

To:	Stantec
From:	Agrimin Technical Team
Subject:	Island Impacts Groundwater Memo – 20yr LOM Scenario
Date	24 November 2021
Version	RevC

1. Lake Groundwater Levels

The near flat nature of the surface of Lake Mackay over a vast distance result in very low horizontal groundwater flow gradients, ranging from 0.0002 meters/metre (m/m) at the western edge of the lake to 0.00002 m/m in the centre of the lake with an average of approximately 0.000045 m/m across the lake in a northwest to southwest direction (Stantec 2020) (Figure 1 and 2).

Long term (> 4 years) groundwater level data from 11 monitoring bores across the lake plus shorter term (< 2 years) (Figures 3 and 4) monitoring of groundwater in trenches and associated monitoring piezometers, have recorded fluctuations in groundwater levels over a range of approximately 0.4 to 0.7 meters below the lake surface. The average depth to groundwater across the lake at the end of the 2019 wet season was approximately 0.40m below ground level or 360.93m AHD. At the end of the 2019 dry season the average depth to groundwater was 0.70m below surface or 360.62m AHD. The average water level fluctuation (across 51 monitoring bores) between the 2019 wet and dry season was 0.31m. The average depth to groundwater below surface was 0.55m for the 2019 wet and dry season.

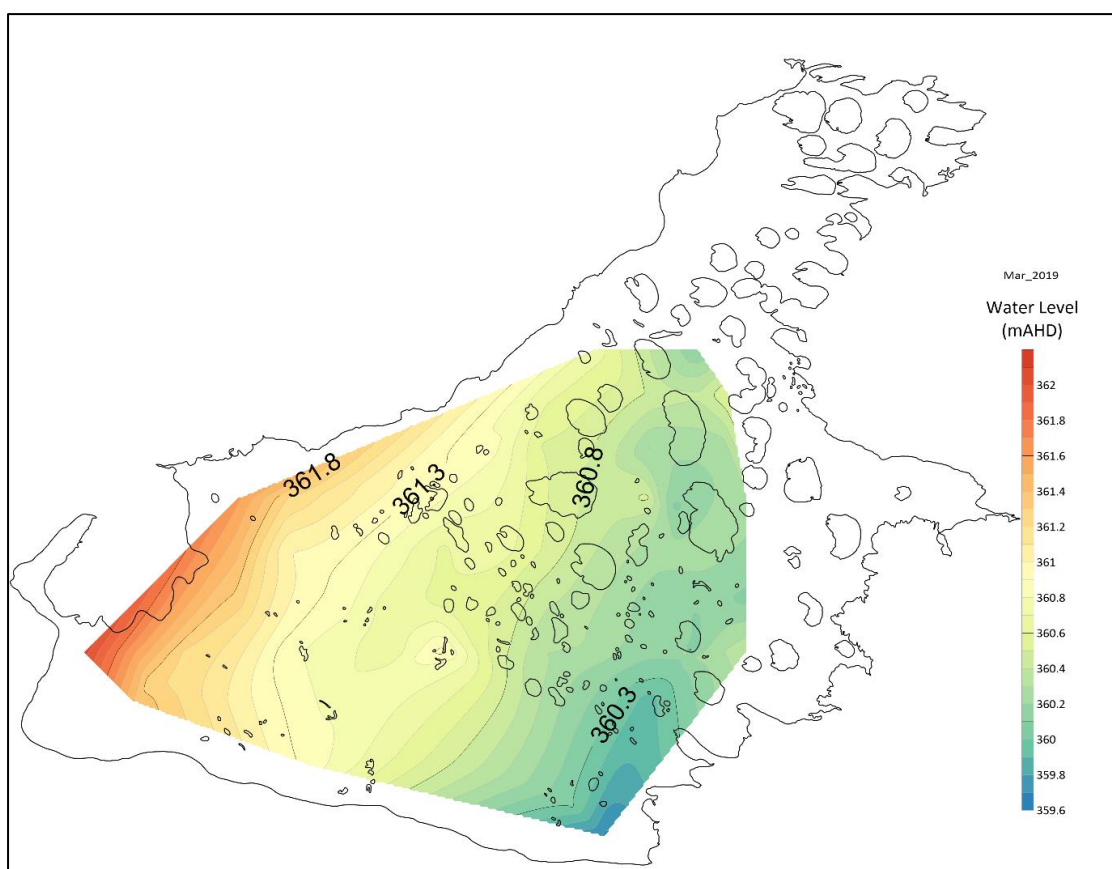


Figure 1: March 2019 groundwater contour map

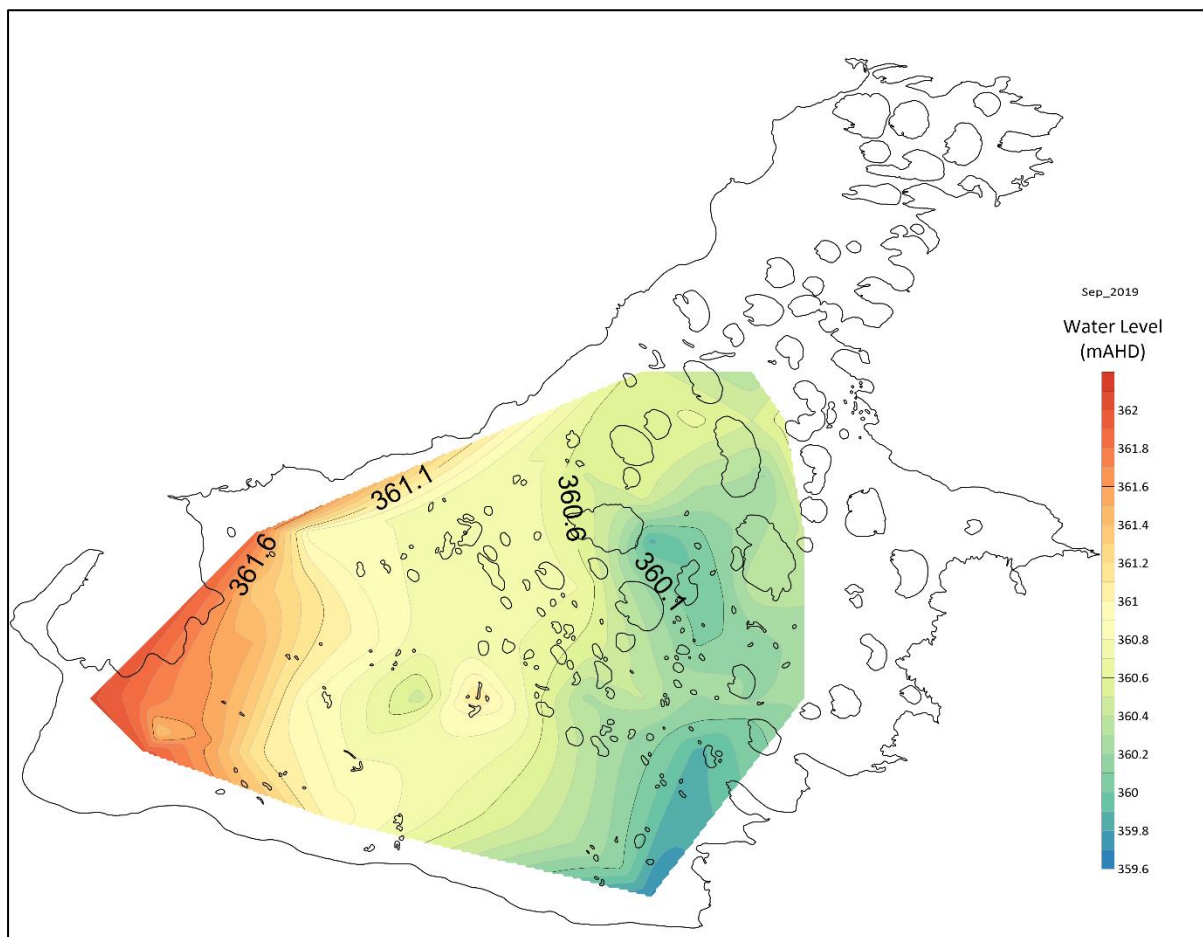


Figure 2: September 2019 groundwater contour map.

