Fingerboards Mineral Sands EES

Groundwater impact assessment

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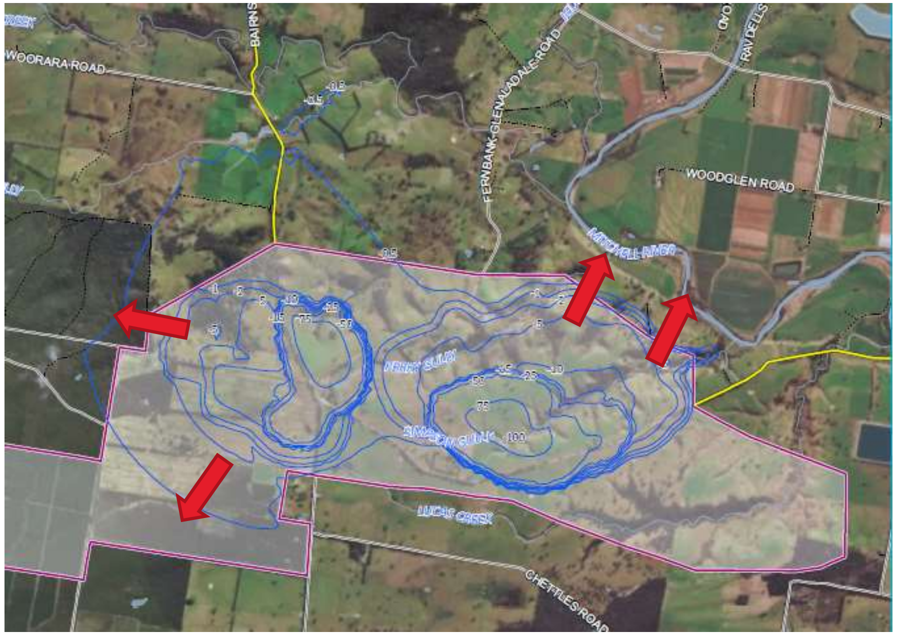
Scope of my assessment

- Reviewed the EES, particularly A006 Groundwater and Surface water impact assessment, and related technical appendices:
- Groundwater modelling report
- Geochemical testing of tailings & overburden
- Water supply options technical groundwater assessment
- Plus, two subsequent technical notes (centrifuges and seep-w modelling)
- Did not conduct (or discuss in conclave) detailed surface water impact assessment, or water balance analysis of the mine.
- Assumed water requirements from river/bore-field as presented in the EES and additional technical notes are reasonable (being cautious that there may be uncertainties in these).

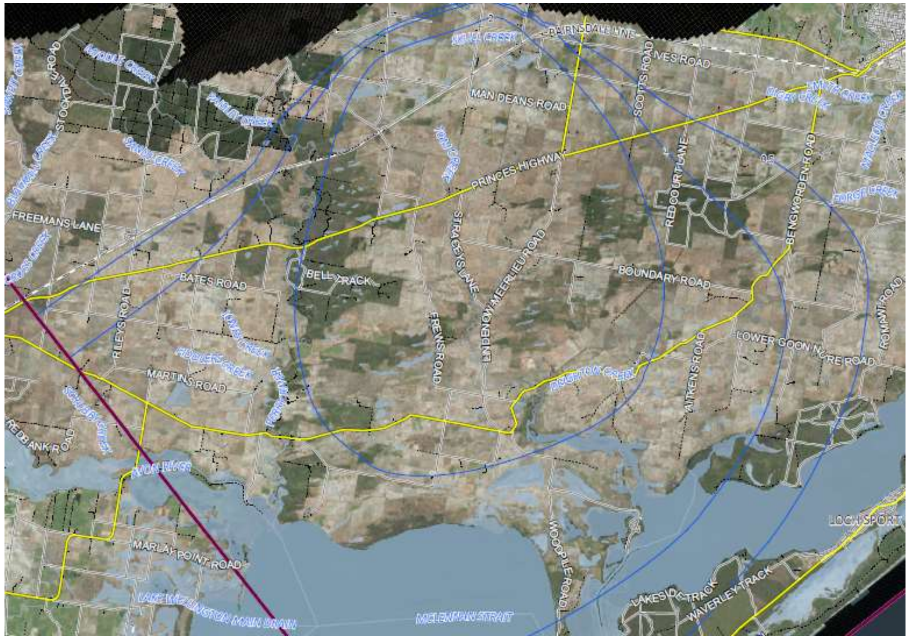
Major potential impacts on groundwater

1. **Groundwater mounding & movement of contaminants away from the site** *(e.g., toward surface water & GDEs)*



EES predicted mounding contours after 5 years mining

2. Impacts of bore-field water supply (e.g. Drawdown, bore interference, impacts on GDEs) & viability of supply



EES predicted drawdown contours (La Trobe aq.) after 5 years mining

How thoroughly have these impacts been assessed?

