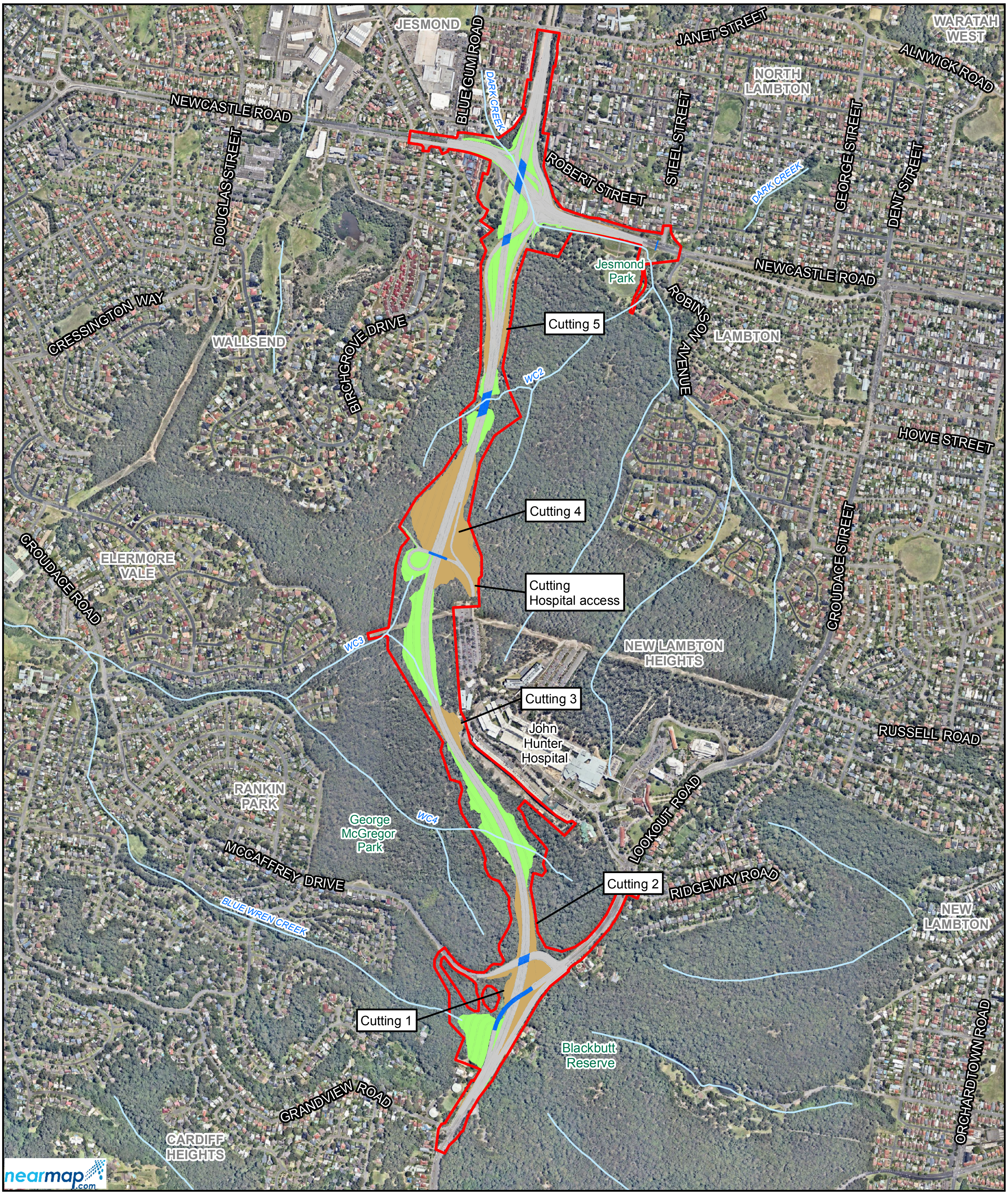


LEGEND

Construction footprint	Design features	Earthworks cut
Watercourse	Pavement	Earthworks fill
	Bridge	

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

GHD

Rankin Park to Jesmond
Groundwater Assessment

Job Number 22-17656
Revision 0
Date 26 Aug 2016

Proposed cuttings

Figure 3-2

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_GW004_ProposedCuttings_0.mxd

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

Relevant equations presented in Marinelli and Niccoli (2000) are:

$$h_o = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left(r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \left(\frac{r_o^2 - r_p^2}{2}\right)\right)}$$

$$Q_1 = W\pi\left(r_o^2 - r_p^2\right)$$

$$Q_2 = 4r_p\left(\frac{K_{h2}}{m_2}\right)\left(h_o - d\right)$$

$$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$

Where:

- h_o = Initial (pre-mining (cutting)) saturated thickness (metres above base of pit (cut))
- h_p = Saturated thickness at pit wall (metres above base of pit (cut))
- W = Distributed recharge flux (metres per day)
- Kh_1 = Horizontal hydraulic conductivity Zone 1 (metres per day)
- Kh_2 = Horizontal hydraulic conductivity Zone 2 (metres per day)
- Kv_2 = Vertical hydraulic conductivity Zone 2 (metres per day)
- r_p = Effective pit (cut) radius (metres)
- r_o = Radius of influence (metres)
- d = Depth of the pit (cut) lake (metres)

3.2.2 Input Data

Data sources and assumptions used to derive input values for each of the parameters required for the equations developed by Marinelli and Niccoli (2000) are outlined in the following section.

Initial (pre-construction) saturated thickness (h_o)

The initial (pre-construction) saturated thickness was estimated to be equal to the height of groundwater (indicated by the groundwater monitoring data) above the base of the cutting. It should be noted that monitored groundwater levels are indicative of conditions at the time at which monitoring occurred and that groundwater levels may increase or decrease over time.

Saturated thickness at pit wall (h_p)

The cuttings are assumed to be fully dewatered during construction and fully drained during operation. Therefore, the saturated thickness at pit wall (h_p) was assumed to be equal to zero.

Distributed recharge flux (W)

Based on other numerical modelling work carried out by GHD in the Newcastle Coal Measures, a net recharge rate of two to four per cent of long-term average rainfall recorded at Newcastle Nobbys Signal Station AWS Bureau of Meteorology Station (station number 061055) was adopted for the assessment. This station was adopted for the assessment based on the length and the quality of the data record and the proximity to the site. Long-term average annual rainfall over the period 1862 to 2014 was 1125.8 millimetres per year. A net recharge rate of two per cent gives an estimated long-term average recharge rate of 22.5 millimetres per year or 6.17×10^{-5} metres per day. A net recharge rate of four per cent gives an estimated long-term average recharge rate of 45 millimetres per year or 1.23×10^{-4} metres per day.

Hydraulic conductivity Zones 1 and 2 (Kh_1, Kh_2 and Kv_2)

Hydraulic conductivities of the perched aquifer have been assumed to be equal to generally accepted values for sandstone/dense rock. Boreholes across the site indicate that the strata vary from highly weathered sandstone and siltstone to slightly weathered sandstone and siltstone to claystone and siltstone. Based on the hydraulic conductivity values adopted by Kruseman and de Riddler (1994) for sandstone of 1 x 10^{-3} metres per day to one metre per day and for dense solid rock of less than 1 x 10^{-5} metres per day, a horizontal hydraulic conductivity of 0.1 metres per day was adopted. It was assumed that the horizontal hydraulic conductivity is 10 times the greater than vertical hydraulic conductivity.

Effective radius (r_p)

Effective pit (cut) radius was estimated by calculating the area of the cutting based on the length and the width of the cutting. The area of inflow was estimated by comparing available water level data to project design levels and cutting widths along the length of each cutting. The calculated area was input into the formulae for the area of a circle (ie $A = \pi r_p^2$) in order to calculate the effective radius. The calculated length and width and effective radius of each cutting is shown in Table 3-2.

Radius of influence (r_o)

The radius of influence (r_o) of any groundwater abstraction represents a balance between the hydraulic conductivity of the strata and the rate of recharge incident at the water table. The radius of influence is therefore significantly affected by the presence or absence of hydrogeological recharge (such as perennial rivers) and/or no flow boundaries (such as geological boundaries) and therefore cannot be accurately predicted in advance.

Due to the perched nature of the intercepted aquifer, the radius of influence is limited by outcropping of the aquifer. The radius of influence has therefore been limited to the geological boundaries of each perched aquifer.

Table 3-2 Calculated cut radius and groundwater elevation

Cutting	Cutting length (m)	Cutting width (m)	Effective pit radius (r_p) (m)	Groundwater elevation (m AHD)	Initial (pre-construction) saturated thickness (h_o) (m)
Cutting 1	140	34.1	39.0	112.83	6.23
Cutting 2	100	30.9	31.3	89.17	3.63
Cutting 3	140	23.1	32.1	70.32	2.74
Cutting 4	340	54.2	76.6	70.32	7.25
Cutting 5	260	38.0	56.1	–	0
Cutting hospital access road	120	29.93	33.8	77.22	2.94

Note: Groundwater monitoring data indicates no groundwater in Cutting 5.

