Lue Action Group
www.lueactiongroup.org

ATTACHMENT 4

Aquifer Connectivity Study

(AWE, 5 June 2018)

AQUIFER CONNECTIVITY STUDY

This report considers groundwater connectivity around the proposed Bowdens Silver (Bowdens) mine near Lue, NSW.

As part of the mining application, Bowdens is currently applying for an aquifer interference approval under the *Water Management Act 2000*. This report shares a preliminary understanding of current groundwater flows and the changes that may occur should approval be granted.

1.1 Aquifer Interference

Aquifer interference refers to changes to groundwater availability and groundwater quality. Regulators are principally concerned with activities that impact ecosystems or bore users. Bowdens may interfere with groundwater during mine dewatering, from spills of tailings to shallow aquifers, leaching after abandonment and while taking groundwater for processing ore. Taking and dewatering activities can redirect local groundwater flow towards the site, interfering with the current groundwater regime.

At the site, groundwater is expected to be discharged via

- Evaporation
- Surface water discharge
- Groundwater injection/inter-aquifer flow

Groundwater injection may be designed to control the impacts of dewatering and extraction. If treated water is to be reinjected, appropriate management of the waste stream will be required long after the mine is abandoned. This mitigatory approach has not yet been presented by Bowdens and as such, is not further considered in this report. Each form of groundwater management will impact surrounding groundwater users and the beneficial use of groundwater to varying degrees.

1.2 Regulation of Groundwater

Groundwater is listed as being Vulnerable under the Mid-Western Regional Local Environmental Plan (2012) (Figure 8). Vulnerability is designated by the susceptibility of the resource to contamination from a surface source, implying surface water/groundwater connectivity. A High Vulnerability status has been assigned to areas around the mine site (Figure 9). A demonstrated remedial action plan/prohibition requirement is placed upon developments in areas of High Vulnerability (DLWC, 2001).

Aquifer interference impacts the beneficial uses of groundwater. These uses are considered in published information including (DLWC, 2001), (DPI Water, 2017), (DPI Water, 2012) and (DPI Water, 2017) and discussed further in Section 1.4.

This report assumes that groundwater will be taken from NSW Murray Darling Basin (MDB) Fractured Rock and Porous Rock Groundwater Sources. These Plans require wetlands, lagoons, Aboriginal sites, irrigators and mining to be considered as beneficial uses. The scope of this report is limited to the beneficial uses of aquatic groundwater dependent ecosystems (found in surface water bodies), terrestrial groundwater dependent ecosystems (found without surface expression of water) and irrigators.

1.2.1 Lachlan Fold Belt MDB

The Lachlan Fold Belt MDB of the MDB Fractured Rock Groundwater Source is overlain by the younger Sydney Basin Groundwater Source. (DPI Water, 2012) expects a low-moderate connection between surface and groundwater from this Source. Groundwater Dependent Ecosystems (GDEs) are protected under the Plan, although no High Priority GDEs have been identified within the study area.

1.2.2 Sydney Basin MDB

The Sydney Basin MDB Porous Rock Groundwater Source includes all water contained in alluvium (excluding Macquarie Bogan Alluvium) or Permian/Triassic/Jurassic/Cretaceous or Tertiary age.

1.3 Geology and Local Aquifer Connectivity

Aquifers are geological units that can store and transmit water in reasonable amounts. Groundwater can flow through the pore spaces of geological units and fractures in brittle rock such as the volcanic rocks in the region. The geological units in the local area are shown in Table 1, including map codes used in **FIGURE 1**.

TABLE 1: MAP CODES AND GEOLOGICAL DESCRIPTIONS FROM (COLQUHOUN, ET AL., 1999)

Map Code	Name (youngest to oldest)	Geological Description
Qa	Cainozoic units	Alluvial silt, clay and sand
Ma	Mesozoic igneous	Fine grained, mid-grey phonolite
Rn	Sydney Basin - Narrabeen Group	Pebbly lithic-quartz sandstone, red-brown to green mudstone
Pi	Sydney Basin Illawarra coal measures	Lithic sandstone, mudstone, tuff
Ps	Sydney Basin - Shoalhaven Group	Conglomerate, sandstone, shale, siltstone
Pr	Sydney Basin - Rylstone Volcanics	Rhyolite, sandstone and tuff
Ccg	Pyangle Pass Granite	Biotite granite, aplite, pegmatite
Std	Dungeree Volcanics	Rhyolite to dacite lava
Stdt	Dungeree Volcanics	Volcanic conglomerate and lithic sandstone
Ocd	Coomber Formation	Volcanics, siliceous mudstone and limestone blocks
Oa	Adaminaby Group	Fine volcanics - quartz sandstone, slate and chert

Hydrogeological information obtained from the NSW Groundwater Database Pinneena CD 2009 v10.1 informed hydrogeological cross sections showing standing water levels, yields and electrical conductivities presented in Figure 2 and Figure 3.

There are no deep bores in the database which creates uncertainty regarding groundwater in deeper strata. The Coomber Formation and Adaminaby Group are from the Ordovician Period of the Palaeozoic Era, deposited 444-448 million years ago are assumed to form the basement in this area.

The principal rock type is fractured volcanics. Groundwater storage and flow within this type of rock is dictated by the fracturing caused as these extrusive rocks cooled and were subsequently folded. While some weathering of shallower sequences may cause a decrease in fracture permeability, zones where groundwater can reasonably be expected to flow (aquifers) and those where groundwater is unlikely to flow (aquitards) are highly variable. As such, no barriers to flow have been identified from inspection of the cross sections.

Where conductive fractures are present, the majority of rock has low-moderate yield (0.5-3 L/s) with electrical conductivity of 150-800 µS/cm (potable water quality). Exceptions to this are GW802779 (20 L/s yield) and GW802778 which yielded 20 and 15 L/s respectively from fractured volcanics between 20-140 m below natural surface (BNS). Despite being <1km apart, the conductivities were 800 and 2000 µS/cm in these bores which suggests they are not connected. Both of these bores are located on the proposed mine site, with GW802779 shown on **FIGURE 1**.

The yields of overlying alluvial aquifers are more predictable but are generally reported as low (0.1-2 L/s). These porous aquifers include younger Cainozoic units which are primarily deposited along water courses (Qa in **FIGURE 1**). These alluvium (Qa) are part of the Sydney Basin MDB to the northeast of NW-SE section line shown in **FIGURE 1**.

