LEGEND

- Study Area
- Construction footprint
- Watercourse
- Groundwater monitoring location

Paper Size A4

0 62.5 125 250 375 500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Rankin Park to Jesmond
Groundwater Assessment

Job Number	22-17656
Revision	0
Date	26 Aug 2016

Groundwater monitoring locations

Figure 2-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17656\GIS\Maps\Deliverables\Groundwater\2217656_GW003_GWMonitoring_0.mxd

Data source: Nearmap: Aerial Imagery, 20160331; Aurecon: Construction footprint, 2016; LPI: DTDB, 2012. Created by: fmackay, tmorton

Table 2-1 Groundwater monitoring locations

ID	Easting	Northing	Ground level (m AHD)	Standpipe depth (m bgl)	Screened depth (m bgl)	Proposed Structure	Screened strata
BHAG01	377621.09	6355517.02	131.59	8.7	5.3 – 8.5	Fill 1	Gravelly clay, sandy gravel
BHAG03	377689.3	6355729.58	121.83	11.76	1.75 – 11.76	Cut 1 (Bridge 1)	Residual soil possibly fill (sandy clay), extremely weathered sandstone, tuff, tuffaceous sandstone, coal
BHAG06	377637.87	6355610.93	109.17	25.19	19 – 25.19	Fill 1 (Bridge 1)	Slightly fractured Sandstone, siltstone,
BHAG11	377612.32	6356410.59	54.914	15	9 – 15	Fill 3 (Bridge 3)	Tuffaceous sandstone, tuff, coal (Yard seam), interlaminated sandstone and siltstone
BHAG15	377448.4	6356907.7	63.536	9.78	-	Fill 4	-
BHAG18	377411.59	6357260.53	84.452	28.1	22.1 – 28.1	Cut 4	Tuff
BHAG21	377585.18	6357096.99	83.409	12.19	6.2 – 12.19	Fill 4/Cut 4	Highly fractured to slightly fractured Siltstone, fractured sandstone, fractured coal
BHAG22	377463	6357375	78.5	-	-	Cut 4	-
BHAG23	377607.26	6357608.96	32.718	15.3	9.3 – 15.3	Cut 4	Siltstone, coal, sandstone.
BHAG30	377719.13	6358283.46	10.145	12.09	0.8 – 5.1	Fill 7 (Bridge 6)	Sandy clay, silty clay, silty clayey gravelly sand
BHAG34	377753.43	6358470.76	16.554	10	6 – 9	Bridge 6	Fill (silty clay), gravel, claystone
BHAG41	377394.88	6356950.45	56.124	15	12 – 15	Fill 4	Interlaminated sandstone and mudstone

ID	Easting	Northing	Ground level (m AHD)	Standpipe depth (m bgl)	Screened depth (m bgl)	Proposed Structure	Screened strata
BHAG42	377540.08	6357219.91	85.116	24	15 – 21	Cut 4	Conglomerate, fractured to slightly fractured siltstone, fractured coal, fractured claystone
BHSM05G	377649.35	6357749.55	31.51	33.5	4 – 10	Fill 5 (Bridge 5)	Highly weathered siltstone, interbedded sandstone and siltstone
BHSM08	377633.63	6357882.14	37.326	29.6	24 – 29.6	Cut 5	Coal, sandstone (Waratah sandstone)
BHSM11G	377676.24	6357990.35	30.305	20.2	1.25 – 14	Cut 5	Some silty clay, extremely weathered siltstone, moderately fractured claystone/siltstone, moderately plastic siltstone

m AHD – metres Australian Height Datum

m bgl – metres below ground level

Groundwater levels

All depth to groundwater and groundwater elevation data are provided in Appendix A. Monitoring of groundwater levels has been carried out on a number of occasions (up to five rounds) between 25 May 2015 and 27 August 2015 and an additional round of groundwater level monitoring was carried out on 24 March 2016.

In general, there is considerable spatial variability in groundwater elevations as shown in Figure 2-2. Groundwater elevations tend to vary with topography, indicating perched groundwater conditions. As shown in Figure 2-2, the monitoring locations at higher elevation appear to be intercepting perched groundwater above a siltstone layer of the Newcastle Coal Measures. Recorded groundwater levels at monitoring locations intercepting perched groundwater range from about 21.5 metres AHD at BHSM05G to 125 metres AHD at BHAG01.

