Memo

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File:	**Lake Mackay Salt Balance and Ionic Composition Memorandum RevE**	Date:	September 10, 2021

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INTRODUCTION

Agrimin Limited (Agrimin) commissioned Stantec Australia Ltd (Stantec) to undertake a salt balance for the development of the Mackay Sulphate of Potash (SOP) Project located on Lake Mackay in Western Australia. Agrimin propose to extract brine (hypersaline groundwater) from the void spaces in the lakebed sediments and harvest the precipitated potassium-bearing salts to produce a SOP product. The development of a series of preconcentration ponds and salt piles is associated with the operations. During operations, runoff from these ponds and salt piles will be prevented from entering the lake system by a series of bunds with minimum 0.5 m freeboard. Bunds are constructed with on-lake construction materials and are lined.

At closure, the pond embankments will be breached, with the resulting brine returned to the environment during runoff events. This salt balance assesses dissolution rates and compares salt loads entering the system from the pond area with the salt loads entering the baseline system and the salt loads present in the baseline system.

This salt balance supports the accompanying December 2020 Lake Mackay Stage 1 and Stage 2 Surface Water Assessment.

BACKGROUND

The Indicative Footprint indicates that approximately 1.3% or up to 4,790 ha of the lake surface will be directly disturbed by evaporation ponds and salt piles during planned 20-year life of mine (LOM) operations. Staged development of the pond system for the first 10 years of operation is approximately 3,260 ha, increasing by another 1,530 ha by year 20. **Figure 1** shows the area in which the evaporation ponds and salt piles will be located relative to Lake Mackay and the trench network.

The evaporation ponds are anticipated to produce approximately 17 million tonnes of salt per year of operation, accumulating approximately 350 million metric tonnes of salt over 20 years of operation. This will comprise 120 Mt within the salt piles for P6 and P7 which are anticipated to reach 20m high and to occupy an area of approximately 500 ha, respectively after 20 years of operation. Residual salts within all other preconcentration ponds are predicted to reach less than 5 m in height. It is anticipated that ponds P3, P4 and P5 will need to be replaced with new ponds at year 10. At closure, residual salt stored in the ponds and salt piles during operations will be allowed to reintegrate naturally back into the lake with the breaching of the pond embankments. **Figure 2** shows the initial pond area prior to the replacement of ponds P3, P4, and P5.

Accumulated salts will be removed from the ponds P6 and P7 as a slurry in the pond brine with floating dredge style harvesters. It is anticipated booster pumps will be required to reach the salt piles adjacent to respective ponds, particularly as the salt piles expand during LOM operations. The brine contained in the slurry will be recovered and returned to the respective ponds to minimise potassium losses.

The salt piles will comprise a series of deposition cells, each approximately 25 ha in area, that will be constructed adjacent and to the north of P6 and P7. Each deposition cell will consist of a perimeter cut-off trench, nominally 2m deep, with the trench spoil deposited to form a berm on the outside of the cell. The salt will be open pipe discharged in the cell, with the brine draining into the cut-off trench and then flowing back to a sump pump to be pumped into the pond. As each cell is filled with salt the open pipe discharge point will be moved to another cell so that the salt can completely drain of brine. The salt slurry pipe discharge point will be managed to prevent salt discharging beyond the cut-off trench bund area, in order to recover the brine and prevent brine spilling out onto the lake. The brine recovery infrastructure will be relocated as the salt pile footprint increases as part of the pile management strategy.