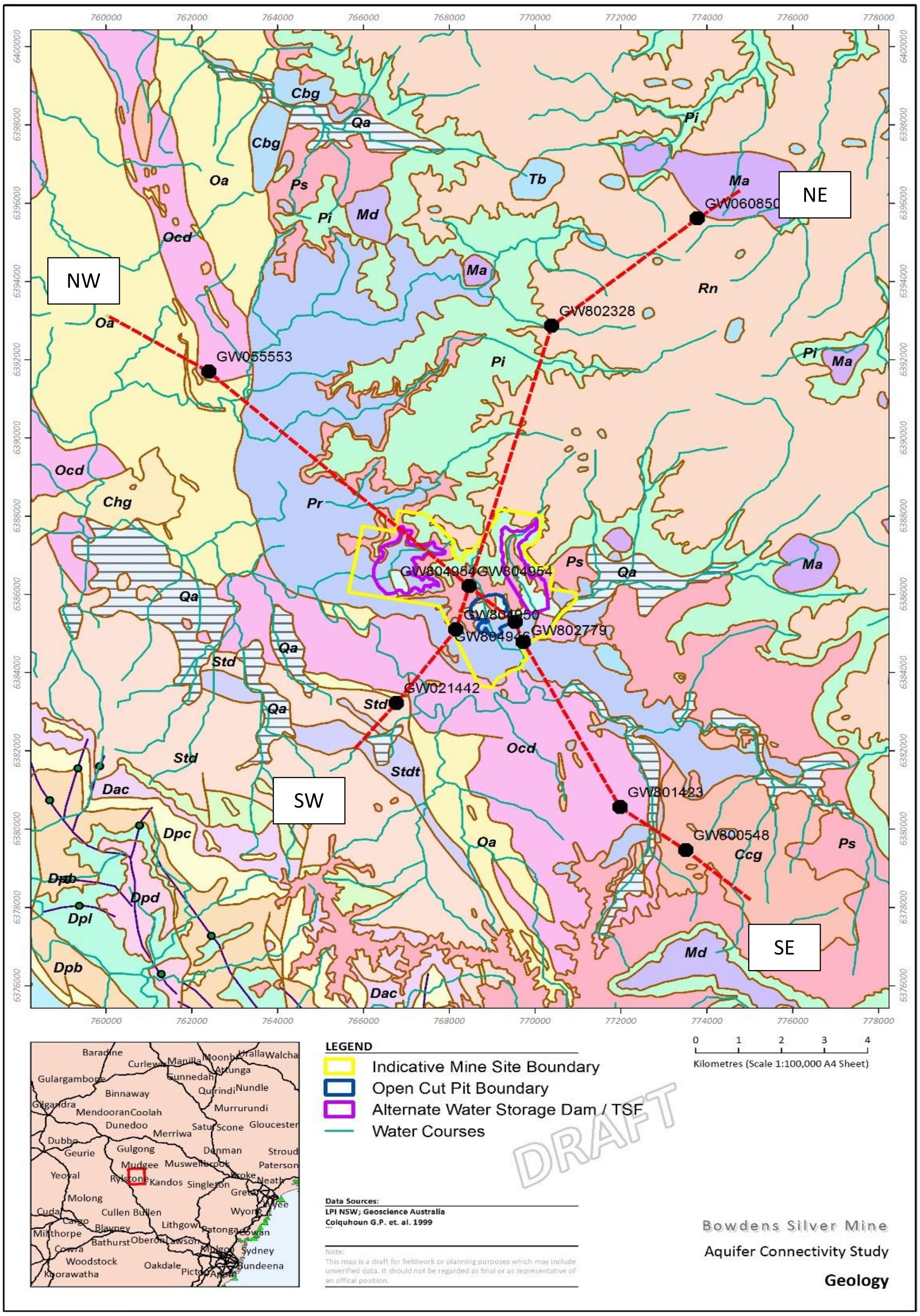

FIGURE 1: CROSS SECTIONS AND GEOLOGY

Using the hydrogeological bore data, the estimated groundwater flow and areas of surface expression are shown using blue arrows on the cross sections (Figure 2 and Figure 3). These infer that groundwater discharge is occurring to surface water courses in low-lying areas. Also shown in the sections are the potential groundwater dependent ecosystem zones (GDE Atlas, 2018) along tributaries of the Cudgegong river.

Figure 4 and Figure 5 indicate the possible change in groundwater flows should dewatering of the proposed excavation occur without controls in place.