3.3 Predictions of inflow and radius of influence

As discussed in Section 3.1, the concept design for the project has minimised cuttings as far as practicable to minimise groundwater inflow. Groundwater inflows have been estimated for each of the proposed cuttings using the analytical equations developed by Marinelli and Niccoli (2000) as described in Section 3.2. Groundwater inflows have been estimated for a range of scenarios. Table 3-3 to Table 3-8 provide the predicted inflows for each of the cuttings for the following scenarios:

- Scenario 1 is considered to be a base case, where the best estimate for hydraulic conductivity, mean recharge and initial saturated thickness (height of groundwater level above pit floor) were used in the assessment.
- Scenario 2 reduced the recharge to two per cent of rainfall.
- Scenario 3 increased the water level in each of the cuts by two metres.
- Scenario 4 increased hydraulic conductivity by 10 times.
- Scenario 5 decreased hydraulic conductivity by 10 times relative to Scenario 1.

Table 3-3 Predicted groundwater inflows – Cutting 1

Scenario	Distributed recharge flux, W (m/d)	Horizontal hydraulic conductivity k_h (m/d)	Radius of influence r_o (m)	Initial saturated thickness h_o (m)	Horizontal groundwater inflow Q_1 (m^3/day)	Vertical groundwater inflow Q_2 (m^3/day)	Total groundwater inflow Q_t (m^3/day)
1	1.23×10^{-4}	0.1	175.0	6.23	11.3	3.1	14.4
2	6.17×10^{-5}	0.1	223.4	6.23	9.4	3.1	12.5
3	1.23×10^{-4}	0.1	212.7	8.23	16.9	4.1	21.0
4	1.23×10^{-4}	1	411.2	6.23	65.0	30.7	95.7
5	1.23×10^{-4}	0.01	87.7	6.23	2.4	0.3	2.7

m – metres, m/d – metres per day, m^3/day - cubic metres per day

Table 3-4 Predicted groundwater inflows – Cutting 2

Scenario	Distributed recharge flux, W (m/d)	Horizontal hydraulic conductivity k_h (m/d)	Radius of influence r_o (m)	Initial saturated thickness h_o (m)	Horizontal groundwater inflow Q_1 (m^3/day)	Vertical groundwater inflow Q_2 (m^3/day)	Total groundwater inflow Q_t (m^3/day)
1	1.23×10^{-4}	0.1	113.6	3.63	4.6	1.4	6.1
2	6.17×10^{-5}	0.1	143.0	3.63	3.8	1.4	5.2
3	1.23×10^{-4}	0.1	152.5	5.63	8.6	2.2	10.9
4	1.23×10^{-4}	1	257.1	3.63	25.2	14.4	39.6
5	1.23×10^{-4}	0.01	60.5	3.63	1.0	0.1	1.2

m – metres, m/d – metres per day, m^3/day - cubic metres per day

Table 3-5 Predicted groundwater inflows – Cutting 3

Scenario	Distributed recharge flux, W (m/d)	Horizontal hydraulic conductivity k_h (m/d)	Radius of influence r_o (m)	Initial saturated thickness h_o (m)	Horizontal groundwater inflow Q_1 (m^3/day)	Vertical groundwater inflow Q_2 (m^3/day)	Total groundwater inflow Q_t (m^3/day)
1	1.23×10^{-4}	0.1	96.4	2.74	3.2	1.1	4.3
2	6.17×10^{-5}	0.1	119.6	2.74	2.6	1.1	3.7
3	1.23×10^{-4}	0.1	136.6	4.74	6.8	1.9	8.8
4	1.23×10^{-4}	1	209.5	2.74	16.6	11.1	27.7
5	1.23×10^{-4}	0.01	54.6	2.74	0.8	0.1	0.9

m – metres, m/d – metres per day, m^3/day - cubic metres per day

Table 3-6 Predicted groundwater inflows – Cutting 4

Scenario	Distributed recharge flux, W (m/d)	Horizontal hydraulic conductivity k_h (m/d)	Radius of influence r_o (m)	Initial saturated thickness h_o (m)	Horizontal groundwater inflow Q_1 (m^3/day)	Vertical groundwater inflow Q_2 (m^3/day)	Total groundwater inflow Q_t (m^3/day)
1	1.23×10^{-4}	0.1	244.8	7.25	21.0	7.0	28.0
2	6.17×10^{-5}	0.1	305.3	7.25	16.9	7.0	24.0
3	1.23×10^{-4}	0.1	285.4	9.25	29.3	9.0	38.3
4	1.23×10^{-4}	1	539.7	7.25	110.6	70.3	180.9
5	1.23×10^{-4}	0.01	135.7	7.25	4.9	0.7	5.6

m – metres, m/d – metres per day, m^3/day - cubic metres per day

Table 3-7 Predicted groundwater inflows – Cutting 5

Scenario	Distributed recharge flux, W (m/d)	Horizontal hydraulic conductivity k_h (m/d)	Radius of influence r_o (m)	Initial saturated thickness h_o (m)	Horizontal groundwater inflow Q_1 (m^3/day)	Vertical groundwater inflow Q_2 (m^3/day)	Total groundwater inflow Q_t (m^3/day)
1	1.23×10^{-4}	0.1	–	0	0	0	0
2	6.17×10^{-5}	0.1	–	0	0	0	0
3	1.23×10^{-4}	0.1	107.0	2	3.2	1.4	4.6
4	1.23×10^{-4}	1	200.0	2	14.3	14.2	28.5
5	1.23×10^{-4}	0.01	73.3	2	0.9	0.1	1.0

Note: Groundwater monitoring data indicates no groundwater in Cutting 5. Groundwater level increased to two metres above base of cut for scenario 3, 4 and 5

m – metres, m/d – metres per day, m^3/day - cubic metres per day

Table 3-8 Predicted groundwater inflows – Cutting hospital access road

Scenario	Distributed recharge flux, W (m/d)	Horizontal hydraulic conductivity k_h (m/d)	Radius of influence r_o (m)	Initial saturated thickness h_o (m)	Horizontal groundwater inflow Q_1 (m^3/day)	Vertical groundwater inflow Q_2 (m^3/day)	Total groundwater inflow Q_t (m^3/day)
1	1.23×10^{-4}	0.1	102.7	2.94	3.6	1.3	4.9
2	6.17×10^{-5}	0.1	127.5	2.94	2.9	1.3	4.2
3	1.23×10^{-4}	0.1	142.9	4.94	7.5	2.1	9.6
4	1.23×10^{-4}	1	223.7	2.94	19.0	12.6	31.5
5	1.23×10^{-4}	0.01	57.9	2.94	0.9	0.1	1.0

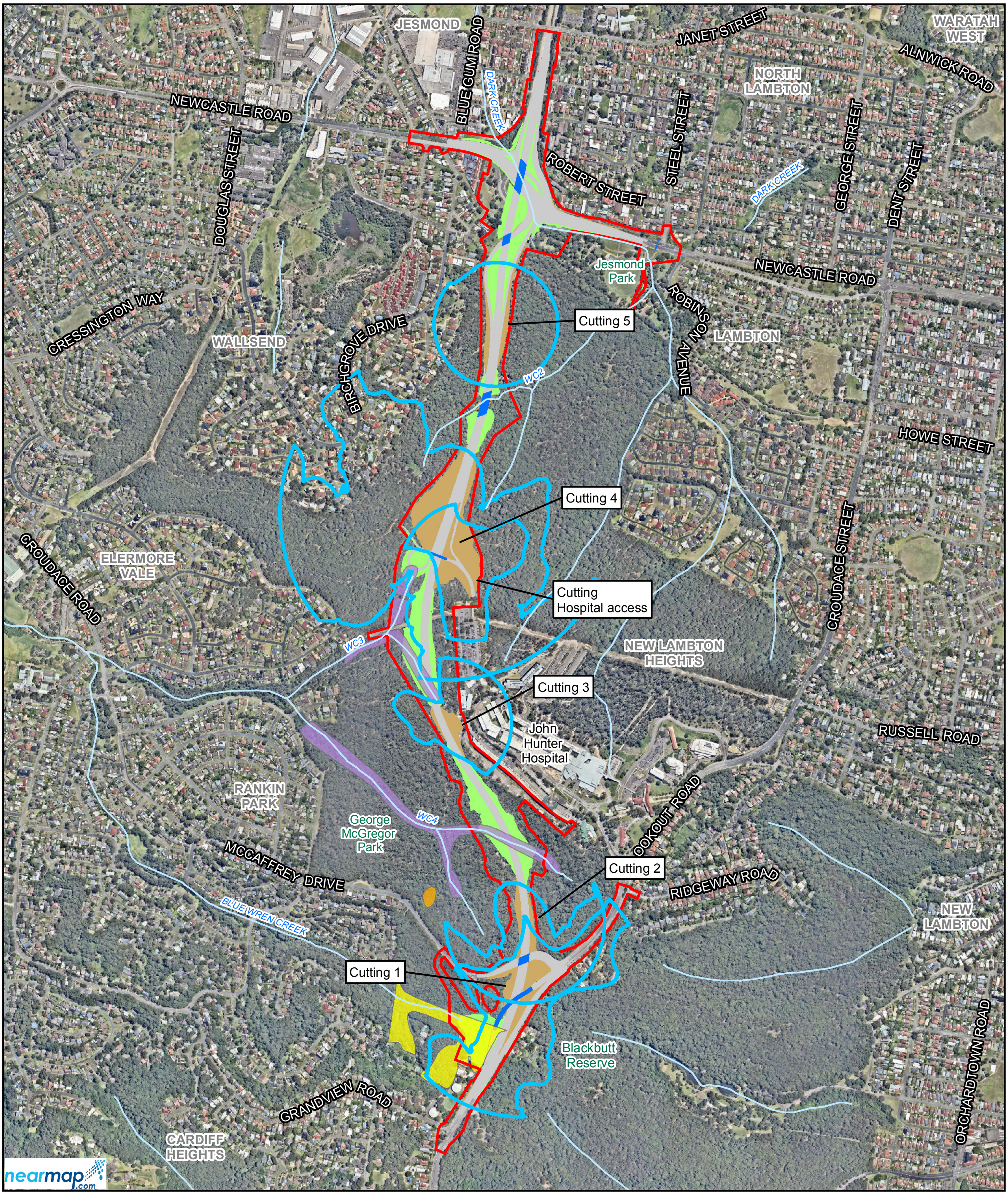
m – metres, m/d – metres per day, m^3/day - cubic metres per day

