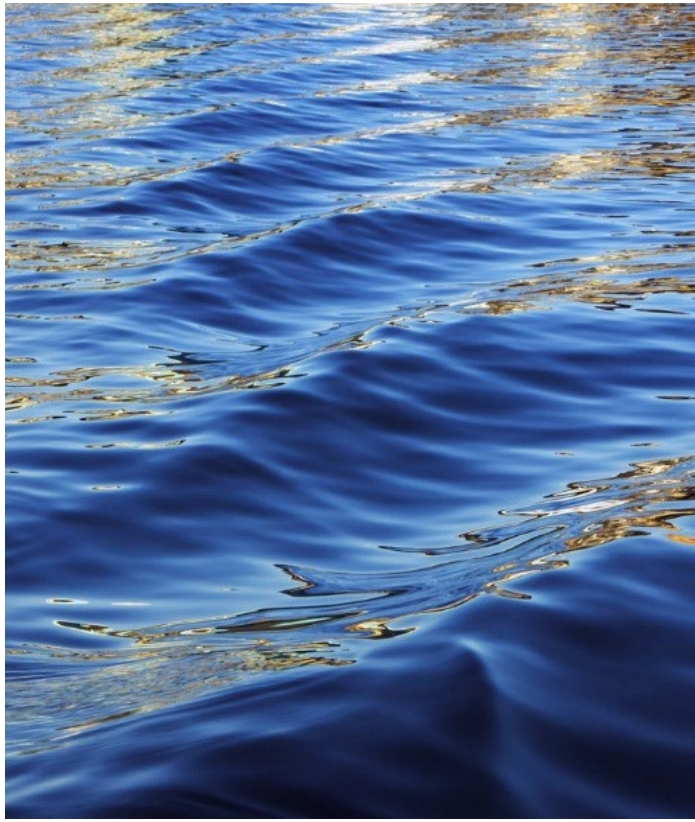
FDP
Field Development Planning

Bowdens Proposal: Hydrogeology

IPC 15 Feb 2023

Lue Action Group

Craig Flavel - Field Development Planning



Presentation Objectives

- Encourage leading practice to enable sustainable resources development
  - Create a 2023 industry ‘roadmap’ by requiring application of the latest risk management and water resources management
- Clearly demonstrate the link between the environment and human health
  - Develop a robust model between (ground)water quality, significant species and people
  - Bring evidence, policy and practical solutions to address biodiversity loss and climate change
  - Adopt a collaborative partnership in NSW to showcase a behavioural change
- Ensure any proposal aligns with 2022 WaterNSW strategy and principles for sustainable development

Content: Key groundwater concerns

1. An unclear definition of groundwater users is influencing risk conceptualisation and conclusions
    1. Significant or unique endemic species in groundwater dependent ecosystems are not presented
    2. Neither licensed nor unregistered bore users have an activity-pathway-likelihood-consequence risk assessment
    3. Lack of hydrogeological investigations between the Lue village and the site
2. Conceptualisation of acid mine drainage
    1. Inconsistent groundwater flow direction
    2. Lack of clarity around containment of Waste Rock Emplacement and cyanide leachate
3. Lack of a formal risk assessment
    1. Long term / indefinite ‘Take’ from (ground)water resources through evaporation
    2. Insufficient data for Trigger Action Response Plan or Water Management Plan

1. Unclear definition of groundwater users is influencing risk conceptualisation and analysis

1.1 Risks to licensed bore users

1. Groundwater yield is “highly productive” and thus protected by the AIP
2. Regional groundwater quality is likely potable
   (details in LAG Attachment 3, Planning Portal)
3. Bowdens has insufficient water supply approvals
   a. Groundwater: No guarantee of Water NSW/NRAR approval of an extraction borefield even if sufficient water allocation licences are obtained DPIE (2018)

1. Unclear definition of groundwater users is influencing risk conceptualisation and analysis

1.2 Risks to listed species in groundwater dependent ecosystems

1. Creeks and surrounding alluvium aquifers can support significant aquatic species
2. No evidence of investigations targeting endemic aquatic species in local springs, nor the nature of their groundwater dependence
3. Under-utilised hydrogeological information:
   - The conceptual model appears to be based on a literature review rather than site data
   - No evidence of significant hydraulic barriers laterally or vertically around the site
   - R.W Corkery & Co. (2021) state that the objective of the numerical groundwater simulation model was **not** to consider contamination of local springs nor dependent ecosystem health

> 'no water quality impacts beyond 40 m from the Mine Site boundary and no changes to the beneficial uses of aquifers are predicted'

RW. Corkery & Co. Appendix 9 p. A9-6 Mar 22

40 m in Context: potential to alter regional hydrology

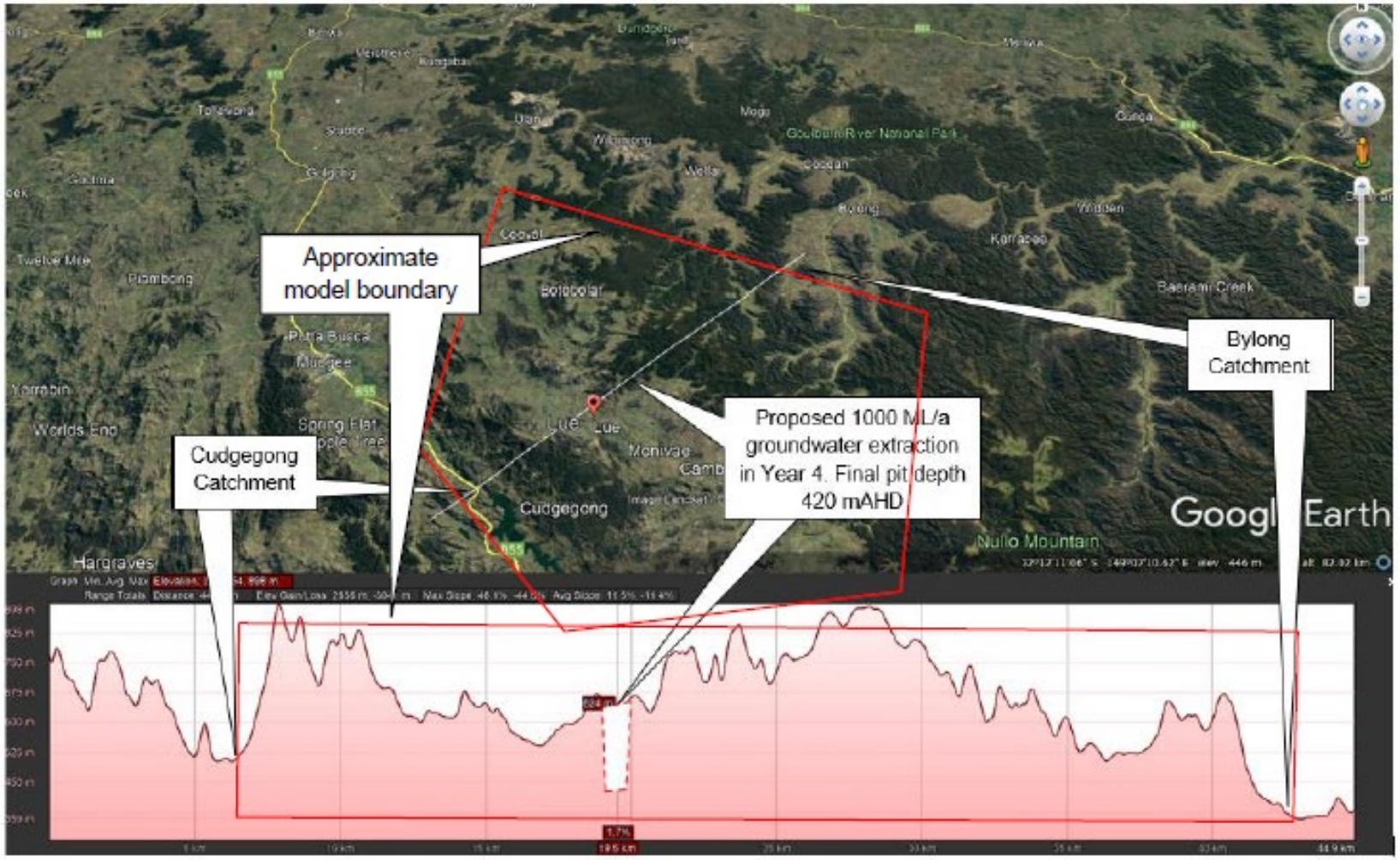
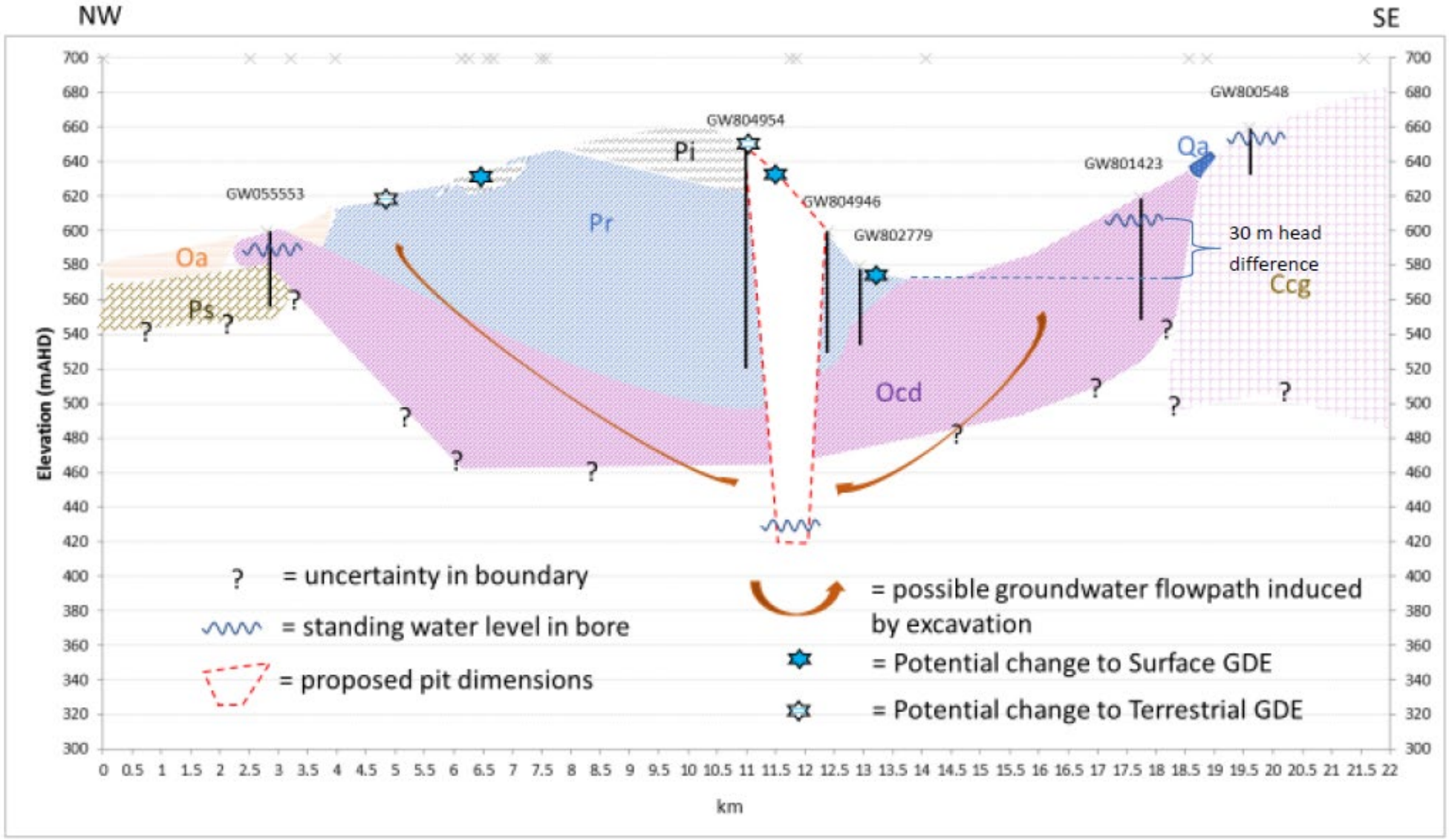


Figure 3: SW-NE Cross Section Source: GoogleEarth 2022

NW-SE Section during proposed dewatering – showing potential GDEs



Source: LAG report by Australian Water Environments (2018) indicating water salinity and regional impact

1. Unclear definition of groundwater users is influencing risk conceptualisation and analysis

1.3 Lack of hydrogeological data between the Lue village and the site

1. R.W. Corkery & Co. A4 (Feb 2022): enhanced permeability within fractured rock aquifers near major geological structures
2. Aquifer Interference Policy
    1. AIP 14: there is potential for causing and enhancing hydraulic connections that has not been clearly presented.
    2. AIP Table 4: potential unquantified water quality impacts on nearby licensed groundwater users