However, there is minimal temporal variation in groundwater levels, with groundwater levels varying by less than one metre at almost all monitoring locations. Exceptions to this includes BHSM05G which screens shallow siltstone and sandstone strata, BHAG34 which monitors groundwater levels in fill material to the north of Newcastle Road, and BHAG06 which screens sandstone and siltstone strata. All of these monitoring locations went dry (under natural conditions) in the monitoring period. This suggests that the perched aquifers may be subject to complete drying in some areas under lower rainfall conditions.

At lower topographic elevations, it is considered that groundwater monitoring bores are intercepting regional groundwater of the lower Newcastle Coal Measures and underlying Tomago Coal Measures. Regional groundwater is monitored mostly at the northern portion of the study area. Since the strata dips regionally to the south, it is unlikely that regional groundwater seeps out along the incised valleys in the study area. Monitoring location BHSM08 screens coal (likely to be the Borehole Seam) and the Waratah sandstone at a depth of over 24 m bgl or an elevation of about 8 to 13 metres AHD. Groundwater elevations at BHSM08 were relatively stable over the monitoring period, varying between 11.33 and 11.38 metres AHD during August 2015.

Monitoring bores BHSM11G and BHAG23 screen a range of strata including coal, siltstone and sandstone between about 16 and 29 metres AHD and 17 and 23 metres AHD respectively. Both monitoring bores are also considered to be intercepting regional groundwater. Groundwater level at BHSM11G varied between 14.8 and 16.5 metres AHD during August 2015 while groundwater level at BHAG23 varied between 17 and 18.4 metres AHD during August 2015.

BHAG30 screens a range of strata including shallow sandy clay, silty clay and silty clayey gravelly sand to the south of Newcastle Road. Groundwater levels in the shallow strata varied between 8.15 and 8.64 metres AHD between mid-July and late August 2015.

Groundwater quality

Groundwater sampling was carried out on 20 August 2015 at standpipes BHAG03, BHAG11, BHAG41, BHAG21, BHAG42, BHAG23, BHSM08, BHSM11G, BHAG30 and BHAG06 to characterise existing groundwater quality. Analytical results are summarised in Table 2-2 and Appendix B.

Table 2-2 Groundwater quality summary

Parameter	Units	ANZECC[(a)]	Regional groundwater	Perched groundwater
Arsenic (dissolved)	mg/L	0.013	0.002	0.001 to **0.02**
Cadmium (dissolved)	mg/L	0.0002	< 0.0001 to **0.0102**	< 0.0001 to 0.0001
Chromium (dissolved)	mg/L	0.001	< 0.001 to **0.002**	< 0.001 to **0.002**
Copper (dissolved)	mg/L	0.0014	0.001 to **0.087**	<0.001 to **0.002**
Nickel (dissolved)	mg/L	0.011	**0.139** to **1.750**	0.005 to **0.024**

(a) ANZECC (2000) Fresh water ecosystem trigger values for 95% species protection (used for reference only).

