Report

21 July 2023

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Project Name	Macraes Phase 4		
Subject	Golden Bar Dewatering Assessment		

1. Introduction

Golden Bar Stage 2 Open Pit (GB Stg.2) is proposed to be mined between 2029 and 2031 with the proposed GB Stg. 2 pit shown in Figure 1. To enable mining of the open pit, dewatering of the existing Golden Bar Open Pit will be required as this began filling once mining concluded in 2005 and reached overflow in 2015. Dewatering of the open pit will remove water accumulated within the pit and draw down the surrounding groundwater table with discharge directed to the Golden Bar Creek (tributary of the North Branch Waikouaiti River, downstream of Golden Bar Pit).

This report provides an estimate of the time required to dewater the pit at defined pumping rates and resultant water quality outcomes in the receiving environment.

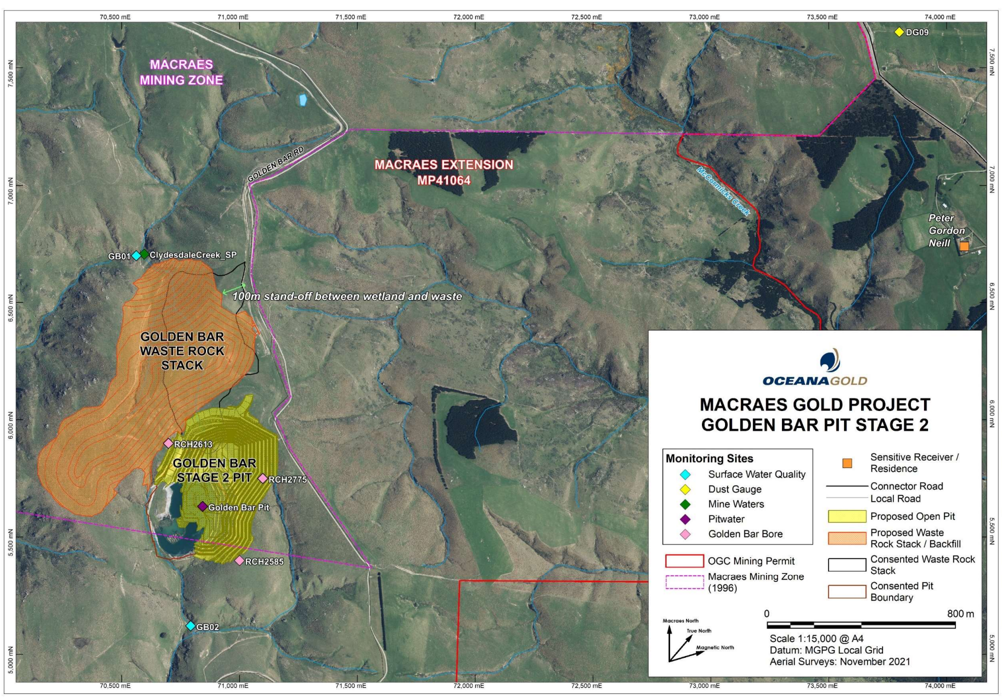

Figure 1 Proposed Golden Bar Stage 2 Elements (Source: OGNZL)

1.1 Purpose of this report

The purpose of this report is to present the results from surface water modelling for proposed dewatering of Golden Bar Pit prior to the mining the next stage. It provides estimates of the rate at which the Golden Bar pit lake level could be drawn down at given pumping rates and assesses the likely change in water quality within the receiving environment.

2. Scope and limitations

2.1 Scope of work

OGNZL have engaged GHD to assess potential rates of dewatering of Golden Bar Pit and the change in water quality within the receiving environment during dewatering. The scope of this work is to apply the site water balance model and investigate the following:

- Assess pumping rates and the resulting dewatering time for the pit,
- Determine the change in water quality at the existing monitoring points GB02, NB01 and NB03 with a focus on sulphate and arsenic as key contaminants of consideration compared to other contaminants controlled by the existing NB03 compliance point.

2.2 Limitations

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3. Hydrology and model

The existing Golden Bar Pit is proposed to be dewatered by pumping to a discharge point within Golden Bar Creek before feeding into the North Branch Waikouaiti River (NBWR). Figure 2 provides an indicative location for the discharge upstream of the GB02 monitoring point as assessed in the WBM. Also shown are the established monitoring and compliance locations in the area. The Golden Bar Pit Lake currently overflows to the Golden Bar Creek upstream of the GB02 and NB01 monitoring and compliance points, and before the confluence with the North Branch Waikouaiti River and NB03 compliance point. NB03 also receives water influenced by mine operations related to Frasers Pit and Frasers Waste Rock Stacks (WRS) via Murphys Creek and upper reaches of NBWR.

