GHD

Roads and Maritime Services

Princes Highway Upgrade - Foxground to Berry Bypass Project

Water Quality Monitoring Groundwater Monitoring Plan

July 2014

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1. Introduction

1.1 Background

Roads and Maritime Services (RMS) is undertaking a series of upgrades to sections of the Princes Highway between Gerringong and Bomaderry in order to provide a continuous four lane divided highway. The Foxground and Berry Bypass comprises of an 11.6 km upgrade of the existing Princes Highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry which includes bypasses of Foxground and Berry (Appendix 2). The project will result in improved road safety and traffic efficiency, including for freight.

An Environmental assessment including appendices and submissions report has been prepared which identifies and assesses potential water quality impacts associated with the project. The project approval was granted on 22 July 2013, under Part 3A of the Environmental Planning and Assessment Act 1979 with conditions of approval (CoA).

These conditions (CoA B15 and CoA B16) require RMS to prepare and implement a water quality monitoring program (WQMP) and undertake groundwater modelling on the concept design. The WQMP will establish baseline water quality data prior to construction, guide monitoring during construction to ensure mitigation measures are effective and guide monitor post construction to ensure permanent measures are effective. The groundwater modelling will assess the construction and operational impact of the concept design on groundwater resources, quality, hydrology, groundwater dependent ecosystems and provide details of contingency and management measures to be implemented in the construction soil and water quality management subplan (COA B26 (d)).

1.2 Project Overview

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

The general features of the proposed upgrade, as approved, are presented in the Director General's Environmental Assessment Report (AECOM, 2012) and are as follows:

- Construction of a four lane divided highway (two lanes in each direction) with median separation (wire rope barriers or concrete barriers where space is constrained, such as at bridge locations).
- Bypasses of the Foxground bends and the Berry township.
- Construction of around 6.6 kilometres of new highway where the project deviates from the existing highway alignment at Toolijooa Ridge, the Foxground bends and the Berry township.
- Provision for the possible widening of the highway (if required in the future) to six lanes within the road corridor and, in some areas, construction of the road formation to accommodate future additional lanes where safety considerations, traffic disruption and sub-optimal construction practices are to be avoided.
- Grade-separated interchanges at:
  - Toolijoola Road.
  - Austral Park Road.
  - Tindalls Lane.

  - East of Berry at the existing Princes Highway, referred to as the northern interchange for Berry.
  - West of Berry at Kangaroo Valley Road, referred to as the southern interchange for Berry.
- A major cutting at Toolijooa Ridge (around 900 metres long and up to 26 metres deep).
- Six lanes (two lanes plus a climbing lane in each direction) through the cutting at Toolijooa Ridge for a distance of 1.5 kilometres.
- Four new highway bridges:
  - Broughton Creek bridge 1, a four span concrete structure around 170 metres in length and nine metres in height.
  - Broughton Creek bridge 2, a three span concrete structure around 75 metres in length and eight metres in height.
  - Broughton Creek bridge 3, a six span concrete structure around 190 metres long and 13 metres in height.
  - A bridge at Berry, a 19 span concrete structure around 600 metres long and up to 12 metres in height.
- Three highway overbridges:
  - Austral Park Road interchange, providing southbound access to the highway.
  - Tindalls Lane interchange, providing southbound access to and from the highway.
  - Southern interchange for Berry, providing connectivity over the highway for Kangaroo Valley Road along its existing alignment.
- Eight underpasses including roads, drainage structures and fauna underpasses:
  - Toolijoola Road interchange, linking Toolijooa Road to the existing highway and providing northbound access to the upgrade.
  - Property access underpass in the vicinity of Toolijooa Ridge at chainage 8400.
  - Dedicated fauna underpass in the vicinity of Toolijooa Ridge at chainage 8450.
  - Property access underpass between Toolijooa Ridge and Broughton Creek at chainage 9475.
  - Combined drainage and fauna underpass in the vicinity of Austral Park Road at chainage 12800.
  - Combined drainage and fauna underpass in the vicinity of Tindalls Lane at chainage 13320.
  - Dedicated fauna underpass in the vicinity of Tindalls Lane at chainage 13675.
  - Property access underpass between the Tindalls Lane interchange and the northern interchange for Berry in the vicinity of at chainage 15100.
- Modifications to local roads, including Toolijooa Road, Austral Park Road, Gembrook Lane, Tindalls Lane, North Street, Queen Street, Kangaroo Valley Road, Hitchcocks Lane and Schofields Lane.
- Diversion of Town Creek into Bundewallah Creek upstream of its confluence with Connollys Creek and to the north of the project at Berry.
- Modification to about 47 existing property accesses.
- Provision of a bus stop at Toolijoola Road and retention of the existing bus stop at Tindalls Lane.

- Dedicated u-turn facilities at Mullers Lane, the existing highway at the Austral Park Road interchange, the extension to Austral Park Road, and Rawlings Lane.
- Roundabouts at the southern interchange for Berry and the Woodhill Mountain Road junction with the exiting Princes Highway.
- Two culs-de-sac on North Street and the western end of Victoria Street in Berry.
- Tie-in with the existing highway about 75 metres north of Toolijooa Road and about 440 metres south of Schofields Lane.
- Left in/left out only provisions for direct property accesses to the upgraded highway.
- Dedicated public space with shared pedestrian/cycle facilities along the southern side of the upgraded highway from the playing fields on North Street to Kangaroo Valley Road.
- Ancillary operational facilities, including permanent detention basins, stormwater treatment facilities and a permanent ancillary facility site for general road maintenance.

As a result of the community consultation during the display of the environmental assessment the following changes have been made to the project:

- Change of ownership status of property access road between chainage 9450 to chainage 9880 about 500 metres north of Broughton Creek crossing number one.
- Removal of turnaround facility on the Austral Park Road extension.
- Property access and boundary adjustment between chainage 11800 and chainage 12300, opposite Austral Park Road.
- Changed property access arrangement at chainage 12260, opposite Austral Park Road.
- Property access adjustment and flood mitigation between chainage 12820 and chainage 13150 about 550 metres south of the Austral Park Road interchange.
- Changed local road access arrangement for Gembrook Lane, opposite the Tindalls Lane interchange.
- Increased curve radius to optimise alignment at the Tindalls Lane interchange, chainage 13850.
- Changed property access at chainage 14430 at the southern end of the Tindalls Lane interchange.
- Removal of retaining wall and reshaping of a constructed dam at the northern interchange for Berry, between chainage 15500 and 15650.
- Realignment of the Town Creek diversion.
- Adoption of Victoria Street option 3 with the modifications presented in Chapter 4 of this report.
- Modified Schofields Lane intersection with the provision of an underpass with connecting property accesses.

An overview of the project is shown in **Figure 1**. A more detailed description of the project is available in Volume 1 Foxground and Berry bypass environmental assessment prepared for RMS by AECOM in November 2012.

1:30,000 (at A3)

0 150 300 600 900 1,200
Metres

N

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

LEGEND

Berry to Foxground upgrade alignment	Railways
Alignment location of interest	Waterways
Roads	Lakes and dams

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Roads and Maritime Services
Water Quality Monitoring

Job Number	21-23174
Revision	0
Date	09 Jul 2014

Overview of the Berry to Foxground upgrade

Figure 1

Z:\TEMP GIS\berry to foxground\GIS\Maps\MXD\21_23174_Z010_BERRY_OverviewFBBUpgrade.mxd

Data Source: NSW Department of Lands: DTDB and DCDB - 2012. Created by: pmcdougall

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2. Regulatory context

2.1 Environmental assessment

The FBB Princess Highway upgrade project has been assessed as a transitional project under Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act). The Director-General's requirements (DGR's) for the FBB Princes Highway upgrade were issued on 11 February 2011.

The DGR's for surface water and groundwater required the assessment of:

- "*Water quality taking into account impacts from both accidents and runoff and considering relevant environmental water quality criteria specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000. The assessment must describe measures to control erosion and sedimentation during construction activities and measures to capture and treat runoff from the site during the operational phase*
- "*Identify potential risks of the project on groundwater resources including: characterising existing local and regional hydrology; potential risks of drawdown; impacts to groundwater quality; discharge requirements; and implications for groundwater-dependent surface flows (including springs and drinking water catchments), groundwater-dependent ecological communities and groundwater users*
- *Identifying potential impacts of the project on existing flood regimes, consistent with the Floodplain Development Manual (Department of Natural Resources, 2005), including impacts to existing receivers and infrastructure and the future development potential of affected land, demonstrating consideration of the changes to rainfall frequency and/or intensity as a results of climate change on the project. The assessment shall demonstrate due consideration of flood risk in the project design*
- *Waterways to be modified as a result of the project, including ecological, hydrological and geomorphic impacts (as relevant) and measures to rehabilitate the waterways to pre-construction conditions or better"*

The assessment of groundwater impacts presented in the Environmental Assessment (EA) Report (AECOM, 2012) was prepared in accordance with the above DGR's. The EA was subsequently exhibited for consultation and a Submissions Report (RMS, 2013a) prepared in response to the concerns raised.

Approval for the project was issued by the Minister for Planning and Infrastructure on 22 July 2013.

2.1.1 Proposed Groundwater Monitoring

Section 7.4.4 of the Environmental Assessment states that the groundwater monitoring plan undertaken at the site should:

"*Establish a groundwater monitoring network along the project to monitor groundwater quality within each lithology and to establish background groundwater quality.*

Detail the establishment of a groundwater monitoring network along the route to adequately characterise groundwater quality and establish background water quality within the alluvial/colluvial aquifers and Shoalhaven Group Sediments, including the Broughton Sandstone and latite.

Install monitoring wells adjacent to major cuts to confirm existing groundwater levels and to monitor the effect on groundwater levels by construction activity, where groundwater is encountered.

Implement a groundwater monitoring plan that would assess the performance of groundwater mitigation measures during and after construction. This plan would provide an assessment of groundwater level and quality trends and identification of exceedances (if any)."

Further to the general text in the EA, Appendix H of the EA states the following in regard groundwater monitoring:

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

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

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

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

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

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

Appendix H also states that:

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

2.2 Conditions of Approval

The Project Approval was issued subject to a range of conditions, which included conditions for environmental monitoring and auditing. In relation to the monitoring of groundwater, Condition of Approval number B16 (CoA No. B16) specifies that:

"*The Proponent shall prepare and implement a Water Quality Monitoring Program to monitor the impacts of the project on surface water and groundwater quality and resources and wetlands, during construction and operation*"

The Water Quality Monitoring Program (WQMP) is required to be developed in consultation with the Office of Environment and Heritage (OEH), Environmental Protection Authority (EPA), Department of Primary Industries (DPI) (Fishing and Aquaculture) and NSW Office of Water (NOW). Table 1 outlines the specific requirements of CoA B16 and provides section references where each criteria is addressed within this monitoring program.

Table 1: Condition of approval B16 (NSW DPI, 2013)

Condition of approval B16	WQMP section reference where addressed
(a) identification of surface and groundwater quality monitoring locations (including watercourse, water bodies and SEPP 14 wetlands), which are representative of the potential extent of impacts from the project	Surface water – Section 3, 4 and 9 Groundwater is in the groundwater quality monitoring document
(b) the results of the groundwater modelling undertaken under condition B15	Within the groundwater quality monitoring plan document
(c) identification of works and activities during construction and operation of the project, including emergencies and spill events, that have the potential to impact on surface water quality of potentially affected waterways	Section 3
(d) development and presentation of parameters and standards against which any changes to water quality will be assessed, having regard to Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC, 2000a)	Sections 7 and 8
e) representative background monitoring of surface and groundwater quality parameters for a minimum of twelve months (considering seasonality) prior to the commencement of construction to establish baseline water conditions, unless otherwise agreed by the Director General	Section 4 and Section 9. Initial monitoring data to be provided to RMS as ongoing monitoring data updates separate to this report
(f) a minimum monitoring period of three years following the completion of construction or until the affected waterways and/or groundwater resources are certified by an independent expert as being rehabilitated to an acceptable condition. The monitoring shall also confirm the establishment of operational water control measures (such as sedimentation basins and vegetation swales)	Operation criteria discussed in Sections 9 to 13
(g) contingency and ameliorative measures in the event that adverse impacts to water quality are identified	Section 11 and 13
(h) reporting of the monitoring results to the Department, OEH, EPA and NOW	To be supplied as monitoring reports to RMS and subsequently to OEH, EPA and NOW

CoA B15 is referenced as part of CoA B16 and is stated below.

"Prior to the commencement of construction, unless otherwise agreed by the Director General, the Proponent shall in consultation with the EPA and NOW, undertake groundwater modelling on the concept design for the project, subject to the modelling being revised should the detailed design have a significantly different impact on groundwater than the concept design.

The modelling shall be undertaken by a suitably qualified and experienced groundwater expert and assess the construction and operational impacts of the proposal on the groundwater resources, groundwater quality, groundwater hydrology and groundwater dependent ecosystems and provide details of contingency and management measures in the groundwater management strategy required under condition B36(d)."

The Program must also be submitted to the Director General for approval six (6) months prior to the commencement of construction of the project, or as otherwise agreed by the Director General. A copy of the Program must also be submitted to OEH, EPA, DPI (Fishing and Aquaculture) and NOW prior to its implementation. This Groundwater Monitoring Program (GWMP) and a separate Surface Water Monitoring Program (SWMP) (GHD, 2014b) have been prepared to meet the requirements of CoA No. B16.

2.3 Statement of commitments

RMS has committed to a range of surface water and groundwater quality protection measures as part of the environmental assessment under Part 3A of the EP&A Act. The primary objective of the measures proposed is to minimise the impacts to downstream surface water quality. The statement of commitments for surface water and groundwater quality, as outlined in the Submission report (RMS, 2013), is provided in Table 2. These commitments have been considered in the preparation of this GWMP and would also be taken into account in the development of the detailed design and project environmental management plans.

Table 2: Statement of commitments – surface water and groundwater quality

Ref No	Commitment	Key Action	Timing	Reference Document
SG1	Minimise impacts to water quality during construction and operation	Water quality measures such as water quality basins, swales or bioretention systems at sensitive receiving environments will be designed and installed to respond to the project water quality design criteria.	Pre-construction and construction	Managing Urban Stormwater: Council Handbook (EPA, 1997) Section 7.4 of the environmental assessment
SG2	Minimise water quality impacts and impacts to the flow regimes of Town Creek and Bundewallah Creek	A design and re-vegetation strategy for the Town Creek diversion will be developed during detailed design and will include measures to: Maintain flushing efficiency. Mitigate erosion risk at the connection with Bundewallah Creek. The design of the diversion will be finalised in consultation with directly affected landowners. The Town Creek diversion will be stabilised to mitigate erosion risk prior to operation.	Pre-construction and construction	Managing Urban Stormwater – Volume 1 (Soils and Construction) (Landcom (2004) Managing Urban Stormwater – Soils and Construction, Volume 2D – Main Road Construction (known as the Blue Book) (DECCW 2008) Guidelines for In stream Works on Waterfront Land (NSW Office of Water, 2012) Section 7.4 of the environmental assessment Section 2.11 of the response to submissions
SG3	Minimise impacts on farm dams	Permanent losses to farm dam catchments and inflows will be identified during detailed design. Mitigation strategies will be developed in consultation with affected landowners and implemented where reasonable and feasible.	Pre-construction	Section 7.4 of the environmental assessment
SG4 and SG5	Minimise impacts on drinking water supply	Drinking water drawn from Broughton Creek will be maintained through measures identified in commitment AQ1. In the event that water drawn from Broughton Creek does not meet existing drinking water quality standards, an appropriate source of potable water will be made available to affected residents, following consultation.	SG4 – Construction SG5 - Pre-construction	Section 2.11 of the response to submissions

Ref No	Commitment	Key Action	Timing	Reference Document
		RMS will consult with landholders along the existing Town Creek alignment, below the proposed diversion, to confirm that there are no Basic Landholder Rights (under the Water Management Act 2000) to access water for domestic or stock purposes.		
SG6	Minimise changes in current flow regimes	Waterway structures will be designed to maintain existing flow regimes, where practicable.	Pre-construction	Section 7.5 of the environmental assessment
SG7 and SG8	Manage the impacts associated with changes to flooding and drainage	Detailed design will seek to minimise increases in peak flood levels in the 1 in 100 year flood event. Changes to flood impacts on property will be identified as part of detailed design. Where increased flood impacts to structures, such as residences, are identified, mitigation measures will be proposed and implemented where reasonable and feasible.	Pre-construction (SG7) Pre-construction and construction.(SG8)	Section 7.5 of the environmental assessment
SG9	Minimise impacts on channel structure	Impacts on stream channel structure diversion will be minimised during detailed design. Measures to be considered may include culvert sizing, energy dissipation measures, scour protection and other design features to control flow intensity and direction.	Preconstruction	Section 7.5 of the environmental assessment
SG10	Minimise the impact on groundwater levels	Groundwater monitoring of water levels and water quality will be undertaken. Where levels and/or quality indicate that the project is potentially having an adverse impact, mitigation measures will be considered and implemented where reasonable and feasible.	Construction	Section 7.4 of the environmental assessment
SG11	Conservation of water	Water efficient work practices, such as water reuse and recycling for road construction and re-vegetation irrigation will be implemented, where feasible. In the event that surface water from watercourses or groundwater is required to supply water to the project, a site specific impact assessment will be carried out in consultation	Construction	Section 7.4 of the environmental assessment Section 2.11 of the response to submissions

Ref No	Commitment	Key Action	Timing	Reference Document
		with the NSW Office of Water and potentially affected stakeholders.		
SW4	Avoid contamination of waterways	Monitoring of water quality upstream and downstream of the project site will be undertaken before and during construction. Also refer to SG4.	Preconstruction and construction	Section 7.4 and 8.1 of the environmental assessment Erosion and Sedimentation Management Procedure (RTA, 2008) Managing Urban Stormwater – Soils and Construction Volume 1 (Landcom, 2004) Managing Urban Stormwater – Soils and Construction, Volume 2D – Main Road Construction (DECCW, 2008) RMS QA Specification G38 Soil and Water Management RMS QA Specification G39 Soil and Water Management (Erosion and Sediment Control Plan)

The statement of commitments within the Submission report list the outcomes for soil and water quality and surface water and groundwater. The outcomes that relate to the WQMP and are outline in the brief are SW4, SG4 and SG10.

3. Regional setting and layout

3.1 Climate

The project area is subject to an oceanic climate characterised by a relatively narrow annual temperature range and evenly dispersed rainfall throughout the year (i.e. lacking a dry season). Climate statistics for the area are based on the two nearest weather stations registered with the Bureau of Meteorology being Nowra Ran Air Station (068072) and Kiama Bowling Club (068038). The Nowra weather station is located approximately 24 km southwest of Berry and 35 km southwest of Gerringong. The Kiama weather station is located approximately 9 km north of Gerringong and 18 km northeast of Berry. A comparison of the data from these two locations is considered representative of the project area that lies central to them.

Temperatures between the two weather stations are comparable and thus considered representative of the project area. Summer temperatures are warm ranging 15-30 °C and winter temperatures are mild ranging 5-20 °C.

Average annual rainfall approximates 870 mm inland (Nowra, approximately 27 km from the coast) and 1250 mm at the coast (Kiama). Average annual rainfall at the project area is considered to lie within this range. Rainfall is dispersed throughout the year with no distinct dry season (Figure 2 and Figure 3).

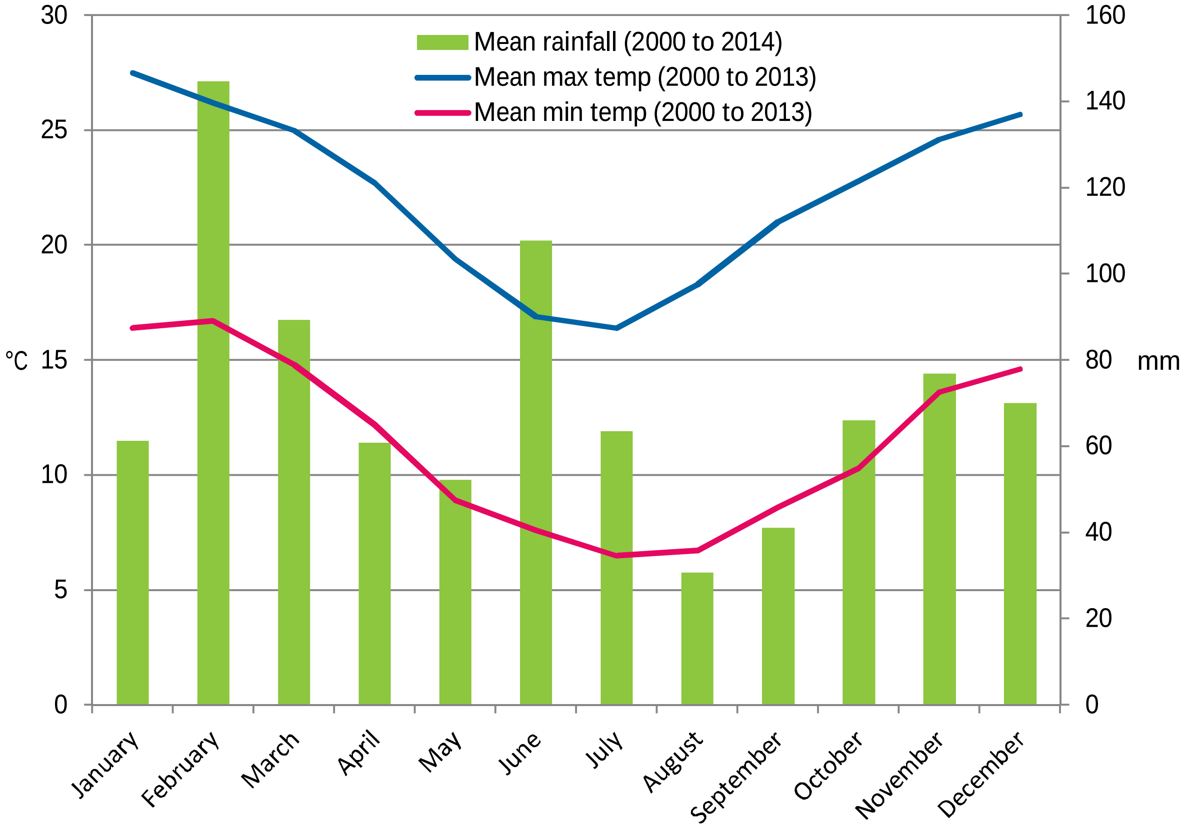

Figure 2: Mean temperature and rainfall for Nowra Ran Air Station (068072)

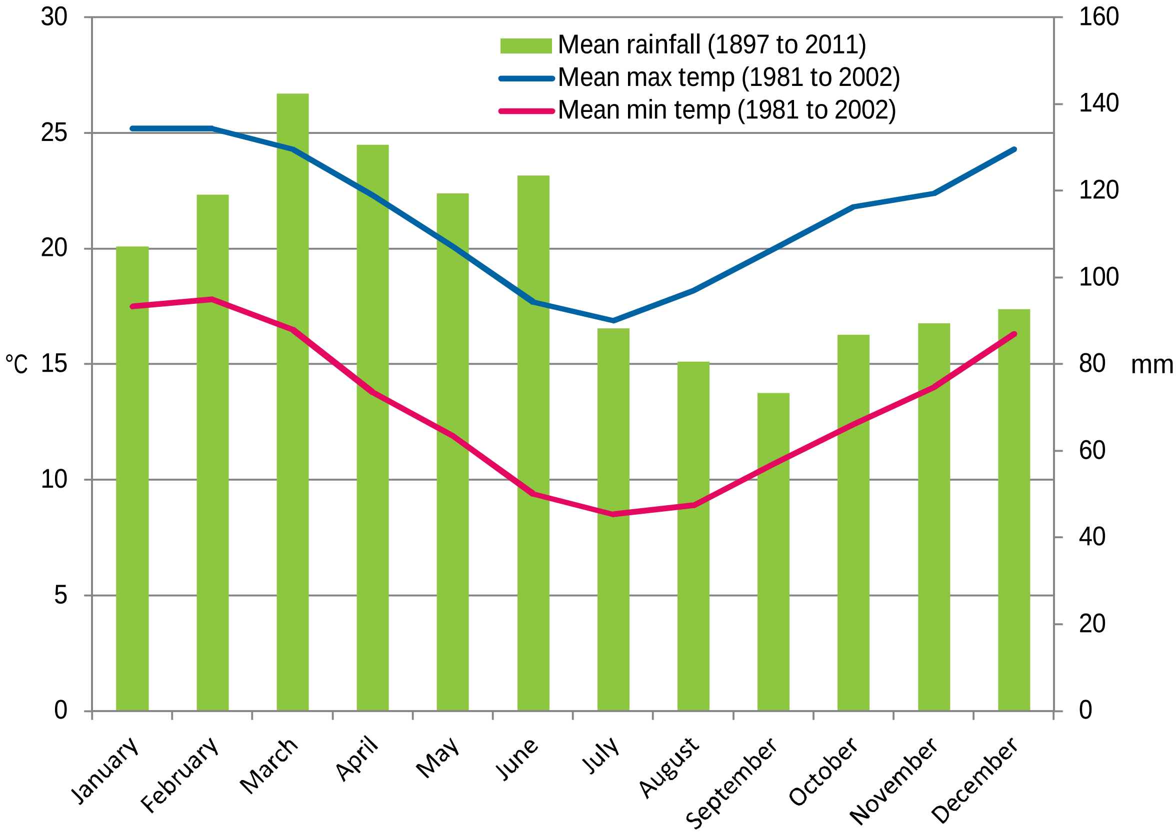

Figure 3: Mean temperature and rainfall for Kiama Bowling Club (068038)

Evaporation rates were not recorded at either weather station. Relative humidity lies around 60% being more variable inland and moderated at the coast.

3.2 Groundwater Recharge

Recharge is expected to occur predominantly via direct infiltration of rainfall. Additional recharge sources are likely to include surface waters (Broughton Creek and tributaries) and through flow within sedimentary sequences of the Shoalhaven Group. Upward flow from underlying basement rock is considered unlikely.

The NSW Office of Water (2011) provides regional estimates of recharge in the area based on a 6% infiltration of rainfall.

Table 3: Average annual rainfall recharge (NSW Office of Water, 2011)

Water Source	Area (km2)	Average Annual Rainfall (ML)	Infiltration (%)	Estimated Average Annual Rainfall Recharge (ML/yr)#
Sydney Basin South	3034.83	3,755,436	6	225,326

#Average annual rainfall recharge (ML/yr) = [{water source area (ha)*mean rainfall (mm)} /100]*% infiltration rate.

The average annual recharge was calculated using rainfall data between 1921 and 1995.

3.3 Topography and drainage

3.3.1 Overview

The topographic setting of the investigation area traverses low relief ridges and alluvial soils near the interface between the foot slopes of the nearby Illawarra escarpment and the low lying Shoalhaven River Floodplain area. A number of secondary streams and creeks migrate from higher elevations from the Cambewarra Range into a dendritic drainage pattern and then flow onwards to the southeast into Broughton Creek (Coffey, *Geotechnical Interpretive Report,* 2 August 2012).

3.3.2 Topography

The nature of the terrain varies greatly between four primary landscape character units. These are described as the steep slopes of the Toolijooa Ridge through to the floodplains of the Broughton Creek and progresses to variable slopes of Berry and flatter land around the northern and western Berry township.

These landscapes are described in more detail as follows:

Toolijooa Ridge: This area is located at the northern end of the site and extends south from Currys mountain. Open pastoral landscape is present along the existing highway until the eastern spur of the Toolijooa Ridge which separates the coastal plain from Broughton Creek to the west.

Broughton Creek: The creek and surrounding floodplains form the valley between the western side of Toolijooa Ridge and the east facing slopes of Camberwarra Range. The creek valley runs north-south with the creek meandering throughout this floodplain. Remnant vegetation is present along the creek line and separates the creek from open pasture and small rural farm dams.

North Berry: The existing highway follows the ridgeline that separates catchments to the east and west from east of the Broughton Creek floodplain. This landscape comprises open pasture, remnant vegetation with variable terrain including undulating to steep slopes.

Berry: The town encompasses flood free land upstream of Broughton Creek and Broughton Mill Creek and flat land within the established section of Berry. It is noted that development of the town and structures such as the railway line forms a physical barrier between the flood prone pastures and flat land of Berry.

3.3.3 Drainage Catchments

The prominent high points within the study area include Mount Pleasant (RL 200 m), Toolijooa Hill (RL130 m), Harley Hill (RL 140 m) Foxground (RL 120 m) and Tomlins Hill (RL 136 m). A ridge of moderate elevation from Foxground to Toolijooa Hill and a flatter ridge to the southeast of Toolijooa Hill separates the Broughton Creek floodplain from the Crooked River floodplain.

Many high sinuosity secondary streams and creeks migrate from higher elevations within the Cambewarra range in a dendritic drainage pattern. These secondary creeks and streams generally flow to the southeast where they merge with either Crooked River in the north or Broughton Creek in the south.

North of Berry township there is a large area of near level land including some low lying areas near the watercourses, with slopes gradually increasing to the north and west. This near level is underlain by alluvial deposits. The existing highway initially follows a narrow ridge to the northeast of Berry then crosses hills and ridges of moderate elevation to Broughton Creek and Foxground Valley which comprises a large area of near level to gently sloping land over the valley floor. The highway passes through a valley and undulating slopes before crossing another high ridge near the southern side of Gerringong township.

The Shoalhaven lowland plain with a surface elevation generally less than RL 5 m includes the Crooked River floodplain and Broughton Creek floodplain (from Coffey, 2007).

The alignment of the FBB Princes Highway upgrade would pass through the six major and three minor catchments identified in this section. The location of the upgrade alignment in relation to the catchments is shown in Figure 4.

Broughton Creek floodplain

The Broughton Creek floodplain and tributary valley floor areas occupy a large portion of the study area to the south and southeast of Berry (mainly floodplains) and tributary valleys to the north and northeast of Berry. Broughton Creek is the dominant watercourse in this area extending back to the escarpment slopes to the north and northeast in the areas of Broughton, Broughton Vale, Bundewallah, Jaspers Brush and Meroo Meadow areas to the south and southeast of Berry. Broughton Creek flows across a broad floodplain in a southerly direction, flowing into the Shoalhaven River about 5 km west of Shoalhaven Heads.

Broughton Mill Creek, Bundewallah and Connollys Creek catchment

To the north and north-west of Berry are the Broughton Mill Creek, Connollys Creek and Bundewallah Creek catchments, respectively. Broughton Mill Creek originates underneath the Illawarra plateau as a number of secondary streams. It flows south through Broughton Vale and crosses the existing Princes Highway near the Woodhill Mountain Road intersection on the eastern edge of Berry, around two kilometres upstream of its confluence with Broughton Creek.

Town Creek catchment

Town Creek is a small ephemeral watercourse that passes directly through Berry township. It has a catchment area of 70 hectares upstream of Berry. Town Creek crosses the undeveloped section of North Street, on the north west edge of Berry, before crossing the town between Princess Street and Queen Street and exiting via Prince Alfred Street. Town Creek flows south east before joining Broughton Mill Creek near its confluence with Broughton Creek. The reach of Town Creek through Berry is in poor condition.

Minor catchments

Hitchcocks Lane Creek, its tributary and an unnamed tributary of Broughton Creek flow across the existing highway, south of Berry. These watercourses join southwest of the existing highway and eventually discharge into the estuarine reach of Broughton Creek. Hitchcocks Lane Creek and its tributary have a catchment area of 68 hectares and 75 hectares respectively. The unnamed tributary of Broughton Creek has a catchment area of 6.2 hectares.

Crooked River floodplain

The Crooked River floodplain where it occurs within the study area includes the low lying areas to the southwest of Gerringong, generally between Toolijooa Road or the Princes Highway and the Illawarra railway. Crooked River originates in the Broughton Vale highlands and flows southeast across the Crooked River floodplain and into Crooked River coastal lagoon.

The crooked river catchment only intersects the very north eastern end of the project alignment.

Farm dams

There are 29 farm dams have catchments that intersect with the project footprint. The locations of these dams are shown in **Figure 4**. Majority of dams would be fed by surface water runoff but some could be through springs.

1:25,000 (at A3)

0 125 250 500 750 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- Catchment Boundaries
- Berry to Foxground upgrade alignment
- Roads
- Railways
- Waterways
- Lakes and dams

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Surface Water Catchments

Figure 4

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data Source: NSW Department of Lands: DTDB and DCDB - 2012. Created by: pmcdougall

3.4 Geology

The regional geology of the area comprises Middle to Late Permian sedimentary sequences of the southern part of the Sydney Basin with minor interbedded lithic volcanics. Unconsolidated Quaternary sediments are deposited on the Broughton Creek and Crooked River Floodplains.

A map presenting the geology of the alignment is presented in Figure 5.

The Sydney Basin is a major structural basin containing a Palaeozoic, Permian-Triassic sedimentary sequence overlying older basement rocks of the Lachlan Fold Belt. The regional dip of the rock strata grades gently to the north and northwest with the oldest rocks generally occurring along the coast in the southeast.

Located within the southern part of the Sydney Basin, the stratigraphy encountered in the study area forms part of the Shoalhaven Group. The Shoalhaven group is of Permian age and comprises the Nowra Sandstone, Berry Siltstone and the Broughton Formation. The Broughton formation includes the Gerringong volcanics, which consist of Bumbo latite and Kiama Trachytic Tuff. This Formation is also the geologically youngest Formation.

Rocks encountered in the study area belong to the Berry Siltstone. This undifferentiated member comprises a series of alternating lithology of siltstone with fine grained sandstones and interbedded shales. The Berry Siltstone consists predominantly of massive, indistinctly bedded (as a result of bioturbation) to horizontally bedded, mid to dark-grey siltstone and very fine feldspathic litharenite. Fine-grained, light-grey, sublithic interbedded sandy phases occur especially towards the top where the rock grades to laminate in parts and form a coarsening upwards trends. Pebbles up to 20 mm in diameter of quartzite, quartz, and basic igneous material occur sporadically throughout the unit with shell fossils also a common constituent. When fresh and slightly weathered, the siltstone is generally of high or very high strength and without significant joints. When weathered, the siltstone and shale beds within this rock mass generally break down and become iron stained and clayey. Much of the unit is not fossiliferous, although at some locations high concentrations of fossils such as brachiopods are found.

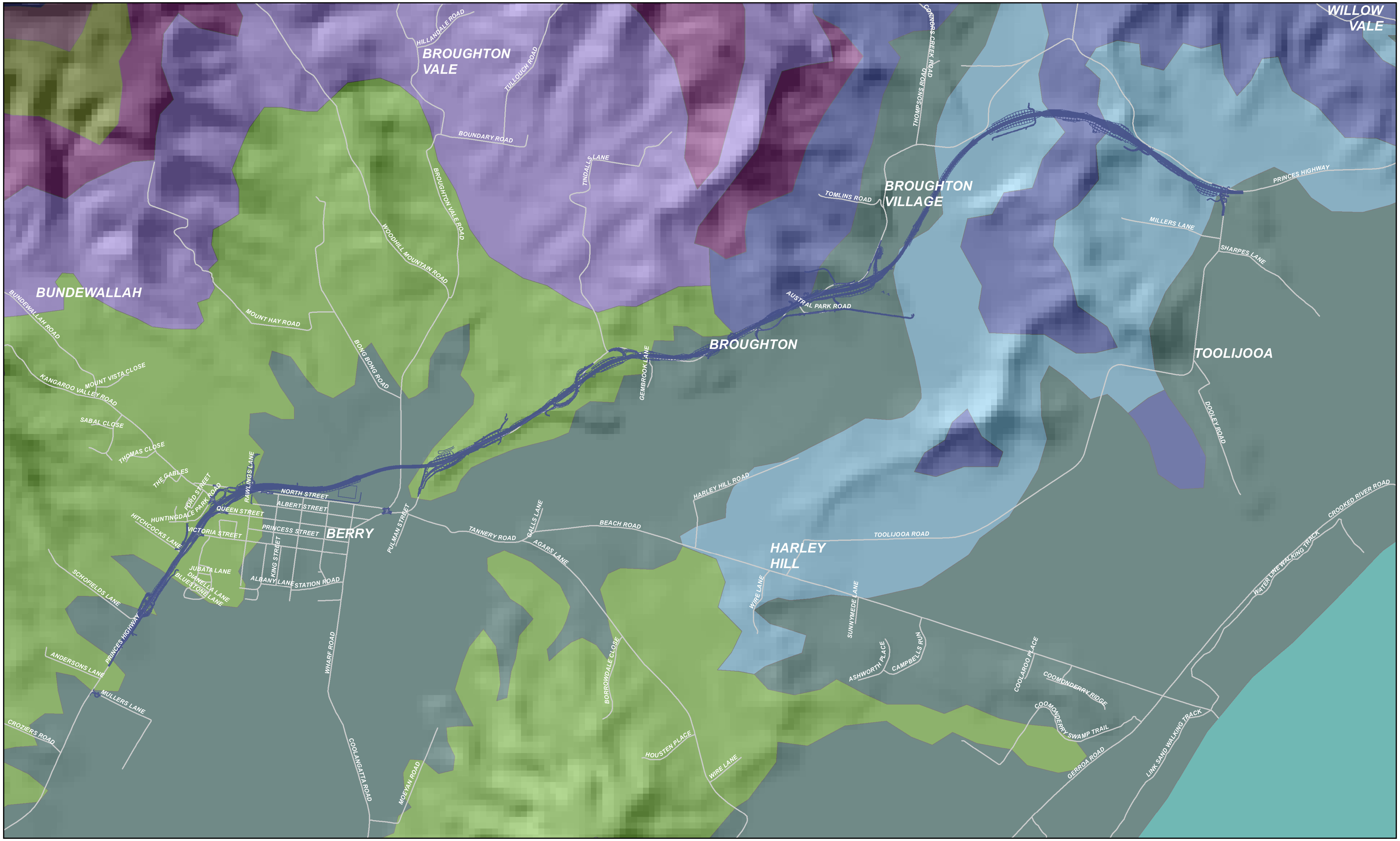
The site is located away from other major structural features such as synclines, anticlines, thrusts and faults that are known within the Sydney Basin. It is assessed that the rocks in this area have not been subject to major folding or tectonic forces. However, minor faults can still be present within the overall rock mass, with a normal fault observed in the Berry Siltstone in a cutting just north of Berry (from Coffey, *Geotechnical Interpretive Report,* 2 August 2012, GEOTWOLL03387AA-AB).

Significant deposits of coarser alluvium are present at the site and have been observed during previous investigations. Reference to the 1:250,00 Geological Sheet for Wollongong (Sheet SI/56-9) suggest some areas of the alignment to be underlain by Quaternary Alluvium of gravel, swamp deposits and sand dunes, overlying undifferentiated Berry Formation as described and shown on Figure 5.

3.4.1 Drilling Observations

Fourteen drill holes were advanced as part of setting up the groundwater monitoring network for this project. The drill/well locations are presented in Figure 6. The wells are numbered MW01 to MW16 and include proposed wells MW14 and MW15, which have not been drilled. MW14 and MW15 are currently not considered necessary to meet the monitoring objectives and will not be installed.

The air rotary drilling methods adopted were primarily for the purpose of installing monitoring wells and did not concentrate of geological characterisation as there is already extensive geological information available for alignment. As such, geological interpretation from the drilling works undertaken has not been included here.



