VicRoads

Western Highway Project – Section 2: Beaufort to Ararat

Surface Water Impact Assessment Report

August 2012

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Executive Summary

The Western Highway is being progressively duplicated for approximately 110 kilometres (km) between Ballarat and Stawell. This report is the surface water assessment as part of the Environment Effects Statement (EES) and Planning Scheme Amendment (PSA) for Section 2 of the Project commencing west of the Beaufort township and extending for a distance of approximately 38 km to Heath Street, Ararat.

The objective of the surface water assessment was to determine the potential impacts related to surface drainage, water quality, flooding/hydrology and the conditions and river health values of waterways and floodplains.

The overall method for surface water assessment for the Western Highway Project EES involved the following assessment stages:

- Existing Conditions Assessment – Existing conditions of the defined study area;
- Options Assessment – Options assessment of the shortlisted alignment options to inform the selection of the preferred Section 2 alignment (note this is not documented within this report); and
- Impact and Risk Assessment – Detailed assessment of the preferred Section 2 alignment in terms of impact on surface water systems.

Existing Conditions Assessment

Among the waterway crossings included in Section 2 are the following main waterways and/or associated unnamed tributaries: Yam Holes Creek, Fiery Creek, Middle Creek, Charliecombe Creek, Billy Billy Creek, Hopkins River, Green Hill Lake (outflow channel) and Cemetery Creek.

The existing conditions were assessed against the key issues to be considered in the impact assessment, including:

- Waterway and river health condition – The identified waterways within the study corridor were assessed, and the status of river health considered. The key findings with respect to waterways and river health for existing conditions included:
  - Billy Billy Creek - Ephemeral waterway with good diversity including in stream pool-riffle features with well vegetated banks and habitat features, where aquatic surveys indicated abundant Dwarf Galaxias;
  - Hopkins River – Main river system with large channel and variable in-stream features and bank conditions; and
  - All other significant waterways – Ephemeral, channelised waterways that are typically highly disturbed with low diversity.
- Floodplain characteristics – The waterway crossings and interaction of the existing highway with the flooding characteristics of the broader study area were assessed. The assessment of floodplain characteristics has been based on interpretation of the flood modelling outputs for a range of events up to the 100 year ARI from the flood investigation undertaken by Bonacci for VicRoads (August 2012) and identifying potential impacts. The following summarises the interaction of the existing highway and modelled 100 year ARI flooding existing conditions flooding:
  - The existing highway is flood effected in a number of locations in the modelled 100 year ARI event from the following waterways:

    - Tributary of Middle Creek (Crossing WB212)
    - Middle Creek and tributary flow path (Crossings WC213 & WC214)
    - Charliecombe Creek (WB217)
    - Billy Billy Creek at Buangor (downstream of proposed WA225)
    - Billy Billy Creek west of Buangor (WB228)
    - upstream tributaries of Billy Billy Creek
    - Cemetery Creek breakway flow east of Ararat (WC245)
  - There are existing dwellings within or near existing flood extents at a number of specific waterway crossings including:
    - Middle Creek
    - Tributary of Charliecombe Creek; and
    - Charliecombe Creek.
  - Where the new alignment is a deviation from existing highway, there are generally no potential impacts to dwellings

The 100 year existing conditions flood modelling was used for developing a preliminary design gradeline for the Project, and for identifying potential flooding impacts (as identified above) where additional hydraulic modelling was undertaken for the impact assessment of the EES.

Impact Assessment

The potential waterway impacts due to construction and operation of the Project were used as a basis for determining the risk pathways in the risk assessment. The key issues are associated with either impacts to river health and water quality of receiving waters or hydraulic impacts to waterways and floodplains:

- River health and water quality – This includes physical disturbance to existing waterways, fragmentation of waterways and water quality impacts; and
- Waterways and floodplain hydraulics – This includes hydraulic conditions of waterway crossings and impacts on flooding.

Six risk pathways were identified and applied to each of the waterway systems associated with either river health or floodplain impacts, and included:

- Construction activities result in disturbance of channel planform, geometry and/or river health values;
- Construction of Western Highway Project results in reduction of hydraulic capacity at crossing location;
- Construction of Western Highway Project results in fragmentation of river health values at crossing location;
- Construction activities result in increased sediment and contaminant loadings of waterway;
- Operation of the new Western Highway road surface results in increased stormwater, sediment and contaminant loadings to waterway; and
- The construction of the Western Highway Project results in changes to floodplain characteristics to waterway.

The key outcomes of the impact assessment is summarised below:

- River Health - The overall impacts on River Health from the Project to the various waterways is generally low, with exception of the following waterways with site specific impacts from the identified risk pathways:
  - Billy Billy Creek (WA225,WA226 at Ch. 18200),
  - Hopkins River (WA243 at Ch. 33800),
  - Billy Billy Creek (WB228 at Ch. 20800 – Option 1 and 3 only) and
  - Charliecombe Creek (WB217 at Ch. 14400 and 14700)
- Flooding – The impact of the Project (where requirements are for a flood free road in 100 year ARI flood conditions) was considered low for the majority of waterway crossing locations, other than the following specific locations
  - Middle Creek (WB213-WB214);
  - Tributary of Charliecombe Creek (WB215); and
  - Charliecombe Creek confluence (WB216-WB217)

Risk Assessment

For the risk assessment it was assumed that standard environmental management measures were in place. With the application of standard environmental management measures, many of the risk items were assigned low residual risk with the exception of the following risks:

- Construction activities result in disturbance of channel planform, geometry and/or river health values for Billy Billy Creek (Ch. 18200) and Hopkins River – *This is to be managed by imposing restrictions on the waterway crossing arrangement in terms of spanning the waterway to minimise any direct impacts*;
- Construction activities result in disturbance of channel planform, geometry and/or river health values for Billy Billy Creek (Ch. 20950 – Option 1 and 3 only)) and Charliecombe Creek (Ch. 14400 and 14700) – *This will require realignment of significant lengths of waterway that will need to be approved by the Glenelg-Hopkins Catchment Management Authority (CMA);*
- Construction of Western Highway Project results in fragmentation of river health values of Billy Billy Creek at crossing location (Ch. 18200) – *This is to be managed as above (i.e. a large span bridge crossing that will minimise potential for fragmentation)*;
- The construction of the Western Highway Project results in changes to floodplain characteristics to waterways with identified potential impacts at the following crossings:
  - Middle Creek (WB213-WB214);
  - Tributary of Charliecombe Creek (WB215); and
  - Charliecombe Creek confluence (WB216-WB217).

  Post conditions flood modelling has been undertaken at the above locations to demonstrate that potential crossing configurations can meet the requirements of being flood free and not impacting existing properties. It is noted there is a potential opportunity to provide localised improved flood conditions where existing properties are flood affected that could be further explored in a more detailed assessment.

There is not a significant difference between the 3 Options from the overall surface water assessment. Option 2 is the marginally preferred Option in relation to surface water impacts due to less potential impact on flooding and least disturbance to significant waterways.

1. Introduction

1.1 Background

The Western Highway (A8) is being progressively upgraded as a four-lane divided highway for approximately 110 kilometres (km) between Ballarat and Stawell. As the principal road link between Melbourne and Adelaide, the Western Highway serves interstate trade between Victoria and South Australia and is the key transport corridor through Victoria's west, supporting farming, grain production, regional tourism and a range of manufacturing and service activities. Currently, more than 5500 vehicles travel the highway west of Ballarat each day, including 1500 trucks.

The Western Highway Project (here within described as 'the Project') consists of three stages:

- Section 1: Ballarat to Beaufort;
- Section 2: Beaufort to Ararat; and
- Section 3: Ararat to Stawell.

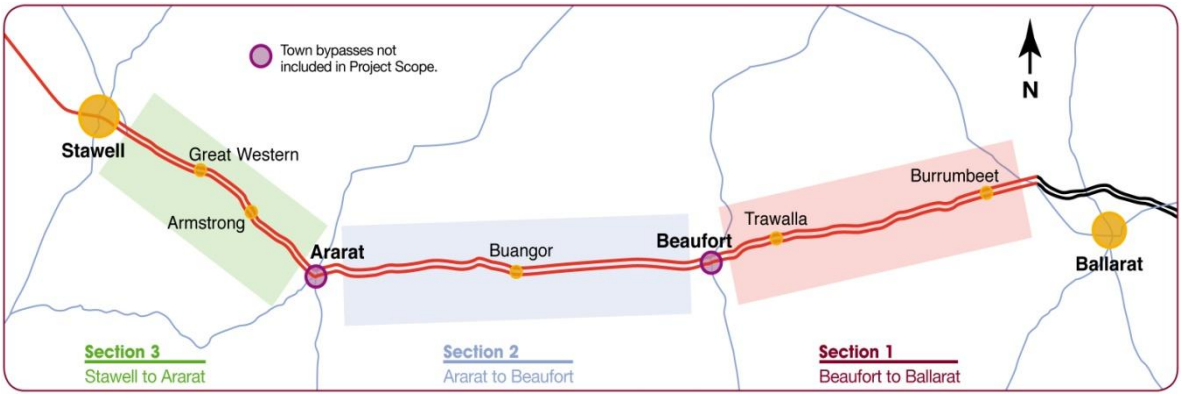

Figure 1 The Western Highway Project

Works on an initial 8 km section between Ballarat and Burrumbeet (Section 1A) commenced in April 2010 and will be completed in 2012. Construction for Section 1B (Burrumbeet to Beaufort-Carngham Road) commenced in early 2012 and is expected to be completed by June 2014. The last 3 km section from Beaufort-Carngham Road to Smiths Lane in Beaufort (Section 1C) commenced in late 2011 and will finish in 2012. Separate Environment Effects Statements (EESs) and Planning Scheme Amendments (PSAs) must be prepared for both Sections 2 and 3. It is expected that Sections 2 and 3 would be completed and opened in stages through to 2016, subject to future funding.

Section 2 of the Project commences immediately west of the railway crossing (near Old Shirley Road), which is west of Beaufort township and extends for a distance of approximately 38 km to Heath Street, Ararat.

Section 3 commences at Pollards Lane, Ararat and extends for approximately 24 km to Gilchrist Road, Stawell.

The EES will focus on assessment of the proposed ultimate upgrade of the Western Highway between Ararat Beaufort and Stawell to a duplicated highway standard complying with the road category 1

(freeway) of VicRoads Access Management Policy (AMP1). The project includes a duplicated road to allow for two lanes in each direction separated by a central median.

The EES has also considered a proposed interim upgrade of the Western Highway to a highway standard complying with the VicRoads Access Management Policy AMP3. When required, the final stage of the project is proposed to be an upgrade to freeway standard complying with AMP1.

The proposed interim stage of the Project (AMP3) would provide upgraded dual carriageways with wide median treatments at key intersections. Ultimately the Western Highway is proposed to be a freeway (AMP1) where key intersections would be grade separated, service roads constructed and there would be no direct access to the highway.

To date $505 million has been committed for the Western Highway Project by the Victorian Government and the Australian Government as part of the Nation Building Program.

Highway improvements for the three sections between Ballarat and Stawell will involve:

- Constructing two new traffic lanes adjacent to the existing highway, separated by a central median.
- Constructing sections of new four-lane divided highway on a new alignment.

In addition to separating the traffic lanes, highway safety would be improved with sealed road shoulders, safety barriers, protected turning lanes, intersection improvements, and service lanes for local access at some locations.

Town bypasses of Beaufort and Ararat are not included in the current proposals. Beyond Stawell to the Victorian border, ongoing Western Highway improvements would continue with shoulder sealing works, new passing lanes and road surface improvements.

The aims/objectives of this Project are to:

- Provide safer conditions for all road users by:
  - Reducing the incidence of head-on and run-off-road crashes;
  - Improving safety at intersections; and
  - Improving safety of access to adjoining properties.
- Improve efficiency of freight by designing for High Productivity Freight Vehicles;
- Provide adequate and improved rest areas;
- Locate alignment to allow for possible future bypasses of Beaufort and Ararat.

1.2 Project and Study Areas

1.2.1 Project Area

The project area was defined for the purposes of characterising the existing conditions for the Project, and to consider alignment alternatives. The project area encompasses a corridor extending up to 1500 metres (m) either side (north and south) of the edge of the existing Western Highway road reserve (encompassing the extent of new alignment possibilities).

1.2.2 Study Area

The study area for this Surface Water assessment is the same as the project area described above. This report details the assessment of the Section 2 stage of works from Beaufort to Ararat. The footprint of the study area for Section 2 works commences west of the railway crossing, which is west of Beaufort township and extends for a distance of approximately 38 km to Heath Street, Ararat. The township of Buangor is located within Section 2.

Waterway crossings included in this Section of the Western Highway Project include the following and associated unnamed tributaries:

- Hopkins River;
- Billy Billy Creek;
- Charliecombe Creek;
- Middle Creek;
- Fiery Creek;
- Yam Holes Creek;
- Green Hill Lake; and
- Cementary Creek

1.3 Proposed Alignment

A multi-criteria assessment of alignment options was conducted based on information from the existing conditions assessments. The outcome was the selection of three proposed alignments to take forward to the risk and impact assessment presented in this report. These three alignments are described in Section 6.1. This report informs the selection of a preferred and alternate alignment from these three alignments for the EES for Section 2. The assessment and selection for the proposed alignments is documented in Chapter 5 of the EES for Section 2, and in the Options Assessment Paper (Technical Appendix to the EES).

2. EES Scoping Requirements

2.1 EES Objectives

For the Surface Water aspects of the Western Highway Project, the relevant draft evaluation objectives outlined in the EES Scoping Requirements are:

- To protect catchment values, surface water and groundwater quality, stream flows and floodway capacity, as well as to avoid impacts on protected beneficial uses.

2.2 EES Scoping Requirements

The EES Scoping Requirements for Surface Water aspects are as follows:

The EES needs to assess potential effects related to surface water environments, including on water quality, hydrology and beneficial uses and values. This should be done in the context of the State Environment Protection Policy (Waters of Victoria), and other water-related legislation, policies and strategies.

The EES should assess potential effects related to stormwater runoff, as well as the hydrology and water quality of waterways and floodplains in the surrounding area. The level of detail of investigation should take account of the local conditions, the occurrence of surface water in the area, including perennial or ephemeral wetlands, drainage reserves, and sensitivity of the beneficial uses and values of the respective water environments.

Specifically, the EES should:

- Characterise surface water environments and drainage features (including tributaries, drains and drainage reserves) in the project area in terms of water quality, hydrology and related beneficial uses and values;
- Identify and assess potential short- and long-term effects of the construction and operation of the duplicated highway on surface water quality and hydrology, surface drainage, flooding, the quantity and quality of surface runoff and river health values of the waterways, tributaries, drains, wetland systems or drainage reserves that may be crossed, including the Hopkins River, Fiery Creek, Middle Creek, Charliecombe Creek, Billy Billy Creek and Green Hill Lake. Consideration should also be given to potential effects on the proclaimed special water supply catchment areas located near the project area;
- Identify proposed measures to avoid, mitigate and manage any potential effects, including design features for the road, preventative techniques for construction and measures to reinstate affected waterways and drains; and
- Describe likely residual effects of road construction and operation activities on waterways in the project area at a level of detail proportionate to the risk to affected assets.

Of particular relevance to road construction activities, the following must be addressed:

- Evaluation of the effects of preferred waterway crossing methods and relevant alternatives;
- Environmental management practices to be employed at waterway crossings in relation to disturbance of stream beds and banks, construction and removal of temporary barriers and

crossings, release of diverted stream flow to watercourses during crossing construction and maintenance of sediment control facilities;

- Environmental management practices to be employed generally along the road alignment for activities, especially in disturbed areas within the construction footprint for sediment control and water quality protection; and
- Contingency plans, in the event of failure of the proposed control measures (i.e. during heavy rainfall or flooding).

3. Legislation and Policy

The following sections provide a brief overview of the legislation and policy documents relevant to surface water investigations. These legislation and policies will need to be adhered to during the preparation of site environmental management plans, planning approvals and design of waterway crossings.

3.1 Water Act 1989

The *Water Act 1989* is intended to ensure that water resources are conserved and properly managed for sustainable use for the benefit of present and future Victorians.

3.2 Environment Protection Act 1970

The *Environment Protection Act 1970* empowers the Environment Protection Authority to implement regulations to maintain the State environmental policy, granting works approvals and licenses in the process. Consideration also needs to be given to the relevant state environment protection policies, such as those for groundwater and surface water.

3.2.1 State Environment Protection Policy (Waters of Victoria)

The *State Environment Protection Policy Waters of Victoria (SEPP, WoV)* aims to provide a coordinated approach for the protection and, where necessary, rehabilitation of the health of Victoria's water environments. The *SEPP (WoV)* contains objectives for the protection of water quality and biological health that describe the conditions required to protect the beneficial uses of the receiving water bodies. Detailed information is documented for each Catchment Management Authority (CMA) region on the following:

- The SEPP segment and water quality objectives that apply at each water quality site; and
- The SEPP segment and biological objectives that apply at each biological site.

For the purpose of the SEPP, the water quality objectives were incorporated within the segments representing the biological regions in the State Environment Protection Policy (Waters of Victoria). The target objectives for this region are shown in Table 1.

Table 1 SEPP WoV – Water Quality Objectives (Table 1, EPA 2003)

Water Quality Parameter	Objective & Trigger Value Relevant for Upland reaches in the Wimmera, Hopkins, Moorabool, Werribee, Maribyrnong, Campaspe, Loddon and Avoca catchments
Dissolved oxygen saturation	25th percentile: 85; Maximum trigger: 110
Electrical Conductivity at 25ºC	75th percentile: 500 mS cm-1
pH	25th percentile 6.5; 75th percentile 8.3
Turbidity (NTU)	75th percentile 10

The waterways affected by the Western Highway would need to be considered under the SEPP WoV. SEPP WoV identifies 'beneficial uses' of waterways and establishes environmental quality objectives at levels that would ensure the protection of these uses. The named waterways within the study area are classified as Waters of Murray and Western Plains in the SEPP WoV Main Schedule (1970). The beneficial uses for these bioregions as identified in SEPP WoV include:

- Maintenance of Aquatic Ecosystems that are slightly to moderately modified;
- Primary contact recreation;
- Secondary contact recreation;
- Aesthetic enjoyment;
- Indigenous cultural and spiritual values;
- Non-indigenous cultural and spiritual values;
- Agriculture and irrigation;
- Aquaculture;
- Industrial and commercial use;
- Human consumption after appropriate treatment; and
- Fish, crustacean and molluscs for human consumption.

These beneficial uses need to be protected from potential impacts resulting from construction and operation of the Project.

3.3 Catchment and Land Protection Act 1994

The *Catchment and Land Protection Act 1994* has the objective of establishing a framework for the integrated and coordinated management of catchments that will:

- Maintain and enhance long-term land productivity while also conserving the environment; and
- Aim to ensure that the quality of the State's land and water resources and their associated plant and animal life are maintained and enhanced.

The Act established ten Catchment and Land Protection Boards, nine of which have since expanded their roles to become Catchment Management Authorities. The *Catchment and Land Protection Act 1994* provides for the development of Regional Catchment Strategies that must assess the nature, causes,

extent and severity of land degradation of the catchments in the region and identify areas for priority attention. Local Planning schemes must have regard for the Regional Catchment Strategies.

3.3.1 Glenelg Hopkins Catchment Management Authority

The Glenelg Hopkins River Health Strategy (RHS) 2004-2009, provided a five year blue print for improving the health of rivers and creeks within the catchment. In protecting and improving the region's rivers and creeks, the main objectives of the River Health Strategy were to:

- Identify and prioritise actions for river restoration, considering environmental, social and economic values;
- Identify threats to waterway health and assesses the level of risk based on the interaction between threats and values;
- Identify priority actions required to protect and enhance high value river reaches;
- Identify opportunities to actively involve the community in river health; and
- Provide the strategic framework for investment in river health for the five year period.

The implementation of this strategy is the responsibility of GHCMA, in partnership with the local community, local government and State Government agencies (Department of Sustainability and Environment, EPA Victoria and Department of Primary Industries).

Recently the GHCMA has launched the Regional Catchment Strategy (RCS) 2102 -2018 and this will be the key planning document for land, water and biodiversity management that will set regional priorities for across the Glenelg Hopkins region. The RCS aims to provide focus, coordination and direction for all natural resource management, and in terms of river health management will build on the work from the RHS.

3.3.2 Licensing – Works on Waterway Approval

Victorian Catchment Management Authorities (CMAs) are delegated the function of issuing permits to carry out works on a 'designated' waterway under the *Water Act 1989* (By-Law No. 1). A designated waterway can generally be defined as a river, creek, stream or watercourse; a natural channel in which water regularly flows; and a lake, lagoon, swamp or marsh.

CMAs have the power to enforce alterations or remove works that are not in accordance with the approval conditions or are constructed without a permit or approval. The intent of the permitting system is to ensure that works are performed using environmentally sound methods and to ensure protection of the waterway.

3.4 Planning Schemes

The following provides a brief summary of the planning overlays that apply to the proposed Western Highway Project Section 2 and are of relevance to the surface water assessment. This section of the alignment is located in the Rural City of Ararat and Shire of Pyrenees.

The objectives of the following planning scheme overlays for the Rural City of Ararat and Shire of Pyrenees are consistent with the surface water requirements of the Western Highway Project EES for Section 2.

3.4.1 Land Subject to Inundation Overlay

The purpose of the Land Subject to Inundation Overlay is as follows:

- To identify land in a flood storage or flood fringe area affected by the 1 in 100 year flood or any other area determined by the floodplain management authority;
- To ensure that development maintains the free passage and temporary storage of floodwaters, minimises flood damage, is compatible with the flood hazard and local drainage conditions and would not cause any significant rise in flood level or flow velocity; and
- To protect water quality in accordance with the provisions of relevant State Environment Protection Policies, particularly in accordance with Clauses 33 and 35 of the State Environment Protection Policy (Waters of Victoria).

3.4.2 Environment Significance Overlay

The purpose of the Environment Significance Overlays is as follows:

- To identify areas where the development of land may be affected by environmental constraints; and
- To ensure that development is compatible with identified environmental values.

Pyrenees Planning Scheme Schedule 2 to ESO (ESO2 – Watercourse Protection Areas). The objectives to be achieved include:

- To maintain the quality and quantity of water within the watercourse;
- To maintain the ability of streams and watercourses to carry natural flows;
- To prevent erosion of banks, stream beds and adjoining land and siltation of watercourses, drains and other features;
- To protect and encourage the long term future of fauna and flora habitats along watercourses;
- To prevent pollution and increased turbidity or water in natural watercourses;
- To prevent increased surface run-off or concentration of surface water run-off leading to erosion of siltation of watercourses;
- To conserve existing wildlife habitats close to natural watercourses and where appropriate to allow for generation and regeneration of habitats; and
- To protect the watercourse and its environs as significant natural landscapes.

Ararat Planning Scheme Schedule 1 to ESO (ESO1 – Watercourse Protection Areas). The objectives to be achieved include:

- To maintain and enhance the environment - economic and scenic values of the Wimmera River, Hopkins River, Fiery Creek and Mt William Creek to maintain the integrity of the ecosystems. To provide for appropriate use and development of land within 100 m of either side of a watercourse to prevent pollution and increased turbidity of water in natural watercourses;
- To prevent increased surface runoff or concentration of surface water runoff leading to erosion or siltation of watercourses; and
- To conserve existing flora and fauna habitats close to watercourses and to encourage generation and regeneration of habitats.

Ararat Planning Scheme Schedule 2 to ESO (ESO2 – Watercourses, Waterbody and Wetland Protection Areas). The objectives to be achieved include:

- To maintain and enhance the environment and to maintain the integrity of the ecosystems;
- To prevent pollution and increased turbidity of water in natural watercourses;
- To maintain the biological, physical and chemical quality and quantity of water within the watercourse, water-body or wetland;
- To maintain the ability of streams and watercourses to carry natural flows;
- To prevent erosion of banks, streambeds and adjoining land and the siltation of watercourses, drains and other features;
- To protect and encourage the long term future of fauna and flora habitats along watercourses;
- To ensure development does not occur on land liable to flooding;
- To prevent waste discharge, nutrients and other pollutants from entering watercourses and water-bodies;
- To prevent increased surface runoff or concentration of surface water runoff leading to erosion or siltation of watercourses;
- To conserve existing wildlife habitats close to natural watercourses and encourage regeneration of riparian and fringing vegetation;
- To minimise the potential damage caused to human life, buildings and property by flood waters;
- To restrict the intensity of use and development of land and to activities which are environmentally sensitive and which are compatible with potential drainage or flooding hazards;
- To promote the use and environmental solutions in siting and design in preference to modification of natural systems through technical and engineering measures;
- To minimise the environmental impact on estuarine environments by controls over water releases and sand bar management in line with the established protocols of Wimmera Mallee Water and Southern Rural Water;
- To maintain the natural role of wetlands in filtering nutrients and absorbing soluble pollutants in water. Further loss of wetlands through drainage would be discouraged; and
- To protect and ensure the long term future of fauna and flora habitats in wetland and estuarine areas.

Ararat Planning Scheme Schedule 3 to ESO (ESO3 – Habitat Protection Areas)

The objectives to be achieved include:

- To protect rare or threatened species or significant habitats for native flora and fauna;
- To protect and enhance remnant native vegetation including understory and ensure the long term future of fauna and flora habitats;
- To ensure development does not impact on significant habitats;
- To restrict the intensity of use and development of land and to activities which are environmentally sensitive;

- To promote the use of environmentally benign solutions in siting and design in preference to modification of natural systems; and
- To promote the maintenance of ecological processes and generic diversity.

3.4.3 Vegetation Protection Overlay

The purpose of the Vegetation Protection Overlay is as follows:

- To protect areas of significant vegetation;
- To ensure that development minimises loss of vegetation;
- To preserve existing trees and other vegetation;
- To recognise vegetation protection areas as locations of special significance, natural beauty, interest and importance;
- To maintain and enhance habitat and habitat corridors for indigenous fauna; and
- To encourage the regeneration of native vegetation.

Ararat Planning Scheme Schedule 1 to VPO (VPO1 – Significant and Remnant Vegetation):

- To protect areas of significant remnant vegetation throughout the municipality.

Ararat Planning Scheme Schedule 2 to VPO (VPO2 – Roadside Vegetation Protection Areas):

- To protect areas of significant remnant vegetation located along roadsides throughout the municipality.

4. Method

The overall surface water assessment method for the Western Highway Project EES has involved the following assessment stages:

- Existing Conditions Assessment – Existing conditions of the study area, refined to focus on the preferred alignment (summarised within Section 4.1 and detailed assessment within Section 5);
- Options Assessment – Options assessment of the shortlisted alignment options in considering the impact on surface water systems to inform the selection of the preferred Section 2 alignment (note this is not documented within this report but in the Options Assessment Report which is a Technical Appendix to the EES); and
- Impact and Risk Assessment – Detailed assessment of the final Section 2 alignment options in terms of impact on surface water systems with respect to waterway and floodplain management (summarised within Section 4.2 and detailed impact assessment within Section 6).

4.1 Existing Conditions

This report summarises the findings of the surface water existing conditions and impact assessment, which forms part of the Western Highway Project EES & PSA – Section 2 Beaufort to Ararat. The study area for the surface water assessment includes all identified watercourses, including rivers, creeks and drainage lines, near or across the highway corridor (approximately 30 crossings of the existing highway). A mapbook showing the alignment of the final options for Western Highway Project Section 2 and location of identified waterways crossings has been included in Appendix A.

The purpose of this assessment is to provide an overview of existing conditions of surface water in the study area. It provides a basis for undertaking an options assessment of the shortlisted alignment options in considering the impact on surface water systems and will inform the determination of the preferred Section 2 alignment.

The existing conditions assessment has been based on a combination of desktop study and field assessment, and included the following tasks:

- Description of the catchment systems that the Project may impact and the catchment characteristics including land use or catchment activities;
- Identification and characterisation of existing watercourses (or “surface water systems”) within the study area that may be impacted from the Project; and
- Identification of the key issues to be assessed against evaluation criteria for an options assessment that has included:
  - Waterway characteristics – number and extent of waterways within the study area as well as considering the status of river health of the catchment system (including downstream receiving waterway) and potential to impact on waterway health and local conditions such as loss of habitat, aquatic invertebrates and riparian vegetation; and
  - Floodplain characteristics – number and extent of waterways within the study area that may impact floodplain characteristics and potential to change the flow hydraulics at waterway crossings as well as encroachment on the floodplain and change of flood flow characteristics.

The existing conditions assessment has therefore focused on the hydrologic, floodplain and waterway characteristics.

The following approach and information has been used to inform the existing conditions assessment:

- Hydrologic and floodplain assessment – A concurrent flood study by Bonacci Water has been commissioned by VicRoads for the existing Western Highway corridor. The following information from this preliminary investigation has been adopted:
    - The catchment delineation and hydrologic assessment to determine existing conditions design flow rates for the surface water systems at the existing crossing locations; and
    - output from 2D floodplain hydraulic modelling including 100 year average recurrence interval (ARI) flood extents.
- Waterway assessment – The assessment was based on the current conditions as defined in the Glenelg Hopkins River Health Strategy and other relevant documents, as well as understanding the long term management objectives and regional significance of the waterways. A desktop condition assessment has also been undertaken using aerial photography and topographical information, as well interpreting other commercially available resources. This has been followed by a field assessment of existing waterway crossings and the field work recording sheets are provided in Appendix B.

4.2 Impact and Risk Assessment

The following impact assessment methodology was used to determine the surface water impact pathways and risk ratings for the Project:

1. Determine the impact pathway (how the Project impacts on a given surface water value or issue).
2. Describe the consequences of the impact pathway.
3. Determine the maximum credible 'consequence level' associated with the impact. Table 2, Table 3 and Table 4 provides guidance criteria for assigning the level of consequence. The method for defining these criteria is described in Section 4.2.1.
4. Determine the likelihood of the consequence occurring to the level assigned in step 3. Likelihood descriptors are provided in Table 5 below; and
5. Using the Consequence Level and Likelihood Level in the Risk Matrix in Table 6 to determine the risk rating.

Table 2 Surface Water Impacts Consequences - physical disruption to waterways

Insignificant	Minor	Moderate	Major	Catastrophic
Medium level impact to waterway, river health or floodplain function on minor waterway *Low level impact to waterway, river health or floodplain function on significant waterway*	*High level impact to waterway, river health or floodplain function on minor waterway* *Medium level impact to waterway, river health or floodplain function on significant waterway* *Low level impact to waterway, river health or floodplain function on major waterway*	*Severe level impact to waterway, river health or floodplain function on minor waterway* *High level impact to waterway, river health or floodplain function on significant waterway* *Medium level impact to waterway, river health or floodplain function on major waterway*	*Severe level impact to waterway, river health or floodplain function on significant waterway* *High level impact to waterway, river health or floodplain function on major waterway*	*Severe level of impact to a major waterway*

Note: The terms Minor, Significant and Major waterway and Low, Medium, High and Severe impacts are defined in Section 4.2.1 below.

Table 3 Surface Water Impacts Consequences - stormwater pollution to waterways

Insignificant	Minor	Moderate	Major	Catastrophic
Minor increases to stormwater runoff, sediment and or contaminant loading to the waterway.	*Significant increases to stormwater runoff, sediment and or contaminant loading to a minor waterway as described in the impact assessment report.*	*Significant increases to stormwater runoff, sediment and or contaminant loading to a significant waterway as described in the impact assessment report.*	*Significant increases to stormwater runoff, sediment and or contaminant loading to a major waterway as described in the impact assessment report.*	*An uncontained spill of contaminants directly to a major waterway as described in the impact assessment report.*

Note: The terms Minor, Significant and Major waterway and Minor and Severe impacts are defined in Section 4.2.1 below.

Table 4 Surface Water Impacts Consequences - for flood impacts

Insignificant	Minor	Moderate	Major	Catastrophic
No additional floodplain impacts to any houses, outbuildings or infrastructure.	*Slight increase in flooding at a rural scale.*	*Medium increase in flooding at a rural scale or slight increase in flooding at a township scale.*	*Significant increase in flooding at a rural scale or medium increase in flooding at a township scale.*	*Significant increase in flooding at a township scale.*

Note: The terms Slight, Medium and Significant increase are defined in Section 4.2.1 below.

Table 5 Likelihood Guide

Descriptor	Explanation
Almost Certain	The event is expected to occur in most circumstances
Likely	The event will probably occur in most circumstances
Possible	The event could occur
Unlikely	The event could occur but not expected
Rare	The event may occur only in exceptional circumstances

Table 6 Risk Matrix

Likelihood	Consequence Level				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	High	Extreme
Possible	Negligible	Low	Medium	High	High
Unlikely	Negligible	Low	Medium	Medium	High
Rare	Negligible	Negligible	Low	Medium	Medium

4.2.1 Consequence Criteria

Consequence criteria range on a scale of magnitude from “insignificant” to “catastrophic”. Magnitude was considered a function of the size of the impact, the spatial area affected and expected recovery time of the environmental system. Consequence criteria descriptions indicating a minimal impact over a local area, and with a recovery time potential within the range of normal variability were considered to be at the insignificant end of the scale. Conversely, catastrophic consequence criteria describe scenarios involving a very high magnitude event, affecting a State-wide area, or requiring over a decade to reach functional recovery.

Impact - Physical Disruption to Waterways

For the purposes of defining the magnitude of impact resulting from physical disruption to waterways it is necessary to consider the significance of the waterway being impacted. Waterways impacted by the proposed alignment were categorised as minor, significant or major:

- **Minor Waterway** – Refers to undefined tributaries and often without permanent water. Many minor tributaries in this area of works are not evident and expected to only flow in significant rainfall events.
- **Significant Waterway** – Refers to waterways with a defined channel, some in-stream vegetation, some sections of permanent water. These waterways include larger waterways that are heavily degraded with low ecological value.
- **Major Waterway -** Well defined channel with permanent water. Moderate to good in-stream vegetation and some stream protection. These waterways include smaller waterways with significant areas of intact vegetation and notable instream features such as deep pools, riffles and/or large woody debris.

The second step in considering the magnitude of the impact resulting from physical disruption was to consider the scale of the impact. Impacts were categorised as low, medium, high or severe by taking into account the size of the area disrupted, the likely extent of impact into adjacent waterway reaches and the expected recovery time for the subject reach.

- **Low** – Perpendicular road crossing with no impact to the adjacent waterway. Recovery could be expected to occur within weeks of completion of construction of the Project.
- **Medium** – Skewed crossings or crossings within interchange structures which impact greater than 100 m of waterway and/or crossings with a potential to impact the waterway immediately adjacent to the crossing location (by increasing the risk of erosion to a downstream bend, for example). Recovery could be expected to occur within months of completion of construction of the Project.
- **High** – Skewed crossings or crossings within interchange structures which impact greater than 200 m of waterway and/or crossings with a potential to impact the whole adjacent reach (by promoting incision of the creek bed level by more than 300 millimetres (mm) for example). Recovery could be expected to occur within years of completion of construction of the Project.
- **Severe** – Skewed crossings or crossings within interchange structures which impact greater than 200 m of waterway and/or crossings with a potential to impact multiple adjacent reaches (by promoting incision of the creek bed level by more than 1000 mm, for example). Full recovery may never occur.

These definitions were used in conjunction with Table 2 to determine the appropriate level of consequence for each waterway crossing.

Stormwater Pollution to Waterways

The significance of the waterway being impacted was taken into account using the waterway classifications described in the above section.

Next, stormwater pollution impacts from stormwater runoff were categorised as minor or significant.

- **Minor** – As a result of the Project, SEPP(WoV) trigger levels in the reach immediately downstream not exceeded
- **Significant** – As a result of the Project, SEPP(WoV) trigger levels in the reach immediately downstream are exceeded for no more than 6 hours in any one week period during which there occurred a rainfall event greater than the 1 in 3 month ARI but less than the 1 in 2 year ARI (1 in 2 year is the construction phase design storm specified by VicRoads). Or, as a result of the Project, SEPP(WoV) trigger levels in the reach immediately downstream are exceeded for any period of time not as a result of a rainfall event.

These definitions were used in conjunction with Table 3 to determine the appropriate level of consequence for each waterway crossing.

Flood Impacts

The consequence of flood impacts was considered in terms of the significance of the area impacted and the magnitude of the flood level increase. The significance of the area was categorised as either:

- **Rural (no properties)** – Where no dwellings or farm buildings or local road infrastructure is affected;
- **Rural** – Where a single farm house, a small number of farm buildings or assets and/or a local road is affected; or
- **Township** – Where multiple buildings (residential, commercial premises, etc) forming part of a town and/or a regionally significant road is affected.

The magnitude of increase was categorised as follows:

- **Slight** – Increase in flood levels at buildings where floor levels are already inundated and/or inundation to below the floor level of properties not currently subject to inundation. No additional buildings flooded to above floor level. Partially obstructing but not completely blocking a public thoroughfare.
- **Medium** – Increase in flood levels to above the floor level at a single residential or commercial building or multiple ancillary buildings (i.e. barns, garages, etc). Completely blocking a public thoroughfare without resulting in the isolation of an area also subject to inundation (i.e. blocking a road, but not restricting evacuation of the area via another route).
- **Significant** – Increase in flood levels at multiple residential or commercial buildings resulting in inundation to above the floor level of properties not currently subject to inundation. Completely blocking public thoroughfares resulting in the isolation of an area also subject to inundation (i.e. blocking roads in a manner that restricts safe evacuation of the area).

These definitions were used in conjunction with Table 2 to determine the appropriate level of consequence for each waterway crossing.

4.3 Limitations

Floodplain assessment limitations include:

The hydrologic and floodplain assessment portion of this report is largely based on work undertaken by Bonacci Water, comprising an initial hydraulic analysis in 2011 and subsequent remodeling completed throughout 2012 documented in the Bonacci Water[1] report (August 2012). The assessment by GHD documented in this report is based on findings from the report and the interpretation of the flood modeling outputs provided by Bonacci Water. We note the following:

- GHD has prepared the floodplain assessment documented in this report based on information provided by Bonacci Water for Vicroads, which GHD has not independently verified or checked beyond the agreed scope of work;
- GHD does not accept liability in connection with such unverified information, including errors and omission in this report which were caused by errors or omissions in the provided information
- Other than what has been documented in the Bonacci Water report GHD has had limited or no access to modeling inputs or assumptions;
- GHD has not been involved in the preparation of the Bonacci Water report and has had no contribution to, or review of the Bonacci Water report. GHD shall not be liable to any person for any error in, omission from, or false or misleading statement in or derived from the Bonacci Water report
- GHD has not been involved in the preparation of the flood mapping extents provided by Bonacci Water and has had no contribution to, or review of the Bonacci Water flood mapping extents. GHD shall not be liable to any person for any error in, omission from, or false or misleading information relating to the interpretation of the flood extents provided by Bonacci Water. GHD has inserted without review or amendment the flood mapping extents from the modeling outputs provided by Bonacci Water, on to the GHD prepared GIS base maps.
- The 100 year ARI flood extent outputs presented on the maps were provided by Bonacci Water on 23 August 2012 and are considered to be a preliminary representation of the 100 year flood conditions prepared for the purpose of the EES assessment only. More detailed and refined hydrologic and hydraulic modeling analysis will be required in preparing a detailed design of the Project.

This report also shares the limitations of Bonacci Water's report, most notably:

- The preliminary TUFLOW modelling used a 10 m grid, which is considered large but allows for faster processing. Further investigation of selected areas was undertaken using a 3 m grid; and
- The hydraulic assessment was only undertaken for the 3 km corridor surrounding the existing highway.

Waterway assessment limitations include:

- The condition assessment undertaken was desktop only, and as such, any waterway features which are not readily apparent from the available photography and topographical information have not been noted in this assessment; and

[1] As of August 2012 the modelling has been undertaken by TGM and Urban Water Solutions (by former employees of Bonacci Water). To avoid confusion the terminology has been kept consistent and any reference to "Bonacci Water" subsequent to August 2012 refers to the work of TGM and Urban Water Solutions.

- The River Health Strategies and Catchment Health Reports used to categorise waterway health are more than five years old, therefore the health of waterways detailed in this report may have improved or declined since these reports were prepared.

5. Existing Conditions Assessment

5.1 Catchment System Descriptions

The catchment systems are part of the Hopkins Basin within the Glenelg Hopkins Catchment Management Authority (GHCMA) region. The Hopkins Basin is located in the eastern section of the Glenelg Hopkins region and covers an area of 10,096 km^2 (GHCMA, 2004).

The major river within this basin is the Hopkins River, which is 25 9 km long. The headwaters of the Hopkins begin just north of Ararat and the existing Western Highway. The other major tributary of the Hopkins River intersected by the Western Highway is Fiery Creek. The GHCMA River Health Strategy (GHCMA RHS) states that there are no priority sub-catchments in the Hopkins Basin for restoration activities (GHCMA, 2004). However, some reaches have been recognised for the maintenance of social and economic values. The existing Western Highway is located within sub-catchments H5, H10 and H12.

Section 2 of Western Highway Project is located within the Hopkins Catchment of the Glenelg Hopkins CMA region. As shown in Figure 2, the alignment crosses three sub-catchments – all located in the upper catchment areas at the north east of the CMA region, including:

- H10: Trawalla Creek - Trawalla to west of Beaufort;
- H12: Upper Fiery Creek -West of Beaufort to West of Buangor; and
- H5: Upper Hopkins River - West of Buangor to west of Ararat.

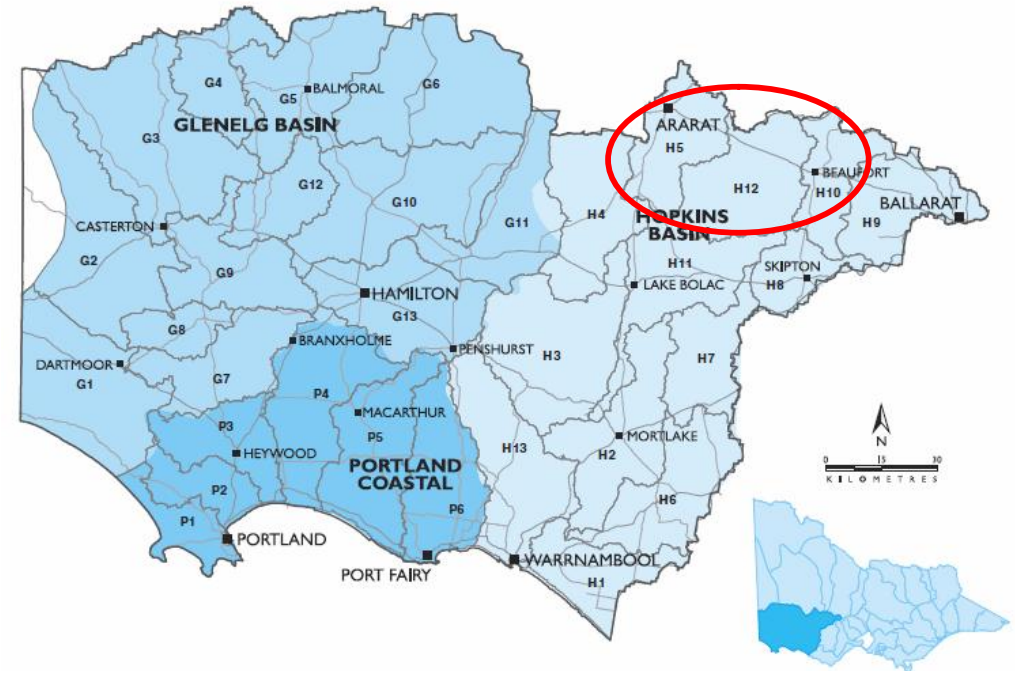

Figure 2 Location of works within Glenelg Hopkins CMA region

5.1.1 Subcatchment H10 - Trawalla Creek

The Trawalla Creek catchment includes the headwaters of Mount Emu Creek including Yam Holes Creek. The Western Highway intersects various tributaries flowing north-easterly that discharge into Yam

Holes Creek. Mount Emu Creek is the major waterway and travels for a length of approximately 60 km through this sub-catchment within the Hopkins Basin. This sub-catchment extends up to 500 km^2 and includes Lake Goldsmith and several State Forests (Trawalla, Ben Major, Waterloo, Andrews Block and Mount Lonarch). The average annual rainfall is 600 mm to 700 mm and the temperature ranges from 3°C to 26°C.

The major waterways within this sub-catchment that are within the study area include:

- Yam Holes Creek - This creek runs north of the highway near Beaufort and discharges into Mt Emu Creek east of Beaufort. The existing Western Highway crosses four tributaries to Yam Holes Creek that are flowing north easterly towards Yam Holes Creek.

5.1.2 Sub-Catchment H12 - Upper Fiery Creek:

The Upper Fiery Creek sub catchment extends over a catchment area of 880 km^2 and has a length of approximately 40 km through this sub catchment within the Hopkins Basin. The Western Highway in Section 2 intersects the main creek as well several major and minor tributaries flowing south-westerly that discharge into Hopkins River. The sub catchment is also noted to contain 242 wetlands over an area of 2293 hectares. This sub catchment contains the Mount Buangor State Park, Mount Cole State Forest, Waterloo State Forest, Fiery Creek Streamside Reserve and Woodnaggerak Bushland Reserve. The average annual rainfall is 500-600 mm and the temperature ranges from 3°C to 26°C.

The major waterways and tributaries within this sub-catchment that are within the study area include:

- Fiery Creek - Fiery Creek is approximately 100 km long from the headwaters near Mount Buangor State Forest north of Buangor on the southern slopes of the Great Dividing Range to Lake Bolac. The creek is a major crossing of the existing highway occurring west of Beaufort. Fiery Creek has a number of smaller tributaries and eventually discharges into Hopkins River. The Creek and its tributaries cross the existing highway alignment at three locations;
- Middle Creek – The Middle Creek headwaters are in Mount Buangor State Forest and discharge into Fiery Creek, with a major crossing at the existing Western Highway. The highway crossings of the creek and its tributaries occur at three locations on the existing alignment. The Fiery Creek River Health assessment indicated that there is an historical diversion on Middle Creek at Listons Road, which was constructed in the 1870-80s for stock and domestic use by several landholders. Approximately a third of the water is diverted from this point into Charliecombe Creek;
- Charliecombe Creek – The Charliecombe Creek headwaters are just north of the highway near Mount Buangor State Forest and discharge into Fiery Creek at Ballyrogan. It is a minor waterway crossing of the highway but also runs along the south side of the highway near Middle Creek. There are three crossings on the existing Western Highway of the creek and its tributaries; and
- Billy Billy Creek - The Billy Billy Creek headwaters are south of the highway near Ballyroger and flow north, crossing the existing highway west of Buangor, then turning south and crossing again through Buangor town. This creek discharges into Charliecombe Creek and then into Fiery Creek, eventually discharging in Hopkins River. There are five crossings of the existing Western Highway of the creek and its tributaries.

5.1.3 Sub-Catchment •H5 - Upper Hopkins River

The Hopkins River is the major waterway of this sub-catchment, with approximately 60 km through this subcatchment. The Upper Hopkins subcatchment encompassing this area is 640 km^2 and contains the Langi Ghiran State Park and the Ararat Regional Park. The existing Western Highway crosses the Hopkins River at one location and also straddles the floodplain at the outlet of Green Hill Lake near the upper Hopkins River and Three Mile Creek. The average annual rainfall is 500-600 mm and the temperature ranges from 4°C to 26°C.

The major waterways and features within this sub-catchment that are within the study area include:

- Hopkins River - The upper tributaries of Hopkins River commence around Mount Langi Ghiran and Telegraph Hill near Ararat and flow south, discharging into the Southern Ocean at Warrnambool. The river crosses the existing and proposed highway alignments at Dobie, and also passes near the south side of existing highway close to Green Hill Lake. This location is near the complex floodplain interaction of the upper Hopkins River, Three Mile Creek (via Green Hill Lake) and Gorrin Creek, to the south of the existing alignment. The Upper Hopkins River and its tributaries cross the existing Western Highway at three locations;
- Green Hill Lake - The Lake is located east of Ararat, is approximately 242 ha and is a major recreational attraction for Ararat. Numerous sub-catchments discharge into the lake, located north of the existing highway, and the lake's spillway discharges under the highway to connect with Hopkins River near the floodplain interaction of the upper Hopkins River; and
- Cemetery Creek – Cemetery Creek is a tributary of the Hopkins River through the Ararat township with source extending to north of Ararat. The confluence of Cemetery Creek with Hopkins River is just downstream of the confluence of Green Hill Lake overflow with the Hopkins River.

5.2 January 2011 Flood Event

5.2.1 Modelling Calibration

High intensity rainfall in mid January 2011 caused major flooding across much of the western and central parts of Victoria. The combination of multiple rainfall events falling in succession on an already saturated catchment led to extensive flooding and road closures along the current Western Highway. During the flooding, the Western Highway was closed from Ballarat to Horsham.

Within the Section 2 study area, major flooding occurred at the Hopkins River (Bonacci 2011) and upstream of Green Hill Lake in Three Mile Creek. The water depth at Green Hill Lake reached 300 mm and a peak discharge for the *Hopkins River at Ararat* stream gauge of 96 m3/s was observed during the flood.

This January 2011 storm event was the largest on record and was used to calibrate the hydrology and hydraulic models that were used for the flood mapping of the 1 in 100 year extents shown in Figure 18, Figure 19 and Figure 20. The storm event could be divided into three defined storm bursts, each with an ARI (Average Reccurance Interval) of between 20-50 years. The storm event resulting from the combination of these three smaller bursts had an ARI (Rainfall) of 90 years and a duration of 101 hours, and the already saturated catchment conditions also contributed to the extensive flooding that occurred as a result of this storm event (Bonacci, 2012). The observed peak discharge for the Hopkins River gauge (95.9 m3/s) was used as the primary target for the calibration process of the hydrology model

developed by Bonacci (2012). In terms of peak flow this equates to an event that is similar to a 1 in 100 year flow on the Hopkins River (although this is not explicitly stated in the Bonacci report). It is worth noting that for the model verification for other locations indicates that the 2011 event may have exceeded the 1 in 100 year event (eg. Concongella Creek near Great Western - relevant for Section 3 of the Western Highway Project).