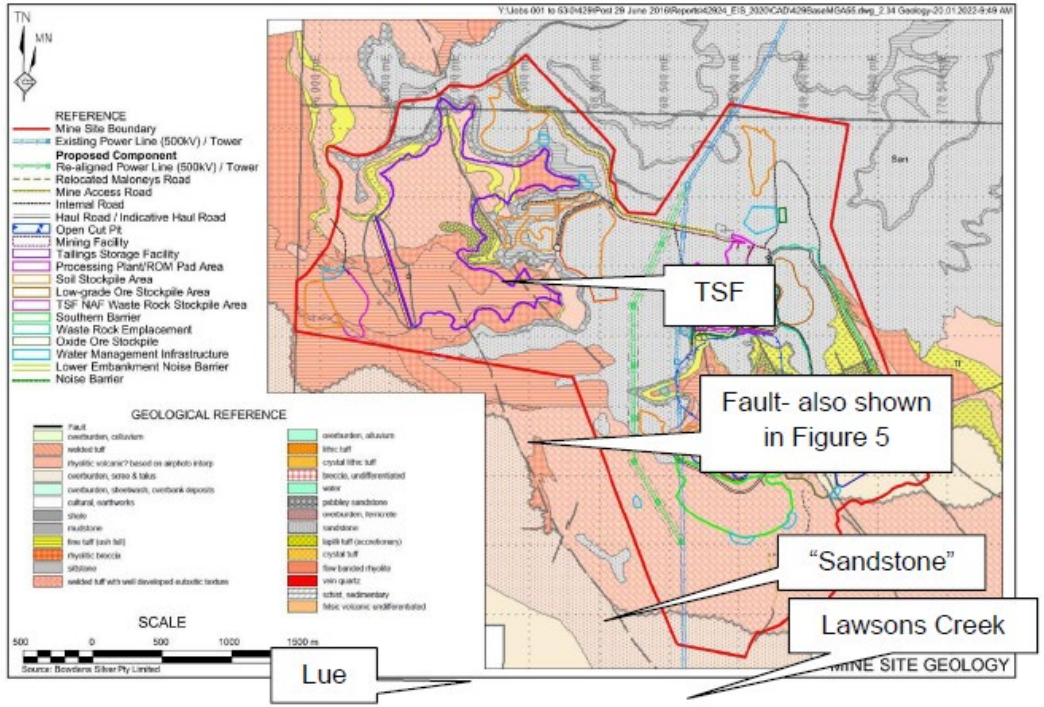


Figure 4: Site Geology, adapted from (R.W. Corkery & Co., March 2022c, pp. 2-10)

2. Conceptualisation of acid mine drainage

2.1 Inconsistent groundwater flow direction

1. The post mining groundwater flows are **unlikely** to be towards the pit (R.W.Corkery & Co. Dec 2022 & HydroGeoLogic Dec 2022)

2. Significant and unexplained alterations to model Layer 1 and 2 were made around the TSF in 2022 (HydroGeoLogic 2022)

2020 Numerical Simulation Modelling

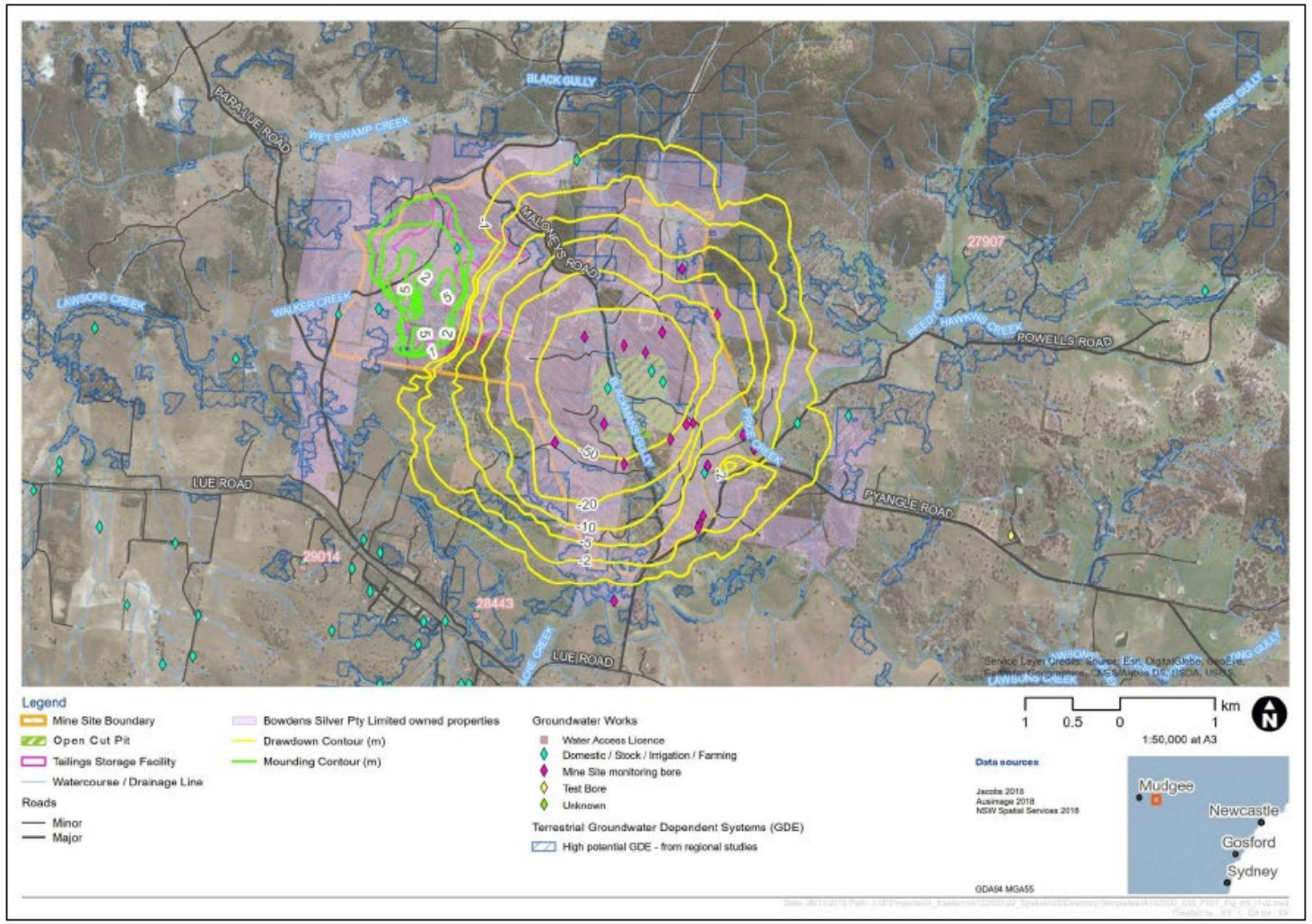


Figure 35 Predicted Drawdown at End of Mining (Year 15.5)

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Source: (R. W. Corkery & Co., March 2021, p. 5-333)

Hydrogeological Model Relayering for 2022

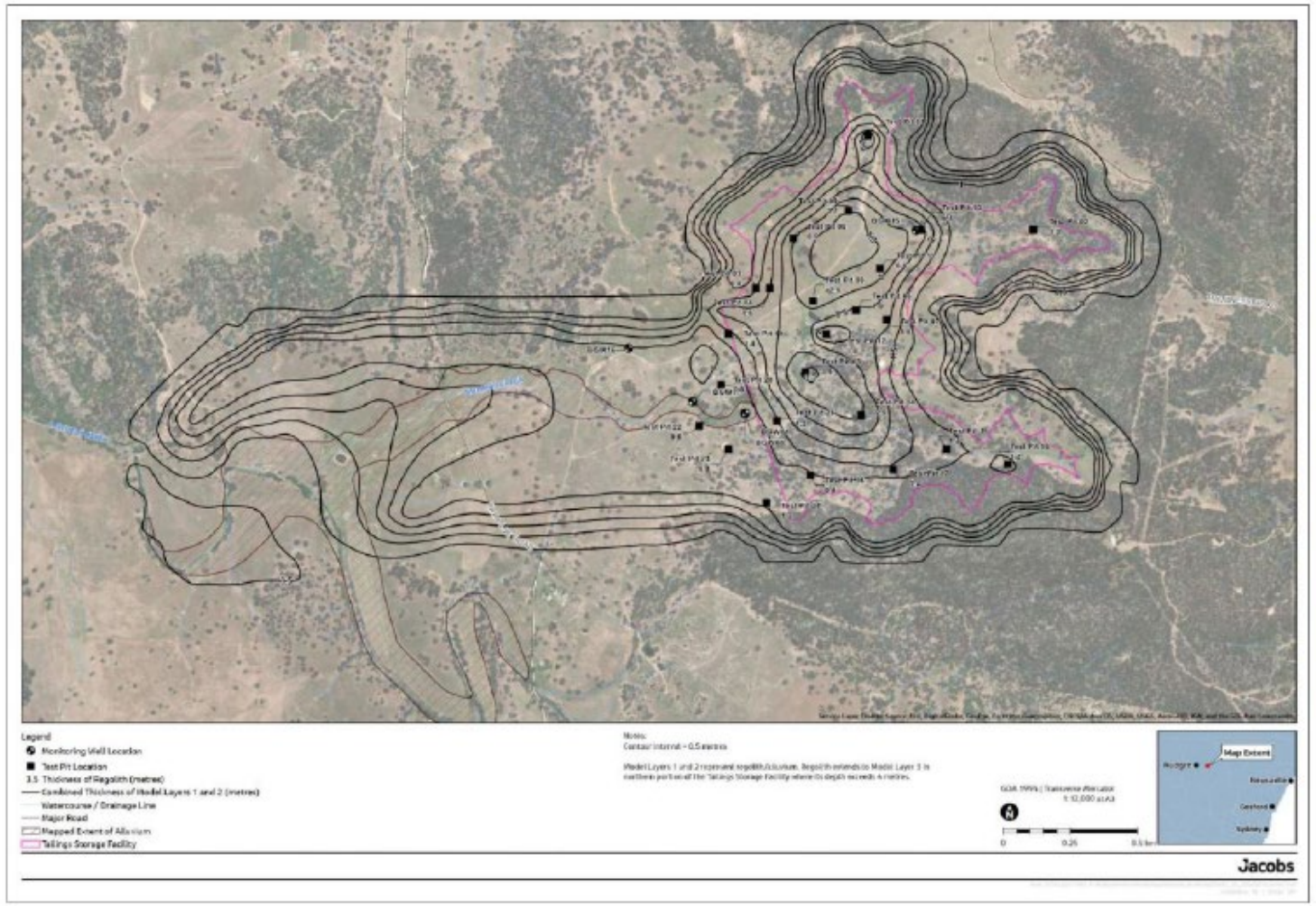
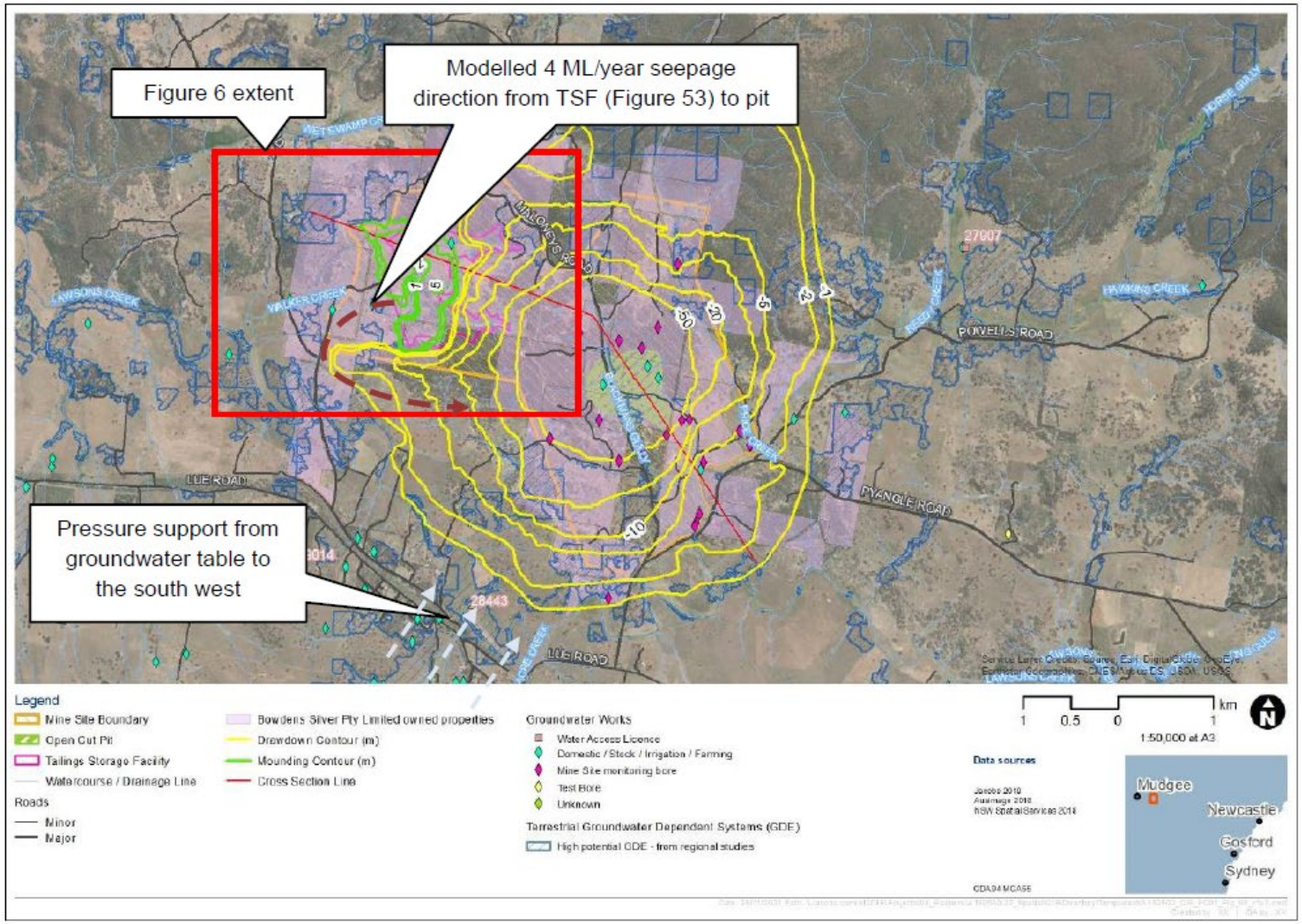


Figure 6: Modelled thickness of combined Layers 1 and 2 (R. W. Corkery & Co., 2022d, pp. 5-397)

