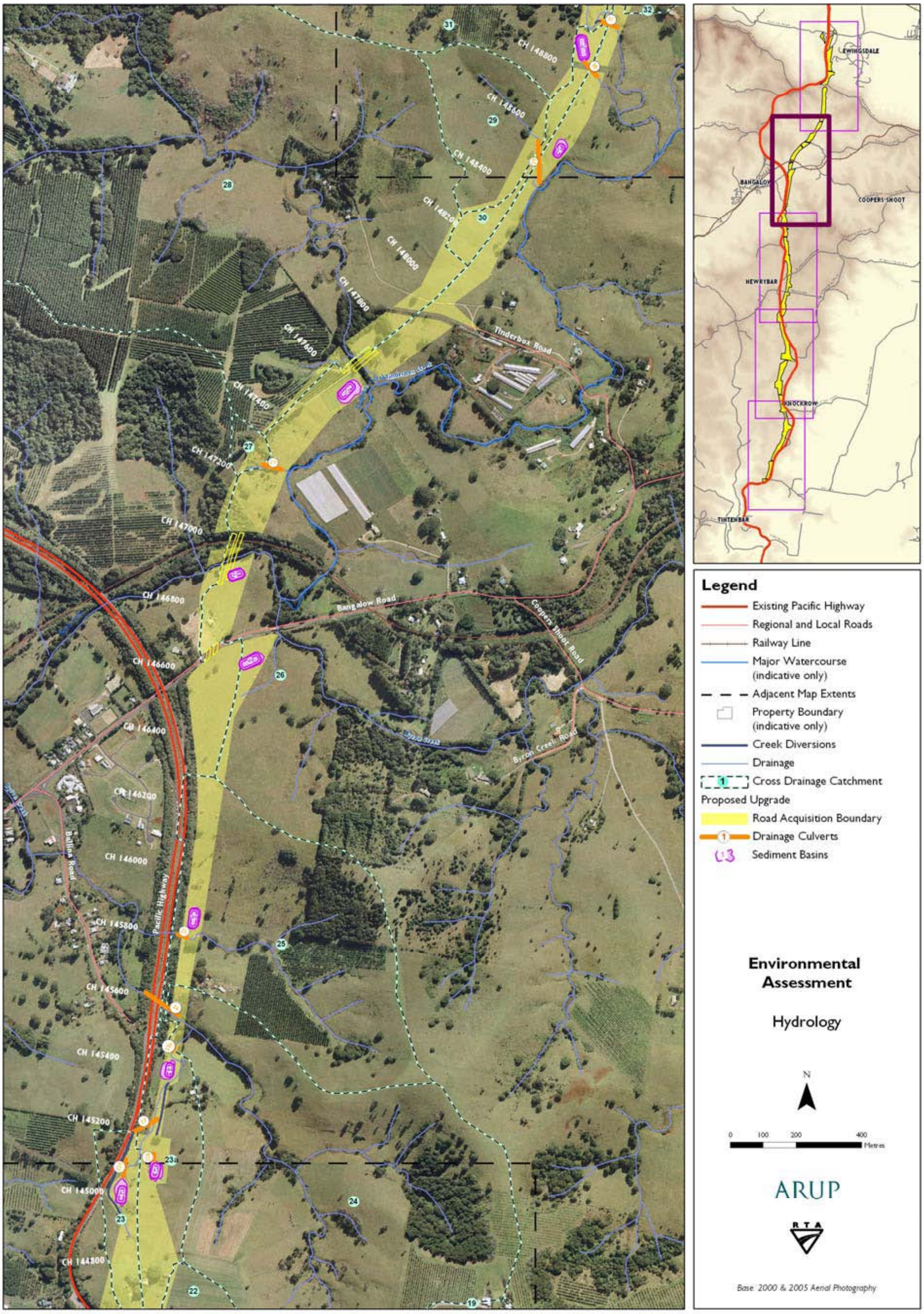