5th June 2018

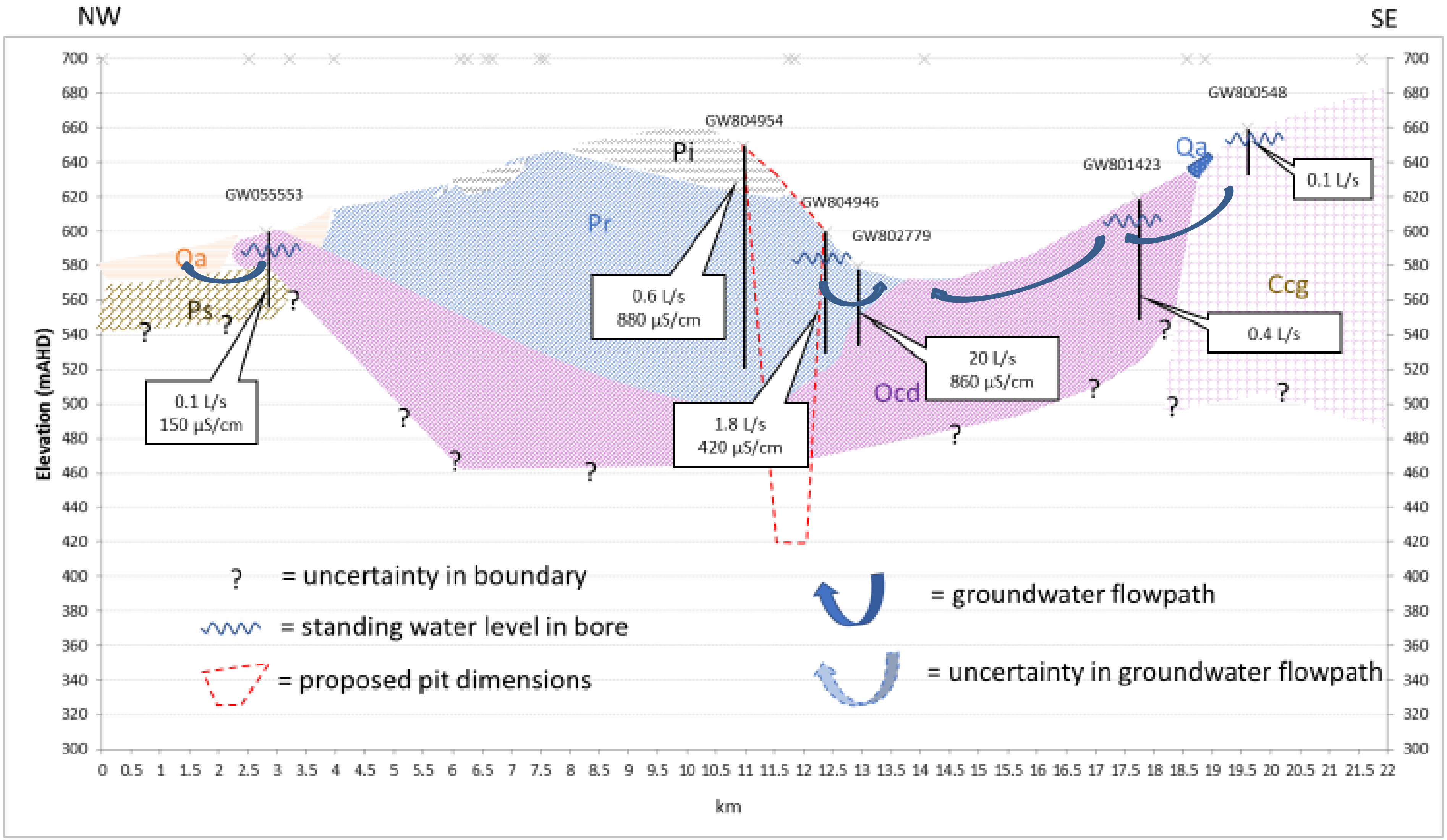

FIGURE 2: NW TO SE SECTION

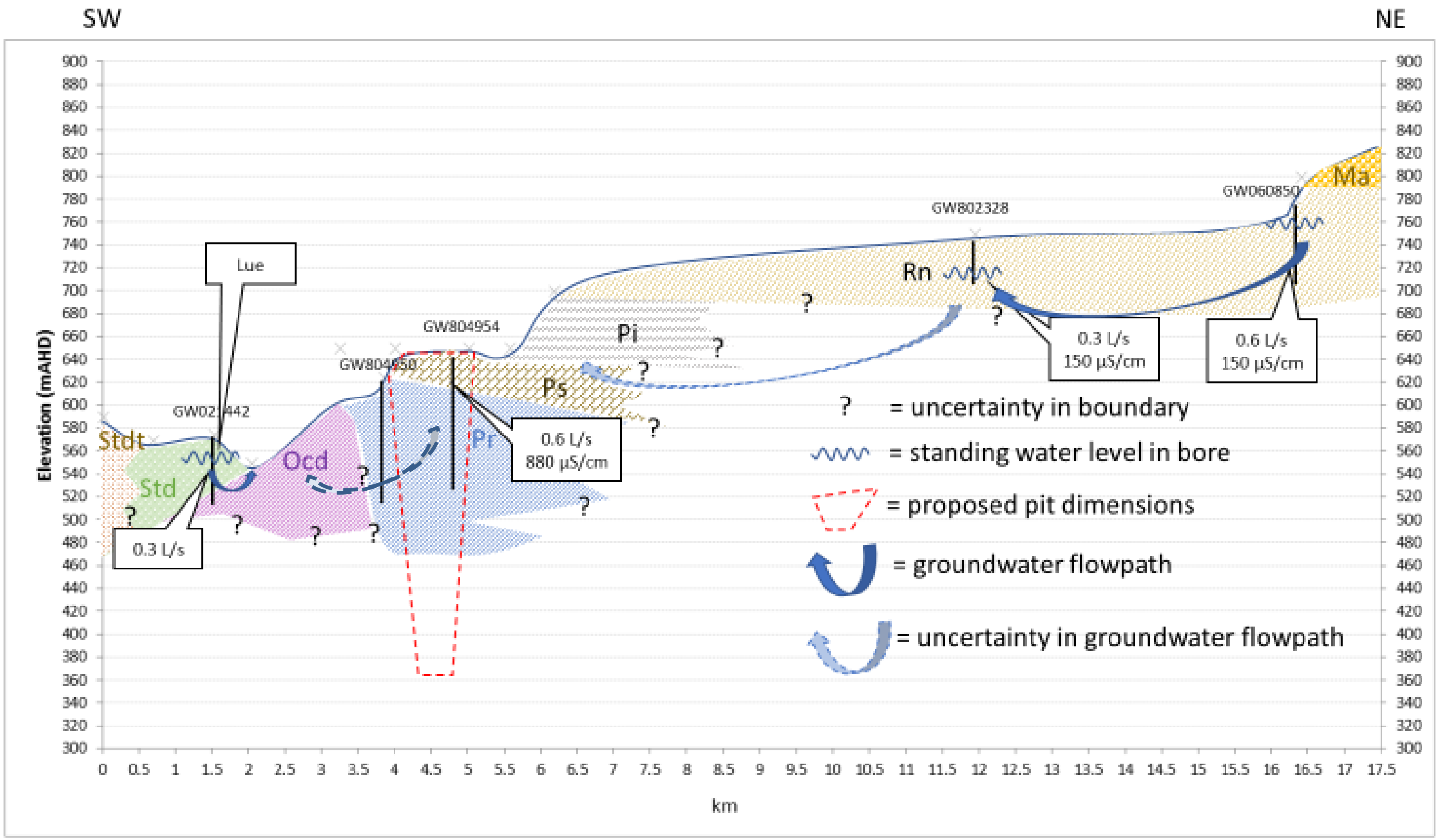

FIGURE 3: SW TO NW SECTION

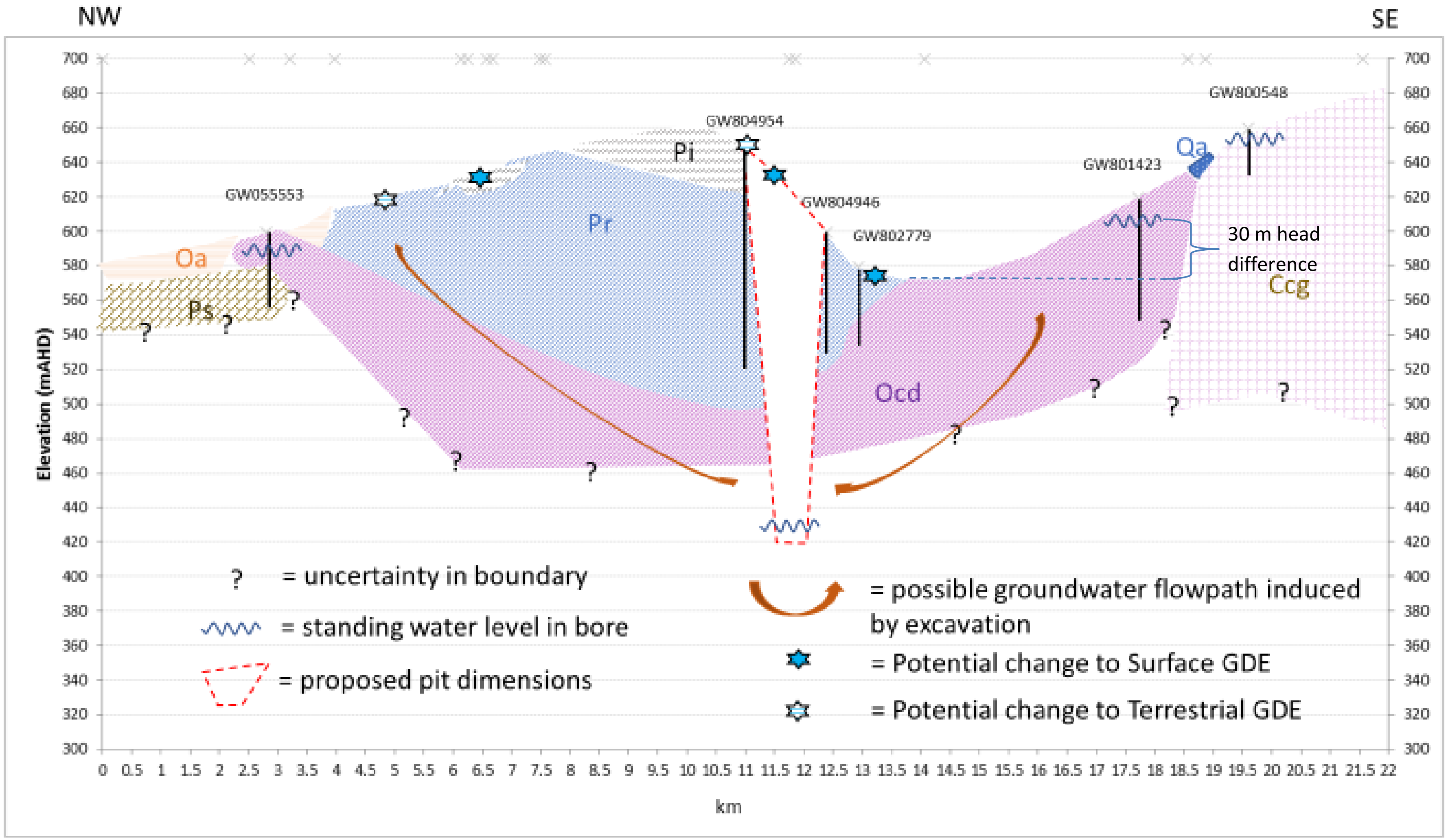

FIGURE 4: POTENTIAL CHANGES TO GROUNDWATER FLOW AND IMPACTS TO GDES

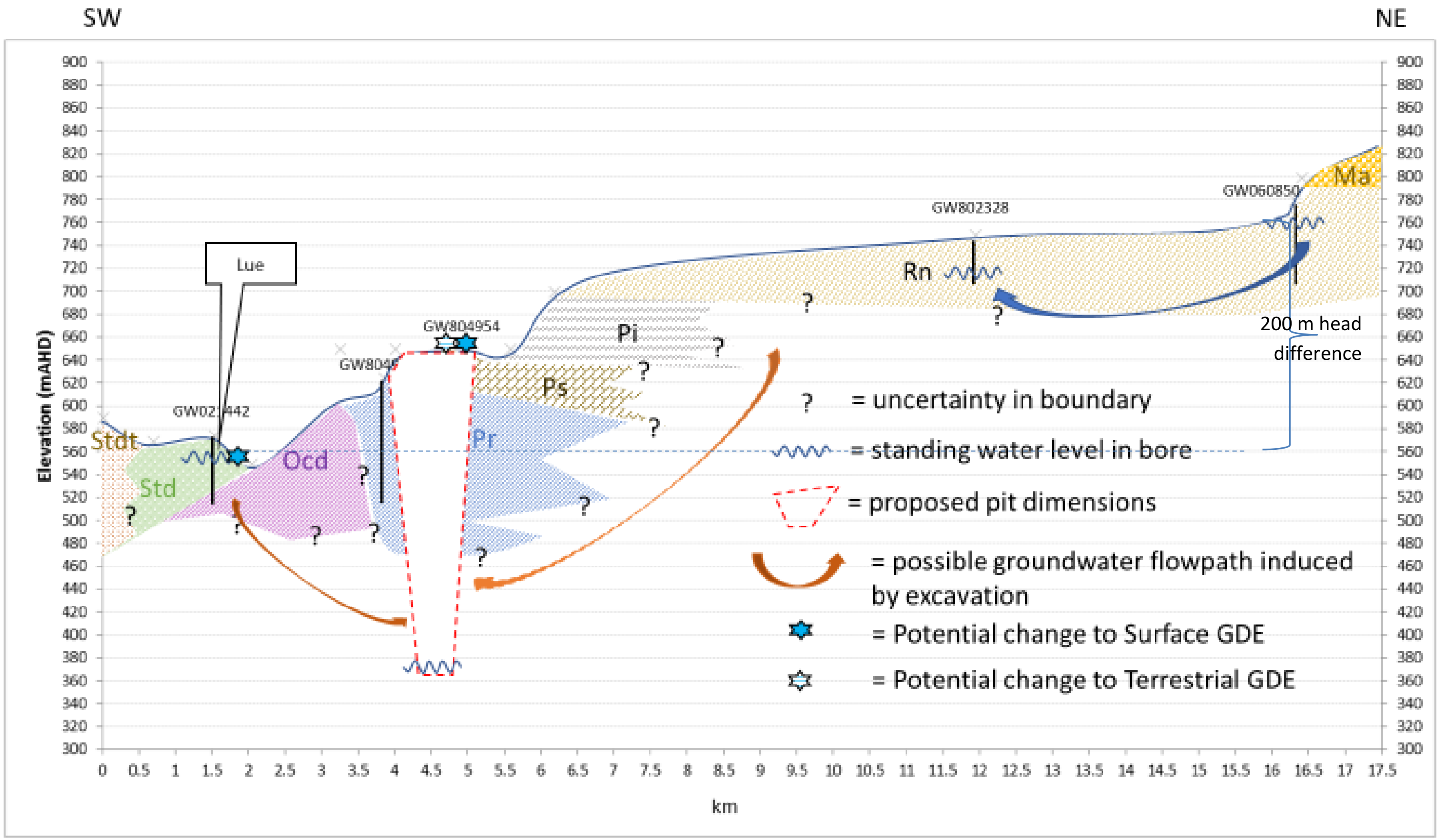

FIGURE 5: POTENTIAL CHANGE IN GROUNDWATER FLOW AND IMPACTS TO GDES

1.4 Impacted Beneficial Uses

The aquifer connectivity with beneficial uses of bore pumping and groundwater dependent ecosystems are discussed below.

1.4.1 Groundwater Users

Fractured breccia of the Rylstone Volcanics is present from 5-90 m BNS on the proposed mine site. Between the mine site and Lue lies the Coomber Formation and Quaternary alluvium. In accordance with the findings of (Noller, 2012), there is no evidence of a barrier to groundwater flows between the Rylstone Volcanics at the site and the downgradient Quaternary alluvium or surface water bodies.

Over the >20 year life of the mine, dewatering at rates up to 20 L/s could impact bores within a large area, depending on the connected fracture network. Groundwater controls