UPGRADING THE PACIFIC HIGHWAY

Woolgoolga to Ballina Planning Alliance

UPGRADING THE PACIFIC HIGHWAY

Woolgoolga to Ballina Upgrade

Working paper – Groundwater

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FINAL

NSW GOVERNMENT Transport Roads & Maritime Services

aurecon

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Acronyms, abbreviations and initialisms

Item	Definition
AASS	Actual acid sulfate soils
AHD	Australian Height Datum
AS/NZS 4360	Precursor to the ISO 13000 Risk Management Standard
ASS	Acid sulfate soils
BLR	Basic landholder rights
CEMP	Contractors Environmental Management Plan
CPT	Cone penetration test
DEM	Digital elevation model
DGR	Director-General’s environmental assessment requirements
DP&I	Department of Planning and Infrastructure
EEC	Endangered ecological communities
EMU	Extraction Management Unit
GDE	Groundwater-dependent ecosystems
GMU	Groundwater management units
HACCP	Hazard Analysis Critical Control Point
ISO 9001	Internationally recognised set of standards for designing and implementing an effective quality management system
ISO 14001	Internationally recognised set of standards for designing and implementing an effective environmental management system
NATA	National Association of Testing Authorities
NHMRC	National Health and Medical Research Council
NRMMC	National Resource Management Ministerial Council
PASS	Potential acid sulfate soils
RMS	Roads and Maritime Services
SEPP	State Environmental Planning Policy
SWMP	Soil and Water Management Plan
WMA	Water Management Areas
WSP	Water sharing plans
WT	Water Table

Glossary

Term	Definition
Acid sulfate soils (ASS)	Soils or sediments that contain iron sulfides that, when disturbed and exposed to oxygen, generate sulfuric acid and toxic quantities of aluminium and other heavy metals. A distinction is made between potential ASS (PASS) whereby the soils are fully saturated and the sulfides stable, and actual ASS (AASS) where previous oxidation has occurred and acid has been released. PASS and AASS can occur in the same soil profile (*see Section 2.1.3)*
Aquifer	Under the *Water Management Act 2000,* an aquifer means a geological structure or formation, or an artificial landfill, that is permeated with water or is capable of being permeated with water. More generally, the term 'aquifer' is commonly understood to mean a groundwater system that is sufficiently permeable to allow water to move within it, and which can yield productive volumes of groundwater
Aquifer interference	The extraction of water from one aquifer resulting in an impact on another. An important consideration is the timeframe of the interaction and the impact on other uses, including the environment
Aquitard	A semi-pervious geologic formation which can store water but transmits water at a low rate compared to an aquifer
Confined aquifer	An underground water system that is overlain and underlain by very low permeability materials that effectively seal the aquifer and isolate it from surrounding formations. Once this system becomes full of water an overpressure develops proportional to the pressure of water backing up to the recharge zone. A bore that penetrates this aquifer will commonly allow the groundwater to rise up the bore casing. If this water reaches the land surface it is known as artesian; if it reaches the shallow unconfined zone then sub-artesian, otherwise, non-artesian. A confined aquifer does not have a watertable; groundwater levels are measured as elevations
Groundwater	Groundwater is all water that occurs beneath the ground surface in the saturated zone. A groundwater system is any type of saturated geological formation that can yield anywhere from low to high volumes of water.
Groundwater bore	A hole punctured in the landscape that penetrates to the water table in an unconfined aquifer, or to the aquifer itself in confined systems. May be cased and slotted at the region of interest or open for the entire zone of interest. May be constructed either as a monitoring bore or as a production bore. All groundwater bores in NSW are required to be registered.
Groundwater connectivity	The interaction between groundwaters in one aquifer and groundwaters in another, or the interaction between groundwater and surface waters
Groundwater dependent ecosystem	An assemblage of flora and fauna that are dependent for at least part of the annual cycle on water derived from water beneath the ground surface. Includes streams and wetlands where groundwater discharges to the surface, as well as environments where shallow watertables provide seasonal water supply to vegetation
Groundwater Source	A defined contiguous region the contributes to a single, connected underground water supply
Impact	A significant change to the existing condition. Generally considered as

	adverse change. Potential impact describes the magnitude of change that may occur
Macro Water Sharing Plan	Generic water sharing rules for the management of water resources where there is minimal use (impact) on the total water resource pool and no WSP has been developed
Monitoring bore	A groundwater bore that is developed (constructed to industry and regulatory guidelines) for the purpose of penetrating an aquifer and providing a window of observation of the properties of the water it contains. May be used to measure the groundwater level (as elevation, commonly known as a piezometer) or as a means to sample the groundwater for additional analysis (eg chemistry, isotopes, contaminants)
Physiography	The description of landscape in terms of relief, elevation and surface attributes (eg land use, vegetation)
Pineena bores	A bore that is listed in the NSW groundwater bore database
Production bore	A groundwater bore that is developed (constructed to industry and regulatory guidelines) for the purpose of extracting groundwater for consumptive use. A license is required to extract more the three ML per year
The Project	The Woolgoolga to Ballina Pacific Highway Upgrade
Regional Water Sharing Plan	A series of regulations under the *Water Management Act 2000* for water use and distribution (including trading) within a defined region where there is significant use of water resources and prescribed limits to water consumption are enacted
Risk	The likelihood of a detrimental activity taking place combined with the consequence of that activity. Typically, a receptor, or target, of the activity is determined to assess the consequence of an activity to have detrimental impacts
Unconfined aquifer	Any formation that contains water and is in contact with the land surface (ie with air). Water is held in the aquifer by gravity only and will drain in the direction of maximum gradient.
Water Management Area	An area defined under the *Water Management Act 2000* as a single region for the purposes of allocation of water resources and managed by a single regulatory agency (eg Rous Water)
Watertable	The level in the ground below which the sediments are completely saturated with water. This level generally varies with seasonal input from rainfall which recharges the groundwater and hence raises the watertable. During dry periods, the groundwater drains due to gravity and the watertable will drop unless there is an alternative source of recharge

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Executive summary

The Roads and Maritime Services (RMS) proposes to upgrade the existing Pacific Highway between Woolgoolga and Ballina (the project). This groundwater working paper has been prepared to support RMS' application for project approval under Part 5.1 of the *Environmental Planning and Assessment Act 1979*.

This working paper identifies the existing groundwater conditions in the study area, assesses potential construction and operational phase groundwater impacts and identifies management measures to minimise potential impacts. Groundwater impact receptors (eg groundwater users, groundwater-dependent ecosystems) may potentially be impacted by changes in groundwater supply and/or groundwater quality.

This assessment has been based on existing available groundwater information and thereby constitutes a desktop study. There is a reasonable level of available information for much of the immediate project boundary, but as the distance from the project increases, the amount and quality of available groundwater information decreases, making regional impacts harder to accurately assess. There is little data between Harwood and Woodburn, and a general paucity of groundwater data from Glenugie to Grafton.

This report does not consider impacts that may be associated with climate change, nor changing weather patterns. Hence there is no consideration of the potential impacts of rising (during wetter periods) or falling (during drier periods) groundwater levels and any consequent interaction with the project. This report assumes that historical weather patterns will continue.

Over one third of the project overlies areas where groundwater is inherently close to the ground surface. There is a high potential impact in those areas. In particular, the floodplains of the Clarence and Richmond Rivers are underlain by shallow groundwater tables. The low groundwater flow gradients in these areas, however, mitigate against a significant regional impact, as any changes to absolute flow will be minimal.

Generally, therefore, the existing groundwater receptors would not be unduly impacted by the project. Groundwater supplies for irrigation, industrial, stock and domestic and environmental use would remain unchanged. The proportion of land with groundwater tables intrinsically within five metres of the surface will remain largely unchanged (Table Ex-1-1), though the proportion of land with very shallow water tables (within two metres of the ground surface) will increase during the construction phase due mainly to the excavation of cuts, which account for twelve per cent of the project. Standard engineering measures will mitigate any potential impacts at these locations and reduce the overall potential for impact from the project during operation.

Perturbations to the groundwater flow during construction at cuts will rapidly relax resulting in reduced potential operational impacts. As a significant portion of the project has pre-existing shallow groundwater tables, however, works in shallow groundwater areas need to be carefully monitored and assessed on a regular basis to ensure no impact occurs.

There is a significant local reserve groundwater supply near Woodburn (managed by Rous Water) and this has shallow groundwater tables and hence a potential for impact. Any potential impacts to this supply, however, will be mitigated during the detailed design of the project and managed in accord with the management strategy outlined below.

Table Ex-1-1 Percentage groundwater potential impact extent for the project

Potential impact[1]	Project phase		
	Pre-construction	Construction	Operation
High	36%	31%	8%
Medium	13%	20%	18%
Low	23%	23%	27%
No potential impact	28%	26%	47%

[1] High potential impact occurs where groundwater is within two metres of the ground surface and/or actively discharging. Medium potential impact is considered where the groundwater table is within three metres of the surface and low potential impact, within five metres. Groundwater below five metres is considered to undergo no potential impact.
All cut locations will include engineering measures to mitigate potential impacts to groundwater

Salinity is not a significant issue for the catchments crossed by the project. No measured data exists to indicate the presence of dryland salinity in any of the coastal catchments, though around 250 hectares has been estimated to be affected by shallow groundwater tables within the Richmond and Clarence catchments. Shallow groundwater tables (<2 metres below ground surface) has been used as an indicator in NSW of areas potentially affected by dryland salinity, but the high rainfall of the catchments of northern coastal NSW generally means that flushing mitigates against the accumulation of salts.

Acid sulfate soils (ASS) are widespread throughout the project in low lying areas, requiring appropriate acid sulfate soil management techniques to be adopted during construction to avoid adverse environmental impacts. Large sections of the project contain potential acid sulfate soils (PASS). In these areas, varying groundwater tables has the potential to lead to oxidation of PASS and development of actual ASS, with associated potential impacts to the environment. However, appropriate monitoring would provide sufficient early warning and maintaining appropriate soil moisture levels during construction would mitigate against this impact.

The project crosses two NSW Water Management Areas (WMAs): Upper North Coast WMA and Northern Rivers WMA. Within these areas, only the Richmond River Area Alluvial Water Sharing Plan is directly impacted by the project. The Rous Water Supply, within this Plan area, is the only Local Area Management Zone associated with the route.

Baseline measurements for water quality and an on-going groundwater monitoring program would aim to identify any potential water pollution problems associated with the project, identify the cause of these problems and recommend appropriate management methods.

The potential impacts on groundwater and surface water systems will differ between the construction and operational phases of the project. The management strategies described below need to be in place prior to construction and carried through to operation. Especially important are the monitoring and management strategies that address the proposed cut sites (identified in Table B-7-1). The concept design incorporates one hundred and fifty-seven cuts. Of these, 97 are considered to present a potential high impact on groundwater. The final design surface of these 97 cuts will either: sit below the current groundwater table and hence instigate ingress of groundwater onto the pavement (62 cuts), or the watertable is likely to be at or very close to the road design surface (35 cuts). Engineering strategies to divert the groundwater will need to be put in place. These cuts are classified as Type A cuts, following the convention of previous cut impact assessments (eg Golder and Associates, 2008). 32 additional cuts are in locations where the final watertable is likely to be within five metres of the road surface (Type B cuts). The remainder of the proposed cut sites are in areas with no potential groundwater impacts (Type C cuts).

Type A cuts have the potential to impact on downstream groundwater flow, flow to springs, baseflow to creeks and hence potentially impact associated groundwater dependent ecosystems (GDEs). The management strategy would be to follow the following four-pronged approach:

- Pre-works investigations ─ geotechnical investigations of all cuts to determine groundwater condition (quality parameters, including electrical conductivity, groundwater depth, geological information), presence of actual or potential acid sulfate soils, presence or potential presence of salinisation, establishing groundwater monitoring sites, and gathering of other pertinent information
- Assessment – involving this study, the pre-works investigations carried out, groundwater modelling of type A cuts (and the Rous Water Woodburn borefield site), and predictions made from those results
- Monitoring – to assess whether the investigation and its predictions are accurate and to instigate early intervention in the unlikely case/s that the actual outcomes deviate from predictions. Monitoring would start before construction, and continue during construction. Monitoring would also continue into the operation phase of the project until groundwater conditions have stabilised
- Mitigation – implement environmental and engineering management measures where predictions and/or modelling and monitoring suggest that these are required to minimise impacts on groundwater.

Type B cuts are unlikely to pose an impact to groundwater, but require sufficient monitoring to assess whether changes to the groundwater regime, for example under a wetter climate, may result in future potential impacts. Types C cuts will have no impact on the groundwater regime under the project.

To effectively manage and mitigate groundwater impacts, and to consider the uncertainties around the actual impacts, the following specific approach is proposed:

- High impact (Type A) cuts:

  There is a high potential that Type A cuts would affect groundwater regimes and any associated groundwater dependent ecosystems. The implementation of engineering measures are required as part of construction to mitigate any groundwater impacts. Monitoring of the groundwater regime in the vicinity of these cuts and groundwater modelling would need to commence in advance of road construction. The results of the modelling and monitoring, before and during road construction, will determine what engineering measures are required to mitigate any impacts.

After road construction, the monitoring should continue to verify the effectiveness of any engineering measures, so that modifications can be made, if required.

- Medium and low potential impact (Type B) cuts:

  These cuts are expected to have no or negligible groundwater impacts. Engineering mitigation measures are not required, but an on-going monitoring regime would fully characterise the groundwater conditions at these locations.

- No potential impact (Type C) cuts:

  These cuts are expected to have no or negligible groundwater impacts. Monitoring and engineering mitigation measures are not required.

  The impact mitigation and management recommendations for all the potentially impacted cut sites would be incorporated into a Water Management Plan, to be prepared for both the construction and operational phases of the project. Surface water runoff from the constructed road is likely to contain contaminants, including elevated concentrations of suspended solids and metals. Surface water runoff from the road would be captured by a drainage system at each cut and would need to be managed prior to any return to the natural groundwater system.

1. Introduction

1.1. Project description

NSW Roads and Maritime Services (RMS) is seeking project approval for the Woolgoolga to Ballina Pacific Highway upgrade project (the project) which is located on the NSW North Coast. The approval is sought under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The project would upgrade around 155 kilometres of highway, forming a major part of the overall Pacific Highway Upgrade Program. The project would provide a four-lane divided carriageway from around five kilometres north of Woolgoolga to around six kilometres south of Ballina. Figure 1-1 shows the regional location of the project.

The project has been divided into eleven sections between tie-ins with the existing Pacific Highway to aid description, and the impact assessment for the project is described for each of these sections (refer to Table 1-1).

Table 1-1 Project sections and lengths

Project section	Location	Station		Length (kilometres)
		Start	Finish	
1	Woolgoolga to Halfway Creek	0	17.0	17.0
2	Halfway Creek to Glenugie upgrade	17.0	28.7	11.7
3	Glenugie upgrade to Tyndale	33.8	68.8	35.0
4	Tyndale to Maclean	68.8	82.0	13.2
5	Maclean to Iluka Road, Mororo	82.0	96.4	14.4
6	Iluka Road to Devil's Pulpit upgrade	96.4	105.6	9.2
7	Devil's Pulpit upgrade to Trustums Hill	111.1	126.4	15.3
8	Trustums Hill to Broadwater National Park	126.4	137.6	11.2
9	Broadwater National Park to Richmond River	137.6	145.1	7.5
10	Richmond River to Coolgardie Road	145.1	158.6	13.5
11	Coolgardie Road to Ballina bypass	158.6	164.0	5.4

An overview of the project alignment and project sections are shown in Figures 1-2 to 1-6.

Figure 1-1 Project overview

The project

Upgrade completed to dual carriageway

Upgrade under construction

Existing Pacific Highway

Figure 1-2 The project alignment - Arrawarra to Glenugie

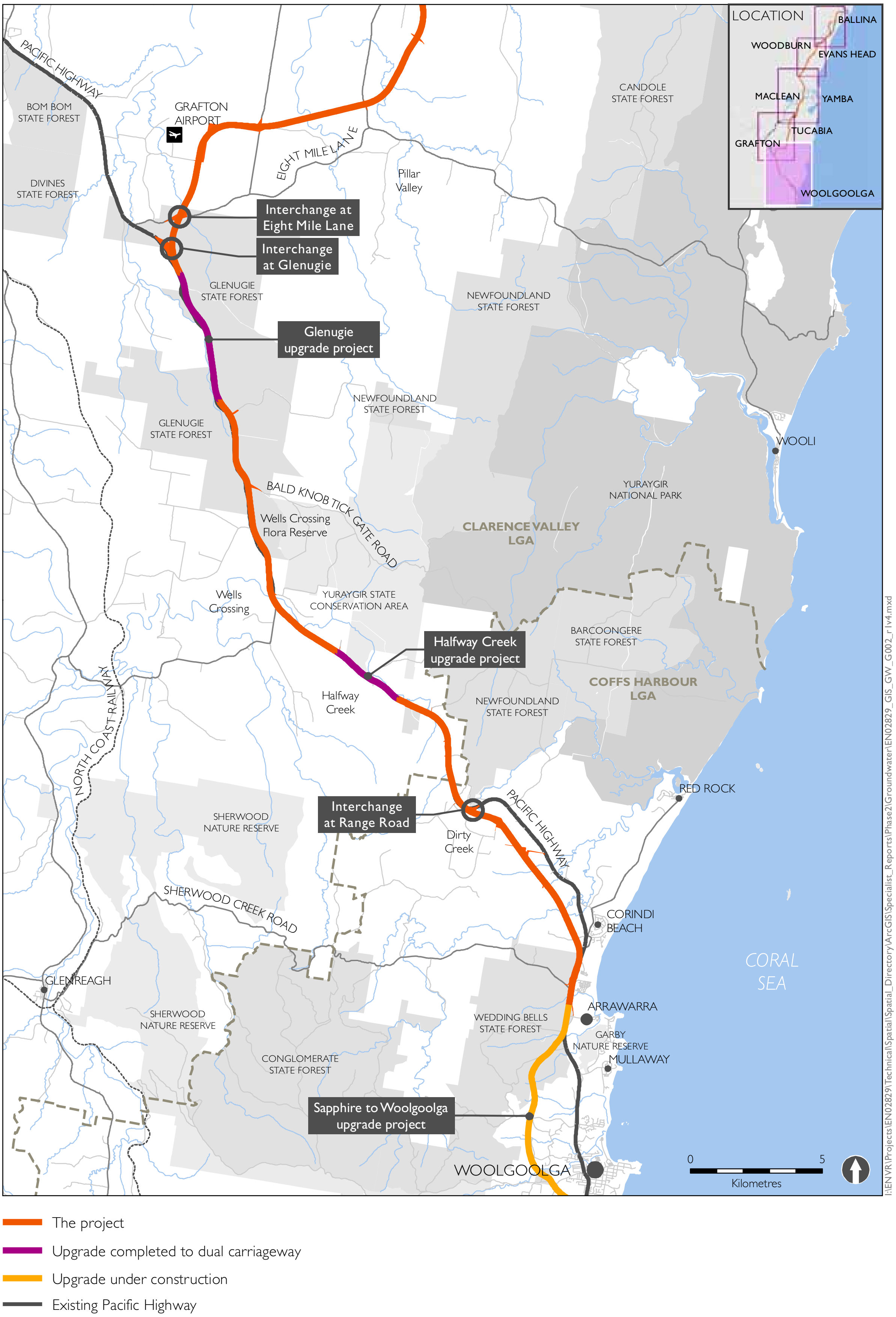
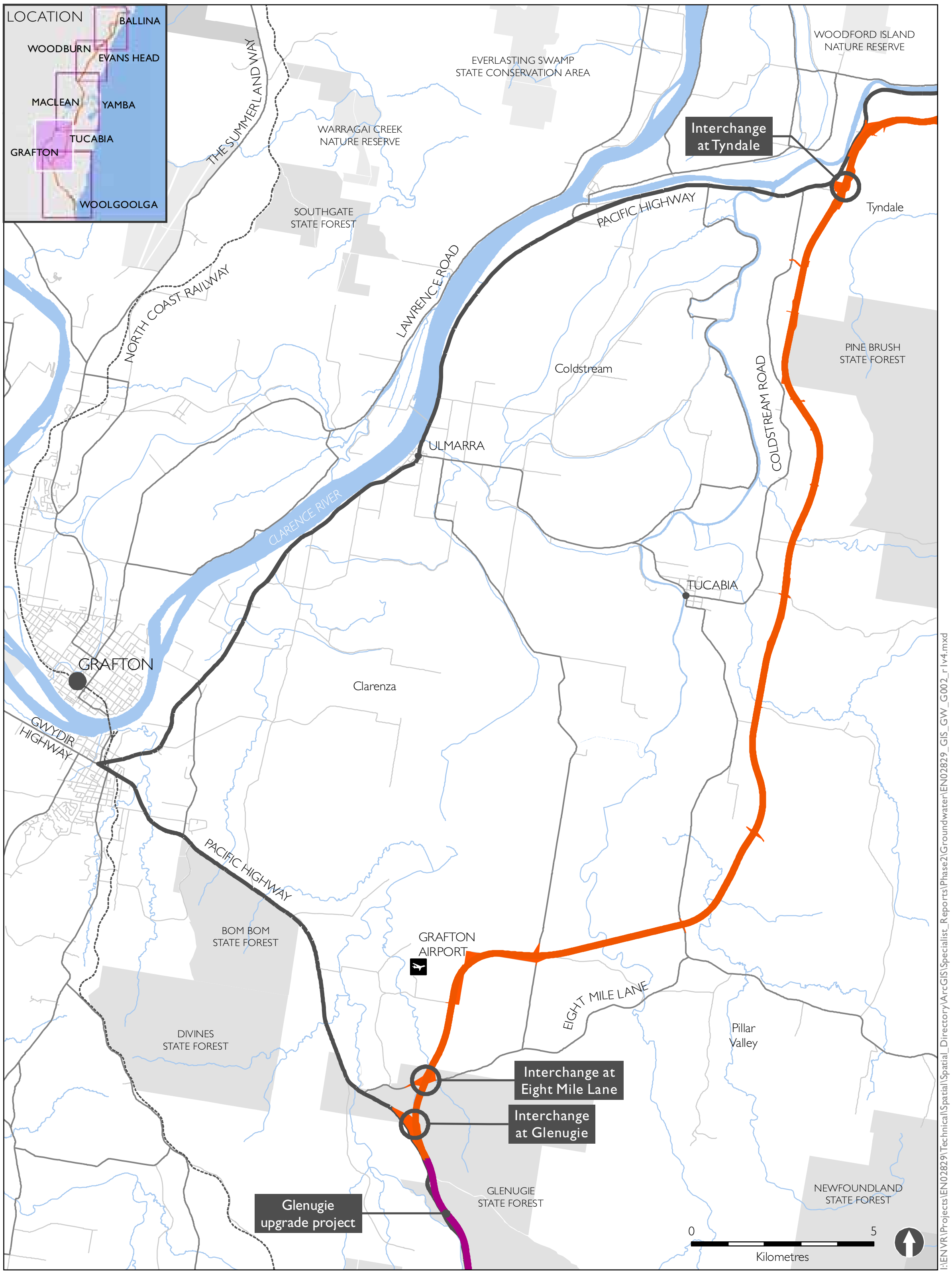


Figure 1-3 The project alignment - Glenugie to Tyndale



The project

Upgrade completed to dual carriageway

Upgrade under construction

Existing Pacific Highway

Figure 1-4 The project alignment - Tyndale to Devils Pulpit

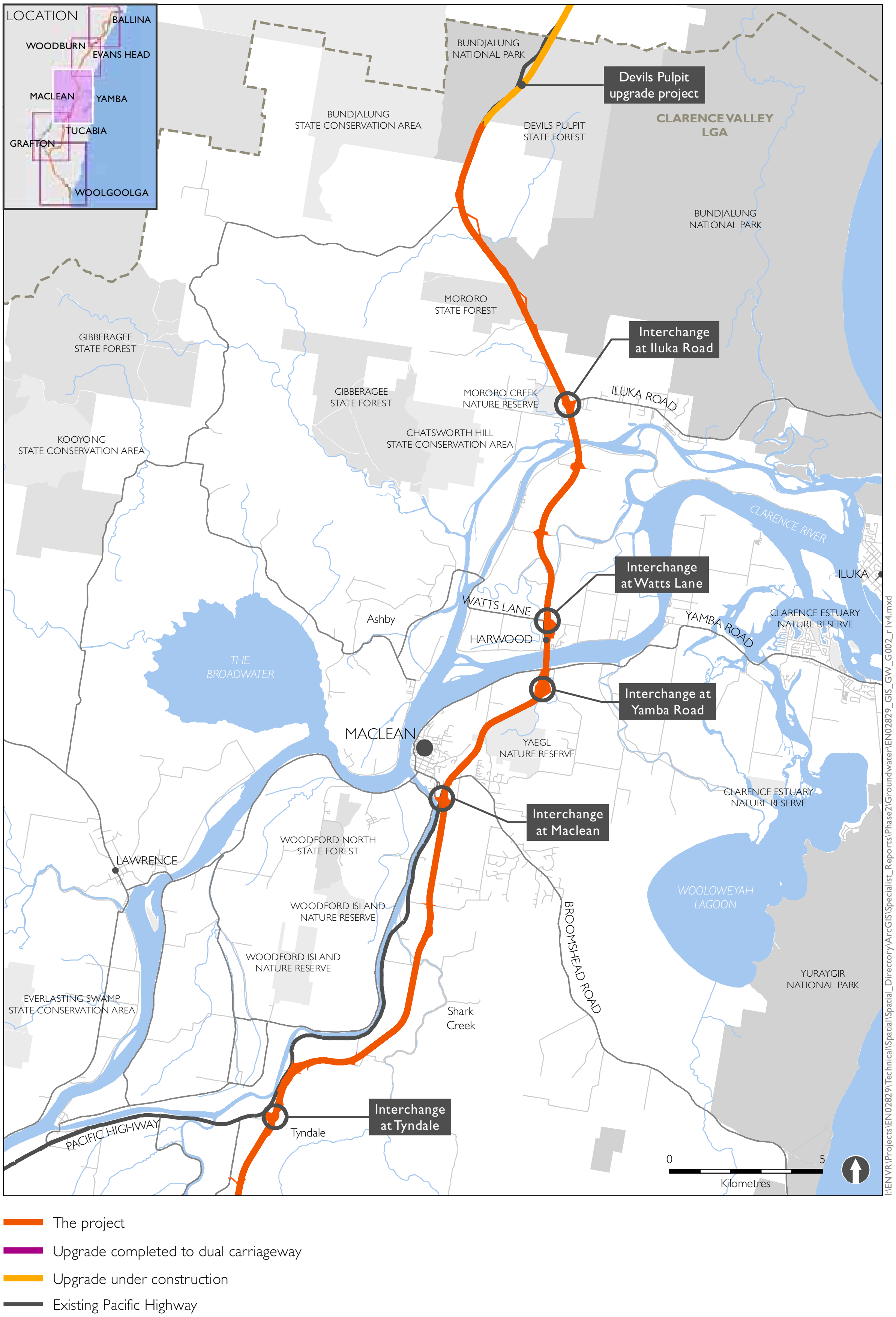
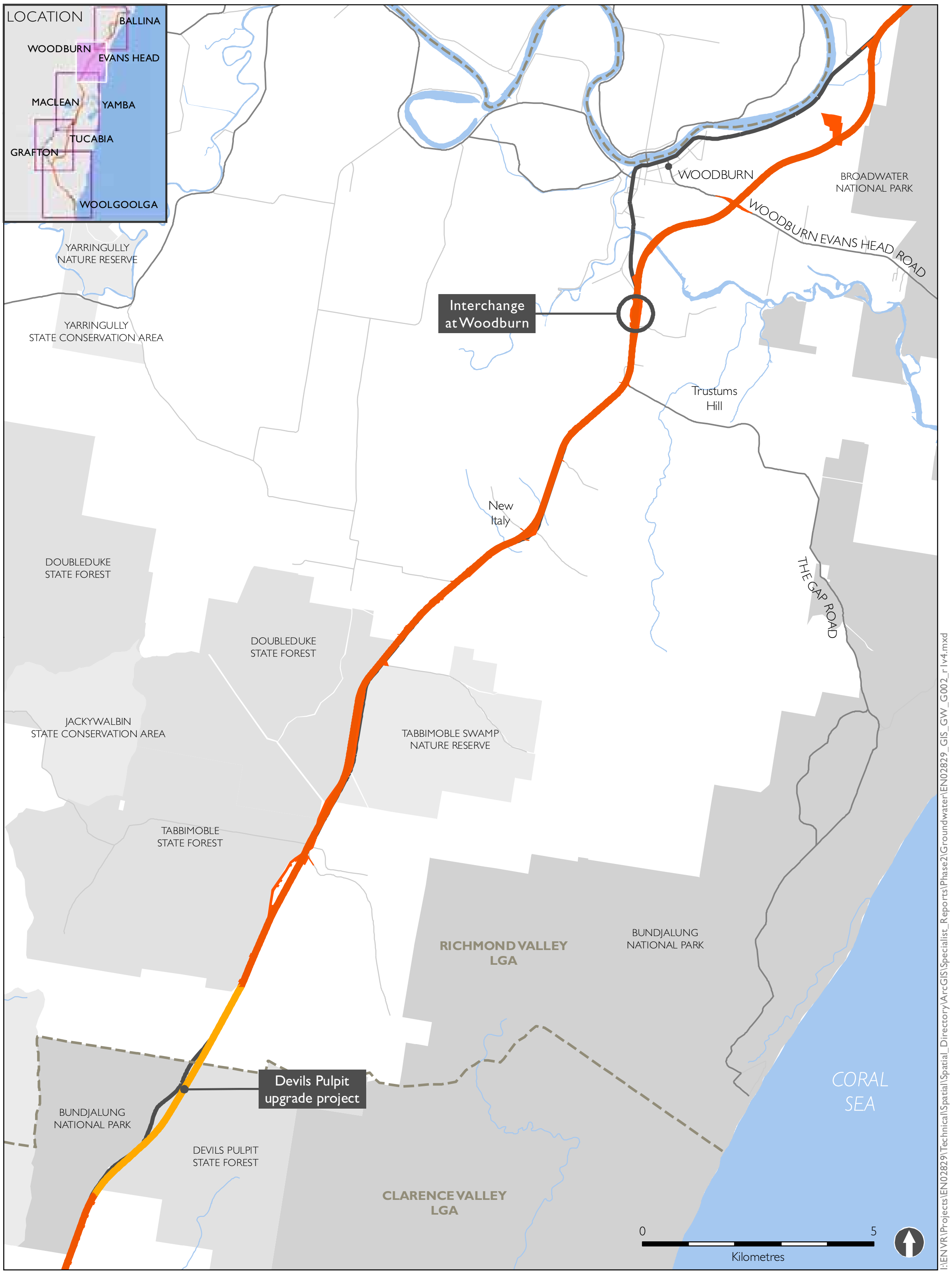
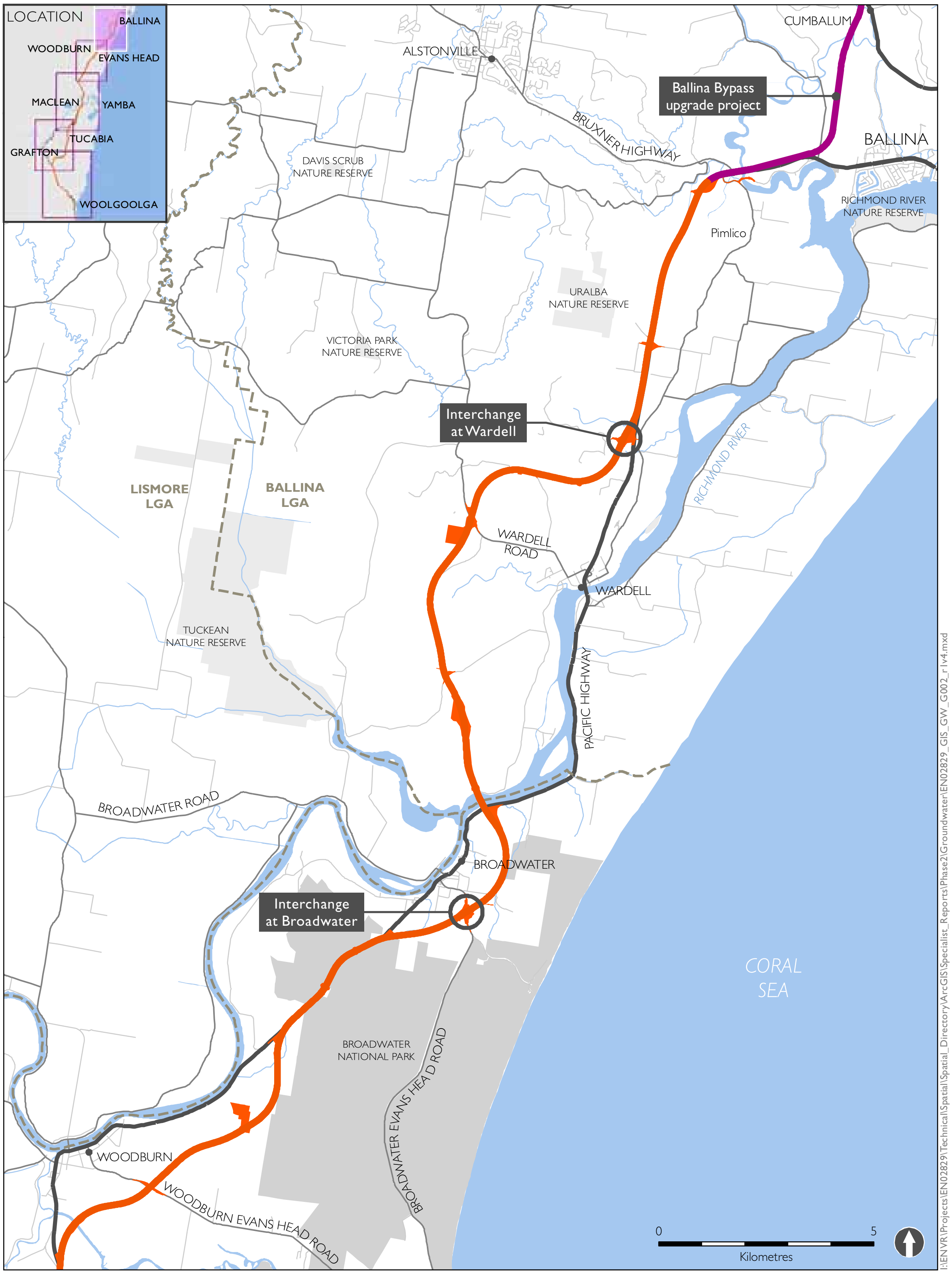


Figure 1-5 The project alignment - Devils Pulpit to Woodburn



The project
Upgrade completed to dual carriageway
Upgrade under construction
Existing Pacific Highway

Figure 1-6 The project alignment - Woodburn to Ballina



The project
Upgrade completed to dual carriageway
Upgrade under construction
Existing Pacific Highway

While the project is for a four-lane motorway standard upgrade, the construction and opening of the project would be staged. Staging could include some sections being constructed and opened initially as a four-lane arterial standard upgrade.

The project does not include the Pacific Highway upgrades at Glenugie and Devils Pulpit, which are located between Woolgoolga and Ballina, as Glenugie is now complete and Devils Pulpit is under construction. Together with the Glenugie and Devils Pulpit upgrades, the project would complete a total of 164 kilometres of upgraded highway between Woolgoolga and Ballina.

The key features of the project include:

- Around 155 kilometres of motorway standard highway, comprising a four-lane divided carriageway (two lanes in each direction) that can be upgraded to a six-lane divided carriageway in the future, if required
- Bypasses of Grafton, South Grafton, Ulmarra, Woodburn, Broadwater and Wardell
- Ten interchanges to provide access to and from the upgraded highway at:
  - Range Road (Corindi)
  - Glenugie (Eight Mile Lane)
  - Tyndale (Sheey's Lane)
  - Maclean (Goodwood Street)
  - Yamba Road (Harwood)
  - Watts Lane (Harwood)
  - Iluka Road (Woombah)
  - Woodburn (Trustums Hill Road)
  - Broadwater (Evans Head Road)
  - Wardell (Coolgardie Road)
- About 40 bridge crossings of waterways or floodplains, including bridges over the Clarence and Richmond rivers
- About 55 overbridge and underpass structures to maintain access along local roads crossed by the project
- Viaducts located where the project would cross low-lying or flood-prone areas
- Service roads and access roads to maintain connections to existing local roads and properties
- Structures to help wildlife cross above or below the project including crossings for tree-dwelling mammals, dedicated culverts under the highway and over-land fauna bridges
- Rest areas located at around 50 kilometre intervals for both northbound and southbound traffic. These are located at:
  - Pine Brush State Forest (north and southbound)

  - North of Mororo Road (southbound)
  - South of Old Bagotville Road (north and southbound)
- Heavy vehicle weigh station located near Halfway Creek.

In addition to these key features, the project would include construction sedimentation basins, operational water quality basins and construction facilities such as compounds and batching plants.

Construction would be staged from 2013 onwards following project approval, depending on the availability of funding. Construction of the project would generally comprise the conventional techniques employed on most major highway projects, modified for specific environmental or engineering constraints. RMS seeks approval for construction working hours for all day (8am–5pm) on Saturdays and between 6am and 7pm on weekdays.

An indicative outline of construction activities may include:

- Establishment of the construction site and ancillary facilities
- Enabling works, including adjustments to utilities, property adjustments, works to existing drainage and provision of construction access roads
- Clearing and grubbing of vegetation, stripping of topsoil and stockpiling for re-use
- Construction of road cuttings and embankments
- Treating areas of soft soil to stabilise the underlying soil sub-layers
- Installing drainage and bridging structures
- Laying of pavement materials
- Installing pavement markings, signposting, street lighting and progressive landscaping.

The project would not be built in one phase. The project would be delivered in stages as further funding becomes available and to best manage construction and material resources. Stages would be identified that prioritise and target upgrades and works that would best deliver safety and traffic efficiency improvements, and best deliver value for money outcomes.

This working paper assesses the potential impacts of the full motorway standard upgrade for construction and operation. Where there are relevant differences between the full motorway standard upgrade and the initial upgrade to arterial standard, those impacts are also assessed. Impacts are generally identified through the eleven project sections identified above.

Further information on the description of the project and the assessment of other environmental aspects can be found in the main volume of the environmental impact statement.

1.2. Study objectives and scope

1.2.1. Objectives

This working paper provides information that addresses the Department of Planning and Infrastructure Director-General's environmental assessment requirements for construction and operation of the project. This paper identifies the existing groundwater conditions in the study area, assesses potential construction and operational phase groundwater impacts and identifies management measures to minimise potential impacts. This assessment aims to establish the significance of the impacts, and suggests mitigation measures for the construction and operational phases of the project to protect environmental receivers and groundwater users.

1.2.2. Scope of work

The following activities have been undertaken:

- Assessment of the current groundwater environment along the project length
- Review of current groundwater management plans impacted by the project
- Identification of the status of existing water rights in relation to Water Sharing Plans and secured suppliers
- Review of bore records and evaluation of groundwater table trends
- Identification of locations and types of known groundwater-dependent ecosystems
- Identification of sensitive receiving environments, including SEPP 14 wetlands and floodplains
- A conceptualisation of interactions between groundwater and the project region, with emphasis on potential impacts on groundwater dependent ecosystems
- Identification of potential impacts on shallow groundwater systems, specifically considering acid sulfate soils and areas of deep cuts and shallow water tables
- A desktop groundwater potential impact assessment for the project
- Assessment of groundwater quality (salinity) impacts
- Assessment of groundwater drawdown consequences of deep cuttings and spring interference
- Input to drainage design to provide for mitigation of impacts as required
- Review of potential impacts to the Rous Water borefield, near Woodburn.

No new groundwater monitoring or modelling was undertaken as part of this assessment. Recommendations for areas where numerical modelling of groundwater might be needed (Type A cuts) are highlighted and results from previous modelling studies have been included. Methodologies used for the potential impact assessment are provided.

It should be noted that additional geotechnical investigations are currently underway and would inform future groundwater investigations.

1.2.3. Study requirements

This assessment was carried out to help address the Director-General's environmental assessment requirements, specifically those detailed in Table 1-2. To address these requirements, potential impact to groundwater systems, groundwater resources and groundwater dependent ecosystems has been assessed. The primary tool used was an assessment of the depth to the groundwater table prior to and during construction and during operation. Particular attention is paid to proposed cut sites and areas where shallow groundwater is present, within two metres of the ground surface. The potential impact assessment process also considers the presence of acid-sulfate soils.

Table 1-2 Director-General's environmental assessment requirements

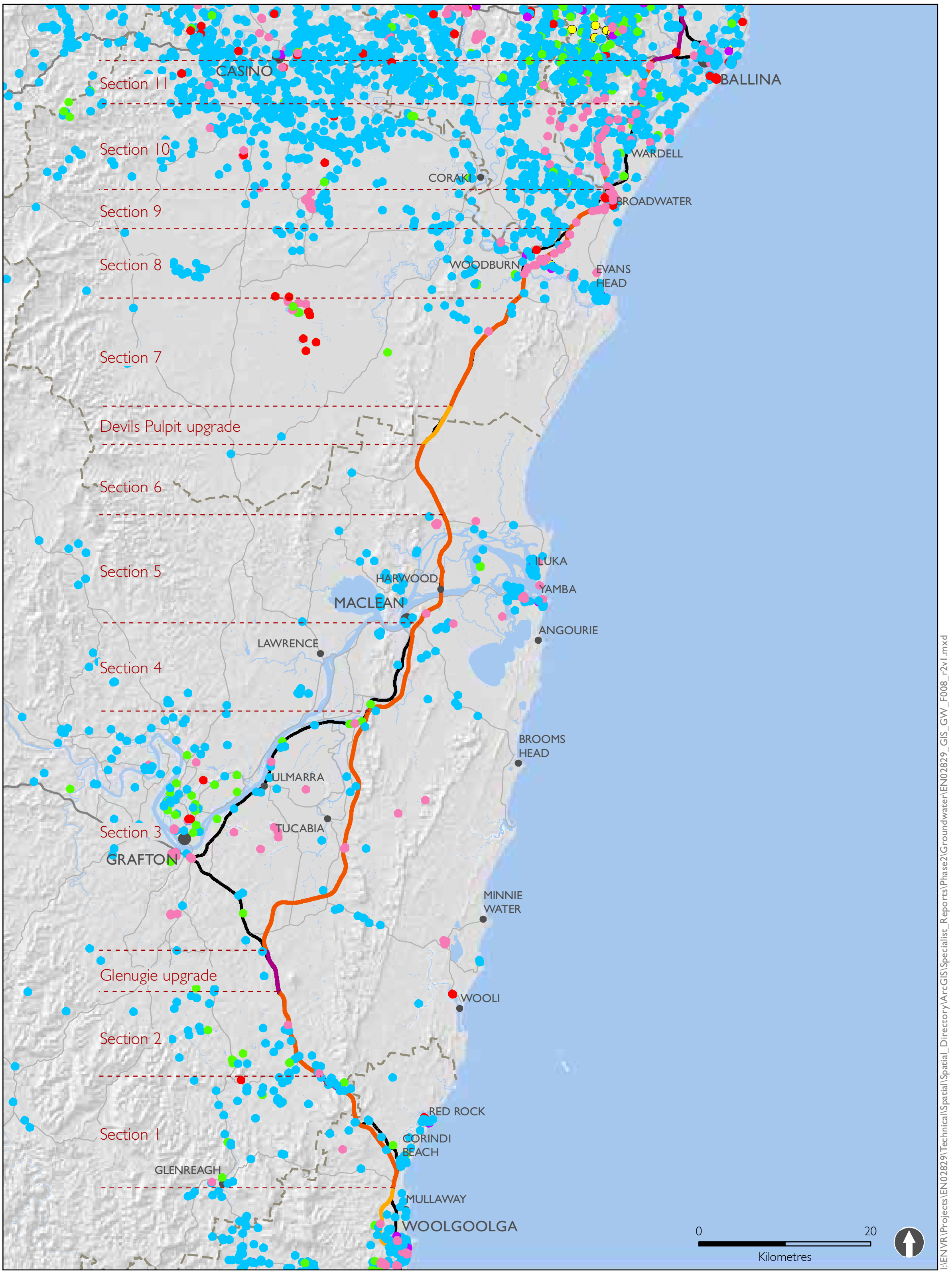
Requirements	Where addressed in report?
Assessment of groundwater impacts, taking into consideration local impacts at deep cuttings and fill locations, and cumulative impacts on regional hydrology. The assessment shall consider: the extent of drawdown, impacts to groundwater characteristics, quality, quantity, and connectivity, discharge and recharge rates, and implications for surface flows, groundwater users, groundwater dependent ecosystems and wetlands;	Existing groundwater conditions described in Section 2.3.1. Detailed assessment of the project impacts described in Section 4.5. A summary of impacts is presented in Section 4.4. Implications are evaluated in Chapter 5
Assessment of impacts to the Rous Water Regional Water Supply (Woodburn) bore fields drinking water source, taking into account discharge/ recharge rates and groundwater yield, and consideration of the relevant public health and environmental water quality criteria specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 ((Australian and New Zealand Environment and Conservation Council) and the Australian Drinking Water Guidelines 2004 (National Health and Medical Research Council and the Natural Resource Management Ministerial Council).	Section 4.5.8

1.2.4. Data limitations

This study had the following data limitations:

- There is a general paucity of groundwater data for much of the project (refer to Figure 1-7 and Appendix A)
- Bores constructed as part of the project are generally not included, though some exist in Sections 8 to 11.
- Existing bores used to support assessment of the upgrade provide a snapshot of regional information, but do not consider long term trends in watertables. An area of 10 kilometres to the west of the project boundary and then east to the coastline was selected to provide reference bores for the potential impact assessment (refer to Figure 1-8 and Appendix A)
- Generally only existing bores being report bores, had precise elevation information. Elevation of Pineena bores was calculated from the project digital elevation model
- Where data is available, there is limited time series information to determine trends and natural variability
- Recent groundwater monitoring (within the last two years) has not been undertaken for all sections, thus restricting knowledge of existing conditions of waterways. When approved for construction, pre-construction groundwater monitoring should be undertaken which would provide the required data
- Groundwater quality information is lacking for most of the project
- On-ground verification of soil and sediment properties was not available for all sections of the project.

Figure 1-7 Groundwater bore distribution in the region surrounding the project

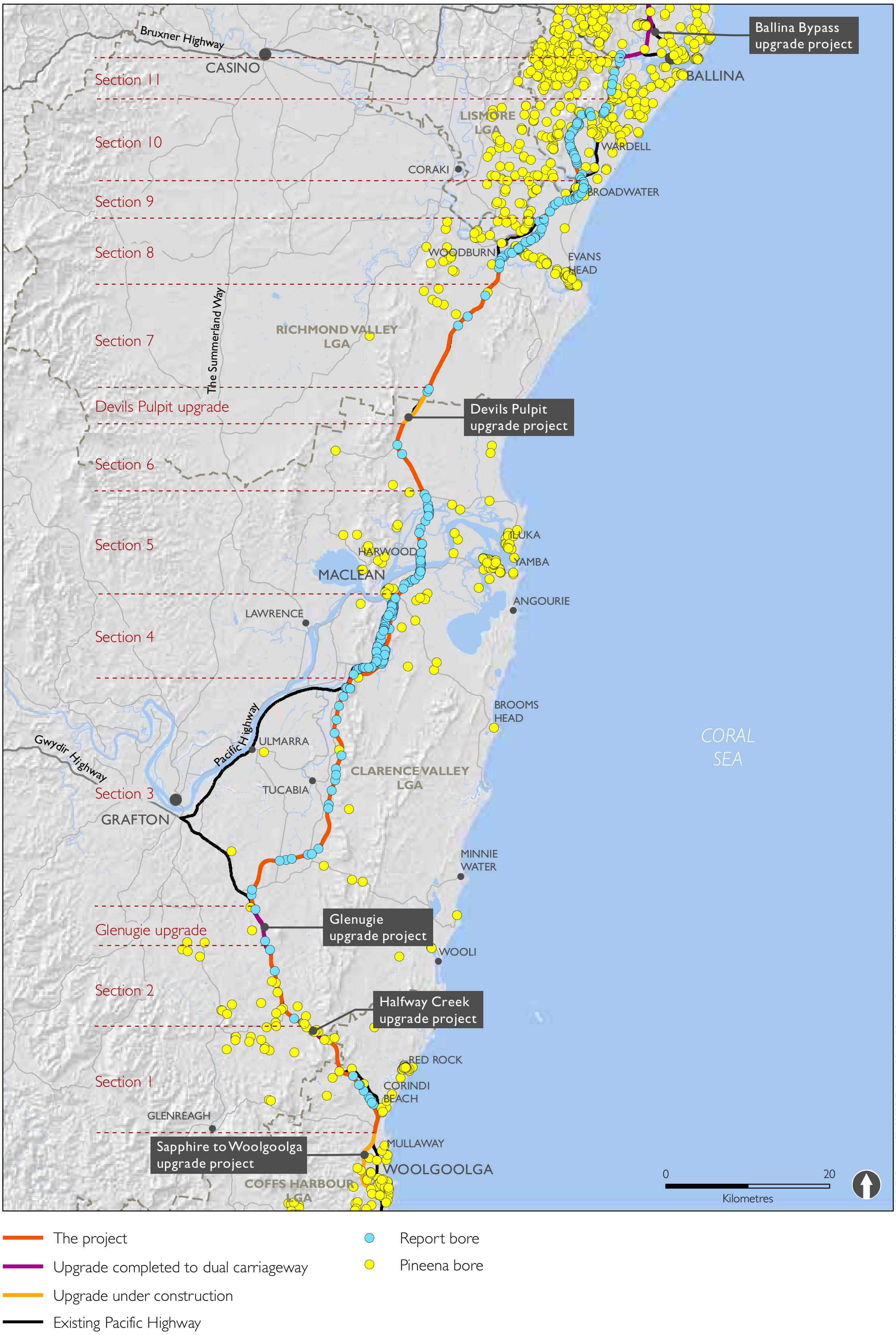


The project
Upgrade completed to dual carriageway
Upgrade under construction
Existing Pacific Highway

Bore types
Industrial & commercial
Irrigation
Not known

Recreation (Groundwater)
Town water supply
Stock & domestic
Test or monitoring

Figure 1-8 Bores used in the production of the groundwater potential impact assessment



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1.2.5. Augmentation of groundwater data with local knowledge

In many areas along the project there is insufficient groundwater data to generate reliable water table depth surfaces to compare with either the current land surface, or the proposed design profile. Two methods have been employed to assess water tables in these areas:

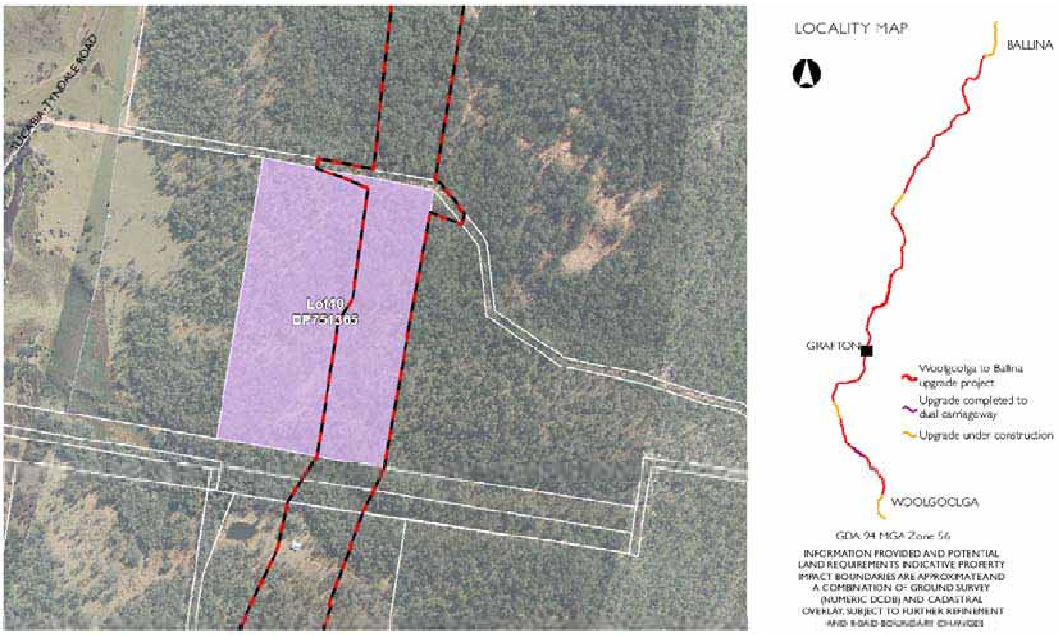
- Assume water table is independent of geology and landform and generate a surface from available data using statistical extrapolation techniques where data is absent
- Assume water table follows the general form of the land surface and use point data from bores to constrain the depth along the project.

Where data exists (at a bore location) these two surfaces coincide. Where no data exists, discrepancies of many metres may occur, particularly in areas of high relief. Consideration of the hydrogeology at specific locations can help determine which methodology is more appropriate, or whether an intermediate level should be assumed. This latter process has not been undertaken at this stage of the project, but should be undertaken during the detailed design phase. For the purpose of identifying locations of potential impact to groundwater, this methodology is conservative and highlights areas that require further investigation; hence providing an adequate level of investigation to satisfy the Director-General's environmental assessment requirements.

Local knowledge can be used to provide specific details on actual groundwater location and quality. Consultation undertaken as part of the project includes an example of where local knowledge has been used to provide specific details on groundwater at a property near Tucabia (Figure 1-9). Using the methodology above, the two methods generated a discrepancy of 25 metres between the watertable surfaces. Local knowledge identified the existence of a semi-permanent waterhole in a depression indicating the groundwater surface intersects with the land surface at that location and suggests a groundwater level that is intermediate between the modelled surfaces.

A window on groundwater
Local knowledge aids groundwater understanding

The project crosses Lot 40 DP751365 near Tucabia, located in undulating hills just inland of the Great Dividing Range. The lot is 16 hectares and adjoins a 40 hectare lot to the west that fronts the Tucabia – Tyndale Road. There is concern that the project would affect the aquifer lying beneath the floodplain and the Chaffin swamp to the west. While a multi-cell culvert under the project should mitigate this, a waterhole has been located inside the project boundary and this waterhole serves as a water source for livestock in drought.