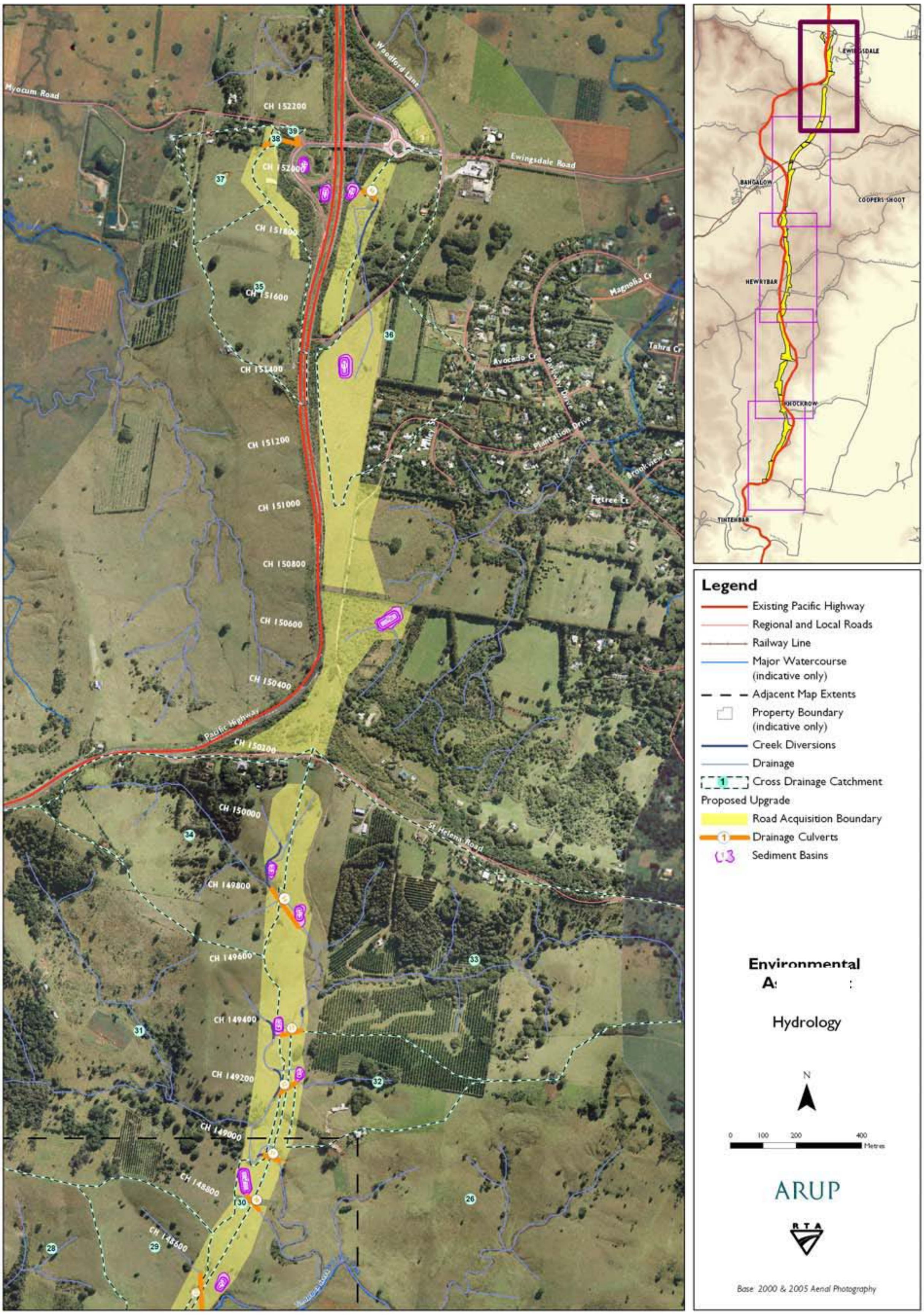


