6.7 Groundwater

This section provides a summary of the assessment of potential groundwater impacts during construction and operation of the proposal and identifies mitigation measures to address these impacts. A detailed assessment of groundwater impacts is provided in the technical working paper – groundwater assessment (Appendix J).

6.7.1 Methodology

The groundwater assessment involved the following:

- Desktop review and analysis to characterise the existing environment and identify potential groundwater risks
- Review and analysis of groundwater levels and groundwater quality data to refine the understanding of potential groundwater issues identified in the desktop assessment and address any knowledge gaps
- Assessment of potential construction and operational impacts on groundwater levels and quality, including:
  - Potential groundwater inflow rates to proposed cuttings and associated groundwater level drawdown was assessed using analytical equations. Details of the approach are provided in Section 3.3 of Appendix J
  - Changes in groundwater levels based on criteria adopted in The NSW Aquifer Interference Policy (DPI, 2012) Minimal Impact Considerations
  - Groundwater quality in accordance with the ANZG (2018) Water Quality Guidelines, the Guidelines for Groundwater Quality Protection in Australia (Australian Government, 2013) and the Minimal Impact Considerations from the Aquifer Interference Policy (DPI, 2012)
  - Groundwater quality assessed against the neutral or beneficial effect (NorBE) principle due to the proposal residing within the Sydney Drinking Water Catchment.
- Qualitative assessment of potential cumulative groundwater impacts, which may occur due to the proposal interacting with other approved or proposed proposals
- Identification of appropriate treatment measures to mitigate potential impacts to groundwater levels, quantity and quality resulting from construction and operation of the proposal.

6.7.2 Existing environment

Groundwater systems and surface water interactions

The following distinct groundwater systems are conceptualised to be present within the construction footprint (RTA/Parsons Brinckerhoff/Sinclair Knight Merz, 2011):

- Semi confined sedimentary rock groundwater systems within Shoalhaven Group siltstone, lithic sandstone and conglomerate
- Semi confined intrusive rock groundwater systems within fractured granite, and
- Localised and relatively minor unconsolidated unconfined to semi confined alluvial groundwater systems.

The degree and type of interaction between groundwater and surface water is largely dependent on topography, stream geomorphology and the underlying groundwater systems. Interactions are also dependent on seasonal variation, as the water table rises and falls in response to seasonal changes, and the fluctuations would be accentuated in particularly dry and wet years.

It is likely that major watercourses in the study area receive groundwater flow during certain periods.

Existing registered bores

There are 63 existing registered groundwater bores within the study area (Figure 4.3 of Appendix J). Nine are located within the construction footprint:

- State bore I.D.s GW070637 and GW104752, which have a purpose of stock and domestic, respectively. GW104752 is located in the CRR construction footprint and GW070637 is located in the FBL construction footprint
- State bore I.D.s GW111924 and GW111961, located in the FBL construction footprint, which have a purpose of monitoring
- State bore I.D.s GW111531 (R2F construction footprint), GW111532 (R2F construction footprint) and GW111530 (L2R construction footprint) and GW111541 (CRR construction footprint), which have a purpose of monitoring and whose locations correspond to a proposal monitoring bore location.

Groundwater levels

Existing groundwater monitoring bores are shown in Figure 6-26. A detailed summary of groundwater levels for each of the identified groundwater monitoring bores is provided in Table 4-3 of Appendix J. Generally, groundwater levels range from shallow (0.5 metres Below Ground Level (BGL)) to moderate (i.e. about 18 metres BGL). Groundwater levels for each construction footprint are estimated below:

- Little Hartley to River Lett groundwater levels range between 18 and seven metres below ground level
- Cox River Road groundwater levels are around 2.63 metres below ground level
- River Lett to Forty Bends groundwater levels range between 15 and 0.5 metres below ground level
- Forty Bends to Lithgow groundwater levels are around 4.85 metres below ground level

It is noted that relatively shallow groundwater depth measurements of less than two metres below ground level may not represent the water table and may be occurring due to semi confined flow conditions in the fractured granite which the bores monitor.