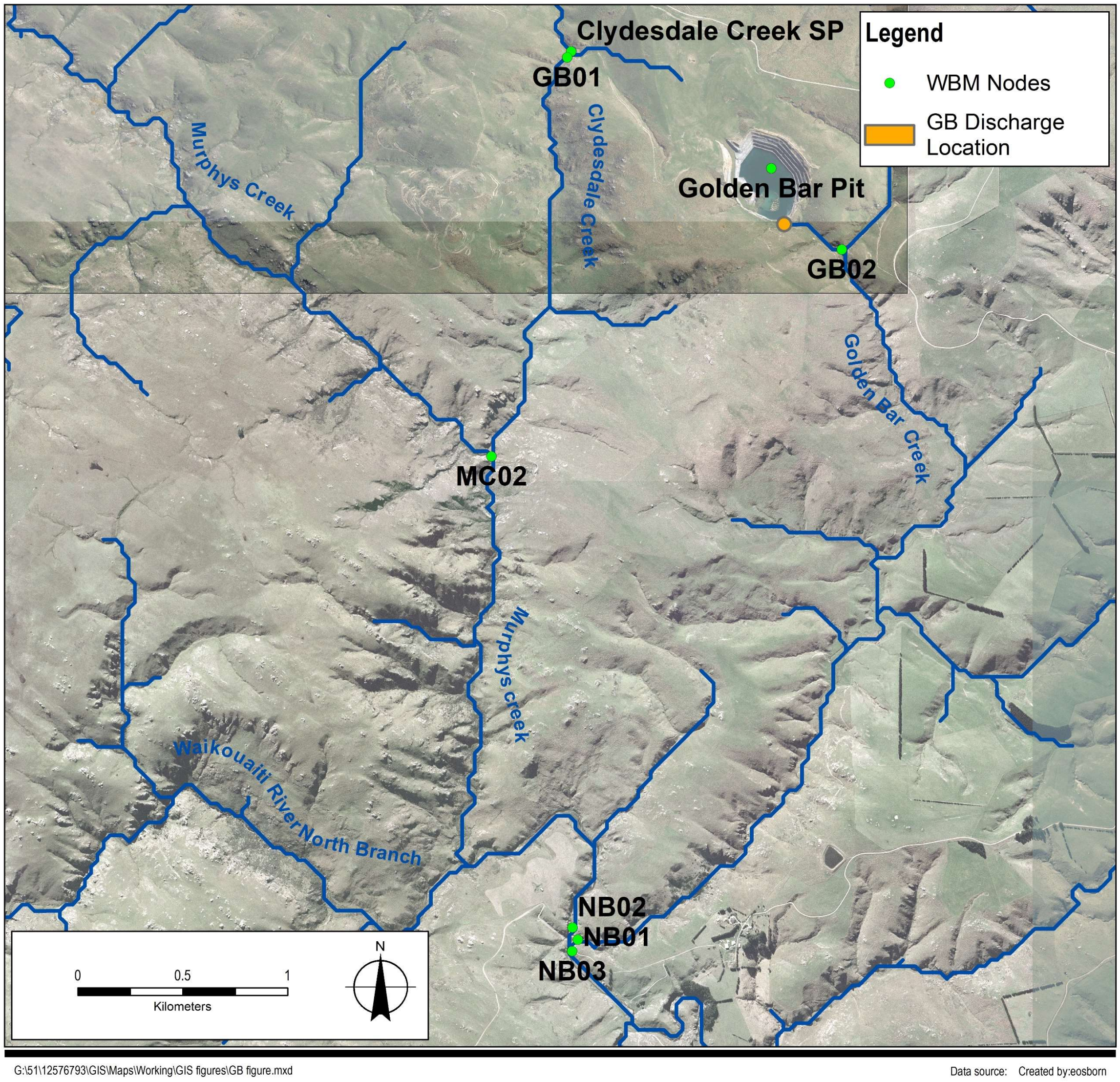

Figure 2 ***Locations of monitoring points***

Flow and water quality modelling was undertaken using a WBM developed for the wider Macraes mine site and further details of this model can be found in GHD 2023[1]. As a brief overview of the model hydrological inputs:

- Rainfall applied in the WBM for predictive analysis is based on a synthetic stochastic data series produced for statistical similarity with recorded rainfall data. Calibration of the model applies daily site rainfall data from the Golden Point Weather Station.
- Evaporation is represented in the model based on monthly statistic derived from pan evaporation data collected from site between 1991 and 2018.
- Runoff is represented in the WBM by two methods, the rational method is applied to areas impacted by mining (e.g. pit walls and WRSs), and a calibrated Australian Water Balance Model (AWBM) is applied to all other areas.
- The Golden Bar Pit is represented by a relationship defining volume and surface area with water elevation for the current as-mined pit geometry.

[1] GHD 2023. Golden Bar – Surface and Groundwater Assessment

- Groundwater inflows are determined by groundwater modelling and show increasing groundwater inflow rates with depth. The model inputs are based on a mean expected inflow, and do not have an uncertainty defined.

A secondary reference point for river flow mean and median flow estimates are considered as defined by NIWA's New Zealand River maps[2]. Table 1 shows the corresponding flow estimates for the three monitoring points.

Table 1 ***NIWA New Zealand River Maps flow statistics***

Shape	GB02 (L/s)	NB01 (L/s)	NB03 (L/s)
Catchment Area (km^2)	1.82	9.30	85.9
Median	5.199	24.17	334.5
Mean	12.44	57.3	628.8
MALF	1.81	10.3	137.0

4. Calibration

The WBM is calibrated against measured water quality data at mine water sources and monitoring points across the model domain. Comparisons between measured sulphate data from 2015 – 2020 and model outputs can be shown through constraining the model to actual rainfall data from the same period. Figure 3 shows the measured NB03 sulphate concentrations versus modelled outputs. At this location the modelled sulphate concentrations are shown to offer a conservative representation of the measured data for this time period.