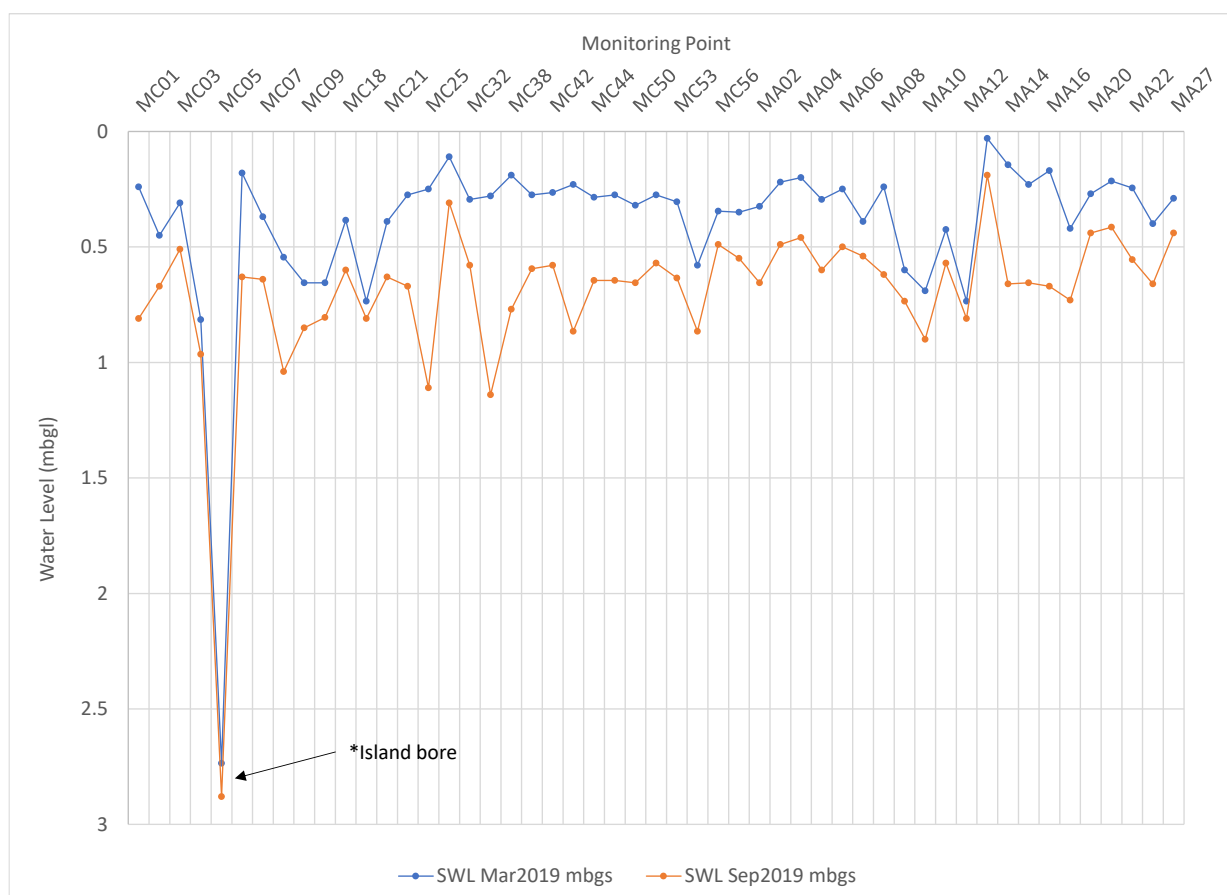


Figure 3: 2019 Seasonal water levels (m bgl)

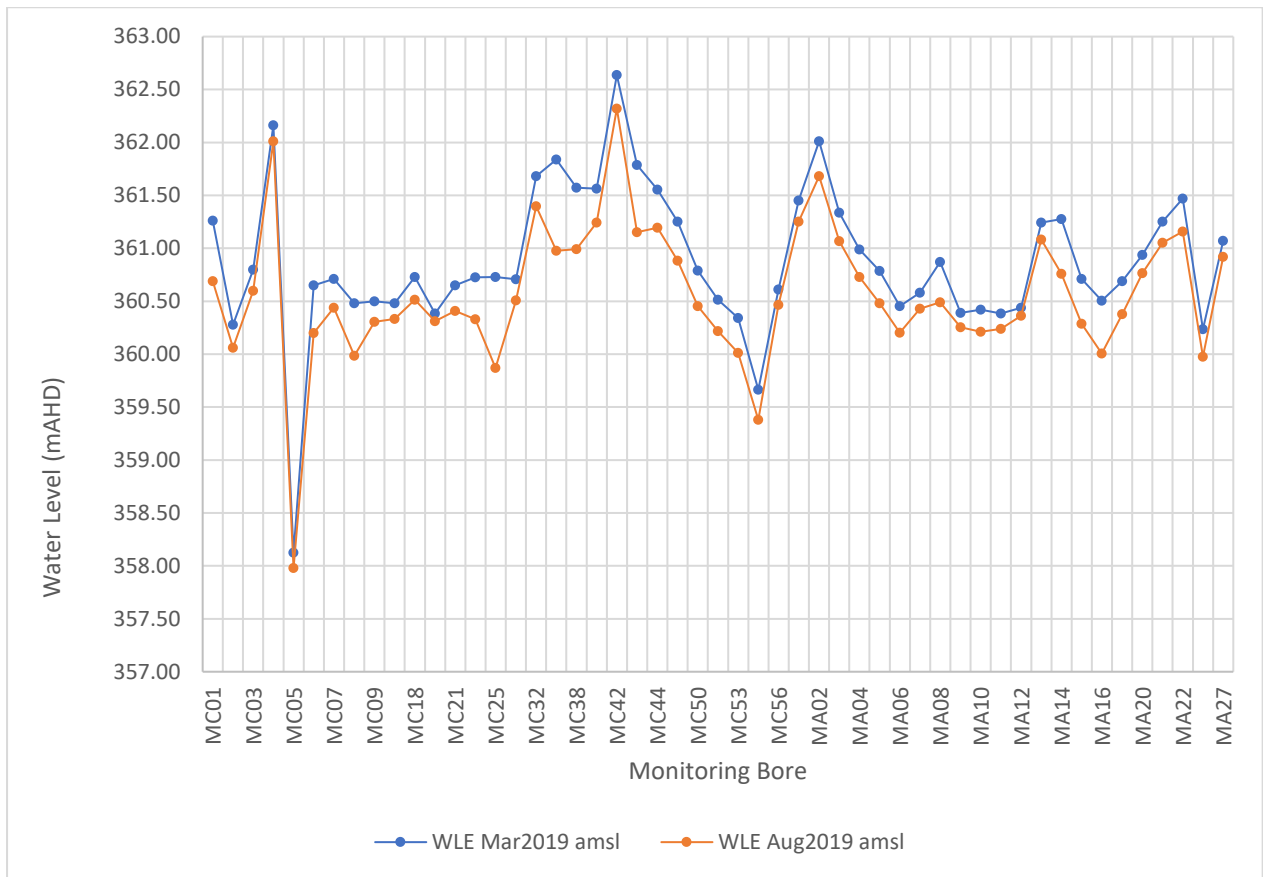


Figure 4: 2019 Seasonal water levels (mAHD)

Summary (Baseline Conditions excluding Island Bore MC05)

	March 2019 Wet Season Water Levels (mAHD)	Sept 2019 Dry Season Water Levels (mAHD)	2019 Water Level (mAHD)	March 2019 Wet Season (mbgl)	Sept 2019 Dry Season (mbgl)	Year (mbgl)
MIN	359.66	359.38		0.03	0.19	
MAX	362.64	362.32		0.815	1.14	
Mean	360.93	360.62	360.72	0.35	0.66	0.55

2. Long Term Seasonal Fluctuations in Groundwater Levels

There is a strong correlation between groundwater fluctuations and seasonal rainfall across the lake. Lake groundwater levels tend to sharply increase in response to the first major rainfall event of the wet season. As the rainfall frequency decreases toward the end of the season, the lake groundwater levels begin to recede in response to groundwater discharge via evaporation. This gradual decline in water levels continues until the cycle resets at the commencement of the following wet season.

The long-term hydrographs show an overall declining groundwater trend in the water levels over the wet season/dry season cycles over a four-year monitoring period. This trend has been attributed to a large, regional rainfall event of >200mm recorded in December 2016 that led to lake inundation and, the below average rainfall received in the region since wider groundwater monitoring began in 2017. The 25-year average rainfall for the region is 290.5 mm (BOM, 2020). Rainfall for the previous two years of monitoring has been significantly below average, with 169 mm received in 2018 and 30.4 mm for 2019. Data for the 2020 period is not yet complete, however; to date the amount of rainfall received has been below average.

On-lake groundwater trends and the influence of rainfall typically seen across the lake, are shown in the hydrograph example in Figure 5.

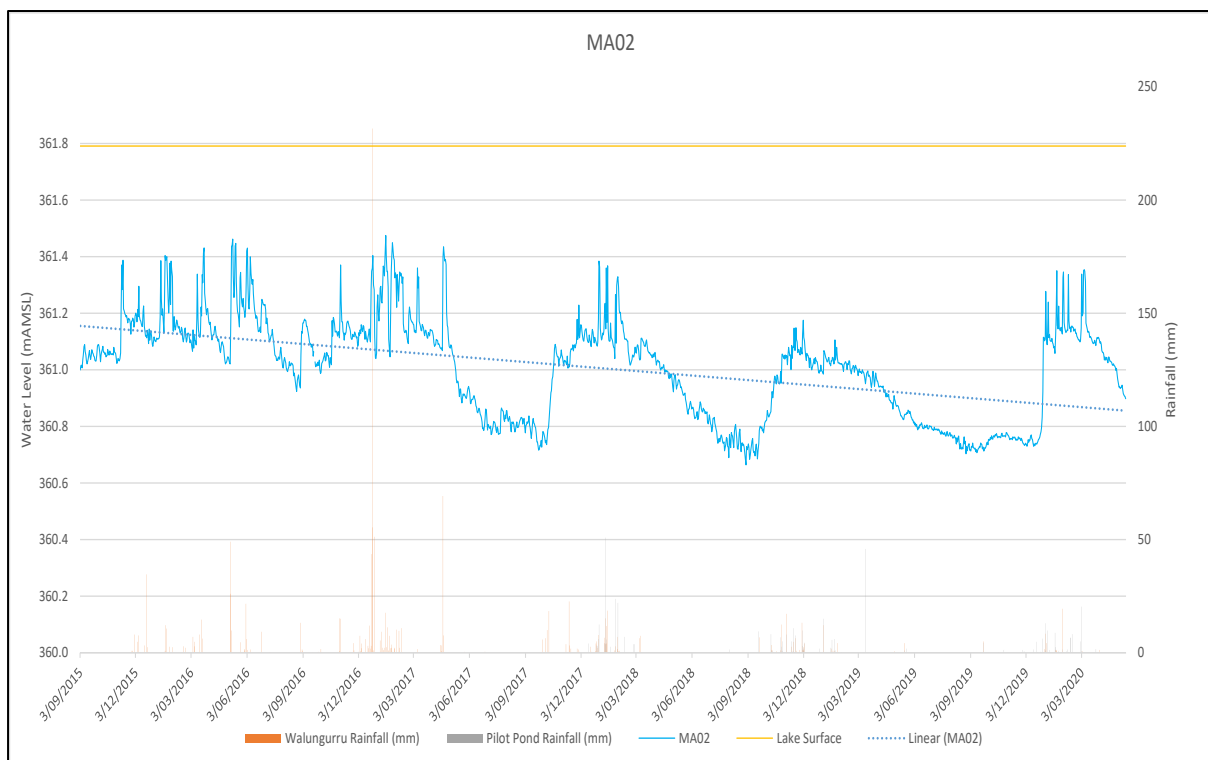


Figure 5: MA02 Hydrograph

Hydrographs for bores located on lake islands (MC13 and MC05) do not display the same sharp level increases in response to rainfall events; however, MC05 has shown a sharp response to a single rainfall event (Figure 6). The two island bores are not directly influenced by surface inundation due to their elevation above the surface of the lake and relative increased depth to groundwater.