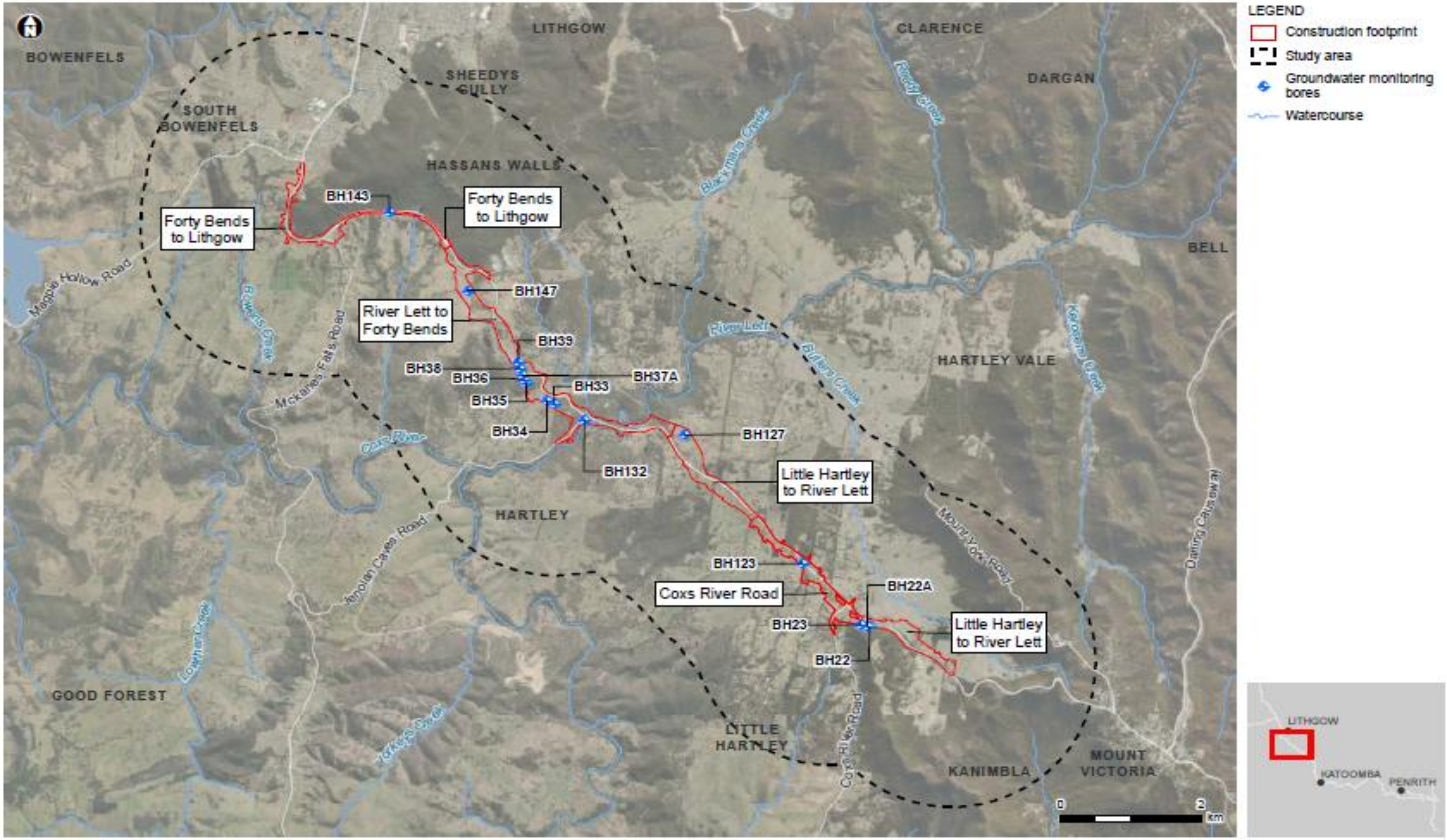

Figure 6-26 Existing proposal groundwater monitoring bores

Groundwater flow directions

Groundwater in the study area is conceptualised to generally flow from areas of relatively high elevation towards areas of relatively low elevation, before discharging to creeks as baseflow, or via evapotranspiration in areas of relatively low elevation where groundwater levels are close to the surface.

Hydraulic conductivity

There is currently no hydraulic conductivity test data or results for the various proposals.

Based on the groundwater system rock types and characteristics, hydraulic conductivity is inferred to be generally relatively low in the groundwater study area for rock groundwater systems. For rock groundwater systems, the bulk hydraulic conductivity is expected to typically be around 0.001 metres to day to 0.01 metres per day but could vary outside this range by multiple orders of magnitude.

There is potential for hydraulic conductivity to be relatively elevated for alluvial groundwater systems.

Groundwater recharge and discharge

Groundwater recharge in the study area is conceptualised to primarily occur through rainfall recharge.

Groundwater discharge is conceptualised to occur as outflow to watercourses, through evapotranspiration in areas of relatively low lying land with shallow water table and at springs, slope breaks, and by groundwater extraction bores.

Groundwater dependent ecosystems

Existing groundwater dependent ecosystems are outlined in Section 6.1 Biodiversity.

Groundwater quality

Groundwater quality data is available for monitoring bores in the study area (refer to Figure 6-26) for field parameters, major ions and dissolved heavy metals, iron and manganese. Groundwater quality results are summarised in Table 6-84 based on whether the monitoring bore is located in granite or Shoalhaven Group (comprising siltstone, lithic sandstone and conglomerate).