The observation that the waterhole survives dry conditions suggests it is fed by shallow groundwater recharged to the east in the higher country. The site is classified as low potential impact by the project, based on the estimated water table level from published bore data. If ground investigations confirm that the waterhole represents a window to the water table, this would result in a re-classification to high potential impact.

This location is currently designated as fill in the design, hence the low potential impact assigned. There are areas of cut immediately to the north and south, identified as high risk as they are expected to intersect the water table during construction and potentially during operation. Subsequent risk mitigation measures might include:

- Reduce the toe of fill to boundary distance from 30 to 15 metres to preserve the waterhole (preferred measure)
- Locally review the project geometry and decrease road radius from 4507 metres to ~2000 metres to move the alignment to the east, but still in the project boundary, achieving a 10-15 metres shift (achievable during detail design)
- Modify the alignment. This may result in impacts on the project boundary and alterations to the boundary in the adjacent areas north and south (not the preferred approach)
- Do not change the existing design; the impact is not avoided. Mitigation would entail compensation and provision of an alternative water supply, possibly via a water quality basin (also not preferred; requiring further detailed negotiations).

Figure 1-9 Example of groundwater data augmentation from local knowledge

1.2.6. Groundwater management considerations

The NSW regulatory framework for groundwater management is described in detail in Section 2.2. A summary of the regulatory framework is as follows:

- NSW Macro Water Sharing Plan regulations are in force for most of the project. These consist of generic rules that may or may not have local applicability
- Regional Water Sharing Plans are only used in areas of significant groundwater abstraction. The role of these plans is to provide equitable and sustainable to all users, including the environment, under the principles of the *Water Management Act 2000*. As such, the plans consider the recharge and take from specific groundwater sources and these may be wholly or partly contained within a groundwater aquifer system or systems. There are three regions along the project for which this is the case:
    - "The Coffs Harbour Regulated and Alluvial Water Sources" is crossed by the southern sections of the project and is considered below
    - The Water Sharing Plan for the "Alstonville Plateau Groundwater Source" considers supply and use in the region to far north and west of the project, serving the Atherton Tablelands. As this source is not crossed by the project there would be no impact from either construction or operation of the highway on, or from, this groundwater source and it is not considered further
    - Across the Richmond River floodplains, the Water Sharing Plan for the "Richmond River Regulated, Unregulated and Alluvial Water Sources" applies. The Alluvial Source relates specifically to the groundwater resource. The project bisects this area and is considered below
- Within the Richmond River Alluvial Groundwater Source, the only significant user along the project (other than for stock and domestic and environmental needs) is Rous Water, forming a Local Area Management Zone, and who operate the Woodburn Borefield as a reserve water supply for the region around Lismore. Consideration of the impacts on this borefield is given under the discussion of Section 8 in Section 4.5.8 of this report.

1.2.7. Application of the 2011 Framework for Management of Drinking Water Quality

The most effective means of assuring drinking water quality and the protection of public health is through adoption of a preventive management approach that encompasses all steps in water production from catchment to consumer.

The NHMRC/ NRMMC Framework for Management of Drinking Water Quality was developed to guide the design of a structured and systematic approach for the management of drinking water quality from catchment to consumer, to assure its safety and reliability. The Framework incorporates a preventive risk management approach; it includes elements of

HACCP, ISO 9001 and AS/NZS 4360:2004, but applies them in a drinking water supply context to support consistent and comprehensive implementation by suppliers. The Framework addresses four general areas (comprising 12 elements), which are described below and illustrated in Figure 1-10:

- Commitment to drinking water quality management. This involves developing a commitment to drinking water quality management within the organisation. Adoption of the philosophy of the Framework is not sufficient in itself to ensure its effectiveness and continual improvement. Successful implementation requires the active participation of senior executive and a supportive organisational philosophy
- System analysis and management. This involves understanding the entire water supply system, the hazards and events that can compromise drinking water quality, and the preventive measures and operational control necessary for assuring safe and reliable drinking water
- Supporting requirements. These requirements include basic elements of good practice such as employee training, community involvement, research and development, validation of process efficacy, and systems for documentation and reporting
- Review. This includes evaluation and audit processes and their review by senior executive to ensure that the management system is functioning satisfactorily. These components provide a basis for review and continual improvement.

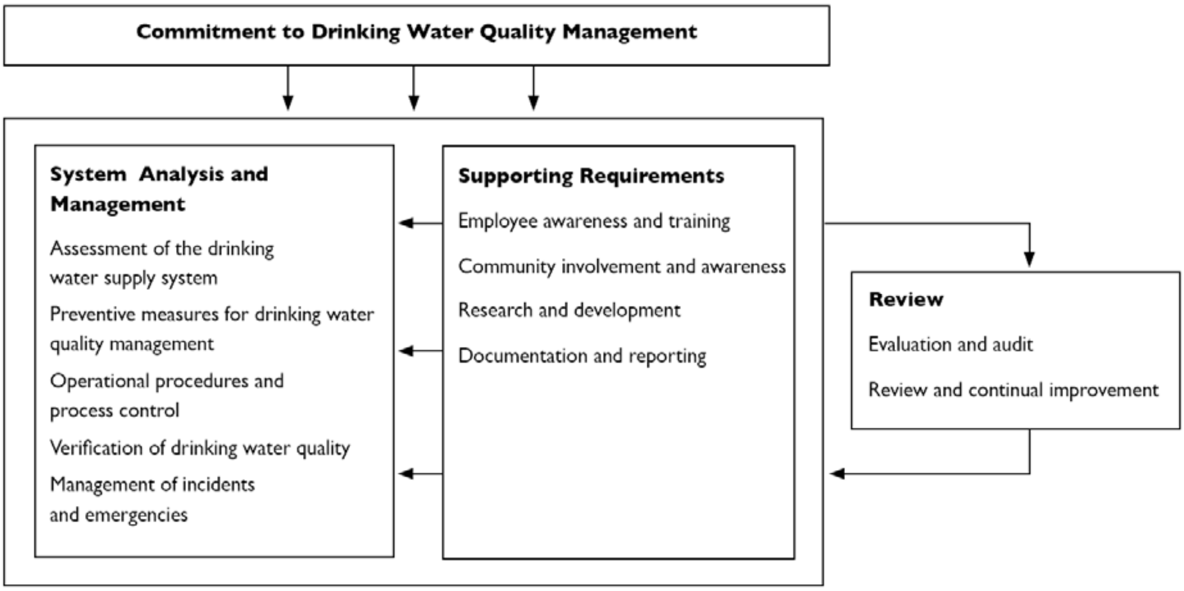


Figure 1-10 Framework for management of drinking water quality (NHMRC, NRMMC, 2011)

Although listed as discrete components, the 12 elements are interrelated and each supports the effectiveness of the others. To assure a safe and reliable drinking water supply, these elements need to be addressed together because most water quality problems are attributable to a combination of factors.

The Framework outlines principles of management applicable to all water supply systems regardless of size and system complexity (ie both small and large supplies, ranging from those with minimal treatment to those with full treatment). To reflect the diversity of individual water supplies and the varying institutional arrangements (eg corporations, local authorities, wholesale, retail and contractors), the Framework is flexible. It provides generic guidance and the content should not be regarded as being prescriptive or exhaustive.

The principles behind this framework have been generally applied in this assessment as there is currently insufficient groundwater data to enable the prescriptive activities to be followed. Full development of the framework would be incorporated into the Groundwater Management Plan for the project.

For the majority of groundwater supplies along the project, consideration has been specifically made of the *Australian Drinking Water Guidelines: Framework for Management of Drinking Water Quality: application to small water supplies* (NHMRC, NRMMC 2011), applicable to supplies serving less than 1,000 people. Whilst the supplies available from the Woodburn borefield in the north of the project are developed with the potential to supply 5,000 people, these supplies are generally used as a reserve supply and the general principles for small supplies provides a good framework for risk assessment of this resource.

This framework states: “Analysis of the water supply system, identification of potential hazards and risk assessment are essential for good management of all supplies. In the case of small supplies, initial steps would be to develop a simple flow diagram of the main features of the system (water sources, treatment or disinfection, service tanks and major piping) and to determine basic water quality characteristics. If groundwater is the source of supply, then chemical quality should be assessed as a priority. In some parts of Australia, concentrations of naturally occurring elements such as arsenic, fluoride and uranium, or nitrates from agricultural land uses, may exceed safe levels.

“The water system should be inspected to identify likely sources of hazards. The greatest sources of microbial hazards are human and livestock wastes; water systems should be inspected to determine the likelihood that this type of contamination will affect water quality. The discharge of septic waste and access of livestock to watercourses, or the proximity of either to supply bores, are likely sources of contamination.

“Risk assessment involves estimating the likelihood that a hazard will occur and the consequences if it does. The aim is to distinguish between high and low risks so that attention and resources can be directed towards those hazards that are most threatening. The risks associated with all hazards identified for a small water supply system should be assessed.”

Where there are hazards that present high risks, measures would be required to remove the hazard or to reduce the associated risks to an acceptable level. If existing measures are in place, the effectiveness of these measures should be assessed and if these are not sufficient, alternative measures would need to be identified. As with all systems, assessment of preventive measures should include consideration of the important principle of the multiple barrier approach. The types of barriers and the preventive measures required would depend on the characteristics of the source water and the associated catchment.

In most cases, contamination of groundwater supplies can be prevented by a combination of simple measures. Groundwater in confined or deep aquifers will generally be free of pathogenic microorganisms and, providing the water is protected during transport from the aquifer to consumers, microbial quality should be assured. The local vicinity of the borehead should be protected from livestock access, and buffer zones should be established between the bore and disposal or discharge of septic wastes. Bores should be encased to a reasonable depth and boreheads should be sealed to prevent ingress of surface water or shallow groundwater (NHMRC NRMMC 2011).

Once the groundwater is pumped out of the aquifer, protection can be achieved by delivering the water through enclosed water systems. Storage tanks should be roofed, pipelines should be intact and cross connections should be protected by the installation of backflow prevention devices (op cit.).

1.2.8. National Water Quality Strategy: Guidelines for Groundwater Protection in Australia and Guidelines for the Assessment and Management of Contaminated Groundwater (NSW)

The aim of the Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC, 1995) was to provide a framework for protecting groundwater from contamination in Australia. This framework enabled each State, Territory and the Commonwealth to develop policies and strategies which were tailored to their specific legislative and resource management situations.

The protection framework involved the identification of specific beneficial uses and values for every major aquifer, ie the classification of groundwater bodies. Depending upon specific circumstances, there are a number of protection strategies which can emerge to protect each aquifer, but all involve monitoring. A public planning process is required in order to examine possible options and select the best set of strategies. The protection strategies which emerge will mainly be pro-active in nature but some current problems will also require remedial action.

The major types of protection strategies are classified into three 'legislative' groups. First, there is a whole range of traditional groundwater management measures available, such as vulnerability maps, aquifer classification systems and wellhead protection plans. Secondly, there is a range of land-use planning measures which can help prevent contamination occurring at inappropriate locations. Finally, there is a variety of environmental protection measures emerging which tackle modern waste management problems in progressive ways.

Nearly all protection strategies will rely on government intervention backed by community support and development of a beneficial use classification for all significant aquifers.

The guidelines for Assessment and Management of Contaminated Groundwater (DEC, 2007) recognise that groundwater contamination can arise from either point sources or diffuse sources. Common examples of point sources that could contaminate groundwater are leaking underground storage tanks, inadequately-managed waste disposal sites and accidental chemical spills. An example of a diffuse source is pesticides and nutrients applied to broad-acre agricultural land that infiltrate through soils to groundwater.

These guidelines focus on groundwater pollution arising from point source contamination rather than on broad-scale groundwater issues arising from diffuse sources covered by the NSW Groundwater Quality Protection Policy (NSW DLWC, 1998). Contaminated groundwater can be unsuitable for use and may also adversely affect the quality of surface water and sediments. It may then harm human and ecological health. Contaminated groundwater may also affect the types of land uses that may safely be carried out above a contaminant plume.

The legacy of groundwater contamination can be a major burden on the community because once groundwater is contaminated it is generally difficult and costly to remediate. Therefore, preventing groundwater contamination is the most practical way of protecting groundwater quality.

Where contamination of groundwater is identified, acute risks, such as the possible accumulation of explosive vapours in subsurface utilities, must be immediately managed. The source of contamination must be removed to ensure the protection of human health and the environment. The following actions should also be taken whenever practicable: the environmental values of the groundwater must be restored groundwater quality must be restored to its natural background concentration.

The *Guidelines for the assessment and management of groundwater contamination* outline a best-practice framework for assessing and managing contaminated groundwater in NSW.

The NSW Office of Water must be notified about certain groundwater contamination under the *Contaminated Land Management Act 1997* and the *Protection of the Environment Operations Act 1997*. Following notification, NSW Office of Water may decide that the contamination warrants regulatory intervention.

1.3. Potential groundwater issues

Groundwater impacts may be considered in relation to risks to consumptive use requirements and risks to natural habitats and pre-development needs. That is, risks to supply and risks to the environment. Specifically, receptors may be identified that may be adversely impacted by changes in groundwater condition. Such receptors would include groundwater users (such as for stock and domestic supplies, irrigation needs or municipal reserves, that is, groundwater extracted via bores) and natural environments that require sufficient groundwater supply and quality to maintain function and health (for example, through seasonal water supply to vegetation, spring-fed ecosystems, groundwater-reliant ecosystems). Whilst not all potential risks will apply to all locations, all must be considered during the environmental assessment process. Potential risks that were considered as part of this project are described below and considered only at locations where the potential impact to groundwater is determined to be significant.

1.3.1. Potential risks to supply

Supply water quantity risks

Groundwater is not a major source of consumptive water throughout the project area. Of nearly 10,000 bores investigated as part of this assessment, covering all catchments that are intercepted by the project, less than 3 per cent have an allocation for irrigation and an additional 1 per cent of bores are licensed to extract groundwater for commercial ventures. Combined, this accounts for an entitlement of 30 gigalitres per year, though only an estimated 8.5 gigalitres was used in 2010/11. Eighty-five per cent of registered bores are licensed for stock and domestic use, with an annual entitlement of generally 1 to 3ML per year each (but up to 14 megalitres per year in one case). Ten per cent of bores are rated as “lapsed” or “cancelled” and the remainder are monitoring or test bores, with no water requirements.

Under normal climatic conditions, therefore, groundwater is a minor water source, with surface water supplies sufficient for most operations. During periods of drought, as occurred between 2000 and 2007, however, groundwater becomes an increasingly important water source. Currently, groundwater use is minimal along the project area.

An important groundwater source is located near Woodburn, where up to 242 megalitres per year can be taken by three bores in the north of the project as part of the Rous Water town water supply entitlement.

The risks to water supply quantity arise from interruption of groundwater flow caused either by physical interception (damming or diversion) or through pressure loss (increased discharge or reduced supply). The former may be likely to occur where thick infill causes compaction of the surface sediments and hence reduction in permeability and impedance to flow, or where structures are put in place to divert groundwater flow away from works or deep cut areas. The latter may occur either as a consequence of the physical change to flow conditions, or increased flow to the surface caused by cuts intercepting watertables. The location of the reduced water supply, therefore, depends on the cause of the reduced flow and should be considered accordingly. The former generally leads to reduced supply downstream of the works; the latter to upstream loss of supply.

If reduction in supply is caused by physical obstruction; by-pass flow needs to be coordinated to facilitate adequate downstream flow beyond the barrier. Alternatively, diverted water can be re-diverted back to areas where demand is high, such as for wetlands or stock and domestic requirements. For localised systems, the construction of pavement may reduce recharge to shallow groundwaters. In general, however, this is a minor areal loss and does not constitute a significant loss to supply.

If reduction in supply is caused by pressure loss (generally due to exposure of the watertable at cuts), then artificial containment of supply may be warranted (through artificial damming upstream of the cut or sealing of the exposed surface); alternatively, the increased water generation at the site of groundwater loss may be diverted (or pumped) back to locations where supply is vital.

Supply water quality risks

Potential contamination of groundwater may be from natural or anthropogenic sources. The former include salinisation and acidification; the latter may include introduction of hydrocarbons or other potential pollutants due to spills or leaching of chemicals from construction materials.

Salinity

Salinisation due to discharging groundwaters is not known to occur along the project. In inland NSW, salinisation is a common condition anywhere that poorly-constructed roads (with inadequate drainage) cut across shallow groundwater flow lines. In the high rainfall areas of the project, however, any accumulation of surficial salts from the evaporation of discharging groundwaters is periodically and effectively flushed away and there are no known occurrences of natural salinisation associated with the project area.

A common criterion for assessing the potential for dryland salinity in an area is to assess the area with groundwater tables within 2 metres of the land surface. In the Richmind River catchment, around 155 hectares has been identified as affected by shallow water tables (Littleboy, et al., 2001) whilst the Clarence River catchment has 91 hectares of potentially affected land. Most of this land is inland of the project. None of this land has been shown to express salinity.

The northern sections are within the seaward floodplains of the Richmond River. Groundwater interference may cause seawater ingress into the coastal aquifers, such as the Woodburn Sands, which are an important groundwater resource for Rous Water. Rous Water is not aware of this ever having represented a risk to Rous Water bores to Woodburn.

Acid sulfate soils

Acid sulfate soils are found in every coastal estuary and embayment in NSW. There are over 260,000 hectares of high risk areas, including about 150,000 ha under agricultural production. The largest of these areas are on the coastal floodplains of northern NSW, particularly the floodplains of the Tweed, Richmond, Clarence, Macleay, Hastings, Manning and Hunter Rivers.

Conditions for the development of acid sulfate soils commonly occur in coastal lagoons and in the estuarine parts of coastal rivers. Acid sulfate soils have been forming in coastal estuaries since the sea level rose to near the present level in the early Holocene period (after the end of the last ice age). Sea levels rose to about 2 metres above present levels around 6,000 years ago, with a subsequent gradual decline. At the time, coastal floodplains were largely open estuaries, but they have since infilled with estuarine and alluvial sediments.

Acid sulfate soils are common in areas of mangroves and salt marsh as well as underlying large areas of rivers and deltas, levees, backswamps and other formerly brackish seasonal or permanent freshwater swamps, and their coastal flats. The environment at the time of sediment deposition can be ascertained by palynological methods (ie by studying pollen grains and other spores found in the sediments).

Due to its estuarine origin, the upper surface of acid sulfate soil is usually close to sea-level, generally lower than 1 m AHD and often 0-0.3 m AHD. Translocation of the products of pyrite oxidation may extend acid sulfate soils above this elevation.

Therefore, areas with high risk acid sulfate soils close to the soil surface, including acid sulfate soil scalds, are generally wetlands, degraded wetlands, or were previously wetlands. In their natural (pre-drainage or disturbance) range of hydrologic states, the native vegetation of backswamp (extending to backplain) sites would have varied from woodland around swamp margins, through to sedgeland or rushland in the generally wettest sites, which are usually treeless. Areas of sulfidic sands may also occur, particularly in higher energy, lower estuarine and coastal locations.

Referring to the Tuckean in the Richmond, Sammut (1996) found that these drains may store 25 tonnes of acid, with up to 40 tonnes of sulfuric acid exported in a single day (Sammut 1995). The static load of acid in the Broadwater was found to be about 16 tonnes. It was also found that over 90 km of the river and over 150 km of drains and other waterbodies are frequently acidified. During the 1994 flood, 950 tonnes of sulfuric acid and 450 tonnes of aluminium were discharged through the barrage (Sammut 1996).

Fluctuating shallow watertables in acid-sulfate prone areas are also at risk of developing acidic conditions and acidifying the local groundwaters. This is of greater concern where there is a reduction in groundwater flow and potential acid-sulfate soils are exposed to the air and hence oxidise, releasing acidity to the soils as reduced sulphur-rich minerals weather, releasing sulphuric acid to the environment. Re-wetting of the soils can ameliorate the condition, but generally secondary acid-forming minerals may also dissolve in the aqueous environment exacerbating the condition. Neutralisation of the soils may be required and isolation and stagnation of the groundwater supply may be needed. Ideally, this situation should be avoided.

Anthropogenic contamination

Containment of spills and points sources of contaminants should be integral to any surface water management design. This source of contamination is particularly crucial for downstream supplies of groundwater and provision of adequate storage and filtration basins on the downstream side of the project should be emphasised.

1.3.2. Potential impacts on the environment

The *Water Management Act 2000* (see Section 2.2) requires that water be allocated for the fundamental health of a water source and its dependent ecosystems, such as wetlands and floodplains, as a first priority. Consideration of the consequences of construction can allow avoidance strategies to be incorporated at the design phase of the project and reduce the need for subsequent re-design or mitigation works.

Ponding and waterlogging

In the same way that construction of roads can lead to increases and decreases in water supply, so these changes can have negative impacts on the environment. In areas of fill, or where physical barriers to near-surface flow have been incorporated into the design, the increased groundwater supply can lead to increased ponding on the up-stream side of the road and waterlogging can become an issue. This is particularly the case in areas of clay-rich soils and especially if the soils are rich in swelling clays (illite, smectite). These areas also become prone to salinisation, as indicated above. In sandy soils this is not a big issue due to enhanced drainage, but permanent barriers may cause seasonal waterlogging.

Improved drainage would be required to mitigate this response.

Increased drainage

Conversely to sites where ponding occurs, in areas where either increased drainage is employed to reduce inflows to the project, or where groundwater supply has decreased allowing downstream drainage to exceed recharge, then water supply would be reduced leading to a water-deficit in the soil profile. Augmentation of water supply in these areas may be required.

Groundwater dependent ecosystems

Groundwater dependent ecosystems are ecosystems which have their species composition and natural ecological processes determined to some extent by the availability of groundwater. Groundwater dependent ecosystems can include cave systems, springs, wetlands and groundwater dependent endangered ecological communities. Important conditions for groundwater dependent ecosystems are similar to those for impacts to supply (above). As there are no important or endangered listed groundwater dependent ecosystems along the route, conditions to satisfy supply of groundwater will address the needs of the environment.

Groundwater dependent ecosystems are typically areas where the water table is at the surface, or periodically at the surface. While the degree of groundwater dependency is variable, groundwater plays an important role in wetlands found on alluvial floodplains. Many wetlands are extremely species rich with a mixture of plants and animals and are often considered to have high conservation value.

1.3.3. Estuary health

Groundwater flow towards the ocean is an important constraint on ingress of seawater to inland communities and tidal fluctuations as well as seasonal groundwater flow variability creates a dynamic mixing zone of alternating fresh and saline waters that support diverse and prolific ecosystems. Significant change to the pressure gradients and/or water quality of the groundwater system would disrupt this balance and potentially lead to changes in ecosystem diversity and fertility.

Streamflow and groundwater discharge influence many ecological components of an estuary, and play a significant role in the health of these systems. Therefore, water extraction from surface water or groundwater sources may impact the ecological health of estuaries. Some estuaries are highly sensitive to freshwater inflows, whilst others are more resilient to changed inflows. The size and shape of estuaries vary and this, combined with the amount of freshwater inputs and extractions, determines the estuary’s overall sensitivity to freshwater extraction. Where possible, extractions will be limited in catchments found to be highly sensitive to freshwater inflows. Small estuaries, such as coastal lagoons, tend to be highly sensitive to inflow variations, with most being only intermittently connected to the ocean. Barrier estuaries are generally less sensitive to inflow variations.

Monitoring is the key to recognising any potential changes and hence any potential impacts to these systems.

2. Existing environment

2.1. Regional context

2.1.1. Physiography

Topographic conditions throughout the project are variable, but can be broadly categorised as either lowland areas or elevated areas. Lowland areas are mostly located in the central and northern parts of the project, where the elevation is less than around 15 metres Australian Height Datum (AHD). Elevated areas are predominantly confined to the southern parts of the project and rise to a maximum elevation of around 135 metres AHD on the Coast Range. General descriptions of each landscape are provided below. Topographic conditions within each section of the project are summarised in Table 2-1 and are illustrated in Figure 2-1.

Lowland areas

Lowland areas are less than 15 metres AHD (typically less than 10 metres AHD) and are characterised by level to gently undulating coastal floodplains, estuarine back swamps, drainage depressions and extra tidal flats, where slopes are generally less than five per cent. Lowland topography is predominately associated with the surrounds of the Clarence and Richmond Rivers and is present between Tyndale and Maclean and between Broadwater and Ballina (project sections 4, 5 and 8 to 11).

The floodplains of the Clarence and Richmond rivers contain moderate and high risk acid sulfate soils. Additional details relating to geotechnical and soil issues are detailed in previous geotechnical assessments for the project.

East of Woodburn, the project crosses though a bore field, operated by Rous Water, which is used as a potable water source for the local area. This site is covered in more detail in the notes to Section 8 (page 101).

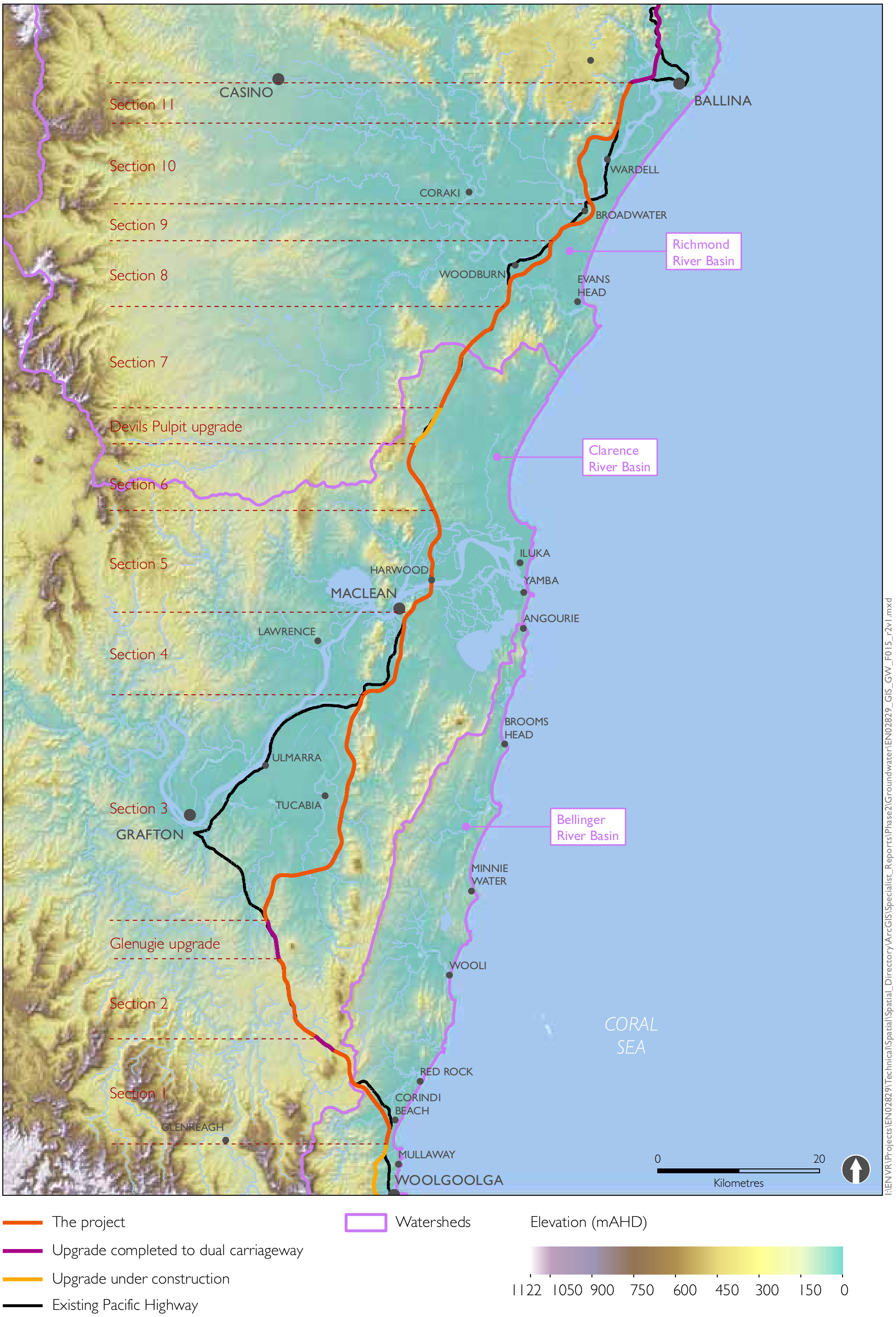
Elevated areas

Elevated areas are areas greater than 15 metres AHD and are characterised by undulating rises, rolling low hills, foot slopes and summit surfaces, with slopes typically between five and 20 per cent. Elevated topography is predominantly associated with the Coast Range and foot slopes of the Pillar and Richmond Ranges, and is present within project sections 1, 2, 3, 6 and 7.

Table 2-1 Summary of topographic conditions within the project

Project section	Dominant landform	Proportion of section (%)	Typical elevation (m AHD)	Description
1	Elevated	70	30 – 135	Foot slopes, low hills, undulating rises and summit surfaces of the Coast Range around the Dirty Creek locality. Lowland coastal plains of elevation 2 – 15 m located within the southern portion of the section.
2	Elevated	100	55 – 95	Rolling low hills and undulating terrain between the Halfway Creek and Glenugie localities.
3	Elevated	80	15 – 45	Low rounded hills and narrow drainage plains of the Pillar Valley in the southern portion of the section. Foot slopes and gullies of the Pillar Range in the northern portion. Lowland alluvial valleys and narrow floodplains of elevation 1 – 15 m located in the central portion of the section.
4	Lowland	95	1 – 10	Low, mostly level terrain of the Clarence River (South Arm) floodplain between the Tyndale and Maclean localities. Isolated areas of low hills and undulating rises of elevation 15 – 40 m located in the central and northern portions of the section.
5	Lowland	100	1 – 5	Low, mostly level terrain of the Clarence River floodplain (North and South Arm) and Clarence River delta (Harwood/Chatsworth Island) between the Maclean and Mororo localities. Section crosses Clarence River and Clarence River North Arm.
6	Elevated	80	15 – 30	Gently undulating terrain comprising the eastern foot slopes of the Richmond Range between the Mororo and Tabbimoble localities. Lowland terrain of elevation 5 – 15 m located at the southern end of the section.
7	Elevated	65	15 – 45	Gently undulating terrain comprising the eastern foot slopes of the Richmond Range between the Tabbimoble and Trustums Hill localities. Lowland terrain of elevation 1 – 12 m located at the northern end of the section.
8	Lowland	85	1 – 15	Low, mostly level terrain between the Trustums Hill and Kilgin localities. Gently undulating terrain of elevation 15 – 20 m located at the southern end of the section.
9	Lowland	100	1 – 10	Low, mostly level terrain of the Richmond River floodplain between the Kilgin and Broadwater localities.
10	Lowland	100	1 – 5	Low, mostly level terrain of the Richmond River floodplain between the Broadwater and Coolgardie localities bounded by the Blackwall Range to the west. Some isolated low rises of maximum elevation 20 m at southern end of section. Section crosses Richmond River.
11	Lowland	100	1 – 5	Low, mostly level terrain of the Richmond River floodplain between Coolgardie and Emigrant Creek bounded by the Blackwall Range to the west.

Figure 2-1 Topography of the study region



2.1.2. Geology and groundwater systems

The geology of the project area is summarised in this section with reference to aquifers, groundwater sources and groundwater flow systems.

The project traverses the geological sequence of the Clarence-Moreton Basin. This basin is an extensive Mesozoic age sedimentary basin extending from south Queensland to the New South Wales North Coast. The basin sequence comprises fluvial deposited sedimentary rocks with a thickness of around 2.5 – 4.0 kilometres.

The north-eastern extent of the Clarence-Moreton Basin is underlain by a small Triassic age geological basin known as the Ipswich Basin. The Ipswich Basin is dominated by sandstones, shales, conglomerates and coals deposited in alluvial, fluvial and lacustrine environments. The Ipswich Basin rocks rarely outcrop within the project area, although they may be present directly below the extensive unconsolidated Quaternary deposits associated with the Clarence and Richmond rivers.

Both the northern and southern extents of the project extend beyond the sedimentary basins, with the underlying Palaeozoic basement rocks of the New England Fold Belt outcropping near Woolgoolga and west of Ballina. Tertiary volcanics associated with significant lava flows in the Murwillumbah region extend across the Clarence-Moreton Basin rocks and the Palaeozoic basement rocks.

Recent alluvial deposits occur throughout the project area, laid down by the numerous rivers emanating from the Great Dividing Range. The most significant of these are the Clarence and Richmond River alluvial floodplain sequences underlying the northern half of the project. These are connected along the project by unconsolidated coastal sediments and deposits, the most important being the Woodburn Sands which provide potable (though with locally high iron and aluminium content) groundwaters as a supply for the Lismore region. These sediments are generally poorly consolidated, but locally hard-pans have developed and the floodplains commonly are capped with a variable thickness of clay-rich deposits that forms an impermeable seal to the underlying sands, gravels and other sediments.

Recharge to the coastal sediments is generally considered to be via direct infiltration of rainfall and floodwaters, though the impermeable nature of the surficial clays in many areas means that localised recharge is probably the dominant recharge mechanism. As such, estimates of recharge using rainfall as an indicator (as is commonly done) may not be accurate.

Groundwater and surface waters are inextricably linked. The actual connections between surface and groundwater systems vary significantly between systems. Surface waters recharging alluvial aquifers, for example, may emerge again at a discharge point in the river within hours, whereas the water recharging aquifers of the Great Artesian Basin may not discharge for some tens of thousands of years. The connection characteristics need to be considered in linking surface water and groundwater planning given that, in some cases, the same resource is being accessed. For the purposes of water sharing, aquifer types have been grouped into four basic categories:

- Porous rock aquifers found in rock formations such as sandstone or limestone. Groundwater occurs within the pore space in the rock matrix
- Fractured rock aquifers found in rock formations such as granite or basalt, or ancient (often metamorphosed) sediments of Precambrian and Palaeozoic age

(>200 million years old). Groundwater in these rocks occurs mainly within the fractures and joints

- Coastal sand aquifers, where groundwater is contained in the pore spaces in the unconsolidated sand sediments
- Alluvial aquifers, where groundwater is contained in the pore spaces in the unconsolidated floodplain material.

In addition, in northern NSW, a thick sequence of basalts has been laid down in sub-horizontal beds and hence exhibits a relationship to groundwater flow that has elements of both porous rock aquifers and fractured rock aquifers. Hence, we may distinguish an additional aquifer type:

- Tertiary Basaltic Volcanic aquifers – layered fractured and weathered units of the Alstonville Plateau.

These types are distinguished as different groundwater management units depending on location and connectivity (Figure 2-2 and Appendix A), with each groundwater management unit treated as a single groundwater source for the purposes of water management.

2.1.3. Groundwater flow systems

The concept of groundwater flow systems (Coram, et al., 1998) classifies groundwater into definable systems where particular management activities will lead to similar responses and hence provides a framework for action and coherent management. The classification is based on recharge and flow behaviour and uses measures such as length of flow paths through aquifers, aquifer permeability and driving pressure gradients for groundwater flow.

Groundwater flow systems can be classified as local, intermediate or regional on their spatial extent and influence. The extent of the system has implications for its responsiveness to change in water balance and therefore influences the types of management options that are more appropriate for modifying the water balance.

- Local groundwater flow systems respond rapidly to increased groundwater recharge. Watertables rise rapidly and saline discharge typically occurs within 30 to 50 years of clearing of native vegetation for agricultural development. These systems can also respond relatively rapidly to salinity management practices and afford opportunities to mitigate salinity at a farm scale
- Intermediate groundwater flow systems have a greater storage capacity and generally higher permeability than local systems. They take longer to 'fill' following increased recharge. Increased discharge typically occurs within 50 to 100 years of clearing of native vegetation for agriculture. The extent and responsiveness of these groundwater systems present much greater challenges for dryland salinity management than local groundwater flow systems
- Regional groundwater flow systems have a high storage capacity and permeability. They take much longer to develop increased groundwater discharge than local or intermediate flow systems-probably more than 100 years after clearing the native

vegetation. The full extent of change may take thousands of years. The scale of regional systems is such that farm-based catchment management options are ineffective in re-establishing an acceptable water balance. These systems will require widespread community action and major land use change to secure improvements to water balance.

The hydrogeological and topographical features associated with the groundwater flow systems provide a basis for evaluating the appropriateness of management options.

The capacity of a given groundwater flow system to respond to changes in land use is driven mainly by its ability to move groundwater and is defined by:

- the groundwater gradient (water flows from a higher to a lower position in the landscape); and
- permeability of the material (gravel, sand or clay) through which the groundwater flows.

If both gradient and permeability are high, the time it takes a groundwater system to respond to changes in land use is likely to be fast (a decade or so); if both are low, the response time is likely to be slow (hundreds of years). Low permeability local groundwater flow systems experiencing significant groundwater elevation within the catchment respond poorly to recharge management (alone) as a management measure.

Groundwater flow systems have much slower response times to changes in land use than is widely recognised. Once those changes are initiated, it takes a long time to reach a balance. Even if we manage to reduce recharge, it will take time for the excess water to flow out from the system once the groundwater system is full.

Local flow systems have a relatively small capacity to store any additional recharge and so respond relatively rapidly to changes in land use; in many cases, they also have a relatively small discharge capacity through which to drain any excess water.

In contrast, regional flow systems have a very large capacity to fill and subsequently respond very slowly to changes in land use, they will also take a long time to empty of excess water. Intermediate flow systems behaviour falls between local and regional systems.

The dominant aquifer types outlined above may, therefore, be classified based on their systems characteristics specifically in relation to this project (refer to Table 2-2).

Table 2-2 Groundwater Flow Systems encountered within the project

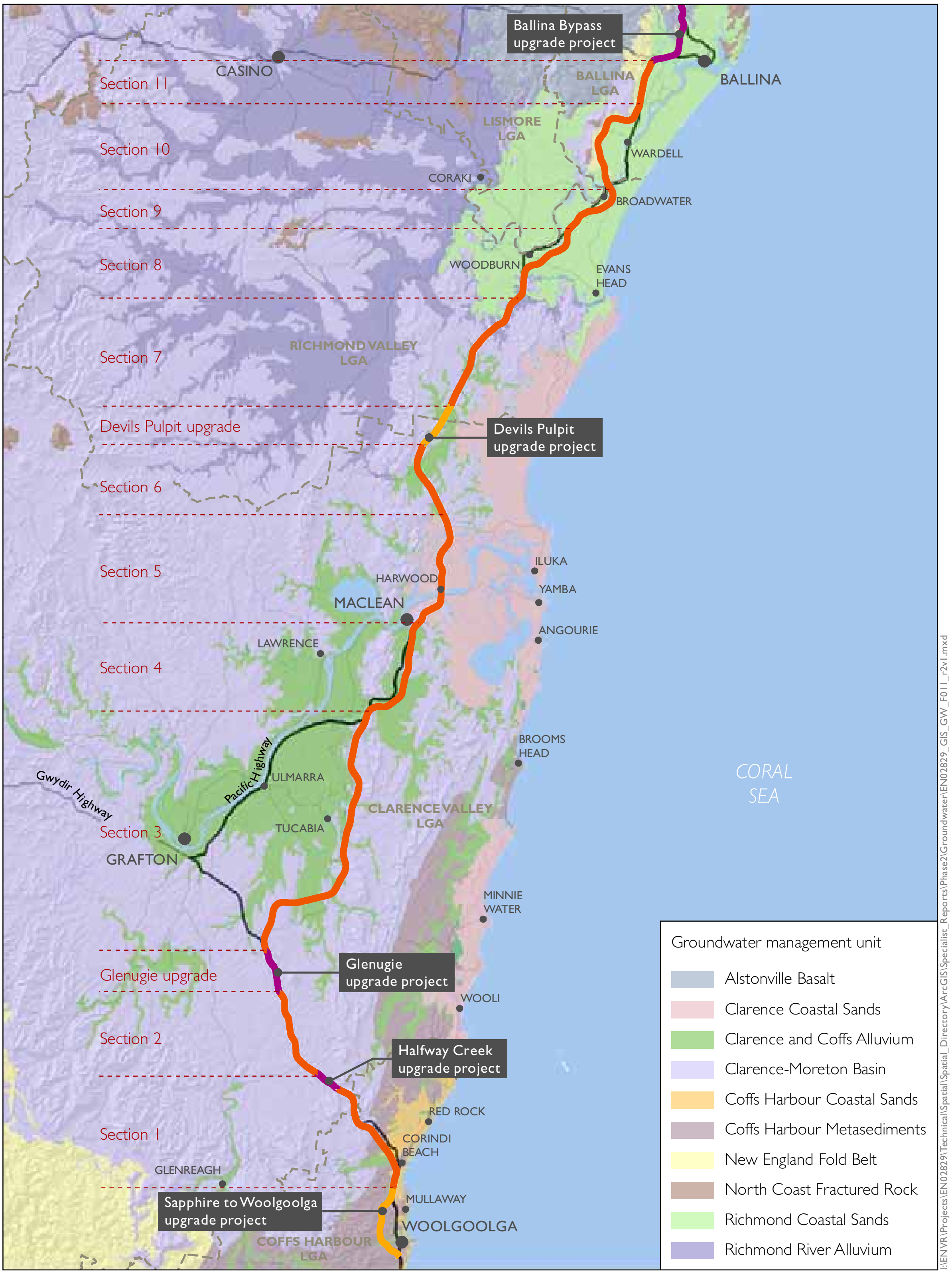
Aquifer type	Groundwater flow system characteristics	Response characteristics
Porous rock aquifers	Intermediate sedimentary sequences	Relatively slow response
Fractured rock aquifers	Intermediate fractured rocks	Spatially variable response dependent on structure
Coastal sand aquifers	Intermediate sedimentary systems	Fast response to recharge with low flow gradients
Alluvial aquifers	Local mixed sediments	Variable response dependent on local conditions, materials and gradients
Tertiary Basaltic Volcanic aquifers	Layered regional fractured rocks	Localised and variable response via springs and fractures.

Local alluvial systems overlying fractured rocks and porous rock aquifers dominate the southern portion of the project. These systems are variably connected and responses tend to be rapid and seasonally driven. These systems are easily perturbed, but respond rapidly to mitigation and management.

Floodplains on the coastal sand aquifers dominate the northern parts of the project. These broad, low-gradient systems provide a large buffer to any perturbation though they can take a long period to recover if impacted. The low gradients and large groundwater stores mitigate against local impacts to the system and may require on-going intervention if water tables are required to be lowered as part of a management strategy.

These broad concepts are developed further within the context of the Water Sharing Plans described below (Sections 2.2.5 and 2.2.6).

Figure 2-2 Groundwater management units (GMUs) along the project



The project
Upgrade completed to dual carriageway
Upgrade under construction
Existing Pacific Highway

2.1.4. Acid sulfate soils

Acid sulfate soils are soils and sediments containing iron sulfides that, when disturbed and exposed to oxygen, generate sulfuric acid and toxic quantities of aluminium and other heavy metals. The sulfuric acid and heavy metals are produced in forms that can be readily released into the environment, with potential adverse effects on the natural and built environment and human health. Activities that would be undertaken during construction, such as drainage, excavation, dewatering and clearing, pose a significant environmental risk when they are carried out in areas with acid sulfate soils.

The majority of ASS are formed by natural processes under specific environmental conditions. This generally limits their occurrence to low lying sections of coastal floodplains, rivers and creeks where surface elevations are less than about five metres AHD. New South Wales contains about 600,000 hectares of ASS along its coastline, with ASS found in every coastal estuary between the Victorian and Queensland borders.

The term ASS includes both actual acid sulfate soils (AASS) and potential acid sulfate soils (PASS). Actual and potential ASS can occur together within the same soil profile, with AASS usually overlying PASS horizons. Based on the definitions included in the *Acid Sulfate Soil Management Advisory Committee Manual* (Stone et al, 1998), AASS are soils containing highly acidic soil horizons, or layers resulting from the previous oxidation of soil materials that are rich in iron sulfides, and can usually be identified by the presence of pale yellow mottles or coatings of jarosite. PASS are soils containing iron sulfides or sulfidic material that have not been exposed to the atmosphere but will become highly acidic when oxidised due to disturbance. The oxidation of iron sulfide in PASS as a result of disturbance (such as excavation) or lowering the groundwater table can lead to AASS conditions.

2.1.5. Groundwater Dependent Ecosystems

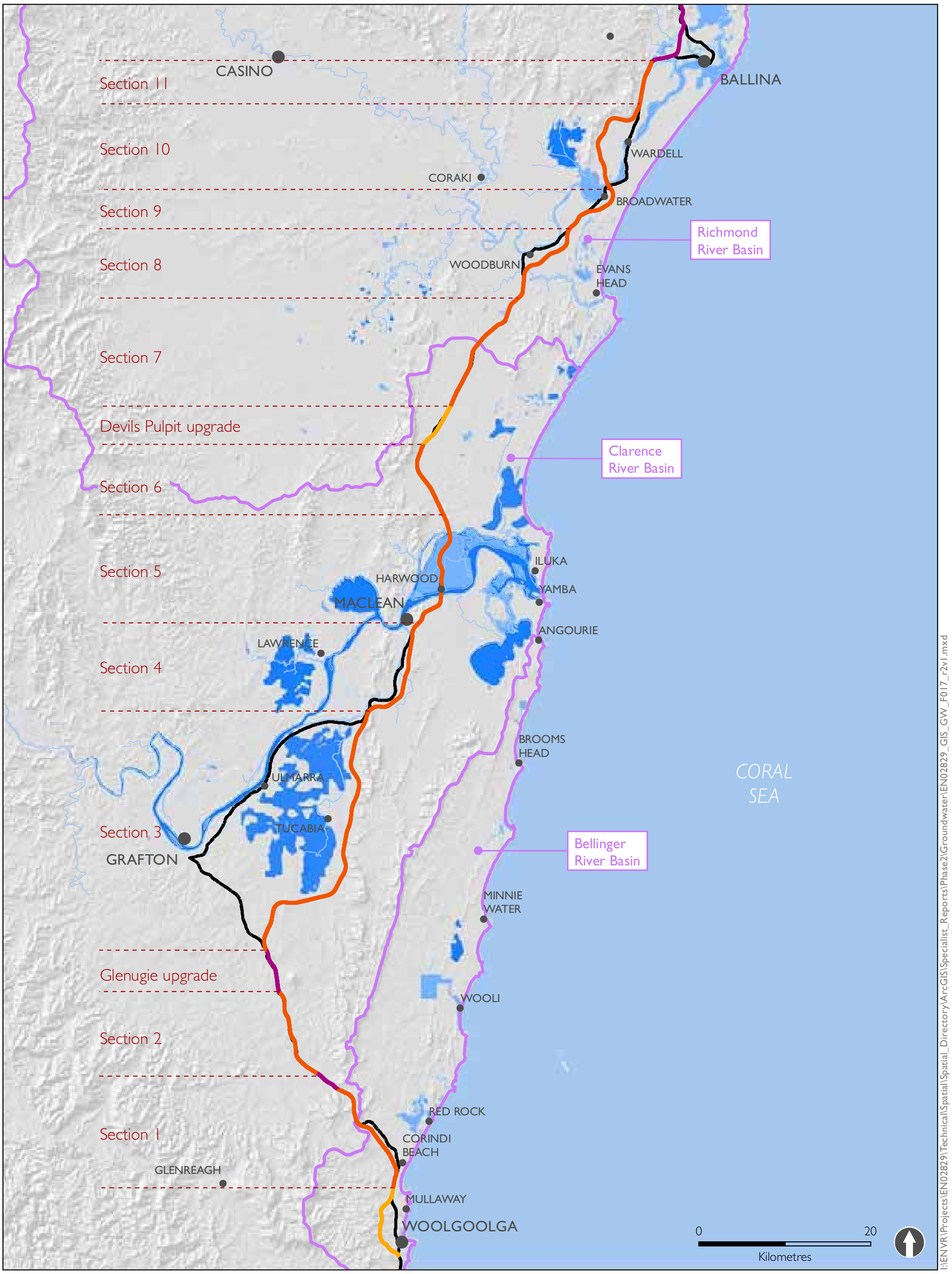
There are a large number of listed wetlands (which are intermittently supported by groundwater) that may be adversely affected by the project. Sensitive waterways and environments within or adjacent to the project are shown in Figure 2-3. Potential impacts on SEPP-listed wetlands are discussed in the Working Paper - Water Quality.

The project has the potential to impact groundwater through lowering or raising watertables and through contamination of groundwater supplies. Watertables may be raised where the project results in either ponding of shallow groundwaters due to compaction associated with fill, or where the project results in increased flow to downstream sites due to intersection of the watertable by a cut. Conversely, watertables may be lowered in the downstream area of the filled section, or upstream of a cut. Important factors influencing the extent of impacts are the initial watertable level, seasonal variability in water levels and the extent to which the wetlands rely on groundwater supply.

Many coastal wetlands are predominantly supported by shallow, perched groundwater systems (on a clay layer, for example) that effectively arrest the infiltration of surface waters. These systems are thus surface water reliant, with the shallow groundwater acting as a local storage that reduces effective evaporation and sustains wetland species. Elsewhere, groundwater is sourced from further afield and is brought to the surface due to impediment to flow, or via a topographic low. These groundwater-reliant systems therefore occur in many valleys and also in coastal sand environments.

The optimal management measure to support groundwater dependent ecosystems is to maintain the existing water environment. That is, ensure that the groundwater regime following the project mimics that prior to development. This requires an understanding of the groundwater conditions at each designated site and consideration of these conditions in design. This assessment outlines the pre-existing groundwater conditions and estimates the consequent potential impact of the project during the construction and operation phases of the project. Where the potential impact increases compared to pre-existing conditions (see charts in Section 4.6), mitigation measures should be considered to maintain the groundwater regime (Section 5.3). In these cases, any impact would be averted.

Figure 2-3 Sensitive waterways and environments



The project
Upgrade completed to dual carriageway
Upgrade under construction
Existing Pacific Highway
Watershed
Nationally important wetland (Directory of Important Wetlands)
DECCW designated wetland that is not nationally recognised
Perennial waterway

2.2. Regulatory framework

New South Wales water resources are managed through a range of legislation, initiatives and cooperative arrangements with the Commonwealth and other state government departments. The two key pieces of legislation for the management of water in NSW are the *Water Management Act 2000* and the *Water Act 1912*.

2.2.1. Water Management Act 2000

The object of the *Water Management Act 2000* is the sustainable and integrated management of the state's water for the benefit of both present and future generations.

The *Water Management Act 2000* recognises the need to allocate and provide water for the environmental health of our rivers and groundwater systems, while also providing licence holders with more secure access to water and greater opportunities to trade water through the separation of water licences from land. The main tool *the Act* provides for managing the State's water resources are water sharing plans (WSPs). These are used to set out the rules for the sharing of water in a particular water source between water users and the environment and rules for the trading of water in a particular water source.

Since the legislation was passed in 2000, some amendments have been necessary to better implement the new arrangements and also give effect to the National Water Initiative signed on 25 June 2004, including creation of perpetual or open-ended water licences. *The Act* was also amended in 2008 to strengthen compliance and enforcement powers in response to water theft.

The Act has been progressively implemented and since 1 July 2004 the new licensing and approvals system has been in effect in those areas of NSW covered by operational WSPs. These areas cover most of the State's major regulated river systems and therefore the largest areas of water extraction. As WSPs are finalised and commenced for the remainder of the state, the licensing provisions of *the Act* are introduced extending the benefits for the environment of defined environmental rules and for licence holders of perpetual water licences, including greater opportunities for water trading.

By the end of 2010, around 90 per cent of the water extracted in NSW was covered by the *Water Management Act 2000*.

2.2.2. Macro sharing plans

In recent years, water sharing plans for unregulated rivers (being those typically dependent on rainfall and natural river flows rather than water released from dams) and groundwater systems have been completed using a 'macro' or broader scale river catchment or aquifer system approach.

The macro planning process is designed to develop water sharing plans covering most of the remaining water sources across NSW. Each macro plan covers a large river basin rather than a single sub-catchment, or in the case of a groundwater system, covers a particular type of aquifer (eg fractured rock) within the river basin. These macro plans generally apply to catchments or aquifers where there is less intensive water use compared with the areas that were covered by plans in 2004.

2.2.3. Water sharing plans

Water sharing plans are being progressively developed for rivers and groundwater systems across New South Wales following the introduction of the *Water Management Act 2000*. These plans protect the health of our rivers and groundwater while also providing water users with perpetual access licences, equitable conditions, and increased opportunities to trade water through separation of land and water. Currently, there are “Plans Commenced” and “Plans under exhibition”. Commenced groundwater water sharing plans covering areas either in or adjacent to the project boundary are as follows:

- Alstonville Plateau
- Richmond River Area Alluvial
- Coffs Harbour Area Alluvial
- Bellinger River Alluvial
- Of these, the Coffs Harbour Area Alluvial and Richmond River Area Alluvial WSPs may be directly impacted by the project (Figure 2-4).

The proposed water sharing rules for licences in alluvial aquifers are based on the following principles:

- A recognition that in alluvial river reaches, the surface and groundwater is considered to be a single resource
- Manage growth in use through a common set of available water determinations for both surface and groundwater users
- Manage existing bores located within 40 metres of an unregulated river to surface water daily access rules (from year six of the plan), except access licences for stock and domestic, local water utility or food safety or essential dairy care purposes. These are not subject to access rule constraints
- Prohibit new bores within 40 metres of a third order or higher stream except for bores as a result of a conversion of an unregulated river access licence or when:
  - They are drilled into the underlying non-alluvial material, and the slotted intervals of the production bore commence deeper than 30 metres
  - The applicant can demonstrate that the bore will have minimal impact on base flows in the stream
- Allow trading of groundwater licences
- Manage the trade of alluvial groundwater licences with the same trading rules as the adjoining surface water. In effect, this would prohibit trading into areas identified

as having high in-stream values, or are characterised as having high hydrological stress

- Trade, where permitted between water sources, would only be from a river alluvial area to another river alluvial area
- Manage to a combined long-term average annual extraction limit for the unregulated surface water and alluvial groundwater. This would be based on the sum of existing unregulated and alluvial groundwater entitlement, plus a basic landholder rights estimate, plus an allowance for exemptions such as water for Aboriginal Community Development or town water purposes (where these apply)
- Permit within water source licence conversion between licence categories, assignment or allocation of account water from unregulated river to alluvial groundwater licences but not the reverse (ie one way only)
- Minimise and manage any local impacts such as groundwater pollution or drawing down of the water table as a result of groundwater extraction
- Protect groundwater dependant ecosystems
- Apply the standard local impact rules for alluvial groundwater and standard provisions for identified Groundwater Dependent Ecosystems.