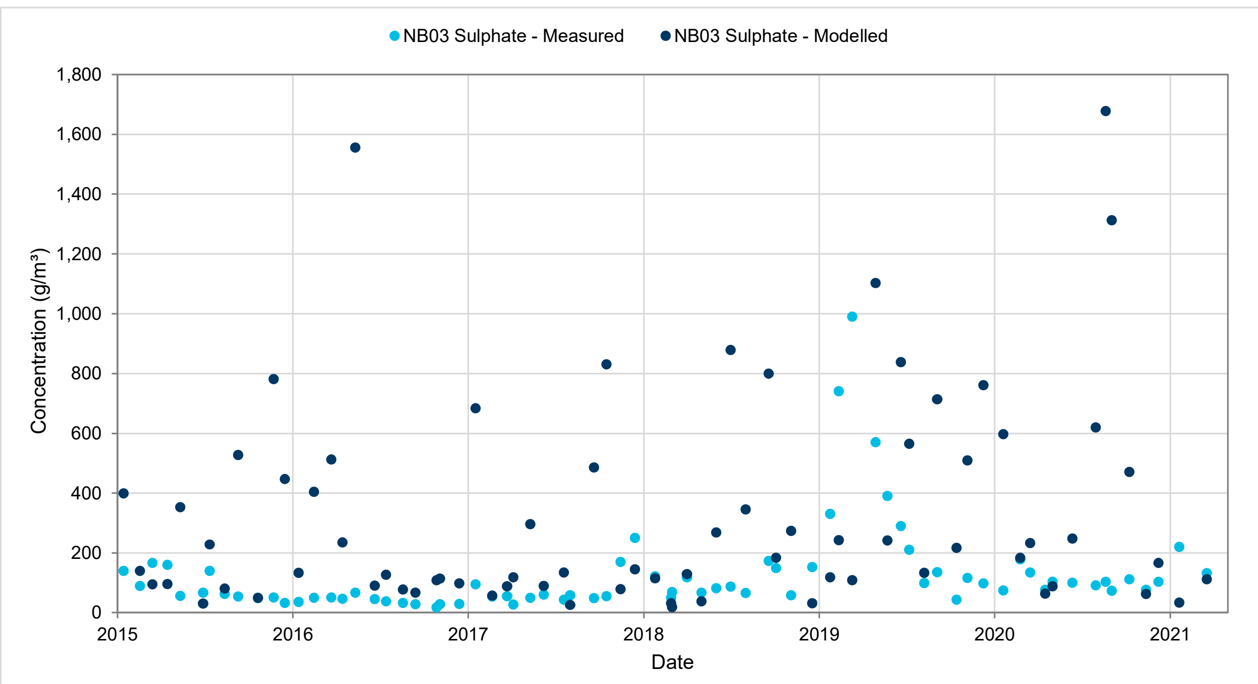

Figure 3 ***Historical rainfall calibration at NB03***

[2] Whitehead, A.L., Booker, D.J. (2020). NZ River Maps: An interactive online tool for mapping predicted freshwater variables across New Zealand. NIWA, Christchurch. https://shiny.niwa.co.nz/nzrivermaps/

A statistical comparison for NB01 and NB03, shown in Figure 4, indicates that the median concentrations agree and the modelled data represents a greater spread near the extremes of the data ranges. Differences in the upper and lower flow estimates (compared to the measured data) are likely due to:

- The model does not allow for active management of silt pond discharges (Murphys Creek and Frasers West Silt Ponds) to be applied and this is likely a factor contributing to the difference between modelled and measured results. It would typically be beneficial to discharge higher concentration water where flows in the receiving environment are high allowing for dilution and to avoid discharges when flows are low. The consequence is that modelled result will show higher peaks and lower lows than actual as seen in Figure 4.
- It is also likely that there is a higher base flow contribution to the river (less affected by seasonal variation) than that represented by the AWBM calibrated to a flow gauge on Deepdell Creek (with the calibration focussed on low flow periods) - there is no stream flow gauging data available in the lower reaches of the NBWR. The flow estimates given in Table 1 are higher than those represented by the model by a factor of two to three, indicating a possibility that the modelled flow underrepresents baseflow.