Inputs into the hydrologic model used as part of the calibration process included environmental conditions, natural losses, soil conditions and flow characteristics. To verify the model, a comparison between the output hydrograph from the hydrology model at the *Hopkins at Ararat* gauge location for the January 2011 event and the actual Hopkins River gauge recorded hydrograph was made by plotting the two hydrographs. The general shape of the river hydrograph was reproduced by the hydrology model and was accepted by Bonacci (2012) as a reasonable outcome.

The final calibrated model was run to simulate a range of storm events using design storms of different ARI's. The outputs of the hydrologic model were input into the Tuflow hydraulic model to generate flood extents and depths across the study area. Results from the hydraulic model were then compared against surveyed flood marks, and levels and extents estimated from photographs of the 2011 event and aerial photography in order to verify the model (Bonacci, 2012).

5.2.2 Anecdotal Flood information

For Section 2 there was limited data available for direct calibration. We note at a location on the highway between Ararat and Green Hill Lake there was observed overtopping of the highway.

From the photos at Figure 3 of the 2011 flood event, it is evident that there was flooding over the existing highway within the section of highway between Ararat and Green Hill Lake. The flood conditions appear to be combination of local catchment flows combining with a breakaway flow path from Cemetery Creek. The flow condition at the highway crossing is compounded by the low lying area downstream of the highway that causes backing up of floodwaters. Subsequent modelling was undertaken to reconcile these local flood conditions during the 2011 event.

Figure 3 **Photos from VicRoads of the January 2001 event showing flooding over the existing Western Highway between Ararat and Green Hill Lake**

5.3 Hydrologic Assessment of Study Area

VicRoads had commissioned Bonacci Water to undertake a flood study for the existing Western Highway. This included an analysis of topographic data and preparation of a digital terrain model for the hydrological and hydraulic assessments relevant to the Western Highway between Beaufort and Stawell. The stormwater sub-catchments were determined for input into the model, the definition of which impacts the project area and assessment of flood interaction with the highway. Some key findings from the Final Report (April 2012) are summarised below:

Topographical data used in the assessment included:

- Light Detection and Ranging (LIDAR) data for the 3 km wide strip running the length of the highway alignment commissioned by VicRoads, allowing for 1 m contours;
- Contour data from DSE for the entire catchment – 10 m contours; and
- Commissioned survey at Green Hill Lake and Ararat Prison. ; and
- Data collected during field inspections.

The existing data was deemed sufficient for the purpose of flood investigation along the highway alignment, with insufficient data only in areas south of the alignment, not expected to affect the flooding upstream.

Rainfall gauges at Ararat and Ararat Prison were used to determine the ARI events and long term annual rainfall for this section of the Western Highway, with average annual rainfall depths mostly between 400-800 mm. The stormwater catchments contributing to the existing highway alignment were then determined, with catchment identification shown in Figure 4 and catchment flow in relation to the highway shown in Figure 5.

A Water Urban Flow Simulator (WUFS) hydrology model was set up with design storm parameters from Australian Rainfall and Runoff (IEAust 1987). The model included analysis of the upper Hopkins River, enabling the model to be calibrated and confirmed to recorded flows at a nearby gauging station on the Hopkins River (236219). The data used was from DSE data warehouse between May 1989 and August 2011. A description of these sub-catchments, their location within Glenelg Hopkins CMA defined subcatchments (described above in Section 5.1) and the major waterways are detailed in Table 7.

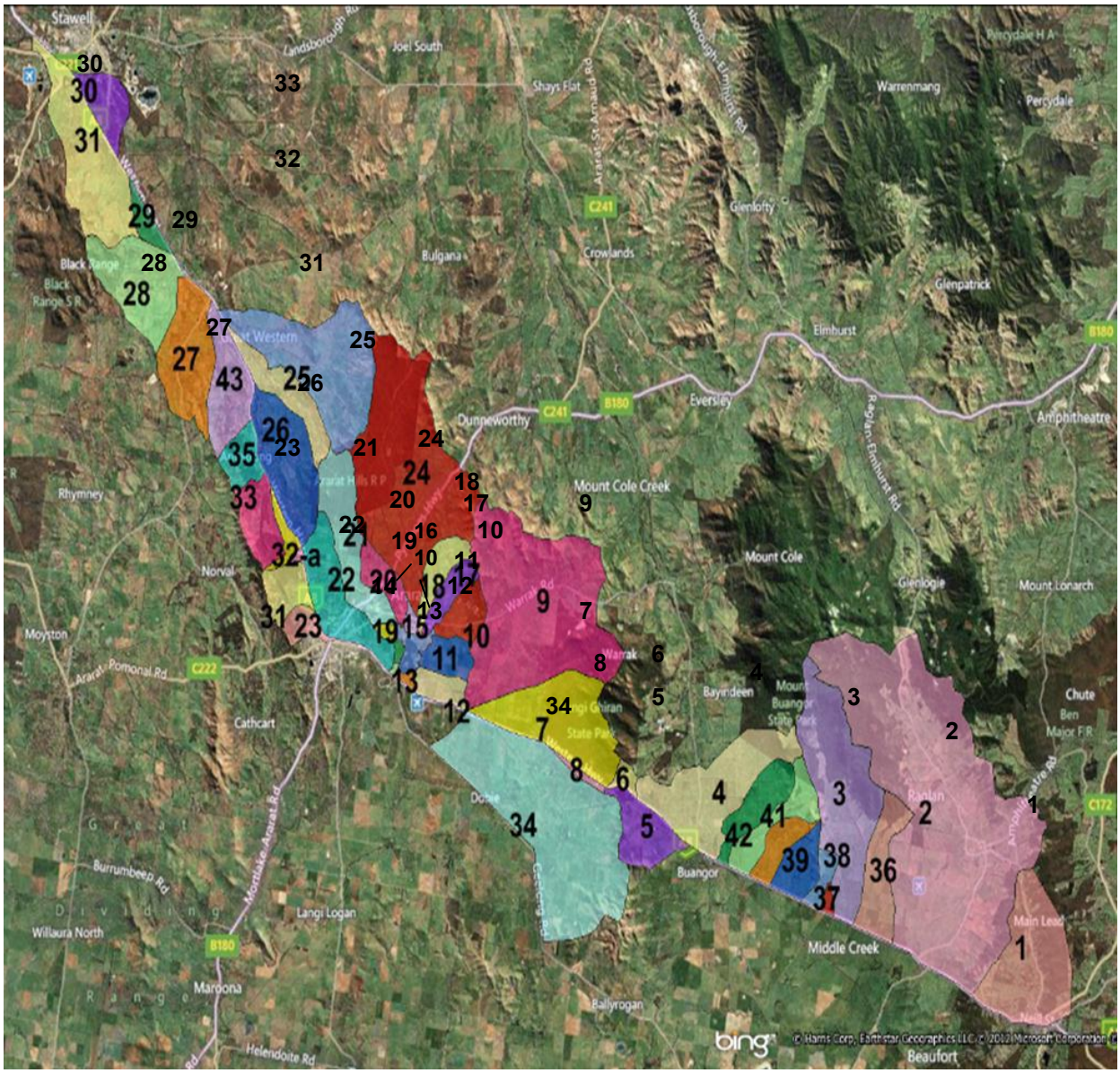

Figure 4 Identification of the Western Highway Stormwater Catchments (Bonacci 2012)

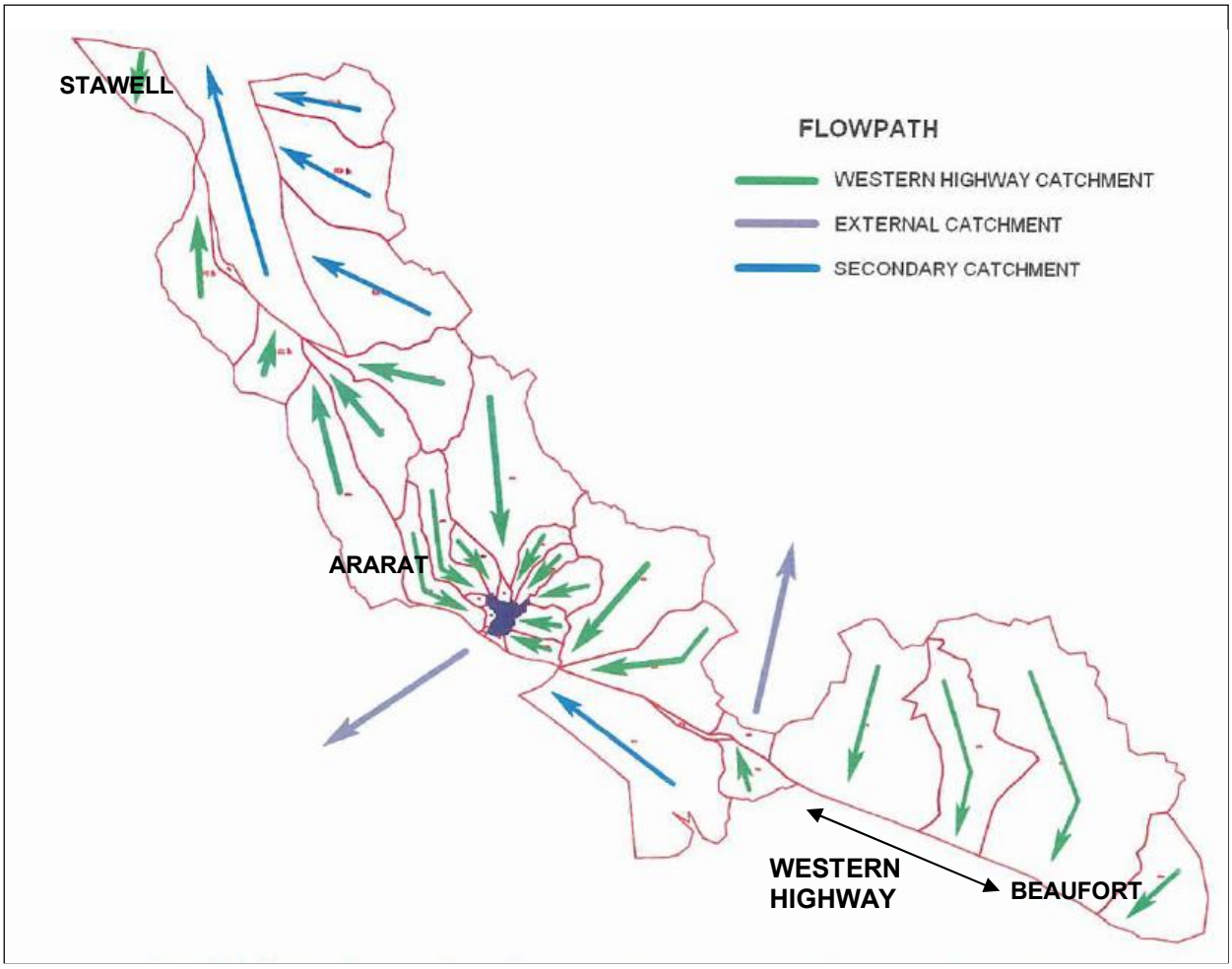

Figure 5 **Stormwater flowpaths in the stormwater catchments adjacent to the Western Highway (Bonacci 2012)**

Table 7 Sub-catchment Details

GHCMA Sub Catchment	Bonacci Subcatchment (Figure 4)	Surface Water System	Interference with existing Western Highway
H10	**1**	Yam Holes Creek	Tributaries to Yams Hole Creek west
H12	**2**	Fiery Creek	Fiery Creek and its tributaries
	3	Middle Creek	Middle Creek and its tributaries
	4	Charliecombe Creek/Billy Billy Creek	Billy Billy Creek, Charliecombe Creek and their tributaries
	5	Billy Billy Creek	Billy Billy Creek, and its tributaries
	6	Billy Billy Creek	Tributaries to Billy Billy Creek
H5	**7**	Major tributary to Hopkins River	Does not Cross until 9
	8	NA	No obvious drainage paths
	34	Gorrin Creek	Does not cross (upper tributaries)
	9	Hopkins River	Hopkins River
	10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	All drain to Green Hill Lake	Green Hill Lake spillway channel crosses highway
	22	Cemetery Creek	Cemetery Creek crosses highway outside of study area – flood flows diverted to within study area

5.3.1 Estimation of Flows

From the Bonacci Flood study, the hydrologic assessment was used to determine flow estimates for the flood modelling. The flood modelling was undertaken for the main flood plain systems and did not extend to each identified crossing location. Many of the minor crossings that are in the upper catchment areas or are minor drainage flow paths and were not modelled. Table 8 provides a summary of the interpreted flow information from the Bonacci modelling as well corresponding estimates of flow at crossings using the VicRoads rational method for estimating peak flows (it is noted estimates are available for identified crossing locations including non-modelled locations). Refer to Appendix A for the GHD referenced crossing locations.

Table 8 VicRoads Rural Rational Method 100 year ARI peak discharge

GHD Crossing reference	Bonacci Catchment	Bonacci Culvert crossing	Bonacci 100 year ARI Flow (m3/s)	Catchment Area (ha)	VicRoads Rational Method 100 year ARI Flow (m3/s)
WB211	2	1	40	9250	30
WB212	3	2	8.2	930	9.3
WB213	3	3	16.6	2460	15.8
	3	3 East			
WC214	3	4	0.95	38	1.0
WC215	4	5	3.0	174	3.3
WC216	4	6	7.2	505	6.7
WC217	4	7	5.8	1323	11.4
(WC221)	4	8		653	7.8
(WC223)	4	9		643	7.8
(WA225)	4	10		2835	17.2
(WB228)	5	11	9.4	787	8.4
(WC237)	6	11 W, 11 N		142	2.9
WA243	9	12	46.8	6955	26.2
WB244	Green Hill	13	28.2	8380	29.5
WC245		14	0.3	23	0.7
Cemetery Ck	22	15	35	1200	

5.4 Identification of Waterways

This section identifies the waterways likely to be impacted by the Western Highway Project Section 2 study area between Beaufort and Ararat. The identification of waterways has been based on a review of the Vicmap Hydro Watercourse dataset (December 2007).

Table 9 provides a summary of the identified waterway crossings. The crossings have been divided into major waterways (designated river or stream) and minor waterways (unnamed tributary stream or drainage line). A mapbook showing the location of each waterway crossing has been included in Appendix A.

Table 9 Summary of Existing Waterway Crossings

	Number of Crossings	Waterway
"Major" Waterways	2	Hopkins River Billy Billy Creek (×2)
"Significant" Waterways	7	Fiery Creek Middle Creek Charliecombe Creek (x3) Billy Billy Creek (×1) Green Hill Creek
"Minor" Waterways	22	Tributary of Cemetry Creek (x1) Tributary of Hopkins River (x5) Tributary to Billy Billy Creek (× 4) Tributary of Charliecombe Creek (×2) Drainage line and Tributary of Middle Creek (x2) Tributary of Fiery Creek (x2) Tributary of Yam Holes Creek (x6)

Table 10 provides details of each of the waterway crossings identified within the Bonacci hydrologic assessment and identification of waterways from VicMap where they cross the proposed alignments. A summary of the waterway crossings within the Bonacci catchment systems and distinction between major/significant and minor crossings is provided below (including reference to whether the crossing is a duplication or deviation). There are 3 options where specific crossing locations are indicated.

Table 10 Details of Waterway Crossings of Proposed Alignments

Bonacci Subcatchment	Highway Alignment Option	Chainage ref	Major/Significant Watercourse Crossings	Minor Watercourse Crossings
1	Duplication/ Deviation (all Options)	**Ch. 840 – 2400**		Tributaries to Yams Hole Creek (WC203, WC204, WC205, WC206, WC207)
2	Duplication (all Options)	**Ch. 2400 – 7200**	Fiery Creek x1 (WB211)	tributaries to Fiery Creek (WC206, WC207, WC208, WC209-side road, WC210-side road)
3	Duplication (all Options)	**Ch. 7200 – 11800**	Middle Creek (WB213)	2 x tributaries to Middle Creek (WC212, WC214)
4 Ch. 11800 – 20000	Duplication	**Ch. 11800 – 16000**	Charliecombe Creek (WB216, WB217)	2 x tributaries of Charliecombe Creek (WC216, WC218)
	Deviation (all Options)	**Ch. 16000 – 20000**		2 x tributaries of Billy Billy Creek (WC220, WC221, WC222-side road)
	Deviation (Option2)		Billy Billy Creek (WA226)	tributaries of Billy Billy Creek (WC223)
	Deviation (Option1,3)		Billy Billy Creek (WA225)	tributaries of Billy Billy Creek (WC224, WC227)
5 (flowing north-east) Ch. 20000 - 25000	Deviation (Option2)			tributaries of Billy Billy Creek (WC229, WC230, WC231, WC232)
	Deviation (Option1,3)		Billy Billy Creek (WB228)	
6 (flowing south-east) Ch. 20000 - 25000	Deviation (Option 1)			tributaries of Billy Billy Creek (WC236, WC237)
	Deviation (Option 2)			tributaries of Billy Billy Creek (WC233, WC234)
	Deviation (Option 3)			tributaries of Billy Billy Creek (WC238)

Bonacci Subcatchment	Highway Alignment Option	Chainage ref	Major/Significant Watercourse Crossings	Minor Watercourse Crossings
7 **Ch. 25000 - 33600**	Duplication			NA – no identified waterways Tributary to Hopkins River (New crossing WB243A – side road)
8	Duplication		NA	NA – no identified waterways
34	Deviation (Option 1)	**Ch. 25000-28000**		tributaries of Gorrin Creek (WC239, WC240, WC242) and 1x tributary of Hopkins River
9 **Ch. 33600**	Duplication (all Options)		Hopkins River (WA243)	
Green Hill Lake **Ch. 38200**	Duplication (all Options)		Green Hill Lake outflow channel (WB244)	
22	Duplication (all Options)			Tributary to Cemetery Creek/Hopkins River (WC245)

Further details of the major waterways and their condition, focused on the existing highway crossing, can be found in Appendix B.

A listing of waterway crossings of all alignments is provided in Appendix E.

5.5 Waterway Characteristics

The following section provides a general description of the waterways identified in Section 0. These waterways are included as part of the Hopkins Basin within the Glenelg Hopkins Catchment Management Authority (GHCMA) region. The Hopkins Basin is located in the eastern section of the Glenelg Hopkins region and covers an area of 10,096 km^2 (GHCMA, 2004).

The GHCMA River Health Strategy (GHCMA RHS) states that there are no priority sub-catchments in the Hopkins Basin for restoration activities (GHCMA, 2004). However, some reaches have been recognised for the maintenance of social and economic values. The existing Western Highway is located within sub-catchments 5, 10 and 12. These catchments are not listed as containing priority reaches (GHCMA, 2004).

A detailed assessment of the waterway conditions has been undertaken. This was initially done via desktop assessment, and subsequently field investigations were undertaken of select existing and proposed crossing locations subject to accessibility.

A summary of the key features of the “significant” and “major” waterways is summarised in Table 11 .

Table 11 Summary of Waterway Characteristics

Waterway Crossing	Waterway	Description	River Health (observation)
WB211	Fiery Creek	Straightened channelized creek with exposed banks with slumping in some sections	Low diversity with channel choked with reeds
WB213	Middle Creek	Perennial waterway with well vegetated channel (including willows) and pool-riffle features	Some diversity (reeds, rushes), although vegetation dominated by willows
WB215, WB216, WB217	Charliecombe Creek	Ephemeral waterway, well vegetated in patches but predominately cleared banks with uncontrolled stock access	Highly disturbed, with some reeds and pastoral grasses
WA225, WA226, WB228	Billy Billy Creek	Ephemeral waterway with pool-riffle features with well vegetated banks and habitat features (eg large woody debris)	Good diversity including in stream pool-riffles with sedges and reeds, and pockets of woody vegetation
WA243	Hopkins River	Large channel with variable in stream features and bank conditions alternating between dense vegetation and exposed banks	Variable bed and bank condition with high value features
WB244	Green Hill Creek	Ephemeral, channelised waterway that connects Green Hill Lake with the Hopkins River	Highly disturbed, dominated by pastoral grasses

Fiery Creek

(WB211 – Significant)

Fiery Creek is a low sinuosity, incised channel composed of fine grained sediments. The channel is approximately 1.5 m deep and 6-8 m wide. The channel is set within ledges that extend for 5 m on either bank up to the floodplain (Figure 6 and Figure 7). The ledges are sculptured features that have formed through the removal of soil from the floodplain over time during overbank flows.

Downstream of the existing highway crossing the channel widens to 10 m wide and 4 m deep. Undercutting and slumping of the banks was observed during the field visit along sections of the waterway upstream of the existing highway crossing. Downstream of the existing crossing areas of mass slumping and incision had exposed banks. Instream features include vegetated islands with riparian and aquatic species including sedges, reeds, grasses and willows (Figure 7).

This section of Fiery Creek is located within ISC reach #29 and has a very poor condition score.

Figure 6 Fiery Creek looking upstream, just north of existing highway bridge

Figure 7 Fiery Creek looking downstream, north of existing bridge

Middle Creek

(WB213 – Significant)

Middle Creek is a perennial waterway approximately 6-10 m wide and less than 1 m deep. The channel is well vegetated and shade is provided to most of the waterway (Figure 8). Riparian vegetation is made up of some native species but downstream of the existing highway crossing the channel is choked with exotic species such as willows.

The existing highway crossing is composed of two outer culverts with 1 m diameters and a middle culvert with a trapezoidal shape. A permanent pool extends 15 m upstream and 20 m downstream of the existing crossing. Willows located at the end of the pool (Figure 9) provide substantial grade control as the waterway undergoes a 2 m drop.

The Middle Creek floodplain contains large red gums that spread at least 100 m along either bank. Some exposed sections of bank were observed downstream of the existing crossing. There is some potential for lateral adjustment of the creek on the floodplain but any movement would be constrained by the root mass of the riparian vegetation which hold the bank in place.

Figure 8 Middle Creek, looking upstream beyond pool; channel becomes narrow

Figure 9 Middle Creek, looking downstream from right bank showing the root mass that controls water levels in the pool under the existing crossing.

Charliecombe Creek

(WB215, WB216, WB217 – Significant)

Charliecombe Creek is an ephemeral waterway which intersects the existing highway three times. The channel is well vegetated along most of its course (Figure 10 and Figure 11) although some exposed banks were observed as the waterway flowed through paddocks and agricultural areas. Pugging from stock access was also observed along the creek.

The creek runs parallel with Highway in road reserve for approx. 70 m before turning north through open paddocks. The creek is shallow for most of its course but widens at each of the highway crossings. Broad floodplains run from either side of the creek for approximately 150 m and because of this there is potential for lateral adjustment of the channel.

Figure 10 Charliecombe Creek, looking upstream, north of the Highway

Figure 11 Charliecombe Creek, facing east, downstream of road bridge

Billy Billy Creek

(WA225, WA226 - Major, WB228 – Significant)

Billy Billy Creek is an ephemeral waterway that intersects the existing highway three times. Two of the crossings are major crossings and one is significant. The waterway is located within Crown land but the floodplain has been cleared for grazing and blue gum plantations. The floodplain extended for 60 m from either side of the creek. Within the Crown reserve the riparian zone is well vegetated (Figure 12).

The channel is unconfined and approximately half a metre deep and 3 m wide. The channel is composed of pools and runs and widens at the pools. Standing water observed in the pools indicated that the pools were deeper than the runs (Figure 13). As identified in the Flora and Fauna report (Ecology and Heritage Partners 2012) there are Dwarf Galaxias present in Billy Blly Creek.

The channel has gently sloping banks but there is evidence of undercutting and scour around the pools. Along the creek runs, the banks are well vegetated to the toe. Some large woody debris was present instream.

Figure 12 Billy Billy Creek, looking upstream at the top of the reach

Figure 13 Billy Billy Creek, looking downstream from the large pool

Hopkins River

(WA243 – Major)

The Hopkins River at the existing road crossing is a low sinuosity, ephemeral waterway. Downstream of the existing crossing, the channel is approximately 3.5 m deep and 15 m wide. The Ballarat - Ararat railway line runs parallel to the highway on the upstream side at this site and there is an open pool under the existing bridges. The channel narrows again upstream of the railway crossing.

Sand deposition and scour were observed within the Hopkins River channel during the site visit. The river banks were very steep in some sections and undercutting of the banks was also observed. Along this section of channel the areas of bank alternate between regions of dense vegetation and exposed bank (Figure 14). The floodplain is estimated to be over 500 m wide on either side of the river.

The Index of Stream Condition (ISC) 2004 provides a bench mark of Victorian river conditions for a number of waterways across the state. This section of the Hopkins River is located within ISC reach #12 and has a moderate condition score.

The existing highway crossing is a bridge with two columns, 4.5 m high and a span of 25.8 m (Figure 15). The railway crossing is made up of nine 3.5 m diameter culverts.

Figure 14 Hopkins River, looking from the existing highway bridge, facing south west

Figure 15 Hopkins River, looking upstream from the south side of the existing highway bridge

Green Hill Creek

(WB244 – Significant)

Green Hill creek is a small, ephemeral, waterway that connects Green Hill Lake with the Hopkins River. The creek is located within the Hopkins River floodplain. The creek banks are well vegetated with grasses (Figure 16) and there is some instream vegetation present upstream of the existing highway crossing.

Green Hill Creek is approximately 2 m deep and 12-15 m wide. The current highway crossing consists of five 1.8 m by 3 m box culverts (Figure 17). Downstream of the current crossing the creek grade has been reinforced by a rock chute.

The creek is geomorphologically unconfined but channel mobility is restricted by the rail and highway embankments. The channel has incised (Figure 16) due to a reduced supply of sediment to the waterway as a result of Green Hill Lake acting as a sediment trap.

Figure 16 Green Hill Creek, looking downstream from the existing highway crossing

Figure 17 Green Hill Creek, looking downstream at the existing highway crossing

5.6 Floodplain Hydraulic Assessment

The hydrologic and floodplain assessment portion of this report is largely based on work undertaken by Bonacci Water, comprising an initial hydraulic analysis in 2011 and subsequent remodelling completed throughout 2012 documented in the Bonacci Water[2] report (August 2012). The assessment by GHD documented in this report is based on findings from the report and the interpretation of the flood modelling outputs provided by Bonacci Water, subject to the limitations and assumptions outlined in Section 4.3 of this report.

A summary of the flood mapping undertaken for the main sub catchment systems is summarised in Table 12 below.

[2] As of August 2012 the modelling has been undertaken TGM and Urban Water Solutions (by former employees of Bonacci Water) To avoid confusion the terminology has been kept consistent and any reference to "Bonacci Water" subsequent to August 2012 refers to the work of TGM and Urban Water Solutions.

Table 12 Summary of Flood Mapping (Section 2)

Sub Catchment	Surface Water System	Flood Extent Mapping
H10 Trawalla Ck (GHCMA)	Yam Holes Creek	Beaufort township - No mapping within study area
H12 – Upper Fiery Creek (GHCMA)	Fiery Creek & tributaries	Fiery Creek & Middle Creek Charliecombe Creek & Billy Billy Creek
H5 – Upper Hopkins River (GHCMA)	Hopkins River & tributaries	Hopkins River & Tributaries (inc Green Hill Lake and Cemetery Creek)

At this stage, the flood mapping provides information of locations of major highway flooding and approximate extents. The outputs from the Bonacci report for Section 2 can be seen in Figure 18, Figure 19 and Figure 20. The flood extents have also been shown with respect to the proposed alignment options within the maps in Appendix C. A summary of the sections of existing highway impacted by flooding are detailed below.

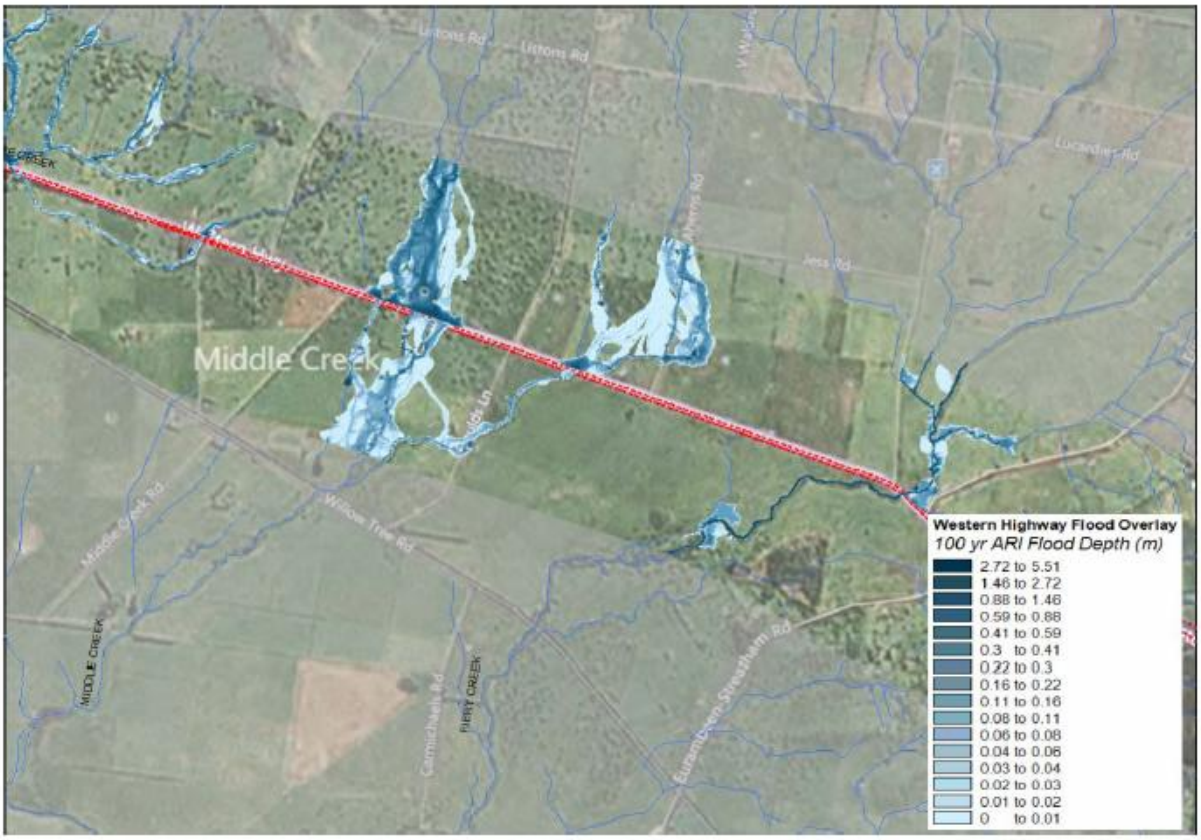

Figure 18 100 Year ARI Flood Overlay for Beaufort section of works (Bonacci Water, August 2012)

The above Figure 18 includes the alignment from Beaufort to Middle Creek and includes the sub-catchments 1, 2 and 3 and the waterways Fiery Creek and Middle Creek. In summary, from the interpretation of the modelling information:

- Fiery Creek (first waterway from the right in Figure 18) is obstructed by the highway, causing shallow backwater flooding behind the road over a width of 400m. The flow is contained within the existing larger bridge structure and there is no flow over the road;
- Middle Creek including tributary (waterway central in Figure 18) – Flooding occurs across road at both the tributary and at the main Middle Creek crossing where there is a wide braided floodplain upstream of existing highway with Middle Creek and associated flow paths resulting in backwater flooding . Flow sheets across the road over a width of 700m

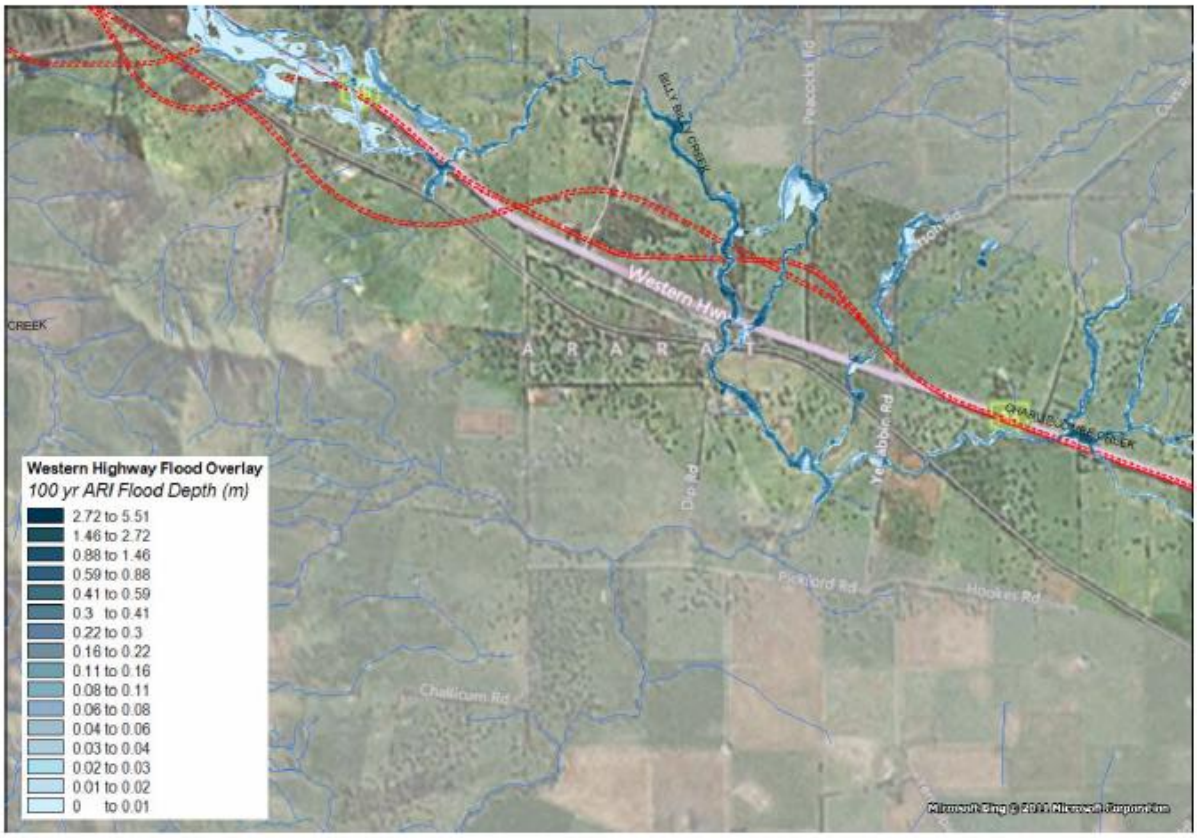

Figure 19 100 Year ARI Flood Overlay for Beaufort to Ararat section of works (Bonacci Water, August 2012)

Figure 19 includes the alignment from Middle Creek to west of Buangor and includes the sub-catchments 4, 5 and 6 and the watercourses Billy Billy, Charliecombe and Middle Creeks. In summary, from the interpretation of the modelling information:

- Charliecombe Creek including tributary(Figure 19) - Flow backs up and overtops existing highway at confluence of Charliecombe Creek with tributaries, with upstream property impacted; and
- Billy Billy Creek at Buangor (Figure 19) – Significant backwater flooding is occurring behind the existing highway from both Billy Billy Creek and tributaries. Significant flooding is indicated across the existing highway. It is noted that the proposed road options deviate from the existing highway alignment where this flooding occurs.
- Billy Billy Creek west of Buangor and upstream tributaries (Figure 19) – There is a relatively narrow crossing under the existing highway west of Buangor, however there is overbank flooding of many tributaries of Billy Billy Creek that will also affect proposed road option alignments. The modelling indicates that the existing highway is flood affected at various locations, but it is noted that for the majority of this length the proposed road options deviate from the existing highway alignment.

Figure 20 100 Year ARI Flood Overlay for Ararat & Green Hill Lake section of works (Bonacci April 2012)

The above Figure 20 shows the alignment from west of Buangor to Ararat and includes the Bonacci sub-catchments 7 to 24. Water courses included in this section are the Hopkins River and Green Hill Lake. In summary, from the interpretation of the modelling information:

- The Hopkins River (right side of Figure 20) backs up behind the highway and railway embankments at Dobie, but does not overtop the highway ;
- Three Mile Creek subcatchment (middle of Figure 20) discharges to Green Hill Lake whose spillway channel crosses the existing highway just east of Ararat prior to discharging into Hopkins River, south of the highway. This is a complex floodplain area with the interaction of the upper Hopkins River, Three Mile Creek (via Green Hill Lake) and Gorrin Creek. There is some backwater flooding behind the length of the existing highway south of Green Hill Lake from Green Hill Lake and confluence of Hopkins River as it runs adjacent to the south of the highway; and
- Cemetery Creek (left side of Figure 20 near Ararat) overtops the road near Ararat (outside of the study area), but breakaway flows are directed toward a local catchment and low point in the existing highway where overtopping occurs (as was evidenced in January 2011).

The existing Western Highway and associated road features are located within complex floodplain environments such as Middle Creek, Charliecombe Creek and Billy Billy Creek. From the modelling results, at a number of locations the 100 year ARI flood extent behind the highway stretches for several hundred metres, and in some locations property and dwellings are affected. There are a number of crossings where a significant portion of flood flows currently overtop the highway, indicating the level of protection for the road is relatively low.

For the following locations the existing highway is overtopped in the modelled 100 year ARI flood event:

- Tributary of Middle Creek (Crossing WB212)
- Middle Creek and tributary flowpath (Crossings WC213 & WC214)
- Charliecombe Creek (WB217)
- Billy Billy Creek at Buangor (downstream of proposed WA225)
- Billy Billy Creek west of Buangor (WB228)
- upstream tributaries of Billy Billy Creek
- Cemetery Creek break away flow east of Ararat (WC245)

For the proposed Western Highway Project in Section 2 various major road features including proposed interchanges are located in areas of complex floodplain structure. Detailed flood extent maps are provided in Appendix D of the various modelled flood extents and the interaction with the existing highway and footprint of the proposed highway. A listing of the modelled waterway crossings is provided in Appendix F. Table 13 contains an outline of the flooding issues interpreted from the 100 year ARI flood mapping.

Table 13 Interpretation of Existing Flood Conditions (100 Year ARI)

Section	Sheet No.	Waterway	Crossing ID	Description of Existing Flooding Conditions
Section 2 Beaufort to Ararat	1	Fiery Creek	WB211	The flow is contained within the existing bridge structure with no flow over the road. There is shallow backwater ponding upstream of the existing highway embankment across a width of 300m in the eastern floodplain.
	2	Tributary of Middle Creek	WC212	Flow spills out of the tributary of Middle Creek and backs up behind the Highway for a width of >500 m, with sheet flow over the road across a width of >100m.
	3	Middle Creek and tributary of Middle Creek	WC213	Complex braided floodplain upstream of existing highway with Middle Creek and associated flow paths resulting in backwater flooding over a width of ~1 km causing flooding to properties immediately upstream. Flow sheets across the road over a width of ~700m with greater depths at locations away from the main channel to the east. There is limited culvert connection across the width of the upstream floodplain.
	4	Charliecombe Creek	WB215	Flow backs up behind the existing highway and spills out of the channel, causing flooding to the property immediately upstream. Significant flow appears to be diverted to the adjacent catchment but there is no flooding over the road.

Section	Sheet No.	Waterway	Crossing ID	Description of Existing Flooding Conditions
	5	Charliecombe Creek	WB216 WB217	Complex confluence of waterways where several tributaries converge with Charliecombe Creek north of the Highway. There are properties upstream of crossing WB217 that remain unaffected by flooding. The existing highway is not overtopped at WC216 but is overtopped within the confluence backwater at WB217 over a width of >100m.
	6	Tributaries of Billy Billy Creek	WC219, WC220, WC221	Backwater ponds behind the existing highway embankment. Flow is diverted parallel with the road towards the adjacent catchment. However water does not overtop the road. The proposed highway deviation and interchange is within the flooding backwater. There will need to be significant new crossings as part of the interchange footprint.
		Tributaries of Billy Billy Creek	WC223, WC224	Floodwaters backup behind existing highway. New highway is deviation upstream of existing highway and will require significant new crossings as part of the interchange footprint.
		Billy Billy Creek	WC225, WC226	Floodwaters backup behind the existing highway. New highway is deviation upstream and will require significant new crossings.
	7	Billy Billy Creek	WB228	Backwater ponds behind the existing highway embankment. Water overtops the road across a width of <100m at this crossing location. Modelling currently shows significant flooding at several locations along the existing highway from upstream flow paths of Billy Billy Creek.
	8	Hopkins River	WA243	Some backwater ponds behind the existing highway embankment and upstream railway embankment, however water does not overtop the road. The downstream flow path is relatively confined.
	9	Green Hill Creek	WB244	Some backwater ponds behind the existing highway, but flow remains predominately within the channel.
		Tributary of Cemetery Creek	WC245	Local flooding compounded with overflow from Cemetery Creek leads to significant flooding of the existing highway.

5.7 Waterway Health Assessments

The following provides a broad overview of current waterway condition based on information documented in the Glenelg Hopkins River Health Strategy, the Glenelg Hopkins Regional Catchment Strategy, Catchment Health Report on Fiery Creek and a desktop assessment of waterway condition at each crossing location.

5.7.1 Regional River Health Strategy

The Glenelg Hopkins River Health Strategy 2004-2009 (RHS), provides a five year blue print for improving the health of rivers and creeks in the region. The RHS identifies the regional importance of waterways within each catchment area and sets management objectives to improve the current condition of these waterways. The following provides a summary of the sections of the RRHS relevant to the waterways identified in Section 5.1 of this report.

Hopkins Basin: Apart from small areas of remnant forest, the basin has been substantially cleared of native vegetation and now supports significant agricultural activity. There are no priority sub-catchments in the Hopkins Basin for restoration activities, however, some reaches are recognised for maintaining high social and economic values. The environmental quality of the various waterways within the identified catchment systems varies between reaches.

Index of Stream Condition (ISC) is a rapid assessment method, that was applied statewide in Victoria in the 1990s and 2004 to indicate river issues and provide a river condition benchmark. Table 14 presents a summary of the sub index ratings of various ISC key parameters for relevant waterway reaches based on the 2004 assessment, available at Victorian Water Resources Data Warehouse.

Table 14 Condition of River Health relevant Waterway Reaches 1999 and 2004 Assessment

Reach Name	Upper Hopkins River H5-Reach 12		Upper Hopkins River H5-Reach 11		Fiery Creek H12-Reach 29	
Relevance to Highway	From headwater to just downstream of highway		Commences just south of highway Green Hill Dam		From headwater to south of highway	
Length (km)	22.5		15		32.5	
	1999	2004	1999	2004	1999	2004
Hydrology	6	6	6	6	2	2
Physical Form	5	3	4	3	2	1
Streamside Zone	5	4	6	3	7	2
Aquatic Life			NA	4+		
Overall ISC Score	NA	20	NA	18	NA	8
ISC Condition	Marginal	Moderate	Poor	Moderate	Poor	Very Poor

Sub index ratings are 1-10 (very poor to excellent), 1999 values were revised to suit the 2004 methodology (overall score not revised).

A summary of the River Health Condition of the catchment systems is provided in Table 15.

Table 15 River Health Condition Summary

Sub Catchment	Surface Water System	ISC Condition Assessment	Other Comments
Section 2			
H10 Trawalla Ck (GHCMA)	Yam Holes Creek	n/a	
H12 – Upper Fiery Creek (GHCMA)	Fiery Creek & Tributaries	Very Poor	Riparian vegetation – poor; Significant flow stress; Habitat value varies; Dwarf Galaxias on Billy Billy Ck
H5 – Upper Hopkins River (GHCMA)	Hopkins River & Tributaries	Moderate	Environmental values varies between reaches; Brown Toadlet

5.7.2 Glenelg Hopkins Regional Catchment Strategy

The Glenelg Hopkins Regional Catchment Strategy 2012-2018 (RCS), which is currently in draft form, sets the direction for how the region's land, water and biodiversity resources should be managed, by providing a framework for the coordinated management of sub-catchments within the broader Glenelg-Hopkins catchment area.

The RCS provides information on the catchment area, including the assets and their current condition. The assets considered are Community, Rivers and Floodplains, Wetlands, Estuaries, Coasts, Marine, Terrestrial Habitat, Species Populations and Communities and Soil/Land.

The main threats to the environmental, social and economic values of the rivers in the region are listed as:

- stock access to riparian zones;
- land use change to more intense farming practices;
- pest plants and animals;
- flow deviation; and
- barriers to native fish migration.

These threats lead to multiple impacts including bank and bed instability, loss of instream and riparian habitat, reduced water quantity, reduced water quality, and reduced aquatic and terrestrial biodiversity.

Despite these threats, the RCS states that streams within the Hopkins Catchment are generally physically stable, with only minor erosion associated with stock access. Blue-green algal blooms have occurred with increasing frequency in some areas. Other threats impacting on streams and rivers in the Hopkins catchment are clearing of native vegetation and the introduction and spread of exotic species. Poor water quality due to rising salinity, increased sedimentation and nutrient enrichment has been a problem in some areas although this has improved recently with the return of high flows after the drought.

5.7.3 Catchment Health Report Fiery Creek

A study was undertaken in 2006 by Dion Gervasi for GHCMA on H11 & H12 Catchment Health report which included Lake Bolac, Fiery and Salt Creeks. The report was undertaken to identify knowledge gaps in the information relating to waterway health, land use and management within the Fiery and Salt Creeks and Lake Bolac sub-catchments within GHCMA. Some key details identified in the study about Fiery Creek and its tributaries are detailed below:

- Riparian vegetation in the H12 catchment can be considered poor as only 7% of the waterways in the catchment have a good natural vegetation cover (GHCMA 2004);
- Groundwater is a significant water resource with an estimated 90 bores in the H12 catchment (Interactive Maps- Catchment and Water Mapper, www.dse.vic.gov.au); and
- Western Victoria is home to many natural wetlands. Specifically, the H12 catchment has 242 wetlands covering an area of 2293 hectares (GHCMA 2006b).

From the above detailed GHCMA RHS, none of the waterways in subcatchment H12 was classified as ecologically healthy, however it is worth noting that there are many reaches on Fiery Creek, its tributaries and wetlands that provide habitat for a wide variety of wildlife. During a recent walk (2006 hEELing Walk) from the headwaters of Fiery Creek to Lake Bolac, participants observed many areas where the creek appeared to have a high value (good riparian vegetation, good water quality etc.), although many degraded areas were also noted along the creek.

In relation to steam flow, the impact water extractions are having on stream flow is determined by comparing predicted natural stream flows to current stream flows. Flow Stress Ranking data for Fiery Creek indicates that it is under significant flow stress. Fiery Creek was among the lowest ranking streams in the State, i.e. current flows have been substantially modified. In particular, flows over summer have been reduced with both low flows and cease to flow periods being the flow components most affected.

The report concludes that the surface water resources are stressed with large flows (<100 ML/day) not occurring in Fiery Creek (Streatham) since 1995 (however, the large event on 13 Jan 2011 recorded a peak of 1560 ML/d). Despite the salinity discharge pattern from the Fiery Creek not appearing to have changed a great deal from 1990-98, the decreased flow causes the impacts of elevated salinity levels in Fiery Creek to be exacerbated.

5.7.4 Ecological Assessment of Waterways

An ecological assessment of Flora and Fauna, including aquatic and riverine species has been undertaken as part of the EES by Ecological and Heritage Partners.

From their investigation a number of Nationally significant and State significant species are known to exist within the study area associated with the waterways:

- Nationally Significant – Growling Grass Frog, Dwarf Galaxias.
- State Significant – Brown Toadlet, Goldern Perch, Mountain Galaxias.

As part of the flora and fauna investigations, targeted aquatic surveys were undertaken on the various waterways including in stream habitat assessments, macro invertebrate and aquatic (fish) surveys. A summary of the findings documented in the Flora and Fauna report (Ecological and Heritage Partners 2012) is provided in Table 16.

Table 16 Summary of Waterway Characteristics

Waterway Crossing	Waterway	In stream Habitat	Macro invertebrate	Aquatic Surveys
WB211	Fiery Creek	Riparian condition (very poor) Overhanging vege (10%) Macrophyte cover (10-30%)	Family taxa (27-high) Macroinvertebrae (SIGNAL score 5.56 - moderate)	No Significant species Southern Pigmy Perch (100)
WB213	Middle Creek	Riparian condition (poor) Overhanging vege (<10%) Macrophyte cover (3-5%)	Family taxa (18-high) Macroinvertebrae (SIGNAL score 6.0 – High, indicating healthy)	No Significant species Southern Pigmy Perch (107)
WB215, WB216, WB217	Charliecombe Creek	Riparian condition (average) Overhanging vege (0-80%) Macrophyte cover (5-50%)	Family taxa (27-high) Macroinvertebrae (SIGNAL score 5.56 - Average)	No Significant species Southern Pigmy Perch (9), high number of exotics
WA225, WA226, WB228	Billy Billy Creek	Riparian condition (very poor) Overhanging vege (<10%) Macrophyte cover (20-40%)	Family taxa (12-low) Macroinvertebrae (SIGNAL score 5.0 - Mild)	Significant species - Dwarf Galaxias (156) Southern Pigmy Perch (389)
WA243	Hopkins River	Riparian condition (very poor) Overhanging vege (10-20%) Macrophyte cover (20-60%)	Family taxa (15-moderate) Macroinvertebrae (SIGNAL score 4.94-5.83 mild to moderate)	No Significant species Common Jollytail (95)
WB244	Green Hill Creek	N/A	N/A	N/A

6. Impact Assessment

The detailed impact assessment documented in this report addresses the potential impacts of the construction and operation of the final alignment options of Section 2 of the Project. The alignments assessed are a culmination of progressive deletion of earlier options, refinement of the design and consideration of potential impacts.

The Existing Conditions section of this report covers an area encompassing the long list of alignment options considered for the Project. Potential impacts of each option in the long list of alignments were considered in Phase 1 of the options assessment process, and were used to reduce the initial long list to a short list of alignment options.