1:30,000 (at A3)

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

Berry to Foxground upgrade alignment	Pbb	Pgc	Qal	water
Roads	Pbk	Pi	Rh	
Railways	Pgb	Psb	Tek	

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Geology of the Berry to Foxground upgrade

Figure 5

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3.5 Hydrogeological Conditions

Two main aquifer systems are present along the project alignment. These include unconsolidated and unconfined alluvial/colluvial aquifers and deeper systems within the Shoalhaven group sediments.

The alluvial aquifer occurs as sand, silt, clay and gravel flanking the creek systems and as more widespread floodplain deposits. Groundwater flow within the alluvial aquifer is via pathways of higher permeability. Within the flood plain sediments, localised perched groundwater is expected above interbedded clay horizons. Due to the limited information available online in regards to the alluvial aquifers, it is considered that groundwater available for abstraction within the alluvial aquifer is limited and local land holders use other water supply options. Groundwater movement within the alluvial aquifer and flood plain sediments is expected to flow towards low lying topographical features discharging into local creek systems or as springs.

Groundwater within the Shoalhaven Group sediments within the study area is present within the volcanocalstic Broughton Sandstone as well as within latite and underlying Berry Siltstone. Groundwater within the Shoalhaven Group sediments occurs in perched horizons within the weathered sandstone, siltstone and latite and within the deeper regional aquifer. Groundwater flow within the generally shallow perched horizon is limited and dominated by intergranular flow in the weathered sedimentary rocks. Groundwater in the deeper aquifers is along both primary features, such as less well cemented zones within the rocks and secondary structural features such as joints, shear zones, faults and bedding plane partings.

Licensed bores in the area constructed within the Shoalhaven Group sediments indicate variable yields with deeper aquifers accessed by the majority of licensed bores extracting water from depths ranging from 30 and 50 metres below ground level.

3.5.1 Aquifer Parameters

The primary aquifer parameters characterising intrinsic ability of an aquifer to store and transmit water are hydraulic conductivity and storativity. The data collated to describe these parameters are provided below.

Preliminary groundwater modelling has been undertaken as part of this project where values for hydraulic conductivity, storativity and specific yield have been predicted for the different geological units as part of model calibration. The values adopted for the groundwater modelling are presented in the groundwater modelling report, which is located in **Appendix A**. Horizontal hydraulic conductivity values for the calibrated model ranged between $3.2E^{-4}$ m/day and $4.8E^{-3}$ m/day with an average of $3E^{-3}$ m/day. A value of 1 m/day was adopted for alluvial soils. Storage values were not required in the model as it was run under steady state conditions.

Hydraulic testing of installed wells was undertaken on site between the 8 and 14 April 2014. This included undertaking short term pumping tests using a submersible pump and data logger with subsequent analysis of the groundwater elevation recovery using the Theis recovery analytical method in the AQTESOLV software. A summary table, analytical outputs and field sheets are presented in Appendix B. A total of ten tests were completed successfully with nine of the tests on wells screened within bedrock material (MW01, MW03, MW07, MW08, MW09, MW11, MW12, MW13, MW16) and one well screened in residual soils (MW04). The locations of the bores are presented on Figure 6. The calculated hydraulic conductivities ranged between $2.8E^{-3}$ m/day and $5.5E^{-2}$ m/day with an average of $1.6E^{-2}$ m/day. This is generally higher than the values established by model calibration although there is some overlap in the two data sets. A value of 0.02 m/day was calculated for the residual soils at MW04.

The pumping test methods adopted used cannot be used to establish storage values. Specific yields for fractured bedrock aquifers, which broadly corresponds with storativity under unconfined aquifer conditions are generally less than 0.05 (dimensionless). Unconsolidated alluvial systems generally have specific yields between 0.1 and 0.3 (dimensionless).

The aquifer parameters outlined above suggest that the aquifer systems in this area have overall low permeability, which will result in relatively slow groundwater migration.

1:25,000 (at A3)

0 125 250 500 750 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- Groundwater Sampling Locations
- Proposed Groundwater Sampling Locations
- Surface Water Sampling Locations
- Berry to Foxground upgrade alignment
- Roads
- Railways
- Waterways
- Lakes and dams

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Surface water and Groundwater Sampling Locations

Figure 6

Z:\TEMP GIS\berry to foxground\GIS\Maps\MXD\21_23174_Z014_BERRY_SurfacewaterandGroundwaterSamplingLocations.mxd

Data Source: NSW Department of Lands: DTDB and DCDB - 2012. Created by: pmcdougall

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3.6 Groundwater Elevations

3.6.1 Overview

Coffey (2010) suggested that groundwater levels were elevated in topographical ridge areas, with lower elevations in valley floors. Groundwater levels are expected to generally increase and decline in accordance with topography, following a subdued image of the ground surface. As such, groundwater is expected to flow from elevated ridges to valley floors.

The depth to groundwater along the route is influenced by positioning in the landscape and proximity to discharge features. Shallow groundwater has been identified within the Broughton Creek floodplain immediately north of Berry where a number of water courses converge. This is supported through previous groundwater investigations conducted between November 2009 and January 2010.

Monitoring of groundwater levels undertaken by Coffey in 2010 indicated that groundwater was shallow and less than ten metres below ground level across all lithologies. This investigation also indicated that the water table naturally oscillates in response to climatic variation. However, the groundwater response was variable and dependent upon landscape position and aquifer type (AECOM, *Foxground and Berry bypass Volume 2- Appendix H*, November 2012).

3.6.2 Groundwater Levels

Coffey Geotechnics conducted a geotechnical investigation in October 2007 which included the installation of eleven groundwater monitoring wells as part of a broad assessment of groundwater levels. They were installed within alluvial and residual soils as well as weathered rocks. On average, the wells positioned on the elevated ridgelines (CBH15, CBH16, CBH19 and CBH20) had standing groundwater occurring at depths between 3.297 m to 6.995 m bgl. These wells demonstrated slower recharge rates although it was noted the water targeted may have been perched groundwater. The wells installed in the alluvial floodplains and low lying estuarine floodplains (CBH5, CBH6, CBH8, CBH11 and CBH17) recorded levels between 0.369 m and 2.541 m bgl. Continuous recharge rates were recorded at all locations except CBH8 and CBH11.

Groundwater level monitoring was carried out in four boreholes as detailed in the RMS *Geotechnical Investigation – Factual Report* completed in May 2013 (P1, P3, BH12 and BH13).

A map presenting the previous groundwater wells along the alignment is presented in Figure 7**.**

It was noted in this investigation that groundwater levels respond to changes in rainfall, rising during heavy rainfall and falling in dryer periods. Groundwater levels have also shown to vary seasonally. The lowest groundwater level recorded during a dry period was approximately 9 m bgl (BH12) and the highest level after a rain event was approximately 0.15 bgl (P3). The average groundwater over this period of monitoring was around 4 to 6 m bgl.

A summary of groundwater levels are presented in **Appendix C**.

1:30,000 (at A3)

0 150 300 600 900 1,200
Metres

N

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

LEGEND

- Existing groundwater observation wells
- Berry to Foxground upgrade alignment
- Roads
- Railways
- Waterways
- Lakes and dams

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Berry to Foxground upgrade
Existing groundwater wells

Figure 7

Z:\TEMP GIS\berry to foxground\GIS\Maps\MXD\21_23174_Z017_BERRY_Overview_ExistingGroundwaterWells.mxd

Data Source: NSW Department of Lands: DTDB and DCDB - 2012. Created by: pmcdougall

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3.7 Acid Sulphate Soils

A preliminary Acid Sulphate Soils (ASS) assessment was carried out by Coffey Geotechnics Pty Ltd for the upgrade of the Princess Highway from Gerringong to Bomaderry in 2007 and has been summarised below.

ASS is a naturally occurring soil and sediment containing iron sulfides which when exposed to oxygen can generate sulfuric acid. ASS generally occurs in marine or estuarine sediments of recent geological age (Holocene), within soil horizons typically less than 5 m above Australian Height Datum (AHD).

3.7.1 ASS Risk mapping

ASS risk maps for the NSW coastline have been prepared by the Soil Conservation Service of NSW. The mapping was designed to provide information on ASS distribution and indicate land uses which are likely to create environmental risk by exposing ASS to air.

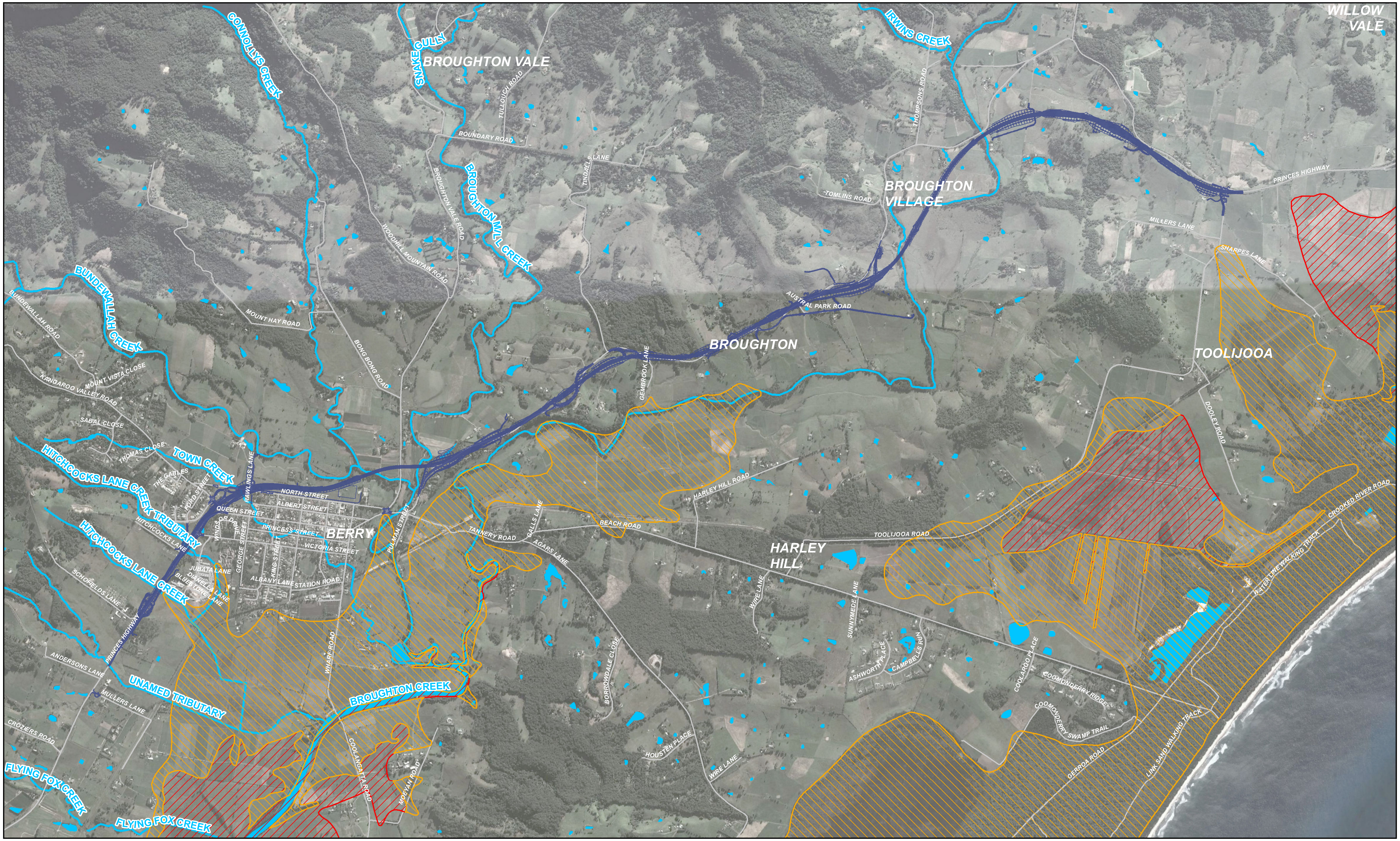
The majority of the study area is covered by three maps (Kiama, Burrier / Berry and Gerroa). A copy of these maps showing the study area is presented in Figure 8.

Reference to the Kiama 1:25,000 Acid Sulphate Soil Risk Map (1997) Edition 2, indicates that a section of the site where the Princes Highway intersects with Ooaree Creek (Rose Valley) is an area of high probability of ASS occurrence being described as low alluvial plains, estuarine sandplains, estuarine swamps, backswamp and supratidal flats, alluvial plains, alluvial swamps, alluvial levees and sandplains in estuarine reaches of catchments.

ASS, if present, are considered to be widespread or sporadic in occurrence and pose a severe environmental risk if disturbed. The map shows areas immediately to the east of this section of the study area as having a low to high probability of ASS occurrence.

Reference to the Burrier / Berry 1:25,000 Acid Sulphate Soil Risk Map (1997) Edition 2, indicates that land on the western side of the South Coast railway includes areas of low probability of ASS occurrence. These areas are described as elevated alluvial plains and levees dominated by fluvial sediments, plains and dunes dominated by aeolian sands, pleistocene plains and lacustrine and alluvium bottom sediment. ASS, if present, are considered to be sporadic and may be buried by alluvium and windblown sediments. Areas on the eastern side of the railway line that are encompassed by the study area are in areas of high probability of ASS occurrence being described as estuarine swamps, intertidal flats, supratidal flats, low alluvial plains, estuarine sandplains, estuarine swamps, backswamps, surpatidal flats, alluvial plains, alluvial swamps, alluvial levees, sandplains, elevated levees and sandplains in occurrence and pose a severe environmental risk if disturbed.

Reference to the Gerroa 1:25,000 Acid Sulphate Soil Risk Map (1997) Edition 2, indicates that a section of the site between the southern side of the Princes Highway and the Crooked River is an area of high probability of ASS occurrence being described as low alluvial plains, estuarine sandplains, estuarine swamps, backswamp and supratidal flats, alluvial plains, alluvial swamps, alluvial levees, sandplains and elevated levees in estuarine reaches of catchments. ASS, if present, are considered to be widespread or sporadic in occurrence and pose a severe environmental risk if disturbed. The map shows land immediately to the west of this area at Toolijooa as having a low probability of ASS occurrence.



1:30,000 (at A3)

0 150 300 600 900 1,200

Metres

N

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

LEGEND

Berry to Foxground upgrade alignment	Roads
Disturbed soils	Railways
High risk	Waterways
Low risk	Lakes and dams

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Berry to Foxground upgrade
Acid sulphate soils

Figure 8

Z:\TEMP GIS\berry to foxground\GIS\Maps\MXD\21_23174_Z018_BERRY_Overview_AcidSulphateSoils.mxd

Data Source: NSW Department of Lands: DTDB and DCDB - 2012. Created by: pmcdougall

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3.7.2 Limited ASS field investigation

Based on the desktop assessment and the findings of the ASS risk maps, Coffey undertook limited field testing as part of the broader geotechnical investigation.

A total of 25 samples were collected from 30 test pits and 20 boreholes throughout the area and were screened using the field pH and peroxide test.

A field pH below 4 can indicate that actual acid sulphate soils are present (i.e. soils in which oxidation of iron sulfides has occurred and have produced acid). Generally a pH drop below 3 following oxidation with hydrogen peroxide indicates the probable presence of unoxidised sulfides in the samples, and for the purposes of the screening test, is taken as an indication of the probable presence of potential acid sulphate soils.

3.7.3 Conclusion of preliminary ASS investigation

Based on the results of the desk studies and fieldwork, Coffey 2007 concluded that portions of the study area are likely to be affected by ASS.

Soils showing typical characteristics normally associated with ASS and located in lower lying parts of the study area (less than about 10 m AHD) were identified at locations south and south west of Berry and north of Gerringong. These soils were typically limited to the upper parts of the soil profile in the upper 1.5 m to 3 m. Both locations have been identified as 'high probability' of the occurrence of ASS at or near the ground surface.

In general, field screening results confirmed the field observations and correlated well with the ASS risk map.

Lower lying areas in the eastern parts of the study area have a high likelihood of being ASS, particularly within the alluvial and estuarine units. Other geotechnical units in the study area generally have a low likelihood of potential acid sulphate occurrence.

Appropriate identification of potential high hazard and high risk ASS zones should be carried out along the preferred route at the planning and design stage. Activities such as creek culverts, drainage works, and stormwater basins become a high risk if they are likely to intersect zones with a high ASS hazard rating. Proper planning may avoid placing these high risk activities in areas of high ASS hazard.

4. Overview of environmental impacts

4.1 Background

Potential impacts of the FBB Princes Highway upgrade on water quality were investigated as part of the project approval assessments under Part 3A of the EP&A Act and are discussed in detail in Chapter 7.4.3 of the EA Report (AECOM, 2012). An understanding of the risks to groundwater quality associated with the construction and operational phases of the project is critical in developing an adequate monitoring program.

The following sections provide an overview of the key sources of impact and associated impacts to guide the development and assessment of performance objectives, standards and measurement criteria.

4.2 Sources of Impact

The key sources of risk can differ significantly between construction and operation and as such have been reviewed independently in the following sections. The review of construction and operational risks below is provided to identify the potential sources of risk and does not discuss management of these risks or represent the residual risk to water quality following implementation of mitigation measures (Aurecon, 2010b).

This section reviews the potential sources of risk rather than the significance of the impact on water quality, a subsequent interpretation of the significance of those risks and measures to mitigate the risks are provided in following sections.

4.2.1 Construction impact sources

Construction impacts may include potential changes to groundwater quality and groundwater levels. Further detail on these impacts is provided below.

Reduced groundwater recharge

The construction of access roads, tracks and the isolation of areas for stockpiling of construction materials can alter groundwater recharge. Compaction of shallow soils due to construction works may be caused in areas of unconsolidated alluvial sediments which can also result in reduced groundwater recharge. Excavation of road cuttings can also locally reduce groundwater recharge and lower the water table, which may impact surrounding groundwater dependent systems.

Groundwater drawdown

Deep excavations (such as for bridge footings) and cuttings may require temporary localised dewatering during the construction phase and the drawdown associated with this can affect groundwater elevations and yields/flows at key receptors such as the surface water features, groundwater dependent ecosystems and groundwater users.

Localised dewatering would temporarily alter groundwater flow conditions but after dewatering is completed original groundwater flows would be re-established.

Should dewatering be required during the construction of road cuttings, the impacts will depend on the local hydraulic conductivity of the aquifer matrix and secondary water bearing structural features. This drawdown would be permanent and would remain after construction as cuttings would act as an ongoing groundwater discharge point.

Table 4 summarises the expected drawdowns at cuttings along the alignment.

Table 4: Assessment of Potential Impacts at Cuttings (adapted from Coffey, 2010, Table 8)

Chainage of Cutting (m)	Degree of Impact or Risk	Comment
07980 to 08420 (Up to 9 m deep)	Low to Moderate	This cutting may slightly modify groundwater levels in its vicinity and result in localised drawdown of up to 3 m.
08480 to 09400 (Up to 27 m deep)	Moderate	Existing groundwater levels will be affected by this cutting and may result in localised drawdown of up to approximately 15 m.
11360 to 11700 (Up to 12 m deep)	Low	Existing groundwater levels are unlikely to be affected by this cutting.
11920 to 12160 (Up to 7 m deep)	Moderate	This cutting will have an impact on groundwater, causing a localised drawdown of up to 4 m.
12200 to 12580 (Up to 12 m deep)	Moderate	Groundwater levels will experience localised drawdown of up to 2 m.
12880 to 13280 (Up to 12 m deep)	Moderate	This cutting will impact existing groundwater levels, causing potential localised drawdown of up to 5 m.
13780 to 14150 (Up to 11 m deep)	Low to Moderate	This cutting will have an impact on groundwater, causing a localised drawdown of up to 3 m.
14580 to 14980 (Up to 4 m deep)	Low	Existing groundwater levels are unlikely to be affected by this cutting.
15300 to 15820 (Up to 13 m deep)	Low	Existing groundwater levels are unlikely to be affected by this cutting.
17540 to 17760 (Up to 7 m deep)	Low	Existing groundwater levels are unlikely to be affected by this cutting.
18220 to 19160 (Up to 5 m deep)	No data	No groundwater level data is available for the two cuttings.
20020 to 20300 (Up to 5 m deep)	No data	No groundwater level data is available for the two cuttings.

In addition to the above impacts, groundwater elevation impacts can also be created by extraction for water supply during construction.

Lowering the groundwater table may also have other impacts such as exposing ASS, if present, which can impact the water quality at sensitive receptors. It may also result in the settlement of unconsolidated soils which may result in movement and damage of existing structures.

Groundwater quality

Potential groundwater quality risks include spills and accidents throughout construction and through diffuse impacts associated with general site activities. Contaminants of primary concern generally consist of hydrocarbon contamination and other residual chemicals associated with the use of explosives for blasting. Impact is likely to occur through the infiltration of spilt or diffuse contamination through surfaces or treatment facilities (such as sediment dams) to the underlying groundwater systems.

The location of construction sediment dams is currently unknown.

4.2.2 Operational impact sources

On-going impacts may also occur during the long-term operation phase of the project. These impacts may include changes to groundwater quality and groundwater levels. Further detail on these impacts is provided below.

Reduced Groundwater Recharge

Increasing the hard surface roads and associated project infrastructure area will increase runoff and decrease groundwater recharge. This may reduce groundwater elevations resulting in potential impacts to surrounding groundwater dependent systems on a permanent basis.

Interception of groundwater and groundwater drawdown

Significant drawdown will occur during construction of cuttings which will remain after construction and throughout the lifetime of the upgrade. This may impact result in potential impacts to surrounding groundwater dependent systems on a permanent basis

The deepest road cutting is up to 27 metres below ground surface through the Toolijooa Ridge cut, bypassing Broughton Village. Preliminary assessments indicate that groundwater would seep into the cutting from the latite and Kiama Sandstone.

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

Groundwater quality

Road runoff can contain pollutants associated with vehicular movement and normal use due to leaks, spills and accidents. The contaminants can include hydrocarbons (petrol, diesel and oils), metals, suspended solids and other compounds.

It is noted that the current environment included Princes Highway runs through this area and as such the groundwater environment will already be reflective of this type of land-use.

Operational water quality basins and roadside swales are to be established to remove suspended solids to meet surface water quality criteria. They may be responsible for infiltration of low level diffuse contamination to groundwater, however, the improved designs will result in less infiltration than the current highway.

The locations of roadside swales are currently unknown but are assumed to be located along the alignment where conditions are suitable for directing run-off to swales. A total of 18 operational water quality basins are planned along the project highway alignment. Locations of the water quality basins are summarised in Table 5.

Table 5: Proposed water quality basin locations

Proposed Water Quality Basin	Chainage
1A	7700
2A	7950
3A	9800
4A	9425
5A	11000
6A	11350
7A	12100
8A	12700
8B	13450
9A	13500
9B	13750
9C	14350
10A	15000
11A	15800
12A	15950
13A	16150
14A	16400
15	18000

4.3 Sensitive Receptors

Sensitive receptors associated with groundwater related impacts on linear alignment projects in an area similar to the current project generally include:

- groundwater users and the existing beneficial use of the aquifer systems in this area;
- surface water features;
- farm dams;
- groundwater dependent ecosystems (GDE's);
- acid sulphate soils (while this not a specific sensitive receptor, it represents a point or location where exposure may initiate impacts to the range of sensitive receptors listed above); and
- existing structures located on areas prone to dewatering settlement.

Further details on the locations and characteristics of these potential receptors along the alignment are provided below.

4.3.1 Groundwater Users

A review of water bores registered with NOW indicates there are 33 registered bores within 1 km of the project. Although the data within the database are limited, analysis indicates that groundwater along the alignment is used predominantly for stock, domestic and agricultural purposes to supplement surface water supplies collected in farm dams and pumped from creeks. Groundwater is extracted from a variety of aquifers including latite, gravels, sandstone, shale and fractured rock. The groundwater yield is variable but typically less than two litres per second.

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

Table 6 summarises the registered groundwater bores within a 1 km radius of the project alignment.

Table 6: Summary of registered groundwater bores within 1 km of the project alignment

Work No	Completed depth (m bgl)	Date completed	Licensed Purpose (Status)	Yield (L/s)	Salinity (ppm or description)	Other Comments
GW047344	45.80	01/04/1979	Stock (cancelled)		Good	
GW072784	36.00	02/02/1995	(Unknown)		Good	
GW054770	12.20		Domestic (active)			Site visited, owner informed that well had collapsed. No longer used.
GW107697	30.00	07/12/2005	Domestic	5.0	360	
GW015286	25.90	01/01/1957	Recreation – Groundwater (cancelled)		0-500	Site walk over conducted, well no longer appears to exist. Now owned by RMS.
GW011451	27.40	01/02/1956	Domestic (active)		0-500	Site visited, well not in use and no plans to use it in future.
GW010826	22.90		(Unknown)		(Unknown)	
GW028887	28.60	01/04/1962	Stock (active)		(Unknown)	
GW065515	48.80	13/09/1991	(Unknown)		Good	Spoke with owner, well no longer exists.
GW025595	6.00	01/01/1965	Irrigation (cancelled)		(Unknown)	Site visited and found not be used and unlikely to be usable.
GW042994	36.30	01/01/1970	Irrigation		(Unknown)	

Work No	Completed depth (m bgl)	Date completed	Licensed Purpose (Status)	Yield (L/s)	Salinity (ppm or description)	Other Comments
			(lapsed)			
GW016425	25.20	01/01/1942	Farming (active)		(Unknown)	
GW100567	24.00	03/04/1997	Domestic (active)		Good	
GW101971	24.00	13/03/1997	Stock (active)	1.11	Good	
GW108622	36.00	31/10/2006	Domestic (active)	1.67		
GW105826		27/04/2005	Stock (active)			Site visited, pump still present and suggests this well could be being used.
GW109881	36.00	01/01/1999	Stock (active)	0.30		
GW015221	9.70		Stock (active)		(Unknown)	
GW013536	36.10	01/12/1957	Stock (active)		(Unknown)	
GW103006	90.00	23/02/2000	Domestic (active)			
GW102017		17/03/1999	Stock (active)			
GW029638	30.40	01/10/1968	Stock (active)		(Unknown)	
GW028837	32.30	01/08/1968	Farming (active)			
GW015223	15.20	01/02/1957	Stock (active)		0-500	Site visited and found not be used. Now owned by RMS.
GW103077	36.00	13/06/2000	Stock (active)		240	
GW054712	44.00		Stock (active)		(Unknown)	Site visited, pump still present but very old. Could be being used. Now owned by RMS.
GW023627	25.60	01/11/1965	Not known (cancelled)		(Unknown)	
GW102391	36.60	01/01/1975	Stock (active)	1.26		
GW103007	17.98	01/01/1950	Domestic (active)			
GW049981	38.00	01/03/1979	Stock (active)		Good	
GW102335	15.24	01/01/1990	Stock (active)	1.30		
GW101850	33.50	01/01/1977	Domestic	12.6		

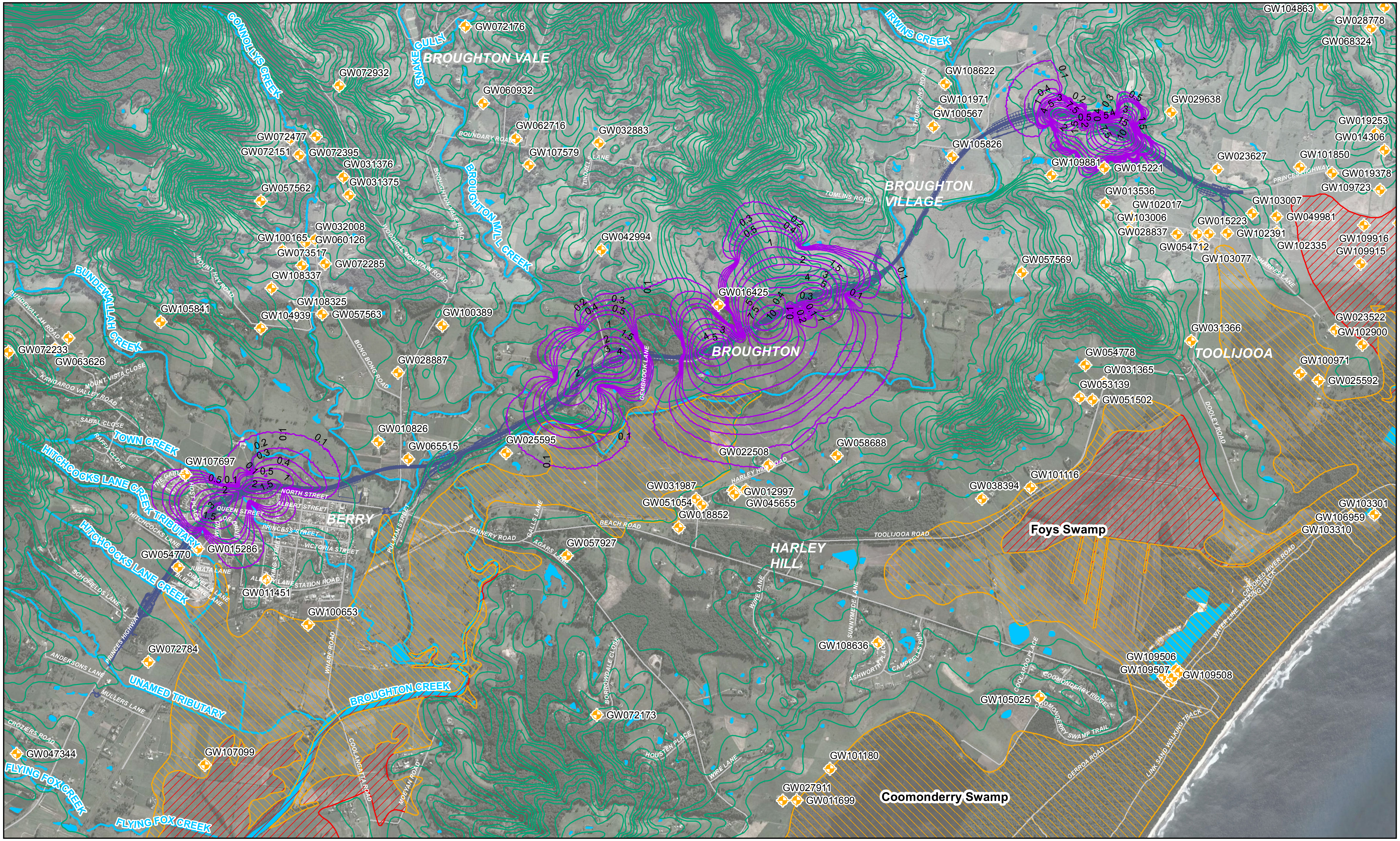
Work No	Completed depth (m bgl)	Date completed	Licensed Purpose (Status)	Yield (L/s)	Salinity (ppm or description)	Other Comments
			(active)	0		
GW019378	20.10	01/09/1961	Stock (active)		Hard	

Figure 9 presents the location of the registered groundwater bores alignment. These wells could potentially be impacted by project related groundwater drawdown impacts.

Based on the topographical and groundwater conditions along alignment, the wells located within 1 km of the alignment that are interpreted to be potentially down gradient of alignment include:

- GW102391, which is currently registered as being active for stock purposes.
- GW054712, which is present in a potentially suitable condition but does not appear to be being used.
- GW015223, which is present in a potentially suitable condition but does not appear to be being used.
- GW028837, which is currently registered as being active for farming purposes.
- GW023627, which has a registered status of being cancelled and is there not anticipated to be used.
- GW105826, which may currently be being used. Given the proximity of this well to the alignment it would appear likely that RMS now own this well which would provide flexibility to decommission the well if it as considered to be negatively impacted.
- GW065515, which after discussions with site owners appears to no longer exist.
- GW011451, which site visits suggest is no longer used and will not be used in future.
- GW015286, which site visits suggest no longer exists.
- GW054770, which site visits suggest is no longer used and has collapsed.

The five wells are interpreted to still be used or to be potentially used in the list above wells may potentially be impacted by changes in groundwater quality associated with the project.



1:30,000 (at A3)

0 150 300 600 900 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- Registered Groundwater Wells
- Simulated Groundwater Drawdown
- Elevation Contours
- Berry to Foxground upgrade alignment
- Disturbed soils
- High risk
- Low risk
- Railways
- Waterways
- Lakes and dams
- Roads

Roads and Maritime Services
Water Quality Monitoring

Berry to Foxground upgrade
Overview of Groundwater Receptors and Project Impacts

Job Number	21-23174
Revision	0
Date	09 Jul 2014

Figure 9

Z:\TEMP GIS\berry to foxground\GIS\Maps\MXD\21_23174_Z019_BERRY_Overview_GWReceptors.mxd

Data Source: NSW Department of Lands: DTDB and DCDB - 2012. Created by: pmcdougall

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4.3.2 Farm Dams, watercourses and water bodies

Most surface water bodies (streams, lakes, reservoirs, wetlands, and estuaries) interact with groundwater to some degree. Groundwater-surface water interactions may take place where streams gain water due to the inflow of groundwater through the streambed or where streams lose water to groundwater due to outflow through the streambed. A combination of both inflows and outflows may occur along various stream reaches. For example, a stream may be gaining water along selected reaches while losing water along other reaches. As such, surface water features potentially in hydraulic connection with groundwater passing beneath the alignment may be impacted by changes to groundwater elevations and quality at the alignment.

The project alignment also crosses several surface water catchment areas. From north to south these are: The Crooked River Catchment, Broughton Creek Catchment, Broughton Mill Creek Catchment, Connollys Creek Catchment, Bundewallah Creek Catchment, Town Creek Catchment, Hitchcocks Lane Creek Catchment, and the unnamed Tributary of Broughton Creek Catchment.

The majority of the alignment is located within the Broughton Creek Catchment, with Broughton Creek crossing the alignment three times. Broughton Creek also runs parallel to the alignment between chainage CH 14600 and CH 15700, coming as close as 40 m towards the boundary of the alignment.

Minor ephemeral surface water runoff lines are located within grass paddocks of bordering farms. These water courses are believed to only contain any flow after major rainfall events, discharging into the major creeks within the catchment systems.

Table 7 summarises the major creeks that cross the project alignment.

Table 7: Summary of creeks crossing the project alignment

Creek	Chainage
Broughton Creek	CH 9950; CH 10750; CH 11200
Broughton Mill Creek	CH 15850
Connollys Creek (including Bundewallah Creek	CH 16250
Town Creek	CH 17450
Hitchcocks Lane Creek Tributary	CH 18100
Hitchcocks Lane Creek	CH 18580
Unnamed Tributary of Broughton Creek	End of chainage

The flows and water quality in these surface features may be impacted by project construction and operation at the point of crossing.

Approximately 29 farm dams have been identified along the alignment (AECOM, 2012). The farm dams are anticipated to be primarily reliant on surface water run-off harvesting and are unlikely to have significant connections to groundwater systems. Contact with groundwater for the farm dams is therefore likely to be negligible, however, with the current conceptual understanding interaction of farm dams with groundwater cannot be ruled out.

4.3.3 Groundwater dependent ecosystems

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

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

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

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

Coomonderry Swamp and Foys Swamp are coastal freshwater wetlands, located east of Broughton Creek (See Figure 9). Due to their distance from the alignment and the intervening geological and topographical conditions, these systems are not expected to be in significant hydraulic connection with groundwater flowing beneath the alignment. The Sydney Basin Southern management zone of the Greater Metropolitan Region Water Sharing Plan for the project area identifies Coomonderry Swamp as a high priority GDE in Schedule 4 of the Plan (NOW, 2011a). Coomonderry Swamp is a large (429 hectare) semi-permanent freshwater swamp, northeast of Nowra that is listed on the register of the National Estate. Foys Swamp is not listed in the Water Sharing Plan.

Floodplain swamp forest is a low, dense forest tolerant of brackish groundwater that was identified along Toolijooa Road and the railway line between Berry and Gerringong (Maunsell, 2007). This community may grade into estuarine fringe forest with increasing groundwater salinity. Due to their distance from the alignment and the intervening geological and topographical conditions, these systems are not expected to be in significant hydraulic connection with groundwater flowing beneath the alignment.

No groundwater springs of significance have been identified to be potentially impacted by the alignment.

4.3.4 Acid sulphate soils

There is a low risk that ASS may be present near to the alignment in low lying areas around Broughton Creek (see Figure 9). Should the water table be lowered where ASS is present, ASS may become exposed and oxidation of sulphide minerals could result. This process generates sulphuric acid and increases metal concentrations in solution, which can lead to degradation of groundwater quality. Rainfall runoff could cause low pH water to migrate within the shallow groundwater system and discharge into surface water systems and groundwater receptors.

According to the ASS risk maps (Coffey, 2007), no known occurrence has been reported for ASS along the project alignment north of Berry.

Low probability of ASS occurrence within 1 and 3 metres below ground surface is reported for the area to the south and south east of Berry and in a number of areas extending along Broughton Creek to central areas of the alignment around Tindalls lane.

4.3.5 Existing structures on soils prone to settlement

There is a potential risk associated with settlement of unconsolidated sediments where they have been dewatered. This may result integrity issues to existing structures located on these sediments. Figure 9 of Coffey Geotechnics, Maunsell Aecom (2007) suggests that soft soils of generally less than 3 m in thickness are generally located between Broughton Creek and the proposed alignment, Austral Park Road and Berry. These sediments are also located in southern areas of Berry Township.

4.4 Assessment of Impacts

This section further characterises the significance of groundwater quality and groundwater elevation/drawdown changes associated with the project on the groundwater receptors identified above.

The section focuses on the primary sources of risk discussed in Section 4.2 and the impacts that these sources may have on the identified receptors discussed in Section 4.3.

4.4.1 Recharge Reduction Impacts

Recharge reduction impacts resulting in lowering of the groundwater table are expected to have a very small impact on overall groundwater elevations yields/flows at the identified receptors. This is because reduction in recharge associated with compaction, paved surfaces and infrastructure during construction and operation are very insignificant compared to the overall size of the catchments contributing to groundwater recharge. As such, this is not considered to represent a significant impact.

The reduction in recharge may contribute slightly to cumulative impacts associated with groundwater drawdown around cuttings, however, these would be relatively insignificant compared with the large changes created by cuttings.

4.4.2 Groundwater Drawdown Impacts

Localised drawdown during construction associated with bridge footing installation will mainly occur in the vicinity of existing surface water features where bridge construction is occurring. The extent of overall drawdown would be limited as dewatering would be temporary in nature and localised to small footprints. Surface water flows will have the potential to be impacted by drawdown and management measures will be required to limit this impact. Acid sulphate soils maps suggest that acid sulphate soils are unlikely to be intercepted by the localised and temporary drawdown impacts. There are no identified sensitive groundwater wells identified within the vicinity of these localised drawdowns. There may be some potential for settlement of sediments in the vicinity of any bridge footing near surface water structures.

A numerical groundwater model has been developed to assess the impact of the project on groundwater users and groundwater dependent systems associated with drawdown around cuttings, which represent the primary source of groundwater elevation changes. The groundwater modelling report is presented in **Appendix A**.

The modelling approach and complexity was been based on that undertaken prior to construction for other major road upgrade projects in NSW where groundwater is considered to be sensitive.

Changes in groundwater recharge due to the development of the project and associated increases in sealed and compacted surfaces have not been simulated by groundwater modelling. This is because these impacts are expected to be small given that sealed and compacted areas are likely to represent a small percentage of the overall catchment recharge.