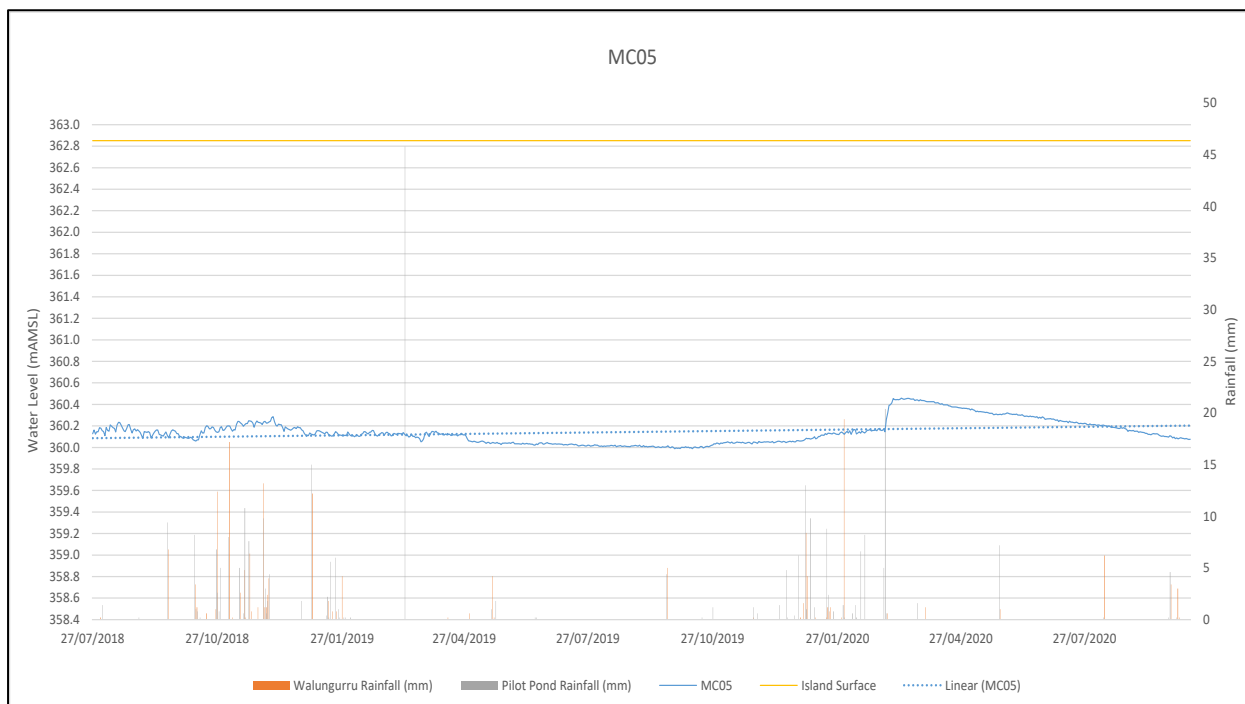


Figure 6: MC05 Hydrograph (island monitoring bore)

3. BMU Implementation

A numerical groundwater flow and mass transport model was constructed for mine planning and reserves determination (Stantec 2020). Mine planning was facilitated by the implementation of Brine Mining Units (BMU's) operating on variable schedules over the 20-year LoM. BMUs represent the trenching network in portions of the lake required to extract brine of economical potassium grade over the 20-year LoM. Water levels within the trench network of operating BMU's will be drawn down to a sustained level of approximately 3 metres below lake bed surface in the trenches themselves which in turn, will result in the drawdown of water levels between the trenches.

The BMUs are categorised by the hydrological properties and potassium grade of the area of the lake they cover. The initial BMU implementation will commence in the southern section of the lake. Further staging of BMU construction will be generally from south to north. All 17 BMU's are constructed over a period of 17 years and are operating on a variable schedule over the 20-year LoM. The operations schedule of individual BMUs is shown in Table 1 below, and the full BMU network is shown in 7.

Table 1: BMU mine plan schedule

MINE PLAN SCHEDULE		
BMU	Start of Pumping	Stop Pumping
	Mine Year	Mine Year
1	11	20
2	3	20
3	1.8	20
4	13	20
5	5	20
6	1	20
7	1	20

MINE PLAN SCHEDULE		
BMU	Start of Pumping	Stop Pumping
	Mine Year	Mine Year
8	7	20
9	1	20
10	14	20
11	9	20
12	1.3	20
13	16	20
14	2.1	20
15	1	20
16	18	20
17	1.5	20

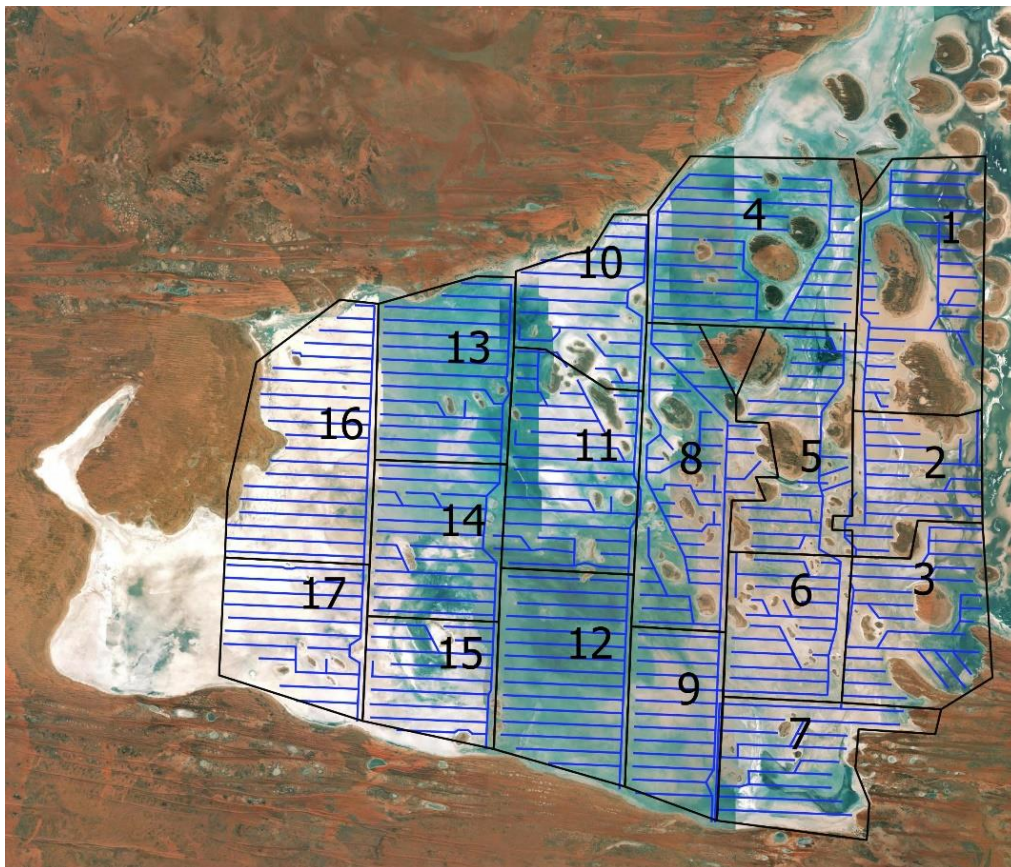


Figure 7: The Full BMU network after 17 years of construction

4. Drawdown from Brine Abstraction

The vast expanse of Lake Mackay, the associated variability in hydrogeological properties, and the BMU operating schedule results in drawdown depths and water level recovery varying spatially and temporally across the lake. Water levels (and drawdown) will fluctuate across the lake over the 20-year LoM. These fluctuations are attributed to:

- Varying pumping rates within individual BMU's to optimize flow and brine grade to the evaporation ponds.
- Adjacent BMU's starting up as per the mine plan.

Groundwater abstraction from a typical borefield results in drawdown, both vertically and laterally within an aquifer. These physical parameters are in general, readily modelled and easily described due to the "usual" close proximity of the abstraction bores within a borefield. The abstraction of brine from trenches over a vast area (2,340km²) and over 20 years, with several influencing factors including staged abstraction, periods of lower or higher pumping rates, rainfall, recharge, and evaporation, all contribute to a large data set of water levels.

