

**Before an Expert Panel  
Bendigo-Ophir Gold Project**

**FTAA-2507-1089**

**Under the**

Fast Track Approvals Act 2024

**In the matter of**

an application for approvals to establish, operate, and remediate an open pit and underground gold mine at Bendigo and Ardour Stations

**By**

**Matakanui Gold Limited**

Applicant

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**STATEMENT OF EVIDENCE OF DR LEANNE MORGAN  
GROUNDWATER HYDROLOGY**

**10 April 2026**

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## Table of Contents

<i>Introduction</i> .....	4
<i>Qualifications and experience</i> .....	4
<i>Code of conduct</i> .....	5
<i>Material considered and site visit</i> .....	5
<i>Bendigo-Ophir Gold Project (BOGP)</i> .....	6
<i>Scope of evidence</i> .....	7
<i>Limited data collection relating to groundwater hydrology</i> .....	7
Summary .....	7
Assessment.....	8
<i>Groundwater modelling of flow to the mining pits, drawdown and stream depletion is based on limited data</i> .....	12
Summary .....	12
Assessment.....	13
<i>Uncertain estimates of underground tunnel dewatering</i> .....	20
Summary .....	20
Assessment.....	21
<i>Loss of wetlands from water table drawdown</i> .....	21
Summary .....	21
Assessment.....	22
<i>Hydrodynamic containment and seepage risk</i> .....	25
Summary .....	25
Assessment.....	26
<i>Solute transport into the Ardgour Aquifer</i> .....	33
Summary .....	33
Assessment.....	33
<i>Bore water take assessment</i> .....	36
Summary .....	36
Assessment.....	36
<i>Consent conditions, water management planning and adaptive management</i> .....	38
Summary .....	38
Assessment.....	39
<i>List of outstanding questions</i> .....	41

*Conclusion* ..... 43  
*References* ..... 46

## **Introduction**

1. My name is Dr Leanne Kaye Morgan.
2. I have been asked by the Environmental Defence Society (EDS) to independently review groundwater hydrology matters related to the Bendigo-Ophir Gold Project (BOGP).

## **Qualifications and experience**

3. I am an Associate Professor in Groundwater Hydrology at the University of Canterbury, Christchurch, where I have worked since 2016. Prior to that, I worked at Flinders University as a Postdoctoral Fellow and the South Australia government as a groundwater modeller. I have also been contracted to deliver and peer review conceptual and mathematical groundwater models by the South Australia government, Western Australia government, Geosciences Australia, Greater Wellington Regional Council, Wellington Water, Stantec, Otago Regional Council, Earth Sciences NZ and the Climate Change Commission.
4. My research involves characterising groundwater systems using various methods and parameters including pressure, conductivity, natural tracers and geophysics. I test processes and perform sensitivity analyses using analytical and numerical modelling.
5. My qualifications and experience include:
  - a. A PhD in groundwater hydrology from Flinders University, South Australia in 2015.
  - b. Publishing more than 45 articles in international peer reviewed journals on the topic of groundwater hydrology.
  - c. Supervising to completion more than 25 PhD and Masters research thesis students on groundwater hydrology projects.
  - d. Serving as Associate Editor (2019-2025) of the Hydrogeology Journal, the flagship journal of the International Association of Hydrogeologists.
  - e. Serving on the Marsden Earth Sciences and Astronomy panel in 2022-2025.
  - f. Coordinating and teaching groundwater hydrology related courses at the University of Canterbury including ENGE414/WATR414 Applied Hydrogeology (to postgraduate Masters students) and GEOL345 Groundwater and Geothermal Systems (to 3rd year undergraduate students).

- g. Being the Principal/Associate Investigator on projects with grants totalling over \$30 M, since 2020.
- h. Being the keynote speaker at both the New Zealand Hydrological Society and New Zealand Coastal Society conferences in 2024 on the topic of climate change impacts to groundwater.

### **Code of conduct**

6. I have read the code of conduct for expert witnesses contained in the Environment Court's Practice Note 2023 (the Code). I have complied with the Code when preparing this written statement of evidence. The data, information, facts, and assumptions I have considered in forming my opinions are set out in my evidence. Unless I state otherwise, this evidence is within my sphere of expertise, and I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

### **Material considered and site visit**

7. In preparing this evidence the principal documents I have reviewed are:
  - A.10 Section 3 Project Description
  - A.13 Section 6 Assessment of Environmental Effects
  - B.02 Kōmanawa Solutions Limited - Bendigo Groundwater Bore Take Effects Assessment (Kōmanawa 2025a)
  - B.03 Kōmanawa Solutions Limited - Groundwater Existing Environment and Effects Assessment (Kōmanawa 2025b)
  - B.04 Kōmanawa Solutions Limited - Surface Water and Catchment Existing Environment and Effects Assessment (Kōmanawa 2025c)
  - B.05 Kōmanawa Solutions Limited - Groundwater Modelling Analysis for Mining Bendigo-Ophir Gold Deposit (Kōmanawa 2025d)
  - B.06C Mine Waste Management Limited Mine Impacted Water Overview Report - Appendix N
  - B.12 RMA Ecology Ltd. (2025) Bendigo-Ophir Gold Project: Wetland Values Assessment. Report prepared for Matakanui Gold Ltd
  - B.22 Engineering Geology Limited Site Geotechnical Factual Report Part 1
  - B.42 Hydro Geochem Group - BOGP Wetland Drawdown Assessment (HGG 2025a)
  - D.02 Otago Regional Council Consents and Conditions
  - D.04 Schedule Two - General Conditions for Otago Regional Council Resource

- G.01 Water Management Plan
- K.01 Kōmanawa Solutions Limited - Post Closure Impacts on the Ardour Aquifer dated February 2025 (10 March 2026)
- K.05 Hydro Geochem Group - BOGP MWSF Seepage Risk Assessment (10 March 2026)

8. These documents are referred to below using the report number in bold.
9. I attended a site visit hosted by Santana Minerals Ltd in March 2026 and am familiar with the BOGP site.
10. In preparing this evidence, I am aware that the Panel has issued a number of requests for further information from the applicant dated 1 April 2026, some of which are relevant to my area of expertise. My evidence has been prepared in advance of the applicant's responses being provided to the Panel and parties, including EDS.
11. As a result, I wish to reserve my ability to update my evidence in light of the additional information provided, where material and relevant to my expertise. In addition, I understand that proposed consent conditions may evolve during the fast-track process, and I request an opportunity to comment on material changes to these, again where relevant to my area of technical expertise.
12. In this evidence, I have provided a high level review of consent conditions pending a more comprehensive analysis once I have reviewed the applicant's responses to the requests for further information, participated in expert caucusing which I understand the Panel has indicated will occur, and once the uncertainties identified in my evidence are addressed. All of these things will impact the appropriateness of the consent conditions framework.

### **Bendigo-Ophir Gold Project (BOGP)**

13. Matakanui Gold Ltd propose a gold mining operation that will include four open cast mines: Rise and Shine (RAS), Come in Time (CIT), SREX and SRE. The largest pit is RAS which is around 1 km by 800 m and a depth of ~ 200 m. This will be continued as an underground mine extending to a depth of ~ 300 m and length of 12 km (**A.10, B.03**).
14. There will be a tailings storage facility (TSF) in the head of Shepherds Creek, three engineered landforms (ELFs) to store overburden waste rock, temporary waste rock stacks, an ore processing plant in lower Shepherds Creek, and

administration/operational buildings on Ardgour Terrace further down the catchment.

15. Water will be supplied from a bore in the Bendigo Aquifer and conveyed to the processing plant via a pipeline over a distance of approximately 6.5 km.
16. The BOGP is predicted to be an active mining operation for 14 years, and continue after that for the next 20 years in 'active' closure. Thereafter, it will be in 'post' closure and minimal site maintenance is anticipated.
17. In the post closure phase, it is anticipated that the RAS and SREX pits will become pit lakes (the other two open cast mines being back-filled as operations progress). The underground tunnels will be filled with tailings paste. A passive treatment system will treat seepage and run-off from the site.

### **Scope of evidence**

18. The scope of this evidence is the effects on groundwater hydrology of the BOGP. Principal issues addressed in this evidence are:
  - a. Limited data collection related to groundwater hydrology
  - b. Groundwater modelling of flow to the mining pits, drawdown and stream depletion is based on limited data
  - c. Uncertain estimates of underground tunnel dewatering
  - d. Loss of wetlands from water table drawdown
  - e. Hydrodynamic containment and seepage risk
  - f. Solute transport into the Ardgour Aquifer
  - g. Bore water take assessment
  - h. Consent conditions, water management planning and adaptive management

### **Limited data collection relating to groundwater hydrology**

#### *Summary*

19. Understanding and managing impacts from mining on groundwater, connected surface water systems, and groundwater users requires development of defensible science supported by adequate field data. Unfortunately, there has been limited data collection relating to groundwater hydrology at the BOGP site, and data that has been collected has not been combined to form a robust conceptual model of groundwater flows in the vicinity of the pits and mine waste storage facilities

(MWSF). Information relating to surface water / groundwater connection, and transport of seepage is particularly lacking. This leads to high levels of uncertainty in conceptualisation of groundwater flows, surface water / groundwater interaction and solute transport at the site. It also leads to uncertainty in planning for monitoring and mitigation of effects.

### *Assessment*

20. Hydrogeological conceptualisation is the process of creating a simplified representation of the groundwater system incorporating geology, hydraulic properties, water levels and the water balance (recharge to the system and discharge to receiving environments). It is the foundational step for any further work to address groundwater management questions, such as those in mining operations. Overall, the hydrogeological conceptualisation of the BOGP site, as detailed in **B.03**, is limited, with critical gaps in data that lead to overall uncertainty in the assessment of groundwater effects.
21. The geology at the site is well described in **B.03**, the Otago Schist is the main hydrogeological unit intercepted by the BOGP mine features. The shallow heavily weathered schist, along with alluvium and colluvium (unconsolidated materials that are deepest in the valley floors) are referred to as a 'vener aquifer'. Below this is the unweathered schist fractured rock. This is further subdivided into three zones which, in order of increasing depth below ground, are the TZ3, RSSZ (which contains the gold) and the TZ4.
22. To carry out quantitative assessments of groundwater flow and impacts from mining it is important to have estimates of three key properties of subsurface materials:
  - a. Hydraulic conductivity (also commonly referred to as permeability), which is a measure of the material's ability to transmit water and is important for estimating groundwater flow volumes;
  - b. Storativity, which is a measure of the material's ability to store and release water and is needed to estimate how groundwater levels will change with time in response to pumping or dewatering; and
  - c. Porosity, which is the volume of water held within the pores and is required to estimate the speed of groundwater flow and solute transport.
23. Only hydraulic conductivity was estimated as part of the hydrogeological investigations for the BOGP, but it does not account for fractured flow (as detailed below). The failure to measure storativity and porosity (often collectively referred

to as 'storage') means predictions of water table changes over time cannot be made and predictions of the speed of groundwater movement (important for assessing contaminant transport) can also not be made.

24. Hydraulic conductivity was measured at two locations in the RAS pit using packer tests, at depths between ~ 60 and 266 m below ground. Hydraulic conductivity values ranged between ~  $10^{-10}$  and  $10^{-7}$  m/s (**B.03**, Table 3). It is noted in **B.03** that these values likely underestimate hydraulic conductivity because the packer method is most suited to testing unfractured rock. While the schist rock at the BOGP is described in **B.03**, p. 1 as having "generally poor groundwater transmission properties" it can nevertheless transmit water, particularly at locations of fracture networks. However, the density of fracture networks and possible anisotropy from fractures (propensity for water to flow in a certain direction) was not assessed.
25. There are no measurements of hydraulic parameters in the shallower more weathered portion of the schist rock nor in the alluvial/colluvial unconsolidated materials (the 'veneer aquifer') reported in **B.03**.
26. No investigations have been completed in the Ardgour Aquifer, a key receiving environment.
27. Testing has been carried out within the Bendigo Aquifer (to estimate hydraulic conductivity and storativity) for the purpose of gaining a groundwater take consent.
28. Groundwater levels were measured on 4 occasions (20 Jan 2023, 1 August 2023, 28 November 2023, and 20 Jan 2024) using gold exploration holes within the proposed pit areas. This data is not provided in the application and there is no assessment of seasonality in groundwater levels. This is a gap. Potentiometric contours showing directions of groundwater flow and hydrographs showing groundwater level fluctuations near the pits and in receiving environments need to be compiled and presented to enable understanding of groundwater flows, surface water / groundwater connection and solute transport.
29. However, the data from 20 Jan 2023 was used to derive an inferred water table elevation which indicates that groundwater levels and flow tend to follow the topography i.e., from topographic highs to lows (e.g., toward local creeks), as shown in Figure 1.