The potential impacts of each option in the short list of alignment options were considered in more detail in Phase 2 of the option assessment process. Three proposed alignments were selected for further detailed assessment in the EES. The impacts of the proposed alignments, together with potential mitigation measures, were considered in detail through the environmental risk assessment process. The outcomes of the risk assessment process were used to finalise the alignment options assessed in the EES.

The proposed alignments assessed in this report are the outcome of progressive refinement through each phase of the options assessment process. The proposed alignments were also refined following the initial consideration of the environmental risk assessment.

The alignment options assessment process is described in in the 'Western Highway Project Section 2 Options Assessment Report' (February 2012). The environmental risk assessment methodology and complete risk register for all specialist disciplines is presented in 'Western Highway Project Section 2 EES Environmental Risk Assessment' (February 2012) report.

Extracts form the environmental risk register are provided in this report and the identified impacts of the preferred proposed alignments are considered in detail in the following sections.

6.1 Project Description

The Project provides two lanes in each direction and associated intersection upgrades to improve road safety, and facilitate the efficient movement of traffic. It commences at the railway overpass west of Old Shirley Road, Beaufort and extends for approximately 38 km to Heath Street, Ararat. The upgrade assessed in this impact assessment is a combination of freeway standard (AMP1) and highway standard (AMP3). For the first length from the railway overpass to approximately Ch. 800, near McKinnon Lane, there are no works proposed. Then from Ch. 800 to Warrayatkin Road on the outskirts of Ararat the proposed upgrade would be to freeway standard (AMP1). For the final length from Warrayatkin Road to Heath Street the proposed upgrade would be to highway standard (AMP3). Grade separated interchanges are proposed at Eurambeen-Streatham Road, Peacocks Road, Hillside Road, and Langi Ghiran Picnic Ground Road. An at-grade intersection with a wide median treatment is proposed for Warrayatkin Road.

There are three proposed alignment options that are being assessed. These share a common alignment from Beaufort to near the Anderson Road intersection, east of Buangor (Ch. 16800), retaining the existing single carriageway footprint, and providing a duplicate carriageway located approximately 15 to 100 m to the north. Thereafter the options differ in their geometry, and whether a duplication or an entirely new dual carriageway is constructed. The alignment options are summarised in Table 17.

All alignment options bypass the small township of Buangor, which is currently accessed via local roads from the Western Highway. The Project proposes access to Buangor via grade separated interchange facilities.

There are steep grades from Beaufort through to Fiery Creek, before the highway levels for 18 km. To the west of Buangor the topography undulates as the highway crosses the Melbourne to Ararat railway line, and passes to the south of Langi Ghiran State Park. The highway then levels once again from the west side of Langi Ghiran State Park through to Ararat. Apart from the State Park and small areas of remnant forest, the surrounding land use is predominately agricultural (grazing and cropping).

Other than the Melbourne to Ararat railway which carries local passengers, no State significant infrastructure such as major pipelines or powerlines, is located within the study area. The alignment options all involve a crossing of the railway, six major waterways and 21 minor waterways (tributaries, drainage lines and irrigation channels).

Table 17 Alignment Option Descriptions for AMP1 Duplication

Option	Location and Chainage (m) East to West	Description
Common to all options	Box's Cutting to Warrayatkin Road (Ch. 840 to 34400)	**Duplication to AMP1 standard**
	Warrayatkin Road to Heath Street (Ch. 34400 to 39600)	**Duplication to AMP3 standard**
	Beaufort to the base of Box's Cutting (Ch. 840 - 3400)	**New dual carriageway** north of the existing highway (the existing highway would be used as a service lane). No duplication works undertaken between Ch. 0-840.
	Box's Cutting to Waldrons Road (Ch. 3400 – 12000)	**Duplication** of existing highway on the northern side then transferring to the southern side at Fiery Creek (Ch. 5900), with a median treatment from approximately 15 m to 30 m depending on the extent of constraints. Includes a new interchange at Eurambeen-Streatham Road / Eurambeen-Raglan Road
	Waldrons Road to east of Anderson Road (Ch. 12000 – 15700)	**Duplication** of the existing highway on the southern side, maintaining a median from approximately 15 m in the east to 40 m in the west.
Option 1	Anderson Road to Pope Road (Ch. 16500 – 22400)	**New dual carriageway** to the north of Buangor, and meeting the existing highway west of Buangor-Ben Nevis Road. Alignment common to Option 3
	Pope Road to the eastern end of Hillside Road (Ch. 22400 – 24800)	New dual carriageway, extending southwest from the existing highway and crossing the rail line.
	Eastern end of Hillside Road to Heath Street, Ararat. (Ch. 24800 – 39600)	New dual carriageway located approximately 700 m south of the existing highway until Ch. 28400 where it converges over a 1.5 km distance. A duplication of the existing carriageway occurs from Ch. 28400 with the new carriageway to the south. The median width varies from 30 m in the east to a narrow 6 m treatment in the west.

Option	Location and Chainage (m) East to West	Description
Option 2	Anderson Road to Pope Road (Ch. 16600 – 24600)	**New dual carriageway** that bypasses Buangor to the north, then extends south over the existing highway and rail line.
	Pope Road to the eastern end of Hillside Road (Ch. 22600 – 24200)	**New dual carriageway**, extending along the southern side of the railway line, meeting the existing highway.
	Eastern end of Hillside Road to Heath Street, Ararat. (Ch. 24200 – 39400)	**Duplication** of the existing highway on the southern side. Alignment common to Option 3.
Option 3	Anderson Road to Pope Road (Ch. 16500 – 22400)	Common alignment with Option 1 **New dual carriageway** to the north of Buangor, and meeting the existing highway alignment west of Buangor-Ben Nevis Road.
	Pope Road to the eastern end of Hillside Road (Ch. 22400 – 24800)	**New dual carriageway**, extending southwest across the rail line further than Option 2, then meeting the existing highway alignment in a similar location to Option 2.
	Eastern end of Hillside Road to Heath Street, Ararat. (Ch. 24800 – 39600)	Alignment common to Option 2. **Duplication** of the existing highway on the southern side.

6.1.1 Proposed Waterway Crossing Treatments

It is proposed that the waterway crossing treatments for the existing highway would typically be matched for the duplication. Where there is currently a culvert, a culvert is proposed for the duplicated highway and where there is a bridge, a bridge is proposed for the duplicated highway. The piers of these bridges would be constructed outside of the low flow channel extents. Flood modelling may influence the design of new waterway crossings to differ from existing crossings. The existing highway would also be the subject of the flood modelling. If existing drainage is found to be inadequate then it would also have to be upgraded.

In order to prevent exacerbation of flooding it is likely that some existing bridges would require upgrades to accommodate the duplicated crossing. Modelling is available at a coarse 10 m grid resolution, and indicates that many of the major stream crossings are likely to be within the 100 year Average Recurrence Interval (ARI) flood extent. Detailed flood modelling is being completed for each crossing and will inform the EES when available. The status of waterway crossings assessed and proposed treatments are described in Table 18.

Table 18 Waterway Crossings and Treatments Beaufort to Ararat (major and significant waterways)

Waterway crossed	Approx. Design Chainage (m)	Crossing Status and Treatment		
		Option 1	Option 2	Option 3
Goodes Gully (WC201)	400	Prior to beginning of upgrade works at Ch. 840		
Fiery Creek (WB211)	5900	Existing Bridge	Existing Bridge	Existing Bridge
Middle Creek (WB213)	10600	Existing Culvert	Existing Culvert	Existing Culvert
Charliecombe Creek (WB215)	12600	Existing Culvert	Existing Culvert	Existing Culvert
Charliecombe Creek (WB216)	14400	Existing Culvert	Existing Culvert	Existing Culvert
Charliecombe Creek (WB217)	14700	Existing Bridge	Existing Bridge	Existing Bridge
Billy Billy Creek (WA225, WA226)	18200	Proposed new crossing Bridge	Proposed new crossing Bridge	Proposed new crossing Bridge
Billy Billy Creek (WB228)	20800	Existing Culvert	-	Existing Culvert
Hopkins River (WA243)	33800	Existing Bridge	Existing Bridge	Existing Bridge
Green Hill Creek (WB244)	38300	Existing Culvert	Existing Culvert	Existing Culvert

6.2 Key Issues and Impact Pathways

The key issues are associated with either impacts to river health and water quality of receiving waters, or hydraulic impacts to waterways and floodplains:

- River health and water quality – This includes physical disturbance to existing waterways, fragmentation of waterways and water quality impacts.
- Waterways and floodplain hydraulics – This includes hydraulic conditions of waterway crossings and impacts on flooding.

Construction of the Project would involve replacing or constructing new culverts and bridges at most waterway crossing and potential disturbance to significant reach lengths of waterway. Construction of

these features may involve physical disruption to the waterway as well as works to waterway banks and floodplains and may result in changes to the ecological or geomorphological nature of the waterway as well as floodplain characteristics. The alignment of the highway upgrade would also intersect the catchment area of a number of waterways and may alter the flood regime and flooding patterns as flows across the catchment are impeded. The additional traffic volumes may lead to an increase of contamination of storm water runoff from the road which would ultimately end up in the waterways.

In defining Impact Pathways from the key issues the Project may cause impact surface water impacts due to:

- **Construction activities** during the implementation of the Project – The construction activities associated with the Project impacts the river health characteristics of the waterways
- The **construction of the Project** – The Project impacts the physical characteristics of the waterways and floodplain
- The **Operation of the Project** - The Project impacts the river health characteristics of the waterways

The impact pathways have been defined based on the above and applied to each of the waterways. The impact of the Project on each waterway crossing was assessed and summarised through the risk assessment framework.

Impact pathways are replicated for each of the waterways relevant to Section 2 of the Western Highway Project, which include the following:

- Hopkins River;
- Billy Billy Creek;
- Charliecombe Creek;
- Middle Creek;
- Fiery Creek;
- Yam Holes Creek; and
- Green Hill Creek.

A summary of the identified impact pathways is given in Table 19.

Table 19 Summary of General Impact Pathways, Consequences and Controls

Risk No.	Impact Pathway Description	Description of Consequences	Planned Controls to Manage Risk
SW1	**Construction activities** result in disturbance of channel planform, geometry and/or river health values.	Local destruction or destabilisation of waterway banks and channel profile; reduction of aquatic and terrestrial habitat in the crossing vicinity.	Reinstatement of waterway in accordance with the CMA requirements. Avoid unnecessary work in the channel and riparian zone.
SW2	**Construction of** Western Highway results in a change in hydraulic capacity and geomorphologic response at crossing locations.	Increased erosion potential due to concentration of flows/increased velocity through bridge or culvert (reduction of hydraulic capacity)	Implement appropriate design standards for bridges and culverts (e.g. adequate culvert sizing or open span bridges).
SW3	**Construction of** Western Highway result in fragmentation of river health values at crossing location.	Restrictions to aquatic and terrestrial fauna movement. Impediments to future waterway and catchment rehabilitation efforts.	Implement appropriate design standards (e.g. adequate light penetration to encourage fish passage)
SW4	**Construction activities** result in increased sediment and contaminant loadings of waterway.	Degradation of water quality in receiving waters. Impact on aquatic ecosystems.	Implement erosion and sediment control measures. Comply with SEPP WoV requirements. Prompt covering of exposed surfaces, progressive revegetation of the site, avoid unnecessary works in channel/on banks.
SW5	**Operation of** Western Highway road surface results in increased stormwater, sediment and contaminant loadings to waterway.	Increase in quantity of stormwater runoff compared to the existing flow regime. Degradation of water quality in receiving waterways, impact on aquatic ecosystems.	Water Sensitive Road Design measures included in the detailed design phase, as described in VicRoads Integrated Water Management Guidelines (August 2011). SEPP WoV objectives for water quality met.
SW6	The **Construction of** the Western Highway results in changes to floodplain characteristics to waterway.	Increased afflux and extent of upstream flooding and/or redistribution of flows or local drainage results in increased in flooding at various scales (rural, township, *in situ*).	Implement appropriate design standards to achieve highway flood risk requirements (e.g. adequately sized culverts or bridge spans).

Section 6.3 and 6.4 below provides a detail description of the impacts of the risk pathways for both River Health and Floodplain Management respectively.

Section 6.5 provides an overview of the impacts on each of the waterways due to construction and operation of the Project. The impact of the Project on each waterway crossing was assessed and summarised through the risk assessment framework. The expected consequences, likelihood levels and risk ratings for each of the identified risk pathways relevant to surface water investigations is documented in Section 6.5. The risk assessment provides an important framework for ensuring all key issues have been identified at each identified waterway and that high-risk pathways receive an appropriate level of consideration in the impact assessment.

Section 7 of this report outlines the management measures proposed to lower risks associated with medium to high risks associated with the impacts to river health and water quality of receiving waters or hydraulic impacts to waterways and floodplains.

6.3 River Health Impacts

The Project may affect river health and water quality characteristics of the various waterways due to the construction of the Project, construction activities during the implementation of the Project, and operation of the Project. The Project would interact with the various waterways as described in Section 5 with potential impacts includes physical disturbance to existing waterways, fragmentation of waterways and water quality impacts.

For each River Health impact pathway, detailed descriptions of the potential impacts and level of impact to specific waterways is outlined below. Also we have described potential opportunities and mitigation beyond standard controls that may need to be considered.

6.3.1 Physical Disturbance to Waterway (Channel Form and Vegetation)

This is relevant for risk pathway SW1 (refer to Table 23).

Description of Impact - The Construction of the Project would result in local removal of riparian and in-stream vegetation and habitat values at waterway crossing locations. The magnitude of the disturbance is the effective footprint or reach length of waterway disturbed by the Project. Removal of vegetation may impact bed and bank stability and increase the potential for channel erosion.

The loss of native riparian vegetation and decline in vegetation condition can present a threat to the health of surface water systems. A decline in vegetation condition may include increased fragmentation, weed invasion and the loss of vegetation diversity. Loss of riparian vegetation can also lead to an increase in bank erosion and bed degradation.

Bank instabilities threaten remnant riparian vegetation and provide a source of sediment that can have an adverse impact on the waterway. Bed and bank instabilities refers to accelerated rates of erosion associated with either channel enlargement or meander development. These can be the result of direct impacts or more indirect processes such as channel incision. Bank instabilities threaten remnant riparian vegetation and provide a source of sediment that can have an adverse impact on the waterway.

The significance of the impact of the physical disturbance at each waterway crossing location is dependent on the status or value of the waterway, as well as the magnitude or extent of disturbance to the waterway. The status of waterways impacted by the proposed alignment were categorised as minor, significant or major (as defined in Section 4.2.1). The magnitude of the disturbance were categorised as

low, medium, high by considering the scale of the impact disrupted (footprint area or reach length of waterway) i.e.

- Where a crossing is a straight perpendicular crossing at an existing crossing location then the scale of disturbance is low.
- Where a crossing is skewed and leads to significant lengths of waterway potentially disturbed the scale of disturbance is high.

For minor waterways the significance the impact is generally low. For the significant and major waterways, the significance of the impact is determined by the magnitude of the disturbance and this is summarised in the table below:

Table 20 Significance of Waterway Impacts ("Significant" and "Major" waterways)

Waterway Crossing	Waterway (Status)	Magnitude of Disturbance	Significance of Impact
WB211	Fiery Creek (Significant)	Duplication of existing crossing, Skewed crossing the degraded Fiery Creek channel	Low Impact
WB213	Middle Creek (Significant)	Duplication of existing crossing, slightly skewed crossing	Low Impact
WB215	Charliecombe Creek (Significant)	Duplication of existing crossing, Straight perpendicular crossing	Negligible Impact
WB216, WB217	Charliecombe Creek (Significant)	Duplication of existing crossing, Skewed crossing over 200 m potential waterway realignment required	Low Impact
WA225 (Option 1,3)	Billy Billy Creek (Significant)	Deviation, New crossing of Significant waterway with good habitat and river health values (inc Dwarf Galaxias)	Medium Impact
WA226 (Option 2)	Billy Billy Creek (Significant)	Deviation, New crossing of Significant waterway with good habitat and river health values (inc Dwarf Galaxias)	Medium Impact
WB228 (Option 2)	Billy Billy Creek (Significant)	Deviation, New crossing of Significant waterway with skewed crossing over 200 m potential waterway realignment required	Low Impact
WA243	Hopkins River (Major)	Duplication of existing crossing, Major waterway with slightly skewed crossing	Medium Impact
WB244	Green Hill Creek (Significant)	Duplication of existing crossing, Significant waterway with slightly skewed crossing	Low Impact

Benefits and Opportunities – For any disturbed water following the construction works, there is an opportunity to locally improve the waterway condition and ecological health within the vicinity of the works. The standard requirements would be to reinstate to match existing conditions, but a whole of reach improvement could be achieved through revegetation and other waterway enhancement works within the reach. The CMA may consider pursing these discrete opportunities through the Project in the context of the overall priority reaches as set out the river health strategies.

Mitigation Measures – Where the magnitude of disturbance of the Significant waterways leads to a Medium impact or greater there would be mitigation required. This may lead to requirements to minimise footprint areas of disturbance to the waterway (eg. imposing open span bridges). If a realignment of waterway is required then a formal concept design plan endorsed by the CMA may be required with.

6.3.2 Water Quality Impacts

This is relevant for risk pathways SW4 and SW5 (refer to Table 23).

Description of Impact - Construction activities on the proposed alignment have the potential to impact water quality due to increased sediment loading resulting. The sediment load can be generated from general construction activities from the overall footprint of works (typically managed within a Site Environmental Management Plan) prior to discharge to receiving waterways. Water quality impacts associated with direct disturbance of bed and bank from works within the waterways at crossing locations is covered by risk pathway SW1. The degradation of water quality in receiving waterways can impact on aquatic ecosystems. A greater level of concern or impact would occur to higher value waterways that have high value aquatic ecosystems (eg.in particular where Dwarf Galaxias may exist). Any construction activities around the waterways would be required to maintain water quality parameters within the SEPP WOV objectives.

The operation of the Project has the potential to impact water quality due to increased contaminants from the additional road surface being discharged to receiving waterways, including particulate matter, nutrients (nitrogen and phosphorous), heavy metals, petroleum based products, organic compounds and rubber products.

Water quality decline is an adverse change in water parameters such as water temperature, pH, dissolved oxygen, turbidity, pathogens, nutrients, pesticides, chemicals and heavy metals. Changes to water quality outside the bounds of natural variability for the waterway can reduce river health values by adversely impacting aquatic life and vegetation.

The significance of the impact of water quality degradation to each receiving waterway is dependent on the status or value of the waterway, as well as the level of water quality pollution to the waterway. The status of waterways impacted by the proposed alignment were categorised as minor, significant or major (as defined in Section 4.2.1). For all locations the level of water quality pollution were categorised as Low assuming that standard controls are in place i.e.

- Construction Phase - appropriate site environmental management controls for construction phase,
- Operation Phase - appropriate WSRD measures are implemented as part of the works for the managing runoff from the road in operation).

There is considered to be a medium impact of water quality degradation for the “Major” waterways (i.e. Billy Billy Creek where there are Dwarf Galaxias present). For all other significant and minor waterways the significance the impact is low as summarised in the table below.

Table 21 Significance of Water Quality Impacts ("Significant" and "Major" waterways)

Waterway Crossing	Waterway (Status)	Water Quality Pollution	Significance of Impact
WB211	Fiery Creek (Significant)	Low – assuming standard controls	Low Impact
WB213	Middle Creek (Significant)	Low – assuming standard controls	Low Impact
WB215	Charliecombe Creek (Significant)	Low – assuming standard controls	Low Impact
WB216, WB217	Charliecombe Creek (Significant)	Low – assuming standard controls	Low Impact
WA225 (Option 1,3)	Billy Billy Creek (Significant) with good habitat values (inc Dwarf Galaxias)	Low – assuming standard controls	Medium Impact
WA226 (Option 2)	Billy Billy Creek (Significant) with good habitat values (inc Dwarf Galaxias)	Low – assuming standard controls	Medium Impact
WB228 (Option 2)	Billy Billy Creek (Significant)	Low – assuming standard controls	Low Impact
WA243	Hopkins River (Major)	Low – assuming standard controls	Medium Impact
WB244	Green Hill Creek (Significant)	Low – assuming standard controls	Low Impact

Benefits and Opportunities – For the existing road there is currently no formal stormwater quality treatment measures in place or WSRD. The previous road was built prior to there being a requirement to address stormwater quality from road runoff. As there is a requirement for the new the road to manage water quality from runoff from the road, there is an opportunity to provide WSRD treatments for all hardstand areas (including where the existing carriageway is being retained as a carriageway or maintained as a service road or local road. The WSRD elements could be located and sized to treat the whole surface footprint of hardstand road surfaces.

At the more ecologically sensitive locations (higher value waterways with good habitat with presence of Dwarf Galaxias), there is an opportunity to locally enhance the habitat by including a water quality treatment wetland as an offline habitat pond for the Dwarf Galaxias. This would not only provide the water quality requirements but could improve the waterway condition and ecological health within the vicinity of the works. The CMA may consider pursing these discrete opportunities through the Project in the context of the overall priority reaches as set out the river health strategies.

Mitigation Measures – Where the magnitude of water quality degradation of the Significant/Major waterways leads to a Medium impact or greater there would be mitigation required. For the locations

where Dwarf Galaxias are present this may lead to requirements to limit the timing of the works (eg to non-breeding periods of the year) or may lead to requirements to impose greater level of site controls or WSRD measures to protect the receiving waterway environment. This may be in the form of a construction wetland that provides habitat value as described above in the potential opportunities.

6.3.3 Change in Hydraulic Capacity and Geomorphologic Response (Stream Bed Degradation and Aggradation)

This is relevant for risk pathways SW2 (refer to Table 23).

Description of Impact - Works on waterways during construction of the Project has the potential to increase sediment loading to the downstream waterway in the short term, as a result of channel disturbance and removal of stabilising bed and bank vegetation. The construction of culvert crossings also has the potential to accelerate stream bed degradation and aggradation (sediment accumulation) processes due to the change in hydraulic conditions (i.e. increased scour potential downstream of the culvert) and discontinuity of sediment transport processes.

Stream bed degradation refers to the lowering of the stream bed elevation through ongoing erosion processes. Most often the erosion is headward progressing (i.e. moving in an upstream direction) associated with the movement of nick points or head cuts. This can impact waterway health through the loss of existing instream features and can result in destabilisation and the production of sediment that may have adverse downstream impacts.

Stream bed aggradation is a process of net sediment deposition within a stream channel that results in the ongoing rise in bed elevation. This can lead to the decline in waterway health by smothering of bed forms and associated loss of bed diversity including pools, riffles and instream structure. Ongoing aggradation can accelerate channel avulsion (i.e. stream process where a new channel formation occurs and abandonment of the old stream channel) and the creation of a new one).

The significance of the impact of the geomorphologic response for each waterway crossing location is dependent on the geomorphologic status or current stability of the waterway (Significant and Major), as well as the magnitude or extent of disturbance caused by the change to the waterway. The geomorphologic status of the waterways that are impacted by the proposed alignment were considered to be stable. The magnitude of the disturbance to the waterway is assumed to be low given the requirements to size culverts to reduce velocities and provide appropriate protection to bed and banks as part of the works. Therefore for all waterways the significance of the impact is generally low.

Benefits and Opportunities – For any disturbed waterway where there is an existing crossing there is an opportunity to address the downstream condition with stabilisation works. It is noted there were no sites observed that required stabilisation works.

Mitigation Measures – There is no requirement for mitigation beyond the standard controls (i.e. appropriately sized waterway openings and downstream bed and ban protection works).

6.3.4 Fragmentation of River Health values

This is relevant for risk pathway SW3 (refer to Table 23).

Description of Impact - The Project could lead to fragmentation of River Health values in form instream barriers at the waterway crossings that could prevent the passage of instream sediments, detritus, macroinvertebrates and fish. Examples of instream barriers include weirs, road culverts and causeways.

Such barriers can halt ongoing stream processes downstream of the barrier, prevent the recolonisation of stream reaches with species following disturbance, result in the isolation of fish populations and prevent completion of fish breeding cycles. The barrier to fish migration can result in the loss of fish populations from waterways and potential loss of species. Furthermore the fragmentation not only leads to restrictions for aquatic and terrestrial fauna movement, but impediments to future waterway and catchment rehabilitation efforts.

Culvert crossings constructed as a result of the Project may create instream barriers that isolate or restrict the movement of native fish populations, and interfere with or prevent fish spawning.

The significance of the impact of the fragmentation for each waterway crossing location is dependent on the status of the waterway reach near the location of the crossing (Significant and Major), as well as the magnitude of the discontinuity to the waterway. The magnitude of the discontinuity to the waterway would vary from low (eg where there is an existing crossing at a straight perpendicular location) to potentially more significant at deviation locations where there is a new crossing proposed. The standard requirements for crossing include sizing culverts to reduce velocities, and arrange culverts so that invert level match bed levels, and provide appropriate protection to bed and banks as part of the works. Therefore for all waterways the significance of the impact is generally low with application of standard controls. The proposed new crossing at Billy Billy Creek (WB225 or WA226) where there are Dwarf Galaxias) is considered a higher impact and may warrant further design considerations to reduce the impacts (eg open span bridge).

Benefits and Opportunities – For any disturbed waterway where there is an existing crossing causing fragmentation (eg restrictive culvert, bed level discontinuity) then there is an opportunity to address the fragmentation caused by the existing crossing. Where waterway crossings are being upgraded then this may reduce the level of fragmentation. There may be opportunities to retrofit existing culverts (eg. with baffles to reduce low flow velocities - subject to capacity) to improve connectivity.

Mitigation Measures – Where a new crossing is proposed the standard mitigation controls would apply (i.e. culvert sized appropriately and set at bed level of waterway). In some cases where impacts are considered medium to high more stringent design requirements may be imposed (an open span bridge where required, provision of adequate light penetration to encourage fish passage where applicable).

6.3.5 Overall Assessment of River Health Impacts

The overall impacts on River Health from the Project to the various waterways is generally low.

The impacts described at the following specific locations are medium or higher and warrant additional mitigation or management measures:

- Construction of Western Highway in disturbance of channel planform, geometry and/or river health values for Billy Billy Creek (WA225,WA226 at Ch. 18200), Hopkins River (WA243 at Ch. 33800), Billy Billy Creek (WB228 at Ch. 20800 – Option 1 and 3 only) and Charliecombe Creek (WB217 at Ch. 14400 and 14700)
- Construction of Western Highway results in fragmentation of river health values at crossing location for Billy Billy Creek (WA225,WA226 at Ch. 18200);
- Construction activities and Operation result in increased sediment and contaminant loadings of for Billy Billy Creek (WA225,WA226 at Ch. 18200)

The Project would provide opportunities to improve existing conditions of reaches within the vanity of the works, as well as improve discontinuities and provide water quality treatment outcomes that are better than existing conditions.

6.4 Floodplain Management Impacts

The Project may affect the hydraulic behaviour of the waterways and associated floodplains and may cause obstruction to flow paths leading to increase in flood levels and/or redistribution of flood flows. The Project will impact the flood extent and flow paths of the various waterways systems and associated floodplains as described in Section 5 with potential impacts on flood levels and/or redistribution of flood flows.

6.4.1 Afflux and Floodplain Function

This section is relevant for the assessment of risk pathway SW6 (refer to Table 23)

Afflux refers to the rise in water level (above existing) on the upstream side of a bridge or obstruction, such as a culvert (or blocked culvert). Afflux can result from a number of causes such as when the effective flow area is reduced by an obstruction. The construction of the Project has the potential to result in afflux in areas upstream of the new roadway. For example New culvert and bridge crossings may allow more flow through than under existing conditions however a higher road crest may result in increased flood levels for large events which overtopped under existing conditions. The potential impact of this will vary depending on individual circumstances.

Flooding is defined as the inundation of land that is not normally covered by water. It may occur for a number of reasons including when the channel of a waterway is unable to contain the volume of water flowing from the catchment. Under such conditions, the waterway and its associated floodplain form an integrated system for the passage of flood flows. Floodplains augment the capacity of a waterway to discharge floods by providing additional flow capacity and temporary storage of floodwaters, thus attenuating peak flood flows. The removal of floodplains can result in higher velocities and deeper flood flows. As the fringe between land and water based ecosystems, floodplains are a key element in the natural environment due to their support of both terrestrial and aquatic communities.

Construction of the Project may result in changes in floodplain characteristics. This has the potential to impact floodplain function and flow conveyance.

Where a new waterway crossing may be required, the proposed road for Western Highway Project EES comprises either a duplication along the existing alignment, or a deviation for new dual carriageways. As a minimum, the proposed road design includes two 2-lane carriageways and potentially, access ramps and/or service roads. The existing road may be used as either of the carriageways or may become an access road or service road where the current flood standard would generally be maintained. In terms of the surface water assessment for the Western Highway Project EES, the three options vary predominantly with their interaction with Billy Billy Creek.

The significance of flood impacts was considered in terms of the status of the area impacted and the magnitude of the flood level increase. The significance of the area was categorised as described in Section 4.3 of the report. For the Project, there is only Rural (property without dwellings) – low impact and Rural (property with dwellings) with medium impact. The magnitude of the flood level increase where there is a medium impact is required to be reduced to zero.

Table 22 provides a summary of the potential flooding impacts of the Project as presented in the detailed flood extent maps in Appendix D.

Table 22 Potential 100 year ARI Flooding Impacts of Proposed Highway

Section	Sheet No.	Waterway	Crossing ID	Description of Potential 100 year ARI Flooding Impacts-Proposed Highway
Section 2 Beaufort to Ararat	1	Fiery Creek	WB211	**Duplication**: No change required to highway level and bridging assumed to match existing openings
	2	Tributary of Middle Creek	WC212	**Duplication:** The existing highway is overtopped from flooding and the upgraded highway will need to be raised and culvert opening increased – Upstream property is flood free but there may be impacts in attempting to contain the flow to an upgraded waterway opening. Oversizing waterway opening could further reduce flood levels but this would increase peak flows downstream (no identified potential impacts downstream)
	3	Middle Creek and tributary of Middle Creek	WC213	**Duplication**: The existing highway is overtopped from flooding over a width of 700m and therefore significant raising of highway and additional waterway openings will be required. Upstream property is currently flood affected, and therefore stringent requirements will be imposed. There may be an opportunity to reduce upstream flooding by having distributed culvert opening across the extent of backwater flooding, with no identified downstream impacts if this were to increase peak flows downstream.
	4	Tributary of Charliecombe Creek	WB215	**Duplication**: The existing highway is not affected by flooding but current opening results in backwater flooding and diversion of flows to the adjacent catchment – Upstream property is flood free and a larger waterway opening could change the flow distribution which could cause impacts to a downstream property that is upstream of crossing WB226.
	5	Charliecombe Creek	WB216 WB217	**Duplication**: The existing highway is flood affected by flooding in the complex floodplain where there is the confluence of Charliecombe Creek and tributaries– Upstream property is flood free, and a larger waterway opening could further reduce flood levels.
	6	Tributaries of Billy Billy Creek	WC219, WC220, WC221	**Deviation:** Proposed Highway deviation and interchange is within the backwater and intersects the floodplain by 500 m and will require new crossing of the tributary main flow path.

Section	Sheet No.	Waterway	Crossing ID	Description of Potential 100 year ARI Flooding Impacts-Proposed Highway
	6	Billy Billy Creek	WB225, WB226	**Deviation:** Proposed Highway deviation options are within the floodplain and will require a significant new crossing structure.
	7	Billy Billy Creek	WB228	**Deviation:** The existing highway is overtopped from flooding and the upgraded highway will need to be raised and waterway opening increased. Additional culvert openings will need to be provided for the upstream flow paths where the modelling indicates the existing road overtops.
	8	Hopkins River	WA243	**Duplication**: No change required to highway level or bridging can match existing openings.
	9	Green Hill Creek	WB244	**Duplication**: No change required to highway level or bridging can match existing openings.
	10	Breakaway flow of Cemetery Creek	WC245	**Duplication**: The existing highway is overtopped from flooding and the upgraded highway will need to be raised and culvert opening increased

The interpretation of existing conditions flooding and potential impacts of the Project is in the context of determining the locations that require significant upgrade works and where there may be properties impacted by the change in flood conditions. The following summarises the interaction of the Project and existing conditions flooding:

- The flood modelling indicates the existing highway is flood affected at the following locations, where significant upgrade works will be required in terms of raising road levels and increasing waterway openings;
  - Tributary of Middle Creek (Crossing WB212)
  - Middle Creek and tributary flowpath (Crossings WC213 & WC214)
  - Charliecombe Creek (WB217)
  - Billy Billy Creek at Buangor (downstream of proposed WA225)
  - Billy Billy Creek west of Buangor (WB228)
  - upstream tributaries of Billy Billy Creek
  - Cemetery Creek break away flow east of Ararat (WC245)
- Where there is significant flooding over the road, the upgraded highway will have a more significant impact on upstream flooding. A combination of raising the road and upgrading the waterway openings to convey the additional flow previously overtopping the road will be required;
- At most of the locations where the Billy Billy Creek system overtops the road, the proposed highway options are deviations from the existing highway and flood affected locations. Therefore the existing

road in most cases becomes an access road where it has been assumed the current flood standard will be acceptable (i.e. no change to the existing highway);

- Where the new alignment is a deviation from the existing highway and a new crossing is required, there is generally no significant or direct impact to dwellings that have been identified;
- Where the new alignment is a duplication of the existing highway and there is no overtopping of the road the waterway opening will need to be increased to maintain similar hydraulic conditions. This is to compensate for the significant lengthening of the waterway crossing to include all carriageways and ancillary roads.

Where upstream properties are potentially affected by the proposed highway, preliminary modelling of proposed conditions has been undertaken.

Where there is currently no overtopping of the road, it is assumed that crossing arrangements can be readily determined that have no or minimal adverse impact on upstream flooding (i.e.by sizing relative to existing waterways areas), and therefore we have assumed no modelling is required for the EES.

The following locations have been identified as having properties immediately upstream of the existing highway that may be impacted by the proposed highway conditions:

- Middle Creek - Bonacci Crossing 3 East, 3 and 4;
- Tributary of Charliecombe Creek - Bonacci Crossing 5; and
- Charliecombe Creek confluence – Bonacci Crossing 6 and 7.

Benefits and Opportunities – There is an opportunity for improving flood conditions within the study area, eg reducing upstream flood levels through increasing current waterway openings.

Mitigation Measures – At the nominated locations waterway crossings would need to be sized to produce no afflux. This is likely to require a slightly larger waterway opening (to account for losses of the extended length of crossings)

Overall Assessment of Impact - The Construction of the Western Highway results in changes to floodplain characteristics to waterways with identified potential impacts at the following crossings:

  - Middle Creek (WB213-WB214);
  - Tributary of Charliecombe Creek (WB215); and
  - Charliecombe Creek confluence (WB216-WB217).

It is noted that all other crossing locations were considered to be of insignificant consequence, leading to a low risk rating. It is assumed that waterway crossings that provide a minimum flow capacity equivalent to the current crossing would be required. This is likely to result in slightly larger waterway openings (to account for losses of the extended length of crossings).

6.5 Risk Assessment

6.5.1 Planned Controls - VicRoads

VicRoads has a standard set of environmental protection measures which are typically incorporated into its construction contracts for road works and bridge works. These are described in *VicRoads Contract Shell DC1: Design & Construct, April 2012*, hereafter referred to as the "VicRoads standard environmental protection measures". These measures have been used as the starting point for the impact assessment. Those that are relevant to surface water are included in the "planned controls" column of the risk assessment (Table 23).

As a result of the initial risk assessment, in some cases additional Project specific controls have been proposed to reduce risks. These are outlined in the "additional controls" column of the risk assessment in Table 23, and are described in more detail in Section 7.

Both VicRoads standard environmental protection measures and the additional Project specific controls have been included in the Environmental Management Framework for the Project.

- 1200.03 Environmental Management Plans (EMP)

Environmental Management Plans shall be prepared taking into account:

  - The Site's environmental features;
  - The nature of the works to be undertaken;
  - Any potential environmental impacts as identified in VicRoads Project Environment Protection Strategy;
  - Any permits and/or approvals and related conditions;
  - The findings of environmental investigations; and
  - The results of any environmental investigations undertaken by the Contractor

- 1200.04 Water

The quality of water in existing drainage infrastructure after acceptance of runoff/discharge from the Site shall not be detrimentally impacted by runoff from the site.

- 1200.08 Erosion and Sediment Control
  - All exposed surfaces shall be free of erosion.
  - Soil conservation measures shall include but are not limited to:
    - Minimising the amount of exposed erodible surfaces during construction - this may include staging of works;
    - Installation and maintenance of erosion and sedimentation controls, established in accordance with EPA best practice guidelines for the treatment of sediment laden run-off resulting from construction activities;
    - Installation and maintenance of catch drains to divert and segregate water runoff from catchments outside the construction site from water exposed to the construction site and to adequately control and route runoff within the construction site to the appropriate sedimentation control installation;
    - Treatment of open drains to prevent erosion before adjacent ground is disturbed and excavation is commenced;

- Prompt covering of exposed surfaces (including batters and stockpiles) that would otherwise remain bare for more than 28: days - cover may include mulch, erosion control mat or seeding with sterile grass;
- Minimising the timing between clearing and stripping of the Site and covering of erodible surfaces; and
- Where trees are required to be removed more than two months in advance of any construction works, remove only that part of the tree that is above ground level and where possible allow the roots to remain intact beneath the ground surface to assist with erosion control.

– Works shall be programmed and managed so as to avoid work in waters. Where work in waters is unavoidable, procedures shall be developed and implemented to satisfy the requirements of VicRoads standard environmental protection measures and as required by any permits from the responsible authority(s) (refer to Section 3).
– Where construction activities are undertaken in, near or over waters, Environmental Management Plan(s) shall be prepared to protect beneficial uses in accordance with any permit, the State Environment Protection Policy (Waters of Victoria), its schedules and best practice guidelines.

In addition to the VicRoads standard environmental protection measures, it is planned that the Project would be designed in accordance with VicRoads Water Sensitive Road Design Guidelines. The VicRoads document *Integrated Water Management Guidelines* (VicRoads, 2011), which replaces *Applying Water Sensitive Road Design Guidelines* (VicRoads, 2007), is designed to provide a general overview of the principles of Water Sensitive Road Design and a framework for applying to road projects.

Water Sensitive Road Design is the application of the principles of Water Sensitive Urban Design (WSUD) relevant to the road network. It seeks to minimise the extent of impervious surfaces and mitigate changes to the natural water balance. Specifically, WSUD (and WSRD) attempts to manage the impacts of:

- Reduced quality of stormwater run-off;
- Increase peak and total stormwater flows; and
- Decreased base flows, due to increase catchment imperviousness.

Further discussion on WSRD is in Appendix G.

6.5.2 Planned Controls – Other

As mentioned above, the VicRoads standard environmental protection measures specify that, “where work in waters is unavoidable, procedures shall be developed and implemented to satisfy the requirements of VicRoads standard environmental protection measures and as required by any permits from the responsible authority(s)”.

As mentioned in Section 3, Glenelg Hopkins CMA (GHCMA), as caretaker for waterways under the *Catchment and Land Protection Act 1994,* are responsible for issuing permits for works on waterways and their permission would need to be sought prior to undertaking the works on waterways for this project.

For the proposed works a Works on Waterways application would need to be submitted to GHCMA for assessment. The key issues to address in a Works on Waterway application are under the following headings:

- Environmental Management Plan;
- Water Quality and Water Sensitive Road Design; and
- Effect of works on floodplain function.

Waterway crossing locations would require reinstatement following construction works associated with the Project. Works should be undertaken in accordance with the CMA's specific requirements with reference to the *Technical Guidelines for Waterway Management (DSE, 2007*).

The Technical Guidelines for Waterway Management represent current best management practice and incorporate advances in environmental and technical practice for river health restoration and protection.

In order to achieve the most effective beneficial river health outcomes for the resources and effort invested, program implementation should be in accordance with best management practice and in recognition of the underlying geomorphologic and ecological processes operating within the waterway.

In conducting this interpretation it has been assumed that the ultimate road design would be to the following standards (as per the Section 1 specification):

- Traffic lanes to be one metre above the 100 year average recurrence interval (ARI) flood level;
- No increase in afflux above existing conditions; and
- No significant change in downstream flow distribution leading to increase in downstream flooding.

6.5.3 Risk Assessment Outcomes

Table 23 below summarises the outcomes of the risk assessment process.

Table 23 Surface Water Risk Assessment

Risk No.	Impact Pathway Description (how the project interacts with assets, values and uses)	Description of consequences	Planned Controls to Manage Risk (as per Project Description, and VicRoads Contract Shell DC1: Design & Construct (April 2012)).	Initial Risk			Additional Controls Recommended to Reduce Risk	Residual Risk		
				Consequence	Likelihood	Risk Rating		Consequence	Likelihood	Risk Rating
SW1A	Construction activities at **Hopkins River and Billy Billy Creek** at Ch.18200 resulting in disturbance of channel planform, geometry and river health values.	Local destabilisation of waterway banks, channel profile and pools. Reduction in aquatic and terrestrial habitat value in the vicinity of the crossing location.	Reinstatement of waterway in accordance with GHCMA requirements (channel profile, floodplain revegetation).	Minor	Almost Certain	Medium	Construction of bed control and/or bank protection works to protect vulnerable areas within or adjacent to the work area.	Minor	Possible	Low
SW1B	Construction activities on **Billy Billy Creek at Ch. 20950** and Charliecombe Creek at Ch. 14400 & 14700) resulting in disturbance of channel planform, geometry and river health values.	Service road overlays 250 m of waterway banks, channel profile and pools. Reduction in aquatic and terrestrial habitat value in the vicinity of the crossing location.	Reinstatement of waterway in accordance with GHCMA requirements (channel profile, floodplain revegetation); avoid unnecessary work in channel.	Minor	Almost Certain	Medium	Partial realignment of waterway to limit the length of waterway beneath carriageways or construction of realignment of service road to cross at more perpendicular angle.	Insignificant	Almost Certain	Low
SW1C	Construction activities on crossings of all other **named waterways** resulting in disturbance of channel planform, geometry and river health values.	Local destabilisation of waterway banks, channel profile and pools. Reduction in aquatic and terrestrial habitat value in the vicinity of the crossing location.	Reinstatement of waterway in accordance with GHCMA requirements (channel profile, floodplain revegetation); avoid unnecessary work in channel.	Minor	Almost Certain	Medium	Construction of bed control and/or bank protection works to protect vulnerable areas within or adjacent to the work area.	Minor	Possible	Low

Risk No.	Impact Pathway Description (how the project interacts with assets, values and uses)	Description of consequences	Planned Controls to Manage Risk (as per Project Description, and VicRoads Contract Shell DC1: Design & Construct (April 2012)).	Initial Risk			Additional Controls Recommended to Reduce Risk	Residual Risk		
				Consequence	Likelihood	Risk Rating		Consequence	Likelihood	Risk Rating
SW1D	Construction activities on **all other waterways** resulting in disturbance of channel planform, geometry and/or river health values.	Local disturbance or destabilisation of waterway banks and channel profile. Reduction in aquatic and terrestrial habitat value in the vicinity of the crossing location.	Reinstatement of waterway in accordance with GHCMA requirements (channel profile, floodplain revegetation); avoid unnecessary work in channel.	Insignificant	Almost Certain	Low	Construction of bed control and/or bank protection works to protect vulnerable areas within or adjacent to the work area.	Insignificant	Unlikely	Negligible
SW2	Construction of the Western highway results in the change in hydraulic capacity and geomorphological response at crossing locations.	Increased erosion potential due to the concentration of flow through a culvert or beneath a bridge.	Appropriate design standards (e.g. adequately sized culverts, rock protection to stabilise waterway bed and banks at the crossing location if required).	Moderate	Rare	Low		Moderate	Rare	Low
SW3A	Construction of the crossing at **Billy Billy Creek at Ch. 18200** results in fragmentation of river health values at crossing locations.	Restrictions to aquatic and terrestrial fauna movement, impediments to future waterway and catchment rehabilitation efforts.	Road to cross main channel, designed from a flood perspective only.	Moderate	Possible	Medium	Appropriate design standards (e.g. culvert sized appropriately and set at bed level of waterway or span bridge where required, adequate light penetration to encourage fish passage where applicable).	Moderate	Rare	Low
SW3B	Construction of the Western Highway results in fragmentation of river health values at crossing locations.	Restrictions to aquatic and terrestrial fauna movement, impediments to future waterway and catchment rehabilitation efforts.	Duplication of existing road crossing type where applicable.	Minor	Unlikely	Low	Appropriate design standards (e.g. culvert sized appropriately and set at bed level of waterway or span bridge where required, adequate light penetration to encourage fish passage where applicable).	Minor	Rare	Negligible

Risk No.	Impact Pathway Description (how the project interacts with assets, values and uses)	Description of consequences	Planned Controls to Manage Risk (as per Project Description, and VicRoads Contract Shell DC1: Design & Construct (April 2012)).	Initial Risk			Additional Controls Recommended to Reduce Risk	Residual Risk		
				Consequence	Likelihood	Risk Rating		Consequence	Likelihood	Risk Rating
SW4A	Construction activities result in increased sediment and contaminant loadings to Hopkins River and **Billy Billy Creek at Ch. 18200**.	Degradation of water quality in receiving waterways, impact on aquatic ecosystems.	Implement Erosion and Sediment Control Measures and SEPP WOV requirements for receiving waterways through an EMP, including but not limited to: minimising the amount of exposed erodible surfaces, installation of erosion and sedimentation control, prompt covering of exposed surfaces, progressive revegetation of the site, management of stockpiles and co-ordination to avoid works near watercourses.	Moderate	Unlikely	Medium	Increase design standard for erosion control measures from 1 in 2 year ARI to 1 in 10 year ARI.	Moderate	Rare	Low
SW4B	Construction activities result in increased sediment and contaminant loadings to **all other named waterways**.	Degradation of water quality in receiving waterways, impact on aquatic ecosystems.	Implement Erosion and Sediment Control Measures and SEPP requirements for receiving waterways through an EMP, including but not limited to: minimising the amount of exposed erodible surfaces, installation of erosion and sedimentation control, prompt covering of exposed surfaces, progressive revegetation of the site, management of stockpiles and co-ordination to avoid works near watercourses.	Minor	Unlikely	Low		Minor	Unlikely	Low
SW4C	Construction activities result in increased sediment and contaminant loadings to **all other waterways**.	Degradation of water quality in receiving waterways, impact on aquatic ecosystems.	Implement Erosion and Sediment Control Measures and SEPP requirements for receiving waterways through an EMP, including but not limited to: minimising the amount of exposed erodible surfaces, installation of erosion and sedimentation control, prompt covering of exposed surfaces, progressive revegetation of the site, management of stockpiles and co-ordination to avoid works near watercourses.	Insignificant	Unlikely	Negligible		Insignificant	Unlikely	Negligible

Risk No.	Impact Pathway Description (how the project interacts with assets, values and uses)	Description of consequences	Planned Controls to Manage Risk (as per Project Description, and VicRoads Contract Shell DC1: Design & Construct (April 2012)).	Initial Risk			Additional Controls Recommended to Reduce Risk	Residual Risk		
				Consequence	Likelihood	Risk Rating		Consequence	Likelihood	Risk Rating
SW5A	Operation of the Western Highway road surface results in increased stormwater, sediment and contaminant loadings to **Hopkins River and Billy Billy Creek at Ch. 18200**.	Increase in quantity of stormwater runoff compared to the existing flow regime. Degradation of water quality in receiving waterways, impact on aquatic ecosystems.	Water Sensitive Road Design measures would be evaluated for inclusion in the detailed design phase, as described in VicRoads Integrated Water Management Guidelines (August 2011). SEPP objectives for water quality met.	Moderate	Rare	Low		Moderate	Rare	Low
SW5B	Operation of the Western Highway road surface results in increased stormwater, sediment and contaminant loadings to **all other named waterways.**	Increase in quantity of stormwater runoff compared to the existing flow regime. Degradation of water quality in receiving waterways, impact on aquatic ecosystems.	Water Sensitive Road Design measures would be evaluated for inclusion in the detailed design phase, as described in VicRoads Integrated Water Management Guidelines (August 2011). SEPP objectives for water quality met.	Minor	Rare	Negligible		Minor	Rare	Negligible
SW5C	Operation of the Western Highway road surface results in increased stormwater, sediment and contaminant loadings to **all other waterways.**	Increase in quantity of stormwater runoff compared to the existing flow regime. Degradation of water quality in receiving waterways, impact on aquatic ecosystems.	Water Sensitive Road Design measures would be evaluated for inclusion in the detailed design phase, as described in VicRoads Integrated Water Management Guidelines (August 2011). SEPP objectives for water quality met.	Insignificant	Rare	Negligible		Insignificant	Rare	Negligible
SW6B	Construction of the Western Highway results in changes to the floodplain characteristics for **[Minor flood risk]**	Increased afflux and extent of upstream flooding and/or redistribution of flows or local drainage results in a slight increase in flooding at a rural scale.	Appropriate design standards to achieve highway flood risk requirements (e.g. adequately sized culverts or bridge spans where required).	Minor	Almost Certain	Medium	Compensation works for loss of floodplain storage where required. Redesign highway bridge structure to increase waterway passing flow capacity.	Insignificant	Possible	Negligible

6.5.4 Discussion on Risk Ratings

The following section documents the assigning of risk ratings to the pathways identified in Table 23. As mentioned previously, any works near to a designated waterway or any works resulting in direct connections to the waterway for drainage purposes would require approval by the relevant CMA. A number of the risks identified below would need to be addressed in works on waterway applications.

Construction activities result in disturbance of channel planform, geometry and/or river health values (impact pathway SW1)

For assessment against this impact pathway, the waterways in Section 2 were separated into three groups. The groups related to the value of the reach being crossed and the level of impact expected once the planned controls were taken into account.

The additional controls “Construction of bed control and/or bank protection works to protect vulnerable areas within or adjacent to the work area” was recommended for all waterways as this is a common approach for road and waterway protection even when not specified explicitly in contract documents or CMA requirements. This control helped to reduce residual risks in all groups.