The predicted impacts to identified receptors are presented in Figure 9 and summarised below:

- Significant drawdown impacts have been identified to occur at five main locations including the Toolijooa Ridge cut, at three separate locations between Austral Park Road and Tomlins Lane and at the western end of Berry Township.
- The impacts are likely to develop during construction with subsequent stabilisation during operation of the project.
- Impacts to surrounding registered groundwater wells are simulated to be within acceptable ranges, with the maximum predicted drawdown within impacted registered groundwater wells approximating less than 0.2 m.
- The drawdowns are expected to result in a less than 1 % reduction in the base flow component of catchment surface water features. This is anticipated to have negligible impacts on in-stream aquatic ecology and existing surface water users' supplies; however, further consultation with ecological specialists is required to validate this.
- Impacts to sensitive surface water features such as Coomonderry Swamp and Foys swamp are simulated to be negligible.
- The zones of drawdown influence created by the cuttings near to Tindalls Lane and Tomlins Road are simulated to intersect areas where there is low potential for the presence of Acid Sulphate soils. The exposure of acid sulphate soils in these areas could result in pH and metals impacts within Broughton Creek.
- The zones of drawdown influence created by the cuttings extend under isolated developments along the alignment, particularly in the Berry area, that are potentially situated on unconsolidated materials.
- Ten farm dams are intersected by the zone of drawdown influence of which six are interpreted to be within zones of drawdown greater than 0.2 m. Given that the farm dams rely primarily on surface water harvesting it is considered unlikely that they will be impacted by groundwater drawdown unless they have significant contact with groundwater, which is currently unknown.

Given the current understanding of design and construction of the alignment it is recommended that the modelling is revised when there is more certainty on the design levels and construction program. At this time more detailed assessment of non-uniqueness in the modelling outcomes should be considered.

It is not expected that groundwater extraction for water supply will be required during construction and or operation as such no impacts are considered likely. If this need is identified during detailed design, further investigation would be required to be undertaken to quantify the impacts and develop appropriate mitigation measures.

4.4.3 Groundwater Quality Impacts

The sources for groundwater quality impacts differ between construction and operation however, ultimately the impacts will arise from infiltration of residual or spilt chemicals during the construction and operation phases.

Based on the current understanding of aquifer properties and likely groundwater migration rates it is expected that the impacts will emerge slowly as impacted groundwater migrates down hydraulic gradient.

This does not include impacts associated with the generation of acid sulphate soils which may be more rapid and have been discussed previously.

The primary receptors potentially down gradient of the alignment include all surface water features located down gradient particularly Broughton Creek, farm dams and the five registered groundwater wells GW102391 , GW054712 (owned by RMS), GW015223 (owned by RMS), GW028837 and GW105826 (owned by RMS). The wells owned by RMS are not considered likely to be adversely impacted. There are no other identified sensitive groundwater dependent ecosystems down gradient of the alignment and other receptors identified in Section 4.3 (i.e. structures and acid sulphate soils) are not expected to be affected by water quality impacts.

Any emerging impacts are expected to be diffuse and minor/low level in nature as mitigation measures will be adopted during construction and operation to prevent infiltration of chemicals to groundwater, appropriately treat infiltrating surface water and/or prevent contact of surface water run-off with groundwater. These mitigation measures are discussed further in the following sections.

Water quality impacts to farm dams are expected to be negligible because connection with groundwater is expected to be limited if at all present and because the primary water inputs to the dams are from surface water harvesting.

Water quality impacts to down gradient groundwater users may be compounded by pumping at these wells which will result in increased capture zone size and a greater potential to draw in diffuse impacts associated with the alignment.

The existing highway will have already resulted in low level impact to the groundwater system. The adoption of more advance capture and treatment systems for the upgrade is anticipated to result in a reduction in any existing low level contaminant infiltration to groundwater, which may improve current groundwater quality along the alignment.

Groundwater monitoring will be required to assess whether diffuse impacts associated with construction and operation are creating an adverse impact that needs to be mitigated.

4.5 Management of environmental risks

The assessment of potential impacts presented in Section 4.4 suggests that mitigation measures will be required to:

- Prevention of drawdown impacts including:
  - temporary impacts associated with construction works for bridge footings.
  - reduced flow to farm dams.
  - exposure of acid sulphate soils, especially within the vicinity of cuts located near to Tindalls Lane.
  - settlement along the alignment and hence impacts to building structures during both construction and operation.

- Minimise potential for contamination to underlying groundwater during both construction and operation.

The mitigation measures to be adopted to manage/mitigate these impacts are discussed below.

4.5.1 Management of Drawdown Impacts

Temporary drawdown during construction

Should dewatering of the alluvial aquifer be required during the construction of bridge footings, groundwater drawdown will be limited to the base of the footing, and the zone of influence or induced cone of depression (which is expected to be limited due to the more transmissive nature of an alluvial aquifer soils).

The management of the impacts will be dealt with in the construction and environmental management plan (CEMP) and/or with the adoption of construction methods/design that limit interaction with groundwater. Any requirement to monitor for the effectiveness of the methods implemented would be dealt with in the CEMP.

This drawdown will most likely occur within the immediate vicinity of surface water features and targeted flow monitoring at surface water locations will likely deal with these issues.

Additional groundwater modelling may be required to assist in quantifying the amount of groundwater drawdown and any potential impacts.

Dewatered groundwater, if impacted by construction activities, may require appropriate treatment primary to re-infiltration back into the groundwater system. This would be dealt with in the CEMP.

Management of flow to farm dams

Given the low probability of impacts to farm dam water supply, if impacts to farm dams were to become apparent an additional groundwater supply well would be provided.

While the potential for impacts to farm dams is expected to be very low infiltration of dewatered groundwater during construction and operation up gradient of farm dams would further minimise the potential for groundwater related impacts.

Management of Acid Sulphate Soil Exposure

It is expected that the overall likelihood of impact from acid sulphate soil exposure is low as cut induced drawdowns are only expected to intersect zones of low probability acid sulphate soils. Further consideration of this potential impact has been recommended by the EPA to be undertaken at detailed design phase. The following additional management measures will be considered:

- investigations to delineate the presence of acid sulphate soils and hence the presence of an actual risk.
- re-infiltrating dewatered groundwater upgradient of potential acid sulphate soil areas. There would be an opportunity to optimise construction mitigation using the existing groundwater model.

If all groundwater is returned to the groundwater system down gradient of the cut it would be expected that drawdown impacts would be limited to the immediate area around the cuts upgradient of seepage zones and would minimise the development of drawdown impacts down gradient of the seepage zone.

A strategically placed groundwater elevation monitoring bore would be useful to assess the effectiveness of implemented solutions to mitigate this potential impact. It could also act as an early warning mechanism for the presence of emerging impacts and hence a requirement to investigate and implement additional mitigation measures.

Settlement Related Impacts

At present there is a predicted risk of groundwater drawdown to intersect soft soil sediments that have the potential to settle and damage overly structures especially in Berry Township. Further investigation is required by an appropriately qualified professional in characterising settlement issues to determine in this intersection actually represents a settlement risk. Subject to a settlement risk being identified the design and construction methods will be required to negate impacts.

Given the potential cost associated with the mitigating these impacts after they occur. Groundwater monitoring will be required to assess the adequacy of mitigation measures and act as a trigger to that additional actions can be taken of impacts were to emerge.

4.5.2 Management of Groundwater Quality Impacts

Construction

It is expected that the risk posed by this type of source would be low due to stringent management measures imposed during construction as part of the CEMP. The CEMP will provide methods and procedures for:

- storage and handling of site chemicals.
- spill management and clean-up.

Further to the above, site practices will be adopted to prevent interaction of surface water with groundwater by diverting groundwater seepage away from construction activities and surface water run-off and capture systems and re-infiltrating the unimpacted groundwater back to the groundwater system downgradient of the site.

Groundwater monitoring will be required to assess the overall effectiveness of these management measures.

Operation

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

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

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

The system will be designed to reduce infiltration of contaminants to groundwater by redirecting any rainfall and associated run-off from the project through a treatment train of swales and water quality basins that will have limited connection to the underlying groundwater systems. The systems will be appropriately designed to facilitate this. The small quantity of run-off that may ultimately enter the groundwater system would have a low risk of impact to the existing groundwater quality beyond the immediate road corridor.

Further to this groundwater seepage will be kept separate from interaction with surface water and re-directed within separate infrastructure to down gradient locations where it will be re-infiltrated to the groundwater system.

Groundwater monitoring will be required to assess the overall effectiveness of these management mitigation measures. However, the mitigation measures implemented are expected to result in a reduction on potential contaminant infiltration to groundwater compared to the current highway system.

5. Consideration of surface water interactions

Condition of Approval B16 requires that 'The Proponent shall prepare and implement a Water Quality Monitoring Program to monitor the impacts of the project on surface and groundwater quality and resources and wetlands, during construction and operation. The surface water and groundwater monitoring programs have been divided into two separate reports.

A monitoring program has subsequently been developed for surface water quality and is presented in the *Surface Water Monitoring Program – Berry to Foxground Princes Highway Upgrade* (GHD, 2014b).

The groundwater modelling report presented in **Appendix A** outlines the interactions between groundwater and surface water.

6. Monitoring Objectives

6.1 Performance objectives

When developing a monitoring program, performance objectives must be clearly stated to identify the goals of the monitoring program – i.e. what does the monitoring program aim to achieve. It is important the performance objectives are identified early and are agreed by stakeholders to ensure that the monitoring plan is focused on meeting these objectives.

The performance objectives for the FBB Princes Highway upgrade GWMP are based on the findings of the Environmental Assessment investigations, take into account the key concerns of stakeholders, and reflect the intent of the Director General's Conditions of Approval.

The performance objectives are outlined in Table 8, which reflect the performance criteria adopted for the T2E Upgrade.

Table 8: Performance objectives for the monitoring program (adapted from Aurecon 2012).

Performance Objective
1. To monitor for the potential impact of the Upgrade on surface water and groundwater quality to protect the existing and ongoing human, horticultural and agricultural uses of that water
2. To monitor for the potential impact of the Upgrade on water quality to protect existing and future status of aquatic ecology and ecosystem characteristics in all catchments intersected by, and downstream of, the Upgrade

6.2 RMS water policy

The above objectives also support the RMS water policy (RTA, 2010):-

'*The Roads and Traffic Authority would use the most appropriate water management practices in the planning, design, construction, operation and maintenance of the roads and traffic system in order to:-*

- *conserve water;*
- *protect the quality of water resources; and*
- *preserve ecosystems'.*

7. Performance standards

The performance objectives of this monitoring plan focus on three key areas – that is, protection of groundwater quality; protection of groundwater hydrology; protection of licensed bores and dams and protection of groundwater dependent ecosystems. The proposed performance standards provide a framework against which the protection of these aspects can be assessed.

In accordance with recommendations provided in the EA this section mimics that presented in the water quality monitoring documents for the T2E project developed by Aurecon, in 2010.

7.1 Protection of groundwater quality

7.1.1 Water quality guidelines

There are several water quality standards of relevance to a project of this nature and each have been reviewed in determining an appropriate performance standard for the FBB Princes Highway upgrade. The standards include:-

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000a);
- Australian Drinking Water Guidelines (NHMRC, 2004); and
- Guidelines for Groundwater Protection in Australia (ANZECC, 1995).

A brief summary of these documents and discussion of their relevance to the project is provided below.

ANZECC guidelines

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC guidelines) provide a management framework, guideline water quality triggers, protocols and strategies to assist water resource managers in assessing and maintaining aquatic ecosystems. The guidelines are intended to provide government, industry, consultants and community groups with a sound set of tools that would enable the assessment and management of ambient water quality in a wide range of water resource types, and according to designated environmental values.

The primary objective of the ANZECC guidelines is:-

To provide an authoritative guide for setting water quality objectives required to sustain current or likely future environmental values for natural and semi-natural water resources in Australia and New Zealand.

The ANZECC guidelines provide the following water quality management framework:-

1. Identify the environmental values that are to be protected in a particular water body and the spatial designation of the environmental values (i.e. decide which values would apply where).
2. Identify management goals and then select the relevant water quality guidelines for measuring performance. Based on these guidelines, set water quality objectives that must be met to maintain the environmental values.
3. Develop statistical performance criteria to evaluate the results of the monitoring programs (e.g. statistical decision criteria for determining whether the water quality objectives have been exceeded or not).

4. Develop tactical monitoring programs focusing on the water quality objectives.

5. Initiate appropriate management responses to attain (or maintain if already achieved) the water quality objectives.

The guidelines recommend numerical and descriptive water quality guidelines to help managers establish water quality objectives that would maintain the environmental values of water resources. They are not standards, and should not be regarded as such (ANZECC, 2000a).

Of particular importance to note is the philosophical approach for using the ANZECC guidelines of: '*protect environmental values by meeting management goals that focus on concerns or potential problems'* (ANZECC, 2000a). That is, development of a monitoring program, including the objectives, standards and measurement criteria, should focus on specific issues not on pre-determined guideline values.

The philosophy, management framework and guiding principles outlined in the ANZECC guidelines have formed the basis for development of project specific performance standards for the FBB Groundwater Monitoring Program.

The following guidance is provided for the application of the ANZECC guidelines to groundwater management:

Groundwater is an essential water resource for many aquatic ecosystems, and for substantial periods it can be the sole source of water to some rivers, streams and wetlands. Groundwater is also very important for primary and secondary industry as well as for domestic drinking water, particularly in low rainfall areas with significant underground aquifers.

Generally these Guidelines should apply to the quality both of surface water and of groundwater since the environmental values which they protect relate to above-ground uses (e.g. irrigation, drinking water, farm animal or fish production and maintenance of aquatic ecosystems). Hence groundwater should be managed in such a way that when it comes to the surface, whether from natural seepages or from bores, it would not cause the established water quality objectives for these waters to be exceeded, nor compromise their designated environmental values.

As a cautionary note the reader should be aware that different conditions and processes operate in groundwater compared with surface waters and these can affect the fate and transport of many organic chemicals. This may have implications for the application of guidelines and management of groundwater quality.

Australian Drinking Water Guidelines

The Australian Drinking Water Guidelines (ADWG), published by the National Health and Medical Research Council, 'provide the authoritative Australian reference for use within Australia's administrative and legislative framework to ensure the accountability of drinking water suppliers (as managers) and of state/territory health authorities (as auditors of the safety of water supplies)' (ADWG, 2004).

With appropriate consultation with the community, the ADWG may be used directly as agreed levels of service or they may form the basis for developing local levels of service. In the case of health-related water quality characteristics there is less latitude for variation because the safety of drinking water is paramount. However, with regard to aesthetic characteristics, what is acceptable or unacceptable depends on public expectations and can therefore be determined by water authorities in consultation with consumers, taking into account the costs and benefits of further treatment of the water. The ADWG provide a starting point for that process (ADWG, 2004).

The ADWG include both health-related and aesthetic guideline values to guide the short and long term management of drinking water quality. The guidelines do not provide a framework for the management of environmental and catchment values and as such cannot be directly applied to this project. The guidelines do, however, provide a number of principles that have been considered in the preparation of project specific performance standards for the FBB Princes Highway upgrade.

There are no drinking water catchments in the project area (AECOM 2012) and reference to the ADWG (2004) will only be made in the event that groundwater is identified to be used as a potable source.

Guidelines for Groundwater Protection in Australia

The *Guidelines for Groundwater Protection in Australia* form part of the National Water Quality Management Strategy and have been developed with the primary objective of providing ‘a national framework for the protection of groundwater from contamination’.

The guidelines ‘are intended to address a broader range of basin/catchment management issues than are currently considered in groundwater protection strategies elsewhere, and allow for integration of groundwater planning with surface water planning. The guidelines are based on a planning approach. They adopt the principle of beneficial use of groundwater classification and risk assessment to derive appropriate protection measures’ (ANZECC, 1995).

The guidelines do not provide trigger criteria, but rather provide the framework for development of groundwater management plans. For trigger criteria the ANZECC (currently ANZECC, 2000b) water quality guidelines are referenced.

7.2 Protection of groundwater hydrology and groundwater dependent ecosystems

While the performance objectives identify the goals of the monitoring program, the performance standards define the benchmark and measures against which the performance is assessed. It is critical that the performance standards adopted provide a meaningful and quantifiable measure of ‘performance’. Setting performance standards for the protection of groundwater hydrology and subsequent impacts on licensed bores, dams and groundwater dependent ecosystems that are capable of quantifying the impact that is directly attributable to the FBB Princes Highway upgrade is complex. For groundwater quality the performance standards allow for an assessment based on changes in quality up-gradient and down-gradient of the project alignment. For groundwater hydrology, the impact must be assessed by review against a baseline data set and, as such, is more open to outside influences such as changing weather, climate or local groundwater resource use. For groundwater dependent ecosystems, any changes in composition or distribution may also be affected by external factors and, as such, would be difficult to attribute to the FBB upgrade.

To assist in the analysis of impacts that can be attributed to the construction and operation of the alignment, hydrology data may be compared to control sites. It is proposed to monitor sites up-gradient of a number of cuts (See Section 9).

7.3 Proposed performance standards

The potential impacts on groundwater water quality, groundwater hydrology, licensed bores and dams and groundwater dependent ecosystems of the FBB upgrade are outlined in Section 4.4. Consideration must be given to external drivers of change in groundwater when determining appropriate performance standards. As discussed above, factors such as groundwater extraction by local users or variability in rainfall and climatic patterns have the potential to impact on groundwater hydrology and groundwater dependent ecosystems, while changes in catchment condition or land use have the potential to impact on groundwater quality. The nature of each of the potential impacts requires a varied approach to setting performance standards.

For the assessment of impacts on groundwater quality and hydrology, the sampling results for each sample event would be compared against site specific control charts. Control charts present a 'baseline' data set (refer Section 7.4) and are developed based on data from a reference site. The baseline will be comprised of data collected in the 12 months prior to the commencement of construction activities. The control chart for each site provides the performance standard for that site.

For the assessment of impacts on groundwater dependent ecosystems, the performance standards would be based on changes in species (floristic) composition, abundance and distribution/extent over time. These assessments are not part of this monitoring plan.

7.4 Control charts

The Australian Guidelines for Water Quality Monitoring and Reporting (Water Quality Monitoring Guidelines) (ANZECC, 2000b), provide guidance for the development of monitoring programs and assessment of water quality. They form Volume 7 of the National Water Quality Management Strategy (ANZECC, 2000a) of which the ANZECC guidelines are also part.

The Water Quality Monitoring guidelines provide the following discussion of control charts:-

Control charting techniques used for the last 70 years in industry have an important role to play in an environmental context. They are particularly relevant to water quality monitoring and assessment. Regulatory agencies are moving away from the 'command and control' mode of water quality monitoring, and recognising that, in monitoring, the data generated from environmental sampling are inherently 'noisy'. The data's occasional excursion beyond a notional guideline value may be a chance occurrence or may indicate a potential problem. This is precisely the situation that control charts target. They not only provide a visual display of an evolving process, but also offer 'early warning' of a shift in the process level (mean) or dispersion (variability).

The advantages of the use of control charts are identified as:-

- minimal processing of data is required;
- they are graphical: trends, periodicities and other features are easily detected; and
- they have early warning capability: the need for remedial action can be seen at an early stage.

This ability to recognise 'noise' in the water quality data and the early detection of changing trends makes the use of control charts a powerful tool for assessing the impact of the FBB upgrade within a drinking water catchment where other land use factors may be contributing to a change in water quality.

The use of control charts is also suitable for the assessment of impacts on groundwater hydrology. The control chart includes plots of data over time (refer Figure 8) and as such would allow for the assessment of impacts on groundwater hydrology to incorporate potential seasonal variability in the data set.

7.4.1 Development of site specific control charts

For each of the proposed monitoring sites, a site specific control chart would be developed to provide a suitable reference criterion and performance standard. The control chart is produced by plotting the median concentration from the test site against the 80th percentile of the reference site/reference data (i.e. pre-construction data).

The Water Quality Monitoring Guidelines (ANZECC, 2000b) recommend the following procedure for calculating the 80th percentile of the data set:

- arrange the 24 data values in ascending order (i.e. lowest to highest); then
- take the simple average (mean) of the 19th and 20th observation in the ordered set.

An example control chart is provided in Figure 10.

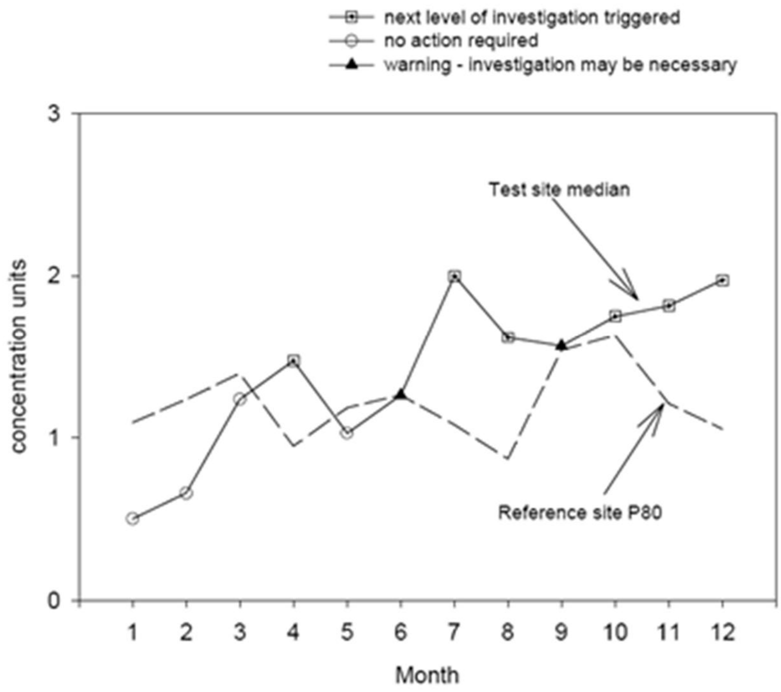

Figure 10: Example control chart

8. Measurement and assessment criteria

Measurement criteria provide the ‘trigger’ for a management response, are related to the risks associated with the FBB Princes Highway upgrade and allow for assessment against the performance standards. They mimic those adopted for the T2E Upgrade (Aurecon, 2010).

The following sections provide an overview of the measurement criteria, while the processes for assessment that would result in the triggering of a management action are presented in Section 11.

8.1 Groundwater quality trigger criteria

The ANZECC guidelines (ANZECC, 2000a) provide a framework for setting trigger criteria. In the development of this framework the following criteria were considered:-

- explicit recognition of the inherent (and usually large) variability of natural systems;
- robustness under a wide range of operating conditions and environments;
- no, or only weak, distributional assumptions about the population of values from which the test and reference data are obtained;
- known statistical properties, consistent with and supporting the monitoring objectives [of the ANZECC guidelines];
- ease of implementation and interpretation;
- suitability for visual display and analysis; and
- intuitive appeal.

The trigger criterion recommended by the ANZECC guidelines for physio-chemical stressors, and subsequently adopted for the assessment of groundwater quality impacts of the FBB Princes Highway upgrade is stated as:

“A trigger for further investigation would be deemed to have occurred when the median concentration of n independent samples taken at a test site [i.e. down-gradient of the highway] exceeds the eightieth percentile of the same indicator at a suitably chosen reference site [i.e. up-gradient of the highway].”

The above trigger criterion does not define or represent a point where an ecologically significant impact would occur. This approach is intended as an early warning mechanism to alert the catchment manager of a potential or emerging change that would require further investigation (ANZECC, 2000a).

The ANZECC guidelines also note that ‘the statistical significance associated with a change in condition equal to or greater than a measurable perturbation [i.e. median of down-gradient sample exceeding 80th percentile of up-gradient sample] would require a separate analysis (ANZECC, 2000a). This analysis is discussed in the following sections.

8.2 Groundwater hydrology trigger criteria

Changes in groundwater hydrology would be assessed using a statistical analysis to test for significant change. The trigger for a management action in relation to groundwater hydrology would be when a statistically significant difference in groundwater levels or flow from groundwater springs (refer Section 9) is shown in the analysis. An overview of the statistical analysis approach is provided in Section 8.4.

In areas impacted by cut drawdown, a comparison of observed and simulated elevations from modelling will be undertaken, observations outside those predicted would represent a trigger for further investigation/characterisation works.

8.3 Groundwater dependent ecosystem trigger criteria

As discussed in Section 7.3, the assessment of impacts on groundwater dependent ecosystems would be based on changes in species/floristic composition, abundance and distribution over time and, as such, a specific trigger criterion may not be set. Sampling would then be undertaken at intervals throughout the operational phase of the project and the data assessed against the baseline. This requires a more subjective assessment and would be undertaken by an ecologist with experience in the assessment of groundwater dependent ecosystems. These assessments are not dealt with as part of this plan.

8.4 Statistical analysis

For the assessment of impacts on groundwater hydrology, the following statistical analysis would be used for the trigger of management actions. For groundwater quality the statistical analysis would be used in addition to the assessment against the trigger criteria outlined in Section 8.1. The statistical analysis would be used to test the significance of any observed difference between the baseline data set and test data for groundwater quality and elevations hydrology. Both a Paired t-Test and a Sign Test would be used in determining statistical significance.

8.4.1 Paired t-Test

A paired t-Test would be used to test the null hypothesis that there is no difference in the pairs (i.e. up- gradient and down-gradient samples at each time step or between the baseline and test data for groundwater hydrology) of data. The paired t-Test assumes that the paired differences (i.e. the difference between the up-gradient and down-gradient samples) are normally distributed around their mean. The two groups of data are assumed to have the same variance and shape. As such, if they differ, it is only in their mean. The null hypothesis can be stated as:-

$$H_0 : \mu_x = \mu_y$$

i.e. the means for group *x* (upstream) and *y* (downstream) are identical.

If the differences are not normally distributed and especially when they are not symmetric, the probability (i.e. p-values) from the t-Test would not be accurate. The primary consequence of overlooking the normality assumption underlying the t-Test is a loss of power to detect differences which may truly be present. The second consequence is an unfounded assumption that the mean difference is a meaningful description of the differences between the two groups (Helsel and Hirsch, 2002). Consequently, when assessing results of a t-Test, any large variance of significant outliers in either the up-gradient or down-gradient data set may influence the results.

8.4.2 Sign Test

A Sign Test would also be used to test for significant difference between the up-gradient and down-gradient samples or between the baseline and test data for groundwater hydrology. The Sign Test is used for pairs of data to determine whether one data set (up-gradient) is generally larger, smaller or different than the other (down-gradient). The null hypothesis can be stated as:

$$H_0 : PROB[x > y] = 0.5$$

Two paired groups of data are compared, to determine if one group tends to produce larger (or different) values than the other group. No assumptions about the distribution of the differences are required. This means that no assumption is made that all pairs are expected to differ by about the same amount. Numerical values for the data are also not necessary, as long as their relative magnitudes may be determined (Helsel and Hirsch, 2002). As such, the Sign Test is non-parametric and can be used regardless of distribution. The hypothesis, however, is more general than the t-Test.

The t-Test and Sign Test have both been proposed as each has strengths and weaknesses. The t- Test is a more powerful parametric test that uses all the information available while the Sign Test makes no assumption of distribution and is less affected by outlying data or significant variance.

9. Monitoring program

9.1 Monitoring sites

9.1.1 Site selection criteria

The selection of groundwater monitoring sites for monitoring for impacts has been based on the monitoring recommendations made in the EA outlined in Section 2.1.1 and the outcomes of the assessment and modelling of impacts outlined in Section 4.

For the purpose of clarifying the monitoring recommendations outlined in the EA, the key requirements have been summarised below:

- *“Establish a groundwater monitoring network along the project to monitor groundwater quality within each lithology and to establish background groundwater quality.”*
- “*Detail the establishment of a groundwater monitoring network along the route to adequately characterise background water quality within the alluvial/colluvial aquifers and Shoalhaven Group Sediments, including the Broughton Sandstone and latite.”*
- *“Install monitoring wells adjacent to major cuts to confirm existing groundwater levels and to monitor the effect on groundwater levels by construction activity, where groundwater is encountered.”*
- *“Implement a groundwater monitoring plan that would assess the performance of groundwater mitigation measures during and after construction. This plan would provide an assessment of groundwater level and quality trends and identification of exceedances (if any).”*
- *“The monitoring program would be required to monitor groundwater level fluctuations and groundwater quality parameters within the existing groundwater monitoring network. During the field program the following field parameters and laboratory analyses would be collected from a minimum of four monitoring wells.*
  - o *pH, dissolved oxygen, redox, electrical conductivity and temperature (field parameters).*
  - o *Total petroleum hydrocarbons/benzene, toluene, ethylbenzene, xylene (TPH/BTEX), PAH, heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn).*
  - o *Installation of dataloggers in four key monitoring wells to monitor groundwater levels on a daily schedule.”*

The assessment of potential impacts outlined in Section 4 suggests that monitoring is undertaken to:

- Assess the effectiveness of management measures developed for installation of bridge footings during construction. This monitoring would be dealt with in the CEMP and is not considered to form part of the broader groundwater monitoring regime outlined in this document.
- Assess drawdown at potential acid sulphate soil areas surrounding cuts near Tindalls Lane. Further investigations should be undertaken during construction to assess if the acid sulphate soils identified to have a low probability of occurrence actually represent a risk in this area. Subsequently, management measures would be implemented to mitigate these impacts. Monitoring would be implemented during construction to assess the effectiveness of any management solutions adopted to mitigate the impact.

- Assess drawdown in soft soils resulting in settlement and hence movement/damage to structures. Further investigation is required to assess if this represents an issue. Subject to the outcomes of this assessment, design changes will be required to mitigate this impact. Groundwater elevation monitoring maybe required to assess the adequacy of adopted mitigation measures.
- Assess the effectiveness of water quality management mitigation measures implemented during construction and operation and to monitor for the emergence of diffuse low level contamination infiltrating from the site and from surface water capture and treatment infrastructure.

9.1.2 Monitoring locations

Monitoring of groundwater quality and groundwater level will be undertaken via suitably designed and installed monitoring bores. The monitoring bore sites have been selected to:

- meet the recommended parameters outlined in the EA including:
  - establish baseline water quality in a range of lithological units;
  - establish baseline water quality along the entire alignment;
  - characterisation of groundwater elevations around cuttings;
  - assess groundwater mitigation measures along the alignment;
  - includes monitoring of a minimum of four wells; and
  - groundwater elevation monitoring in four wells using data loggers.
- monitor for groundwater quality impacts to potentially impacted receptors down gradient of the alignment, particularly including Broughton Creek and currently used groundwater bores.
- monitoring for settlement and acid sulphate soils is not currently recommended as it dependent on further investigation. Subsequent to the findings of these investigations it may necessitate the expansion of the monitoring program.

It is noted that Appendix H of the EA suggests a minimum of four wells should be sampled. The sampling of four wells is considered unlikely to provide a suitable amount of information to address the criteria listed above. As such, an expanded monitoring network has been recommended and is detailed below.

Fourteen wells have been installed along the alignment to meet the listed criteria. The well locations are presented in Figure 6. The wells are numbered MW01 to MW16 and include proposed wells MW14 and MW15, which were not installed. The wells have been screened at depths, and across water bearing units, that enable characterisation of groundwater drawdown as wells as migration of contamination downgradient of the cuttings.

The monitoring wells have been installed in the three major areas impacted by cut drawdown:

- **Near Foxground Road:** Monitoring wells MW01 to MW06 are located at the north eastern end of the project within the Broughton Creek Catchment and Crooked River Catchment (refer to Figure 6). These sites are up-gradient (MW02, MW04) and down-gradient (MW01, MW03, MW05, MW06) of road cuts 1 and 2.
- **Near Tindalls Lane and Tomlins Road:** Monitoring wells MW07 to MW12 are located near Austral Park Road (refer Figure 6) within the Broughton Creek Catchment. These sites are up-gradient (MW07 and MW11) and down-gradient (MW08, MW09, MW10 and

MW12) of road cuts 4 and 5). MW13 is located near to Tindalls Lane and located up-gradient of Cut 6 and is located within the Broughton Mill Creek Catchment.

- **Berry Town:** Monitoring well MW16 is located within Berry Town near North Street. It is located on the up-gradient of cut 9 and is located within the Town Creek Catchment.

Of these wells, MW01, MW02, MW03, MW04, MW06, MW08, MW09, MW12 and MW16 are generally located downgradient of the alignment and can be used for the purposes of assessing broad scale baseline groundwater quality.

It was noted during drilling works undertaken in February and March 2014 that locations MW02 and MW06 were dry at depths greater than 10 m below the alignment and have remained dry since installation. MW01 is considered to be best for assessing emergence of broad scale impacts between the alignment and the four potentially impacted registered groundwater wells down gradient of the alignment in this area. Other wells in the area, not owned by RMS, are not considered to be potentially impacted. Well GW105826 (see Figure 9), which is located on an RMS property, has no upgradient monitoring well to monitor for emerging water quality impacts. As such, this well should be decommissioned (or prevented from being used), or if on-going use is intended, then this well should be added to the groundwater quality monitoring schedule.

The wells have been distributed along the length of the alignment to provide an understanding of groundwater elevations and water quality. Based on the geological information presented in Figure 5 the wells are also interpreted to be screened within a range of different lithologies associated with the Shoalhaven Group lithology. This includes Gerringong Volcanics and Berry Formation sandstones, siltstones and shales. MW04 is also screen within residual/colluvial soils.

It is noted that these wells do not monitor for potential impacts associated with the acid sulphate soil exposure. Additional wells may be required for this purpose and should be considered if the infiltration of groundwater in the identified areas cannot be included in the design of the road.

Additional monitoring wells maybe required to monitor for settlement impacts which will be subject to the outcomes of a settlement assessment associated with groundwater drawdown along the alignment.

To meet the recommendations made in the EA and monitor for the key impacts identified by impact assessment presented in Section 4, the following groundwater sampling strategy has been implemented at the site.

- Groundwater elevation sampling of all fourteen wells along the alignment; and
- Groundwater quality sampling of six wells including MW01, MW04, MW09, MW12 and MW16.

9.2 Groundwater quality monitoring parameters

The proposed monitoring parameters, as outlined in Table 9, are based on a review of potential pollutant sources and reflect those recommended in the EA.

Table 9: Construction and operational phase monitoring parameters and sampling schedule

Parameter	Unit	Locations	Frequency
Groundwater elevation	m bgl	MW01, MW04, MW09, MW10, MW12 and MW16.	Monthly for baseline, Quarterly during construction and six monthly during operation.

Parameter	Unit	Locations	Frequency
		MW03, MW08, MW13, MW16 (groundwater level loggers installed)	Loggers to be installed and set at daily sampling rate during construction and operation.
Dissolved oxygen	mg/L	MW01, MW04, MW09, MW10, MW12 and MW16	Monthly for baseline, Quarterly during construction and six monthly during operation.
Electrical conductivity	µS/cm	MW01, MW04, MW09, MW10, MW12 and MW16	Monthly for baseline, Quarterly during construction and six monthly during operation.
Oxygen Reduction Potential	mV	MW01, MW04, MW09, MW10, MW12 and MW16	Monthly for baseline, Quarterly during construction and six monthly during operation.
pH		MW01, MW04, MW09, MW10, MW12 and MW16	Monthly for baseline, Quarterly during construction and six monthly during operation.
Temperature	°C	MW01, MW04, MW09, MW10, MW12 and MW16	Monthly for baseline, Quarterly during construction and six monthly during operation.
Total Petroleum Hydrocarbons (TPH) & Benzene, Toluene, Ethylbenzene and Xylene (BTEX)	mg/L	MW01, MW04, MW09, MW10, MW12 and MW16	Monthly for baseline, Quarterly during construction and six monthly during operation.
Heavy Metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn)	mg/L	MW01, MW04, MW09, MW10, MW12 and MW16	Monthly for baseline, Quarterly during construction and six monthly during operation.

9.3 Sampling frequency

As outlined in Section 2 the conditions of approval and the EA require/recommend:

- "*Representative background monitoring of surface and groundwater quality parameters for a minimum of twelve months (considering seasonality) prior to the commencement of construction to establish baseline water conditions, unless otherwise agreed by the Director General*".
- Quarterly monitoring of groundwater elevations and water quality during construction.
- Six monthly monitoring during operation for a minimum of two years.

Based on this the sampling regime outlined in Table 9 is proposed to be undertaken to collect a baseline data set for groundwater quality and levels prior to construction and to assess impacts during the construction and operational phases of the project.

A monthly monitoring program will be undertaken for baseline monitoring to provide an expanded data set that characterises the range of potential climatic conditions. The baseline data gathering exercise will focus on the collection of data under a range of climatic conditions (wet and dry periods) on which construction and operation can be compared. This approach is considered to provide a better representation of the range in groundwater conditions expected along the alignment as opposed to adopting the seasonal characterisation approach recommended in the conditions of approval.

The EA also recommends the installation of data loggers in four wells along the alignment to monitor for daily changes in groundwater elevations. It is expected that these loggers will be preferentially located in wells MW03, MW08, MW13 and MW16 to monitor for groundwater elevation impacts outside of those simulated by groundwater modelling around major cuts. Consideration will be given to changing these locations during construction to facilitate a more comprehensive characterisation of groundwater elevations around specific cuts as construction occurs..

9.4 Visual observations

During the construction phase of the project, records of visual observation will be kept and photographs taken where groundwater flows are observed from cuts during construction. While this data will not form part of the assessment methodology, it will aid in the interpretation of data collected from adjacent bores in determining the potential impacts of the construction works on groundwater hydrology.

9.5 Sampling protocol

The potential for significant variability exists within each of the monitoring locations. The source of this variability may be natural or it may be as a result of sampling error – i.e. where the sample collection process has influenced the observed pollutant concentration or groundwater level.

To reduce the risk of sampling error, all sampling would be undertaken in accordance with the following standards and appropriate groundwater sampling techniques:-

- Australian Standard AS/NZS 5667.11: 1998 Water quality – Sampling Part 11: Guidance on sampling groundwaters
- Australian Standard AS/NZS 5667.1 1998: Water quality – Sampling Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples; and
- Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (EPA, 2004).

A Chain of Custody (CoC) form would also be used to ensure chronological documentation of data collection, transfer and analysis. The following is an overview of the key procedures that are proposed for the groundwater sampling methodology:-

- Depth to water table would be measured using an electric calibrated water level meter.
- Prior to sample collection, monitoring wells would be purged. The groundwater monitoring well will be considered to be purged when one of the following criteria is achieved (whichever occurs first):
  - Three well volumes of water have been purged; or
  - The well is purged until no more water can be removed (considered dry); or
  - The water quality parameters are stabilised within 10% over three consecutive recorded measurements.
- The groundwater will be purged and sampled using a submersible pump, foot-valve pump or a down-hole bailer. Purged groundwater would be disposed of into nearby drains or onto adjacent land.

- Physico-chemical parameters would be recorded during the purging of each monitoring well using a calibrated water quality (multi-parameter) meter.
- Groundwater samples would be collected following the purging of groundwater from each well. Effective purging is demonstrated by the stabilisation of physico-chemical water quality parameters.
- Groundwater sampling devices should be comprised of dedicated (i.e. Waterra footvalve pump) and/or disposable down-hole bailers.
- Groundwater samples would be collected in laboratory supplied water sampling containers that would be appropriately dosed with preservative for the analysis required.

A Surface Water and Groundwater Sampling Protocol (GHD, 2014a) has been developed to ensure consistency in the sampling technique and methodology adopted during each sampling event and should be referred for additional detail on this topic.