Table 6-84 Groundwater quality

Parameters	Geology	Description
pH and conductivity	Shoalhaven Group	• Groundwater is characterised as fresh to brackish • pH ranged from 5.14 to 7.37, with an average value of 6.61. The sample with the minimum pH value of 5.14 (BH123) was outside of the ANZECC 2000 lowland rivers physical and chemical stressors guideline pH range of 6.5 to 8.5.
	Granite	• Groundwater is characterised as fresh • pH ranged from 6.55 to 7.47, with an average value of 7.12. All samples were within the ANZECC 2000 lowland rivers physical and chemical stressors guideline pH range
Cations and anions	Shoalhaven Group	• There is no dominant cation at BH22a. At BH23 and BH123 the dominant cation is sodium. At BH143 the dominant cation is calcium. The anions are dominated by sulfate except at BH143 where they are

Parameters	Geology	Description
		dominated by bicarbonate. The overall water type is mixed (BH22a), sodium chloride (BH23 and BH123) or calcium bicarbonate (BH143).
	Granite	• The dominant cation is calcium, the dominant anion is bicarbonate and the overall water type is calcium – bicarbonate. Exceptions include bores BH132 (no dominant cation) and BH147 (dominant anion was sulfate and overall water type was calcium carbonate).
Dissolved heavy metals	Shoalhaven Group	• Dissolved manganese ranged from 0.183 milligrams per litre to 1.88 milligrams per litre, with an average value of 0.93 milligrams per litre, indicating background concentrations of manganese • Dissolved iron ranged from 0.18 milligrams per litre to 40.6 milligrams per litre, with an average value of 11.21 milligrams per litre, indicating background concentrations of iron.
	Granite	• Dissolved manganese ranged from 0.134 milligrams per litre to 1.11 milligrams per litre, with an average value of 0.50 milligrams per litre, indicating background concentrations of manganese • Dissolved iron ranged from <0.05 milligrams per litre to 42 milligrams per litre, with an average value of 7.63 milligrams per litre (average calculation used 0.05 value for the <0.05 results), indicating background concentrations of iron.

Groundwater contamination

Potential areas of groundwater contamination are considered in Section 6.12 Contamination.

6.7.3 Potential impacts

Little Hartley to River Lett

Potential for groundwater inflows, drawdown, and changes to flow regime

For the purpose of the assessment of impacts to groundwater inflows, drawdown and changes in flow regime, the Little Hartley to River Lett alignment has been divided up into six sections as shown in Figure 6-27. Of these six sections the only section where groundwater interception is predicted is L2R-2. The calculated drawdown extent for this section ranged from about 26 metres to 81 metres.

The calculated groundwater inflow rates are low and the associated drawdown extents are sufficiently small that changes to groundwater flow regimes would be localised to the vicinity of the proposal, with no material changes to regional groundwater flow conditions likely.

Material changes of baseflows to water courses due to groundwater level drawdown would not occur.