Based on the analytical calculations, cumulative groundwater inflows (all cuttings combined) are between 12.4 and 403.9 cubic metres per day with the most likely estimate considered to be 57.7 cubic metres per day (based on scenario 1). Note that the groundwater inflow rates are average long-term rates along each cutting. The actual rate of inflow is unlikely to be constant along the entire length of each cutting. The actual inflow rate would likely change along the length of each cutting as the base of each cutting changes in level and as groundwater levels vary along the length of each cutting.

The groundwater levels utilised in calculating groundwater inflows may vary over time. It is expected that groundwater inflows into the proposed cuttings would increase following rainfall events due to recharge of the perched aquifer. Conversely groundwater inflows would likely be low to potentially negligible following extended periods of little or no rainfall (once all groundwater has been released from storage).

The radius of influence on groundwater of each cutting has been estimated. The perched aquifer is bounded by the outcropping of the aquifer which limits the actual radius of influence of each cutting. The estimated radius of influence calculated for scenario 4 (the most conservative scenario), considering the outcropping of the aquifer, is shown in Figure 3-3.

Due to the small distance between the proposed cuttings and the outcropping of the intercepted aquifer it is anticipated that the most of the inflows into each cutting would occur soon after the start of construction. There is limited up gradient areas to provide ongoing groundwater inflows to each pit. Ongoing flow into each of the cuts is anticipated to only occur following rainfall events.



LEGEND

Predicted radius of drawdown
Construction footprint
Watercourse

Design features
- Pavement
- Bridge
- Earthworks cut
- Earthworks fill

Vegetation communities
- Smooth-barked Apple - Red Bloodwood open forest - *Gahnia clarkei variant* (HU833)
- 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

N

Rankin Park to Jesmond
Groundwater Assessment

Job Number	22-17656
Revision	0
Date	26 Aug 2016

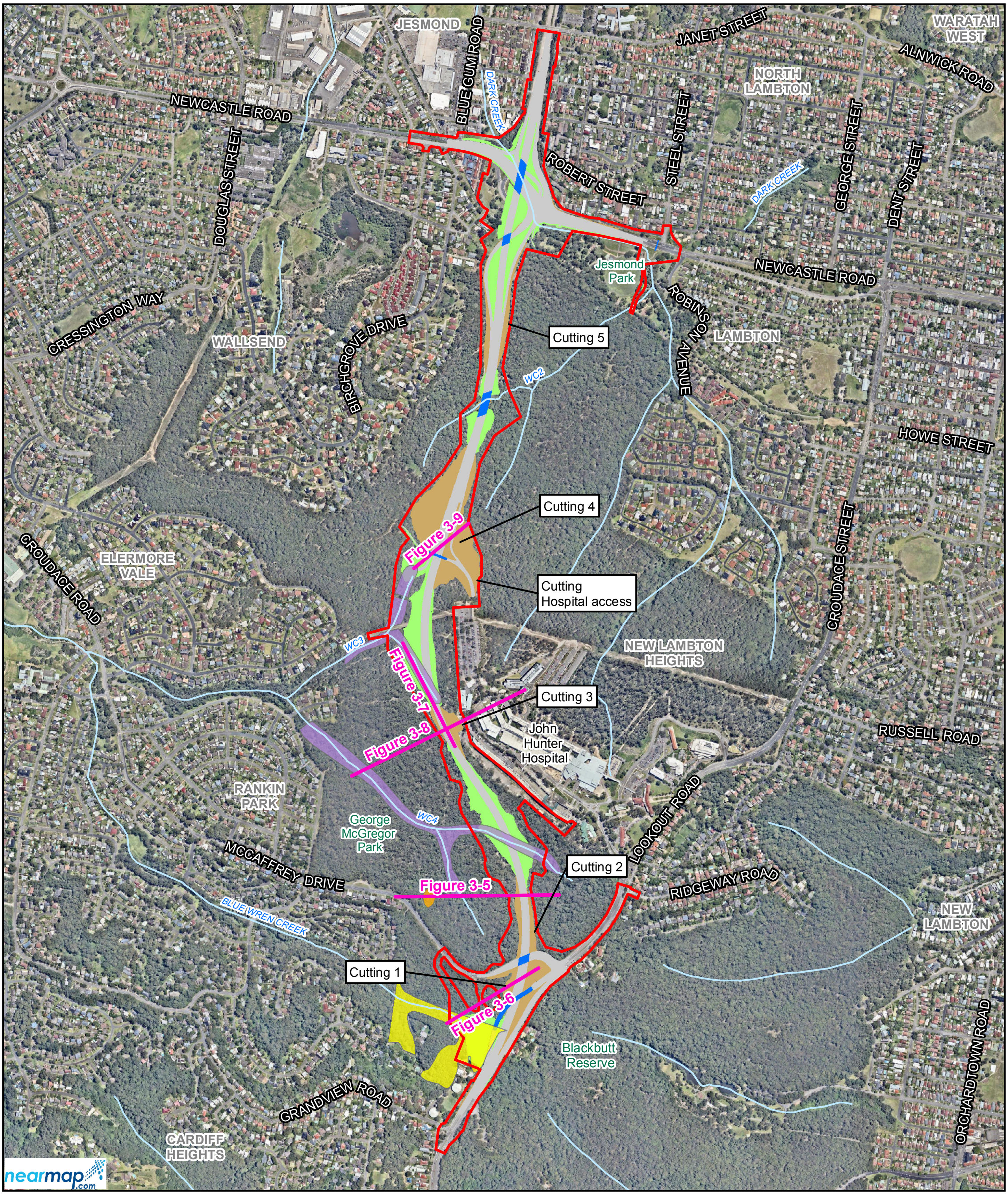
Predicted radius of influence (groundwater drawdown) for cuttings

Figure 3-3

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

G:\22\17656\GIS\Maps\Deliverables\Groundwater\2217656_GW005_PredictedInfluence_0.mxd

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



LEGEND

- Construction footprint
- Watercourse
- Cutting cross sections

Design features

- Pavement
- Bridge
- Earthworks cut
- Earthworks fill

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

N

GHD

Rankin Park to Jesmond
Groundwater Assessment

Job Number	22-17656
Revision	0
Date	26 Aug 2016

Cutting cross sections

Figure 3-4

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G:\22\17656\GIS\Maps\Deliverables\Groundwater\2217656_GW008_CrossSectionLocations_0.mxd

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

3.4 Aquifer interference policy

Due to there being no known groundwater usage or reliance on groundwater for domestic or irrigation purposes in or near the study area, and the limited extent of the groundwater source, the perched groundwater has been classified as a less productive fractured rock groundwater source under the *NSW Aquifer Interference Policy* (DTI 2012). A less productive groundwater source is defined by the AIP as a groundwater source having total dissolved solids greater than 1500 milligrams per litre or does not contain water supply works that can yield water at a rate greater than five litres per second.

The *NSW Aquifer Interference Policy* (DTI 2012) requires that potential impacts on groundwater sources, including their users and groundwater dependant ecosystems, be assessed against the minimal impact considerations outlined in the policy. If the predicted impacts are less than the Level 1 minimal impact considerations for less productive fractured rock groundwater sources, then the potential groundwater impacts of the project are acceptable. The Level 1 minimal impact considerations for less productive fractured rock groundwater sources are:

- Water table:
  - Less than or equal to 10 per cent cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, at a distance of 40 metres from any high priority GDEs or high priority culturally significant site listed in the schedule of the relevant water sharing plan.
  - A maximum of a two metre water table decline cumulatively at any water supply work
- Water pressure - a cumulative pressure head decline of not more than a two metre decline at any water supply work.
- Groundwater quality - any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres of the activity.

Water supply works

There are no water supply works listed in the WSP for the North Coast Fractured and Porous Rock Groundwater Sources. Further there are no water supply works in or near the study area. Therefore, the project would not result in any impacts to a water supply work.