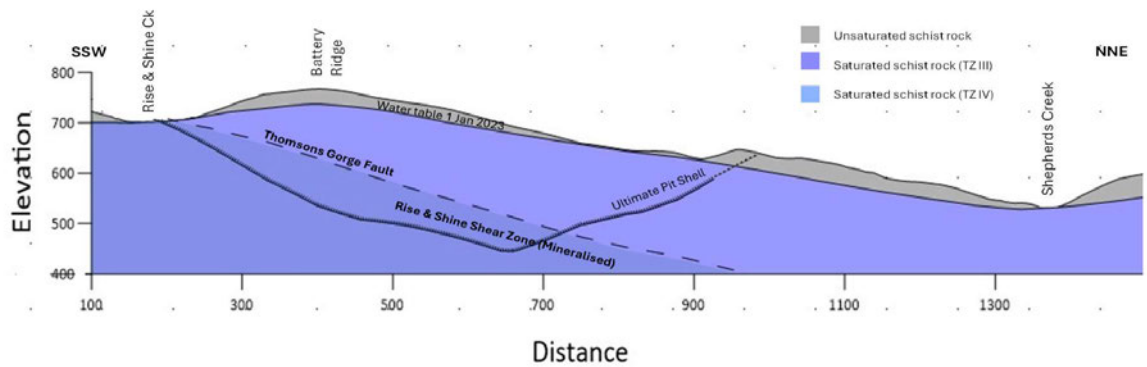


Figure 1. Profile looking down-valley, including water table, schist zones and RAS pit floor/wall outline (B.03, figure 10).

30. There is evidence of artesian flow in some deep bore holes, indicating possibly confined conditions at depth.
31. Time series groundwater pressure / level monitoring was carried out at two locations in the RAS pit at a series of depths within the fractured rock. Vertical gradients (and groundwater flow direction) were mixed, with some upwards and some downward. However, there was an overall upward hydraulic gradient (indicating upward flow).
32. In relation to surface hydrology, the BOGP activities occur across the Shepherds Creek and Rise and Shine Creek catchments. Rise and Shine Creek is a tributary of Clearwater Creek, which in turn coalesces with Bendigo Creek (Figure 2). Shepherds Creek flows to the Ardgour Aquifer (also referred to as the Lindis Alluvial Aquifers). Bendigo Creek flows to the Bendigo Aquifer. In both cases the creeks are connected to the aquifers through a drying front connection, where the creeks run dry in their lower reaches, and water is transmitted through alluvium under the creek bed (Figure 3).

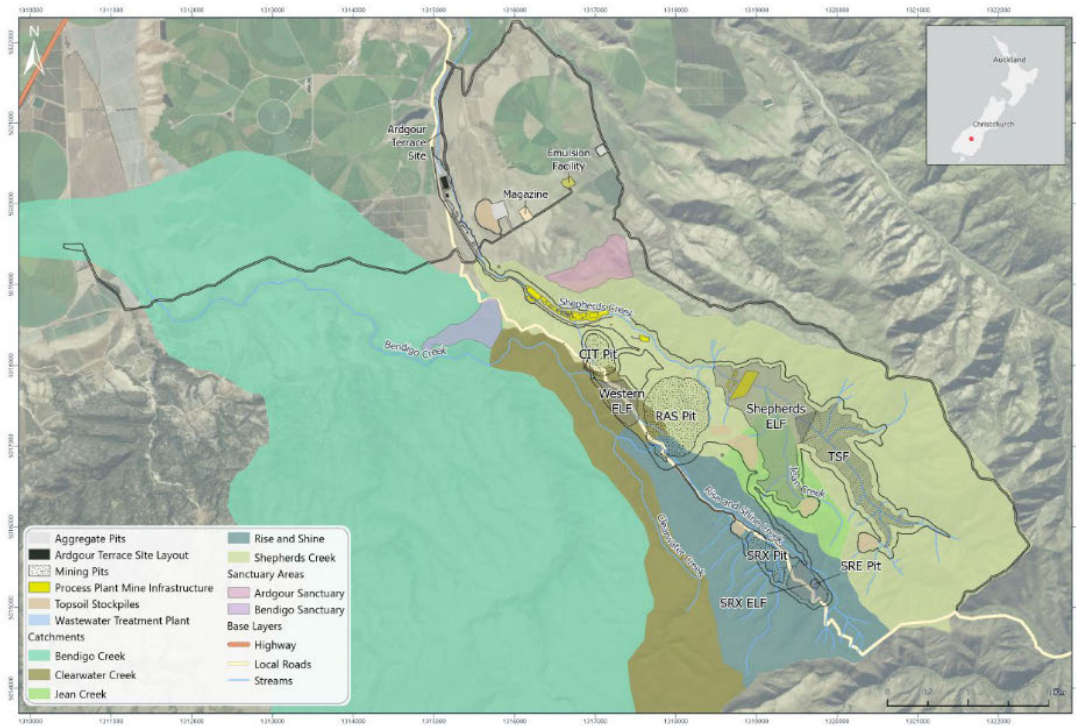


Figure 2. BOGP surface hydrology and planned infrastructure (B.40, figure 2).

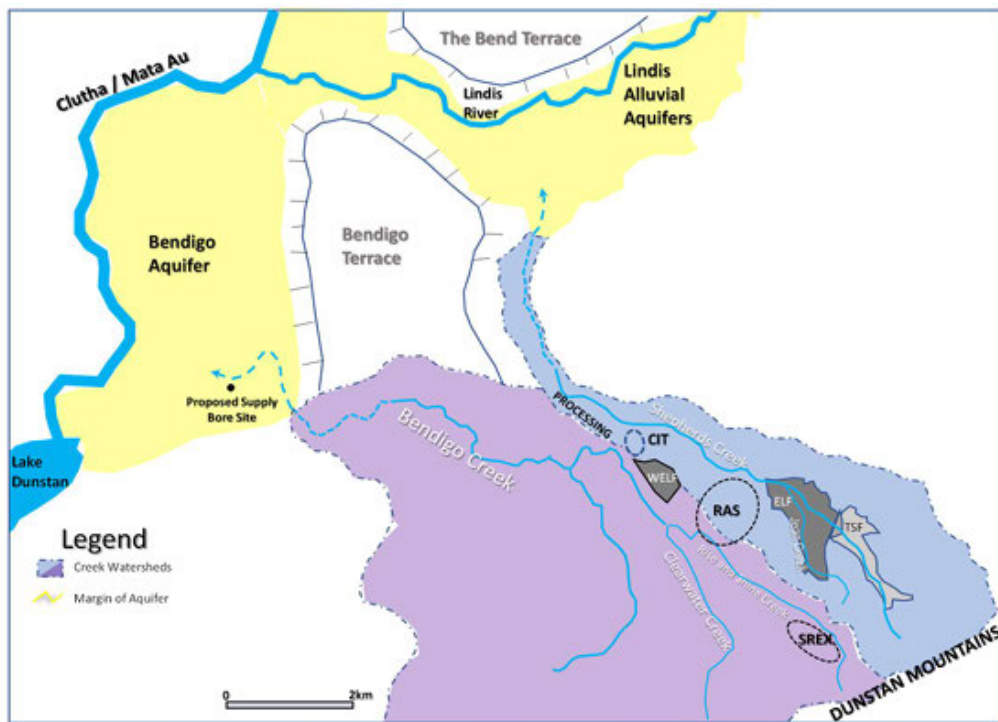


Figure 3. Creek catchments and their termination with aquifer, including proposed gold pit locations (B.04, figure 24).

33. A regression correlation was undertaken to generate a 75-year synthetic daily rainfall record for the BOGP rainfall at Lake Clearwater. Rain totals across the BOGP site ranged from 451 to 507 millimetres per year.

34. Flow in Shepherds Creek and Rise and Shine Creek were monitored over 2 years (2022 – 2024) with mean flows of 15.6 L/s and 8.8 L/s measured, respectively (**B.04**). There is a strong seasonal pattern, with higher flows in the wetter winter months and lower flows in the drier summer months. However, the assessment is limited by the short measurement period, and it is acknowledged that more than 10 years of data is needed for a good record (**B.04**, p. 28).
35. The measured flow was extended using regression correlation with the flow records of nearby Cluden Stream, but there are large differences between the measured and modelled values which are not explained e.g., modelled 7-day mean annual low flow is double the measured.
36. There has been no assessment of flood frequency for Shepherds Creek or Rise and Shine Creek, and **B.04** notes that the two-year recording period limited measurement of high flows. The modelled 12-year maximum (356 L/s) is more than double the measured maximum (141 L/s), confirming the monitoring period did not capture flood events.
37. Groundwater levels in the vicinity of Shepherds Creek and Rise and Shine Creek and near wetlands are not reported in **B.04**, which limits conceptual understanding of surface water / groundwater interactions and wetland hydrology.

#### **Groundwater modelling of flow to the mining pits, drawdown and stream depletion is based on limited data**

##### *Summary*

38. A numerical groundwater model was developed to assess flow to mining pits, drawdown from pit dewatering and stream depletion. Overall, while the model uses a relatively sophisticated stochastic optimisation approach, it is based on limited data (as set out above).
39. Limited data means that the modelling is not based on a robust conceptual framework, especially for surface water / groundwater interactions.
40. Additionally, limited data has meant the model is unable to replicate measured groundwater levels very well which increases uncertainty of the model predictions.
41. Steady-state modelling was used which means that changes in groundwater levels and stream depletion over time could not be assessed. Also, the model does not

assess groundwater levels post-closure. Therefore, potential for permanent stream depletion and wetland loss has not been assessed.

42. Most of these and other limitations (noted below) are acknowledged in **B.05** and suitable statements around uncertainty have been provided. Nevertheless, using the Australian Groundwater Modelling Guidelines the model is classified as a Class 1 low confidence model.

43. As discussed below, it is likely that the model underestimates flow to the pits, drawdown and stream depletion.

44. The modelling predicts significant impacts to wetlands.

#### Assessment

45. When open-pit and underground tunnel mines extend below the position of the natural water table, they require dewatering to create a dry mining environment. This is achieved by creating a cone of depression in groundwater levels centred at the pit. A cone of depression lowers the regional water table in a cone shape centred on the location of the pumping (as shown in Figure 4). The difference in groundwater levels before and after dewatering is called drawdown. It is common for the water table to be drawn down by 10's of metres at distances of several kilometres from an open pit mine, as shown in Figure 5 for the Hope Downs mine in the Pilbara region of Western Australia (Cook et al. 2017). In the case of the RAS pit, it has a depth of around 200 m and therefore drawdown at the pit will be of that order.