on mine abandonment must be in place for a much longer period. More detailed geological analysis and modelling that considers the uncertainties in storage and permeability of fractured rock would be required to predict the impacts.

The standing water levels (SWLs) generally follow the ground elevation, with a 200 m head difference across the steeper SE-NW section compared to a 30 m head difference on the flatter NW-SE section to the point of likely surface discharge (Figure 4 and Figure 5). If the permeability and storage of the rock is constant, this would result in a greater impact to bores located in the NW-SE trend. This is relevant because of the high concentration of bores to the southwest of the mine near the township of Lue which indicates a productive groundwater zone.

With reference to the higher bore yields in the Quaternary alluvium and mapping conducted by the Bureau of Meteorology (GDE Atlas 2018) at Lawsons Creek (Figure 6), surface water/groundwater interaction is also likely occurring near Lue which can impact ecosystems reliant on groundwater.

1.4.2 Groundwater Dependent Ecosystems (GDEs)

The beneficial use of groundwater can contribute to the sustainable function of ecosystems. While there are no significant GDEs currently identified in the area (DPI Water, 2012), they must be protected if they are identified. (DPI Water, 2012) states that the fractured rock aquifer of the Lachlan Fold Belt MDB has low-moderate connection between surface and groundwater, with years to decades of travel time between surface and groundwater. As such, groundwater quality changes would be detected in neighbouring bores a significant time after pollution occurs.

1.5 Summary of Aquifer Interference

The local Groundwater Sources may experience:

- Decreased water supply due to mine dewatering which may impact surface water;
- Compaction of the aquifer caused by subsidence after de-watering, resulting in a lower long term water storage capacity;
- Contamination of water quality due to
    - mine waste discharge, including acid mine drainage
    - poorly sealed exploration bores
    - mine workings that enable inter-aquifer flow

  These may damage ecosystem health due to mine waste discharge.