Groundwater quality & quantity impacts

- In the case of both issues, there are data gaps and oversights which result in ongoing uncertainty about potential impacts on groundwater dependent ecosystems (GDEs), groundwater users in the area and the viability of water supply for the mine.
- Some of the key oversights are discussed in the following slides, as well as my expert witness statement and JER.

Potential contamination issues

Oversights in the EES:

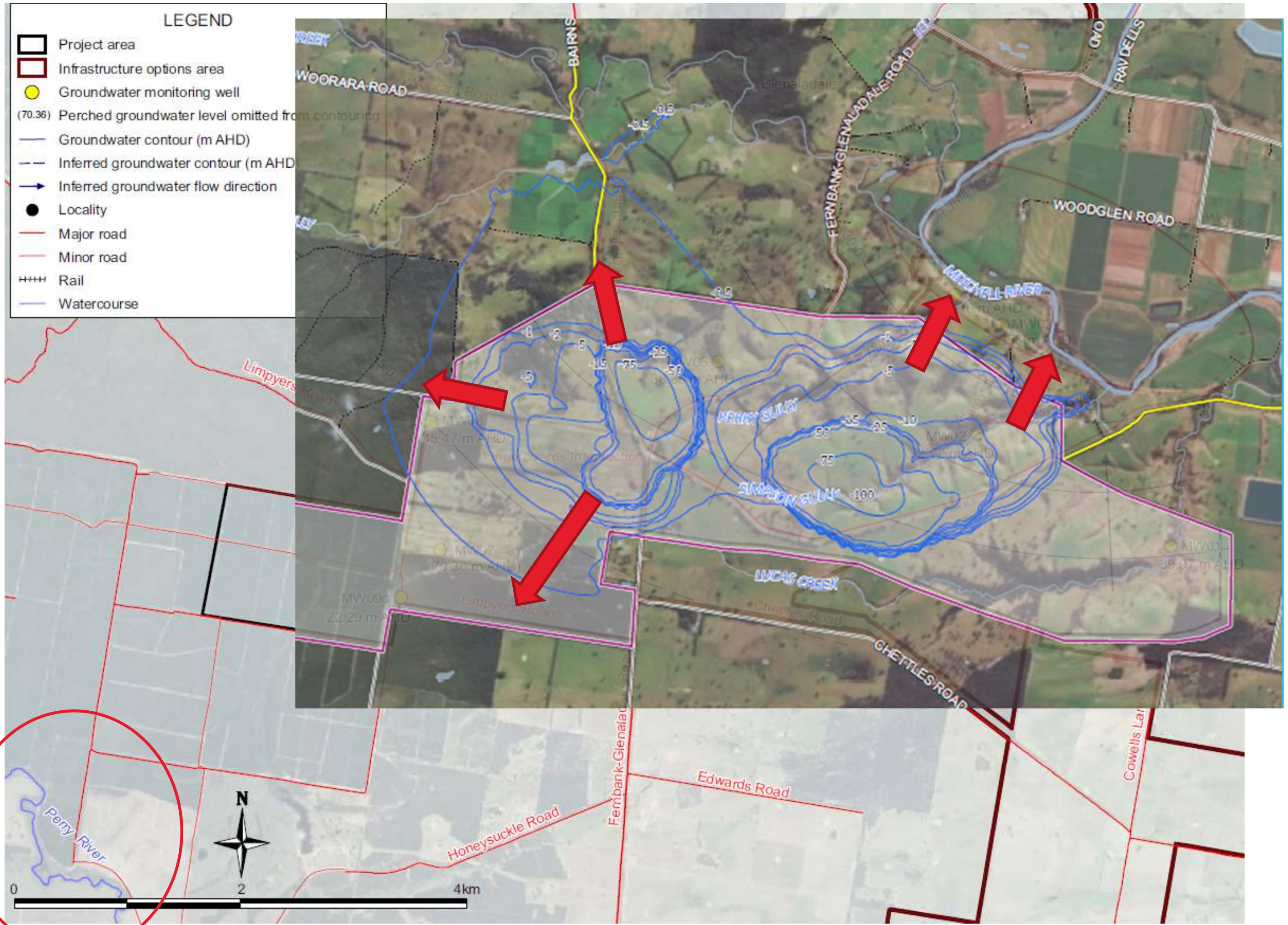
- Insufficient analysis of potential risk of contaminant movement to surrounding receptors – e.g. Mitchell River & alluvium (e.g. no calculation of additional potential contaminant load under modelled scenarios).

- Lack of field data collected in Perry River/Chain of Ponds area to understand how the surface water relates to groundwater & the hydrogeological setting

- Gaps in baseline groundwater quality monitoring & lack of explanation of anomalous water quality data.