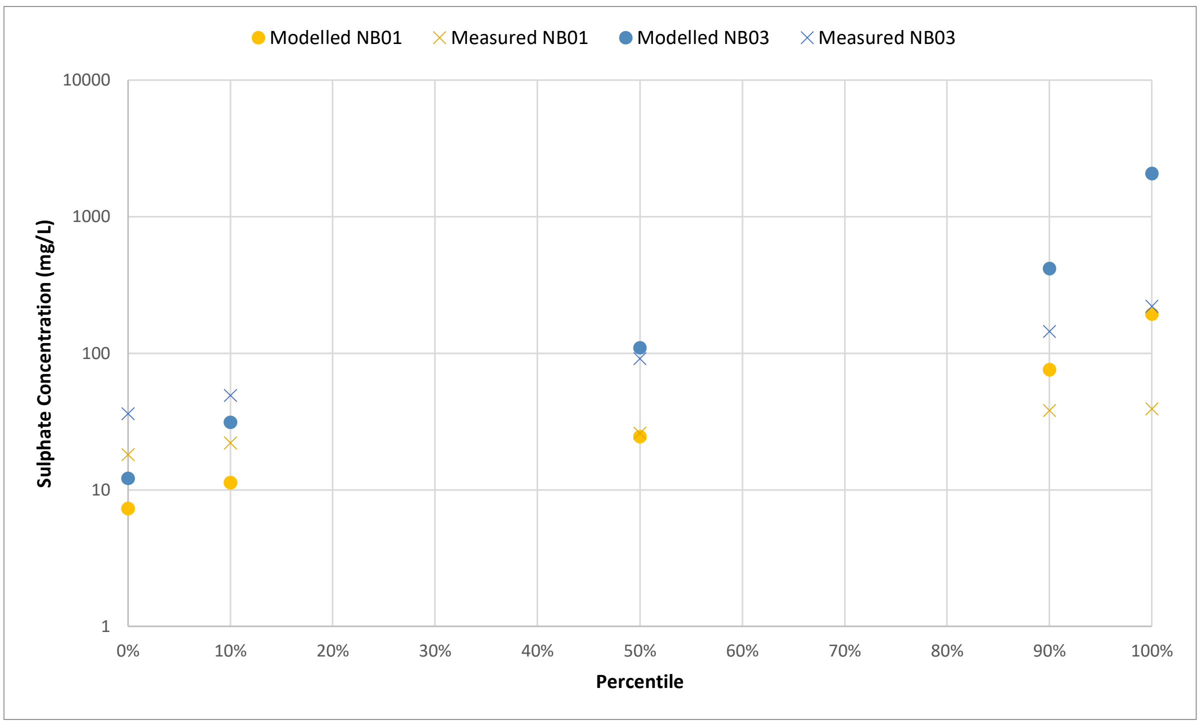

Figure 4 ***Synthetic statistical rainfall calibration at NB01 and NB03***

5. Dewatering assessment

5.1 Assessment rational

The current monitoring points downstream of Golden Bar Pit (GB02, NB01 and NB03. NB01 and NB03) are established compliance points and have limits set for water quality as shown in Table 2. For comparison, mean and maximum statistics for Golden Bar Pit water quality are included to identify constituents of concern for this assessment. Two constituents within the pit water exceed the existing NB03 compliance criteria - Arsenic and Sulphate, while the other constituents are an order of magnitude less. pH values fall within the defined range. Recent sampling (data provided by OGNZL) has investigated water quality variation with depth and results from this sampling are presented in Table 3. These two discrete sampling events indicate that the constituents considered are either maintaining or improving since the end of the data set presented in Table 2. For the latest sampling round it can be seen that Arsenic increases with depth, reaching 0.167 g/m^3 at the lower depth of 35 m.

Nitrate N and Ammoniacal N are not included within the existing consent constituents, however, are of growing interest. The National Policy Statement for Freshwater Management (2023)[3] (NPSFM) defines the highest attribute band (A) to have an annual median of ≤1.0 g/m³ for Nitrate N and ≤0.03 g/m³ for Ammoniacal N and these standards are currently met by water discharging from the lake. Based on this consideration these constituents are not assessed in further detail in this report.

Table 2 Current water quality compliance criteria at NB01 and NB03 and Golden Bar Pit water quality

Constituent (g/m³)	NB01 Compliance	NB03 Compliance	Golden Bar Pit Mean[1]	Golden Bar Pit Max[1]
pH	6.0-9.5	6.0-9.5	8.38 – 8.5 (range)	
Arsenic	0.15	0.01	0.15	0.19
Cyanide	-	0.1	-	-
Copper	0.009	0.009	0.0006	0.0007
Iron	1	0.2	0.02	0.02
Lead	0.0025	0.0025	0.0001	0.0002
Zinc	0.12	0.12	0.001	0.002
Sulphate	-	250	287	320
Nitrate – N	-	-	0.008	0.023
Ammoniacal Nitrogen	-	-	0.016	0.1

[1]. Calculated based on measured water quality data between 2015 and April 2022

Table 3 Golden Bar Pit Lake water quality sampling with depth

Depth (m)	pH (pH Units)	Arsenic g/m³	Copper g/m³	Iron g/m³	Lead g/m³	Zinc Tot. g/m³	Ammoniacal-N Tot. g/m³	Nitrate-N g/m³	Sulphate g/m³
Sampled: 31/03/2023									
1	8.4	0.127	< 0.0005	< 0.02	< 0.00010	< 0.0011	< 0.010	< 0.002	260
5	8.4	0.128	0.0005	< 0.02	< 0.00010	0.0014	< 0.010	< 0.002	260
10	8.4	0.127	< 0.0005	< 0.02	< 0.00010	< 0.0011	< 0.010	< 0.002	260
15	8.2	0.114	< 0.0005	< 0.02	< 0.00010	< 0.0011	< 0.010	< 0.002	260
20	8.1	0.115	< 0.0005	< 0.02	< 0.00010	< 0.0011	< 0.010	< 0.002	260
30	8	0.147	< 0.0005	< 0.02	< 0.00010	0.0014	0.029	0.081	260
35	8	0.167	< 0.0005	< 0.02	< 0.00010	0.0015	0.072	0.047	260
Sampled: 25/10/2022									
1	8.5	0.114	0.0006	< 0.02	< 0.00010		< 0.010	< 0.002	270
5	8.5	0.115	< 0.0005	< 0.02	< 0.00010		< 0.010	0.002	260
10	8.5	0.116	< 0.0005	< 0.02	< 0.00010		< 0.010	< 0.002	260
15	8.5	0.117	< 0.0005	< 0.02	< 0.00010		< 0.010	< 0.002	270
20	8.4	0.113	< 0.0005	< 0.02	< 0.00010		< 0.010	< 0.002	260
30	8.3	0.11	< 0.0005	< 0.02	< 0.00010		0.032	0.038	270
35	8.3	0.107	< 0.0005	< 0.02	< 0.00010		0.054	0.045	270

[3] NPSFW 2023. National Policy Statement for Freshwater Management 2000. Ministry for the Environment. February 2023.

5.2 Water balance modelling

Dewatering pumping scenarios are defined with the intent to dewater the pit within a timeframe of approximately 1 to 3 years. To achieve this, three scenarios are represented with dewatering pump rates of 30 L/s, 20 L/s and 15 L/s. Figure 5 shows the mean modelled Golden Bar pit pond levels for the three dewatering rates. Year 0 indicates the start of dewatering.