The main risk expected from this pathway is at the crossing of the Hopkins River (Ch. 33800) and Billy Billy Creek (Ch. 18200). At these crossings construction activities may lead to disturbance of channel planform, geometry and river health values. Localised destabilisation of waterway banks, the channel profile and instream pools may also occur. This has the potential to lead to a reduction in aquatic and terrestrial habitat value in the vicinity of the crossing location, therefore a risk rating of medium was assigned to this impact pathway.

At crossing of Billy Billy Creek (Ch. 20950) a carriageway would be built overlying 250 m of the creek, necessitating the realignment of the creek through the adjacent paddock. The section of creek to be relocated has established vegetation and instream features such as large woody debris, riffles and persistent pools. Detailed design of the realigned section would be required for installation of bed control structures, bank stabilisation, revegetation and recreation of natural features such as pool and riffle sequences. With appropriate detailed design as per the additional controls, the consequence of this impact can be mitigated from moderate to minor. The likelihood remains almost certain. GHCMA may require additional compensation works as part of the realignment of this creek to provide an overall improved condition to the reach. A medium risk rating was also provided for this impact pathway.

Several other waterways showed signs of active erosion in the vicinity of the proposed crossings. These waterways were grouped together as they would require extra attention to bed and/or bank erosion control works in order to mitigate likelihood of worsening erosion from almost certain to possible (in the case of freeway crossings) and from possible to unlikely (in the case of side road / ramp crossings).

A summary of the specific waterway impacts associated with the proposed Western Highway Project is provided in Table 24. This table provides a summary of the key waterway impacts of the “significant” and “major” waterways, as well as more significant impacts to some minor waterways.

Table 24 Key Waterway Impacts of the "significant" and "major" waterways

Waterway Crossing	Waterway	Description of Impact	Consequence Rating
WC206-WC207	Unnamed tributary of Fiery Creek	no actual crossing - up to 1000 m of minor water affected by highway footprint	Minor
WC208	Unnamed tributary of Fiery Creek	>500 m of minor waterway affect by interchange	Minor
WB211	Fiery Creek	Skewed crossing the degraded Fiery Creek channel	Minor
WB213	Middle Creek	Significant waterway with slightly skewed crossing	Minor
WB215	Charliecombe Creek	Significant waterway with straight crossing	Insignificant
WB216, WB217	Charliecombe Creek	Significant waterway with skewed crossing over 200 m potential waterway realignment required	Minor
WA225 (Option 1,3)	Billy Billy Creek	Significant waterway with good habitat and river health values	Moderate
WA226 (Option 2)	Billy Billy Creek	Significant waterway with good habitat and river health values	Moderate
WB228 (Option 2)	Billy Billy Creek	Significant waterway with skewed crossing over 200 m potential waterway realignment required	Minor
WA243	Hopkins River	Major waterway with slightly skewed crossing	Moderate
WB244	Green Hill Creek	Significant waterway with slightly skewed crossing	Minor

Typically, where the consequence rating is minor, through application of waterway management works to the CMA requirements within the existing footprint of the channel, the risks can be managed to low. Where the consequence is moderate, this is due to higher value waterways being affected and/or the need for more significant waterway management works such as diversions. These would require more specific works to be developed to meet waterway and river health objectives subject to the CMA requirements.

The above summary has also been used to inform the preferred option alignment from a surface water perspective (refer to Section 6.5.5).

Construction of the Project results in change in the hydraulic capacity and geomorphological response at crossing locations on waterways (impact pathway SW2)

Where flow is concentrated through a culvert or a bridge there is increased erosion potential. As flow constrictions (culvert or bridge) already exist at each waterway crossing, a low residual risk rating for all waterway crossings has been assigned.

If, during detailed design, it is determined that erosion and incision of the waterway through the concentration of flow is an issue, then additional culvert capacity or open span bridge could be considered to reduce the risk associated with the concentration of flows through the road embankment. Consideration could also be given to energy dissipation, such as rock beaching, downstream of the culverts.

Construction of the Project results in fragmentation of river health values in the local catchment (impact pathway SW3)

Construction of the crossing at Billy Billy Creek at Ch. 18200 upstream of the existing highway results in fragmentation of river health values at crossing locations. This can lead to restrictions to aquatic and terrestrial fauna movement, impediments to future waterway and catchment rehabilitation efforts. A risk rating of medium was assigned to this impact pathway.

For named waterways, the bridges would be designed so that the piers are not placed in the low flow channel of the creek bed. At the minor waterway crossings, where culverts are intended, the culverts would be placed at or slightly below the bed level, therefore minimising the fragmentation of the waterway. The ephemeral nature of many of the waterways implies that there are natural stream flow barriers to aquatic movement through a number of the catchments already. As a result, a low residual risk rating has been assigned.

Construction activities result in increased sediment and contaminant loading to waterways (impact pathway SW4)

The Construction Environmental Management Plan (CEMP) would include sediment control measures such as silt fences and sediment traps and the contractor would need to demonstrate competence and suitable experience in environmental management in a construction environment. Relevant personnel may be required to have successfully completed a nationally accredited training course which addresses management practices for erosion and sediment control.

Construction activities result in increased sediment and contaminant loadings to Hopkins River (Ch. 33600) and Billy Billy Creek (Ch. 18200).

Additional sediment and contaminant loadings can lead to the degradation of water quality in receiving waterways, impact on aquatic ecosystems. As a result, a medium residual risk rating has been assigned.

A low residual risk rating has been assigned for all other named waterway crossings as their habitat quality is lower in the vicinity of the proposed works. A negligible residual risk rating has been assigned to all remaining waterways as they have little or no quality habitat in the vicinity of the proposed works.

Construction of the additional road surface results in increased stormwater runoff to waterways (impact pathway SW5)

The road area generating surface runoff to each of the waterways is generally less than 1% of the total catchment area upstream of the discharge location. In the case of a number of very small catchments (less than 10 ha) this proportion could be as high as 5%, however these small catchments are generally highly modified with dams, unfenced grazing access etc. The proportional increase in stormwater runoff from the construction would be relatively small. The peak flows from the road would be expected to coincide with the rising arm of the main catchment hydrograph (rather than the peak) and therefore the magnitude of the peak flow events would not increase.

In addition, Water Sensitive Road Design measures would be evaluated for inclusion in the detailed design and SEPP (WoV) water quality objectives would be required to be met. On this basis, a low residual risk rating has been assigned for the Hopkins River (Ch. 33600) and Billy Billy Creek (Ch. 18200) where deep pools persist and a negligible residual risk rating has been assigned to all other waterways.

Construction of the Project results in changes to the floodplain characteristics of waterways (impact pathway SW6)

For all waterways, prior to any construction of bridge and/or culvert crossings it would need to be demonstrated, through hydraulic modelling, in the Works on Waterways application, that no hydraulic impacts occur which alter (or increase) flows, depths and flow velocities across property boundaries up to and including the 100 year ARI event subject to the approval of the CMA.

A summary of the specific potential flooding impacts associated with the proposed Western Highway Project alignment (including options) is provided in Table 25.

Table 25 Specific Potential Flooding Impacts associated with the proposed Western Highway Project

Waterway Crossing	Waterway	Description of Potential Impact	Consequence Rating
WB213-WB214	Middle Creek	Properties upstream affected	Minor
WB215	Tributary of Charliecombe Creek	Upstream property affected	Minor
WB216-WB217	Charliecombe Creek confluence	Properties upstream and downstream adjacent to existing flood extent	Minor

The minor consequence assigned to the above locations coupled with the “almost certain” likelihood leads to a moderate risk rating. The above locations have flooding over the road/or the properties immediately upstream (or downstream) in close proximity too or affected by the existing conditions flood extents. For the purpose of the EES, additional post highway upgrade conditions flood modelling has been undertaken for the above locations to determine proposed highway crossing arrangements that meet the requirements. This has involved an iterative modelling analysis supported by documentation from Bonacci Water.

The selection of appropriate waterway opening/culvert sizing needs to be based on updated flood modelling. From the preliminary modelling analysis (without determining the required crossing configurations) it can be interpreted that the flooding impacts can be managed. VicRoads intends to undertake more detailed hydraulic assessments at the waterway crossings to inform detailed design of the Project. For the purpose of the risk assessment, it has been assumed that these criteria would be met during detailed design.

It is noted all other crossing locations were considered to be of insignificant consequence, leading to low risk rating. It is assumed that waterway crossings that provide a minimum flow capacity equivalent to the current crossing would be required. Where the road is a duplication of the existing highway, this is likely to result in slightly larger waterway openings (to account for losses of the extended length of crossings). It is noted all crossing locations would need to be modelled and sized in the development of the detailed design of the Project.

6.5.5 Selection of Preferred Option

In terms of selecting a preferred option, the key issues of waterway disturbance and potential flooding impacts have been compared for the relevant waterways.

In terms of selecting a preferred option from a waterway disturbance perspective, this has been considered in terms of the following for each option:

- Total number of waterways affected that result in “minor” or above consequence; and
- Total number of identified significant waterway crossings or interactions.

In terms of selecting a preferred sub-option from a potential flooding perspective, this has been considered in terms of the following for each option:

- Total number. of identified potential flooding impacts associated with the modelled waterways – this is based on the presence of properties immediately upstream (or downstream) in close proximity too or affected by the existing conditions flood extents; and
- Total number of identified waterway crossings or flood interactions of modelled waterways.

For the various options, these vary in terms of the interaction with Billy Billy Creek and its various tributaries. It is noted there are no significant potential flooding impacts identified for Billy Billy Creek and its various tributaries. However, in terms of total number of waterway disturbance footprints of significant waterways and flood interactions with identified waterway crossings, Table 26 provides a summary of variation between options.

Table 26 Alignment Option Assessment

Waterway	Waterway Crossing	Description of Impacts (Flooding Interaction and Waterway disturbance)
Billy Billy Creek (Ch. 18200)	**WA225 (Option 1,3)**	Significant waterway with crossing requirements to be defined by river health objectives
	WA226 (Option 2)	Significant waterway with crossing requirements to be defined by river health objectives
Billy Billy Creek & Minor tributaries (Ch. 20800)	**WC229-WC232 (Option 1, 3)**	Crossing near stream confluence and complex flood extent and with skewed crossing of Billy Billy Creek required with over 200 m waterway realignment required
	WB228 (Option 2)	**No crossing of Billy Billy Creek** – outside of main floodplain. Crossing of several minor tributaries of Billy Billy Creek (refer to WC229-WC232)
Minor (upper) tributaries Billy Billy Creek	**Option 1 (WC236, WC237)**	Crossing of several minor tributaries of Billy Billy Creek (more significant flood extent)
	Option 2 (WC234, WC238)	Crossing of minor tributaries of Billy Billy Creek (**outside of modelled floodplain**)
	Option 3 (WC233, WC234, WC235)	Crossing of several minor tributaries of Billy Billy Creek and some minor realignment

From Table 26, it can be concluded that there is no distinction between the crossing requirements at Billy Billy Creek at Ch. 18200. However, Options 1 and 3 result in an additional complex crossing at Ch. 20800 and therefore the preferred option is Option 2. Furthermore, Option 2 is outside of the main floodplain and is less affected by flood extents at the minor upper tributaries of Billy Billy Creek.

Option 2 is therefore the preferred Option for a least potential impact on flooding and least disturbance to significant waterways.

6.6 Benefits and Opportunities

This section identifies key potential benefits or opportunities to surface water that the Project could provide, rates the significance of these, and outlines measures to enhance and capture these benefits.

There is considered to be the following potential benefits (*minor to significant benefits at a local level*):

- **Improvement to waterway condition** - Following construction works, as part of rehabilitation there would be opportunities to improve waterway condition and ecological health to beyond the current condition. This can be achieved through revegetation and other waterway stabilisation works; and
- **Improvement to local flood conditions** - There is opportunity for improving flood conditions at specific locations throughout the study area (eg. reducing upstream flood levels through increasing current waterway openings).

For Section 2 of the Project there are no township scale flooding issues (*regional scale*) that could be addressed (i.e. reducing downstream flows and flood extents by providing additional attenuation storage or flood retarding basins).

Benefit ratings are described in Table 27.

Table 27 Benefit Ratings

Rating	Potential Project benefits
Very well	Significant benefit to the State Superior benefit to the region Policy consistency with superior positive impact
Well	Moderate benefit to the State Significant befit to the region Superior benefit to the locality Policy consistency with significant positive impact
Moderately well	Moderate benefits to the region Significant benefit to the locality Policy consistency with moderate positive impact
Partial	Minor benefits as a local level or significant benefits for a small number of individuals
Negligible	Minimal benefit at any level

7. Mitigation Measures

7.1 Construction

VicRoads would require the construction contractor to develop and implement a Construction Environmental Management Plan (CEMP) for the Project. VicRoads standard environmental protection measures and some additional Project specific controls identified below have been incorporated into the Environmental Management Framework for the Project. VicRoads would require the construction contractor to incorporate all of these measures into the CEMP.

VicRoads standard environmental protection measures for surface water that would be adopted for this Project include:

- Waters shall be monitored for the parameters identified in Table 1200.041 during all stages of construction to ensure that the water quality in the receiving waters:
  - does not deteriorate between the upstream and downstream limits of the work site during the construction period (where upstream results become the background limits); or
  - is as agreed between the Contractor, the Superintendent and EPA.
- The Contractor shall provide and maintain equipment capable of providing instantaneous monitoring of parameters as required in Table 1200.041 and have such equipment available on-site at all times. All equipment associated with monitoring shall be maintained and calibrated in accordance with the manufacturer's or equipment supplier's requirements.
- Table 1200.041 Construction Monitoring

Parameter	Method
Turbidity (Turb) – NTU	Measure with on-site meter
Electrical Conductivity (EC) – µS/cm	Measure with on-site meter
pH	Measure with on-site meter
Dissolved oxygen (DO) – mg/L	Measure with on-site meter
Temperature (°C)	Measure with on-site meter
Suspended Solids (SS) – mg/L	Measure with on-site meter
Litter (definition, including solid inert waste)	Visual (prevent litter from entering waters and drainage systems)
Oils and Greases	Visual (No visible free oil or greases)

- All exposed surfaces shall be free of erosion.
- Soil conservation measures shall include but are not limited to:

- Minimising the amount of exposed erodible surfaces during construction - this may include staging of works;
- Installation and maintenance of erosion and sedimentation controls, established in accordance with EPA best practice guidelines for the treatment of sediment laden run-off resulting from construction activities;
- Prompt temporary and/or permanent progressive revegetation of the Site as work proceeds;
- Installation and maintenance of catch drains to divert and segregate water runoff from catchments outside the construction site from water exposed to the construction site and to adequately control and route runoff within the construction site to the appropriate sedimentation control installation;
- Treatment of open drains to prevent erosion before adjacent ground is disturbed and excavation is commenced;
- Prompt covering of exposed surfaces (including batters and stockpiles) that would otherwise remain bare for more than 28 days - cover may include mulch, erosion control mat or seeding with sterile grass;
- Minimising the timing between clearing and stripping of the Site and covering of erodible surfaces; and
- Where trees are required to be removed more than two months in advance of any construction works, remove only that part of the tree that is above ground level and where possible allow the roots to remain intact beneath the ground surface to assist with erosion control.

- Works shall be programmed and managed so as to avoid work in waters. Where work in waters is unavoidable, procedures shall be developed and implemented to satisfy the requirements of this Clause 1200 and as required by any permits from the responsible authority(s).
- Where construction activities are undertaken in, near or over waters, Environmental Management Plan(s) shall be prepared to protect beneficial uses in accordance with any permit, the State Environment Protection Policy (Waters of Victoria), its schedules and best practice guidelines.
- Sedimentation basins shall be modelled and sized to manage rainfall intensities and soil characteristics specific to the region shall be used. The sizing and modelling of sedimentation basin(s) shall consider the expected works and associated area of disturbance within catchment areas(s) within the site.
- The sizing and modelling of temporary sedimentation basins shall be undertaken utilising recognised ‘best practice’ modelling techniques or by utilising ‘VicRoads Temporary Sedimentation Basin Design Tool’.
- Spillways or bypass systems (installations that divert all clean surface flows around a works site) shall be designed for an event having an Average Recurrence Interval of 5 years.
- Sedimentation basins shall be cleaned out whenever the accumulated sediment has reduced the capacity of the basin by 30 percent or more, or whenever the sediment has built up to a point where it is less than 500 mm below the spillway crest, whichever occurs earlier.
- The waterway at bridge and culvert structures shall be sufficient to prevent scour and to limit afflux to not exceed the pre-existing afflux conditions.

- Existing drainage catchments and flow patterns shall be maintained where practicable and drainage flows shall not cause damage or nuisance to landowner's access, facilities and/or properties including crown land. The Contractor shall not permit re-direction, concentration or diversion of drainage flows for the Works except with the written consent of the responsible drainage authority and any other affected parties.
- Drainage systems including culverts, drainage networks, kerb and channel and open drains shall cater for the design storm event (1 in 100 year ARI) and shall have sufficient capacity to accommodate the design drainage flow in accordance with the drainage condition requirements and without causing damage or nuisance to landowner's access, facilities and/or properties including crown land.
- Ground surfaces upstream and downstream of drainage structures, bridge and culvert structures including spillways inlets, outlets, and including swales, open drains and watercourse, WSRD elements and water treatment structures shall be protected from scour. Appropriate measures shall be in place to prevent scour for flows of not less than the design drainage flow. Such measures shall include, but are not limited to, beaching, provision of rip rap, erosion matting and control of flow velocities as appropriate.
- The Contractor shall design and construct water quality treatment measures to collect and treat runoff from all pavement areas to the required levels prior to discharging into surrounding drainage networks and / or waterways.
- Stormwater runoff from the road pavement discharged both directly and indirectly into any surrounding waterways and /or drainage network, shall meet the water quality performance criteria requirements of the State Environmental Protection Policy (Waters of Victoria) 2003, Australian Runoff Quality Guidelines, this Specification and requirements of any relevant authority.
- The Contractor shall undertake the Works in such a manner that the completed Works do not have a detrimental impact on the beneficial uses of the waterways as defined in the State Environmental Protection Policy, WSUD Engineering Procedures: Stormwater and the Australian Runoff Quality Guidelines.
- The following treatment objectives, in terms of pollutant load reductions for storm water runoff shall be achieved:
  - Suspended Solids 80% retention of the typical urban annual load;
  - Total Phosphorus 45% retention of the typical urban annual load;
  - Total Nitrogen 45% retention of the typical urban annual load; and
  - Litter 70% retention of the typical urban annual load.

Additional, Project specific controls are also proposed to reduce risks to surface water include:

- Compliance with all requirements of the relevant waterway manager, Glenelg Hopkins CMA.
- Realignment of waterway where required to maintain hydraulic capacity and allow appropriate reinstatement of waterway values. Associated works could include bed control structures, bank stabilisation using a combination of rock, vegetation and biodegradable erosion matting, creation of meanders, reintroduction of large woody debris and creation of pool and riffle arrangements.
- Construction of bridge spans longer than required for flow conveyance in order to bridge areas of high river health value.

- Construction of bank and/or bank protection works using a combination of rock, vegetation and biodegradable erosion control matting to protect vulnerable areas within or adjacent to the work area.
- Increasing the design standard for temporary erosion control measures such as sediment ponds from 1 in 2 year ARI to 1 in 10 year ARI.
- Compensation works for loss of flood plain storage where required due to a risk of increasing flood levels.
- Where a waterway has the potential to offer passage of aquatic fauna the road crossing would be designed in a manner that would not discourage fauna passage.

7.2 Operation

During operation, VicRoads would comply with Water Sensitive Road Design practices, including regular maintenance of design features intended to capture and treat stormwater run-off from the road. VicRoads would also regularly maintain all culverts and bridge openings ensuring that they remain free of debris and other blockages and can adequately pass their design flows.

7.3 Reducing Water River Health Impacts

Where significant or major waterways are potentially disturbed, large span bridge structures may be imposed to minimise any disturbance within the waterway footprint. It is assumed at crossing at Ch. 18200 for the new highway alignment, the type of bridge crossing imposed would be a large span bridge structure.

Also, where diversions of significant lengths of waterways are required, further investigations are required to be undertaken to develop a design concept for the realignment of the creek which would form part of the works on waterway application to the CMA's. In particular, crossing at Ch. 20800 would require a detailed concept plan.

The concept plan would include consideration of the following:

- Natural channel design in terms of planform and shape;
- Stable longitudinal gradients with possible grade control structures;
- Varying bank slopes to a maximum of 1:3;
- Additional protection of bank toes at bends;
- Vegetated and protected banks with appropriate species selection;
- Creation of habitat values (e.g. placement of pools and riffles); and
- Include planting of trees to provide shading and habitat benefit.

Increased sediment loading to significant waterways may have a moderate consequence for downstream river health values. Additional controls to minimise potential impacts would include measures such as scheduling of construction works on these creeks (including realignment works, installation of piers and earthworks around the waterway) to occur during no-flow or low-flow periods and outside of the breeding and dispersal period for the Dwarf Galaxias (August – September) restricting the timing of works on waterways to low or no flow periods and no activity on Billy Billy Creek during the breeding season of the Dwarf Galaxias would minimise potential impacts. For further discussion on Dwarf Galaxias refer to Ecology and Heritage Partners 2012 Flora and Fauna report.

7.4 Reducing Flood Risk

Preliminary post conditions flood modelling was undertaken by Bonacci Water for the specific crossings where the flood risk was moderate. The following crossings were assessed:

- Middle Creek (Crossings 3 East, 3 and 4)
- Tributary of Charliecombe Creek (Crossing 5).
- Charliecombe Creek and tributary of Charliecombe Creek (Crossing 6 and 7).

The results of this preliminary assessment are documented in Bonacci Water's Report, VicRoads Western Highway Duplication Project: Flood Investigation of Sector 2 alignments – Summary Report (June 2012).

From the preliminary modelling analysis it can be interpreted that the flooding impacts can be managed at the higher flood risk crossings including Middle Creek and Charliecombe Creek. During the detailed design phase more rigorous hydraulic modelling would be undertaken to determine the crossing configurations that meet the requirements of the CMA including no flooding impacts to properties. VicRoads intends to undertake more detailed hydraulic assessments at the waterway crossings to inform detailed design of the Project.

The proposed crossing configurations are listed in Table 28 below.

Table 28 Modelled Post-Conditions Culvert Configuration

Waterway Crossing Location	Existing Waterway Opening Description	Description of Proposed Works
Middle Creek and tributary flowpath (Crossings WC213 & WC214)	WB213 - 2 x 1800dia + 1800h x 1950w culvert WB214 – 2 x 1.2 x 0.9	Significant raising of the road and replace with box culverts distributed across the width of the floodplain
Tributary of Charliecombe Creek (WC215)	3 x 1800w x 1200h RCBC	Road remains at current level (not overtopped) and water way opening to be slightly increased (e.g. additional culvert cell). It is noted that changing the hydraulics at this location may impact the next location downstream at WC216.
Charliecombe Creek and tributary of Charliecombe Creek	4 x 1800w x 1200h RCBC Bridge, 14m span	Significant raising of the road required and waterway opening requirements to be determined subject to modelling. Existing highway appears to be subject to backwater flooding, and therefore may not need to be upgraded.

7.5 Summary

Table 29 presents a summary of the mitigation measures that have been identified to avoid, reduce or minimise impact risk. The measures comprise both relevant requirements of the VicRoads standard environmental protection measures as well as the additional measures identified by this impact assessment. The aim to achieve the relevant EES Objectives described in Section 2.

Table 29 Environmental Management Measures

Risk No.	Risk Description	Management Measures	Responsibility
SW1	Construction activities could result in disturbance to channel planform, geometry and river health values.	Waterways upstream and downstream of the road would be protected from scour. Appropriate measures would be in place to prevent scour for flows of not less than the design drainage flow. Waterways could be realigned where required to maintain hydraulic capacity and allow appropriate reinstatement of waterway values. Construction of bridge spans longer than required for flow conveyance in order to bridge areas of high river health value.	Designer
SW2	Construction of the Western highway results in the change in hydraulic capacity and geomorphological response at crossing locations.	There is no requirement for additional management measures beyond the standard controls (i.e. appropriately sized waterway openings and downstream bed and ban protection works)	Designer
SW3	Restrictions to aquatic and terrestrial fauna movement, impediments to future waterway and catchment rehabilitation efforts.	Where a waterway has the potential to offer passage of aquatic fauna the road crossing would be designed in a manner that would not discourage fauna passage.	Designer
SW4	Degradation of water quality in receiving waterway and impact on aquatic ecosystem as a result of increased sediment and contaminant loadings during construction of the road.	Water quality upstream and downstream of works would be monitored. Soil conservation measures would be employed on site to minimise the amount of sediment mobilised. Works would be scheduled to avoid working in flowing waterways where possible. Sediment basins would be designed to 'best practice' standard and sized specifically for each site. Water quality treatment measures would collect and treat runoff from all pavement areas to the required levels prior to discharging into surrounding drainage networks and / or waterways.	Contractor
SW5	Degradation of water quality in receiving waterway and impact on aquatic ecosystem as a result of increased sediment and contaminant loadings during the operation of the road.	Stormwater runoff from the road pavement shall meet the water quality performance criteria requirements of the SEPP (WoV). Best practice pollution reduction targets achieved. During operation VicRoads would comply with Water Sensitive Road Design practices, including regular maintenance of design features intended to capture and treat stormwater run-off from the road.	Designer VicRoads

Risk No.	Risk Description	Management Measures	Responsibility
SW6	Increased afflux and extent of upstream flooding and/or redistribution of flows results in an increase in flooding.	Waterway crossings shall cater for the design flood event (1 in 100 year ARI) and shall have sufficient capacity to accommodate the design flow without casuing unacceptable flooding impacts. Compensation works for loss of flood plain storage where required due to a risk of increasing flood levels may involve upgrading waterway openings.	Designer

8. Conclusion

The objective of the surface water assessment was to determine the potential impacts related to surface drainage, water quality, flooding/hydrology, and the conditions and river health values of waterways and floodplains. The waterway crossings in Section 2 included the following main waterways and/or associated unnamed tributaries: Yam Holes Creek, Fiery Creek, Middle Creek, Charliecombe Creek, Billy Billy Creek, Hopkins River, Green Hill Lake (outflow channel) and Cemetery Creek.

The potential waterway impacts due to construction and operation of the Project were used as a basis for determining the risk pathways in the risk assessment. The key issues are associated with either impacts to river health and water quality of receiving waters or hydraulic impacts to waterways and floodplains:

- River health and water quality – This includes physical disturbance to existing waterways, fragmentation of waterways and water quality impacts; and
- Waterways and floodplain hydraulics – This includes hydraulic conditions of waterway crossings and impacts on flooding.

The potential waterway impacts due to construction and operation of the Project were considered under the following six risk pathways for each of the waterway systems:

- Construction activities result in disturbance of channel planform, geometry and/or river health values;
- Construction of Western Highway Project results in reduction of hydraulic capacity at crossing location;
- Construction of Western Highway Project results in fragmentation of river health values at crossing location;
- Construction activities result in increased sediment and contaminant loadings within the waterway;
- Operation of the new Western Highway road surface results in increased stormwater, sediment and contaminant loadings to waterway; and
- The construction of the Western Highway Project results in changes to floodplain characteristics of the waterway.

The key outcomes of the impact assessment are summarised below:

- River Health - The overall impacts on River Health from the Project to the various waterways is generally low, with exception of the following waterways with site specific impacts from the identified risk pathways:
  - Billy Billy Creek (WA225,WA226 at Ch. 18200),
  - Hopkins River (WA243 at Ch. 33800),
  - Billy Billy Creek (WB228 at Ch. 20800 – Option 1 and 3 only) and
  - Charliecombe Creek (WB217 at Ch. 14400 and 14700)
- Flooding – The impact of the Project (where requirements are for a flood free road during 100 year ARI flood conditions) was considered low for the majority of waterway crossing locations, other than the following specific locations
  - Middle Creek (WB213-WB214);

- Tributary of Charliecombe Creek (WB215); and
- Charliecombe Creek confluence (WB216-WB217)

For the risk assessment it was assumed that standard planning controls (including the VicRoads standard environmental protection measures) were in place. With the application of standard planning control measures, many of the risk items were assigned Low residual risk with the exception of the following risks:

- Medium - Construction activities result in disturbance of channel planform, geometry and/or river health values for Billy Billy Creek (at Ch. 18200) and Hopkins River;
- Medium - Construction activities result in disturbance of channel planform, geometry and/or river health values for Billy Billy Creek (at Ch. 20950 – Option 1 and 3 only) and Charliecombe Creek (at Ch. 14400 and 14700) ;
- Medium - Construction of Western Highway results in fragmentation of river health values at crossing location for Billy Billy Creek (at Ch. 18200);
- Medium - Construction activities result in increased sediment and contaminant loadings of for Billy Billy Creek at Ch. 18200;
- Medium - The Construction of the Western Highway results in changes to floodplain characteristics to waterways with identified potential impacts at the following crossings:
  - Middle Creek (WB213-WB214);
  - Tributary of Charliecombe Creek (WB215); and
  - Charliecombe Creek confluence (WB216-WB217).

The above medium risks can be mitigated to acceptable risk levels through a combination of the following mitigation measures:

- Construction of bed control and/or bank protection works associated with crossing works so that vulnerable areas are protected within or adjacent to the work area subject to the requirements of the CMA;
- Where significant or major waterways are potentially disturbed, large span bridge structures may be imposed to minimise any disturbance within the waterway footprint. It is assumed at crossing at Ch. 18200 for the new highway alignment, the type of bridge crossing imposed would be a large span bridge structure.
- Where diversions of significant lengths of waterways are required, further investigations are required to be undertaken to develop a design concept for the realignment of the creek which would form part of the works on waterway application and be subject to CMA approval.
- Post highway upgrade conditions modelling has indicated that the potential flood impacts upstream can be managed through design of appropriate waterway crossing sizing's and arrangements, to be determined subject to more detailed modelling in the detailed design.

There is not a significant difference between the 3 Options from the overall surface water assessment. Option 2 is the marginally preferred Option in relation to surface water impacts due to less potential impact on flooding and least disturbance to significant waterways.

9. References

EPA Victoria Publications

Biological Objectives for Rivers and Streams – Ecosystem Protection (March 2004), Information Bulletin – Publication Number 793.2

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Glenelg Hopkins CMA 2004 – River Health Strategy 2004-2009.

Gervasi, D, 2006, H11 & H12 Catchment Health Report- Lake Bolac, Fiery and Salt Creeks, March 2006.

Project Specific Reports

Bonacci 2011, VicRoads Western Highway Duplication, Projects 320 1203 and 320 1204: Phase A – Preliminary Data analysis and requirements for additional data.

Bonacci 2012, VicRoads Western Highway Duplication Project: Flood Investigation, Projects 320 1203 and 320 1204.

Bonacci 2012, VicRoads Western Highway Duplication Project: Flood Investigation of Sector 2 alignments – Summary Report

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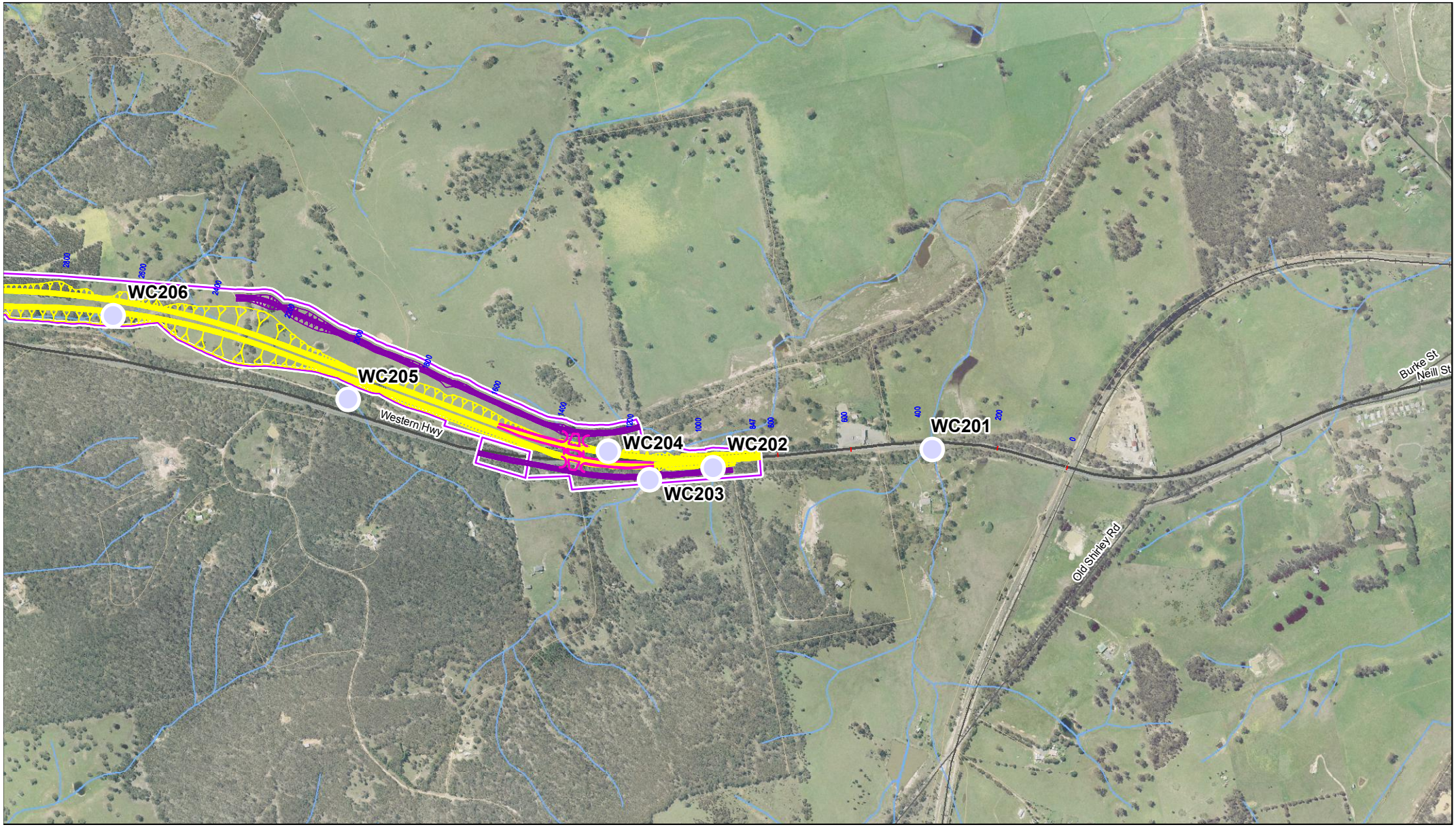
Waterway Crossing & Alignment – Mapbook



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LEGEND

Waterway Crossings
- Minor
- Moderate
- Major
- Lake

- River
- Stream
- Channel / drain
- Connector

- Maximum Construction Footprint
- Carriageway & Interchanges
- Service Road
- Service road to be built under AMP-3 conditions

- Highway
- Sealed road (arterial & local)
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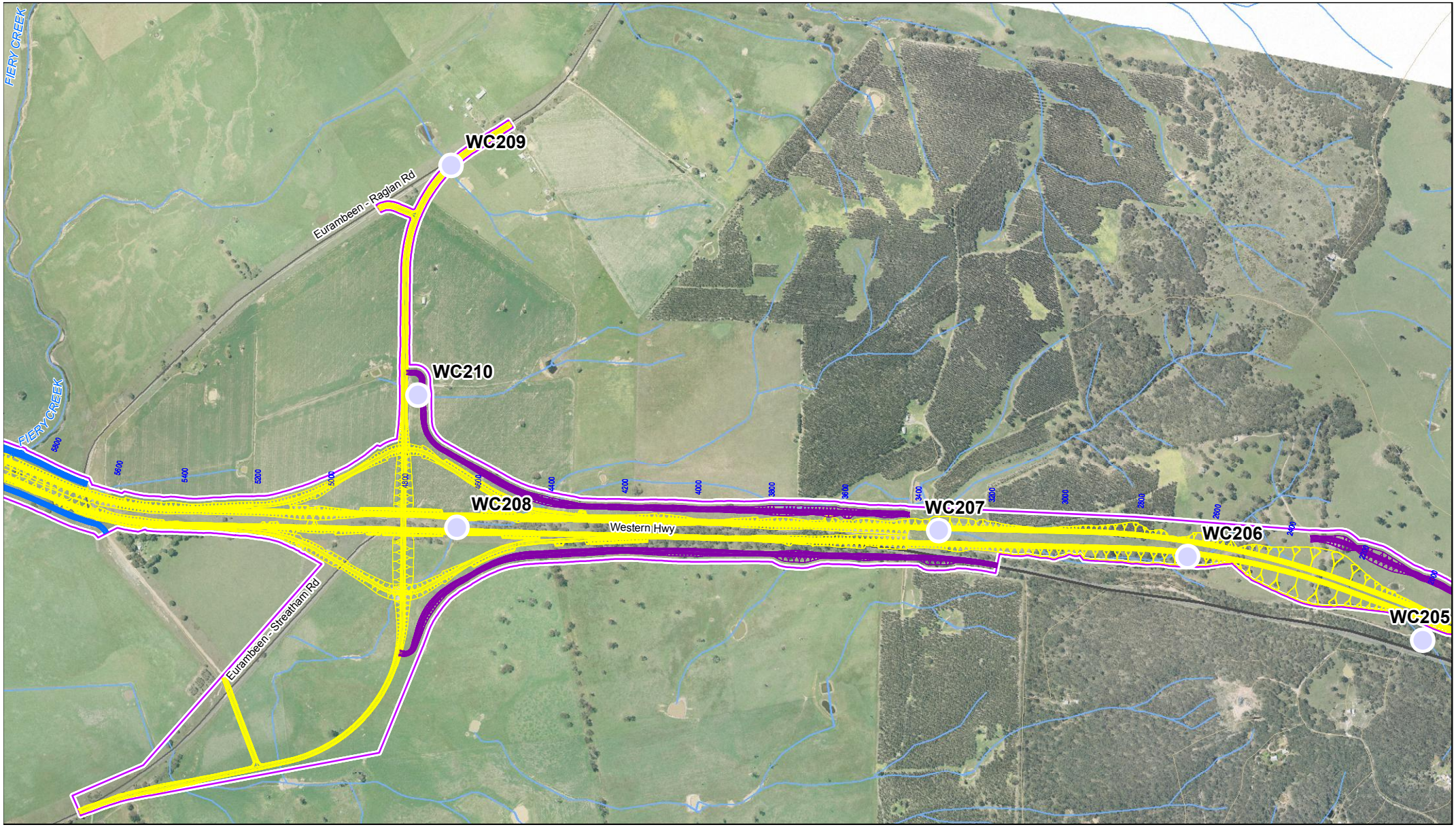

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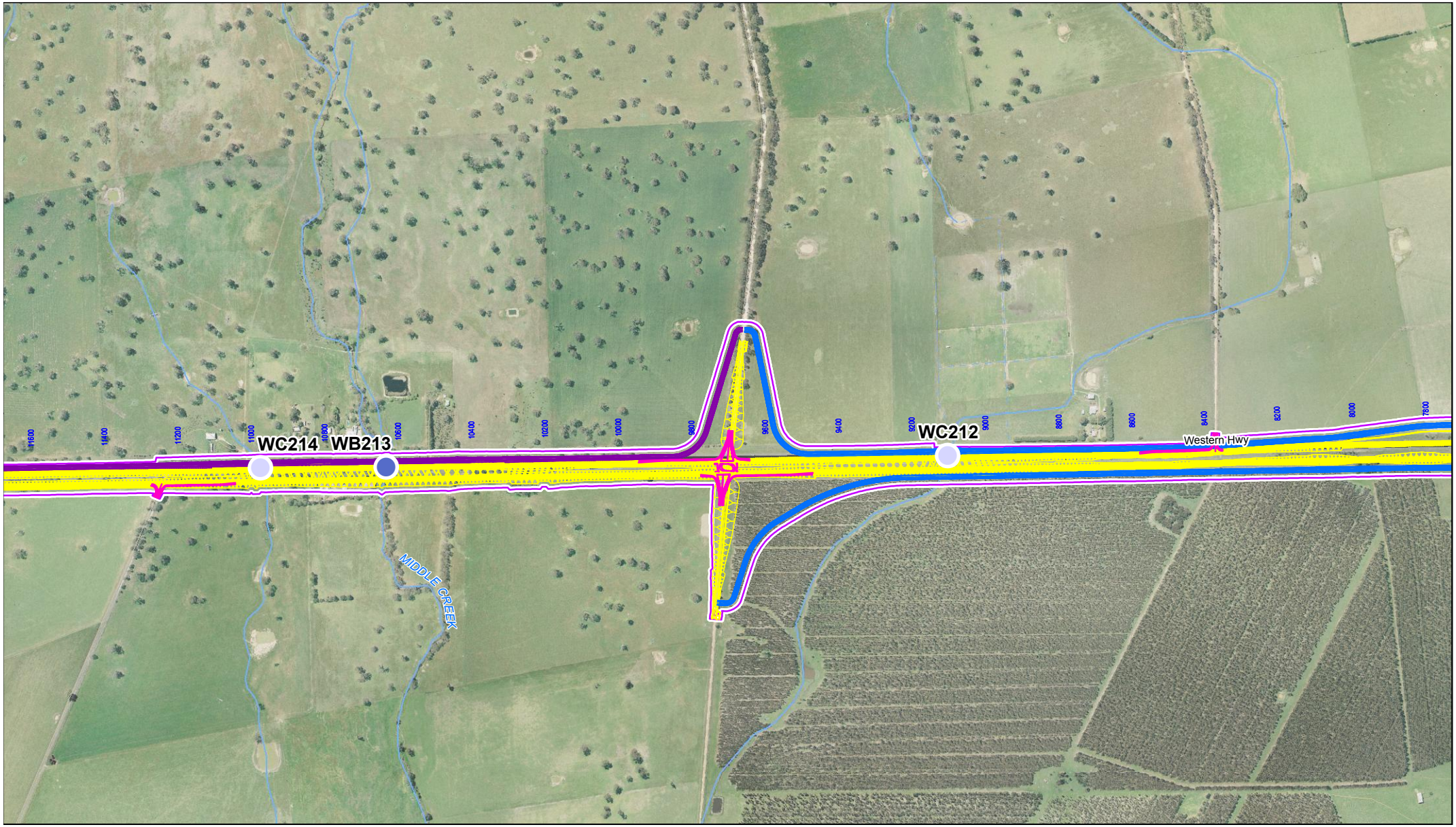

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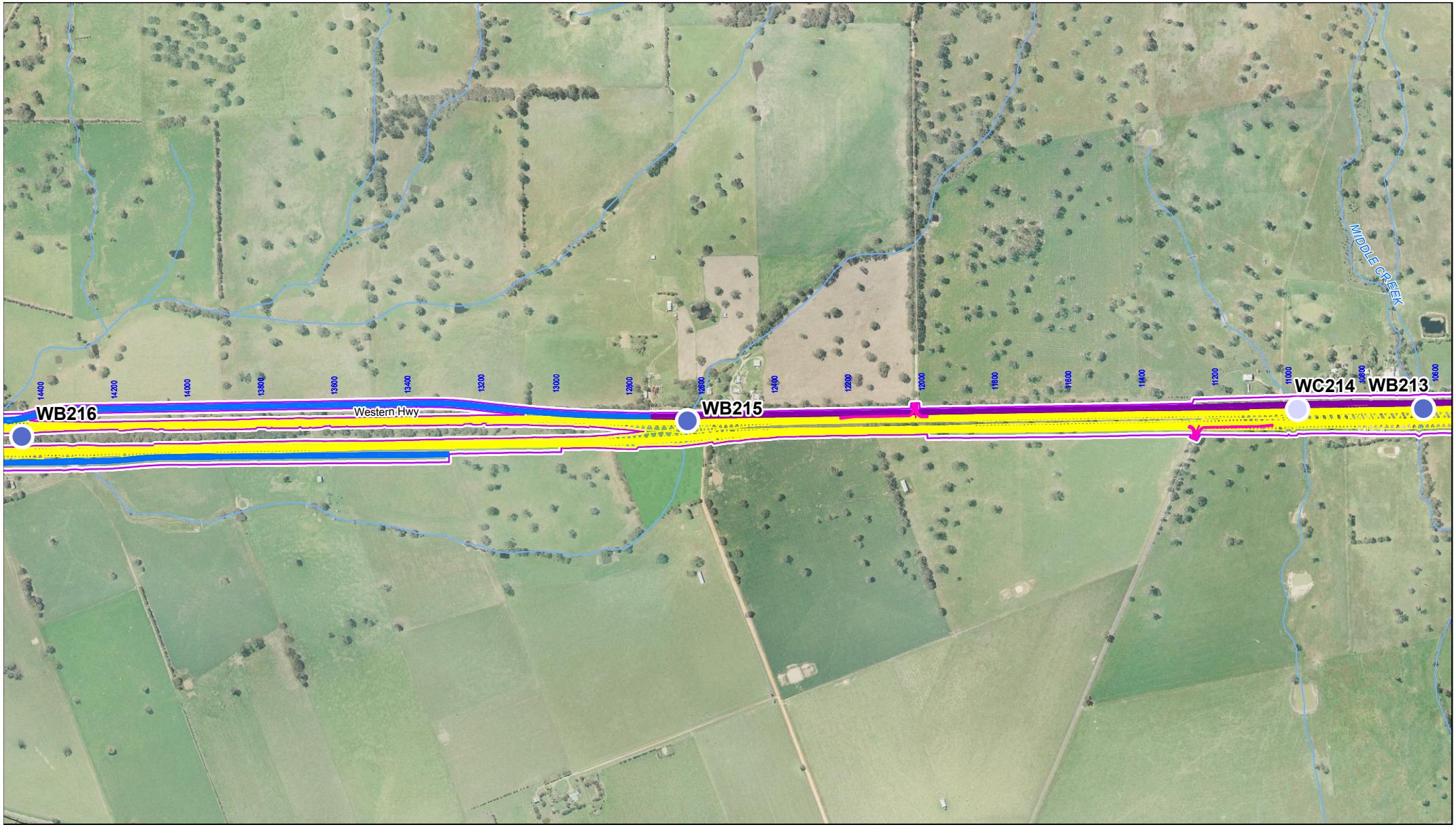

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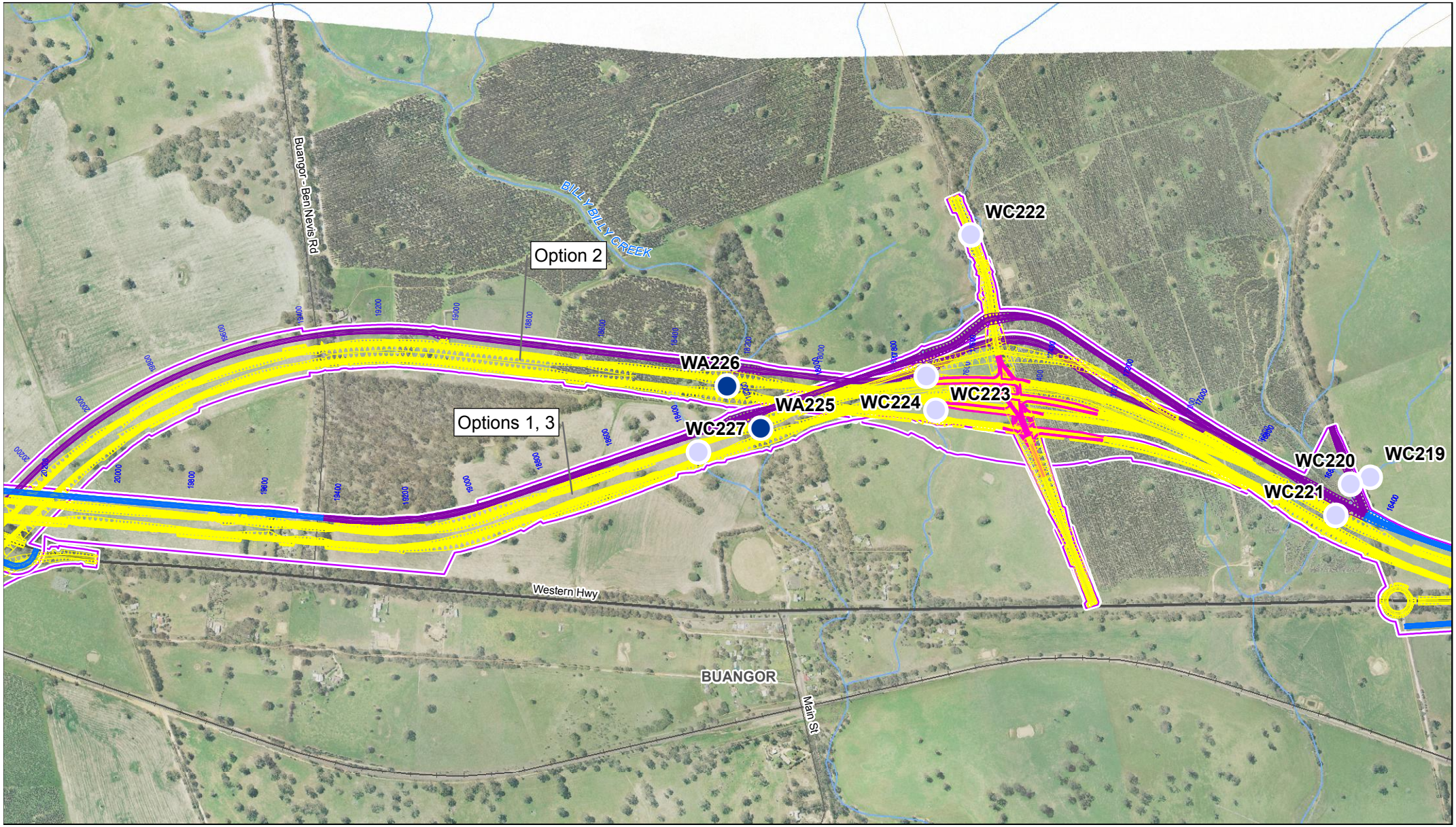