Access licences for groundwater extraction under these Plans have thus been subject to annual limits rather than daily management. When a plan commences, surface water licences in all unregulated water sources are subject to cease-to-pump rules (excluding licences held by local water utilities, licensed stock and domestic users, and licences used for food safety and essential dairy care). From year six of the plan these rules will also apply to any users extracting from any alluvial via a work located within 40 metres of the high bank of a river. This recognises the high degree of connectivity between alluvial aquifers and river flows and the potential impact that pumping from an aquifer can have on surface water flows. In instances where the existing cease-to-pump rule under the *Water Act 1912* is based on a higher flow rate than the rule proposed by the plan, the existing cease to pump rule will take precedence.

Water sharing plans sets out schedules of high priority (high conservation value) groundwater dependent ecosystems. Their location is mapped and proposed distance rules will cover new or replacement bores which will not be permitted within a buffer zone around the groundwater dependent ecosystem. Existing bores will not be affected by the proposed buffer zones and are able to continue operating (ie within the existing conditions of their access licences). The groundwater-dependent ecosystem schedule may be updated throughout the life of the plan. Updating of the schedule is considered to be an amendment to the plan, and as such would require the concurrence of the Minister of the Environment and the Minister of Water. Currently, there are no listed groundwater dependent ecosystems that will be affected by the project.

2.2.4. Aquifer Interference Policy – Stage 1

In September 2012, the NSW Government released the policy for the licensing and approval of aquifer interference activities (NSW Office of Water, 2012). The *Water Management Act 2000* defines an aquifer interference activity as that which involves any of the following:

- The penetration of an aquifer
- The interference with water in an aquifer
- The obstruction of the flow of water in an aquifer
- The taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations
- The disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

Any activity that results in a reduction in the groundwater resource pool of three megalitres per year or more, or at an instantaneous rate of greater than 5 litres per second will require a groundwater extraction and aquifer interference license. The primary potential interference posed by this project involves the obstruction of flow of water in an aquifer, but also any activities with the potential to contaminate groundwater or result in unacceptable loss of storage or structural damage to an aquifer.

However, there is an exemption from requiring a volumetric access licence where water is taken as a result of road or rail infrastructure construction undertaken by a roads authority within the meaning of the *Roads Act 1993* or an authority within the meaning of the *Transport Administration Act 1988* if the environmental impact of the construction or maintenance has been considered under section 111 of the *Environmental Planning & Assessment Act 1979* (or is exempt from the need for such consideration under section 110E of that Act). For such activities the extractions are typically small and measuring and monitoring them is impractical. Notwithstanding, if the activity occurs within a Water Protection Zone or Limited Intrusion Zone or on Biophysical Strategic Agricultural Land (BSAL), assessment of environmental impacts are required and minimal harm criteria thresholds needs to be met. As currently defined, the project does not intersect BSAL.

2.2.5. Water Sharing Plan for the Coffs Harbour Area Alluvial Groundwater Source

The level of connectivity, the relative level of impact and the timing of connection have been considered in developing both the unregulated river and the associated groundwater sharing plans for the Coffs Harbour area. One of the key factors in determining the sustainable yield for various aquifers is the downstream values in associated streams.

The aquifer types and groundwater sources that occur within the Coffs Harbour water sharing plan and their connectivity characteristics are given in Table 2-3. It is based on principles and recommendations in *Towards a National Framework for Managing the Impacts of Groundwater and Surface Water Interaction in Australia* (Sinclair Knight Merz 2006).

Figure 2-4 Water Sharing Plans in the vicinity of the project

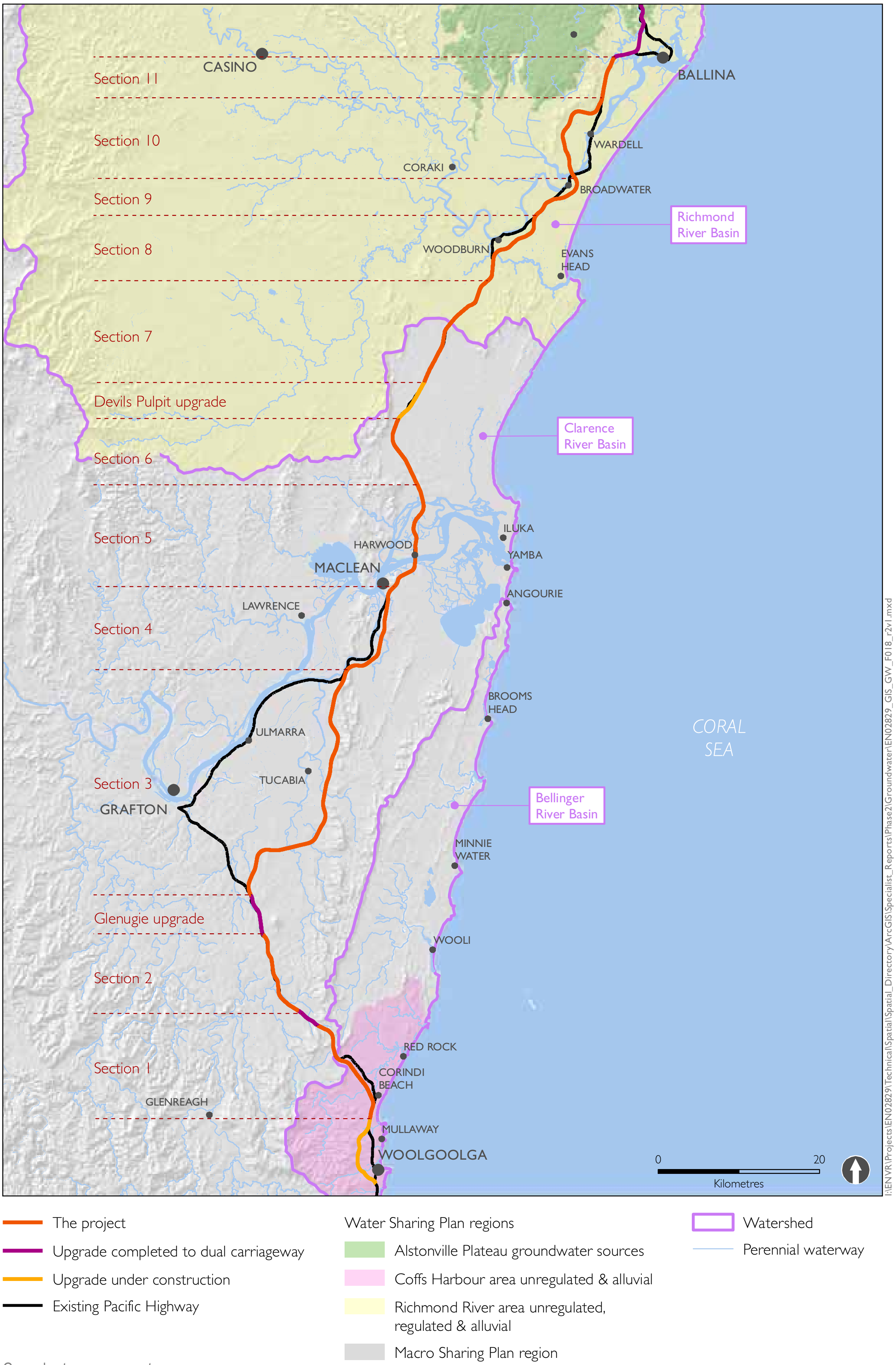


Table 2-3 Connectivity between aquifer types and surface water in the Coffs Harbour area

Aquifer type	Water sources	Level of connection between surface and groundwater	Level of impact on instream values	Estimated travel time from groundwater and unregulated river
Coastal sands	Coffs Harbour Coastal, Sands and all unregulated rivers	Significant (tidal section only)	Low due to connection with saline water	Days to months
Up-river Alluvial	All unregulated rivers	Significant	High due to impact on base flows	Days to months
Coastal Floodplain Alluvial	Most unregulated river water sources except Dirty Creek, Corindi River, Red Bank River and Arrawarra Creek	Low – moderate (tidal section only)	Low since not major contributor and low level of connection	Season
Fractured rock	All unregulated rivers	Low - moderate	Low since not major contributor	Years to decades

Alluvial aquifers are often connected to their parent streams. The degree of connectivity is dependant amongst other things, on the type of alluvial material within the aquifer. For example, groundwater in alluvial aquifers consisting of coarse materials such as sands and gravels strongly interacts with adjoining surface waters, whereas groundwater in aquifers consisting of finer alluvial materials such as silts and clays displays a weaker connection with the surface waters.

Based on differences in alluvial material and therefore degree of connectivity, the alluvial aquifers in the Coffs Harbour Area unregulated river and alluvial aquifer water sharing plan have been grouped into two different categories, both of which show connectivity to surface waters.

- Shallow 'upriver' alluvial aquifers are characterised by coarse materials and are generally located in the upstream part of the catchment. These aquifers are strongly connected to the adjoining stream and the travel time between ground and surface waters is short
- Coastal floodplain alluvial aquifers are characterised by interspersed silts, clays and fine sands and are located further downstream within the catchment where the alluvial floodplain flattens and widens.

Compared to the upriver alluvial aquifers, the connection between ground and surface waters in coastal floodplain alluvial aquifers is weaker and therefore the travel time between these waters are longer.

For the Coffs Harbour Area unregulated river and alluvial aquifer water sharing plan, the boundary between the coastal floodplain and the shallow upriver alluvial aquifers is the tidal limit. This limit generally coincides with a change in slope, and a fining of the alluvial material, resulting in changes to the degree of connectivity between the ground and surface waters.

It should be noted that no significant or high-priority groundwater dependent ecosystems (of any kind – cave systems, wetlands or endangered ecological communities) have been identified within the Coffs Harbour Area.

A number of the creeks within the Coffs Harbour area are of economic importance, providing water sources for irrigation for horticulture. These include Boambee Creek, Bonville Creek, Coffs Creek, Korora Creek and Woolgoolga Creek. These sources are required to be protected under the Plan.

2.2.6. Water Sharing Plan for the Richmond River Alluvial Groundwater Source

The Richmond River catchment is made up of several groundwater sources including the aquifers of the New England Fractured Rocks, the porous rocks of the Clarence Morton Basin, the North Coast Fractured Rocks, the unconsolidated alluvial aquifers and the Richmond Coastal Sands.

Aside from the basalt aquifer of the Alstonville Plateau, the unconsolidated alluvial aquifers are a major source of groundwater in the Richmond River catchment. The alluvial aquifers make up the large coastal floodplain and also the smaller floodplains deposited along most major and minor streams.

Although the Richmond River catchment contains by far the most alluvium of north coast valleys, there has been relatively little development of this groundwater system. This relates to the alluvial aquifers often not producing high yields. Bores upstream of Casino usually yield <10 litres per second, whereas south of Casino, notably around Bungawalbyn Creek, bores in the alluvial aquifers can yield in excess of 20 litres per second.

Total entitlements granted within the Plan area are given in Table 2-4.

Table 2-4 Total entitlement and number of licences for each water resource within the Richmond River Water Sharing Plan

Water resources	Entitlement (ML)	Number of licences
Unregulated River	81,428	1,194
Groundwater Alluvial	4,151	624
Regulated River	10,330	68
• general security	-10,203	- 61
• high security	-127	-7

The alluvial groundwater licences are located mainly in the alluvium along the main trunk of the Richmond River (Kyogle Area Water Source) and on the Richmond Floodplain in the Coraki Area and Wyrallah Area Water Sources. Around 60 per cent of all alluvial aquifer licences are located in the upriver alluvium with 40 per cent located in the downstream floodplain alluvium (ie that part of the floodplain adjacent to the estuary), which constitutes the Richmond Floodplain. Like the surface water licences, the south and south western part of the Richmond River catchment has the least number of alluvial aquifer licences. In 2008 an embargo was placed on the granting of new access licences in the alluvial aquifers in the Richmond River catchment.

The regulated system experiences considerable losses to groundwater which are in the order of 4,000 – 5,000 megalitres per year accounting for around 40 per cent of dam capacity.

The plan includes all the alluvial aquifers within the plan area. Due to the nature of the connectivity between the alluvial aquifers and the rivers system (refer to Table 2-5), the surface water and groundwater associated with the alluvial aquifers will be managed as a single resource. This approach is consistent with the national framework for managing the impacts of groundwater and surface water interaction.

Table 2-5 Connectivity between aquifer types and surface water in the Richmond River catchment

Aquifer type	Ground water sources	Level of connection between surface and groundwater	Level of impact on in-stream values	Estimated travel time from groundwater and unregulated river
Coastal sands	Richmond Coastal Sands	Significant (tidal section only)	Low due to connection with saline water	Days to months
Up-river Alluvial	Unregulated rivers and the Richmond Regulated	Significant	High due to impact of base flows	Days to months
Coastal Floodplain Alluvial	Unregulated rivers	Low - Moderate	Low since not major contributor and low level of connection	Season
Fractured rock	New England Fold Belt, North Coast Fractured Rocks	Low - Moderate	Low since not major contributor	Years to decades
Porous Rock	Clarence Morton Basin	Low - Moderate	Low since not major contributor	Years to decades

The aquifers of the New England Fold Belt fractured rocks, the porous rocks of the Clarence Morton Basin, the North Coast Fractured Rocks and the Richmond Coastal Sand aquifers will be covered in a future groundwater water sharing plan.

The Extraction Management Unit is the highest level in the hierarchy of planning units and may consist of one or several sub-catchments ('water sources' – see the *WMA 2000* for definition). An extraction management unit is specified for the purpose of establishing a geographic area over which the long-term average annual extraction limit applies. This plan contains three extraction management units including:

- Richmond River – all unregulated surface water and alluvial groundwater in the Richmond River catchment
- Evans River Catchment – all unregulated surface water and alluvial groundwater in the Evans River Catchment
- Richmond Regulated Water Resource.

An initial assessment has been undertaken to determine whether there are any significant groundwater dependent ecosystems reliant on the alluvial groundwater. The only groundwater dependent ecosystem identified in this initial assessment was a wetland located at the downstream end of the Tuckean Area Water Source. This identified wetland, known as the Tuckean Swamp, is a large estuarine back-swamp within the Richmond Floodplain. The swamp has been highly modified with the construction of drains and a tidal barrage, which among other things have lowered the shallow water table. Part of the Tuckean Swamp is now protected as a nature reserve.

The estuaries of the Richmond River and Evans River are considered of medium sensitivity to changes in inflow both for low and high flows.

Under the *Water Management Act, 2000*, extraction of water for basic landholder rights does not require a licence, although in the case of accessing groundwater under basic landholder rights the bore must still be approved by the NSW Office of Water.

The Integrated Water Cycle Management Strategies developed by both Richmond Valley and Kyogle Councils identified the need for each council to source alternate sources to enhance their existing supplies. Options being considered include groundwater, off-stream storage, accessing water from Toonumbar Dam and water reuse.

2.2.7. Rous Water Local Area Management Zone

Rous Water operates groundwater sources from bores in the Woodburn Sands aquifer and the Alstonville Plateau groundwater source (Innovation Planning Australia 2009). Of these two areas, only the Woodburn Sands aquifer is in the project area. This borefield is located about two kilometres southeast of the Woodburn township. Three bores are operational and provide drought relief and auxiliary supply for the region. Screens are installed into the Woodburn Sand aquifer (Coffey 2006) which underlies a thin and variable thickness of low permeability alluvial clay (0 to 2 metres) (Coffey 2009). The sand aquifer ranges from seven to 17 metres thick and overlies a low permeability, marine clay of variable thickness (0 to10 metres). Where the clay is absent (for example to the south-west of the bore field) the Woodburn sand directly overlies a consolidated sandstone, possibly of Jurassic age, which also appears to exhibit low permeability except where jointing and fracturing are present.

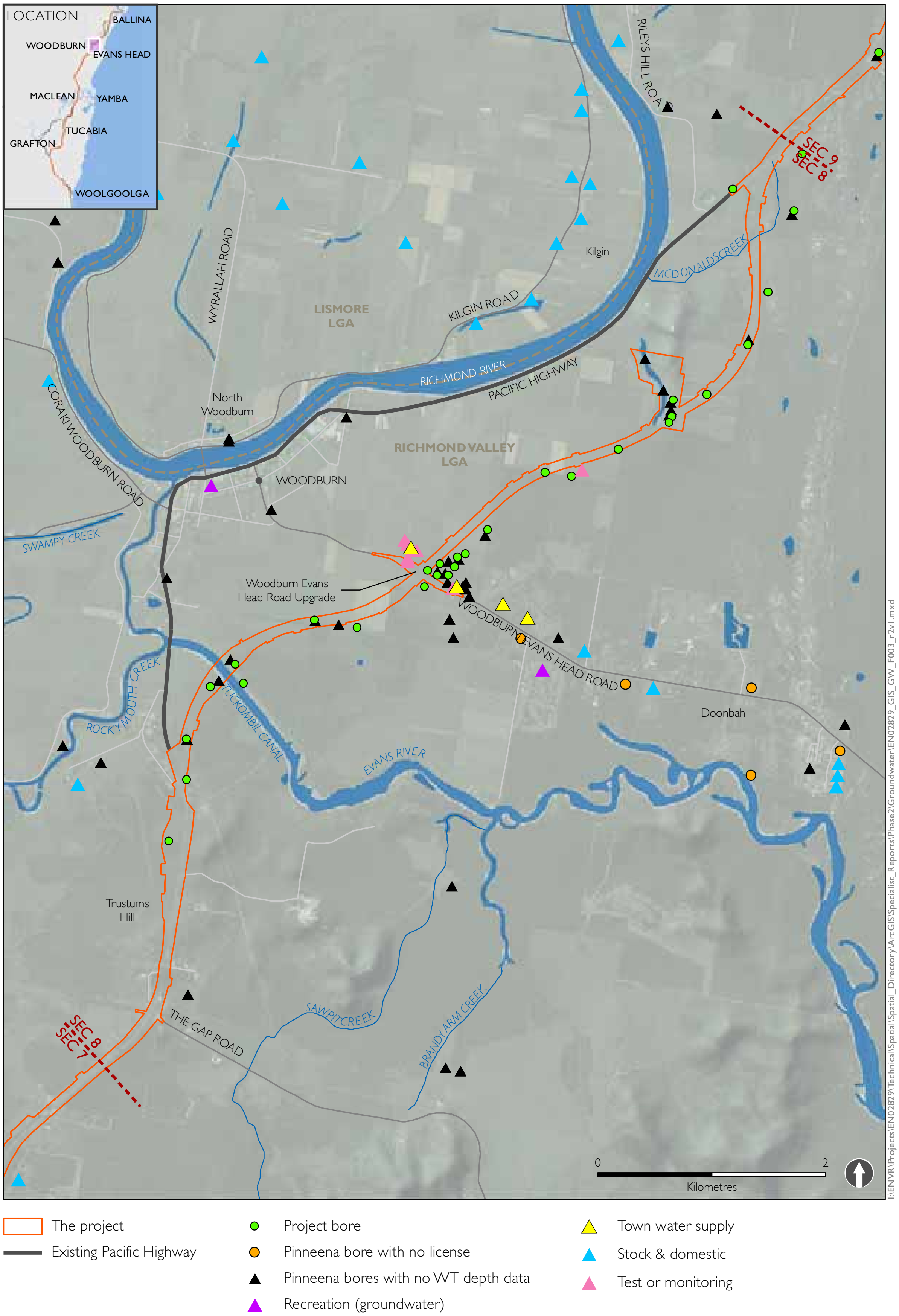
Aquifer pump tests (Coffey 2006) indicate that the aquifers can generate extraction rates of 15 to 30 litres per second. Sustainable rates were determined by the Department of Primary

Industries Office of Water as a requirement of licence conditions and these restrict each of these bores to a maximum abstraction rate of 12 litres per second and a maximum abstraction volume for the bore field of 242 megalitres in any 12 month period.

Groundwater quality is rated as good, but may contain elevated levels of iron and aluminium. Treatment involves aeration and filtration, followed by addition of sodium hypochlorite to provide a disinfection residual.

The Woodburn Sands bores are currently located across the project and parallel to the proposed Woodburn-Evans Head Road overpass as shown in Figure 2-5. Not all bores could be used in the groundwater assessment, however, as not all have recorded water level data.

Figure 2-5 Location of the Rous Water Woodburn Borefield and other groundwater bores in the region



2.3. Existing groundwater conditions

An assessment for groundwater condition has been carried out at the regional (aquifer), local (groundwater management unit) and design scale.

2.3.1. Groundwater analysis

Groundwater information was compiled for all groundwater management units that were crossed by the project (Figure 2-1). Groundwater bores within these units were used to generate water table surfaces across the region. This dataset was reduced to bores within 10 kilometres of the project for detailed groundwater evaluation (Figure 1-8). This formed the primary dataset used in the potential impact assessment.

Significant stretches of the project are data-poor. Extrapolation of surfaces across these areas must be treated with caution. Cross-sectional plots of the project provided in Chapter 3 indicate the distance to the nearest bore, both along the project and orthogonal to the project. Also important is the direction from which the extrapolated information is derived. The cross-sectional plots, therefore, also indicate if the off-axis bore is landward or seaward of the project. Reference to the location with respect to local topography assists in determining the efficacy of the information.

Using all the information in Figure 1-7, a depth-to-watertable surface can be created (refer to Figure 2-6 and Appendix A). This does not consider the different characteristics of groundwater flow through different media and does not consider the presence of impediments to flow, such as faults and dykes. Thus, this represents a stylised water table assuming a contiguous surface across the region. Future assessments should consider these potential variations at a local scale for detailed assessment.

Comparison to the topography (via a digital elevation model) then permits creation of the theoretical water table surface which helps in the interpretation of groundwater flow and gradients of flow along the project. Figure 2-7 provides a regional perspective on groundwater flow, from high to low areas and indicates the regions where groundwater flow approaches sea-level, the equilibrium surface for the earth's water.

It can be seen in Figure 2-6 and Figure 2-7 that groundwater beneath the broad floodplain regions of the project is both close to the surface and also close to sea-level. These surfaces are generated from a broader spread of data (Figure 1-8) and cropped to a buffer 10 km either side of the project. Paucity of groundwater data precludes further extrapolation for most of the route. Elevations used were those recorded for report bores, while for Pinneena bores they were derived by subtraction of the recorded depth-to-water table from the digital elevation model (DEM)

A further important consideration is the pervasive occurrence of potential ASS, especially in the low-lying areas of the floodplains of the Clarence and Richmond rivers. These regions generally correspond to areas where the groundwater table is within three metres of the surface. Activities such as drainage, excavation, dewatering and clearing pose a substantial environmental risk within these areas if not managed effectively. A summary of the risk of ASS occurring in each section of the project is provided in Table 2-6 and shown in Figure 2-8 and Appendix A.

Figure 2-6 Estimated water table depth for the project

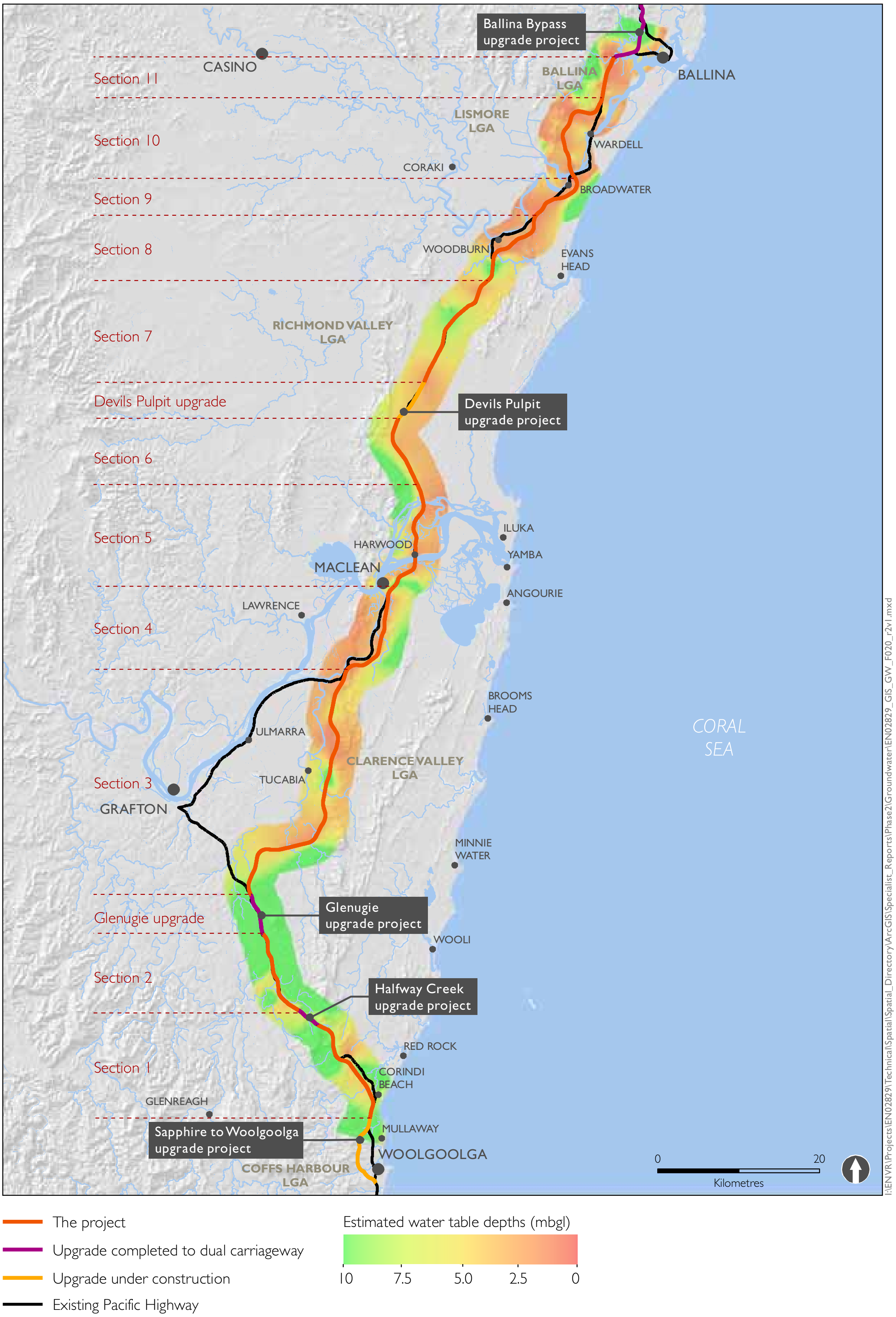
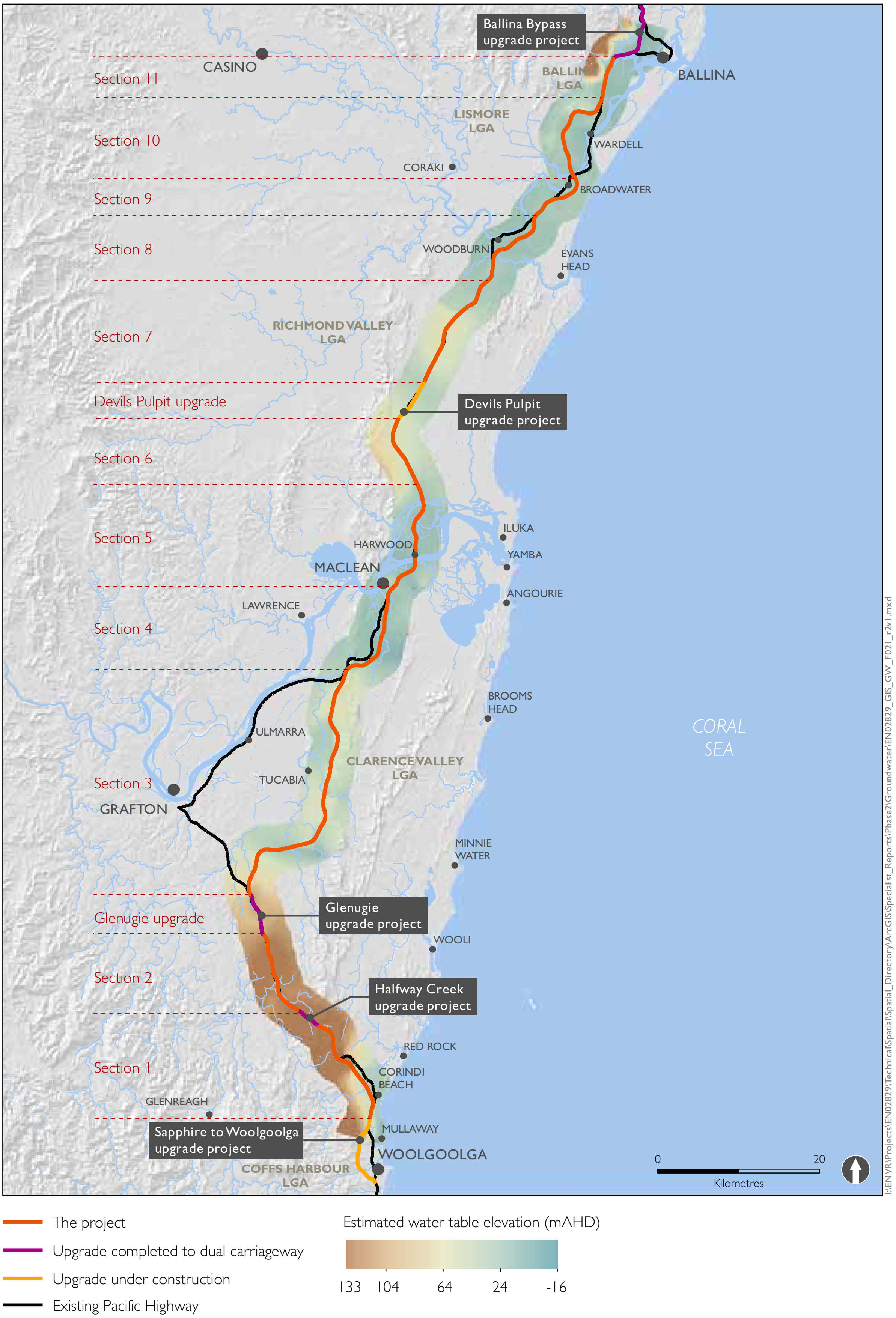


Figure 2-7 Modelled groundwater surface along the project

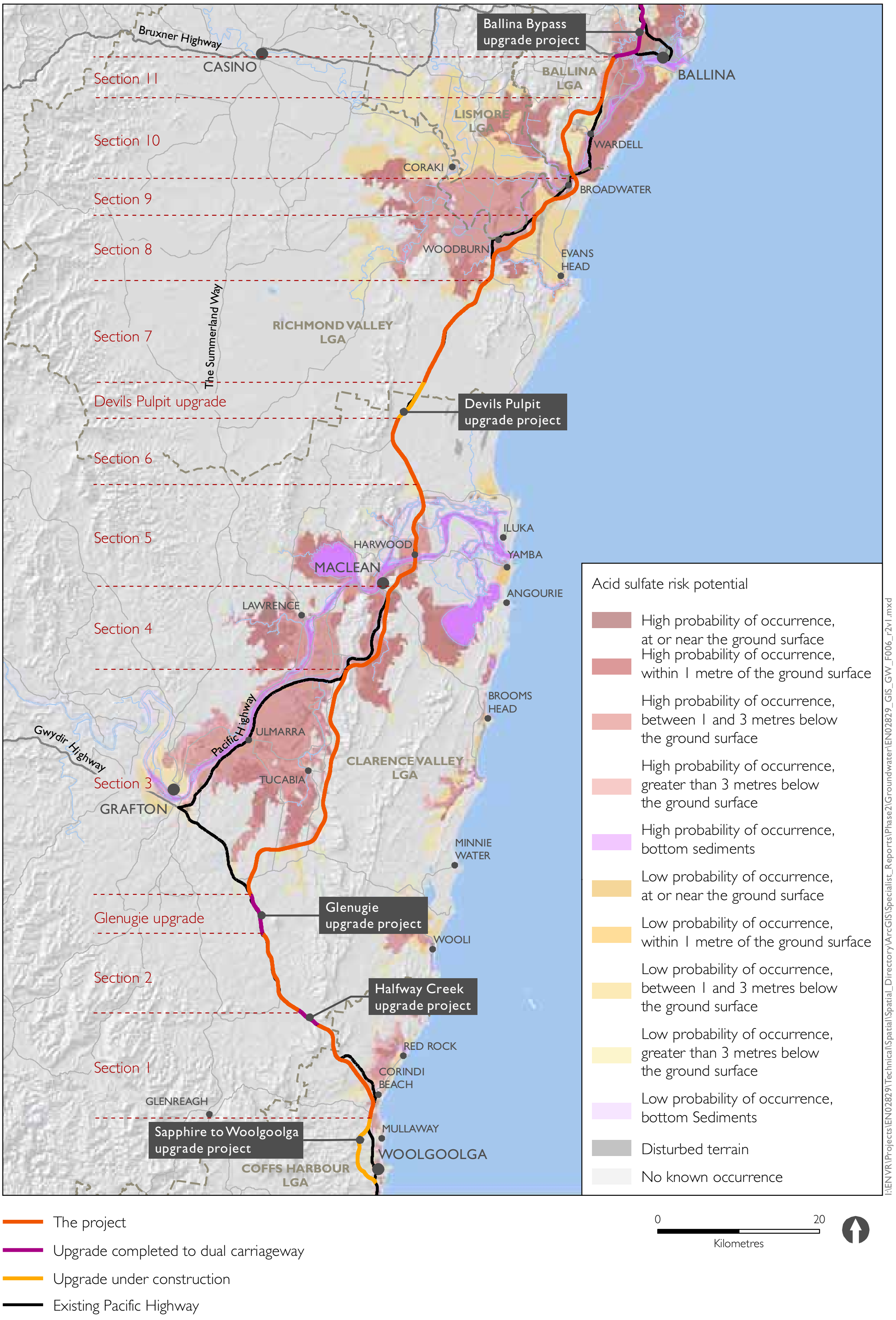


Disturbance of the groundwater table leading to exposure of sulfur-rich soils can release sulfuric acid to the environment. Even subsequent wetting may actually increase the acidity of the landscape through dissolution of sulfur-rich efflorescence and release of retained acidity (in minerals such as jarosite).

Table 2-6 Summary of risk of occurrence of acid sulfate soil in the project

Project section	Risk of occurrence	Portion of section (%)	Description
1	No known occurrence	65	Majority of section mapped as having no known occurrence of ASS. Areas of low and high probability of occurrence mapped for the lowland coastal plains in the southern portion of section near the Arrawarra and Corindi Beach localities.
2	No known occurrence	100	Entire section mapped as having no known occurrence of ASS. Section is located within elevated terrain where acid sulfate soils are not expected to occur.
3	No known occurrence	80	Majority of section mapped as having no known occurrence of acid sulfate soils. Section traverses several isolated areas of low and high probability of occurrence in the southern and central portions.
4	High probability	65	Majority of section mapped as having a high probability of occurrence. Isolated areas of no known occurrence located in the central and northern portions near the Maclean locality.
5	High probability	100	Entire section mapped as having a high probability of occurrence.
6	No known occurrence	100	Entire section mapped as having no known occurrence of acid sulfate soils. Section is located within elevated terrain where acid sulfate soils are not expected to occur. Area of low probability of occurrence noted to be mapped immediately west of the section in the southern portion.
7	No known occurrence	95	Majority of section mapped as having no known occurrence of acid sulfate soils. Isolated areas of low and high probability located in the northern portion of section on both the eastern and western sides of the project.
8	High probability	80	Majority of section mapped as having a high probability of occurrence and is located close to the boundary of low and high probability areas to the north of Woodburn. Southern extremity of section mapped as having no known occurrence of acid sulfate soils.
9	High probability	60	Majority of section mapped as having a high probability of occurrence. Southern portion of section mapped as having a low probability of occurrence.
10	Low probability	55	Majority of section mapped as having a low probability of occurrence. Northern portion of section mapped as having no known occurrence of acid sulfate soils.
11	High probability	85	Majority of section mapped as having a high probability of occurrence. Southern extremity of section mapped as having a low probability of occurrence.

Figure 2-8 Acid-sulfate soil risk map of the project

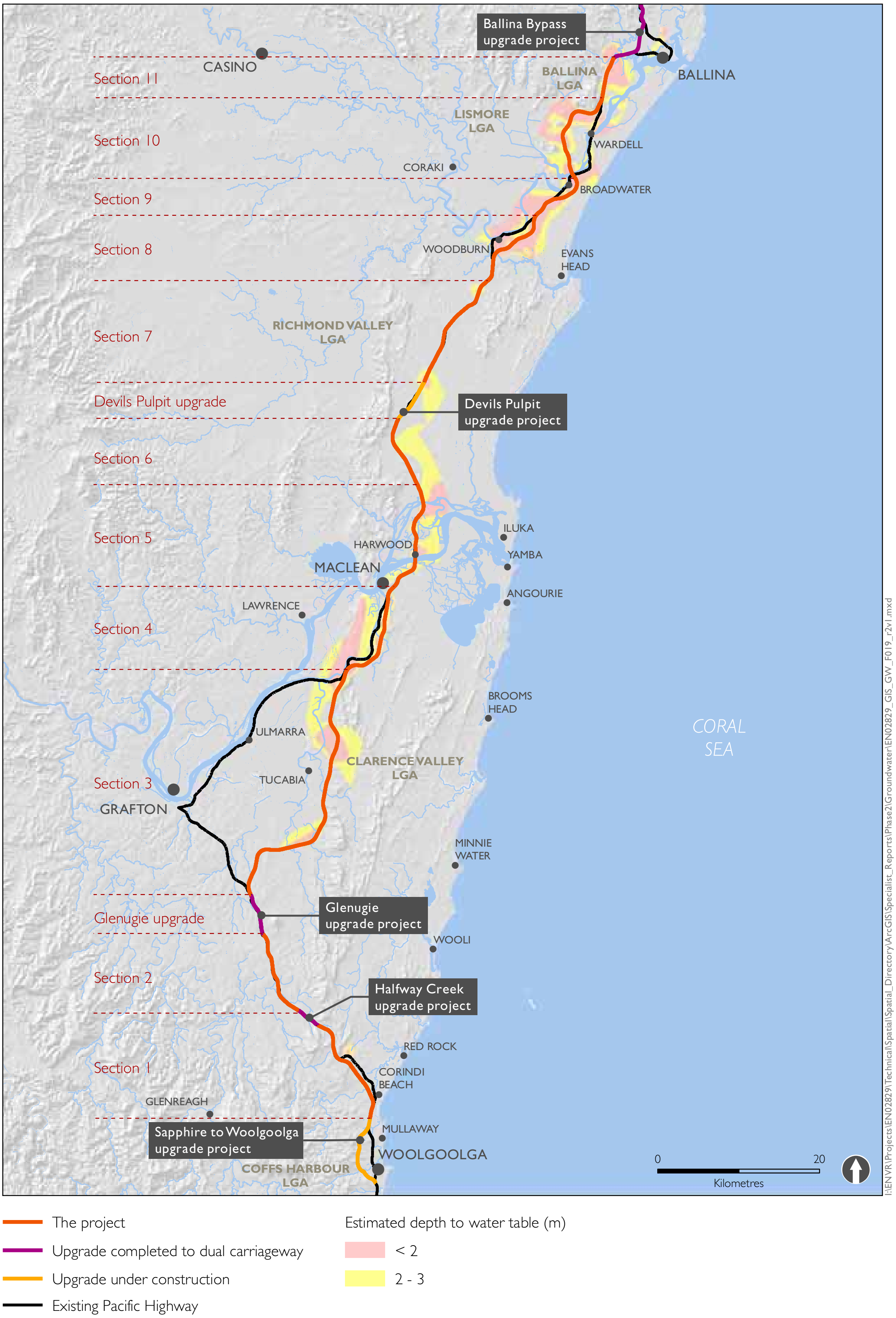


2.3.2. Summary of groundwater conditions

An assessment of groundwater levels was undertaken for pre-construction conditions. Areas that were identified as having shallow (water tables less than three metres below the ground level) and very shallow (less than two metres) water tables are shown in Figure 2-9. Where watertables are less than two metres from the ground surface, there is a potential high potential impact from the project activities; less than three metres are considered as having a medium potential impact. These areas are primarily where elevation and relief is low and these occur across the floodplains of the major river systems and the coastal floodplains of the northern sections of the project. The very shallow conditions also include groundwaters that are actively discharging (ie above ground level) as groundwater levels under ambient conditions have either equilibrated with evaporative loss and are effectively below the ground surface, or present as water bodies (ie through baseflow to creeks and as waterholes) and are identified as such . Seasonal fluctuations, however, result in periodic discharge to the surface across large areas of the floodplains and the numerous wetlands are supported by near surface groundwaters for at least part of the year.

For each section of the project, pre-construction conditions are evaluated in terms of: groundwater management units; water sharing arrangements, ASS and groundwater levels below ground to provide an indication of the current potential impact experienced at each station. Summary maps of high and medium potential impact areas and areas of potential acid sulfate soil are also provided for reference.

Figure 2-9 Areas of shallow estimated water table



3. Methodology

3.1. General principles

The primary factor determining potential impact for this groundwater impact assessment is the presence of shallow water tables. The presence of groundwater within two metres of the ground surface will indicate a high potential impact and measures are likely to be required to avoid, mitigate and manage these impacts. Where water tables are more than five metres below the surface, however, there are unlikely to be any adverse impacts on the groundwater resource, or the project. Water tables of intermediate depth are associated with medium potential impact levels (where groundwater is two to three metres below ground level) or low potential impact levels (where ground water is three to five metres below ground level) and requires further assessment and monitoring to determine whether or not impact mitigation would be required. A medium potential impact indicates that impact mitigation measures are likely to be required but that the requirements should be confirmed with monitoring; a low potential impact suggests mitigation may not be required, but monitoring should be carried out to confirm the groundwater status over time.

A high potential impact level was assigned for project sections that include a cut intercepting the watertable. In such locations, the watertable would be effectively above the ground surface of the pavement and on-going mitigation of groundwater impacts would be required. The potential impact criteria are summarised below (Section 3.2).

A potential impact assessment is undertaken at each phase of development, as relative watertables will vary depending on the stage of works. Thus, a location may have a low potential impact condition (deep watertables) prior to construction, but develop increasing potential impact if a cut excavates the land surface down to the watertable. In contrast, a fill area may reduce the potential impact level by raising the land surface, and hence relatively lowering the watertable. Care must be taken, however, as compaction of fill sediments can have adverse impacts on very near-surface groundwater flow (less than two metres) where compaction may lead to subsurface damming of groundwater flow and consequent ponding and elevated watertables. To account for this phenomenon, an extra metre is added to the potential impact margin to compensate for the compaction. Thus, the two metre level for high potential impact is increased to three metres.

Table 3-1 Summary of potential impact levels based on watertable depths along the project

Potential impact level	Watertable depth below ground level (bgl)	Cut type	Mitigation requirement
HIGH	< 2m	Type A	Monitoring to determine if mitigation is required; consideration during design phase may be necessary. On-going drainage relief may be required where groundwater tables are intercepted by the cut.

Potential impact level	Watertable depth below ground level (bgl)	Cut type	Mitigation requirement
			On-going monitoring to check status. Mitigation may be required, particularly for deeper cuts.
MEDIUM	2 – 3 m	Type B	Monitoring to determine if mitigation is required; consideration during design phase may be necessary. Mitigation unlikely to be required.
LOW	3 – 5 m	Type B	On-going monitoring to assess seasonal and inter-annual variability. Mitigation unlikely to be required.
MINIMAL	> 5 m	Type C	No mitigation required.

3.2. Impact assessment framework

An initial assessment was made on existing ground conditions to highlight areas of existing high potential impact to groundwater disruption; this was followed by an assessment based on the proposed new topographic conditions imposed by the development and subsequent operating conditions.

For each project section the procedure follows that illustrated in Figure 3-1. For each ten metre stretch of the project, the flow chart is used to determine the level of further investigation to be undertaken and ultimately the level of potential impact and corresponding impact mitigation requirements.

A rapid assessment of each project section is carried out to determine if there are potential environmental impacts or whether a Water Sharing Plan is in operation. If either situation applies, a detailed investigation is required.

There are no officially-listed GDEs along the project, but there are a number of wetlands and park areas that may receive groundwater as part of their water budget. Where such a feature is present, a high potential impact is assumed (that is, shallow water tables) and a detailed investigation is required.

If no GDEs are identified, but the area is included under a Water Sharing Plan, then this also instigates further investigation. If the area is not part of a Plan, then Macro Water Sharing Plan conditions apply and the potential impact is determined following the process outlined in the flow chart.

A review of available data is undertaken and where no groundwater data is available, guidelines for monitoring the potential impacts of the project are indicated. Where possible, data is extrapolated from outside the area to estimate potential future impact.

Crucial data includes: water levels below ground surface, water quality and abstraction information. In general, where there is high abstraction, the area will be covered under a water sharing plan. Extraction for stock and domestic purposes generally do not fall under detailed plans and are not metered. In the absence of groundwater extraction metering, NSW Office of Water assign nominal extraction volumes to bores used for stock and domestic purposes.

Potential impact to existing conditions gives an indication of potential impact from ANY activity at that location and has been undertaken to indicate the inherent potential impact to groundwater as a comparison to subsequent potential impact from the project.

Potential impacts during construction relates primarily to potential groundwater ingress at cuts and impacts from impediments to groundwater flow, such as deep fill in areas of shallow groundwater tables.

Potential impacts during operation takes into consideration the fact that groundwater tables would relax following initial interference and we can characterise a location based on the expected depth to water tables. Areas where groundwater is expected to remain above the ground surface, generally at deep cut locations, are designated as high potential impact.

All groundwater depths are extrapolated from the closest bore information, which may be several hundred metres from the project. The accuracy of the determination, therefore, reflects this spatial closeness and the distance to the bore used in the analysis is also indicated on the sections below. Further, in areas of little or no groundwater information, extrapolations may be over several hundred metres and the postulated watertable cannot be accurately determined. In these cases, two methods of interpolation have been used, representing the end-members of possible watertable depth:

- Assume the water table is a reflection of the overlying topography and interpolate between two bores assuming a water table form that mimics the surface
- Create an independent surface from bore information that does not consider the topography and superimpose this on the section.

For consistency, the potential impact analysis has been created using the former (following the topography) method. This should be refined as more information is made available (for example, see Figure 1-9).

The charts in Section 4.6 graphically illustrate the potential impact to groundwater as the impacts change with each phase of the project. The assessment uses the data in Appendix B, together with the project alignment and high resolution digital elevation model data to assign potential impact based on the criteria outlined in Chapter 1.

The relative intensity of data is illustrated on the charts and bore information has been used from bores up to 500 metres from the project axis. Two important caveats must be stated:

- Bores further from the project will provide less precise data than those on, or immediately adjacent to the project, but there has been no attempt to weight the information for this assessment. As further bores are drilled along the project route, this assessment can be rapidly up-dated to reflect the greater level of data confidence

- The relative location of groundwater bores may place them upstream or downstream of the project. Upstream bores can give more information on the nature and gradient of groundwater moving towards the project; those downstream give information on groundwater moving away from the site. Bores upstream of a cut section may respond more rapidly than those downstream, whilst bores downstream may respond more rapidly to fills that overlie very shallow groundwater systems.

Two methods for evaluating the watertable have been employed:

- Generate a surface from the available bore information and superimpose this on the topography. This would be the best methodology if data is sufficient to generate a continuous surface. Unfortunately, the low density of bore data means that long stretches are without watertable information and the interpolated surface is insufficiently constrained, especially where there is significant relief along the project
- A surface is generated by subtracting watertable depths for the local land surface and the depth is interpolated between points. The surface is created that follows the land surface subtracting the modelling depth below ground. This method more closely realises the true watertable surface where bores are not exactly on the project axis, but does not realise the moderating effect across significant topographic relief, so may generate a surface that is too deep across valley floors.

Where data exists, the two methods coincide, but in areas of little groundwater information there can be significant differences (up to 30 metres), particularly in areas of high relief.

Figure 3-1 Schematic of the groundwater potential impact assessment process

Water table maps were produced and these were compared to the topography and geomorphic features to determine the potential impact of high watertables and hence waterlogging and potential for salinity. If time series data is available then the natural variability in water tables was assessed for seasonal wetting and drying of the landscape. The distribution of soils potentially susceptible to ASS is reasonably well known and this layer was superimposed on the water table map to highlight areas of high potential impact of actual ASS.

In areas with little data, a baseflow assessment on proximal streams was carried out where stream gauges permitted. Where a significant component of baseflow was established, then groundwater was assumed to be close to the ground surface and the area downstream of the gauge was considered to have high water tables for the purposes of the potential impact assessment.

Other environmental factors that may have an impact on, or be impacted by, groundwater are also assessed. These factors include: presence of springs; Aboriginal sites (such as water holes, fish traps and seeps); heritage sites (such as wells, bores and windmills); estuaries and coastal marshes. Each ascribes specific constraints on groundwater use and requirements.

Once the assessment under current conditions was completed, each station was evaluated for cut, fill and by-pass locations and the assessment process was repeated to determine the revised groundwater levels in the vicinity of the new works. A potential impact level based on the rules outlined in Chapter 3.2 was then assigned to the section.

A groundwater potential impact may thus be assigned to each station along the project, based on the methodology outlined above. This potential impact must then be evaluated on whether the potential impact is to or from groundwater, a potential impact during the construction phase, or operational phase, or an intrinsic potential impact in the area. Much of the area passes through low-lying floodplains near the coast. These floodplains are the site of groundwater confluence with seawater, which dips below the coastal groundwater bodies due to the higher density of seawater. This seawater wedge is significantly deeper than the depth of influence of the project, but the overlying fresher groundwaters, emanating from the Great Dividing Range to the west of the coast, are maintained at or near sea-level throughout the floodplain areas. This is particularly evident across the floodplains of the Clarence and Richmond Rivers, particularly where the project crosses below the tidal reach and there would be on-going maintenance requirements for these stretches of the highway, with both the impact from groundwaters moving towards the ocean as well as impacts from sea-water inundating the floodplains during high tides. With the threat of increasing sea-levels over the next century, the latter would become more prevalent for the northern sections (8-11).

Principle potential impact in areas away from the coast will be where the route requires cuts through existing country. This will be considered in Chapter 4.

3.2.1. Cuts and fills

Of particular interest are areas where there will be significant change to the landscape. That is, where there are cuts and fills. No *a priori* cut and fill locations were assumed by the model, as the criticality is the height of the new road surface relative to the original ground and the revised relationship with the underlying watertable. The process to determine the potential impact associated with cut and fill areas is shown in Figure 3-2. Locations of planned cut and fill are shown in (Figure 3-3).