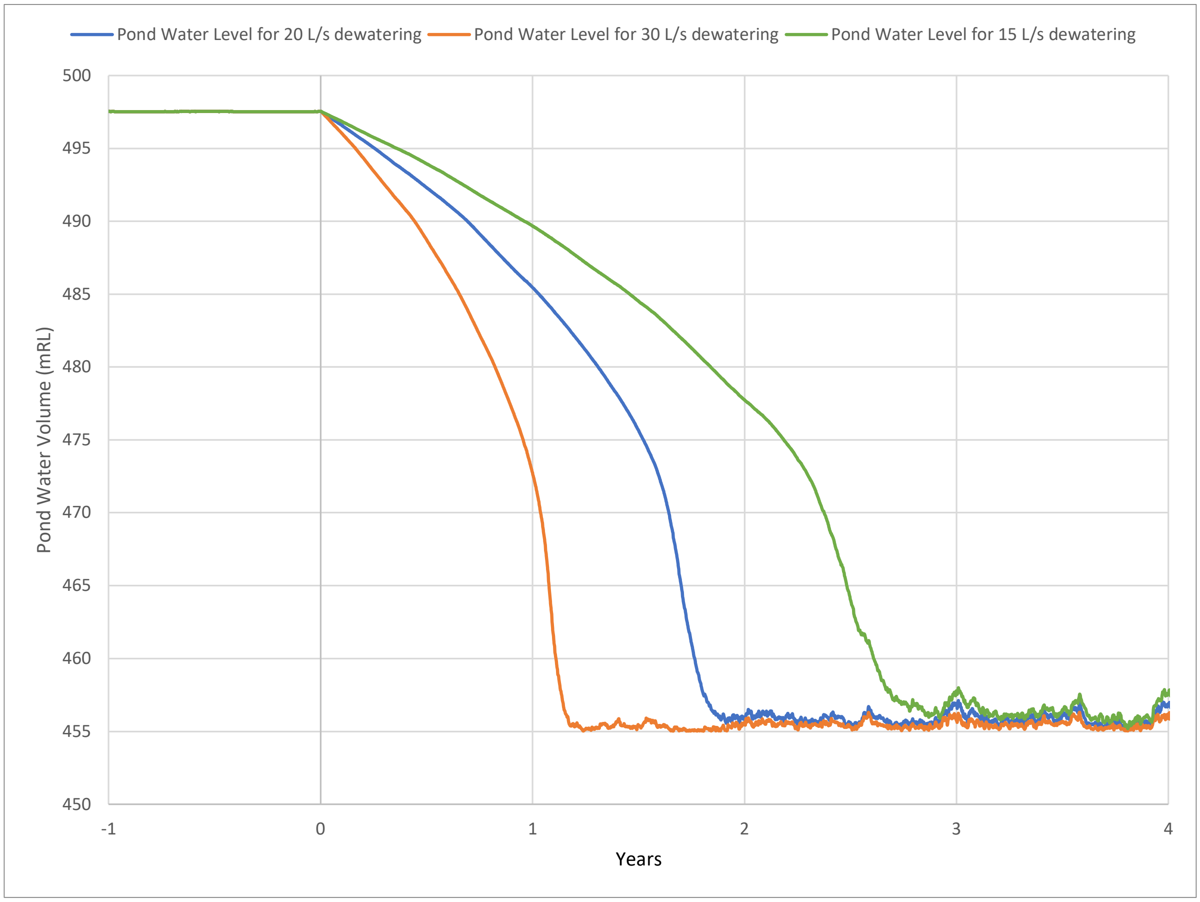

Figure 5 Pit water level over time with the proposed dewatering rates

Figure 6 shows the mean, 5th and 95th percentile pit water levels with a dewatering rate of 30 L/s. This is shown to allow for Golden Bar Pit to be dewatered in approximately 1 year. There is uncertainty with the dewatering duration based on the potential for different rates of rainfall and evaporation to occur during the chosen dewatering years.

There is not a large variation between the mean and the 95th percentile dewatering duration estimates, however uncertainty in groundwater inflow rates may affect this expected drawdown rate. On completion of the initial dewatering phase, modelling allows dewatering to continue to manage surface and groundwater flows entering the pit and fluctuations associated with this can be seen in the years following dewatering. It is noted that this does not represent the proposed Golden Bar Stage.2 pit expansion, and hence, the deepening of the pit (dewatering of the Stage 2 pit expansion is covered in GHD, 2023[4]).

[4] GHD 2023. Macraes Phase IV. Golden Bar – Surface and Groundwater Assessment. Draft Report 18 May 2023