9.6 Sample analysis

The following key points are noted for the analysis of water quality data:-

- To reduce the potential for error resulting from sample analysis, a laboratory NATA accredited for the analysis undertaken would be utilised for analysis of water quality samples to ensure a high standard of analysis.
- Where an in-situ measurement is taken, the water quality sonde would be calibrated prior to each sampling event. A copy of the calibration certificate would be included with the copy of all sample results.
- A qualified ecologist with experience in monitoring groundwater dependent ecosystems would be used for the monitoring of floristic composition and distribution.

10. Data analysis and interpretation

10.1 Analysis of groundwater quality and groundwater hydrology data

During the construction and operational phases, the monitoring program would focus on assessing whether any changes in groundwater quality and groundwater hydrology have occurred in comparison to the baseline dataset and also whether this change is attributable to the FBB Princess Highway upgrade. An overview of the process for assessing the performance against the agreed objectives and standards is provided in the following sections and summarised in the flowchart in Figure 11. The management response to any observed impacts are outlined in Section 11.

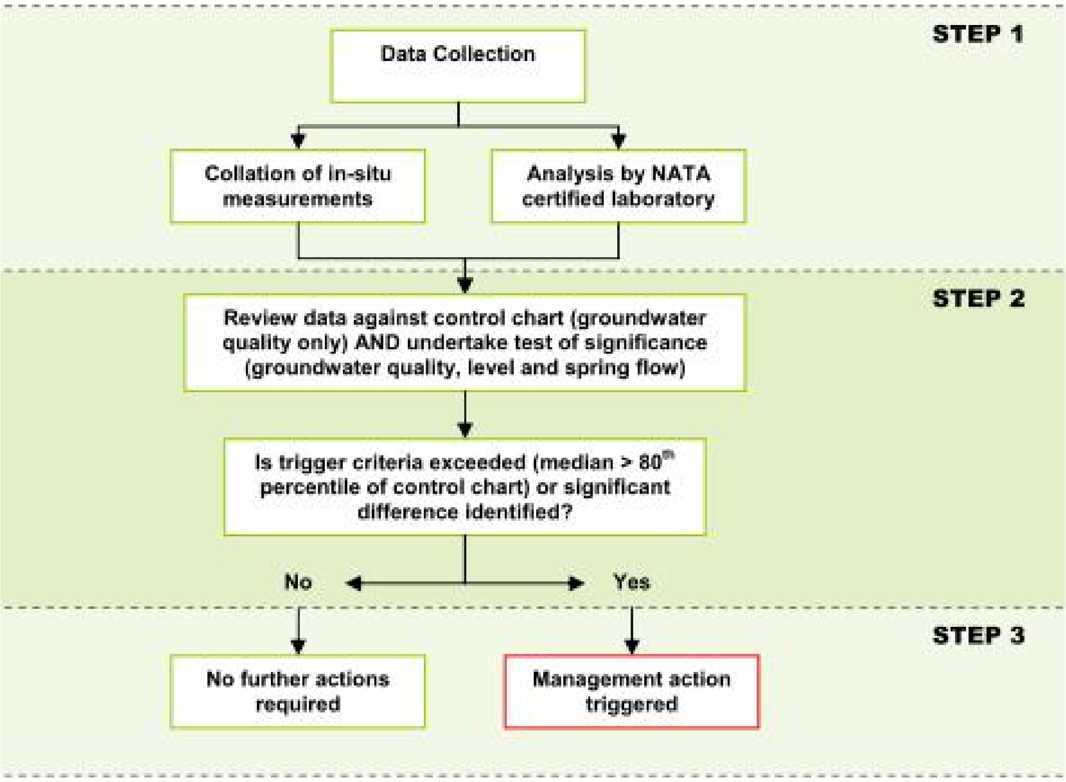

Figure 11: Groundwater quality /hydrology assessments (Aurecon 2010b)

10.1.1 Step 1: Data collection and collation

Groundwater quality and level samples would be collected in accordance with the procedures outlined in Section 9. This would include the use of a water quality probe for assessment of a range of field parameters, while other parameters would be assessed by collecting samples for analysis at a NATA certified laboratory.

The timing between receipt of results and proceeding to the next step in the process would vary between those samples collected using in-situ measurements and those samples collected for measurement at a laboratory.

10.1.2 Step 2: Analysis and interpretation

The second stage of the assessment process would include a review of the data against control charts and an assessment of the statistical significance of any observed change. Whilst the majority of steps in this methodology allow for a clear process to be followed, the objectivity and understanding of the user in reviewing the findings would play a significant part in the assessment of potential impacts.

Review against control chart

There would be two stages in the assessment of the data against the control chart. Firstly, the data would be assessed to determine whether the trigger criterion has been exceeded. That is, does the median of the test site exceed the 80^{th} percentile value of the control chart (long term data). Where the trigger criterion is exceeded a management action is triggered.

Secondly, the control chart would be reviewed to assess for any trends. While the trigger criteria may not be exceeded, the control chart has the ability to facilitate the early identification of potential catchment impacts that may require further investigation. A gradual increase in the up-gradient/baseline data may be the result of increasing pressures on the catchment. Whilst these impacts would not be attributable to the FBB Princes Highway upgrade, they would be of interest to catchment managers. Review of data against the control chart would be undertaken for the assessment of impacts on groundwater quality only.

Assessment of significance

A test of significance would be undertaken to compare the samples against the pre-construction baseline. The significance would be tested using both a t-Test and Sign Test as described in Section 8.4, or in the case of groundwater drawdown, comparison of observed levels against levels predicted by modelling. The methodology would allow an assessment of the pollutants that are directly attributable to the highway during each event and is independent on the variable influences such as the volume of rainfall or time since last rain event. This process provides a direct comparison and assessment of impacts. An assessment of significance using statistical analysis would also be undertaken for groundwater level measurements.

11. Management actions

For a monitoring program to be effective, the performance objectives, performance standards and measurement criteria trigger must be linked to management actions. The management actions outlined in this section relate specifically to where the monitoring program has identified a potential impact. Management actions and responses for all other environmental impacts would be covered under the Construction Environmental Management Plans (CEMPs) and operational environmental management systems.

Section 8 outlines the criteria for triggering a management action, and Section 10 provides an overview of the process for assessment against these criteria. The following sections describe the management actions to be undertaken during the construction and operational phases of the project, should a trigger criteria be exceeded.

The environmental controls proposed in the EA Report (AECOM 2012) for treatment of surface water runoff from the FBB Princes Highway upgrade would significantly reduce the risks of pollutants entering the groundwater system. Should the environmental controls perform as predicted there should be no measurable effect as a result of the operation of the FBB project and consequently no management actions would be triggered.

The flow chart presented in Figure 12 provides an overview of the key steps in the assessment of construction and operational phase impacts in the event of a management action being triggered. The flow chart is provided as a guide only and should not be considered the only path for the investigation of management responses. All management triggers would include an investigation of the reasons for exceedance of the trigger and ensure that all practicable actions have been undertaken to prevent further incident.

In the event that management actions are triggered any short term solutions will be implemented where possible to prevent ongoing impacts while detailed investigations are being undertaken to isolate the source.

Subsequent to the identification of the source of the issues, long term solutions will be developed to mitigate the impact or appropriately manage the ongoing impact.

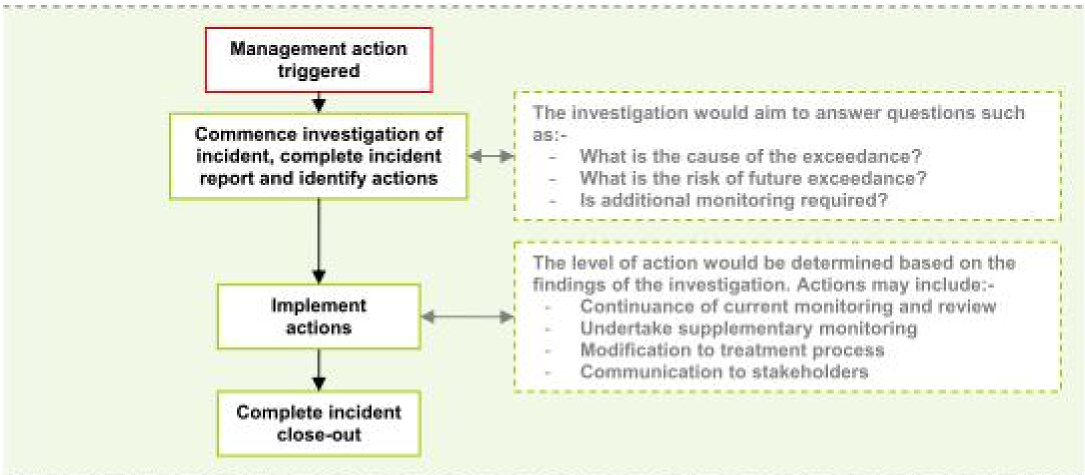

Figure 12: Management action framework (Aurecon 2010b)

Reporting following the triggering of a management action would be undertaken in accordance with the processes outlined in Section 12.

12. Management framework

The implementation of the proposed environmental controls, in combination with effective monitoring and management, would ensure that the risk from the FBB Princes Highway upgrade on the water quality of the local catchments would be significantly reduced. The following sections provide the framework for implementation, adaptation, review and management of the FBB GWMP. These mimic those adopted for the T2E upgrade developed by Aurecon in 2010.

12.1 Adaptive management approach

RMS recognises the importance of undertaking environmental management using an adaptive management approach and as such the GWMP would be a working document. The nature of groundwater quality monitoring is such that there is no simple solution that provides a monitoring and management response to all scenarios.

Whilst this monitoring program has been developed based on the best available information at the time, it must be recognised that an adaptive approach is required to deliver an effective monitoring program into the future. Where the review and audit process identify opportunities for improvement, or areas where the monitoring approach may be refined, the FBB GWMP would be reviewed and updated. This would ensure that the monitoring program outlined within this groundwater monitoring plan is capable and would continue to be capable of assessing the performance of the construction and operational phase environmental controls against the defined performance objectives and standards.

12.2 Roles and responsibilities

For the FBB groundwater monitoring program to be implemented effectively, the roles and responsibilities for the implementation, management, review and auditing, must be clearly defined. Separate responsibilities are defined for the construction (refer Table 10) and operational (refer Table 11) phases of the project.

Table 10: Construction Phase Roles and Responsibilities

Organisation	Responsibility	Personnel and Contact Details
RMS	Implementation of the GWMP Assessment against performance objectives and standards Ensuring a CEMP is developed and implemented effectively Ensuring appropriate measures are implemented for management of acute impacts Investigation of any potential or observed impacts Identification and implementation of management actions as required Review and updating of GWMP Reporting	Ron De Rooy Senior Project Manager Ph: 02 4221 2585 Email: Ron.DE.ROOY@rms.nsw.gov.au
NOW	Review of Annual Progress Report and Incident Reports. Provide feedback as necessary.	Bob Britten Water Regulation Officer Ph: 6491 8209 Email: Bob.Britten@water.nsw.gov.au
NSW DP&I - Fisheries	Review of Annual Progress Report and Incident Reports.	Dr Trevor Daly Fisheries Conservation Manager –

Organisation	Responsibility	Personnel and Contact Details
	Provide feedback as necessary.	South Coast. Ph: 02 4478 9103 Email: trevor.daly@dpi.nsw.gov.au
NSW EPA	Review of Annual Progress Report and Incident Reports. Provide feedback as necessary.	Julian Thompson Unit Head - South East Region Ph: (02) 6229 7002 Email: julian.thompson@epa.nsw.gov.au
OEH	Review of Annual Progress Report and Incident Reports. Provide feedback as necessary.	Peter Marczan A/manager noise policy Ph: (02) 9995 6059 Email: peter.marczan@epa.nsw.gov.au

Table 11: Operation Phase Roles and Responsibilities

Organisation	Responsibility	Personnel and Contact Details
RMS	Implementation of the GWMP Assessment against performance objectives and standards Ensuring appropriate measures are implemented for management of acute impacts Regular inspection of treatment measures (water quality basins) Maintenance of treatment measures Investigation of any potential or observed impacts Identification and implementation of management actions as required Review and updating of GWMP Reporting Consultation	Ron De Rooy Senior Project Manager Ph: 02 4221 2585 Email: Ron.DE.ROOY@rms.nsw.gov.au
NOW	Review of Annual Progress Report and Incident Reports. Provide feedback as necessary.	Bob Britten Water Regulation Officer Ph: 6491 8209 Email: Bob.Britten@water.nsw.gov.au
NSW DP&I - Fisheries	Review of Annual Progress Report and Incident Reports. Provide feedback as necessary.	Dr Trevor Daly Fisheries Conservation Manager – South Coast. Ph: 02 4478 9103 Email: trevor.daly@dpi.nsw.gov.au
NSW EPA	Review of Annual Progress Report and Incident Reports. Provide feedback as necessary. The EPA have stated that while the project will be licensed by the EPA during the construction phase, the EPL will not be required during the operational phase of the project. In light of this, the EPA will not have a formal management role post construction, except in the case of	Julian Thompson Unit Head - South East Region Ph: (02) 6229 7002 Email: julian.thompson@epa.nsw.gov.au

Organisation	Responsibility	Personnel and Contact Details
	pollution incidents where it assumes the role of Appropriate Regulatory Authority under section 6 of the Protection of the Environment Operations Act 1997 for the activities of RMS. GHD notes that the Conditions of Approval B16(h) require the reporting of monitoring results to the EPA.	
OEH	Review of Annual Progress Report and Incident Reports. Provide feedback as necessary.	Peter Marczan A/manager noise policy Ph: (02) 9995 6059 Email: peter.marczan@epa.nsw.gov.au

12.3 Reporting and auditing

Condition of Approval B16(g) requires 'reporting of the monitoring results to the Department, OEH, EPA and NOW'. The following sections outline the reporting process to be implemented during the construction and operational phases of the project to meet this requirement and to ensure the delivery of an effective monitoring program.

12.3.1 Reporting

Regular reporting would be undertaken to allow assessment against the surface water objectives and performance standards. A brief factual monitoring report would be prepared after each sampling event, to present the data collected and ensure the environmental controls are effective.

A more comprehensive progress report would be prepared annually. The review and preparation of the progress report would not only report on the data collected during the year, but would also allow for an assessment of gradual trends and changes within the system – i.e. this review would provide early detection of any potential impacts and allow management actions to be triggered to address them before an impact occurs.

Incident reporting would also be undertaken where a performance standard has not been met. Exceedance of a performance standard does not necessarily mean that an impact has occurred, but provides a trigger for further review. The preparation of an incident report would be the first step in this process and would identify the management approach to be adopted to resolve any potential concerns.

Following all audits (internal and external), a close-out report would be prepared. Where non-conformances are noted, the report would include a summary of the actions undertaken to address the non-conformance and the steps that have been put in place to prevent further occurrence.

A summary of the reporting for the FBB Groundwater Monitoring Program is presented in Table 12.

Table 12: Summary of reporting requirements (adapted from Aurecon, 2010a)

Report	Condition of Approval Reference	Content	Timing	Circulation
Monitoring Report	B16 (h)	Following each sampling event a brief report would be prepared that describes water quality performance against the agreed objectives and standards for that particular event.	All phases until monitoring no longer required.	EPA, NOW, OEH DPI.
Annual Progress Report	B16 (h) B29 (c), (g)	As a minimum the progress report would include: A summary of the monitoring results recorded during the previous 12 months; An assessment of performance against defined objectives, standards and measurement criteria; An overview of any environmental incidents recorded and the corresponding action taken; Details and rationale for any modification to the surface water sampling program; An outline of any changes to the environmental controls; Findings of all audits and details of any corrective actions required; Recommendations for any changes to the monitoring program or control measures; and Review of any complaints and actions from the ERG.	Annual – No long operational period specified in COA	EPA, NOW, OEH DPI.
Incident Report	A5, B29 (e), (f), (g)	In the event of an exceedance in water quality performance standards, a brief report would be prepared to examine all relevant data and to determine a likely source and appropriate management action. An action plan would be developed and would include a timeframe for implementation.	Initial notification to DG in 24 hours with report provided within 7 days	EPA, NOW, OEH DPI.

13. Consultation

Consultation undertaken during development of the GWMP

The Conditions of Approval for the project require that the GWMP is ‘developed in consultation with the OEH, EPA, DPI (Fishing and Aquaculture) and NOW.

Contacts for these have been contacted and have been supplied with the brief for the project as a means of providing familiarity with the project prior.

A copy of this document, the sampling protocol document and groundwater management plan will be provided to the key stakeholders for comment prior to finalisation of the documents.

If required additional meetings will be undertaken with stakeholders to further explain the contents of the documentation being submitted.

A summary of the comments submitted on this document and how these have been dealt with are presented in the Table 13. Additional correspondence is provided in Appendix A.

Table 13: Stakeholder Comments and Response

Organisation	Date submitted to stakeholder	Contact	Document section and document page number	Comments	Comment date	GHD response	Response Date
Fisheries NSW - DPI	10/06/2014, Rev 4 submitted	Trevor Daly	General comment	The report has been provided and no comments were provided. The groundwater model report was not provided to the DPI.	-	Trevor Daly has been communicated with on a number of occasions via telephone and has suggested that they are concerned primarily with surface water issues, which have been dealt with in the SWMP	02/07/2014
NSW office Water	08/04/2014, Rev 1 submitted 01/07/14	Bob Britten	General comment	The groundwater modelling report has been provided and a letter was received in response from Bob Britten dated 1 July 2014. This letter is included in **Appendix D**. All comments were in agreement with the groundwater modelling report.	01/07/2014	No response required.	02/07/2014
	GWMP_DRAFT_7 _Rev4 – _Submitted 03/07/2014	Bob Britten	General comment	The GWMP report has been provided and a letter was received in response from Bob Britten dated 8 July 2014. This letter is included in **Appendix D**. All comments were in agreement with the groundwater modelling report.	08/07/2014	No response required	09/07/2014

Organisation	Date submitted to stakeholder	Contact	Document section and document page number	Comments	Comment date	GHD response	Response Date
OEH	Not submitted.	James Dawson		The report has not been provided to OEH.		An informal face to face meeting was held with James Dawson on the 3 April 2014. During that meeting James stated that he was currently dealing with Toby Lambert from Parsons Brinkerhoff who were developing the monitoring plan for instream ecology. He noted that this was more relevant to biodiversity and threatened species. As such, it was considered that the surface water monitoring plan was of lower importance. James noted that Peter Marczan and Tim Pritchard of the OEH Water and Coastal team may have some interest in the project. At this time contact has not been made with Tim or Peter.	02/07/2014
		Peter Marczan		The report has not been provided to OEH.	19/06/2014	Email received from Peter Marczan detailing that he is currently in a different position and forwarded the email to Penny Vella of OEH who is currently acting team leader for Water Quality.	30/06/2014
		Penny Vella		The report has not been provided to OEH.	20/06/2014	Email received from Penny Villa of OEH stating the "she can confirm that OEH does not need to review the surface water and groundwater monitoring plan document, or the sampling protocol." She acknowledged that the EPA are already engaged on this issue.	30/06/2014

Organisation	Date submitted to stakeholder	Contact	Document section and document page number	Comments	Comment date	GHD response	Response Date
EPA	14/04/2014	Julian Thompson	Table 9, pg 53-54	Details the roles and responsibilities for management in the operational phase of the Foxground Berry Bypass. The NSW EPA is listed in this table as having part responsibility for the review of the Annual Progress Reports and Incident Reports, and to provide feedback as necessary. It should be noted that while the project will be licensed by the EPA during the construction phase, the Environment Protection Licence will not be required during the operational phase of the project. The EPA will therefore not have a formal management role post-construction, except in the case of pollution incidents where it assume the role of Appropriate Regulatory Authority Role for RMS under section 6 of the Protection of the Environment Operations Act 1997.	20/05/2014	The reference to EPL for operational phases of the project has been removed from the document text. EPA will still receive the annual progress reports as per the conditions of approval.	13/06/2014
	14/01/2014	Julian Thompson		Before undertaking any detailed assessments of the presence and risk of ASS, the EPA recommends seeking advice on appropriate sampling design and analytical framework from a practitioner with ASS experience. Consultation with appropriate topic specialists should also be arranged in order to assess the potential impacts of groundwater drawdown on in-stream aquatic ecology and groundwater dependent ecosystems and the risk of settlement issues.	20/05/2014	Following a telephone discussion with EPA on the acid sulphate soil issue they raised in their correspondence it was recommended by the EPA that further investigations should be undertaken in this area and that this should be undertaken as part of detailed design phase investigations. An email (dated 09/07/2014) documenting the outcomes of the conversation are provided in Appendix D. Settlement issues are currently being considered by an appropriate specialist.	08/07/2014
	14/01/2014	Julian Thompson		Groundwater well GW105826 does not have an upgradient monitoring well to monitor for emerging water quality impacts, and should therefore be decommissioned, or should be added to the groundwater quality monitoring schedule. Also, additional wells may be required to monitor for potential impacts associated with acid sulphate soil exposure and settlement impacts.	20/05/2014	Reference has been made in the text to implementing these actions as required. See Section 9.1.2 and Section 4.5.1. Monitoring Well MW16 may be suitable for settlement monitoring if further investigations of settlement highlight a potential risk.	08/07/2014

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Appendices

Appendix A – Groundwater Modelling Report

Roads and Maritime Services

Princes Highway Upgrade – Foxground to Berry Bypass Project

Groundwater Flow Model

July 2014

Executive summary

Roads and Maritime Services (RMS) is undertaking a series of upgrades to sections of the Princes Highway between Gerringong and Bomaderry in order to provide a continuous four lane divided highway. The Foxground to Berry Bypass (FBB) is comprised of an 11.6 km upgrade of the existing highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry and includes bypasses of Foxground and Berry.

The project approval was granted on 22 July 2013 under Part 3A of the Environmental Planning and Assessment Act 1979 with conditions of approval (CoA).

CoA 15 requires that groundwater modelling on the concept design be completed to assess the construction and operational impact of the concept design on groundwater resources, quality, hydrology, groundwater dependent ecosystems and provide details of contingency and management measures to be implemented for construction.

To meet this requirement a numerical groundwater model has been developed to assess the impact of the Project on the surrounding groundwater environment and potentially dependent systems.

The modelling approach and complexity has been based on those undertaken prior to construction for other major road upgrade projects in NSW where groundwater is considered to be sensitive.

The modelling has been designed to focus on changes in groundwater elevations and flow volumes associated with the project. Impacts to groundwater quality and associated management measures are summarised in the GWMP document.

This report has been designed as a technical appendix to the GWMP and should be read in conjunction with the GWMP.

The model was developed using the Groundwater Vistas modelling Graphical User Interface (GUI) which was set up to simulate groundwater flow using MODFLOW SURFACT (Hydrogeologic, 1996). MODFLOW-SURFACT was selected for this application because it allows for improved representation of groundwater flow in the saturated and unsaturated zone.

One model domain was constructed to assess impacts along the entire alignment. Surfaces and layering in the model domain were developed using a large volume data from previous geotechnical investigations completed along the alignment and from detailed topographical data. This was used to develop a two layer model representing the inferred change between unconsolidated and consolidated sediments.

Calibration of the groundwater flow model was undertaken in steady state through comparison of observed and modelled groundwater levels at 60 borehole locations and assessed baseflow from observation data at 3 flow gauging stations. Calibration of the steady-state model was carried out using the PEST suite of software (Doherty, 2010). The calibration results had typically acceptable limits, as recommended in the Australian Groundwater Flow Modelling Guideline (National Water Commission, 2012).

The groundwater modelling results suggest that the primary impacts will be associated with drawdown around cuttings along the project alignment. The predicted impacts and proposed management measures are summarised below:

- Impacts to surrounding registered groundwater wells are simulated to be within acceptable ranges, with the maximum predicted drawdown within impacted registered groundwater wells approximating less than 0.2 m.

- The drawdowns are expected to result in a less than 1 % reduction in the base flow component of catchment surface water features. This is anticipated to have negligible impacts on in-stream aquatic ecology and existing surface water user supplies, however, further consultation with ecological specialists is required to validate this.
- Impacts to sensitive surface water features such as Coomonderry Swamp and Foys swamp are simulated to be negligible.
- The zones of drawdown influence created by the cuttings near to Tindalls Lane and Tomlins Road are simulated to intersect areas where there is low potential for the presence of Acid Sulphate soils. In terms of managing this risk there are a number of potential options, which could include either of, or a combination of:
  – Additional intrusive soil investigations to characterise the actual potential for the generation of acid sulphate soils within the simulated drawdown zone.
  – Implementation of measures to recharge dewatered groundwater from the cuttings to downgradient locations flanking acid sulphate soil areas and hence reduce drawdown impacts. This measure could be assessed within the groundwater model.
  – An assessment of road design and construction to minimise drawdown impacts at these cuttings and hence prevent the potential for the generation of adverse impacts. These measures could be assessed within the groundwater model.
  – Implementation of a monitoring regime in this area to monitor for pH impacts and provide an early warning mechanism for enhanced mitigation measures to be implemented. Sampling location SW03 would act to identify impacts in Broughton Creek. A strategically placed monitoring bore, would perhaps provide an early warning mechanism for the presence of emerging groundwater elevation impacts.
- The zones of drawdown influence created by the cuttings extend under isolated developments along the alignment, particularly in the Berry area, that are potentially situated on unconsolidated materials. This may represent a settlement risk that should be considered further by appropriate specialists.

The modelling undertaken provides an understanding of the likely impacts associated with the project based on the conceptual design, which will require further investigation at detailed design stage. At this time, further modelling should be undertaken to assess non-uniqueness in the modelling outcomes, paying particular attention to the potential variation in impacts associated with changes in storage and under high and low flow conditions. Further consideration of available hydraulic data that has become available since model development should also be undertaken at detailed design phase. It is noted that the conditions of approval only require further consideration of the model at detailed design phase where the detailed design has a significantly different impact on groundwater than the concept design.

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1. Introduction

1.1 Background

Roads and Maritime Services (RMS) is undertaking a series of upgrades to sections of the Princes Highway between Gerringong and Bomaderry in order to provide a continuous four lane divided highway. The Foxground to Berry Bypass (FBB) is comprised of an 11.6 km upgrade of the existing highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry and includes bypasses of Foxground and Berry. The project will result in improved road safety and traffic efficiency, including for freight. An overview of the project is provided in Figure 1.

An environmental assessment including technical appendices and a submissions report have been prepared which identify and assesses potential water quality impacts associated with the project. The project approval was granted on 22 July 2013, under Part 3A of the Environmental Planning and Assessment Act 1979 with conditions of approval (CoA).

These conditions (CoA B15 and CoA B16) require RMS to prepare and implement a water quality monitoring program (WQMP) and undertake groundwater modelling on the concept design. The WQMP will establish baseline water quality data prior to construction, guide monitoring during construction to ensure mitigation measures are effective and guide monitor post construction to ensure permanent measures are effective. The groundwater modelling will assess the construction and operational impact of the concept design on groundwater resources, quality, hydrology, groundwater dependent ecosystems and provide details of contingency and management measures to be implemented in the construction soil and water quality management sub-plan (CoA B26 (d)).

This document has been developed to describe the monitoring works undertaken to assess impacts on the surrounding groundwater system. This report has been designed as a technical document to be included as an annex to the groundwater quality monitoring plan (GQMP) document and should be read in conjunction with the GQMP. In particular the GQMP provides an overview of the existing environmental conditions and the key environmental risks associated with the project, which have been used for the assessment of the impacts by the groundwater model.

1.2 Objectives

Condition of approval CoA 15 provides the basis for the groundwater modelling objectives and is stated below.

"Prior to the commencement of construction, unless otherwise agreed by the Director General, the Proponent shall in consultation with the EPA and NOW, undertake groundwater modelling on the concept design for the project, subject to the modelling being revised should the detailed design have a significantly different impact on groundwater than the concept design.

The modelling shall be undertaken by a suitably qualified and experienced groundwater expert and assess the construction and operational impacts of the proposal on the groundwater resources, groundwater quality, groundwater hydrology and groundwater dependent ecosystems and provide details of contingency and management measures in the groundwater management strategy required under condition B36(d)."

Based on the above, the objectives for the modelling are to use the existing understanding of the concept design to develop a numerical groundwater model that assesses the cons*truction and operational impacts of the Project on the groundwater resources, groundwater quality,* *groundwater hydrology and groundwater dependent ecosystems and provide details of contingency and management measures in the groundwater management strategy.*

The modelling is based on conceptual design information, which has meant that some aspects of the modelling may not represent final design conditions, particularly in regards to the staging and rates of construction works. As such, the modelling is preliminary in nature and it is recommended that further modelling is undertaken at detailed design stage.

Further to this, the groundwater modelling does not account for short term fluctuations in groundwater associated with dewatering around bridge pilings as the impact is likely to be highly localised temporally and spatially and may differ significantly due to specific design and methods adopted for construction. As such, these impacts would be best managed and assessed as part of construction management works and/or detailed design works, when there is more certainty over design and construction.

The detail of the modelling has been designed in accordance with CoA 15 and the level of modelling that has been undertaken at conceptual design stage for similar projects within NSW, such as for the Tintenbar to Ewingsdale Pacific Highway upgrade project, which is currently under construction.

Other limitations and assumptions for this report are presented in Section 7.

1:30,000 (at A3)

0 150 300 600 900 1,200
Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

Berry to Foxground upgrade alignment	Railways
Alignment location of interest	Waterways
Roads	Lakes and dams

GHD

Roads and Maritime Services
Water Quality Monitoring

Job Number 21-23174
Revision 0
Date 09 Jul 2014

Overview of the Berry to Foxground upgrade

Figure 1

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Z:\TEMP GIS\berry to foxground\GIS\Maps\MXD\21_23174_Z010_BERRY_OverviewFBBUpgrade.mxd

Data Source: NSW Department of Lands: DTDB and DCDB - 2012. Created by: pmcdougall

2. Conceptual Model

2.1 Geology and Hydrostratigraphic Units

The FBB project is located within the Broughton Creek catchment. The Project alignment is approximately parallel to the north-east to south-west flow direction of the Broughton Creek.

The superficial geology along the alignment is characterised by estuarine, alluvial and colluvial deposits. The superficial geology is dominated by sandy clay and clay deposits. Coarser deposits such as gravels and cobles are found in areas south of the town of Berry, which is further away from the Project alignment. The superficial deposits are laterally and vertically very heterogeneous and therefore are conceptualised as a single hydrostratigraphic unit.

The solid geology in the Broughton Creek catchment is characterized by elevated sedimentary (sandstone) reliefs and igneous (latite) intrusions. The solid geology of the Brounghton catchment is described in detail in other reports such as Coffey (2010). The main units present in the area are:

- The Berry Siltstone which lithology is characterised by interbedded mid grey to dark grey siltstone and fine sandstone.
- Jamberoo Sandstone, Kiama Sandstone and only marginally the Westley Park Sandstone which lithology is characterised by red, brown and grey volcanic lithic sandstones.
- Bumbo and Blow Hole Latite Members which are volcanic flow facies characterised by columnar jointing.

All the solid geology units described above outcrop to some extent within the Broughton Creek catchment. Given the dominant presence of siltstone and sandstone units, the solid rock units are conceptualised as a single hydrostratigraphic unit. Differences in hydraulic properties are likely to exist between the siltstone / sandstone units and the latite units. Different hydraulic conductivity values will be assigned to the latite and siltstone / sandstone outcrop areas.

2.2 Groundwater Levels, Groundwater Flow Directions and Recharge Estimates

Analysis of the available groundwater levels in the area suggests that the water table is likely to represent a subdued image of the ground surface. Thus groundwater levels are high in topographically elevated areas and low along the Broughton Creek valley. Groundwater flows from highland recharge areas, primarily the sandstone and latite outcrops, to discharge to the main creeks and low-lying areas.

Evidence of a topographically driven groundwater flow is provided by groundwater levels ranging from elevations in excess of 80 mAHD (boreholes BH12, BH13, P01, P02 and P03) in the outcrop highs of the Bumbo Latite to elevations lower than 5 mAHD (CBH05, B08 and CBh08) in low-lying areas to the south of Berry town.

Evidence of groundwater discharging to the main creeks is provided by the relatively large baseflow component of the total creek flow for the Broughton Mill Creek. Time series of creek flows are available for the Broughton Mill Creek at Broughton Vale (flow gauge reference number 215018), the Broughton Mill Creek at Berry (flow gauge reference number 215015) and Jaspers Creek at Jaspers Brush (flow gauge reference number 215019). However, only gauges 215018 and 215019 have a relatively long and continuous flow record and are therefore suitable to quantify the baseflow component of the total creek flow. The dataset for flow gauge 21015, provided by The Office of Water (NSW) has a very discontinuous record and it appears that this station is not currently being maintained.

The Lyne and Hollick (1979) method was used to estimate the baseflow for the streams with suitable data. Appendix A provides plots of the estimated baseflow components for the available stream flow gauging data. Baseflow separation of creek flows recorded at gauging station 215018 suggests around 6 Ml/d of baseflow or around 16% of long term average total creek flow. Baseflow separation of creek flows at gauging station 215019 suggests around 2.4 Ml/d of baseflow or around 12% of long term average total creek flow. It is expected that the flows presented in the appendix are inclusive of water already abstracted for irrigation and basic landholder rights.

Given the baseflow estimates provided above and the sub-catchment areas, recharge can be estimated as described in Table 1.

Table 1 Recharge Estimates from Baseflow Separation

Zone	Creek Name	Creek Gauging Station	Baseflow Estimate (m^3/d)	Sub-catchment Area (Km^2)	Recharge (mm/d)
215018	Broughton Mill	Broughton Vale	5,986	18.324	0.32
215019	Jaspers	Jaspers Brush	2,400	13.0904	0.18
Average Value:					0.25

The estimated recharge value of 0.25 mm/d which corresponds to around 6% of long term average rainfall at rain gauge 68003 (Berry Masonic Village) was used as initial recharge value in the steady-state model. This estimation of recharge percentage approximates that stated in the groundwater sharing plan for this area (NOW, 2011), which suggests that the method adopted to derive recharge rates (i.e. from base flow estimates) is realistic.

3. Model Construction

3.1 Model Grid

Three main considerations were taken into account during the design of the numerical model grid for the FBB, as follows:

1. The purpose of the FBB is to assess the impacts of road construction on groundwater levels as well as baseflow to the Broughton Creek and tributaries. Therefore the model should be large enough to encompass the whole Broughton Creek catchment. The model should also be oriented with the dominant south-westward groundwater flow direction which corresponds approximately to the overall drainage direction of the Broughton Creek.
2. The model boundaries should be placed at a sufficient distance from the site to minimise the interaction of model prediction results with the model boundaries. The catchment boundaries of the Broughton Creek were identified as suitable boundaries to the north and north-east. The Shoalhaven River was identified as suitable boundary to the south-west and the coastline was identified as suitable boundary to the south and south-east.
3. The model grid horizontal resolution should be fine enough in the surrounding of the proposed road reserve boundary to ensure that sufficient detail of the road design is represented in the model. Furthermore the model resolution should be fine enough for the model predictions to replicate the detail of the phreatic surface in the surrounding of the proposed road during development.

Based on these considerations the model was oriented on a north-east to south-west direction with the x-axis of the model grid approximately parallel to the main drainage direction of the Broughton Creek. The model grid was given variable resolution to ensure a resolution of 10 m by 10 m in a region of 13 Km (north-east to south-west) by 4 Km (north-west to south-east) surrounding the proposed road and coarser resolution up to 100 m by 100 m at the boundaries of the active model domain. The current model grid for the FBB groundwater model is illustrated in Figure 2.

The model comprises 558 rows by 1,397 columns with up to 779,526 model cells in each layer. Given that the hydrostratigraphic model developed is of two layer system (see Section 3.3 for details on the model layering) this gives up to 955,184 active model cells.

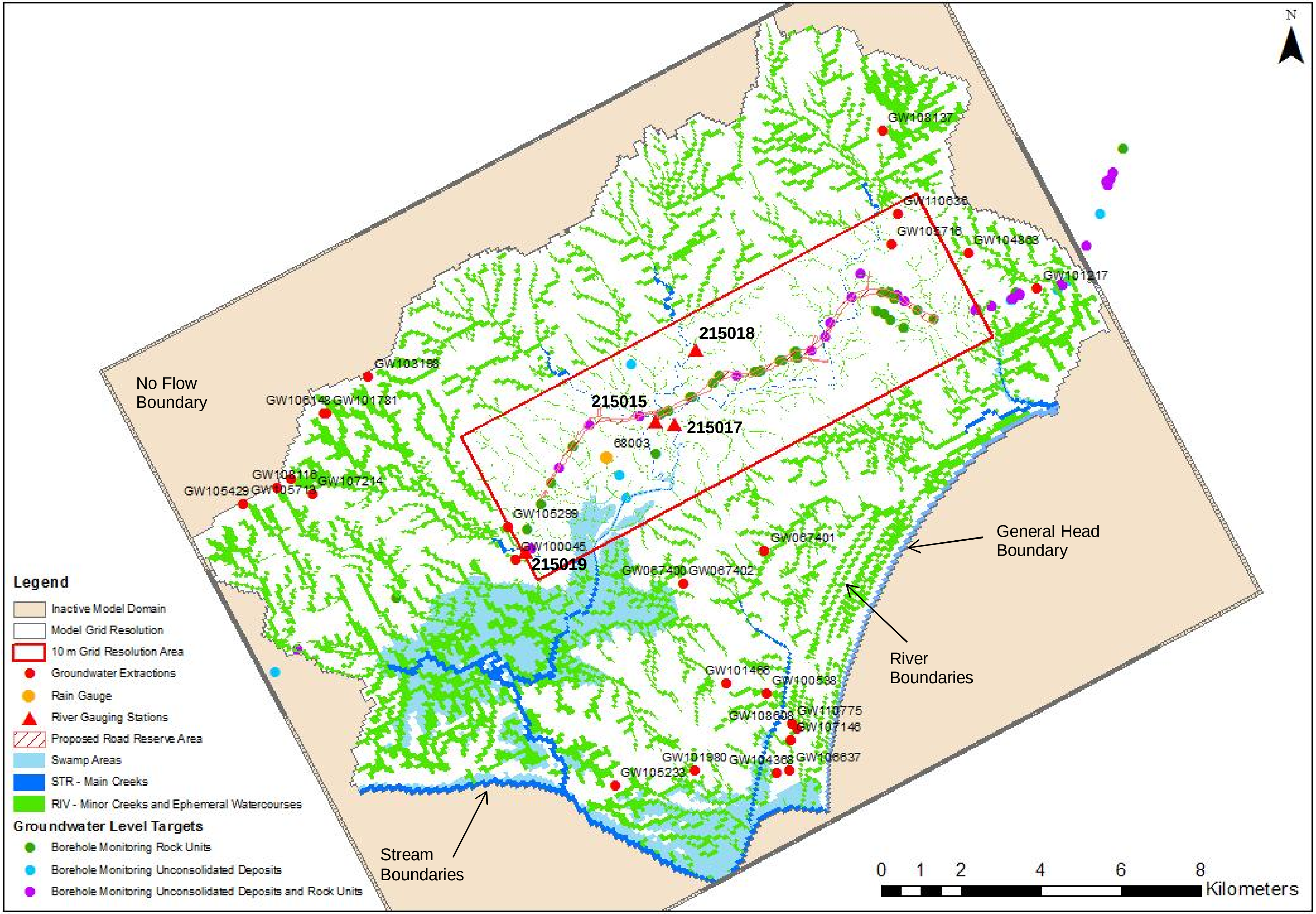


Figure 2: Foxground to Berry Model Grid and Boundaries

3.2 Model Code Selection

Numerical model development was undertaken using the Groundwater Vistas modelling Graphical User Interface (GUI) which was set up to simulate groundwater flow using MODFLOW SURFACT (Hydrogeologic, 1996). MODFLOW-SURFACT is an enhancement to the MODFLOW 96 suite of groundwater modelling code. In particular MODFLOW-SURFACT was selected for this application because it provides additional capabilities which include representation of groundwater flow in the saturated and unsaturated zone.