2022 Numerical Simulation Modelling



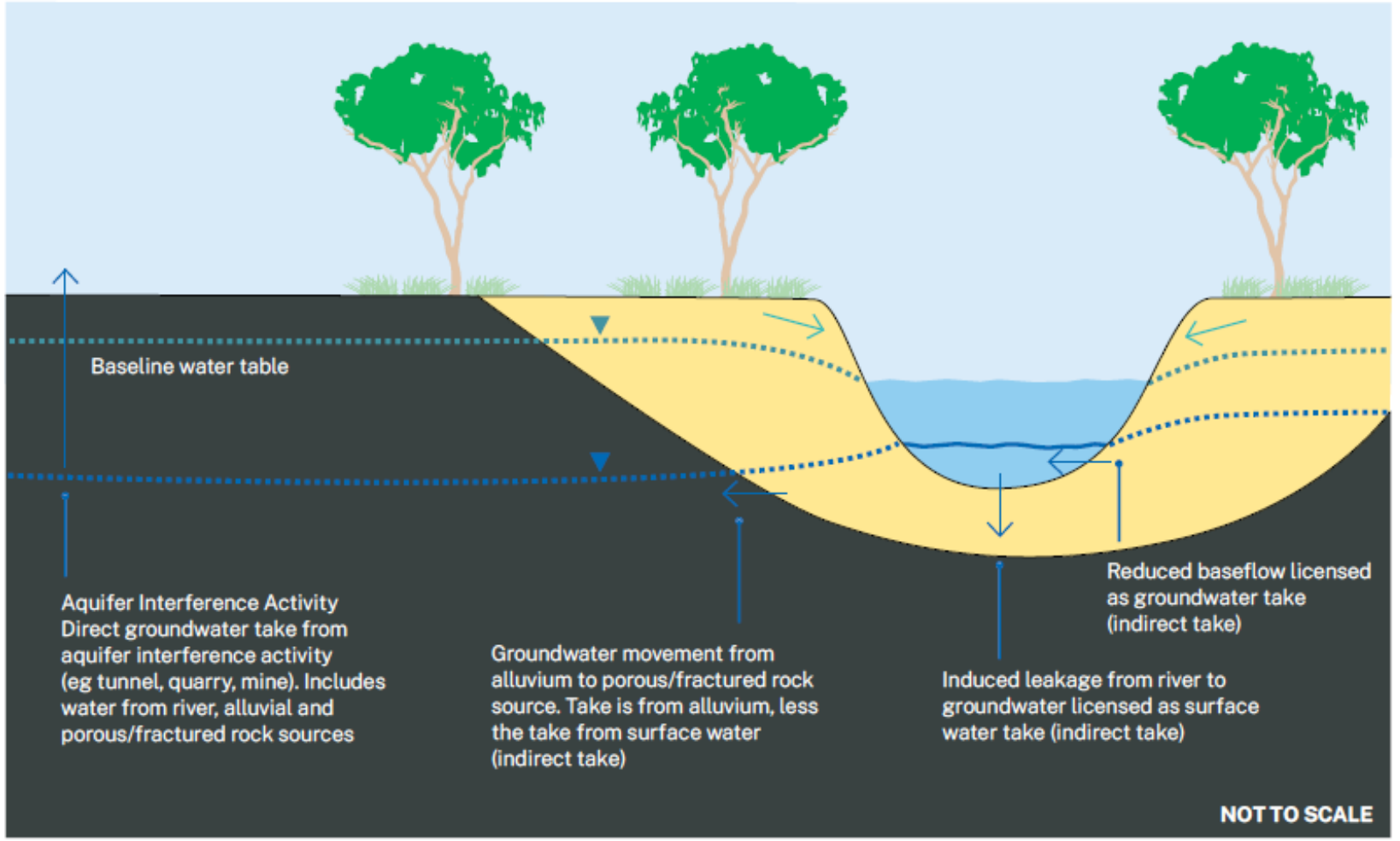
Source: Modified Figure 45 from R. W. Corkery & Co. 2022, p. 5-127

2. Conceptualisation of acid mine drainage

2.2 Lack of clarity around containment of Waste Rock Emplacement and cyanide

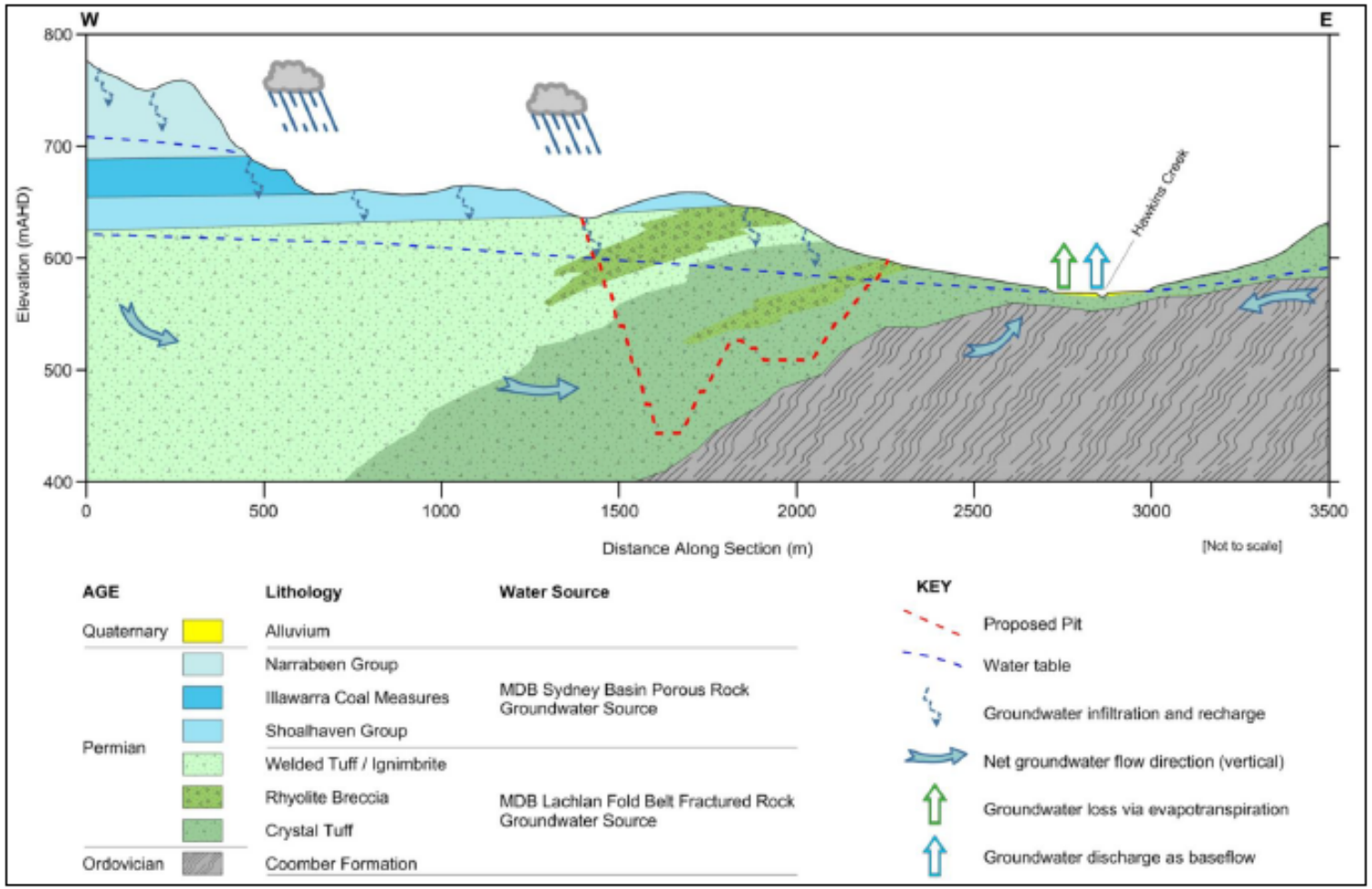
1. Potential seepage is predicted from the TSF and WRE (and Leachate Dam) (Jacobs 2020, 5-125)
2. 200 litres/day of seepage under the (ANCOLD 2012) TSF embankment (ATC Williams, 2020, p.24)
    1. The nature, mass or attenuation of contaminants leaching from the TSF or WRE to the south and west of the site after 100 years has not been provided.
    2. Seepage collection is uncertain in fractured rock aquifers.
    3. Long term management and response has not been specified
3. Amendment 2-45: An *unconditional* commitment to applying a bituminous liner to the entire area *and* monitoring integrity *and* specific response would help limit seepage

Groundwater flowthrough to Hawkins Creek



Aquifer interference diagram from DPE's Draft Guide to Groundwater Management in NSW p.30 Jul. 2022

Groundwater flowthrough to Hawkins Creek



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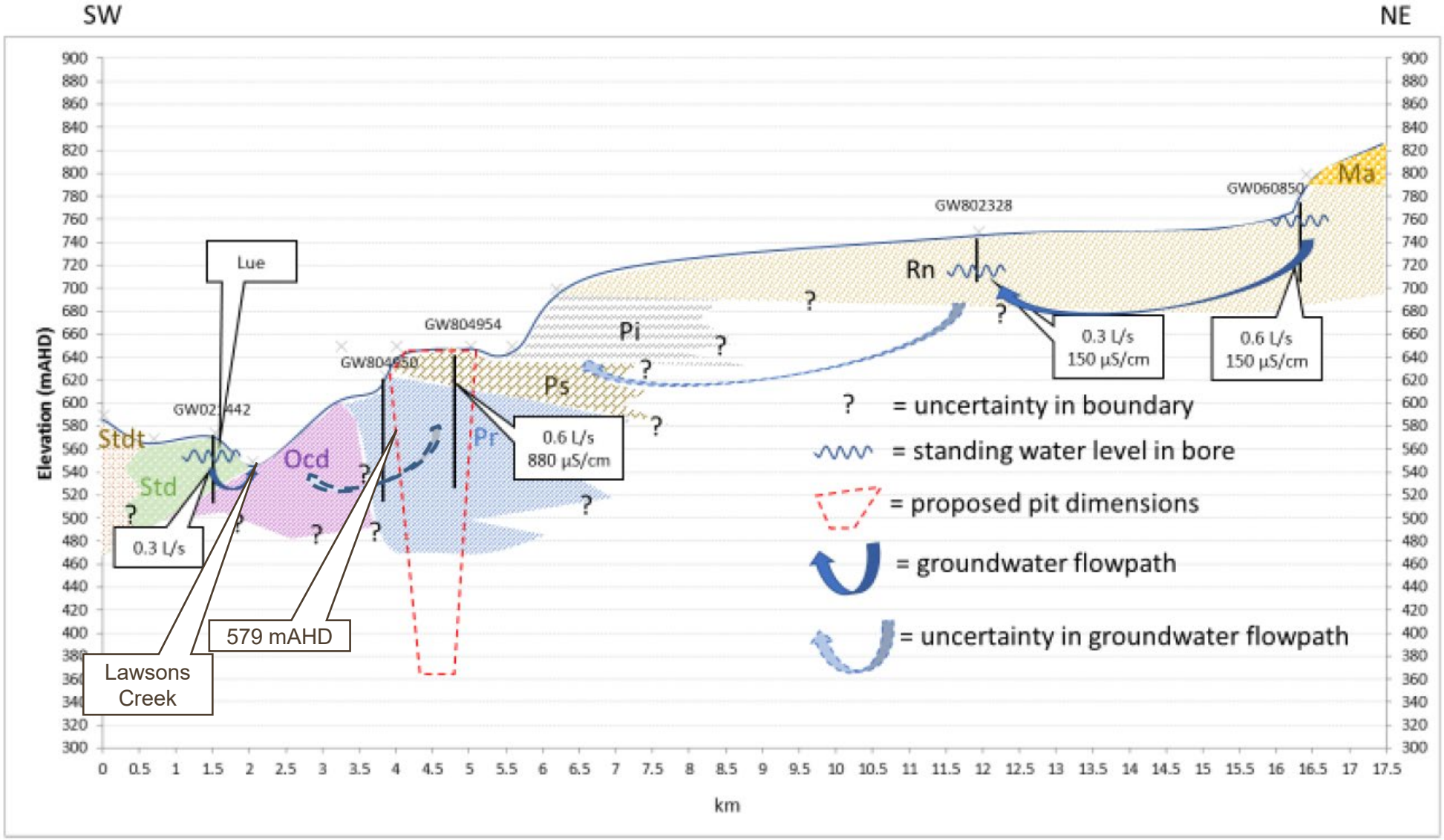
BOWDENS SILVER PTY LIMITED
Bowdens Silver Project
Report No. 429/25

Figure 40 Conceptual Hydrogeological Model – Pre-Mining (View looking north)

SPECIALIST CONSULTANT STUDIES
Part 5: Groundwater Assessment

Water source inflows (R. W. Corkery & Co., March 2022b, p. 20)

Natural conditions - 18 km SW-NE Section



Source: LAG report by Australian Water Environments (2018) indicating water salinity and regional impact

3. No formal risk assessment

3.1 Long term / indefinite ‘Take’ from (ground)water resources through evaporation

1. How much Take… and how has Take been calibrated?
    1. Evaporation: 309 ML/yr & groundwater inflow of 102 ML/yr
    (Section 4.7.5.5 R. W. Corkery & Co. Pty. Limited, 2020, pp. 4-161)
    2. Aquifer Interference Assessment submission “anticipates a long term take of 200 ML/yr.”
    (Q11 of Jacobs (2020) p 5-197)
2. Evaporation reduces water availability for ecosystems and people indefinitely (quality and quantity)