➢ These result in residual uncertainty as to the level of risk from mounding & associated movement of contaminants in groundwater

Location of mine site & key receptors



- Pathways exist for additional groundwater discharge to rivers (particularly Mitchell River) due to influence of the mine.
- Potential water quality impact of this has not been modelled.
- River is known to be heavily dependent on groundwater (baseflow) during dry periods

Risk of contaminant movement to surrounding receptors – e.g. Mitchell River & alluvium

- EES modelling shows that a groundwater ‘mound’ would likely develop below the mine site following excavation of pits and disposal of tailings
- Based on modelling, will create an outward hydraulic gradient, causing groundwater in the Coongulmerang Formation to flow away from the site, including to the north (Mitchell River) and southwest (towards Perry River).
- Baseline groundwater quality data (next slide) shows elevated concentrations of nutrients and heavy metals in this aquifer. Currently, water table is deep below the ground at the mine site, but closer to surface near streams (though water table configuration not fully characterized).
- During mining, the water table would rise, and movement of ‘mounded’ groundwater within this aquifer may pose a (new/additional) risk to surface water features which receive increased groundwater discharge

Baseline assessment of groundwater quality

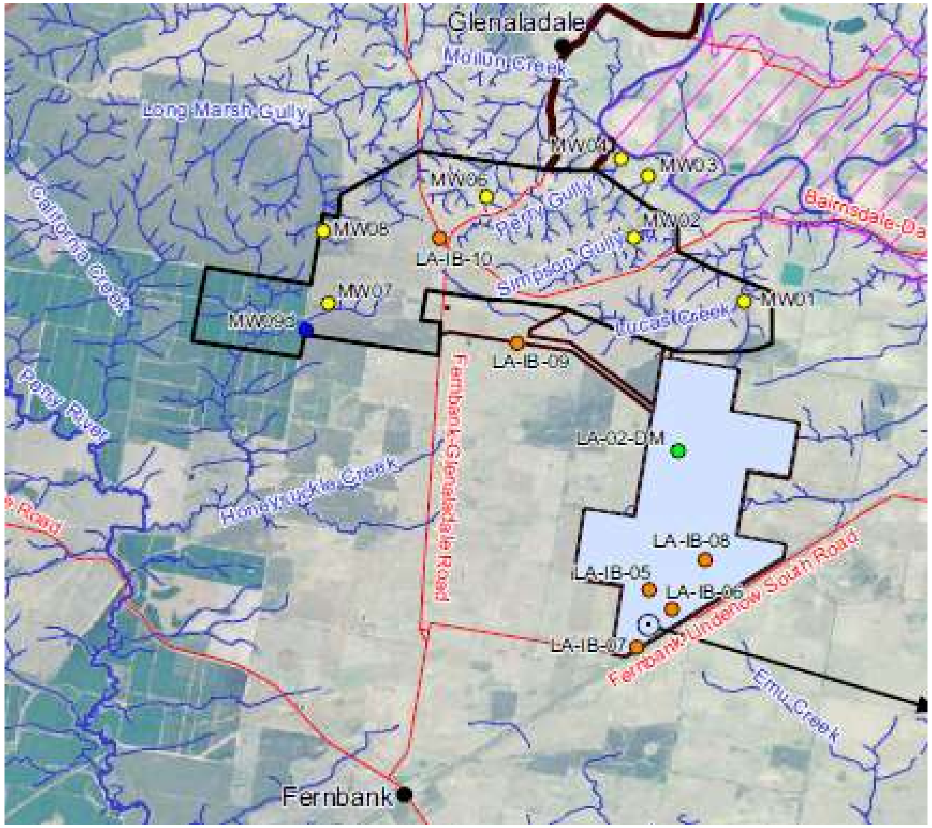


Table 4-18: Beneficial Uses and assessment guidelines for groundwater – Coongulmerang Formation