The numerical code selected for this model is MODFLOW-SURFACT v4 (HydroGeoLogic, 1996), a proprietary modification to the United States Geological Survey's open source MODFLOW-96 (finite difference) code. MODFLOW-SURFACT v4 provides several useful enhancements to MODFLOW-96 including:

- A more robust and flexible numerical solver (PCG5);
- Simulation of saturated and unsaturated zone flow, resolving many of the issues with cell drying and rewetting and associated numerical instabilities of standard MODFLOW;
- A more flexible and robust well boundary package (FWL4/5);
- A more flexible recharge package (RSF4), which allows for simulation of recharge rejection when groundwater levels are shallow.

3.3 Model Layering

The conceptual model identifies two main hydrostratigraphic units in the area:

1. Superficial unconsolidated deposits including alluvial and colluvial deposits, estuarine deposits.
2. Solid rock units of the Shoalhaven Group comprising Budgong Sandstone, Gerringong Volcanic Facies and Berry Siltstone.

Based on the conceptual model of the site and the NSW Department for Mines Geological Series Sheet S1 56-9 for Wollongong 1:250,000 outcrop geology map of the area a two layer representation of the system has been modelled numerically as follows:

- Layer 1 – Unconsolidated deposits.
- Layer 2 – Solid rock units.

The areal extent of the unconsolidated deposits was defined based on the 250,000 outcrop geology map. Differentiation of the various rock geological units comprising model layer 2 was obtained through parameterisation of the hydraulic conductivity (see Section 3.4).

The elevations of the rock unit and the thickness of the unconsolidated deposits was derived using a combination of:

- Topographic surface based on 1 meter resolution LIDAR data for the whole Broughton Creek catchment provided by RMS.
- Interpreted borehole logs, test pits and CPT tests for all geotechnical investigations carried out since 2007 and are primarily located in the close proximity of the Project alignment.
- Interpreted borehole logs from the NSW Groundwater Works database.

Geotechnical and geological investigations used in the construction of the three-dimensional model included data contained in the following reports provided by RMS:

- Maunsell-Aecom and Coffey Geotechnics, (October 2007), "Preliminary Geotechnical Report - Gerringong to Bomaderry Princes Highway Upgrade".
- Coffey Geotechnics, Maunsell Aecom (16 November 2007) Princes Highway Upgrade, Route Selection Study, Geotechnical Investigation, Gerringong To Bomaderry NSW, Volume 1: Interpretation Report, Report Ref: GEOTUNAN02580AA-AZ.
- Maunsell-Aecom, (February 2009), "Gerringong to Bomaderry Princes Highway Upgrade – Geotechnical Interpretive Report", Report ref: DEV06/04-GE-MA No: 60021933.
- Golder Associates Pty Ltd, (draft, undated), "Princes Highway Upgrade – Gerringong to Bomaderry. Additional Geotechnical Investigation – Factual Report". Report Ref: 087622122.
- Coffey Geotechnics, (May 2010), "Geotechnical Interpretive Report for Concept Design". Preferred Route of the Princes Highway, Gerringong to Bomaderry. Report Ref: GEOTWOLL02580AE-BL.
- Coffey Geotechnics, (February 2010), "Geotechnical Factual Report for Concept Design". Gerringong to Bomaderry. Report Ref: GEOTWOLL02580AE-BD.
- Roads and Maritime Services, (March 2011), "HW1 – Princes Highway, Gerringong Upgrade, Mt Pleasant to Toolijooa Road. Geotechnical Overview Report" File No. 10-04.
- Coffey Geotechnics, (2 August 2012), "Geotechnical Interpretive Report, South Berry Option, Foxground to Berry Bypass, Berry NSW." Report Ref: GEOTWOLL03387AA-AB.
- Roads and Maritime Services (21 May 2012) Foxground and Berry Bypass Project, Proposed South Berry Option, Princes Hwy (HW1), Berry NSW, Factual Geotechnical Investigation Report, Job Ref: 11- 02.
- Roads and Maritime Services, (9 May 2013), "HW1 – Princes Highway, Proposed Cutting, Foxground NSW. Geotechnical Investigation Factual Report" File No. 11-02.
- Roads and Maritime Services, (31 July 2013), "HW1 – Princes Highway Foxground and Berry Bypass, NSW. Geotechnical Information Document – Issue 3". File No. 11-02.

3.4 Initial Model Parameters

Hydraulic conductivity was assigned as zones in the model domain based on the outcrop geology map. Given the lack of hydraulic testing data for the rock and unconsolidated units the initial model parameter values were obtained from literature (Anderson and Woessner, 1992 and Domenico and Schwartz, 1998). Table 2 summarises the initial hydraulic conductivity values as well as the range of permissible values for each zone specified in the model. Figure 3 shows the spatial extent of the hydraulic conductivity zonation as specified in the steady-state model.

Table 2 Initial Hydraulic Conductivity and Permissible Range

Zone	Geological Unit	Initial Horizontal Hydraulic Conductivity (m/d)	Lower Bound Horizontal Hydraulic Conductivity (m/d)	Upper Bound Horizontal Hydraulic Conductivity (m/d)	Ratio Kh and Kv
1	Superficial Unconsolidated Deposits	1.0×10^{-01}	1.0×10^{-02}	$1. \times 10^{+01}$	1
2	Basement Unit (general)	5.0×10^{-03}	8.6×10^{-07}	1.2×10^{-03}	10
3 & 8	Bumbo and Blow Hole Latite Members	4.0×10^{-04}	2.6×10^{-09}	5.0×10^{-01}	10

Zone	Geological Unit	Initial Horizontal Hydraulic Conductivity (m/d)	Lower Bound Horizontal Hydraulic Conductivity (m/d)	Upper Bound Horizontal Hydraulic Conductivity (m/d)	Ratio Kh and Kv
4	Berry Siltstone (east of Berry)	$1.0x10^{-03}$	$8.6x10^{-07}$	$1.2x10^{-03}$	10
7	Berry Siltstone (west of Berry)	$1.0x10^{-03}$	$8.6x10^{-07}$	$1.2x10^{-03}$	10
5	Jamberoo Sandstone	$1.0x10^{-03}$	$2.6x10^{-05}$	$5.0x10^{-01}$	10
6	Kiama Sandstone	$1.0x10^{-03}$	$2.6x10^{-05}$	$5.0x10^{-01}$	10

The initial hydraulic conductivity values were allowed to vary within the specified parameter range in the calibration process (Section 4).

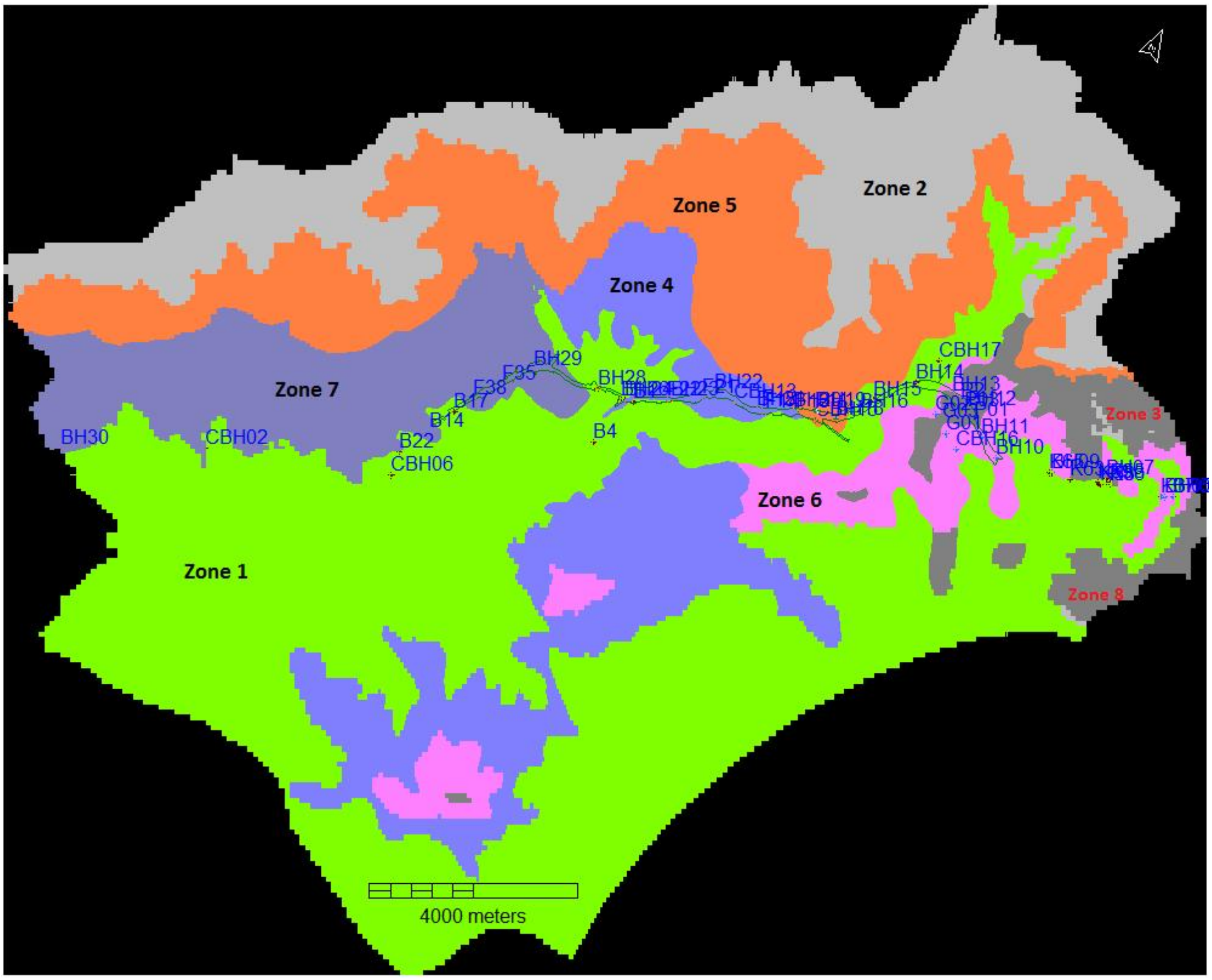


Figure 3: Foxground to Berry Model - Hydraulic Conductivity Zonation

3.5 Boundary Conditions

3.5.1 Recharge and Evapotranspiration

Recharge was implemented in the model via the Modflow Recharge Package (RCH). Recharge is applied to the top active model layer.

An initial recharge value of 0.25 mm/d was assigned at different recharge zones in the model. Recharge zones were identified based on outcrop geology and qualitative analysis of groundwater level hydrographs as follow:

1. Alluvial, Colluvial deposits. Lack of time series logger data monitoring this unit does not allow a qualitative assessment of recharge in this unit, however spot readings (borehole B8 and CBH05) indicate groundwater levels close to surface and thus suggest high recharge in this unit;
2. Berry Siltstone (East of Berry). Time series logger data (boreholes BH21, BH24 and F21) suggest significant response to rainfall events with post-rainfall event groundwater level fluctuations up to 6 m. The Berry Siltstone outcrop area, east of Berry, is considered a high recharge area;
3. Berry Siltstone (West of Berry). Groundwater hydrograph for borehole F35 suggests little response to rainfall events. Conversely data for borehole BH29 located close by shows up to 1.7 m groundwater level fluctuations during intense rainfall events. The Berry Siltstone outcrop area, west of Berry, is considered a medium / low recharge area;
4. Bumbo Latite member. Time series logger data (boreholes BH12, BH13, P3) suggest significant response to rainfall events with post-rainfall event groundwater level fluctuations up to 8 m. The outcrop areas of the Bumbo Latite are considered high recharge areas;
5. Kiama Sandstone. Time series logger data (boreholes BH10) suggest moderate response to rainfall events with groundwater level fluctuations generally less than 1 m. The outcrop area of the Kiama Sandstone is considered a medium-low recharge area.

The initial recharge value assigned to each zone listed above was subsequently adjusted in the calibration process against groundwater levels and river baseflow (see Section 4).

In addition to the zones listed above a further recharge zone was specified for the low-lying swampy areas present to the south-west of Berry which are drained by Broughton Creek and its tributaries. These areas are characterised by water table close or at ground surface all year round and thus a recharge of 3.98 mm/d, equivalent to the long term average rainfall, was adopted. Given that the water table is close to ground surface it has been assumed that evapotranspiration occurs at its maximum possible rate determined by the meteorological conditions. Evapotranspiration was simulated in the model via the Modflow Evapotranspiration Package (EVT). The extinction depth was set to 0.5 m below the evapotranspiration surface which was set to coincide with the modelled topographic surface.

The recharge / evapotranspiration zone corresponding to swampy areas was not adjusted during the calibration process and thus the model parameters were kept fixed to its initial value during the calibration process.

3.5.2 Stream and River Boundaries

The Broughton Creek and Crooked River drainage systems were simulated via a combination of the Modflow Stream (STR) and River (RIV) Packages as illustrated in Figure 1 and Figure 2.

The main rivers and creeks, i.e. the Broughton Creek including the tributaries Broughton Mill Creek, the Bundewallah Creek and Jaspers Creek as well as the Shoalhaven River and the Crooked River were simulated using the Stream Package which allows for a more sophisticated simulation of surface and groundwater interactions than the simple River Package. Stream stage elevation was set to the minimum of the 10 m DEM within each model grid cell, with some manual modification to certain areas of the drainage network to guarantee the downstream flow of the main rivers. The stream bed top was set to 0.3 m below the stream stage and a thickness of 0.2 m was assigned to the stream bed. Stream conductance was set to an initial value of 100 m^2/d and it was subsequently adjusted in the calibration process.

The remaining minor creeks and water courses were simulated with the River Package. The River bed has been set to have a zero thickness meaning that these River boundaries act in the same fashion as Modflow Drain boundaries, i.e. allowing baseflow out of the aquifer but not allowing leakage from watercourses to the aquifer. Similarly to the streams the river stage elevation was set to the minimum of the 10 m DEM within each model grid cell. River conductance has been set to 100 m^2/d and it was subsequently adjusted in the calibration process.

3.5.3 General Head Boundaries

General head boundaries (GHB) have been applied along the coastline at the edge of the active model domain to simulate the sea (see Figure 2). The elevation of the GHBs was set consistently to the minimum stream stage specified for the Shoalhaven River.

3.5.4 No-Flow Boundaries

No flow boundaries were assigned at the edge of the northern and western edges of the Broughton Creek catchment based on the assumption that there is no significant subsurface groundwater inflow from adjacent catchments into the Broughton Creek groundwater system (see Figure 2).

3.5.5 Groundwater Extractions

According to the NSW groundwater works there are 26 groundwater extraction bores with known extraction yields within the model active domain as illustrated in Figure 2. Groundwater extraction bores in the area are primarily used for agricultural and stock and domestic purposes. According to the database yields range from 12.4 L/s in borehole GW108608 to 0.01 L/s in borehole GW103198.

Groundwater extractions were simulated using the Modflow-Surfact FWL4 package which allows a reduction in the volume of groundwater extracted if a specified in-bore target water level is achieved during the model simulation. Given the lack of information regarding the depth of the pump in the boreholes the target water level was set to the bottom elevation of each borehole.

4. Model Calibration

4.1 Model Calibration Strategy

Calibration of the groundwater flow model was undertaken in steady state through comparison of observed and modelled groundwater levels at 60 borehole locations and observed and modelled baseflow at 3 flow gauges.

Calibration of the steady-state model was carried out using the PEST suite of software (Doherty, 2010) and adopting the following overall framework:

1. The initial horizontal hydraulic conductivity was allowed to vary within suitable bounds as defined in Table 2 in each hydraulic conductivity zone defined in Section 3.4. The vertical hydraulic conductivity was 'tied' to the horizontal hydraulic conductivity in all zones but the Latite units where both the horizontal and the vertical hydraulic conductivity were allowed to vary within pre-defined bounds;
2. The initial recharge value was allowed to vary between 1 and 10 per-cent of long term average rainfall in each recharge zone defined in Section 3.5.
3. The river and stream conductances were allowed to vary between 1 m^2/d and 1000 m^2/d in each sub-catchment for which a river baseflow target was available.

A total of 26 parameters were adjusted in the calibration process. The use of both groundwater levels and river baseflow targets in the calibration process allowed a more robust estimation of interlinked model parameters such as hydraulic conductivity and recharge.

4.2 Calibration Targets

4.2.1 Groundwater Levels

Groundwater levels were provided by RMS in the form of logger data and manual readings. The average groundwater level elevation was calculated for the 60 groundwater bores present within the active model area and used as targets in the model calibration.

Groundwater level targets range from a maximum of around 112.3 mAHD in the Bumbo Latite outcrop highs in the north-east of the Broughton catchment to -0.2 mAHD in the low-lying swampy areas to the south-west of Berry.

Groundwater level statistics for each hydraulic conductivity zone in the model are listed in Table 3. The distribution of groundwater targets with the model domain that were used for calibration are presented in Figure 2. Groundwater levels are generally very high in the highland outcrop areas of the Bumbo Latite with a zone average value of 76.1 mAHD.

Zone average groundwater level for the Berry Siltstone (east of Berry – Zone 4) is higher than the zone west of Berry (Zone 7) suggesting that these two zones are hydrogeologically different.

Table 3 Groundwater Level Targets by Hydraulic Conductivity Zone

Zone	Geological Unit	Number of Observed Groundwater Level Targets	Zone Avg. Groundwater Level (mAHD)	Zone Min. Groundwater Level (mAHD)	Zone Max. Groundwater Level (mAHD)
1	Superficial Unconsolidated Deposits	6	21.4	-0.2	57.8

Zone	Geological Unit	Number of Observed Groundwater Level Targets	Zone Avg. Groundwater Level (mAHD)	Zone Min. Groundwater Level (mAHD)	Zone Max. Groundwater Level (mAHD)
2	Basement Unit (general)	12	19.3	1.9	41.1
3 & 8	Bumbo and Blow Hole Latite Members	11	76.1	54.9	112.3
4	Berry Siltstone (east of Berry)	10	33.8	12.1	48.0
7	Berry Siltstone (west of Berry)	7	14.3	8.1	20.3
5	Jamberoo Sandstone	4	44.1	33.9	55.3
6	Kiama Sandstone	10	30.8	17.7	62.8

4.2.2 Creek Baseflow

Time series of creek flows for Broughton Mill Creek at Broughton Vale and Jaspers Creek at Jaspers Brush suggest a baseflow component of around 6 Ml/d and around 2.4 Ml/d, respectively (see Section 2.2).

Flow time series are also available at gauging station 215015 (Broughton Mill Creek at Berry) but given the discontinuous dataset it was not possible to carry out a baseflow separation at this location. However, a baseflow target for Broughton Mill Creek at Berry was calculated based on the assumption that the Broughton Mill Creek sub-catchment area between Vale and Berry would produce the same amount of baseflow per unit area as the one produced by Broughton Mill Creek sub-catchment at Broughton Vale. Given that assumption, it was assumed a baseflow of around 13.4 Ml/d for the Broughton Mill Creek at Berry.

The baseflow estimates provided above were used as targets in the model calibration.

4.3 Calibration Results

4.3.1 Calibrated Hydraulic Conductivity

Calibrated horizontal and vertical hydraulic conductivity values are shown in Table 4. Calibrated hydraulic conductivity for the FBB model suggest that three major changes were required to achieve a good match between modelled and observed groundwater levels and baseflows as follows:

- The initial horizontal hydraulic conductivity of the superficial unconsolidated deposits (zone 1) was increased by one order of magnitude;
- The initial horizontal hydraulic conductivity of the Kiama Sandstone (zone 6) was reduced by a factor of 0.3;
- The initial vertical hydraulic conductivity of the Bumbo Latite units was increased by a factor larger than 100.

The substantial increase in vertical hydraulic conductivity of the Bumbo Latite is consistent with the geological nature of this unit where columnar jointing is often found within these volcanic facies and thus a vertical groundwater flow direction is preferred to horizontal flow direction.

Calibrated horizontal and vertical hydraulic conductivity are well within the permissible ranges specified in Table 2 for all zones. A comparison of calibrated values and test data was not possible at this stage of the project as testing is currently being undertaken as part of on-going fieldwork activities. The comparison with test data however will be undertaken at later stages of the project as part of the model validation phase.

Table 4 Calibrated Horizontal and Vertical Hydraulic Conductivity

Zone	Geological Unit	Calibrated Horizontal Hydraulic Conductivity (m/d)	Calibrated Vertical Hydraulic Conductivity (m/d)	Ratio Kh/Kv
1	Superficial Unconsolidated Deposits	$1.0x10^{+00}$	$1.0x10^{+00}$	1
2	Basement Unit (general)	$4.8x10^{-03}$	$4.8x10^{-04}$	10
3	Bumbo Latite Member	$7.4x10^{-04}$	$6.8x10^{-03}$	0.1
4	Berry Siltstone	$4.8x10^{-03}$	$4.8x10^{-04}$	10
7	Berry Siltstone	$3.6x10^{-03}$	$3.6x10^{-04}$	10
5	Jamberoo Sandstone	$4.5x10^{-03}$	$4.5x10^{-04}$	10
6	Kiama Sandstone	$3.2x10^{-04}$	$3.2x10^{-05}$	10

4.3.2 Calibrated Recharge

Calibrated recharge values for each model zone are shown in Table 5. Calibrated recharge for the FBB model suggest that two major changes were required to achieve a good match between modelled and observed groundwater levels and baseflows as follows:

- Recharge was increased from 6 per-cent to around 8 to 10 per-cent of long term average rainfall in the highland areas north of Berry;
- Recharge for the Kiama Sandstone and the Berry siltstone (west of Berry, only) was decreased from 6 per-cent to around 1 to 1.5 per-cent of long term average rainfall.

The increase of recharge in the highland catchment areas to the north of Berry (zone 2 and 6) is consistent with the relatively large baseflow component observed for Broughton Mill Creek at Vale and Berry. The calibrated recharge value for zone 2 and 6 are also consistent with the recharge estimated from baseflow for the Broughton Mill Creek at Vale sub-catchment (see Section 2.2).

Conversely the decrease of recharge in zone 7 (Berry Siltstone, west of Berry) is consistent with lower observed baseflow for Jaspers Creek catchment as well as lower observed groundwater levels west of Berry town. The calibrated recharge value for zone 7 is consistent with the recharge estimated from baseflow for the Jaspers Creek at Jaspers Brush sub-catchment (see Section 2.2).

The low recharge values for the Kiama Sandstone is associated with a lack of baseflow targets in that area and thus the calibrated recharge value is only determined matching the available observed groundwater levels in recharge zone 9.

Table 5 Calibrated Recharge Values

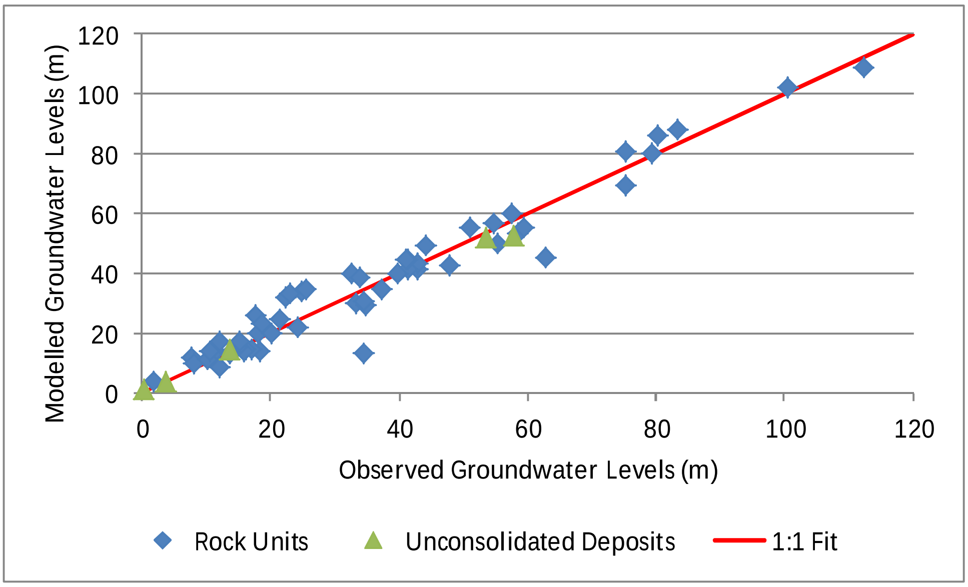
Zone	Geological Unit	Calibrated Recharge (mm/d)
1 & 4	Superficial Unconsolidated Deposits	0.398
2	Basement Unit (general)	0.33
3	Swampy Areas	3.98 *
5	Bumbo Latite	0.32

Zone	Geological Unit	Calibrated Recharge (mm/d)
6	Berry Siltstone (East of Berry)	0.398
7	Berry Siltstone (West of Berry)	0.058
9	Kiama Sandstone	0.045
* Recharge in swampy areas was not calibrated but kept fixed to long term average rainfall		

4.3.3 Comparison of Observed and Modelled Groundwater Levels

Scatter plots of modelled against observed average groundwater levels for all head targets used to calibrate the steady-state model are shown in Figure 4.

Various calibration statistics are presented in Figure 4. The scaled root mean square error (sRMS) is less than five per cent, which is within the typically accepted limits, as suggested in the Australian Groundwater Flow Modelling Guideline (National Water Commission, 2012). Calibrated model water balance errors are well below one per cent, which is also within the guidelines' suggested limits. The statistical distribution of modelled head error is approximately normal, with the greatest density of errors within the +/- 5 m error band (Figure 4), and relatively evenly spread positive and negative head errors either side of that. The mean absolute head error is 4 m, with only two bores (b01 and bh11) with head errors larger than 15 m. However, it should be noted that at both of those locations only one manual groundwater level reading was available at the time of the model calibration. It is therefore possible that the targets used for boreholes b01 and bh11 are not representative of average groundwater conditions and thus are considered of low reliability.



No Calibration Bores	60	Root Mean Square Error	5.5
Sum of Square Errors	1815	Overall Scaled RMS Error	4.9%

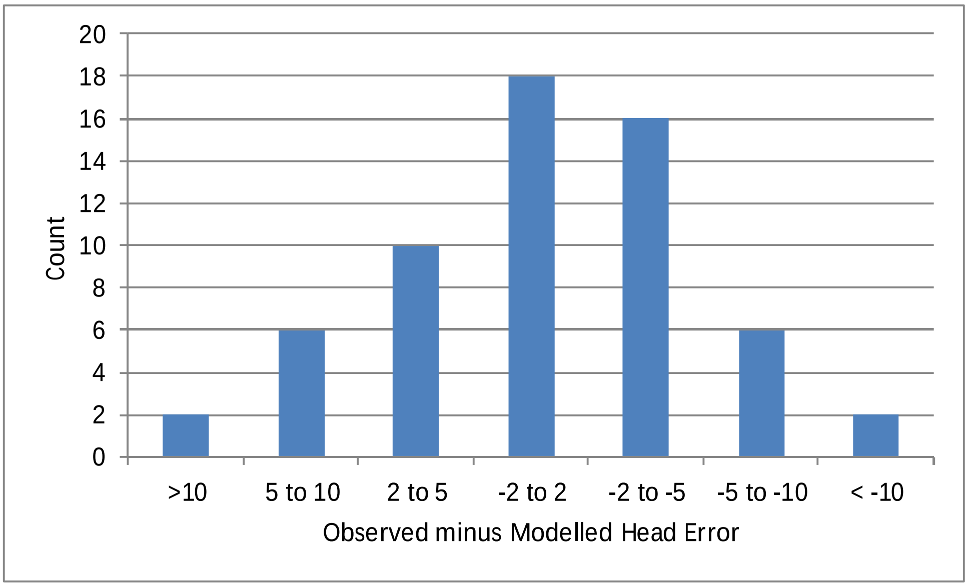


Figure 4: Steady State Groundwater Level Calibration Statistics

4.3.4 Comparison of Observed and Modelled Baseflow

Model calibration suggests a good match between observed and modelled creek baseflows as illustrated in Table 6. Calibrated model results suggest that modelled baseflow is within +/- 10 % of observed baseflow at the two Broughton Mill Creek gauging stations used in the model calibration. Model results however suggest a larger baseflow for Jaspers Creek with the calibrated value sitting outside the +/- 10 % error bar.

Modelled baseflow is also listed for Broughton Creek at the Oaks although a calibration baseflow target is not available at this location.

Table 6 Observed and Modelled Baseflow Comparison

Gauging Station ID	Catchment	Target Baseflow (Ml/d)	+/- 10% of Baseflow Target	Modelled Baseflow (Ml/d)	Within +/- 10% Error Bound
215018	Broughton Mill Creek at Broughton Vale	6.0	5.4 - 6.6	6.19	Yes
215015	Broughton Mill Creek at Berry	13.4	12.1 - 14.7	14.22	Yes
215019	Jaspers Creek at Jaspers Brush	2.4	2.2 -2.6	3.01	No
215017	Broughton Creek at The Oaks	-	-	13.13	-

5. Model Predictions

5.1 Predictive Model Objectives

The primary purpose of developing a groundwater flow model for the FBB was to provide a tool to predict:

- Groundwater inflows to the Project cuttings for road construction planning:
- Groundwater level changes to the hydrogeological units present in the Broughton Creek catchment in response to dewatering of the Project workings:
- Potential baseflow impacts on local water courses; and
- Impacts on local hydrological features of environmental or economic importance, which might be sensitive to groundwater level decline.

5.2 Predictive Model Construction

Construction of the predictive model was relatively straightforward as it required minimal modification of the steady-state model input files.

5.2.1 Stress Periods and Time Steps

At the current stage of the project a detailed road construction program is not available including a start and end date of the road workings. Therefore the predictive model was set-up to assess the long term impact of the proposed development post-construction. A long term transient model comprising 120 yearly stress periods was created and the impacts are assessed once the groundwater system has re-equilibrated to steady-state conditions.

To assess the inflow changes during construction of the Project an additional model was set up with daily stress periods that simulated for a period of 10 years. The 10 year period was based on the above model design suggesting that steady state conditions would be reached within 10 years of construction completion. At the time of developing this model little information was available to characterise the staging of construction. As such, the following conditions were assumed:

- Construction occurs over a period of two years,
- Construction commences at the south western extent of the Project alignment and finishes at the north eastern extent of the Project alignment.
- Construction progresses at a constant rate.

5.2.2 Initial Groundwater levels and Model Parameters

Initial groundwater levels, hydraulic conductivity, recharge and stream / river conductances were taken from the calibrated steady state model.

Modelled storage values adopted for predictive modelling are summarised in Table 7. It should be noted that given that a transient calibration of the model was not undertaken at this stage the storage values were taken from reference groundwater modelling books including Anderson and Woessner,(1992) and Domenico and Schwartz (1998).

Confined storage values for each model layer are input to MODFLOW-SURFACT in the form of total storativity (i.e. specific storage multiplied by the layer thickness).

Table 7 Predictive Model - Storage Values

Zone	Geological Unit	Storativity	Specific Yield
1	Superficial Unconsolidated Deposits	$1x10^{-01}$	$1x10^{-01}$
2	Outcrop Basement Units	$1x10^{-02}$	$1x10^{-02}$
3	Confined Basement Units	$6.9x10^{-03}$ *	$1x10^{-02}$
* Base on a specific storage value of $6.9x10^{-5}$ m^{-1} and a constant thickness of 100 m.			

5.2.3 Simulation of Road Workings

The Project has been simulated in the model using the Modflow Drain (DRN) package.

As already mentioned previously due to the lack of a construction schedule at this stage of the Project the model drains for the whole road extent are active from the first stress period of the predictive model simulation in the yearly time step model with a constant progression of construction over two years in the daily time step model.

The drain elevations were set to one meter below the elevation of the proposed road centreline. The elevations were provided directly by RMS at approximately 10 m interval for the whole road bypass. The width of the road was obtained from design drawings (60021933-xrf-10-02-rd_des_mc2a_2d_130723.dwg) provided by RMS and was generally around 25 m. The same elevations as the road centreline were specified for the whole width of the road giving therefore a flat profile to the base of the road

The drain conductance was set to a relatively large value of 1,000 m^2/d, which is equivalent to a vertical hydraulic conductivity value of 1 m/d. Thus the equivalent hydraulic conductivity value used to parameterisation of the Modflow drain cells is greater than the calibrated vertical hydraulic conductivity of the modelled layers; hence the material properties of the modelled layer will tend to control the modelled flow to drain cells rather than the modelled drain conductance.

5.3 Predictive Model Results

5.3.1 Predicted Inflows to Road Workings

Figure 5 presents the predicted inflows to the cuttings along the project alignment during construction. There are three peaks in the drain outflow in Figure 5 that correspond to the three main road cuttings detailed as follows:

- The first peak is associated with the major cutting(s) near Berry (see Figure 8), At this time flows peak at approximately 0.14 ML/day
- The second peak is associated with the major cutting(s) between Tindalls Lane and Tomlins Road (see Figure 7). At this time flows peak at approximately 0.25 ML/day
- The third peak is associated with the major cutting(s) Foxground Road (Figure 6). At this time flows peak at approximately 0.27 ML/day.

It is noted that these results represent an overview of the potential inflows based on a limited understanding of how the construction will progress. A more detailed assessment of each cutting will be required at detailed design stage when appropriate staging information for the cutting is available.

The predictive model results suggest that the groundwater system will take around 10 years to re-equilibrate to steady-state conditions. The model suggests a long-term post-construction groundwater inflow to the road cuttings of around 0.14 Ml/d.

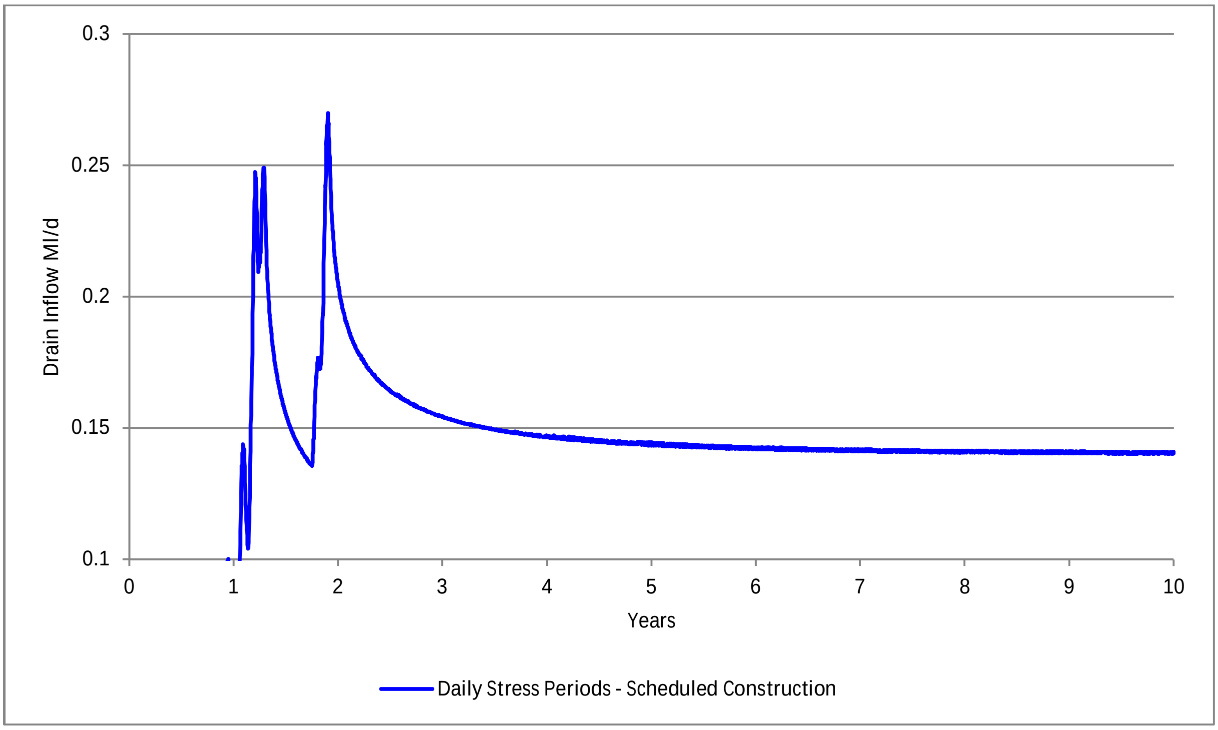


Figure 5: Predicted inflows during and after construction

5.3.2 Predicted Groundwater Level Impacts

Road elevations are generally above ground surface in areas where alluvial deposits are present. Therefore little or no groundwater level impacts are anticipated in alluvial deposits and this is confirmed by predictive model results.

Groundwater level impacts are expected in the rock unit aquifers at the location of the three main road cuttings and surrounding areas. Groundwater level impacts at the location of the three main road cuttings along the proposed road bypass are shown in Figure 6 to Figure 8. Predictive model results suggest around a 20 m impact to the water table in the road cutting close to Foxground Road. Predictive model results suggest a water table impact up to 10 m and 3 m in the Project cuttings between Tindalls Lane and Tomlins Road and the cuttings close to Berry town, respectively. Predictive model results suggest groundwater level impacts further away from the main road potentially impacting registered groundwater bores located in the area. Groundwater level impacts at specific registered bores are listed in Table 8.

Impacts to registered groundwater users

Groundwater level impacts greater than 0.1 m are predicted at three registered groundwater bores. Predictive model results also suggest a less than 0.1 m groundwater level impact at the other 20 registered groundwater bores.

Table 8 Groundwater Level Impacts at Registered Bores

Bore ID	Distance From Road (m)	Model Layer	Drawdown (m)
GW107697	383	2	0.18
GW022508	1110	2	0.13
GW016425	313	2	0.12
GW025595	163	2	0.06
GW011451	740	2	0.04
GW010826	244	2	0.01
GW015221	337	2	0.01
GW022506	1216	2	0.01
GW065515	70	2	0.01
GW015286	102	2	0.01
GW057927	1188	2	0.01
GW054770	43	2	0.01
GW108622	553	2	0.01
GW017029	1252	2	0.01
GW045655	1242	2	< 0.01
GW051054	1291	2	< 0.01
GW101971	396	2	< 0.01
GW028843	1852	2	< 0.01
GW012997	1245	2	< 0.01
GW019253	794	2	< 0.01
GW028887	809	2	< 0.01
GW031987	1226	2	< 0.01
GW105716	1171	2	< 0.01

Groundwater impacts approximating 0.18 m or less are not anticipated to represent an adverse impact to the water supply in these wells and would be considered to be negligible impact under the NSW Aquifer interference policy (NOW, 2012).