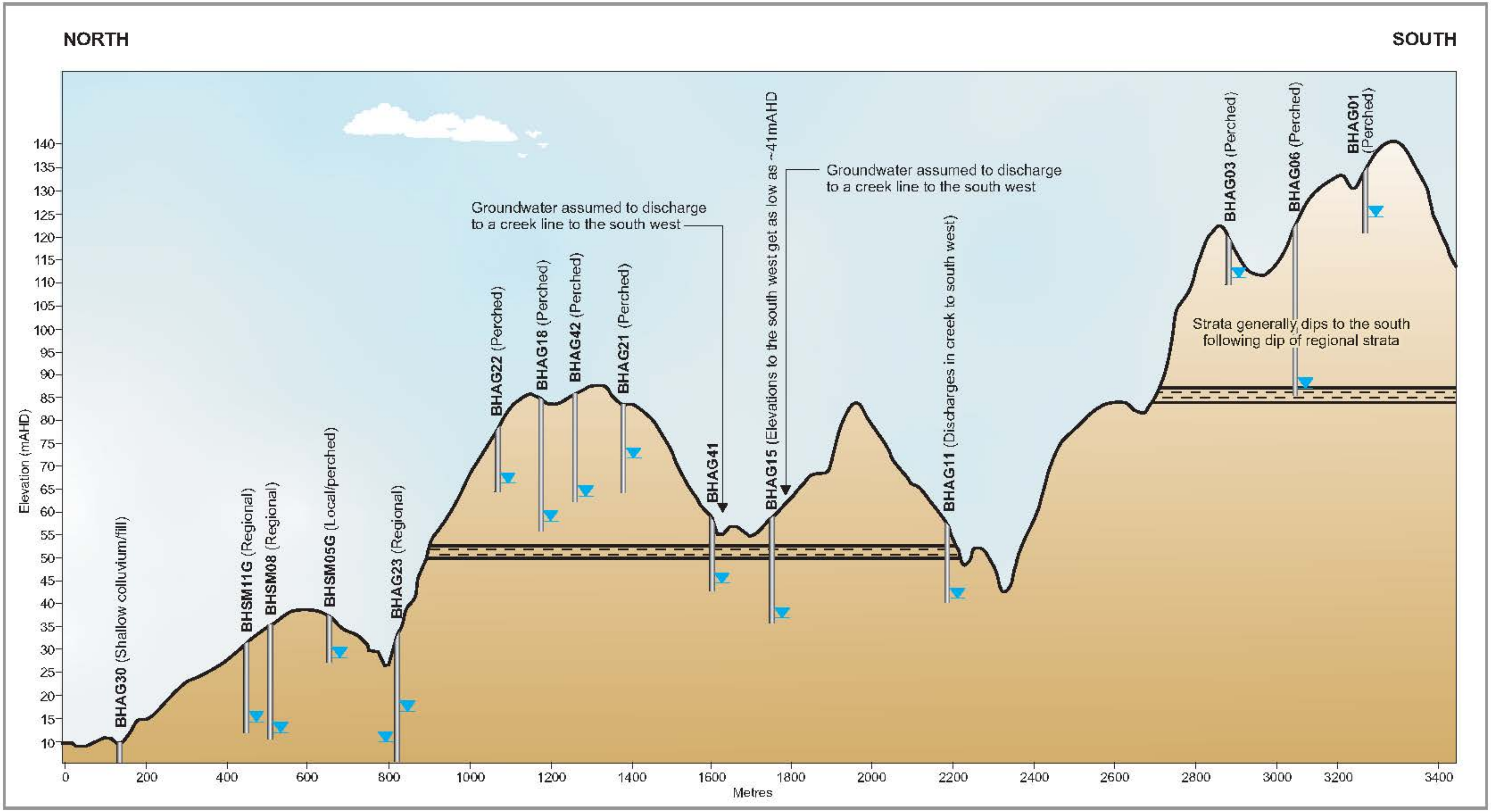
Regional groundwater is represented by monitoring bores BHSM11G and BHSM08. ANZECC (2000) freshwater trigger values for 95% species protection were exceeded at regional monitoring bore BHSM11G for dissolved cadmium by two orders of magnitude; copper by one order of magnitude and nickel by two orders of magnitude. ANZECC (2000) freshwater trigger values for 95% species protection were exceeded at regional monitoring bore BHSM08 for dissolved nickel by one order of magnitude and dissolved chromium by less than one order of magnitude.

As concentrations of heavy metals in the regional groundwater do not generally correspond with any particular source, it is considered that the elevated heavy metal concentrations are likely to be naturally occurring and potentially indicative of regional water quality.

Soil sampling carried out as part of geotechnical investigations (Aurecon, 2015) for the project indicated concentrations of some contaminants above ecological assessment criteria and health investigation levels in shallow fill/soil samples. The results indicate there is a low potential for significant widespread soil contamination associated with previous land uses in the study area. Based on the standing water levels (generally greater than six metres bgl) it is considered that there is a low potential for the observed soil contamination to have migrated to groundwater and potentially contaminated groundwater to have migrated from the study area (GHD, 2016a).

It should be noted that regional groundwater at the northern end of the study area will not be intercepted by the project and therefore this groundwater with elevated metal concentrations will not be discharged into local waterways. Based on the available groundwater quality data, the beneficial use of this regional groundwater would be limited to industrial use. As outlined in Section 2.3.2, there is no known existing usage of this groundwater.