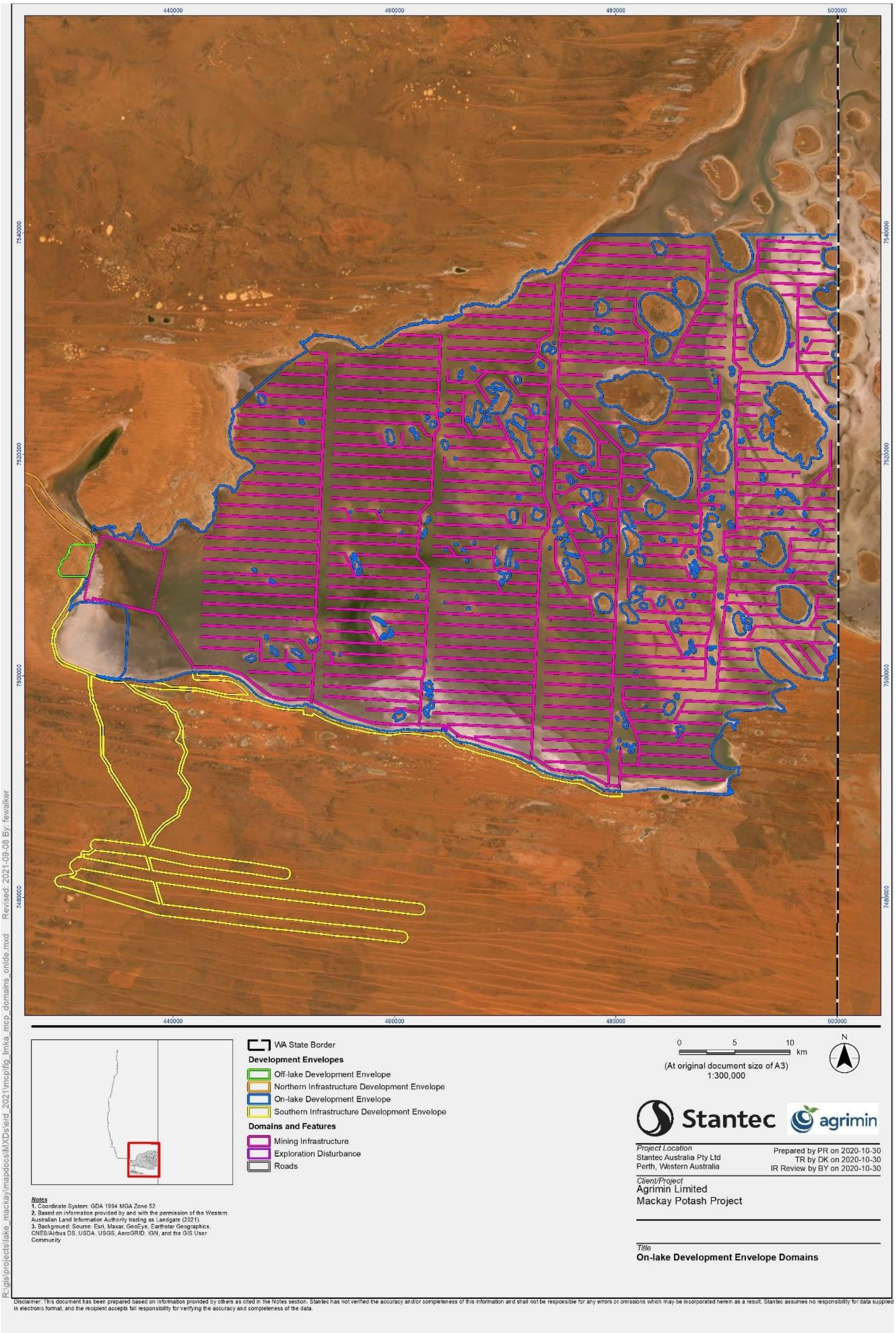

Figure 1: Indicative pond area relative to Lake Mackay and trench network.

Dozers will be used to heap and profile the salt piles, integral for efficient pile management and brine recovery operation. Once a particular cell reaches its capacity, the slurry will be directed to adjacent cells, where the dozers will continue to manage the pile. **Table 1** shows the annual salt deposition rates for each of the ponds. **Table 2** shows the accumulated salt deposition by pond at mine closure (year 20), including each of the reconstructed pond footprints.

Table 1: Annual salt deposition rates.

Location	Gypsum	Halite	Polyhalite	Thenardite	Hexahydrite	Total (MTPA)
P1	60,600	-	-	-	-	60,600
P2	43,300	597,800	-	-	-	641,100
P3	19,400	3,403,000	-	-	-	3,422,400
P4	15,800	3,396,100	-	-	-	3,411,900
P5	11,300	3,254,100	-	312,700	-	3,578,100
P6	-	2,768,600	20,500	612,900	-	3,402,000
P7	-	1,443,700	-	-	1,033,700	2,477,400
TMA	-	439,430	-	-	-	439,430
TOTAL	150,400	15,302,730	20,500	925,600	1,033,700	17,432,930