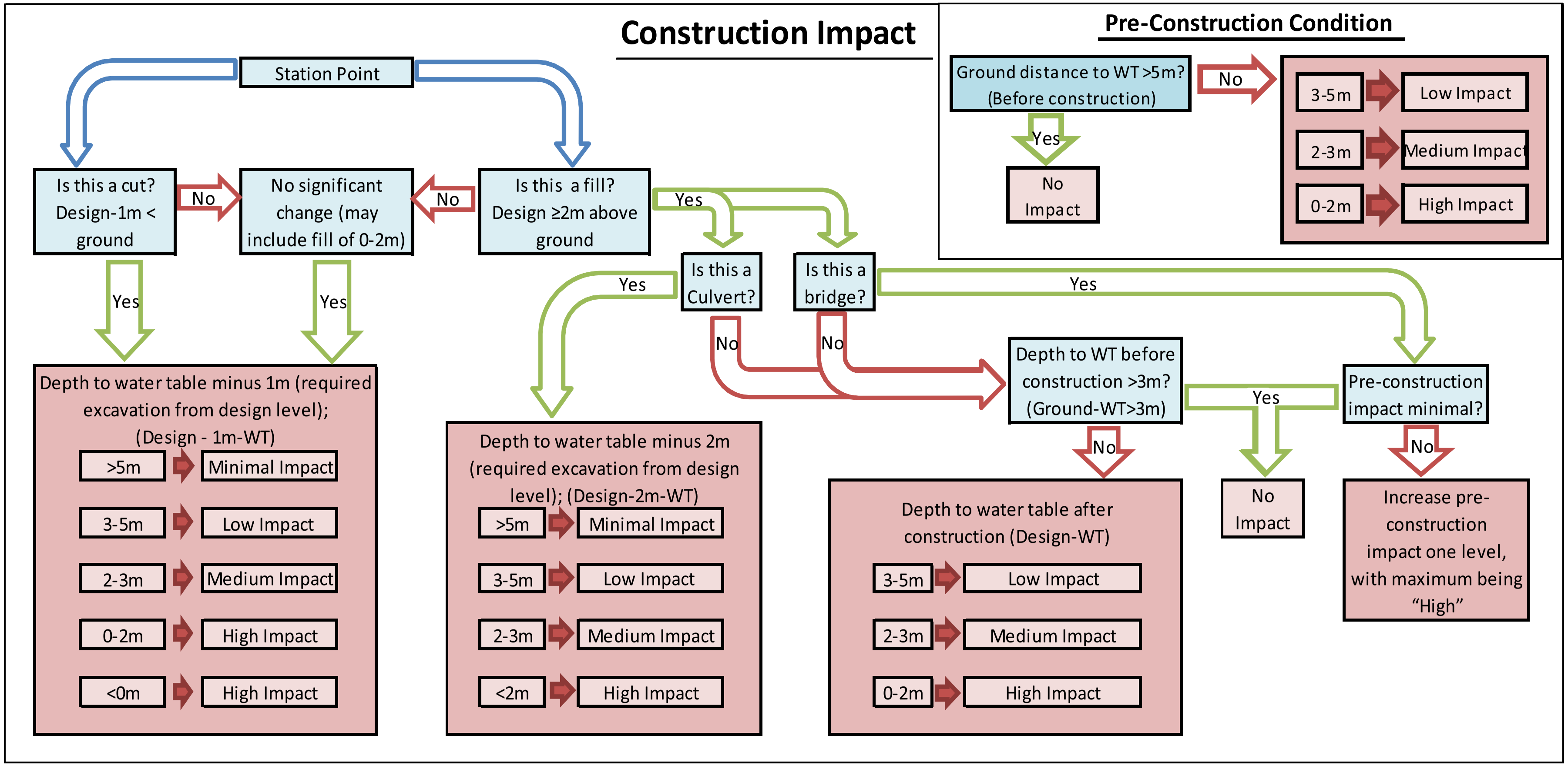
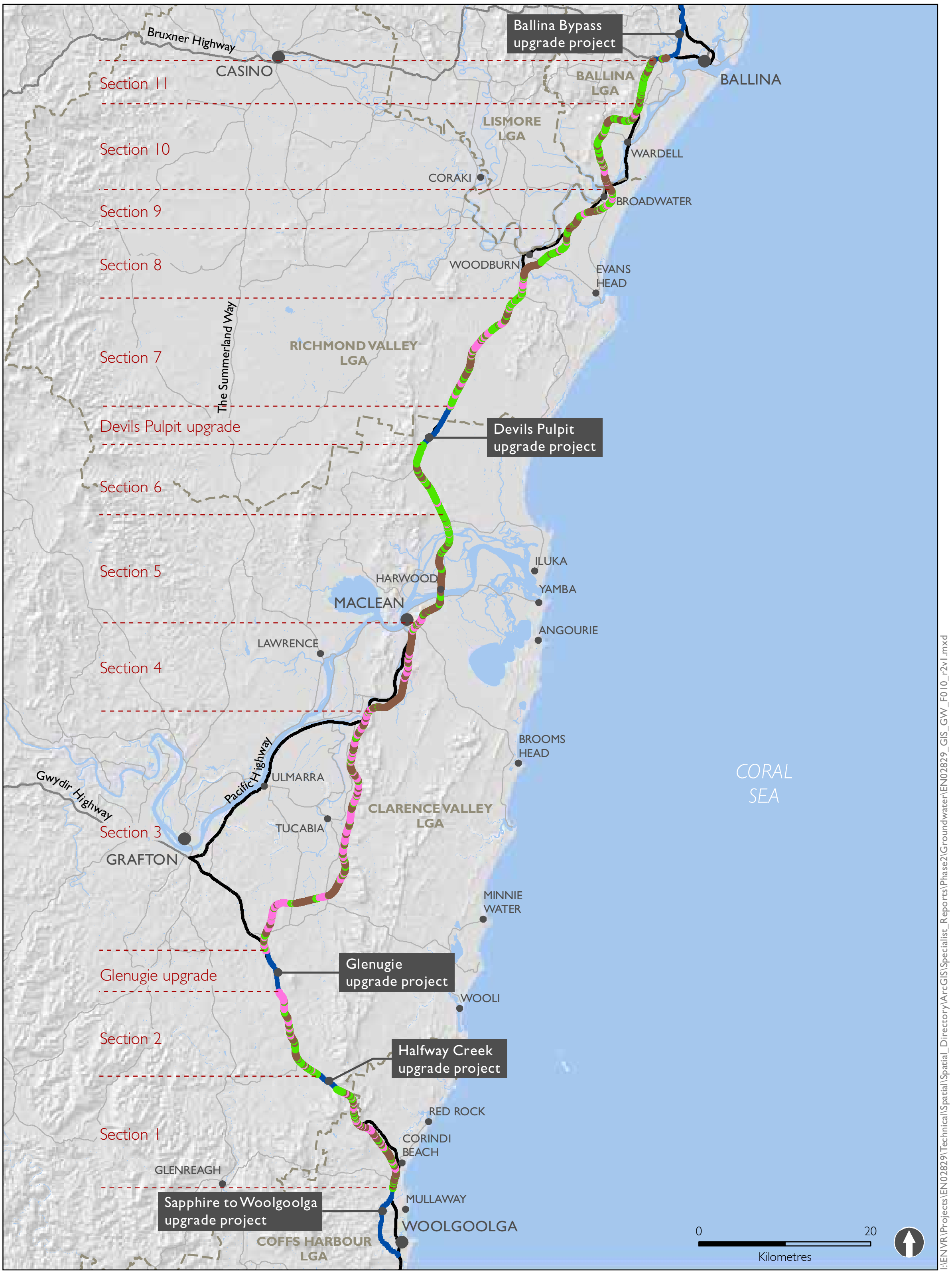


Figure 3-2. Logic diagram for determination of potential impacts to groundwater.

Figure 3-3 Cut and fill locations along the project



Pacific Highway upgrade
Existing Pacific Highway

Design change
- No change
- Fill
- Cut

3.3. Assessing impacts on the project

While the high potential impacts associated with the project are to the receiving environment, consideration should also be made of the impacts of groundwater on the project during both construction and operation.

3.3.1. Construction impacts

The main impacts of groundwater on the project construction phase are associated with ingress of groundwater at construction sites. Comparison to the pre-construction condition, therefore, provides an indication of appropriate measures to manage seepage during the construction phase. Groundwaters that are intercepted during the construction of cuts, for example, would initially seep at high rates, but this would subside as groundwater pressures are released due to free drainage. In general, areas of construction that are filled would have a lower potential impact from groundwater ingress relative to the natural (pre-construction) condition, while areas of cuts would have a higher potential impact.

3.3.2. Operation impacts

During operation, the primary potential impact areas would be those where cuts have penetrated into, or near, watertables and on-going seepage is likely unless alternative drainage or impedance measures are put in place. Cuts in areas of naturally high drainage (coastal sands, alluvial aquifers) would see a decrease in potential impact over time as groundwater pressures relax and re-equilibrate under the elevated discharge regime. In areas cut into rocks of low permeability (fractured rocks, porous sediments), the potential impact would remain high as groundwater pressures would not relax and seepage may continue throughout the life of the road. Thus, the former may require early and substantial impact mitigation measures but would not require on-going maintenance, while the latter may not require more than rudimentary drainage mitigation during construction and on-going maintenance of low seepage.

4. Groundwater impact assessment

4.1. General comments

During the pre-construction phase, that is, under current conditions, high levels of potential impact to groundwater from any activity would occur in the following two parts of the project (Figure 4-1)

- Sections 3 to 5, across the low and undulating landscape of the Clarence River floodplain
- Sections 8 to 11, across the floodplains of the Richmond River where the river meets the coastal lowlands between Woodburn and Ballina.

Potential impacts to groundwater in both these areas will rise during construction, particularly in areas of cuts where groundwater ingress is likely and these locations may develop a high potential impact. The areas that have the potential to impact (and be impacted by) groundwater during the construction phase are illustrated in Figure 4-2.

The percentage of the project affected by each identified groundwater impact level is identified in **Error! Reference source not found.** and illustrated in Figure 4-1 to Figure 4-3.

Table 4-1 Percentage groundwater potential impact extent for the project

POTENTIAL IMPACT[1]	Project Phase		
	Pre-construction	Construction	Operation
High	36%	31%	8%
Medium	13%	20%	18%
Low	23%	23%	27%
No potential impact	28%	26%	47%

[1] High potential impact occurs where groundwater is within two metres of the ground surface and/or actively discharging. Medium potential impact is considered where the groundwater table is within three metres of the surface and low potential impact, within five metres. Groundwater below five metres is considered to undergo no potential impact. All cut locations will include engineering measures to mitigate potential impacts to groundwater

Once the construction is complete, water tables will re-equilibrate with the new landscape. For most of the project alignment there will be little or no change compared to the initial conditions. In areas of fill the risk to groundwater may actually be reduced by the project. In cut areas, however, a number of locations will have a high potential impact and will require management to control groundwater ingress and to maintain the local groundwater conditions. Cuts will be designed to mitigate against groundwater impact. Subsequently, there will be only a few locations requiring additional and on-going investigation to determine the on-going potential impact to groundwater. These occur where shallow groundwaters occur and do not coincide with the cut locations (Figure 4-3 and Appendix A).

4.1.1. Potential impacts on groundwater-dependent ecosystems

There are several vegetation communities potentially impacted by the project which are considered to be a form of groundwater dependent ecosystem. These comprise vegetation occurring on waterways and floodplains which are likely to be reliant on groundwater, particularly during drought periods. Five vegetation communities and habitats have the potential to be affected by impacts to groundwater:

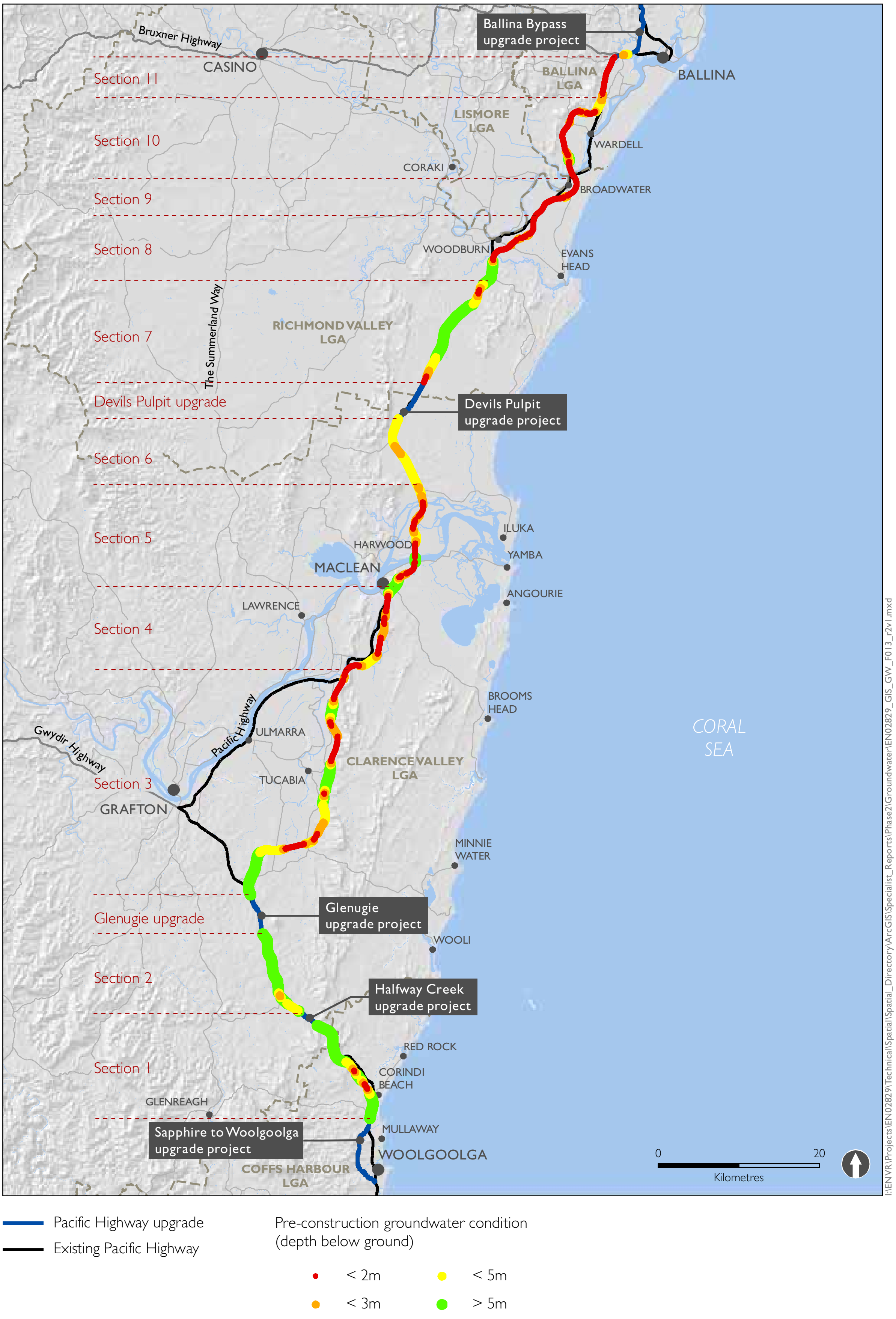
- Freshwater wetlands
- Sub-tropical coastal floodplain forest
- Swamp sclerophyll forest
- Swamp oak floodplain forest
- Lowland rainforest.

These communities are in part supported by shallow groundwater systems that effectively arrest the infiltration of surface waters. These systems are thus surface water reliant with the shallow groundwater acting as local storage that reduces effective evaporation and sustains each species. Elsewhere, groundwater is sourced from further afield and is brought to the surface due to impediment to flow or via a topographic low. Groundwater dependent systems therefore occur in many valleys and also in coastal sand environments. Road crossings of these communities can impact on the subsurface flows by blocking drainage passages and groundwater flows. Potential impacts on groundwater recharge rates from general road construction are generally greatest in areas where significant cuttings are required as they have the potential to intersect the water table and affect groundwater levels downstream.

The greatest impacts to groundwater dependent ecosystems are likely to occur within freshwater wetlands located in low lying floodplain areas which are intersected or near the project including the Upper Coldstream Wetland (Section 3), Clarence River Estuary (Section 5), Bundjalung National Park Wetlands (Section 6) and the wetland cluster on Tabbimoble Creek (Section 6). These wetlands have already been identified as under pressure from changed hydrological conditions, exotic weeds and grazing.

Oxleyan Pygmy Perch is an indicator species associated with swamps, streams and dune lakes that lie in the coastal lowland, ‘wallum’ ecosystems. These systems are typified as having little or no flow. Significant changes to the water table in these areas would, therefore, result in reduction of suitable habitat for these fish. Oxleyan Pygmy Perch is likely to occur in Redbank and Cassons Creek (Section 1), Tabbimoble Swamp Nature Reserve (Section 7) and Macdonalds Creek (Section 8)(Appendix A1-11 to A1-21).

Figure 4-1 Pre-construction groundwater levels along the project



4.2. Potential construction impacts

4.2.1. Potential construction impacts on groundwater supplies

Stock and domestic supplies

Assessment of specific stock and domestic bore impacts is beyond the scope of this assessment, but any bores located within potential high impact areas should be assessed during the detailed design phase with the aim of avoiding impacts on supplies.

Rous Water

The new highway will bisect the Rous Water Woodburn Sands borefield which has groundwater levels that are close to the surface. Construction works will mainly involve placement of fill for the new pavement. As such, construction of the project will have little or no impact on water levels, and hence no impact on water supply in this area.

4.2.2. Potential construction impacts on groundwater quality

Impact of surface water quality on groundwater

The main potential impact on groundwater quality would be contamination as a result of infiltration of polluted surface waters, or direct infiltration of contaminants from construction areas. Assessment of surface water quality impacts has been undertaken (Working Paper – Water Quality) and there is potential for changes to relative groundwater levels and potentially to groundwater quality.

Intersection of the water table during excavation works is likely at a number of locations and this will result in groundwater ingress and mixing with surface water. Localised diversions, or dewatering, may be required. Potential impacts to groundwater quality during construction include:

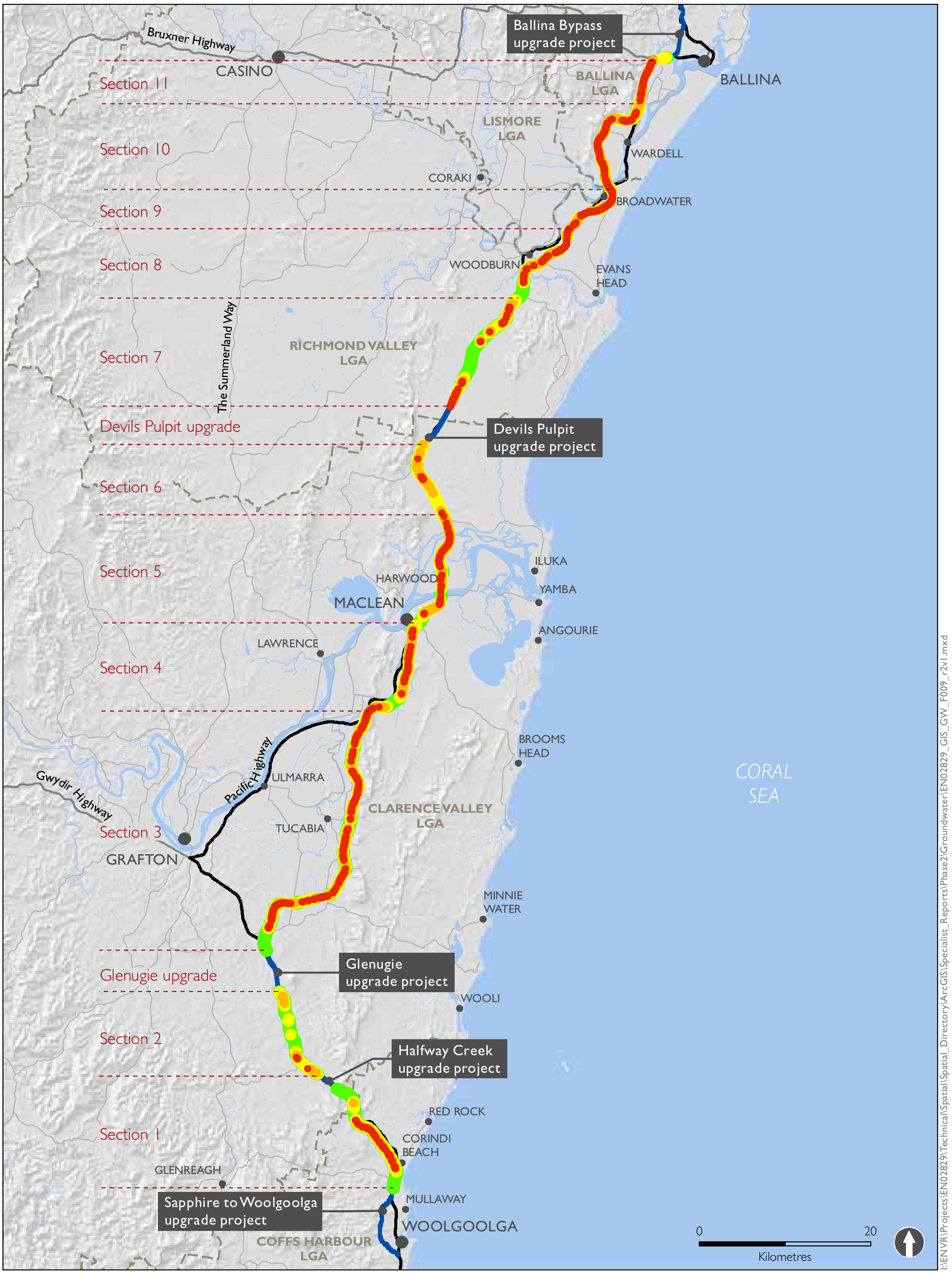
- Contamination by hydrocarbons from accidental fuel and chemical spills during construction activities, refuelling or through storage facilities
- Infiltration of contaminated surface water runoff from unpaved surfaces.

Infiltration of site runoff to groundwater sources is also possible. The process of infiltration, however, is generally effective in filtering polluting particles and sediment. Hence the risk of contamination of groundwater from any pollutants bound in particulate form is low. During construction, pollutants are most likely to be bound to particulate matter and would therefore be filtered during infiltration. However, some pollutants, such as hydrocarbons and solubles, may not be filtered through this process. The former will be trapped in the water quality basins and removed; the latter would need to be monitored and, if necessary, mitigation measures may need to be adopted.

Rous Water Woodburn borefield

In Section 8 of the project, there are three groundwater bores operated by Rous Water Regional Water Supply located east of Woodburn in the Richmond Valley. Groundwater from the bores is designated for a variety of purposes including for drinking water, agriculture and domestic purposes. Construction in the catchment of these bores could pollute surface water which may affect the quality of the groundwater source. Particular attention is needed to manage any construction activities that may impact on the bores. Mitigation measures are outlined in the Water Quality Report (RMS, 2012).

Figure 4-2 Construction phase groundwater potential impact for the project



Pacific Highway upgrade
Existing Pacific Highway

Construction phase potential impact level
High
Low
Medium
Minimal

4.2.3. Groundwater impacts on construction

As much of the route has existing groundwater levels that are close to the ground surface, there is a strong likelihood that groundwater exposure and discharge will be an issue for construction in areas where watertables are shallow. In particular, if construction proceeds during wet conditions, waterlogging through groundwater discharge is likely in all areas where watertables are naturally within two metres of the land surface. Areas of cut with high potential impact will require engineering measures to transfer discharging groundwater away from the construction site.

Construction and use of embankments will preferentially direct surface runoff and concentrate recharge to groundwaters. On soft soils, compaction may also occur restricting near-surface groundwater flow resulting in discharge and waterlogging.

4.3. Potential operational impacts

4.3.1. Potential operational impacts on groundwater supplies

Once the construction phase is complete, groundwater levels will re-equilibrate with the new topographic surface. In areas of fill there will be no impact on groundwater supplies. In areas of cut, watertables up-stream of the project may lower as the cut will increase discharge to the downstream side of the project. Thus, areas of cut that are designated high potential impact should be further evaluated, through ground surveys and monitoring before, during and following construction, to determine the potential impact on groundwater supplies.

4.3.2. Potential operational impacts on groundwater quality

Potential impact of surface water contamination on groundwater sources

Potential operational impacts to groundwater quality are similar to those described above for construction impacts.

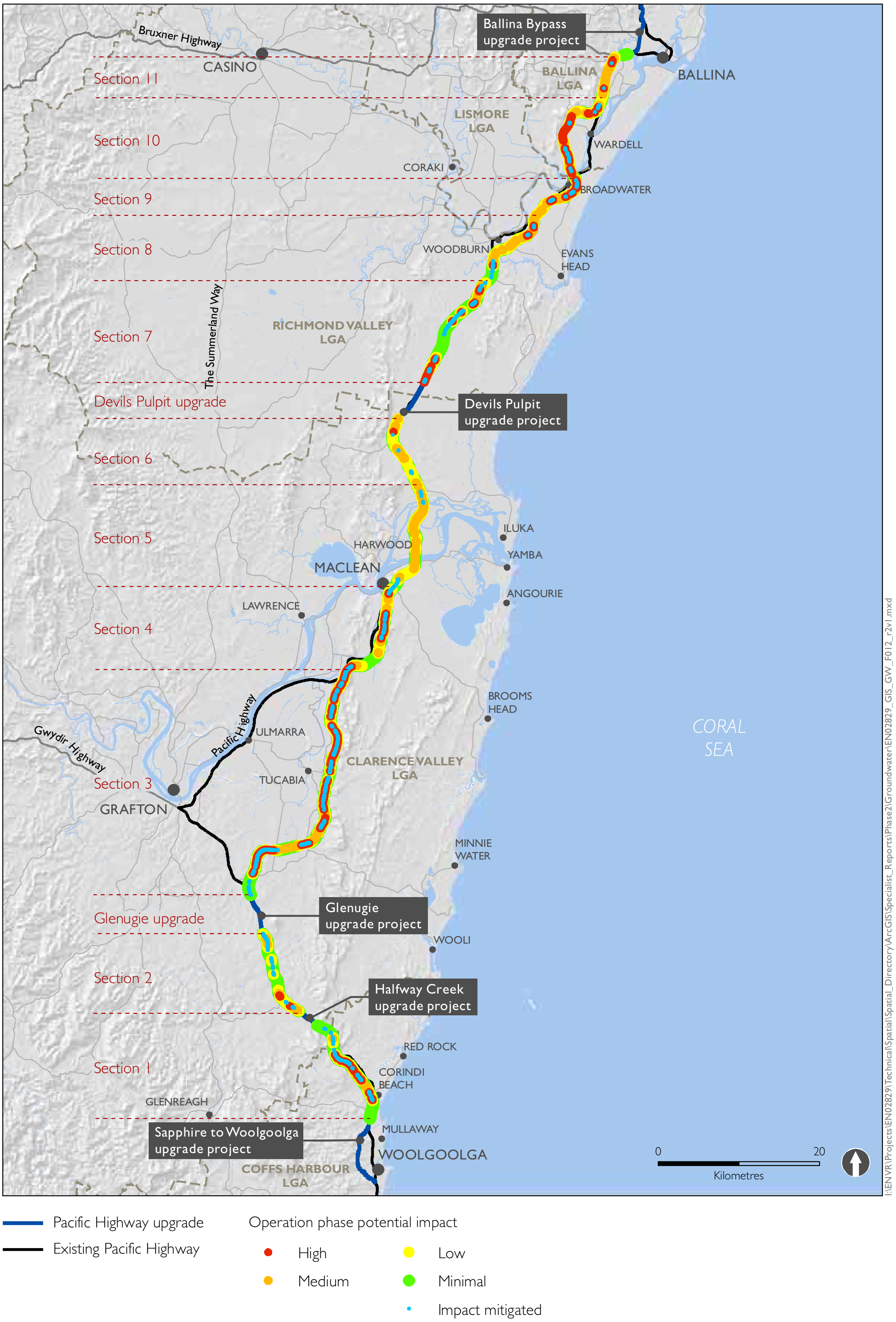
Rous Water Woodburn borefield

If left unmitigated, polluted runoff, spillages and leakages from the highway could flow with surface water and infiltrate into the shallow groundwater sources of the Rous Water Woodburn Sands borefield, polluting the groundwater source. Water quality structures would need to be designed to capture and divert road runoff so that seepage into groundwater sources does not occur.

Groundwater flow interference

In locations of significant cuts that intersect the existing water table, infiltration of unpolluted groundwater back into the ground would be facilitated by collection of the groundwater in grassed swales. Treatment of groundwater that contains pollutants would be treated in basins before either discharge to natural waterways, evaporation, or infiltration to downstream groundwater. Monitoring would be required to confirm that groundwater mounding does not become a problem.

Figure 4-3 Operation phase groundwater potential impact for the project



4.4. Potential impact summary

The percentage of the project affected by each identified groundwater impact level was collated in **Error! Reference source not found.** and illustrated in Figure 4-1 to Figure 4-3. A full list of cut locations and potential impacts prior to mitigation is given in Table 4-2.

Table 4-2 Summary table of potential impacts at all cut and bridge locations

Note: light grey shading denotes "out-of-scope – upgrade under construction"; dark grey denotes "bridge over North Arm of Clarence River"; OPP = Oxleyan Pygmy Perch

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
			Section 1			
2.3	2.7	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, coastal lagoon/lake	No known occurrence	Subtropical coastal floodplain forest
3.0	3.1	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, coastal lagoon/lake	No known occurrence	None
3.2	3.5	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, coastal lagoon/lake	No known occurrence	None
5.2	5.6	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, OPP habitat	No known occurrence	Subtropical coastal floodplain forest
5.9	6.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, OPP habitat	No known occurrence	Swamp sclerophyll forest
6.9	7.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, OPP habitat	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
7.6	8.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
8.2	8.4	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
8.8	8.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
9.1	9.2	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact.*	No	No known occurrence	None
9.4	9.5	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
9.8	10.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
10.1	10.2	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	Swamp sclerophyll forest
10.4	10.5	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
11.2	11.3	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
11.3	11.7	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
11.9	12.0	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
12.6	12.7	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
13.5	13.7	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
Section 2						
18.1	18.1	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
18.2	18.2	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
18.3	18.3	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
18.32	18.32	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
18.4	18.4	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
19.3	19.5	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
23.3	23.6	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
24.1	24.4	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
24.9	25.4	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
26.5	27.3	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
27510	29200	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
29460	29740	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
29910	30140	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
30220	30650	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
31810	32040	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
32450	32590	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
32940	33020	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
33060	33660	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
Section 3						
33.8	34.1	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
34.5	34.9	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
35.4	35.6	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
36.5	37.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-*	No	No known occurrence	Subtropical coastal floodplain forest

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
			reliant wetlands are present in the area of potential impact).			
37.5	38.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
38.1	39.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
39.1	39.6	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
39.7	40.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
40.2	41.3	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
41.6	41.7	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	Subtropical coastal floodplain forest
44.6	45.7	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
48.1	48.6	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
48.9	49.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
50.5	50.7	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
50.9	51.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
51.6	52.3	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
52.7	53.6	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	Subtropical coastal floodplain forest
53.8	54.6	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
55.2	56.6	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
57.5	58.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
58.3	58.6	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	Swamp sclerophyll forest
58.8	59.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
59.4	59.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	Lowland rainforest on coastal floodplains
60.3	60.7	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
61.2	61.4	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	Subtropical coastal floodplain forest
62.5	62.7	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
63.0	63.5	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
63.6	63.8	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
64.7	65.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
65.7	65.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
66.5	66.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
67.6	67.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
68.1	68.4	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
68.4	68.6	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
Section 4						
68.7	68.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
69.1	69.4	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
75.2	75.4	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
76.0	76.4	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
76.6	77.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).High probability of acid sulfate soils occurring in part of the cutting*	No	High probability of occurrence (partial)	None
77.6	77.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).High probability of acid sulfate soils occurring in part of the cutting*	Close, estuarine wetland	High probability of occurrence (partial)	Swamp sclerophyll forest
78.1	78.4	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
80.9	81.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
81.3	81.7	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
81.7	81.8	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
81.9	81.9	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
Section 5						
82.1	82.2	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
82.5	82.9	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
82.9	83.0	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
83.0	83.1	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
94.0	94.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut , Groundwater-reliant wetlands are present in the area of potential impact. High probability of acid sulfate soils occurring throughout cutting*	Yes, estuarine wetland (Chatsworth Island)	High probability of occurrence	None
94.0	94.04	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut , Groundwater-reliant wetlands are present in the area of potential impact. High probability of acid sulfate soils occurring throughout cutting*	Yes, estuarine wetland (Chatsworth Island)	High probability of occurrence	None
94.1	94.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut , Groundwater-reliant wetlands are present in the area of potential impact. High probability of acid sulfate soils occurring throughout cutting*	Yes, estuarine wetland (Chatsworth Island)	High probability of occurrence	None
94.1	94.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut , Groundwater-reliant wetlands are present in the area of potential impact. High probability of acid sulfate soils occurring throughout cutting*	Yes, estuarine wetland (Chatsworth Island)	High probability of occurrence	None
94.2	94.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut , Groundwater-reliant wetlands are present in the area of potential impact. High probability of acid sulfate soils occurring throughout cutting*	Yes, estuarine wetland (Chatsworth Island)	High probability of occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
94.2	94.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut , Groundwater-reliant wetlands are present in the area of potential impact. High probability of acid sulfate soils occurring throughout cutting*	Yes, estuarine wetland (Chatsworth Island)	High probability of occurrence	None
94.9	94.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact). Low probability of acid sulfate soils occurring throughout the cutting*	Close, estuarine wetland	Low probability of occurrence	None
95.1	95.1	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact). Low probability of acid sulfate soils occurring throughout the cutting.*	Close, estuarine wetland	Low probability of occurrence	None
95.3	95.3	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
95.3	95.4	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
95.4	95.5	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
95.5	95.5	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
Section 6						
98.0	98.2	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
101.2	101.3	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
103.4	103.4	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no*	No	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
			groundwater-reliant wetlands are present in the area of potential impact).			
105.8	106.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
107.2	107.8	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
108.3	109.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
110.0	110.1	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
110.3	110.4	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	Subtropical coastal floodplain forest
110.6	110.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	Subtropical coastal floodplain forest
110.9	111.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	Subtropical coastal floodplain forest
111.0	111.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
111.1	111.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
Section 7						
111.1	111.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
111.2	111.5	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
112.6	113.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
114.1	114.6	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No, close to OPP habitat	No known occurrence	None
117.6	117.7	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No, close to OPP habitat	No known occurrence	Close to swamp sclerophyll forest
118.1	118.3	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No, close to OPP habitat	No known occurrence	None
118.6	119.7	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	No	No known occurrence	None
119.9	120.0	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	No	No known occurrence	None
120.2	120.5	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands*	No	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
			are present in the vicinity of the cut.			
120.8	121.4	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, floodplain wetland	No known occurrence	None
122.8	123.3	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, floodplain wetland	No known occurrence	Swamp sclerophyll forest
124.8	125.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, floodplain wetland	No known occurrence	None
125.3	125.3	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, floodplain wetland	No known occurrence	None
125.4	125.4	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, floodplain wetland	No known occurrence	None
126.0	126.0	B	*No significant impacts to groundwater or water course related GDE's anticipated, but monitoring required to confirm long-term status (no groundwater-reliant wetlands are present in the area of potential impact).*	Yes, floodplain wetland	No known occurrence	None
			Section 8			
127.0	127.0	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	Yes, floodplain wetland	No known occurrence	None
127.1	127.1	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	Yes, floodplain wetland	No known occurrence	None
127.1	127.2	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	Yes, floodplain wetland	No known occurrence	None
127.2	127.2	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands are present in the vicinity of the cut.*	Yes, floodplain wetland	No known occurrence	None
127.7	127.9	C	*No measurable impact on local or regional groundwater systems or resources anticipated. No groundwater-reliant rainforest clusters or wetlands*	Yes, floodplain wetland	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
			are present in the vicinity of the cut.			
128.1	128.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	Swamp sclerophyll forest
129.0	129.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	Swamp sclerophyll forest
134.7	134.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact). Low probability of acid sulfate soils occurringoccurring throughout the cutting*	Close, estuarine wetland	Low probability of occurrence	Swamp sclerophyll forest
136.0	136.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact). Low probability of acid sulfate soils occurring throughout the cutting*	Close, estuarine wetland	Low probability of occurrence	None
136.3	136.3	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact). Low probability of acid sulfate soils occurring throughout the cutting*	Close, estuarine wetland	Low probability of occurrence	None
Section 9						
140.1	140.5	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact). Low probability of acid sulfate soils occurring throughout the cutting*	Close, coastal lagoon/lake	Low probability of occurrence	None
142.1	142.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland; close OPP habitat	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
142.9	142.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
142.9	142.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
143.0	143.3	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
144.0	144.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
144.3	144.5	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
144.8	144.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	Swamp sclerophyll forest
Section 10						
146.1	146.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
146.5	146.5	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
147.4	147.9	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).Low probability of acid sulfate soils occurring in parts of the cutting*	Close, reservoir	Low probability of occurrence (partial)	None
148.2	148.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, reservoir	No known occurrence	None
148.3	148.4	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, reservoir	No known occurrence	None
148.9	149.0	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, reservoir	No known occurrence	None
149.0	149.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, reservoir	No known occurrence	None
152.4	152.5	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, reservoir	No known occurrence	None
156.5	156.6	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
157.2	157.2	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	Lowland rainforest/subtropical coastal floodplain forest

Approx station		Cut type *	Potential impact prior to mitigation	Over wetlands / aquatic systems	Acid sulfate soils risk	Threatened ecological community
Start	Finish					
157.3	157.4	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
157.4	157.6	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut (no groundwater-reliant wetlands are present in the area of potential impact).*	Close, estuarine wetland	No known occurrence	None
Section 11						
159.8	159.8	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut , Groundwater-reliant wetlands are present in the area of potential impact. High probability of acid sulfate soils occurring throughout cutting*	Yes	High probability of occurrence	None
163.0	163.1	A	*Reduction of groundwater to local creeks, streams, springs and local water resource in the vicinity of the cut - within approximately 100m of cutting. Likely impact to water course related GDE's present in the vicinity of cut , Groundwater-reliant wetlands are present in the area of potential impact. High probability of acid sulfate soils occurring throughout cutting*	Yes, floodplain wetland	High probability of occurrence	Swamp oak floodplain forest

Note: light grey shading denotes "out-of-scope – upgrade under construction"; dark grey denotes "bridge over North Arm of Clarence River"

4.5. Section assessments

Each section of the project has been assessed for potential impact to groundwater based on existing conditions (see previous chapter), potential impact during construction of the project and potential impact during operation. Groundwater impacts are distinguished through the resultant groundwater table levels, as indicated in Figure 3-2, with high potential impact indicating that the project intersects the water table, medium potential impact due to water tables within 3 metres of the surface, low potential impact within 5 metres and minimal potential impact greater than 5 metres below ground level.

Summary results of the assessment are presented below for each Section.

4.5.1. Section 1 – Woolgoolga to Halfway Creek

From Woolgoolga, the project leaves the coastal sediments of the Coffs Harbour Region to rise over the Great Divide and on to the consolidated sedimentary aquifers of the Clarence-Moreton Basin. Water tables tend to follow the landscape and can be shallow in places.

There is a general lack of groundwater information in this section, although water tables are naturally shallow from station 4.0 through to station 7.0, and are deeper in the higher country.

The major cut centred at station 2.5 is likely to intersect the water table and seepage is likely. Seepage from the unconsolidated sediments may generate significant water initially, and would impose a potential impact during construction, but ingress would decrease rapidly and is unlikely to be an issue during operation. Conversely, the major cut centred at station 7.9 will be through fractured rocks (Carboniferous greywackes), so while initial seepage would be low, there is unlikely to be adequate relaxation of the water-table and ingress may continue to be an issue through the operational phase.

Small areas of threatened ecological communities will be impacted (see Biodiversity Working Paper), most notably subtropical coastal floodplain forest and swamp sclerophyll forest (Appendix A1) and the route crosses Casson Creek, a known habitat for the Oxleyan Pygmy Perch between stations 5.0 and 7.0.

As the project progresses over the Great Dividing Range and back into an undulating landscape, groundwater flow is to the west and lower rainfall results in decreasing recharge rates compared to rates east of the range. Consequently, water tables are generally low and groundwater constitutes a low potential impact to construction and construction constitutes a low potential impact to groundwater supplies.

Table 4-3 Summary groundwater impact assessment for Section 1

Underlying aquifers (GMU)	Coffs Harbour Coastal Sands; Coffs Harbour Metasediments; Clarence and Coffs Alluvium; Clarence-Moreton Basin consolidated Mesozoic sediments.
Water Sharing arrangements	Water Sharing Plan for Coffs Harbour Area Alluvial Aquifers for lower half of section. Clarence River Macro Water Sharing Plan inland.
Acid sulfate soils	Largely no known occurrence of ASS. Areas of low and high probability of occurrence mapped for the lowland coastal plains in the southern portion of route

	near the Arrawarra and Corindi Beach localities.
Groundwater levels	Little bore information, but generally groundwater levels appear to be deep, except where the project crosses creeks and lows in the landscape.
Level of potential construction impact	Locally high potential impact related to cut locations at Stations 2.5 and 7.9 which will intersect water tables.
Level of potential operational impact	Minimal potential impact throughout the section.

Table 4-4 Section 1 cut classification and potential groundwater impact assessment

Approx station		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
2.3	2.7	A	Yes	Yes	Likely
3.2	3.5	A	Yes	Yes	Likely
5.2	5.6	A	Yes	Yes	Likely
5.9	6.0	A	Yes	Yes	Likely
6.9	7.1	A	Yes	Yes	Likely
7.6	8.1	A	Yes	Yes	Likely
8.2	8.4	A	Yes	Yes	Likely
8.8	8.9	A	Yes	Yes	Likely
9.4	9.5	A	Yes	Yes	Likely
9.8	10.0	A	Yes	Yes	Likely
3.0	3.1	B	Probable	Yes	Unlikely
9.1	9.2	B	Probable	Yes	Unlikely
11.3	11.7	B	Probable	Yes	Unlikely
11.9	12.0	B	Probable	Yes	Unlikely
10.1	10.2	C	No	No	Not required
10.4	10.5	C	No	No	Not required
11.2	11.3	C	No	No	Not required

12.6	12.7	C	No	No	Not required
13.5	13.7	C	No	No	Not required

4.5.2. Section 2 – Halfway Creek to Glenugie upgrade

Groundwater levels appear to be deep through project section 2, except where local recharge via creeks causes elevated levels. These are generally observed where the project crosses Halfway Creek.

The project crosses the consolidated sediments of the Clarence-Moreton Basin and the project only requires minimal changes to the existing landscape through this section. There are only a few places where groundwater may impact on construction. It is unlikely that groundwater would have an impact on operation.

Very small areas of threatened ecological communities will be impacted (see Biodiversity Working Paper), most notably subtropical coastal floodplain forest, swamp sclerophyll forest and swamp oak floodplain forest (Appendix A1)

The project will have a minimal level of impact on groundwater throughout the section.

Table 4-5 Summary groundwater impact assessment for Section 2

Underlying aquifers (GMU)	Clarence-Moreton Basin consolidated Mesozoic sediments.
Water Sharing arrangements	Clarence River Macro Water Sharing Plan.
Acid sulfate soils	Entire section mapped as having no known occurrence of ASS.
Groundwater levels	Within five metres of the land surface in the southern part; becoming deeper to the north as the elevation rises.
Level of potential construction impact	Low potential impact associated with shallow watertables in the southern portion, reducing to minimal potential impact as the topography rises above 50 m AHD.
Level of potential operational impact	Minimal potential impact throughout the section.

Table 4-6 Section 2 cut classification and potential groundwater impact assessment

Approx station		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
18.1	18.1	B	Probable	Yes	Unlikely
18.2	18.2	B	Probable	Yes	Unlikely
18.3	18.3	B	Probable	Yes	Unlikely
18.32	18.32	B	Probable	Yes	Unlikely
18.4	18.4	B	Probable	Yes	Unlikely
19.3	19.5	B	Probable	Yes	Unlikely
23.3	23.6	B	Probable	Yes	Unlikely
24.9	25.4	B	Probable	Yes	Unlikely
26.5	27.3	B	Probable	Yes	Unlikely
24.1	24.4	C	No	No	Not required

4.5.3. Section 3 – Interchange at Glenugie to Tyndale

As the project diverges east from the existing Pacific Highway, it cuts through the headwaters of a number of tributaries of the Clarence River. Construction of the pavement requires numerous cuts and fills which may potentially impact and be impacted by groundwater. Data availability for this region, however, is extremely poor and a precautionary approach has been adopted until further information is gathered. Cuts have therefore been assessed a high potential impact during construction and minimal during operation, the latter due to the expected low seepage rates from the consolidated and fractured sediments and the expectation of engineering measures to mitigate potential impacts.

Cut and fill along this section of the project will alternate between cuts in consolidated (and often fractured) sediments with low, but continuous seepage through the construction and operational phase and fill in the intervening valleys where unconsolidated river alluvium dominates.

While information on groundwater is limited, local knowledge and the presence of waterholes (refer to Figure 1-9) associated with depressions suggests groundwater is near the surface. Culverts should be designed to cope with continuous discharge as baseflow in these creeks is expected to be high.

Small areas of threatened ecological communities will be impacted (see Biodiversity Working Paper), most notably subtropical coastal floodplain forest, swamp sclerophyll forest and swamp oak floodplain forest (Appendix A1).

Table 4-7 Summary groundwater impact assessment for Section 3

Underlying aquifers (GMU)	Clarence and Coffs Alluvium; Clarence-Moreton Basin consolidated Mesozoic sediments.
Water Sharing arrangements	Clarence River Macro Water Sharing Plan.
Acid sulfate soils	Largely no known occurrence of ASS. Route traverses several isolated areas of low and high probability of occurrence in the southern and central portions.
Groundwater levels	Deep in the southern, but rolling country in the central and northern areas results in the water table intersecting valley floors.
Level of potential construction impact	High potential impact for much of the section, especially in the north, where the project crosses valley floors and is associated with extensive cuts required in the northern hills.
Level of potential operational impact	Minimal potential impact throughout most of the section. Low potential impact in valley floors.

Table 4-8 Section 3 cut classification and potential groundwater impact assessment

Approx station		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
36.5	37.0	A	Yes	Yes	Likely
37.5	38.0	A	Yes	Yes	Likely
38.1	39.0	A	Yes	Yes	Likely
39.1	39.6	A	Yes	Yes	Likely
39.7	40.1	A	Yes	Yes	Likely
40.2	41.3	A	Yes	Yes	Likely
44.6	45.7	A	Yes	Yes	Likely
48.1	48.6	A	Yes	Yes	Likely
48.9	49.1	A	Yes	Yes	Likely
50.5	50.7	A	Yes	Yes	Likely
50.9	51.2	A	Yes	Yes	Likely
51.6	52.3	A	Yes	Yes	Likely

Approx station		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
52.7	53.6	A	Yes	Yes	Likely
53.8	54.6	A	Yes	Yes	Likely
55.2	56.6	A	Yes	Yes	Likely
57.5	58.2	A	Yes	Yes	Likely
58.3	58.6	A	Yes	Yes	Likely
58.8	59.2	A	Yes	Yes	Likely
59.4	59.9	A	Yes	Yes	Likely
60.3	60.7	A	Yes	Yes	Likely
61.2	61.4	A	Yes	Yes	Likely
62.5	62.7	A	Yes	Yes	Likely
63.0	63.5	A	Yes	Yes	Likely
63.6	63.8	A	Yes	Yes	Likely
64.7	65.2	A	Yes	Yes	Likely
65.7	65.9	A	Yes	Yes	Likely
66.5	66.9	A	Yes	Yes	Likely
67.6	67.9	A	Yes	Yes	Likely
68.1	68.4	A	Yes	Yes	Likely
68.4	68.6	A	Yes	Yes	Likely
68.7	68.9	A	Yes	Yes	Likely
41.6	41.7	B	Probable	Yes	Unlikely
33.8	34.1	C	No	No	Not required
34.5	34.9	C	No	No	Not required
35.4	35.6	C	No	No	Not required

4.5.4. Section 4 – Tyndale to Maclean

Section 4 of the project runs adjacent to the South Arm of Clarence River until just south of where it crosses the river near Maclean. It crosses Shark Creek and runs in close proximity to SEPP 14 wetland (Wetland No. 232). This wetland will be supported by groundwater discharge to the floodplain, with most observed groundwater levels at or close to sea-level.

The numerous cuts through unconsolidated sediments of the Clarence River Alluvium will potentially invoke ingress of groundwater during construction, although potential operational impact is low as the water levels equilibrate with those of the surrounding floodplain. Preferential recharge from the rises may cause operational load on the road in fill areas. Shallow groundwaters are likely to vary in depth with the seasons leading to a wetting-drying regime. The route passes through a region of high acid sulfate soil risk and areas of fill may induce variable ponding on the upstream side of the project during operation and drying on the downstream side. Due to the very low groundwater gradients in this area, upstream and downstream may alternate with the seasons which can further exacerbate the risk of acid release along the section.

Very small areas of threatened ecological communities will be impacted (see Biodiversity Working Paper), most notably subtropical coastal floodplain forest and swamp sclerophyll forest (Appendix A1).

Table 4-9 Summary groundwater impact assessment for Section 4

Underlying aquifers (GMU)	Clarence and Coffs Alluvium; Clarence-Moreton Basin consolidated Mesozoic sediments.
Water Sharing arrangements	Clarence River Macro Water Sharing Plan.
Acid sulfate soils	Majority of section mapped as having a high probability of occurrence. Isolated areas of no known occurrence located in the central and northern portions near the Maclean locality.
Groundwater levels	Shallow groundwaters associated with the floodplain of the Clarence River tributaries.
Level of potential construction impact	High potential impact at cut locations and along the floodplain.
Level of potential operational impact	Minimal potential impact throughout most of the section. Possible medium potential impact along the floodplain.

Table 4-10 Section 4 cut classification and potential groundwater impact assessment

Approx station		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
69.1	69.4	A	Yes	Yes	Likely
75.2	75.4	A	Yes	Yes	Likely
76.0	76.4	A	Yes	Yes	Likely
76.6	77.1	A	Yes	Yes	Likely
77.6	77.9	A	Yes	Yes	Likely
78.1	78.4	A	Yes	Yes	Likely
80.9	81.0	A	Yes	Yes	Likely
81.3	81.7	B	Probable	Yes	Unlikely
81.7	81.8	C	No	No	Not required
81.9	81.9	C	No	No	Not required

4.5.5. Section 5 – Maclean to the interchange at Iluka

Section 5 crosses the main waterways of James Creek, Clarence River at Harwood Bridge, Serpentine Channel and North Arm (upstream of Clarence River). Major works at the sites of bridges would be impacted by shallow groundwater tables but are unlikely to impose any impact on the groundwater resource, or on groundwater supply for wetlands.

Acid sulfate soils are known to occur and there is a high probability of disturbance along the route (Appendix A1).

Table 4-11 Summary groundwater impact assessment for Section 5

Underlying aquifers (GMU)	Clarence Coastal Sands.
Water Sharing arrangements	Clarence River Macro Water Sharing Plan.
Acid sulfate soils	High probability of acid sulfate soils along entire section.
Groundwater levels	Shallow water tables across the floodplains of the Clarence River, deepening through elevated areas.
Level of potential	Medium to high potential impact throughout the section, except for the elevated

construction impact	area between stations 8.1 and 8.3.
Level of potential operational impact	Minimal potential impact throughout most of the section.

Table 4-12 Section 5 cut classification and potential groundwater impact assessment

Approx station		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
94.0	94.0	A	Yes	Yes	Likely
94.0	94.04	A	Yes	Yes	Likely
94.1	94.1	A	Yes	Yes	Likely
94.1	94.1	A	Yes	Yes	Likely
94.2	94.2	A	Yes	Yes	Likely
94.2	94.2	A	Yes	Yes	Likely
94.9	94.9	A	Yes	Yes	Likely
82.9	83.0	B	Probable	Yes	Unlikely
83.0	83.1	B	Probable	Yes	Unlikely
95.1	95.1	B	Probable	Yes	Unlikely
95.3	95.3	B	Probable	Yes	Unlikely
95.3	95.4	B	Probable	Yes	Unlikely
95.4	95.5	B	Probable	Yes	Unlikely
95.5	95.5	B	Probable	Yes	Unlikely
82.1	82.2	C	No	No	Not required
82.5	82.9	C	No	No	Not required

4.5.6. Section 6 – Interchange at Iluka to Devils Pulpit upgrade

Section 6 crosses the main waterways Nyrang Creek and Tabbimoble Creek. Tabbimoble Creek recorded high levels of aluminium, which could be a result of acid leaching from acid sulfate soils in the area. Elevated country in the southern part should mean there will be minimal or no impacts, though there is not much data to confirm this.

Culverts and cuts pose the highest potential impact to groundwater levels, but this potential impact will dissipate during construction and be minimal for the operational phase.

Small areas of threatened ecological communities will be impacted (see Biodiversity Working Paper), most notably subtropical coastal floodplain forest and swamp sclerophyll forest (Appendix A1).

Table 4-13 Summary groundwater impact assessment for Section 6

Underlying aquifers (GMU)	Clarence and Coffs Alluvium; Clarence-Moreton Basin consolidated Mesozoic sediments.
Water Sharing arrangements	Clarence River Macro Water Sharing Plan.
Acid sulfate soils	Entire section mapped as having no known occurrence of acid sulfate soils. However an area of low probability of occurrence is located immediately west of the route in the southern portion.
Groundwater levels	Very little data, but watertables appear to be relatively deep through this section.
Level of potential construction impact	Minimal potential impact throughout most of the section. Possible low potential impact along the floodplain.
Level of potential operational impact	Minimal potential impact throughout the section.

Table 4-14 Section 6 cut classification and potential groundwater impact assessment

Approx station		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
101.2	101.3	A	Yes	Yes	Likely
98.0	98.2	B	Probable	Yes	Unlikely
103.4	103.4	B	Probable	Yes	Unlikely

4.5.7. Section 7 – Devils Pulpit upgrade to Trustums Hill

Along this section of the project, the waterways are mostly ephemeral and only flow after heavy or prolonged rainfall. The landscape is subdued and watertables, where measured, are relatively deep (generally greater than five metres), implying little or no impact, but the lack of groundwater data means additional measurements need to be taken before and during construction to check the depth to the watertable in the low-lying country.

Areas of threatened ecological communities will be impacted (see Biodiversity Working Paper), most notably subtropical coastal floodplain forest and swamp sclerophyll forest (Appendix A1). Habitat for Oxleyan Pygmy Perch occurs at Station 114.0 and Tabbimobile Swamp (east of Stations 116.0 to 119.0), but the deep apparent groundwater tables suggest that groundwater is not a primary source of water, though additional measurements should be undertaken to determine whether perched systems are present.

Table 4-15 Summary groundwater impact assessment for Section 7

Underlying aquifers (GMU)	Clarence-Moreton Basin; Clarence and Coffs Alluvium; Richmond River Alluvium; Richmond Coastal Sands.
Water Sharing arrangements	Clarence River Macro Water Sharing Plan; Richmond River Area Alluvial Aquifer Water Sharing Plan.
Acid sulfate soils	Majority of section mapped as having no known occurrence of acid sulfate soils. Isolated areas of low and high probability located in the northern portion of route on both the eastern and western sides of the project.
Groundwater levels	Very little data. Watertables are expected to be deep in elevated areas and shallow within the floodplain.
Level of potential construction impact	High potential impact due to location across floodplain, but needs verification of water levels prior to construction.
Level of potential operational impact	Minimal potential impact.

Table 4-16 Section 7 cut classification and potential groundwater impact assessment

Approx Chainage		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
110.6	111.0	A	Yes	Yes	Likely
110.9	111.0	A	Yes	Yes	Likely
111.0	111.1	A	Yes	Yes	Likely

Approx Chainage		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
111.1	111.1	A	Yes	Yes	Likely
111.1	111.2	A	Yes	Yes	Likely
111.2	111.5	A	Yes	Yes	Likely
112.6	113.0	A	Yes	Yes	Likely
114.1	114.6	A	Yes	Yes	Likely
118.6	119.7	A	Yes	Yes	Likely
120.8	121.4	A	Yes	Yes	Likely
122.8	123.3	A	Yes	Yes	Likely
124.8	125.0	A	Yes	Yes	Likely
110.0	110.1	B	Probable	Yes	Unlikely
110.3	110.4	B	Probable	Yes	Unlikely
125.3	125.3	B	Probable	Yes	Unlikely
125.4	125.4	B	Probable	Yes	Unlikely
126.0	126.0	B	Probable	Yes	Unlikely
117.6	117.7	C	No	No	Not required
118.1	118.3	C	No	No	Not required
119.9	120.0	C	No	No	Not required
120.2	120.5	C	No	No	Not required

4.5.8. Section 8 – Trustums Hill to Broadwater National Park

Section 8 of the project crosses the main waterways of Macdonalds Creek and Tuckombil Canal (which feeds into Evans River). Both Rocky Mouth Creek (upstream of Tuckombil Canal) and Tuckombil Canal have highly variable water quality and are subject to acidic influxes from acid sulfate soils in the catchment. Mid-way through this section, the project crosses (bisects) the Woodburn Borefield, an important drought relief supply for the region, managed by Rous Water.

Most of this section has a high inherent potential impact from shallow groundwater, though most of the section will be fill, which would reduce operational impact. Compaction of shallow sediments, however, may lead to ponding of groundwater upstream of the project and lowering of watertables downstream. The latter may cause oxidation of ASS and subsequent re-wetting may lead to generation of sulphuric acid, while salinisation of the landscape is possible if there is inadequate drainage to remove remobilised salts. Additional culverts may be required.

A further complication is that the landscape and hence groundwater flow gradients are extremely low (sub-horizontal) in this section and flow may vary seasonally and with wetting-drying climate cycles. Hence, groundwater flow may not always coincide with surface water features.