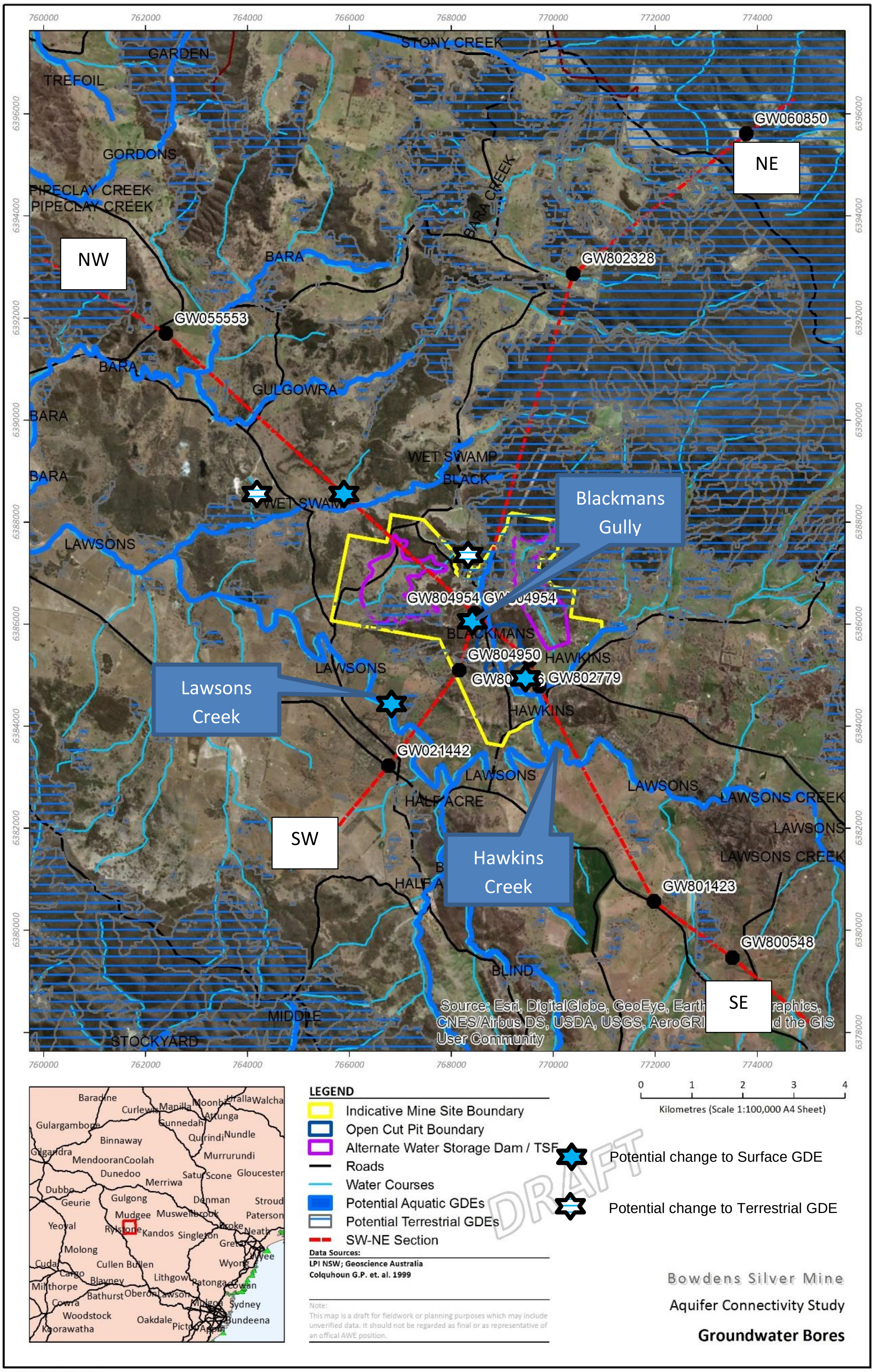

FIGURE 6: POTENTIAL TO IMPACT GDES

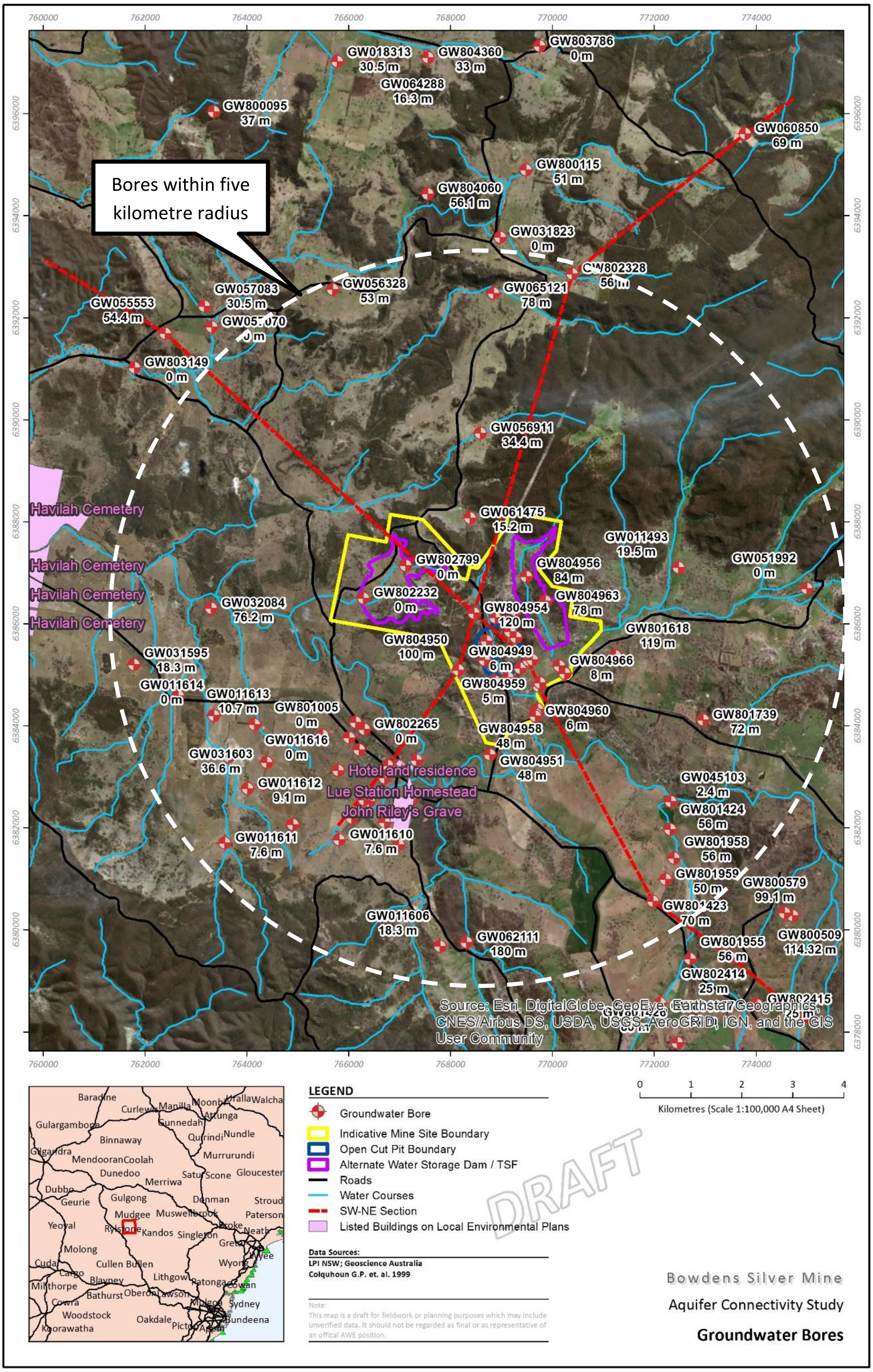

FIGURE 7: LISTED SITES AND REGISTERED BORES IN THE AREA SHOWING THEIR REPORTED DEPTHS

1.6 Conclusion

This aquifer connectivity study has concluded that:

- Groundwater in the area has been categorised as Vulnerable by State and Local government;
- The area is underlain by an extensive and well-connected fractured rock aquifer with variable yield from 0.1-20 L/s;
- Aquifers in shallow alluvium are likely connected to both the fractured rock aquifer and water courses;
- No continuous barriers to groundwater flow (aquitards) were identified; and
- Weathering of the extrusive rocks is likely to have created high variability in storage and permeability. This may result in unpredictable flowpaths which may result in interference to bores distant from the proposed mine.