Impacts to Sensitive Surface Water Features

A number of potentially sensitive surface water features are present in the vicinity of the project alignment. This includes Foys Swamp and Coomonderry Swamp, which are located near to Seven Mile beach at distances of greater than 2 km to the south east of the Project. These systems are also likely to be hydraulically separated from the Project by the ridgeline that separates the Broughton Creek and Crooked River Catchments. Further to this the groundwater elevation changes created by the project do not intersect these surface water features. Therefore, groundwater changes associated with the project are not expected to have an adverse impact on these systems.

Impacts to Acid Sulphate Soils

The long term drawdown response created by the cuttings at Tindalls Lane and Tomlins Road (see Figure 7) are simulated to intersect potential acid sulphate soils to the south east located in low lying areas along Broughton Creek. These areas are identified as having a low potential for the presence of acid sulphate soils in Maunsell (2007).

In terms of impacts to sensitive features, the generation of acid sulphate soils in this area is unlikely to impact existing groundwater users, however, impacted groundwater is likely to discharge to Broughton Creek.

In terms of managing this risk there are a number of potential options, which could include either of, or a combination of:

- Additional intrusive soil investigations to characterise the actual potential for the generation of acid sulphate soils within the simulated drawdown zone.
- Implementation of measures to recharge dewatered groundwater from the cuttings to downgradient locations flanking acid sulphate soil areas and hence reduce drawdown impacts. This measure could be assessed within the groundwater model.
- An assessment of road design and construction to minimise drawdown impacts at these cuttings and hence prevent the potential for the generation of adverse impacts. These measures could be assessed within the groundwater model.
- Implementation of a monitoring regime in this area to monitor for pH impacts and provide an early warning mechanism for enhanced mitigation measures to be implemented. Sampling location SW03 would act to identify impacts in Broughton Creek. A strategically placed monitoring bore, would perhaps provide an early warning mechanism for the presence of emerging groundwater elevation impacts.

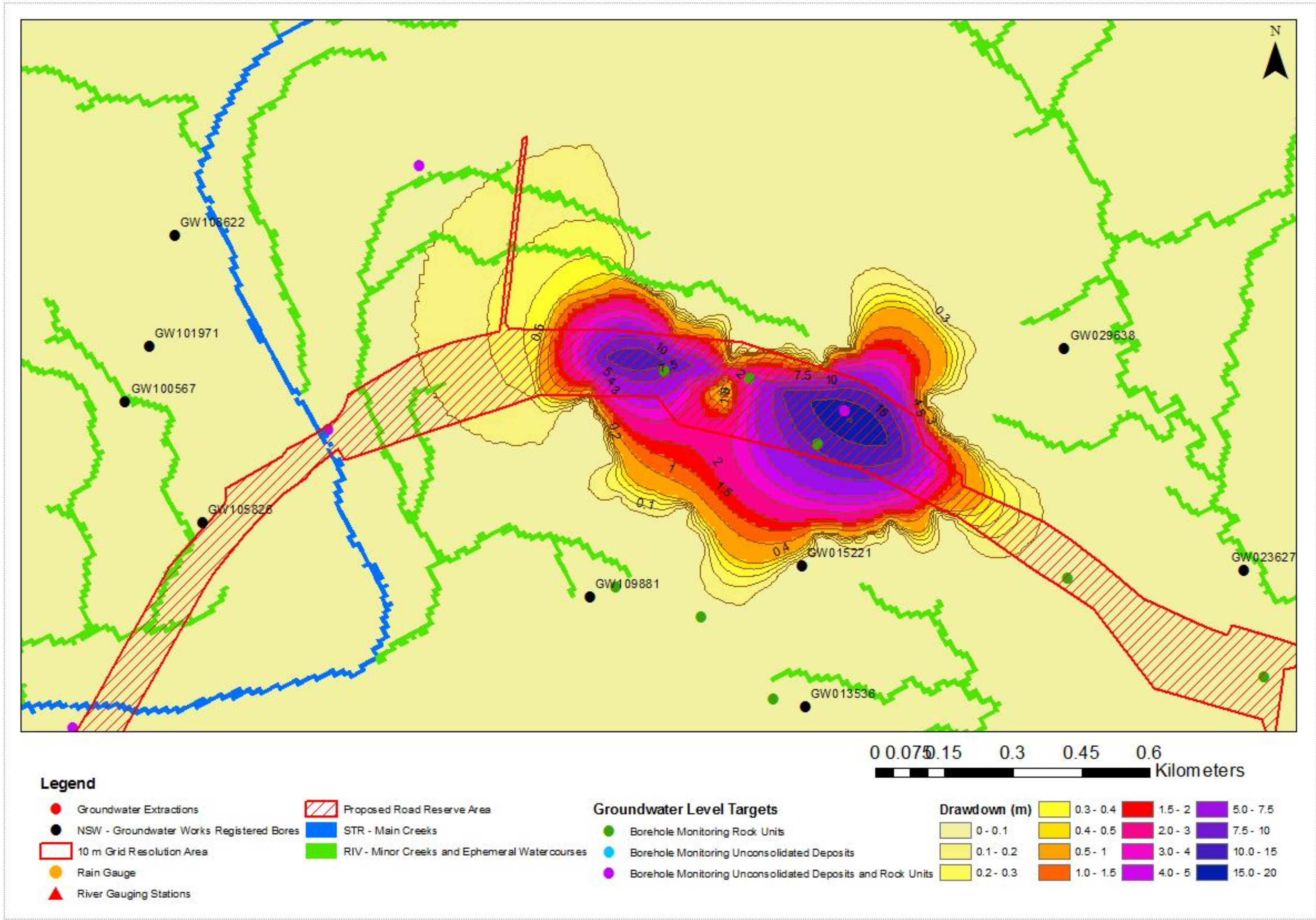


Figure 6: Predicted Groundwater Level Impacts – Cuttings close to Foxground Road

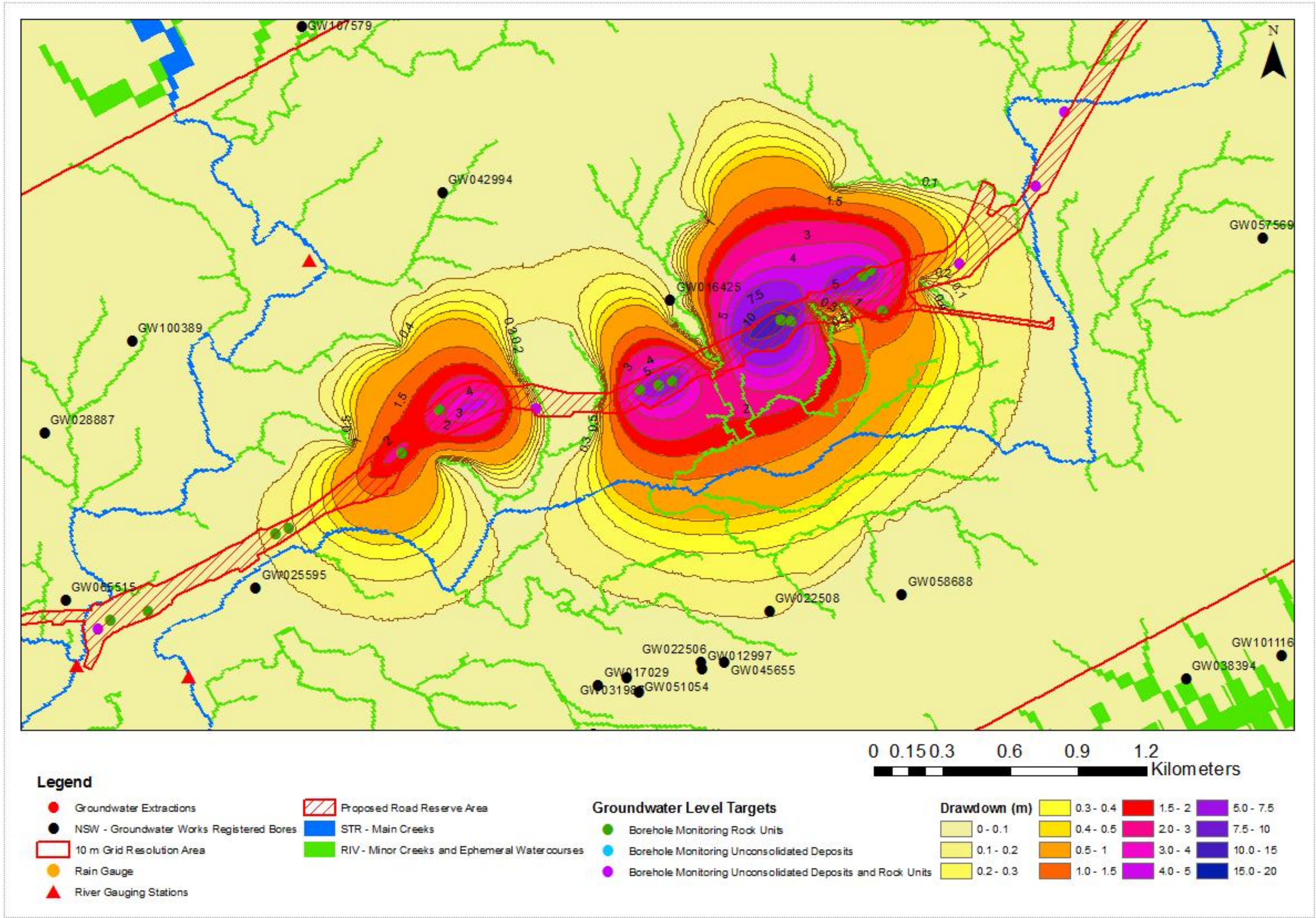


Figure 7: Predicted Groundwater Level Impacts – Cuttings between Tindalls Lane and Tomlins Road

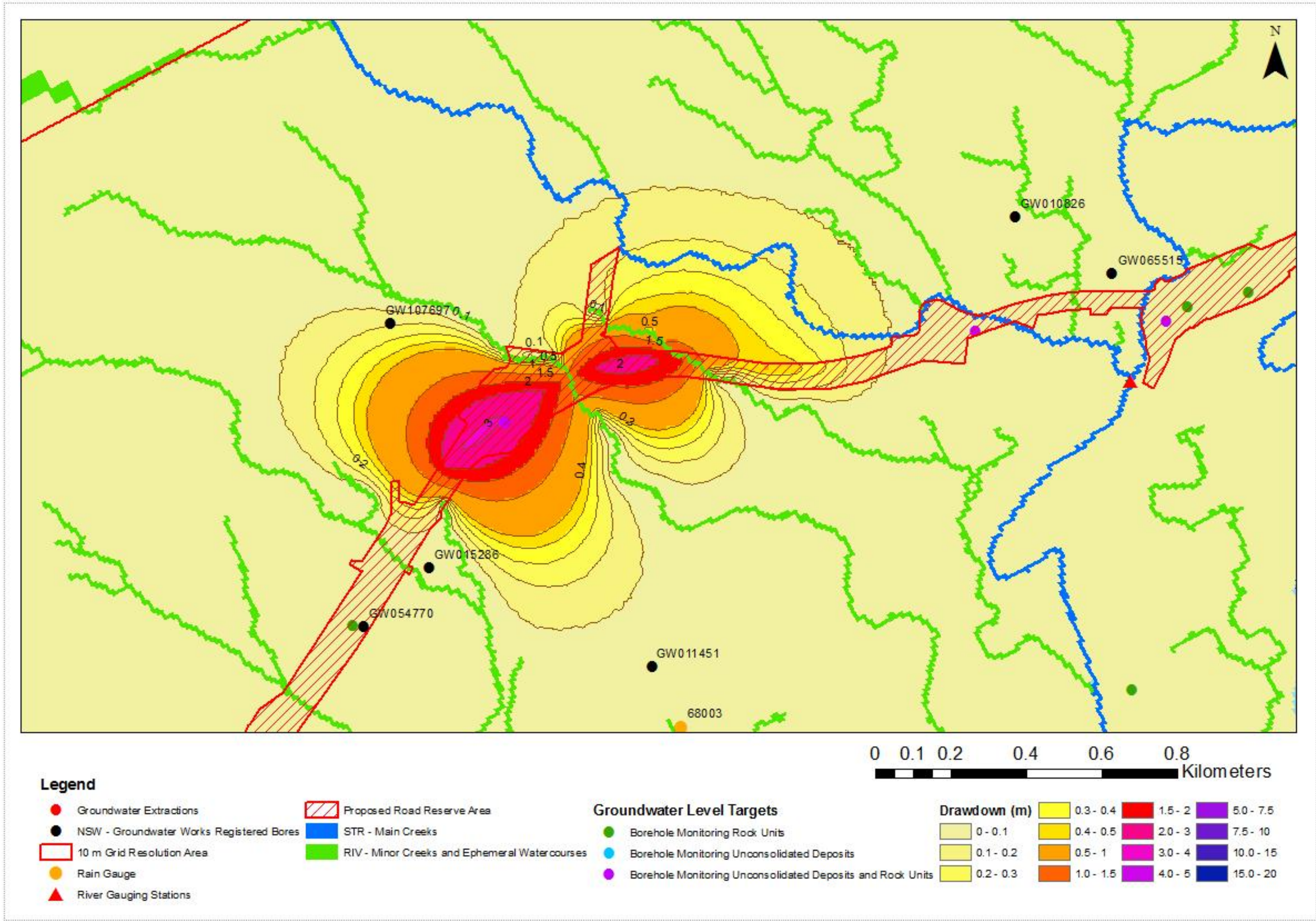


Figure 8: Predicted Groundwater Level Impacts – Cuttings nearby Berry town

5.3.3 Predicted Baseflow Impacts

Baseflow impacts at gauging stations in the Broughton Creek catchment are shown in Table 9.

Predictive model results suggest up to 0.2% baseflow reduction from the calibrated baseflow value across the whole model domain, which includes the Broughton Creek and Crooked River catchments.

The majority of baseflow impact is associated with the Broughton Creek. Predictive model results suggest up to 0.6% baseflow reduction for the Broughton Creek at The Oaks. Baseflow to the Broughton Creek is impacted by the project cuttings between Tindalls Lane and Tomlins Road as well as the major cutting close to Foxground Road.

Predictive model results suggest a small baseflow reduction for Broughton Creek at Berry caused by the project road cutting near Berry.

As expected no baseflow impacts are predicted at Jaspers Creek at Jaspers Brush and Broughton Mill Creek at Broughton Vale as the upstream reaches of these sub-catchments drain areas which are located at a significant distance from the project road cuttings.

Table 9 Baseflow Impacts at Creeks Gauging Stations

Gauging Station ID	Catchment	Calibrated Baseflow (Ml/d)	Predicted Baseflow (Ml/d)	Percentage Baseflow Reduction
215018	Broughton Mill Creek at Broughton Vale	6.19	6.19	No Impact
215015	Broughton Mill Creek at Berry	14.22	14.21	0.04
215019	Jaspers Creek at Jaspers Brush	3.01	3.01	No Impact
215017	Broughton Creek at The Oaks	13.13	13.05	0.6
Total (whole model active area)*		74.1	73.9	0.2
* Include Broughton Creek and Crooked River				

Impacts to aquatic ecology and surface water supplies

The predicted reduction in groundwater baseflows are expected to be at percentages that are within background fluctuations and are expected to be relatively insignificant in terms of impacts to aquatic ecology and ongoing surface water supplies obtained under basic landholder rights. Despite this, further quantification of these reductions relative to existing basic landholder right abstractions and aquatic health are required.

5.3.1 Impacts to Farm Dams

There are approximately ten farm dams located along the alignment that are within the location of the zones of drawdown influence create by project alignment cuttings. Of these farm dams only four are located in zones where the drawdown influence is greater than 0.2 m.

The farm dams along the project alignment are anticipated to be primarily reliant on surface water harvesting and are unlikely to have significant connections to groundwater systems. As such, they are considered unlikely to be adversely impacted. Consideration could be given to monitoring the water level in and/or groundwater elevations surrounding the dam in the four most potentially impacted farm dams prior to construction and operation in order to monitor for groundwater related impacts after construction.

5.3.2 Settlement Impacts

The drawdown in groundwater elevations can be associated with settlement. The significance of the impacts are likely to be most pronounced in areas where there is significant development and where there are unconsolidated sediments that have the potential to settle with dewatering. Based on this it is anticipated that the drawdown cones created beneath Berry may present a settlement risk. There may also be isolated risks to housing located within zones of drawdown influence intersection unconsolidated sediments elsewhere along the alignment.

It is recommended that the results of this report are provided to appropriate settlement specialists to assess the potential for settlement. Subject to the findings of this review appropriate mitigation measures can be developed.

5.3.3 Recharge Impacts

Changes in groundwater recharge due to the development of the project and associated increases in sealed surface have not been simulated by the modelling. This is because these impacts are expected to be small given that sealed areas are likely to represent a small percentage of the overall catchment recharge.

6. Conclusions

A numerical groundwater model has been developed to assess the impact of the project on groundwater users and groundwater dependent systems.

The modelling approach and complexity has been based on that undertaken prior to construction for other major road upgrade projects in NSW where groundwater is considered to be sensitive.

The modelling has been designed to focus on changes in groundwater elevations and flow volumes associated with the project. Impacts to groundwater quality and associated management measures are summarised in the GQMP document.

The report has been designed as a technical appendix to the GQMP and should be read in conjunction with the GQMP.

The groundwater modelling results suggest that the primary impacts will be associated with drawdown around cuttings along the project alignment. The predicted impacts and proposed management measures are summarised below:

- Impacts to surrounding registered groundwater wells are simulated to be within acceptable ranges, with the maximum predicted drawdown within impacted registered groundwater wells approximating less than 0.2 m.
- The drawdowns are expected to result in a less than 1 % reduction in the base flow component of catchment surface water features. This is anticipated to have negligible impacts on in-stream aquatic ecology and existing surface water user supplies, however, further consultation with ecological specialists is required to validate this.
- Impacts to sensitive surface water features such as Coomonderry Swamp and Foys swamp are simulated to be negligible.
- The zones of drawdown influence created by the cuttings near to Tindalls Lane and Tomlins Road are simulated to intersect areas where there is low potential for the presence of Acid Sulphate soils. In terms of managing this risk there are a number of potential options, which could include either of, or a combination of:
  - Additional intrusive soil investigations to characterise the actual potential for the generation of acid sulphate soils within the simulated drawdown zone.
  - Implementation of measures to recharge dewatered groundwater from the cuttings to downgradient locations flanking acid sulphate soil areas and hence reduce drawdown impacts. This measure could be assessed within the groundwater model.
  - An assessment of road design and construction to minimise drawdown impacts at these cuttings and hence prevent the potential for the generation of adverse impacts. These measures could be assessed within the groundwater model.
  - Implementation of a monitoring regime in this area to monitor for pH impacts and provide an early warning mechanism for enhanced mitigation measures to be implemented. Sampling location SW03 would act to identify impacts in Broughton Creek. A strategically placed monitoring bore, would perhaps provide an early warning mechanism for the presence of emerging groundwater elevation impacts.
- The zones of drawdown influence created by the cuttings extend under isolated developments along the alignment, particularly in the Berry area, that are potentially situated on unconsolidated materials. This may represent a settlement risk that should be considered further by appropriate specialists.

- Ten farm dams are intersected by the zone of drawdown influence of which four are in zones of drawdown greater than 0.2 m. Given that the farm dams rely primarily on the surface water harvesting it is considered unlikely that they will be impacted by groundwater drawdown unless they have significant contact with groundwater. Consideration could be given to monitoring the water level in and/or groundwater elevations surrounding the dams in the four most potentially impacted farm dams prior to construction and operation in order to monitor for groundwater related impacts after construction.

Given the current understanding of design and construction of the alignment it is recommended that the modelling is revised when there is more certainty on the design levels and construction program. At this time more detailed assessment of non-uniqueness in the modelling outcomes should be considered.

7. Limitations

7.1 Modelling limitations

The model has the following key assumptions/limitations.

The model has been calibrated to observed stream flow data and groundwater observations along the alignment using automatic calibration software PEST. In the absence of site specific hydraulic conductivity data a larger range, based on literature data, has been specified for the calibration. This increases the potential for the introduction of non-uniqueness into the model, which means the ability to get the same calibration with equally plausible inputs. The overall recharge to the model appears to be realistic. It is based on back calculation of base flows from stream data and compares well with rates used in the groundwater sharing plan for this area. A realistic and well constrained recharge within the model domain is likely to result in estimates of hydraulic conductivity that are also realistic in order for a reasonable calibration to stream flows and groundwater elevations to be achieved. Hydraulic data is being collected along the alignment and will be compared against values derived from automatic calibration to provide further evidence of the robustness of the calibrated model.

Geological and groundwater elevation data is primarily focused on the alignment. This means that in model areas further away from the alignment data becomes scarce and therefore the model design relative to geological layering and calibration becomes more uncertain in its ability to provide realistic outcomes. LIDAR topographical information has been used to represent topography through the model domain while detailed geological data for the alignment has been coupled with geological map information. These factors combined will provide a reasonably tight understanding of the shallow groundwater system within the model domain, which is anticipated to be the main aquifer system impacted by the alignment. The locations where potential impacts extend to greater depth are usually at cuts along the alignment. At these locations there is abundant geotechnical data to confidently constrain the model design. Given this approach uncertainties associated with model design and layering are anticipated to be relative minimal with regard to providing a realistic estimate of impacts. Nevertheless, there is inherent uncertainty in all numerical groundwater models which is reflective or the limitation of the available data on which a model is designed.

The modelling undertaken provides an understanding of the likely impacts associated with the project based on the conceptual design, which will require further investigation at detailed design stage. At this time further modelling should be undertaken to assess non-uniqueness in the modelling outcomes, paying particular attention to the potential variation in impacts associated with changes in storage and under high and low flow conditions.

7.2 General Limitations

This report has been prepared by GHD for RMS and may only be used and relied on by RMS for the purpose agreed between GHD and the RMS as part of contract no. 13.2574.1729.

GHD otherwise disclaims responsibility to any person other than RMS arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 3 to 5 of this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by RMS and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

8. References

See Section 3.3 for geotechnical reports used in this groundwater modelling work.

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Appendices

Appendix A – Stream gauging data and estimated groundwater base flows

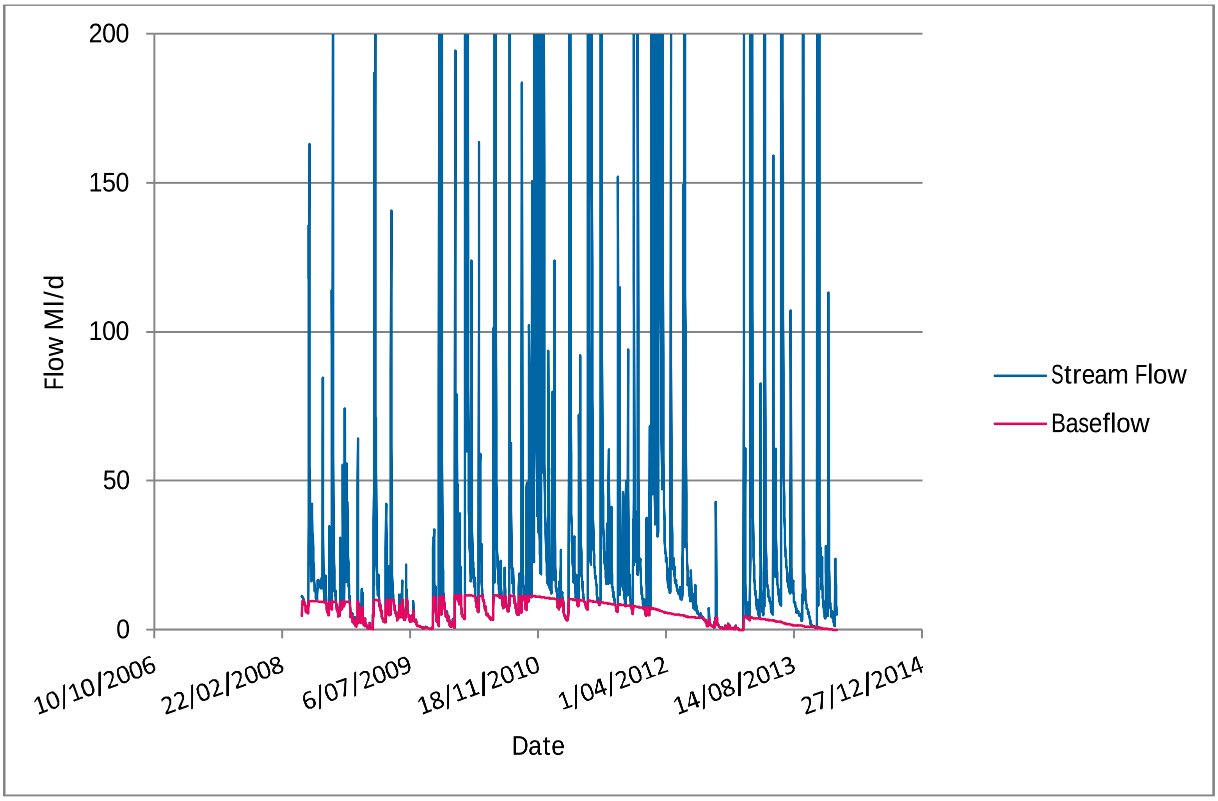

Figure A 1: Gauging data and Groundwater Baseflow Estimate for Surface Water Gauging Station 215018 (Broughton Mill Creek at Broughton Vale)

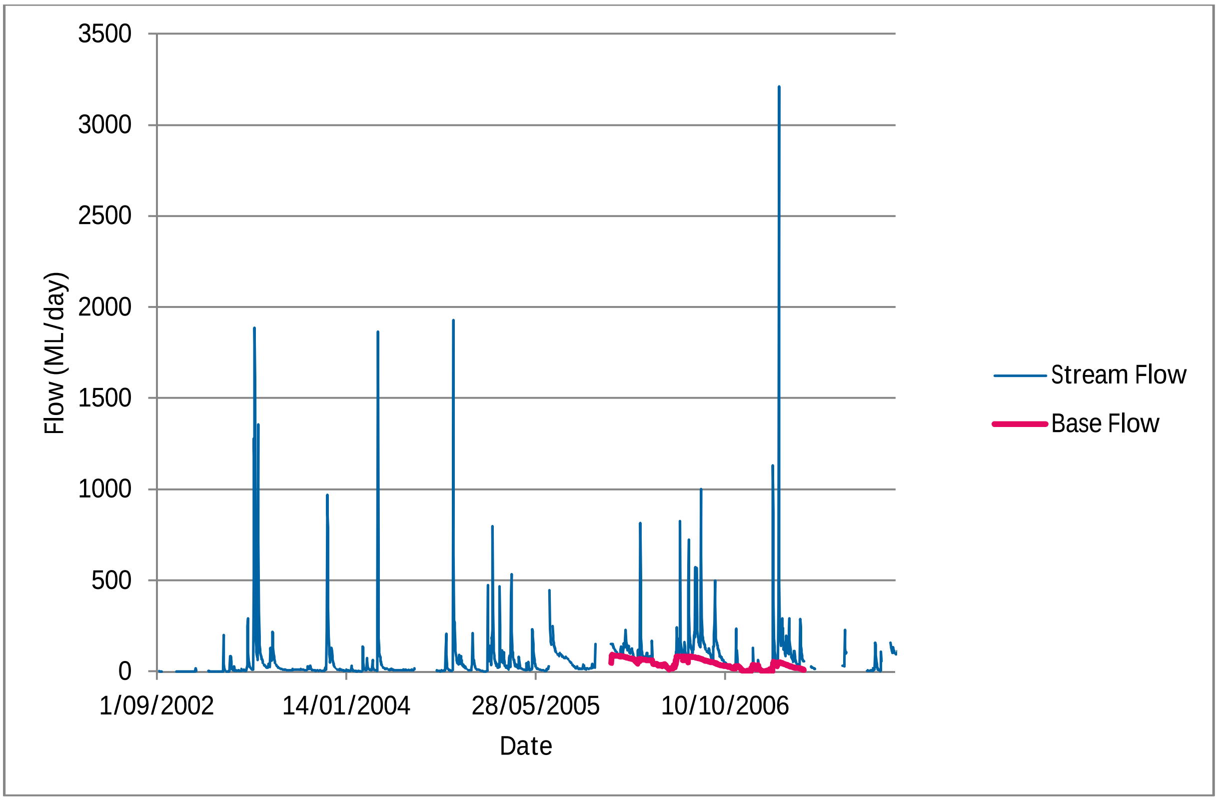

Figure A 2: Gauging data and Groundwater Baseflow Estimate for Surface Water Gauging Station 215015 (Broughton Mill Creek at Berry)

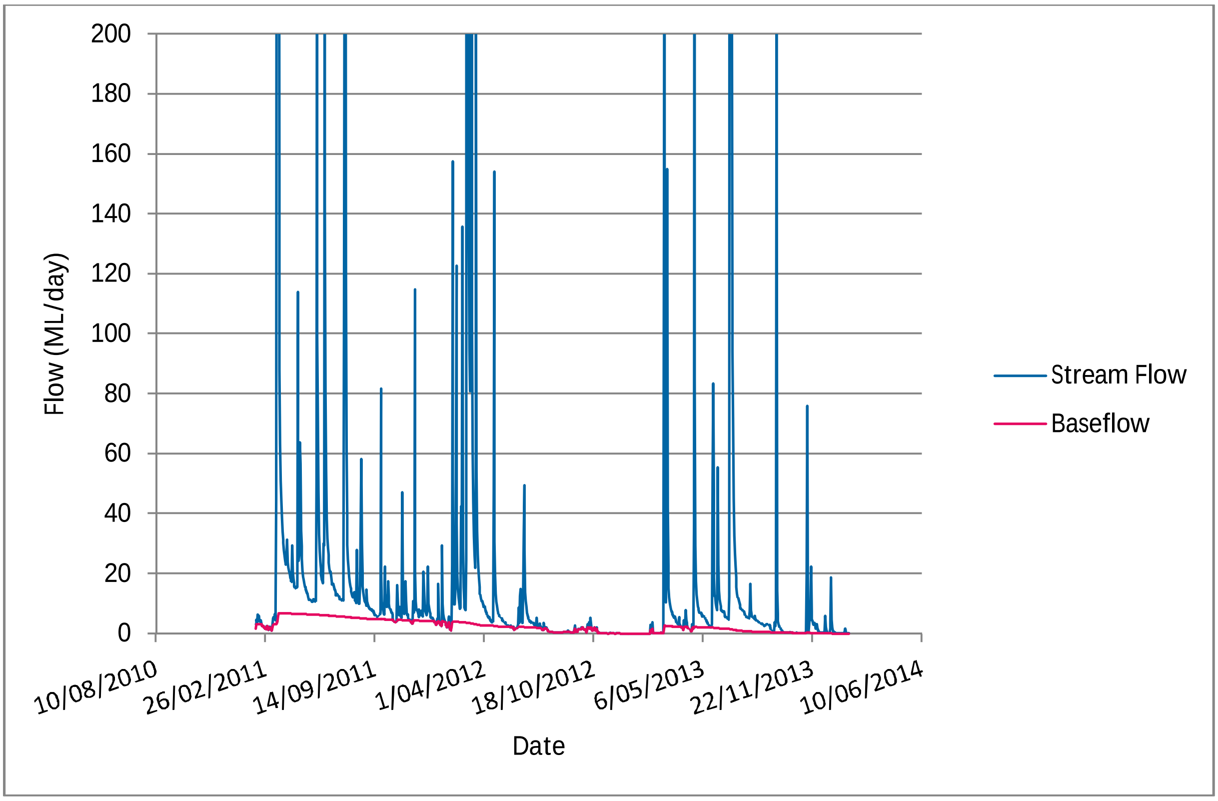

Figure A 3: Gauging data and Groundwater Baseflow Estimate for Surface Water Gauging Station 215019 (Jaspers Creek at Jaspers Brush)

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	L. Traverso	S. Charteris		J. Hallchurch		09/07/2014

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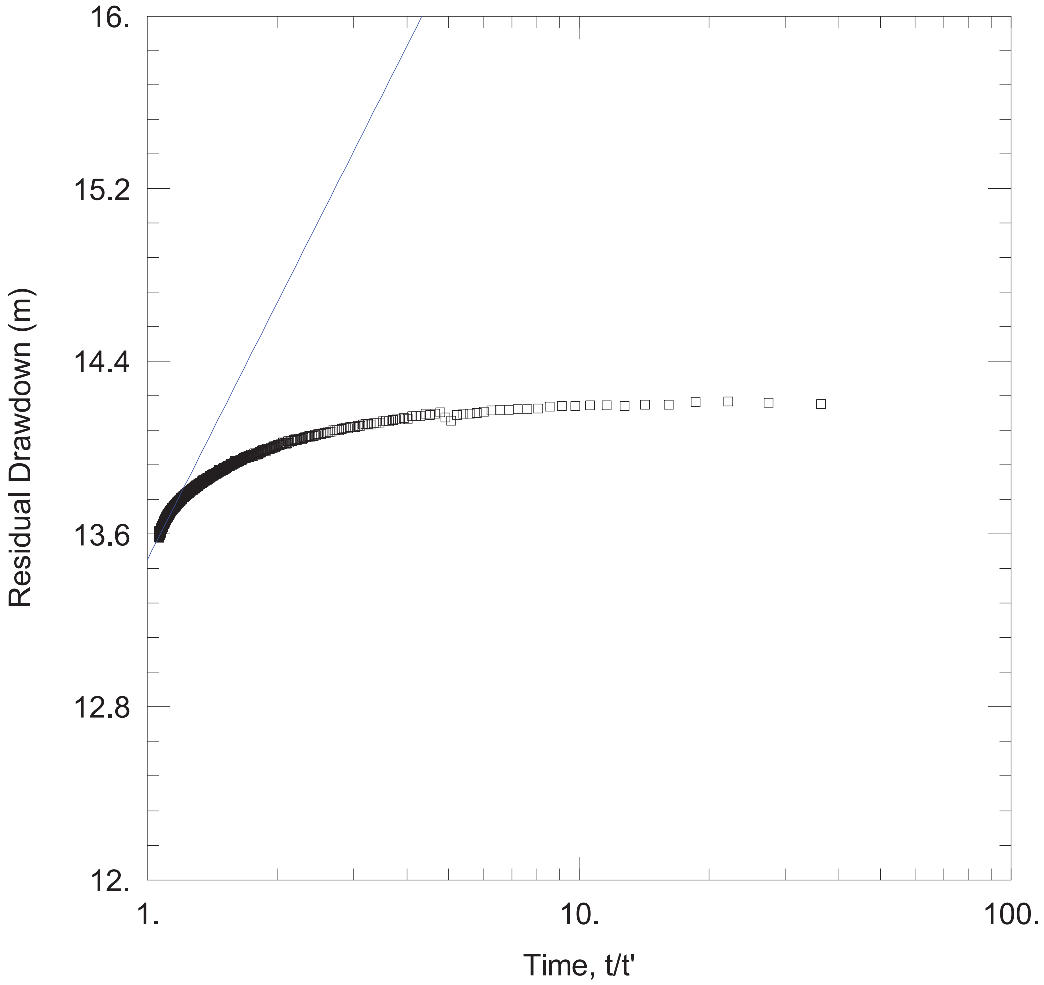
Appendix B – Pumping Test Results

Well	Test Notes	Logger	Approx. Pumping Start Time	Approx. Pumping Finish Time	Pumping Duration (min)	Volume removed (L)	Average pumping rate (L/s)	Average pumping rate (m^3/s)	Logger installation time	Pre-test GWL (m bgl)	Time	Well Depth (m bgl)	Water Column (m)	End test GWL reading (mbgl)	Manual reading time	GW Diff. Start to End	Trans. Est. 1 (m^2/day)	K Est. 1 (m/day)	Geology of Screen
MW08	Test completed - logger had to be inserted after pumping due to space.	118386	8/04/2014 15:19	8/04/2014 15:31	11.17	24	0.036	3.58E-05	8/04/2014 15:32	2.498	8/04/2014 15:08	10.65	8.15	2.88	8/04/2014 16:52	-0.38	0.024	0.003	Sandstone, Silstone and Shale bands.
MW12	Test completed - logger had to be inserted after pumping due to space.	118386	14/04/2014 10:31	14/04/2014 10:36	4.32	15.5	0.060	5.98E-05	14/04/2014 10:37	6.720	14/04/2014 10:23	10.66	3.94	7.40	14/04/2014 16:25	-0.68	0.141	0.036	Weathered Shale
MW01	Test completed - logger had to be inserted after pumping due to space.	118389	8/04/2014 9:23	8/04/2014 9:50	26.42	50	0.032	3.15E-05	8/04/2014 9:51	6.745	8/04/2014 9:00	22.89	16.15	20.36	8/04/2014 16:23	-13.61	0.126	0.008	Shale/Siltstone
MW16	Test completed - logger had to be inserted after pumping due to space.	118389	9/04/2014 8:47	9/04/2014 9:11	23.88	60	0.042	4.19E-05	9/04/2014 9:12	0.761	9/04/2014 8:37	10.76	10.00	0.69	9/04/2014 13:53	0.08	0.061	0.006	Weathered to competent Siltstone
MW07	Test completed - logger had to be inserted after pumping due to space.	118529	9/04/2014 10:03	9/04/2014 10:42	38.93	75	0.032	3.21E-05	9/04/2014 10:43	11.027	9/04/2014 9:56	45.21	34.18	11.02	9/04/2014 15:05	0.01	1.894	0.055	Siltstone
MW10	Test completed - logger had to be inserted after pumping due to space. Dipper not working for manual readings. Data logger has no recovery response.	118529	14/04/2014 9:40	14/04/2014 9:58	17.58	60	0.057	5.69E-05	14/04/2014 9:59	12.141	22/04/2014 0:00	14.85	-	-	-	-	-	-	Hard Siltstone
MW04	Test completed - logger had to be inserted after pumping due to space.	122479	8/04/2014 12:56	8/04/2014 13:12	15.05	40	0.044	4.43E-05	8/04/2014 13:13	0.691	8/04/2014 12:55	7.00	6.31	0.75	8/04/2014 16:01	-0.05	0.129	0.020	Clay
MW13	Test completed - logger had to be inserted after pumping due to space. Pumped well dry.	122479	9/04/2014 14:18	9/04/2014 14:33	14.45	29	0.033	3.34E-05	9/04/2014 14:34	7.180	14/04/2014 14:15	14.80	7.62	7.11	10/04/2014 7:51	0.07	0.024	0.003	Weathered Shale
MW11	Test completed - logger had to be inserted after pumping due to space.	122487	9/04/2014 11:20	9/04/2014 11:56	35.20	43	0.020	2.04E-05	9/04/2014 11:57	11.252	9/04/2014 11:12	36.50	25.25	24.22	9/04/2014 15:37	-12.96	0.484	0.019	Siltstone
MW03	Test completed - logger had to be inserted after pumping due to space.	122491	8/04/2014 14:01	8/04/2014 14:31	29.62	60	0.034	3.38E-05	8/04/2014 14:32	11.600	8/04/2014 13:45	21.82	10.22	14.10	8/04/2014 16:37	-2.50	0.028	0.003	Shale/Siltstone
MW09	Test completed - logger had to be inserted after pumping due to space - Well bailed as too dirty to pump.	122491	9/04/2014 12:48	9/04/2014 12:53	5.00	10	0.033	3.33E-05	9/04/2014 12:54	4.413	9/04/2014 12:42	10.74	6.33	4.50	9/04/2014 15:20	-0.08	0.060	0.009	Sandstone and Siltstone
MW02	Well dry no test completed.	-	-	-	-	-	-	-	-	28.160	15/04/2014 10:59	28.18	0.02	-	-	-		-	Siltstone
MW05	No test completed. Could not pump water out of well. It appeared the pump could not pump up the level of head required.	-	-	-	-	-	-	-	-	31.205	-	41.025	9.820	-	-	-		-	Siltstone
MW06	Well dry no test completed. 0.5 L of sediment in bottom of well.	-	-	-	-	-	-	-	-	25.025	-	25.855	0.830	-	-	-		-	Siltstone
MW14	Well not installed as yet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
MW15	Well not installed as yet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-