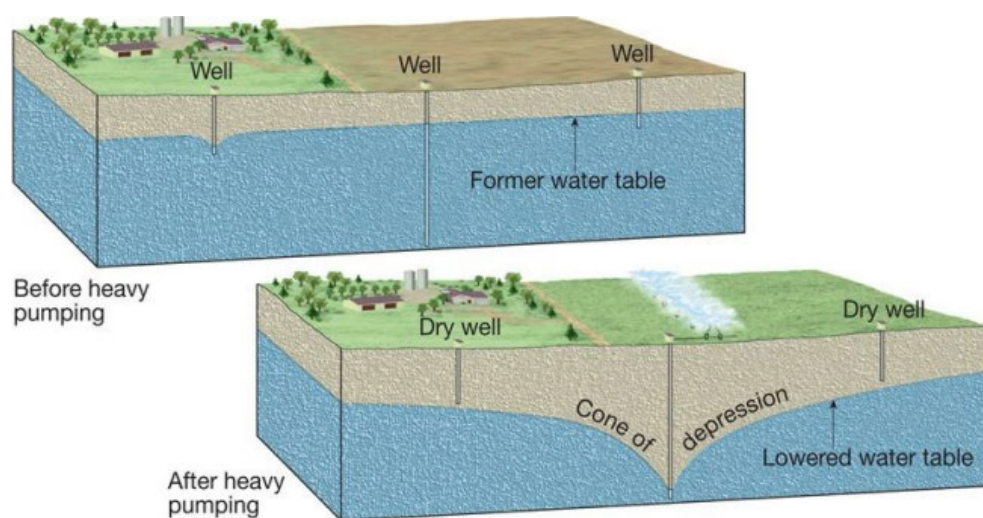


Figure 4. Schematic showing a cone of depression from groundwater pumping (<https://chem.libretexts.org/>)

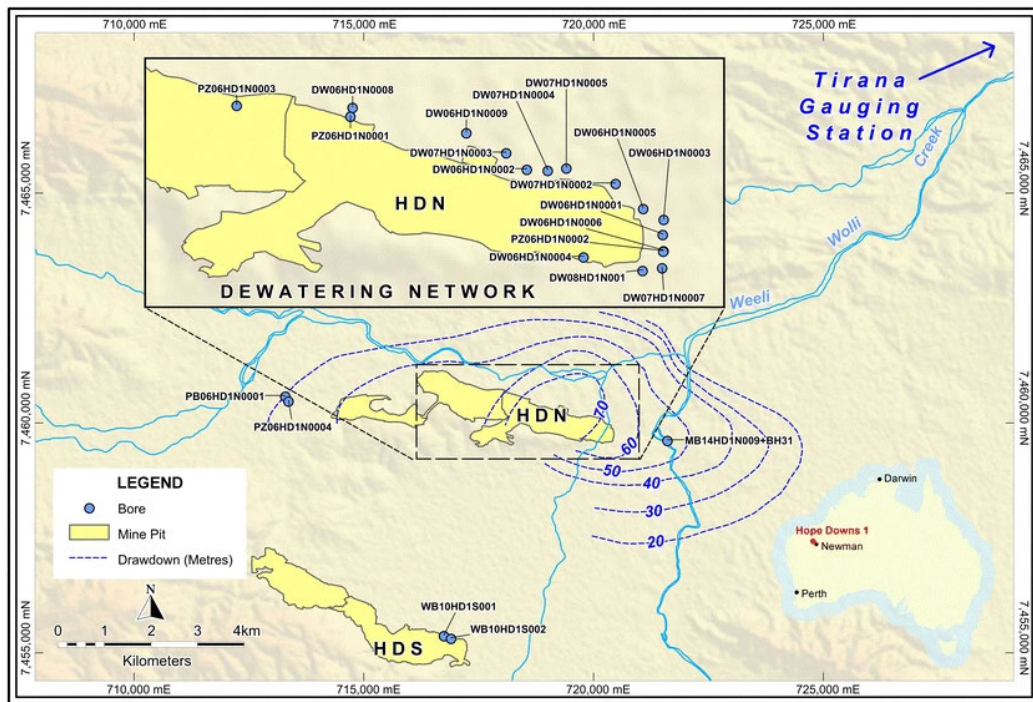


Figure 5. A cone of depression from dewatering of the Hope Downs mine in Western Australia. Dashed lines indicate difference in the water levels (drawdown) from pit dewatering. Dewatering sites are shown as blue dots (Cook et al. 2017).

46. Lowering of the water table is accompanied by depletion of hydrologically connected streams or creeks and wetlands. Figure 6 illustrates this process, known as stream depletion. As pumping increases, streams are increasingly depleted of water and can change from a gaining stream (i.e., gaining groundwater from the aquifer) to a losing stream (i.e., losing water to the aquifer/pumping). For the Hope Downs mine, Cook et al. (2017) found that during 7 years of pit dewatering, groundwater flows near the Weeli Wolli Creek (shown in Figure 5) changed direction, and water from the creek was an increasingly large proportion of the pumped groundwater.

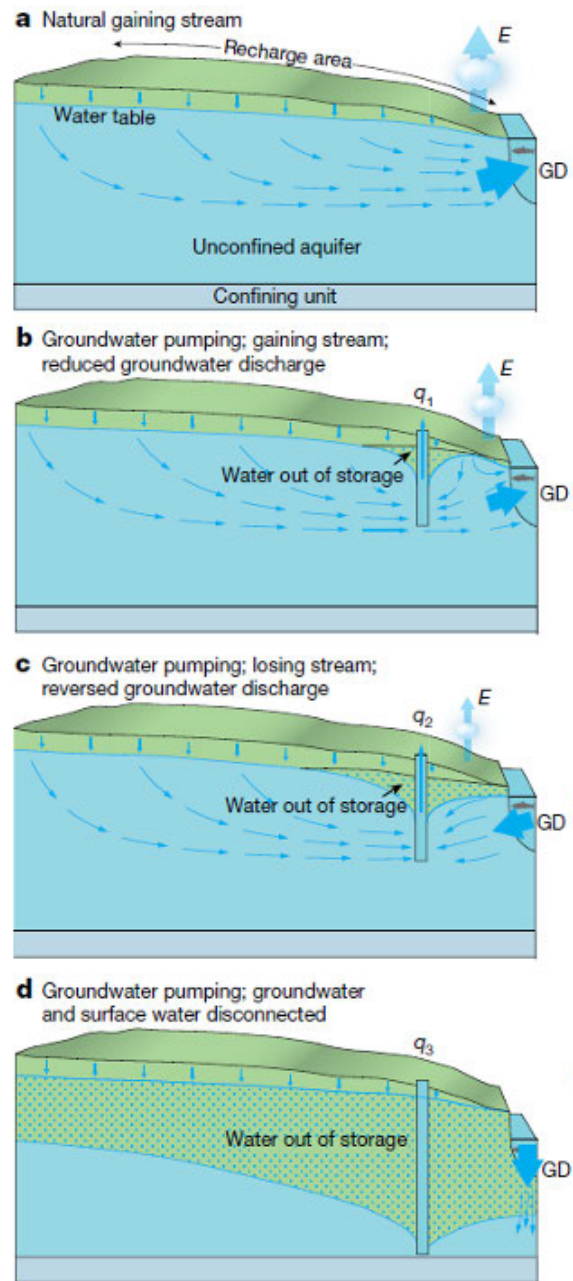


Figure 6. The process of stream depletion: (a) shows a stream that is gaining groundwater under natural conditions; (b) with limited pumping some of the water that would have flowed to the stream is captured by the pumping; (c) with a greater rate of pumping the stream changes from gaining to losing water; (d) with more intense pumping rates there is a disconnection of the groundwater and surface water systems. Surface water infiltration reaches a maximum, independent of groundwater depth (de Graaf et al, 2019). Note that the stream is in the upper right of each subfigure; GD refers to groundwater discharge (flow); E refers to evapotranspiration;  $q_1$ ,  $q_2$ ,  $q_3$  refers to increasingly larger rates of groundwater pumping.

47. As part of the BOGP application, groundwater modelling (detailed in **B.05**) was carried out to assess groundwater flow to the pits (that will require dewatering), drawdown and stream depletion.
48. Overall, while the groundwater modelling is reasonably sophisticated in terms of using a stochastic optimisation approach, the data and conceptualisation underpinning the model is limited, especially for surface water / groundwater interactions, which increases the uncertainty of predictions made using the model.
49. Key issues with the model are set out below.
50. **There is a lack of a conceptual model:** The conceptual description of the system is minimal, especially of surface water / groundwater interactions. It is usual to present a conceptual model diagram describing key features of the hydrogeological system being simulated, but this is not provided, which is a gap.
51. **The groundwater model domain size needs justification and may be too small:** Individual models were developed for the RAS, CIT and SREX pits. The RAS pit has dimensions of ~1 km by 800 m and a depth of ~ 200 m and the model used to represent it has a domain extending 3 km by 2 km (**B.05**, Figure 7.2).
52. In contrast, for the Hope Downs open cast mine, the pit has dimensions of ~ 1 km by 2 km and a depth of ~ 90 m deep and the model domain size was 100 km in both x and y directions (Cook et al. 2017; Bozan et al., 2022). A large model domain size was used for the Hope Downs mine to ensure that model boundaries are sufficiently far from the open-pit area to not impact groundwater levels at the pit during dewatering simulations. The choice of a relatively small model domain size for the RAS pit model (and the CIT and SREX models) has not been sufficiently justified, and boundaries (no flow and constant head) may be impacting simulated groundwater levels at the pit.
53. An assessment of boundary condition effects on model outputs should be carried out. Modelled drawdowns extend to the boundaries in both the CIT and SREX models (**B.05**, Figures 8.12 and 9.12), which indicates that the model domain is not large enough.
54. The RAS pit model domain should likely also include the Clearwater Creek catchment (it currently does not) as subsurface flows originating from Clearwater Creek are likely to flow into the RAS pit. This is because the permeability structure in the vicinity of Clearwater Creek and the RAS pit is dipping west to east (**B.05** Figure 7.3 transect B-B') and this will likely cause the water flowing in Clearwater

Creek to move through the subsurface toward the pit. Clearwater Creek is less than 1 km from the RAS pit at the closest point.

55. **Cumulative impacts are not assessed:** It is important to note that drawdown from dewatering at individual pits will be cumulative and therefore should not be considered in isolation. However, it was assumed in the modelling that: “It is unlikely that the impacts of the mining activities in any given model area will impact the other model areas, so the models can be considered in isolation” (**B.05**, p. 3). This assumption needs further testing for the CIT and RAS pits, which are in proximity. The drawdown assessment in report **B.42** (detailed below under discussion on loss of wetlands from water table drawdown) indicates overlap of drawdown from the CIT and RAS pits.
56. The model should also include the underground mining tunnels as drawdown and stream depletion from the tunnels will likely overlap with the RAS and CIT pits.
57. **Boundary conditions need justification:** The domain of the RAS pit model (**B.05**, Figure 7.4) uses a no-flow boundary in the south-east and north-west portions. This means that no lateral groundwater flow from upgradient or downgradient of the RAS pit can enter the model domain. This may be unrealistic conceptually if the cone of depression extends beyond these no flow boundaries because then water will be flowing through them. A no-flow boundary too close to the pit will incorrectly minimise the amount of water flowing to the pit.
58. A constant head boundary condition has been used to represent the portions of Shepherds Creek and Rise and Shine Creek included within the RAS model domain (**B.05**, Figure 7.4). The fluxes to / from the constant head boundary cells in the model are sensitive to the connection with the aquifer. This constant head boundary has been placed directly on the low hydraulic conductivity fractured rock (the TZ3 layer) which does not consider the potential for a more weathered upper portion or veneer aquifer. This likely effectively blocks interactions between the creek and the underlying aquifer. This would explain the comment in **B.05**, p. 27: “We note that the model predicts almost no impacts to the constant head boundary representing the creek within the model domain.” From this, I consider the streams may not be simulated adequately within the model and stream depletion is likely underestimated for the RAS model.
59. It is also hard to understand how the recharge to, and discharge from, the shallow unit of the model is being handled by the drain package. A conceptual diagram would have helped. Parameters used in the drain package will be unconstrained due to a lack of data.

60. **Implications of assuming homogeneity and isotropy:** Strata within the deeper fractured rock aquifer was included and represented in the model using three zones which, from land surface downward, are the TZ3, RSSZ and TZ4. The RSSZ zone is the higher hydraulic conductivity fractured zone containing the gold deposit. Despite the complexity of the fractured rock aquifer, it is assumed in **B.05** p. 6: “that the hydraulic conductivity of each zone is homogeneous (the same across the entire zone), and isotropic (the same in all directions). These assumptions are a simplification of the true geological environment as conductivity in the hard rock aquifer is driven by fracture density and connectivity; however, in the absence of compelling evidence to the contrary, it is better to assume homogeneity and isotropy than to *a. priori*. assume a more complex structure.”
61. A better approach would have been to start out with homogeneity and isotropy but provide parameter flexibility within the calibration<sup>1</sup> so the model can accommodate heterogeneity and anisotropy if needed to match observations. It is common in fractured rock environments that flow is anisotropic (Anderson et al., 2015) and as the permeability structure at the BOGP site dips west to east this further suggests anisotropy. It is likely that that the hydraulic conductivity in the calibrated model reflect the simplified conceptualisation rather than the more complex reality (of fractured rock flow) that produces the observations (Doherty and Christenson, 2011).
62. The result of this simplification is that preferential groundwater flow paths and directions will not be incorporated into the calibrated model. This is acknowledged in **B.05**, p.30: “Should there be a highly fractured connection between the pit and Shepherds Creek, the model will not capture this and will significantly underestimate the impacts of the pit on the creek. We note that there is no evidence of such a connection; however should pit dewatering yield significantly higher than predicted volumes we would recommend further investigation.”
63. **There are limitations of a steady state model:** Most mine developments undertake numerical groundwater modelling of the magnitude and rate of water table drawdown and the time for water table recovery following mine closure (Bozan et al. 2022). However, the model detailed in **B.05** is steady state. This means that groundwater levels and flows are being simulated as constant in time. Another way to see this is that the model is representing long term average conditions

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<sup>1</sup> Groundwater model calibration is the process of adjusting hydrogeologic parameters in the model (such as hydraulic conductivity) within reasonable ranges until the simulated outputs (such as groundwater levels) closely match the measured data from the field.

where there is an equilibrium between recharge and discharge and no change in groundwater levels.