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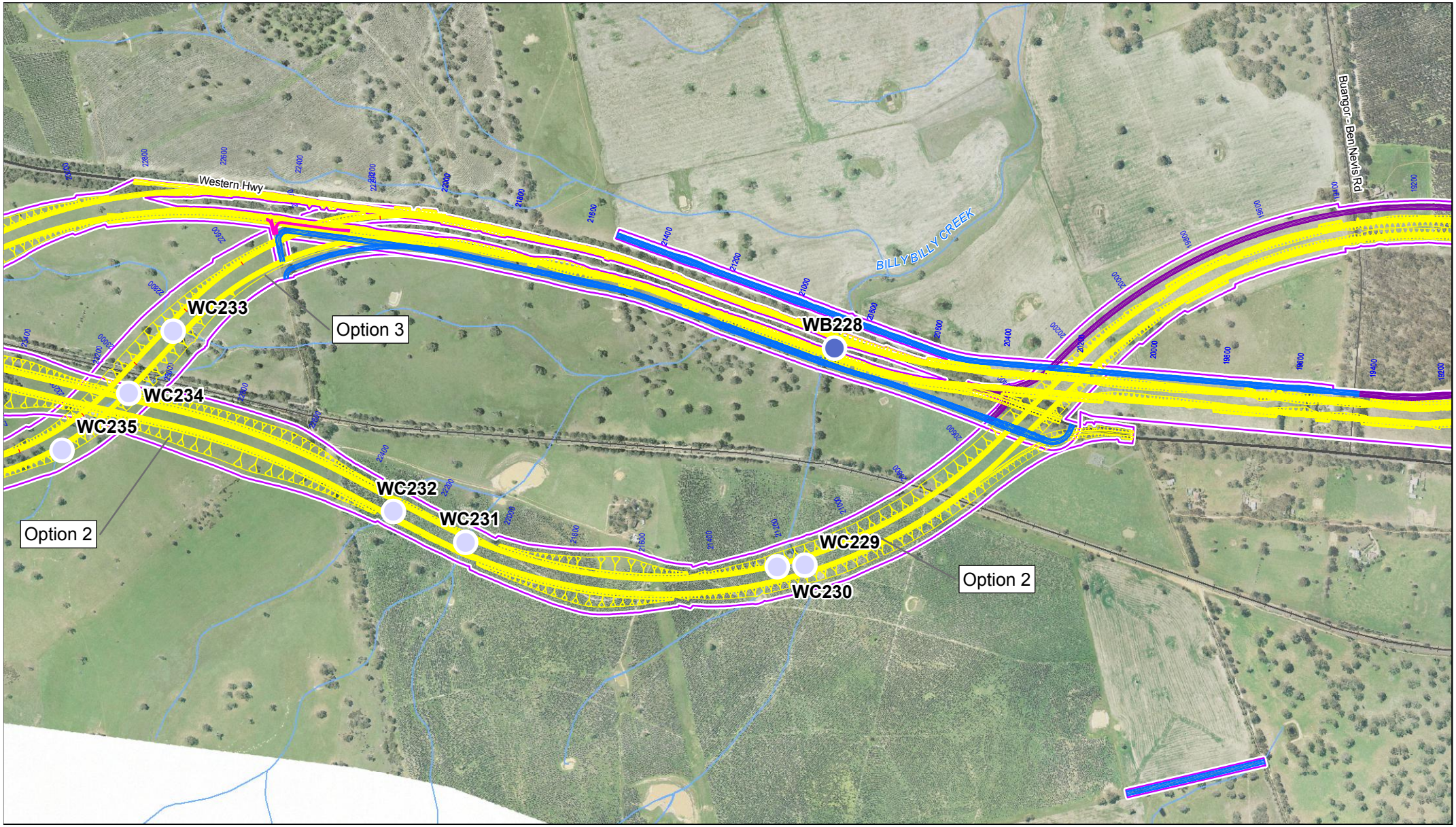

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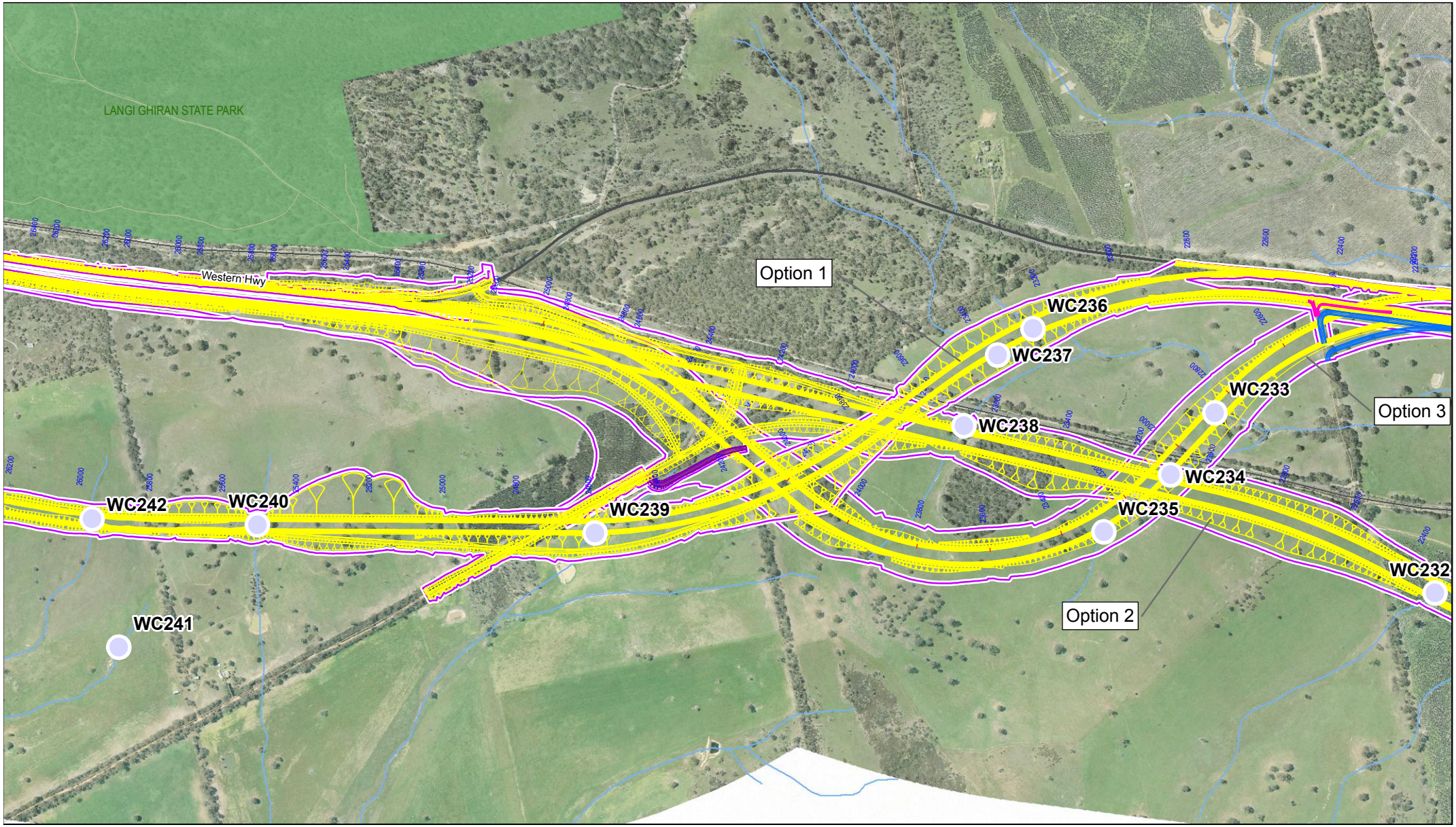

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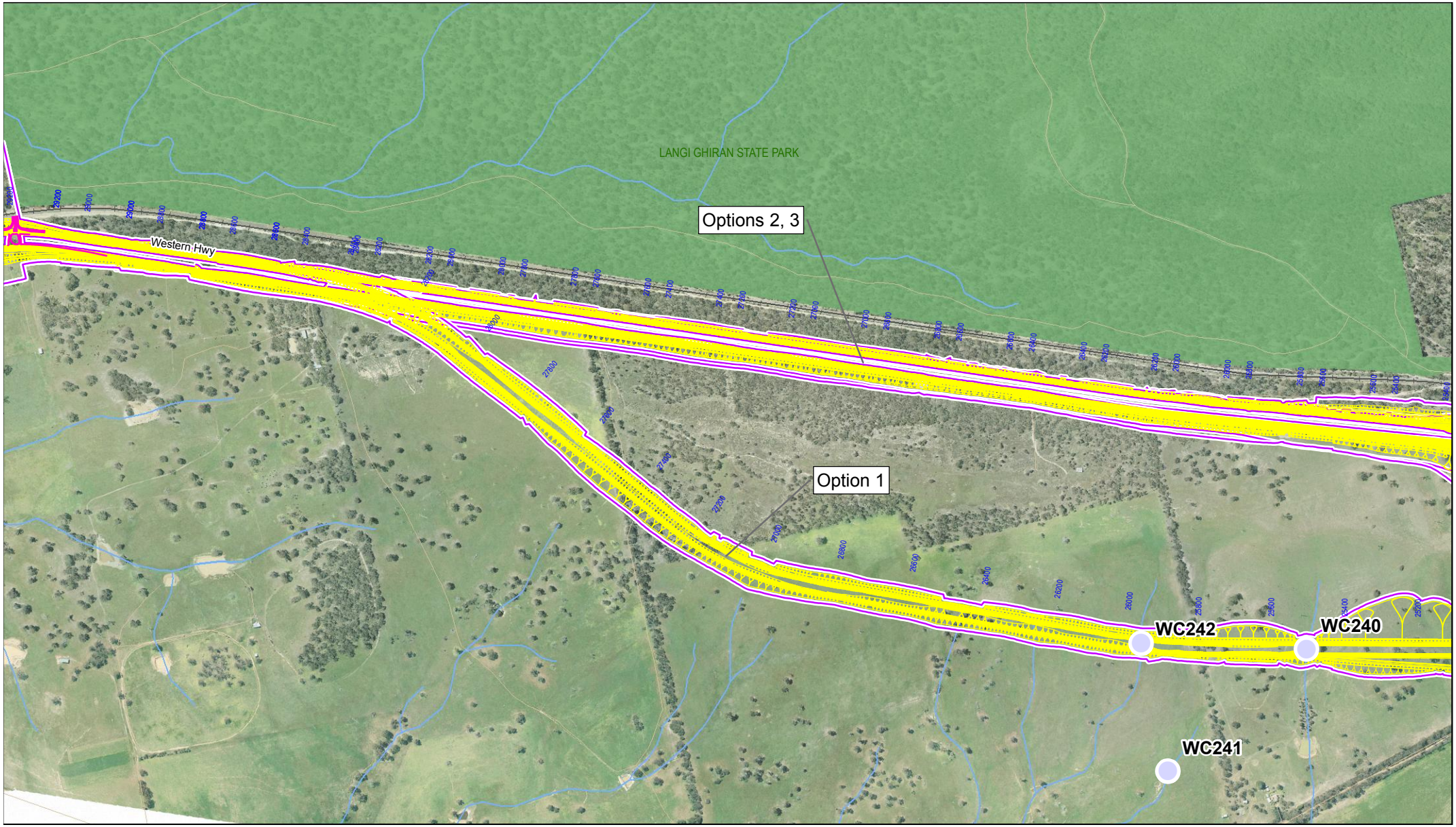

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

Waterway Crossings
- Minor
- Moderate
- Major
- Lake

- River
- Stream
- Channel / drain
- Connector

- Maximum Construction Footprint
- Carriageway & Interchanges
- Service Road
- Service road to be built under AMP-3 conditions

- Highway
- Sealed road (arterial & local)
- Unsealed road

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings
Sheet 10

Job Number 31-27558
Revision B
Date 06 Sep 2012

Appendix A

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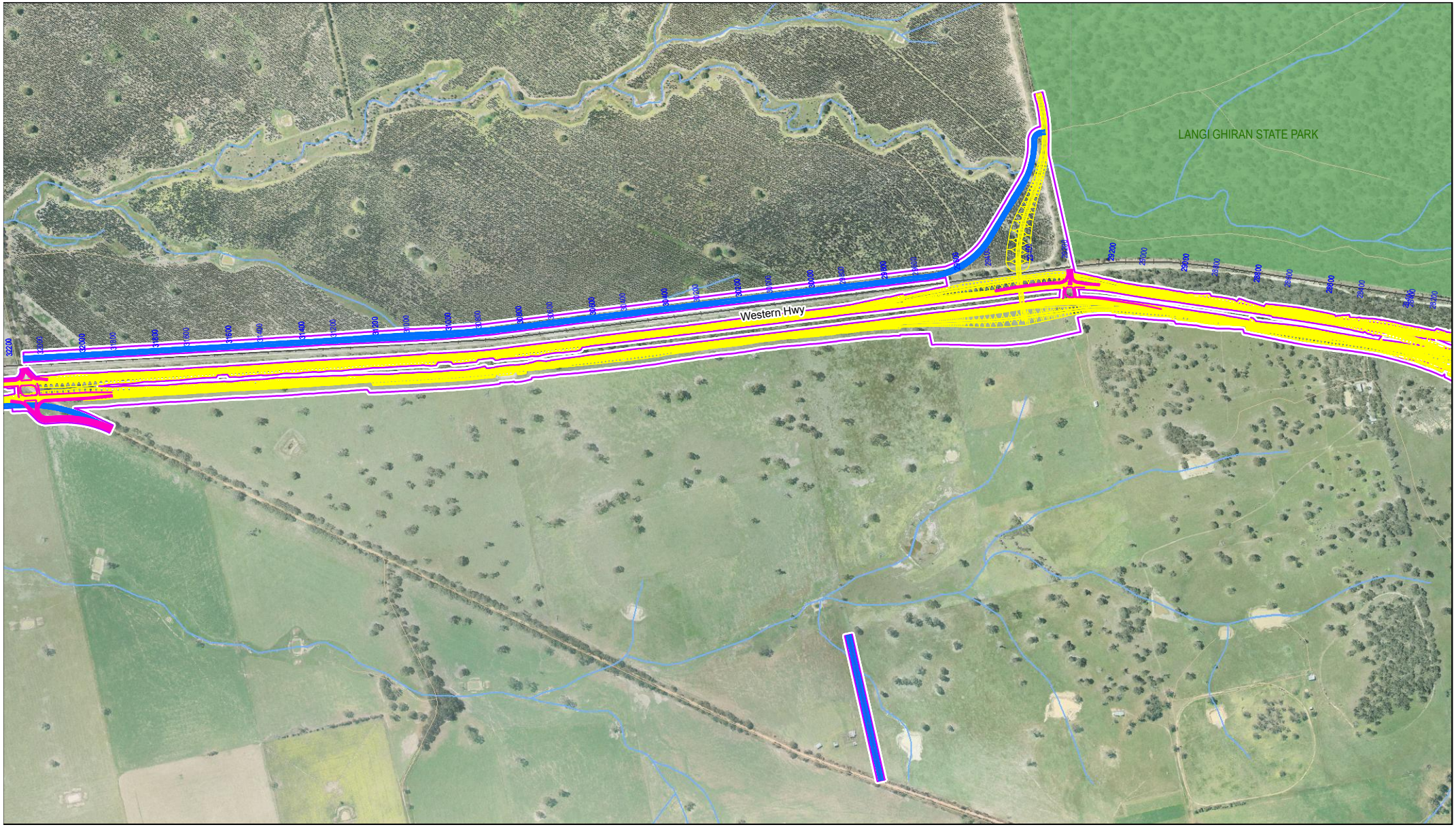

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

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Western Highway Project

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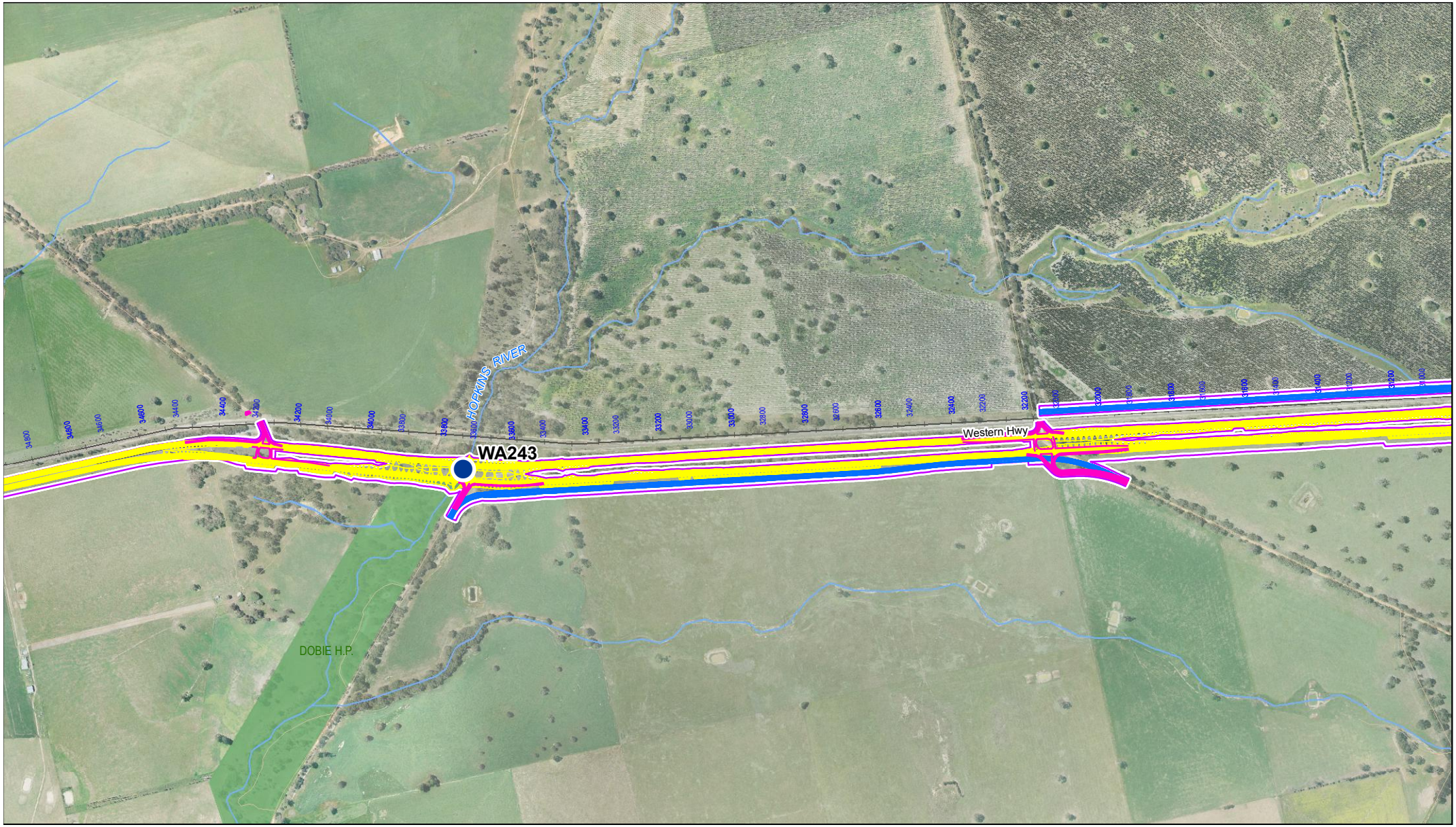

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Horizontal Datum: GDA 1994
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Beaufort to Ararat Waterway Crossings
Sheet 12

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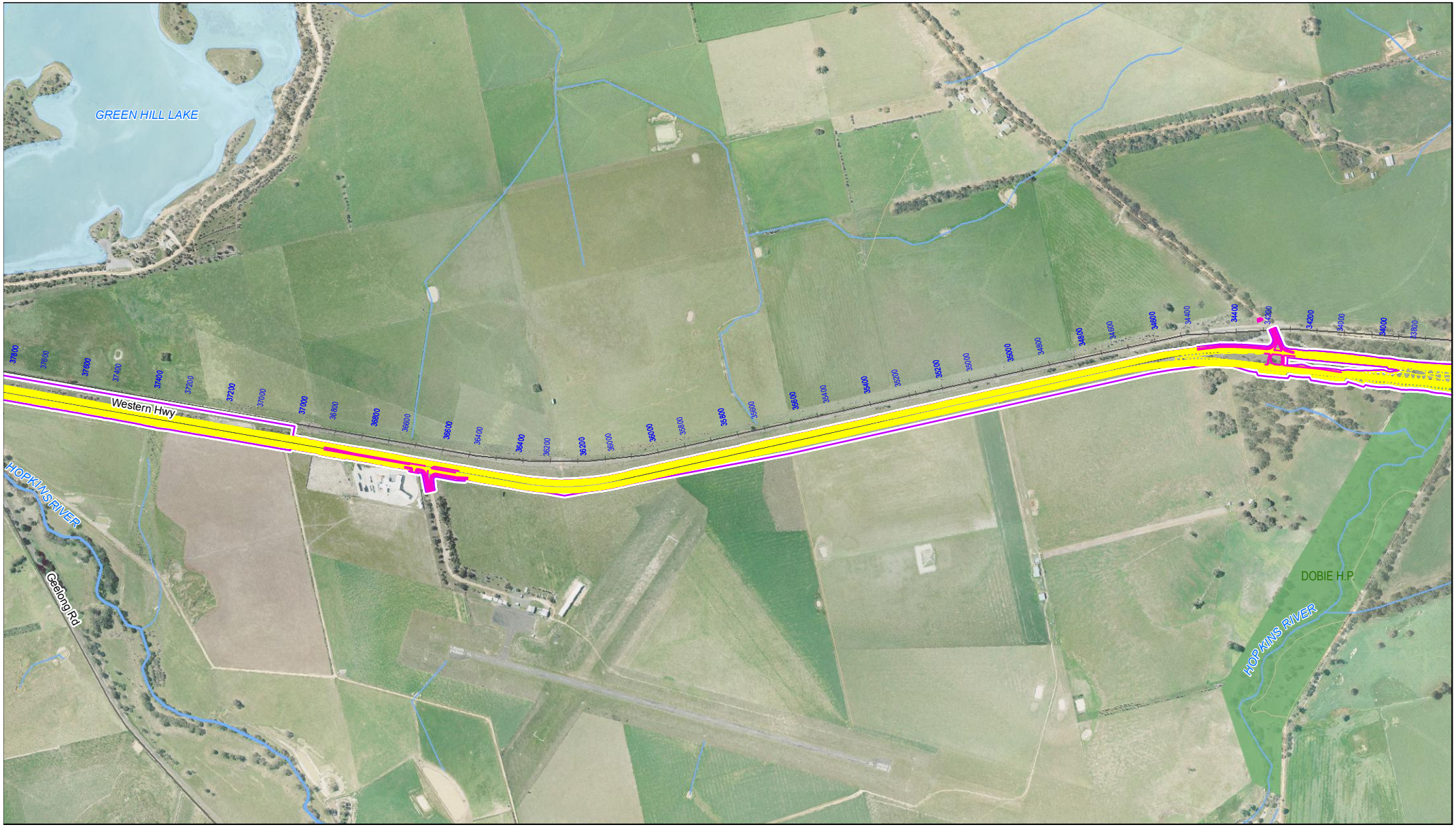

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Beaufort to Ararat Waterway Crossings
Sheet 13

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Appendix A

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Appendix A

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Appendix B

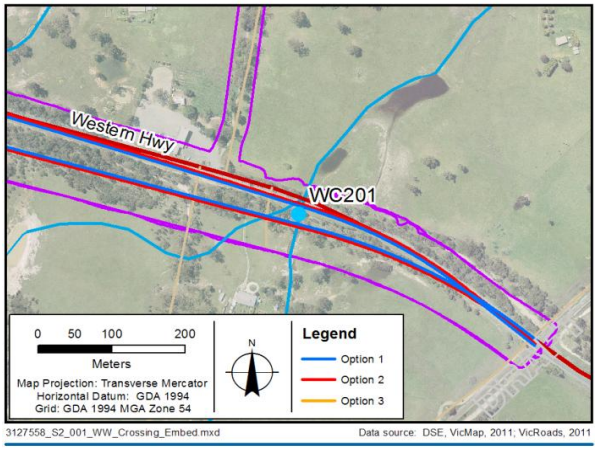
Waterway Crossing Field Inspection Proformas

SECTION 2 ARARAT TO BEAUFORT

Crossing ID	Waterway name	Site Inspected?	Easting	Northing
WC201	Unnamed Tributary of Yam Holes Creek	Y	708500	5855295
WC202	Unnamed Tributary of Yam Holes Creek	N	707936	5855496
WC203	Unnamed Tributary of Yam Holes Creek	Y	707662	5855506
WC204	Unnamed Tributary of Yam Holes Creek	N	707680	5855620
WC205	Unnamed Tributary of Yam Holes Creek	Y	707075	5856016
WC206	Unnamed Tributary of Fiery Creek	Y	706567	5856467
WC208	Unnamed Tributary of Fiery Creek	Y	705965	5856810
WC208	Unnamed Tributary of Fiery Creek		704750	5857285
WC209	Unnamed Tributary of Fiery Creek	N	705010	5858204
WC210	Unnamed Tributary of Fiery Creek	N	704784	5857687
WB211	Fiery Creek	Y	703663	5857909
WC212	Unnamed Tributary of Middle Creek	Y	700826	5859065
WB213	Middle Creek	Y	699275	5859645
WC214	Unnamed Tributary of Middle Creek	N	698963	5859771
WB215	Charleycombe Creek	Y	697404	5860366
WB216	Charleycombe Creek	Y	695715	5861021
WB217	Charleycombe Creek	Y	695449	5861127
WC218	Unnamed Tributary of Billy Billy Creek	N	694855	5861296
WC219	Unnamed Tributary of Billy Billy Creek	Y	694036	5862024
WC220	Unnamed Tributary of Billy Billy Creek	Y	693979	5862027
WC221	Unnamed Tributary of Billy Billy Creek	Y	693910	5861963
WC222	Unnamed Tributary of Billy Billy Creek	Y	693271	5862985
WC223	Unnamed Tributary of Billy Billy Creek	Y	693014	5862636
WC224	Unnamed Tributary of Billy Billy Creek	Y	693017	5862732
WA225	Billy Billy Creek	Y	692546	5862769
WA226	Billy Billy Creek	Y	692536	5862906
WC227	Unnamed Tributary of Billy Billy Creek	Y	692364	5862772
WB228	Billy Billy Creek	Y	690043	5863643
WC229	Unnamed Tributary of Billy Billy Creek	N	689774	5863119
WC230	Unnamed Tributary of Billy Billy Creek	N	689649	5863149
WC231	Billy Billy Creek	N	688940	5863522
WC232	Unnamed Tributary of Billy Billy Creek	N	688789	5863674
WC233	Unnamed Tributary of Billy Billy Creek	Y	688416	5864354
WC234	Unnamed Tributary of Billy Billy Creek	N	688241	5864242
WC235	Unnamed Tributary of Billy Billy Creek	N	688014	5864166
WC236	Unnamed Tributary of Billy Billy Creek	N	688042	5864752
WC237	Unnamed Tributary of Billy Billy Creek	N	687926	5864721
WC238	Unnamed Tributary of Billy Billy Creek	Y	687769	5864577
WC239	Unnamed Tributary of Gorrin Creek	Y	686733	5864666
WC240	Unnamed Tributary of Gorrin Creek	N	685883	5865046
WC241	Unnamed Tributary of Gorrin Creek	N	685408	5864878
WC242	Unnamed Tributary of Gorrin Creek	N	685471	5865229
WA243	Hopkins River	Y	678812	5868736
WB244	Greenhills Creek	Y	674658	5870428
WC245	Unnamed Tributary of the Hopkins River	N	674125	5870837

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC201		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Yam Holes Creek		Sub-catchment	H10: Trawalla Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 23
Highway Reference	Ch. 350 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural- cleared for grazing, and roadside reserve.		Disturbance rating	High
Catchment Area	250 ha		Aquatic ecology	Grasses, reeds
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 704504 **N** 5855276	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	Channel bound by road on left bank for part of reach. Channel 7 m wide, 1 m deep at face of culverts. Incised 30 cm deep low flow channel. Channel significantly smaller upstream and through open paddock, to approx. 0.5 m deep and 3 m wide. High flow channel splits upstream across paddock and rejoins main channel within road reserve near road culverts.		
- Channel gradient	0.8 %	**- Channel sinuosity**	Low sinuosity; 1.03
Banks	Some undercutting and scour along banks.		
Instream Features	1350 x 3 road culverts with rock protection. Woody debris caught on upstream side of culverts. Some permanent pools. Dam in paddock further upstream. Deep pools (only one filled with water at time of inspection; does not look permanent)		
Floodplain Description	Very wide floodplain. Channel converges at pool immediately upstream of culverts, from main flow and second high flow channel through paddock.		
Comments			

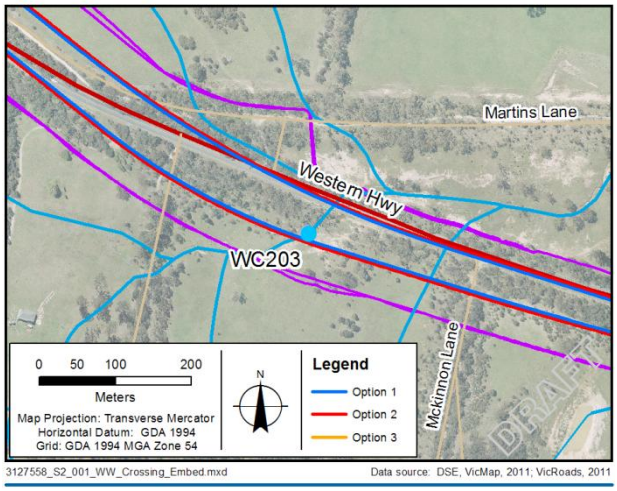


GIS aerial image of the site

Looking downstream in road reserve

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC203		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Yam Holes Creek		Sub-catchment	H10: Trawalla Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 23
Highway Reference	Ch. 1150 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural- cleared for grazing, and well treed Crown Land		Disturbance rating	High
Catchment Area	110 ha		Aquatic ecology	Reeds, yabbies?
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 707739 **N** 5855500	**Geomorphic Classification**	Partially confined
Channel planform			
- Channel geometry	Permanent pool extends under road downstream for 6 m. 2 smaller ponds upstream from there. Becomes unchannelled once beyond Crown Land onto open paddock, at upstream end of reach. There is one permanent pool in the unchannelled section, approx. 2 m wide, 6 m long and 0.4 m deep.		
- Channel gradient	1.2 %	**- Channel sinuosity**	Low sinuosity; 1.09
Banks	Undercut at pools.		
Instream Features	Road culvert 2225 wide x 2000 (mm) high. Permanent pools.		
Floodplain Description	Partially confined, very wide and flat valley floor with hills on either bank. Potential for lateral adjustment away from confining hills.		
Comments			

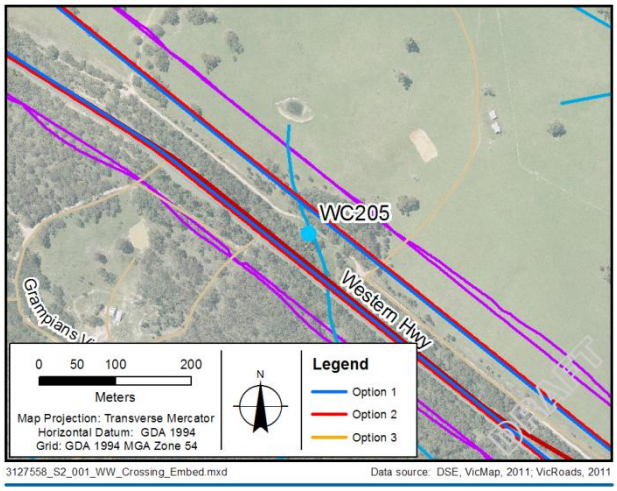


GIS aerial image of site

Looking west, upstream, near road culverts

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC205		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Yam Holes Creek		Sub-catchment	H10: Trawalla Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 23
Highway Reference	Ch. 1950 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural- cleared for grazing, and well treed Crown Land		Disturbance rating	Medium
Catchment Area	10 ha		Aquatic ecology	Nil.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 707072 **N** 5856025	**Geomorphic Classification**	Unconfined
Channel planform	Shallow opening nearer to Existing Highway, then scrubby undefined flow area upstream		
- Channel geometry	Unchannelled hillslopes.		
- Channel gradient	3.3 %	**- Channel sinuosity**	n/a
Banks	n/a		
Instream Features	n/a		
Floodplain Description	n/a		
Comments			

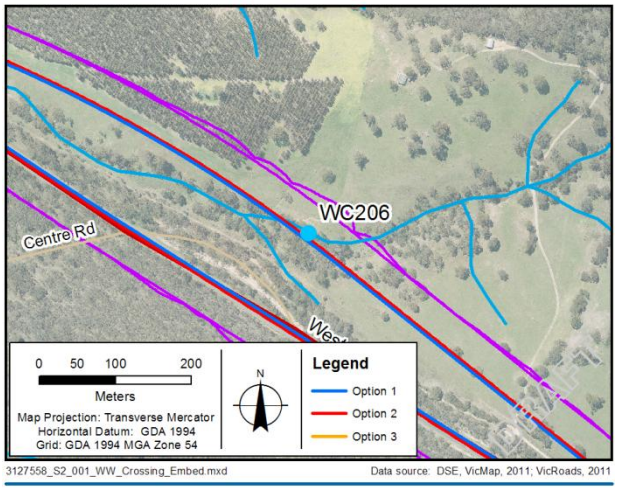


GIS aerial image of site

Looking upstream

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC206		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Fiery Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 2750 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Cleared agricultural and bush block.		Disturbance rating	Medium
Catchment Area	19 ha		Aquatic ecology	Nil.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 706547 **N** 5856475	**Geomorphic Classification**	Confined
Channel planform			
- Channel geometry	Minor, stable head cuts. Mostly unchannelled. Broad gully. Where channel does exist <1 m wide and deep.		
- Channel gradient	5.1 %	**- Channel sinuosity**	Low sinuosity; 1.08
Banks	Head cuts and some sections of exposed bank (<5% or reach length)		
Instream Features	Some woody debris over gully through wooded area		
Floodplain Description	Confined within gully; no floodplain. Some bedrock outcrops within gully walls.		
Comments			

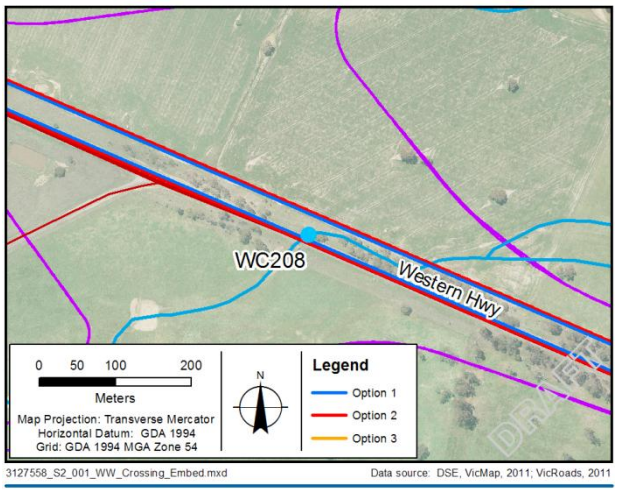


GIS aerial image of site

Looking upstream

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC208		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Fiery Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 4450 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural- cleared for grazing and road reserve		Disturbance rating	High
Catchment Area	40 ha		Aquatic ecology	Grasses
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 704913 **N** 5857236	**Geomorphic Classification**	Unconfined
Channel planform	Channel alignment altered through road reserve		
- Channel geometry	Channel through paddock up to 0.6 m deep, 5 m wide with incised low flow channel. Some dried pools, 4 m across, 0.3 m wide. Further downstream channel becomes straight roadside drain approx. 0.8 m deep, 1.5 m wide.		
- Channel gradient	0.7 %	**- Channel sinuosity**	Low sinuosity; 1.09.
Banks	Some undercutting. Likely stock access to channel upstream in paddock.		
Instream Features	Culvert under road, 2 x 0.9 m x 1.2 m.		
Floodplain Description	Very wide floodplain, greater than 200 m either bank, though current highway acts as barrier.		
Comments			

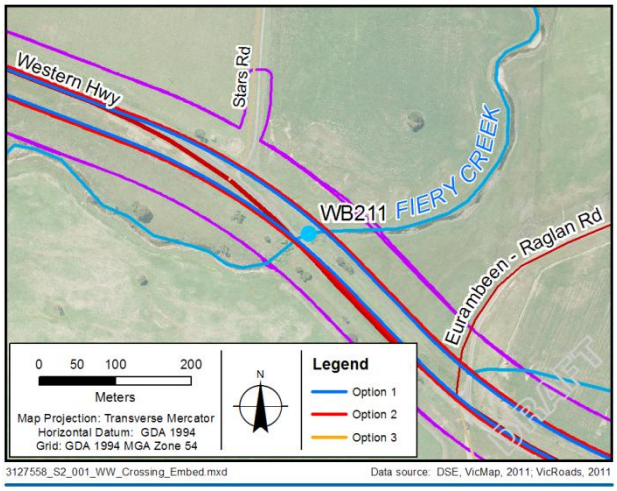


GIS aerial image of site

Looking upstream through road reserve

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WB211		Basin	Upper Hopkins River, GHCMA
Waterway Name	Fiery Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 5950 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural- cleared for grazing		Disturbance rating	High
Catchment Area	9250 ha		Aquatic ecology	Sedges, reeds, grasses, willows.
Flow Characteristics	Permanent (flow observed)			

Site Inspection			
GPS Location	**E** 703665 **N** 5857924	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	Channel set deeper with benches on either bank. Channel 1.5 m deep, 6-8 m wide. Benches extend 5 m either side. Downstream from bridge channel up to 4 m deep and 10 m wide.		
- Channel gradient	0.5 %	**- Channel sinuosity**	Moderate sinuosity; 1.08
Banks	Undercutting and slumping in some sections upstream of road bridge. Areas of mass slumping and lots of incision and exposed bank downstream of road bridge.		
Instream Features	Road bridge across reach- 36 m span. Vegetated island upstream of road. Downstream of road larger island with established willows, approx. 8 m tall. Permanent pools.		
Floodplain Description	Approx. 100 m on left bank, 80 m on right bank.		
Comments	Mostly straight reach at road crossing site. Approx. 350 m downstream creek comes within 10 m of construction footprint (service road).		

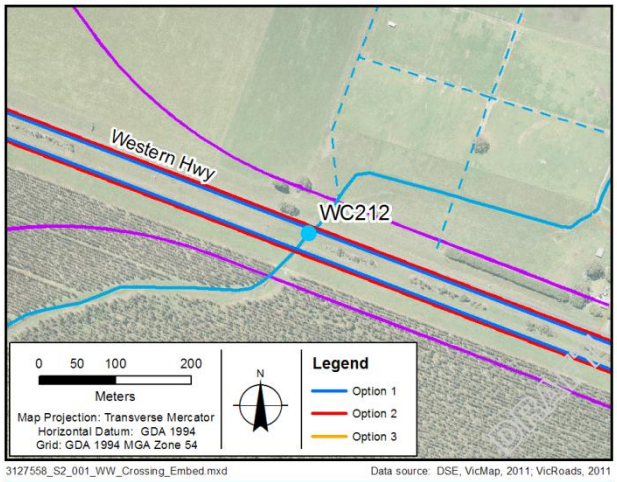


GIS aerial image of the site

Looking downstream, north of Existing Highway bridge

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC212		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Middle Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 9100 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural- cleared for grazing, and blue gum plantation		Disturbance rating	High
Catchment Area	930 ha		Aquatic ecology	Reeds, grasses
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 700693 **N** 5859068	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	0.2 m deep, up to 7 m across, for approx. 10 m upstream of road and 15 m downstream. Then channel narrows and deepens- 3 m across, 0.5 m deep.		
- Channel gradient	0.5 %		
- Channel sinuosity	Low sinuosity; 1.12. Highly altered channel alignment.		
Banks	Some erosion- undercutting in channel where it deepens downstream of road bridge. Densely vegetated banks with dry grasses.		
Instream Features	Road culvert: 4 x 1.2 m x 9 m.		
Floodplain Description	Very wide floodplain. Runs through blue gum plantation so levelling of ground and internal drainage within plantation would impose floodplain.		
Comments			

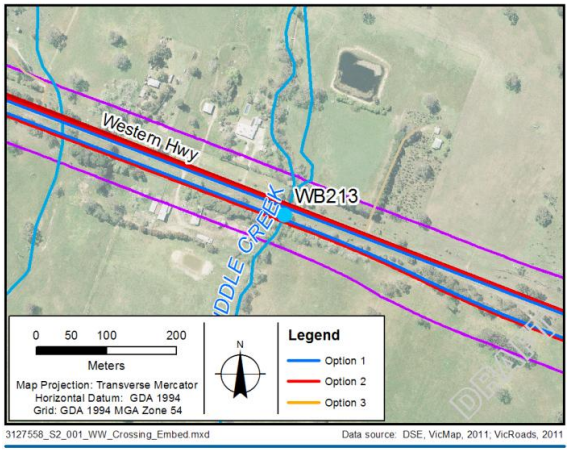


GIS aerial image of the site

Looking downstream from existing road bridge

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WB213		Basin	Upper Hopkins River, GHCMA
Waterway Name	Middle Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 10650 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural grazing. Vegetated banks along road reserve.		Disturbance rating	High
Catchment Area	2460 ha		Aquatic ecology	Ducks, reeds, rushes, grasses, willows, sedge, mint, yabbies(?).
Flow Characteristics	Permanent (flow observed)			

Site Inspection			
GPS Location	**E** 699279 **N** 5859671	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	Up to 0.8 m deep in pool extending either side under road bridge (bridge 10 - 6 m wide). Water 30cm below toe of bank in pool. Channel narrows downstream then opens into another pool after willow riffle.		
- Channel gradient	0.6 %	**- Channel sinuosity**	Low sinuosity; 1.08
Banks	Well vegetated. Some exposed bank of downstream bridge. Some small, steep bank sections.		
Instream Features	Road culverts: 2x approx. 1 m diameter with middle culvert trapezoidal shape, unknown dimensions. Permanent pool, 15 m long, upstream of bridge, extends 20 m downstream. Downstream pool held by mass of willow roots, providing substantial grade control (rapids over roots) of approx. 2 m drop. Big cluster of debris- roots, branches etc. - at downstream end of pool.		
Floodplain Description	Wide floodplain. Large red gums spread at least 100 m either bank. Potential for lateral adjustment, though root mass quite dense along some sections holding channel in place.		
Comments			

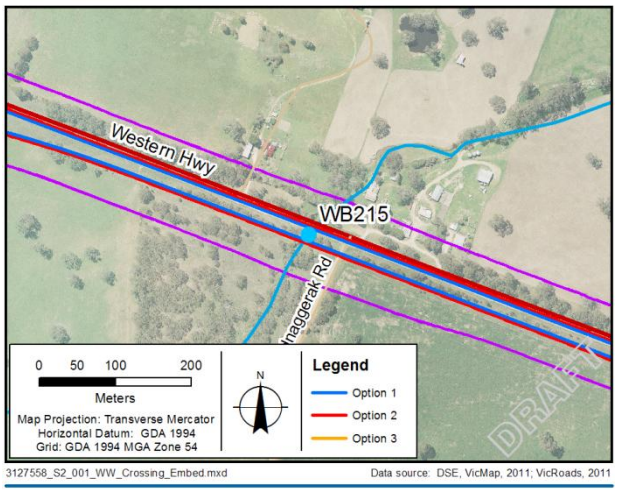


GIS areial image of the site


Looking upstream beyond pool on north side of Existing Highway bridge; channel becomes narrow.

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WB215		Basin	Upper Hopkins River, GHCMA
Waterway Name	Charliecombe Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 12600 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural- cleared for grazing		Disturbance rating	High
Catchment Area	174 ha		Aquatic ecology	Pastoral grasses, grasses, reeds, arum lily
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 697404 **N** 5860366	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	Shallow channel upstream of road bridge, 0.3 m deep, 1 m wide. Widening of channel under bridge, approx. 10 m.		
- Channel gradient	0.4 %	**- Channel sinuosity**	Straight; 1.04
Banks	Well vegetated on downstream bridge side. Exposed banks through paddock upstream of road reserve with obvious stock access.		
Instream Features	Widening of channel at bridge. Large tree down across channel at upstream end of reach.		
Floodplain Description	Broad floodplain- 150 m either side on downstream side. Houses very close to creek on upstream side.		
Comments			

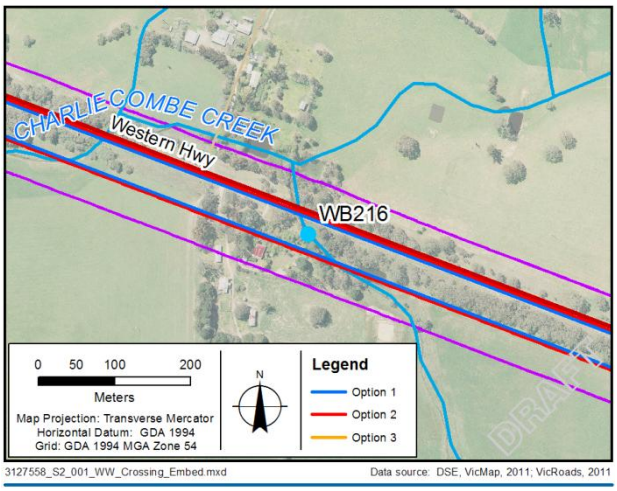


GIS aerial image of site

Looking upstream, north of Existing Highway

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WB216		Basin	Hopkins River, GHCMA
Waterway Name	Tributary of Charliecombe Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 14400 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Part residential, part cleared agricultural grazing.		Aquatic ecology	Reeds, grasses.
Catchment Area	505 ha		Disturbance rating	Medium.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 695779 **N** 5860934	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	Evident channel for part of reach, approx. 1.5 m wide, 1 m deep. Shallow bar, approx. 20 cm above channel invert u/s from road culvert. Channel broadens to shallow pool on downstream side of road culvert.		
- Channel gradient	0.4 %	**- Channel sinuosity**	Low sinuosity; 1.07
Banks	Some undercutting along channelled section. Channelled section has some exposed banks. Highly vegetated (grasses) either end of channel section.		
Instream Features	Highway culvert: 4 x 1.2 m height x 2 m width. Through channelled section many exposed tree roots. Areas of bank slump. Bar covered in vegetation. Some fallen logs across channel. Off-line dam beside middle channel section.		
Floodplain Description	Floodplain extends 50 m to the south, gently sloping topography. To the north confined by the Highway. Small hill downstream from dam- possibly spoil from constructing dam- confines middle channelled section. Potential for lateral adjustment across open paddock to the south of the proposed alignment.		
Comments	Would require realignment of the channel- possibly through the middle of the proposed road and service road- and must also deal with the incision occurring through channelled section.		

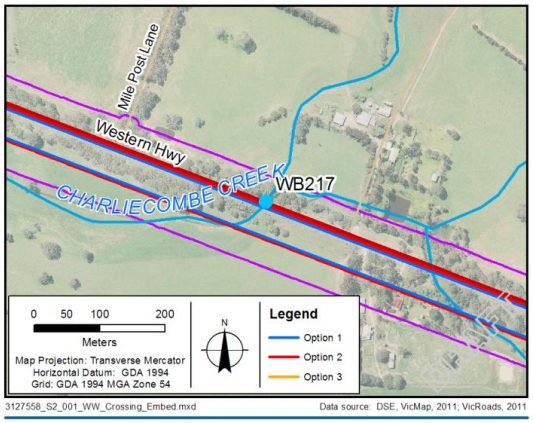


GIS aerial image of waterway crossing

Looking north, cross-channel from left bank, south of Existing Highway.

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WB217		Basin	Upper Hopkins River, GHCMA
Waterway Name	Charliecombe Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 14750 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural- cleared for grazing		Disturbance rating	High
Catchment Area	1323 ha		Aquatic ecology	Pastoral grasses, grasses, reeds
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 695449 **N** 5861127	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	Reach channel through 50 m upstream of Existing Highway bridge up to 0.4 m deep and 2 m wide. Straight alignment through road reserve. Upstream reach becomes shallower/unchannelled. Channel opens out at bridge crossing. Downstream of road reserve channel up to 0.5 m deep and 2 m wide.		
- Channel gradient	0.5 %	**- Channel sinuosity**	Low sinuosity; 1.09
Banks	Some localised areas of scour, no more than a few metres each.		
Instream Features	Some woody debris within road reserve.		
Floodplain Description	Broad floodplain. Potential or lateral adjustment.		
Comments	Approx. 400 m downstream from waterway crossing channel comes to within 10 m of southern service road.		

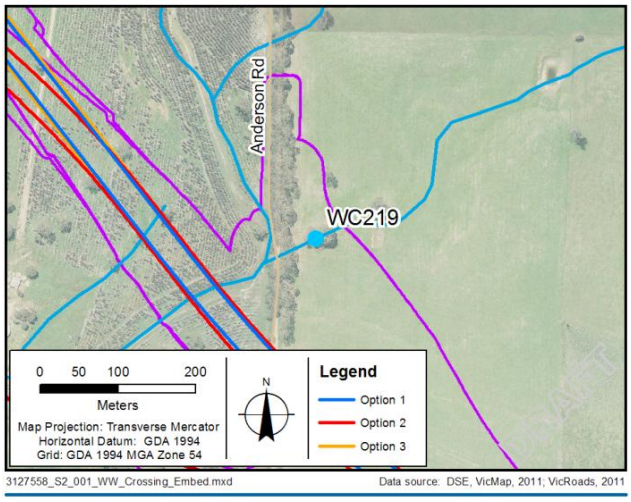


Looking downstream to the west, downstream end of reach

 Looking upstream, north of the Highway. Creek runs parallel with Highway in road reserve for approx. 70 m north through	 Looking upstream, facing north east, across open paddock.