The numerical groundwater model constructed for mine planning and reserve determination was applied to assess drawdown across the lake. The model was run to simulate groundwater flow and mass transport during the 20-year period of mining operations and an additional 20-year period of post-mining water level recovery. The groundwater model domain for the detailed mine planning scenario consisted of 50m x50m model cells and 5,617,260 active cells.

Lake wide drawdown statistics for the four recharge zones (Stantec 2020) are presented in Table 2, while the position of the recharge zones is shown in Figure 8. The statistics for each zone provide a snapshot of the drawdown at time intervals throughout the operational mining period, these are mine year 5, 10, and 20.

In addition to lake wide drawdown, Table 2 also provides the percentage of the brine aquifer impacted by drawdown and is calculated based on the resource model brine aquifer thickness of 10.5m which corresponds to the saturated zone of the UZT and UZB (see Appendix A).

Table 2: Drawdown statistics for the lake zones

Zone and Drawdown		Year 5	Year 10	Year 20
ZONE 1	Maximum drawdown (m)	2.79	2.54	2.07
	Average drawdown (m)	0.57	0.52	0.41
	Percentage of aquifer impacted	5%	5%	4%
ZONE 2	Maximum drawdown (m)	3.00	3.00	2.73
	Average drawdown (m)	0.58	0.57	0.47
	Percentage of aquifer impacted	6%	5%	4%
ZONE 3	Maximum drawdown (m)	2.90	2.65	2.43
	Average drawdown (m)	0.53	0.81	0.59
	Percentage of aquifer impacted	5%	8%	6%
ZONE 4	Maximum drawdown (m)	2.64	2.39	1.68
	Average drawdown (m)	0.75	0.73	0.74
	Percentage of aquifer impacted	7%	7%	7%

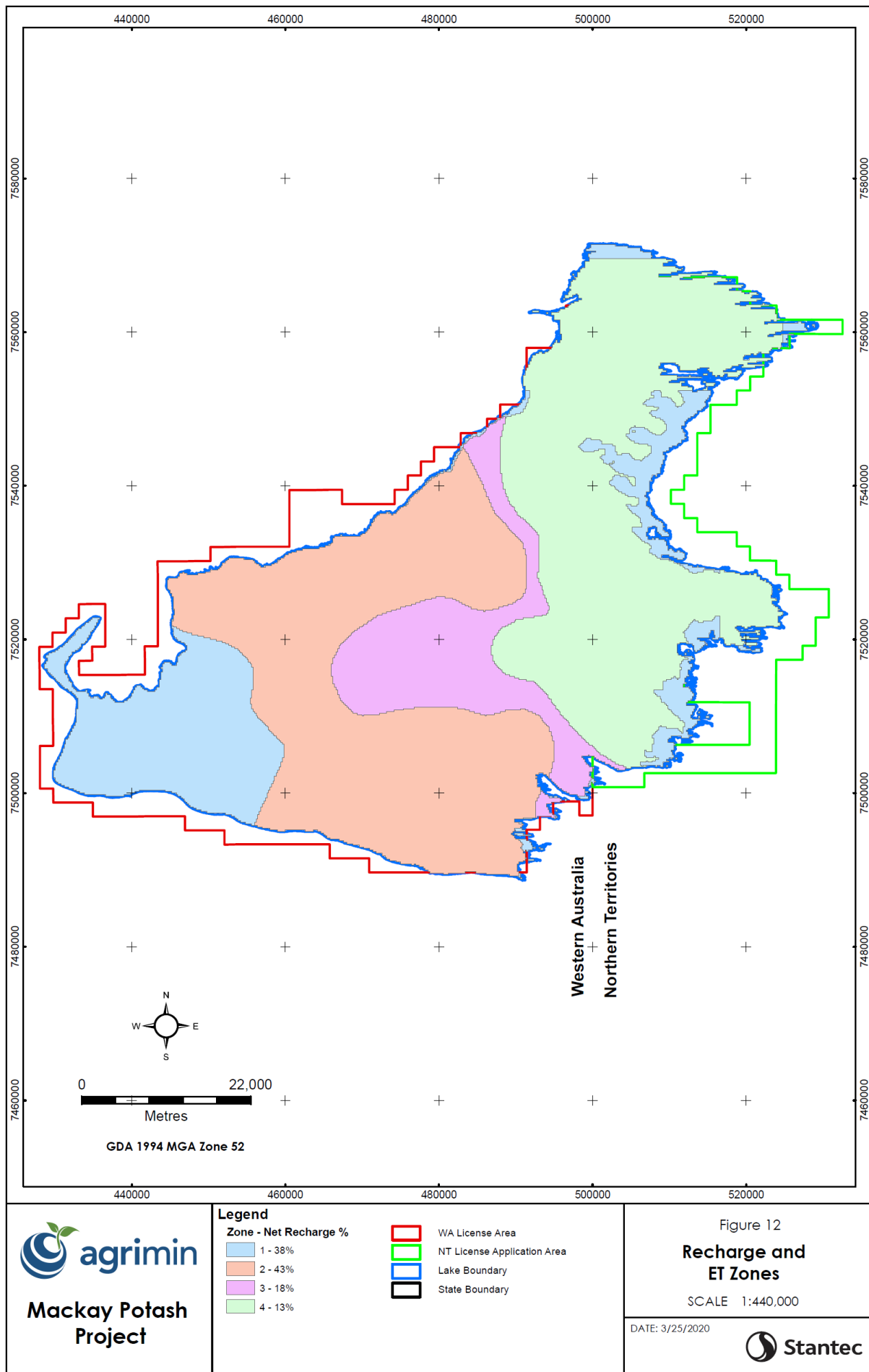


Figure 8: Zonation of lake surface (from Agrimin DFS)

To provide indication of the variability of drawdown across the lake, 3 areas are focused on as detailed below.

4.1 Regional Lake Groundwater Drawdown

Figure 9 and Figure 10 show drawdown over the production area of Lake Mackay at year 10 and year 20 of the mine plan. The BMU rollout commences in the southern region of the lake and by mine year 10 has progressed into the western, eastern, and northern sections of the lake. At the start of mine year 10, a total of 13 out of 17 BMU's will be in operation. Mine year 20 drawdown represents the drawdown levels at the end of brine abstraction from the brine resource.

As brine abstraction progresses along the southern and western portions of the lake during the first 10 years of development, maximum drawdown reaches 2.7m in zone 1 and 3m in zone 2 within the immediate vicinity of the trenches. Drawdown is generally between 0 to 1.5m in the areas between trenches (infiltration trenches are 1km apart) and the average drawdown across these 2 zones at year 10, is 0.54m. At year 20 the average drawdown across these 2 zones is 0.43m.

As abstraction of brine progresses to the north and east and into the higher hydraulic conductivity/lower recharge zones in the eastern portion of the production area, drawdown of up to 3m is expected at the trenches and between 0m and 1.8m between trenches. The average drawdown across zones 3 and 4 at mine year 10 is 0.77m and at mine year 20, is 0.66m. Across the entire mine plan model domain (zones 1-4), the average drawdown in year 5 is 0.61m, in year 10 is 0.66m, and in year 20 is 0.55m.

To quantify the drawdown in terms of impact on lake-wide regional groundwater levels, drawdown as a percentage of the brine aquifer thickness (saturated UZ zone of the resource model) has been assessed. Over the entire 20-year LoM and across all 4 net recharge zones these values range between 4-8%.