MW01 PUMP TEST

Data Set: N:\AU\Sydney\Projects\21\23174\Technical\Pump tests\MW01b.aqt
Date: 05/30/14 Time: 13:50:02

PROJECT INFORMATION

Company: GHD
Client: RMS
Project: 2123174
Location: Berry to Foxground
Test Well: MW01
Test Date: 08/04/2014

AQUIFER DATA

Saturated Thickness: 16.15 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW01	0	0

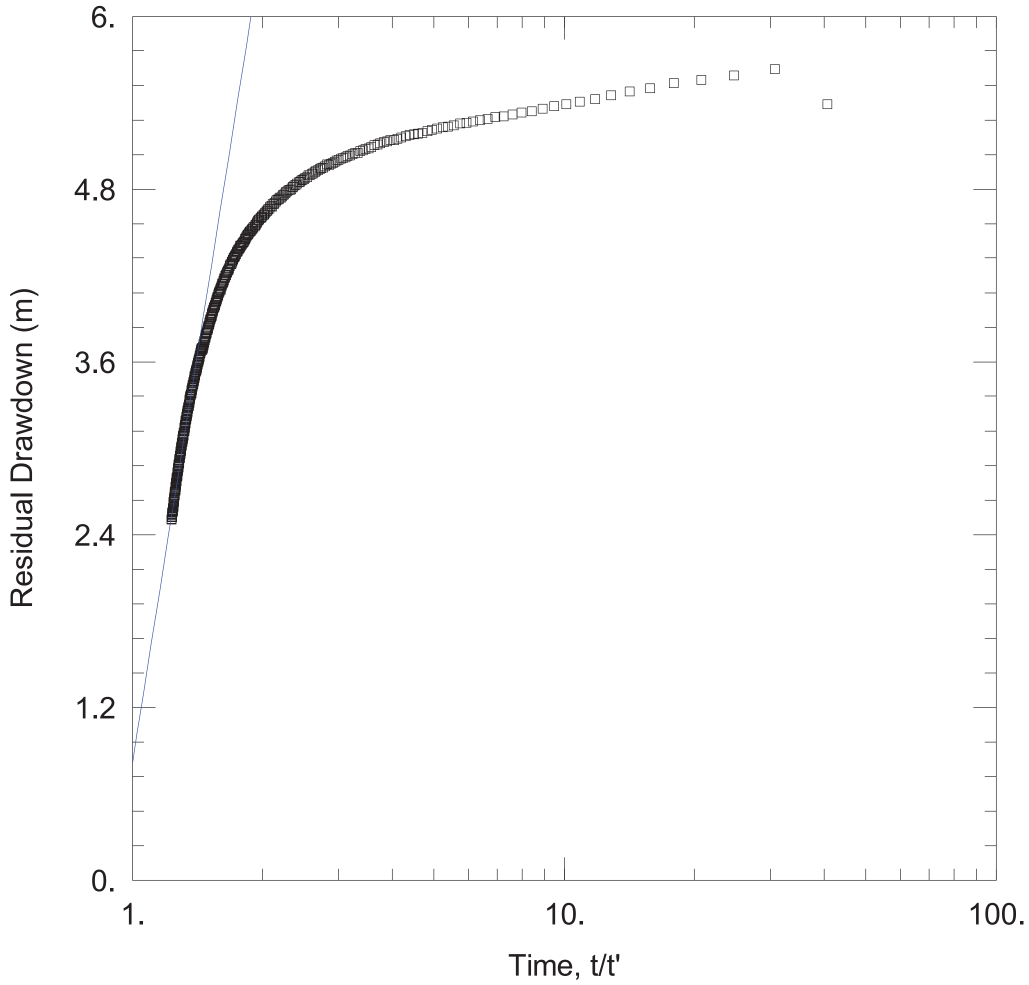
Observation Wells

Well Name	X (m)	Y (m)
□ MW01	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.1262 m^2/day S/S' = 0.0003934



MW03 PUMP TEST

Data Set: N:\AU\Sydney\Projects\21\23174\Technical\Pump tests\MW03a.aqt
Date: 05/30/14 Time: 13:58:45

PROJECT INFORMATION

Company: GHD
Client: RMS
Project: 2123174
Location: Berry to Foxground
Test Well: MW03
Test Date: 08/04/2014

AQUIFER DATA

Saturated Thickness: 10.22 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW03	0	0

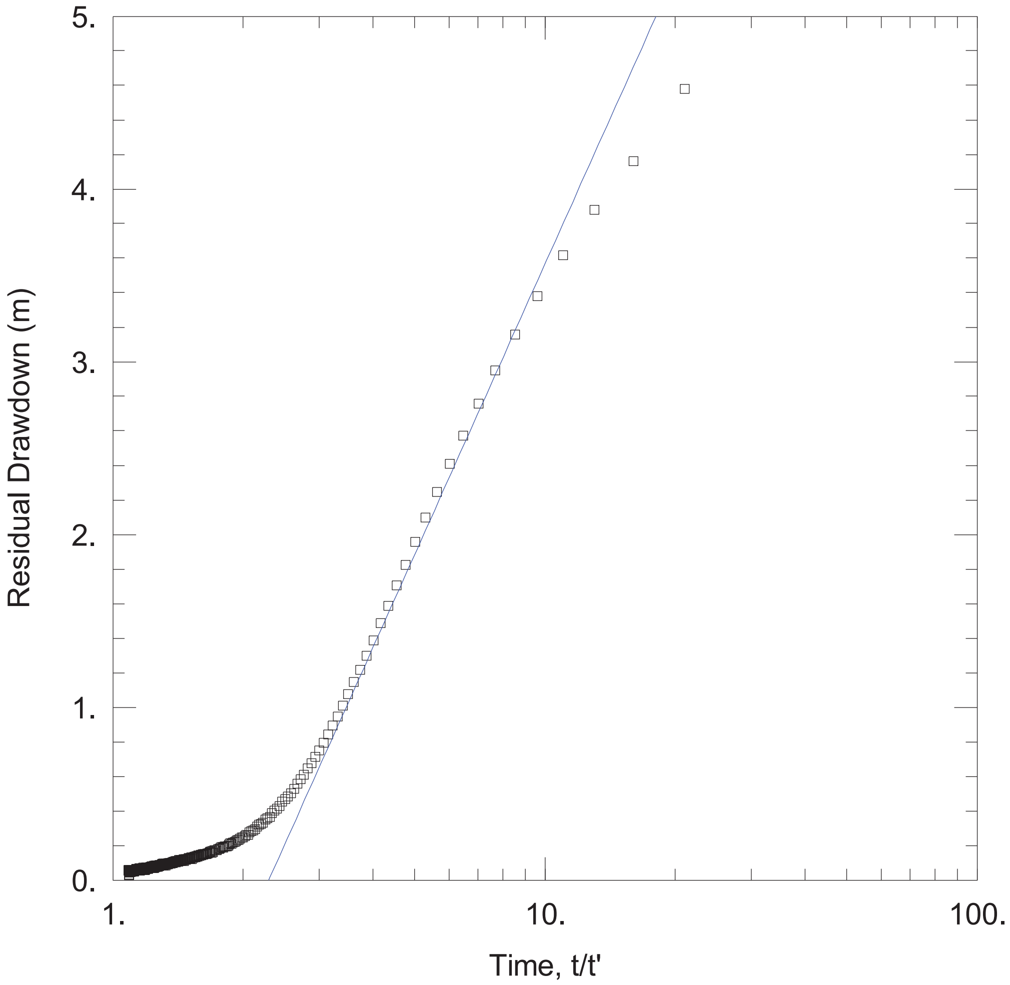
Observation Wells

Well Name	X (m)	Y (m)
□ MW03	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.02833 m^2/day S/S' = 0.906



MW04 PUMP TEST

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Date: 05/30/14 Time: 13:56:49

PROJECT INFORMATION

Company: GHD
Client: RMS
Project: 2123174
Location: Berry to Foxground
Test Well: MW04
Test Date: 08/04/2014

AQUIFER DATA

Saturated Thickness: 6.309 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW04	0	0

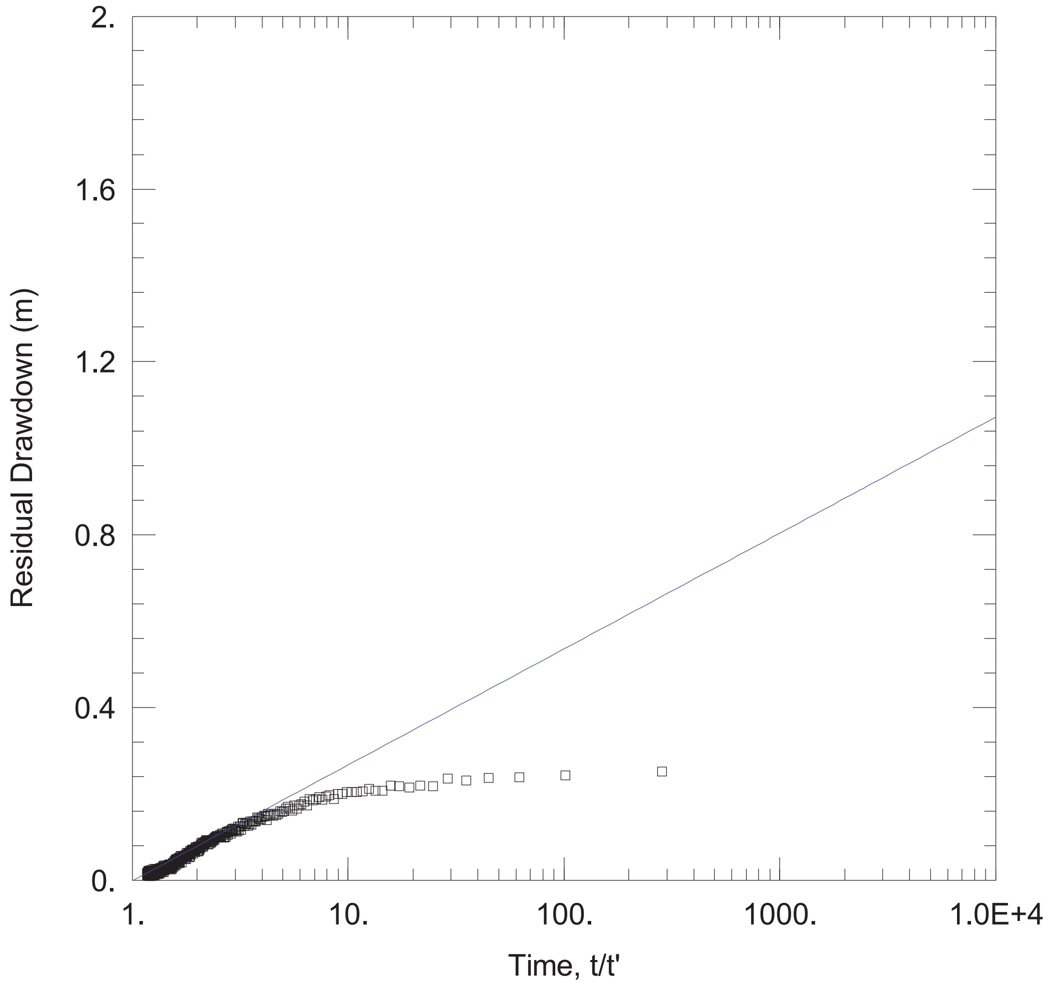
Observation Wells

Well Name	X (m)	Y (m)
□ MW04	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.1257 m^2/day S/S' = 2.295



MW07 PUMP TEST

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Date: 05/30/14 Time: 13:54:31

PROJECT INFORMATION

Company: GHD
Client: RMS
Project: 2123174
Location: Berry to Foxground
Test Well: MW07
Test Date: 09/04/2014

AQUIFER DATA

Saturated Thickness: 34.18 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW07	0	0

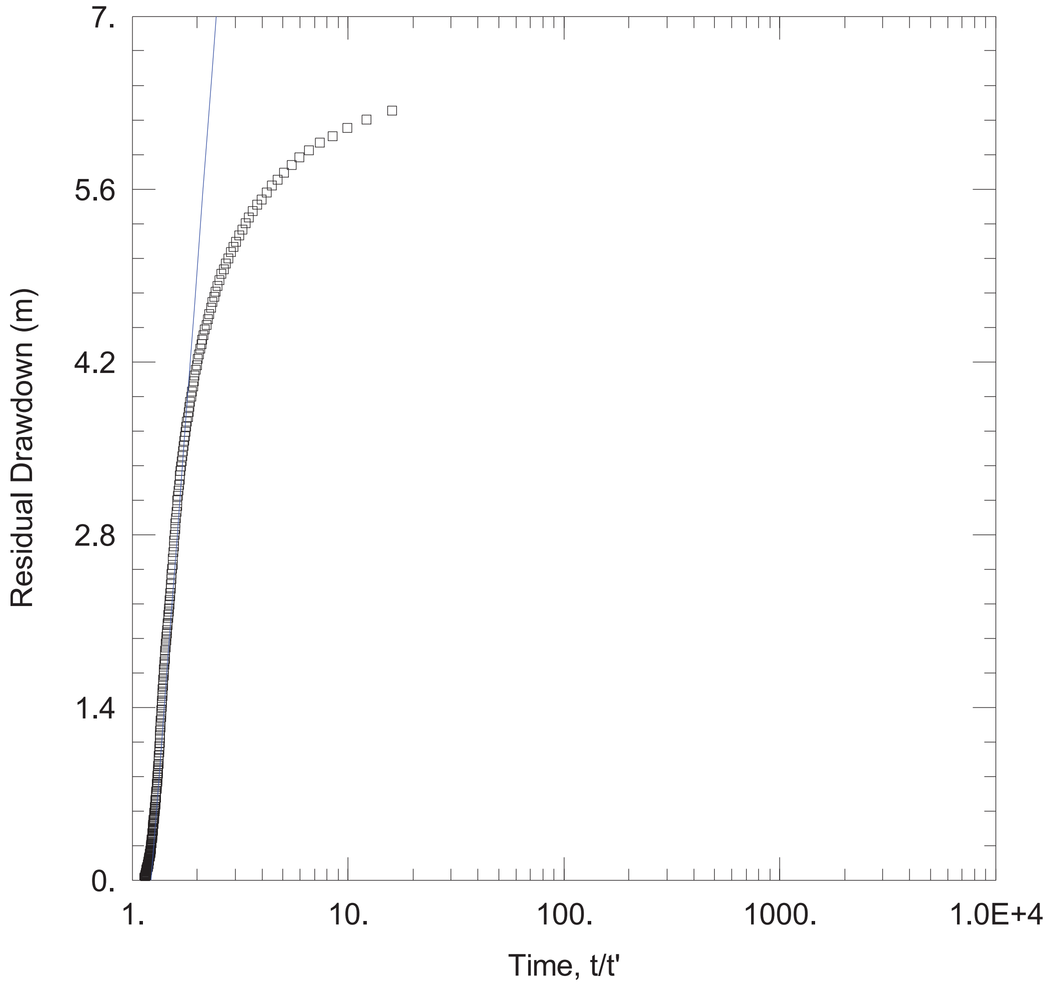
Observation Wells

Well Name	X (m)	Y (m)
□ MW07	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 1.894 m^2/day S/S' = 1.019



MW08 PUMP TEST

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Date: 05/30/14 Time: 13:51:04

PROJECT INFORMATION

Company: GHD
Client: RMS
Project: 2123174
Location: Berry to Foxground
Test Well: MW08
Test Date: 08/04/2014

AQUIFER DATA

Saturated Thickness: 8.15 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW08	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ MW08	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

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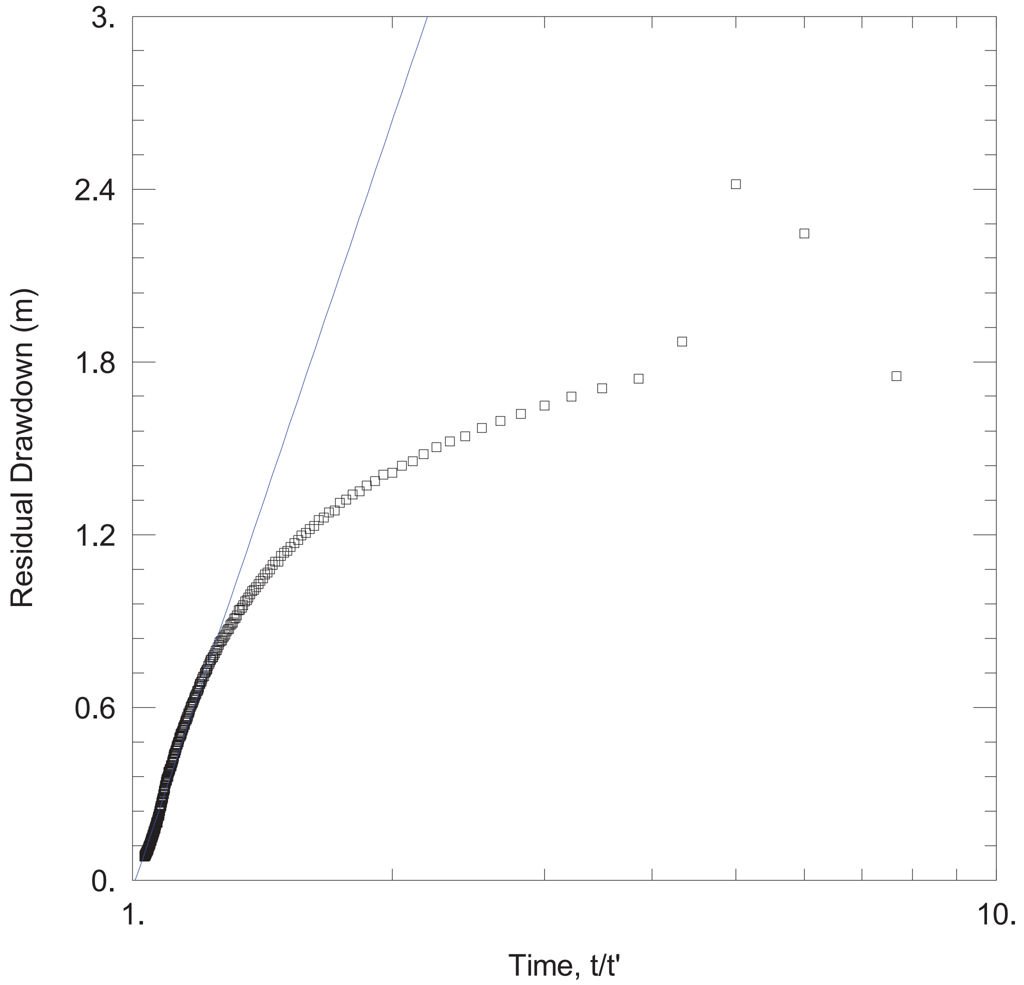

MW09 PUMP TEST

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Date: 05/30/14 Time: 13:59:21

PROJECT INFORMATION

Company: GHD
Client: RMS
Project: 2123174
Location: Berry to Foxground
Test Well: MW09
Test Date: 09/04/2014

AQUIFER DATA

Saturated Thickness: 6.327 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW09	0	0

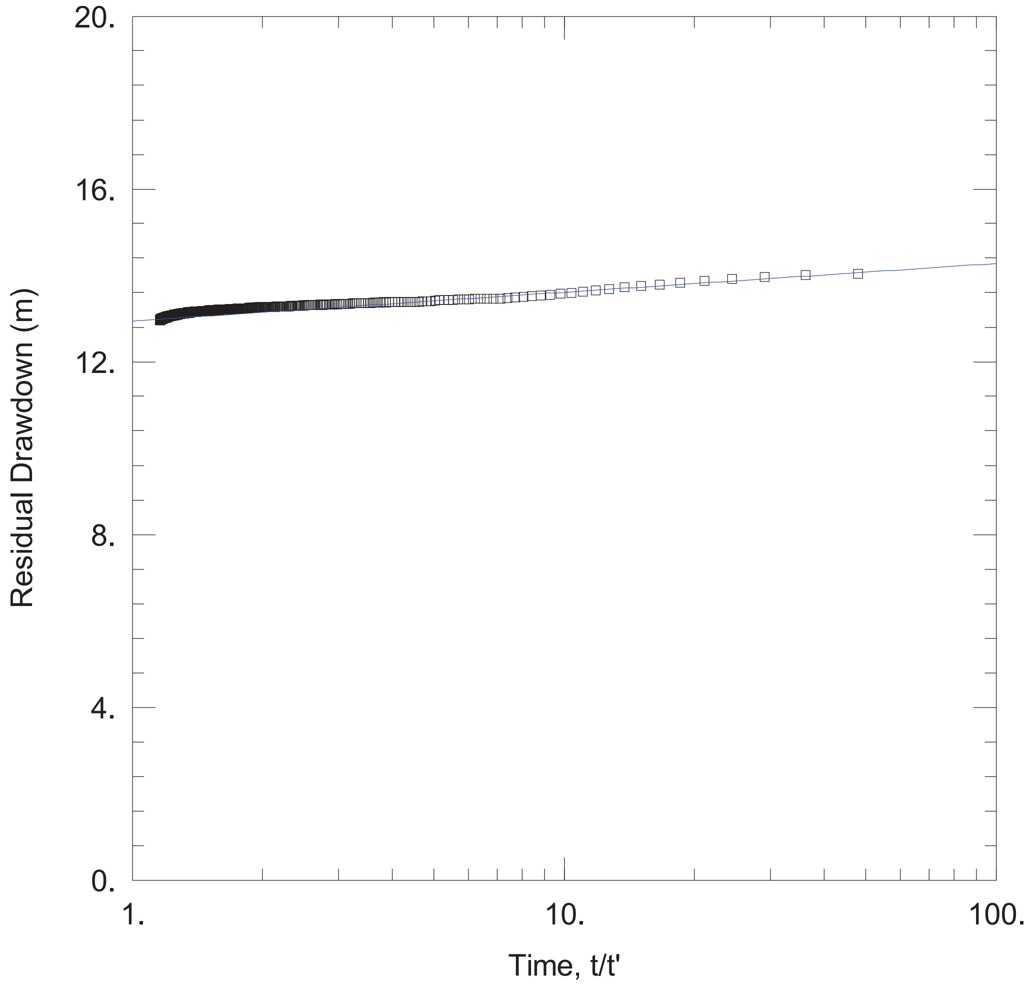
Observation Wells

Well Name	X (m)	Y (m)
□ MW09	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.0595 m^2/day S/S' = 1.009



MW11 PUMP TEST

Data Set: N:\AU\Sydney\Projects\21\23174\Technical\Pump tests\MW11a.aqt
Date: 05/30/14 Time: 13:58:17

PROJECT INFORMATION

Company: GHD
Client: RMS
Project: 2123174
Location: Berry to Foxground
Test Well: MW11
Test Date: 08/04/2014

AQUIFER DATA

Saturated Thickness: 25.25 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW11	0	0

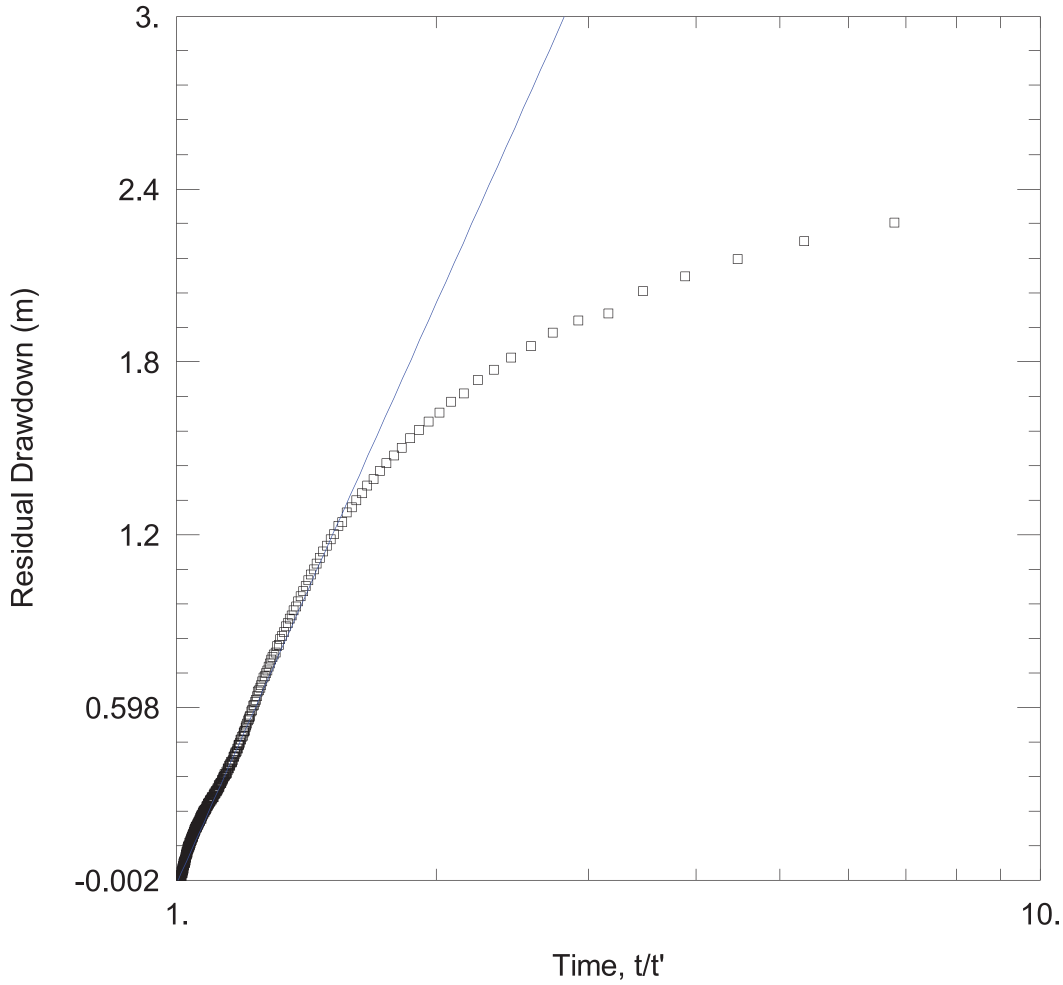
Observation Wells

Well Name	X (m)	Y (m)
□ MW11	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.4844 m^2/day S/S' = 3.556E-20



MW12 PUMP TEST

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Date: 05/30/14 Time: 13:51:23

PROJECT INFORMATION

Company: GHD
Client: RMS
Project: 2123174
Location: Berry to Foxground
Test Well: MW12
Test Date: 14/04/2014

AQUIFER DATA

Saturated Thickness: 3.936 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW12	0	0

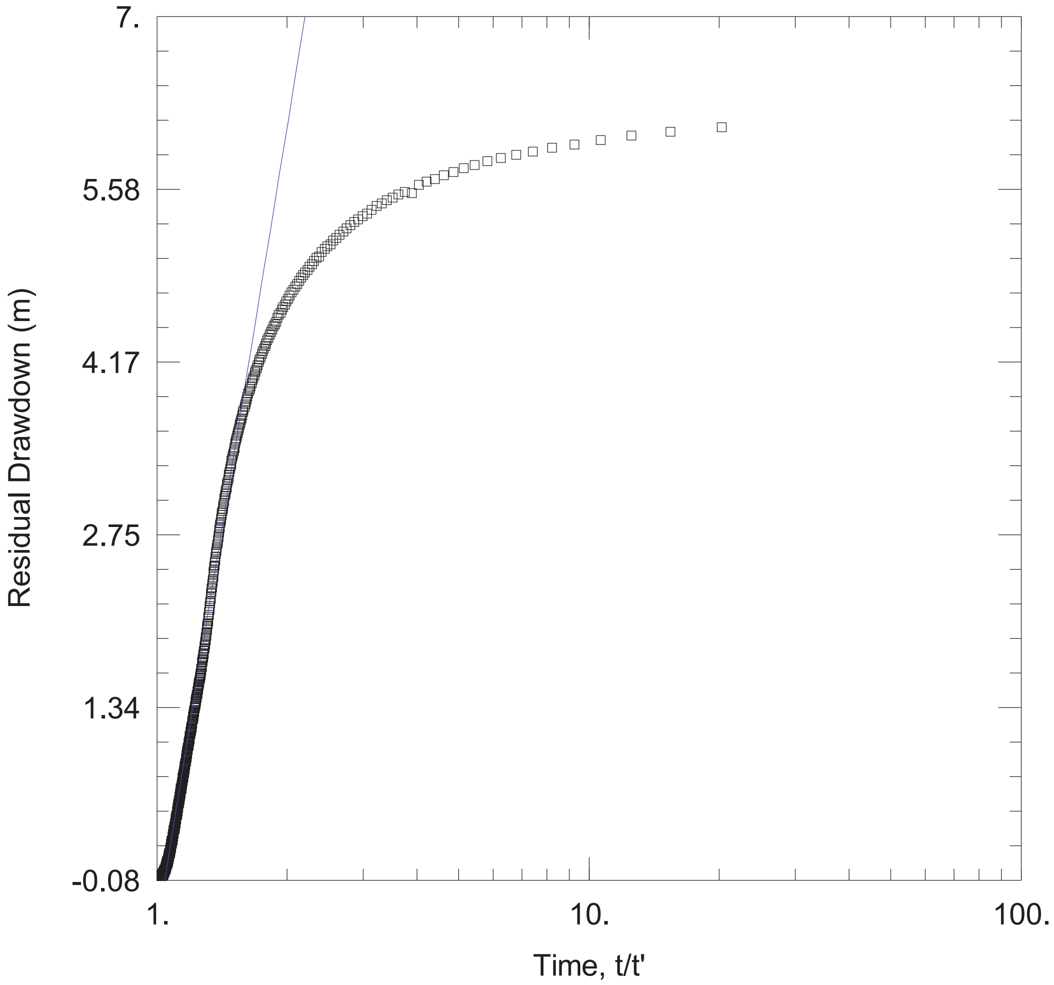
Observation Wells

Well Name	X (m)	Y (m)
□ MW12	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.1413 m^2/day S/S' = 1.006



MW13 PUMP TEST

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Date: 05/30/14 Time: 13:57:18

PROJECT INFORMATION

Company: GHD
Client: RMS
Project: 2123174
Location: Berry to Foxground
Test Well: MW13
Test Date: 08/04/2014

AQUIFER DATA

Saturated Thickness: 7.62 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW13	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ MW13	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

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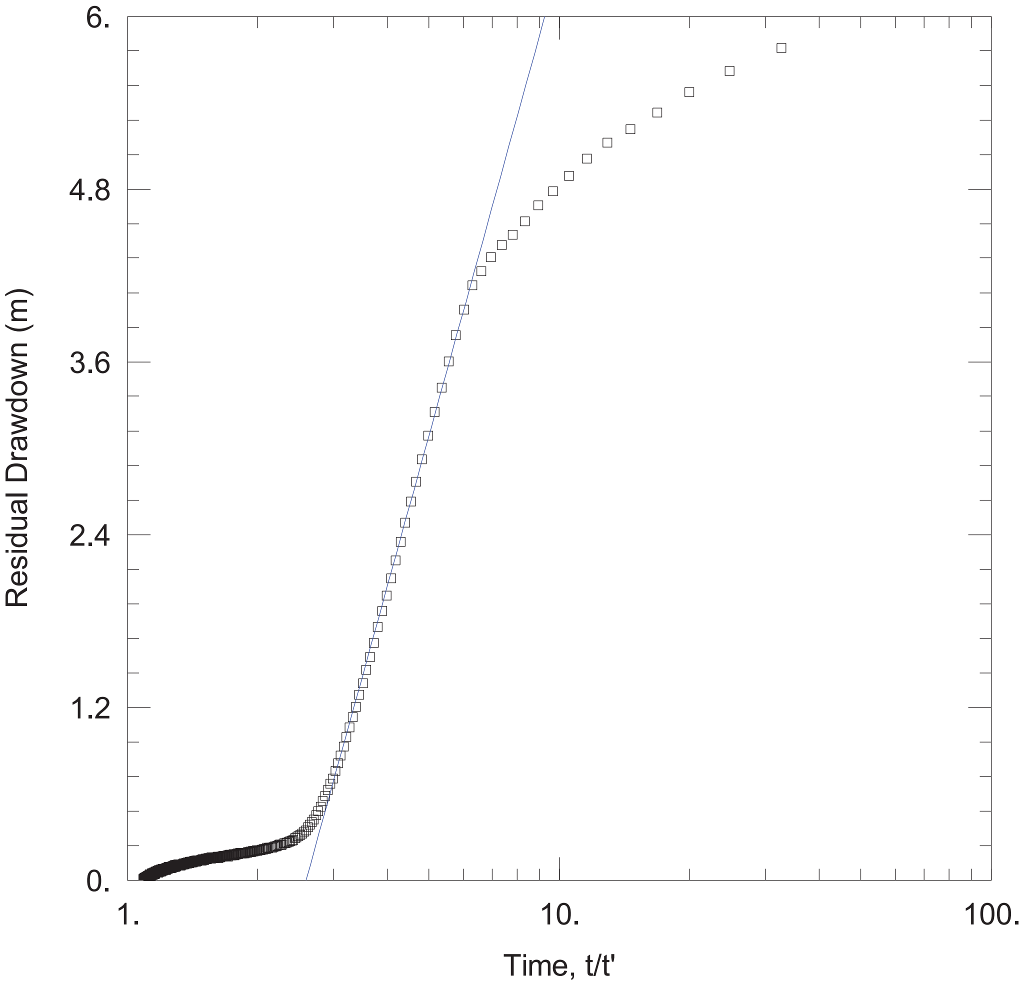

MW16 PUMP TEST

Data Set: N:\AU\Sydney\Projects\21\23174\Technical\Pump tests\MW16a.aqt
Date: 05/30/14 Time: 13:52:05

PROJECT INFORMATION

Company: GHD
Client: RMS
Project: 2123174
Location: Berry to Foxground
Test Well: MW16
Test Date: 08/04/2014

AQUIFER DATA

Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
MW16	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ MW16	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.06107 m^2/day S/S' = 2.595

Client: RMS	**Monitoring Well ID:** MW01
Project: FBB	**Date:** 8/4/14
Job Number: 21/23174.	**Logged by:** NR.
Subject: Hydraulic Conductivity Testing	**Checked by:**
Slug Test: GHD Procedure E13.	22.890
SWL (m) prior logger:	6.745 S/N 118389 - install @ 9.00
SWL (m) with logger:	6.743
Depth (from TOC m) of logger:	20m
Scan Rate (Seconds):	15 sec
SLUG used:	
Conduct Test (See computer file)	Pump
SWL post test with SLUG in hole	
1min-	15L = 6.06
2min-	30L = 13.15
SWL post test with SLUG removed	45L = 22.15
1min-	50L = 26.25
2 min-	- Well dry
Falling / Rising Head Test	
Minutes after SLUG test:	Pull up pump - disturb logger
SWL (m) pre-test with logger:	
Depth (from TOC m) of logger:	log back in @ 9:51
Litres introduced (falling head)	21.050 SWL.
Duration of pump out / litres pumped out (rising head)	20.975 956
Conduct Test (See computer file)	
SWL post test (logger still in hole)	20.355 @ 16:23
1min-	
2min-	logger removed
3min-	16:24
4min-	
5min-	
Repeat Test (if appropriate)	

Client: RMS	**Monitoring Well ID:** MW02
Project: FBB	**Date:** 15/4/14
Job Number: 21/23174	**Logged by:** NR.
Subject: Hydraulic Conductivity Testing	**Checked by:**
Slug Test: GHD Procedure E13.	
SWL (m) prior logger:	28.160m @10:59
SWL (m) with logger:	DT Bottom at 28.180 m
Depth (from TOC m) of logger:	
Scan Rate (Seconds):	Dry - confirmed
SLUG used:	w/ bailer.
Conduct Test (See computer file)	
SWL post test with SLUG in hole	
1min-	
2min-	
SWL post test with SLUG removed	
1min-	
2 min-	
Falling / Rising Head Test	
Minutes after SLUG test:	
SWL (m) pre-test with logger:	
Depth (from TOC m) of logger:	
Litres introduced (falling head)	
Duration of pump out / litres pumped out (rising head)	
Conduct Test (See computer file)	
SWL post test (logger still in hole)	
1min-	
2min-	
3min-	
4min-	
5min-	
Repeat Test (if appropriate)	

no lock - Jane to buy one

Access Gate → #368
Girrakool letter box
Push button to open gate

/

13:45.