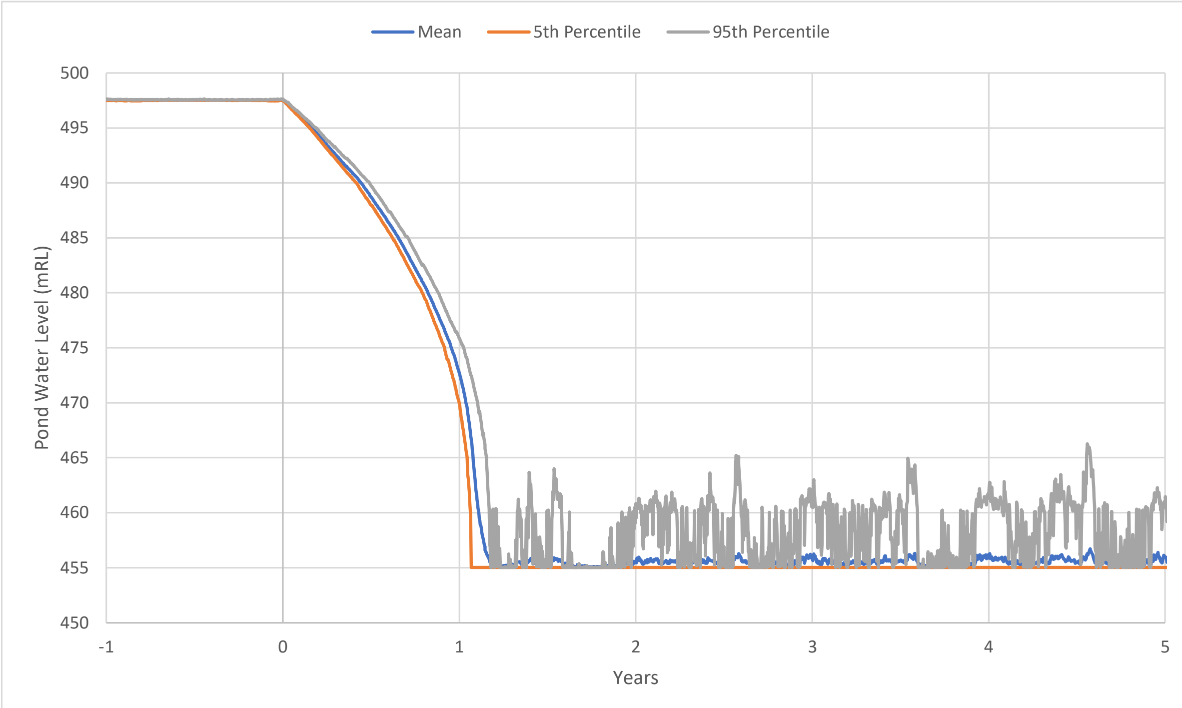

Figure 6 ***Pit water level over time for a dewatering rate of 30 L/s***

A dewatering rate of 20 L/s is estimated to allow for Golden Bar Pit to be dewatered in approximately 1.75 years as shown in Figure 7. There is a 3 month spread between the 5th and 95th percentile dewatering durations in this scenario. There is a larger variation between the average dewatering time and the 95th percentile dewatering time during the dewatering period compared to the 30 L/s dewatering rate. As dewatering occurs over a longer period it poses more opportunity for unpredictable weather events to affect the inflow volume into the pit during dewatering.

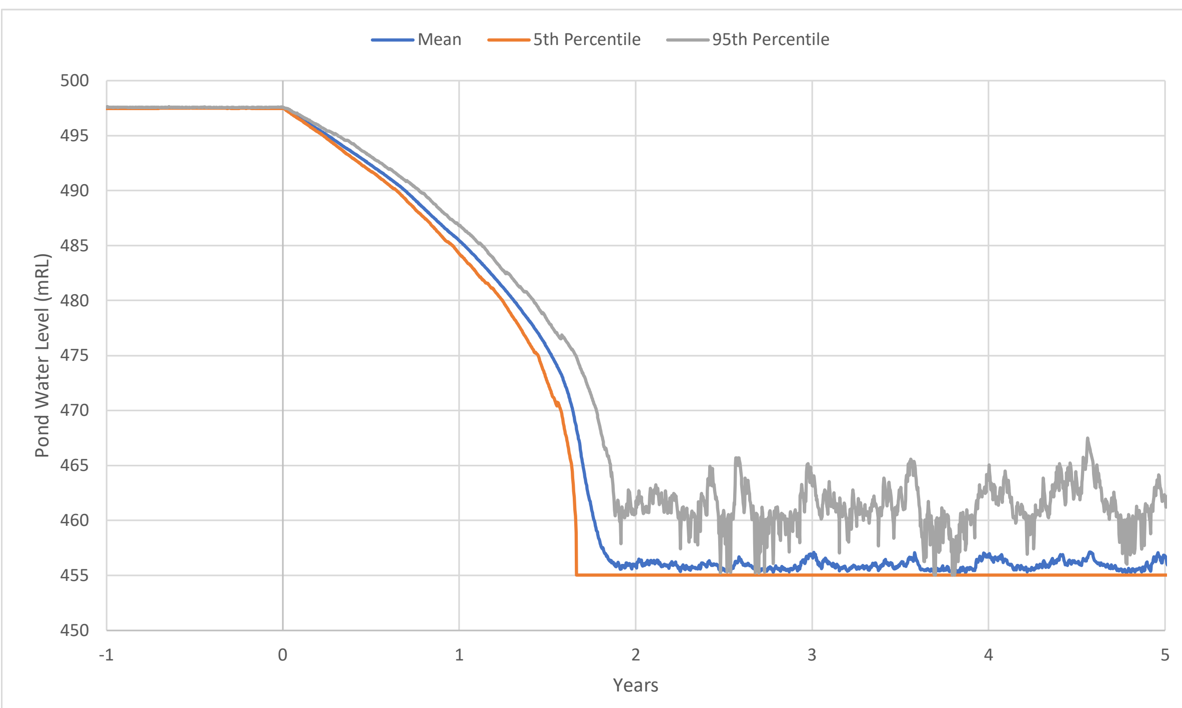

Figure 7 ***Pit water level over time for a dewatering rate of 20 L/s***

A dewatering rate of 20 L/s is estimated to allow for Golden Bar Pit to be dewatered in approximately 2.5 years as shown in Figure 8. The 5th to 95th percentile estimates have a spread of approximately 6 months, giving greater uncertainty when compared with higher dewatering rates. This follows the trend that shows greater uncertainties in dewatering time as the dewatering rate decreases.