64. Scenarios with changing pit depth were set up as a series of steady state models. It is assumed changes to the water table are instantaneous. This approach precludes assessment of how groundwater drawdown or recovery (once dewatering has ceased) will develop over time and how long term stream and wetland depletion will continue post mining.
65. Use of a steady state model also means that the storage component of pit water inflow is not simulated, which means that flows to the pit will be underestimated.
66. **Limited data has been used to calibrate the model:** When calibrating a steady state model you need to have a well constrained estimate of either the recharge or hydraulic conductivity parameters. If not, then you face a non-unique solution whereby you can get the same results (i.e., groundwater levels) with different values of recharge and hydraulic conductivity – because they trade off against each other (Anderson et al. 2015, p. 79; Haitjema 2006; Knowling and Werner, 2016).
67. For the BOGP’s modelling, the recharge is not well constrained and there is limited hydraulic conductivity data. The lack of constraint on both the recharge and hydraulic conductivity impacts the capacity to calibrate the model. One way to overcome this issue is to include flux estimates such as base flow in creeks within the calibration (Knowling and Werner, 2016; Anderson et al. 2015). However, flux estimates were not used in the modelling.
68. The calibrated model has not been able to replicate the measured groundwater levels very well. Comparison between the modelled and measured groundwater levels indicate modelled groundwater levels are up to 30 m too high and 20 m too low in the RAS pit (**B.05**, Figure 7.7); up to 20 m too high and 20 m too low in the CIT pit (**B.05**, Figure 8.8); and up to 15 m too high and 15 m too low in the SREX pit (**B.05**, Figure 9.8). For all pit models the groundwater levels are overestimated in the discharge areas and underestimated in the recharge areas. The accuracy of the predictions (flows into the pit and stream depletion) will be impacted by these discrepancies between the modelled and measured groundwater levels.
69. **Drawdown prediction uncertainty is not reported:** Predicted uncertainty of groundwater drawdown is not presented which limits the ability to assess the impact of dewatering on regional water levels. The importance of this is further detailed below under the section on hydrodynamic containment and seepage risk.

70. **Confidence classification is too low:** The Australian Groundwater Modelling Guidelines (Barnett et al., 2012) contains standards for groundwater model confidence-level classifications and includes indicators to assess the classification of a particular model. Using these indicators, the groundwater model reported in **B.05** is within the Class 1 low confidence level. A Class 1 model has relatively low confidence associated with any predictions and is best suited for managing low value resources and for assessing impacts of low-risk developments or when the modelling objectives are relatively modest (Barnett et al. 2012).

71. Relevant Class 1 indicators include:

- Few or poorly distributed existing wells from which to obtain reliable groundwater and geological information.
- Little or no useful data on land-use, soils or river flows and stage elevations.
- No calibration is possible.
- Calibration is based on an inadequate distribution of data.
- The model has not been reviewed.

72. It is standard practice for groundwater models to be peer reviewed, and I recommend that this occur in consultation with the modelling team for future modelling activities as part of the BOGP.

73. It is important to note that most of the model limitations are appropriately and extensively detailed in **B.05**.

74. Overall, considering the model limitations noted above and in **B.05**, it is likely the model underestimates groundwater flow to the pits, drawdown and stream depletion.

75. Despite this, **B.05** found that dewatering of the SREX pit “is likely to have a significant impact on the adjacent wetland”. This is detailed below in the section on loss of wetlands from water table drawdown.

### **Uncertain estimates of underground tunnel dewatering**

#### *Summary*

76. Underground tunnel dewatering requirements were estimated using an analytic equation. Values obtained with this approach are very uncertain. This uncertainty has not been communicated sufficiently in the application.

## *Assessment*

77. The amount of water flowing into the underground mining tunnels ('tunnel water make') that needs dewatering was assessed in **B.03** p. 70 using an analytic model from Goodman et al. (1964). A maximum tunnel water make of 30 L/s (at full tunnel development of 12 km) was calculated.
78. Unfortunately, the parameter values used in the calculation of tunnel water make are not provided. By my calculations, a hydraulic conductivity of  $10^{-8}$  m/d, tunnel radius of 5 m and saturated thickness of 200 m gives a maximum tunnel make of 34 L/s and so I assume parameter values similar to these were used.
79. By the Goodman et al. (1964) equation, tunnel water make is directly proportional to hydraulic conductivity. For the RSSZ/TZ4 units (where the tunnelling will occur) hydraulic conductivity measurements ranged from  $10^{-8}$  –  $10^{-7}$  m/s (**B.03**, p. 32). Therefore, the maximum tunnel make could easily range between 34 L/s and 340 L/s, and this is considering only hydraulic conductivity measured ranges, let alone other possible uncertainties in parameter values. The only comment around uncertainty for tunnel water make is: "The fact of concurrent depressurisation by the overlying pit and adjoining tunnels is a significant source of uncertainty and likely over-estimation of tunnel water make using the Goodman Equation" (**B.03**, p. 72).
80. The maximum tunnel make assessment is very uncertain (orders of magnitude difference are feasible) but this has not been acknowledged. This means that it is possible that considerably more water will need to be pumped from the tunnels to maintain dry conditions and that there could be impacts to groundwater levels. Currently, the impact of tunnel dewatering on water table drawdown and stream depletion has not been assessed as part of the modelling in **B.05**. This is a gap.

## **Loss of wetlands from water table drawdown**

### *Summary*

81. There will likely be a significant impact to wetlands from water table drawdown, and especially wetlands in the Rise and Shine Creek area which have been classed as being of highest value at the BOGP site. Mitigation measures are noted as being augmentation of the Rise and Shine Creek using groundwater from the Bendigo Aquifer. However, there has been no assessment of hydrogeology in the vicinity of the wetlands and there are many questions about the efficacy of this mitigation. There are no mitigation measures planned for the hillslope seepage or gully fen

wetlands. It cannot be ruled out that the impacts to wetlands will be irreversible and result in their permanent loss. I consider that to be the likely outcome.

### Assessment

82. Wetlands at the BOGP site were classified in **B.12** as hillslope seepages, fens in narrow gullies, and swamps and marshes in flat wide valleys. The extent of mapped wetlands is shown in Figure 7.

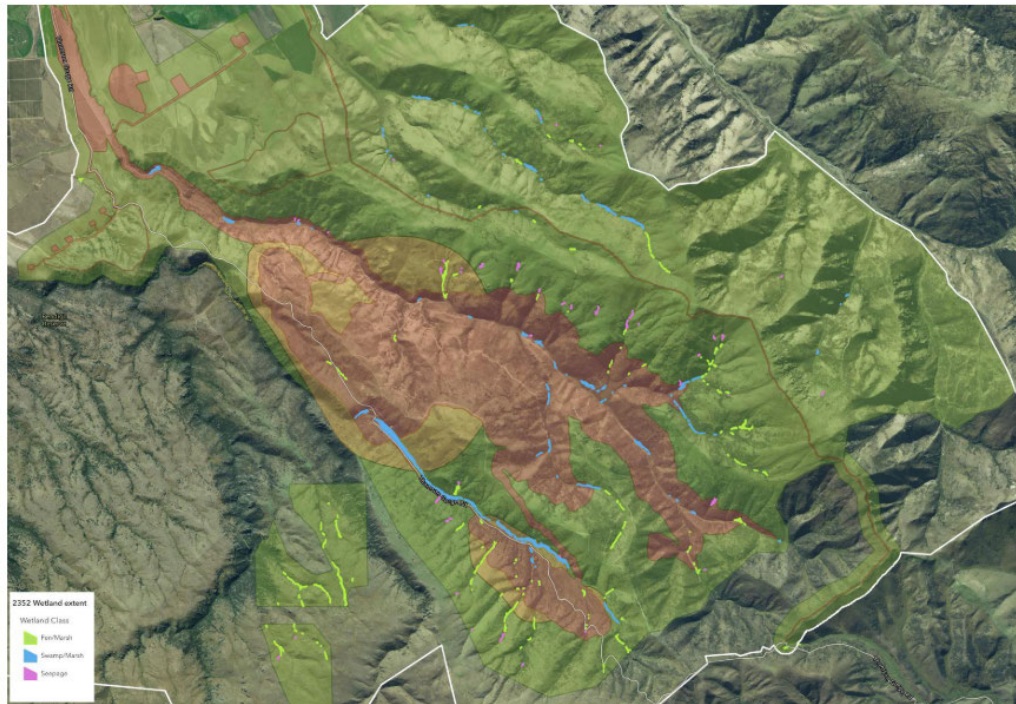


Figure 7. Distribution of wetlands within the direct disturbance zone (red polygon), drawdown disturbance zone (orange) and surrounding landscape surveyed for wetlands (green polygon). Wetlands are displayed by wetland class (**B.12**).

83. It was concluded in **B.12** that potential adverse effects on wetland values relating to mining construction include, among others, wetland habitat loss totalling 3.12 ha, through vegetation clearance and earthworks within the direct disturbance footprint, including excavation, as well as infilling through deposition of overburden, waste-rock, and tailings. Of this area, 0.13 ha is seepage, 0.48 ha is fen, and 2.51 ha is swamp and marsh.

84. It was noted that “Uncertainty exists around the indirect effects of groundwater drawdown and surface water diversion, particularly in Rise and Shine Valley, where the greatest potential effects and highest value wetlands occur”. These highest value swamp / marsh wetlands can be seen in Figure 7 as the bright blue area along the Rise and Shine Creek, and a photo is shown in Figure 8.



*Figure 8. A typical valley floor (swamp and marshland) wetland in Rise and Shine Valley, with large areas of swamp dominated by native sedgeland, with marshland on the margins (B.12 plate 3)*

85. Report **B.42** calculated the potential radius of influence and drawdown magnitude associated with dewatering of mine pits. The radius of influence can be defined as the maximum distance from a pumping well up to which the influence of pumping is significant (Bresciani et al., 2022). Put another way, it is the distance from the pit to where the influence on the water table is measurable.
86. The assessment approach used in **B.42** is appropriate for providing an order of magnitude estimate of the radius of influence, as detailed in the review on this topic by Bresciani et al, (2020).
87. It is worth noting that the formula that was applied to estimate radius of influence, which originates from Bear (1979), is less conservative than others available (Bresciani et al. 2022). Also, the storativity value used in the analysis is assumed which adds uncertainty. The estimated radius of influence is, therefore, not necessarily conservative, as claimed in **B.42**.
88. The estimated radius of influence encompasses all three wetland types, as shown in Figure 9. The swamp and marsh wetlands associated with the Rise and Shine Creek make up most of the wetland area that could be impacted. This is expected given their proximity to the RAS and SRX pits. Hillslope seepage and gully fen wetlands within the drawdown areas are mainly located on the northern flank of the Shepherds Creek valley and upslope of the SRX pit on the southern flank of the Rise and Shine Creek valley.