Areas of threatened ecological communities will be impacted (see Biodiversity Working Paper), most notably swamp oak floodplain forest, with some subtropical coastal floodplain forest in the southern parts (Appendix A1).

Rous Water borefield

Rous Water operates two groundwater sources: one from bores in the Woodburn Sands aquifer and one tapping the Alstonville Plateau groundwater source (Innovation Planning Australia, 2009). The Woodburn Sands aquifer underlies the northern portion of the project, from station 131.4 through to the end of the project at station 164.0 and beyond past Ballina. The Woodburn Borefield is about two kilometres southeast of Woodburn Township and the project crosses the borefield at station 132.3. The report *Additional Hydrogeological studies near Rous Water's Woodburn Borefield* (Coffey 2006) (prepared as part of the Woodburn to Ballina Pacific Highway project) identified that three bores are operational (Table 4-17) and are installed into the Woodburn Sand aquifer.

Licence conditions restrict each of these bores to a maximum abstraction rate of 12l/s and a maximum abstraction volume of 242 megalitres in any 12 month period.

Table 4-17 Rous Water groundwater extraction bores in the Woodburn Borefield

Bore ID	Date completed	License numbers	Screened intervals (metres below ground level)	Easting / Northing (GDA 94 / MGA 56)
GW040869	13/11/2002	30BL180631 (Town Water Supply), 30BL180469 (Test Bore)	10.5 – 14.5	535458 / 6783035
GW040868	13/11/2002	30BL180469 (Test Bore) 30BL180632 (Town Water Supply)	16.0 – 20.0	535058 / 6783482
GW053237	01/01/1971	30BL119125 (Town Water Supply)	13.0 – 17.0	536113 / 6782778

Groundwater levels in the area are generally close to the ground surface. Groundwater flow is broadly to the north towards the Richmond River, although the very low gradients mean that this flow direction can change between wet and dry seasons. The area is also listed as susceptible to acid sulfate soils in the subsurface, which would be an issue if the watertable were to significantly drop. Proximity to the ocean, however, means that the floodplain elevation is less than three metres and the corresponding groundwater levels are at or slightly above sea-level and are unlikely to drop significantly. Hence, while there is a high probability of acid sulfate soils at depth, it is unlikely that these would be exposed as the project does not require excavation in this area. Thus, while watertables remain within two metres of the ground surface, there is unlikely to be any acid sulfate soil impact on the borefield (Figure 4-4).

The project in this area is along a new alignment with an overpass for Woodburn Evans Head Road over the highway. Watertables are shallow in this region and pose a potential impact to construction, though this would dissipate in the operational phase, once the bridge and new highway are completed. The existing Pacific Highway is two kilometres to the west. The distances of each bore to the new road alignments are shown in Table 4-18.

Table 4-18 Distance of Rous Water bores to the project

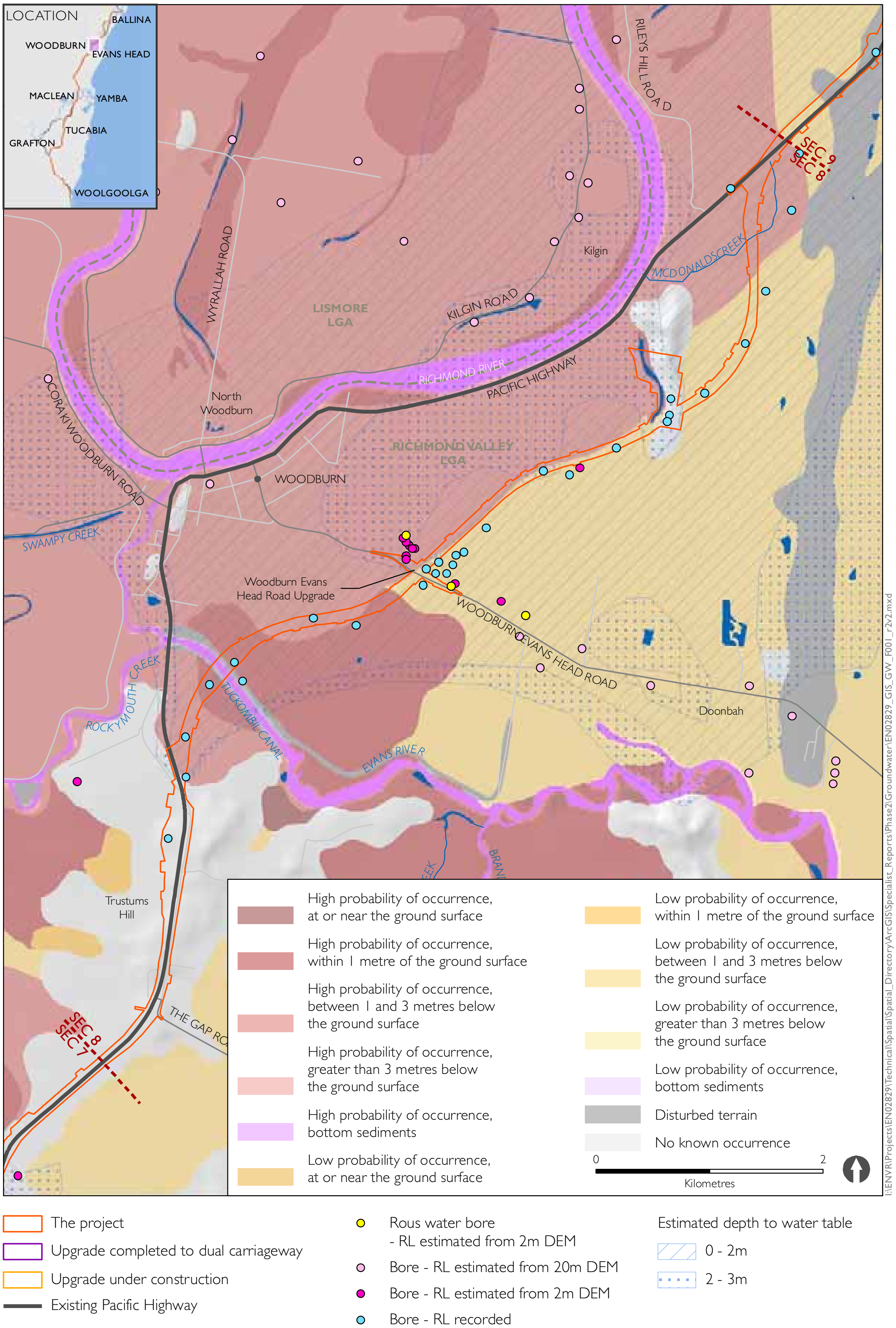
Bore ID	Distance to project (metres) / Station ID	Distance to Woodburn - Evans Head Road* (m) / Station ID
GW040869	296 / 132.3	27 /780
GW040868	303 / 132.3	210 / 240
GW053237	930 / 132.6	597 / 890

*Distance calculation to Woodburn-Evans Head Road only considers the road in the project.

Rous Water bores are used intermittently for reserve supply and the groundwater contains relatively high concentration of dissolved solids (principally iron) requiring treatment at site before transfer to the municipal system. Rous Water have indicated that they regard the Woodburn Sands borefield as an important water resource which should be protected from the potential impacts of the project (W. Franklin, Rous Water, *pers. comm. 22nd February, 2012.*). Important to this, is the preservation of a clay layer that overlies the Woodburn Sands aquifer and acts as an intermittently impermeable barrier in the vicinity of the borefield. The clay appears to be between 0.6 and 2.2 metres in the immediate area, but there are no direct measurements in the vicinity of the project (Figure 4-5). Coffey (2006), note, however, that *"in a number of locations drainage ditches were observed to transect the study area. The depth of these ditches was estimated to range up to around 1m. Given the observed thickness of the clay in the study area, it is possible that these drainage ditches (and possibly some nearby farm dams) have penetrated the clay, with the waters within these ditches and dams directly connected to the underlying Woodburn Sands."*

"The clay unit appears to have been penetrated in a number of locations by drainage ditches. To date the location of these ditches and/or similar penetrations to the clay unit have not been identified. Anecdotal evidence from farmers in the district suggest that local clays may fissure under drying, although no evidence of this was noted during the field work component of this study. Penetrations of the clay unit (including drying fissures, if indeed present) would allow surficial contaminants to enter the Woodburn Sand aquifer within potentially a short period of time." (op cit., p.13).

Figure 4-4 Combined watertable and acid sulfate soils risk map for Woodburn area



Coffey (2006) provided an interpreted geological sequence in the vicinity of Woodburn Sands borefield as follows:

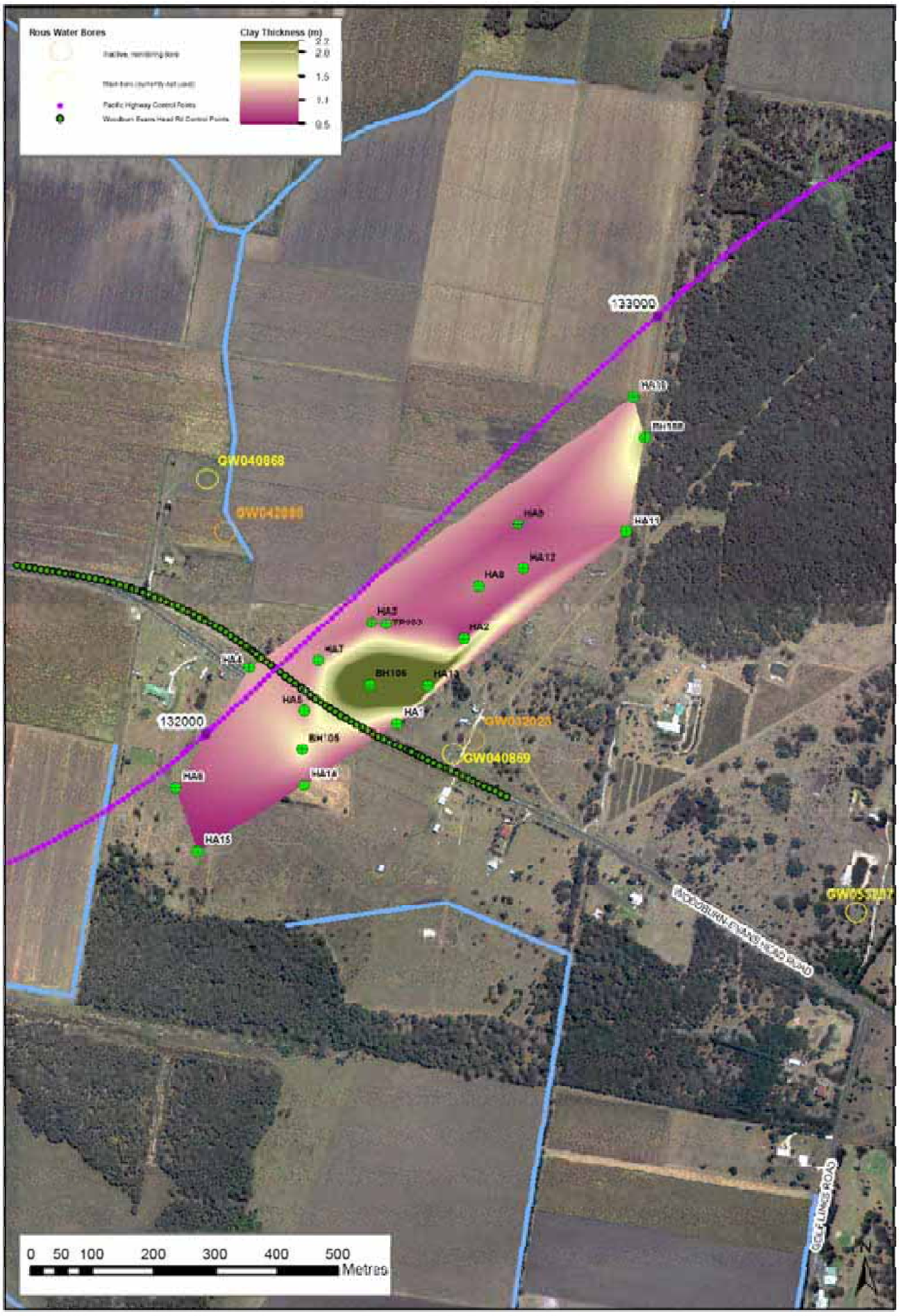
- **Alluvial clay**. The observed thickness of this low permeability unit ranges between 0.6 and 2.1 metres, averaging about one metre thick
- **Woodburn Sand**. A fine to medium sand with some silt content, this high permeability unit ranges from 7.7 to 16.8 metres in this vicinity and is reported to be the most important water bearing unconsolidated deposit in the Richmond River Valley. Groundwater levels recently measured in boreholes located near the Rous Water borefield indicate depths of around 1.4m to 1.5m below the surface. This is the principal aquifer for the region and the borefield bores are screened across this unit
- **Doonbah Clay**. A highly weathered, low permeability, marine clay sequence with minor sand lenses that unconformably overlies consolidated bedrock. The measured thickness ranges from 4.5 to 10.3 metres, averaging towards the thicker value, but locally absent
- **Sandstone.** A consolidated, orange/brown to grey, thickly-bedded, coarse-grained quartzose sandstone that probably represents the Jurassic Gatton Sandstone of the Bundamba Group. Groundwater movement is mostly via joints and fractures and the unit is generally of low permeability. This unit was intercepted in deeper bores at 17 to 23 metres and constitutes the bedrock of the sequence.

Coffey (2006) determined aquifer parameters for the aquifer based on earlier pump tests which gave a transmissivity value of 163 metres squared per day (m^2/day) for GW040869 (also known as Woodburn 1) and 326 m^2/day for GW040868 (Woodburn 2). Groundwater flow was determined to be to the north-west, towards the Richmond River, 1.6 to 1.9 kilometres to the north of the borefield. It is expected, however, that natural flow gradients in these floodplain environments will be very low and flow may vary with seasonal conditions. As a precautionary approach, it should be assumed that flow may be in any direction to or from the borefield.

Coffey (2006) used the Wellhead Protection Zone approach outlined in the NSW Groundwater Protection Policy to assess whether the project may present potential risks to the Rous Water Woodburn Sands borefield. Specifically, Coffey (2006) estimated the 50 day and 400 day travel time radii (representing possible Wellhead Protection Zones I and II) for Woodburn 1 Bore under abstraction at the maximum licensed pumping rate. Thus, 50 day travel times are estimated at 80 metres and 65 metres for GW040869 and GW040869, respectively, while 400 days travel times are 185 metres and 148 metres. These distances are based on applying the maximum pump rate (12l/s) to each bore for 50 days and an optimum pump rate (7.7 litres per second) over 400 days.

Recharge to the Woodburn Sands aquifer is via direct (diffuse) recharge from local rainfall infiltrating through the soil profile, with additional lateral recharge from local elevated areas. This recharge is directed to zones where the alluvial clay is thin or absent and local groundwater mounds would develop in these areas during wet periods, relaxing during dry periods. The presence of clay in the vicinity of the borefield suggests that recharge is from further afield in this area, likely from Trustums Hill and other local high ground. As Coffey (2006) note, however, penetration of the clay by drainage ditches may also provide preferential flow conduits for recharge in the area and local runoff would concentrate in these features.

Figure 4-5 Modelled clay thickness above the Woodburn Sands aquifer in the vicinity of the Woodburn Borefield (Rous Water)



Key elements that need to be further investigated during the detailed design phase of the project include:

- Temporal flow information is required to confirm the natural of groundwater flow in the area, including the flow paths during wet and dry years and the corresponding impact on bore sites

- Further geotechnical investigation of clay thickness is required to determine the depth within the Wellhead Protection Zones and the nature of the clays to identify their context, specifically whether they represent cracking clays or whether there are potential leakage pathways, such as deep drains. The clay layer in the area is an important aspect to protecting the groundwater

- The sand aquifer sits between two clay layers. The important issue is to prevent any pathway for road surface water to enter the aquifers. Appropriate design of the contamination mitigation from surface waters is the key to aquifer protection.

Groundwater modelling may be required, but analytical solutions are suggested rather than numerical models as the flat gradients of the water table and varying flow direction of groundwater waters depending on the season is not conducive to accurate modelling results. General trends and limits to surface-groundwater interactions will provide a clearer guide to possible impacts and hence mitigation measures.

In general, as construction proceeds, potential impact to the groundwater supply should decrease as the filled sections provide an additional buffer between the road and the watertable. The primary potential impact during operation would be via spills and preferential, localised, recharge of contaminants. Design features should be incorporated into the surface water/water quality basin design to mitigate this possibility.

A particular area to note is the potential earthworks borrow area at Lang Hill, station 13.5. An unnamed waterway runs through the site, which is potential habitat for Oxleyan Pygmy Perch. Removal of material below the height of the stream bed may induce enhanced groundwater flow away from the waterway resulting in reduction in low flow conditions. The detailed design would need to provide controls to ensure the works do not impact the water quantity and quality of the Oxleyan Pygmy Perch habitat during construction or rehabilitation of the site.

Table 4-19 Summary groundwater impact assessment for Section 8

Underlying aquifers (GMU)	Clarence-Moreton Basin; Richmond River Alluvium; Richmond Coastal Sands.
Water Sharing arrangements	Richmond River Area Alluvial Aquifer Water Sharing Plan.
Acid sulfate soils	Majority of section mapped as having a high probability of occurrence and is located close to the boundary of low and high probability areas to the north of Woodburn. Southern extremity of route mapped as having no known occurrence of acid sulfate soils.
Groundwater levels	Shallow watertables across the floodplains, deepening in higher areas.
Level of potential construction impact	High potential impact across the floodplain; Woodburn Borefield requires careful management, with additional geotechnical investigations needed to determine appropriate mitigation strategies.
Level of potential operational impact	On-going monitoring required; potential impact should be minimal following mitigation measures.

Table 4-20 Section 8 cut classification and potential groundwater impact assessment

Approx station		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
128.1	128.9	A	Yes	Yes	Likely
129.0	129.1	A	Yes	Yes	Likely
134.7	134.9	A	Yes	Yes	Likely
136.0	136.2	A	Yes	Yes	Likely
136.3	136.3	A	Yes	Yes	Likely
127.0	127.0	C	No	No	Not required
127.1	127.1	C	No	No	Not required
127.1	127.2	C	No	No	Not required
127.2	127.2	C	No	No	Not required
127.7	127.9	C	No	No	Not required

4.5.9. Section 9 – Broadwater National Park to Richmond River

Located within Section 9 are the Tuckean Broadwater, Montis Gully and Eversons Creek. These waterways would have a considerable contribution from groundwater (baseflow) and it can be expected that shallow groundwater will pose a potential impact to construction in these perennially wet areas, and potential impact to groundwater during the construction phase will be high as there is potential to interfere with groundwater flow. As most of this project section will be fill, however, potential impacts during operation are expected to be low. If wetter conditions prevail, however, watertables may rise and there would be some risk of pavement damage as well as potential salinisation caused by ponding associated with near-surface compaction. Seasonally varying shallow watertables characterise the region and this may cause local impacts during wetter periods.

Operational impacts are likely to be minimal, though shallow groundwaters in the floodplain must be protected from contamination from any surface water runoff.

Areas of threatened ecological communities will be impacted (see Biodiversity Working Paper), most notably swamp oak floodplain forest and swamp sclerophyll forest (Appendix A1). Habitat for Oxleyan Pygmy Perch occurs east of Stations 138.0 to 139.5), but the deep apparent groundwater tables suggest that groundwater is not a primary source of water, though additional measurements should be undertaken to determine whether perched systems are present.

Table 4-21 Summary groundwater impact assessment for Section 9

Underlying aquifers (GMU)	Richmond Coastal Sands; Richmond River Alluvium; New England Fold Belt.
Water Sharing arrangements	Richmond River Area Alluvial Aquifer Water Sharing Plan.
Acid sulfate soils	Majority of section mapped as having a high probability of occurrence. Southern portion of section mapped as having a low probability of occurrence.
Groundwater levels	Shallow watertables recorded along the entire section.
Level of potential construction impact	High potential impact throughout the section due to shallow and discharging groundwater interference across the floodplains. Potential impacts to wetlands.
Level of potential operational impact	Minimal potential impact throughout most of the section. Possible medium potential impact along the floodplain.

Table 4-22 Section 9 cut classification and potential groundwater impact assessment

Approx station		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
140.1	140.5	A	Yes	Yes	Likely
142.1	142.2	A	Yes	Yes	Likely
142.9	142.9	A	Yes	Yes	Likely
142.9	142.9	A	Yes	Yes	Likely
143.0	143.3	A	Yes	Yes	Likely
144.0	144.2	A	Yes	Yes	Likely
144.3	144.5	A	Yes	Yes	Likely
144.8	144.9	A	Yes	Yes	Likely

4.5.10. Section 10 – Richmond River to Coolgardie Road

Richmond River and Randals Creek are located within Section 10. Shallow groundwater will impose a construction impact in these perennially wet areas and construction may potentially impact groundwater flow. As most of the section will be fill, however, impact during operation are expected to be low. There is also the potential for oxidation of PASS and corresponding release of acidity down-gradient of the project due to seasonally variable watertables. Cuts in this section will initially encounter groundwater, though seepage would rapidly diminish as the project forms a drain to the groundwater flow and any localised groundwater mounds will decrease to the level of the surrounding groundwater systems across the floodplain. Construction needs to be mindful of on-going seepage. Appropriate drainage and transfer of seepage to the downstream side of the project would be required.

Operational impacts are likely to be minimal, though shallow groundwaters in the floodplain must be protected from contamination from any surface water runoff.

Table 4-23 Summary groundwater impact assessment for Section 10

Underlying aquifers (GMU)	Richmond Coastal Sands; New England Fold Belt.
Water Sharing arrangements	Richmond River Area Alluvial Aquifer Water Sharing Plan.
Acid sulfate soils	Majority of section mapped as having a low probability of occurrence. Northern

	portion of route mapped as having no known occurrence of acid sulfate soils.
Groundwater levels	Shallow watertables recorded along the entire section.
Level of potential construction impact	High potential impact throughout the section due to shallow and discharging groundwater interference across the floodplains. Potential impacts to wetlands.
Level of potential operational impact	Minimal potential impact throughout most of the section. Possible medium potential impact along the floodplain.

Table 4-24 Section 10 cut classification and potential groundwater impact assessment

Approx station		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
146.1	146.1	A	Yes	Yes	Likely
146.5	146.5	A	Yes	Yes	Likely
147.4	147.9	A	Yes	Yes	Likely
148.2	148.2	A	Yes	Yes	Likely
148.3	148.4	A	Yes	Yes	Likely
148.9	149.0	A	Yes	Yes	Likely
149.0	149.1	A	Yes	Yes	Likely
152.4	152.5	A	Yes	Yes	Likely
156.5	156.6	A	Yes	Yes	Likely
157.2	157.2	A	Yes	Yes	Likely
157.3	157.4	A	Yes	Yes	Likely
157.4	157.6	A	Yes	Yes	Likely

4.5.11. Section 11 – Coolgardie Road to Ballina Bypass

Section 11 of the project crosses the main waterways of Randals Creek, Duck Creek, and Emigrant Creek. Groundwater conditions in this section will be similar to the previous two sections, with shallow groundwaters throughout. As most of the section will be in fill, however, operational impacts are expected to be minimal, although shallow watertables might pose a risk to pavement damage and careful monitoring for potential salinisation is advised. There is also the potential for oxidation of potential acid sulfate soils and possible release of acidity down-gradient of the project induced by seasonally varying groundwater tables. Cuts in this section will initially encounter groundwater, however seepage will rapidly diminish as the project forms a drain to the groundwater flow and any localised groundwater mounds will decrease to the level of the surrounding groundwater systems across the floodplain. Construction needs to be mindful of on-going seepage. Appropriate drainage and transfer of seepage to the downstream side of the project would be required.

Operational impacts are likely to be minimal, though shallow groundwaters in the floodplain must be protected from contamination from any surface water runoff.

Table 4-25 Summary groundwater impact assessment for Section 11

Underlying aquifers (GMU)	Richmond Coastal Sands; New England Fold Belt.
Water Sharing arrangements	Richmond River Area Alluvial Aquifer Water Sharing Plan.
Acid sulfate soils	Majority of section mapped as having a high probability of occurrence. Southern extremity of route mapped as having a low probability of occurrence.
Groundwater levels	Shallow watertables recorded along the entire section.
Level of potential construction impact	High potential impact throughout the section due to shallow and discharging groundwater interference across the floodplains. Potential impacts to wetlands.
Level of potential operational impact	Minimal potential impact throughout most of the section. Possible medium potential impact along the floodplain.

Table 4-26 Section 11 cut classification and potential groundwater impact assessment

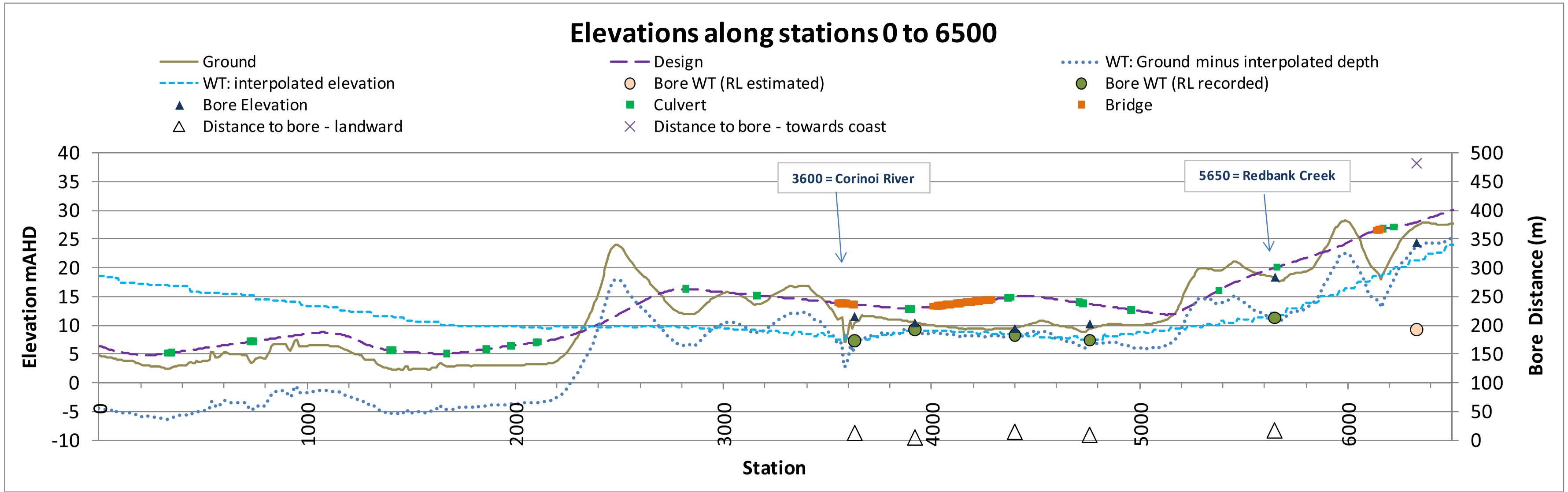
Approx station		Cut type*	Water Table penetration	Monitoring required	Impact mitigation measures required
Start	Finish				
159.8	159.8	A	Yes	Yes	Likely
163.0	163.1	A	Yes	Yes	Likely

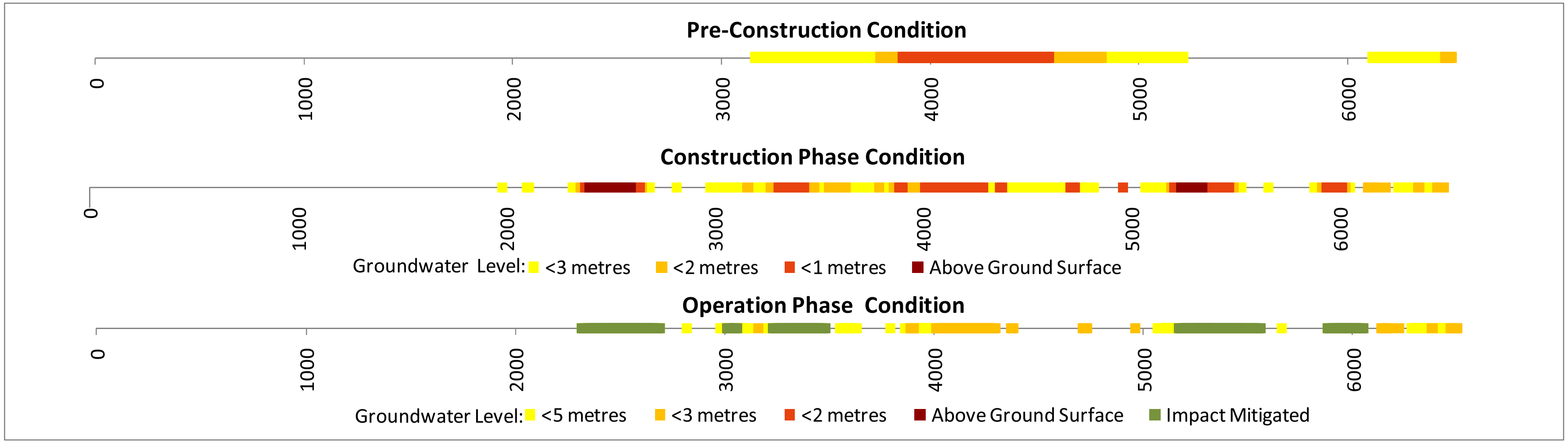
4.6. Continuous section potential impact charts

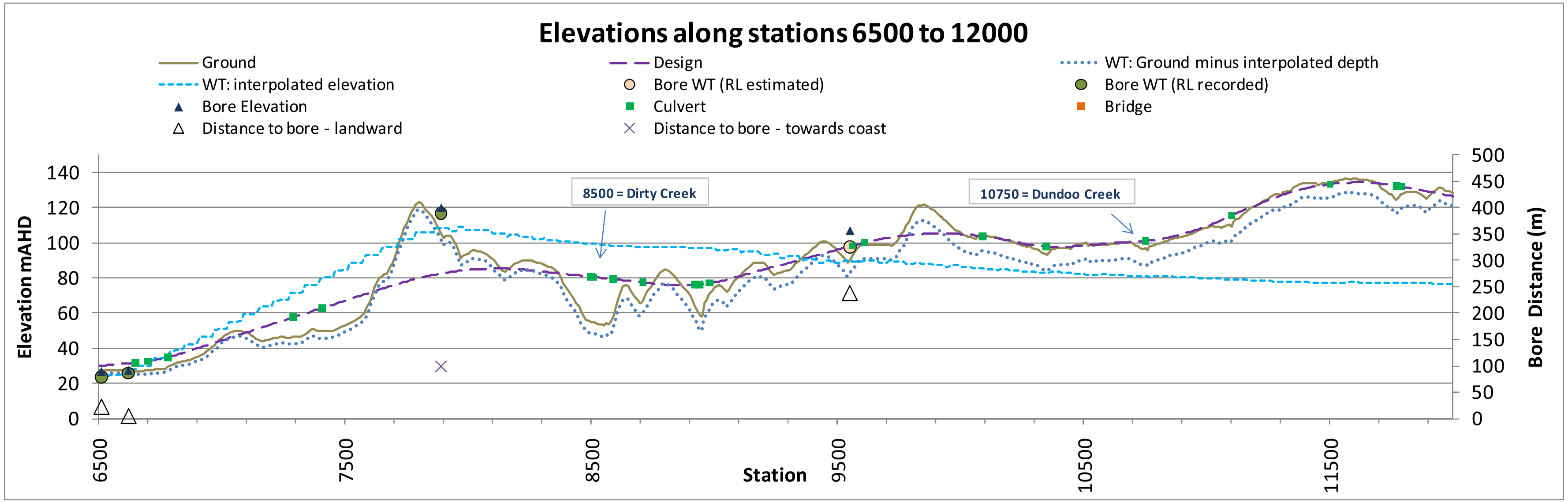
Potential impact to groundwater is illustrated in the charts below via a continuous, colour-coded strip beneath a cross-section of the project that provides a continuous profile of the project station. Groundwater levels below ground are illustrated for: pre-construction (Pre-Construction Condition); during construction (Construction Phase Condition) and following construction (Operation Phase Condition). Changes reflect the nature of the up-grade (cut, fill or minimal change) and the consequent interaction with the underlying groundwater. Where the modelled watertable suggests that there will be groundwater ingress to the location, the potential impact is designated as “Above Ground Surface” and mitigation measures are required. Those areas designated as cuts in the current design are expected to include appropriate mitigation to groundwater impacts and are highlighted as “Impact Mitigated” on the Operation Phase Condition charts.

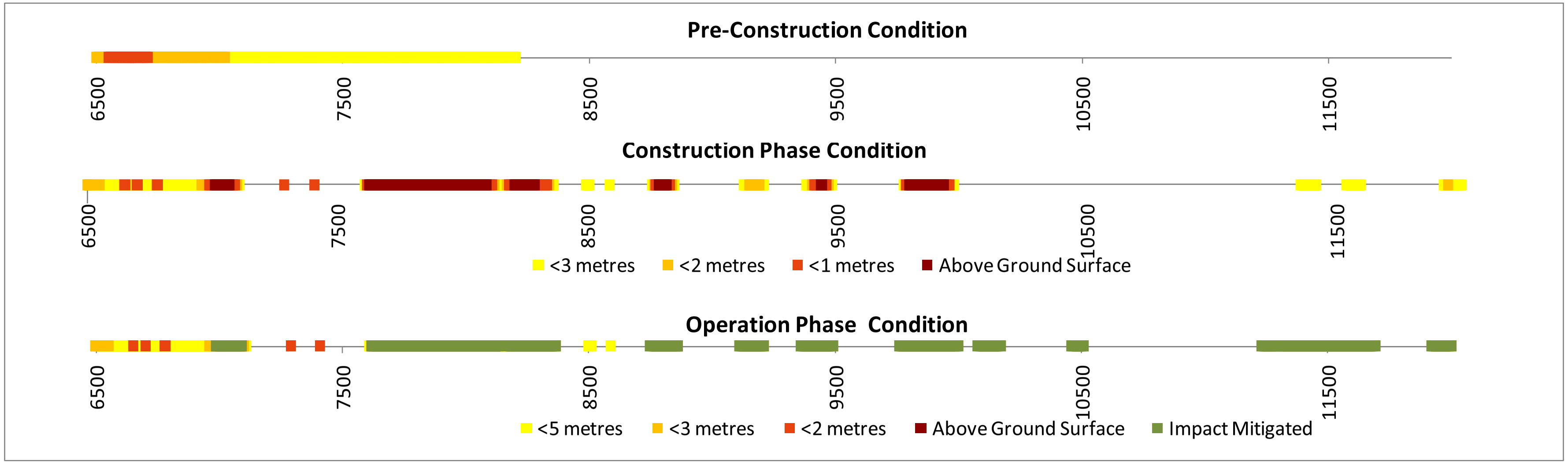
Areas for further investigation are those that still indicate groundwater levels under Operation Phase Conditions that are less than two metres from the ground surface or where groundwater is expected to intersect the ground surface, ie discharge (and designated Above Ground Surface on the charts). Areas where water tables may be less than three metres below ground deserve additional monitoring; those within five metres may require additional monitoring following further site investigations to determine the local nature of the groundwater table.

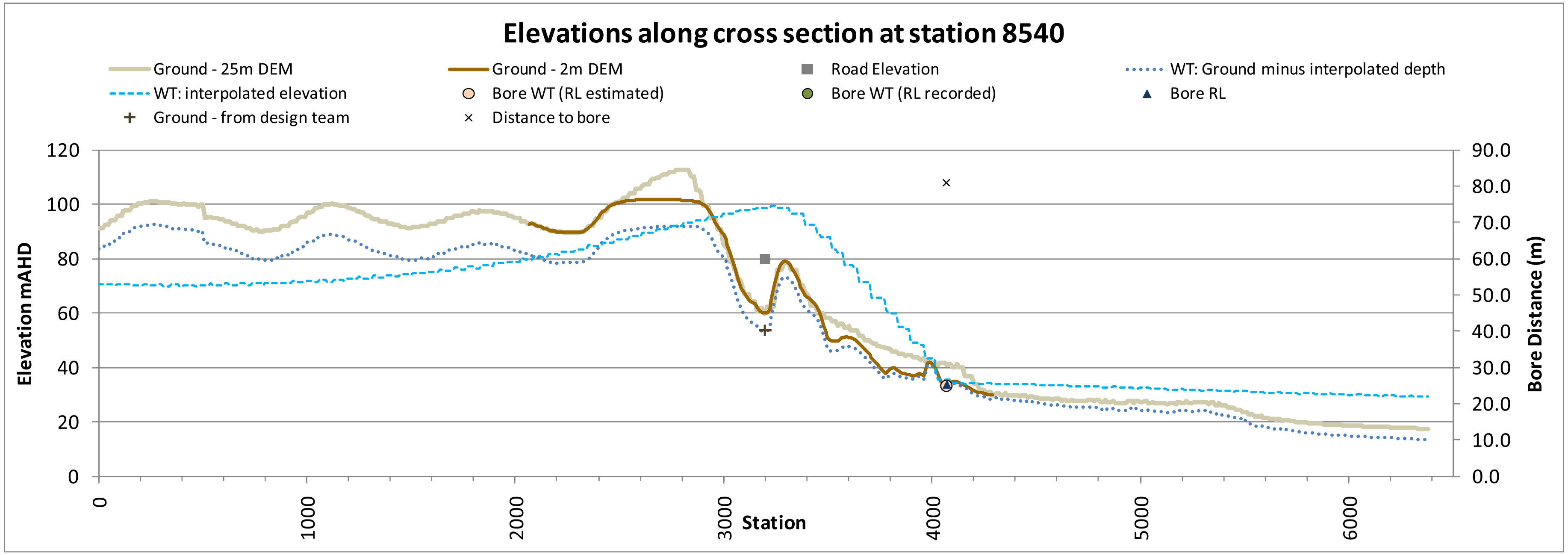
Management and mitigation measures are further described in Chapter 5.

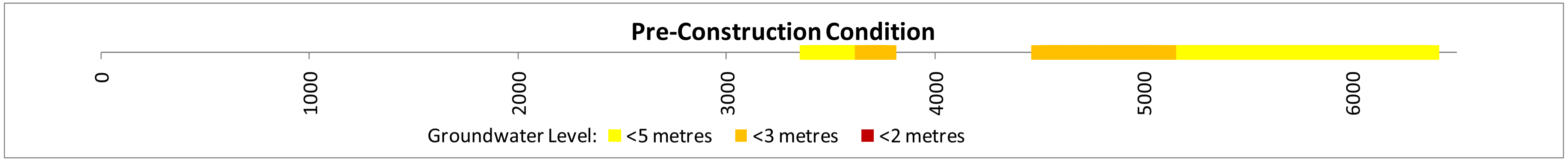

Elevations along stations 0 to 6500
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
3600 = Corinoi River
5650 = Redbank Creek
Elevation mAHD
Bore Distance (m)
Station
40
35
30
25
20
15
10
5
0
-5
-10
500
450
400
350
300
250
200
150
100
50
0
1000
2000
3000
4000
5000
6000

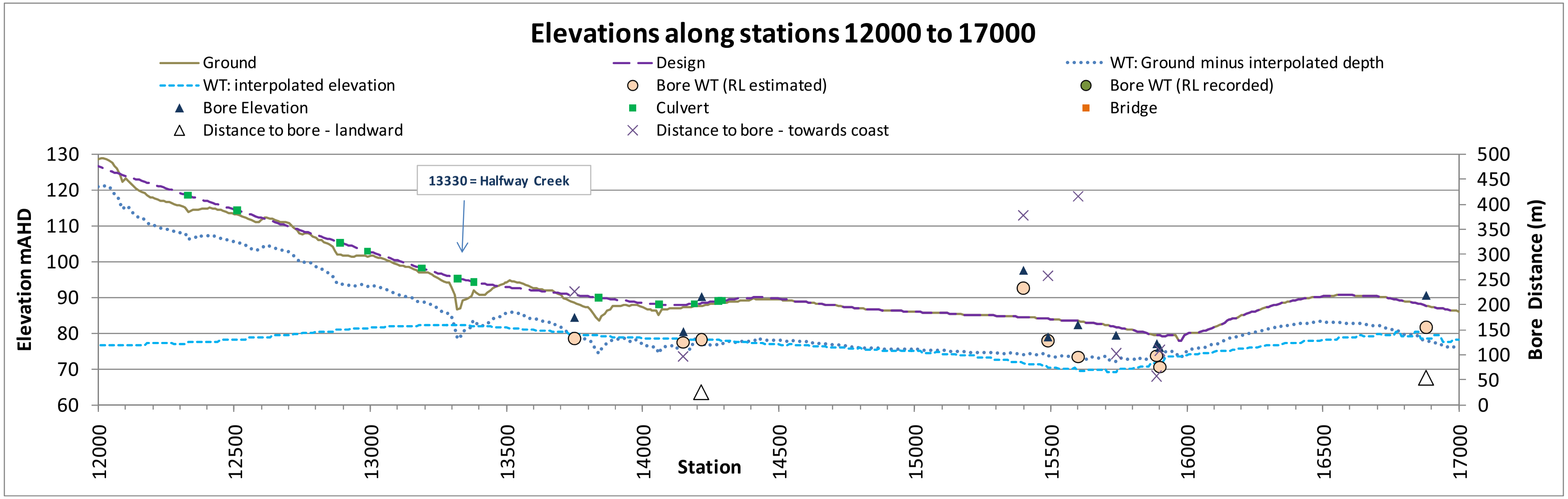

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated
0
1000
2000
3000
4000
5000
6000


Elevations along stations 6500 to 12000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
Station
8500 = Dirty Creek
10750 = Dundoo Creek

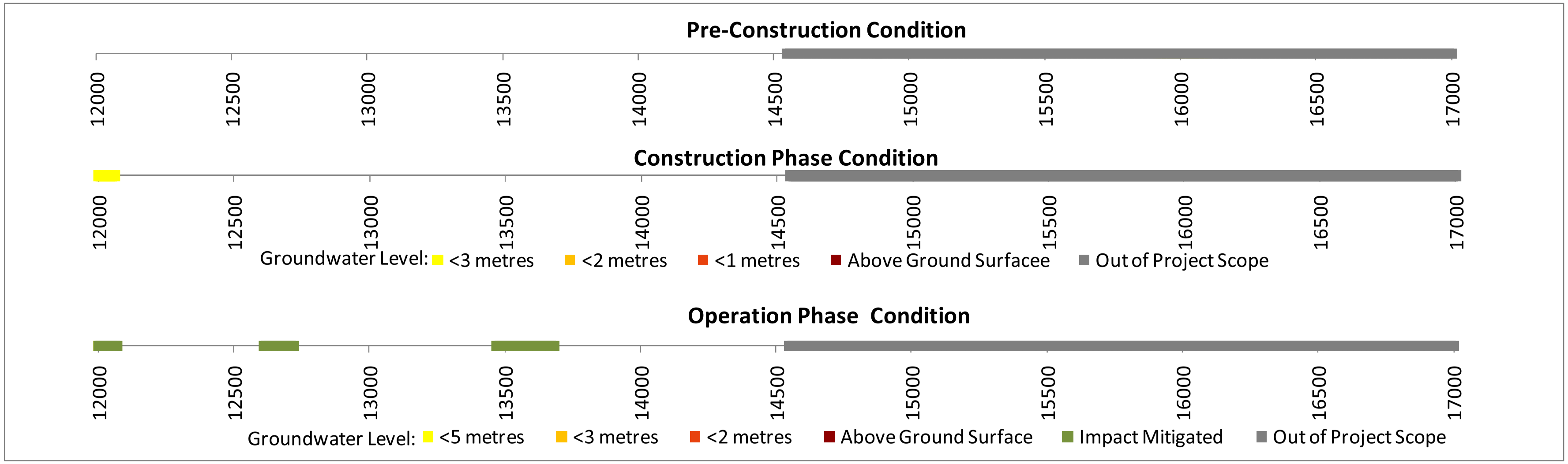

Pre-Construction Condition
Construction Phase Condition
<3 metres
<2 metres
<1 metres
Above Ground Surface
Operation Phase Condition
<5 metres
<3 metres
<2 metres
Above Ground Surface
Impact Mitigated


Elevations along cross section at station 8540
Ground - 25m DEM
Ground - 2m DEM
Road Elevation
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore RL
Ground - from design team
Distance to bore
Elevation mAHD
Bore Distance (m)
Station
0 20 40 60 80 100 120
0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0
0 1000 2000 3000 4000 5000 6000

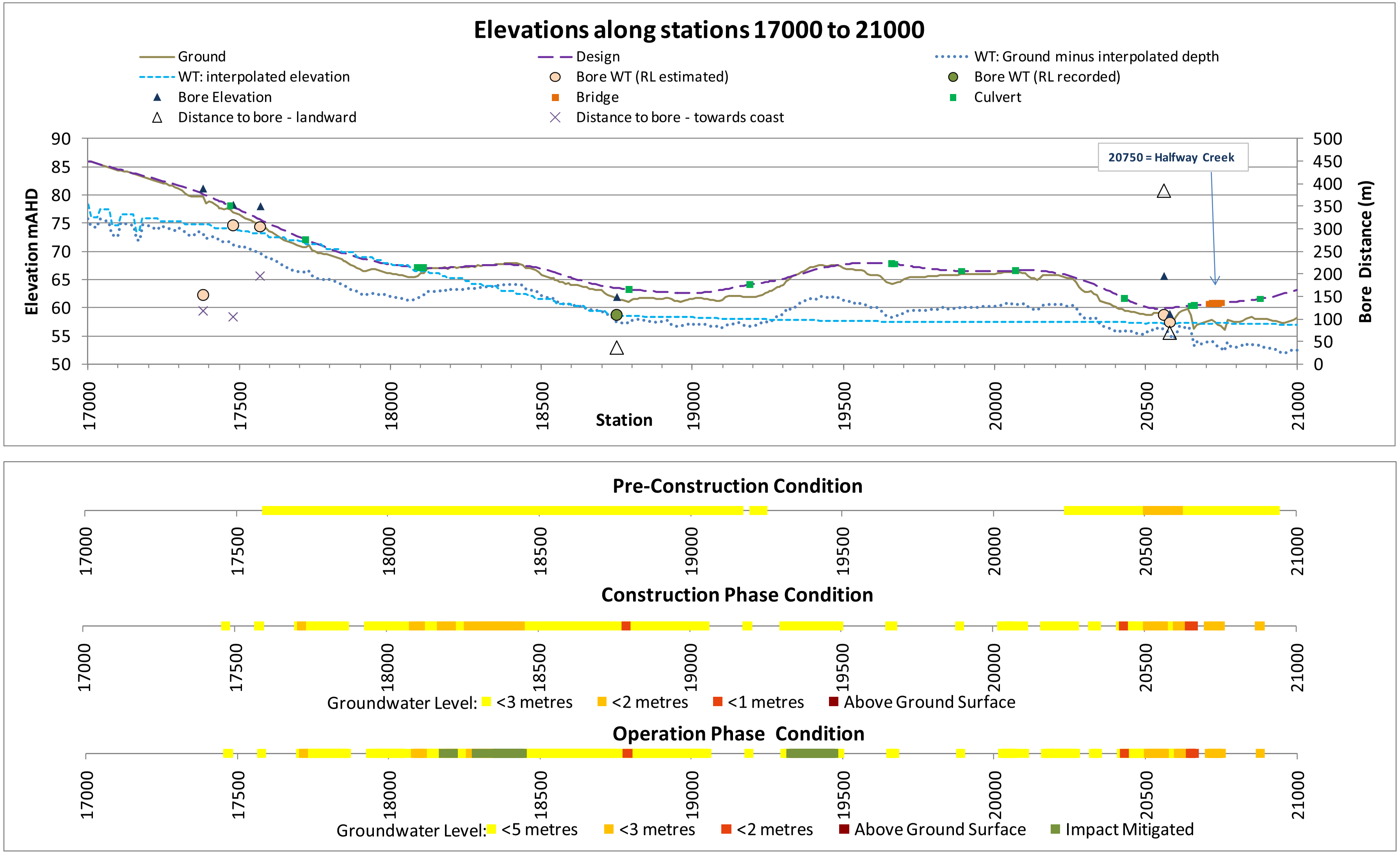

Pre-Construction Condition
0 1000 2000 3000 4000 5000 6000
Groundwater Level: <5 metres <3 metres <2 metres

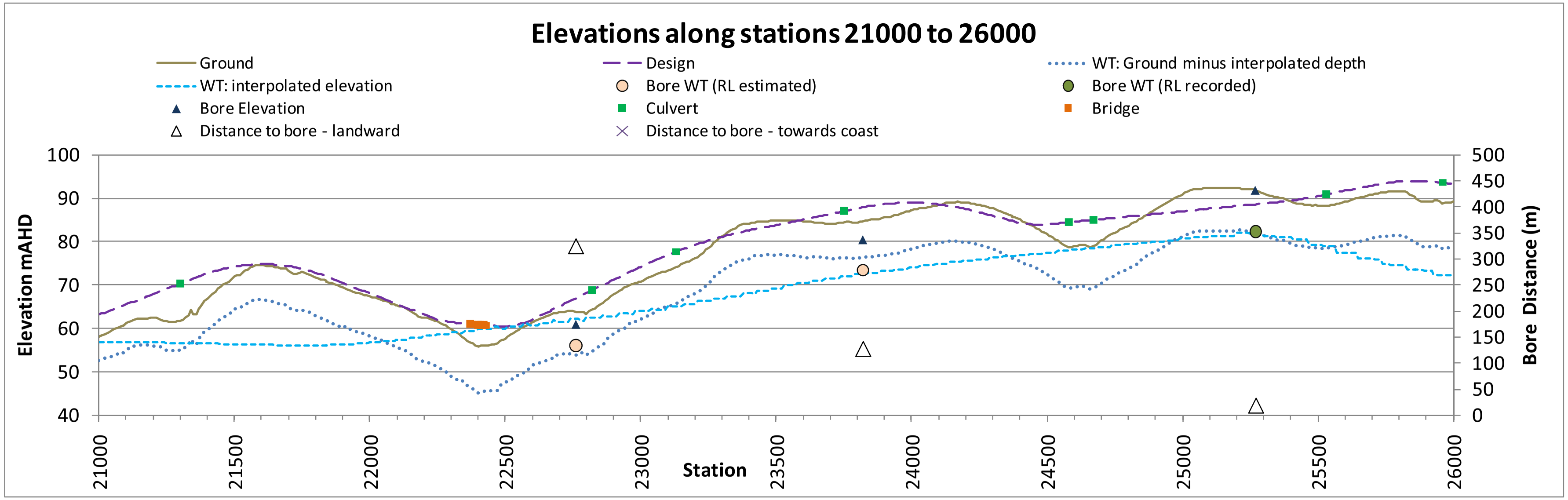


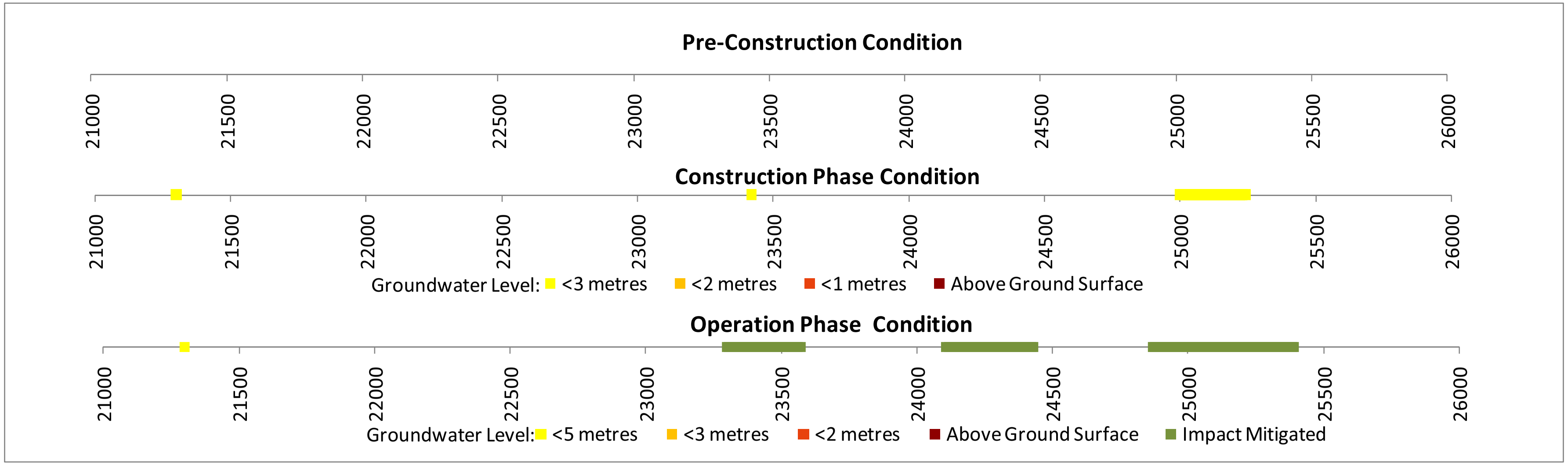
Elevations along stations 12000 to 17000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
13330 = Halfway Creek
Elevation mAHD
Bore Distance (m)
Station