Beneficial Use	Guideline Exceeded by	Location
Water dependent ecosystems and species	Nitrate	MW01, MW07
	Nitrogen (Total)	MW01, MW03, MW04
	Aluminium	MW01, MW02, MW03, MW04, MW06, MW07, MW08
	Cadmium	MW01, MW04, MW06, MW08
	Chromium (III + VI)	MW01, MW02, MW03, MW06, MW07
	Copper	MW01, MW02, MW03, MW04, MW07, MW08
	Total Cyanide	MW07
	Manganese	MW04, MW06
	Nickel	MW02, MW03, MW04, MW06, MW07, MW08
	Phosphorus	MW01, MW02, MW03, MW04, MW06, MW07, MW08
	Zinc	MW01, MW02, MW03, MW04, MW06, MW07, MW08
Potable water supply (Aesthetic)	Chloride	MW02, MW04, MW06, MW07, MW08
	TDS	MW01, MW02, MW04, MW06, MW07, MW08
	Hardness	MW04
	Iron	MW01, MW02, MW03, MW04, MW06, MW08
	Sodium	MW02, MW04, MW06, MW07,
	Aluminium	MW01, MW03, MW04, MW06, MW07
	Manganese	MW01, MW02, MW03, MW04, MW06, MW07, MW08
	Turbidity	MW01, MW02, MW03, MW04, MW06, MW07, MW08
Potable water supply (Health)	Arsenic	MW04
	Cadmium	MW04
	Manganese	MW02, MW04, MW06
	Nickel	MW02, MW03, MW04, MW06, MW07, MW08
Agriculture and Irrigation (irrigation)	Iron	MW01, MW02, MW03, MW04, MW06, MW07, MW08
	Manganese	MW01, MW02, MW04, MW06, MW08
	Nickel	MW04
	Phosphorus	MW01, MW02, MW03, MW04, MW06, MW07, MW08
	Nitrogen (Total)	MW04

Key uncertainties (I)

How quickly would mounding occur? What gradients and flow rates could develop?

- Difficult to model using EES methodology.
- Additional information gained from seep-w modelling and column tests (recent tech note) provides further information on seepage from tailings; however, behavior of the seepage below the site still not well understood.
- No field-based groundwater recharge studies conducted to date
- Currently Kalbar believe ‘perching’ (above clays) is a ‘localized’ effect. While this may be the case, more detailed understanding of the process and likely impact during mining is (in my view) needed - flagged by AECOM peer reviewer.
- Data from one monitoring well (MW7) shows large contrast in water level with other nearby bores. This implies groundwater may hit certain layers and begin mounding quickly, pushing groundwater back towards the surface.

Perched water(?)