If the proposed mine proceeds:

- Bores in a northwest to southeast trend from the proposed mine site are likely to be impacted to a greater extent due to the difference in groundwater head;
- There may be interference with aquatic groundwater dependent ecosystems in Lawsons Creek, Hawkins Creek and Blackmans Gully;
- The amount of interference to groundwater levels and quality will be related to the nature of the proposed development and the mitigations (such as water reinjection) used to mitigate interference; and
- Monitoring groundwater levels in bores and local ecosystems in the areas where GDEs may be impacted (Figure 6) can be used to create reference points to monitor change.

Impacted beneficial uses of lagoons, Aboriginal sites, wetlands and waterways (other than GDEs) are not considered in this report and should be considered separately.

Bibliography

Centre for Natural Resources. (2001). *Groundwater vulnerability map explanatory notes - Macquarie Catchment.* Parramatta: NSW Department of Land and Water Conservation.

Colquhoun, G. P., Meakin, N. S., Henderson, G. S., Krynen, J. P., Jagodzinski, E. A., Watkins, J. J., & Yoo, E. K. (1999). *Mudgee 1:100 000 Geological Sheet 8832, 1st Ed.* Orange, Sydney, Canberra: Geological Survey of New South Wales.

DLWC. (2001). *Groundwater vulnerability map explanatory notes - Maquarie Catchment.* Parramatta: NSW Department of Land and Water Conservation.

DLWC. (2001). *New South Wales Groundwater Vulnerability Map Series: Macquarie Catchment.* Dubbo: Department of Land and Water Conservation.

DPI Water. (2012). *Water Sharing Plan Murray-Darling Basin Fractured Rock Groundwater Sources.* Sydney: Department of Primary Industries.

DPI Water. (2017, 2 3). *AllWaterData*. Retrieved 12 6, 2017, from Hydstra Web Portal: http://allwaterdata.water.nsw.gov.au/water.stm

DPI Water. (2017). *Western Porous Rock (GW6) and Eastern Porous Rock (GW16) Water Resource Plans, Groundwater, Status and Issues Paper.* Sydney: NSW Department of Industry, Skills and Regional Development.

Noller, B. (2012). *Assessment of the potential effects of a proposed lead/silver mine at Lue, NSW.* Lue: Lue Action Group.

Noller, B. (September 2017). *Comment for Lue Action Group.* Lue: Lue Action Group.

Appendix: Detail Maps

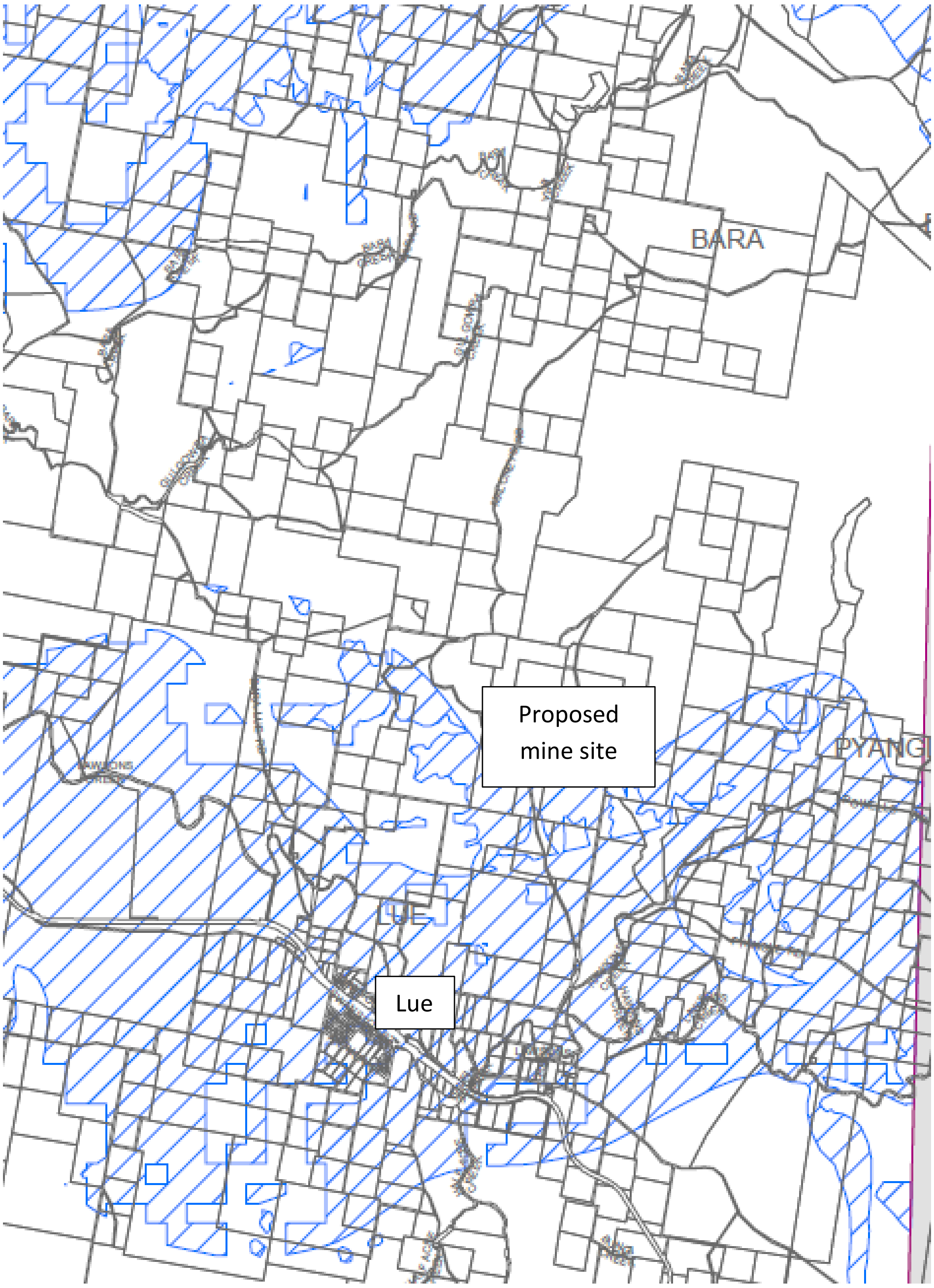

FIGURE 8: VULNERABLE GROUNDWATER ZONES (MID-WESTERN COUNCIL)