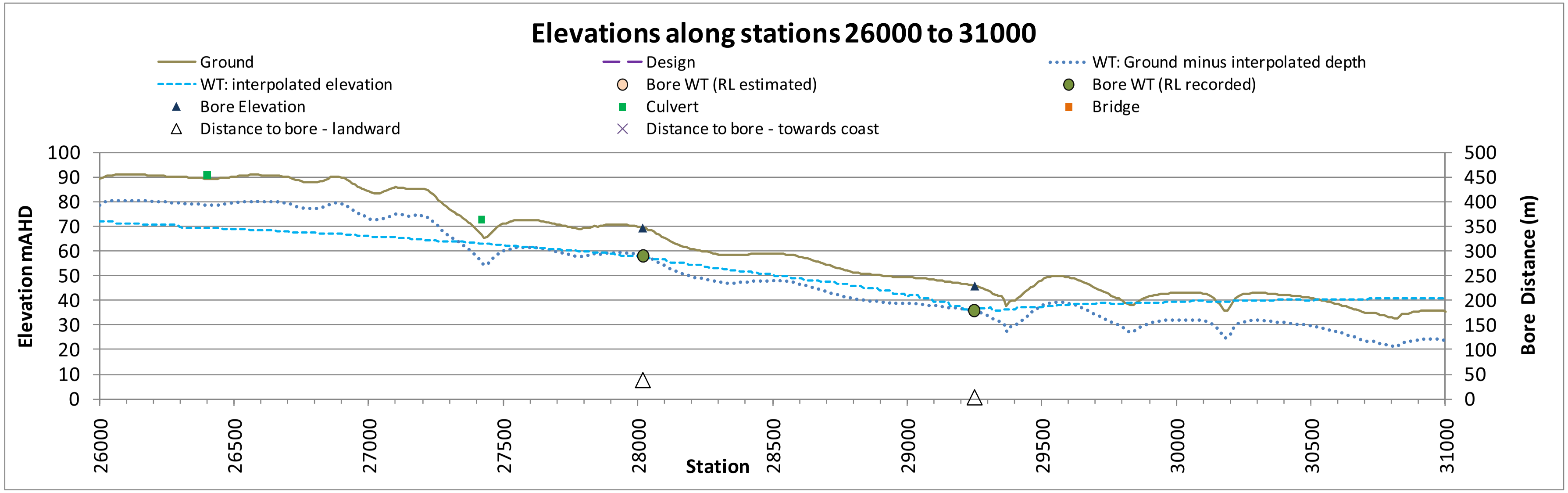


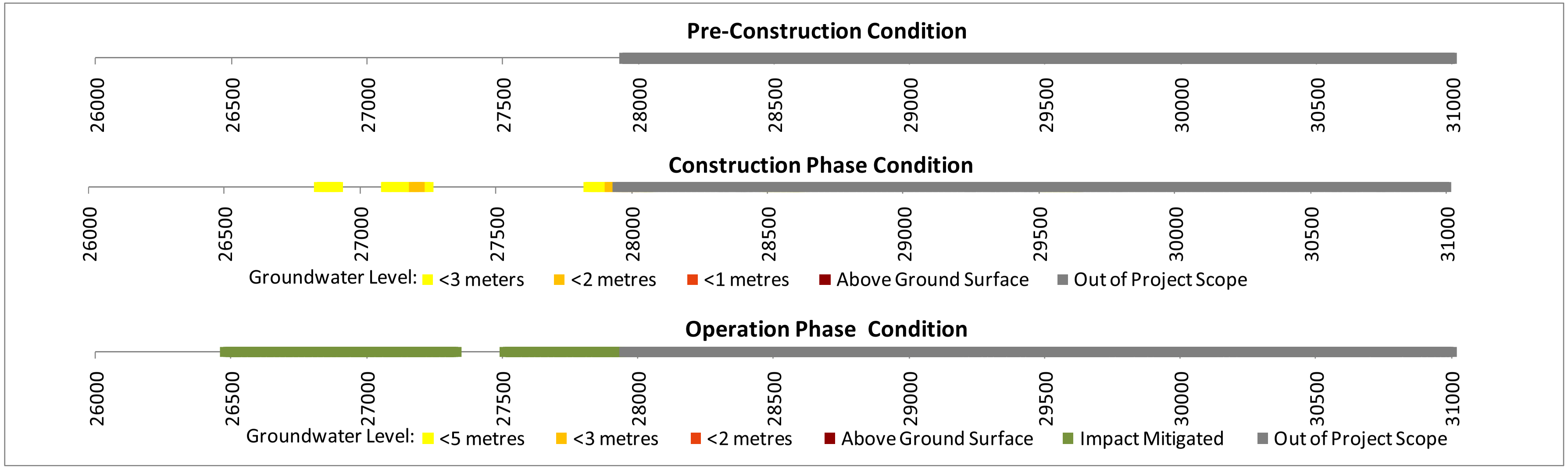
Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surfacee Out of Project Scope
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated Out of Project Scope

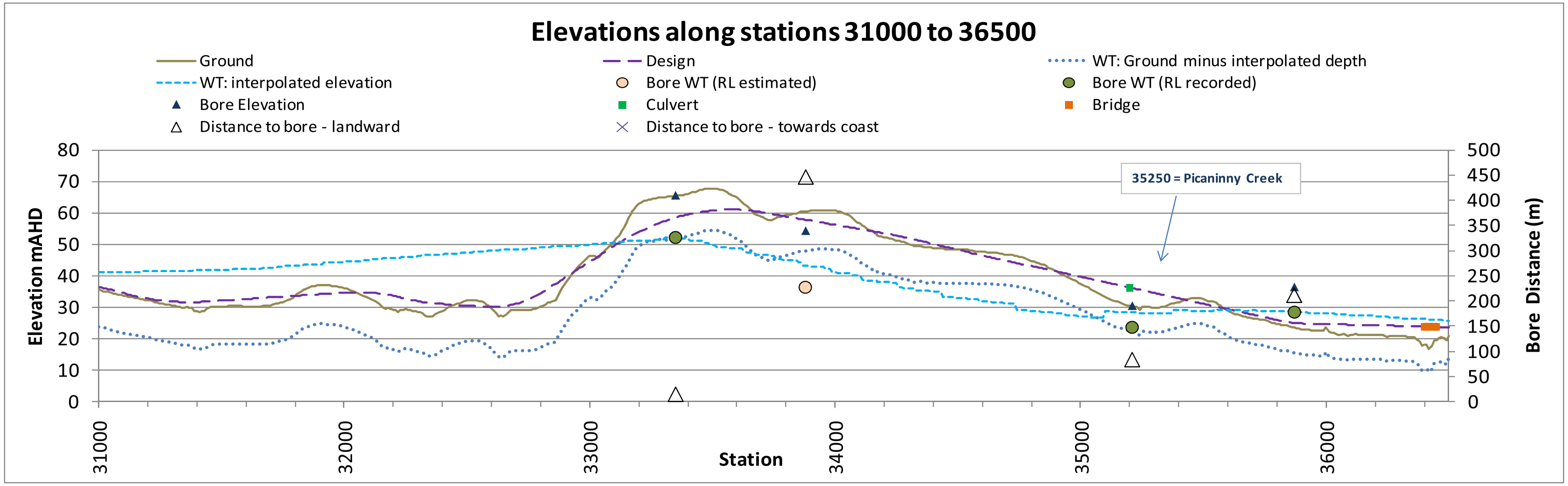

Elevations along stations 17000 to 21000
Ground
Design
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore Elevation
Bridge
Culvert
Distance to bore - landward
Distance to bore - towards coast
20750 = Halfway Creek
Elevation mAHD
Bore Distance (m)
Station
Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated

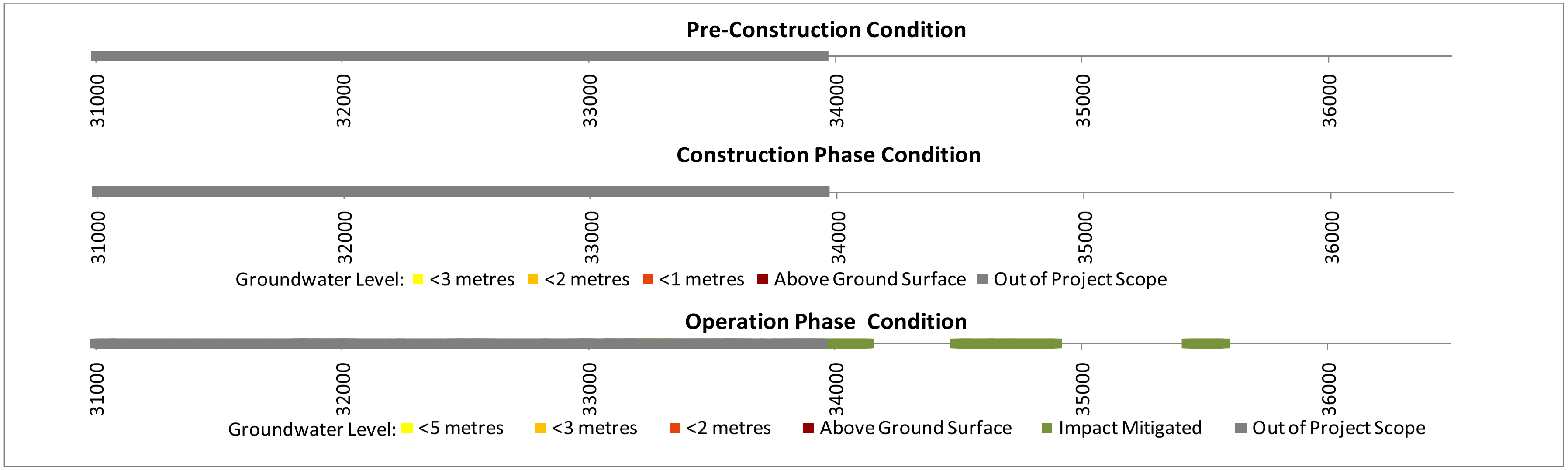

Elevations along stations 21000 to 26000
Ground
Design
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore Elevation
Culvert
Bridge
Distance to bore - landward
Distance to bore - towards coast
Elevation mAHD
Bore Distance (m)
Station

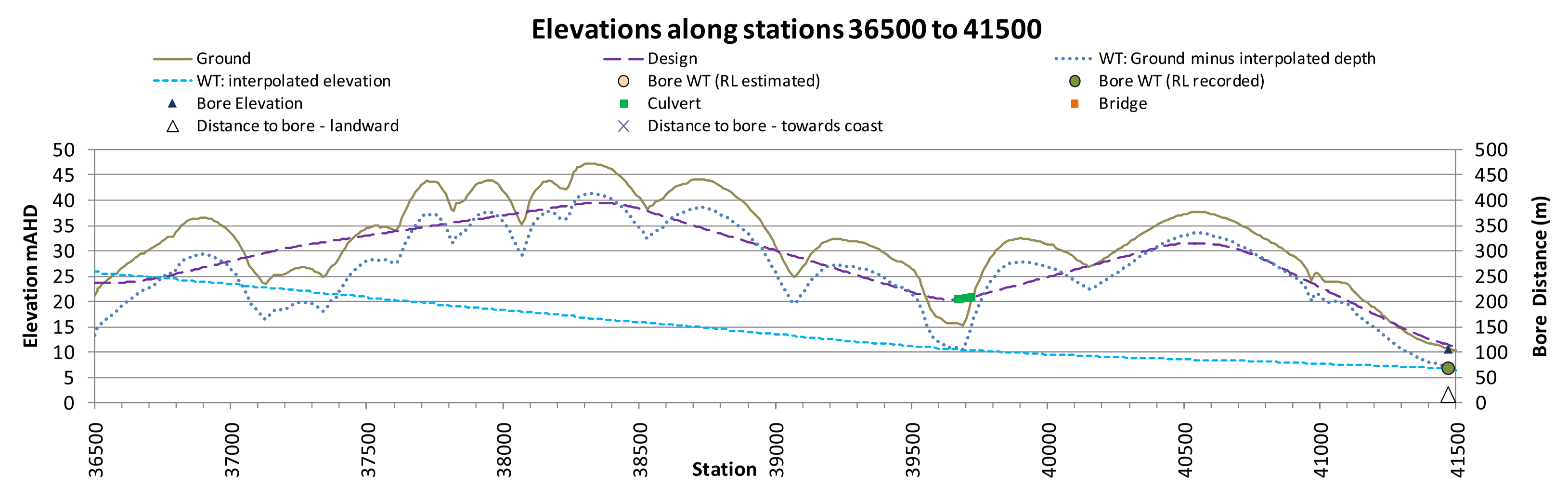

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated

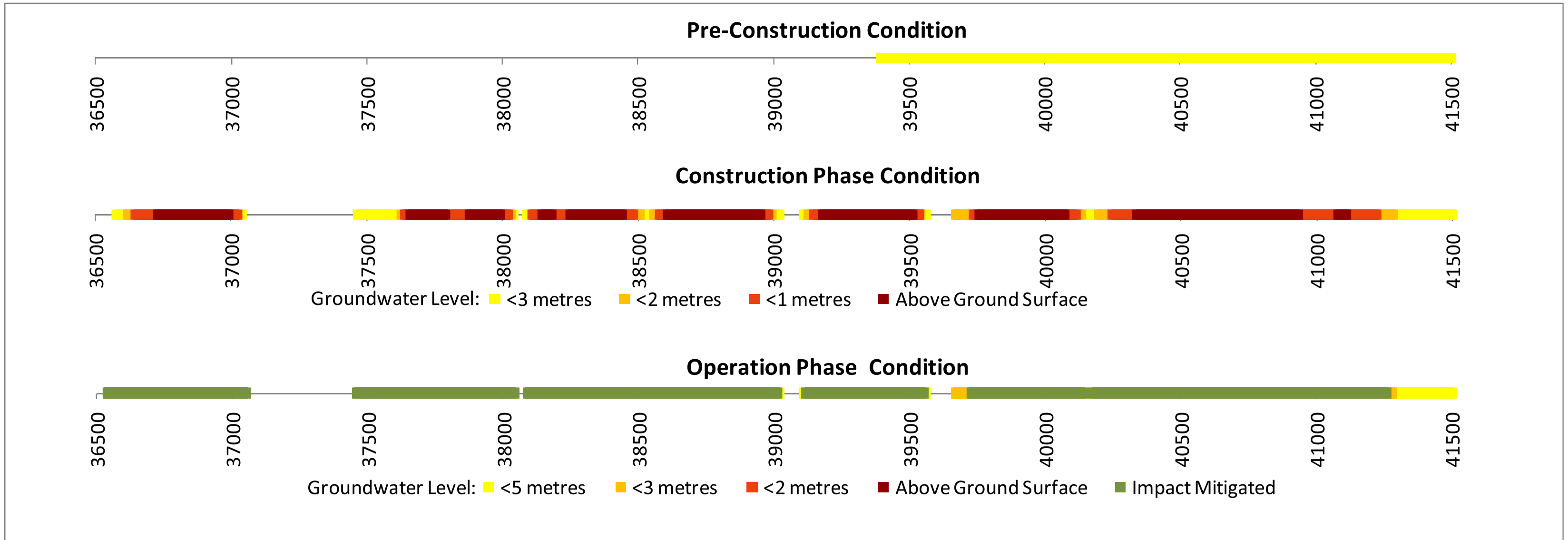

Elevations along stations 26000 to 31000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
Station
100
90
80
70
60
50
40
30
20
10
0
500
450
400
350
300
250
200
150
100
50
26000
26500
27000
27500
28000
28500
29000
29500
30000
30500
31000

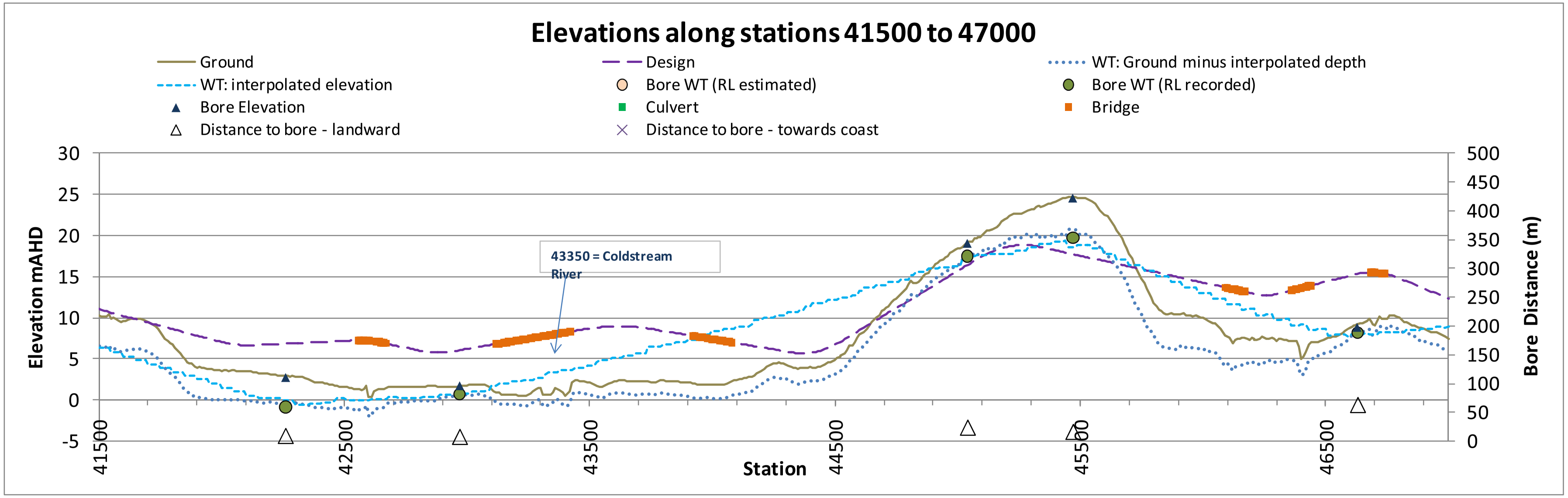

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 meters
<2 metres
<1 metres
Above Ground Surface
Out of Project Scope
Operation Phase Condition
Groundwater Level: <5 metres
<3 metres
<2 metres
Above Ground Surface
Impact Mitigated
Out of Project Scope
26000
26500
27000
27500
28000
28500
29000
29500
30000
30500
31000

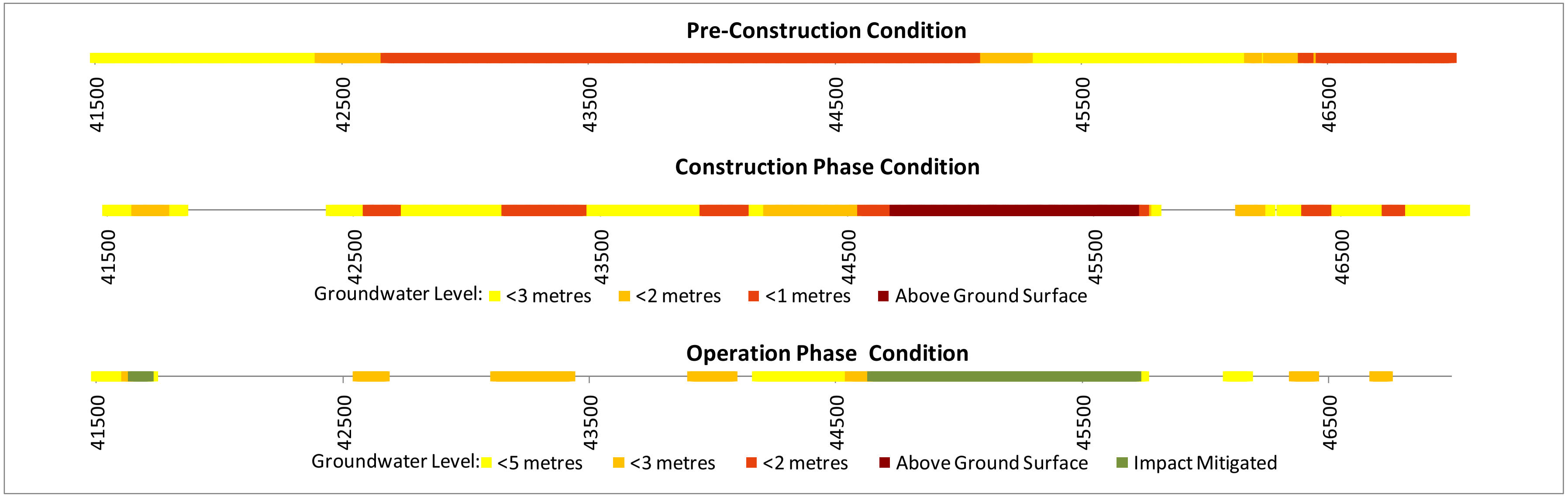

Elevations along stations 31000 to 36500
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
35250 = Picaninny Creek
Station
31000
32000
33000
34000
35000
36000

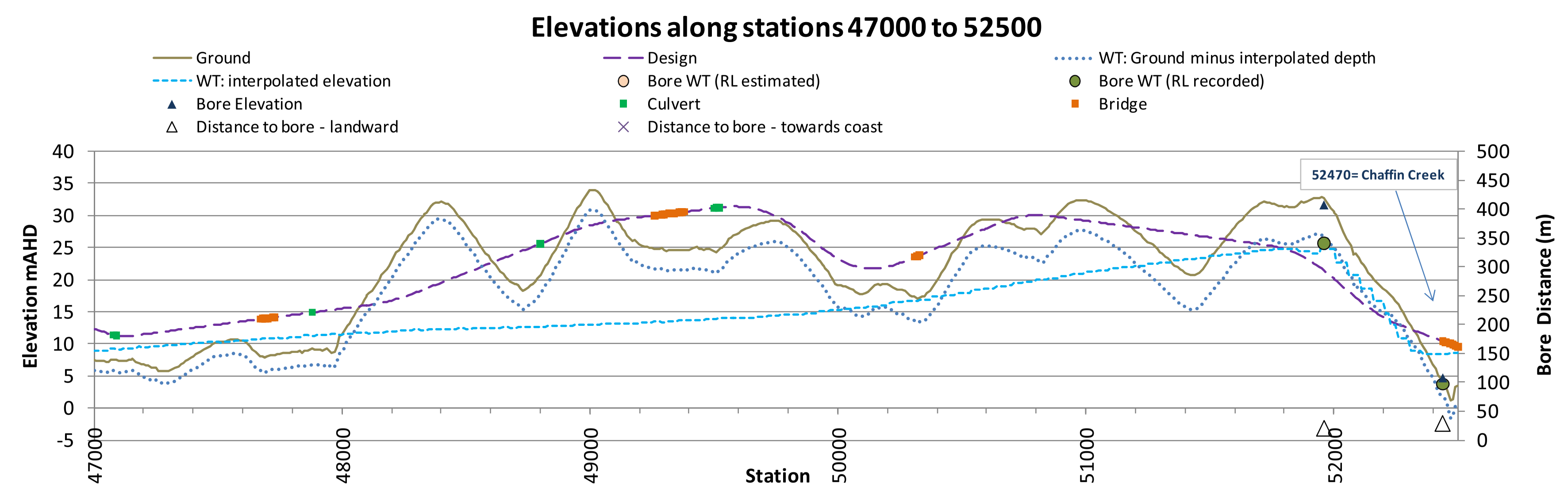

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface Out of Project Scope
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated Out of Project Scope
31000
32000
33000
34000
35000
36000

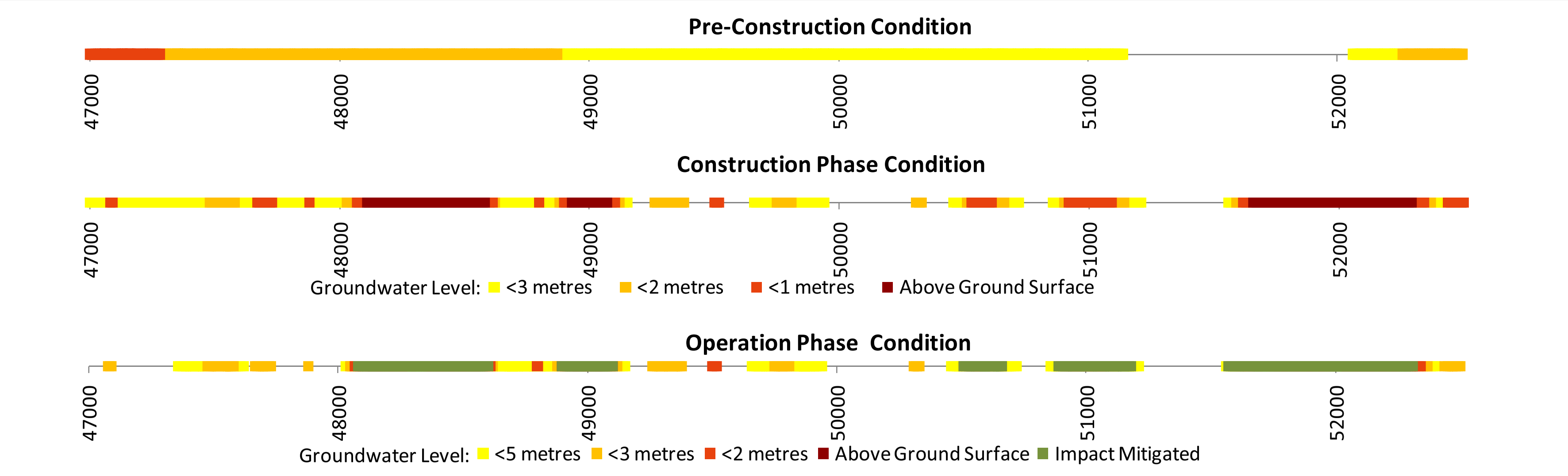

Elevations along stations 36500 to 41500
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
Station
36500
37000
37500
38000
38500
39000
39500
40000
40500
41000
41500

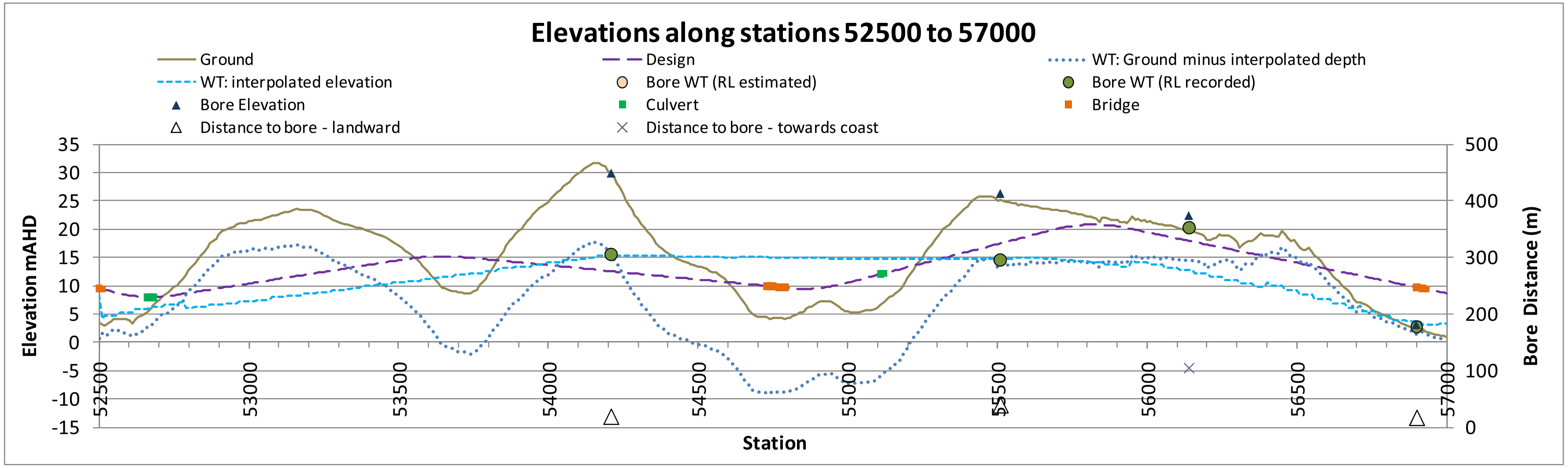

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated
36500
37000
37500
38000
38500
39000
39500
40000
40500
41000
41500

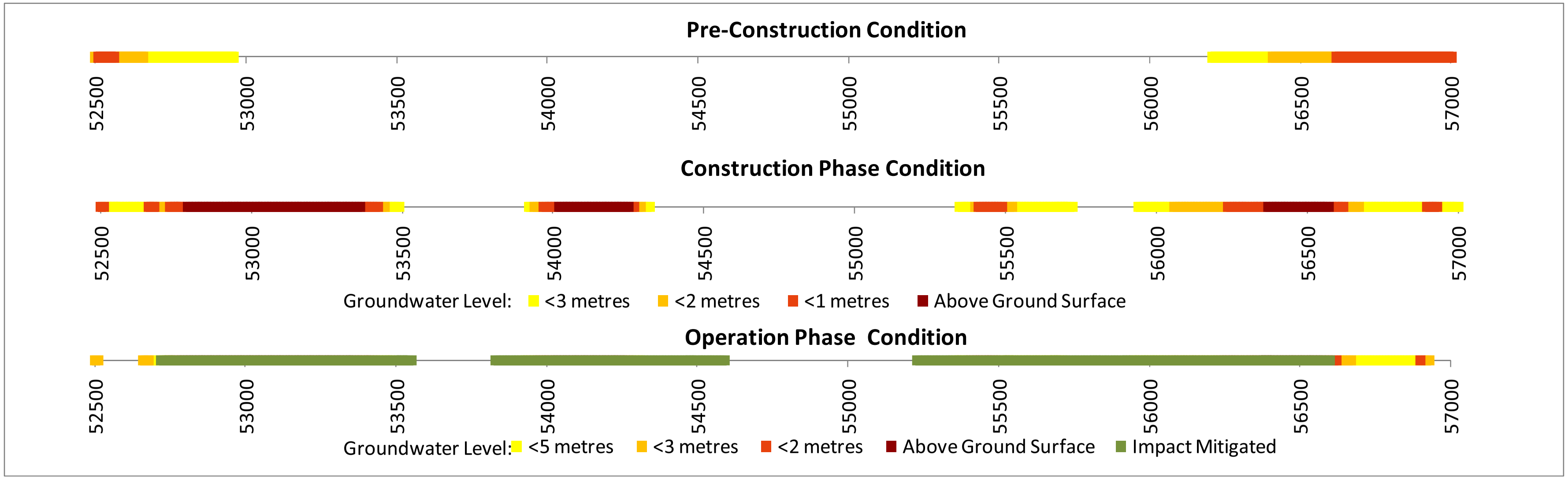

Elevations along stations 41500 to 47000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
43350 = Coldstream River
Station
41500
42500
43500
44500
45500
46500

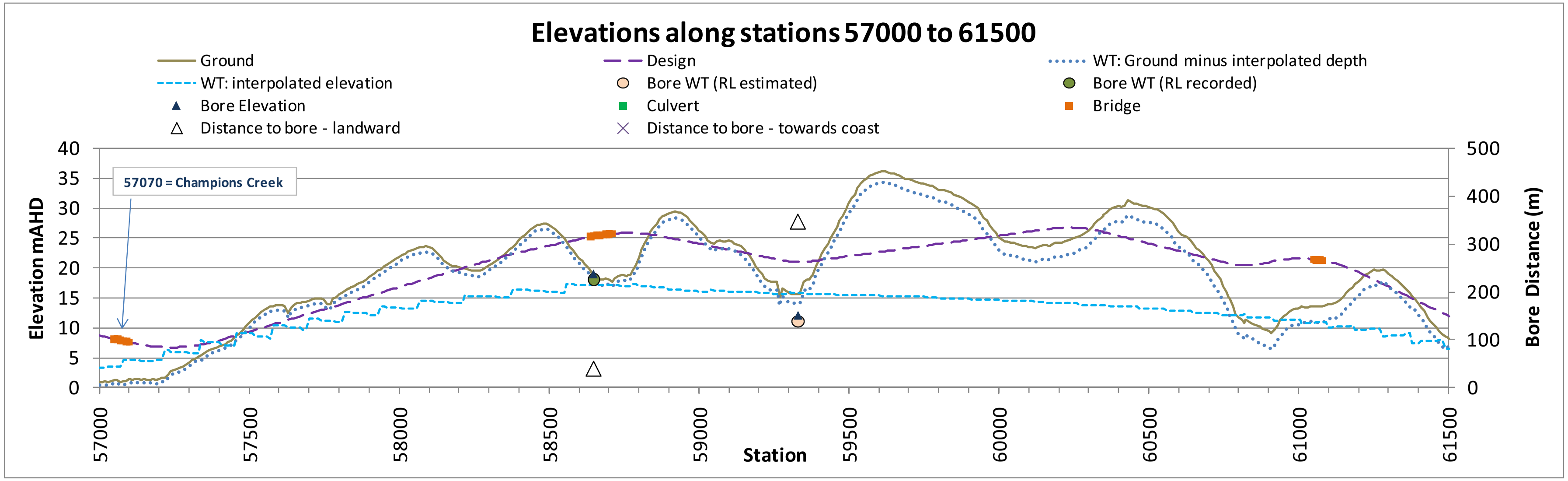

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated
41500
42500
43500
44500
45500
46500

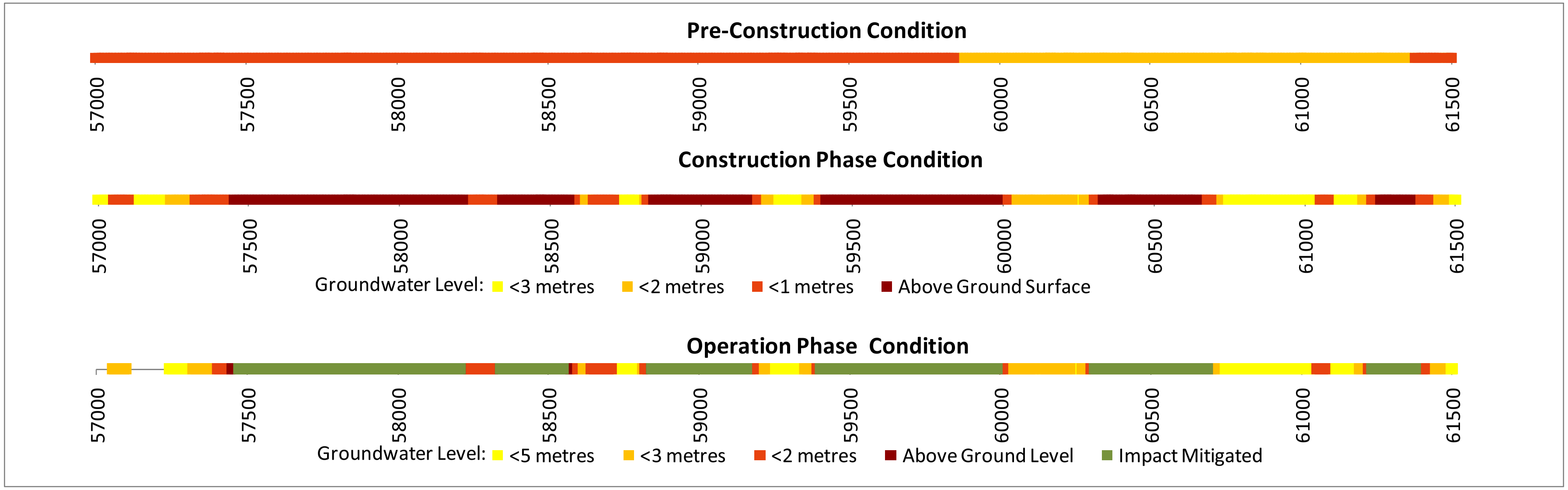

Elevations along stations 47000 to 52500
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
52470= Chaffin Creek
Elevation mAHD
Bore Distance (m)
Station
40
35
30
25
20
15
10
5
0
-5
500
450
400
350
300
250
200
150
100
50
0
47000
48000
49000
50000
51000
52000

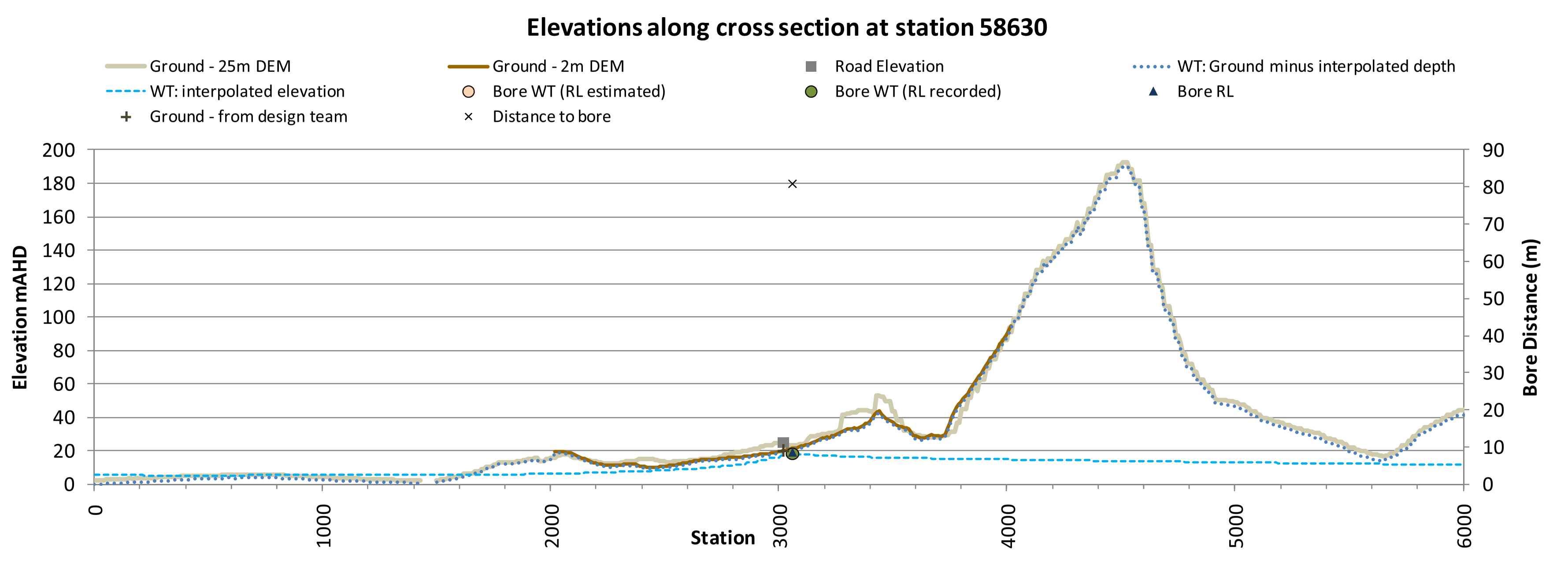

Pre-Construction Condition
47000
48000
49000
50000
51000
52000
Construction Phase Condition
47000
48000
49000
50000
51000
52000
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
47000
48000
49000
50000
51000
52000
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated

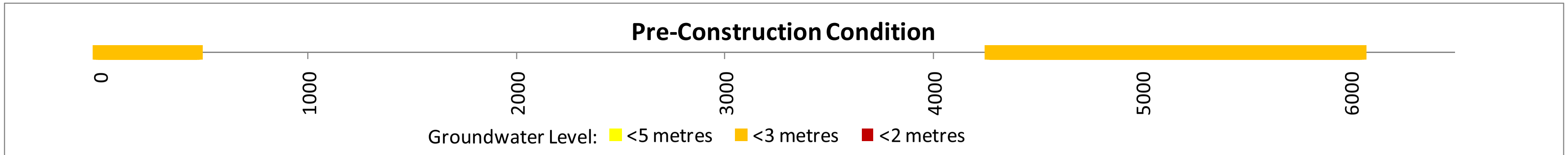

Elevations along stations 52500 to 57000
Ground
Design
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore Elevation
Culvert
Bridge
Distance to bore - landward
Distance to bore - towards coast
Elevation mAHD
Bore Distance (m)
Station
35
30
25
20
15
10
5
0
-5
-10
-15
500
400
300
200
100
0
52500
53000
53500
54000
54500
55000
55500
56000
56500
57000

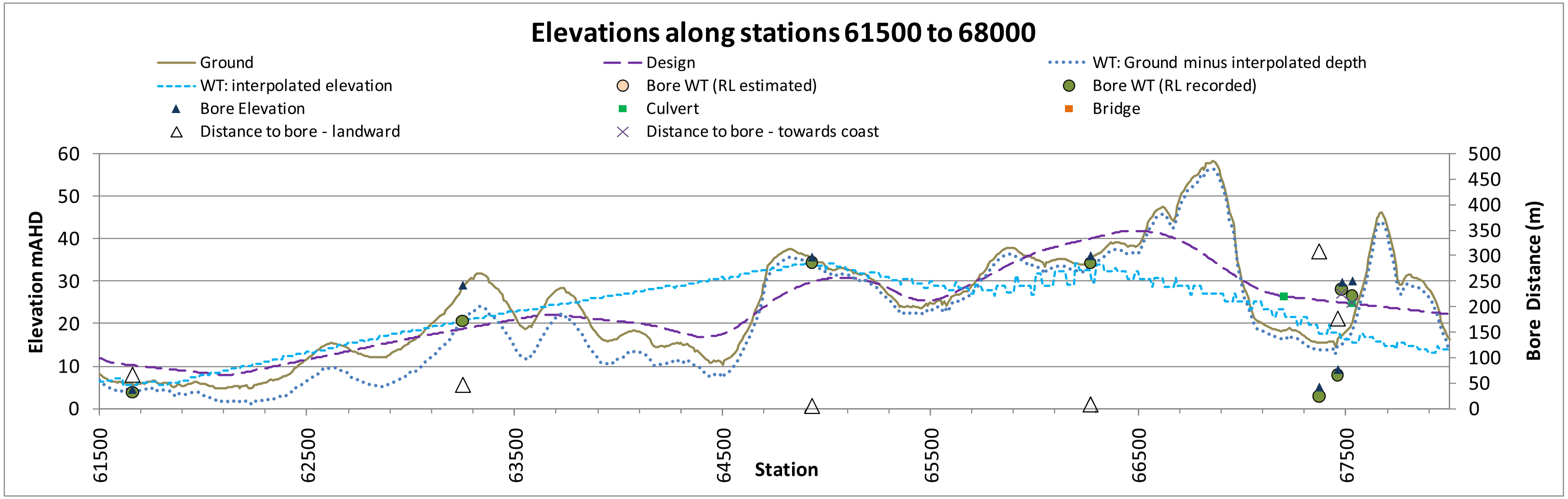

Pre-Construction Condition
52500
53000
53500
54000
54500
55000
55500
56000
56500
57000
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated

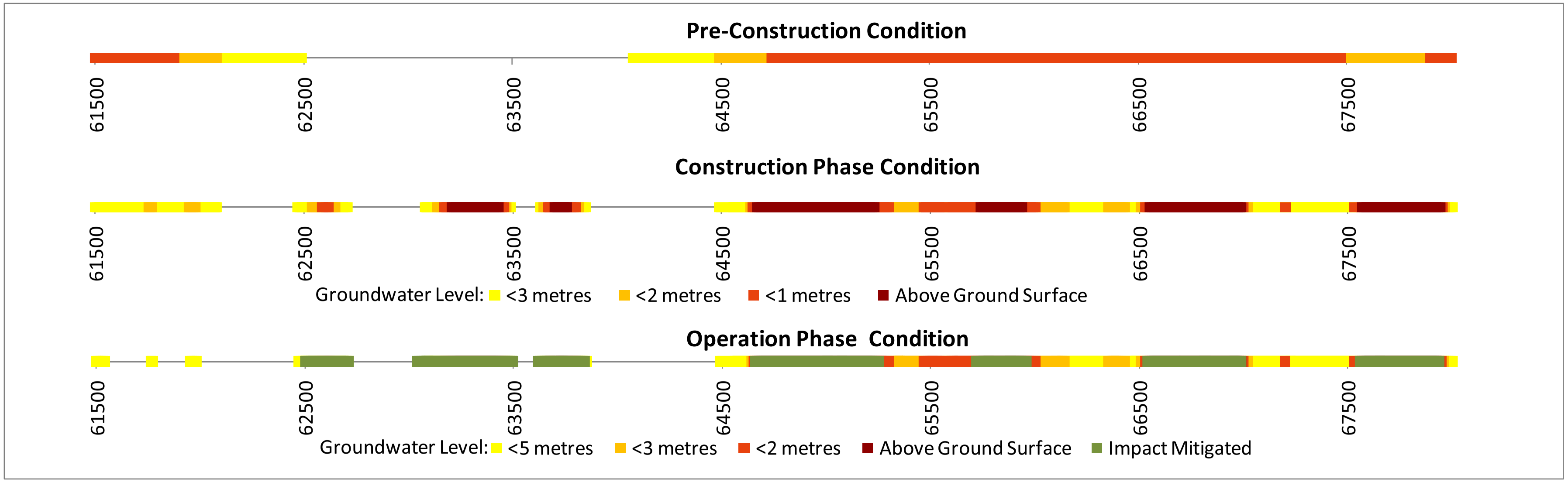

Elevations along stations 57000 to 61500
Ground
Design
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore Elevation
Culvert
Bridge
Distance to bore - landward
Distance to bore - towards coast
57070 = Champions Creek
Elevation mAHD
Bore Distance (m)
Station
40
35
30
25
20
15
10
5
0
500
400
300
200
100
0
57000
57500
58000
58500
59000
59500
60000
60500
61000
61500

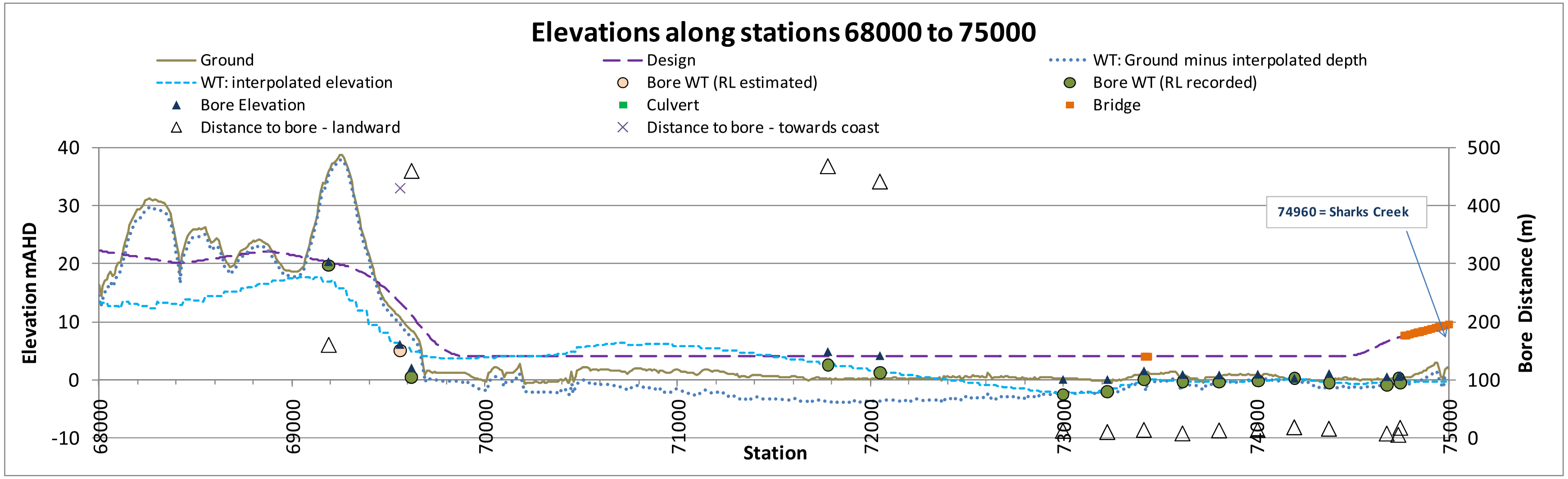

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Level Impact Mitigated
57000
57500
58000
58500
59000
59500
60000
60500
61000
61500

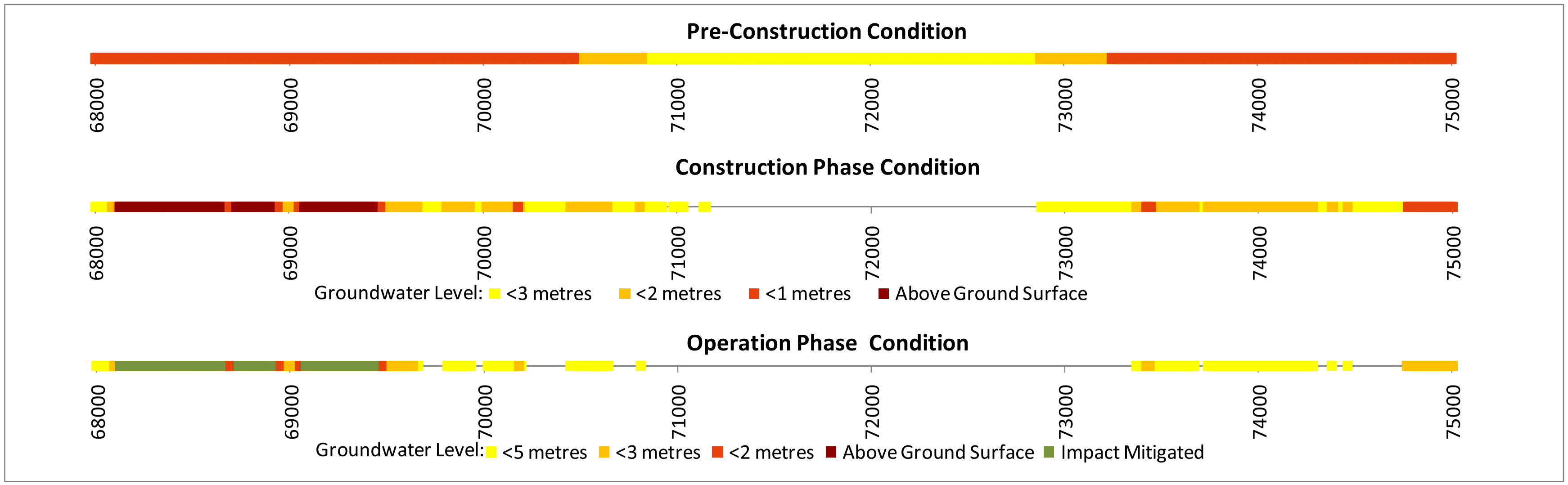

Elevations along cross section at station 58630
Ground - 25m DEM
Ground - 2m DEM
Road Elevation
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore RL
Ground - from design team
Distance to bore
Elevation mAHD
Bore Distance (m)
Station
0
1000
2000
3000
4000
5000
6000
200
180
160
140
120
100
80
60
40
20
0
90
80
70
60
50
40
30
20
10
0

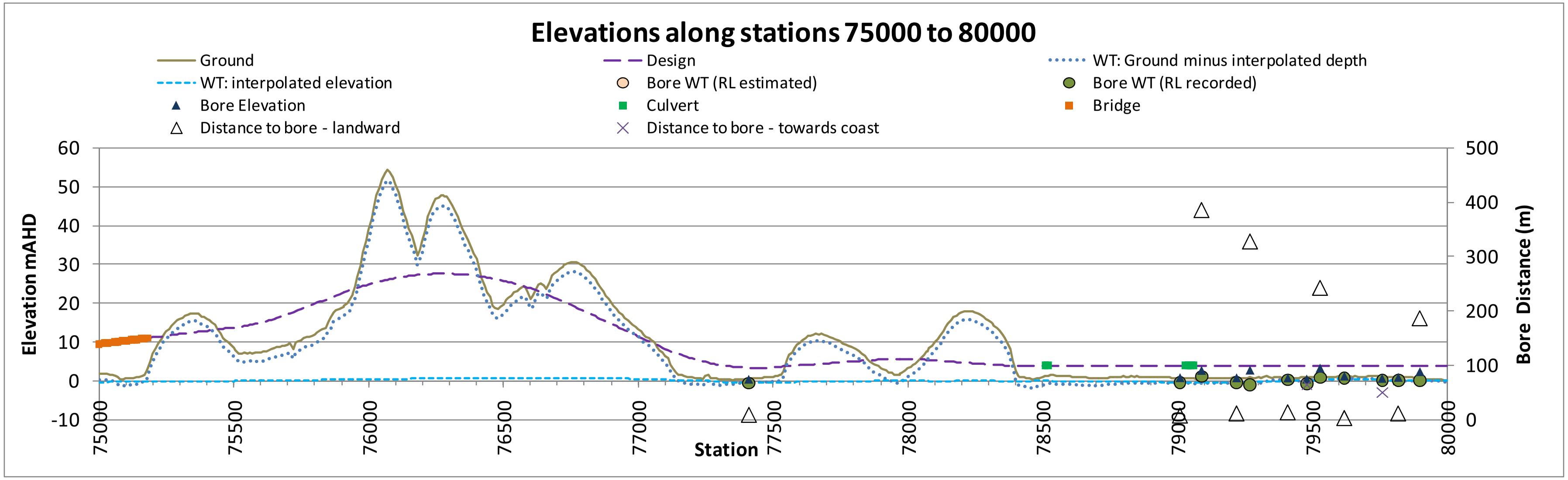

Pre-Construction Condition
0
1000
2000
3000
4000
5000
6000
Groundwater Level:
<5 metres
<3 metres
<2 metres

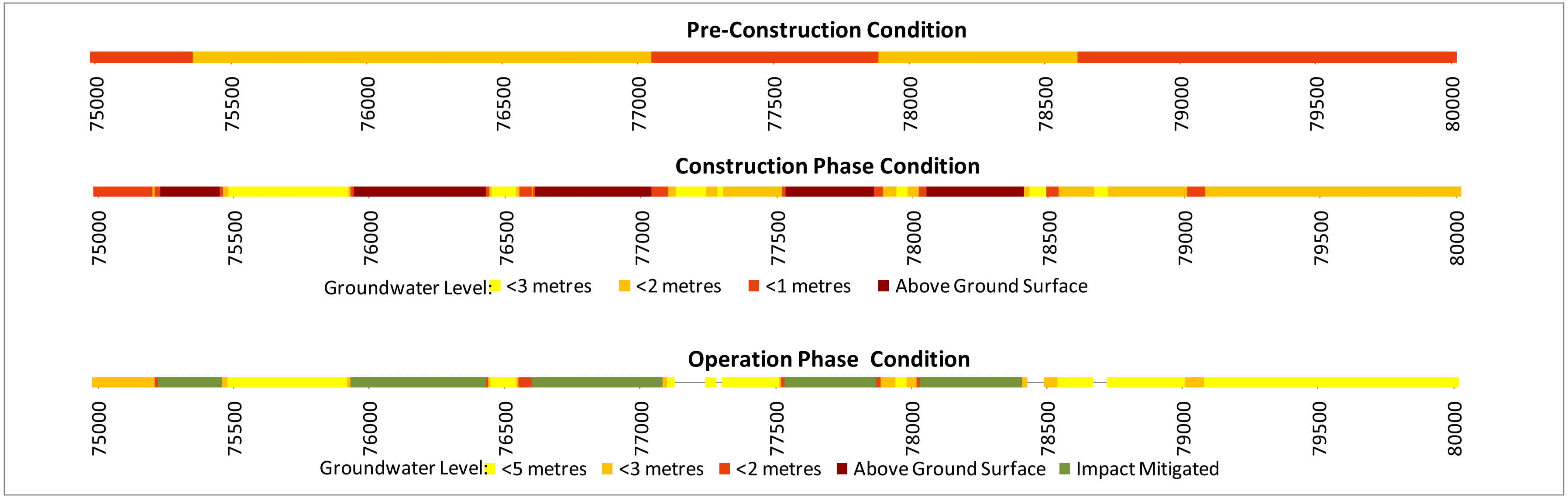

Elevations along stations 61500 to 68000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
Station
0 10 20 30 40 50 60
0 50 100 150 200 250 300 350 400 450 500
61500 62500 63500 64500 65500 66500 67500