High priority culturally significant sites

There are no high priority culturally significant sites listed in the WSP for the North Coast Fractured and Porous Rock Groundwater Sources. Aboriginal heritage assessments conducted for the project have not identified any cultural sites in or near the study area. Therefore, the project would not result in any impacts to a culturally significant site.

Groundwater dependent ecosystems

As discussed in Section 2.3.2 the project is not predicted to result in any variation in the water table within 40 metres of any high priority GDEs. As shown on Figure 3-3 the identified GDEs are located in the predicted radius of influence of Cuttings 1, 2, 3 and 4. In order to assess the potential impacts on GDEs a number of cross sections of the proposed cuttings and the GDEs have been developed. The locations of these cross sections are shown in Figure 3-4.

The known GDE, a *Gahnia clarkei* variant of the Smooth-barked Apple Red Bloodwood open forest as mapped by Parson Brinckerhoff (2015), occurs more than 250 metres from the nearest proposed cutting (Cutting 2). As shown in Figure 3-5 the perched aquifer likely to be intercepted by Cutting 2 is separate from the perched aquifer that supports the GDE. It is likely that any groundwater near Cutting 2 will discharge to the outcrop areas of the perched aquifer. Due to the hydrogeological separation of the perched aquifer that feeds the known GDE and the proposed cutting by a steep sided valley, the known GDE will continue to be fed by seepage from the perched aquifer. Therefore, Cutting 2 would not have any impact on the known GDE.

An intermittent GDE, an atypical variant of the Sydney Blue Gum – White Mahogany shrubby tall open forest as mapped by Parsons Brinckerhoff (2015), occurs about 90 metres from the closest proposed cutting (Cutting 1). This intermittent GDE is in the predicted zone of impact on groundwater as shown in Figure 3-3. Cutting 1 is predicted to intercept a perched aquifer that occurs along the top of the ridgeline as shown in Figure 3-6. This may result in some reduced baseflow to the intermittent GDE. However, the intermittent GDE would continue to be fed by surface water runoff and from groundwater flow from aquifers that are underlying Cutting 1. In addition, groundwater inflow into Cutting 1 would ultimately drain back to the watercourse that supports the intermittent GDE during both construction and operation.

An intermittent GDE, a *Syncarpia glomulifera* variant of the Sydney Blue Gum – White Mahogany shrubby tall open forest as mapped by Parsons Brinckerhoff (2015), occurs in two locations near Cutting 3. One community is mapped as occurring next to the proposed cutting to the north-west and the second occurrence of the GDE is located about 230 metres to the south-west of the proposed cutting.

Figure 3-7 shows a north-west to south-east cross section that runs through Cutting 3 generally along the centreline of the proposed road. Figure 3-7 shows the extent of the GDE that occurs to the north-west of Cutting 3. This intermittent GDE, at the closest point to Cutting 3, would be cleared and covered with a fill embankment. The impact on the intermittent GDE from the placement of fill is detailed in the biodiversity assessment for the project (GHD, 2016c). There would be limited impact on the intermittent GDE outside the footprint of the fill as it would continue to be fed by seepage from aquifers that lie below the proposed Cutting 3 and from surface water runoff. In addition, groundwater inflow into Cutting 3 would ultimately drain back to the watercourse that supports the intermittent GDE during both construction and operation.

Figure 3-8 shows a south-west to north-east cross section through Cutting 3 and shows the intermittent GDE that lies to the south-west of this cutting. Figure 3-8 indicates that the impact on this intermittent GDE would be limited to some loss of seepage from the aquifer intercepted by the cutting. This GDE will continue to be fed by surface water runoff and seepage from aquifers that occur below the cutting. In addition, groundwater inflow into Cutting 3 would ultimately drain back to the watercourse that supports the intermittent GDE during both construction and operation.

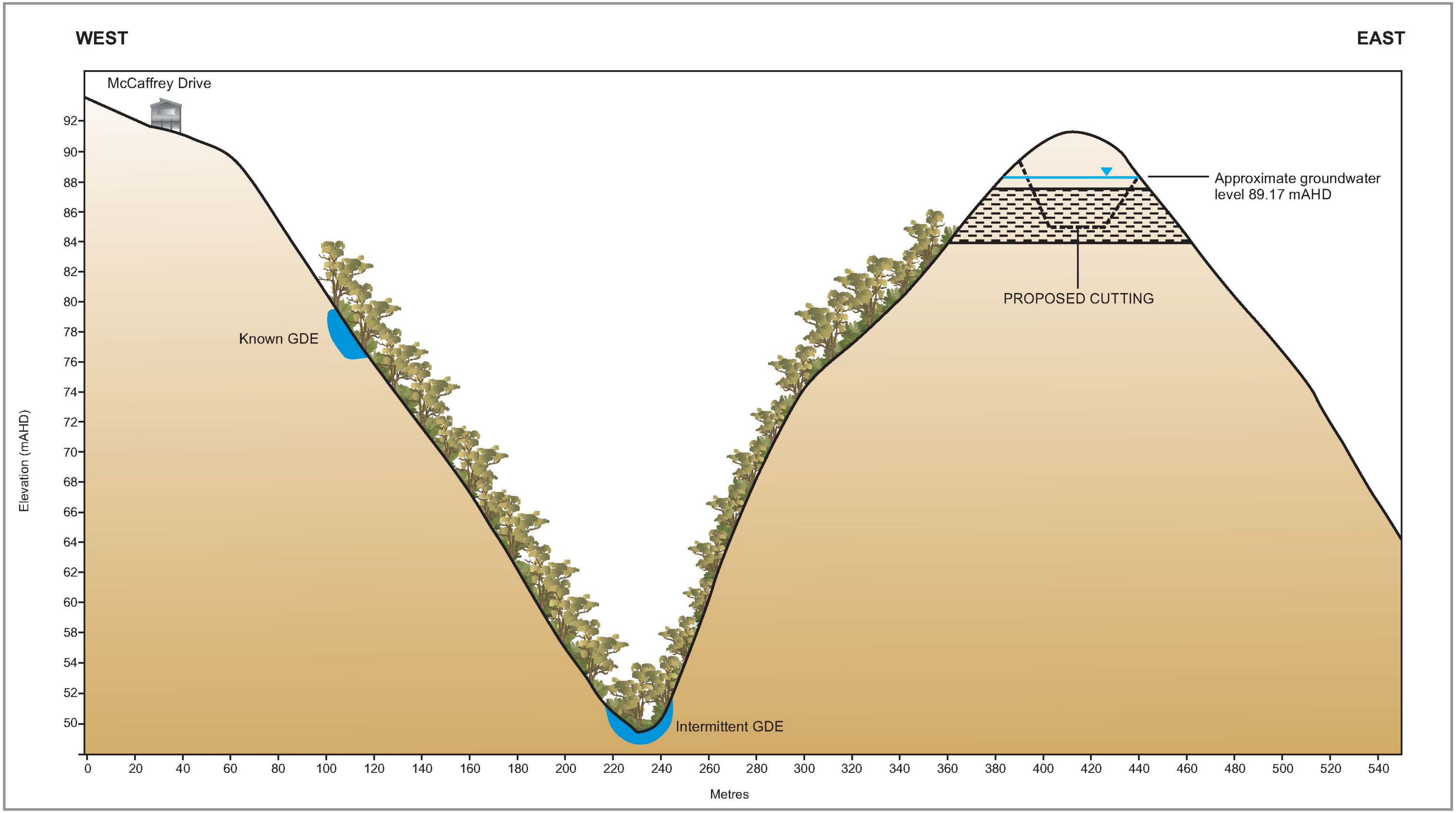
An intermittent GDE, a *Syncarpia glomulifera* variant of the Sydney Blue Gum – White Mahogany shrubby tall open forest as mapped by Parsons Brinckerhoff (2015), occurs within about 50 metres of the proposed Cutting 4. Figure 3-9 indicates that the impact on the GDE would be limited to loss of seepage from the aquifer intercepted by this cutting. The GDE would continue to be fed by groundwater seepage from aquifers that are located below the proposed cutting and from surface water runoff. In addition, groundwater inflow into Cutting 4 would ultimately drain back to the watercourse that supports the intermittent GDE during both construction and operation.

The project design, including the operational drainage system, aims to maintain flows to GDEs including maintaining seepage from the perched aquifer below the base of any cuttings and ensuring that groundwater inflows into cuttings ultimately drain back to watercourses that support GDEs.

Recharge and flow paths

The project would involve the construction of new fill and hardstand areas that may change the local movement of perched groundwater in some areas. This may result in a minor localised change to where perched groundwater seeps in these areas, however the project design does not change the drainage line to which this seepage reports. Based on available groundwater information, the design has been developed so that where fill is placed over existing seepage areas, groundwater seepage would occur at or near the base of the new fill and as such this would not change the drainage line to which this seepage reports. Therefore, it is not expected that this change to perched groundwater flow pathways would impact on intermittent GDEs since the drainage lines that currently support these GDEs would continue to receive the same seepage from the perched aquifer.