Perched groundwater quality (sampled at bores BHAG03, BHAG11, BHAG41, BHAG21, BHAG42, BHAG23, BHAG30 and BHAG06) is generally characterised by dissolved metal concentrations that are below the ANZECC (2000) freshwater trigger values for 95% species protection. Exceedances of ANZECC (2000) freshwater trigger values for 95% species protection include dissolved copper and dissolved nickel at BHAG03; dissolved arsenic and dissolved nickel at BHAG21; dissolved chromium at BHAG30 and; dissolved nickel at BHAG06. All exceedances of ANZECC (2000) freshwater trigger values for 95% species protection for dissolved metals were by less than one order of magnitude. Total suspended solids (TSS) concentrations in the groundwater samples were likely to be high, as indicated by total metal concentrations generally being substantially higher than dissolved metal concentrations. High TSS concentrations in the samples is likely to be attributable to insufficient purging before sampling and does not indicate a TSS risk associated with groundwater inflows into cuttings or high concentrations of bioavailable metals.



LEGEND

Siltstone aquitard

Indicative groundwater level

Schematic diagram only - not to scale

Aurecon Australia
Newcastle Inner City Bypass - Rankin Park to Jesmond
Groundwater Assessment

Groundwater Monitoring Long Section

Job Number	22-17656-29
Revision	A
Date	23 Nov 2015

Figure 2-2

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The solids content in the groundwater samples likely resulted in the high total nitrogen (TN) concentrations at most locations as well as the presence of hydrocarbons at some locations. Therefore, it is not considered that these results (total concentrations) provide a true representation of the perched groundwater quality that may be discharged to local waterways.

Given the isolated minor exceedances of a few analytes are distributed throughout the study area and they do not generally correspond with any particular source, it is considered that they are likely to be naturally occurring and potentially indicative of perched groundwater water quality. The perched groundwater currently naturally seeps into local watercourses and is already influencing surface water quality in the surrounding ephemeral watercourses that drain to Dark Creek and Ironbark Creek.

Based on the available groundwater quality data, the beneficial use of the perched groundwater in the study area would be aquatic ecosystem support and, as outlined in Section 2.3.2, it is considered that perched groundwater in the study area provides some support to groundwater dependent ecosystems (GDEs). It is considered that the 95% level of species protection is appropriate for the slightly disturbed freshwater environment near the study area.

2.3.2 Groundwater receptors

NSW bore database search

Searches of the NSW Groundwater Bore Database (Department of Primary Industries – Water, carried out on 24 May 2016) and of the NSW Office of Water Waterinfo Pinneena Database (carried out on 24 May 2016) were carried out to identify registered bores within a one kilometre radius of the construction footprint. The search identified eight bores, one of which had a cancelled licence while the remainder were registered as monitoring bores and all outside of the study area. Bore locations are shown in Figure 2-3 and details are outlined in Table 2-3.

Overall the search of the database indicates that there is no known groundwater usage or reliance on groundwater for domestic, industrial or irrigation purposes in or near the study area. There are no known private bores operating under basic landholder rights within a one kilometre radius of the construction footprint.

The perched aquifer is not used for any other purposes such as groundwater extraction via groundwater bores. The identified groundwater bores near the study area extract groundwater from the regional aquifer and not from the perched aquifer.

Table 2-3 Results of NSW bore database search

Bore No	Licence No	Easting	Northing	Authorised use	Depth (metres)	SWL (m bgl)	Salinity (ppm)	Yield (L/s)
GW202023	20BL168685	377010	6358275	Monitoring Bore	5.3	3	–	–
GW202024	20BL168685	376985	6358340	Monitoring Bore	4.3	1	–	–
GW202025	20BL168685	377075	6358320	Monitoring Bore	10	2	–	–
GW202753	20BL173083	377087	6358861	Monitoring Bore	4.2	1.62	–	–
GW202754	20BL173083	377101	6358892	Monitoring Bore	3	0.88	–	–
GW202755	20BL173083	377114	6358871	Monitoring Bore	3.4	1.47	–	–
GW202756	20BL173083	377115	6358855	Monitoring Bore	3.5	1.79	–	–
GW053186	20BL118687	377409	6358935	Cancelled Licence	32.0	0	–	–

m bgl – metres below ground level

ppm – parts per million

L/s – litres per second

LEGEND

Construction footprint

Bore location

Paper Size A4

0 12.5 25 50 75 100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Rankin Park to Jesmond
Groundwater Assessment

Job Number	22-17656
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Date	26 Aug 2016

NSW bore database

Figure 2-3

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

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Data source: Aurecon: Construction footprint, 2016; Nearmap: Aerial Imagery, 20160331; LPI: DTDB, 2012 Created by: fmackay, tmorton

Groundwater dependent ecosystems (GDEs)

Two intermittently dependent and one dependent ecosystem have been identified in and surrounding the study area as part of biodiversity surveys conducted for the project by Parsons Brinckerhoff (2015). Details regarding these are shown in Table 2-4 and Figure 2-4.