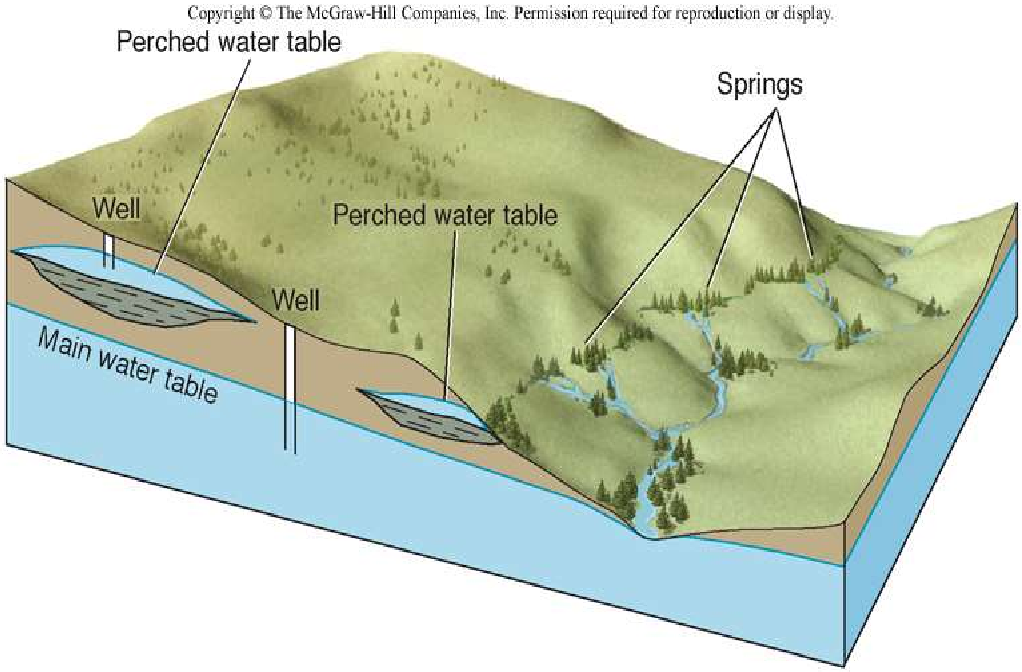
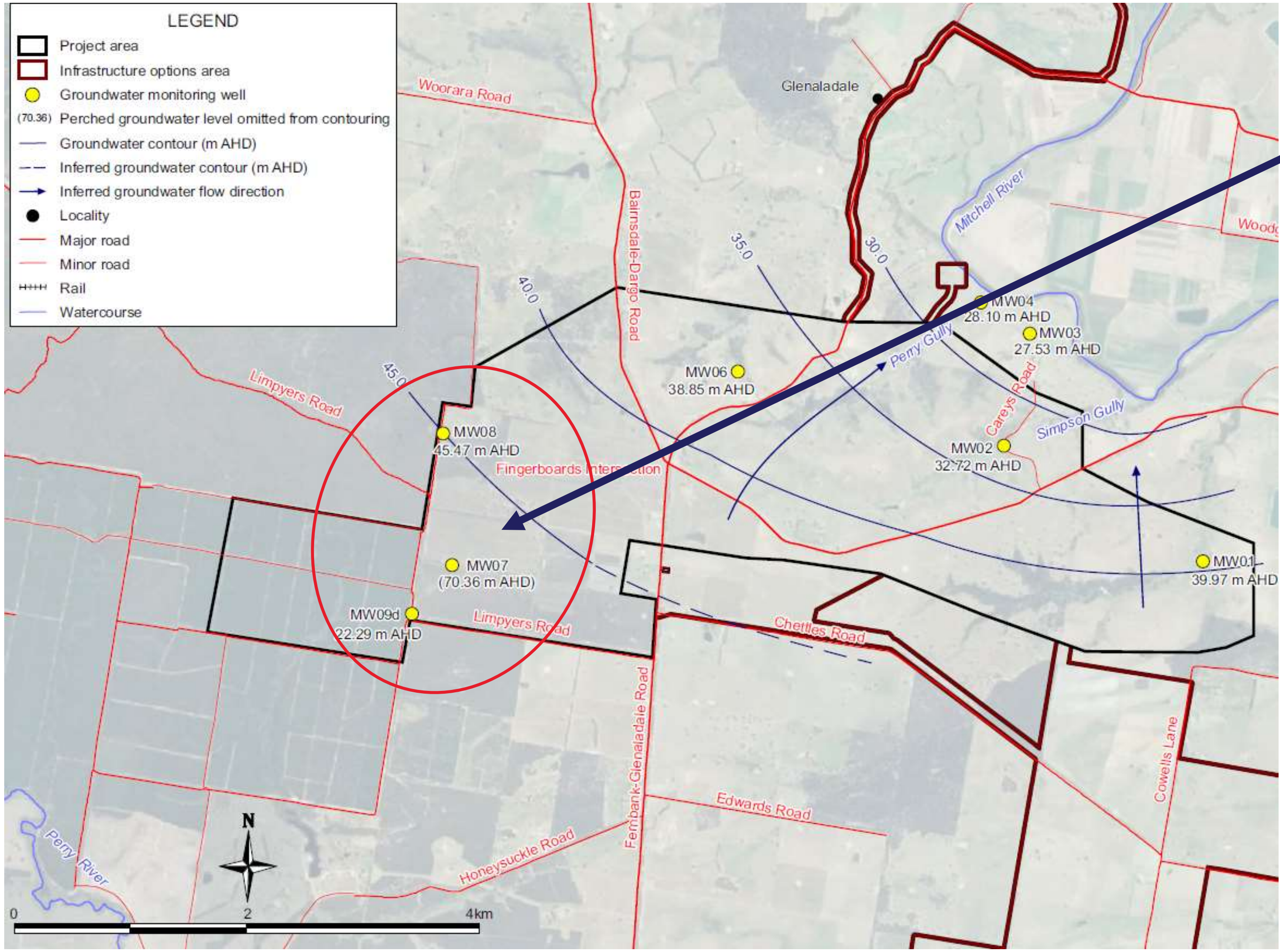


Image source: Plummer, C., Carlson, D., Hammersley, L. *Physical Geology* (McGraw Hill). Reproduced with permission

- So far, mechanism and likely extent of perching has been hypothesized, and explored through drill hole water 'strikes' but not resolved conclusively at key receptors (e.g. Perry River).
- Unclear how far (and how quickly) perched water might move in response to increased seepage below the mine
- Could form new surface seeps with potentially poor water quality 'daylighting'.



- MW7 water level significantly higher than nearby bores
- This (and other) bores have poor groundwater quality including high nutrients and heavy metals concentrations
- Cause of these water quality issues not thoroughly investigated (legacy contamination?)
- Potential risk of mobilizing contaminants to the surface?

Key uncertainties (II)

What water quality will develop below the site, and migrate in the aquifer towards surface water systems/groundwater dependent ecosystems (GDEs)?

- Leaching tests between sediment and water (de-ionized & river water) were conducted in the Geochemical study; however, number of samples insufficient (JER section 5). Limited replicates, water from bore-field not used to leach samples, even though this is a major possible water source.
- Not fully clear what geochemistry / water quality will develop below the mine, and how this might change when seepage mixes with pre-existing groundwater.

➢ There is a pathway for potential increased movement and discharge of this water to surface. As such, its likely quality must be characterized carefully.