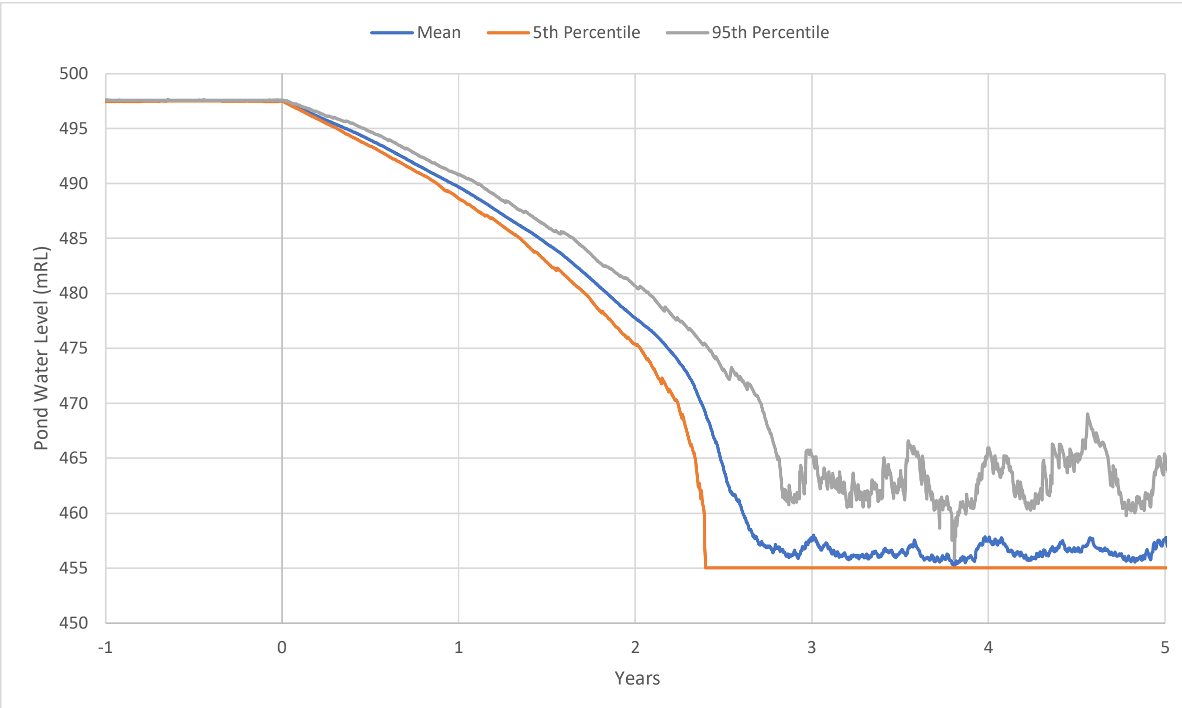

Figure 8 Pit water level over time for a dewatering rate of 15 L/s

The modelled flow statistics at GB02, NB01 and NB03 are presented in **Error! Reference source not found.**. The mean and median values are based on a representative hydrological year taken before dewatering commences (i.e. current conditions) and during dewatering for each of the proposed dewatering rates.

Table 4 Modelled flow rates at GB02, NB01 and NB03

Dewatering Scenario	GB02 Flow (L/s)		NB01 Flow (L/s)		NB03 Flow (L/s)	
	Median	Average	Median	Average	Median	Average
GB Pit overflowing (current)	2	5	11	29	89	229
Dewatering (30 L/s)	31	33	40	58	118	258
Dewatering (20 L/s)	21	23	30	48	108	248
Dewatering (15 L/s)	16	18	25	43	103	243

5.3 Water Quality

5.3.1 Sulphate

The yearly average, median and 95th percentile Sulphate concentrations at GB02, NB01 and NB03 have been calculated for each stage of dewatering and presented in Table 5. The modelling indicates that the established compliance limit for sulphate of 250 g/m³ would be exceeded by the 95th percentile water quality statistic for each of the scenarios. However, as discussed in Section 4 with the model calibration active management of discharges may play a role in this compliance limit being meet more regularly.

The modelling indicates that at the 95th percentile, water quality is likely to improve while dewatering is being undertaken. This is due to the pit water sulphate concentration being lower than the modelled inflows to NB03 via the NBWR upstream catchment. The effect of this can be seen in Figure 9 where dewatering at a rate of 30 L/s could reduce concentration above the 80th percentile while increasing the lower percentile concentrations. Similar is true at the lower dewatering rates with the cross over being at a higher percentile.

Table 5 Sulphate concentration statistics at GB02, NB01 and NB03

Dewatering Scenario	GB02 Sulphate (mg/L)			NB01 Sulphate (mg/L)			NB03 Sulphate (mg/L)		
	Median	Average	95th	Median	Average	95th	Median	Average	95th
GB Pit overflowing (current)	108	115	238	25	35	91	109	180	572
Dewatering (30 L/s)	273	264	283	213	195	271	154	174	377
Dewatering (20 L/s)	273	260	284	191	178	268	141	170	402
Dewatering (15 L/s)	270	255	284	173	164	263	133	168	419