Client:	RMS	**Monitoring Well ID:**	MW03
Project:	FBB	**Date:**	8/4/14.
Job Number:	21/23174	**Logged by:**	NR
Subject: Hydraulic Conductivity Testing		**Checked by:**	
Slug Test: GHD Procedure E13.		S/N 122491	
SWL (m) prior logger:		11.600 21.815	
SWL (m) with logger:			
Depth (from TOC m) of logger:		10L = 4.25	
Scan Rate (Seconds):		20L = ~~[illegible]~~ 9.19	
SLUG used:		30L = 14.05	
Conduct Test (See computer file)		40L = 19.05	
SWL post test with SLUG in hole		50L = 24.27	
1min-		60L = 29.46	
2min-			
SWL post test with SLUG removed		Logger installed 14:32.	
1min-		16.913 @ 14:33	
2 min-		16.800 @ 14:37	
Falling / Rising Head Test			
Minutes after SLUG test:			
SWL (m) pre-test with logger:		14.103 @ 16:37	
Depth (from TOC m) of logger:			
Litres introduced (falling head)		Logger removed	
Duration of pump out / litres pumped out (rising head)		@ 16:38.	
Conduct Test (See computer file)			
SWL post test (logger still in hole)			
1min-			
2min-			
3min-			
4min-			
5min-			
Repeat Test (if appropriate)			

455
403 Princes

Client: RMS	**Monitoring Well ID:** MW04.
Project: FBB	**Date:** 8/4/14
Job Number: 21/23174	**Logged by:** NR
Subject: Hydraulic Conductivity Testing	**Checked by:** SN 122479
Slug Test: GHD Procedure E13.	12:55
SWL (m) prior logger:	0.691 7.00
SWL (m) with logger:	
Depth (from TOC m) of logger:	
Scan Rate (Seconds):	
SLUG used:	10L 3:35
Conduct Test (See computer file)	15L 5:08
SWL post test with SLUG in hole	20L 7:47
1min-	30L 11:30
2min-	40L 15:03
SWL post test with SLUG removed	
1min-	Grey Turbid water
2 min-	thicker w/ depth
Falling / Rising Head Test	
Minutes after SLUG test:	
SWL (m) pre-test with logger:	
Depth (from TOC m) of logger:	Logger installed
Litres introduced (falling head)	13:13
Duration of pump out / litres pumped out (rising head)	3.80 @ 13:13
Conduct Test (See computer file)	
SWL post test (logger still in hole)	
1min-	
2min-	0.745 @ 16:01
3min-	logger removed
4min-	16:02
5min-	
Repeat Test (if appropriate)	

Client: RMS	**Monitoring Well ID:** MW05.
Project: FBB	**Date:** 8/4/14
Job Number: 2123174.	**Logged by:** NR
Subject: Hydraulic Conductivity Testing	**Checked by:**
Slug Test: GHD Procedure E13.	
SWL (m) prior logger:	31.205 41.025
SWL (m) with logger:	Couldn't pump
Depth (from TOC m) of logger:	Pump would not lift
Scan Rate (Seconds):	water.
SLUG used:	
Conduct Test (See computer file)	
SWL post test with SLUG in hole	
1min-	
2min-	
SWL post test with SLUG removed	
1min-	
2 min-	
Falling / Rising Head Test	
Minutes after SLUG test:	
SWL (m) pre-test with logger:	
Depth (from TOC m) of logger:	
Litres introduced (falling head)	
Duration of pump out / litres pumped out (rising head)	
Conduct Test (See computer file)	
SWL post test (logger still in hole)	
1min-	
2min-	
3min-	
4min-	
5min-	
Repeat Test (if appropriate)	

Client: RMS	**Monitoring Well ID:** MW06
Project: FBB	**Date:** 8/4/14
Job Number: 21/23174	**Logged by:** NR.
Subject: Hydraulic Conductivity Testing	**Checked by:**
Slug Test: GHD Procedure E13.	
SWL (m) prior logger:	25.025 25.856
SWL (m) with logger:	dry
Depth (from TOC m) of logger:	no test
Scan Rate (Seconds):	0.5L sediment in bottom
SLUG used:	of bailer.
Conduct Test (See computer file)	
SWL post test with SLUG in hole	
1min-	
2min-	
SWL post test with SLUG removed	
1min-	
2 min-	
Falling / Rising Head Test	
Minutes after SLUG test:	
SWL (m) pre-test with logger:	
Depth (from TOC m) of logger:	
Litres introduced (falling head)	
Duration of pump out / litres pumped out (rising head)	
Conduct Test (See computer file)	
SWL post test (logger still in hole)	
1min-	
2min-	
3min-	
4min-	
5min-	
Repeat Test (if appropriate)	

S/N 118529

Client: RMS	**Monitoring Well ID:** MW07
Project: FBB	**Date:** 9/4/14
Job Number: 21/23174	**Logged by:** NR.
Subject: Hydraulic Conductivity Testing	**Checked by:**
Slug Test: GHD Procedure E13.	45.21
SWL (m) prior logger:	11.027 @ 9:56
SWL (m) with logger:	
Depth (from TOC m) of logger:	Pump start @10:06
Scan Rate (Seconds):	
SLUG used:	15L @ 6:47
Conduct Test (See computer file)	30L @ 14:40
SWL post test with SLUG in hole	45L @ 22:41
1min-	60L @ 31.07.
2min-	75L @ 38:56
SWL post test with SLUG removed	pump stop.
1min-	
2 min-	Logger installed @ 10:43.
Falling / Rising Head Test	
Minutes after SLUG test:	14.50 @ 10:43
SWL (m) pre-test with logger:	12.680 @ 10:48.
Depth (from TOC m) of logger:	
Litres introduced (falling head)	11.021 @ 15:04
Duration of pump out / litres pumped out (rising head)	
Conduct Test (See computer file)	
SWL post test (logger still in hole)	Logger + baro
1min-	removed
2min-	@15:05.
3min-	
4min-	
5min-	
Repeat Test (if appropriate)	

From neighbour lane - Bush fence. 15m Sump

not stressed minimal drawdown

Client: RMS		**Monitoring Well ID:** MW08	
Project: FBB		**Date:** 8/4/14.	
Job Number: 21/23174		**Logged by:** NR.	
Subject: Hydraulic Conductivity Testing		**Checked by:**	
Slug Test: GHD Procedure E13.		S/N 118386 10.048	
SWL (m) prior logger:		2.498 @ 15.04	
SWL (m) with logger:			
Depth (from TOC m) of logger:		10L @ 3:57.	
Scan Rate (Seconds):		20L @ 8:24	
SLUG used:		24L @ 11:10	
Conduct Test (See computer file)			
SWL post test with SLUG in hole		Logger installed @ 15:32	
1min-		8.675 @ 15:32.	
2min-		7.570 @ 15:38.	
SWL post test with SLUG removed			
1min-			
2 min-			
Falling / Rising Head Test			
Minutes after SLUG test:		2.875 @ 16:52	
SWL (m) pre-test with logger:			
Depth (from TOC m) of logger:		Logger removed	
Litres introduced (falling head)			
Duration of pump out / litres pumped out (rising head)		16:52.	
Conduct Test (See computer file)			
SWL post test (logger still in hole)			
1min-			
2min-			
3min-			
4min-			
5min-			
Repeat Test (if appropriate)			

Client: RMS	**Monitoring Well ID:** MW09
Project: FBB	**Date:** 9/4/14
Job Number: 21/23174.	**Logged by:** NK.
Subject: Hydraulic Conductivity Testing	**Checked by:**
Slug Test: GHD Procedure E13.	10.740
SWL (m) prior logger:	4.413 @ 12:42
SWL (m) with logger:	
Depth (from TOC m) of logger:	S/N 122491
Scan Rate (Seconds):	
SLUG used:	Removed 10L
Conduct Test (See computer file)	by bailing.
SWL post test with SLUG in hole	Too muddy by car
1min-	
2min-	Think bailer was getting
SWL post test with SLUG removed	caught on a join.
1min-	Logger installed @ 12:54.
2 min-	6.04 @ 12.55
Falling / Rising Head Test	
Minutes after SLUG test:	
SWL (m) pre-test with logger:	
Depth (from TOC m) of logger:	4.495 @ 15:20
Litres introduced (falling head)	
Duration of pump out / litres pumped out (rising head)	Logger removed
Conduct Test (See computer file)	15:21.
SWL post test (logger still in hole)	
1min-	
2min-	
3min-	
4min-	
5min-	
Repeat Test (if appropriate)	

Client: RMS	**Monitoring Well ID:** MW10
Project: FBB	**Date:** 14/4/14
Job Number: 21/23174	**Logged by:** NL
Subject: Hydraulic Conductivity Testing	**Checked by:**
Slug Test: GHD Procedure E13.	
SWL (m) prior logger:	~~14/4/14~~ Dip meter not
SWL (m) with logger:	working.
Depth (from TOC m) of logger:	10L @ 3:00
Scan Rate (Seconds):	20L @ 6:14
SLUG used:	30L @ 9:10
Conduct Test (See computer file)	40L @ 12:04.
SWL post test with SLUG in hole	50L @ ~~[illegible]~~ 14:45
1min-	60L a 17:35
2min-	
SWL post test with SLUG removed	S/N 118529
1min-	Clear.
2 min-	
Falling / Rising Head Test	Logger installed @ 9:59
Minutes after SLUG test:	12.550 @ 10:00
SWL (m) pre-test with logger:	
Depth (from TOC m) of logger:	Removed @ 16:17
Litres introduced (falling head)	Well dry.
Duration of pump out / litres pumped out (rising head)	
Conduct Test (See computer file)	
SWL post test (logger still in hole)	
1min-	
2min-	
3min-	
4min-	
5min-	
Repeat Test (if appropriate)	

Client:	AMS	**Monitoring Well ID:**	MW11
Project:	FBB	**Date:**	9/4/14
Job Number:	21/23174	**Logged by:**	NR
Subject: Hydraulic Conductivity Testing		**Checked by:**	

Slug Test: GHD Procedure E13.	S/N122487
SWL (m) prior logger:	11.252 @ 11.12 36.5
SWL (m) with logger:	
Depth (from TOC m) of logger:	10L @ 4:42
Scan Rate (Seconds):	20L @ 10:50
SLUG used:	30L @ 18:25
Conduct Test (See computer file)	40L @ 30:06
SWL post test with SLUG in hole	43L @ 35:12
1min-	
2min-	Pump stop → no longer
SWL post test with SLUG removed	pumping
1min-	
2 min-	
Falling / Rising Head Test	
Minutes after SLUG test:	Logger installed @ 11:57
SWL (m) pre-test with logger:	24.632 @ 12:02
Depth (from TOC m) of logger:	24.610 @ 12:05
Litres introduced (falling head)	
Duration of pump out / litres pumped out (rising head)	24.215 @ 15:37
Conduct Test (See computer file)	
SWL post test (logger still in hole)	Logger removed
1min-	@ 15:37
2min-	
3min-	
4min-	
5min-	
Repeat Test (if appropriate)	

massive drawdown

MW10 removed @16:17, Well dry

Client: RMS	**Monitoring Well ID:** MW12.
Project: FBB	**Date:** 14/4/14
Job Number: 21/23174	**Logged by:** NR
Subject: Hydraulic Conductivity Testing	**Checked by:**
Slug Test: GHD Procedure E13.	
SWL (m) prior logger:	6.720 @10:23 10.650
SWL (m) with logger:	~~9.3 @10.35~~ 9.125m @10.37
Depth (from TOC m) of logger:	
Scan Rate (Seconds):	10L @ 2:24
SLUG used:	15.5 @ 4:19.
Conduct Test (See computer file)	
SWL post test with SLUG in hole	S/N 118386. Logger installed.
1min-	16:25 7.398
2min-	
SWL post test with SLUG removed	Logger removed
1min-	16:25
2 min-	
Falling / Rising Head Test	
Minutes after SLUG test:	
SWL (m) pre-test with logger:	
Depth (from TOC m) of logger:	
Litres introduced (falling head)	
Duration of pump out / litres pumped out (rising head)	
Conduct Test (See computer file)	
SWL post test (logger still in hole)	
1min-	
2min-	
3min-	
4min-	
5min-	
Repeat Test (if appropriate)	

S/N 122479

Client: RMS	Monitoring Well ID: MW13
Project: FBB	Date: ~~8~~ 9/4/14.
Job Number: 21/23174	Logged by: NR.
Subject: Hydraulic Conductivity Testing	**Checked by:**

Slug Test: GHD Procedure E13.	14.80
SWL (m) prior logger:	7.180 @ 14:15
SWL (m) with logger:	
Depth (from TOC m) of logger:	10L @ 4:35
Scan Rate (Seconds):	20L @ 9:29
SLUG used:	29L @ 14:27
Conduct Test (See computer file)	dry.
SWL post test with SLUG in hole	
1min-	Logger installed @ 14:34
2min-	
SWL post test with SLUG removed	~~14~~ 13.465 @ 14:35
1min-	12.660 @ 14:43 - dip meter ~~not working~~ properly.
2 min-	
Falling / Rising Head Test	
Minutes after SLUG test:	
SWL (m) pre-test with logger:	Logger left overnight.
Depth (from TOC m) of logger:	
Litres introduced (falling head)	7.108 @ 7:51
Duration of pump out / litres pumped out (rising head)	
Conduct Test (See computer file)	logger removed
SWL post test (logger still in hole)	@ 7:52
1min-	
2min-	
3min-	
4min-	
5min-	
Repeat Test (if appropriate)	

Client: RMS	**Monitoring Well ID:** BW16
Project: FBB	**Date:** 9/4/14
Job Number: 21/23174.	**Logged by:** NR.
Subject: Hydraulic Conductivity Testing	**Checked by:**
Slug Test: GHD Procedure E13.	S/N 118389.
SWL (m) prior logger:	0.761 @ 8:37. 10.761
SWL (m) with logger:	Logger
Depth (from TOC m) of logger:	10L = ~~4:12~~ 4:19
Scan Rate (Seconds):	20L = 8:04.
SLUG used:	30L = 12:01
Conduct Test (See computer file)	40L = 15:52
SWL post test with SLUG in hole	50L = 20.02.
1min-	60L = 23.53. @ 9.12
2min-	Logger installed @ ~~5.95~~
SWL post test with SLUG removed	5.98 @ 9.12
1min-	5.50 @ 9:13
2 min-	
Falling / Rising Head Test	
Minutes after SLUG test:	
SWL (m) pre-test with logger:	0.686 @ 13:53
Depth (from TOC m) of logger:	
Litres introduced (falling head)	Logger removed
Duration of pump out / litres pumped out (rising head)	13:54.
Conduct Test (See computer file)	
SWL post test (logger still in hole)	
1min-	
2min-	
3min-	
4min-	
5min-	
Repeat Test (if appropriate)	

Appendix C – Summary of Groundwater Levels

Table B1. A summary of groundwater level information

Well ID	EASTING	NORTHING	Well Depth (m blg)	Inside of Boundary?	Average GW Level (m bgl)	Variation in GW levels (m)	Response to rainfall	Period of data
CBH02	283473.35	6145307.28	16.2	No	4.45^^			
CBH05	286506.88	6145441.04	7.5	No	0.65^^			
CBH06	286860.61	6146530	12.5	No	0.36^^			
CBH08	289214.94	6147809.01	6.6	No	2.54			
CBH11	289360.09	6151157.1	4.2	No	-			
CBH13	292004.2	6150866.61	8.95	Yes	3.47^^			
CBH15	293530.18	6151294.7	8.0	Yes	6.67^^			
CBH16	296184.46	6152071.25	9.0	No	3.74^^			
CBH17	295092.08	6153406.06	13.62	No	1.30^^			
CBH19	298874.34	6152750.34	12.0	No	5.0**	3.0**	Moderate to High	20/11/10 to 11/1/11**
CBH20	301239.56	6155714.67	8.5	No	3.30^^			
G1	295864.2	6152239.3	8.0	No	3.0**	5.5**	Negligible	27/5/10 to 07/01/11**
G2	295519.8	6152482.8	20.0	No	4.47^^			
G3	295708.3	6152417.5	40.5	No	7.75^^			
P1	296205.8	6152733.4	8.5	Yes	7.5**	2.0**	Negligible	27/5/10 to 07/01/11**
P2	295813.5	6152940.1	13.4		5.15^^			
P3	295962.6	6152796.3	30.5	Yes	7.5**	6.0**	Moderate to High	27/5/10 to 07/01/11**

Well ID	EASTING	NORTHING	Well Depth (m blg)	Inside of Boundary?	Average GW Level (m bgl)	Variation in GW levels (m)	Response to rainfall	Period of data
BH01	301653.37	6156540.64	5.5	No	0.88	1.46	Moderate - High	20/11/09 to 3/08/10 30/10/10 to 11/1/11
BH02	301250.92	6155730.31	8.0	No	5.31	2.48	Moderate	21/11/09 to 2/06/10 30/10/10 to 11/1/11
BH03A	301104.53	6154902.29	7.5	No				
BH04B	300271.55	6153226.18	5.8	No	1.99	2.22	Moderate -high	22/12/10 to 11/1/11
BH05	300137.54	6153148.58	8.5	No	7.62	6.45	Negligible	21/11/10 to 11/1/11
BH06	300013.93	6153018.17	7.0	No	1.62	0.34	Negligible	30/10/10 to 11/1/11 and manual dip data
BH07	298991.58	6152935.28	7.0	No	8.98	1.66	Negligible	30/10/09 to 25/04/10 30/10/10 to 11/1/11
BH08	298846.28	6152746.64	10.0	No	8.10	3.59	Moderate	21/11/09 to 30/04/10 30/10/10 to 11/1/11
BH09	297999.89	6152536.68	7.0	No	4.79	6.91	Moderate (manual dip data)	21/11/10 to 1/05/10 30/10/10 to 11/1/11
BH10	296938.63	6152286.9	7.38	Yes	0.94	1.15	Moderate -High	20/11/09 to 3/08/10 30/10/10 to 11/1/11
BH11	296508.42	6152503.63	10.0	Yes				

Well ID	EASTING	NORTHING	Well Depth (m blg)	Inside of Boundary?	Average GW Level (m bgl)	Variation in GW levels (m)	Response to rainfall	Period of data
BH12	296021.34	6152870.2	14.0	Yes	7.66	5.34	High responses, not completely related to rainfall	20/11/09 to 3/08/10 30/10/10 to 11/1/11
BH13	295628.48	6152956.87	9.7	Yes	5.81	2.59	Insufficient data to assess	21/11/09 to 14/03/10 30/10/10 to 11/1/11
BH14	294891.84	6152829.45	6.0	Yes	1.57 (++)	1.23 (++)		Nov 2009 to Jan 2010
BH15	294334.18	6152176.02	8.0	Yes	5.42 (++)	1.23 (++)		
BH16	294206.83	6151846.38	7.0	Yes	4.6 (++)	0.71 (++)		
BH18	293870.39	6151503.79	10.0	Yes	8.96 (++)	1.84 (++)		
BH19	293479.76	6151476.89	10.0	Yes	3.06 (++)	1.54 (++)		
BH20	293082.14	6151254.67	9.0	Yes	7.97 (++)	0.76 (++)		
BH21	292462.08	6150947.59	10.0	Yes	9.0**	7.00**	Delayed response for May rainfall event, quick response for June	01/05/13 to 05/07/13**
BH22	291575.71	6150861.51	15.19	Yes	6.72 (++)	0.87 (++)		
BH23	290913.91	6150339.1	7.0	Yes	7.20 (++)	1.30 (++)		
BH24	290127.48	6149931.36	10.0	Yes	6.3 (++)	3.45 (++)		
BH26	290073.85	6149892.06	10.0	Yes	6.5**	4.0**	Moderate to High	01/05/13 to 05/07/13
BH28	289566.37	6149866.52	9.5	Yes	2.64 (++)	0.80 (++)		
BH29	288315.65	6149624.85	10.0	Yes	5.0**	2.5**	Low to Moderate	01/05/13 to 05/07/13

Well ID	EASTING	NORTHING	Well Depth (m blg)	Inside of Boundary?	Average GW Level (m bgl)	Variation in GW levels (m)	Response to rainfall	Period of data
BH30	281033.12	6144003.25	8.0	No	4.45 (++)	3.64 (++)		
BH31	280453.72	6143462.75	9.0	No	5.34 (++)	3.64 (++)		
K01	301412.74	6155949.81		No	1.14	0.28		30/10/10 to 11/1/11
K03	301334.56	6155787.03		No	0.59	1.01	High responses, not related to rainfall	30/10/10 to 11/1/11
K07	301271.11	6155625.53		No	0.84	1.36	High responses, not related to rainfall	30/10/10 to 11/1/11
K31	300752.84	6154119.86		No	1.98	0.24	Negligible	30/10/10 to 11/1/11
K33	300470.23	6153669.94		No				
K37					4.74	3.88	High responses, not related to rainfall	30/10/10 to 11/1/11
K55	299072	6152902.53		No	5.03	0.52	Moderate	30/10/10 to 11/1/11
K56	299084.78	6152874.21		No	8.73	1.13	High	30/10/10 to 11/1/11
K58	298929.77	6152773.79		No	6.47	3.72	High	30/10/10 to 11/1/11
K59	298876.64	6152790.84		No	2.52	3.01	High	30/10/10 to 11/1/11
K63	298379.67	6152587.42		No	4.13	0.61	Negligible	30/10/10 to 11/1/11

Well ID	EASTING	NORTHING	Well Depth (m blg)	Inside of Boundary?	Average GW Level (m bgl)	Variation in GW levels (m)	Response to rainfall	Period of data
K65	297969.91	6152516.88		No	3.41	0.91	High	30/10/10 to 11/1/11
L01	302011	6156755		No				
L18	297699	6152503		No				
L20	298850	6152843		No				
B1	290290.64	6149969.46		Yes				
B4	289982.28	6148914.05		No				
B8	289070.01	6148357.54		No				
B14	287108.99	6147635.18		No				
B17	287355.24	6148169.58		Yes				
B22	286783.31	6147011.35		No				
F01	296595.74	6152458.95		Yes				
F11	293441.97	6151450.61		Yes	8.50**	2.0**	Negligible	01/05/13 to 05/07/13
F13	293128.76	6151250.77		Yes	Well pumped between 06/5/13 to 05/07/13			
F14	292603.54	6150989.12		Yes				
F15	292546.67	6150967.97		Yes	10.00**	0.8**	Negligible	Manual dip data only between 01/5/13 and 05/07/13
F21	291410.7	6150668.84		Yes	6.0**	3.0**	High	01/05/13 to 05/07/13
F22	290853.49	6150312.34		Yes				
F33	288372.45	6149660.88		Yes				

Well ID	EASTING	NORTHING	Well Depth (m blg)	Inside of Boundary?	Average GW Level (m bgl)	Variation in GW levels (m)	Response to rainfall	Period of data
F35	287912.59	6149084.98		Yes	7.0**	1.5**	Negligible	01/05/13 to 05/07/13
F38	287551.95	6148574.66		Yes	4.0**	6.0**	High	01/05/13 to 05/07/13

** Values based on visual assessment of visualised rainfall data. No dataset available.

^^ Single data point observed either during drilling or after development

(++) Calculated by using minimum and maximum SWL (mbgl) using Table 5.3, Golder 2010

Appendix D – Stakeholder Comments

NSW GOVERNMENT | **Department of Primary Industries**
Office of Water

Contact: Bob Britten
Phone: 02 6491 8209
Fax: 02 6492 3019
Email: bob.britten@water.nsw.gov.au

Stefan Charteris
GHD
133 Castlereagh St
Sydney NSW 2000

Our ref: 10 ERM2014/0563
File No:
Your Ref:

8 July 2014

Dear Stefan,

Re: Proposed Development - Princes Highway Upgrade - Foxground Berry Bypass Review of Groundwater Monitoring Plan

This letter is in regard of the NSW Office of Water (NOW) review of Water Quality Monitoring Groundwater Monitoring Plan dated June 2014 for the proposed Princes Highway upgrade – Foxground Berry Bypass Project. Comment is based on a review of the following information:

- GHD, June 2014, "Roads and Maritime Services, Princes Highway Upgrade – Foxground to Berry Bypass Project, Water Quality Monitoring Groundwater Monitoring Plan"

The Groundwater Monitoring Plan provides a sound basis to establish baseline groundwater hydrology and water quality data prior to construction. As previously commented the regional setting and layout as presented for the groundwater modelling is supported. The objectives of the Plan which is to monitor the potential impact of the upgrade on surface and groundwater quality ....is adequately supported in the ensuing sections 7 to 12 of the report.

The NSW Office of Water supports the current Monitoring Plan and looks forward to reviewing the ongoing outcomes as presented in the Annual progress reports

Please direct any questions or correspondence to Bob Britten, bob.britten@water.nsw.gov.au.

Yours sincerely

Bob Britten
Senior Water Regulation Officer
Office of Water - Water Regulatory Operations South

Department of Primary Industries
Office of Water

NSW GOVERNMENT

Contact: Bob Britten
Phone: 02 6491 8209
Fax: 02 6492 3019
Email: bob.britten@water.nsw.gov.au

Graham Roche
Roads and Maritime Services
Level Ground 153 Auckland Street
Bega NSW 2550

Our ref: 10 ERM2014/0563
File No:
Your Ref:

1 July 2014

Dear Graham,

Re: Proposed Development - Princes Highway Upgrade - Foxground Berry Bypass Review of Groundwater assessment

This letter is in regard of the NSW Office of Water (NOW) review of groundwater assessment for the proposed Princes Highway upgrade – Foxground Berry Bypass Project. Comment is based on a review of the following information:

- GHD, 2014, "Roads and Maritime Services, Princes Highway Upgrade – Foxground to Berry Bypass Project, Groundwater Flow Model"
- Discussions with Stephan Charteris from GHD
- Roads and Maritime proposed Schedule of activities - June 2014 to April 2015

The Groundwater Flow Model provides a good representation of the groundwater hydrology and is considered a suitable tool to assess the likely impacts of the proposed highway development on the local groundwater system. The developed model provides a reasonable representation of the landscape geology, geomorphology and hydrogeology, the assumptions are reasonable and with the steady state calibration possible at this stage the model is considered a reasonable representation of the expected groundwater flow regime. The model predictions are subsequently supported. The section on "Model Limitations" is also considered a reasonable reality check/assessment of the model's abilities.

It is noted that the report identifies development/refinement of the model with the collection of ongoing monitoring data, "*paying particular attention to the potential variation in impacts associated with changes in storage under high and low flow conditions*".

With regard to the required time to undertake background monitoring, discussions have included the suitability of some reduction to the proposed 12 months monitoring/benchmarking prior to commencement of works. Notably, if selective works commencement were in areas of modelled low groundwater impact. NOW is of the view that the key, is collecting data representing the likely a range of water level /water quality parameters and that majority of the required information would probably be achieved within the first 9 months. Ongoing review of monitoring data being collected would be able to confirm the suitability of the data set.

Please direct any questions or correspondence to Bob Britten, bob.britten@water.nsw.gov.au.

Yours sincerely

Bob Britten
Senior Water Regulation Officer
Office of Water - Water Regulatory Operations South

Our reference: DOC14/115248

Contact: Michael Heinze 6229 7002

Mr Stefan Charteris
Principal Hydrogeologist
GHD Pty Ltd
Level 15, 133 Castlereagh Street
SYDNEY NSW 2000

2 July 2014

Dear Mr Charteris,

Re: Foxground to Berry Bypass Project – Groundwater Flow Model and Water Quality Monitoring - Groundwater Monitoring Plan

Thank you for your emails on 26 May and 10 June 2014 inviting the Environment Protection Authority (EPA) to comment on GHD's draft *Groundwater Flow Model* and *Water Quality Monitoring: Groundwater Monitoring Plan* (the plans) for the Foxground to Berry bypass project, prepared for Roads and Maritime Services (RMS) as required by the Project Approval under the *Environmental Planning and Assessment Act 1979*.

As you are aware, RMS is proposing to upgrade 11.6 km of the Princess Highway between Toolijooa Road north of Foxground and Schofields Lane south of Berry on the NSW South Coast. As part of the project approval conditions (CoA B15 and CoA B16), RMS is required to prepare and implement a Water Quality Monitoring Program and undertake groundwater modelling on the concept design in consultation with the Office of Environment and Heritage (OEH), EPA, Department of Primary Industries (DPI) (Fishing and Aquaculture) and NSW Office of Water (NOW). The primary objectives of these plans are to detail the groundwater flow modelling and the monitoring plan in order to effectively meet the overall project objectives, which are:

- Assess the construction and operational impact of the concept design on groundwater resources, quality, hydrology, groundwater dependent ecosystems and provide details of contingency and management measures
- Assess the potential impact of the project on the water quality to protect aquatic ecology and ecosystems in all the adjacent catchments and water courses; and
- Assess the potential impact of the program on groundwater hydrology in order to protect licensed bores, dams, watercourses, water bodies and groundwater dependent ecosystems in adjacent catchments.

These steps will help to ensure that appropriate mitigation and management measures are implemented in order to prevent soil erosion, the discharge of sediments and pollutants from the project, and any impacts due to drawdown of groundwater during construction and operational phases to be in accordance with the *ANZECC 2000a Freshwater and Marine Water Guidelines,* and compliant with Section 120 of the *Protection of the Environment Operations Act 1997* and the future Environment Protection Licence (EPL) for the project.

The EPA encourages the development of such plans to ensure that proponents have determined how they will meet their statutory obligations and environmental objectives as specified by any project/development approvals and/or the conditions of the operator's EPL. However, it is not the role of the EPA to approve or endorse such management plans. The EPA's role is to set conditions for environmental protection and management through a licence and regulate compliance with those conditions. Notwithstanding this, the EPA has conducted a brief review of the draft Surface Water and Groundwater Sampling Protocol prepared by GHD Pty Ltd for Roads and Maritime Services.

The plans appear adequate and the EPA has only a couple of comments to make at this stage. The groundwater modelling is based on conceptual design information, which may not represent the final design conditions. As mentioned throughout the plans, the EPA agrees and recommends that the modelling be revised once there is more certainty on the design levels and construction design, and that further modelling should be undertaken to assess non-uniqueness in the modelling outcomes. Additionally, results of the comparison of current hydraulic data that is being collected along the alignment against the values derived from the automatic calibration should be included in these plans when they are complete. Any additional modelling necessary to understand potential impacts should be carried out before construction commences.

Several areas along the preferred bypass route have been identified as having a high probability of acid sulphate soils (ASS) occurrence that may pose severe environmental risks if disturbed. Before undertaking any detailed assessments of the presence and risk of ASS, the EPA recommends seeking advice on appropriate sampling design and analytical framework from a practitioner with ASS experience. Consultation with appropriate topic specialists should also be arranged in order to assess the potential impacts of groundwater drawdown on in-stream aquatic ecology and groundwater dependent ecosystems and the risk of settlement issues.

Groundwater well GW105826 does not have an upgradient monitoring well to monitor for emerging water quality impacts, and should therefore be decommissioned, or should be added to the groundwater quality monitoring schedule. Also, additional wells may be required to monitor for potential impacts associated with acid sulphate soil exposure and settlement impacts.

Finally, Table 11 (page 65) details the roles and responsibilities for management in the operational phase of the Foxground Berry Bypass. The NSW EPA is listed in this table as having part responsibility for the review of the Annual Progress Reports and Incident Reports, and to provide feedback as necessary. It should be noted that while the project will be licensed by the EPA during the construction phase, the EPL will not be required during the operational phase of the project. In light of this, the EPA will not have a formal management role post-construction, except in the case of pollution incidents where it assumes the role of Appropriate Regulatory Authority under section 6 of the *Protection of the Environment Operations Act* 1997 for the activities of RMS. The EPA recommends that this report be updated to reflect these changes before construction commences so that it may be read as a stand-alone report.

As a management tool, such plans should assist RMS in meeting its commitment to statutory compliance and wider environmental management and, where appropriate, should be integrated with other operational or management plans. The EPA recommends that these plans be audited to an industry standard or certified to the ISO 14001 standard (if applicable) as part of any overall environmental management system. The collection of quality assurance and control samples during sampling is an important measure in order to ensure the integrity of the datasets. Additionally, the EPA endorses the use of a nominated NATA accredited laboratory to analyse water quality parameters and contaminants of potential concern.

The EPA reminds RMS that the person or organisation that will manage the premises is required to apply for an environment protection licence under the *Protection of the Environment Operations Act* 1997 (POEO Act) prior to the commencement of any scheduled activities or development work for the Berry to Foxground bypass. This is different and separate from holding a development consent issued by a planning authority such as the Department of Planning or your local council.

I trust this information is of assistance. Should you have any queries or wish to discuss the EPA's response, please contact me on Ph: 6229 7002.

Yours sincerely,

Julian Thompson
Unit Head – South East Region
NSW Environment Protection Authority

Stefan Charteris

From:	Julian Thompson <Julian.Thompson@epa.nsw.gov.au>
Sent:	Wednesday, 9 July 2014 4:57 PM
To:	Stefan Charteris
Cc:	Cristina Venables
Subject:	RE: GHD file(s) . . .Draft groundwater monitoring plan - for you

Hi Stefan,
Your email below reflects the conversation we had yesterday clarify the EPA written comments on the matter.
Cheers
Julian.

Julian Thompson
Unit Head - South East Region | NSW Environment Protection Authority
☎: (02) 6229 7002 | 🖷: (02) 6229 7006 | ✉: julian.thompson@epa.nsw.gov.au

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From: Stefan Charteris [mailto:Stefan.Charteris@ghd.com]
Sent: Tuesday, 8 July 2014 5:59 PM
To: Thompson Julian
Subject: RE: GHD file(s) . . .Draft groundwater monitoring plan - for you

Hi Julian,

Further to our discussion today re-the acid sulphate soils intersection issue raised in your response letter to the review of the FBB groundwater monitoring plan I understand we came to the following conclusions.

- Whether the zone is of high or low risk is to acid sulphate soils is essentially irrelevant as from the EPA's perspective acid sulphate soil maps are for screening purposes only and have raised a potential issue of acid sulphate soil generation that needs to be considered further.
- Consultation with a specialist in acid sulphate soils is required given this risk. Subject to this consultation mitigation measures may or may not be considered necessary.
- Consultation should be undertaken at detailed design phase, with any subsequent mitigation measures built into the design if required.

If you are happy with these conclusions please let me know via email and I will forward them to RMS and include them as part of consultation documentation in the report. Otherwise, if you can provide any changes you feel are necessary to represent your understanding of our conversation that would be greatly appreciated.

Best regards,
Stefan

From: Julian Thompson [mailto:Julian.Thompson@epa.nsw.gov.au]
Sent: Tuesday, 10 June 2014 4:28 PM
To: Stefan Charteris
Subject: RE: GHD file(s) . . .Draft groundwater monitoring plan - for you

Stefan,
10MB should be OK.
Julian.

Nicole Rosen

From:	Stefan Charteris
Sent:	Wednesday, 2 July 2014 4:21 PM
To:	Nicole Rosen
Subject:	FW: File Downloaded

CompleteRepository:	2123174
Description:	Berry to Foxground Water Qaulity Monitoring
JobNo:	23174
OperatingCentre:	21
RepoEmail:	2123174@ghd.com
RepoType:	Job

From: SendThisFile Customer Service [mailto:info@sendthisfile.com]
Sent: Thursday, 12 June 2014 12:47 PM
To: Stefan Charteris
Subject: File Downloaded

Sender: stefan.charteris@ghd.com
Recipient: trevor.daly@dpi.nsw.gov.au
Upload Date: 2014-06-10 00:22:34.0

The following file was downloaded on 2014-Jun-11:
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Nicole Rosen

From:	Stefan Charteris
Sent:	Monday, 30 June 2014 9:34 AM
To:	Nicole Rosen
Subject:	FW: Berry to Foxground Bypass Princes Highway Upgrade

CompleteRepository:	2123174
Description:	Berry to Foxground Water Qaulity Monitoring
JobNo:	23174
OperatingCentre:	21
RepoEmail:	2123174@ghd.com
RepoType:	Job

From: Peter Marczan [mailto:Peter.Marczan@epa.nsw.gov.au]
Sent: Thursday, 19 June 2014 5:06 PM
To: Stefan Charteris
Cc: Graham.Roche@rms.nsw.gov.au
Subject: RE: Berry to Foxground Bypass Princes Highway Upgrade

Stefan, apologies for this, I have just spoken to Graham. I received your message a week or so ago and while on leave but had actioned it. I am currently in a different position and am not the contact for an issue like this. I have forwarded your email to Penny Vella in OEH who is currently acting Team Leader Water Quality and will speak to her in the morning. While I cannot provide firm advice, it is unlikely that OEH will have an interest in this other than any work it has done to provide advice to the EPA. I will ask Penny to confirm a position as soon as possible.

Peter

Peter Marczan
A/Manager Noise Policy | NSW Environment Protection Authority |
☎: (02) 9995 6059 | Mobile ☎: 0429 944 451 | 🖷: (02) 9995 5935 | 🖰: peter.marczan@environment.nsw.gov.au

---

From: Stefan Charteris [mailto:Stefan.Charteris@ghd.com]
Sent: Thursday, 19 June 2014 4:46 PM
To: Pritchard Tim; Marczan Peter; james.dawson@environment.gov.au
Cc: Graham.Roche@rms.nsw.gov.au; saman.liyanaarachchi@rms.nsw.gov.au; ZHIVANOVICH Steve (Steve.ZHIVANOVICH@rms.nsw.gov.au)
Subject: Berry to Foxground Bypass Princes Highway Upgrade

Tim, Peter, James,

As part of developing the groundwater and surface water monitoring network for Roads and Maritime Services (RMS) for the Foxground to Berry Bypass Princes Highway Upgrade we are obliged (as part of the conditions of approval) to consult with OEH.

I spoke on an informal basis with James on 3 April 2014 re-the project and he mentioned that he was having input with the project from a biodiversity and threatened species perspective with the ecological monitoring plan being developed by Toby Lambert from Parsons Brinkerhoff. As such he was of the opinion that our work was not of major significance in regards to biodiversity and threatened species for OEH. James noted however, that both Tim and Peter may have an interest in the project outcomes.

I would like to obtain written feedback from you on whether you are satisfied with the existing level of OEH contact with the project (i.e. with the contact that James has had with the project) or subsequently whether you would like to obtain the surface water and groundwater monitoring plan documents and the sampling protocol document for comment.

For the purposes of understanding the level of consultation that has been undertaken to date, the documents have been provided to the EPA, NOW and DPI from which we've had varying degrees of response. The EPA and DPI have been detailed in their response, while NOW, after a number of teleconferences, have preferred to take an overarching position based on the degree of risk posed to groundwater dependent systems/resources.

If you could get back to me as soon as possible with a preferred position/approach of OEH for consultation on this project that would be much appreciated.

Regards,

Stefan Charteris
Principal Hydrogeologist

GHD
T: 61 2 9239 7472 | F: 61 2 9239 7199 | V: 217472| M: 61 451 576 222 | E: Stefan.Charteris@ghd.com
Level 15 133 Castlereagh St Sydney NSW 2000 Australia | http://www.ghd.com/
Water | Energy & Resources | Environment | Property & Buildings | Transportation

Nicole Rosen

From:	Stefan Charteris
Sent:	Monday, 30 June 2014 9:34 AM
To:	Nicole Rosen
Subject:	FW: Berry to Foxground Bypass Princes Highway Upgrade

CompleteRepository:	2123174
Description:	Berry to Foxground Water Qaulity Monitoring
JobNo:	23174
OperatingCentre:	21
RepoEmail:	2123174@ghd.com
RepoType:	Job

From: Penny Vella [mailto:Penny.Vella@environment.nsw.gov.au]
Sent: Friday, 20 June 2014 4:34 PM
To: Stefan Charteris; Graham.Roche@rms.nsw.gov.au
Cc: Michael Heinze; Anthony Pik; James Dawson; Kylie McClelland; Tim Pritchard; Marlene Van Der Sterren; Peter Marczan
Subject: FW: Berry to Foxground Bypass Princes Highway Upgrade

Dear Stefan and Graham,

I can confirm that OEH does not need to review the surface water and groundwater monitoring plan documents, or the sampling protocol. As you point out, the EPA is engaging on this issue.

Please continue to keep in touch with OEH regarding the ecological monitoring work.

Kind regards,

Penny Vella
Acting Team Leader - Water Quality
(*Working Tuesday - Friday)*
Regional Operations Group
Office of Environment and Heritage
PO Box A290 Sydney South, NSW 1232
T: 02 9995 6058
W: www.environment.nsw.gov.au

From: Stefan Charteris [mailto:Stefan.Charteris@ghd.com]
Sent: Thursday, 19 June 2014 4:46 PM
To: Pritchard Tim; Marczan Peter; james.dawson@environment.gov.au
Cc: Graham.Roche@rms.nsw.gov.au; saman.liyanaarachchi@rms.nsw.gov.au; ZHIVANOVICH Steve (Steve.ZHIVANOVICH@rms.nsw.gov.au)
Subject: Berry to Foxground Bypass Princes Highway Upgrade

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Regards,

Stefan Charteris
Principal Hydrogeologist

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T: 61 2 9239 7472 | F: 61 2 9239 7199 | V: 217472| M: 61 451 576 222 | E: Stefan.Charteris@ghd.com
Level 15 133 Castlereagh St Sydney NSW 2000 Australia | http://www.ghd.com/
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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	N. Rosen	J. Hallchurch		J. Hallchurch		23/04/14
1	N. Rosen	S. Charteris		S Charteris		30/05/14
2	N. Rosen	S. Charteris		J. Hallchurch		09/07/14

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