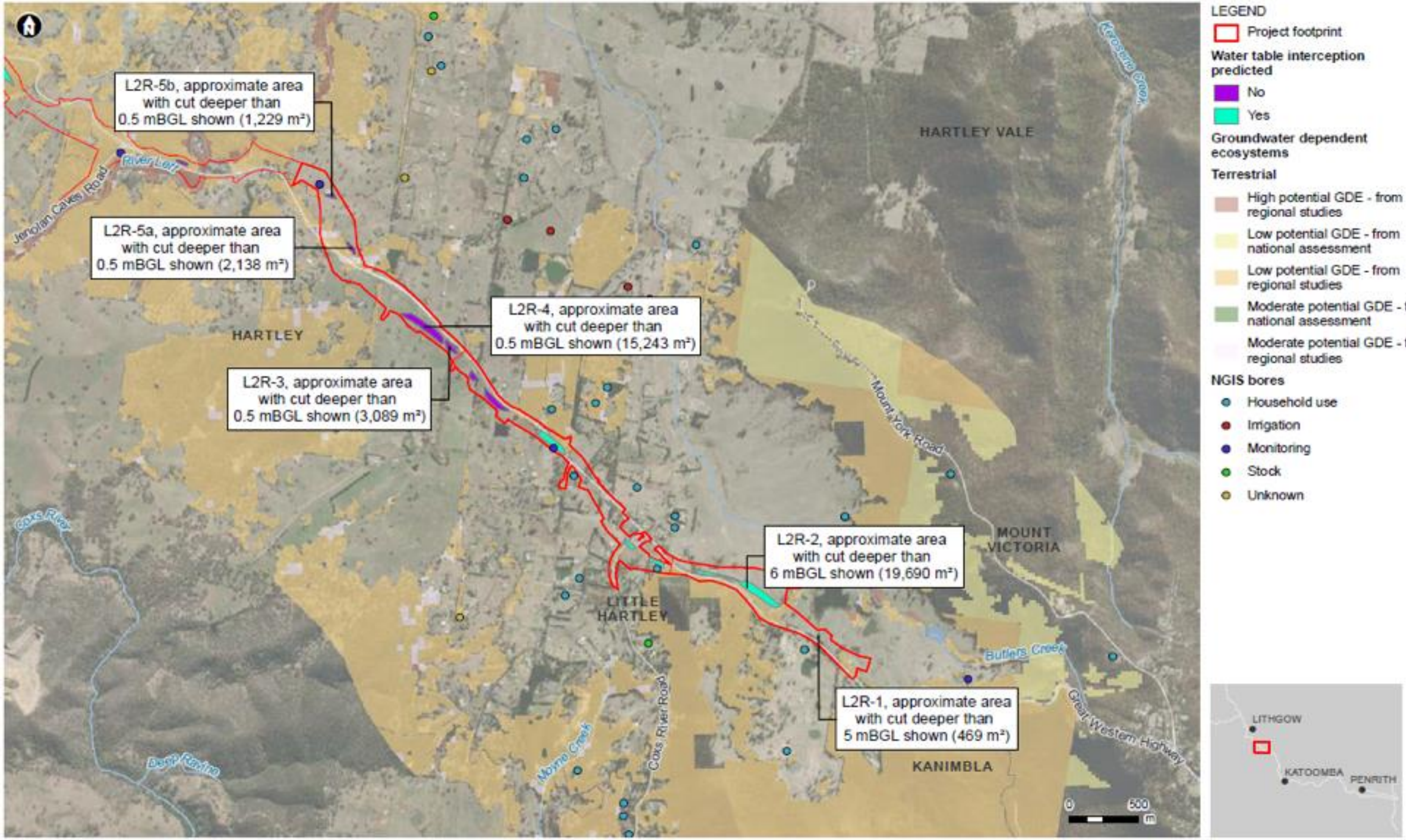

Figure 6-27 Little Hartley to River Lett section for groundwater assessment

Impacts to existing bores

Impacts to existing bores are not anticipated. The zone of influence for groundwater impacts due to water table penetration is predicated to be 81 metres, there are no existing bores within this predicted zone of influence.

Impacts to groundwater dependent ecosystems

Impacts to groundwater dependent ecosystems are considered in Section 6.1 Biodiversity.

Discharge of intercepted groundwater

Discharge of groundwater intercepted by proposed road cuttings could potentially impact receiving environments if the groundwater quality differs significantly from that of the receiving environment water quality and the groundwater discharge rate is sufficiently high that when combined with the groundwater quality, resulting in a significant mass flux of a chemical substance to the receiving environment.

Material impacts associated with discharge of groundwater to receiving environments are considered as unlikely to occur. This is because the calculated groundwater flow of 2.85 kilolitres per day (0.03 litres per second) would be insignificant compared to surface water flows and therefore groundwater would be markedly diluted by surface water flows.

Coxs River Road

Potential for groundwater inflows, drawdown, and changes to flow regime

For the purpose of the assessment of impacts to groundwater inflows, drawdown and changes in flow regime, the Coxs River Road alignment has been divided up into five distinct sections as shown in Figure 6-28. Of these five sections, groundwater interception is predicted is at CRR-1, CRR-2 and CRR3. The calculated drawdown extent for this section ranges from about 13 metres to 53 metres. Estimated groundwater inflow rates for these sections is provided in Table 6-85.

The calculated groundwater inflow rates are low and the associated drawdown extents are sufficiently small that changes to groundwater flow regimes would be localised to the vicinity of the proposal, with no material changes to regional groundwater flow conditions likely.

Material changes to baseflows to water courses due to groundwater level drawdown would not occur.

Table 6-85 Calculated groundwater inflows and drawdown extents for Coxs River Road

Proposed section	Estimated groundwater inflow rate (kL/day)		Estimated groundwater level drawdown extent (metres)	
	Low hydraulic conductivity scenario	High hydraulic conductivity scenario	Low hydraulic conductivity scenario	High hydraulic conductivity scenario
CRR-1	0.04	0.015	13	41
CRR-2	0.06	0.27	16	50
CRR-3	0.13	0.53	17	53