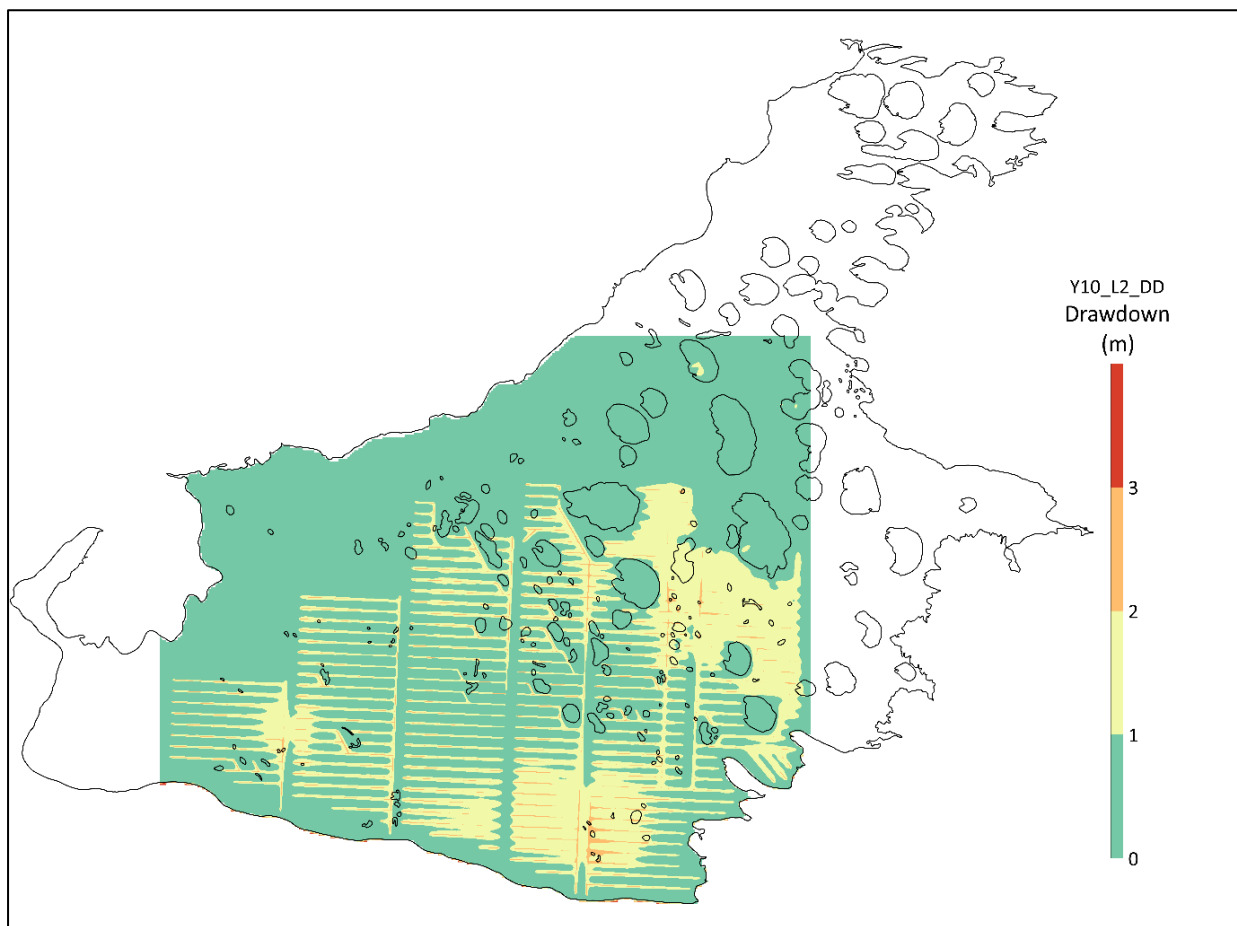


Figure 9: Year 10 drawdown contour plot

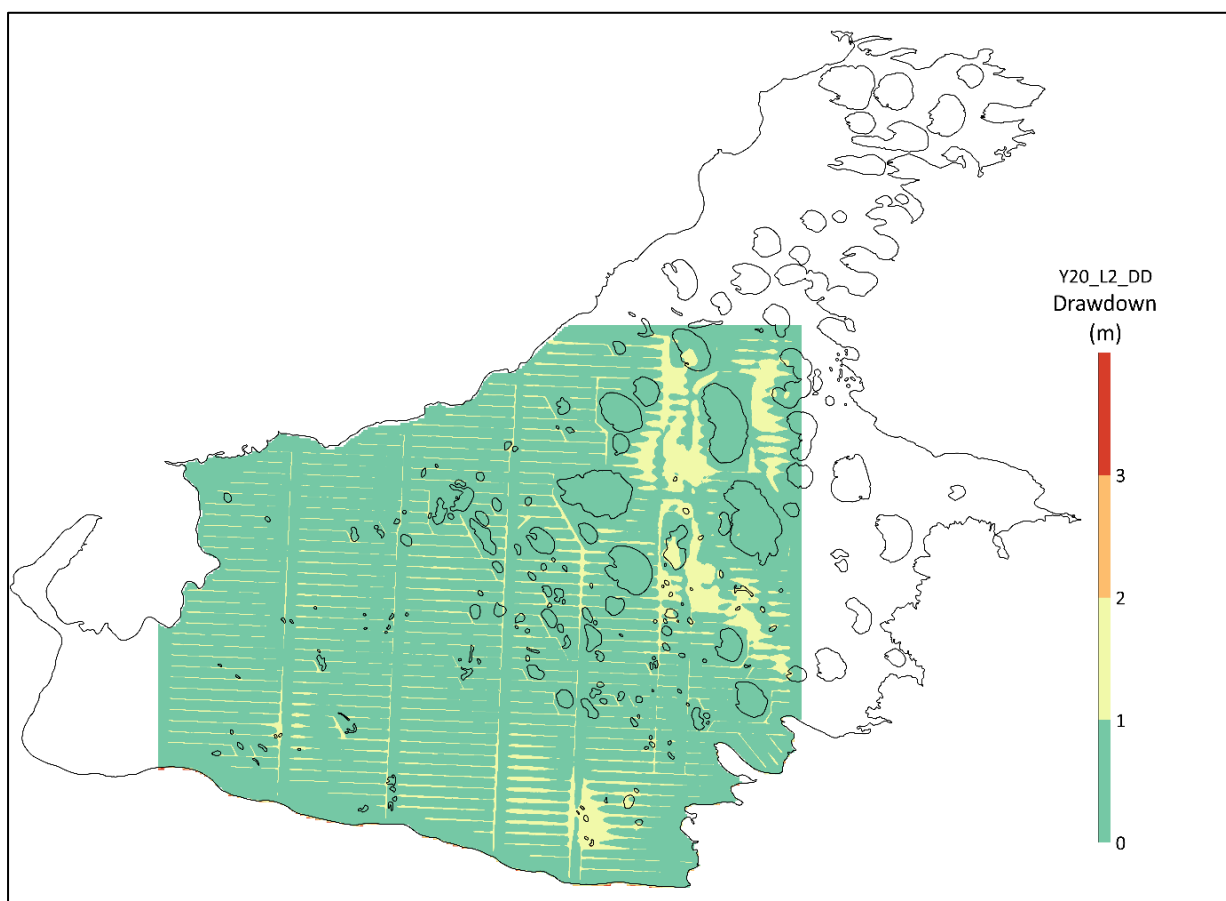


Figure 10: Year 20 drawdown contour plot

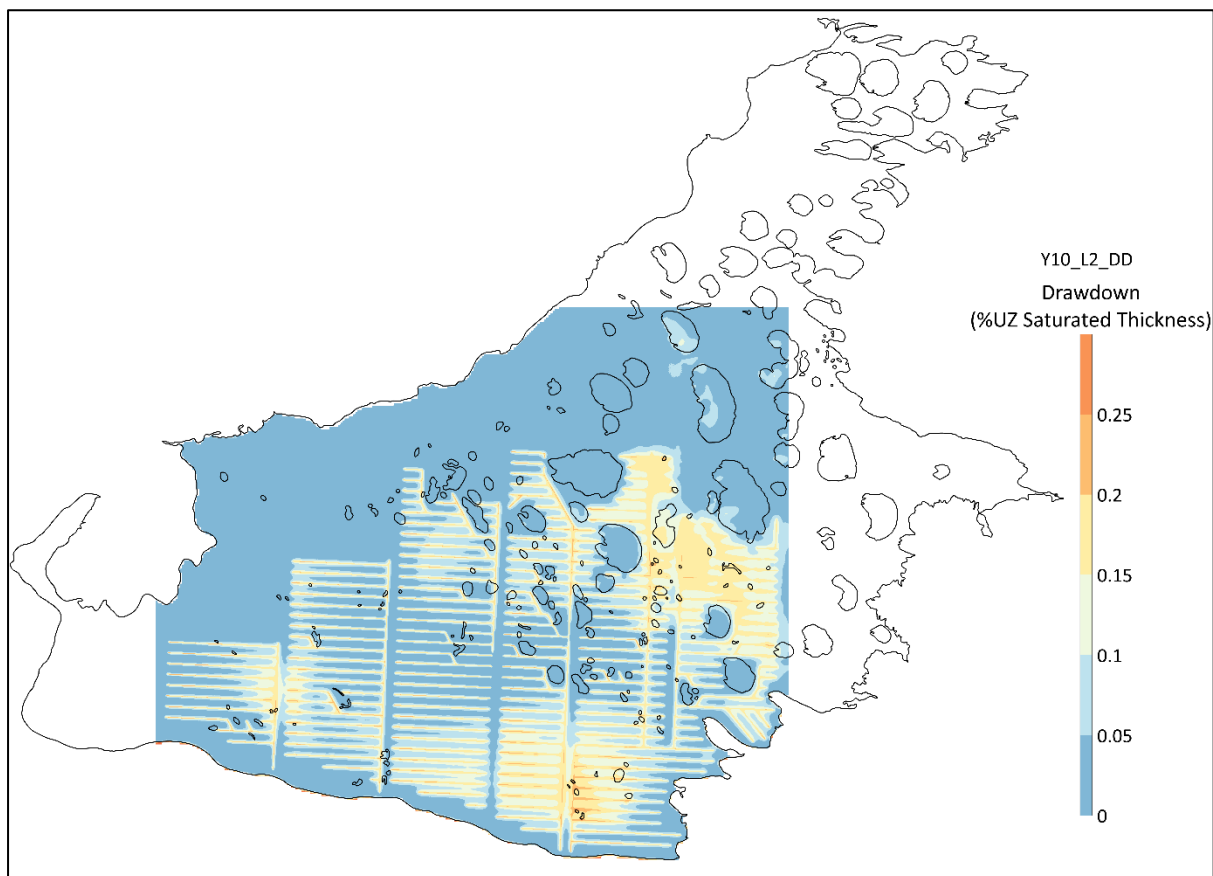


Figure 11: Drawdown as % Saturated Thickness in Year 10

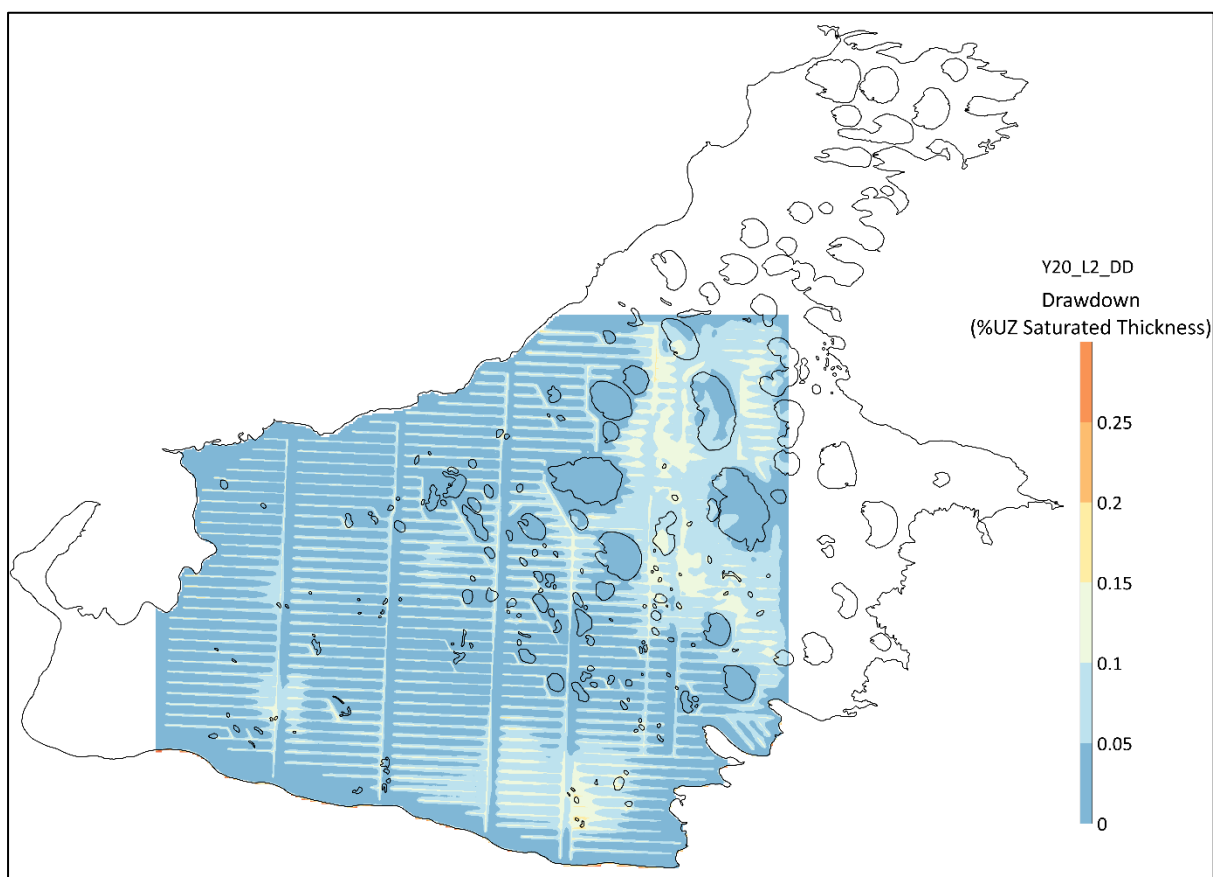


Figure 12: Drawdown as % Saturated Thickness in Year 20

4.2 Central Lake Area (BMU11)

Figure 13 shows a representative hydrograph from a location midway between infiltration trenches in BMU11 located within the central portion of the production area (Figure 7). The hydraulic conductivity in the central and western portions of Lake Mackay (Zones 1 & 2) is lower than in the east and net recharge is higher. As seen in Figure 13, there is no drawdown at this location until the BMU is brought into production in Mine Year 9. After 1 year of operation, the drawdown is 0.53m and reaches a maximum of 0.61m at mine year 12. The drawdown fluctuates (decreases) as pumping levels in this BMU (and surrounding BMU's) are adjusted through years 12-20. Abstraction ceases in BMU11 after mine year 20 and water levels recover to pre-brine abstraction levels within 1 year.

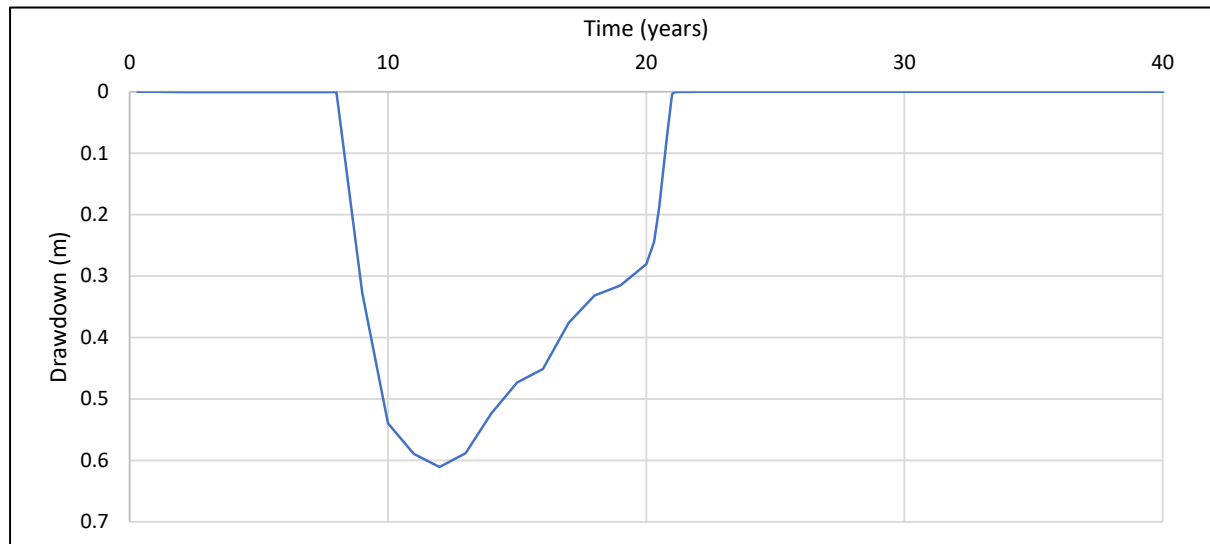


Figure 13: BMU 11 drawdown

4.3 Eastern Lake Area (BMU01)