3. No formal risk assessment

3.2 Insufficient data for Trigger Action Response Plan or Water Management Plan

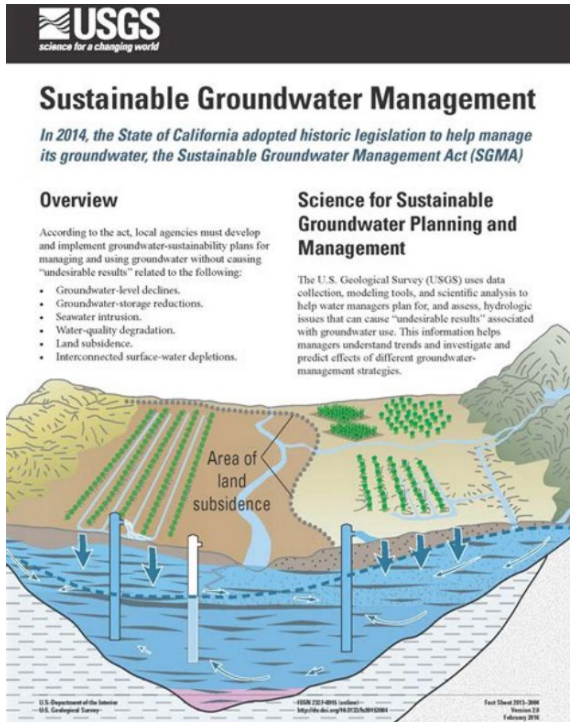
1. Investigating significant groundwater dependent ecosystems would enable an effective monitoring plan.
2. No locations, quantities, controls or triggers for monitoring bores are provided (R. W. Corkery & Co., 2022d, pp. 5-149),
4. A peer reviewed AS/NZS ISO 31000:2009 Risk Assessment would assist

The likelihood of contamination from the final void lake warrants a source-pathway-receptor assessment

Adapted from HydroGeoLogic, 10 Dec 22 p.11 & 26

Review against Objectives

- Does the proposal demonstrate leading practice?
  - 2017 National Groundwater Strategic Framework objectives:
    - Sustainable extraction and optimal use
    - Investment confidence through improved regulation
    - Planning and managing now and for the future
  - Indefinitely evaporating high quality water from year 16 could be replaced by backfilling, rehabilitation, sustainable water treatment and managed aquifer recharge



Leading Groundwater Practice (Source: USGS)

Review against Objectives

- Is there a demonstrable link between the activity, environment and human health?
  - Multiple authors and revisions lead to poorly referenced conclusions
  - No evidence that local perched and non-perched springs will not be drained or polluted
  - Water dependent habitat for critically endangered species that rely on water
  - Scant evidence of a collaborative partnership in NSW to showcase a behavioural change

Review against Objectives

- Does the proposal align with WaterNSW strategy and principles for sustainable development?

> *'making our lives healthier and more productive and our communities more attractive and amenable places to live.'*

(WaterNSW strategy, 2022)

- Sustainable development is challenged by this proposal

> *'If we contaminate our groundwater, it is extremely difficult… to clean up.'*

(modified from the WaterNSW strategy – GWM Guide 2022 p.18)

Specific LAG queries

- Hydrogeological model layering
  - Modelling of fractured rock has high uncertainty. Layering is not explained, thicknesses are not provided and geometry does not honour geology or faults
    (HydroGeoLogic Dec 2022)

- Fault impact
  - Fault behaviour is highly uncertain and may activate during subsidence induced by removal of overburden, blasting or dewatering

Specific LAG queries

- Final pit void flows and quality
  - Estimates of evaporation are uncertain
  - Hydrogeochemical investigations and hydraulic connectivity studies required
  - Experts note the present likelihood of discharge of contaminated water to the south and west (Earth Systems Dec 2022, HydroGeoLogic Dec 2022).

- Leak detection and mitigation – No specific details provided for assessment (Earth Systems Dec 2022, HydroGeoLogic Dec 2022).

Summary

Three key concerns amongst many:

1. An unclear definition of groundwater users is influencing risk conceptualisation and conclusions
2. Conceptualisation of acid mine drainage should be improved
3. No formal risk assessment

Summary

- Proposal is **unclear** on groundwater-:
  - **Movement;** especially from year 16
  - **Quality**: concentration, migration, attenuation and fate of contaminated seepage
  - **Users**: identity of water users at risk and the activity, pathway, likelihood & consequence

- Hence plans to monitor and control risks for groundwater users are unclear
  - A thorough, referenced and peer reviewed risk assessment would enable decision making

Recommendations

- A Conditions of Consent approvals ‘roadmap’ is not particularly collaborative nor transparent for NSW in 2023

- Provide all SEAR information *before* decision-making to clarify the risks of the project to the satisfaction of all parties

Further Detail on Concerns Presented

DPIE Major Projects Portal – Organisation Submissions, page 2:

LAG Attachment 4: AWE Aquifer Connectivity Study, June 2018

- Hydrogeological cross sections, GDEs, conceptual modelling

LAG Attachment 3: FDP Key Hydrogeological Concerns, July 2020

- Detail on all concerns investigated, as well as a summary of the response to the SEARs

LAG Attachment 5: FDP Review Combined 13 August 2021

- Review of Bowdens response to multi-agency feedback

LAG submission to DPIE (not on Portal):

FDP Review of Bowden's Response to Groundwater Questions July 2022

- Identifies which subconsultant reports were updated in 2022, the key changes and suggestions for responsible hydrogeological investigations

References

R. W. Corkery & Co. (2020). *EIS Volume 2 Part 5 Groundwater Assessment - Jacobs.* Sydney: R. W. Corkery & Co.

R. W. Corkery & Co. (2022d). *Appendix 4 - Part 5 - Updated groundwater assessment.* Sydney: R. W. Corkery & Co.

R. W. Corkery & Co. (March 2022b). *Water supply amendment report.* Sydney: R.W. Corkery & Co.

R.W. Corkery & Co. (2021a). *Amendment Report for the Bowdens Silver Project.* Sydney: Bowdens Silver Pty Limited.

R.W. Corkery & Co. (2021b). *Appendix 2 - Updated summary of environmental management and monitoring measures.* Sydney: Bowdens Silver Pty Limited.

R.W. Corkery & Co. (March 2022). *Amendment submissions report.* Sydney: R. W. Corkery & Co.

R.W. Corkery & Co. (March 2022c). *Appendix 1 - Amended Project Description.* Sydney: R. W. Corkery & Co. Pty. Limited.

Review of Bowden's Response to Groundwater Questions:

Bowdens' March 2022 Amendment Report

Version: 4.0

Release Date: 04 July 2022

Prepared By: Craig Flavel, Senior Hydrogeologist

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GLOSSARY

Abbreviation	Term	Description
AIP	Aquifer Interference Policy framework	A regulatory approvals framework
MDB	Murray Darling Basin	
TSF	Tailings Storage Facility	Location for potentially acid forming material extracted during mining that may leach hazardous chemicals into the water table
WAL	Water Access Licence	A permit to take water from a specified water source
WRE	Waste Rock Emplacement	Location for potentially acid forming material extracted during mining that may leach hazardous chemicals into the water table

1 Introduction

Lue Station Pty Ltd engaged Field Development Planning (FDP) to review groundwater related matters in the (second) Bowden's Silver Amendment Report dated March 2022.

Field Development Planning (FDP) is an organisation that interprets and communicates technical groundwater-related matters. FDP staff have reviewed issues with the information presented to support proposals for a mine near Lue since 2018. Two key matters have been raised:

1. If and how information provided up until 2021 met the multi-agency SEARs requirements (FDP, Aug 2021)

2. Questions from local people relating to groundwater (40 Questions)

While some information is provided on the first matter in this report (Appendix Table 5), Lue Station Pty Ltd requested FDP to consider the 40 Questions. The intended audience should have a basic understanding of groundwater and the proposed operation.

1.1 Overview of previous work

People living near the proposed development, including the Lue Action Group (LAG) have considered suggestions by several companies over the past decade to construct an open-cut lead-silver mine within two kilometres of the Lue village school. Most recently, work undertaken by 19 subconsultants in 2020 under head consultants R.W. Corkery & Co. for Bowdens Silver has been updated (R.W. Corkery & Co., March 2022).

Significant changes related to groundwater since the previous amendment include:

- Retraction of a water supply from the Ulan Coalfields and a proposed reliance on local surface and groundwater supplies to meet all project demands
- Introduction of the Environmental Planning and Assessment Regulations (2021)
- Additional groundwater modelling work, which includes the proposed tailings storage facility (TSF).

Within this context, the specific objectives of this project are to:

1. Provide an overview of previous work
2. Summarise the questions previously raised for response as part of the Submissions process
3. Consider whether Bowdens' March 2022 reports have provided sufficient information to determine that adequate water will be available to meet the requirements of the proposed mine and associated infrastructure.
4. Noting that the project now proposes to use local rather than external water resources, review any initial questions about the local impact to water resources

As per previous work, a review of groundwater modelling is outside the project scope. As a locally supported project, this high level review is constrained by budget.

2 Key matters in previous work

Key matters within work presented by R.W. Corkery & Co. for Bowdens Silver (Table 1) include:

- 57% of waste rock is potentially acid forming (PAF). Waste rock to ore ratio 1.6:1. Data on the potential for acid mine drainage within the proposal is sparse.
- Acid leachate from waste rock emplacement (WRE) is designed to flow to a Leachate Dam located north of Lue
- Acid leachate from the tailings storage facility (TSF) is located to the west above a Lawsons Creek tributary.
- Water features including springs, Hawkins Creek and Lawsons Creek (that passes through Lue village and Mudgee) are hydraulically connected to water harvested for or draining from the proposed mine site.
- The aquifer is unconfined and groundwater is within highly heterogenous fractured rock. This means that:
    - Predictions of groundwater movement are highly uncertain without significant baseline monitoring data. No groundwater data has been gathered between the edge of the proposed site and Lue village bores.
    - The proposed TSF lies on mapped faults. One fault trends southeast through Lawsons Creek.
- Groundwater quality data in the 2020 EIS was misreported / misrepresented as non-potable.
- Bowdens identified 106 groundwater bores within 10 km of the site, however, impacts on unregistered bores have not been considered either in the initial or revised EIS.

2.1 Status of groundwater documents

The status of documents relevant to groundwater are shown in Table 1.

Table 1: Documents reviewed and key changes

2022 Report Document	2021 Report Document	Related 2020 Document	Key Changes from previous work
Water Supply Amendment report (R.W. Corkery & Co., March 2022) & Appendix 1 – Updated Project Description (R.W. Corkery & Co., March 2022c)	Amendment Report	EIS	Inclusion of powerline diversion and change in water supply, noting no new groundwater impacts to the EIS (2020)
Appendix 2 - Updated Summary of Environmental Management and Monitoring Measures	Appendix 2	EIS Volume 5	Inclusion of Measure 18 – Seepage Management, one page
Appendix 4 – Groundwater (R. W. Corkery & Co., 2022d)	Appendix 3 – Groundwater (Jacobs, 2021)	EIS Volume 2 Section 5	Additional modelling and consideration of local water sourcing
	Appendix 7 – Health Risk (EnRiskS, 2021)	EIS Volume 3 Part 7	No change
	Appendix 8 – TSF Liner and Seepage Monitoring (ATC Williams, 2021)	EIS Volume 5 Part 16A	No change

The following 2020 documents have not been amended in response to the agencies' recommendations:

- Volume 2 Part 6 Surface Water Assessment Annexures – May 2020
- Volume 4 Part 10 Aquatic Ecology May 2020
- Volume 5 Part 16 B Preliminary Design – WRE, Oxide Ore
- Volume 5 Part 16 C Closure Cover Design – May 2020

2.2 Key groundwater changes in the 2021-22 proposal

An "integrated water management and supply strategy" is presented to manage the loss of the Ulan Coalfield water pipeline which involves:

- Increase in water storage of 65 ML to 130 ML
- Six "harvestable rights" dams within the Mine Site boundary

- Increased utilisation of groundwater bores. Groundwater bores must be located away from the open cut pit area (R. W. Corkery & Co., 2022d, pp. 5-117). Specification of the location of these productive areas would enable extended aquifer pumping tests to consider groundwater impacts. Jacobs notes that additional investigation is required to confirm a sufficient water supply exists. This sentiment is echoed in other reports (DPE Water, 2022).

Bowdens asserts that they are not moving 'Water Licences up or downstream' (CCC Meeting 14, May 2022, p. 24). FDP notes that Bowdens must still prove that water extraction is acceptable to other significant water users in the proposed location. As development consent grants Bowdens the right to take the water, the EIS must contain all information for this decision to be made. Some referral agencies may not be aware that a reduction of baseflow in surrounding creeks is likely under the integrated water management and supply strategy.

Bowdens must also demonstrate to the regulator's satisfaction how they will protect surface and groundwater from acid mine drainage during and after the proposed 16 year project is decommissioned.

Access to water and water contamination are the two key matters of concern within the proposal.

2.2.1 Access to water

Over 1,000 ML/a of groundwater is expected to be harvested in Year 4. Figure 1 indicates that groundwater yields are not expected to change as open cut pit inflow rates change.