As part of biodiversity surveys conducted by Parsons Brinckerhoff (2015) the two variants of the Sydney Blue Gum – White Mahogany shrubby tall open forest (*Syncarpia glomulifera* variant and atypical variant) were identified as being riparian communities. These communities are likely to rely on surface water runoff and accessing groundwater when groundwater levels are high and were therefore classified as being intermittently dependent on groundwater. The *Gahnia clarkei* variant of the Smooth-barked Apple Red Bloodwood open forest was considered by Parsons Brinkerhoff (2015) to likely occur as a result of groundwater seep and be dependent on groundwater sourced from the perched aquifer. These groundwater receptors have developed from the existing perched groundwater quality. As discussed in Section 2.3.1, the beneficial use of the perched groundwater in the study area is aquatic ecosystem support, however the perched groundwater was characterised by a number of exceedances of ANZECC (2000) freshwater trigger values for 95% species protection for dissolved metals.

The identified GDEs are not listed as high priority GDEs in the WSP for the North Coast Fractured and Porous Rock Groundwater Sources. The closest high priority GDEs to the study area are wetlands associated with Hexham Swamp

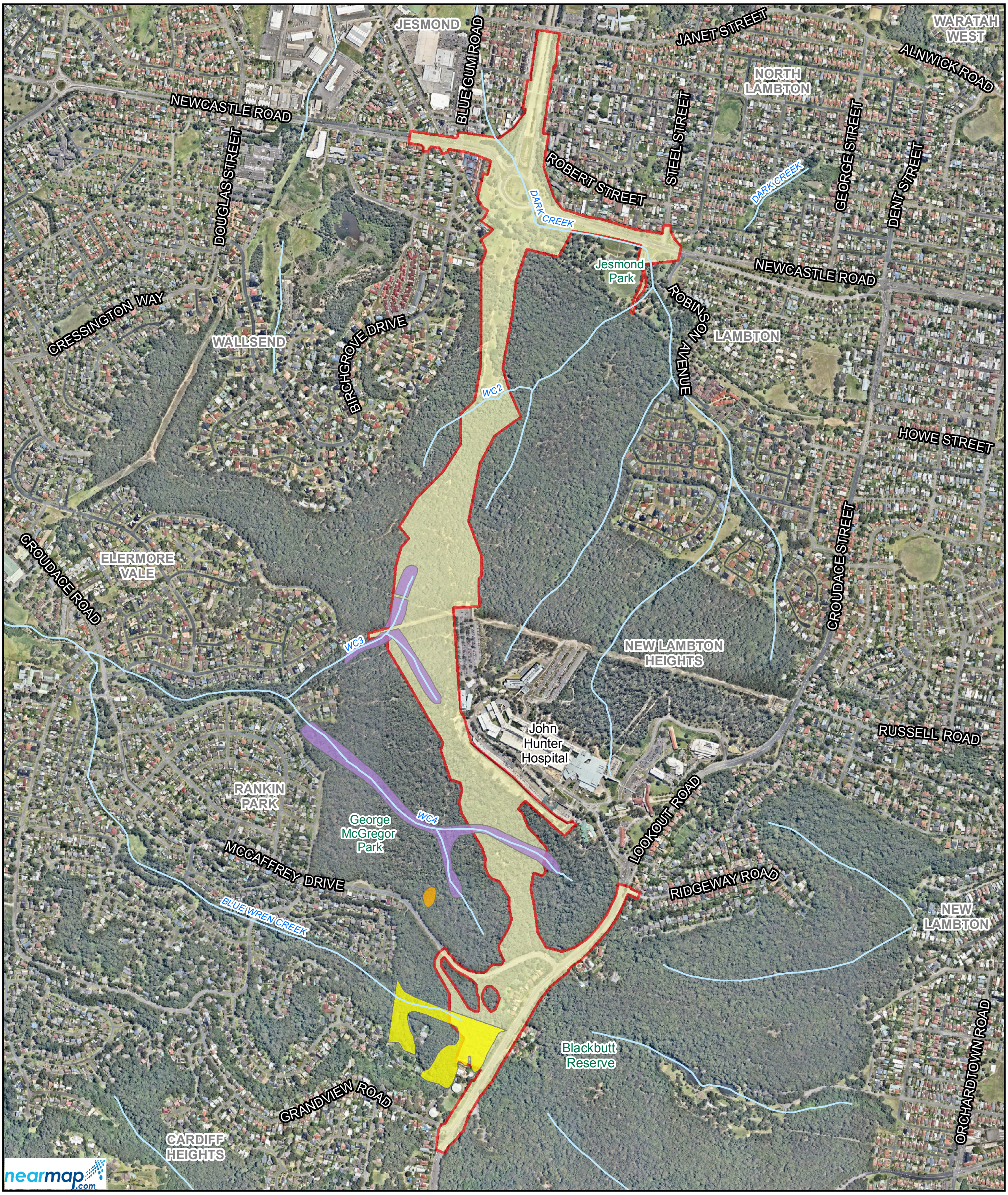
The identified GDEs are not listed under either the NSW *Threatened Species Conservation Act 1995* or Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