Figure 14 shows a representative hydrograph in BMU01 near the shore on an island in the eastern portion of the production area (Figure 7). Hydraulic conductivity in the east is much higher than in the central and western portions of the lake, but net recharge is lower due to increased evaporation of stored water. Production begins in BMU01 in mine year 10 and ceases after mine year 20. The water level in the lake bed sediments beneath the island at this location drops approximately 10 cm in the first two years of operation of BMU01 and fluctuates as the pumping level in the BMU is adjusted until production stops after year 20, at which time the water begins to recover and reaches pre-brine abstraction levels after approximately 7 years.

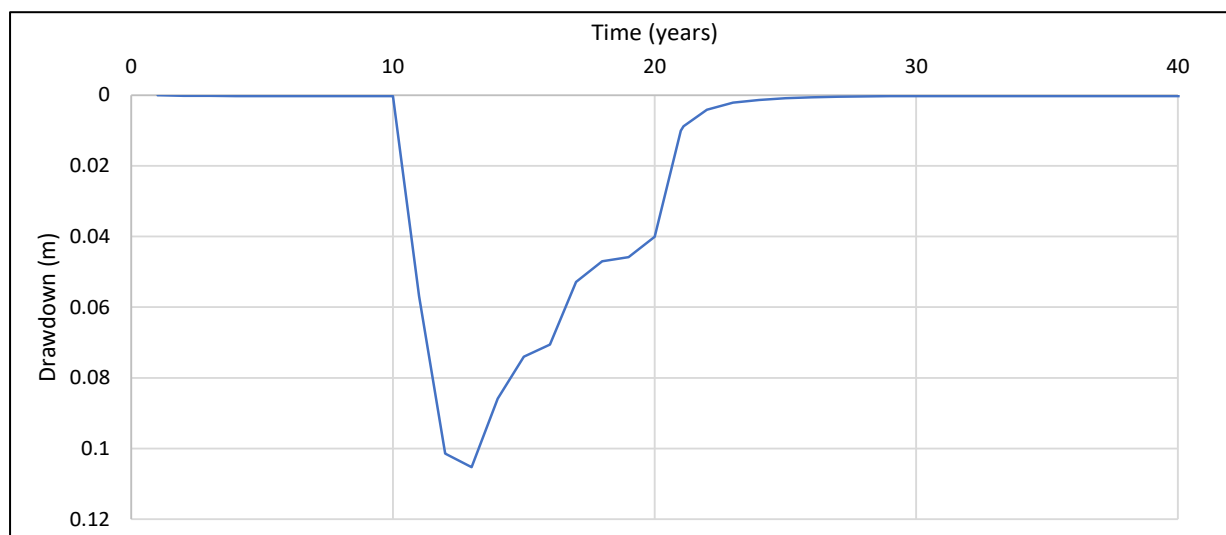


Figure 14: BMU 01 drawdown

4.4 Island Example-Drawdown

The main area of interest relating to environmental impacts due to drawdown in water levels is on the islands. These islands are typically located in the middle to eastern sections of the lake. To minimize drawdown impacts on islands, buffers ranging from 100m to 500m will be implemented around the various classes of islands.

Figure 15 and 16 and Table 3 below provide another example of how drawdown varies with distance and the role applying buffers around the islands will reduce drawdown around certain islands. Figure 15 shows the trench network adjacent to a landform island in BMU 05. Drawdown is measured at distances from the end of the trench at mine year 20, these distances are 50m, 100m, 250, 500m and 1000m as shown below. As this is a large island, a 250m buffer has been applied from the end of the trench to the edge of the island.