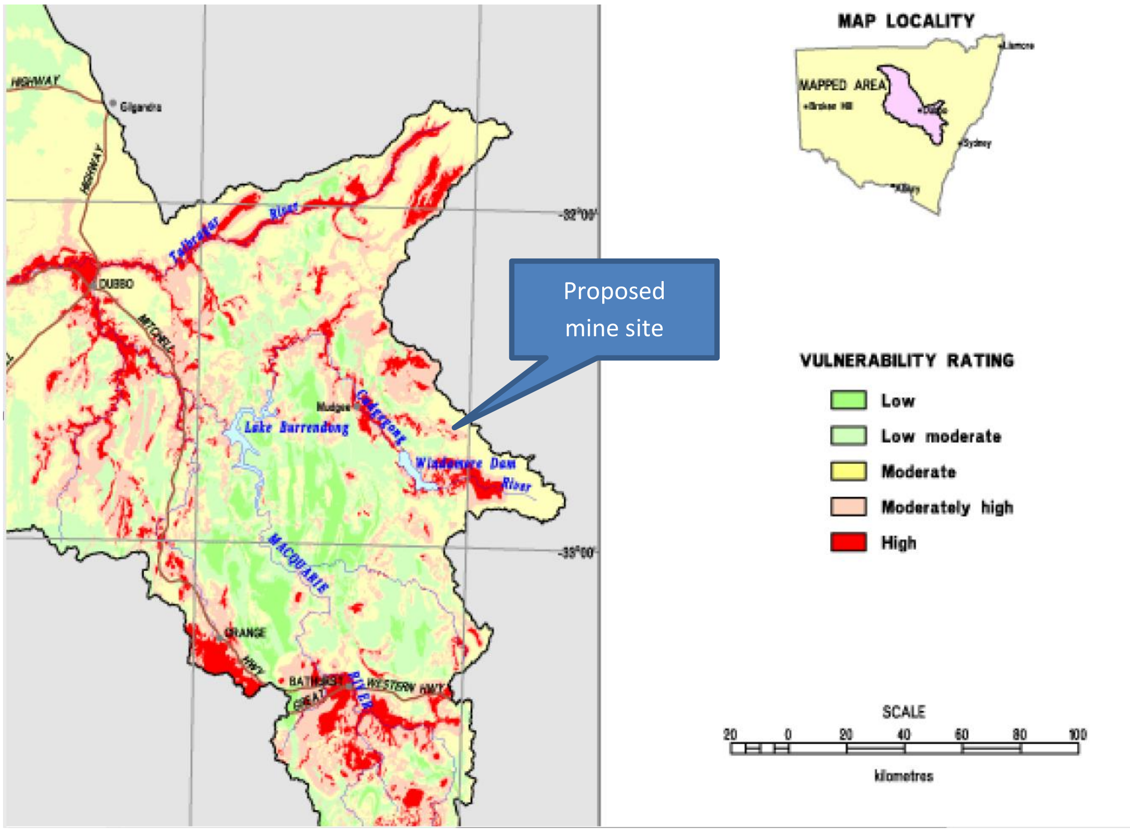

FIGURE 9: AREAS WITH HIGH VULNERABILITY RATING AROUND THE PROPOSED MINE SITE (MACQUARIE CATCHMENT) (DLWC, 2001)

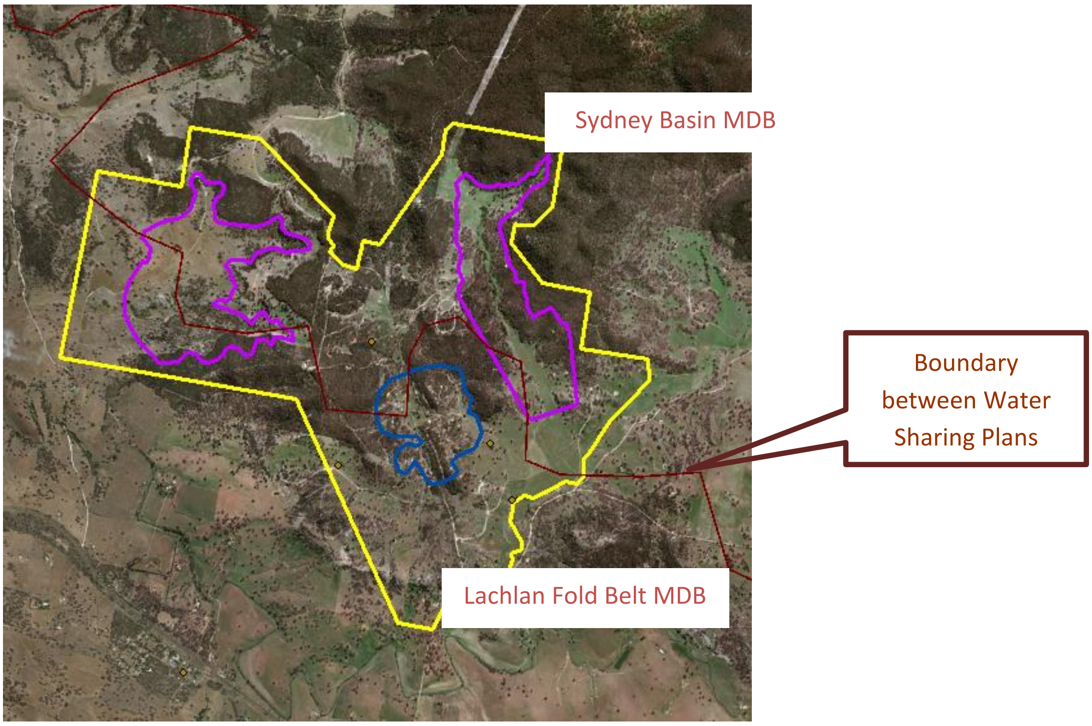

FIGURE 10: WATER SHARING PLAN BOUNDARY SHOWN IN MAROON