Key additional data requirements

1. Greater understanding of ground-surface water interaction, through field-based studies (e.g. bore transects, environmental tracer analysis)

- Particularly, to understand connectivity between Coongulmerang Formation and/or perched layers, and the major surface water systems (Mitchell and Perry River)
- This should consider climatic/seasonal influence, as groundwater dependence of streams can vary greatly through time
- ‘Low-flow’ periods are critical – this is when there is often heightened risk of environmental harm

(See JER section 4 – expert views diverge on the need for such information).

Key additional data requirements

2. More in-depth analysis of:

- Baseline groundwater geochemistry and controls on groundwater quality in aquifer below the site (Coongulmerang Fm). Source(s) of heavy metals?
- More extensive monitoring network (e.g. SW of site) and more water quality parameters needed (e.g., radionuclides).
- Likely impact of changes to recharge rates and mechanism during mining on:

1) Geochemistry/quality of groundwater below the site and
2) Head levels/flow gradients (*partially* addressed by recent technical note).

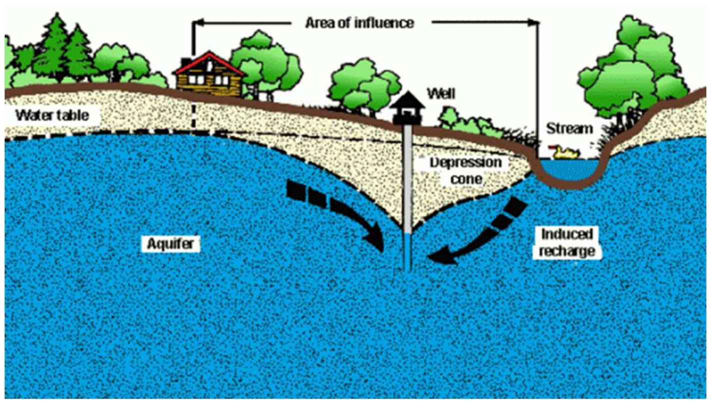
- Potential water quality effects to key surface water/GDE receptors – e.g., through solute transport or other modelling approaches.

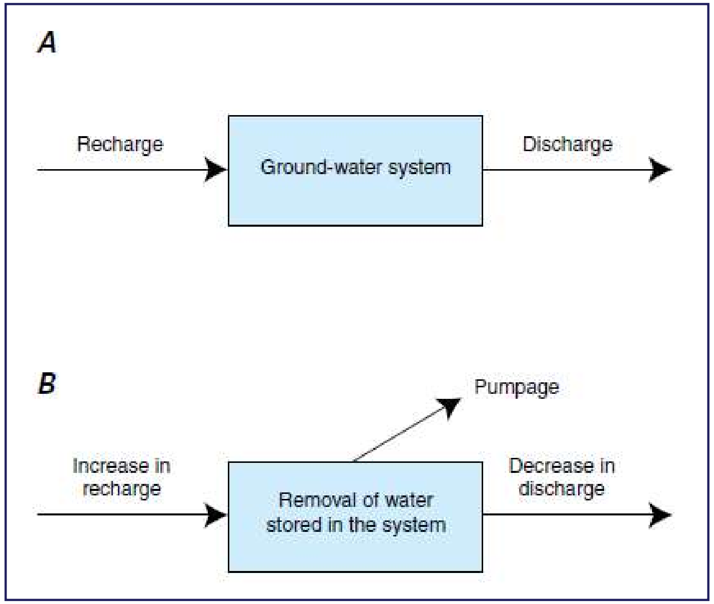
Bore-field impacts

Potential need to extract up to 3 GL/year of water from bore-field, proposed in Latrobe Group aquifer (depending on availability/access to surface water)

Possible impacts:

- Bore interference: Impacts on water levels in other bores in same or overlying/adjacent aquifer units.
- Impacts on aquifer water balance – e.g. recharge/discharge rates.
- Impacts on GDEs/surface water bodies receiving groundwater