The presence of fill and hardstand areas may result in some local changes to the rates of rainfall infiltration into the perched aquifers and hence the recharge of these aquifers. Hardstand areas would be expected to result in some minor localised reductions in recharge. The impacts of the permanent cuttings and road on groundwater drawdown have been taken into account in the determination of radius of influence shown in Figure 3-3. The loss of recharge to perched aquifers is not considered to impact GDEs since the rainfall that would have infiltrated would be collected in the surface water management system and discharged to watercourses downstream of the existing seepage areas.



LEGEND

Siltstone aquitard (approximate extent)

Indicative groundwater level

Schematic diagram only - not to scale

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

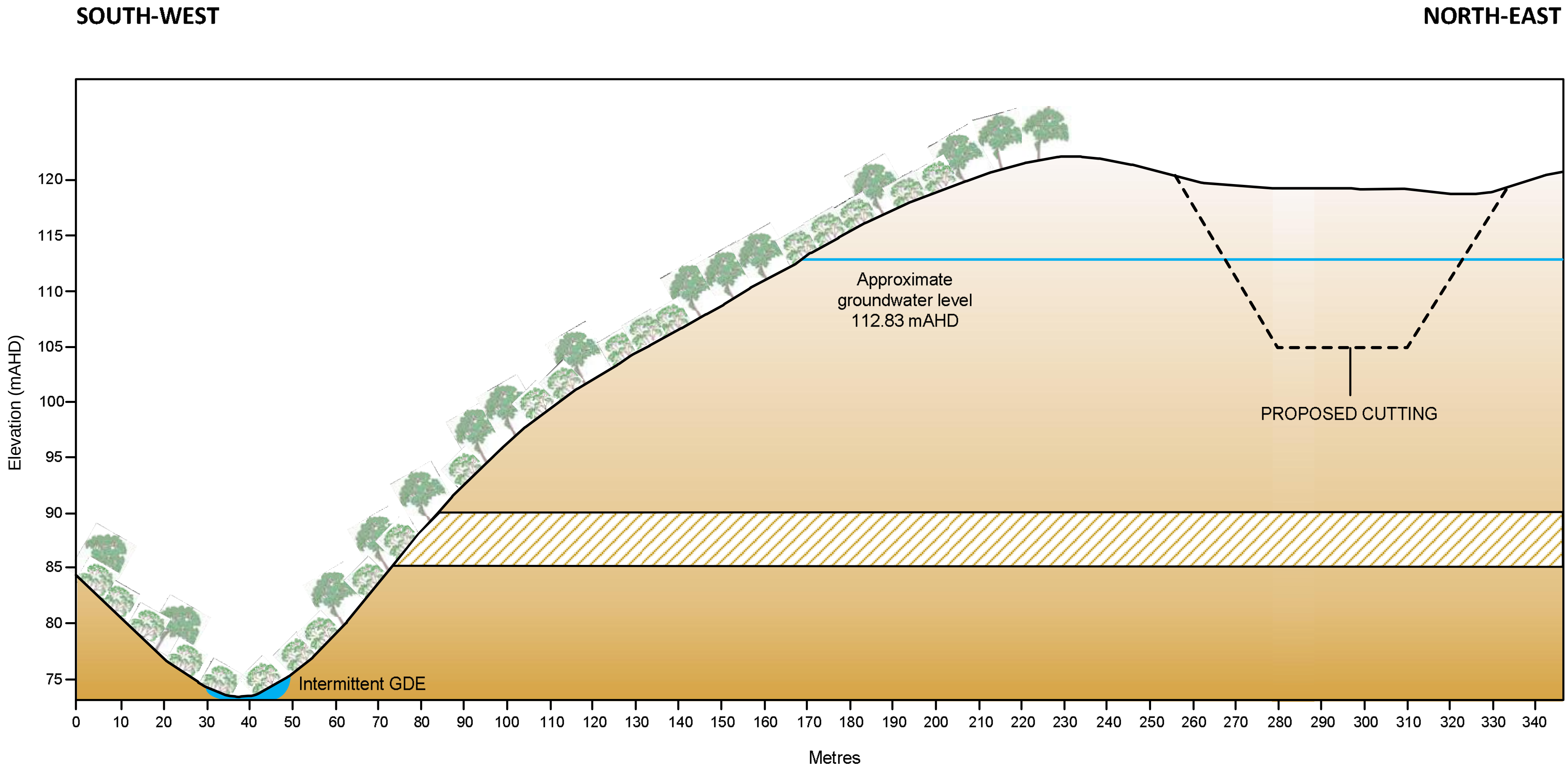
Job Number	22-17656-29
Revision	A
Date	23 Nov 2015

Cutting Two
Conceptual Cross Section

Figure 3-5

GHD\AU\Launceston\Projects\22\2217656_LTN_02.cdr

Level 3, 24 Honeysuckle Drive Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9699 **E** ntlmail@ghd.com.au **W** www.ghd.com



* Schematic diagram only – not to scale

Indicative groundwater level

Siltstone aquitard

LOCATION	Rankin Park
DRAWN	SM
CHECKED	IG
APPROVED	SG
SCALE	NTS

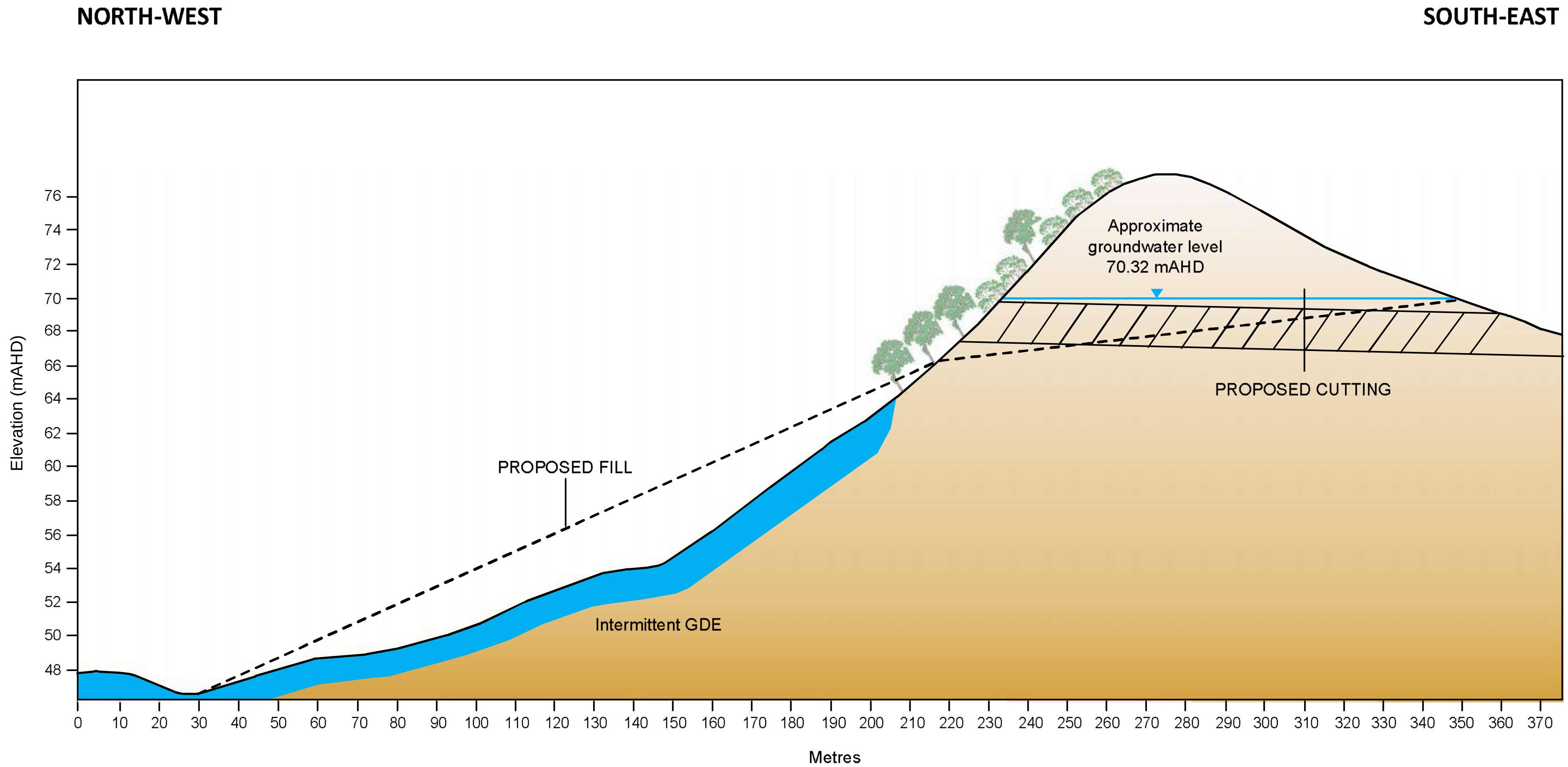
Newcastle Inner City Bypass
Rankin Park to Jesmond

Groundwater Assessment
Cutting One
Conceptual Cross Section

Aurecon Australia

DATE Apr 2016

Figure 3-6



* Schematic diagram only – not to scale

▼ Indicative groundwater level

Approximate extent of conglomerate aquitard

LOCATION	Rankin Park
DRAWN	SM
CHECKED	IG
APPROVED	SG
SCALE	NTS

Newcastle Inner City Bypass
Rankin Park to Jesmond

Groundwater Assessment
Cutting Three – North-west to South-east
Conceptual Cross Section