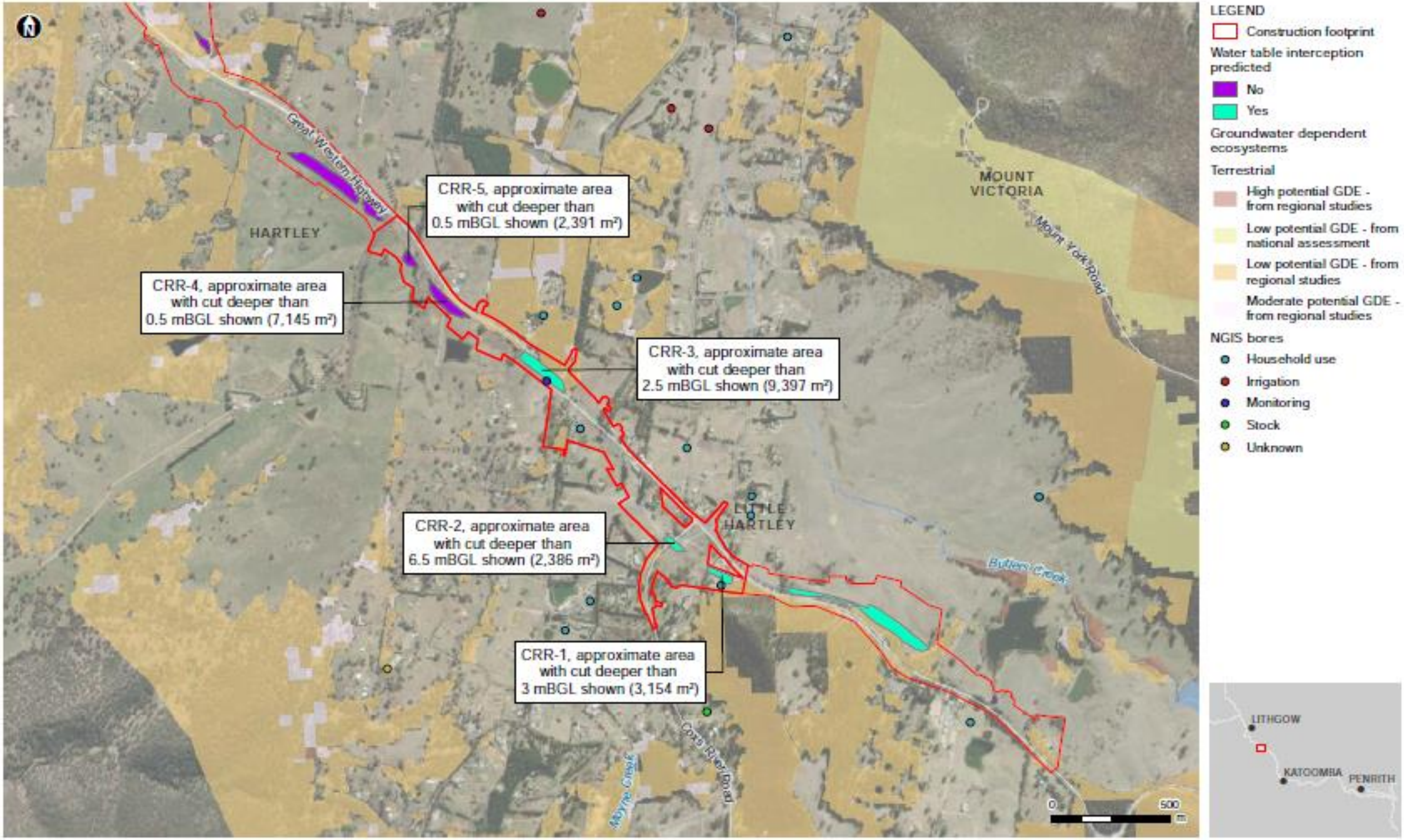

Figure 6-28 Coxs River Road section for groundwater assessment

Impacts to existing bores

Household bore GW104752 is within the construction footprint and will likely require decommissioning; however if retained is not anticipated to be impacted by potential induced groundwater level drawdown resulting from the proposed works. Impacts to other existing bores are not anticipated.

Impacts to groundwater dependent ecosystems

Impacts to groundwater dependent ecosystems are considered in Section 6.1 Biodiversity.

Discharge of intercepted groundwater

Discharge of groundwater intercepted by the Coxs River Road proposal to receiving environments is not anticipated to cause material environment impacts because the calculated groundwater inflow rates are very low and discharged groundwater would be diluted by surface water.

River Lett to Forty Bends

Potential for groundwater inflows, drawdown, and changes to flow regime

For the purpose of the assessment of impacts to groundwater inflows, drawdown and changes in flow regime, the River Lett to Forty Bends alignment has been divided up into three sections as shown in Figure 6-29. Of these three sections, groundwater interception is predicted at R2F-2 and R2F-3. The calculated drawdown extent for this section ranged from about 17 metres to 85 metres. Estimated groundwater inflow rates for these sections is provided in Table 6-86.

The calculated groundwater inflow rates are low and the associated drawdown extents are sufficiently small that changes to groundwater flow regimes would be localised to the vicinity of the proposal, with no material changes to regional groundwater flow conditions likely.

Material changes to baseflows to water courses due to groundwater level drawdown would not occur.

Table 6-86 Calculated groundwater inflows and drawdown extents for River Lett to Forty Bends

Proposed section	Estimated groundwater inflow rate (kL/day)		Estimated groundwater level drawdown extent (metres)	
	Low hydraulic conductivity scenario	High hydraulic conductivity scenario	Low hydraulic conductivity scenario	High hydraulic conductivity scenario
R2F-2	0.70	2.91	27	85
R2F-3	0.17	0.65	17	54