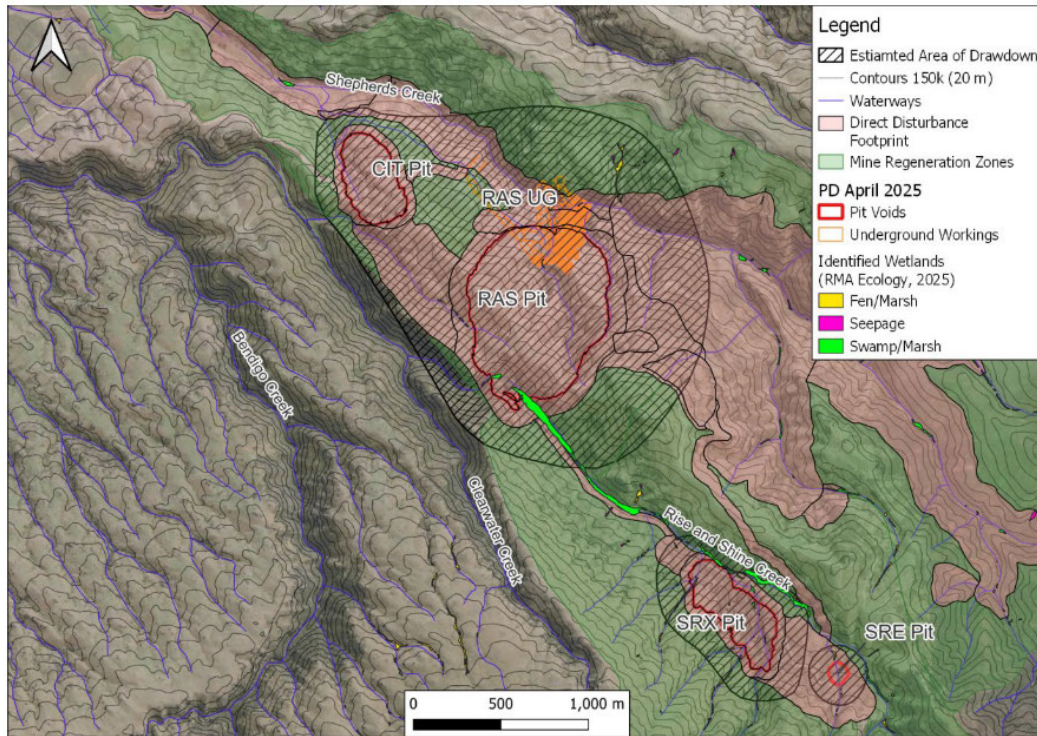


Figure 9. Estimated area of drawdown (radius of influence) (B.42, figure 5).

89. The groundwater modelling detailed in B.05 also found that dewatering of the SREX pit is likely to significantly impact the Rise and Shine Creek and the downstream wetlands, shown in Figure 10. The model suggests “that the most likely outcome is that the alluvial system and any nearby wetlands will be significantly impacted by the mining activities – possibly leading to the drying up of the wetlands and the loss of the alluvial system. There is not currently sufficient data to support more detailed modelling of the alluvial / SREX system, and a data campaign would be required before any further modelling could be undertaken.” As such, wetlands in the vicinity of the SREX pit will most likely be impacted and further work is needed to assess this.

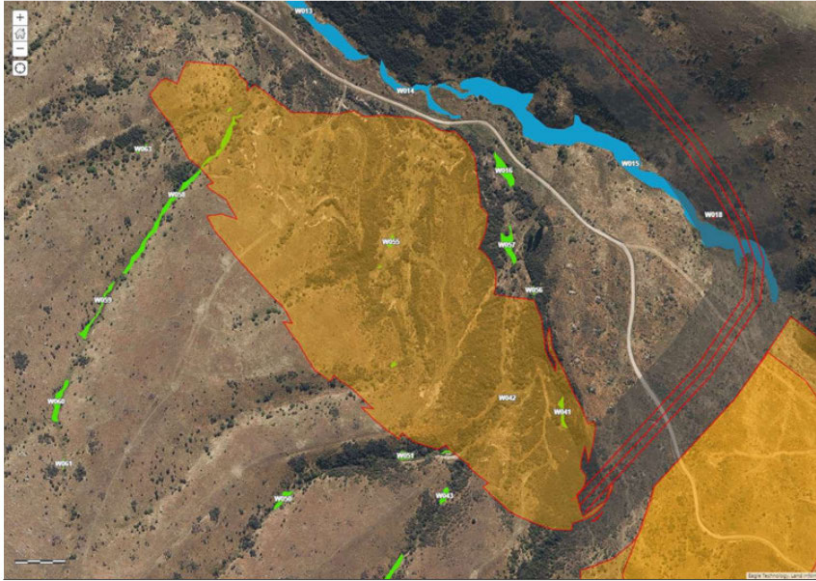


Figure 10. SREX alluvial zone and mapped wetlands (B.05, figure 9.16)

90. Mitigation measures are proposed for the swamp and marsh wetlands through augmentation of Rise and Shine Creek flows using groundwater from the Bendigo Aquifer.
91. However, it is acknowledged in B.42 that the efficacy of this mitigation approach is unknown and recommendations call for further studies prior to mining development to improve understanding of the hydraulic function of the wetlands and to determine whether planned remediation would be effective. I support these recommendations. Additionally, the impact of increased flow and changes to water quality in Rise and Shine Creek post closure should be considered.
92. No mitigation is planned for the hillslope seepage or gully fen wetlands.
93. Overall, I consider that it is most likely that the impacts to wetlands (all types) from drawdown will result in their permanent loss.

### Hydrodynamic containment and seepage risk

#### Summary

94. A central assumption of the BOGP water management is that the Shepherds Creek valley is a contained system and any seepage of contaminated water from MWSF within the valley i.e., the TSF and ELF, will be managed in this closed system. That is, it is assumed that any contaminated water in the Shepherds Creek valley will move from the ridges toward the valley floor and then down the valley floor where

it can be intercepted by drains and treated or reused i.e., hydrodynamic containment will be achieved.

95. However, this assumption has not been tested effectively, and mining will cause a large change in topography and groundwater flow near and below Shepherds Creek. The RAS pit alone will cause the water table to be lowered by hundreds of metres and dewatering of the tunnels which run directly below Shepherds Creek will further change groundwater levels and flow patterns. Instead of groundwater flowing from higher elevations toward Shepherds Creek and along the valley floor it could instead flow away from Shepherds Creek and away from planned interception resulting in an unexpected plume of contaminated groundwater.

96. The assumption of hydrodynamic containment under mining and post mining conditions needs to be rigorously assessed to provide confidence in the proposed water management approach.

97. Even if hydrodynamic containment is maintained, not all contaminated water will be intercepted by drainage infrastructure at the base of the TSF, and other MWSF. Contaminated water can move below or around drains and into the underlying groundwater and into the Ardgour Aquifer. The flow path and speed of this unrecovered seepage needs to be rigorously assessed so that monitoring and mitigation can be planned and enacted. However, there is only minimal information relating to shallow hydrogeology at the site and very limited assessment of seepage risk to date. Detailed assessments and planning for seepage are being deferred to after mining commences but these assessments should be carried out as part of the application.

#### *Assessment*

98. **K.05** was written in response to a site visit and workshop held with representatives of Otago Regional Council on 24 and 25 March 2026. The purpose of the report is to review and assess the risk of seepage migration from surface MWSFs of the BOGP towards downstream receptors.

99. The review provides an overview of the hydrogeological setting, seepage collection systems and performance monitoring. Conceptual diagrams in the Appendices are helpful.

100. The hydrogeology setting description (hydrostratigraphic units and groundwater flow regime) provides a useful summary, despite the limited data. I note that in **K.05**, values of hydraulic conductivity for the shallow weathered schist are

provided ( $\sim 5 \times 10^{-6}$  m/s) and taken from report **B.22**, but these were not reported in the main groundwater report (**B.03**) nor used in the groundwater modelling (**B.05**), despite all work being carried out during the same period (in 2024 and 2025). If this data was included as part of the groundwater model calibration it is likely that predictions of flows to the pits, drawdown and stream depletion would have been higher. **B.22** also details the installation of three piezometers (monitoring wells) at the location of TSF embankment, two lower in Shepherds Creek, and two in the upper RAS catchment. This information was also not included in **B.03** nor used in the groundwater modelling. This indicates a potential lack of coordination and communication between the hydrogeology and geotechnical teams. If this data was included as part of the groundwater model calibration it is likely that predictions of flows to the pits, drawdown and stream depletion would have been higher as this hydraulic conductivity value is significantly higher than those used during model calibration.

101. A central assumption of the BOGP seepage management is that topographically driven flow (i.e., groundwater flows from areas of high to low land surface elevation) will result in hydrodynamic containment within Shepherds Creek (Figure 11). As described by Smith (2021), valleys are often targeted as locations of tailings storage because if the elevation of the groundwater table along the ridges of the valley is maintained at an elevation well above the ultimate water level in the TSF, then the water in the TSF will tend to move down valley, where it can be intercepted. The assumption of hydrodynamic containment in Shepherds Creek is reasonable under current (pre-mining) conditions. However, it has also been assumed under mining and post mining conditions (**K.05**, p. 3): “During mining and post-closure, pit and underground dewatering may alter this flow pattern locally, but at the scale of the BOGP, topographically driven flow will remain the dominant condition”. This assumption needs to be rigorously tested.

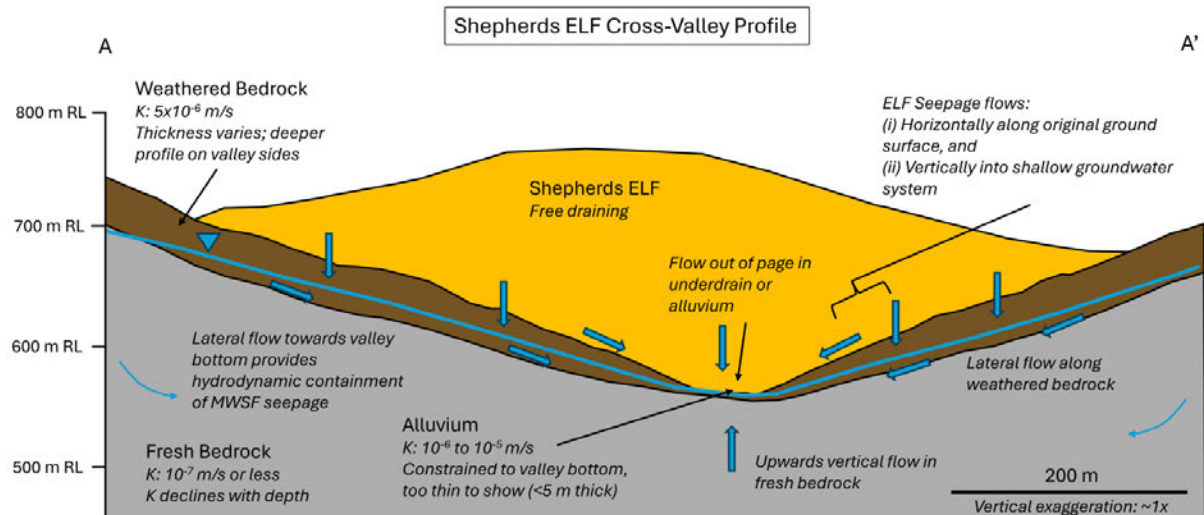


Figure 11. Shepherds ELF cross-valley profile (from K.05, figure 2).

102. During mining, the RAS pit and tunnel dewatering will lower groundwater levels beneath the ridges of Shepherds Creek valley, and the tailings pond level will increase, this creates a risk that hydrodynamic containment will be lost. Figure 11 shows a cross section of Shepherds Creek valley where groundwater levels (the blue line) are higher than the valley floor (the low point in the dark brown weathered bedrock). This is indicating hydrodynamic containment because groundwater will flow to the low point.
103. However, Figure 11 does not include the influence of pit dewatering or tunnels on groundwater levels. The RAS pit bottom is  $\sim 450 \text{ m RL}^2$  (Figure 1) which is considerably lower than the elevation of both the TSF bottom ( $\sim 600 - 700 \text{ m RL}$ ) and the ELF bottom ( $\sim 500 - 600 \text{ m RL}$ ) (Figure 12). Therefore, groundwater levels along the southern ridge of Shepherds Creek (i.e., on the left side of Figure 11) could be below the valley floor of Shepherds Creek. This indicates considerable potential for loss of hydrodynamic containment under mining.

<sup>2</sup> RL means relative to a mean sea level vertical height datum.