Aurecon Australia

DATE Apr 2016

Figure 3-7

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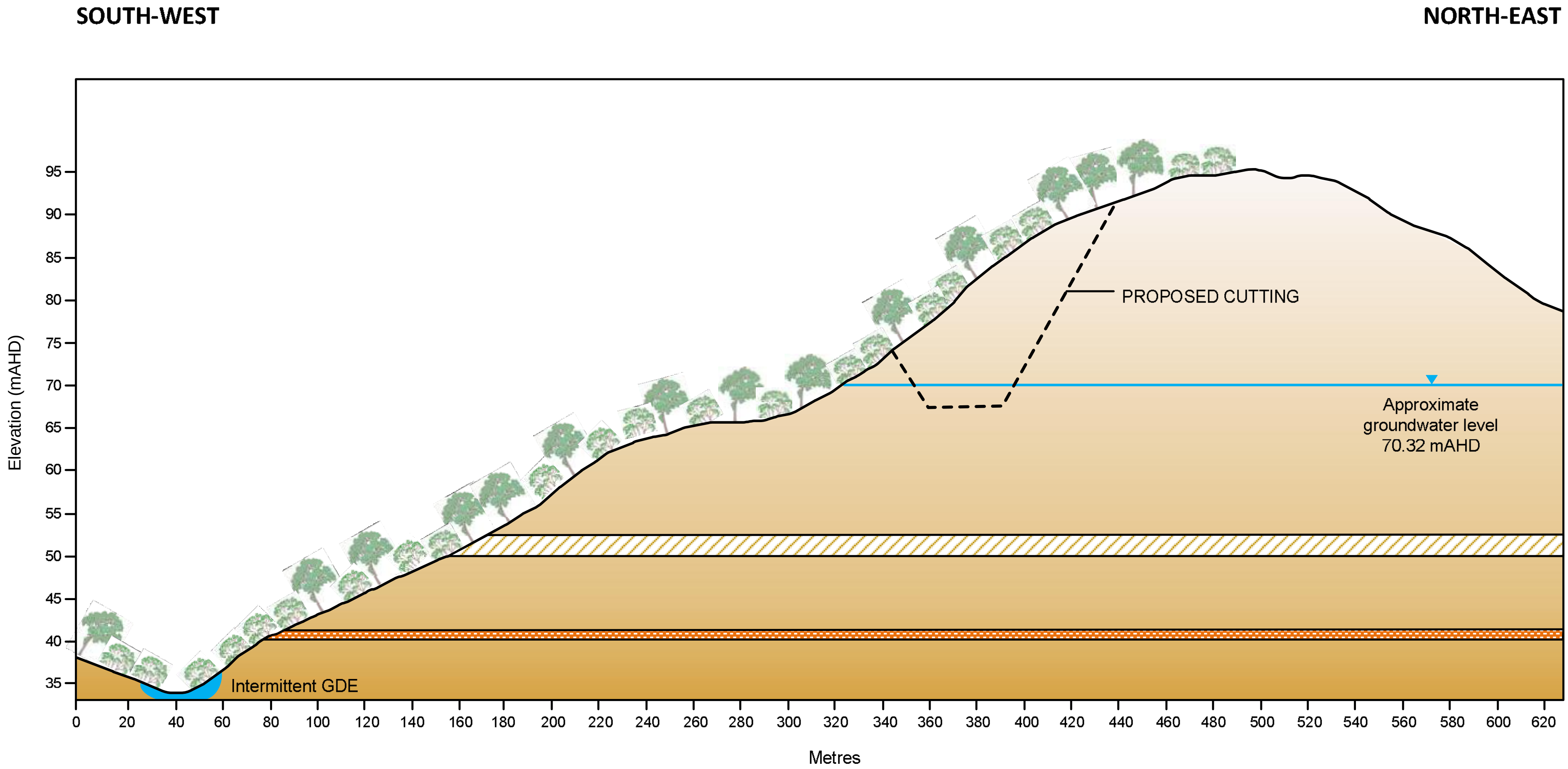


* Schematic diagram only – not to scale

- Indicative groundwater level
- Siltstone aquitard
- Interlaminated sandstone / siltstone aquitard

LOCATION	Rankin Park
DRAWN	SM
CHECKED	IG
APPROVED	SG
SCALE	NTS

Newcastle Inner City Bypass
Rankin Park to Jesmond

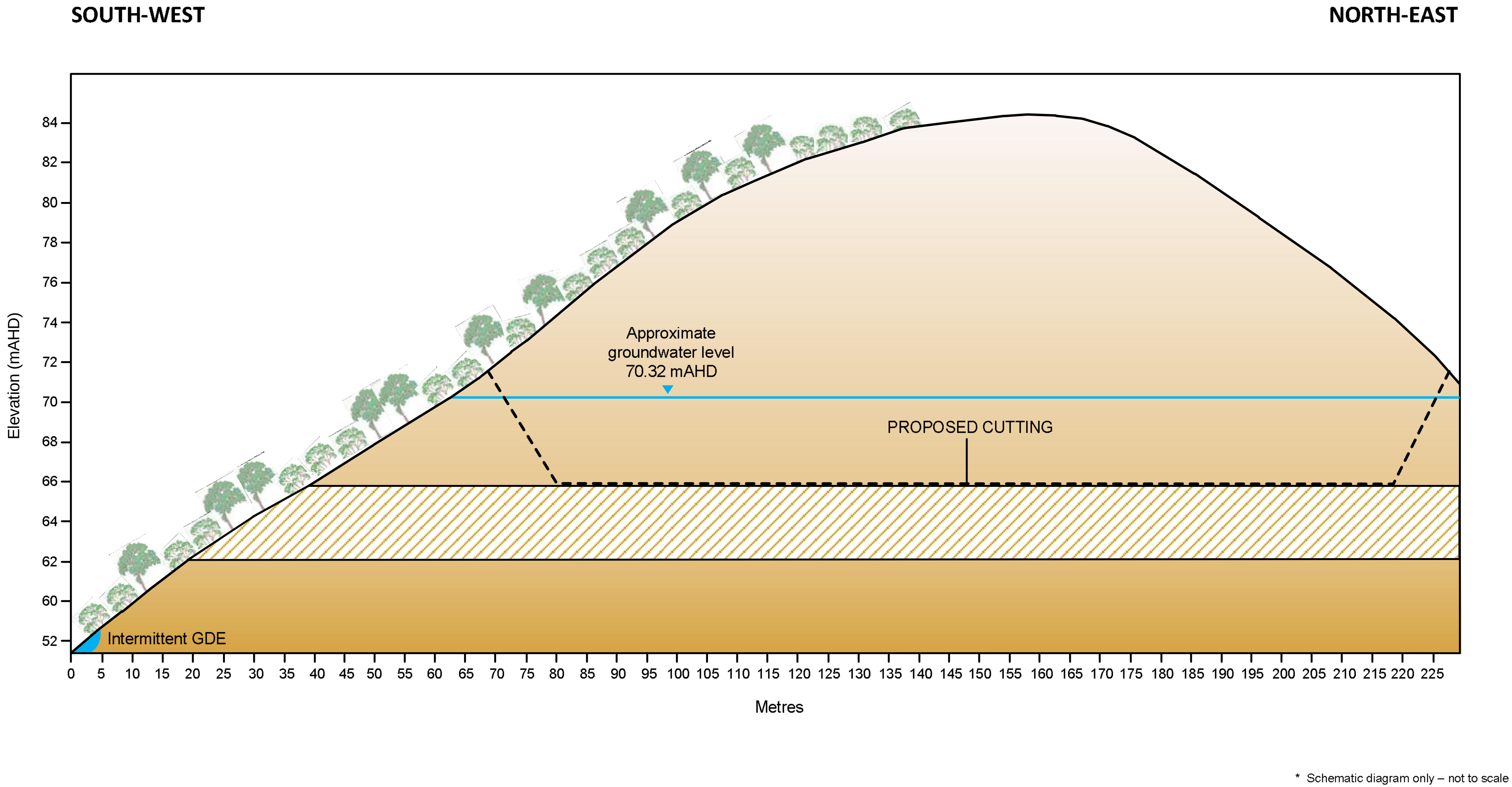
Groundwater Assessment
Cutting Three – South-west to North-east
Conceptual Cross Section

Aurecon Australia

DATE Apr 2016

Figure 3-8

G:\22\17656\Technical\29_EIS - Groundwater Assessment\Conceptual Cross Section\2217656_FIG3-7_CuttingThree.vsdx



Indicative groundwater level

Siltstone aquitard

LOCATION	Rankin Park
DRAWN	SM
CHECKED	IG
APPROVED	SG
SCALE	NTS

Newcastle Inner City Bypass
Rankin Park to Jesmond

Groundwater Assessment
Cutting Four
Conceptual Cross Section

Aurecon Australia

DATE Apr 2016

Figure 3-9

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Groundwater quality and discharge water quality

The project would involve a number of cuttings that would intercept perched groundwater. As discussed in Section 3.1, the concept design for the project has minimised cuttings as far as practicable to minimise groundwater inflow. However, during operation, it is expected that limited volumes of perched groundwater would continue to flow into the cuttings, mostly following rainfall events. Potential surface water impacts from groundwater inflow include the mobilisation of naturally occurring contaminants to surface water impacting on surface water quality, downstream sensitive receptors and/or groundwater dependent ecosystems. There is also a minor potential risk of exposure to site workers and future site users via direct contact. It is noted that the risks are unlikely to be significant with minor consequences (reversible health effects of little concern).