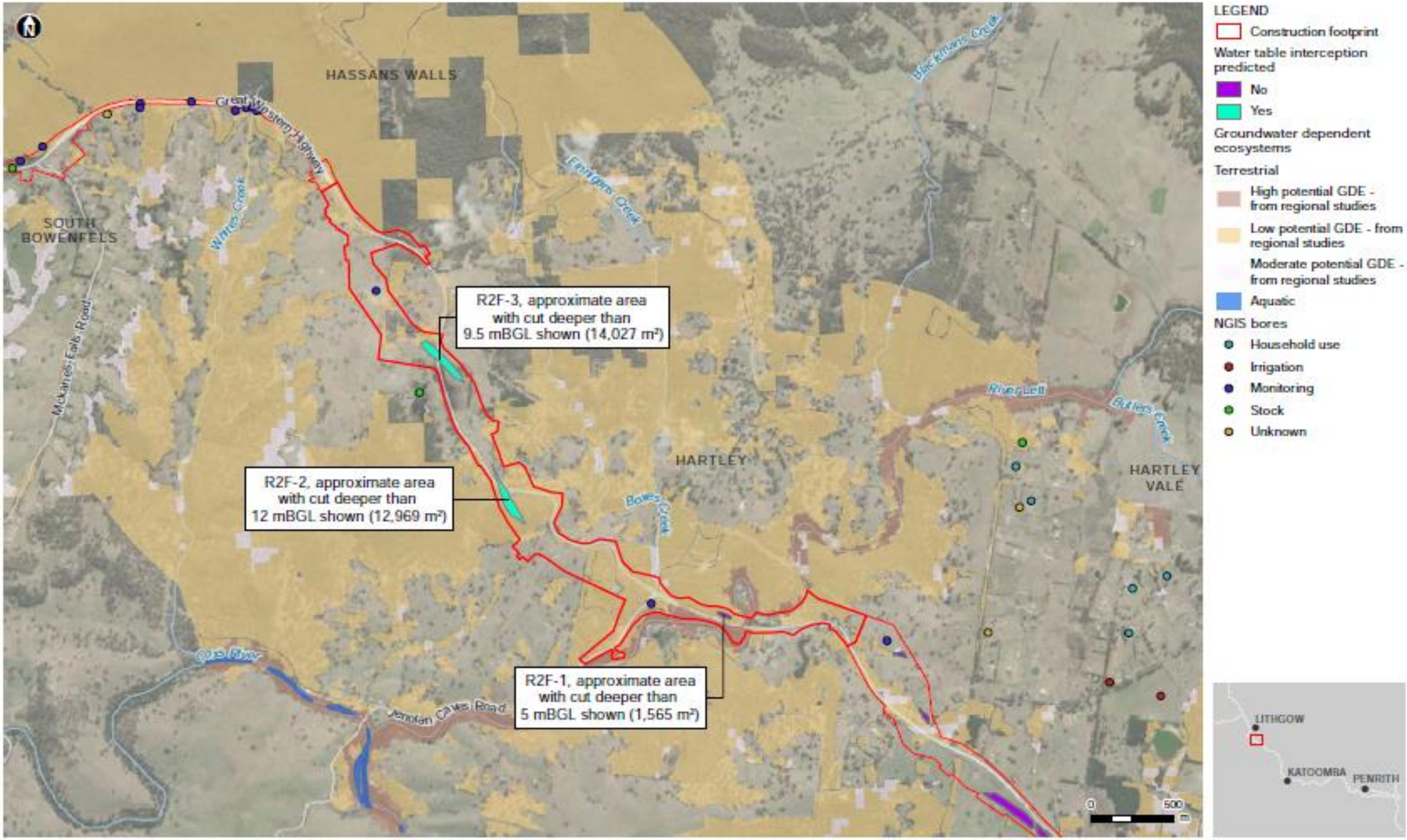

Figure 6-29 River Lett to Forty Bends section for groundwater assessment

Impacts to existing bores

Impacts to existing bores are not anticipated.

Impacts to groundwater dependent ecosystems

Impacts to groundwater dependent ecosystems are considered in Section 6.1 Biodiversity.

Discharge of intercepted groundwater

Discharge of groundwater intercepted by proposed road cuttings to receiving environments is not anticipated to cause material environment impacts because the calculated groundwater inflow rates are very low (calculated maximum rate of 2.91 kilolitres per day, or 0.03 litres per second) and discharged groundwater would be diluted by surface water.

Forty Bends to Lithgow

Potential for groundwater inflows, drawdown, and changes to flow regime

For the purpose of the assessment of impacts to groundwater inflows, drawdown and changes in flow regime, the Forty Bends to Lithgow alignment has been divided up into six sections as shown in Figure 6-30.

Of these sections, groundwater interception is predicted at all six sections. The calculated drawdown extent for this section ranged from about six metres to 50 metres. Estimated groundwater inflow rates for these sections is provided in Table 6-87.

The calculated groundwater inflow rates are low and the associated drawdown extents are sufficiently small that changes to groundwater flow regimes would be localised to the vicinity of the proposal, with no material changes to regional groundwater flow conditions likely.

Material changes to baseflows to water courses due to groundwater level drawdown would not occur.