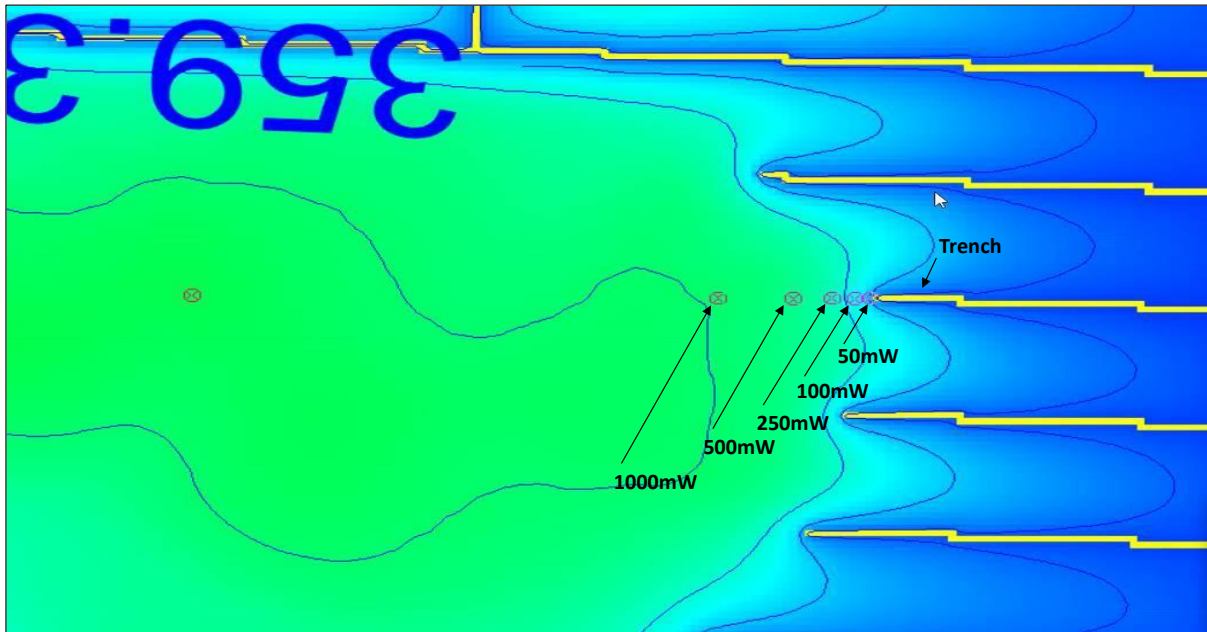


Figure 15: Trench and drawdown points

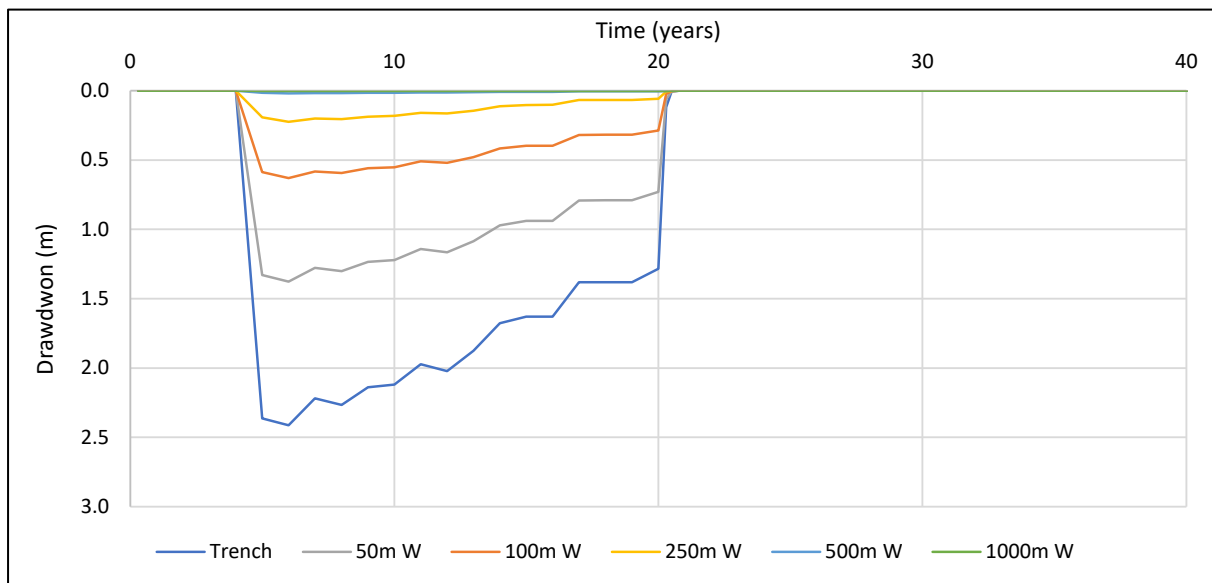


Figure 16: Drawdown over time at a range of distances

A summary of the measured drawdown as a maximum and minimum case are presented in Table 3 below.

Table 3: Summary of groundwater drawdown along trench transect

Location	Maximum drawdown (m) Year 6	Minimum drawdown (m) Year 20
Trench	2.41	1.28
50m West	1.38	0.73
100m West	0.63	0.28
250m West	0.22	0.057
500m West	0.020	0.0040
1000m West	0.002	0.0001

BMU 05 comes into production in mine year 5 (Table 1). A maximum drawdown level of 2.41m is measured within the trench at mine year 6, with the drawdown cone extending westwards. At 50m from the trench the drawdown is measured as 1.38m and at the furthest monitoring point 1000m from the trench, the drawdown is 0.002m in mine year 6. Seasonal fluctuations of groundwater levels below the island will far exceed drawdown at this position (1000m from the trench). At this particular location full recovery of water levels to pre-brine abstraction levels is achieved within a year.

It should be noted that the numerical groundwater model was constructed for mine plan design and reserve determination, and conservative representations of areal recharge and recharge over the islands are applied. The effects of these assumptions on island drawdown and measures planned to mitigate potential drawdown beneath islands are discussed in the following sections.

The range of drawdown across the lake is varied and is dependent on factors such as the brine aquifer hydraulic properties, fluctuating pumping rates and will be further influenced by rainfall and recharge. Overall, drawdown across the lake over the 20-year Life of Mine will range between 0 and 3m with an average of approximately 0.66m during peak abstraction at mine year 10.

4.5 Groundwater Dependent Vegetation

The conceptual understanding of the large and landform islands (based on drill data, vegetation mapping and water level monitoring) is that the growth of flora on the islands is dependent on rainfall and the resultant infiltration of rainfall water through the vadose zone and therefore the island vegetation is not groundwater dependent as is the case with off-lake vegetation.

The shallow root systems of the flora on these islands are shallow (approx. 30cm) and therefore it is most likely that the flora survive off shallow pore water that occurs within the vadose zone as a result of rainfall. Infiltration of rainwater through the aeolian sand horizon eventually blends into the lakebed brine groundwater at a level associated with the lakebed sediments. This blending or mixing horizon results in a zone of less saline water than the underlying lakebed brine groundwater.

Figure 17 shows a conceptual model of the lake and associated islands and an indication of how groundwater drawdown beneath the islands will not affect flora growth on these islands.

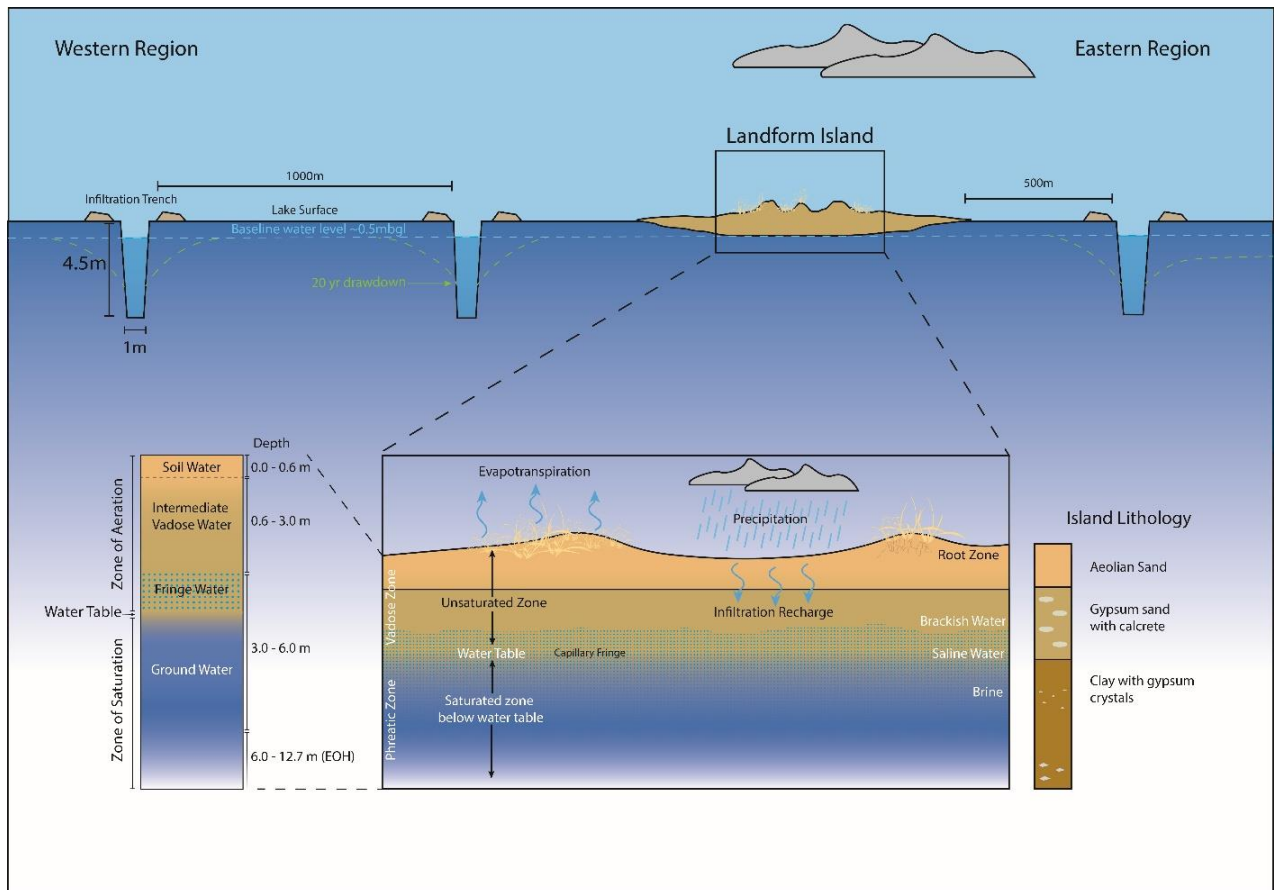


Figure 17: Conceptual trench and island model

5. Mitigation Measures-Minimizing Impacts to Islands

5.1 Island Buffer Zones

Buffers were assigned to the majority of the islands occurring on the lake. These are:

- 211 small islands (100m buffer)
- 56 Large or intermediate islands (250m buffer)
- 3 Landform islands (500m buffer)

The buffer applies to a zone within which construction of trenches was excluded, therefore reducing the extent of drawdown towards those islands as discussed in Section 4.3.