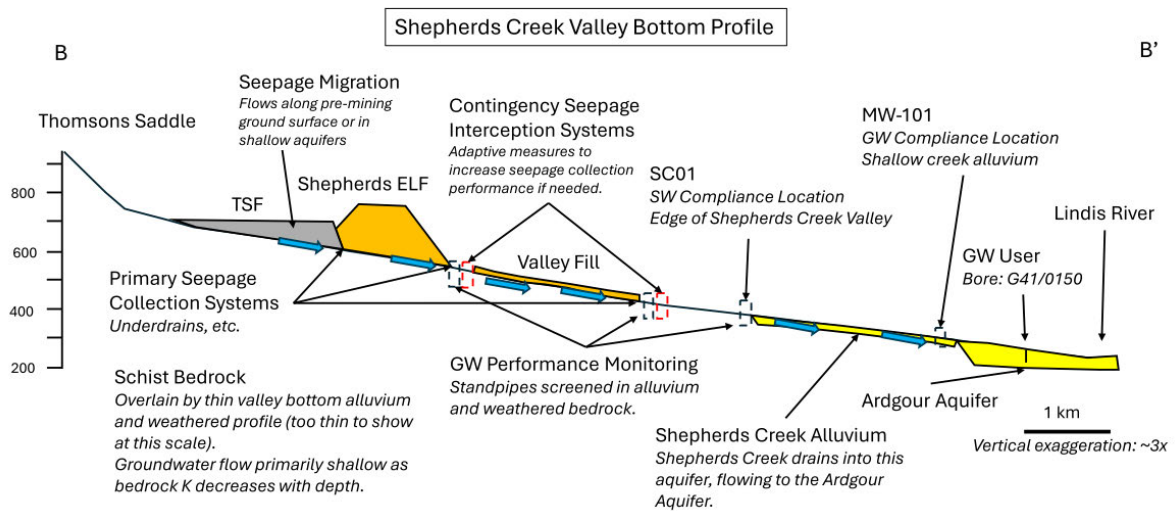


Figure 12. Shepherds Creek valley bottom profile (from K.05, figure 3)

104. Additionally, the underground mining tunnels extend to a depth of ~ 150 m RL under Shepherds Creek (**G.01**) and dewatering will cause further drawdown of groundwater levels in the vicinity of Shepherds Creek increasing the potential for loss of hydrodynamic containment. The impact of tunnel dewatering on groundwater levels is unknown because it was not assessed in **B.05**.
105. The risk of losing hydrodynamic containment will persist after mining and dewatering ceases as it can take extended periods for groundwater levels to return to pre dewatering conditions, if at all (Bosan et al., 2022). The timing of groundwater response to dewatering and cessation of dewatering is unknown because it was not assessed in **B.05**. Also, groundwater level and flow post-closure has not been assessed but will be highly modified relative to predevelopment conditions.
106. Results of the groundwater model detailed in **B.05** Figure 7.22 indicate a groundwater divide between the RAS pit and Shepherds Creek which supports the assumption of hydrodynamic containment under mining – because the mound indicates groundwater levels higher than the valley floor on the southern ridge of Shepherds Creek. However, the model did not include the underground tunnels or cumulative impacts to drawdown from the CIT pit. Also, results presented are only for a single parameter combination and other parameter combinations could result in no groundwater divide. I recommend further modelling is carried out to test the hypothesis that drawdown does induce loss of hydrodynamic containment. This modelling should also consider water levels within the TSF as it is filled (Smith, 2021).

107. Even if hydrodynamic containment is maintained, there is a risk of unrecovered seepage (referred to as bypass seepage in **K.05**) migrating from MWSFs to downstream receptors, as shown in Figure 13.

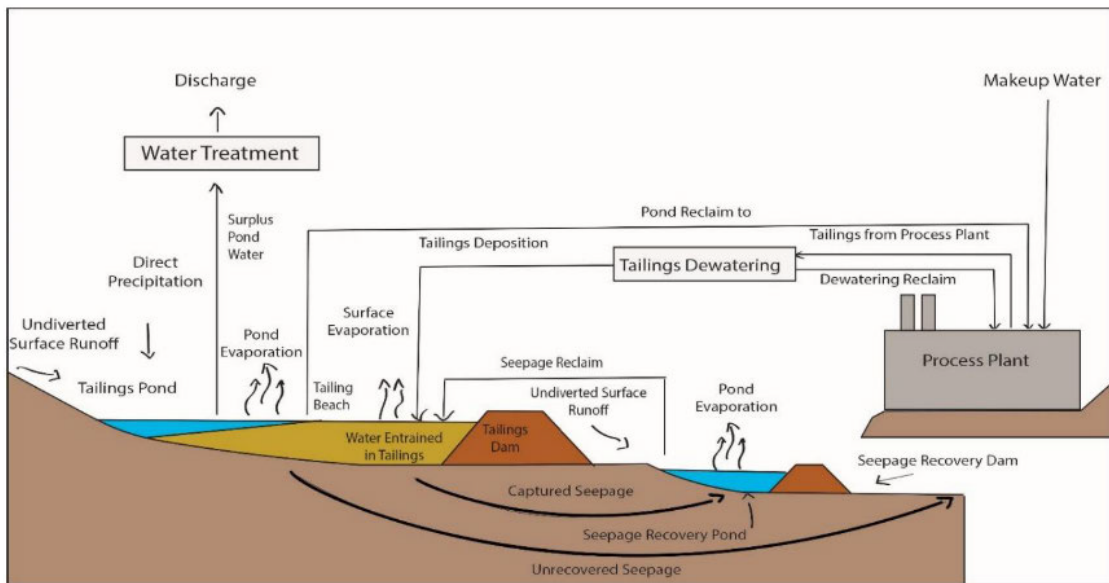


Figure 13. Schematic diagram of water transfers at a conventional tailings facility (from Smith, 2021).

108. Report **K.05** aimed to assess the risk of unrecovered seepage and provides a useful summary of various details including a summary of the source, pathway and receptor for the MWSF (Table 1). From this, receptors are Shepherds Creek/Ardgour Aquifer and Clearwater Creek/Bendigo Aquifer and Rise and Shine Creek, which then runs into Clearwater Creek/Bendigo Aquifer. An additional source not listed here is the tailings paste that will be injected into the underground tunnels. The potential receptor is Shepherds Creek and the Ardgour Aquifer groundwater users.

Table 1. MWSF seepage SPR summary (from **K.05**)

SOURCE	PATHWAY	POTENTIAL RECEPTOR
TSF seepage	Shallow groundwater system (alluvium and weathered bedrock)	Shepherds Creek. Ardgour aquifer groundwater users.
Shepherds ELF seepage	Shallow groundwater system	Shepherds Creek. Ardgour Aquifer groundwater users.
Shepherds Valley Fill seepage	Shallow groundwater system	Shepherds Creek. Ardgour aquifer groundwater users.
Western ELF seepage	Shallow groundwater system	Clearwater Creek Bendigo Aquifer Groundwater users.
SREX ELF seepage	Shallow groundwater system	Rise and Shine Creek <sup>1</sup>

<sup>1</sup>Note: Any shallow seepage migration not discharging to Rise and Shine Creek would report to RAS Pit.

109. Groundwater travel times to performance monitoring infrastructure was estimated using a simple first order approach. Groundwater velocity is inversely proportional to porosity and the assumed porosity of 0.1 could feasibly range between 0.02 and 0.4 (Anderson et al., 2015). Therefore, the estimated travel times could be four times faster or five times slower, and that is just from uncertainty associated with the assumed porosity. Measured porosity values would have helped address this uncertainty. Overall, the uncertainty of groundwater travel times highlights the lack of data collection for seepage transport assessments. This is a critical gap that will impact the ability to effectively design seepage monitoring and mitigation infrastructure.
110. **K.05** provides a useful summary of proposed seepage collection systems (Table 2). The size of the overall footprint is more than 200 ha. Post closure, there will be an additional ~ 12 km of tunnels with mine tailings paste below the water table and two pit lakes. The risk these MWSFs pose in terms of groundwater contamination is detailed in of the evidence of Professor Webster-Brown (2026) for EDS.

*Table 2. MWFS primary seepage collection system elements (from K.05)*

MWSF	MAX FOOTPRINT (ha)	PRIMARY SEEPAGE COLLECTION SYSTEM
Shepherds ELF	111	<ul style="list-style-type: none"> <li>• Toe underdrainage system.</li> <li>• Low permeability toe bund (termed Zone A by EGL).</li> <li>• Seepage collection sump.</li> </ul>
TSF	61	<ul style="list-style-type: none"> <li>• Tailings Underdrainage.</li> <li>• Embankment Chimney drain.</li> <li>• Upstream Cutoff drain.</li> <li>• Low permeability core (termed Zone A by EGL).</li> <li>• Collected water piped to Shepherds ELF seepage collection sump.</li> </ul>
Shepherds Valley Fill	11	Subsurface drains collect seepage at Run of Mine Pad and Process Plant. Water conveyed to collection point for management.
Western ELF	17	<ul style="list-style-type: none"> <li>• Underdrainage system.</li> <li>• Collection sump.</li> </ul>
SREX ELF	16	Seepage collection at toe of ELF via perimeter drain cut to rock to be directed to collection point management.

111. In **K.05** it is stated that “Only minor seepage is expected to bypass collection systems in the valley.” (**K.05**, p. 5). However, this does not appear to have been based on any quantitative site-specific assessments.
112. In **K.05** the author offers personal experience as reassurance that the proposed seepage collection systems will work. They mention McArthur River mine (MRM) in Australia which is well known for issues related to seepage of contaminants to groundwater from mine tailings and concern around effects on sacred sites and local waterways. This issue has been documented in a report by Higgins et al.

(2021) and helpfully summarised in plain language: “At MRM, the water is leaking from underneath the tailings storage through the ground and into Surprise Creek which is close to where the tailings are stored. Surprise Creek joins Barney Creek west of MRM which then joins the McArthur River downstream of the mine. The leaking water into Surprise Creek is a problem because the water may also carry some metals and we do not think that MRM or the IM<sup>3</sup> have done enough testing to fully understand this. The tailings currently in storage will be there until at least 2047. MRM has tried different ways to stop the water reaching the creek, but none have been completely successful. The water leaking from the storage has also made Surprise Creek flow all year; it used to flow for only part of the year.”

113. The paper of Fortuna et al. (2020) is also offered in **K.05** as evidence that the proposed seepage systems can work. This article talks about how it is critical that hydrogeology be included as part of seepage design and provides examples where this has been helpful but also examples where inadequate application of hydrogeological principles has led to adverse outcomes.
114. To date, there has been minimal hydrogeological assessment at the site of the MWSFs as evidenced by a lack of basic hydrogeological parameters for use in modelling as detailed above. There has also been an apparent lack of communication and coordination between groups working on hydrogeology, geotechnical assessment and mine waste seepage assessments, as detailed above. Fortuna et al. (2020) highlight the risk this gap in hydrogeological understanding poses to effective design of seepage and monitoring systems for the BOGP: “The authors’ and others’ global experience across hundreds of TSFs has shown that interactions with groundwater are frequent, and that seepage prevention and mitigation designs routinely fail to perform as expected. This is often due to poorly understood groundwater systems or unforeseen interactions between the natural and built environment that were not considered properly during the design phase. Potential interactions between groundwater and tailings need to be considered from the process of site selection, through design, construction, operations, and into the post-closure period.”
115. In **K.05** the current lack of basic hydrogeological data is acknowledged, and recommendations are made for future work to address this. However, this information should already be available so that an assessment of seepage risk can be carried out as part of the proposal rather than pushing this work to the detailed design stage.

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<sup>3</sup> Independent monitor.

## Solute transport into the Ardgour Aquifer

### *Summary*

116. Shepherds Creek is the primary receiving environment for the proposed mining area. Groundwater modelling has shown that if there is unrecovered seepage of contaminants into Shepherds Creek, these will move into the Ardgour Aquifer and there will be limited dilution of these contaminants. Groundwater users and the Lindis River are very likely to be adversely impacted. It is recommended that further modelling is carried out to determine whether contaminated groundwater within the Ardgour Aquifer could move into the neighbouring Bendigo Aquifer and Lower Tarras Aquifer.

### *Assessment*

117. Shepherds Creek is considered the primary receiving environment for the proposed mining area, with the RAS pit and underground mining tunnels, ELF and TSF located in the Shepherds Creek catchment (Figure 3). Active water treatment of mine impacted water is planned in this catchment followed by passive treatment. An assessment of contaminant seepage into the Ardgour Aquifer from Shepherds Creek is detailed in **K.01**.
118. A numerical groundwater model of the Ardgour Aquifer<sup>4</sup> was developed to quantify mixing between water in the Ardgour Aquifer and Shepherds Creek and other sources to estimate potential dilution of contaminants entering the Ardgour Aquifer from Shepherds Creek, provide an indication of potential timescales of effects, and identify further work to refine the assessment.
119. The model that was developed uses the best available information relating to the Ardgour Aquifer and surrounding surface water bodies. The hydrogeological conceptualisation is well described including figures.
120. There is a lack of measured hydrogeological parameter data, but the modelling applies a range of parameter values to obtain a range of model outputs. The range of parameter values used are reasonable and overall, the approach is appropriate for a first order assessment, and the uncertainty is detailed appropriately.
121. The numerical model set up is sound with appropriate domain size and boundary conditions. Water at a concentration of 1 is added to the model (using the WEL

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<sup>4</sup> Note that the Ardgour Aquifer includes both the Ardgour Alluvial Aquifer and the Lindis River Ribbon Aquifer.

package in MODFLOW) to represent contaminants entering the aquifer from Shepherds Creek. All other inflows to the model have a concentration of 0. This allows for a first order assessment of mixing and dilution.