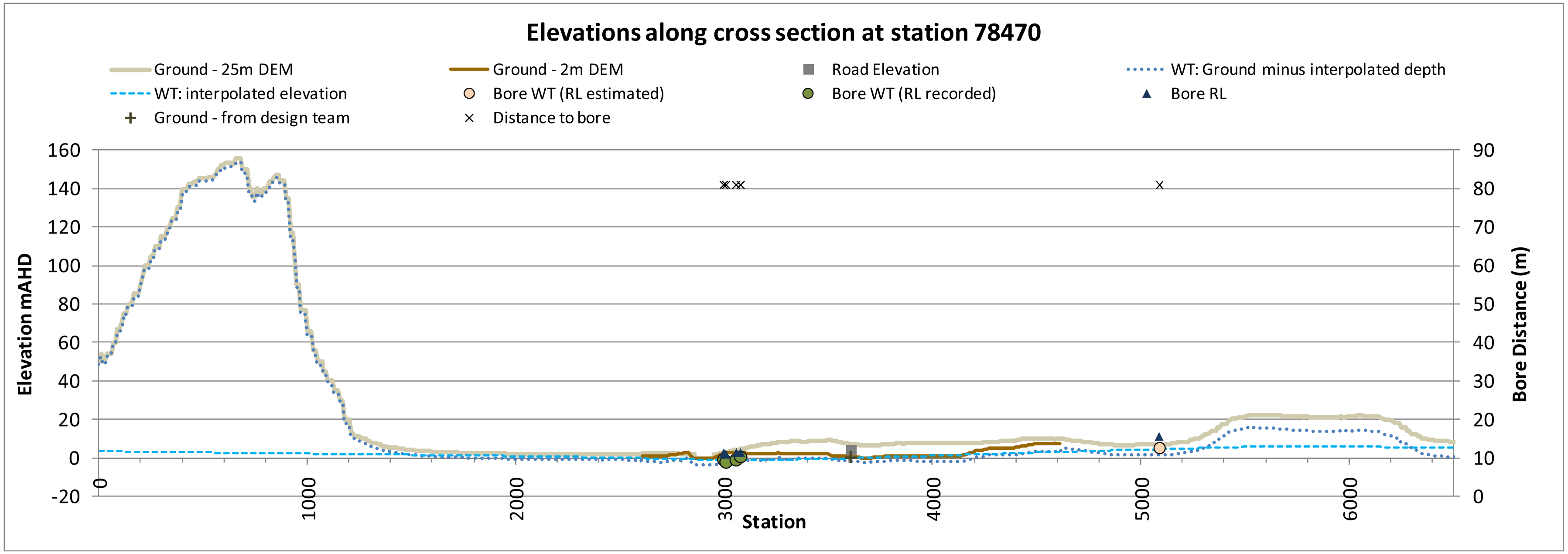

Pre-Construction Condition
61500 62500 63500 64500 65500 66500 67500
Construction Phase Condition
61500 62500 63500 64500 65500 66500 67500
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
61500 62500 63500 64500 65500 66500 67500
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated

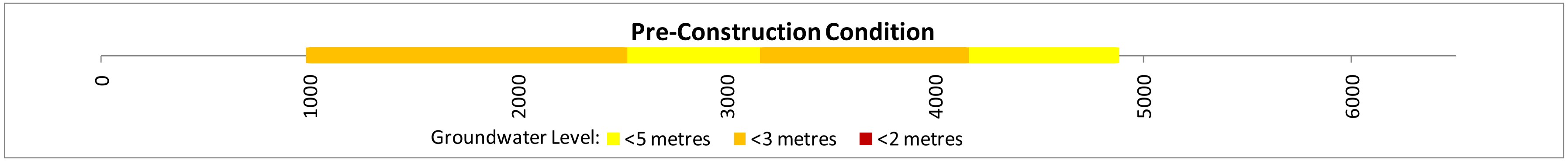

Elevations along stations 68000 to 75000
Ground
Design
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore Elevation
Culvert
Bridge
Distance to bore - landward
Distance to bore - towards coast
Elevation mAHD
Bore Distance (m)
Station
74960 = Sharks Creek
40
30
20
10
0
-10
500
400
300
200
100
0
68000
69000
70000
71000
72000
73000
74000
75000

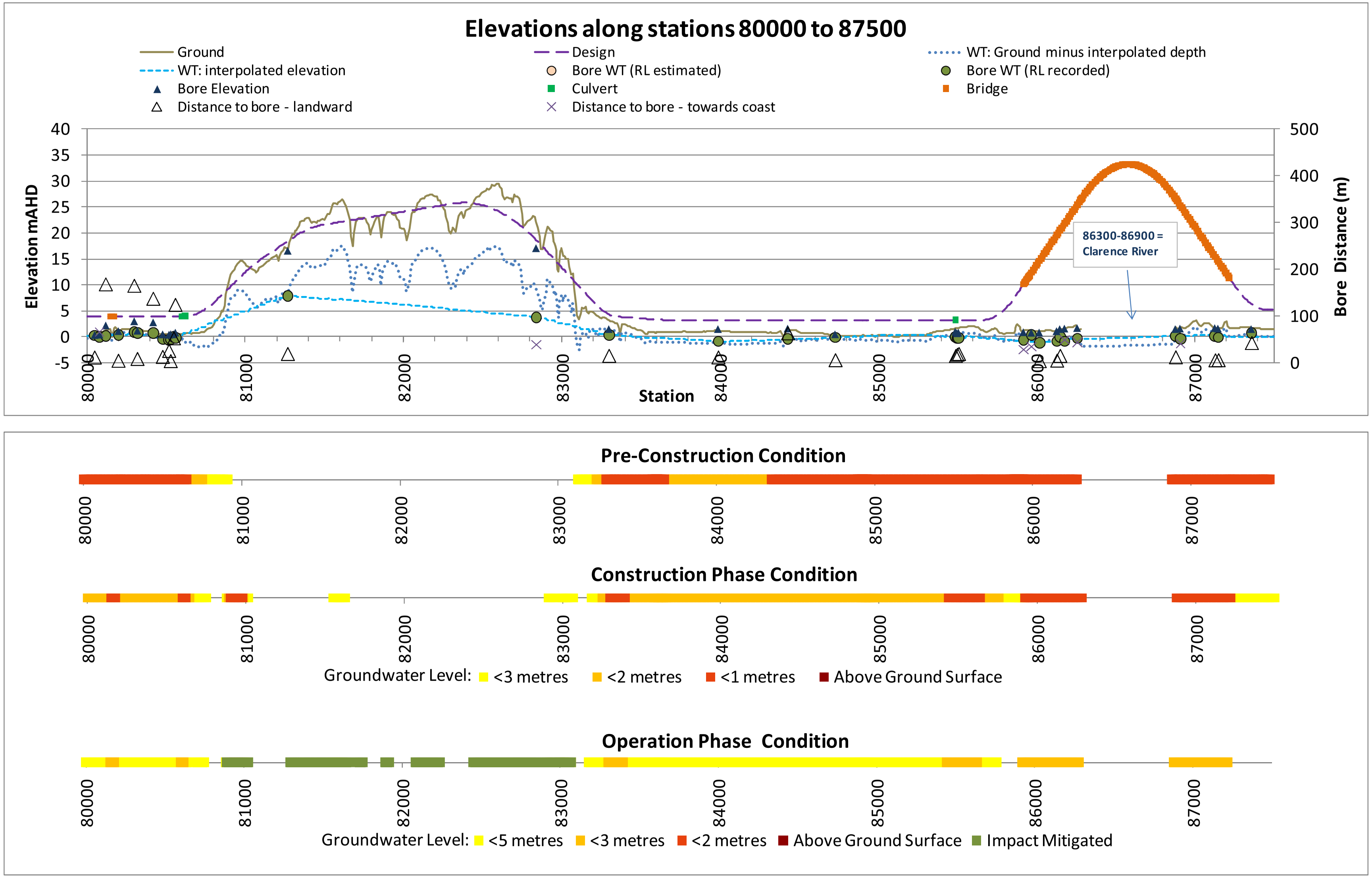

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated
68000
69000
70000
71000
72000
73000
74000
75000


Elevations along stations 75000 to 80000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
Station
60
50
40
30
20
10
0
-10
500
400
300
200
100
0
75000
75500
76000
76500
77000
77500
78000
78500
79000
79500
80000

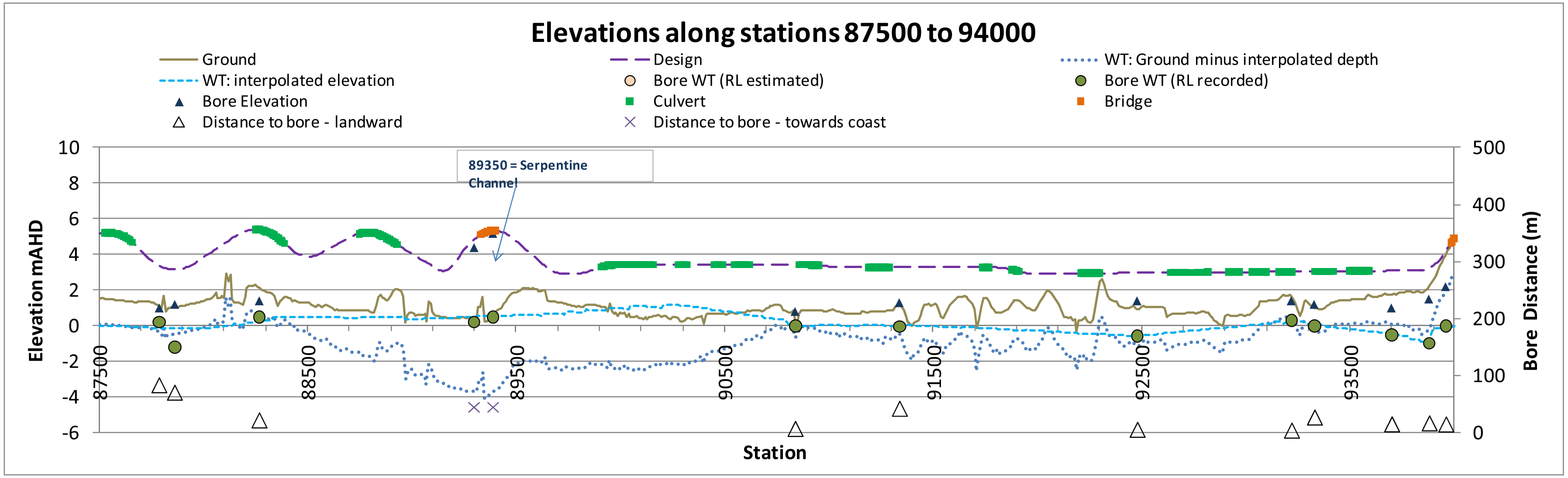

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres
<2 metres
<1 metres
Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres
<3 metres
<2 metres
Above Ground Surface
Impact Mitigated
75000
75500
76000
76500
77000
77500
78000
78500
79000
79500
80000

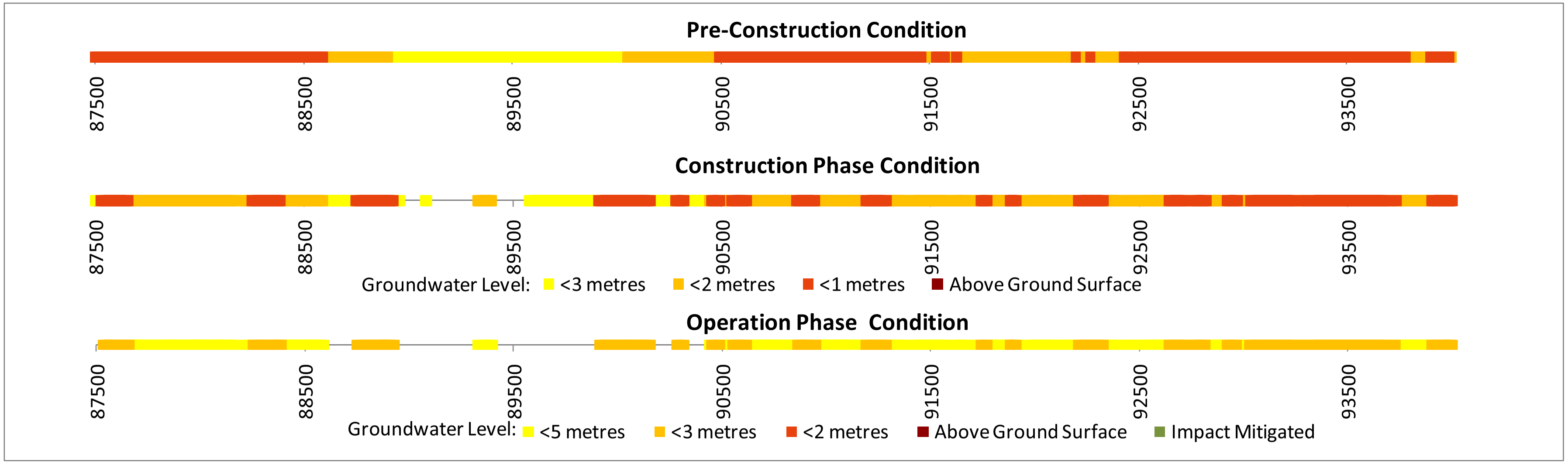

Elevations along cross section at station 78470
Ground - 25m DEM
WT: interpolated elevation
Ground - from design team
Ground - 2m DEM
Bore WT (RL estimated)
Distance to bore
Road Elevation
Bore WT (RL recorded)
WT: Ground minus interpolated depth
Bore RL
Elevation mAHD
Bore Distance (m)
Station
160
140
120
100
80
60
40
20
0
-20
90
80
70
60
50
40
30
20
10
0
1000
2000
3000
4000
5000
6000

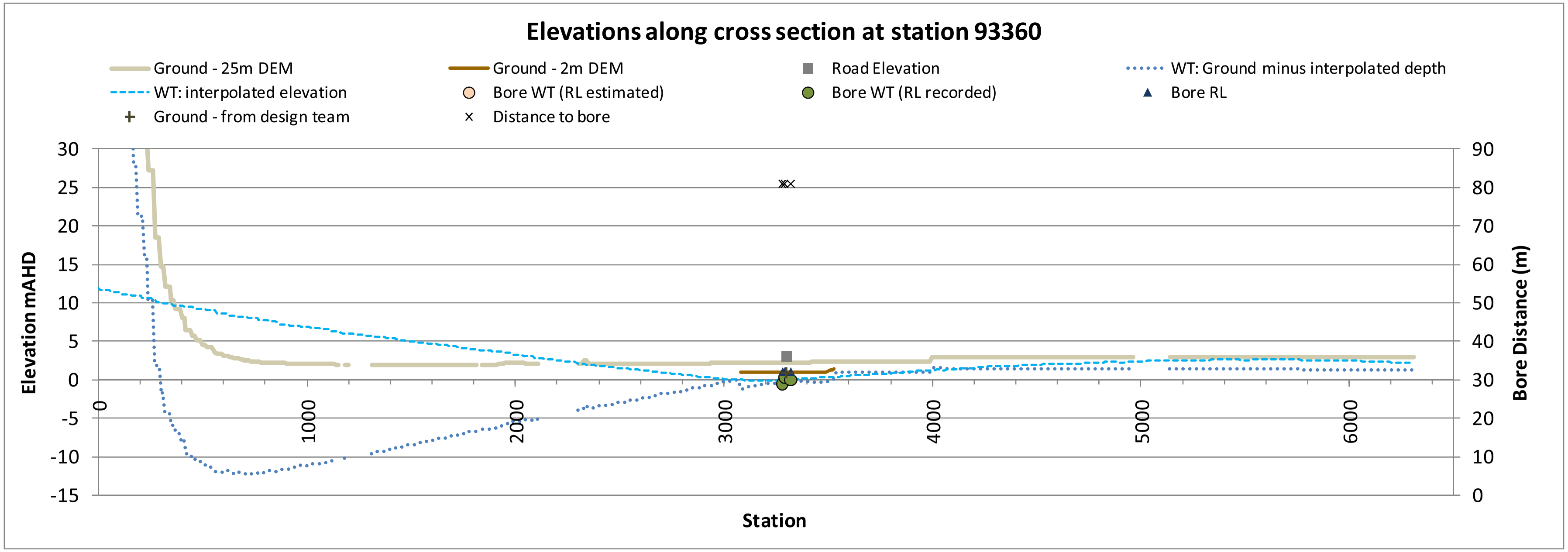

Pre-Construction Condition
0
1000
2000
3000
4000
5000
6000
Groundwater Level: <5 metres <3 metres <2 metres



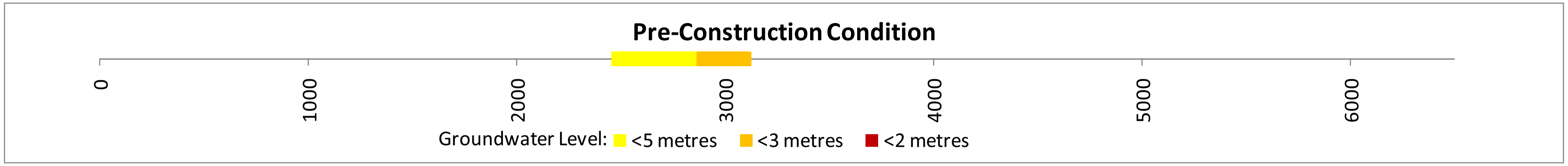
Elevations along stations 80000 to 87500
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
Station
86300-86900 = Clarence River
Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated


Elevations along stations 87500 to 94000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
89350 = Serpentine Channel
Elevation mAHD
Bore Distance (m)
Station
10
8
6
4
2
0
-2
-4
-6
500
400
300
200
100
0
87500
88500
89500
90500
91500
92500
93500

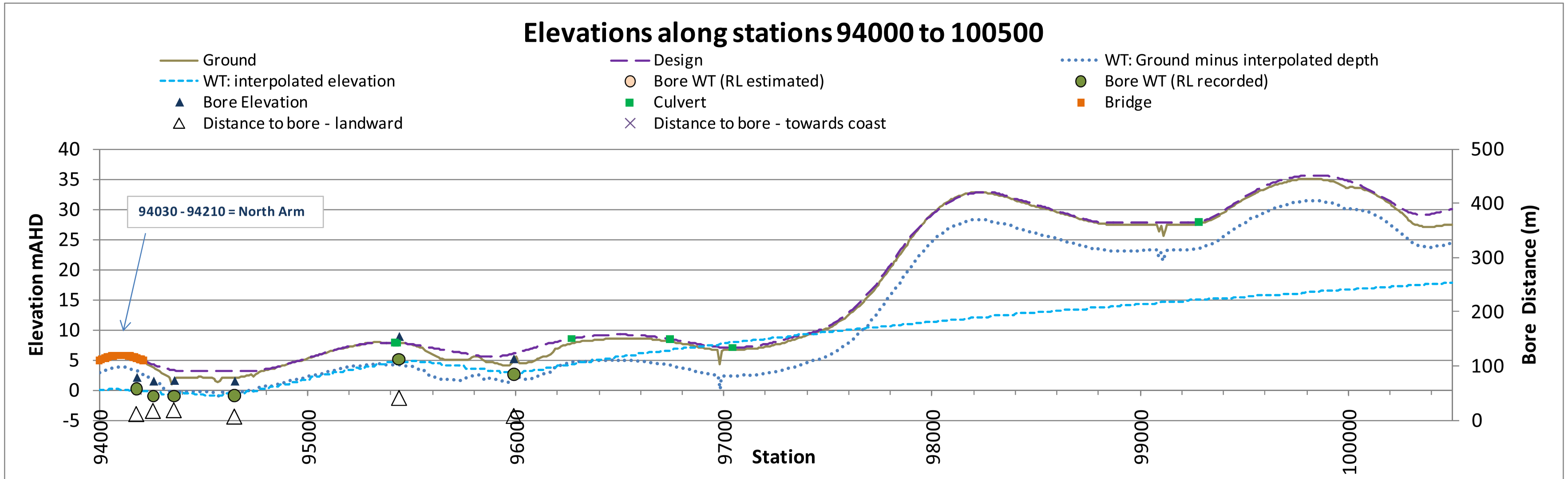

Pre-Construction Condition
87500
88500
89500
90500
91500
92500
93500
Construction Phase Condition
87500
88500
89500
90500
91500
92500
93500
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
87500
88500
89500
90500
91500
92500
93500
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated

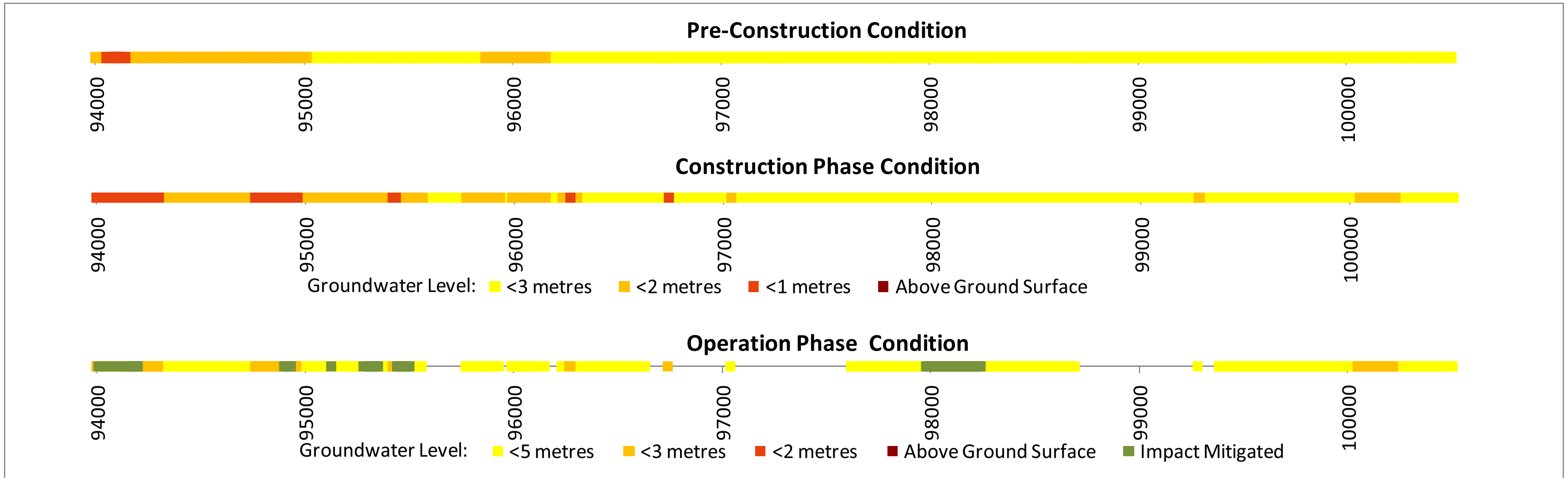


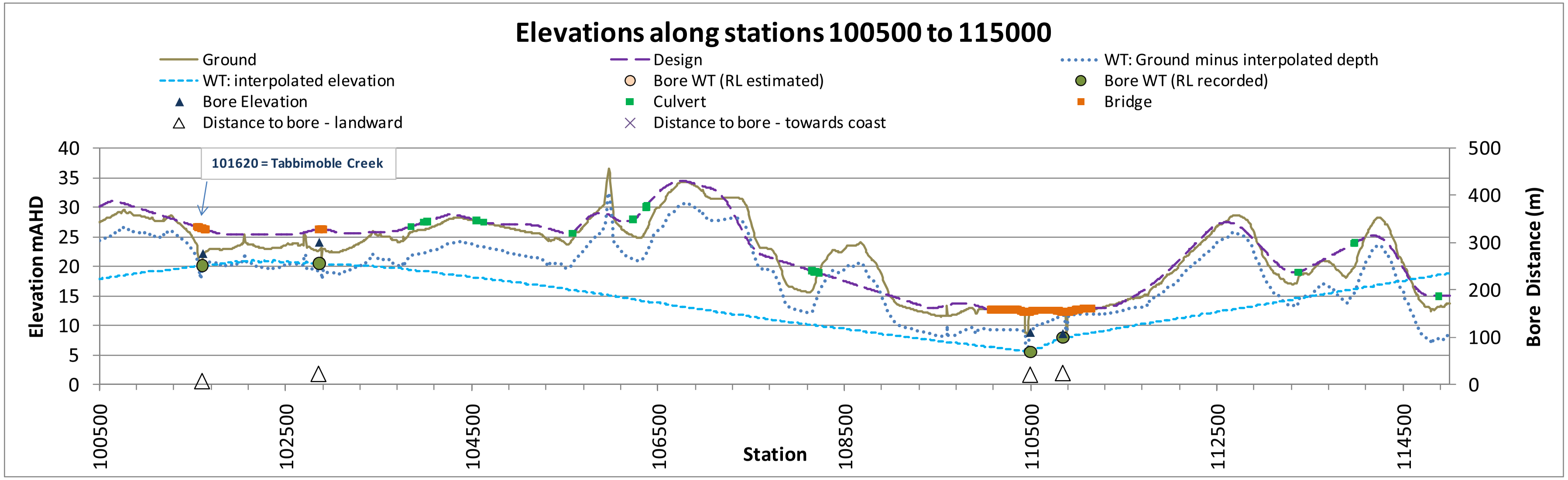
Elevations along cross section at station 93360
Ground - 25m DEM
Ground - 2m DEM
Road Elevation
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore RL
Ground - from design team
Distance to bore
Elevation mAHD
Bore Distance (m)
Station
30
25
20
15
10
5
0
-5
-10
-15
90
80
70
60
50
40
30
20
10
0
1000
2000
3000
4000
5000
6000

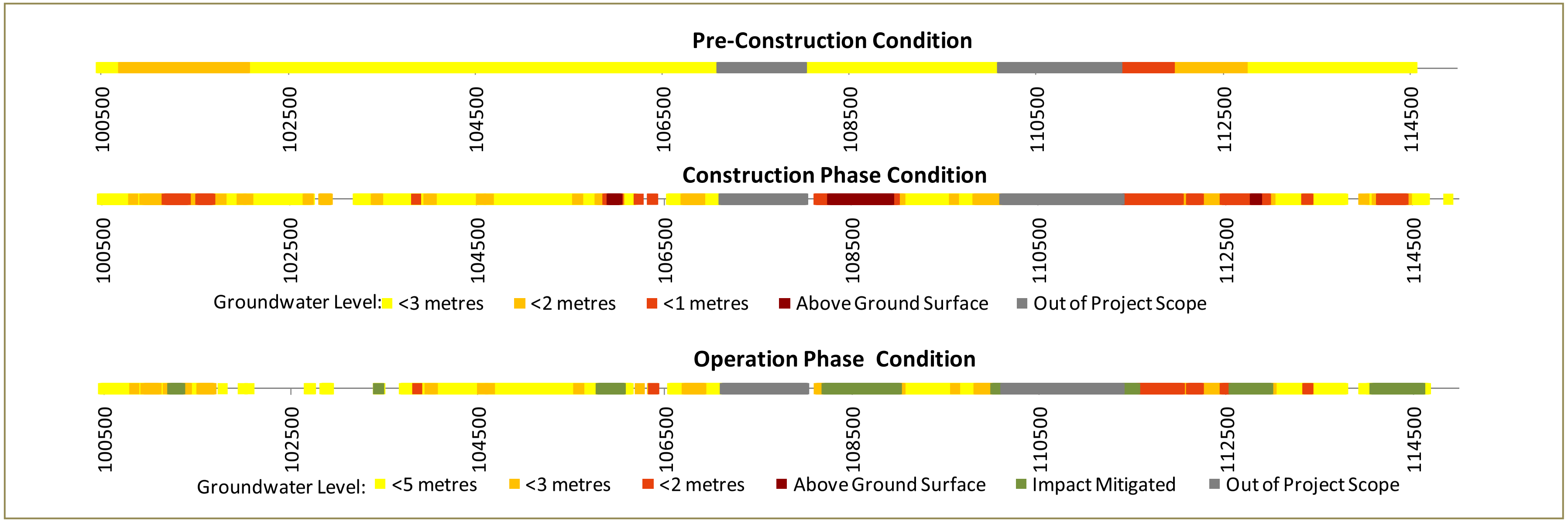


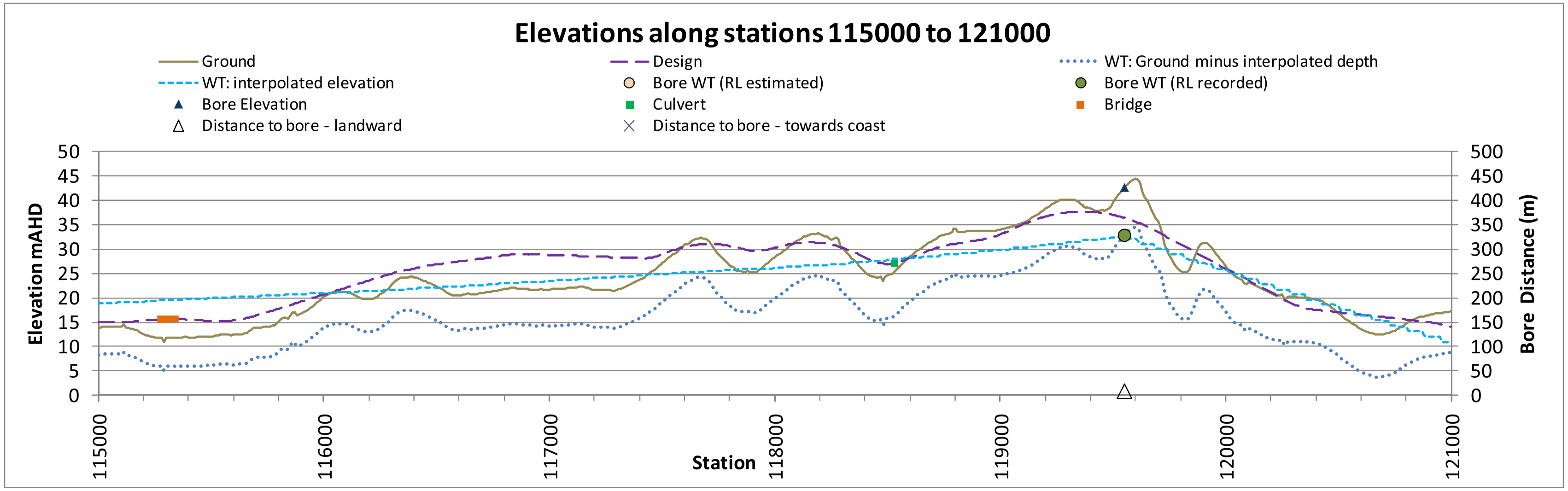
Pre-Construction Condition
0
1000
2000
3000
4000
5000
6000
Groundwater Level:
<5 metres
<3 metres
<2 metres

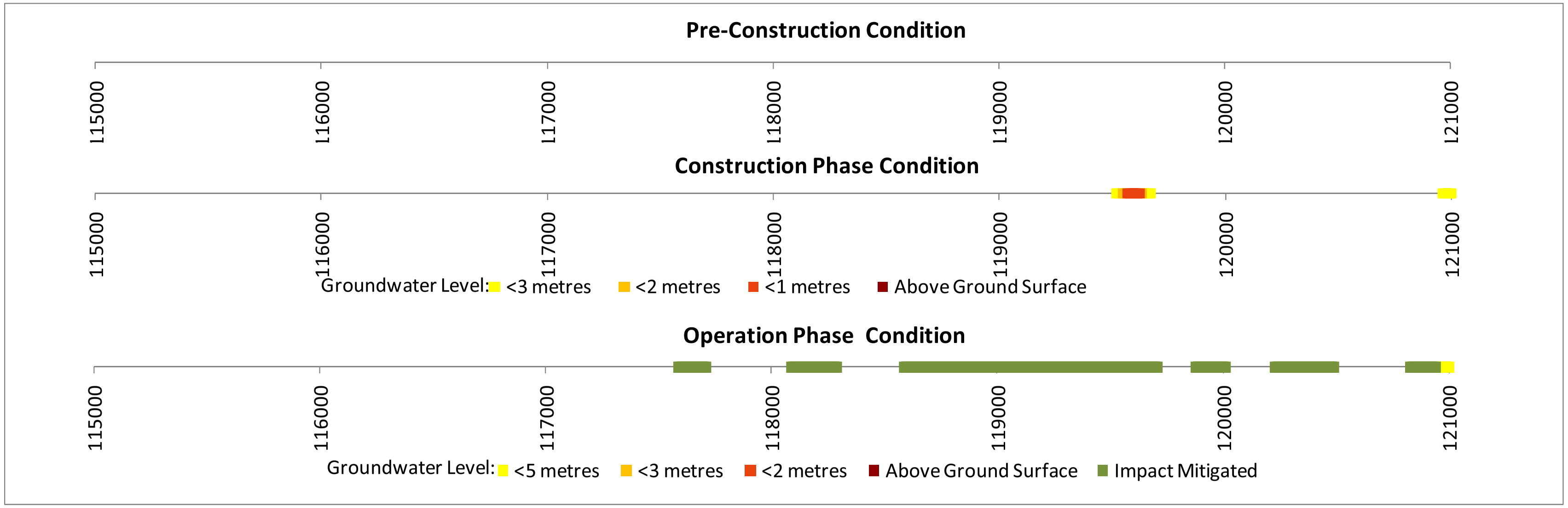

Elevations along stations 94000 to 100500
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
94030 - 94210 = North Arm
Elevation mAHD
Bore Distance (m)
Station
94000
95000
96000
97000
98000
99000
100000

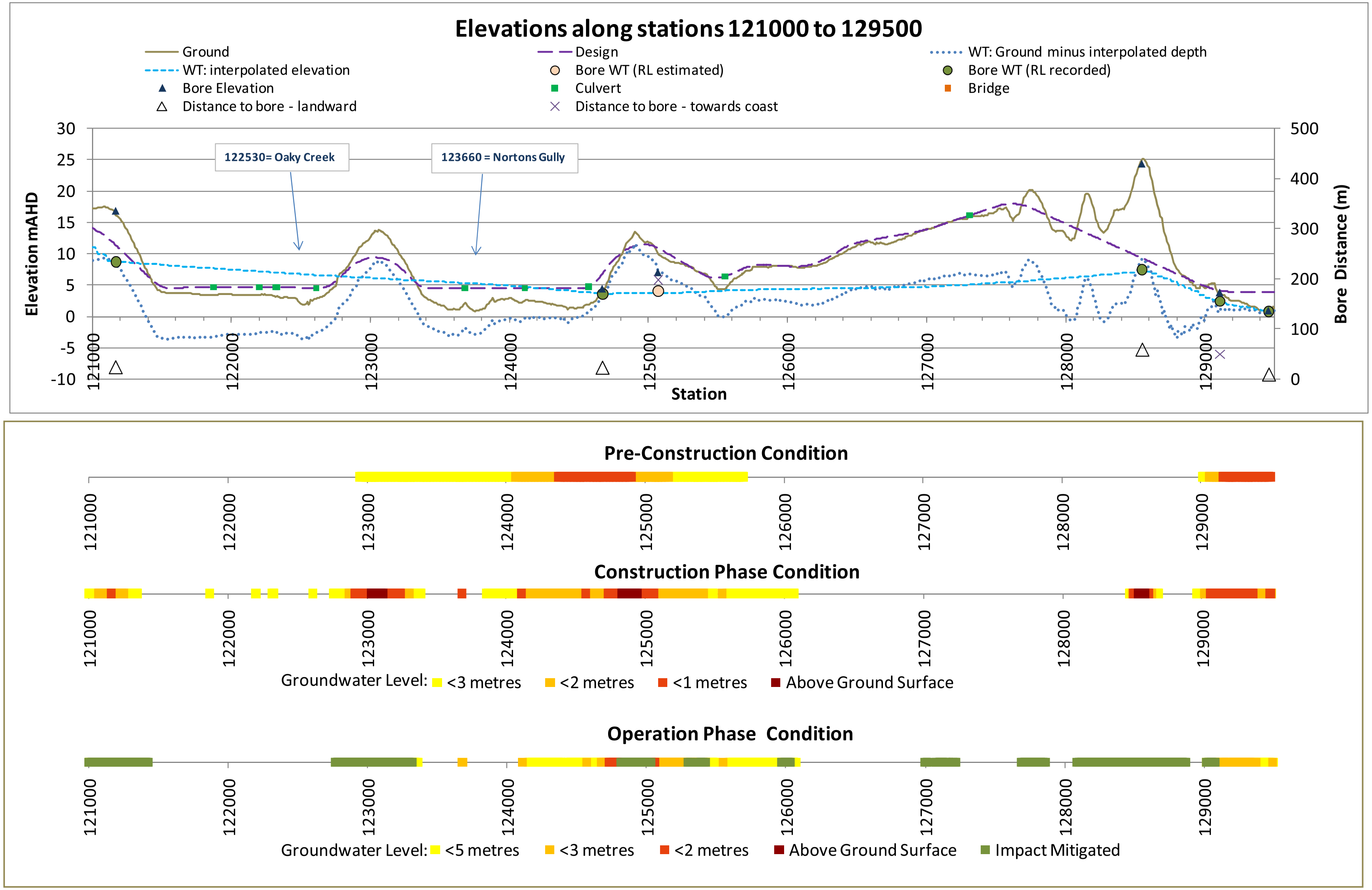

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated
94000
95000
96000
97000
98000
99000
100000

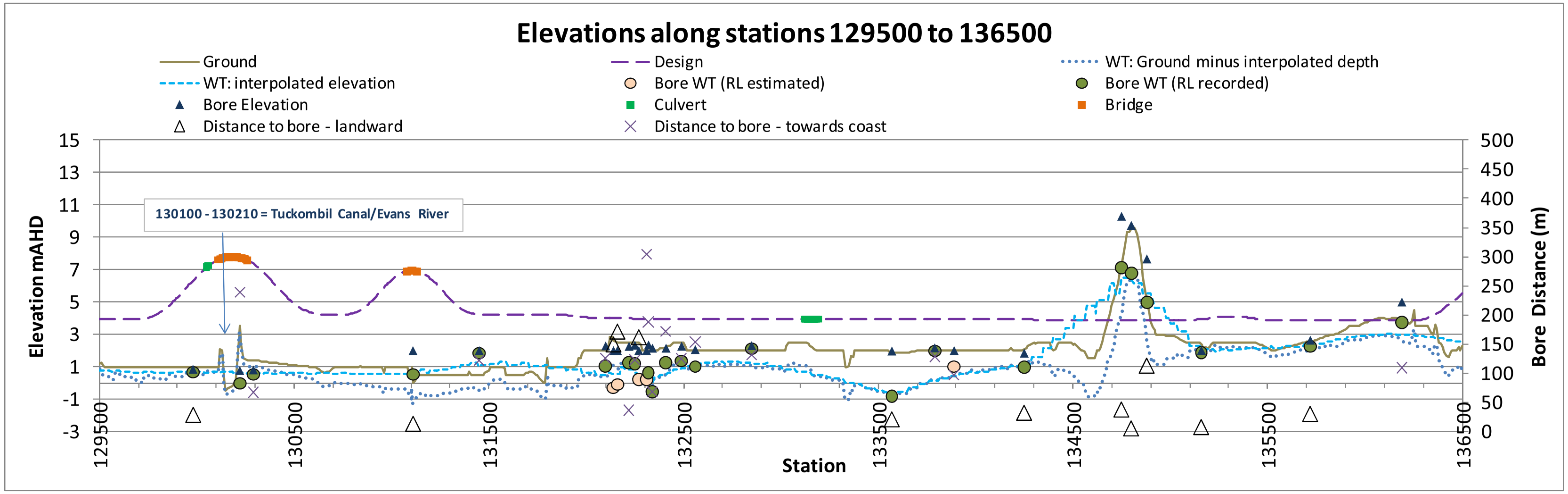

Elevations along stations 100500 to 115000
Ground
Design
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore Elevation
Culvert
Bridge
Distance to bore - landward
Distance to bore - towards coast
101620 = Tabbimoble Creek
Elevation mAHD
Bore Distance (m)
Station
0
5
10
15
20
25
30
35
40
100
200
300
400
500
100500
102500
104500
106500
108500
110500
112500
114500

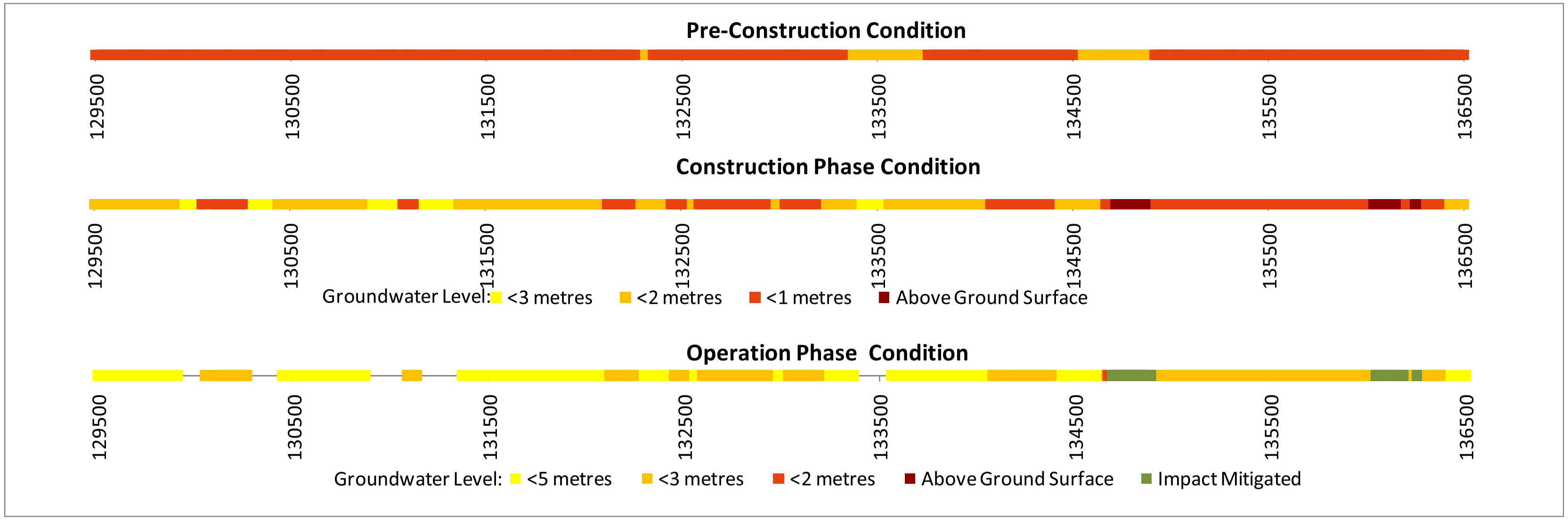

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres
<2 metres
<1 metres
Above Ground Surface
Out of Project Scope
Operation Phase Condition
Groundwater Level: <5 metres
<3 metres
<2 metres
Above Ground Surface
Impact Mitigated
Out of Project Scope
100500
102500
104500
106500
108500
110500
112500
114500

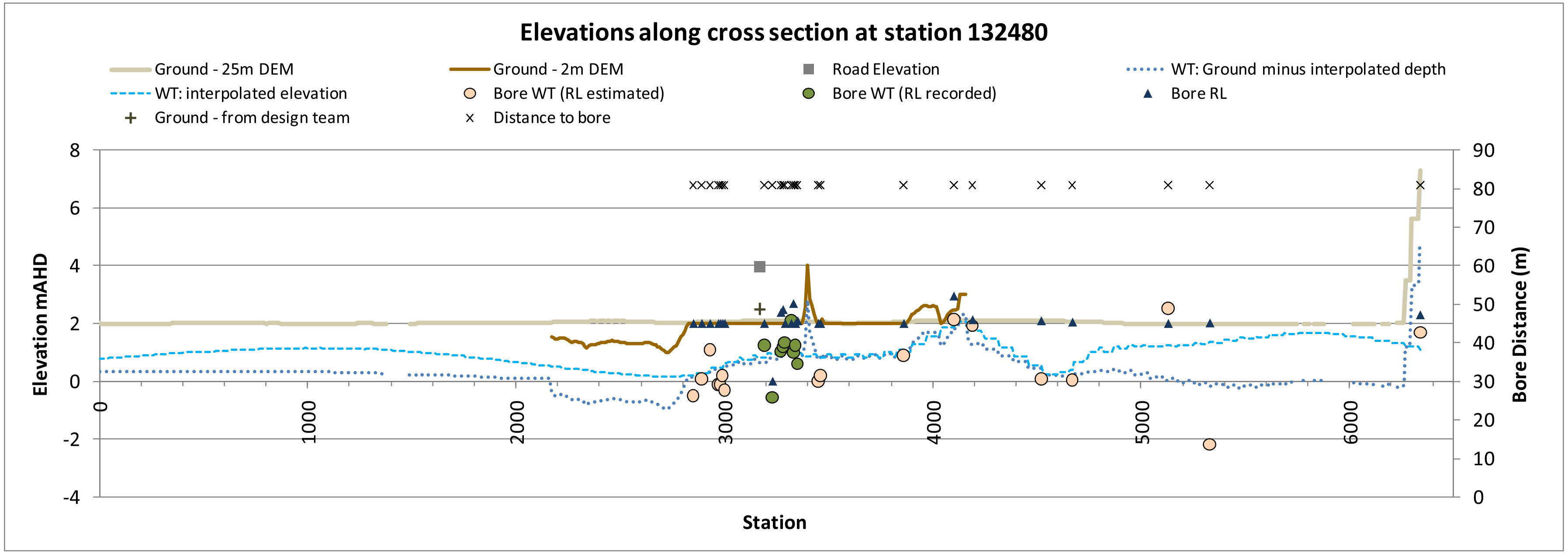

Elevations along stations 115000 to 121000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
Station
115000
116000
117000
118000
119000
120000
121000

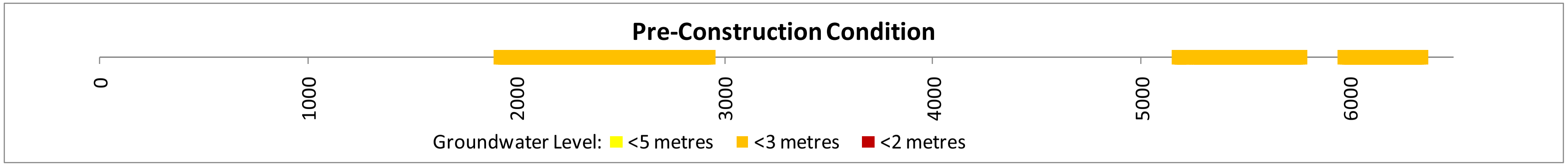

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated
115000
116000
117000
118000
119000
120000
121000

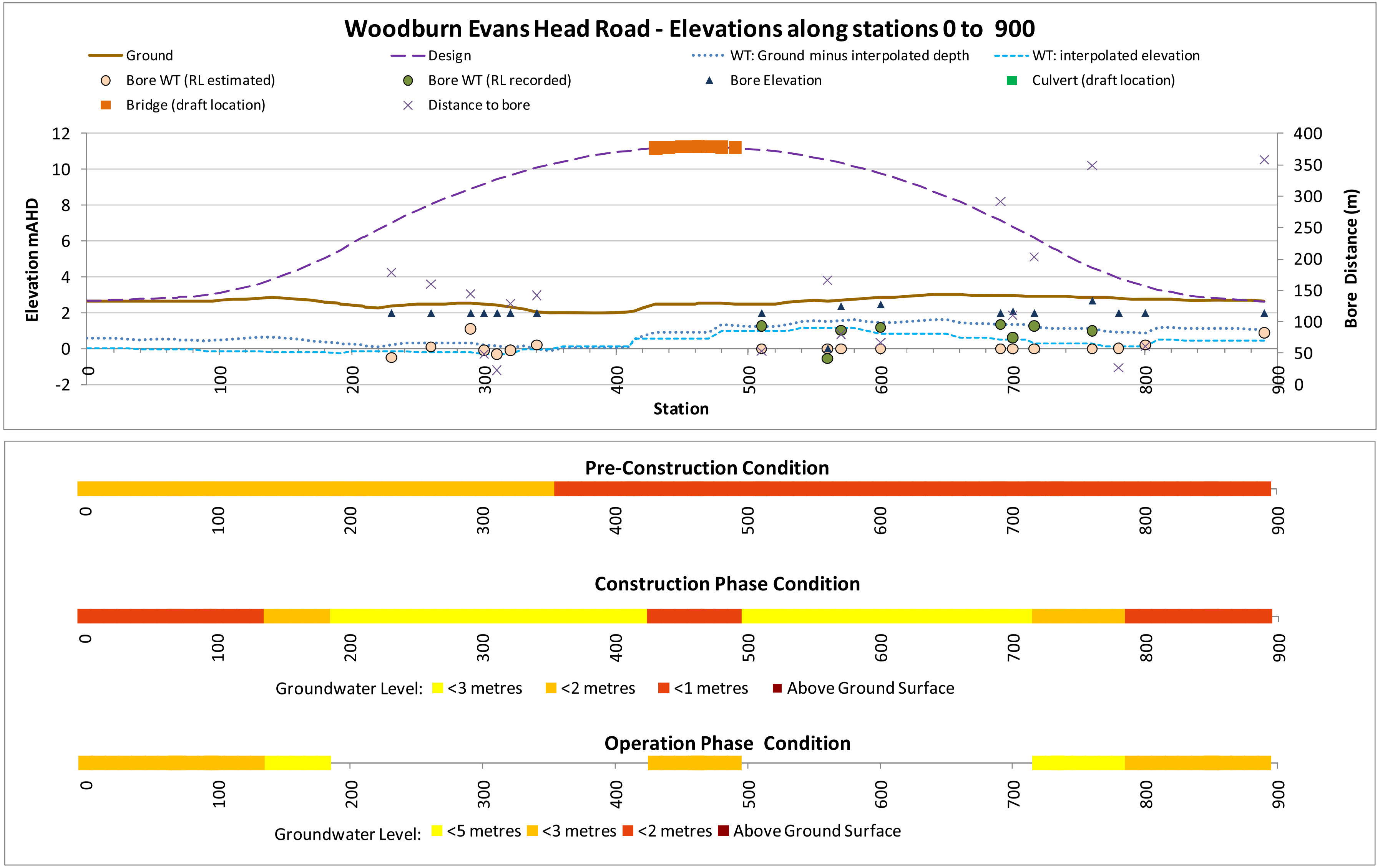

Elevations along stations 121000 to 129500
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
122530= Oaky Creek
123660 = Nortons Gully
Elevation mAHD
Bore Distance (m)
Station
Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated

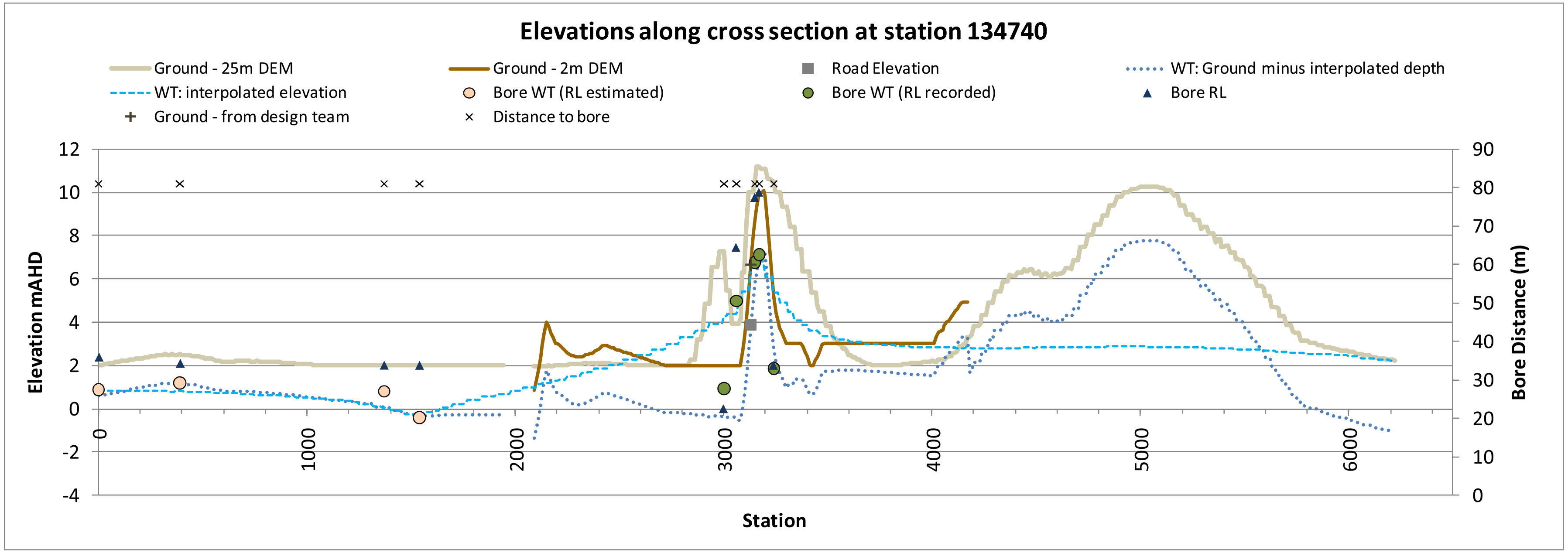

Elevations along stations 129500 to 136500
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
Station
130100 - 130210 = Tuckombil Canal/Evans River
129500
130500
131500
132500
133500
134500
135500
136500

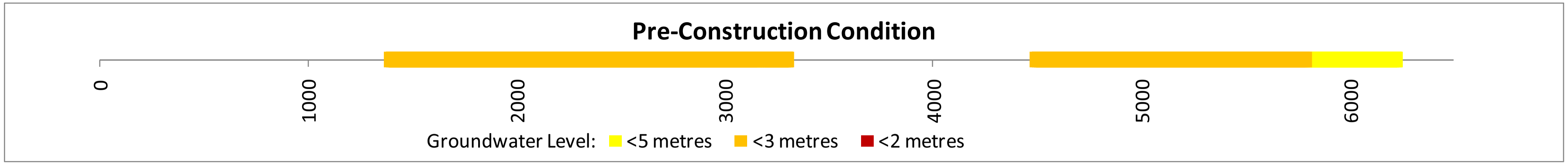

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated
129500
130500
131500
132500
133500
134500
135500
136500