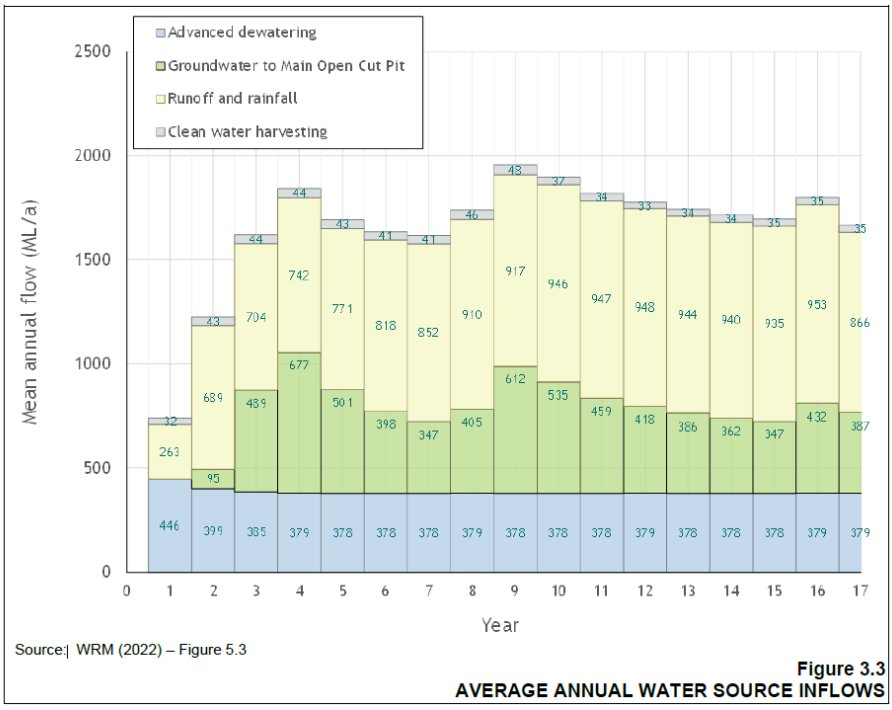

Figure 1: Water source inflows (R. W. Corkery & Co., March 2022b, p. 20)

If no hydraulic barrier is modelled between the production bores and the pit, this implies capture and drainage of groundwater recharge over a large area such as the Cudgegong catchment - Figure 3 – or upstream in the Lawsons Creek Catchment. This water would otherwise report to other groundwater users. An updated water model balance (Table 2) provides useful data on where water enters and leaves the groundwater model (bounded by the red polygon in Figure 3). Production from “well” cells in the model is 1,816 ML/a and more work is required to determine how much is from bores within the site water balance.

Table 2: Groundwater model water balance (R. W. Corkery & Co., 2022d)

Table 16
Water Balance for Transient Calibrated Model

Component (Cell Package)	Inflow (m^3/day)	Outflow (m^3/day)
Storage	18,389	32,111
Well (WEL)	0	4,975
River (RIV)	2,881	24,693
Drain (DRN)	0	74,363
Recharge (RCH)	212,132	0
Evapotranspiration (EVT)	0	97,260
Total	233,402	233,402

There is a risk that the impact of the integrated water management and supply strategy matters has not been effectively communicated amongst the 19 subconsultants. Only some of the reports have been updated in 2022

Volume 3 Part 9A – Biodiversity Assessment was updated in March 2022, however, EnviroKey were not advised that proposed disturbances might extend beyond previously surveyed areas due to the increased groundwater extraction proposed. In other reports, a permanent reduction in streamflows around the site due to reduction of rainfall run-off and a reduction in baseflow from groundwater is predicted (R.W. Corkery & Co., March 2022c, pp. ES-24). The disturbance is thus beyond the Study Area EnviroKey has been directed to consider (Figure 2).

An effective risk assessment follows an activity-pathway-likelihood-consequence process. The pathway linking activities to consequences is clearly defined, aligned to the activity and clearly communicated to share understanding and demonstrate acceptable risks.

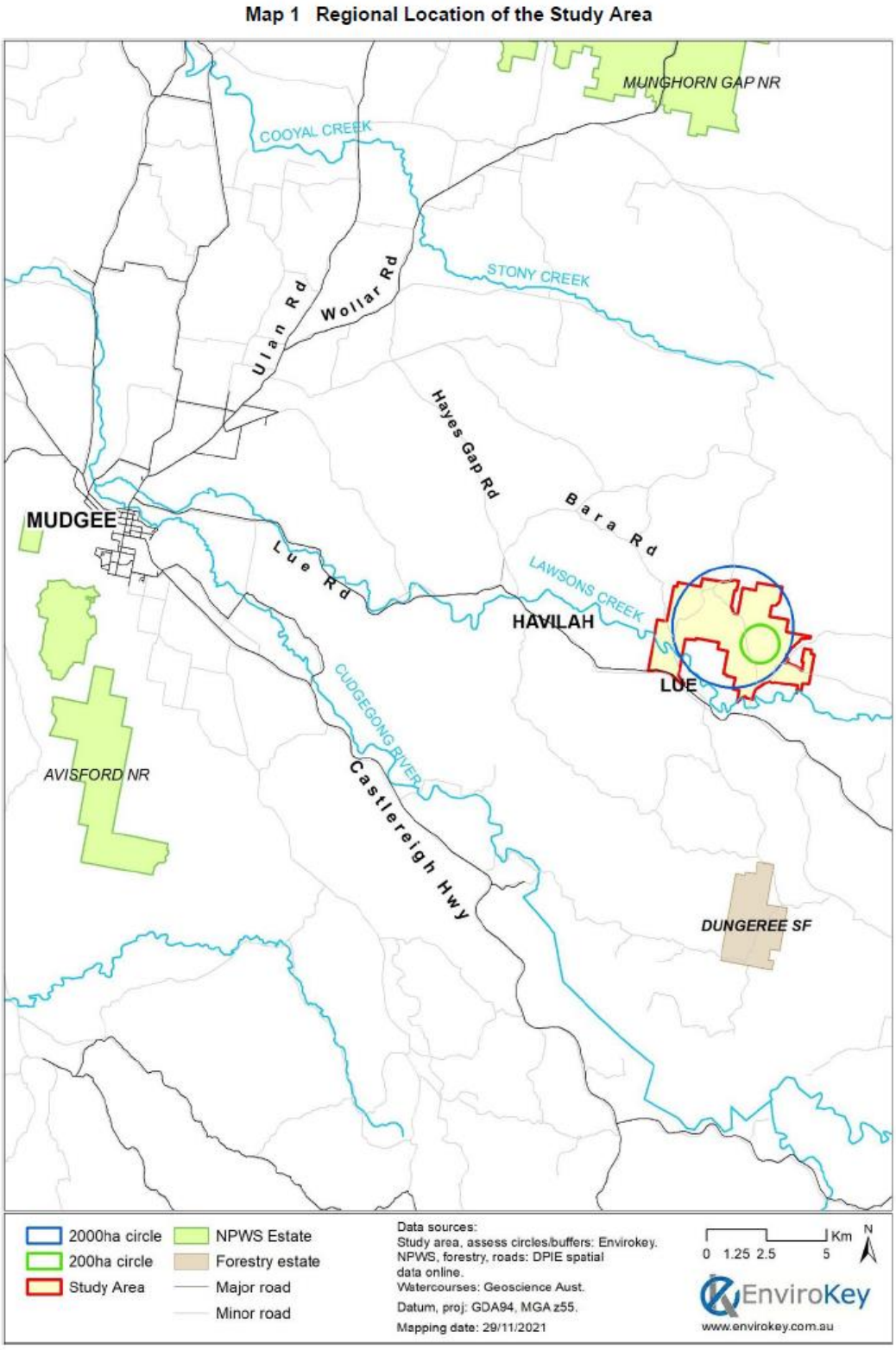

Figure 2: Biodiversity Study Area - does not extend to Lawsons Creek south of the site in R.W. Corkery & Co. 2022 Appendix 5 (EnviroKey) March 2022.

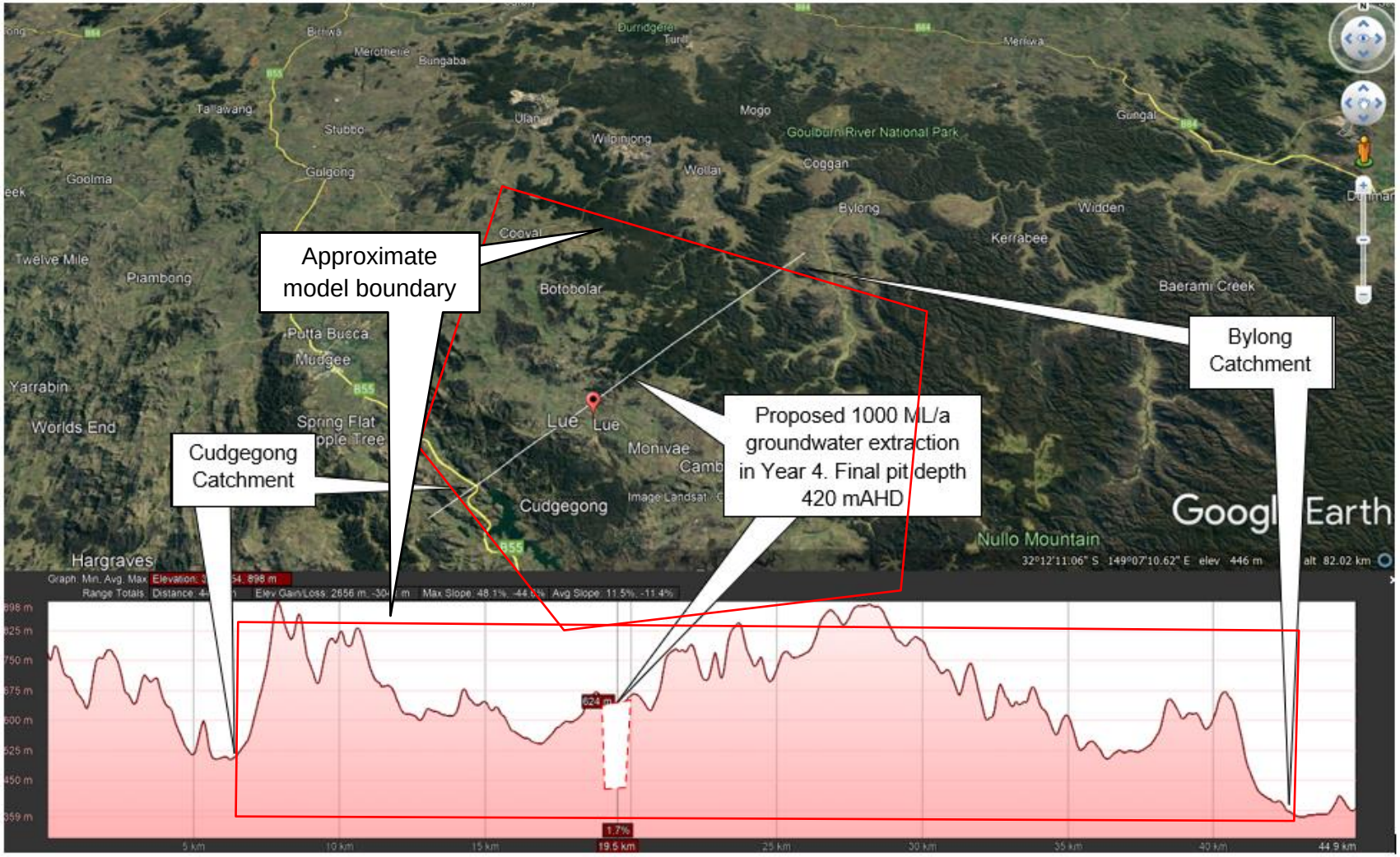

Figure 3: SW-NE Cross Section Source: GoogleEarth 2022

2.2.2 Water contamination

The concentration of contaminants and groundwater flows inform where contamination may occur over time. The Bowdens Regional Groundwater Flow Model (RGFM) assumes no-flow boundaries occur outside the mine site and does not simulate surface water processes. The validity of these assumptions was not verified by Jacobs (Dec-2021) before they were used. The RGFM was regarded as a fit-for-purpose Class 2 model (excluding contamination impacts). Once the model objective is clearly stated, a Class 2 or 3 model may be suitable for high-risk modelling of the tailings storage facility over a fault in a fractured rock environment. As no formal risk assessment has been undertaken, the risk profile of the proposed development is not clear.

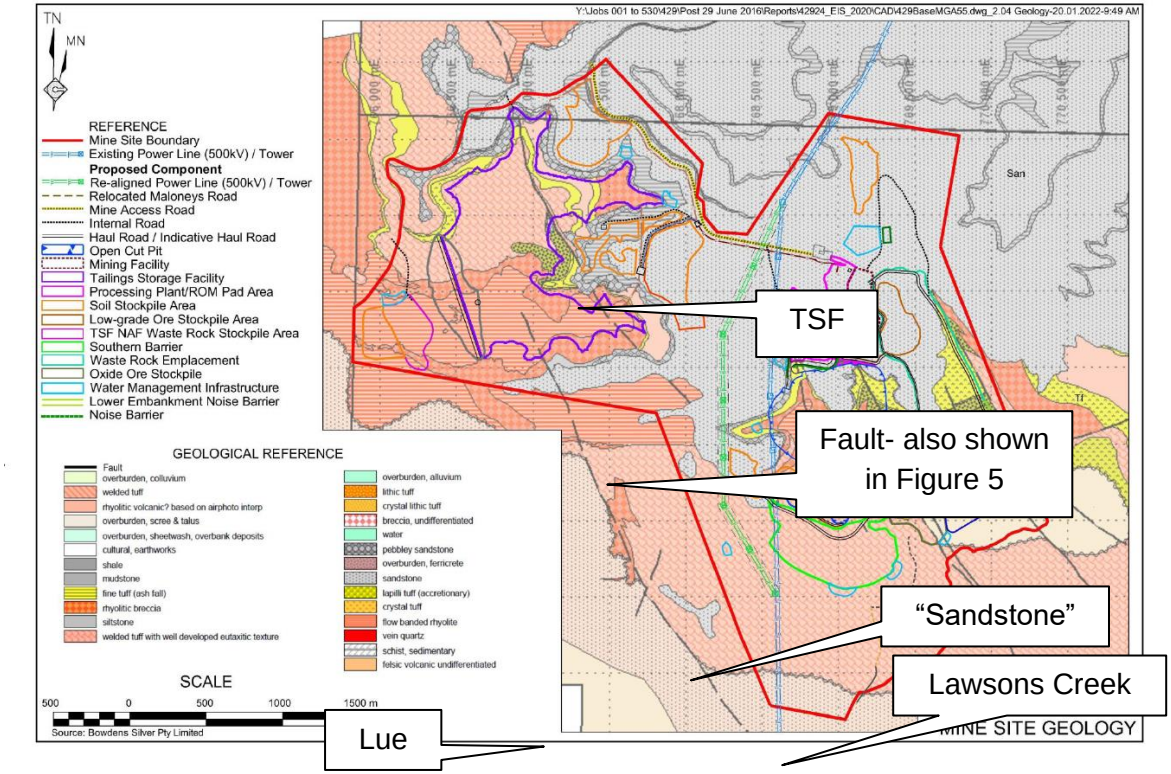

Figure 4: Site Geology, adapted from (R.W. Corkery & Co., March 2022c, pp. 2-10)

The lack of bores to inform (hydro)geological interpretation outside the site reduces confidence in the model outputs. The following figures show recent amendments to the groundwater model and compares these to the data that is presently available to inform these interpretations.