122. An 'affected' period (when contaminants are entering via Shepherds Creek) of 31 years is used followed by an 'unaffected' period (when contaminants are not entering via Shepherds Creek). The choice of this affected period is unclear and the contaminants from Shepherds Creek will not instantaneously cease. However, this approach does allow for first order predictions of the lag between stopping all contamination entering the aquifer and plumes dissipating, which was in the order of decades.
123. Contaminants are shown to be greatest at depth in the Ardgour Aquifer, but no physical reasoning is provided for why this is the case, therefore it is possible that it is an artefact of the model set up.
124. The key prediction of interest is the maximum dilution factor of the contaminant plume spatially in the Ardgour Aquifer (Figure 14). This shows that there is a large plume with dilution less than 50% extending to the Clutha Mata au River. Along the Lindis River this plume has dilution less than 25%. These are estimates and there is considerable uncertainty, but these results highlight the risk that unrecovered seepage of contaminants from the BOGP pose to the Ardgour Aquifer, Lindis River and Clutha Mata au River.

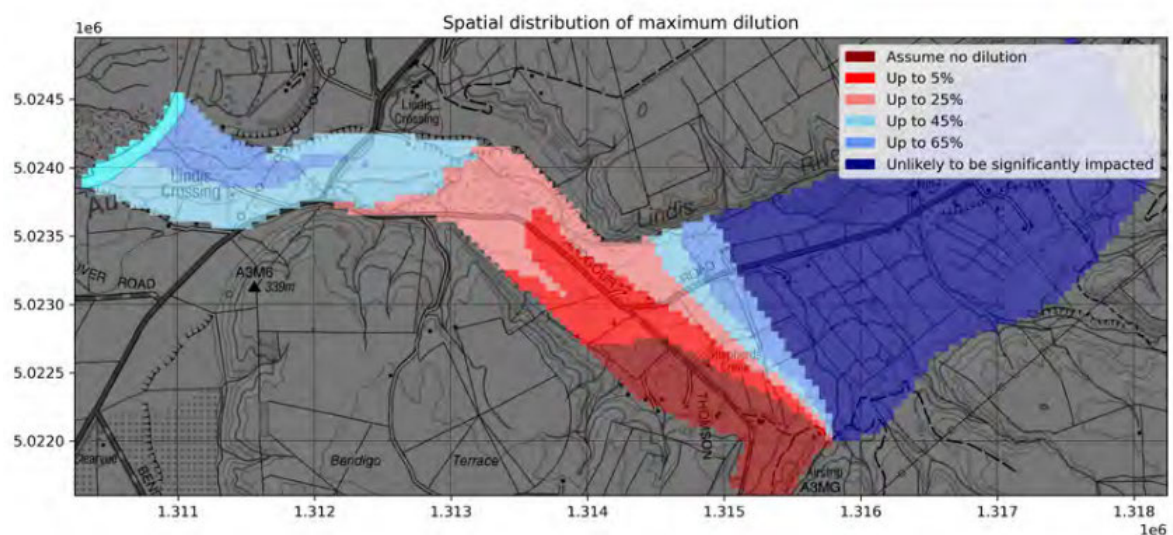


Figure 14. Spatial distribution of maximum contaminant dilution in the Ardgour Aquifer (from K.01, figure 4.2).

125. The report refers to sulphates as the contaminant of concern but there will also be a range of others including nitrogenous compounds, metals and metalloids

particularly arsenic, as detailed in other technical reports. This is covered in more detail in the evidence of Professor Webster-Brown (2026) for EDS.

126. The modelling in **K.01** addresses physical transport processes (advection and dispersion) and it is recommended that reactive transport modelling is carried out which additionally considers geochemical reactions (such as adsorption, dissolution, and reduction).
127. The Rise and Shine Creek catchment and the Bendigo Aquifer is also a receiving environment (Table 1) but modelling of solute transport into the Bendigo Aquifer has not been carried out.
128. The Ardgour Aquifer is connected to neighbouring aquifers including the Bendigo Aquifer to the south and the Lower Tarras Aquifer to the north (Figure 15). Pumping in the Bendigo Aquifer and Lower Tarras Aquifer could feasibly draw groundwater in from the Ardgour Aquifer. It is recommended that further modelling and assessment is carried out to determine whether contaminated groundwater within the Ardgour Aquifer could move into these neighbouring aquifers.

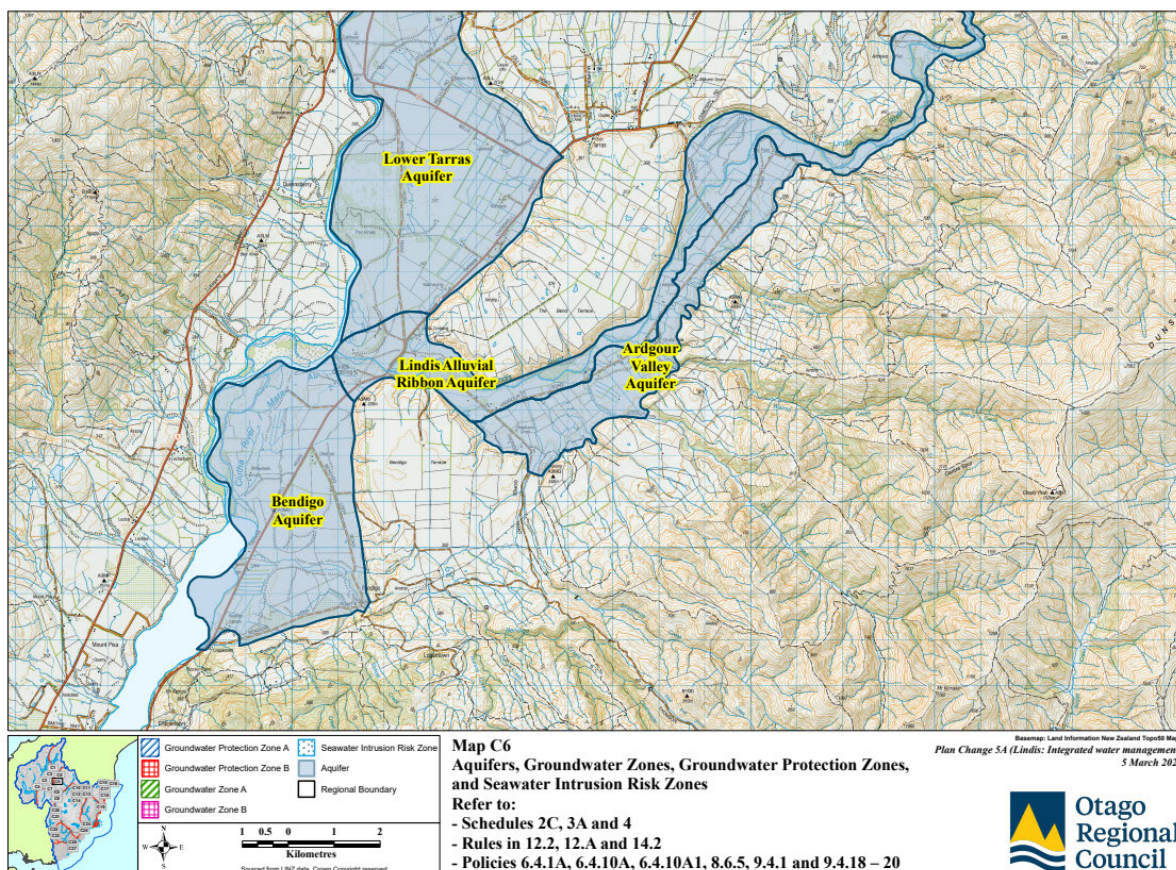


Figure 15. Map C6 showing the location of the Ardgour Aquifer relative to neighbouring aquifers (from <https://www.orc.govt.nz/media/11890/plan-change-5a-map-c6-linds-alluvial-ribbon-aquifer-ardgour-valley-aquifer-bendigo-aquifer-and-lower-tarras.pdf>).

## Bore water take assessment

### Summary

129. Consent is sought for a groundwater take of 110 L/s from the Bendigo Aquifer. The constant rate pump test used for this assessment does not meet minimum standards as set out by the Otago Regional Council. The estimation of drawdown in neighbouring bores concluded that there is a minor effect, however the assessment did not account for cumulative drawdown i.e., impacts from surrounding groundwater users, which would have resulted in a larger drawdown estimate.

### Assessment

130. Report **B.02** (p. 2) is an assessment of mine bore water supply effects on the Bendigo Aquifer and surrounding groundwater users. The purpose is to achieve

consent for a 110 L/s groundwater take (Table 3) at a location 6.5 km west of the proposed gold mining site. The water will be used for process water and dust suppression.

*Table 3. Proposed groundwater pumping rate and volume (from B.02)*

	Rate or Volume	Explanation
Maximum Instantaneous (L/s)	120	Estimated maximum demand and an allowance for instantaneous overshoot.
Maximum Daily (L/s)	110	Based on water demand indications
Maximum Daily (m <sup>3</sup> /d)	9,504	Daily rate multiplied by 86.4
Maximum Monthly (m <sup>3</sup> /month)	285,120	Daily rate multiplied by 30
Maximum Annual (m <sup>3</sup> /year)	3,153,600	100 L/s multiplied by 86.4, multiplied by 365

131. A constant rate pump test was carried out but did not meet the Otago Regional Council minimum aquifer test requirements as it should have been pumped for 72 hours at the highest required rate with two observation bores. The test was only completed for 48 hours at ~ 21 L/s (i.e., only 20% of the proposed abstraction rate) with one observation bore.
132. It is common to apply for a resource consent specifically to do a pumping test that would exceed permitted activity limits (i.e., the reason given for not pumping at higher rates). BOGP should have applied for this consent to get these results to inform the application.
133. The parameters determined from the analysis of the pumping test ( $T = 4500$  m<sup>2</sup>/day,  $S_y = 0.25^5$ ) are reasonable. Houlbrooke (2010) estimated  $T$  ranging between 3000 m<sup>2</sup>/day and 5000 m<sup>2</sup>/day for the Bendigo Aquifer.
134. Drawdown assessment was carried out using the Theis (1935) method and the values were checked and are correct for the parameters provided.
135. Given the size of the take (100 L/s for 365 days a year) and year-round mining operations, the drawdown assessment should have been carried out for longer than one year.
136. The drawdown assessment did not account for cumulative effects of drawdown from consented takes from neighbouring bores. It is standard practice to assess the cumulative effects of other bores, along with the proposed new take, when assessing drawdown impacts on neighbouring bores. However, this was not done

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<sup>5</sup>  $T$  (transmissivity) is hydraulic conductivity multiplied by aquifer thickness.  $S_y$  (specific yield) is storativity in an unconfined aquifer.

here which is a gap, particularly given the high bore density. Calculated drawdown would have been larger if these were included.

137. Stream depletion of the Clutha Mata au River would likely be 70 L/s (64% of the take) after 365 days.
138. Badenhop (2026) notes that the applicants intend to commission an aquifer test “that would provide better information to complete a cumulative drawdown assessment. If the drawdown assessment indicated that groundwater users would be affected by drawdown induced by MGL’s proposed take, MGL would offer remedial actions to the affected bore owner to minimise, offset or compensate for any reduced access to groundwater”.
139. Further details as to the specific methods of remediation and compensation are needed. I agree with Badenhop (2026) that these requirements should be included in conditions rather than the water management plan.
140. I also agree with Badenhop (2026) that: “the monitoring is likely to be adequate, but this should be confirmed after the proposed commissioning test”.

### **Consent conditions, water management planning and adaptive management**

#### *Summary*

141. Consent conditions were proposed in **D.02** and **D.04**. Overall, I agree with Badenhop (2026) p. 23 that “Throughout the technical reports, many management measures were recommended. However, few of these management measures are incorporated into the consent conditions as clear and enforceable conditions”.
142. Within the water management plan (**G.01**), proposed monitoring is inadequate, mitigation measures are defined in only broad terms and there is ambiguity in descriptions of the remedial actions and timing of those actions should trigger levels be exceeded. There is no reassurance of accountability and public access to performance monitoring data. Overall, the water management plan employs an adaptive management framework, but suitability of adaptive management of groundwater effects where lag times are long (in the order of years to decades) and effects are likely permanent is questionable. A precautionary approach is recommended.