Figure 16 Cross Drainage Catchments and Structures, Watercourse Diversions – Map 5 of 5



Waterways would only be diverted from their existing alignments where it is not feasible to provide a culvert on the current alignment, for example:

- Where the proposed upgrade is in a significant cutting. In this instance the creek would be diverted on the upslope side to follow the contours along the top of the cut batter to the first location under which a feasible crossing can be made
- Where the required skew of the culvert would result in a culvert of excessive length.
- Where it is necessary to direct clean water around a water quality sediment basin.
- To combine minor flow paths in a single structure.

Preliminary locations of waterway diversions are indicated in **Figure 12** through **Figure 16** and are outlined in **Table 9** below.

Allowance has been made in the definition of property acquisition boundaries for the construction of watercourse diversions and for the construction of clean water cut off drains to separate clean upslope drainage and highway drainage.

Table 9 Minor surface watercourse diversions

Creek System	Chainage Reference	Diverted Length (m)	Comments
Tributary of Emigrant Creek, south of Emigrant Creek Dam	137000 - 137200	200	Existing alignment beneath footprint of proposed upgrade. Diverted section runs south approximately 40m to the west of the existing alignment. Minor catchment only – rejoins existing alignment immediately downstream
Tributary of Emigrant Creek, upstream of Emigrant Creek Dam	138325 - 138575	250	Minor watercourse diverted to separate clean upslope drainage from highway drainage to be treated in the adjacent water quality basin. Minor catchment at the head end of the watercourse only – rejoins existing alignment immediately downstream
Minor arm of tributary of Skinners Creek	144325 - 144525	200	Minor watercourse diverted to separate clean upslope drainage from highway drainage to be treated in the adjacent water quality basin. Minor catchment at the head end of the watercourse only – rejoins existing alignment immediately downstream
Minor arm of tributary of Byron Creek	144950 - 145350	280 and 170	Two diversions to separate clean upslope drainage from highway drainage. Minor catchment at the head end of the watercourse only – rejoins existing alignment immediately downstream

Creek System	Chainage Reference	Diverted Length (m)	Comments
Tributary of Tinderbox Creek	149000	20	Minor relocation of bend in tributary to minimise the change of direction (and hence reduce scour potential) at the entrance to the proposed cross drainage culvert
Tributary of Tinderbox Creek	149160 - 149260	100	Existing 180 degree bend in tributary located beneath footprint of proposed upgrade. Diverted route is a straight section running parallel to the proposed upgrade, to rejoin existing creek alignment downstream.
Tributary of Tinderbox Creek	149350 - 149410	65	Minor relocation of point of confluence of minor arm with main tributary as existing point of confluence within highway footprint. Minimal change to existing drainage regime.
Tributary of Tinderbox Creek	149800 - 149950	160	Diversion of local overland flow path at the top of the catchment to separate clean upslope drainage around highway drainage water quality basin no. 68..
Tributary of Simpson Creek	151800 - 151950	180	Diverted section runs 20m to the east of the original alignment, due to the footprint of the proposed the southbound on-ramp at Newrybar.

The lengths of diversions required are approximate only. Culvert layouts and diversions would be further assessed during the detailed design phase of the project to determine the form and lining of any diversions, considering appearance as well as maintenance and scour protection where required. It should be noted that the diverted segments within the Tinderbox catchment are more significant in terms of catchment size and flow rate, and detailed design of these would require careful attention to alignment, slope and scour protection to reduce erosion potential.

7.4 Management of impacts

This section addresses management of impacts on surface water flows. Other potential adverse impacts on local waterways and aquatic ecology have been addressed as an integral part of the development of appropriate drainage proposals. Impacts and management measures are described in the Water Quality Working Paper and the Aquatic Ecology Working Paper.

7.4.1 Drainage structures

The concept design has incorporated measures such as culverts and diversion drains to limit the extent of changes to local drainage characteristics. The proposed upgrade incorporates sufficient transverse drainage infrastructure to maintain existing surface water flow regimes.

7.4.2 Scour protection

Appropriate scour protection would be provided on both upstream and downstream ends of all structures where increased velocities have the potential to cause scour. Design of scour protection measures will be undertaken during the detailed design phase based on peak inlet/outlet velocity. The selection of appropriate scour protection depends on the characteristics of the culvert flows. Typically, a headwall and apron would be sufficient to protect against scour when the outlet velocities are low. However, watercourses with high velocity flows may require devices to slow the flow prior to entry to the culvert and protect the stream bed.

The topography of the area requires culverts to be laid on a steep grade in a number of locations, to match existing creek alignments. Energy dissipation structures will be required in these locations to reduce flow velocities and protect against scour.

7.4.3 Potential Flood Impacts

Further modelling combined with refinement of bridges, abutments and sediment basin layouts would be carried out as part of the detail design process, including the extension of abutment retaining walls where required. As such, minimal increase in flood level behind the structures would be anticipated and minimal change to inundation periods and flow velocities. It is not anticipated that further flood management would be required.

References

Acts and Regulations – State

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