Perched groundwater would be intercepted in most cuttings as detailed in Section 3.3. The perched groundwater currently naturally seeps into local watercourses and will continue to do so outside the area of influence of the project. Based on the available groundwater quality data (Section 2.3.1), it is considered that the perched groundwater is suitable for discharge to the local watercourses with only isolated minor exceedances of a few analytes above the 95% species protection guideline values. Any impact on groundwater quality and the receiving environment will be negligible and as per existing conditions the beneficial use of the groundwater seepage will be maintained as aquatic ecosystem support with minor exceedances of a few analytes above the 95% species protection guideline values. Therefore, the proposed interception of perched groundwater does not represent a change from the existing condition and the resulting impacts to water quality are considered to be minimal.

Acid sulfate rock testing was carried out as part of the geotechnical assessment for the project (Aurecon 2016a). Chromium reducible sulfur results for all 21 samples were low, ranging from <0.005 to 0.03 % w/w, indicating low potential acidity in the samples and a low risk of acid generation resulting from the exposure of these samples to the atmosphere. Based on these results, it is unlikely that the quality of perched groundwater would change as a result of the exposure of rock cuttings to the atmosphere, and the beneficial use category (aquatic ecosystem support) would be maintained.

The project would not intercept with, or result in the intrusion of poorer quality regional groundwater into higher quality perched groundwater. The deeper, poorer quality regional groundwater would not be intercepted by the cuttings and the project would not result in regional groundwater being discharged to local watercourses and will not result in any negative impact on the perched groundwater or the receiving environment.

The contamination assessment (GHD 2016a) carried out for the project identified there are no widespread groundwater contamination issues in the study area and given there are no known users of the local groundwater, with the implementation of management measures it is unlikely there would be any impacts to existing or future uses.

During construction, groundwater inflows would be captured and managed in the construction water management system (eg sedimentation basins) before discharge to local watercourses. This would reduce the suspended sediment content of the water and provide some removal of metals, nutrients and hydrocarbons.

During operation, groundwater inflows would continue to be captured by the drainage system and discharged to the local watercourses. While the quality of the captured groundwater is not expected to change significantly, the project includes a range of controls to manage the captured water and these are detailed in the *Water Quality and Watercourse Assessment* (GHD, 2016b). These controls are proposed to include retaining and modifying some of the construction phase sediment basins as operational water quality treatment structures. The design of the operational water quality treatment structures will be refined during the detailed design phase.

As identified in the contamination assessment (GHD 2016a), soil testing results indicate there are no widespread soil contamination issues in the study area. Given the observed exceedances are generally localised, scattered in the construction footprint and are only located in relatively shallow soils, with the implementation of management measures no significant impacts are expected. Potential impacts to surface water and groundwater from contaminated soils are discussed in the *Water Quality and Watercourse Assessment* (GHD 2016b).

The project would encounter coal seams in Cuttings 1, 2, 4 and 5, which could result in groundwater seepage that contains naturally occurring hydrocarbons. Exposing the coal seams has the potential to accelerate the release of these naturally occurring hydrocarbons by increased oxidisation and dewatering. To minimise these risks, the exposed coal seams would be sealed with shotcrete or by over-excavation and backfilling with an inert material. As a result, there are not expected to be ongoing groundwater impacts associated with excavation and exposure of the coal seams. Therefore, the groundwater quality will be maintained and the beneficial use of the groundwater will be maintained as aquatic ecosystem support.

The coal material that would be excavated during construction has been identified to be either of poor quality and/or occurs in seams too thin to be extracted and sold on the market as a coal material. It is proposed that this material be blended with other fill materials and deep buried in the final formation. As a result, there are no expected impacts during construction associated with the excavated coal material.

Mine void grouting, to address future potential subsidence issues associated with historical mining activities, would be required for the bridge over watercourse 2. Mine void grouting would involve pumping of a concrete based material into shallow voids via pre-drilled boreholes. Typical materials required for mine grouting operations are water, flyash, cement and a fine aggregate (crusher dust). Potential risks to groundwater quality include surface spillage during grouting operations and grout interacting with groundwater.

There is the potential for grouting to impact groundwater quality and flow paths in the immediate area, however given the limited extent of grouting and observed depths to groundwater in this area these impacts are not expected to be significant. A mine remediation management plan will be prepared to manage potential risks associated with grouting operations. The plan will detail measures to manage the risk of escape of grout through natural fractures and an emergency spill response procedure. Management measures would be implemented to control and remediate these grout flows particularly those with the potential to interact with groundwater and/or enter surface water. Further groundwater monitoring will be carried out during detailed design and construction to confirm the depth to groundwater near the proposed mine remediation area to help with development of any specific mitigation measures.

Summary

Overall, it is predicted that the groundwater impacts from the project would be less than the Level 1 minimal impact considerations specified in the *NSW Aquifer Interference Policy* (DPI 2012) and therefore are considered to be acceptable.

The project is not predicted to result in any decline in groundwater pressure head at any water supply work (noting there are none near the study area). There are no culturally significant sites in or immediately near the study area.

The project would not result in any changes to the existing groundwater quality and would not result in any impacts to the receiving environment. As a result, there would not be any change to the beneficial use category (aquatic ecosystem support) of groundwater.

3.5 Cumulative impacts

There are no other known projects or activities currently impacting the perched groundwater source and GDEs in the study area. The perched aquifer is a highly localised system that is limited in extent to the higher areas of topography immediately surrounding the study area. It is not connected with any other aquifers in the surrounding area and therefore, the potential for cumulative impacts is very low.

Potential impacts on intermittent GDEs and ephemeral waterways are predicted to occur as a result of changes to both groundwater and surface water flows. The proposed cuttings would result in the interception of perched groundwater (as discussed in Section 3.3), although this water would be returned to the same watercourse following discharge from the project drainage system.

The surface water flow regime would also change as a result of the project, altering runoff volumes, flow rates and flow durations to watercourses as discussed in the *Water Quality and Watercourse Assessment* (GHD 2016b) and the *Flooding and Drainage Assessment* (Aurecon 2016b). It is predicted that the project would increase flows into most of the watercourses due to the increase in impervious surfaces. Further, most of the surface water captured in the project drainage system would be discharged to the same watercourse as it would have drained to under existing conditions.

Therefore, it is expected that there would be minimal loss, if any, in total flow volumes entering each watercourse. Since these waterways are ephemeral, the receiving environment including intermittent GDEs are currently already in an environment of variable flows and therefore the impacts of the changes induced by the project are expected to be minor. Potential impacts to GDEs are discussed further in the *Biodiversity Assessment Report* (GHD 2016c).

The project would intercept some local perched groundwater in the study area. The release of groundwater through the drainage system is not expected to result in any significant impacts to surface waters, including those that drain to the Ramsar wetlands, or any ecological values in or downstream of the study area. These potential impacts are discussed further in the *Water Quality and Watercourse Assessment* (GHD 2016b) and *Biodiversity Assessment Report* (GHD 2016c) carried out for the project.

As discussed in Section 2.3, the natural recharge to the regional groundwater source from the overlaying perched aquifer system is minimal. Therefore, the interception of perched groundwater by the project is not expected to impact the regional groundwater source, which is mostly recharged in areas of outcrop of the lower Newcastle Coal Measures.

3.6 Licensing

Based on a predicted total groundwater inflow of 57.7 cubic metres per day, an annual allocation of up to 21 mega litres per year may need to be licensed under the WM Act may be required and will be confirmed during detailed design in consultation with WaterNSW.

4. Management measures

This assessment has identified that the project would have minimal impacts on the groundwater of the study area in accordance with the *NSW Aquifer Interference Policy* (DTI 2012).

Environmental safeguards listed in Table 4-1 will be implemented.