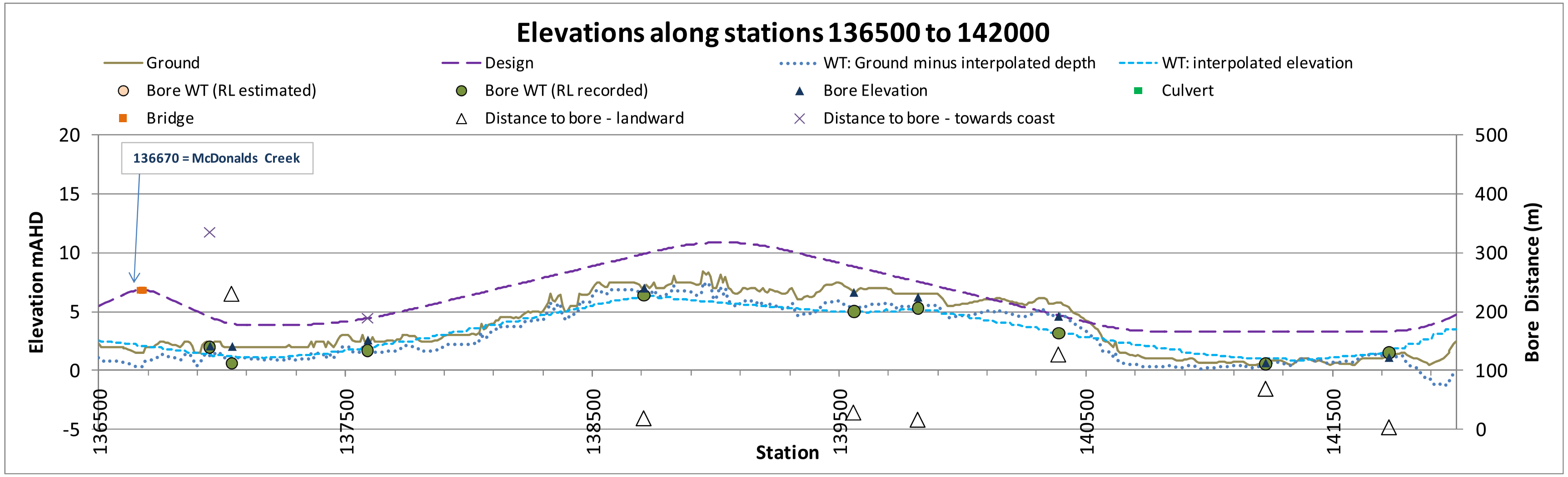

Elevations along cross section at station 132480
Ground - 25m DEM
WT: interpolated elevation
Ground - from design team
Ground - 2m DEM
Bore WT (RL estimated)
Distance to bore
Road Elevation
Bore WT (RL recorded)
WT: Ground minus interpolated depth
Bore RL
Elevation mAHD
Bore Distance (m)
Station
0
1000
2000
3000
4000
5000
6000

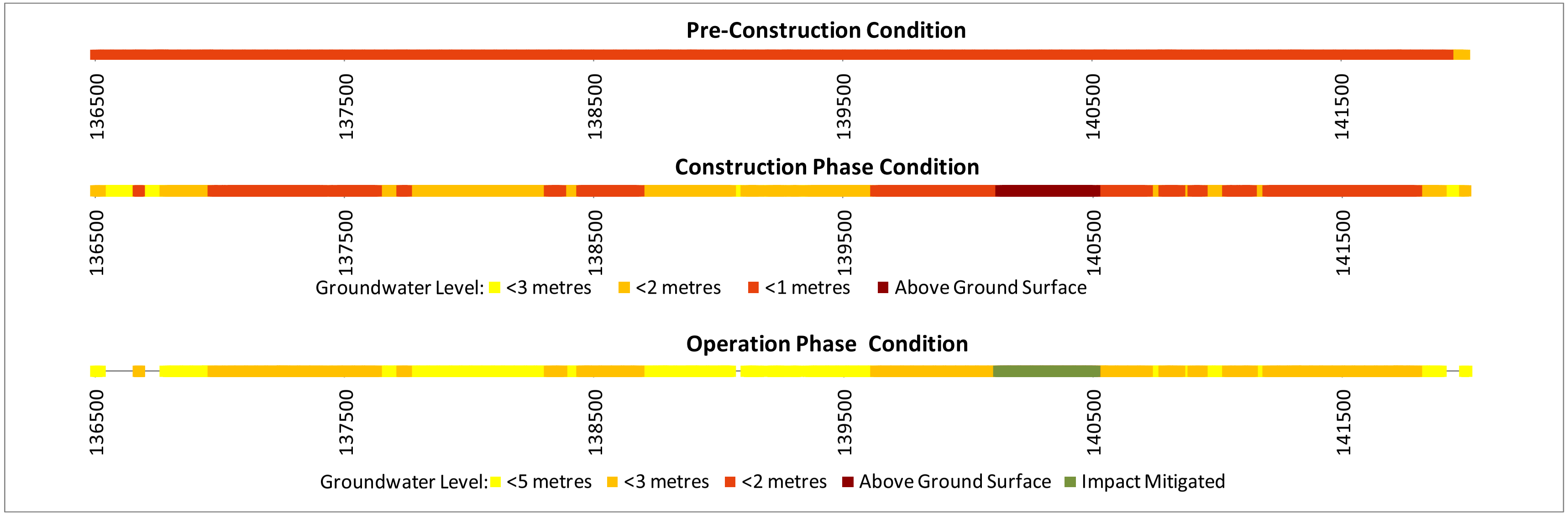

Pre-Construction Condition
0
1000
2000
3000
4000
5000
6000
Groundwater Level: <5 metres <3 metres <2 metres

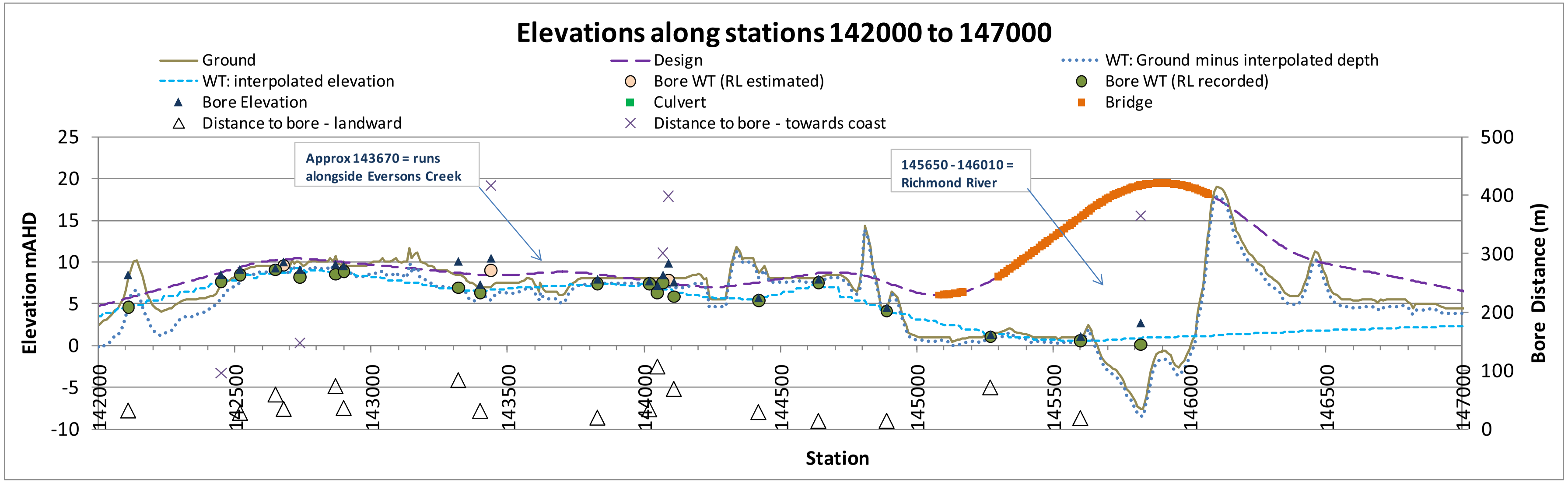

Woodburn Evans Head Road - Elevations along stations 0 to 900
Ground
Design
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore Elevation
Culvert (draft location)
Bridge (draft location)
Distance to bore
Elevation mAHD
Bore Distance (m)
Station
Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface

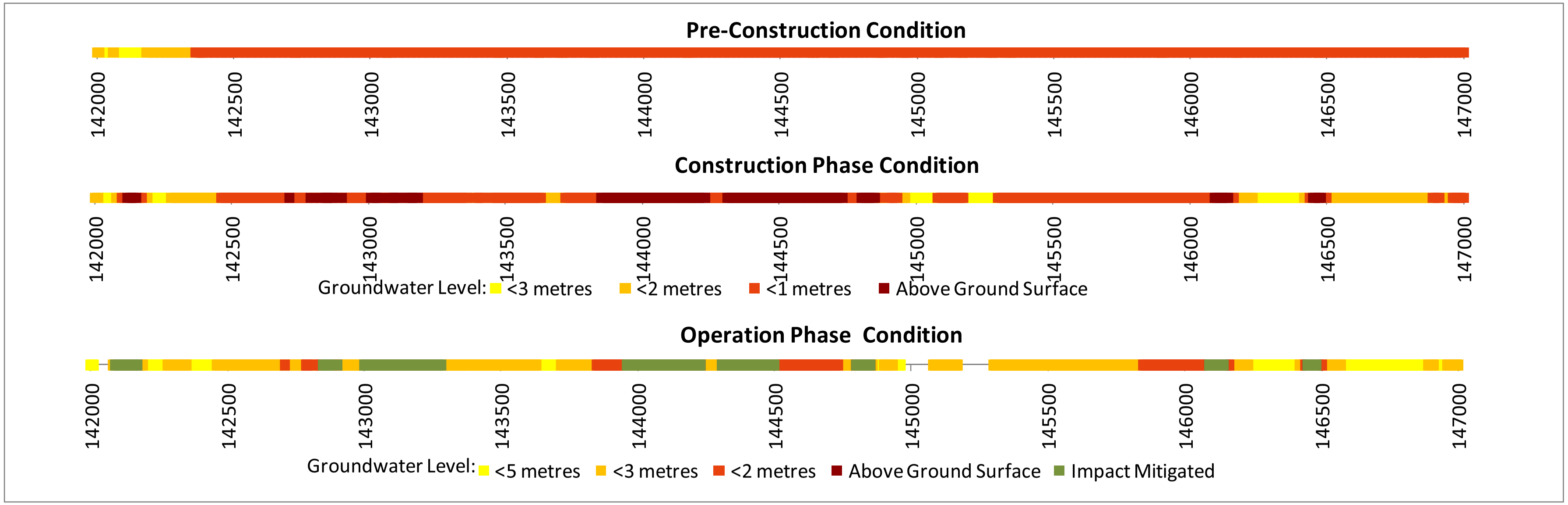

Elevations along cross section at station 134740
Ground - 25m DEM
Ground - 2m DEM
Road Elevation
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore RL
Ground - from design team
Distance to bore
Elevation mAHD
Bore Distance (m)
Station
12
10
8
6
4
2
0
-2
-4
90
80
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
6000

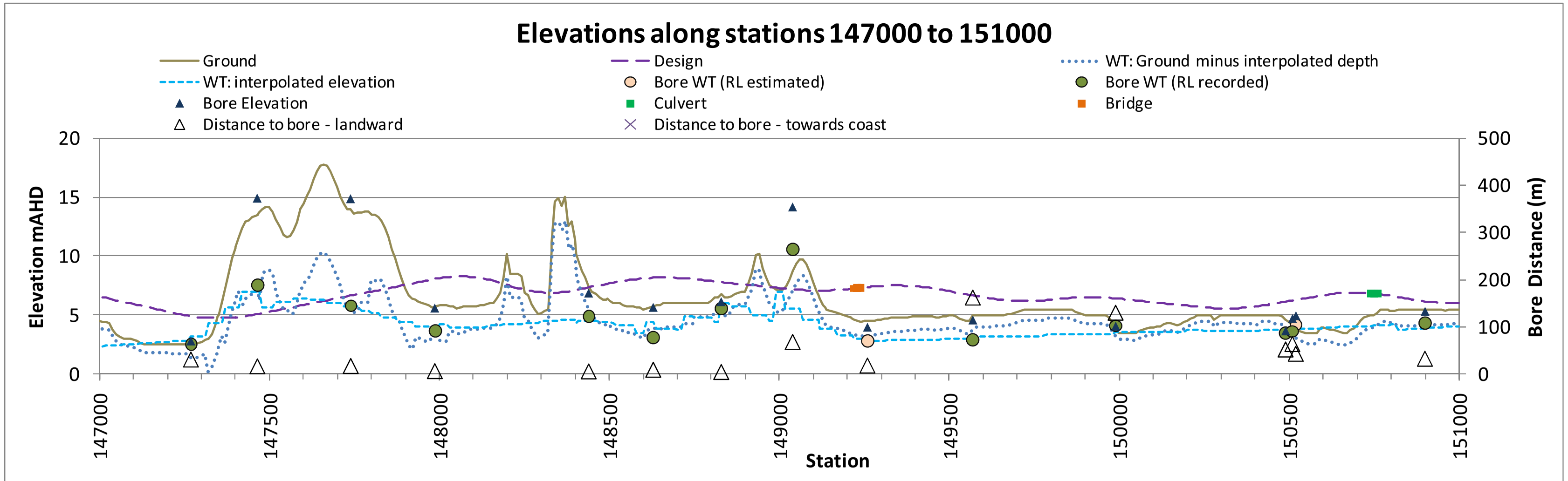

Pre-Construction Condition
0
1000
2000
3000
4000
5000
6000
Groundwater Level: <5 metres <3 metres <2 metres

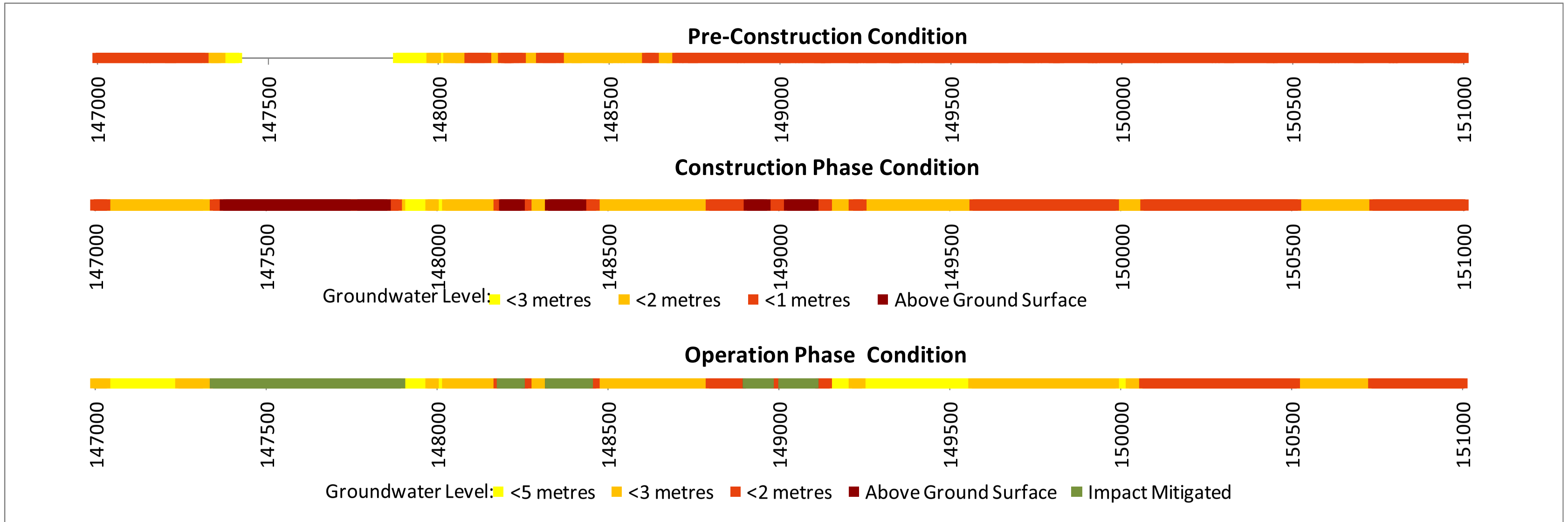

Elevations along stations 136500 to 142000
Ground
Design
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore Elevation
Culvert
Bridge
Distance to bore - landward
Distance to bore - towards coast
136670 = McDonalds Creek
Elevation mAHD
Bore Distance (m)
Station
20
15
10
5
0
-5
500
400
300
200
100
0
136500
137500
138500
139500
140500
141500

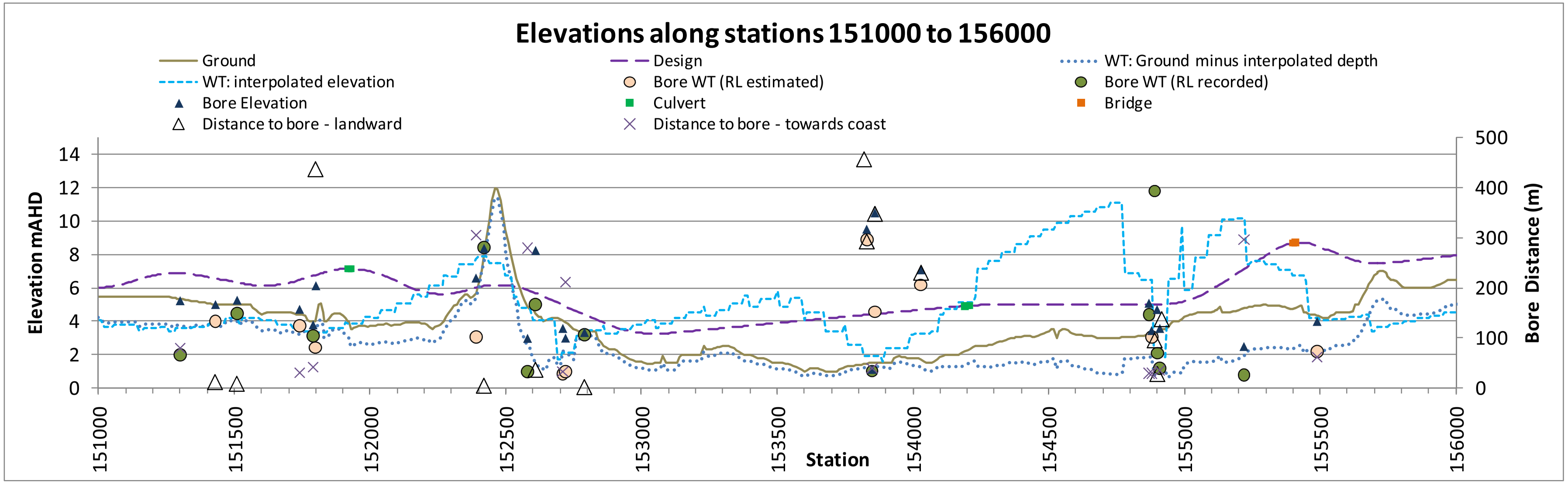

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated
136500
137500
138500
139500
140500
141500

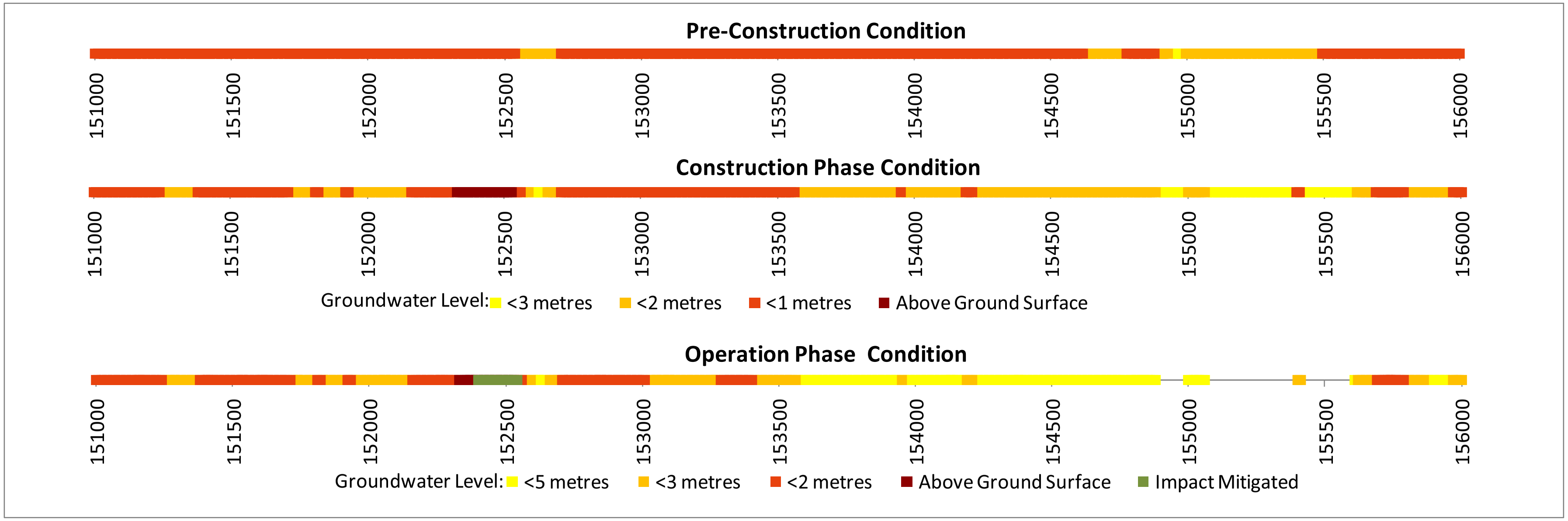

Elevations along stations 142000 to 147000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Approx 143670 = runs alongside Eversons Creek
145650 - 146010 = Richmond River
Elevation mAHD
Bore Distance (m)
Station
25
20
15
10
5
0
-5
-10
500
400
300
200
100
0
142000
142500
143000
143500
144000
144500
145000
145500
146000
146500
147000

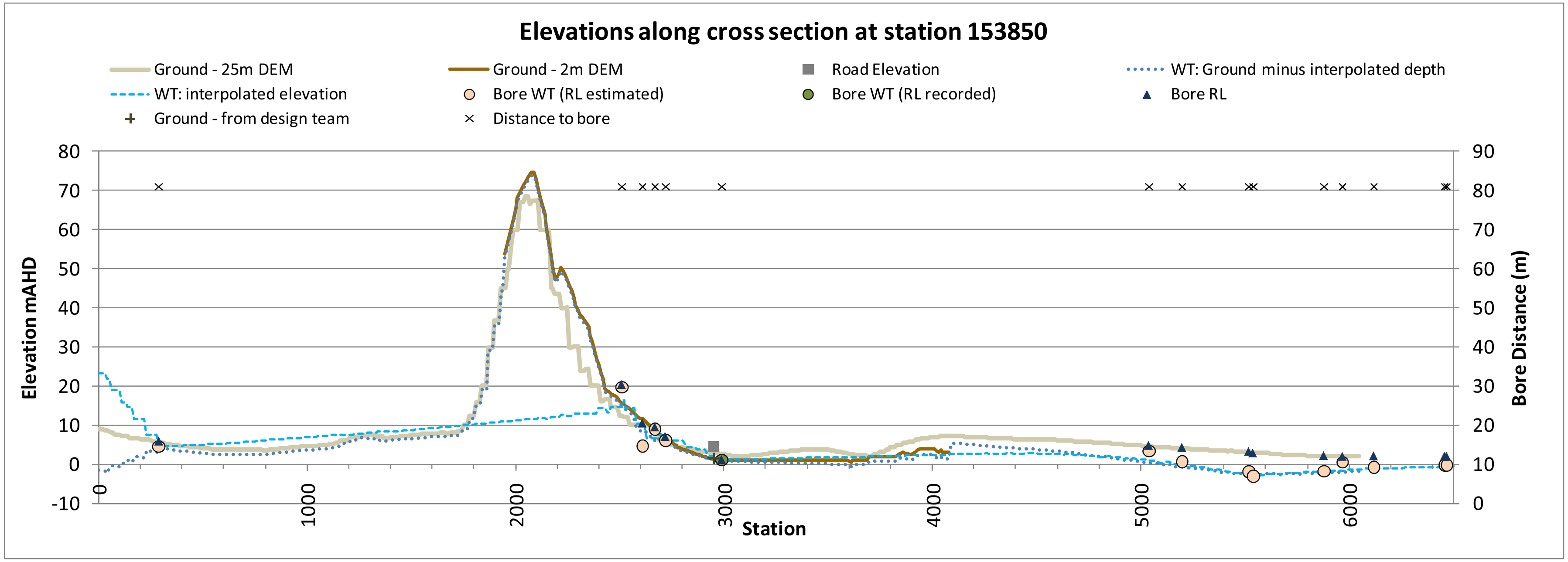

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated
142000
142500
143000
143500
144000
144500
145000
145500
146000
146500
147000

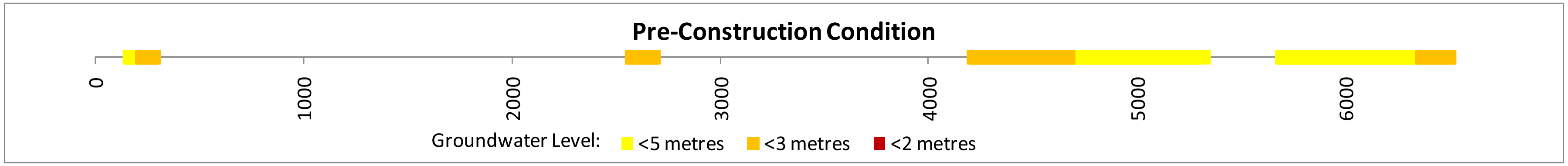

Elevations along stations 147000 to 151000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
Station
147000
147500
148000
148500
149000
149500
150000
150500
151000
0
5
10
15
20
100
200
300
400
500

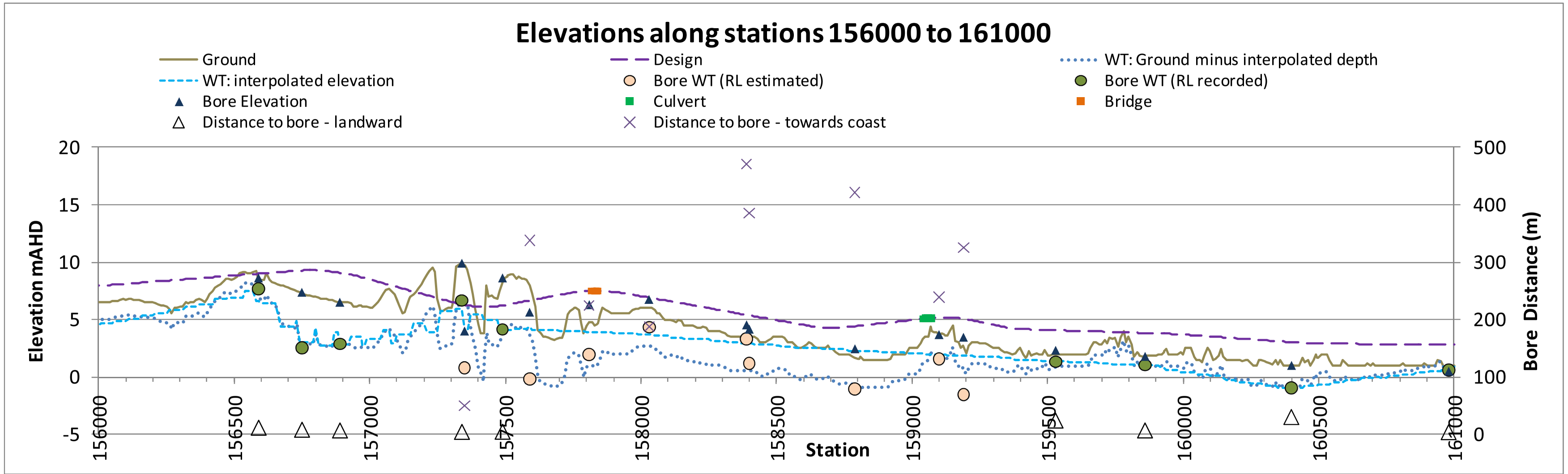

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres
<2 metres
<1 metres
Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres
<3 metres
<2 metres
Above Ground Surface
Impact Mitigated
147000
147500
148000
148500
149000
149500
150000
150500
151000

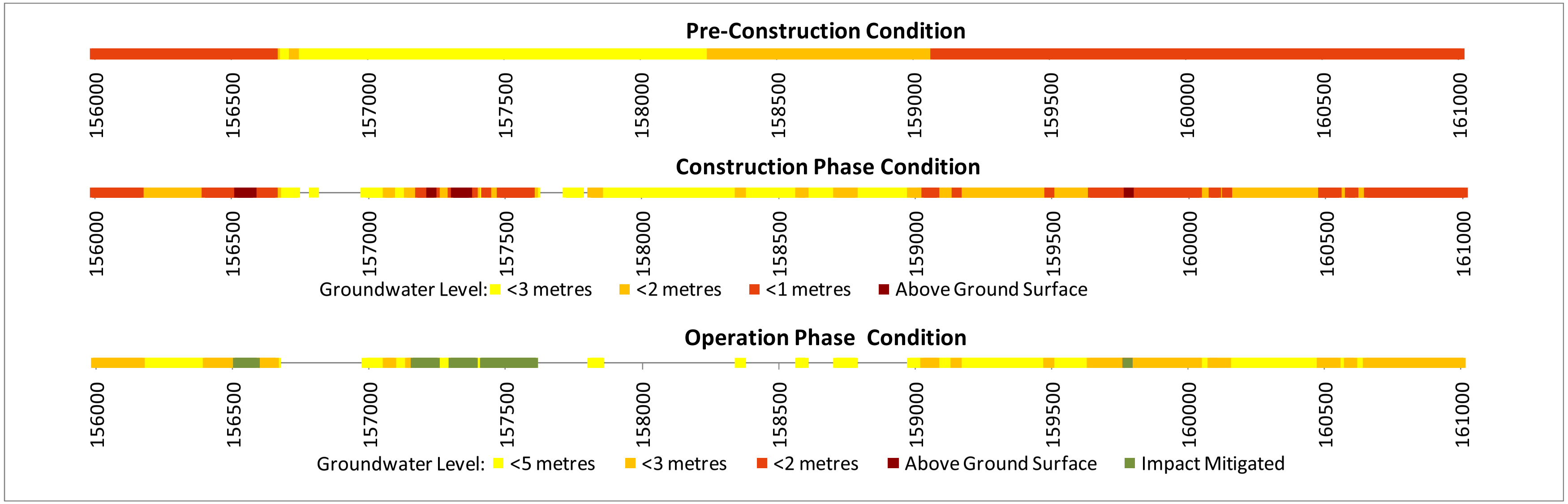

Elevations along stations 151000 to 156000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
Bore Distance (m)
Station
0
2
4
6
8
10
12
14
0
100
200
300
400
500
151000
151500
152000
152500
153000
153500
154000
154500
155000
155500
156000

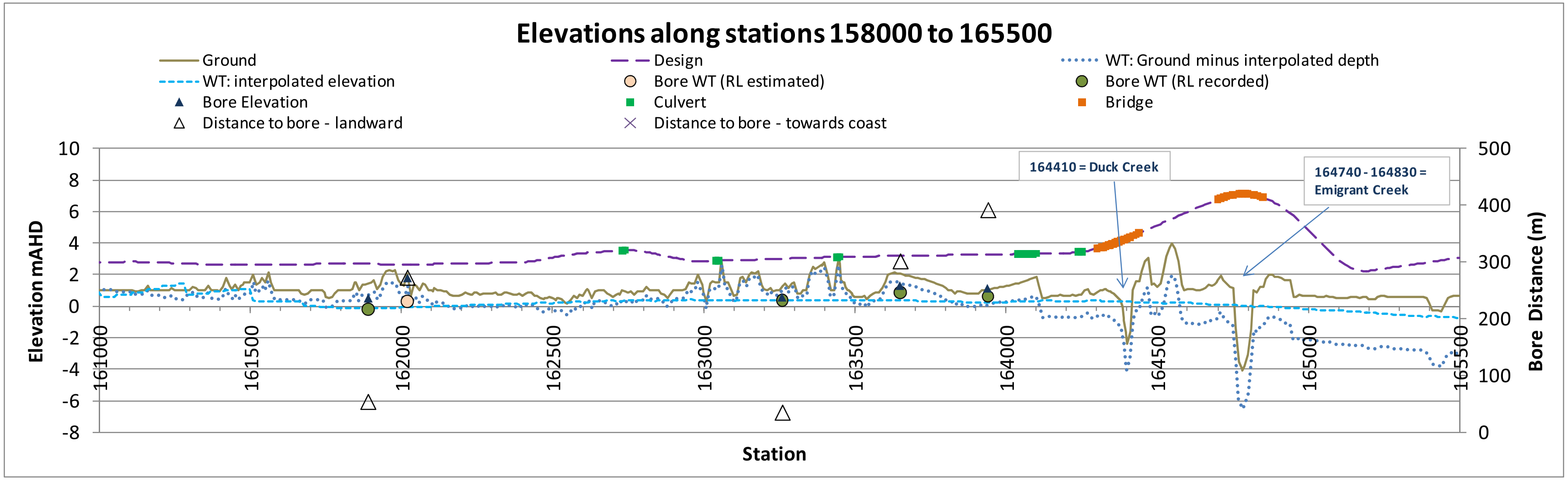

Pre-Construction Condition
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated
151000
151500
152000
152500
153000
153500
154000
154500
155000
155500
156000

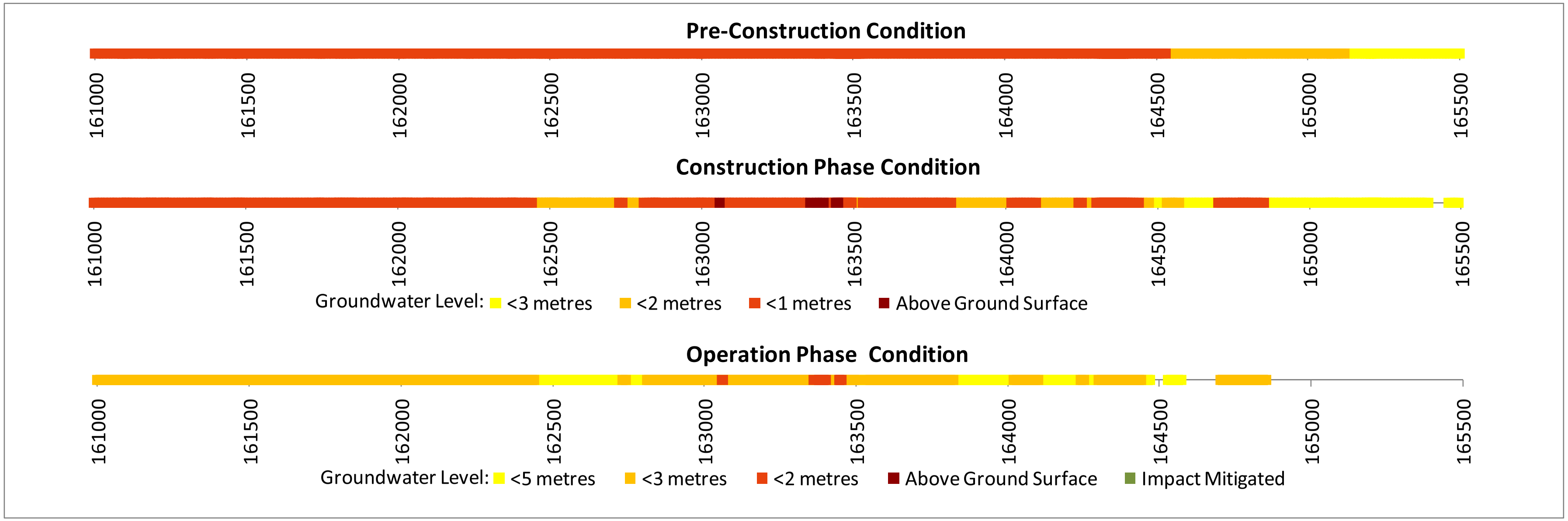

Elevations along cross section at station 153850
Ground - 25m DEM
Ground - 2m DEM
Road Elevation
WT: Ground minus interpolated depth
WT: interpolated elevation
Bore WT (RL estimated)
Bore WT (RL recorded)
Bore RL
Ground - from design team
Distance to bore
Elevation mAHD
Bore Distance (m)
Station
80
70
60
50
40
30
20
10
0
-10
90
0
1000
2000
3000
4000
5000
6000


Pre-Construction Condition
0
1000
2000
3000
4000
5000
6000
Groundwater Level:
<5 metres
<3 metres
<2 metres


Elevations along stations 156000 to 161000
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
Elevation mAHD
20
15
10
5
0
-5
Bore Distance (m)
500
400
300
200
100
0
156000
156500
157000
157500
158000
158500
159000
159500
160000
160500
161000
Station


Pre-Construction Condition
156000
156500
157000
157500
158000
158500
159000
159500
160000
160500
161000
Construction Phase Condition
156000
156500
157000
157500
158000
158500
159000
159500
160000
160500
161000
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
156000
156500
157000
157500
158000
158500
159000
159500
160000
160500
161000
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated


Elevations along stations 158000 to 165500
Ground
WT: interpolated elevation
Bore Elevation
Distance to bore - landward
Design
Bore WT (RL estimated)
Culvert
Distance to bore - towards coast
WT: Ground minus interpolated depth
Bore WT (RL recorded)
Bridge
164410 = Duck Creek
164740 - 164830 = Emigrant Creek
Elevation mAHD
Bore Distance (m)
Station
10
8
6
4
2
0
-2
-4
-6
-8
500
400
300
200
100
0
161000
161500
162000
162500
163000
163500
164000
164500
165000
165500


Pre-Construction Condition
161000
161500
162000
162500
163000
163500
164000
164500
165000
165500
Construction Phase Condition
Groundwater Level: <3 metres <2 metres <1 metres Above Ground Surface
Operation Phase Condition
Groundwater Level: <5 metres <3 metres <2 metres Above Ground Surface Impact Mitigated

5. Mitigation and management

The impact on groundwater and surface water systems will vary during the phases of the project: the construction phase and the operational phase. The management strategy, described below, needs to be in place before the construction phase of the project and carried through to the operational phase. Especially important are the monitoring and management measures that address the cuts which are identified in Table B-7-1. The concept design includes one hundred and fifty-seven cuts. Of these, 62 are located where the final design will sit below the current groundwater table and ingress of groundwater to the pavement can be expected if engineering measures to divert the groundwater are not instigated. A further 35 cuts will be located where the watertable is expected to be at or very close to the design surface and groundwater drainage is likely to be required. These 97 cuts are designated as Type A cuts, following the schema determined for the Tintenbar to Ewingdale Groundwater Assessment (Golders and Associates, 2008). Twenty more cuts are in locations where the watertable is likely to be less than three metres below the ground surface and a further 12 cuts are in locations where the water table is likely to be within five metres of the surface. These cuts are collectively designated as Type B cuts. No impact is expected, but additional monitoring and evaluation is required to determine the local conditions and groundwater trends to determine whether additional drainage is required at these locations. The remainder of proposed cuts are in areas with no potential groundwater impact and are designated Type C cuts.

5.1. Management strategy

Cuts with a high potential impact (Type A cuts) are expected to penetrate to and below the water table, and therefore have the potential to have an impact on downstream groundwater patterns, springs, creeks and any associated GDEs. The proposed management strategy to address this issue involves the following four steps:

- Pre-works investigations ─ geotechnical investigations of all cuts to determine groundwater condition (quality parameters, including electrical conductivity, groundwater depth, geological information), presence of actual or potential acid sulfate soils, presence or potential presence of salinisation, establishing groundwater monitoring sites, and gathering of other pertinent information
- Assessment – involving this study, the pre-works investigations carried out, groundwater modelling of type A cuts (and the Rous Water Woodburn borefield site), and predictions made from those results
- Monitoring – to assess whether the investigation and its predictions are accurate and to instigate early intervention in the unlikely case/s that the actual outcomes deviate from predictions. Monitoring would start before construction, and continue during construction. Monitoring would also continue into the operation phase of the project until groundwater conditions have stabilised
- Mitigation – implement environmental and engineering management measures where predictions and/or modelling and monitoring suggest that these are required to minimise impacts on groundwater.

The general paucity of data, coupled with the inherent variability of actual ground conditions mean that it is possible that the actual groundwater impacts may differ from our predictions. This is because geological conditions are highly variable and can change away from the locations at which investigations were performed in a non-predictive way. Thus, while we have specific point data, we cannot guarantee the efficacy of our interpolations between these points. In addition, groundwater conditions change over time, depending on climatic conditions and seasonal weather variations. For this reason, it is essential that feedback from the monitoring program is used to refine the assessment to determine the appropriate mitigation measure at any given location.

To effectively manage and mitigate groundwater impacts, and to consider the potential uncertainties about the actual impacts, the following approach is proposed:

High potential impact (Type A) cuts

There is a high likelihood that high potential impact cuts would affect groundwater regimes and any associated groundwater-dependent ecosystems (GDEs). The implementation of engineering measures are required as part of construction to mitigate any groundwater impacts. Long term monitoring of the groundwater regime in the vicinity of these cuts should be commenced well in advance of the road construction to determine the impact mitigation requirements. Depending on the results of the monitoring, before and during road construction, it is possible that engineering measures to mitigate impacts may not be required at some (or all) of these cuts. After road construction, the monitoring should continue to verify the effectiveness of any engineering measures, so that modifications can be made, if required.

Medium and low potential impact (Type B) cuts

It is likely that medium impact cuts would not have an adverse impact on groundwater regimes and GDEs and engineering mitigation measures are unlikely to be required at these sites. Long-term monitoring should be carried out, however, commencing prior to construction, with observations of groundwater behaviour and impact during construction used to verify impacts. As an outcome of the monitoring and observations, it may be necessary to implement engineering mitigation measures at some of these cuts.

No potential impact (Type C) cuts

These cuts are expected to have no or negligible groundwater impacts. Monitoring and engineering mitigation measures are not required.

The impact mitigation and management recommendations for all the potentially impacted cut sites would be incorporated into a Water Management Plan, to be prepared for both the construction and operational phases of the project, emphasising the monitoring framework, bore locations and frequency of sampling.

Further, surface water runoff from the constructed road is likely to contain contaminants, including elevated concentrations of suspended solids and metals. Surface water runoff from the road would need to be captured by a drainage system at each cut and would need to be managed before being reintroduced into the natural groundwater system.

5.2. Monitoring

5.2.1. Monitoring requirements

Monitoring of both groundwater level and chemical quality is proposed as an essential measure to mitigate uncertainty and verify predictions about groundwater behaviour. The monitoring would comprise:

- Installation and monitoring of wells
- Groundwater sampling and analyses for salinity, soluble solids and metals
- Visual observations of surface water flows at springs and creeks
- An assessment of local groundwater levels.

It is noted that a series of monitoring bores exist in the vicinity of the Woodburn borefield (Figure 2-5) and these should be used to provide an on-going sentinel function for early detection of surface water and groundwater quality changes.

Additional monitoring bores will be located during and following the completion of the current geotechnical investigations.

The objectives of groundwater monitoring for each of the three phases of the project (pre-construction, construction and operation) are as follows:

- Pre-construction phase
  - Identify parameters for monitoring during construction
  - Determine the indicative existing groundwater conditions – depth below ground surface and groundwater quality
- Construction phase
  - Identify if any groundwater problems are occurring as the result of construction activities
  - Identify where groundwater may be intersected by the construction works and hence require additional constraints for the works
  - Demonstrate compliance with legal and other monitoring requirements including the water quality criteria and/or targets for the project
- Operational phase
  - Assess and manage impacts on the receiving waters as the site stabilises
  - Assist in deciding when the site has stabilised and setting a new baseline condition for each site.

The frequency of monitoring is suggested in Table 5-1.

Table 5-1 Groundwater bore monitoring frequency

Upgrade phase	Sampling type	Sampling frequency
Pre-construction	Water level Water quality: field Water quality: lab	Quarterly, to assess seasonal variability Quarterly, to assess seasonal variability Sample at time of bore installation, then only if field determinations vary by >10%
Construction	Water level Water quality: field Water quality: lab	Wet weather: fortnightly Dry weather: monthly Monthly Only if field measurements vary by >10%
Operational	Water level Water quality: field Water quality: lab	Monthly until results demonstrate site has stabilised, then quarterly at designated monitoring bores Monthly until results demonstrate site has stabilised, then quarterly at designated monitoring bores Only if field measurements vary by >10%

Long-term monitoring of the existing monitoring wells should be continued up to, during and following construction of the cuts and major embankments. The monitoring would be initiated prior to construction (background data collection), and continued during construction and during the early years of operation, at a frequency to be determined (potentially quarterly for the first five years of operation, with a review of data to determine whether further monitoring is required). New monitoring wells will need to be installed at Type A and B cuts if there are currently no monitoring wells present. Additional monitoring wells may also be required at Type C cuts if further assessments suggest these sites are likely to have variable watertables that rise during wet conditions.

The objectives of long-term monitoring would be to:

- Obtain baseline groundwater data over a sufficient period to verify the validity of predicted groundwater levels along the project and to verify long-term and adverse trends
- Permit an early assessment of groundwater behaviour in response to the engineering impact measures applied and verify the effective functioning of these measures
- Verify that there are no adverse impacts as a result of the construction at cuts where mitigation measures are not planned (low and medium potential impact cuts).

The monitoring program would form part of the Contractors Environmental Management Plan (CEMP) and support the Soil and Water Management Plan (SWMP) for the project. The groundwater monitoring program would effectively identify potential groundwater problems from works undertaken, as well as the impact of groundwater on construction activities. The program would identify the cause of the problem and recommends management methods to address any identified concerns.

5.2.2. Parameters to be monitored

Groundwater depth below the surface is the primary parameter that should be monitored. Temporal information is particularly important for the floodplain environments where low flow gradients may change with seasons and across a number of years.

Groundwater quality monitoring should test primarily for salinity (using electrical conductivity as an indicator of salinity), acidity (pH) and the redox condition (using electric potential - Eh - and/or dissolved oxygen as indicators) with testing undertaken in the field at the time of water level monitoring. If these field-measured parameters indicate a change in conditions, then a sample should be collected and submitted for full geochemical analysis. Frequency of sampling would be determined by the variability in the system and changes from baseline conditions.

Sampling parameters are detailed in Table 5-2 for each stage of the works. At monitoring sites identified as potentially impacting bore field sites along the project, supplementary testing is required to determine if surface water quality issues are impacting the local groundwater quality.

Laboratories used to test samples collected at the monitoring sites must be registered in accordance with the National Association of Testing Authorities (NATA) for each analysis required.

Table 5-2 Sampling parameters

Parameter	Field analysis	Laboratory analysis
pH	✓	✓
Alkalinity	✓	✓
Temperature	✓	
Electrical Conductivity (EC)	✓	✓
Electrical potential (Eh)	✓	✓
Dissolved oxygen (DO)	✓	✓
Turbidity	✓	✓
Ferrous ions	✓	
Total Phosphorous (TP)		✓
Total Nitrogen (TN)		✓
Major cations and anions		✓
Minor cations and anions and dissolved metals		✓

5.3. Potential impact mitigation measures

5.3.1. Groundwater quantity: impact mitigation through engineering

Two categories of engineering impact mitigation measures could be considered if monitoring indicates at cutting or embankment locations that such measures are required. These measures would be required at all Type A cut locations and at Type B cuts if monitoring indicates that it is necessary:

- Option A - Engineering impact mitigation measures that transfer the seepage water downstream

  Standard practice would be to collect the seepage from the cut face in the drainage system for the highway, which would be diverted into water quality ponds before being released back into the creek or natural drainage system at some point downstream

- Option B - Engineering impact mitigation measures that transfer the seepage water (where present) into the groundwater ecosystem immediately down-slope of the cut or embankment.

  These measures may involve collecting the seepage water from the cut face just above the level of the road, and piping it under the cut/fill platform to the down-slope side of the highway. This collection and piping system would also likely include seepage collected from the drainage blanket under the highway pavement. The collected water could then be returned to the ground through absorption trenches or discharged directly to the surface water system. Embankments need to be designed to enable distributed flow of surface waters to prevent localised ponding and recharge.

From the perspective of risk to GDEs and the local groundwater flow patterns, Option B would provide the better solution for all risk levels, although a system combining both Option A and Option B may need to be applied in some circumstances (depending on monitoring outcomes). The preferred approach and exact form of the impact mitigation measures would be the subject of ongoing development of the concept design and environmental assessment process. This approach is similar to the measures adopted in the construction of the Tintenbar to Ewingsdale Pacific Highway upgrade.

5.3.2. Groundwater quality: mitigation of surface water infiltration to groundwater

Where the water table is identified as being within two metres of the base of a sedimentation basin, the basin would be lined. Similarly, stockpiles, washdown, refuelling and chemical storage sites would be lined if they are to be located over a shallow groundwater source. If practical, it would be preferable to locate these sites in areas where the water table is more than five metres below the surface. The basins and sites that require lining would be identified during detailed design.

5.3.3. Groundwater quality: mitigation of groundwater interception

Where groundwater is released as a result of a groundwater source being intercepted by a road cutting, recharge of the water table will be facilitated by collection of the groundwater in grassed swales. Where possible, these swales would divert the groundwater around the construction area so that the groundwater does not further mix with construction runoff. If groundwater quality is poor or if it mixes with construction runoff, the groundwater would be treated through temporary storage in sedimentation basins before being discharged. Dewatering should be undertaken in line with RMS' *Technical Guideline – Environmental Management of Construction Site Dewatering* (RMS, 2011).

5.3.4. Rous Water Woodburn borefield mitigation measures

The drinking water catchment of the Rous Water Woodburn Sands borefield is considered to be a sensitive receiving environment. As such, all construction runoff in the catchment of the bores must be diverted to sedimentation basins. No runoff shall bypass the basins untreated, regardless of the size of the footprint of the work. In addition, all basins in the borefields will be clay lined to prevent leakage of water from the basins to the environment. The depth of the sedimentation basins in the borefields will be shallower than standard sedimentation basins (namely one metre in depth rather than two metres in depth) to avoid penetration of the natural clay layer, with an adequate volume achieved by adjusting the basin surface area. Finally, the following construction activities within the borefield catchment should be restricted:

- Refuelling
- Washdown
- Storage of chemicals or other hazardous substances
- Installation of concrete batch plants.

As the region is considered to be a sensitive receiving environment, basins that discharge to the catchment of the borefield shall be designed to the 85^{th} rainfall percentile volume. This is explained further in the Working Paper – Water Quality Report.

On-going consultation with Rous Water will enable mitigation actions to be coordinated and monitoring results to be adequately assessed and interpreted. Rous Water should be involved in all discussions relating to this section of the project, including the identification for appropriate buffer zones between the project and bores.

6. Conclusions

In general, there would not be any undue impact on groundwater as a result of the project. Locally there may be some disturbance, particularly where the project requires deep cuts. A significant portion of the project has inherent shallow groundwater tables and works in these areas needs to be carefully monitored and assessed on a regular basis to prevent the occurrence of adverse effects. The floodplains of the Clarence and Richmond Rivers are regions that are underlain by shallow water tables. These areas have the highest risk of groundwater impacts on construction sites and the highest risk of adverse impacts on groundwater systems. These risks require on-going monitoring, from pre-construction through to construction and operation, to allow impacts to be detected early and rectified.

Any potential impacts from the project are expected to be localised. The generally low elevation and proximity to the ocean means that groundwater sytsems will exhibit low gradients and groundwater tables will have subdued relief. Hence, at the scale of the project there will be negligible impact to the regional groundwater systems. This is due to the substantial volume and inertia of the groundwater sources along the coast that will buffer any short term impacts from construction (such as cuts), while the low groundwater flow gradients moderate any long term impacts from operation (such as compaction).

Cut locations are expected to have the greatest impact during construction, with 12% of the route (constituting 62 out of 157 cuts) expected to directly impact groundwaters during construction (Type A cuts) and require engineering measures to control groundwater seepage. Eight per cent of the route may require on-going management for shallow groundwater impacts on the pavement, though impact to groundwater flow will be minimal.

Key findings include:

- A significant portion of the project has existing shallow groundwaters. Specifically, 36 per cent of the project has groundwater levels that are within two metres of the surface, with an additional 13 per cent of the project having groundwater levels less than three metres below the surface
- The highest potential impact regions are associated with the floodplains of the Clarence and Richmond Rivers and the coastal plains south of Ballina. These regions are characterised by gentle topography and low elevations. In the northern sections, sea-water intrusion is expected to be occurring beneath the shallow fresh groundwaters
- Impacts on and associated with groundwater will be primarily at cut sites. Where cuts intercept, or come very close to, the groundwater table, engineering measures will be required to transfer the groundwater from the up-stream to down-stream locations. These cuts are designated Type A. In areas of shallow water tables, groundwater interception issues are compounded by variable and seasonally changing water flow directions and a general low gradient of flow
- Cuts that are not expected to impact groundwater are designated Types, B and C, dependent on the interpreted depth to groundwater below the ground surface. Depth to groundwater, and hence reduction in potential impact, increases from B to C

- Shallow water tables may impact construction activities, with waterlogging and groundwater ingress occurring at cut locations. Impacts will reduce for the operation phase and engineering measures will adequately mitigate any operation phase impacts at all cut sites
- There is unlikely to be any adverse impacts on any groundwater supplies
- Potential impacts on groundwater quality are minimal, but implementation of the measures proposed for protection of surface water quality, including sedimentation basins and filtration traps should be instigated in areas of shallow groundwater tables and at Type A cut locations
- Water supply from the Rous Water Woodburn Sands borefield is not expected to be impacted. The primary concern would be the need to maintain groundwater quality, which could be compromised by infiltration of any contaminated surface waters. Groundwater is currently thought to be protected by an impermeable clay layer above the main aquifer, which acts to impede recharge in the vicinity of the borefield. This clay layer, however, is leaky and locally exhibits preferential recharge to the sands below. Measures need to be implemented to prevent surface water generated through the project from infiltrating this clay and polluting the groundwater supply.

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