Table 2-4 Identified groundwater dependent ecosystems

Plant community type (1)	Type	Class	Habitat	Dependency on groundwater (2)
HU637 Sydney Blue Gum – White Mahogany shrubby tall open forest – *Syncarpia glomulifera* variant	Riparian and terrestrial vegetation	T1 – Riparian vegetation community	Terrestrial	Intermittently
HU637 Sydney Blue Gum – White Mahogany shrubby tall open forest – atypical variant	Riparian and terrestrial vegetation	T1 – Riparian vegetation community	Terrestrial	Intermittently
HU621 Smooth-barked Apple – Red Bloodwood open forest – *Gahnia clarkei* variant	Wetlands	W10 – Sedge Swamp	Epigean	Known

(1) Vegetation communities as per Parsons Brinckerhoff (2015)

(2) Known groundwater dependency as per (Eamus et al. 2006).



LEGEND

Construction footprint
Watercourse

Known groundwater dependent ecosystems
Smooth-barked Apple - Red Bloodwood open forest - *Gahnia clarkei variant* (HU833)

Intermittent groundwater dependent ecosystems
Sydney Blue Gum - White Mahogany shrubby tall open forest - atypical variant (HU782)
Sydney Blue Gum - White Mahogany tall open forest - *Syncarpia glomulifera variant* (HU782)

Paper Size A4
0 62.5 125 250 375 500
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Rankin Park to Jesmond
Groundwater Assessment

Job Number	22-17656
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Groundwater dependent ecosystems

Figure 2-4

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au
G:\22\17656\GIS\Maps\Deliverables\Groundwater\2217656_GW002_GDE_Vegetation_0.mxd

Data source: Nearmap: Aerial Imagery, 20160331; Aurecon: Construction footprint, 2016; LPI: DTDB, 2012; PB:Vegetation, 2015. Created by: fmackay, tmorton

3. Impact assessment

3.1 Impact avoidance

The project is a regionally significant road infrastructure project which has a long history of design planning and refinement. The preferred corridor for the project was originally identified in 1957 and incorporated at that time into the Northumberland County Planning Scheme for future planning purposes. The alignment for the project has been subsequently refined over many years, specifically in 1985, 2006 and 2016. During each design refinement, environmental and community impacts were specifically considered when carrying out the options evaluation. Several alignment options were discounted over the years due to adverse impacts. The final preferred project alignment was selected based on this process.

Due to the steep undulating topography through which the project passes, the options selection and design development processes have carried out to minimise road grades and earthworks volumes (cuts and fills) as far as practicable while minimising environmental impacts on the surrounding bushland and sensitive receivers including residential areas and the John Hunter Hospital precinct.

In order to meet the required road design criteria for road grades and for the project to provide connectivity to the surrounding road network, areas of cuts and fills are required. The concept design has been further refined to minimise the depth of cuttings as far as practicable while meeting all other project objectives.