Table 6-87 Calculated groundwater inflows and drawdown extents for River Lett to Forty Bends

Proposed section	Estimated groundwater inflow rate (kL/day)		Estimated groundwater level drawdown extent (metres)	
	Low hydraulic conductivity scenario	High hydraulic conductivity scenario	Low hydraulic conductivity scenario	High hydraulic conductivity scenario
FBL-1	0.05	0.23	16	50
FBL-2	0.05	0.24	16	50
FBL-3	0.05	0.22	16	50
FBL-4	0.001	0.01	6	20
FBL-5	0.04	0.19	16	50
FBL-6	0.04	0.21	16	50

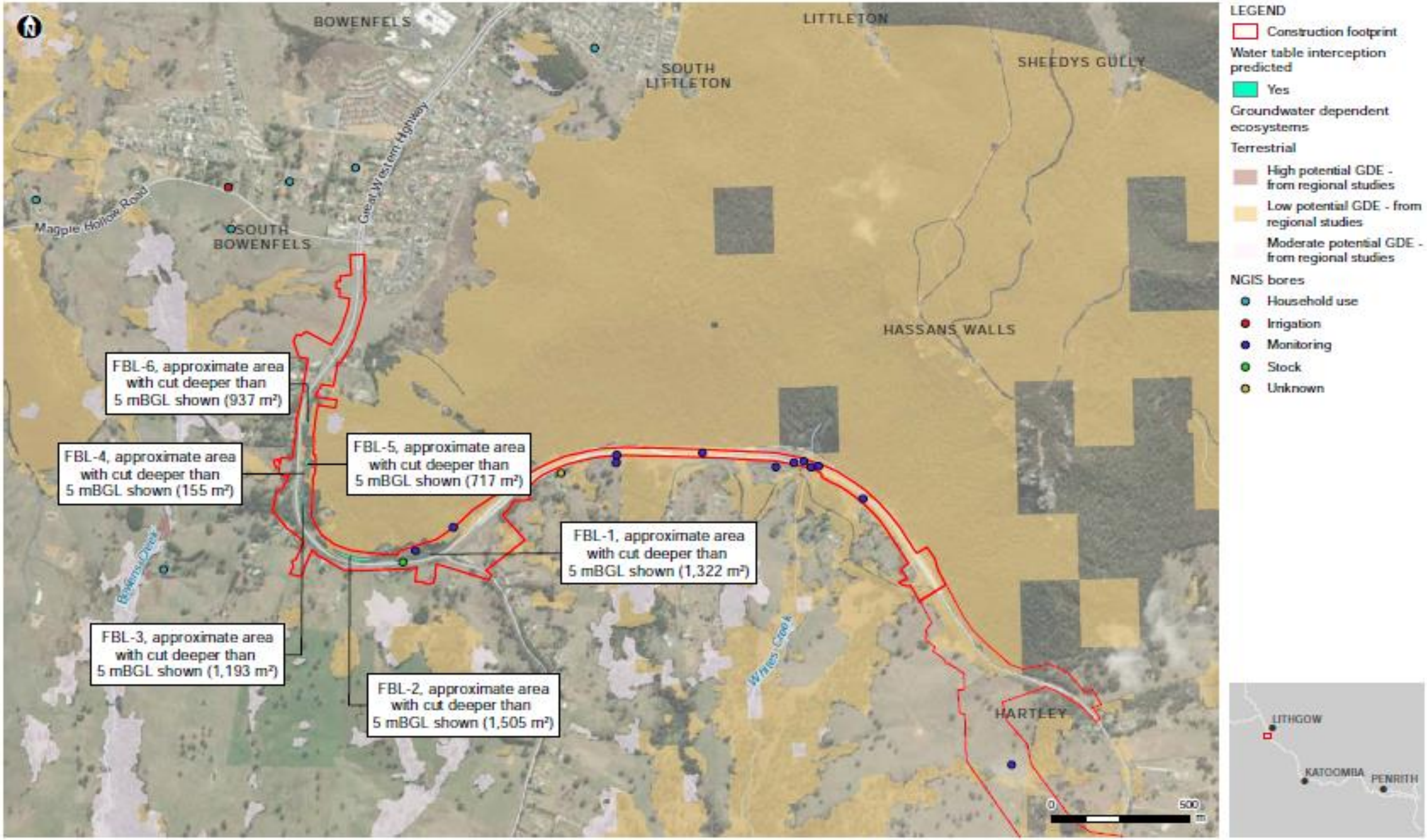

Figure 6-30 Forty Bends to Lithgow section for groundwater assessment

Impacts to existing bores

Stock and domestic bore GW070637 is within the construction footprint and will therefore likely require decommissioning. Monitoring bores GW111924 and GW111961 are also within the construction footprint. Of these monitoring bores, bore GW111961 is on the periphery of the construction footprint and therefore may be able to be retained. However, monitoring bore GW111924 is not on the periphery of the construction footprint and therefore will likely require decommissioning.

Other impacts to existing bores are not anticipated.

Impacts to groundwater dependent ecosystems

Impacts to groundwater dependent ecosystems are considered in Section 6.1 Biodiversity.