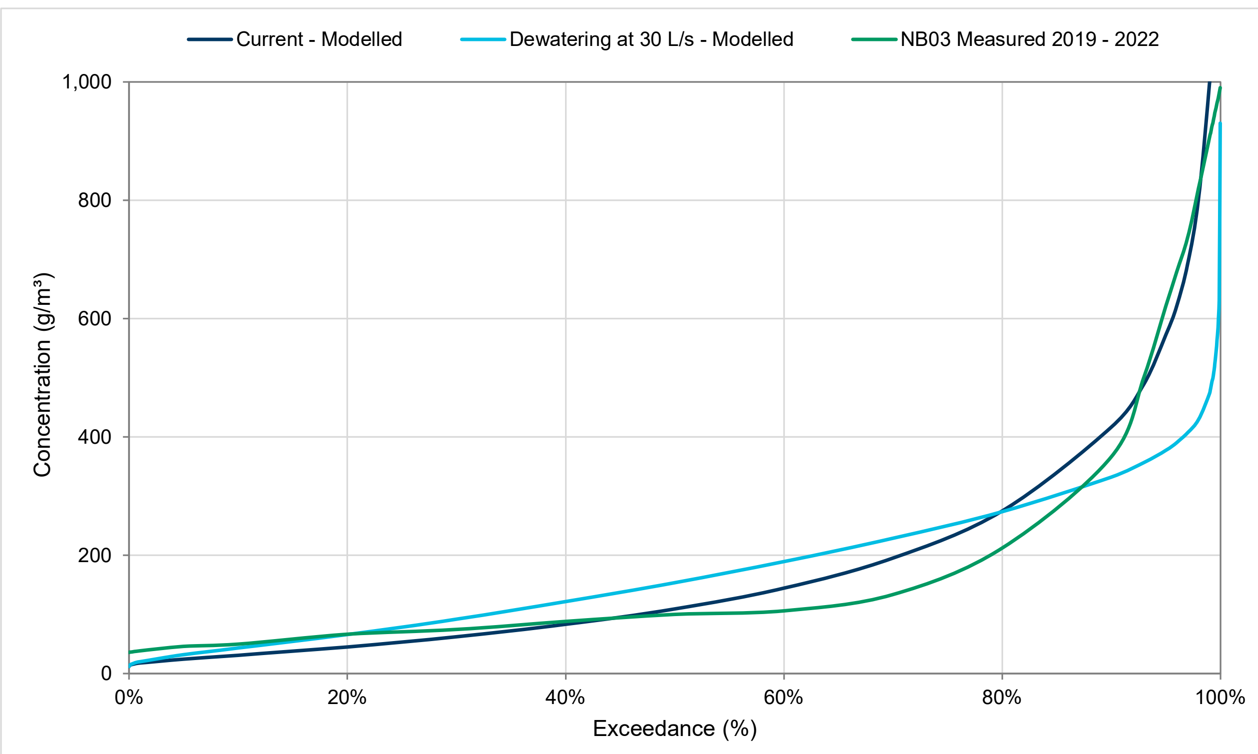

Figure 9 Modelled and measured sulphate concentrations at NB03 for a dewatering rate of 30 L/s

5.3.2 Arsenic

Arsenic levels within the pit lake are currently just below the compliance criteria of 0.15 g/m³ at GB02, however, exceed the NB03 criteria of 0.01 g/m³. Using dilution alone is unlikely to consistently allow discharge from the pit at the proposed dewatering rates while meeting the existing compliance levels defined at NB03 as outlined in this section. However, interventions could be made to improve the discharge regime or reduce Arsenic loads at the source.

The yearly average, median and 95th percentile Arsenic concentrations at GB02, NB01 and NB03 have been calculated for each stage of dewatering and presented in Table 6. The modelling indicates that the established compliance limit for Arsenic of 0.01 g/m³ would be exceeded regularly for each of the scenarios without other interventions being applied and, on this basis, the constant discharge may not be a suitable approach. Possible interventions to maintain Arsenic concentrations below 0.01 g/m³ at NB03 could include:

When operating under the 15 L/s dewatering scenario, modelling indicates that the compliance for Arsenic at NB03 would be met approximately 20% of the time. Dewatering rates would need to be reduced or ceased for the remaining 80% of days to meet the existing compliance limit. This would likely prolong the dewatering timeline significantly. Treatment of Golden Bar Pit Lake prior to commencing dewatering could be undertaken. OGLNZ has successfully carried out ferric dosing (utilising ferric chloride) at the Globe Pit Lake near Reefton to reduce Arsenic concentrations prior to the lake reaching overflow. A similar method could potentially be deployed at Golden Bar Pit Lake to reduce Arsenic concentrations to near or below the 0.01 g/m³ value which could reduce the influence this has on the dewatering regime.

Table 6 Arsenic concentration statistics at GB02, NB01 and NB03

Dewatering Scenario	GB02 Arsenic (mg/L)			NB01 Arsenic (mg/L)			NB03 Arsenic (mg/L)		
	Median	Average	95th	Median	Average	95th	Median	Average	95th
GB Pit overflowing (current)	0.054	0.058	0.123	0.010	0.015	0.045	0.004	0.005	0.009
Dewatering (30 L/s)	0.143	0.138	0.148	0.111	0.101	0.142	0.039	0.045	0.103
Dewatering (20 L/s)	0.143	0.136	0.148	0.099	0.092	0.140	0.030	0.037	0.090
Dewatering (15 L/s)	0.141	0.133	0.148	0.089	0.085	0.137	0.024	0.031	0.080

6. Recommendations and conclusion

This modelling has shown that through applying scenarios with constant dewatering rates of 30 L/s, 20 L/s and 15 L/s the Golden Bar Pit could be dewatered in 1.25, 1.75 and 2.5 years respectively, with an uncertainty of approximately ± 3 months at the lower dewatering rate. Under these dewatering scenarios the constituents Sulphate and Arsenic are at concentrations within the pit that could pose a risk of exceedance to the established consent criteria downstream of the pit. This work does not seek to define water quality compliance exceedance risks at established compliance points while the site is under active management as silt pond discharge controls can result in better outcomes than those modelled. However, it has identified how the proposed discharges may change the water quality in the receiving environment. With respect to Sulphate and Arsenic, management options that would enable the proposed dewatering to be undertaken include:

- Manage discharge to reduce the risk of exceeding the existing compliance criteria for Sulphate at the NB03 monitoring point. This would include active management of discharges to the upper North Branch Waikouaiti River and Murphys Creek catchments as is currently undertaken, then ceasing or reducing dewatering where concentrations upstream of the Golden Bar Creek and/or North Branch Waikouaiti River confluence do not allow for some level of dilution at NB03. Applying this strategy would likely increase the dewatering times by 20% or more depending on the efficiency of the operation and climatic conditions at the time.

- Manage discharge to reduce the risk of exceeding the existing compliance criteria for Arsenic as described previously outlined for Sulphate. This would require more active intervention than for Sulphate as a greater level of dilution is required and would likely increase the dewatering timeline significantly.
- Manage in pit Arsenic concentrations through treating pit lake waters prior to commencing dewatering operations. This would be done with the aim of reducing in pit lake concentrations to a point where a similar dilution is required to achieve Arsenic compliance in the receiving environment as required for Sulphate compliance.

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