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC219		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Billy Billy Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)	4		Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 16550 (Side Road)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural grazing and road reserve.		Aquatic ecology	Nil.
Catchment Area	85 ha		Disturbance rating	High
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 694031 **N** 5862022	**Geomorphic Classification**	Unconfined
Channel planform	Unchannelled, sloping, broad floodplain.		
- Channel geometry	n/a		
- Channel gradient	n/a	**- Channel sinuosity**	n/a
Banks	n/a		
Instream Features	Road culvert at downstream end of reach: Trapezoidal. 0.9 m height, 1.5 m width across top, 1.2 m width across bottom.		
Floodplain Description	300 m floodplain. Very flat across bottom. A few river red gums. Road embankment funnels water through culvert under Anderson Road.		
Comments	No flood extent from Bonacci Report.		

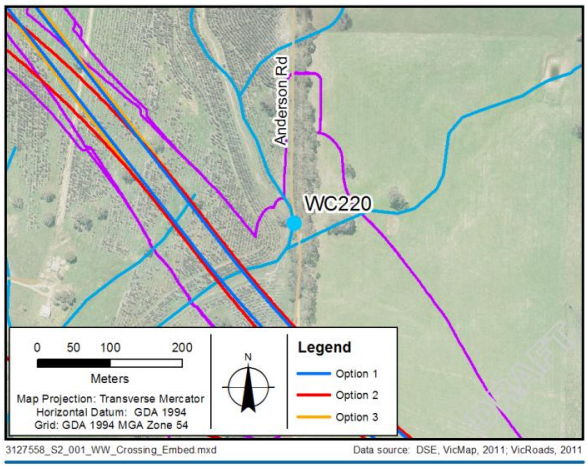


GIS aerial image of waterway crossing

Looking upstream across open paddock – no visible channel

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC220		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Billy Billy Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)	4		Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 16550 (Side Road)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Cleared grazing land upstream, reach through road reserve, then blue gum plantation downstream.		Disturbance rating	High
Catchment Area	549 ha		Aquatic ecology	Nil.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 693978 **N** 5862033	**Geomorphic Classification**	Unconfined, though currently confined by Anderson Road embankment.
Channel planform	Altered as road drain.		
- Channel geometry	Pool up to 3 m deep, 10 m wide at upstream end of reach at Anderson Road culvert outlet (see waterway crossing *WC219* for outlet figure). For majority of reach channel 1 m deep, 2 m wide.		
- Channel gradient	0.6 %	**- Channel sinuosity**	Straight; 1.04.
Banks	Steep banks in pool downstream of road culvert, though look to be stable. No evidence of recent erosion. Some slump and undercutting at base of channel, with slight incision. Moderately vegetated with pastoral grasses.		
Instream Features	Big tree trunk across channel. Sandbar upstream of tree trunk.		
Floodplain Description	Floodplain very confined between road embankment and drainage installed for blue gum plantation. Little potential for lateral adjustment.		
Comments			

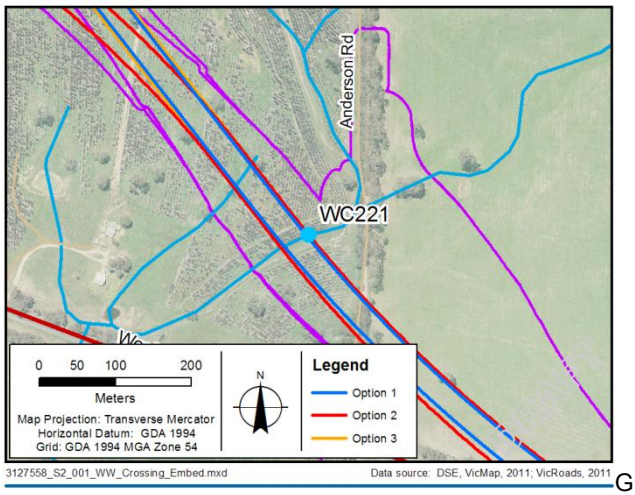


GIS aerial image of waterway crossing.

Looking upstream with Anderson Road in right background.

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC221		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Billy Billy Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)	4		Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 16550 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Swale, in blue gum plantation.		Disturbance rating	High
Catchment Area	653 ha		Aquatic ecology	Reeds, grasses.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 693891 **N** 5861950	**Geomorphic Classification**	Unconfined
Channel planform	Altered and deepened to accommodate agricultural purposes.		
- Channel geometry	2 m deep, 10 m wide. Shallower at the bend at the upstream end of the reach.		
- Channel gradient	0.5%	**- Channel sinuosity**	Straight; 1.03.
Banks	Well vegetated with grasses. Some exposed bank and slight incision in upstream of reach.		
Instream Features	Bank attached sand bars at a few points along the reach.		
Floodplain Description	Wide floodplain on left bank, restricted by a few small rises along right bank. Surface drainage lines on the floodplain may exist inside blue gum plantation. Rows of gums start approx. 10 m back from either bank. Some potential for lateral adjustment.		
Comments	No flood extent from Bonacci Report.		

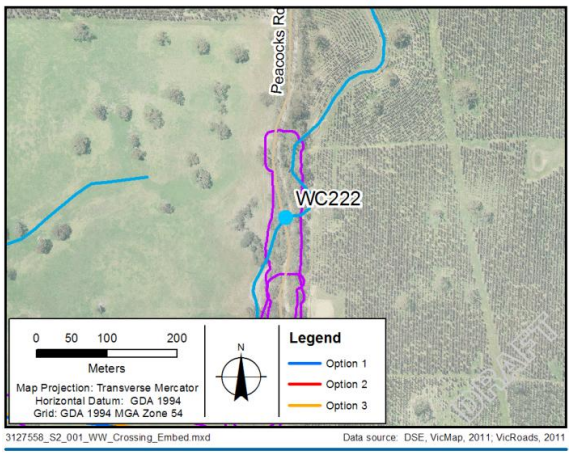


GIS aerial image of site .

Shallow bend in channel at most upstream end of reach.

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC222		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Billy Billy Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)	4		Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 17550 (Side Road)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Blue gum plantation and road reserve		Disturbance rating	High
Catchment Area	590 ha		Aquatic ecology	Very little vegetation in channel. Some grasses and reeds.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 693268 **N** 5863041	**Geomorphic Classification**	Unconfined within greater floodplain. Confined by Peacocks Rd on left bank.
Channel planform	More sinuous upstream of culvert; straight within the road reserve.		
- Channel geometry	Upstream of road culvert: broad 10 m wide, 2 m deep, with incised channel 0.5 m deep, 1 m wide. Downstream culvert: 3 m deep, up to 15 m wide at opening of culvert on bend. 2 m wide incised channel at bottom.		
- Channel gradient	0.7 %	**- Channel sinuosity**	Low sinuosity; 1.15.
Banks	Active erosion including slump, undercutting. Some protection from vegetation but not along the whole length of the reach. Banks approx. between 30 degrees and vertical on right bank at bend, downstream from road culvert.		
Instream Features	Road culvert, 1.5 m diameter with rock work all the way up the banks beside wing walls and approx. 7 m downstream.		
Floodplain Description	Deeply set channel into floodplain downstream of the road culvert, some benches upstream of the road culvert. Current floodplain 50 m wide. Channel bound by road, and mature vegetation to some extent. Potential for lateral adjustment upstream of road culvert and possibly downstream.		
Comments			

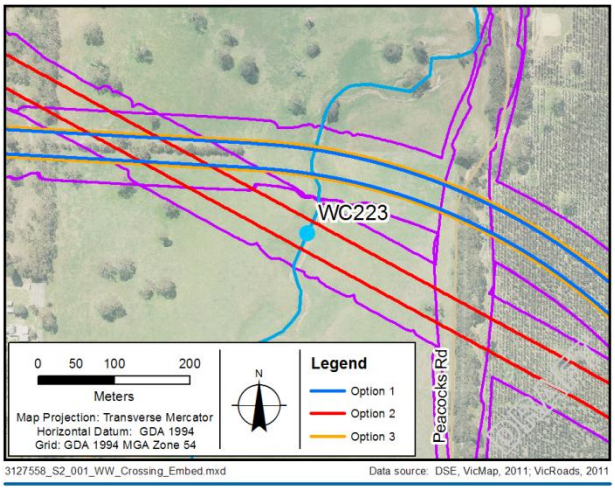


GIS aerial image of site.

Looking downstream from culvert.

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC223		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Billy Billy Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)	4		Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 17700 (Option 2 – Deviation)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Cleared for grazing		Disturbance rating	High
Catchment Area	643 ha		Aquatic ecology	Nil.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 693006 **N** 5862637	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	Channel 1 m deep, 5 m wide.		
- Channel gradient	0.3 %	**- Channel sinuosity**	Low sinuosity; 1.06.
Banks	Evidence of mass slumping and undercutting in some places. Sandy bottom and some exposed earth bank sections.		
Instream Features	Minor bank attached sand bars.		
Floodplain Description	Channel sits within floodplain terrace, up to 40 m wide on right bank, 30 m on left bank. Potential for lateral adjustment, either bank.		
Comment	No flooding- reach is 90 m upstream of Bonacci Report flood extent.		

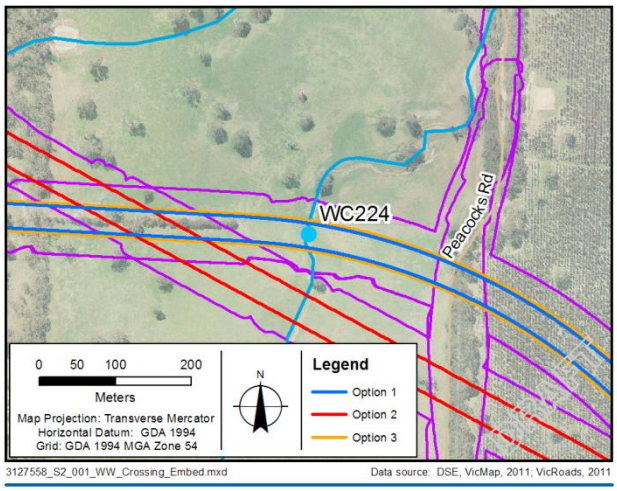


GIS aerial image of site


Looking downstream, from base of gum where channel is wider then narrows again.

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC224		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Billy Billy Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)	4		Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 17700 (Option 1 & Option 3 – Deviation)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural- cleared for grazing		Disturbance rating	High
Catchment Area	634 ha		Aquatic ecology	Nil.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 693017 **N** 5862752	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	Channel 1 m deep, 5 m wide.		
- Channel gradient	0.4 %	**- Channel sinuosity**	Moderate sinuosity; 1.25.
Banks	Evidence of mass slumping and undercutting in some places. Sandy bottom and some exposed earth bank sections.		
Instream Features	Minor bank attached sand bars.		
Floodplain Description	Channel sits within floodplain terrace- terrace evident on left bank. Terrace 20-30 m wide on left bank, approx. 1 m above channel invert. Potential for lateral adjustment, up to 30 m on left bank.		
Comments			

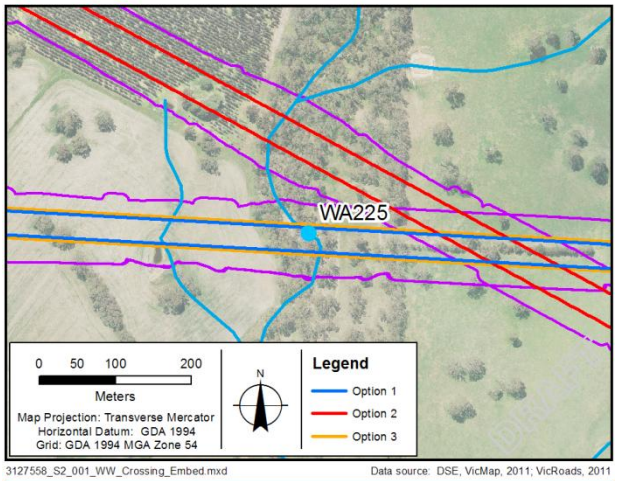


GIS aerial image of the site.

Looking upstream.

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WA225		Basin	Upper Hopkins River, GHCMA
Waterway Name	Billy Billy Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 18200 (Option 1 & Option 3 – Deviation)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Channel within Crown Land. Further upstream, cleared for grazing and blue gum plantation.		Disturbance rating	High
Catchment Area	2835 ha		Aquatic ecology	Frog, sedges, reeds, grasses.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 692559 **N** 5862755	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	Complex geometry with chain of pools and high flow channels. Large pool 30 m diameter max. 0.5 m deep, at bend of reach. Incised channels, pools; constrictions from roots, vegetation & debris.		
- Channel gradient	0.4 %	**- Channel sinuosity**	Moderate sinuosity; 1.2
Banks	Well vegetated in large pool with no erosion evident. Further upstream from large pool incision and undercutting present.		
Instream Features	Permanent pools, constrictions thorough incised channels and tree roots. Some woody debris.		
Floodplain Description	Narrow floodplain, up to 60 m either side.		
Comments			

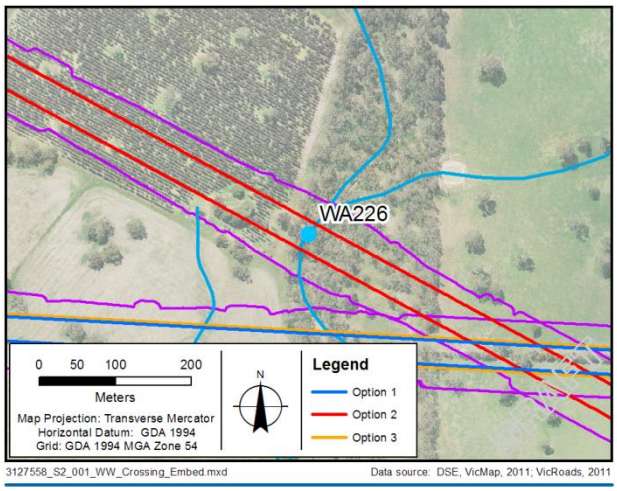


GIS aerial image of the site

Looking downstream from the large pool

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WA226		Basin	Upper Hopkins River, GHCMA
Waterway Name	Billy Billy Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 18250 (Option 2 – Deviation)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Channel within Crown Land. Beyond this, cleared for grazing and blue gum plantation.		Disturbance rating	High
Catchment Area	2900 ha		Aquatic ecology	Grasses, reeds, sedges.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 692516 **N** 5862899	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	0.5 m deep, 3 m wide channel. Chain of pools alternating with narrow section of channel with gentler sloping banks.		
- Channel gradient	0.4 %	**- Channel sinuosity**	Moderate sinuosity; 1.2
Banks	Undercutting in pools and evidence of scour. In higher channel sections between pools bank is well vegetated all the way to the toe.		
Instream Features	Some large woody debris. Some standing water indicating deeper pools.		
Floodplain Description	Floodplain 60 m either side. Lightly forested within Crown Land.		
Comments			

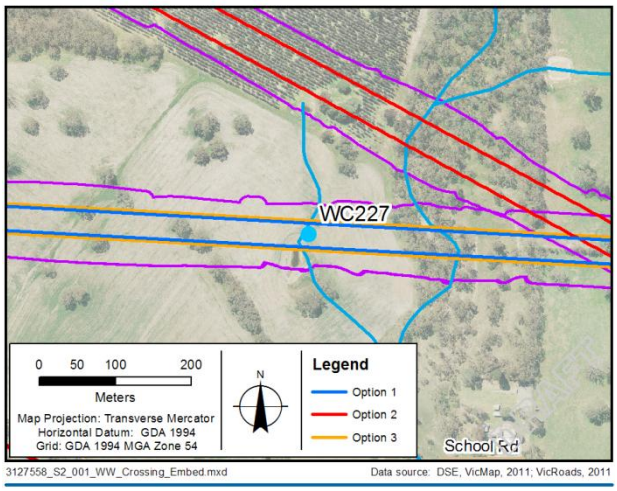


GIS aerial image of site

Looking downstream

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC227		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Billy Billy Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 18400 (Option 1 & Option 3 – Deviation)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Cleared for grazing. Blue gum in upper catchment		Disturbance rating	High
Catchment Area	5 ha		Aquatic ecology	Ducks, water hen, water lily, reeds. Grasses in unchannelled reach.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 692360 **N** 5862777	**Geomorphic Classification**	Unconfined
Channel planform	Unchannelled grassy slope, running into farm dam at downstream end of reach.		
- Channel geometry	Unchannelled.		
- Channel gradient	1 %	**- Channel sinuosity**	n/a
Banks	n/a		
Instream Features	n/a		
Floodplain Description	Farm dam within footprint of proposed alignment. Broad floodplain. Billy Billy Creek lies beyond the left bank, approx. 100 m either side.		
Comments			

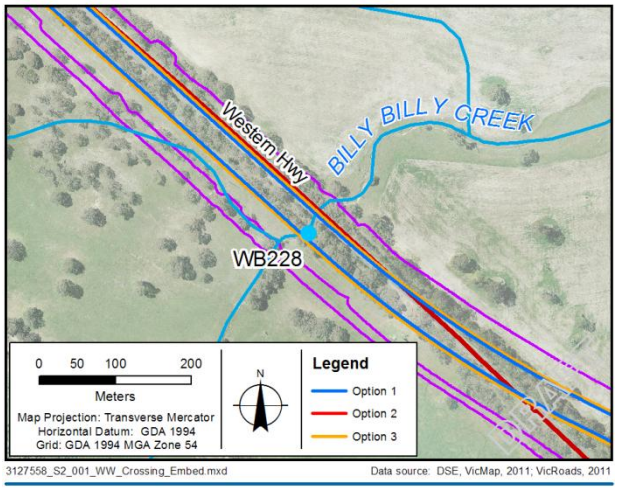


GIS aerial image of the site

Looking north-west, upstream

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WB228		Basin	Upper Hopkins River, GHCMA
Waterway Name	Billy Billy Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 20950 (Duplication)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Agricultural grazing		Disturbance rating	High
Catchment Area	787 ha		Aquatic ecology	Sedges, reeds, pastoral grasses.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 690063 **N** 5863639	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	Chain of pools. Pool under road culverts up to 4 m wide. Downstream of road culvert channel narrows- up to 1 m wide and 0.3 m deep- with pond areas between.		
- Channel gradient	0.7 %	**- Channel sinuosity**	Low sinuosity; 1.1
Banks	Well vegetated banks through higher channel parts, no obvious erosion in pools. Some undercutting and slump further downstream in the reach.		
Instream Features	Some large fallen branches. 3 x circular culverts at road crossing.		
Floodplain Description	Floodplain extends 100 m from right bank and 80 m from left bank. The highway is beyond the left bank, acting as a control.		
Comments	Recommend proposed service road be realigned to limit length of impact to waterway (approx. 30 m to the south). Vicmap watercourse roughly accurate in GIS layer.		

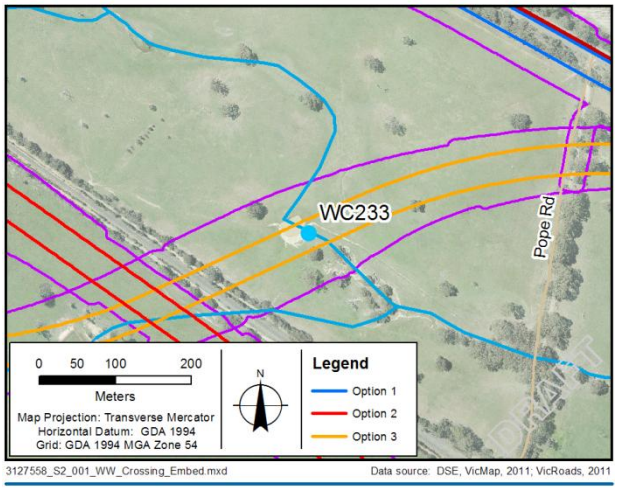


GIS aerial image of site

Looking upstream from the Existing Highway bridge.

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC233		Basin	Upper Hopkins, Glenelg Hopkins CMA
Waterway Name	Tributary of Billy Billy Creek		Sub-catchment	H12: Upper Fiery Creek
Bonacci Reference (Catchment No.)			Reach Number	Reach 29: Fiery Creek
Highway Reference	Ch. 22800 (Option 3 – Deviation)		ISC rating (score)	Poor
General			**Ecological Values**	
Land Use Description	Cleared for grazing		Disturbance rating	High
Catchment Area	239 ha		Aquatic ecology	Nil.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 688411 **N** 5864358	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	Unchannelled through proposed highway alignment. Immediately east of proposed alignment, on toe of batter, highly eroding channel with multiple head cuts and complex geometry- channel up to 2 m deep.		
- Channel gradient	0.9 %	**- Channel sinuosity**	No channel through alignment.
Banks	Multiple advancing head cuts downstream of alignment; undercutting, incision, slumping. No channel through and upstream of alignment.		
Instream Features	Some woody debris immediately downstream of alignment, plus debris including wire, metal, plastic in head cuts. Dam through alignment.		
Floodplain Description	Wide in the order of several hundred metres. Low levee (20 cm) running parallel to channel (perpendicular to alignment) to the north directing water into dam.		
100 Year Flood extent			
Comments	Large potential for head cuts to undermine road. Mitigation works would be required downstream of the alignment (Option 3).		

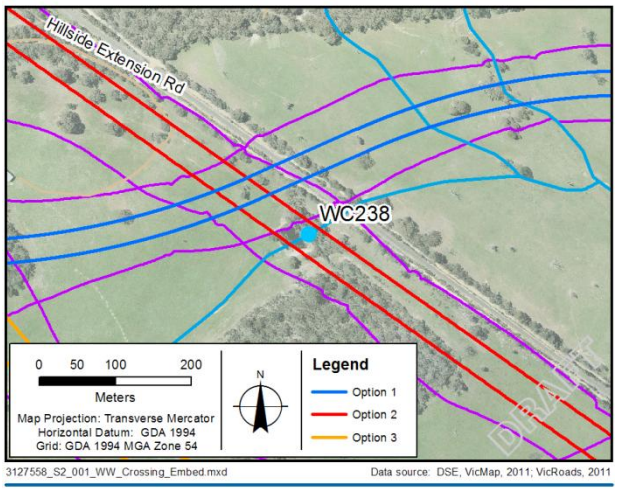


GIS aerial image of the site

Taken from left bank facing east (facing downstream), showing constructed levee on floodplain on the left and the channel downstream of the alignment on the right.

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC238		Basin	Upper Hopkins River, GHCMA
Waterway Name	Tributary of Billy Billy Creek		Sub-catchment	H5: Upper Hopkins River
Bonacci Reference (Catchment No.)			Reach Number	Reach 12
Highway Reference	Ch. 23650 (Option 2 – Deviation. Very close to Option 1 Deviation)		ISC rating (score)	Moderate
General			**Ecological Values**	
Land Use Description	Cleared for grazing		Disturbance rating	High
Catchment Area	17 ha		Aquatic ecology	Nil.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 687769 **N** 5864577	**Geomorphic Classification**	Confined
Channel planform			
- Channel geometry	Unchannelled		
- Channel gradient	3.1 %	**- Channel sinuosity**	n/a
Banks	n/a		
Instream Features	Small dam immediately upstream of the alignment. Culvert under train line downstream.		
Floodplain Description	Head water stream. Waterway abuts valley margins, therefore no floodplain.		
Comments			

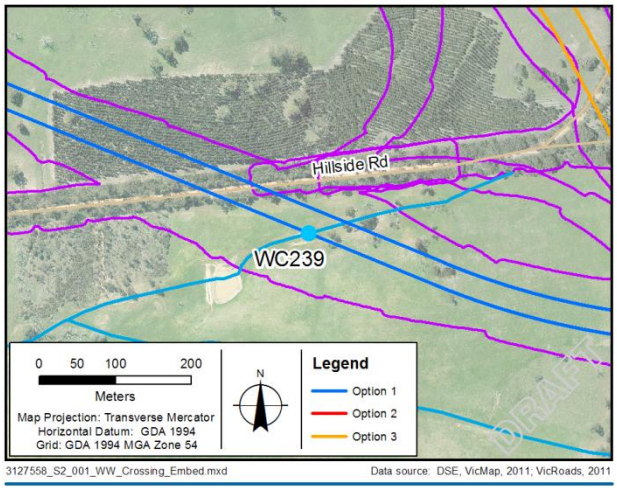


GIS aerial image of the site

Looking downstream

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WC239		Basin	Upper Hopkins, Glenelg Hopkins CMA
Waterway Name	Tributary of Gorrin Creek		Sub-catchment	H5: Upper Hopkins River
Bonacci Reference (Catchment No.)			Reach Number	Reach 12
Highway Reference	Ch. 24500 (Option 1 – Deviation)		ISC rating (score)	Moderate
General			**Ecological Values**	
Land Use Description	Agricultural- cleared for grazing		Disturbance rating	Medium
Catchment Area	23 ha		Aquatic ecology	Nil.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 686743 **N** 5864671	**Geomorphic Classification**	Confined
Channel planform			
- Channel geometry	Unchannelled.		
- Channel gradient	3.0%	**- Channel sinuosity**	n/a
Banks	Some localised areas of scour, no more than a few metres each.		
Instream Features	n/a		
Floodplain Description	Headwater stream confined by hillslopes at valley margin.		
Comments			

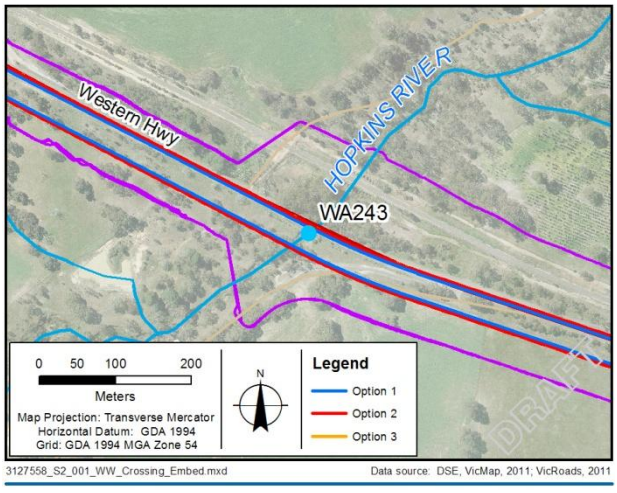


GIS aerial image of site

Looking east from right bank

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WA243		Basin	Upper Hopkins River, GHCMA
Waterway Name	Hopkins River		Sub-catchment	H5: Upper Hopkins River
Bonacci Reference (Catchment No.)			Reach Number	Reach 12
Highway Reference	Ch. 33800 (Duplication)		ISC rating (score)	Moderate
General			**Ecological Values**	
Land Use Description	Reserved river frontage		Disturbance rating	High
Catchment Area	6955 ha		Aquatic ecology	Reeds, rushes, grasses, some saplings in channel incl. red gums, acacias. peppercorns
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 688083 **N** 5869515	**Geomorphic Classification**	Unconfined
Channel planform			
- Channel geometry	3.5 m deep, 15 m wide, downstream of the road bridge. Open pool under bridge. Very open area at upstream face of rail culverts, more than 35 m across. Channel narrows upstream of railway culverts, approx. 2 m deep, 4 m wide		
- Channel gradient	0.5%	**- Channel sinuosity**	Straight; 1.01
Banks	Evidence of scour and deposition of sands. Some undercutting. Very steep bank sections- vertical- through bend downstream of road bridge.		
Instream Features	Railway crossing (upstream of Highway) culverts: 9 x 3.5 m diameter, middle 3 approx. 0.6 m lower invert level. Permanent pool formed upstream of culverts. Concrete inlet apron. Highway bridge: two columns. 4.5 m height. Span 25.8 m total, 8.6 m between columns/abutments. 8 m paved rock channel bed immediately downstream of bridge, 6 m wide. Then drop of 1 m over 10 m of further rock chute. Permanent pool formed upstream and under bridge. Alternating areas of dense vegetation and exposed bank and channel.		
Floodplain Description	Very large floodplain, in the order of 500 m.		
100 Year Flood extent			

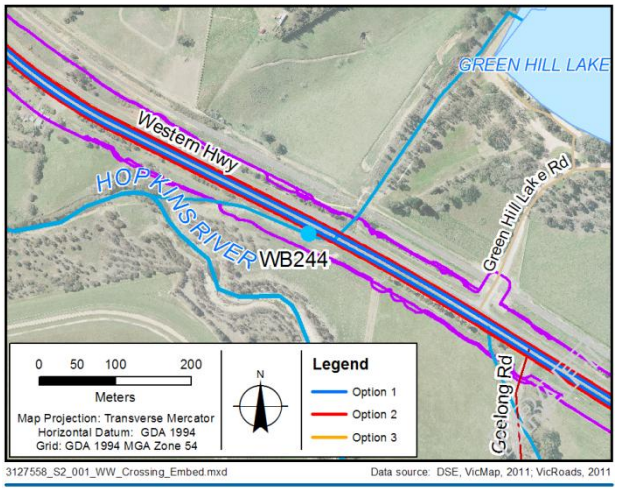


GIS aerial image of site

Looking downstream, facing south west, downstream of Existing Highway bridge

Waterway Crossing			Regional River Health Strategy	
Crossing Number	WB244		Basin	Upper Hopkins River, GHCMA
Waterway Name	Green Hill Creek		Sub-catchment	H5: Upper Hopkins River
Bonacci Reference (Catchment No.)			Reach Number	Reach 12
Highway Reference	Ch. 38350 (Duplication)		ISC rating (score)	Moderate
General			**Ecological Values**	
Land Use Description	River reserve		Disturbance rating	High
Catchment Area	8381 ha		Aquatic ecology	Reeds, rushes, hawthorn, pastoral grasses.
Flow Characteristics	Ephemeral			

Site Inspection			
GPS Location	**E** 674658 **N** 5870428	**Geomorphic Classification**	Unconfined in greater floodplain but constricted by rail & Highway embankments.
Channel planform			
- Channel geometry	Channel 2 m deep and 12-15 m wide.		
- Channel gradient	0.6 %	**- Channel sinuosity**	Straight; 1.01
Banks	Well vegetated with grasses.		
Instream Features	5 x 1.8 m high x 3 wide culverts under road. Rock chute downstream of road culverts. Tyre in channel bed.		
Floodplain Description	Within Hopkins River floodplain. There is some potential for lateral adjustment of the channel towards the Hopkins River beyond the left bank.		
Comments			

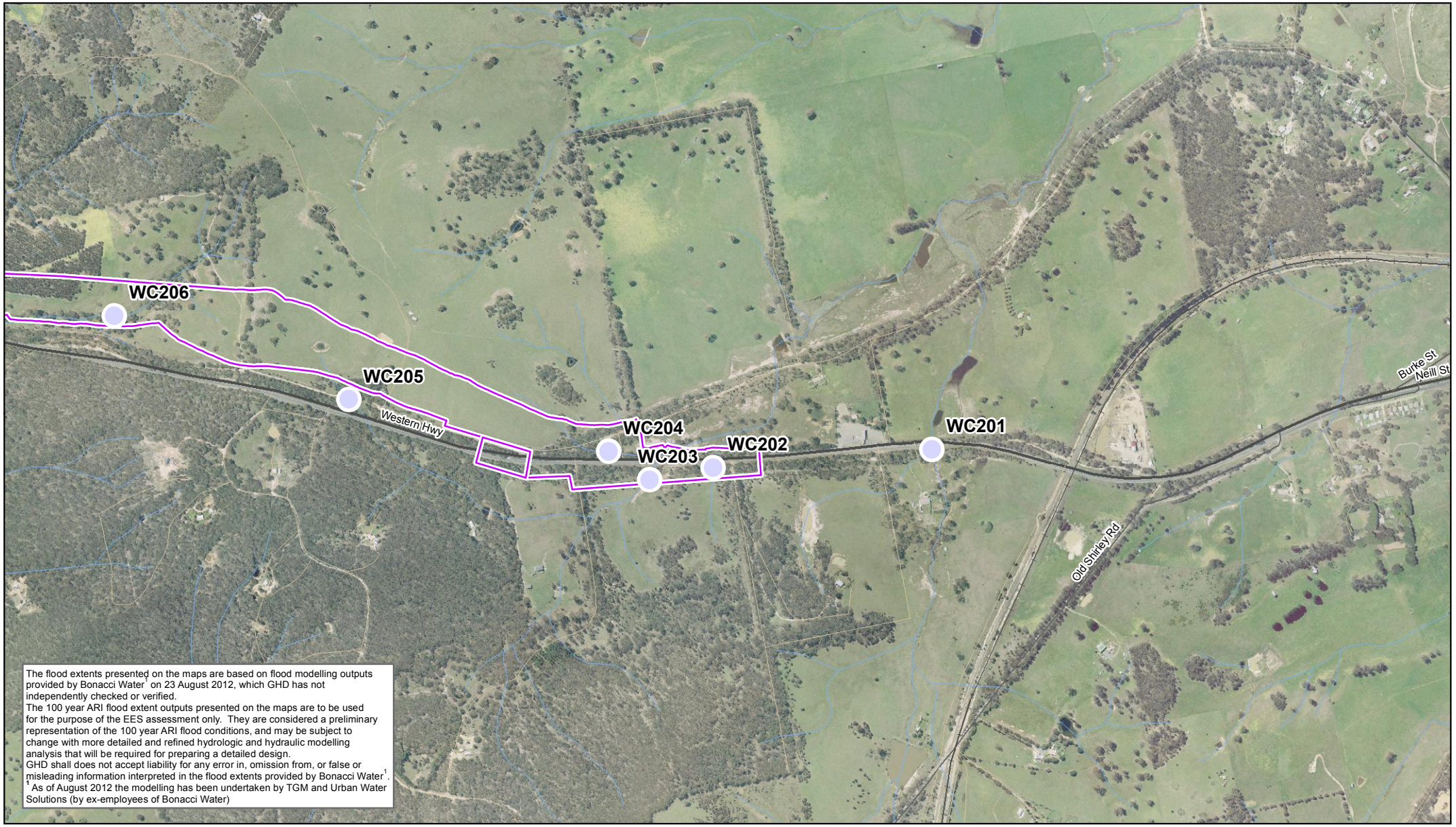


GIS aerial image of site

Looking downstream, left bank; Existing Highway on right.

Appendix C

Waterway Crossing Alignment including Flood Extent – Mapbook



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Paper Size A4

0 140 280 420

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
Low : 0

Waterway Crossings
- Minor
- Moderate
- Major

- Highway
- Sealed road (arterial & local)
- Unsealed road
- Maximum Construction Footprint

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

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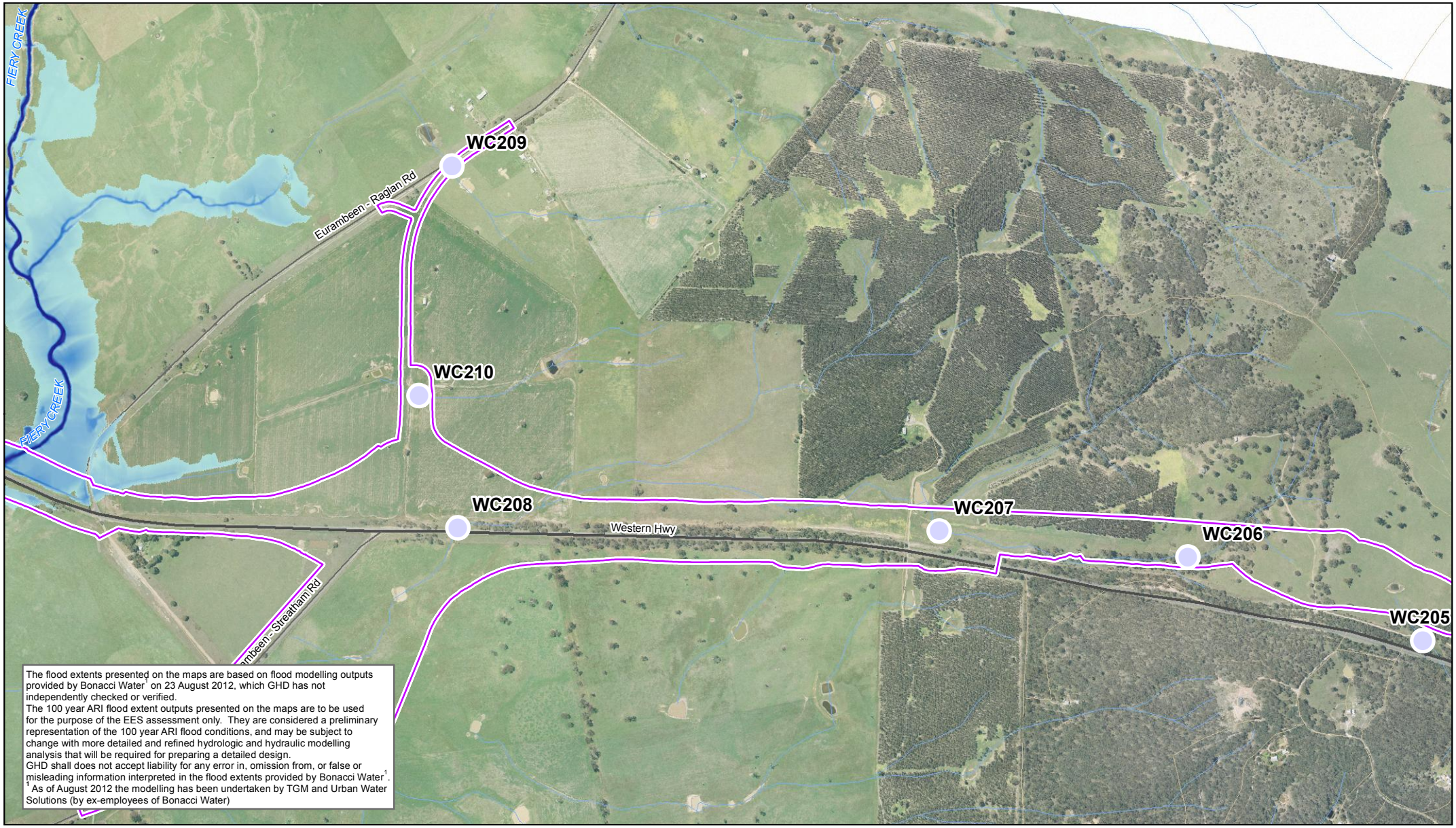

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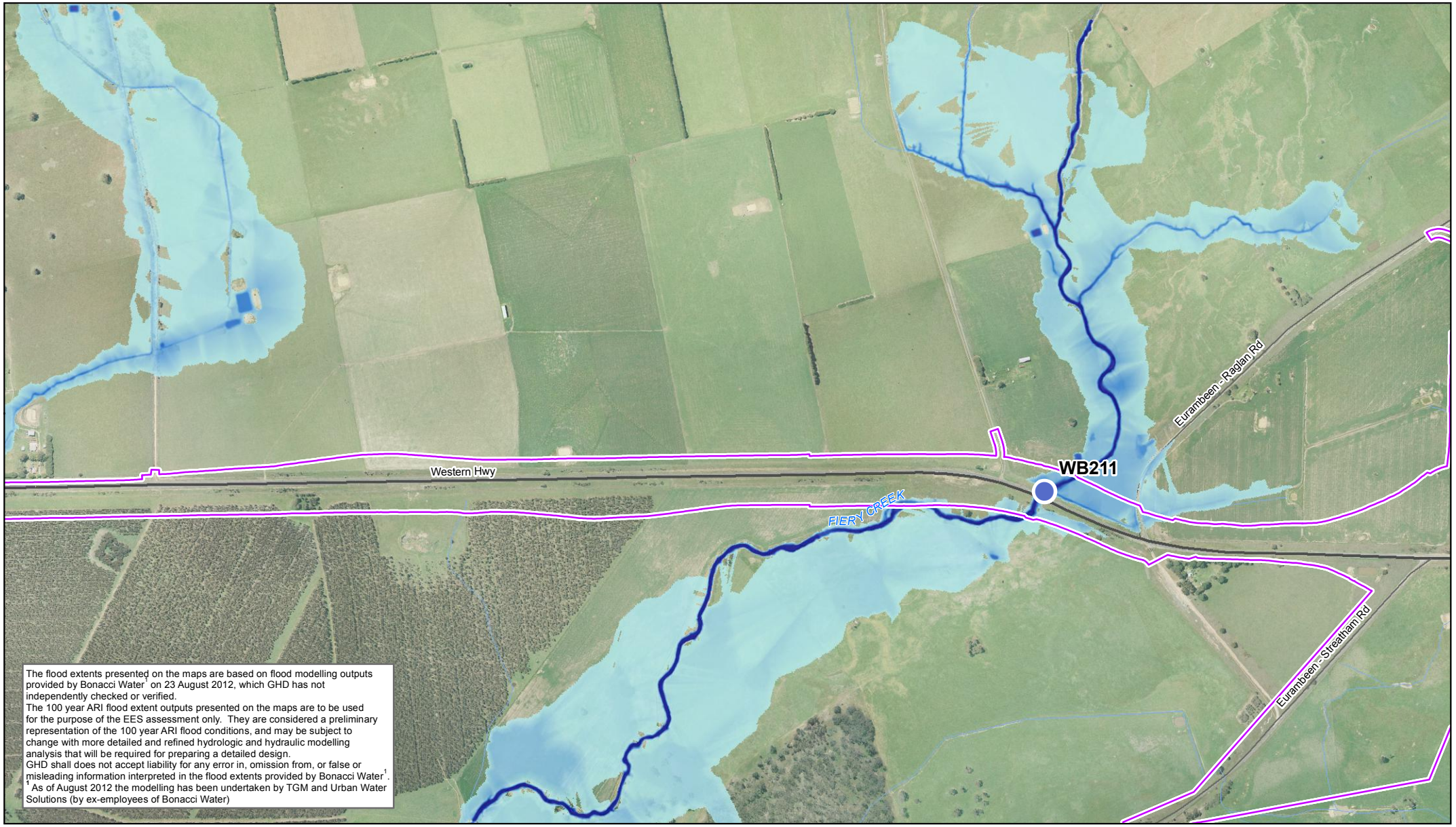

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Grid: GDA 1994 MGA Zone 54

N

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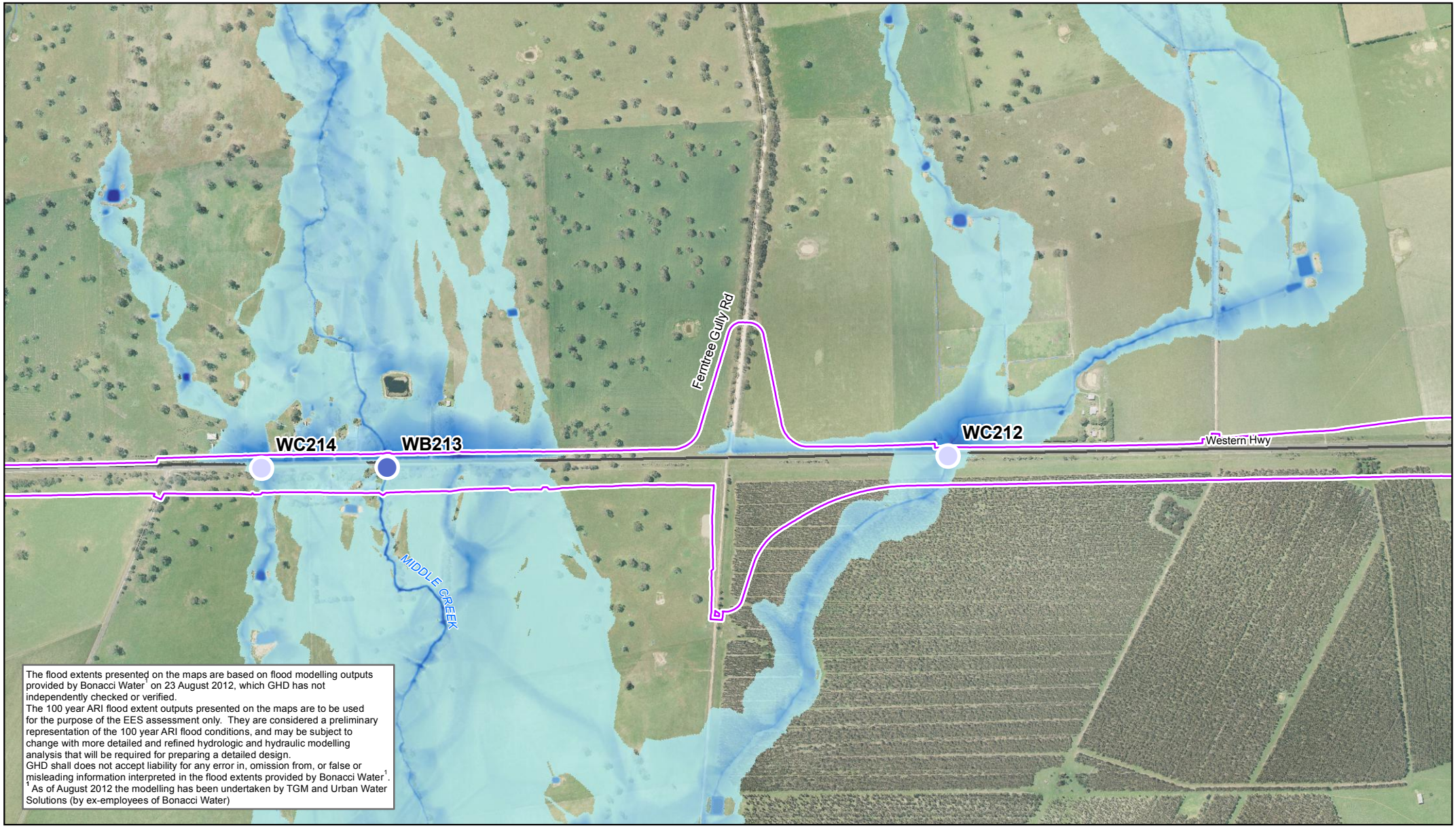

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Low : 0

Waterway Crossings
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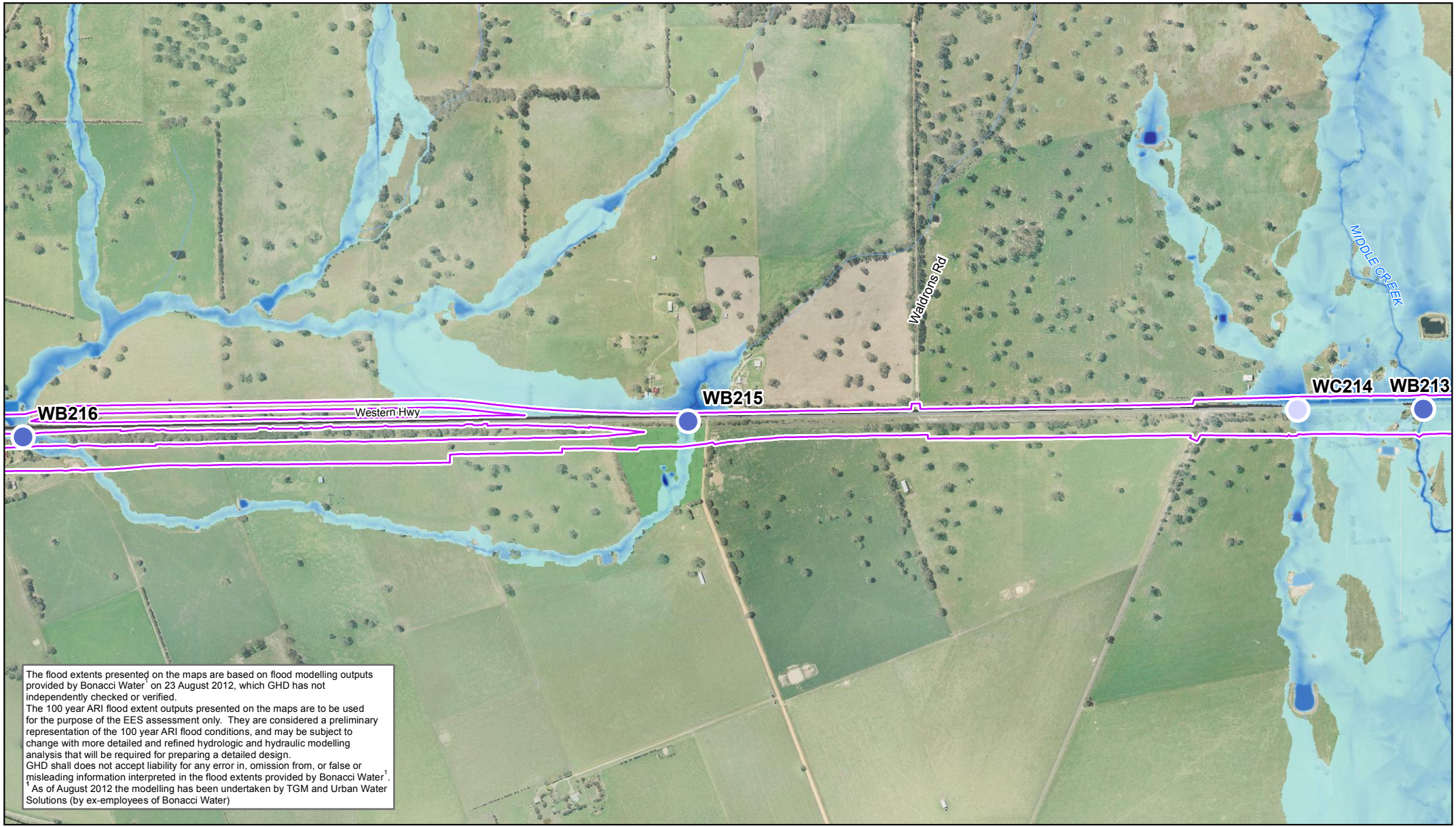

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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