Discharge of intercepted groundwater

Discharge of groundwater intercepted by proposed road cuttings to receiving environments is not anticipated to cause material environment impacts because the calculated groundwater inflow rates are very low (calculated maximum rate of 0.24 kilolitres per day or 0.003 litres per second) and discharged groundwater would be diluted by surface water.

Proposal wide impacts

Changes to baseflow

Material changes to baseflow to watercourses due to the proposal are not anticipated. This is because predicted changes to groundwater levels are small and localised to the vicinity of the proposal.

Potential changes to groundwater quality

Impacts to groundwater quality during construction are outlined below:

- Groundwater systems could become contaminated if accidental spills or leaks of hazardous materials (such as fuels, lubricants and hydraulic oils) occur during construction or operation
- If potential acid sulfate soil or rock is excavated and oxidised or if actual acid sulfate soil or rock is excavated and mobilised, some acidification could occur. Acidification could also occur due to oxidisation as a result of lowered groundwater levels. The acidification could also potentially mobilise heavy metals
- The acidification could worsen the quality of groundwater which may flow into proposed road cuttings and subsequently be discharged to receiving environments. If acid sulfate soil or rock material is used as fill, acidified leachate could migrate to the water table and beyond
- Groundwater salinity could be increased if groundwater levels increase, and salts are mobilised that have natural accumulated in the soil.

With the implementation of the mitigation measures outlined in Table 6-88, the risks of these impacts occurring is considered low.

Potential groundwater contamination

Potential groundwater contamination impacts are considered in Section 6.12 Contamination.

NSW API minimal impact consideration assessment summary

Predicted groundwater level reductions are less than the NSW Aquifer Interference Policy minimal impact considerations. The beneficial use category of groundwater sources is not anticipated to be lowered beyond 40 metres of the proposal, which is an AIP water quality criterion. It is not anticipated that an Aquifer Interference License will be required for the proposal.

Sydney Drinking Water Catchment NorBE assessment

In the context of the Sydney Drinking Water Catchment, with adoption of recommended mitigation measures outlined below, the proposal is assessed as likely to have a neutral impact on groundwater quality.

6.7.4 Safeguards and management measures

Table 6-88 Safeguards and management measures – groundwater

No	Impact	Environmental safeguards	Responsibility	Timing	Reference	Locations
GW01	Evaluation of hydraulic conductivity test data	Once groundwater monitoring bores associated with the current geotechnical drilling program have been installed and slug tested, the hydraulic conductivity assumptions adopted for the Groundwater report (Appendix J) will be reviewed in light of the test data. If test data shows hydraulic conductivity to deviate significantly from the assumed values in this report, then re-assessment of potential groundwater impacts and groundwater inflow rates will be required. A hydrogeologist will review the hydraulic conductivity test data once available and determine whether re-assessment of potential groundwater impacts/groundwater inflow rates with revised hydraulic conductivity assumptions is required.	Transport	Prior to construction	Appendix J	All
GW02	Groundwater monitoring program	Groundwater monitoring will be undertaken to acquire appropriate baseline data and to provide a basis by which the proposal impact on groundwater can be monitored. This would include:	Transport	Prior to construction	Appendix J	All

No	Impact	Environmental safeguards	Responsibility	Timing	Reference	Locations
		• Reviewing groundwater level measurement by data logger at all 26 scheduled proposal monitoring bores (currently in process of being installed as part of geotechnical investigations) • Prior to commencement of construction, a groundwater quality sampling round should be undertaken at the 26 scheduled proposal groundwater monitoring bores. The analytes should comprise field parameters, major ions (chloride, sulphate, sodium, potassium, magnesium, calcium, carbonate and bicarbonate) and dissolved heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, iron and manganese).				
GW03	Construction groundwater monitoring	During the construction phase, the following groundwater monitoring should occur: • Continuation of groundwater level measurement by data logger at all 26 scheduled proposal monitoring bores. The data should be downloaded and reviewed quarterly. • Quarterly groundwater quality sampling rounds at select (locations and quantity to be confirmed at end of baseline period, prior to	Transport	Construction	Appendix J	All

No	Impact	Environmental safeguards	Responsibility	Timing	Reference	Locations
		construction) proposal monitoring bores. The tested analytes should be the same as those outlined in Section 6.3.1 of Appendix J. The data should be reviewed after each sampling round.				
GW04	Operational groundwater monitoring	During the operational phase the following groundwater monitoring should occur: • Continuation of groundwater level measurement by data logger at all 26 scheduled proposal monitoring bores. The data should be downloaded and reviewed quarterly. • Quarterly groundwater quality sampling rounds as per the construction period monitoring regime. The data should be reviewed after each sampling round. After one a year the data should be reviewed, and a decision made as to whether monitoring should continue.	Contractor	Construction	Appendix J	All

Other safeguards and management measures that would address groundwater impacts are identified in sections 6.1 Biodiversity, 6.6 Soils and Surface Water and 6.12 Contamination.