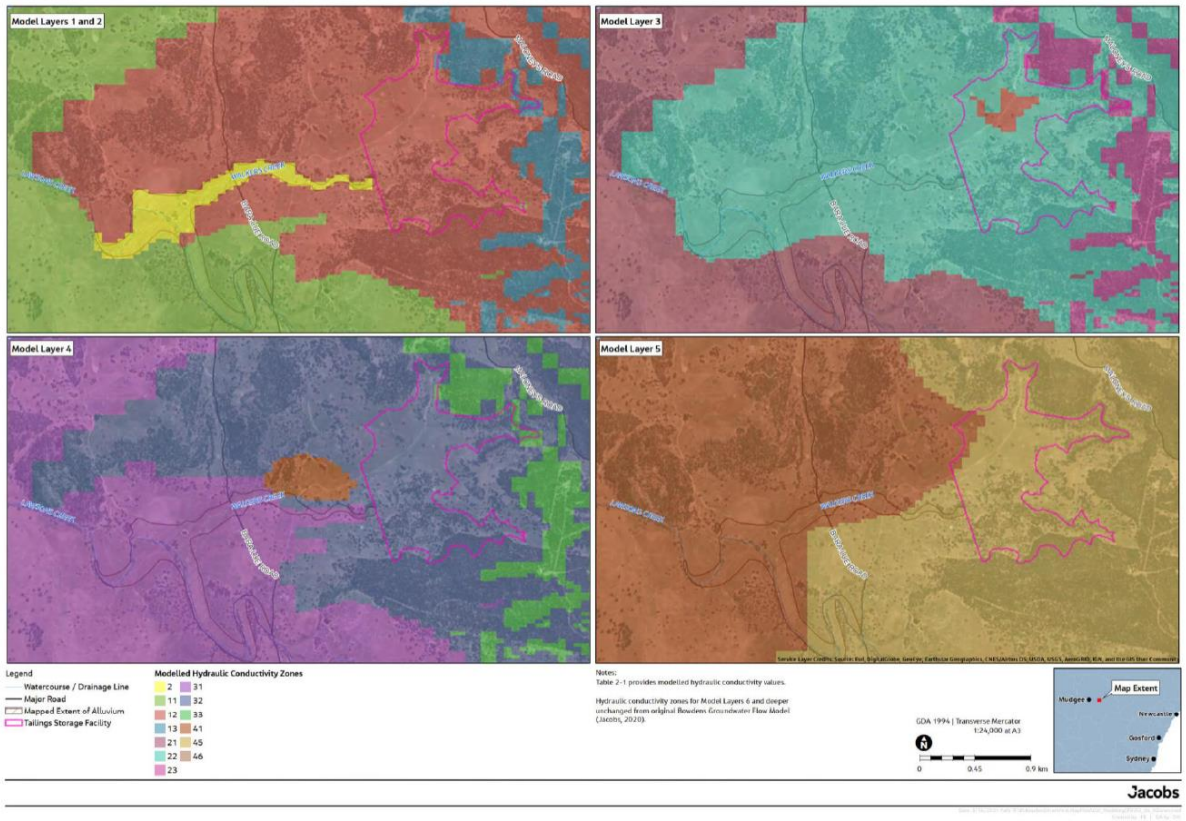

Figure 6 Modelled Hydraulic Conductivity Zones

Figure 11 Surface Geology

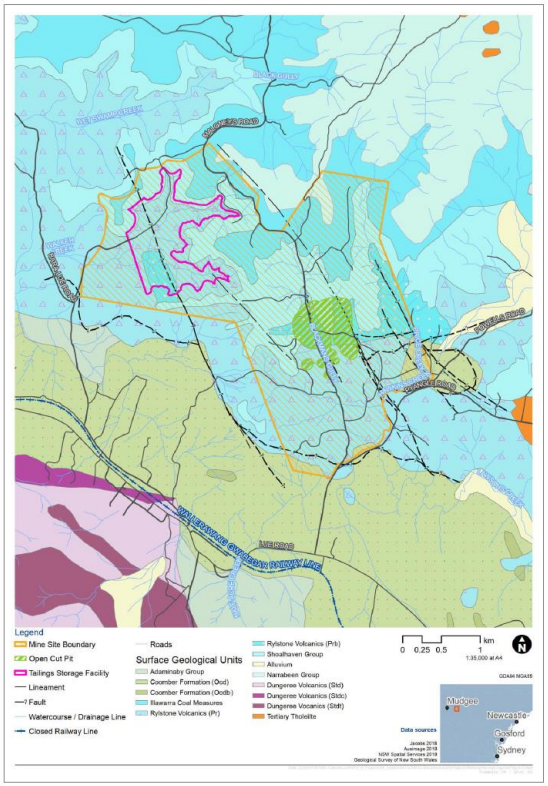

Figure 5: Changes in hydraulic conductivity (R. W. Corkery & Co., 2022d, pp. 5-400) and surface geology (R. W. Corkery & Co., 2022d, pp. 5-56). Codes for modelled hydraulic units are shown on page 5-398. The modelled hydraulic conductivity of the alluvium is truncated by Zone 31 (higher hydraulic conductivity based on Bowdens' regional groundwater flow model). Any aquifer pumping test data undertaken has not been provided to support the interpreted hydraulic conductivity/zone boundaries.

Figure 6 shows the modelled thickness of the upper two layers, but does not provide any guidance regarding the assumptions (e.g. geological logs) supporting this hydrogeological interpretation. Figure 7 and Figure 8 show the impact of the altered hydrogeology on modelled groundwater drawdown impacts; acid leachate is modelled to report to the pit in the outputs provided, not the creeks.

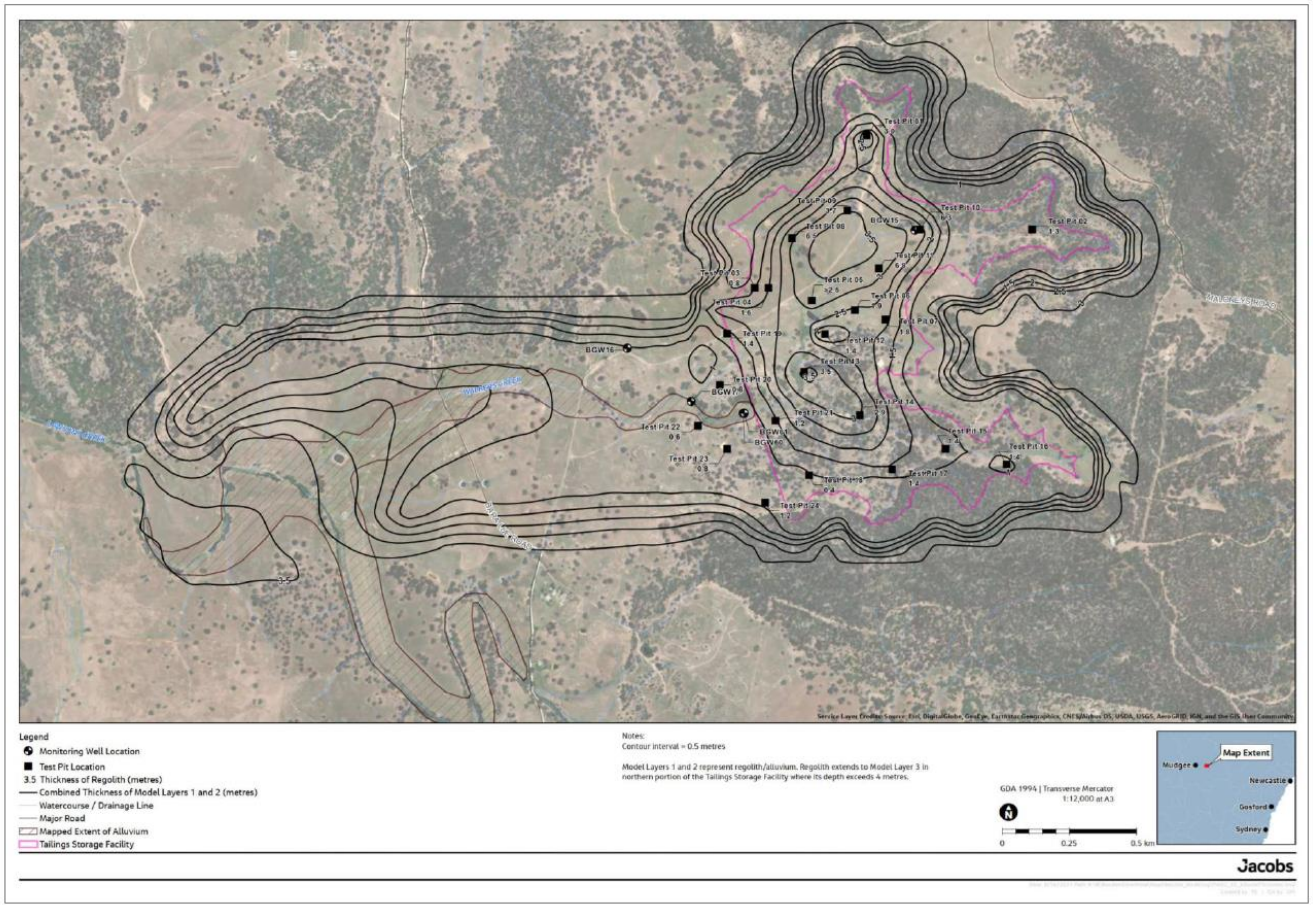

Figure 5 Combined Thickness of Model Layers 1 and 2

Figure 6: Modelled thickness of combined Layers 1 and 2 (R. W. Corkery & Co., 2022d, pp. 5-397)

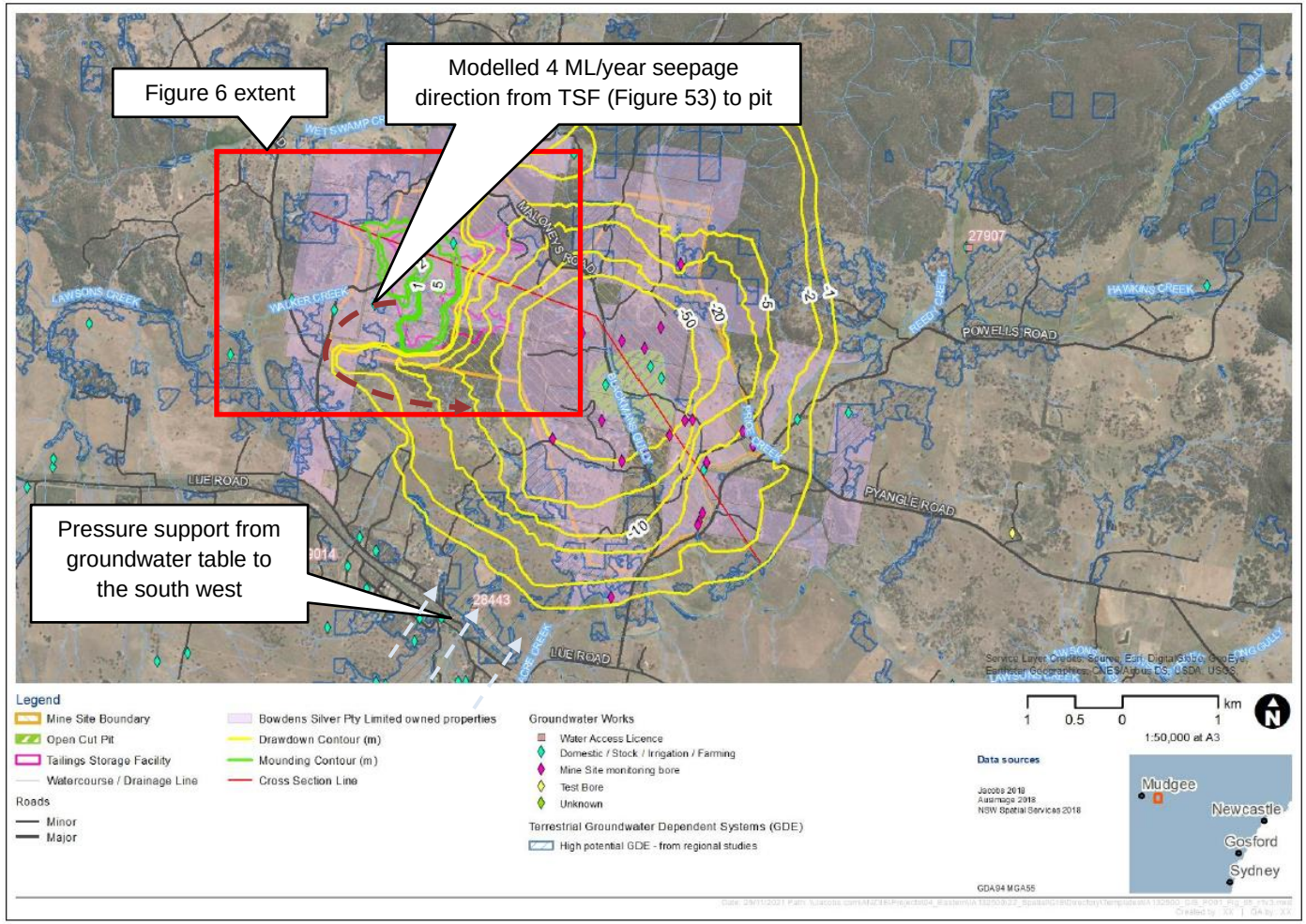

Figure 7: 2022 Year 9 modelled drawdown, influenced by zone/layer distribution, modified from (R. W. Corkery & Co., 2022d, pp. 5-127), showing hydraulic communication between the TSF and the pit, indicating leakage / pressure support from the TSF reporting to the pit as well as groundwater pressure support from the south west. NB. Figure 53 appears to mislabel Option 1 and Option 2 with BGM.