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Waterway Crossings
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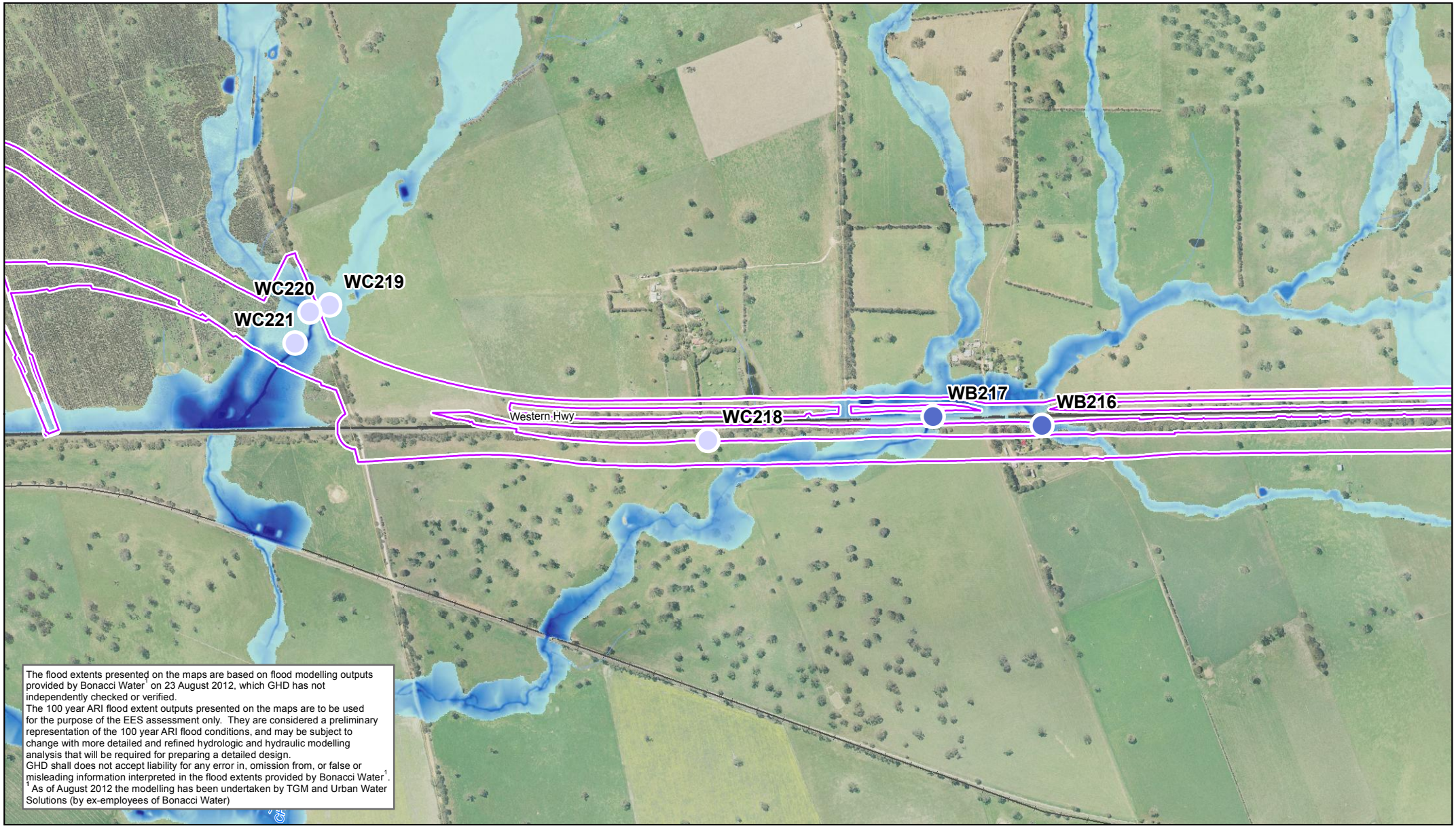

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
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Waterway Crossings
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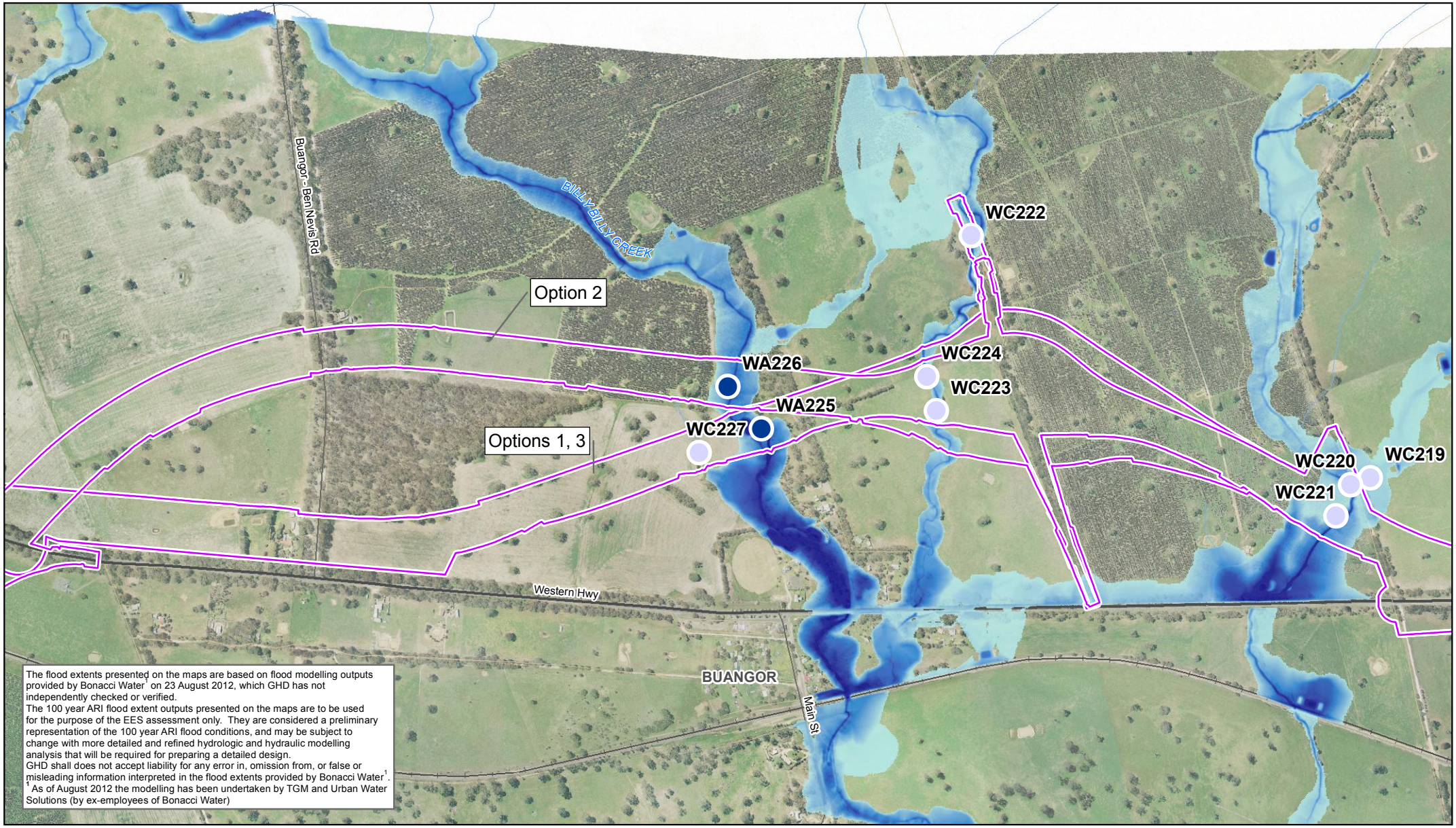

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

LEGEND

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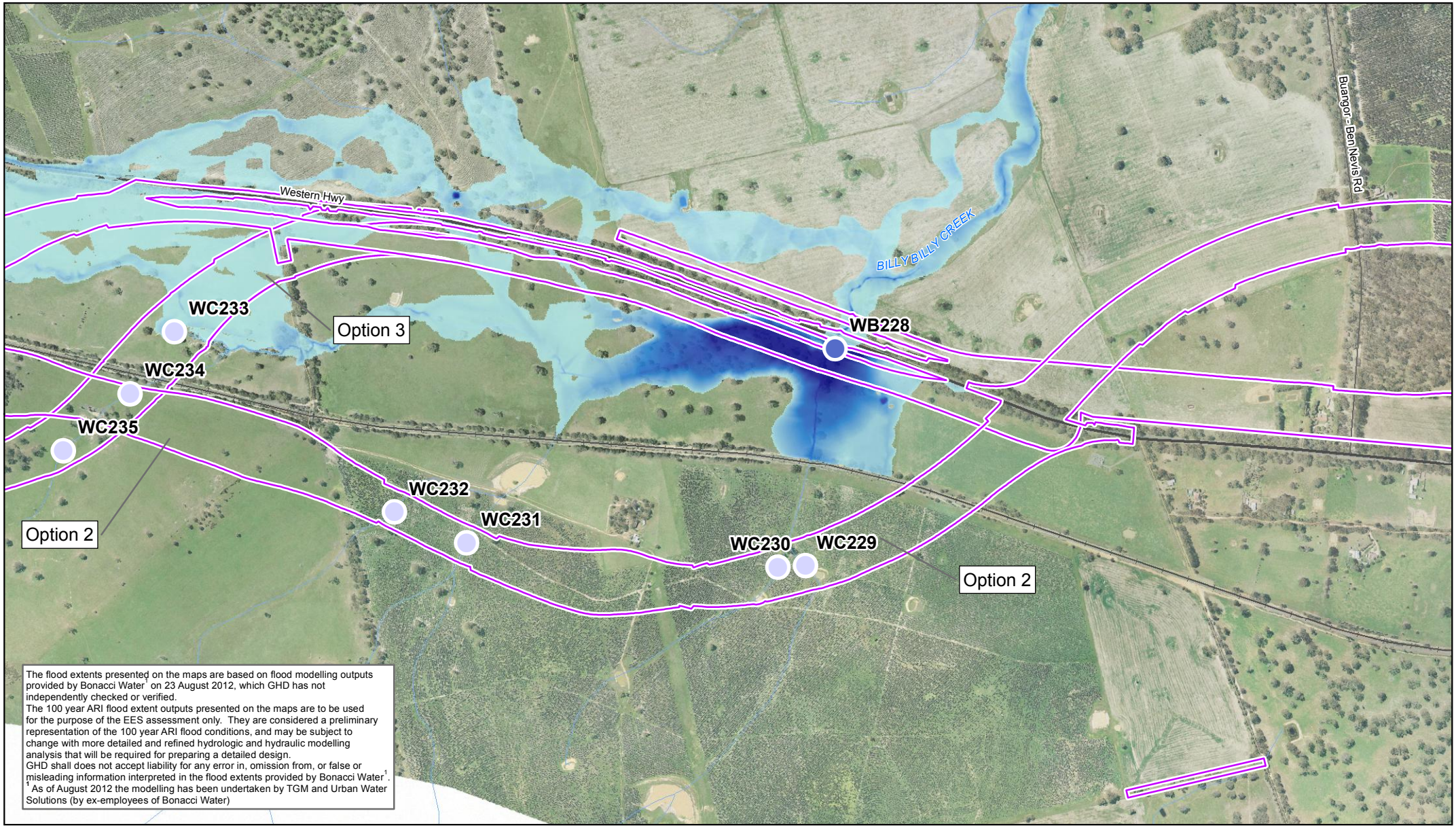

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Map Projection: Transverse Mercator
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Grid: GDA 1994 MGA Zone 54

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LEGEND

100yr Modelled Flood Depth
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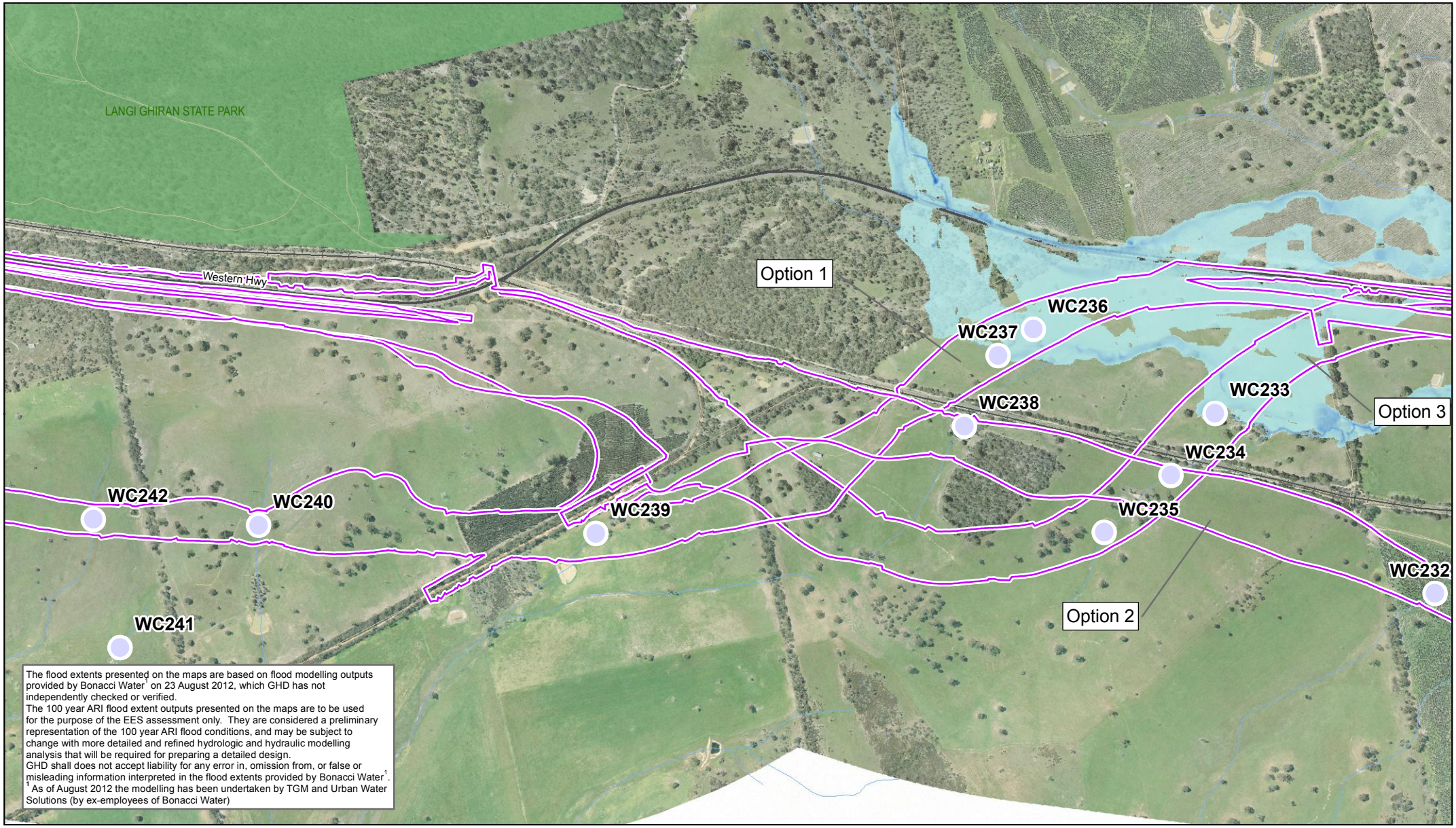

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Map Projection: Transverse Mercator
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N

LEGEND

100yr Modelled Flood Depth
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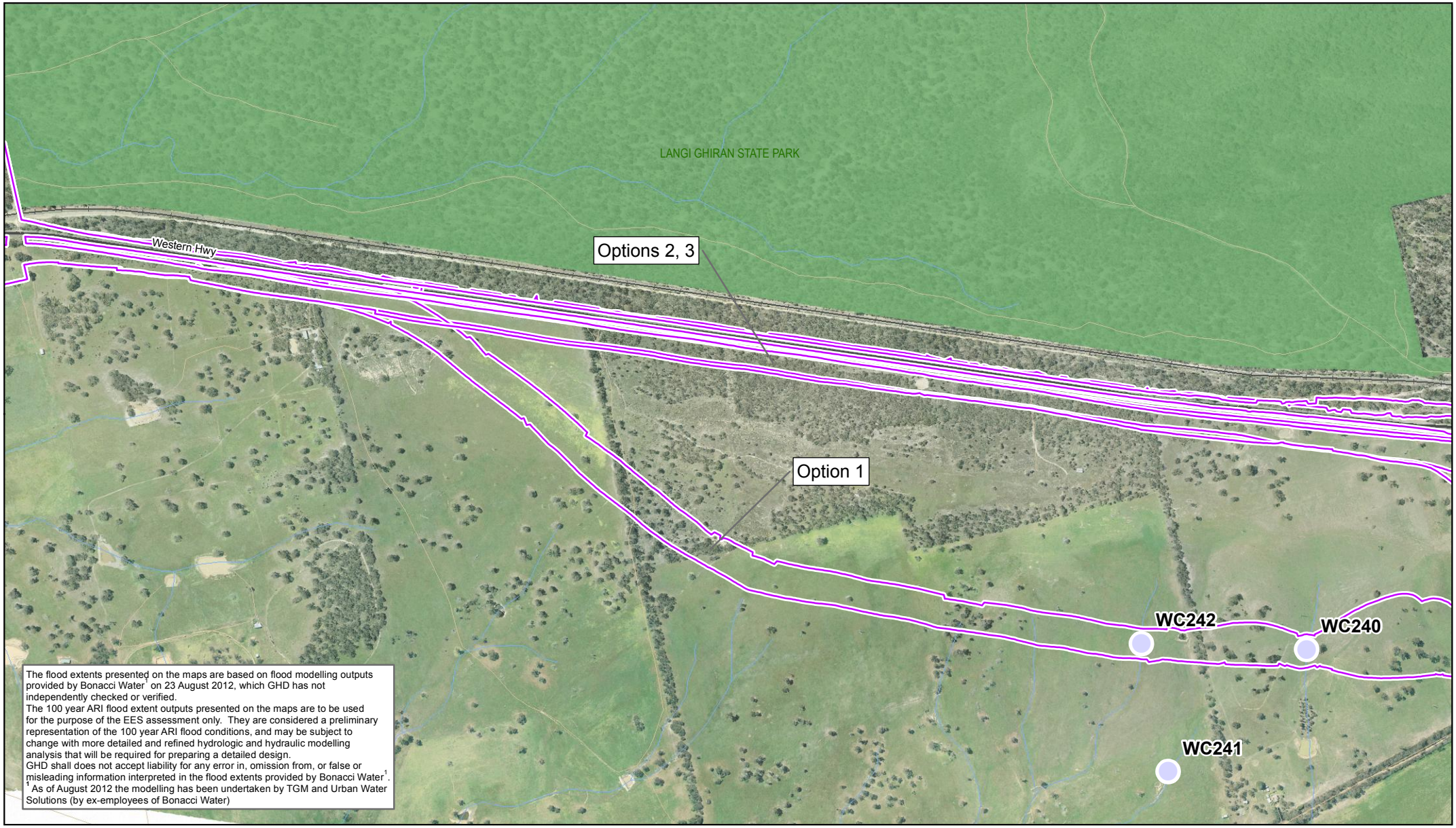

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
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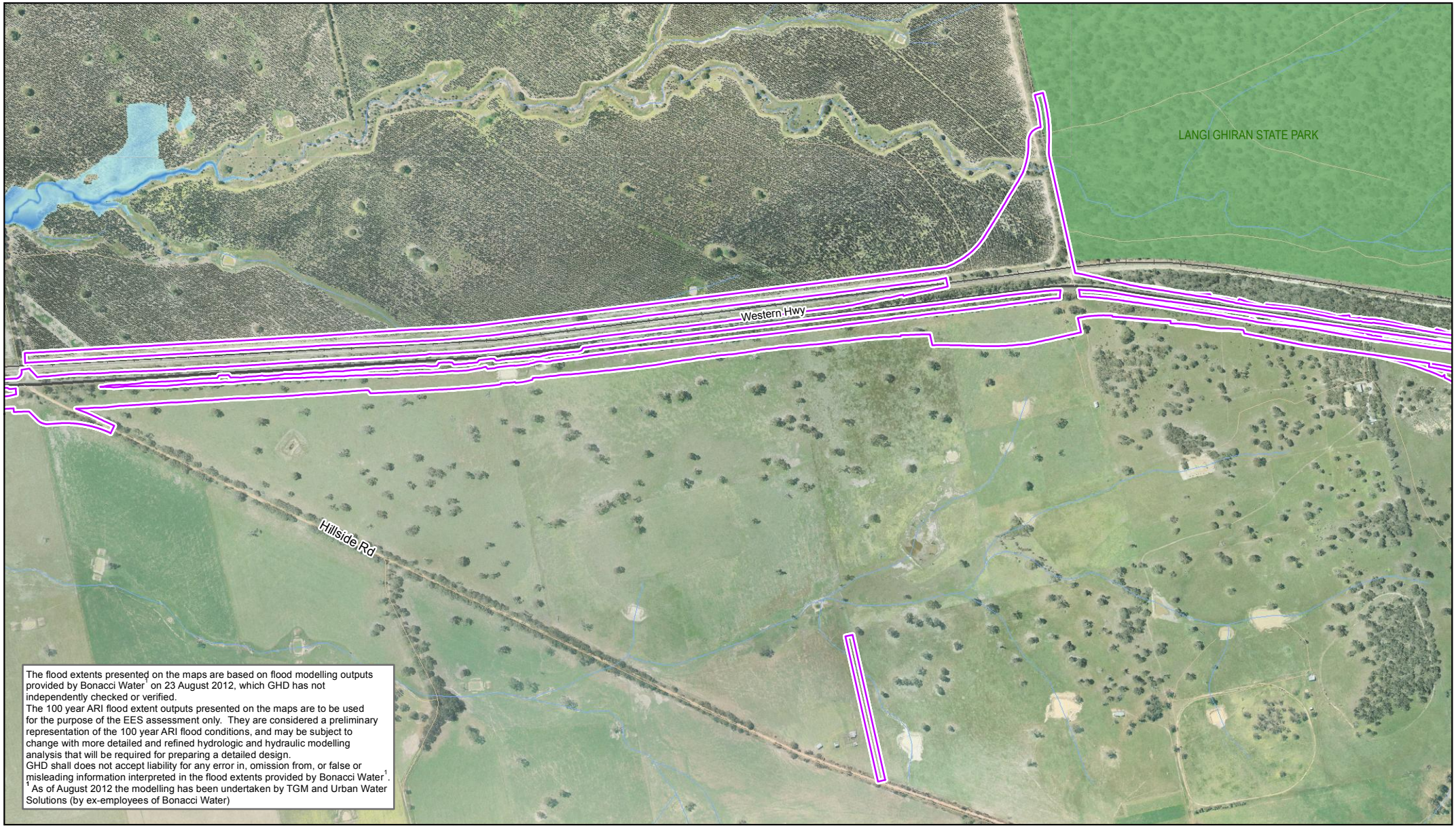

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Paper Size A4

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Meters

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N

LEGEND

100yr Modelled Flood Depth
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Waterway Crossings and Alignments with Existing Conditions Flood Extents
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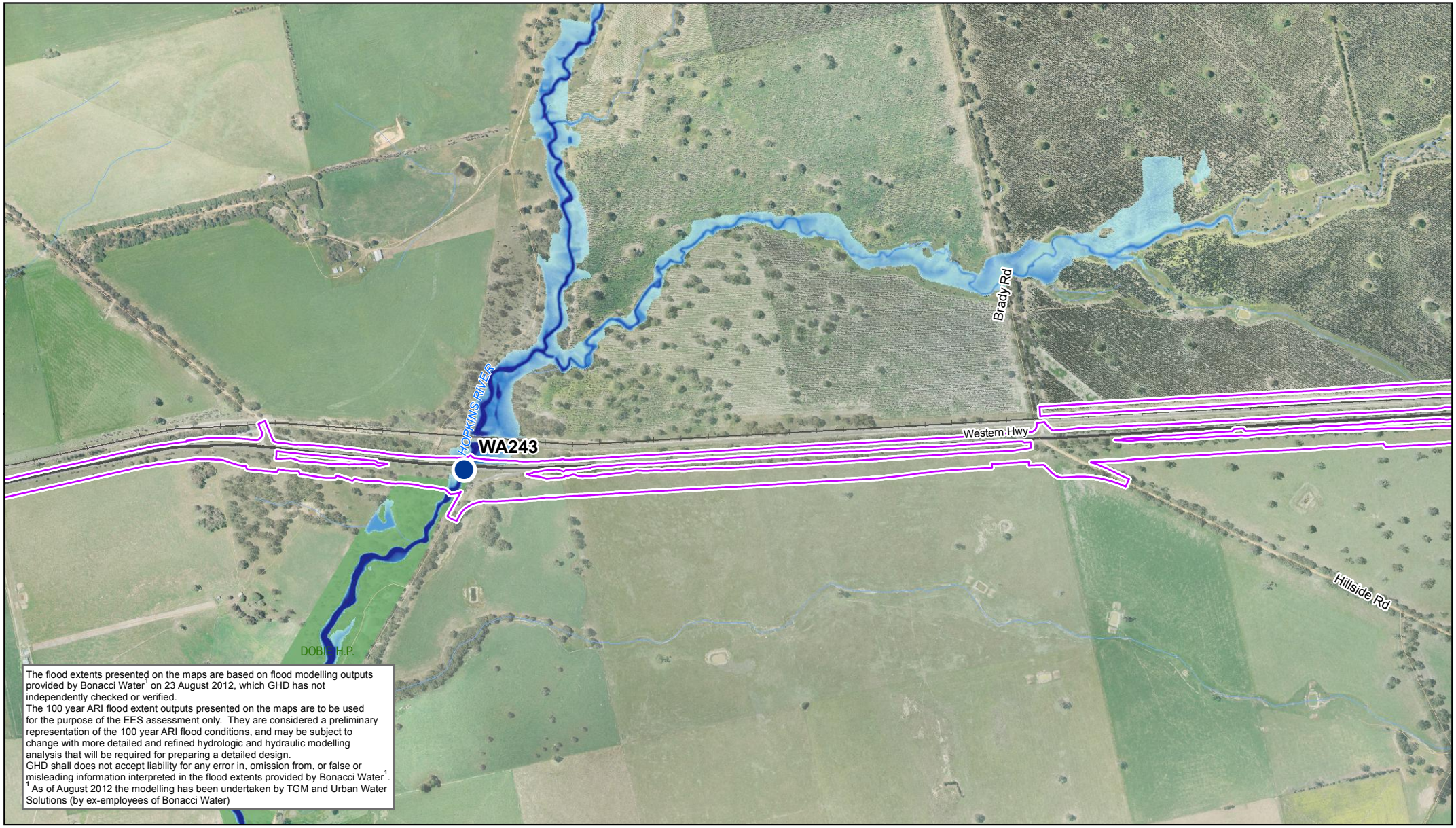

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Meters

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N

LEGEND

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Sheet 12

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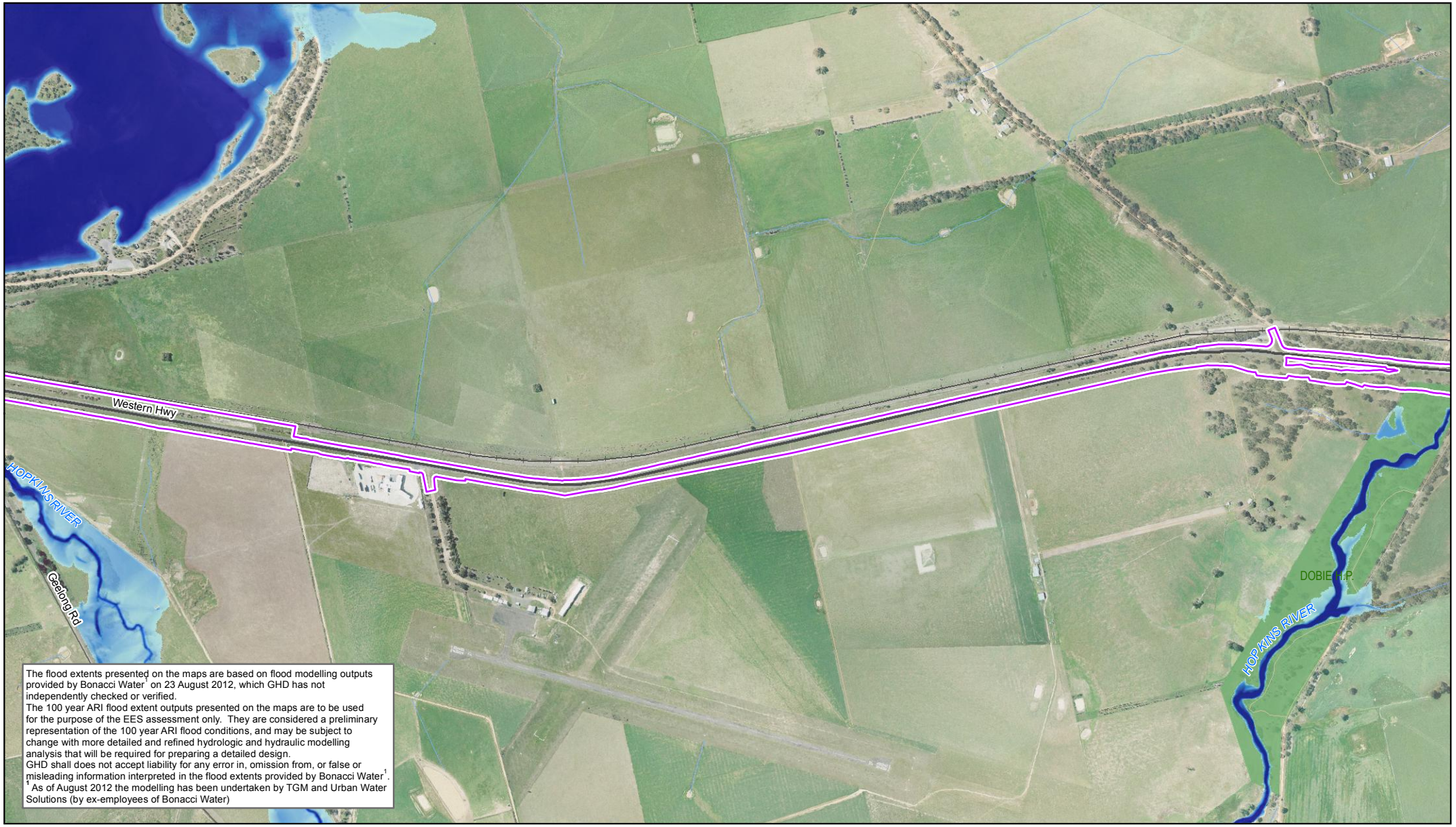

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- Highway
- Sealed road (arterial & local)
- Unsealed road
- Maximum Construction Footprint

GHD
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VicRoads
Western Highway Project

Job Number 31-27558
Revision C
Date 04 Sep 2012

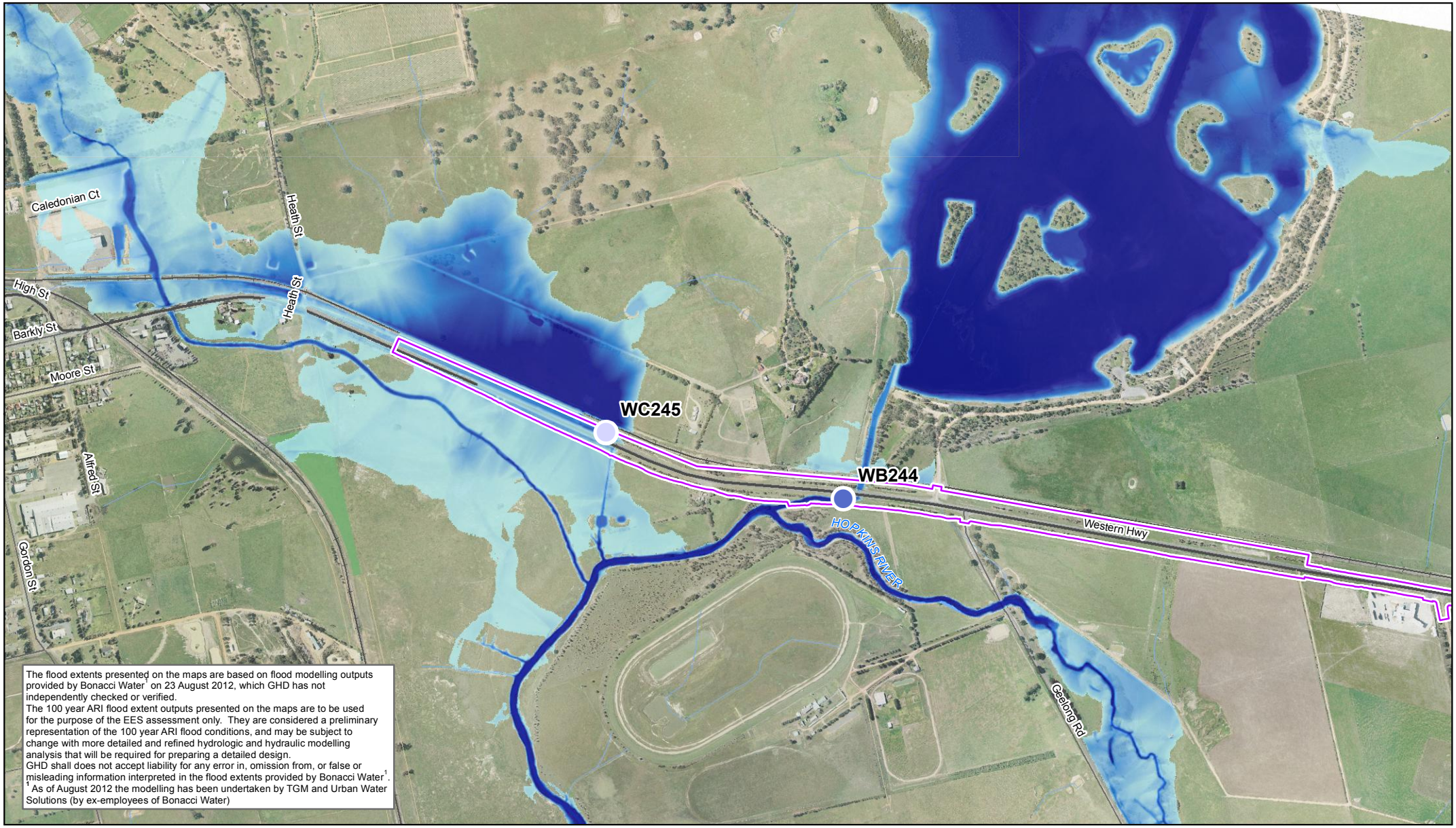
Beaufort to Ararat
Waterway Crossings and Alignments with Existing Conditions Flood Extents
Sheet 13

Appendix C

G:\31\27558\GIS\Maps\Deliverables\Stage 2\RISK AND IMPACT ASSESSMENT\06_SURFACE_WATER\3127558_S2_006_Flood_Extents_A4L.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird



Paper Size A4

0 140 280 420

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
Low : 0

Waterway Crossings
- Minor
- Moderate
- Major

- Highway
- Sealed road (arterial & local)
- Unsealed road
- Maximum Construction Footprint

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings and Alignments with Existing Conditions Flood Extents
Sheet 14

Job Number 31-27558
Revision C
Date 04 Sep 2012

Appendix C

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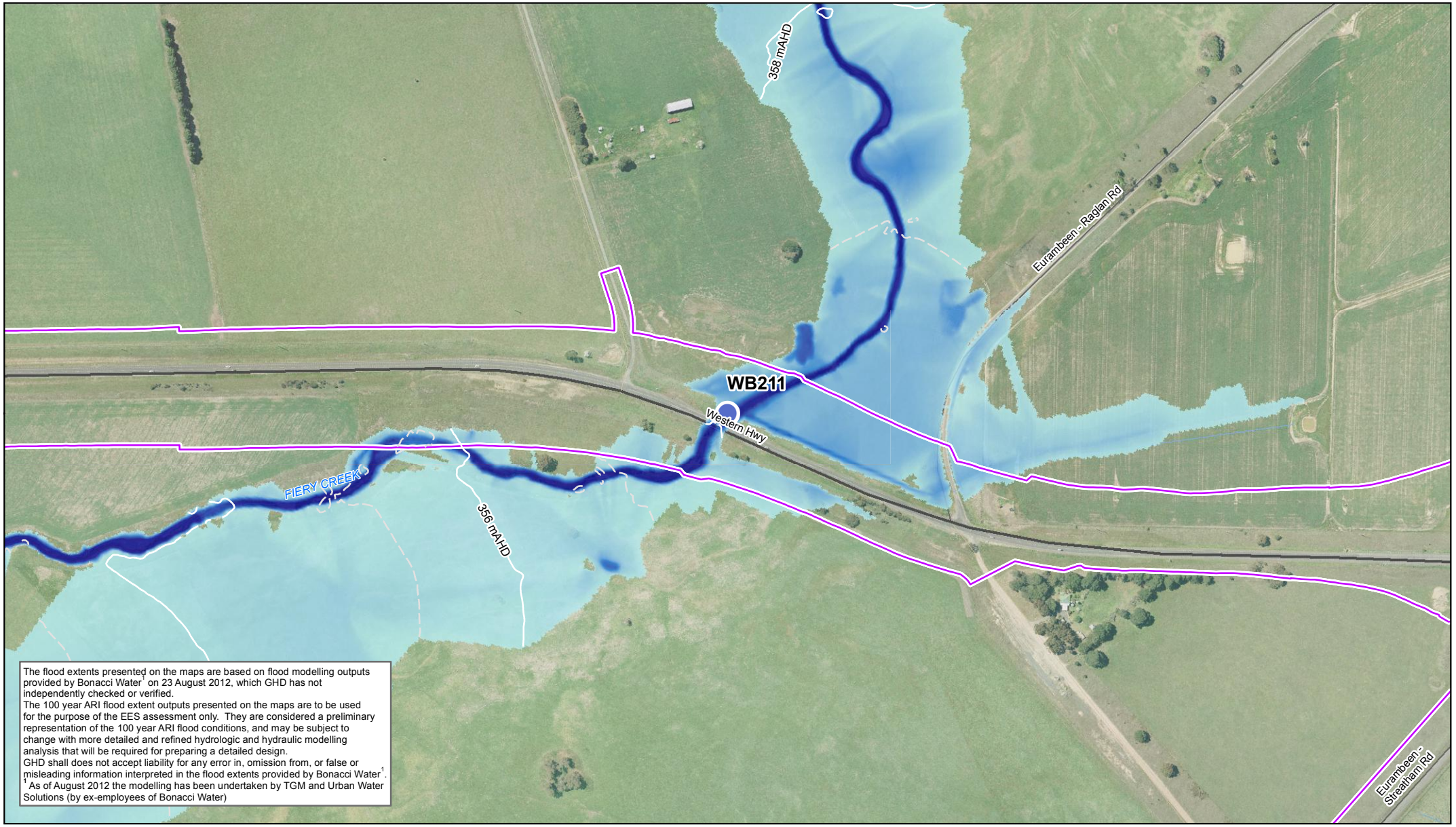
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird

Appendix D

Detailed Flood Extents at Waterway Crossings



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Paper Size A4

0 60 120 180

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
Low : 0

100yr Flood Level Contours
Major
Minor

Waterway Crossings
Minor
Moderate
Major

Highway
Sealed road (arterial & local)
Unsealed road
Maximum Construction Footprint

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with Existing Conditions Flood Extents
WB211 Sheet 1

Job Number 31-27558
Revision C
Date 04 Sep 2012

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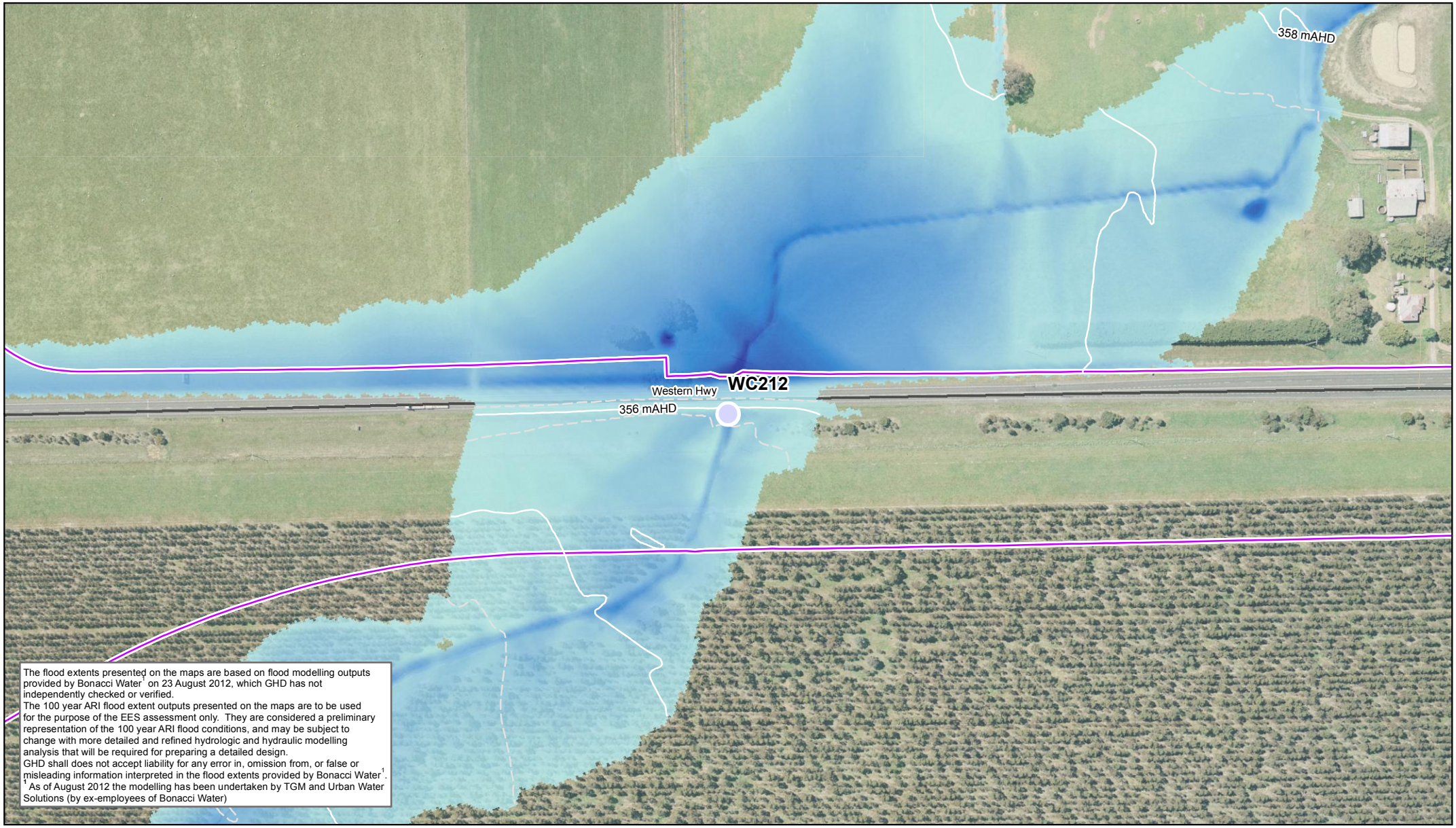
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird



Paper Size A4

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth

High : 2

Low : 0

100yr Flood Level Contours

Major

Minor

Waterway Crossings

Minor

Moderate

Major

Highway

Sealed road (arterial & local)

Unsealed road

Maximum Construction Footprint

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with
Existing Conditions Flood Extents
WC212 Sheet 2

Job Number 31-27558
Revision C
Date 04 Sep 2012

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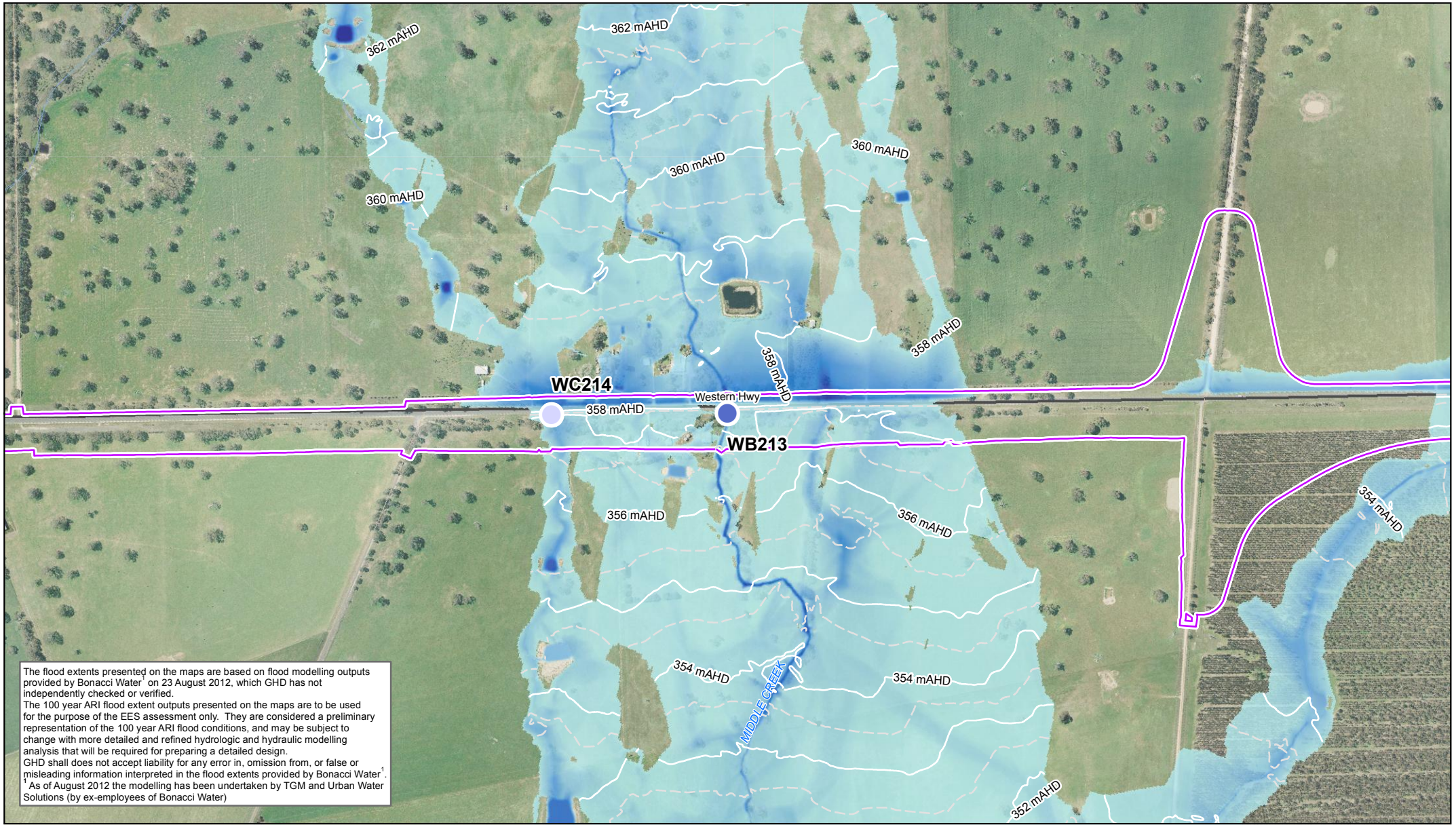
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird



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Paper Size A4

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
Low : 0

100yr Flood Level Contours
Major
Minor

Waterway Crossings
Minor
Moderate
Major

Highway
Sealed road (arterial & local)
Unsealed road
Maximum Construction Footprint

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with
Existing Conditions Flood Extents
WB213 Sheet 3

Job Number 31-27558
Revision C
Date 04 Sep 2012

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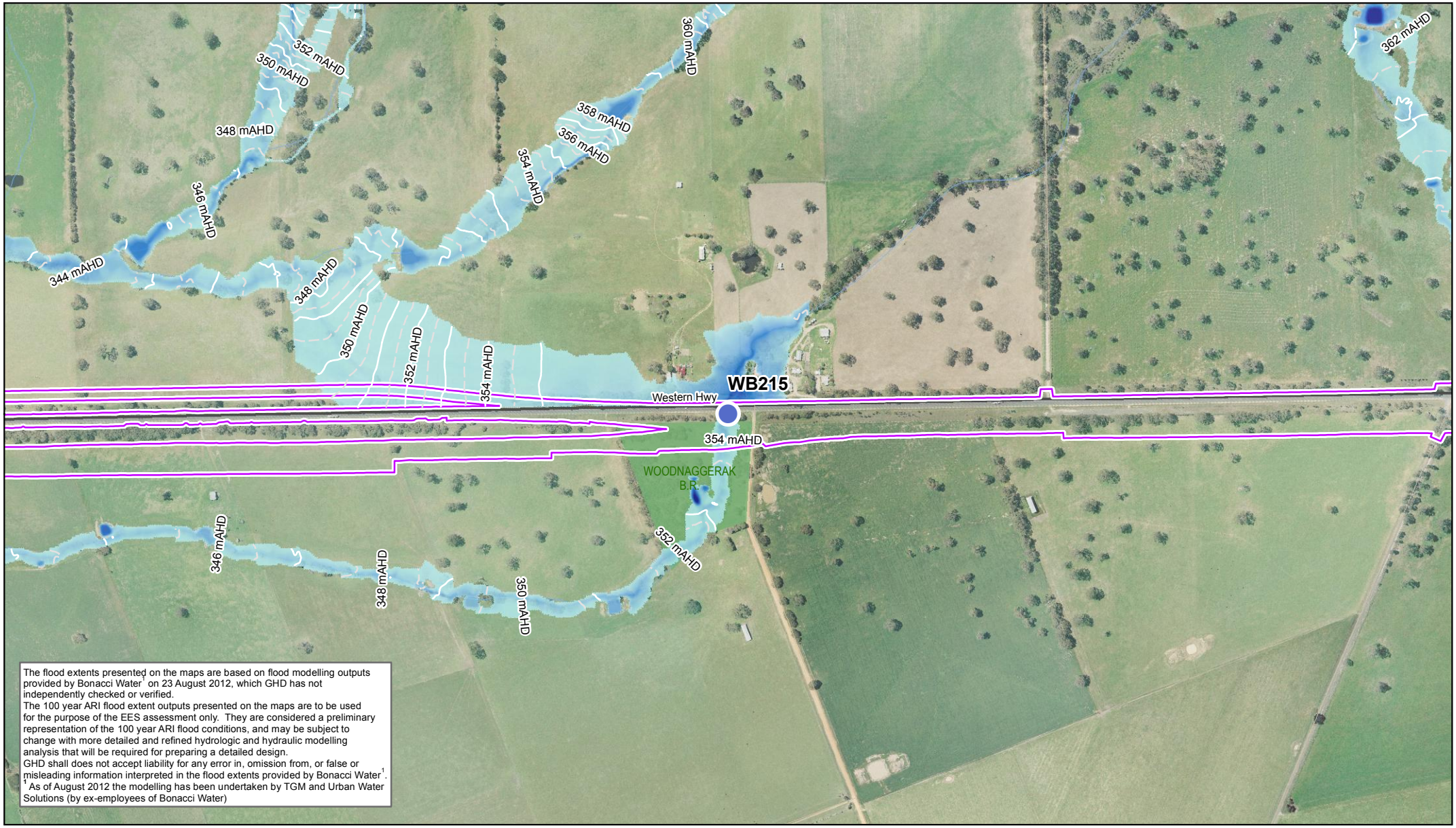
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird