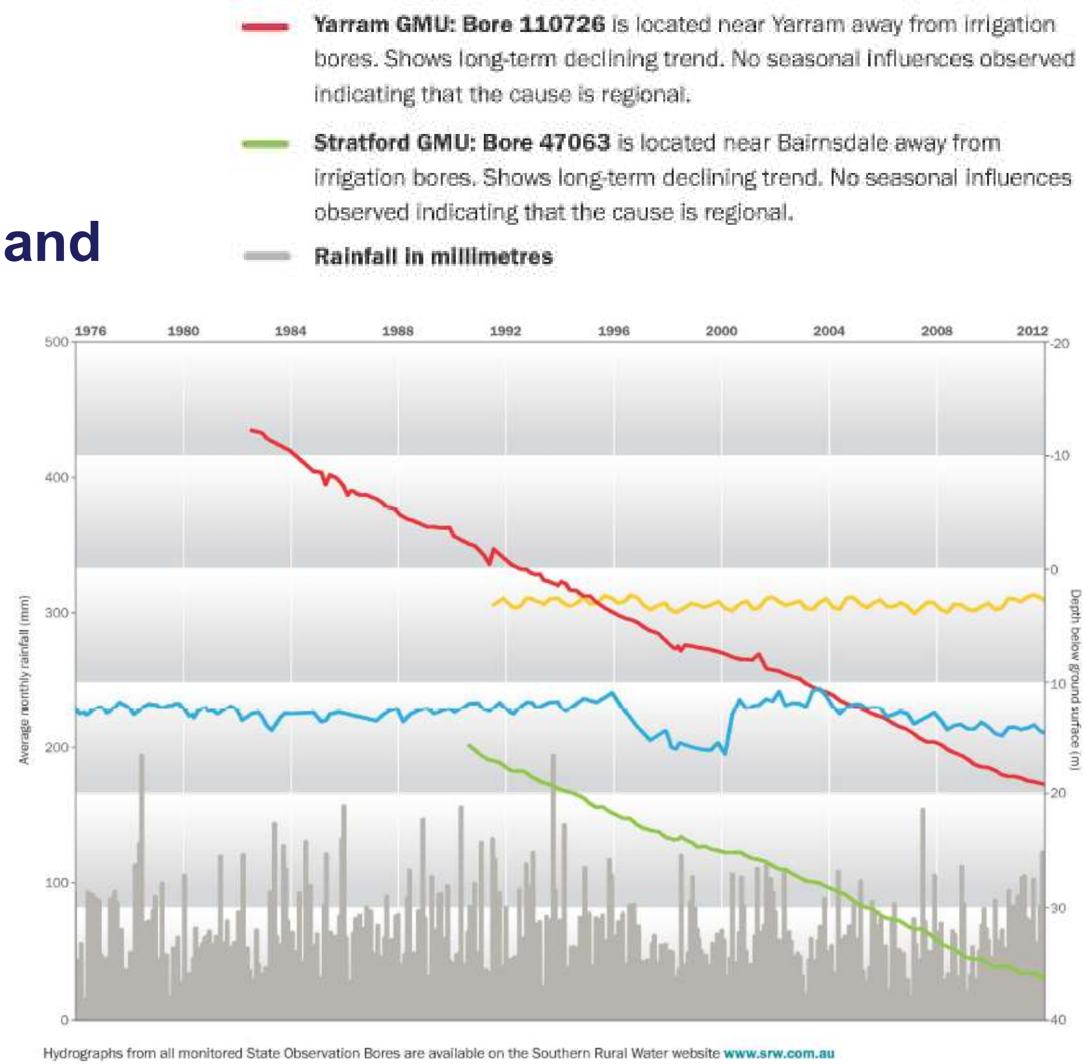


Alley et al., 1999. Sustainability of groundwater resources. *USGS Circular 1186*

Bore-field impacts

Target aquifer (Latrobe) already experiencing significant long-term drawdown due to mining, oil & gas and irrigation

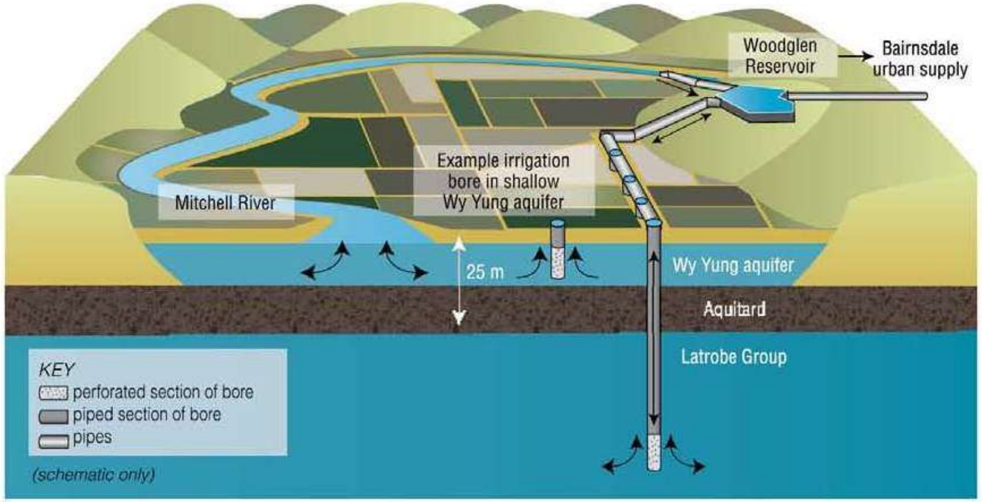
- Southern Rural Water: Aquifer is already fully allocated and extraction > recharge
- Unlikely a large (3 GL/yr) license would be granted in this context.
- Is this a viable water supply?
- Implications if either surface water or groundwater licence (or both) not approved?