Table 4-1 Summary of potential impacts and environmental safeguards

Impact	Environmental safeguards	Responsibility	Timing
Groundwater inflow	During detailed design the cuttings will be designed to minimise the volume of groundwater inflow as far as is practicable.	Roads and Maritime	Detailed design
Groundwater monitoring	A groundwater monitoring program will be prepared and implemented. The program will include: • Installation of monitoring bores (to replace those that would be removed during construction). • New monitoring bores will be installed both inside and outside the predicted zones of perched groundwater drawdown to confirm the conceptual model. New bore(s) will be established in the proposed mine remediation area to confirm the depth to groundwater and groundwater quality. • Establishment of project specific water quality objectives. • Bores will initially be monitored monthly for 12 months to collect baseline data. Monitoring will start as soon as possible and before the start of construction and will continue until completion, which may be after the start of construction. The frequency of monitoring will then be reviewed to determine the appropriate regime. • Bores will be monitored for standing water level and water quality (including pH, total dissolved solids, dissolved metals, nutrients and total recoverable hydrocarbons (silica gel clean-up). • A program of reporting of the monitoring results so that any unforeseen impacts are identified and responded to in a timely manner. • The monitoring program will continue until 12 months after completion of construction with an annual review of groundwater data unless results permit an earlier end date.	Roads and Maritime	Detailed design, pre-construction, construction and operation

Impact	Environmental safeguards	Responsibility	Timing
Groundwater discharge	During detailed design Roads and Maritime will review the monthly groundwater monitoring data to confirm the proposed construction and operational water management controls are appropriate and the project specific water quality objectives can be achieved.	Roads and Maritime	Detailed design
Groundwater dewatering	A construction groundwater and dewatering management plan will be prepared to manage groundwater inflows during construction.	Construction contractor	Pre-construction and construction
Groundwater discharge	During construction, all groundwater seepage in the cuttings will be handled in the construction phase surface water management system.	Construction contractor	Construction
Groundwater quality	Coal seams exposed by cuttings will be sealed with shotcrete or over-excavated and backfilled with an inert material.	Construction contractor	Construction
Mine remediation – grouting	A mine remediation management plan will be prepared to manage potential risks associated with grouting operations. The plan will be prepared with reference to groundwater monitoring data to determine the risk of grouting impacting on groundwater. The plan will detail measures to manage the risk of escape of grout, including into surface watercourses or groundwater, through natural fractures including: • Consultation • Monitoring • Emergency spill response procedure.	Construction contractor	Construction
Groundwater management	An operational groundwater management plan will be prepared if groundwater monitoring results indicate there are likely to be post-construction groundwater quality discharge exceedances of the project specific water quality objectives.	Roads and Maritime	Operation

5. Conclusion

This report has assessed the potential groundwater impacts relating to the project in order to address the Secretary’s Environmental Assessment Requirements (SEARs) and assessment requirements from DPI Water.

The identified groundwater systems include a deeper regional aquifer and perched aquifers above siltstone layers. A conceptual groundwater model has been developed that indicates that the perched groundwater system is present along ridgelines along the study area. The perched groundwater is expected to flow through localised weathered and fractured zones in the Newcastle Coal Measures. Recharge of the system is from the infiltration of rainfall along the ridgeline, with groundwater discharging at surface seepage zones along the slopes.

The proposed cuttings were identified to intercept several perched aquifers. Groundwater inflows into each of the proposed cuttings have been estimated by analytical calculations. Cumulative groundwater inflows are estimated to be between 12.4 and 403.9 cubic metres per day with the most likely estimate considered to be 57.7 cubic metres per day. An annual allocation of up to 21 mega litres per year may need to be licensed under the *Water Management Act 2000*.

Potential groundwater impacts have been assessed against the impact criteria specified in the *NSW Aquifer Interference Policy* (DTI 2012) for less productive groundwater sources. Groundwater impacts have been assessed to be consistently below the Level 1 minimal impact considerations and are considered to be acceptable. In particular, it was found that it is unlikely that Cutting 2 would impact the known groundwater dependent ecosystem, a *Gahnia clarkei* variant of the Smooth-barked Apple Red Bloodwood open forest. Impacts to intermittent GDEs would be mitigated by discharging groundwater inflow back into the local watercourses that support these GDEs.

This assessment has identified that the project is unlikely to result in significant impacts to groundwater, surface water, groundwater dependent ecosystems or sensitive downstream receivers including SEPP 14 and Ramsar wetlands. Management measures have been recommended to manage potential impacts during the detailed design, construction and operation phases of the project, including continued groundwater monitoring to confirm the predictions in this assessment.

6. References

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GHD 2016c. *Newcastle Inner City Bypass – Rankin Park to Jesmond Biodiversity Assessment Report*

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Appendices

Appendix A – Groundwater level data

Name	Depth to groundwater (m bgl)						Groundwater level (m AHD)					
	25/05/2015	10/07/2015	5/08/2015	19/08/2015	27/08/2015	24/03/2016	25/05/2015	10/07/2015	5/08/2015	19/08/2015	27/08/2015	24/03/2016
BHAG01	–	–	6.50	–	6.5	DRY	–	–	125.09	–	125.09	–
BHAG03	–	–	9.00	9.02	9.08	–	–	–	112.83	112.81	112.75	–
BHAG06	–	–	20.00	20.6	20.69	24.35	–	–	89.17	88.571	88.48	84.83
BHAG11	–	–	12.6	12.68	12.67	–	–	–	42.31	42.234	42.24	–
BHAG15	–	26.2	–	–	–	–	–	37.37	–	–	–	–
BHAG18	26.2	–	26.4	27.7	27.64	27.6	58.25	–	58.05	56.752	56.81	56.85
BHAG21	11.6	6.2	11.1	11.3	11.31	–	71.81	77.22	72.31	72.109	72.10	–
BHAG22	14.0	–	–	12.68	–	–	66.51	–	–	67.829	–	–
BHAG23	–	–	14.3	15.1	15.3	15.1	–	–	18.42	17.618	17.42	17.62
BHAG30	–	1.5	1.8	20	2	–	–	8.64	8.37	-9.855	8.15	–
BHAG34	–	7.7	6.5	7.1	DRY	–	–	8.86	10.05	9.454	–	–
BHAG41	–	11.8	11.8	12.55	12.55	12.805	–	44.32	44.32	43.574	43.57	43.32
BHAG42	14.8	–	19.6	21	20.33	–	70.32	–	65.52	64.116	64.79	–
BHSM05G	–	–	10.0	10.13	DRY	–	–	–	21.51	21.38	–	–
BHSM08	–	–	26.0	26	25.95	–	–	–	11.33	11.326	11.38	–
BHSM11G	–	–	13.8	14.8	14.96	–	–	–	16.51	15.505	15.35	–

Appendix B – Groundwater quality data

Analyte	Units	LOR	ANZECC (2000)[1]	BHAG03	BHAG11	BHAG41	BHAG21	BHAG42	BHAG23	BHSM08	BHSM11G	BHAG30	BHAG06
Dissolved Metals													
Arsenic	mg/L	0.001	0.013	0.005	0.001	0.003	**0.020**	0.008	0.002	0.002	0.002	0.010	0.002
Cadmium	mg/L	0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	**0.0102**	0.0001	<0.0001
Chromium	mg/L	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.002**	<0.001	**0.002**	<0.001
Copper	mg/L	0.001	0.0014	**0.002**	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	**0.087**	<0.001	<0.001
Lead	mg/L	0.001	0.0034	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001
Nickel	mg/L	0.001	0.011	**0.019**	0.005	0.006	**0.024**	0.010	0.008	**0.139**	**1.75**	0.007	**0.014**
Mercury	mg/L	0.0001	0.0006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Total Metals													
Arsenic	mg/L	0.001	-	0.038	0.013	0.315	0.215	0.084	0.112	0.196	0.113	0.016	0.080
Cadmium	mg/L	0.0001	-	0.0028	0.0017	0.0074	0.0120	0.0039	0.0038	0.0038	0.0148	0.0004	0.0019
Chromium	mg/L	0.001	-	0.241	0.041	0.805	0.452	0.208	0.305	0.625	0.325	0.010	0.274
Copper	mg/L	0.001	-	0.720	0.115	1.18	2.08	1.19	0.431	1.35	1.18	0.012	0.231
Lead	mg/L	0.001	-	0.248	0.082	0.595	1.45	0.407	0.202	0.518	0.357	0.006	0.247
Nickel	mg/L	0.001	-	0.248	0.052	0.665	1.03	0.247	0.402	1.24	2.69	0.017	0.119
Mercury	mg/L	0.0001	-	0.0002	0.0002	0.0005	0.0002	<0.0001	<0.0001	0.0003	0.0002	0.0004	0.0001

Analyte	Units	LOR	ANZECC (2000)[1]	BHAG03	BHAG11	BHAG41	BHAG21	BHAG42	BHAG23	BHSM08	BHSM11G	BHAG30	BHAG06
Nutrients													
Ammonia (as N)	mg/L	0.01	0.9	0.28	0.41	0.2	0.21	0.31	0.16	0.25	0.38	**1.00**	0.20
Nitrate (as N)	mg/L	0.01	0.7	0.04	0.03	0.04	0.06	0.02	0.03	0.04	0.04	0.03	0.04
Nitrite (as N)	mg/L	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite + Nitrate (as N)	mg/L	0.01	-	0.04	0.03	0.04	0.06	0.02	0.03	0.04	0.04	0.03	0.04
Total Kjeldahl Nitrogen	mg/L	0.1	-	11.8	7.4	10.6	60.8	19.2	7.3	31.2	11.5	12.4	6.8
Total Nitrogen (as N)	mg/L	0.1	-	11.8	7.4	10.6	60.9	19.2	7.3	31.2	11.5	12.4	6.8
Other Parameters													
Sulfate	mg/L	1	-	70	91	79	82	53	82	452	707	21	173
Chloride	mg/L	1	-	56	376	169	248	102	377	303	118	142	210

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

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