Six separate cuttings are proposed along the project as listed in Table 3-1 and shown on Figure 3-2. Based on the groundwater monitoring data, it is considered that perched groundwater interception is possible in five of these cuttings. None of the cuttings would intersect with the regional groundwater aquifer.

Table 3-1 Proposed cuttings

Cutting	Groundwater elevation (metres AHD)	Groundwater system intercepted
Cutting 1	112.83	Perched
Cutting 2	89.17	Perched
Cutting 3	70.32	Perched
Cutting hospital access road	77.72	Perched
Cutting 4	70.32	Perched
Cutting 5	n/a	Nil

3.2 Modelling methodology

3.2.1 Description

Preliminary groundwater inflow estimates have been carried out using the analytical equations and approach outlined in Marinelli and Niccoli (2000). The equations presented by Marinelli and Niccoli (2000) provide a simple means of estimating steady state or long-term average inflows to a pit or cutting.

The solutions presented consider:

- The effect of decreased saturated thickness near the pit (cut) walls.
- Distributed recharge to the water table.
- Upward flow through the pit (cut) bottom.

Separate flow calculations are carried out for inflow into the pit (cut) walls (Q_1, Zone 1) and pit (cut) base (Q_2, Zone 2) (Figure 3-1). Assumptions inherent in the flow calculation for Zone 1 include:

- Pit (cut) walls are approximated as a circular cylinder.
- Groundwater flow is horizontal (Dupuit - Forchheimer approximation is valid).
- The static (pre-mining (cutting)) water table is horizontal.
- Groundwater flow toward the pit (cut) is axially symmetric.
- Uniform distributed recharge occurs across the site as a result of surface infiltration.
- All recharge in the radius of influence is captured by the pit (cut).
- The perched aquifer extends below the base of the pit (cut).

Assumptions relevant to Zone 2 include:

- Hydraulic head is initially uniform throughout the zone. Initial head is equal to the elevation of the initial water table in Zone 1.
- The disk sink has constant hydraulic head equal to the elevation of the pit late water surface. If the pit (cut) is completely dewatered the disk sink is equal to the elevation of the pit (cut) bottom.
- Flow to the disk sink is three dimensional and axially symmetric.
- Materials in Zone 2 are anisotropic and the principal co-ordinate directions for hydraulic conductivity are horizontal and vertical.

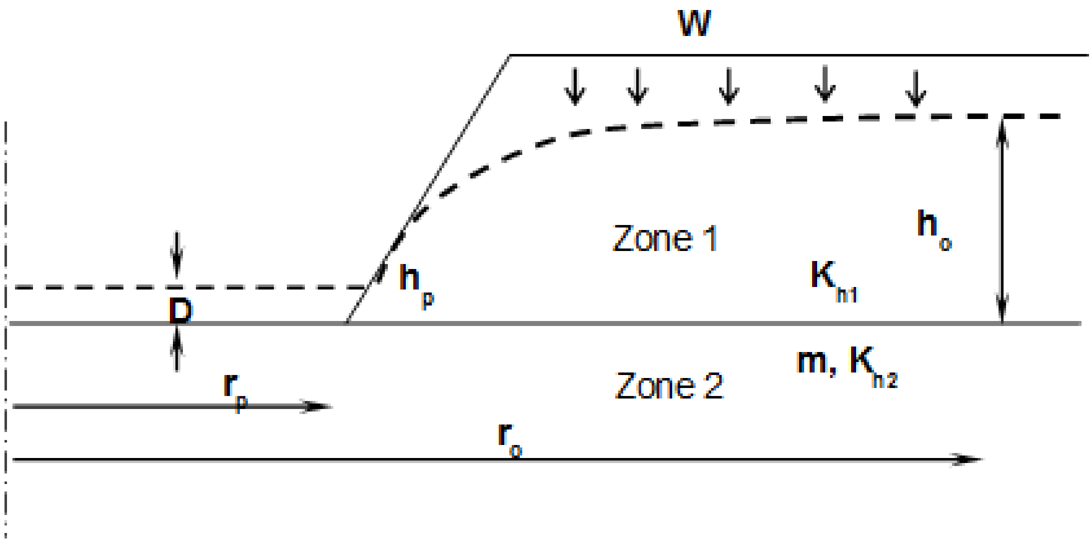

Figure 3-1 Pit inflow hydraulic model (Marinelli and Niccoli 2000)