Source: Southern Rural Water (Gippsland Groundwater Atlas)

La Trobe aquifer

- Recently, initiatives taken to improve sustainability of aquifer utilization and mitigate over-extraction from this aquifer. E.g. East Gippsland Water's Woodglen ASR scheme
- Large new extractive water licence in the aquifer could jeopardize these improvements.



Source: East Gippsland Water - https://www.egwater.vic.gov.au/customer-info/water-supply-systems/woodglen-boosts-the-regions-long-term-water-supplies/

Assessing/predicting bore-field impacts

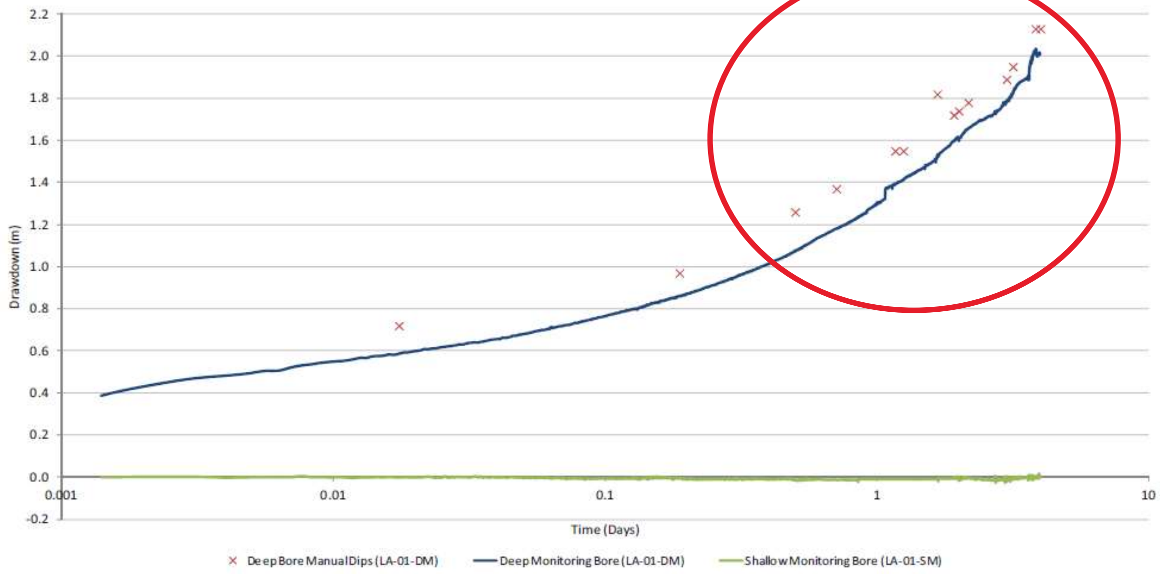
Pumping tests: a sound method to understand an aquifer's response to pumping – e.g., extent of drawdown and potential inter-aquifer connectivity. However, in this case, the test suffered design problems (JER section 2):

- Test period was too short
- Limited monitoring bores
- Pumping rate not steady
- No recovery data recorded.

Missed opportunity to gain better understanding of how aquifer would respond to the proposed bore-field extraction

Borefield impacts

- Major issue in the pumping test data: Increase in rate of drawdown after ~1 day of pumping
- Indicates pumping may have reached a boundary (e.g., edge of the target aquifer), unable to keep drawing water from it.
- Borefield drawdown could migrate into adjacent aquifers and/or areas of outcrop/subcrop of the target aquifer – unintended consequence of the bore-field pumping.



Recorded time-drawdown data from pumping test in Latrobe Group monitoring bore (from Appendix A007)

Borefield impacts

Boundary effect

- Implications of this effect (which are potentially significant) have not been analysed or discussed in the EES.
- Could mean the borefield draws from one of the adjacent/overlying aquifers due to insufficient aquifer capacity in target unit (Latrobe gravels).
- Or, environmental effects such as water table drawdown, impacts on surface ecosystems may arise in areas where edge of target aquifer reaches (or comes close to) the surface:

"The lower sand aquifer (Latrobe Group) rises to the surface in small areas where it interacts with surface environments".

(Southern Rural Water Gippsland Groundwater Atlas)

Predicted drawdown impacts: regional in scale

- Indicates a likelihood of borefield drawdown reaching aquifer boundary
- Potential consequences not (yet) considered.

The environment

Springs and vegetation may interact with groundwater in the fractured rock outcrops of the Great Dividing and Strzelecki Ranges where the connection between the aquifers and the surface environment is strongest. Stream interaction may also occur where the Latrobe Group sands rise to the surface around the basin margin in the area north of Yarram and around the flanks of the Latrobe Valley.

Southern Rural Water, 2012. Gippsland Groundwater Atlas.