## Assessment

143. Report **G.01** contains details of the water management planning for the BOGP. Specific comments related to that report include:

- a. Mitigation measures for the Rise and Shine Creek wetlands involve using groundwater from the Bendigo Aquifer. However, there are many questions about the efficacy of this mitigation that need to be answered.
- b. Additional monitoring for unrecovered seepage in the Shepherds Creek valley is recommended and needs to target a range of depths and be of higher frequency than is currently proposed. Currently there is only one compliance monitoring bore in the Shepherds Creek Valley (MW101), which is inadequate. Further compliance sites are needed to monitor for unrecovered seepage closer to the MWSFs in Shepherds Creek and nearby to Bendigo Creek (where it meets the Bendigo Aquifer). These monitoring bores need to target a range of depths. The design and frequency of monitoring needs to be guided by detailed assessments (based on measured data) of potential unrecovered seepage pathways and travel times. It is important to note that groundwater levels and flows will be highly modified during mining and post closure, relative to undisturbed conditions. Plans for monitoring should account for this.
- c. Additional monitoring locations are required to understand groundwater dynamics and especially surface water / groundwater interactions. Two locations (near the Rise and Shine Creek wetlands) are identified for push point piezometers, but further locations are needed to assess impacts to other wetlands across the BOGP site. It is currently proposed that levels will be monitored but water quality should also be monitored.
- d. Additional surface water compliance monitoring sites are recommended and particularly in the Rise and Shine Creek downgradient from the SREX pit and ELF to detect contaminants before they enter the Rise and Shine Creek wetlands.
- e. Water balance calculations indicate that the site will be in water deficit to year eight of operations. A water deficit in early years is important because it allows time to build water treatment facilities that will treat surplus water before it is released back to the environment. However, water inflows and outflows (detailed in **B.06c** Appendix N) have considerable uncertainty, and some inflow values are on the low end of estimates noted elsewhere in the

application (i.e., groundwater inflow to pits, tunnel dewatering). Therefore, the conclusion that there will be a water deficit until year eight is uncertain and perhaps optimistic. This should be made clear, along with contingency plans for if there is a water surplus in early years.

- f. It is estimated that active water treatment will be required for ~50 years in the Shepherds Creek catchment. After this it is expected that passive treatment will be required for many decades. It is concerning that there is uncertainty as to whether passive treatment is feasible: “further feasibility studies are required to confirm treatment performance and the ability to transfer from active to passive treatment” (**G.01**, p. 25). This is covered in more detail in the evidence of Professor Webster-Brown (2026) for EDS.
  - g. There is no assessment of the potential for remediation of groundwater should it become contaminated. There is no plan for remediation.
  - h. It is noted that “Monitoring results will inform updates to the WMP<sup>6</sup>, risk register, and adaptive management processes” (**G.01**, p. 58). This is a vague statement. There are no time limits associated with responses to exceedances of triggers nor a requirement to report this to external bodies – there is only a requirement to report to an internal risk register.
  - i. I recommend open access and independent external verification of surface and groundwater monitoring data. There needs to be reassurance that there will be ongoing scrutiny from regulators to reassure the local community and surrounding groundwater users. The issues at the MacArthur River Mine (Higgins et al., 2021) and other sites including the Cadia Gold mine in NSW, Australia (Hambrett, 2024; Spencer, 2024) highlight this need for accountability to reassure neighbouring water users.
144. Overall, an adaptive management framework is being used as detailed in **G.01**, p. 7: “Adaptive management is a key component of this management plan which will be supported by performance monitoring and ongoing review.” Adaptive management seeks to address uncertainty in environmental impact assessments. It uses targeted monitoring, and structured and iterative integration of new knowledge of project operations to improve future management practices (Thomann et al. 2022). The approach can be broadly summarised as “learning by doing”.

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<sup>6</sup> Water Management Plan.

145. Thomann et al. (2020, 2022) show that adaptive management is often poorly suited to managing impacts on groundwater. This is especially true in cases where:
  - a. There are long lag times between project activity and the full effects on the groundwater system; and
  - b. The impacts could be irreversible, meaning actions taken to address a change in the condition of the environment may come too late to stop permanent damage.
146. These conditions (long lag times and irreversible impacts) are features of potential effects to groundwater in the BOGP, particularly in relation to aquifer contamination from unrecovered seepage and depletion of streams and wetlands.
147. Given the high, often irreversible cost of groundwater contamination, groundwater scientists urge application of the precautionary principle (e.g., Stewart et al., 2021; Currell and Werner, 2024). Namely, that if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reasoning for postponing measures to prevent environmental degradation. Put another way, this means that if an activity may cause serious or irreversible damage, it should be assessed against a potential worst-case effect.

#### **List of outstanding questions**

148. As a result of my review of the application documents, I have the following outstanding questions. I consider these matters to be of critical importance to understanding the BOGP's material adverse impacts on groundwater hydrology. Without full clarity on the matters addressed in the questions, I do not consider that the project's impacts can be fully assessed and understood.
  - a. Please provide a single table with values for hydraulic conductivity, storativity, porosity and anisotropy of all hydrostratigraphic units, including the shallow weathered schist and veneer aquifer, in the BOGP. Please detail the source of these values and steps underway to reduce uncertainty.
  - b. Please provide a potentiometric contour map showing groundwater levels and flow direction at the site (including receiving environments).

- c. How do groundwater levels across the site (including receiving environments) vary over time? Please provide groundwater level hydrographs.
- d. Provide a conceptual model diagram of groundwater flow and surface water / groundwater interactions at the site. Are there feasible alternative conceptual models?
- e. Considering the size of the pit models in **B.05** and boundary conditions are the flows to the pits underestimated? What is a likely range of groundwater inflow to pits?
- f. Are surface water / groundwater interactions for Shepherds Creek and Rise and Shine Creek adequately represented in the **B.05** groundwater modelling or do they result in an underestimation of stream depletion?
- g. A steady state groundwater model cannot be calibrated to measured groundwater levels if both the recharge and hydraulic conductivity are unconstrained. Given this, please comment on the calibration of the groundwater model in **B.05** and uncertainty of predictions made using this model.
- h. Please provide predictions (with uncertainty) of the regional groundwater levels during mining and post closure, considering all mining features and their cumulative effects.
- i. What is a likely range of groundwater inflow to mining tunnels? And will tunnel dewatering impact groundwater levels and cause stream depletion?
- j. Is there a risk that hydrodynamic containment will be lost during mining and post-mining?
- k. What is the timing of water table drawdown and recovery, and stream depletion during and post mining? Is the assumption in **B.05** of instantaneous change reasonable?
- l. Will the hydraulic functioning of the Rise and Shine Creek wetlands be maintained with flow augmentation using bore water from the Bendigo Aquifer, considering also wetland geochemistry and increased flows in Rise and Shine Creek post closure?

- m. If impacts to other wetlands (hillslope seepage and gully fen) are observed how will this be mitigated and remedied?
- n. What is the volume of seepage through the base of MWSFs?
- o. What is the conceptual model and velocity of unrecovered seepage pathways from MWSFs during mining and post mining?
- p. If there is surplus water before the water treatment plant is built how will this be stored and managed?
- q. Who will be responsible for water treatment if the applicant is no longer able to do so?
- r. What specific mitigation and remedial actions are proposed to address unrecovered seepage if detected in Shepherds Creek and the Ardgour Aquifer or Bendigo Creek and the Bendigo Aquifer? Who will be responsible for actioning these measures?
- s. Is there potential for contaminated groundwater in the Ardgour Aquifer to move into the neighbouring Bendigo Aquifer and Lower Tarras Aquifer?
- t. How will performance monitoring data be made available to the public?

149. I have reviewed the list of questions contained in the Panel's 1 April 2026 request for further information from the applicant. The above questions (f), (n) and (q) are addressed by the Panel's questions. The rest of my questions are not covered by the Panel's questions and remain outstanding.

## Conclusion

- 150. In the Executive Summary of **B.04** (and repeated verbatim in **A.13**) it states: "This is an assessment of the effects on the flow or volume of surface water and provides key inputs to other experts work including aquatic ecology, wetlands and environmental geochemistry modelling undertaken by others. This assessment concludes the abstraction, diversion, use and return of surface water with the proposed mitigations will result in an acceptable outcome."
- 151. In the Executive Summary of **B.05** (and repeated verbatim in **A.13**) it states: "This is an assessment of the effects on groundwater, plus providing key inputs to other experts work including environmental geochemistry modelling undertaken

separately by Mine Waste Management (MWM) to determine solute concentrations and mitigation. This assessment concludes the abstraction, diversion, use and return of groundwater with the proposed mitigations will result in an acceptable outcome.”

152. On balance, from the information I have reviewed, I do not agree that the abstraction, diversion, use and return of surface water or groundwater with the proposed mitigations will result in an acceptable outcome. The evidence in the technical documents indicate considerable potential for irreversible groundwater contamination and loss of wetlands from the BOGP.

153. My key concerns relate to the following:

- a. There has been very limited hydrogeological data collection and particularly as relates to surface water / groundwater interaction and transport of contaminants. This has limited the rigour of effects assessments including stream depletion, effects to wetlands and seepage of contaminants. The groundwater model used to predict flow to pits, water table drawdown and stream depletion is a Class 1 low confidence model according to indicators from the Australian Groundwater Modelling Guidelines. The model likely underestimates flow to pits, drawdown and stream depletion.
- b. Technical assessments indicate that effects on wetlands from mine dewatering and drawdown are likely to be significant. Proposed mitigation for effects to wetlands involves augmenting flows in Rise and Shine Creek with bore water. However, there is large uncertainty regarding the efficacy of this approach. No mitigation is planned for other wetlands.
- c. There has been inadequate quantitative assessment of seepage from MWSFs, which is a critical gap. MWSFs collectively cover a land surface area of more than 200 ha during mining operations. Post closure, there will be an additional ~ 12 ha of tunnels with mine tailings paste below the water table and two pit lakes. These all pose a significant risk of contaminant leakage to groundwater, as examples from other locations internationally have shown. Robust quantitative assessment of seepage should be carried out as part of the application rather than deferred to the detailed design phase.
- d. There needs to be a rigorous assessment of whether changes in groundwater flow patterns from dewatering will cause loss of

hydrodynamic containment in Shepherds Creek valley, which could cause unexpected contaminant plumes.

- e. If contaminant seepage moves into Shepherds Creek and then into the Ardgour Aquifer, groundwater modelling has shown the effects will be considerable as there is limited dilution and effects will persist for decades, even if the contaminant seepage into Shepherds Creek were to stop. Once groundwater is contaminated it is very difficult if not impossible to remediate. Groundwater users, the Lindis River and Clutha Mata au River will be affected. The Bendigo Aquifer is also a receiving environment and there should be an assessment of contamination risk to the Bendigo Aquifer. It is also possible that contaminants in the Ardgour Aquifer could move into the neighbouring Bendigo Aquifer and Lower Tarras Aquifer and this should be assessed.
  - f. In the BOGP water management plan, mitigation measures are defined in only broad terms and there is considerable ambiguity in descriptions of the remedial actions and timing of those actions should trigger levels be exceeded. There are no remedial actions offered for contamination of the Ardgour Aquifer or Bendigo Aquifer. There is also no reassurance of accountability and public access to performance monitoring data.
  - g. An adaptive management approach is proposed that effectively involves learning by doing, but this approach is poorly suited to groundwater because effects (i.e., groundwater contamination) may not appear for years or decades and when they do it is very difficult and expensive to remediate.
154. Given the persistence and high cost of groundwater contamination, I recommend application of the precautionary principle. The precautionary principle in the context of groundwater management requires that proactive protective measures be taken against potential pollution or depletion (and associated loss of wetlands), even if scientific evidence is not yet conclusive.
155. Overall, there remain many uncertainties associated with effects of the BOGP on groundwater and connected surface water. These gaps and uncertainties need to be addressed before conclusions can be drawn regarding the level of these effects. Evidence in the technical documents indicate considerable potential for groundwater contamination and loss of wetlands. It needs to be shown that these can be effectively avoided or mitigated and to date that has not been achieved.

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