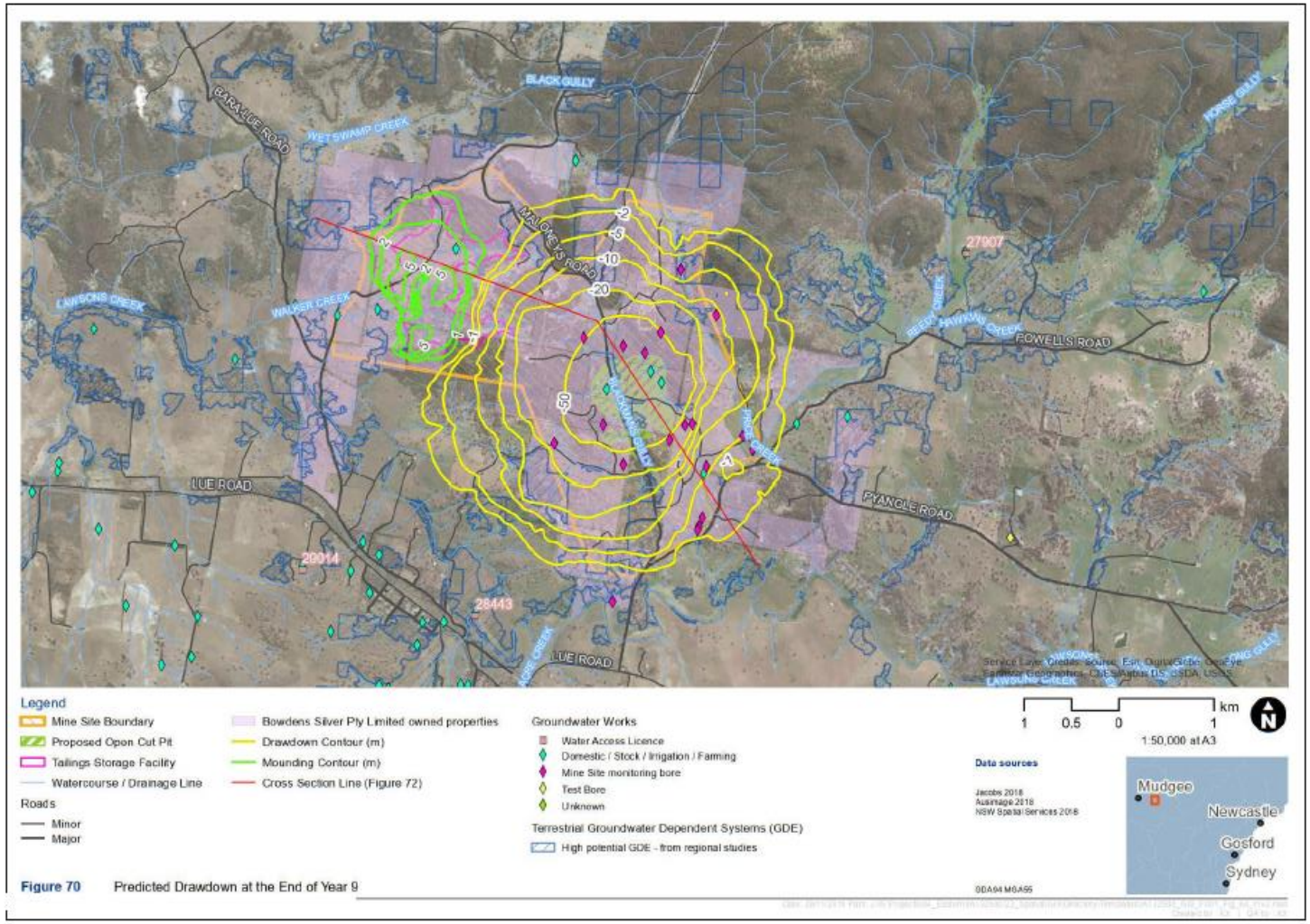

Figure 8: 2020 Year 9 modelled drawdown (R. W. Corkery & Co., 2020, pp. 5-169)

3 Summary of 19 questions raised 27 July 2020

The Lue Action Group (LAG) raised 40 matters of concern after comparing the SEARS to the EIS and supporting documentation. Funds were available for 19 questions to be pursued. These are attached to one of three of LAG's Objection submissions to the proposed development on (NSW Government, 2022) with additional detail beyond the summary extracted for this report. The other 21 questions are listed in Appendix Table 4.

FDP considers the 19 questions raised in 2020 in light of the information provided in 2022 in Table 3.

Table 3: Responses to 19 Questions

Query	Query Summary	2022 Update?	Comment
4.1. Rights of Groundwater Users	The potable water quality sustaining two listed flora, five listed aquatic fauna, two licensed allocations and 15 Stock and Domestic bore users within the Lue Village appears to be at risk	Availability of freshwater in the alluvial groundwater is confirmed (p5-98). 70% of water strikes occur shallower than 60 m within the site, however, drilling >600 m for water is planned.	Extended aquifer pump testing and modelling of acidic leachate would inform the application.
4.2. Risks to licenced bores	No formal risk assessment (with standard risk assessment framework) has been presented.	No	
4.3. Dependence of species on groundwater	No substantive evidence has been provided to conclude that the significant species will not be permanently affected.	Stygofauna are mentioned, however, the rigour applied to identifying unique species is unclear. Figure 32 (and Figure 37 / Table 22) show fresher water in the springs, implying local rainfall recharge, however, long term water levels and associated endemic species dependence is not provided.	Independent studies on significant species and their relationship to the springs, aquifer and creeks would inform the application.
4.4. Impact on Box Gum Woodland	White Box-Yellow Box-Blakely's Red Gum Grassy Woodland is listed as critically endangered. The EIS does not clearly explain how groundwater drawdown from the proposed Project will impact these protected woodlands outside the mine site	EnviroKey (2022) noted that there would be a significant impact on Box-Gum Woodland and that a Biodiversity Management Plan (BMP) is required to mitigate impacts (R.W. Corkery & Co., March 2022). In Section 6, such a plan might include seed collection and weeding (EnviroKey, March 2022).	If implemented, would seed collection and weeding is sufficient to protect a Critically Endangered species?
4.5. Risks to significant species in springs & watercourses	Protected Murray Cod, Silver Perch, Southern Purple Spotted Gudgeon, Trout Cod, Murray Crayfish and Eel Tailed Catfish may exist within the area, as well as species within springs (modified or not). The locations and risks to these protected species should be clearly shown and evaluated in the EIS	95th percentile aquatic ecosystem ANZG values are presented for selected analytes (pH impact not modelled).	
4.6. Relationship between alluvium, fractured rock	There is sparse information on the relationship between hydraulic changes in the fractured rock aquifer and the alluvial aquifers connected to Lawsons Creek/Lue village	Alluvium may be, or may not be, highly productive in the model (R. W. Corkery & Co., 2022d, pp. 5-38). The nature of fractures varies widely.	Extended aquifer pump testing and logging of bores between the site and Lue would inform the application.
4.7. Monitoring wells between Lue and Mine	Investigation wells enable an understanding of the geology between activities and neighbouring beneficial users of groundwater. No investigation bores have been drilled between the site and the Lue Village.	Some monitoring bores planned ‘downgradient of the WRE and TSF’ (R. W. Corkery & Co., 2022d, pp. 5-149), however, no locations, quantities, controls or triggers are set.	Extended aquifer pump testing and logging of bores between the site and Lue would inform the application.
4.8. Paired wells	There are no paired monitoring wells within 1.5 km of Lawson’s Creek near Lue village so the degree of impact on riverine ecosystems and shallow bore users is poorly defined.	No	
4.9. TSF leachate	The native groundwater flow direction from the TSF is misreported; existing groundwater contouring is not well explained; evidence of leachate migrating from the TSF is presented, however, the fate of leachate if it reaches the water table has not been demonstrated.	TSF advection and dispersion modelling conducted, however, the acidic dissolution of minerals, the change in pH at the creeks and release of heavy metals has not been modelled, reviewed or presented (R. W. Corkery & Co., 2022d, p. Table 26).	
4.10. Groundwater flow direction	The baseline groundwater flow direction is not well understood. This raises a concern regarding the prediction of impacts from groundwater contamination during and after mining.	Figure 40 (conceptual E-W model) provided, however, no model linking proposed site with Lue. This may be due to a lack of hydrogeological information in that area. WRM adjusted evaporation rates to make the terminal pit void a sink (increasing permanent groundwater take).	A N-S hydrogeological conceptual model may show flow from the south west (beneath Lue) travelling to the proposed site in Year 9. Seasonal changes to groundwater flow are not presented. Improved evaporation data would clarify whether the final pit void might be a sink or leak*.

4.11. TSF leakage risk	Treatment of contaminants in the TSF is not presented in the EIS. The TSF is planned to be constructed on a fault. 1.6 ML/day of TSF leakage is planned without considering the fault movement risk. The planned monitoring places few controls on compliance with the design and there is no contingency plan to remediate leakage. No peer review of contamination risks has been presented.	Total TSF leakage planned at 11 kL/d (4 ML/year) with 3% of this (0.1 ML/year) reporting to a single area of Lawsons Creek[1]. Some additional modelling has been done with two figures on sensitivity analysis, however, work is unreviewed.	
4.12. WRE and Leachate Dam	57% of waste rock is potentially acid forming (PAF). No acid treatment plan has been presented. Leachate from the waste rock emplacement (WRE) is planned to be sent to a leachate management dam that has a design of 1 m of freeboard proximal to Price and Hawkins Creeks. Despite the presence of local faults, monitoring for leakage, triggers and a contingency plan to remediate leakage in the leachate management dam are not provided. The WRE and leachate dam do not minimise impacts to the greatest extent practicable using best practice.	Some monitoring bores planned 'downgradient of the WRE and TSF' (R. W. Corkery & Co., 2022d, pp. 5-149), however, no locations, quantities, controls or triggers are set.	
4.13. Cyanide containment	Different assumptions regarding volume of cyanide used and whether leakage will occur raise concerns about the projects stated ability to contain cyanide	No	
4.14. Link between TSF and Groundwater Assessment	The groundwater assessment (Jacobs 2020) considers groundwater availability around the site. No peer review has been conducted on groundwater contamination risks.	Leakage considered, however, changes to the MODFLOW model which redirects TSF flow to the proposed pit require review e.g. assumed dispersivity, soil partitioning coefficient, grid changes etc.	
4.15. Hydrogeology around TSF	The geology and hydrogeology around the TSF lacks detail.	Figure 37 / Table 22 show highly variable groundwater quality, implying highly variable groundwater movement and aquifer compartmentalisation. Uniform permeabilities assumed in the model that ignore pumping test data (R. W. Corkery & Co., 2022d, pp. 5-347). The impact of including a new 0.1 - 0.45 m thick clay layer across the entire model is unclear (R. W. Corkery & Co., 2022d, pp. 5-394). Cumulative rainfall is used as a proxy for 'pumping at BGW108' (R. W. Corkery & Co., 2022d, p. 436).	Extended aquifer testing would inform hydraulic conductivity assumptions in key areas. Updating last review of model calibration (2017) and reviewing the TSF modelling would provide confidence in the findings.
4.16. Monitoring - trigger - WMP	A Water Management Strategy and details of a Trigger Action Response Plan are required in the SEARs. Impacts to significant water resources and threatened species must be minimised to the greatest extent practicable. There is no inference of where new monitoring wells will be drilled, nor which locations will be used to monitor what during and post mining. Identifying the dependence of groundwater users, including ecosystems, on the native groundwater system would enable an effective monitoring plan, including trigger levels against analytes or water levels (availability), to be determined.	Some monitoring bores planned 'downgradient of the WRE and TSF' (R. W. Corkery & Co., 2022d, pp. 5-149), however, no locations, quantities, controls or triggers are set.	
4.17. Review against SEARs	See Appendix Table 5		
4.18. General question responses[2]	In general, the EIS does not clearly identify the locations of groundwater users at risk, hence plans to monitor and control risks are premature and vague. The development of a robust Water Management Strategy under a best practice risk management framework should be undertaken before any regulatory approval to enable consideration of a proposal to mine near Lue.	Improved map of two licenced users.	Information on how long the 'outflow' of 1,151 ML/a of water in tailings voids will remain in place during compaction would be helpful.

[1] Bituminous liner TSF Design Option 1, Figure 53 (assumed mislabel) Figure 18, and Figure 16 for planned volumes reaching Lawsons Creek at certain locations (R. W. Corkery & Co., 2022d)

[2] Further questions, such as "Section 4.7.5.5 (R. W. Corkery & Co. Pty. Limited, 2020, pp. 4-161) quotes long term evaporation from the pit lake of 309 ML/a and groundwater inflow of 102 ML/year, yet the Aquifer Interference Assessment submission (Q11 of Jacobs (2020) p 5-197) anticipates a long term take of 200 ML/a." can be found in the 19 Questions submitted on the DPE Planning Portal by the Lue Action Group.

4 Review of initial questions considering change of proposed water source

The initial proposal involved taking water from the Ulan Coalfields. As such, feedback did not consider the possibility of sourcing the required water locally. Local water is used by the environment, providing habitat for listed species, as well as bore users.