5.2 Recharge on islands

Detailed field, laboratory, and modeling studies were conducted to assess recharge and evaporation on Lake Mackay (Stantec 2020a). The mine planning model uses average annual recharge in each of four recharge zones across the lake which does not vary over the year. Model sensitivity runs assessing the effect of variable recharge showed that this assumption does not have a large effect on the final mineral reserve, but it may influence predicted recovery in water levels post-mining. However, as discussed in Section 2, recharge from precipitation is highly variable over the year and from year to year with the majority of annual recharge occurring from large storm events during the summer rainy season.

Post-mining water levels will likely recover much faster after a large storm event than the model predicts using the assumption of average annual recharge spread over the entire year.

It was also assumed in the mine planning model that recharge beneath the islands is the same as that over the surrounding lakebed sediments. This is a conservative assumption for determining brine production and mineral reserves. However, given that the islands are composed of highly permeable

dune sand, the percentage of precipitation that recharges the brine aquifer beneath the islands is likely to be higher than the surrounding lower permeability lakebed sediments, and the model likely overestimates drawdown beneath the islands.

Initial indications from field investigations on one of the major landform islands are that the islands act as recharge zones to the lakebed sediments below them. This will potentially reduce the drawdown depths below the islands associated with brine abstraction.

Rainfall contributes to the survival of the island flora species as opposed to being groundwater dependent. Recent downloaded seasonal data from several island monitoring bores indicates a temporary or perched water level may be associated with the larger islands. This is predominantly driven by infiltration of rainwater into the island sediments from direct rainfall events (Figure 18-T02885mW) in the summer months.

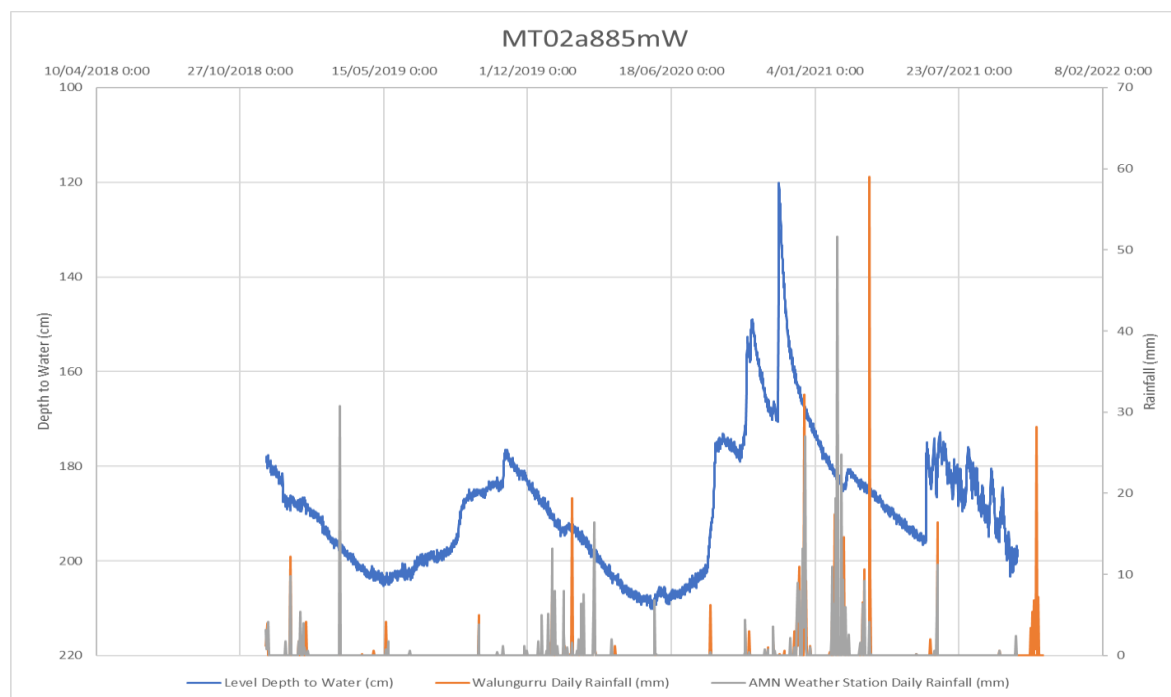


Figure 18: Island Monitoring – Water Level Data

Ongoing monitoring continues on a number of islands and subsequent investigations will focus on the data collected over seasonal variations. Additional investigation work is also planned-see section 6.

5.3 Variable Pumping Rates/Depths

In order to balance brine grade and flow to the evaporation ponds it was necessary to implement fluctuating pumping levels across the trench network.

To mitigate brine grade dilution and optimize produced brine grade and flow volume, the pumping level in the trench network rises from a maximum depth of 3 meters below ground level in mine year 1 and 2 and slowly increases to 1.7m below ground level in mine year 20 (Figure 19). The overall effect of this is that the groundwater drawdown levels on the lake would have been deeper if pumping levels were maintained at 3m below surface for the full 20-year LoM.

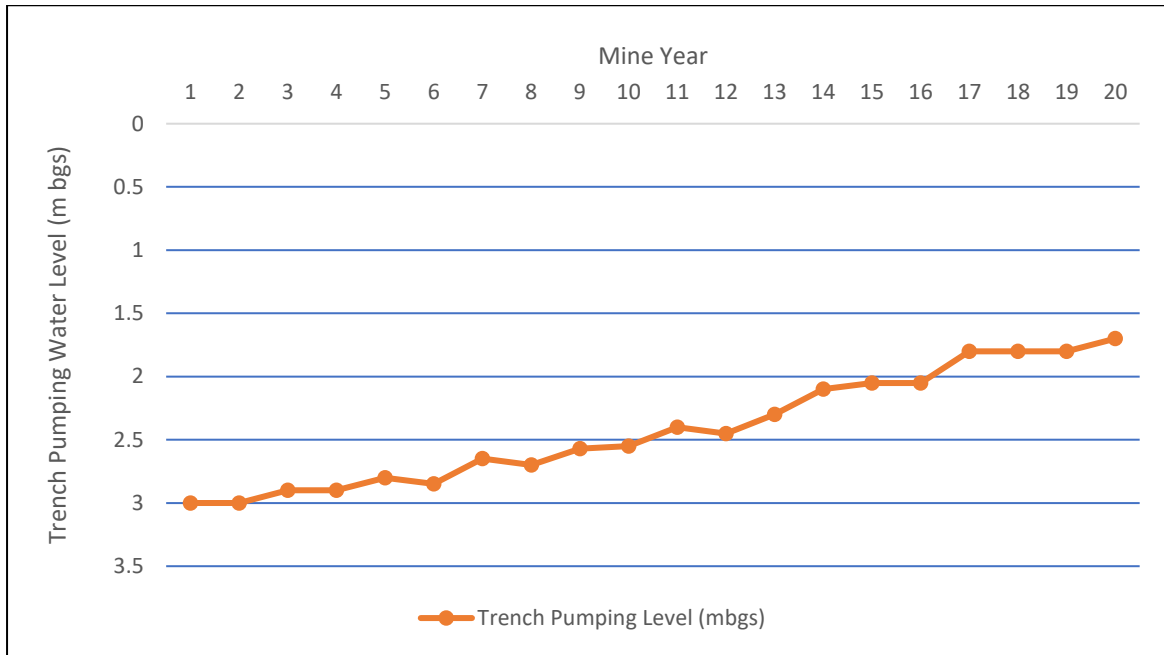


Figure 19: Trench Pumping Water Levels over LoM

6. Future Island Investigations

In order to build on the current data set and understanding of the hydrogeological properties of lake bed and island sediments, additional drilling and hydrogeological studies are required across several islands. Long term data representing several seasonal variations will also be crucial in continuing to develop the understanding of the hydrogeological regime across the lake.

Proposed investigations could include:

- Infill drilling and piezometer construction across aeolian sediments and lakebed sediments to determine if perched water levels are found on the islands during and after the rainy season.
- Hydraulic testing including slug tests, short pump tests and infiltration testing to determine hydraulic conductivity parameters.
- Further detailed brine sampling and salinity profiling with depth.
- Island specific groundwater modelling including the interaction between rainfall/recharge, evapotranspiration, and brine abstraction from trenching.
- Flora and riparian zone monitoring.