Paper Size A4

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
Low : 0

100yr Flood Level Contours
Major
Minor

Waterway Crossings
Minor
Moderate
Major

Highway
Sealed road (arterial & local)
Unsealed road
Maximum Construction Footprint

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with
Existing Conditions Flood Extents
WB215 Sheet 4

Job Number 31-27558
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Date 04 Sep 2012

Appendix D

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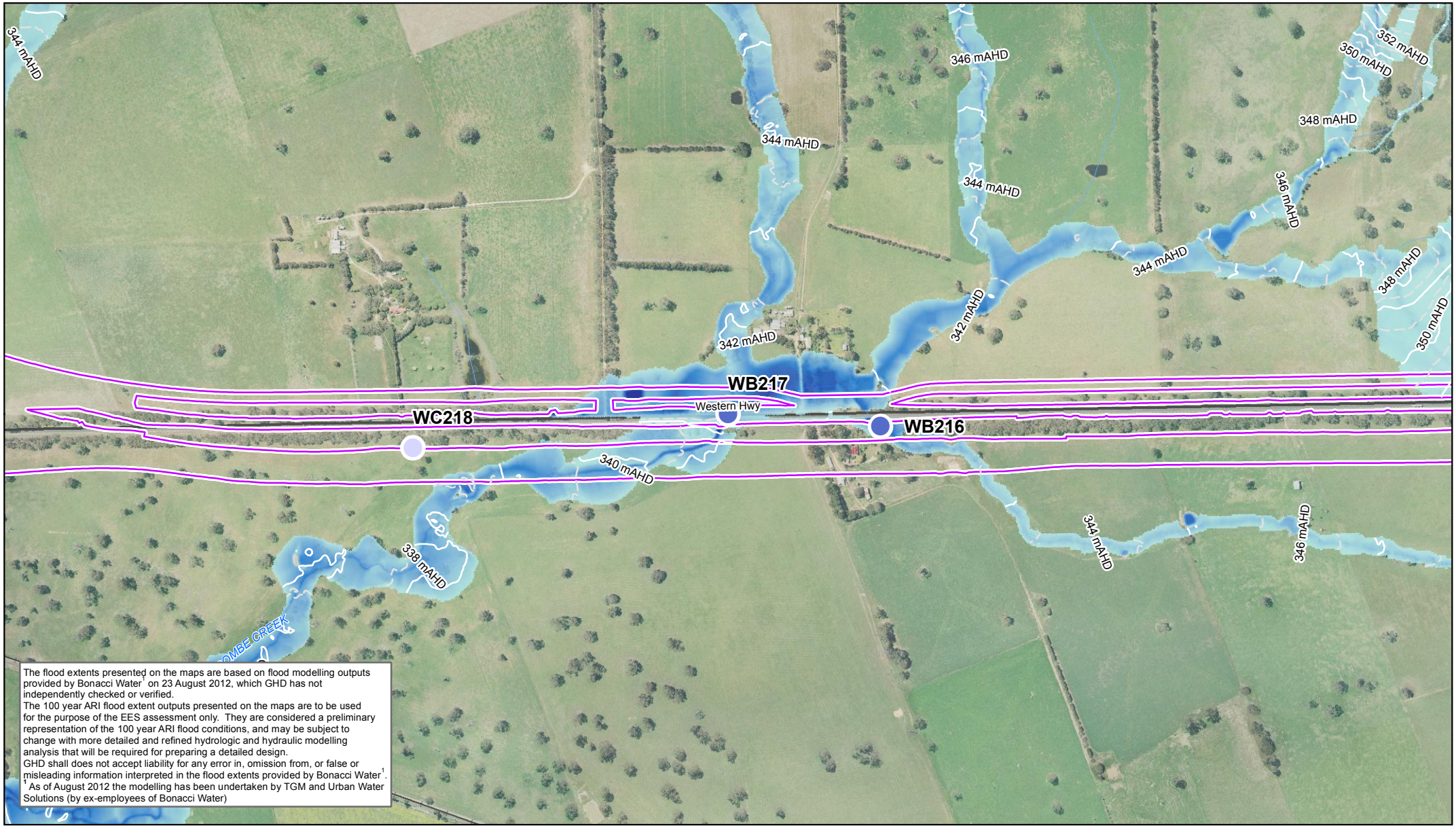
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird



Paper Size A4

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth

High : 2

Low : 0

100yr Flood Level Contours

Major

Minor

Waterway Crossings

Minor

Moderate

Major

Highway

Sealed road (arterial & local)

Unsealed road

Maximum Construction Footprint

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with
Existing Conditions Flood Extents
WB217 Sheet 5

Job Number 31-27558
Revision C
Date 04 Sep 2012

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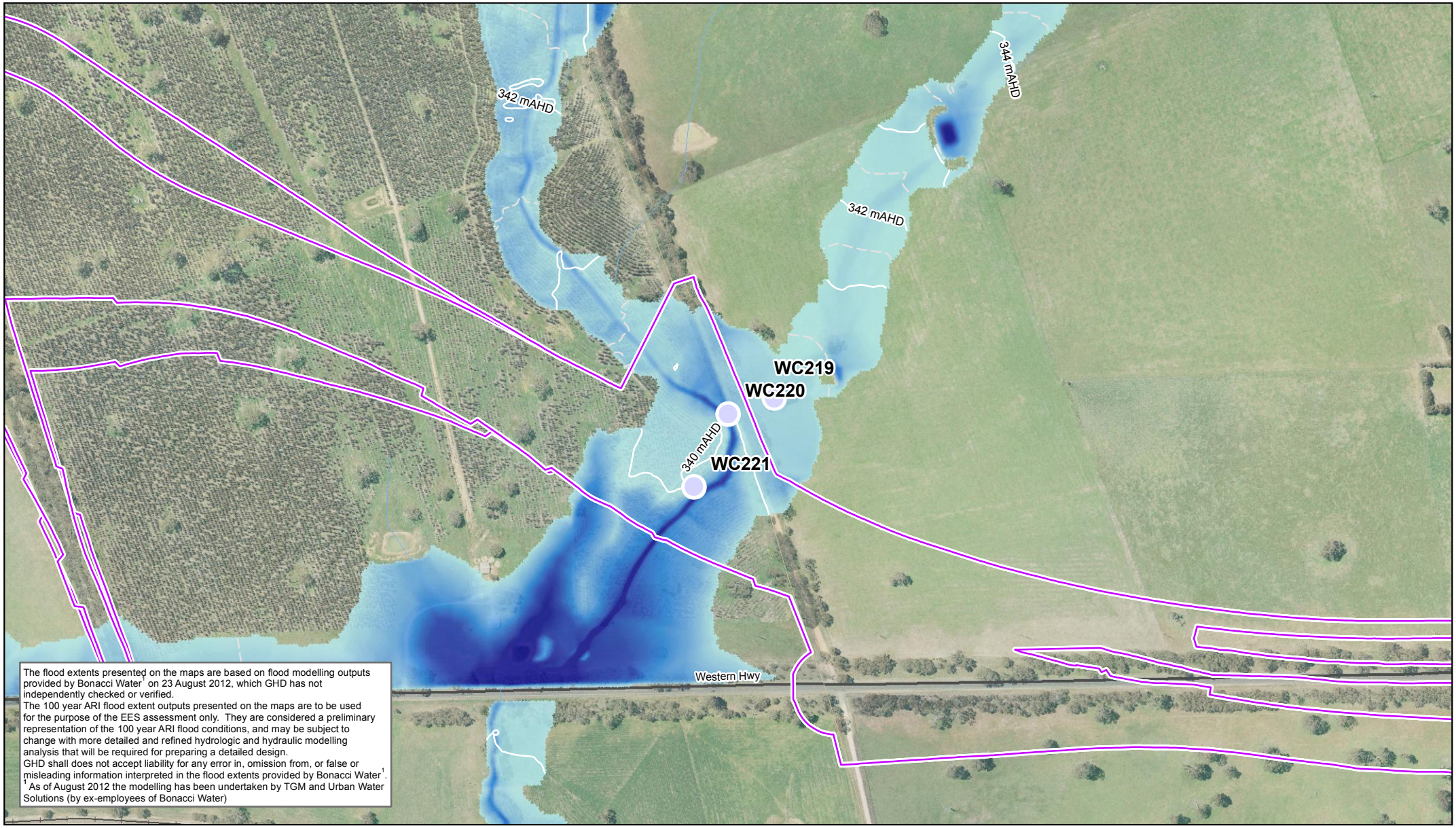
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird



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Paper Size A4

0 60 120 180

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
Low : 0

100yr Flood Level Contours
Major
Minor

Waterway Crossings
Minor
Moderate
Major

Highway
Sealed road (arterial & local)
Unsealed road
Maximum Construction Footprint

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with
Existing Conditions Flood Extents
WC220 Sheet 6

Job Number 31-27558
Revision C
Date 04 Sep 2012

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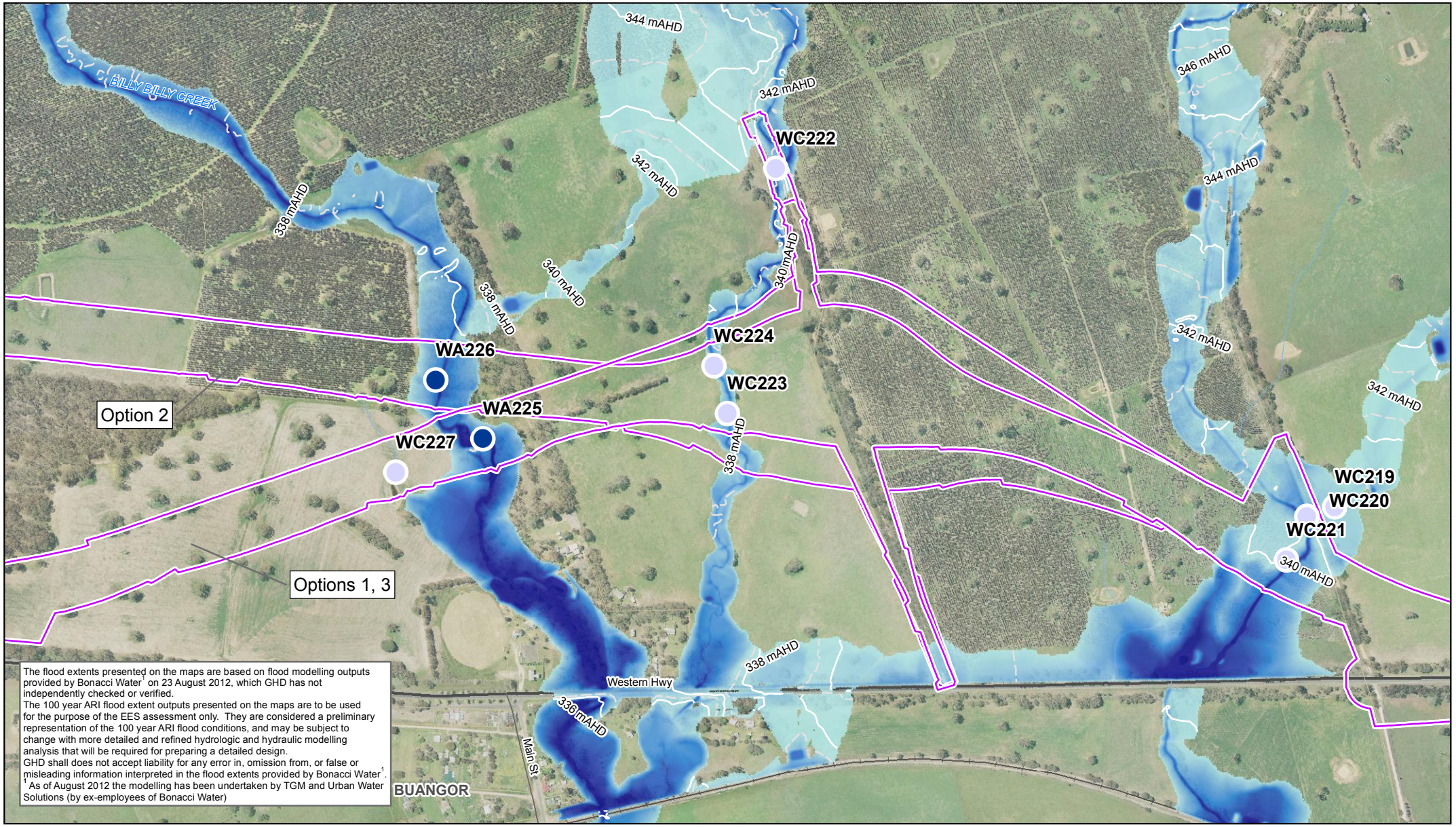
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird



Paper Size A4

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
Low : 0

100yr Flood Level Contours
Major
Minor

Waterway Crossings
Minor
Moderate
Major

Highway
Sealed road (arterial & local)
Unsealed road
Maximum Construction Footprint

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with
Existing Conditions Flood Extents
WC223 Sheet 7

Job Number 31-27558
Revision C
Date 04 Sep 2012

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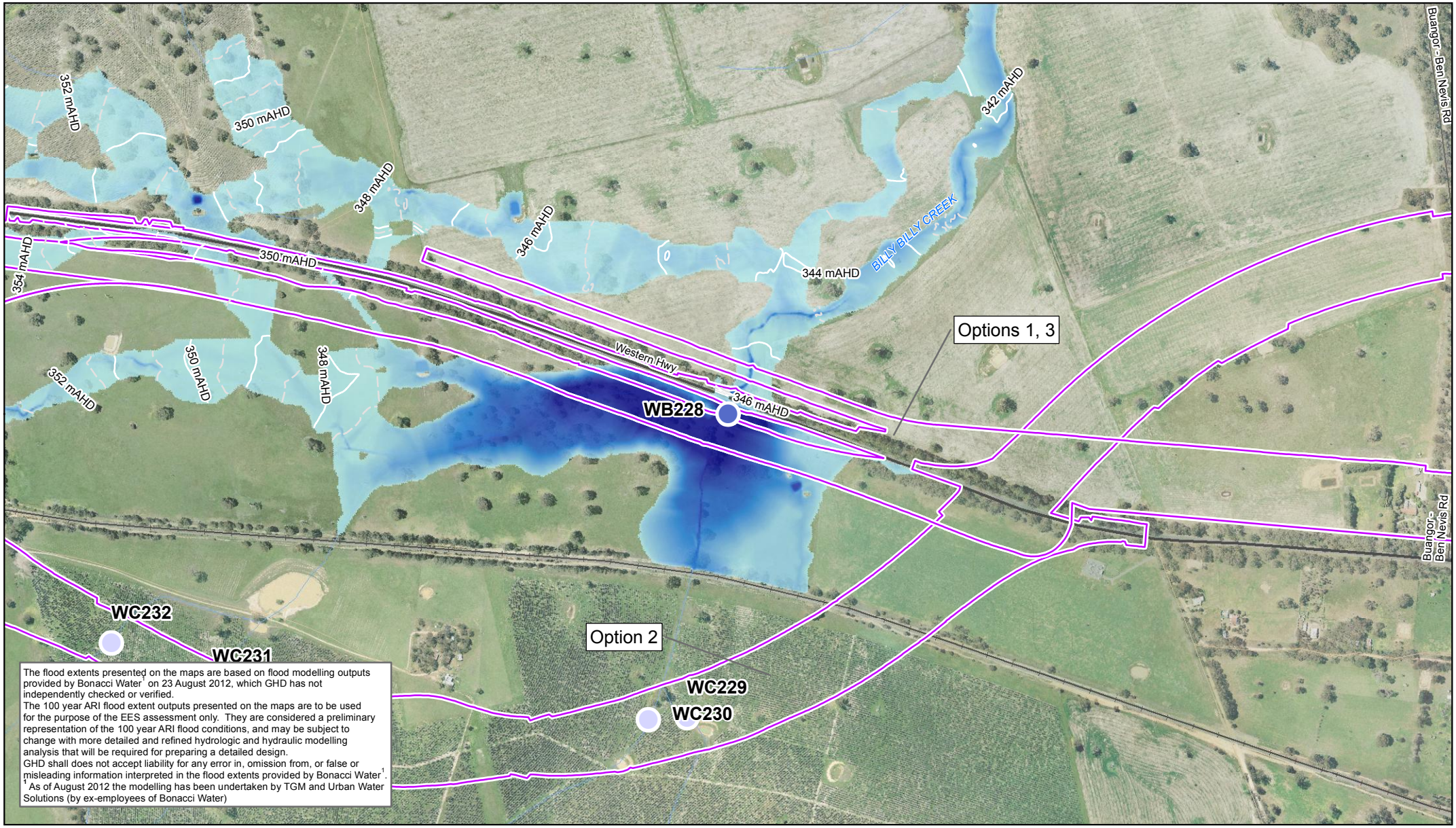
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird



Paper Size A4

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
Low : 0

100yr Flood Level Contours
Major
Minor

Waterway Crossings
Minor
Moderate
Major

Highway
Sealed road (arterial & local)
Unsealed road
Maximum Construction Footprint

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with Existing Conditions Flood Extents
WB228 Sheet 8

Job Number 31-27558
Revision C
Date 04 Sep 2012

Appendix D

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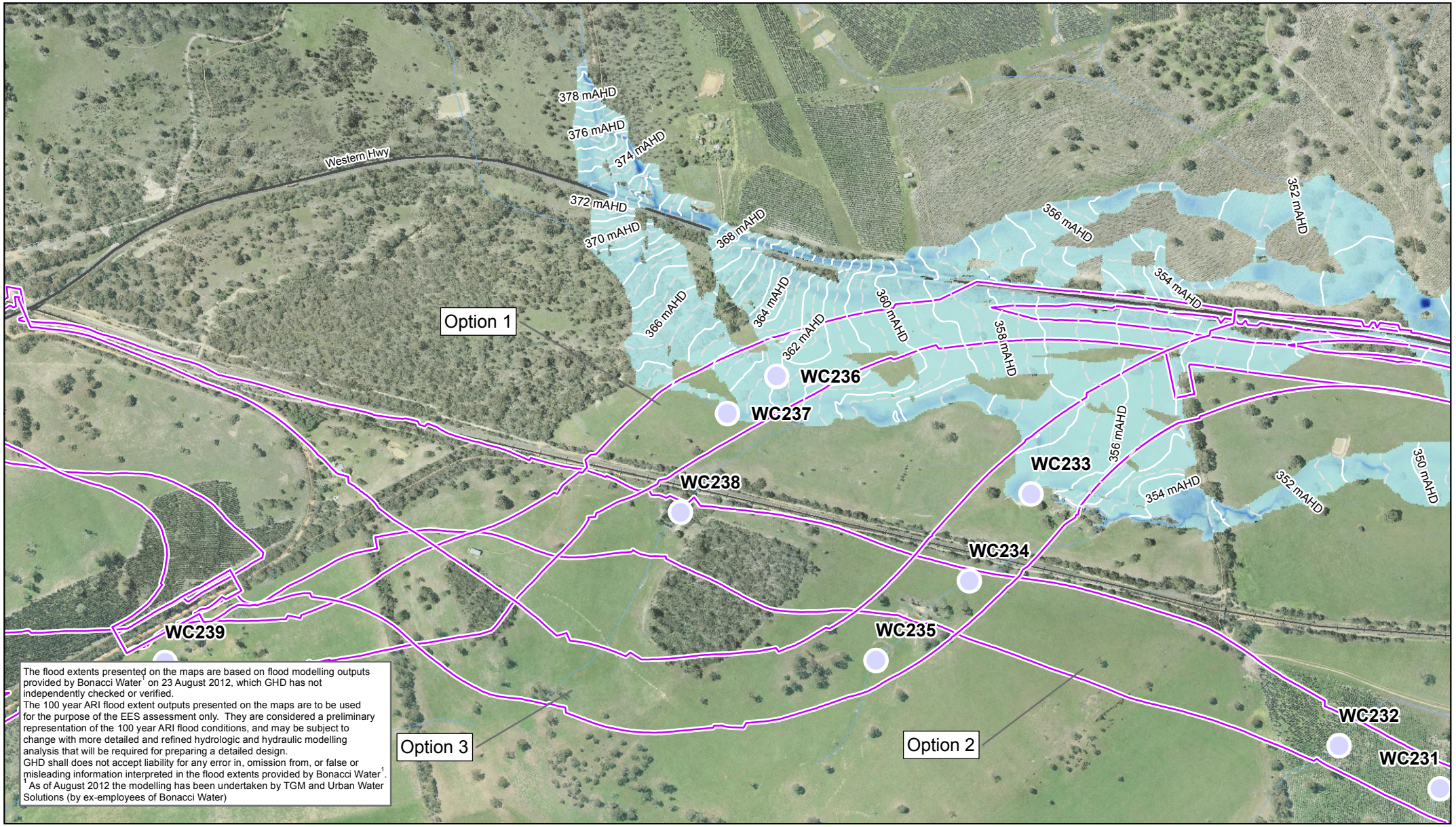
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird



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Paper Size A4

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
Low : 0

100yr Flood Level Contours
Major
Minor

Waterway Crossings
Minor
Moderate
Major

Highway
Sealed road (arterial & local)
Unsealed road
Maximum Construction Footprint

GHD CLIENTS | PEOPLE | PERFORMANCE

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with
Existing Conditions Flood Extents
WC237 **Sheet 9**

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Revision C
Date 04 Sep 2012

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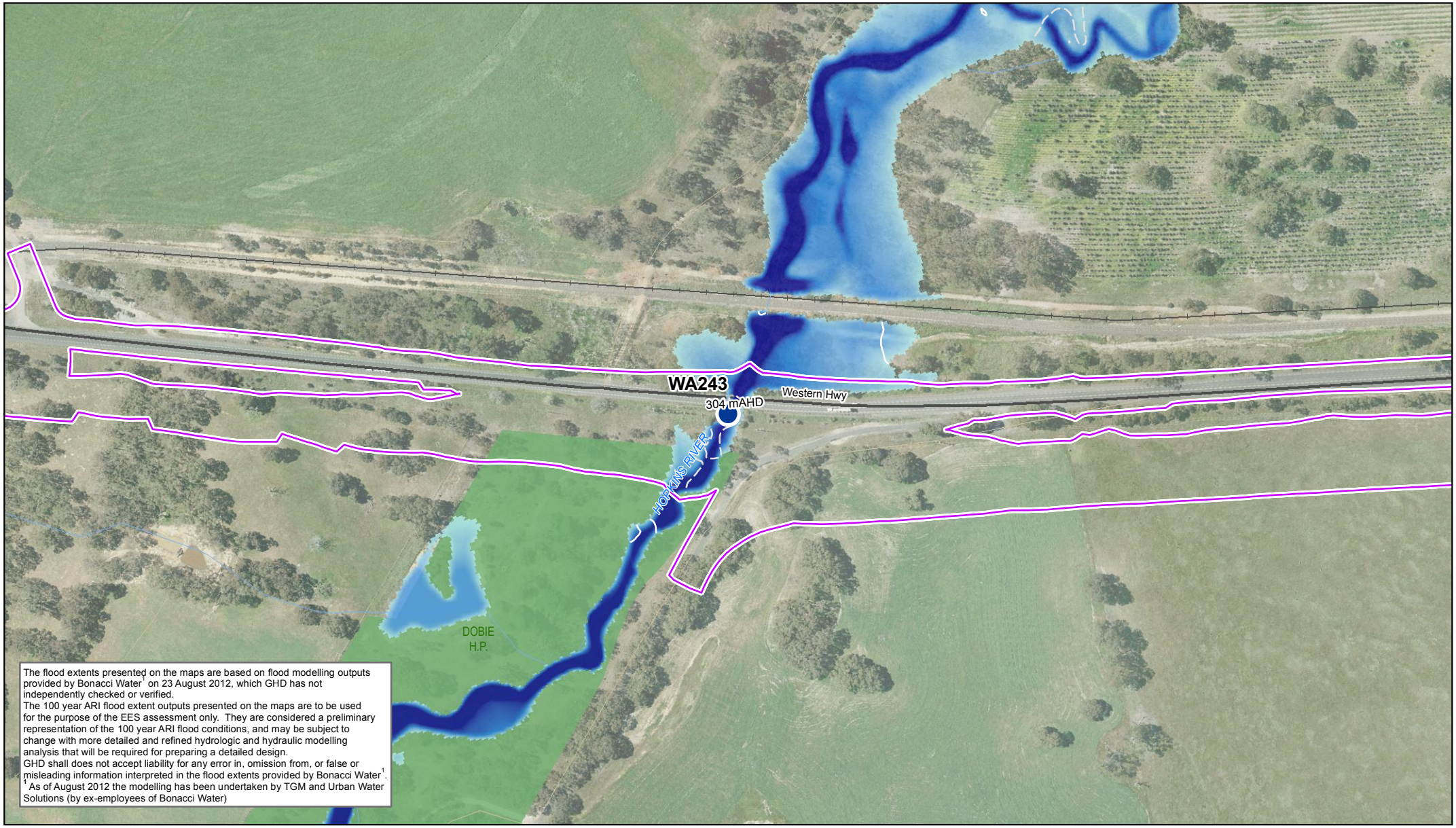
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird



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Paper Size A4

0 40 80 120

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
Low : 0

100yr Flood Level Contours
Major
Minor

Waterway Crossings
Minor
Moderate
Major

Highway
Sealed road (arterial & local)
Unsealed road
Maximum Construction Footprint

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with
Existing Conditions Flood Extents
WA243 **Sheet 10**

Job Number 31-27558
Revision C
Date 04 Sep 2012

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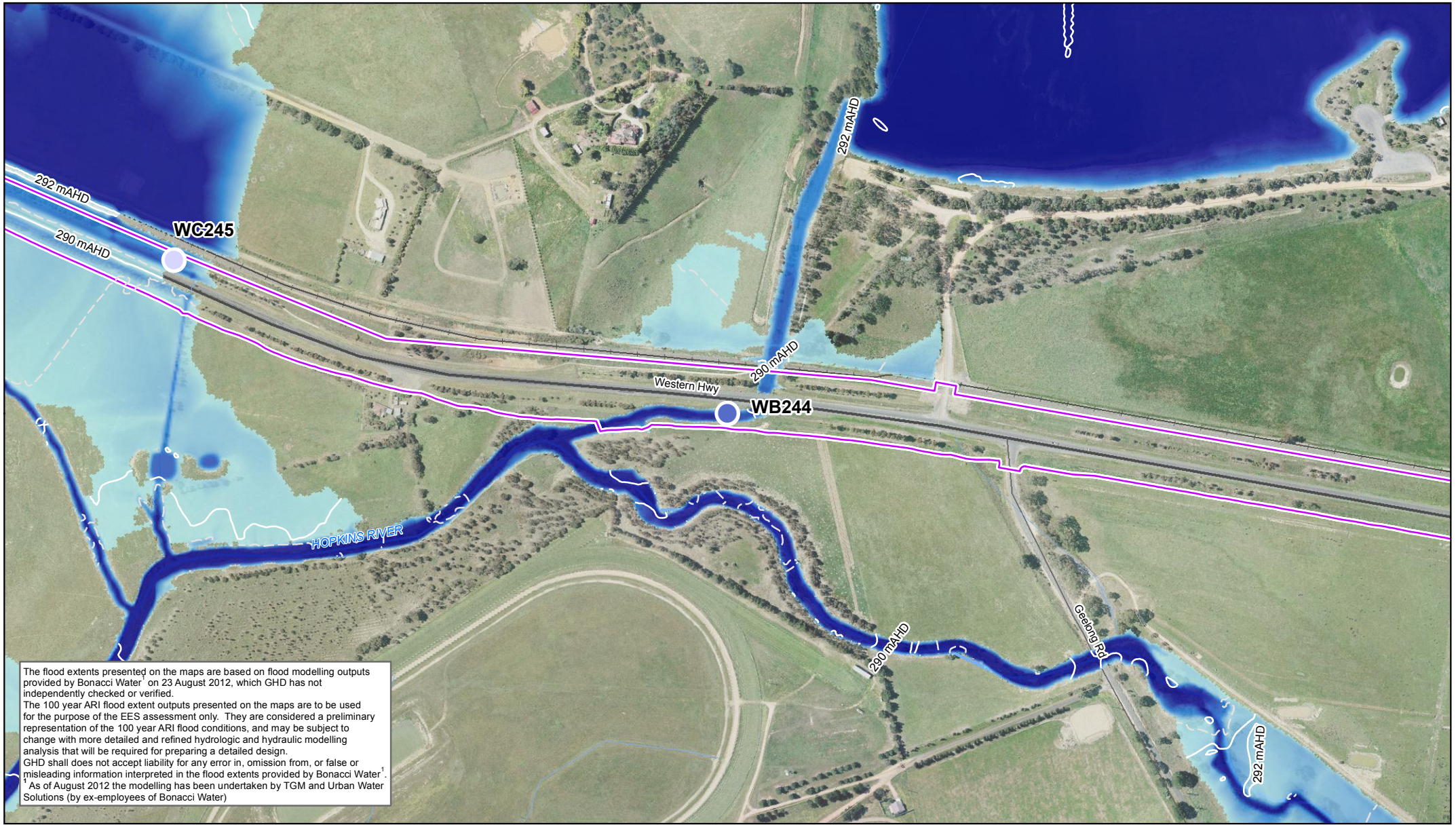
G:\31\27558\GIS\Maps\Deliverables\Stage 2\RISK AND IMPACT ASSESSMENT\06_SURFACE_WATER\3127558_S2_004_Waterway_Crossing_Flood_Extents_A4L.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird



Paper Size A4

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth

High : 2

Low : 0

100yr Flood Level Contours

Major

Minor

Waterway Crossings

Minor

Moderate

Major

Highway

Sealed road (arterial & local)

Unsealed road

Maximum Construction Footprint

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with
Existing Conditions Flood Extents
WB244 **Sheet 11**

Job Number 31-27558
Revision C
Date 04 Sep 2012

Appendix D

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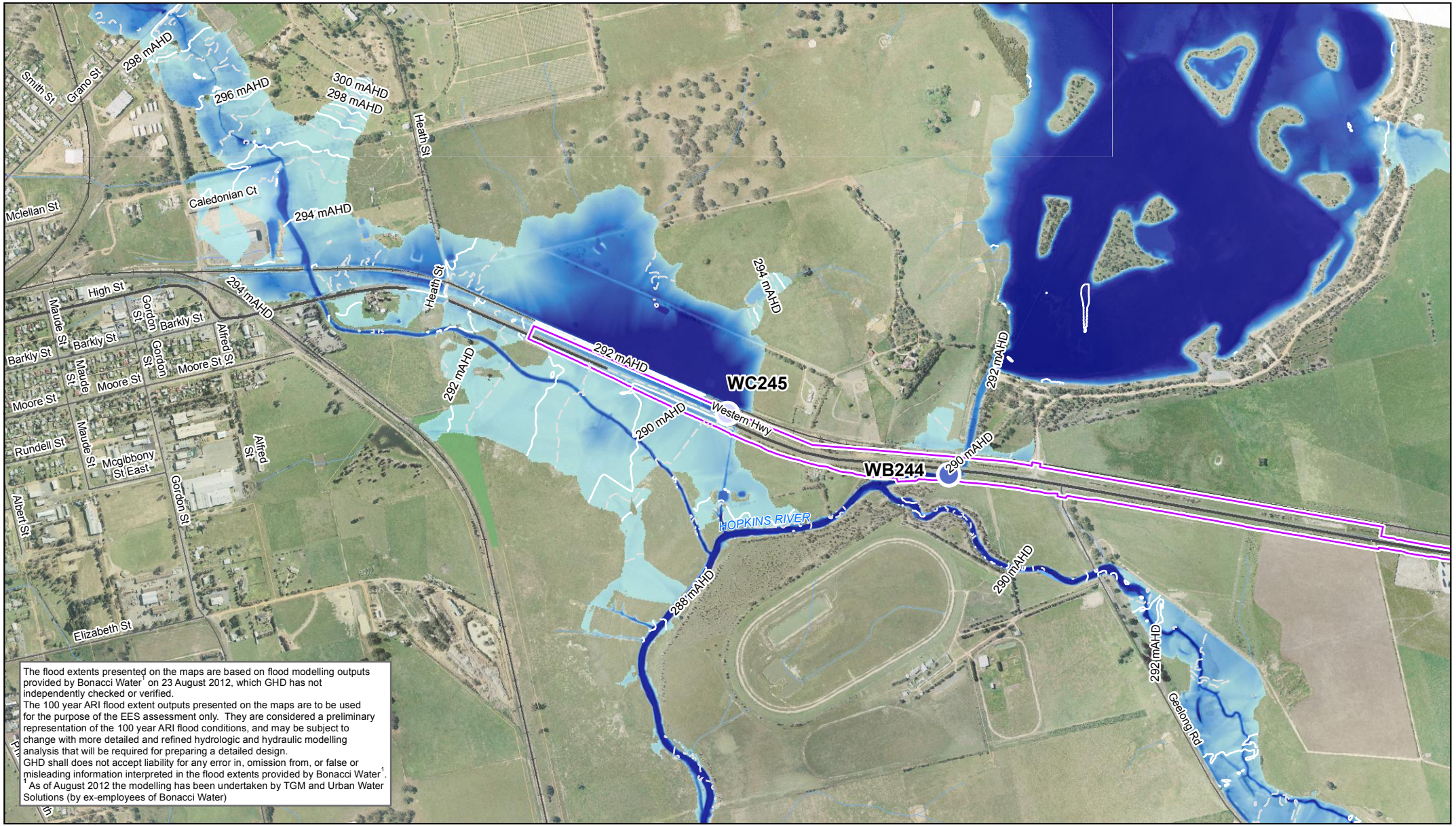

Paper Size A4

0 160 320 480

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 54

N

LEGEND

100yr Modelled Flood Depth
High : 2
Low : 0

100yr Flood Level Contours
Major
Minor

Waterway Crossings
Minor
Moderate
Major

Highway
Sealed road (arterial & local)
Unsealed road
Maximum Construction Footprint

GHD CLIENTS | PEOPLE | PERFORMANCE

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VicRoads
Western Highway Project

Beaufort to Ararat
Waterway Crossings with
Existing Conditions Flood Extents
WC245 Sheet 12

Job Number 31-27558
Revision C
Date 04 Sep 2012

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G:\31\27558\GIS\Maps\Deliverables\Stage 2\RISK AND IMPACT ASSESSMENT\06_SURFACE_WATER\3127558_S2_004_Waterway_Crossing_Flood_Extents_A4L.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DSE, VicMap, 2012; VicRoads, 2012; GHD, Design 2012; Flooding data: Bonacci, 2012; TGM, 2012. Created by:splaird

Appendix E

Table of Waterway Crossings

Option 1	Option 2	Option 3	Crossing Identifier	Bonacci catchment	Bonacci culvert	Chainage	Name	Designation	GHD Classification	Main / Side	Existing Crossing details
Y	Y	Y	WC201			350	Unnamed Tributary of Yam Holes Creek	na	Minor	Main	3 x 1350dia
Y	Y	Y	WC202			950	Unnamed Tributary of Yam Holes Creek	na	Minor	Main	Unknown
Y	Y	Y	WC203			1150	Unnamed Tributary of Yam Holes Creek	na	Minor	Main	2225w x 2000h RCBC
Y	Y	Y	WC204			1150	Unnamed Tributary of Yam Holes Creek	na	Minor	Main	Unknown
Y	Y	Y	WC205			1950	Unnamed Tributary of Yam Holes Creek	na	Minor	Main	Unknown
Y	Y	Y	WC206			2750	Unnamed Tributary of Fiery Creek	na	Minor	Main	None Existing
Y	Y	Y	WC207			3350	Unnamed Tributary of Fiery Creek	na	Minor	Main	None Existing
Y	Y	Y	WC208			4450	Unnamed Tributary of Fiery Creek	1-28-82	Minor	Main	2 x 900h x 1200w RCBC
Y	Y	Y	WC209			4700	Unnamed Tributary of Fiery Creek	na	Minor	Side	Unknown
Y	Y	Y	WC210			4750	Unnamed Tributary of Fiery Creek	na	Minor	Side	None Existing
Y	Y	Y	WB211	2	1	5950	Fiery Creek	1-28	Moderate	Main	Bridge, 36m span
Y	Y	Y	WC212	3	2	9100	Unnamed Tributary of Middle Creek	1-28-80-1	Minor	Main	4 x 1200w x 900h RCBC
Y	Y	Y	WB213	3	3	10650	Middle Creek	1-28-80	Moderate	Main	2 x 1800dia + 1800h x 1950w culvert
Y	Y	Y	WC214	3	4	10950	Unnamed Tributary of Middle Creek	na	Minor	Main	Unknown
Y	Y	Y	WB215	4	5	12600	Charleycombe Creek	1-28-76-6	Moderate	Main	3 x 1800w x 1200h RCBC
Y	Y	Y	WB216	4	6	14400	Charleycombe Creek	1-28-76-6	Moderate	Main	4 x 1800w x 1200h RCBC
Y	Y	Y	WB217	4	7	14750	Charleycombe Creek	1-28-76-6	Moderate	Main	Bridge, 14m span
Y	Y	Y	WC218			15250	Unnamed Tributary of Billy Billy Creek	na	Minor	Main	Unknown
Y	Y	Y	WC219			16550	Unnamed Tributary of Billy Billy Creek	na	Minor	Side	Trapezoidal culvert 900h x 1500w top, 1200w base
Y	Y	Y	WC220			16550	Unnamed Tributary of Billy Billy Creek	1-28-76-7	Minor	Side	None Existing
Y	Y	Y	WC221	4	8	16650	Unnamed Tributary of Billy Billy Creek	1-28-76-7	Minor	Main	None Existing
Y	N	Y	WC222			17550	Unnamed Tributary of Billy Billy Creek	1-28-76-8	Minor	Side	1500dia
N	Y	N	WC223	4	9	17700	Unnamed Tributary of Billy Billy Creek	1-28-76-8	Minor	Main	None Existing
Y	N	Y	WC224			17700	Unnamed Tributary of Billy Billy Creek	1-28-76-8	Minor	Main	None Existing
Y	N	Y	WA225	4	10	18200	Billy Billy Creek	1-28-76	Major	Main	None Existing
N	Y	N	WA226			18250	Billy Billy Creek	1-28-76	Major	Main	None Existing
Y	N	Y	WC227			18400	Unnamed Tributary of Billy Billy Creek	1-28-76-9	Minor	Main	None Existing
Y	N	Y	WB228	5	11	20950	Billy Billy Creek	1-28-76	Moderate	Main	3 x 1200dia approx
N	Y	N	WC229			21100	Unnamed Tributary of Billy Billy Creek	na	Minor	Main	None Existing
N	Y	N	WC230			21200	Unnamed Tributary of Billy Billy Creek	1-28-76-12	Minor	Main	None Existing
N	Y	N	WC231			22050	Billy Billy Creek	1-28-76	Minor	Main	None Existing
N	Y	N	WC232			22300	Unnamed Tributary of Billy Billy Creek	na	Minor	Main	None Existing
N	N	Y	WC233			22800	Unnamed Tributary of Billy Billy Creek	1-28-76-13	Minor	Main	None Existing
N	Y	N	WC234			23020	Unnamed Tributary of Billy Billy Creek	na	Minor	Main	Unknown
N	N	Y	WC235			23250	Unnamed Tributary of Billy Billy Creek	na	Minor	Main	None Existing
Y	N	N	WC236			23250	Unnamed Tributary of Billy Billy Creek	na	Minor	Main	None Existing
Y	N	N	WC237	6	11N, 11W	23400	Unnamed Tributary of Billy Billy Creek	na	Minor	Main	None Existing
N	Y	N	WC238			23650	Unnamed Tributary of Billy Billy Creek	na	Minor	Main	Unknown
Y	N	N	WC239			24500	Unnamed Tributary of Gorrin Creek	1-171-3	Minor	Main	None Existing
Y	N	N	WC240			25600	Unnamed Tributary of Gorrin Creek	na	Minor	Main	None Existing
Y	N	N	WC241			25900	Unnamed Tributary of Gorrin Creek	na	Minor	Side	None Existing
Y	N	N	WC242			26050	Unnamed Tributary of Gorrin Creek	na	Minor	Main	None Existing
Y	Y	Y	WA243	9	12	33800	Hopkins River	1	Major	Main	Bridge, 27m span
Y	Y	Y	WB244	14	13	38350	Greenhills Creek	1-169	Moderate	Main	5 x 3000w x 1800h RCBC
Y	Y	Y	WC245	22	14	39000	Unnamed Tributary of the Hopkins River	na	Minor	Main	Unknown
Y	Y	Y	new - side road			28400	Signifcant tributary of the Hopkins River		Moderate	Side	

Appendix F

Summary of Flood Crossings

Section	Modelled Floodplain system	Waterway	Proposed Highway	GHD Crossing ID (Proposed Hwy)	Bonacci Crossing ID	Bonacci Flow (Q100 m3/s)	Bonacci Flow (Q1 m3/s)	Threshold flow (overtopping)	Existing Bridge/ Culvert Opening	Bridge opening modelled*	Existing Highway flow Conditions	Proposed Highway - Potential Impacts	Proposed Highway Modelling requirements
Section 2													
Beaufort to Ararat	Fiery Creek	Fiery Creek	Duplication	WB211	1	39.7	9.7	no overtopping in Q100	Bridge, 36m span	Gap in road	No overtopping, upstream attenuation	Minimal - Duplication only	No modelling required for EES
	Middle Creek	Tributary of Middle Creek	Duplication	WC212	2	8.2	2.3	?	4 x 1200w x 900h RCBC	culvert opening?	Overtopping with 100m sheet flow, upstream attenuation	Duplication only, but raising of the road required to meet "no flooding" criteria	No modelling required for EES
		Breakaway flow of Middle Creek	Duplication		3 East			~Q10	none				
		Middle Creek	Duplication	WC213	3	16.6	4.1	?	2 x 1800dia + 1800h x 1950w culvert	Gap in road	Significant overtopping, significant upstream attenuation; upstream properties flood affected	Raising of the road required to meet "no flooding" criteria, and impacts/benefits to local properties to be considered	**Modelling Required** - to represent duplicated highway raised to 300mm(?) above flood level, and potentially increased/additional culvert openings
		Breakaway flow of Middle Creek	Duplication	WC214	4	1	0.3	no overtopping in Q100	???	culvert opening?			
	Charliecombe/Billy Billy Ck	Tributary of Charliecombe Creek	Duplication	WB215	5	3	0.9	no overtopping in Q100	3 x 1800w x 1200h RCBC	culvert opening?	No overtopping, attenuation and upstream diversion to adjacent catchment ; upstream property flood affected	Low impact given Duplication only; impacts to both upstream property and property at downstream crossing to be considered	**Modelling potentially Required** - To demonstrate no adverse impact (or assess potential to reduce impact) on existing property
		Tributary of Charliecombe Creek	Duplication	WB216	6	7.2	2.2	no overtopping in Q100	4 x 1800w x 1200h RCBC	culvert opening?	No overtopping	Duplication will require u/s stream realignment - not flooding impact	**Modelling potentially Required** - To demonstrate no adverse impact (or assess potential to reduce impact) on existing property
		Charliecombe Creek	Duplication	**WB217**	7	5.8	1.8	?	Bridge, 14m span	Gap in road	Overtopping within backwater of complex floodplain confluence; upstream properties flood affected	Duplication will require d/s stream realignment - impacts to property to be considered	
		local drainage flow path	Duplication	WC218							not modelled		
		Tributary of Billy Billy Creek	Deviation	WC219, WC220, WC221	8	9.5	2.9	no overtopping in Q100	Trapezoidal culvert 900h x 1500w top, 1200w base	culvert opening?	No overtopping, some upstream attenuation	New alignment - no significant impacts expected	No modelling required for EES
		Tributary of Billy Billy Creek	Access Road	WC222					1500dia		overtopping of access road	Access road to be raised (flood standard?)	No modelling required for EES
		Tributary of Billy Billy Creek	Deviation	WC223, WC224	9	9.6	2.9	?	???	culvert opening?	existing road overtopped, significant upstream attenuation and diversion of flows (new alignment a devaition from existing highway)	New alignment - no significant impacts expected	No modelling required for EES
		Billy Billy Creek	Deviation	WA225	10	14.1	3.2	?	???	culvert opening?		New alignment - no significant impacts expected	No modelling required for EES
		Small tributary of Billy Billy Creek	Deviation	WC227					none		not modelled		
		Billy Billy Creek	Duplication	WB228	11	9.4	1.8	?	3 x 1200dia approx	culvert opening?	Overtopping with 100m sheet flow, upstream attenuation	Minimal - Duplication only	No modelling required for EES
		Upper tributary/flow path of Billy Billy Creek	Duplication		11 West			Q1 yr	???	culvert opening?	No overtopping, cross drainage flow path	Minimal - Duplication only	**Modelling potentially Required** - Existing highway flood affected, however New highway will move away from flood affected locations. New crossing will need to be designed
		Upper tributary/flow path of Billy Billy Creek	Duplication		11 North			Q2 yr	???	culvert opening?	sheet flow (<100mm) over road	New alignment away from existing flooded hwy - no significant impacts expected	
		Upper tributary of Billy Billy Creek	Deviation	WC237, WC236					???		sheet flow (<100mm) over road at 2 locations	New alignment away from existing flooded hwy - no significant impacts expected	
	Hopkins R/ Greehills overflow	Hopkins River		WA243	12	46.8	9.7	no overtopping in Q100	Bridge, 27m span	Gap in road	No overtopping, upstream attenuation provided u/s of railway	Minimal - Duplication only	No modelling required for EES
		Greenhills Creek		WB244	13	28.2	4	Q50 yr	5 x 3000w x 1800h RCBC	Gap in road	No overtopping, significant upstream attenuation	Duplicated highway within current flood extent downstream - realignment in flow path and change in extent to be determined	No modelling required for EES
				WC245	14			?	???		not modelled	Duplication only, but raising of the road required to meet "no flooding" criteria	

Appendix G

Water Sensitive Road Design

Water Sensitive Road Design (WSRD)

Runoff from roads have been shown to have detrimental impacts on receiving waters and the aquatic life they sustain, and can contribute to large pollutant loads compared to runoff from other land uses. These contaminants include:

- Particulate matter;
- Nutrients (nitrogen and phosphorus);
- Heavy metals;
- Petroleum based products;
- Organic compounds; and/ or
- Rubber products.

The treatment of road runoff is an important element of catchment management, owing to the expected high pollutant concentrations of metals and hydrocarbons generated from road surfaces.

There are many stormwater management elements for reducing the pollutants conveyed in road stormwater runoff. It should be noted that no single stormwater management measures can effectively remove the full range of pollutant types and particle sizes. Using a combination of these elements (referred to as a 'treatment train') helps to effectively manage stormwater to meet best practise treatment objectives and minimise environmental impacts.

There are a range of typical WSRD elements that could be adopted to target various pollutant types and particle sizes. Typically for a project of this nature, considering the space available and limited treatment options, a general treatment process using buffer strips and vegetated swales along both sides of the highway (where possible) within the road reserve, would be used. Provided it can be demonstrated, during detailed design, that the best practice treatment standards are being achieved by this regime, no additional treatments are expected to be required to treat stormwater runoff from the Project.

- Buffer Strips

  Buffer strips are basically strips of vegetation, generally located close to pollutant sources i.e. along the edge of the highway, and are usually incorporated as an initial method of pollutant treatment in a treatment train, where appropriate. Buffer strips are used to treat coarse and medium suspended solids from runoff, as well as some nutrients, and work most effectively for distributed runoff.

- Vegetated or Grassed Swales

  Swales are areas of open channel used to convey stormwater in lieu of pipes. They are used for the retention of coarse to fine sediments and reduction of pollutant loading (nitrogen and phosphorus), and provide a desirable buffer between receiving waters and impervious areas of a catchment. The effectiveness of the swale in pollutant treatment depends on factors such as hydraulic loading and the size, type and density of vegetation.

Swales use overland flows and mild slopes to slowly convey water downstream. The interaction with vegetation promotes an even distribution of water and slowing of flows, thus encouraging coarse sediments to be retained.

Swales can use a variety of vegetation types, or can simply be grassed. Vegetation is required to cover the whole width of the swale, be capable of withstanding design flows and be of sufficient density to provide good filtration. For best treatment performance, vegetation height should be above treatment flow water levels. If runoff enters directly into a swale, perpendicular to the main flow direction, the edge of the swale acts as a buffer and provides pre-treatment for the water entering the swale.

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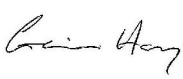
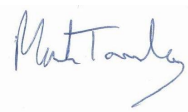
Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Draft						6/7/11
Draft B						14/7/11
Draft C						10/8/11
Draft D						30/5/12
0	A.Roberts	G.Hay		M.Tansley		05/9/12