FDP considered several of the initial questions raised by stakeholders that are published on the NSW Planning Portal. FDP concludes that the matters relating to water in these submissions cannot be separated from the change in proposed water source because of the significant modification of the site water balance. For example, general feedback relevant to local water sourcing include matters raised by the Gallanggabang Aboriginal Corporation (July 2020) intrinsically linked to the site water balance:

- Impact on local endemic flora and fauna
- Drop in groundwater levels for bore users
- Tailings, waste rock and ore leachate contaminating the aquifers

Information regarding the local groundwater response is uncertain with or without external supplies. The impact of seasonal changes to groundwater level (and associated groundwater flow changes) is not presented and the uncertainty in the fractured rock hydrogeology is not shown using a full range of possible outcomes. The 2014 extended aquifer pumping test on BGW10 and BGW108 highlighted the influence of no-flow boundaries/lineaments within 100 m. Groundwater levels did not fully recover after 10 days. Pumping tests over 30 days and dewatering test pits would better reflect the sustainable yield of bores and better inform the hydraulic conductivity and storage of the dual porosity model and inform the new 'horizontal flow barriers / HFBs' used in the model (Figure 5) (R. W. Corkery & Co., 2022d, pp. 5-408).

Deep rooted vegetation, local creek ecosystems and springs depend on shallow groundwater (R. W. Corkery & Co., 2022d, pp. 5-122). The cumulative rainfall distribution analysis contains significant uncertainties. The impact of draining the tight matrix porosity is unclear without extended aquifer pumping test information at locations away from the planned pit.

5 Summary

FDPs high level review, that has been constrained by budget, indicates that changes to selected sections of the proposal does not provide confidence that groundwater related risks would be acceptably managed. The majority of the Recommendations provided by EPA and DPIE/NRAR appear to be unresolved. Linking the TSF to the regional model provides some much needed detail, however, the unreviewed modifications to the model raise further questions both during and post mining. Without gathering hydrogeological data, the information in the proposal to source water locally raises more questions than answers.

R. W. Corkery & Co. state that the impacts to groundwater due to the altered water supply are within the bounds of the impacts assessed. There is no formal activity risk assessment for this statement to be verified. Extended aquifer pumping tests at the locations earmarked

for highly productive bores beyond the inconclusive 2014 results from BGW10 and BGW108 would better determine whether proposed water extraction is sustainable. Extended aquifer pumping tests between the site and the alluvial creek environment would also better quantify the predicted drop in creek water levels seasonally, validate the assumption of uniform hydraulic units in the groundwater model and 'HFBs'.

The presence of significant species and their reliance on site water resources remains unclear, especially within springs. A key matter is that the objective of the numerical groundwater simulation model reviewed by Dr Noel Merrick in 2019 was not to explicitly consider contamination of local springs or dependent ecosystem health. Updated objectives and an independent review of the updated model against the Australian Groundwater Modelling Guidelines would provide confidence in the findings. Information available to populate hydrogeological facies and leachate action (acidic dissolution, not just solute transport), would help verify the information in the application.

The water mass balance, including rainfall recharge/evapotranspiration losses remains a key uncertainty. Neither secure rights to the maximum required water supply from Groundwater Sources at the proposed site, nor alternatives to the possible Ulan Coalfields water supply, have been obtained.

Long term evapo-salinisation at the site and seasonal site releases could be better represented to enable a Determination to be made. Amendments considering the Recommendations for seepage management from the TSF appear to concern plans that would be developed should a positive Determination be received. FDP suggests that development of a robust Water Management Strategy, Risk Assessment and Monitoring Program would enable the public and regulators while facilitating investment planning for Bowdens.

References

ANCOLD. (2019). *Guidelines on tailings dams - planning, design, construction, operation and closure - Revision 1.* Hobart: The Australian National Committee on Large Dams Incorporated.

ATC Williams. (2021). *Appendix 8 - TSF liner and seepage monitoring.* Sydney: Bowdens Silver Pty Limited.

Baguley, S. (May 2022). *Independent review of the Bowdens Silver Pty Ltd surface water assessment.* Sydney: Lue Action Group.

Barnett, B., Townley, L., Post, V., Evans, R. E., Hunt, R., Peeters, L., . . . Boronkay, A. (2012). *Australian groundwater modelling guidelines.* Canberra: Australian National Water Commission.

CCC Meeting 14. (May 2022). *Bowdens Silver Project CCC - Meeting 14.* Sydney: Department of Planning and Environment.

DPE Water. (2022). *Bowdens Silver Project (SSD-5765) - second Amendment Report.* Sydney: NSW Department of Planning and Environment.

DPI. (2018). *Water resource plans fact sheet - Assessing groundwater applications.* Sydney: NSW Department of Industry.

EnRiskS. (2021). *Part 7 - Human health risk assessment - updated.* Sydney: Bowdens Silver Pty Limited.

EnviroKey. (March 2022). *Part 9a Biodiversity Assessment Report - Updated.* Sydney: R. W. Corkery & Co.

FDP. (Aug 2021). *Review of Bowden's response to multi-agency feedback regarding groundwater in Bowden's July 2021 Amendment report.* Sydney: Department of Planning and Environment - Lue Action Group.

Jacobs. (2021). *Groundwater Assessment - Updated.* Sydney: Bowdens Silver Pty Limited.

Jacobs. (March 2022). *Appendix 4 - Groundwater assessment - updated.* Sydney: R.W. Corkery & Co.

NSW Government. (2022, May 5). *State Significant Development Assessment: Bowdens Silver*. Retrieved from NSW Planning Portal: https://pp.planningportal.nsw.gov.au/major-projects/projects/bowdens-silver-temp

R. W. Corkery & Co. (2020). *EIS Volume 2 Part 5 Groundwater Assessment - Jacobs.* Sydney: R. W. Corkery & Co.

R. W. Corkery & Co. (2022d). *Appendix 4 - Part 5 - Updated groundwater assessment.* Sydney: R. W. Corkery & Co.

R. W. Corkery & Co. (March 2022b). *Water supply amendment report.* Sydney: R.W. Corkery & Co.

R.W. Corkery & Co. (2021a). *Amendment Report for the Bowdens Silver Project.* Sydney: Bowdens Silver Pty Limited.

R.W. Corkery & Co. (2021b). *Appendix 2 - Updated summary of environmental management and monitoring measures.* Sydney: Bowdens Silver Pty Limited.

R.W. Corkery & Co. (March 2022). *Amendment submissions report.* Sydney: R. W. Corkery & Co.

R.W. Corkery & Co. (March 2022c). *Appendix 1 - Amended Project Description.* Sydney: R. W. Corkery & Co. Pty. Limited.

Appendix

The 21 additional questions (from 2020) are provided in Table 4.

Table 4: Questions

#	Question (not pursued due to lack of budget)
1	Analyse cause of groundwater drawdown reported at the site in 2013-2017
2	Discuss uncertainties around the impacts to specific listed aquatic GDEs (Murray Cod, Murray Crayfish etc.)
3	Consider the available data and the validity of the assumption of unlimited recharge around creeks in the model and drawdown boundary (Corkery 4-121)
4	Review proposed monitoring of evaporation rates from pit lake/ 'groundwater sink' considering seasonal and inter-seasonal groundwater level changes (and impact to 95th percentile aquatic GDE protection)
5	Review conclusion that springs are 'rainfall fed sub-flow and therefore are not groundwater dependent' (Corkery 2020, 4-125) and consider absence of discussion regarding spring-dependent species
6	Review core logs and bore completion depths to check whether 'deep' groundwater levels are representative of local or subregional levels
7	Seek references/understanding for unqualified conclusions drawn in the EIS such as (Corkery 2020, 4-195): 'no adverse impacts upon water quality are anticipated'
8	Discuss that the proposed pit lake will increase salinity by evapo-concentration and consider whether this will alter the beneficial use of the aquifer over time
9	Consider the lack of discussion of how acid forming material will be neutralised after 100 years and whether p3, s.17 of the SEARs requests a rehabilitation plan under the Act (1997).
10	Noting that background water quality indicators are higher than in other areas, better understand the proposed trigger values for aquatic species and terrestrial fauna.
11	EnviroKey 2020 9a-153 note that vegetation is not likely to be a GDE. A risk assessment could be prepared to highlight likelihoods and consequences to understand and communicate acceptable risks.
12	Consider creek drainage during low-flow/no-flow (p. 4-256) and drainage of regional alluvium through channels.

13	Analyse the likelihood of obtaining groundwater access rights.
14	Consider the uncertainty around the ‘maximum drawdown’ values in Lawson and Hawkins Creeks and provenance of hydraulic properties applied
15	Raise questions evident from the interpreted cross sections presented
16	Check evaporation calculation range and mine water balance
17	Highlight/query missing details in the abandonment plan (including economic and rehabilitation plan), including the continued creation and migration of sulfuric acid leachate from the site via groundwater. Consider the impact of acid on grout curtains and dissolution of fracture/fault infill material (representative elementary volume permeability).
18	Review the hydraulic parameters for rock units; especially the alluvium.
19	Review the site water balance and the Jacobs quotation from Corkery 2020 (4-126) that ‘any potential water quality impacts are not expected beyond 40 m from the Mine Site boundary’ that is not found in Jacobs 2020.
20	Investigate winter evaporation rates, how this relates to the presentation of the final pit void as an unchanging groundwater sink and confirm that leakage will not travel to Lawson’s Creek.
21	Consider if any effective (groundwater) monitoring plan has been provided, including Corkery 2020 (4-196)

Table 5: Reproduced from FDP (2021) - Excerpt quotes from SEARs and recommendations for amendments

Excerpt Quotes from SEARs	Recommendation
A description of the existing environment likely to be affected by the development, using sufficient baseline data;	More baseline data is required to identify and protect significant groundwater receptors. Groundwater contamination is predicted, however, there are few controls on contamination spreading 40 m from the site boundary as prescribed under the Aquifer Interference Policy.
A description of mitigations	Mitigations for potential problems such as TSF or leachate dam leakage are not provided.
Whether these are best practice and represent a full range of measures	Best practice and full range of methods not discussed – examples from Cloudbreak, Renison Bell and Bruckunga's treatment of contaminants should be considered.
Whether they will be effective / key performance indicators	More definitive and robust key performance indicators would instil confidence in the planned management.
Contingency plans for residual risks / monitoring and reporting on environmental performance	A risk framework, including maximal and residual risk assessments should be included within the EIS; before mining starts. Defining community management values and goals needs to be done well in advance. Contingency plans to remediate impacts when the assessment is incorrect should be prepared and ready for approval.
An assessment of the likely impacts of all stages of the development, including any cumulative impacts, taking into consideration any relevant legislation, environmental planning instruments, guidelines, policies, plans and industry codes of practice;	The 2019 ANCOLD dam management guidelines, as well as groundwater management around dams should be implemented. The definition of groundwater dependent ecosystem (GDE) should be updated throughout the EIS.
A summary of commitments	More definitive and robust key performance indicators would instil confidence in the planned management.
Part 3: Any interference with an aquifer caused by the development does not exceed the respective water table, water pressure and water quality requirements specified for item 1 in columns 2, 3 and 4 of Table 1 of the *Aquifer Interference Policy 2012* for each relevant water source listed in column 1 of that Table.	Significant species, especially fauna in springs and water courses, should be surveyed and identified. More confidence that contamination will not breach the 40 m distance from the site boundary is sought.
Part 3: impacts to significant water resources or threatened species are	The impacts to five listed aquatic fauna and two listed terrestrial fauna (outside the mine footprint) should be identified and minimised

minimised to the greatest extent practicable	to the greatest extent practicable. The same applies for the potable water quality available to the people of Lue village.
Assessment of Lawsons Creek and Price Creek	The groundwater analysis should consider the relationship of groundwater, including leakage from the leachate management dam, the TSF and pit lake after 130 years, with each creek separately. The value of Lawsons Creek should be better assessed.
Assessment of likely impacts to aquifers; detailed site water balance, management of excess water and reliability	Stating that the majority of 'outflow' is stored in tailings in the *average* mine water balance should be clarified. The reliability of HDPE and clay liners for the designed operation (~500 years) should be discussed and the likely impacts to aquifers should be more accurately presented.
DRG, Attachment 2A requires rehabilitation methods including	
e) monitoring for rehabilitation	A more detailed and comprehensive monitoring plan is recommended.
i) details of triggering intervention	Quantitative details triggering intervention should be included prior to any regulatory approvals.
k) details of post-rehabilitation management	Details of post-rehabilitation management should be provided prior to any regulatory approvals later.
l)i) assessment of rehabilitation techniques against objectives	Objectives should be clearly stated and assessment indicators agreed prior to any regulatory approvals.
l) ii) assessment of potential acid mine drainage	An assessment of the impact of acid mine drainage seeping from the TSF and pit lake (once full) should be included. The influence of faults should be considered.
l) iii) processes to identify and management geochemical risks throughout mine life	Any proposed treatment should be mentioned and the processes to identify (and remediate) geochemical risks should be included.
m) iii) groundwater assessment for final water level in any tailing storage facility void	The final water level is predicted to stabilise 130 years after mining. Site groundwater contour maps, including maps around the TSF and pit lake, should be included for assessment.
o) consideration of controls	The monitoring network should be improved and detailed. Triggers for action should be agreed with the community now and approved.
DRE/DPE requires a Water Management Strategy that considers:	

the existing surface and groundwater qualities	The existing groundwater quality should be accurately reported around the Lue Village.
a robust baseline	The baseline of ecological receptors and native groundwater flow paths should be made robust.
a description of how groundwater and aquatic ecosystems will be monitored, Trigger Action Response Plan and trend identification	The locations of significant ecosystems should be identified to enable maximal and residual risk assessments and development of a monitoring plan along with triggers and planned remediations that will be effective.