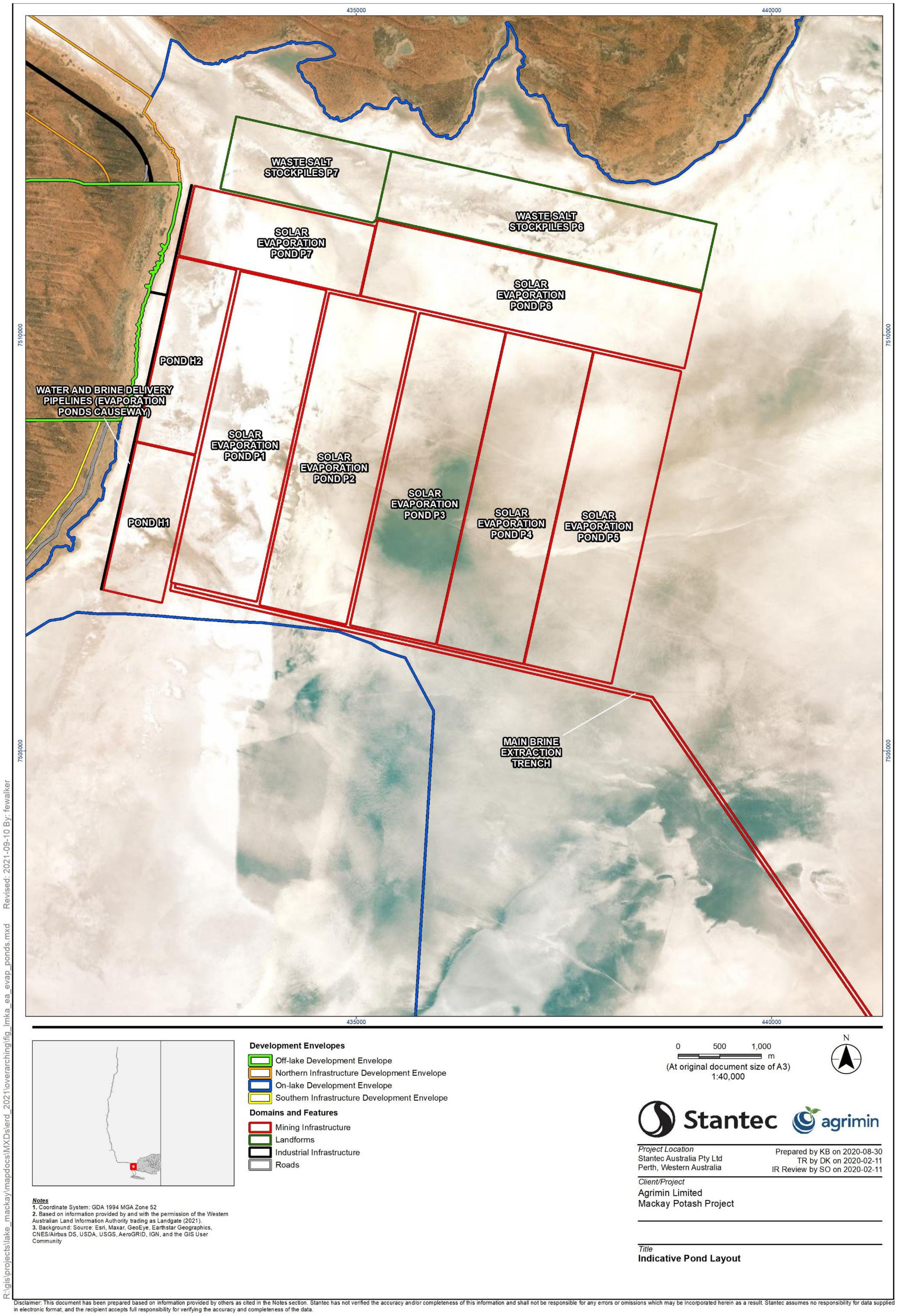

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Figure 2: Indicative location of preconcentration ponds and salt piles.

Table 2: Evaporation ponds indicative footprint and accumulated salt deposition at mine year 20.

Pond No.	Indicative Footprint (ha)	Salt Pile Height (m)	Accumulated Salt (t)
P1	450	0.48	1,212,000
P2	410	5	12,822,000
P3	820	4.6	68,448,000
P4	820	4.6	68,238,000
P5	820	4.95	71,562,000
P6	410	0.15	1,200,000
P7	200	0.15	570,000
H1	180	0.15	470,000
H2	150	0.15	380,000
Salt piles	500	20	124,606,600
Total	4,790	*NA*	349,508,600

The ponds will have a final berm height of between 1 m to 6 m, depending on the engineering design and lake topography. The evaporation ponds have been designed for a 1% AEP flood event, with a minimum bund height of 1 m for salt piles and 1.5 m for the ponds, providing sufficient freeboard (of at least 0.5 m), to prevent overtopping and limit saline runoff into the lake during major rainfall events. This will also prevent localised saline runoff into the riparian vegetation zone comprising *Tecticornia* shrubland. Minimal seepage or loss through the base of the evaporation pond to underlying lakebed sediments will occur due to the natural clay base layer, and high evaporation.

Groundwater salinity of the lakebed sediments is typically >270,000 mg/L, with cation dominance following Na>Mg>K>Ca, and a cation sequence of Cl>SO_4. Background concentrations of Na and Cl are approximately 100,000 mg/L and 145,000 mg/L, respectively, while potassium concentrations range from 3000 mg/L to 3,350 mg/L (Stantec 2020). Any potential seepage from the evaporation ponds will be dominated by sodium (Na) and chloride (Cl) and is not expected to alter the salinity or ionic composition of groundwater within the lakebed sediments.

Lake Mackay is predominantly dry but is inundated following infrequent rains or cyclonic events that occur on average once every five to ten years (Stantec 2020). There is contingency allowance for discharge of brine from evaporation ponds to the lake during operations. Discharge is likely to occur to a dry playa, or rarely, may be discharged into flood waters. However, due to the substantial natural salt load and apparent naturally elevated salinity of surface water during inundation, temporary discharge is unlikely to impact on surface water quality. In addition, during major flood events, the comparatively low discharge volume is unlikely to increase the salinity of lake water. Discharge is also not expected to impact riparian vegetation and will occur on the surface of the playa

The lake is characterised by a naturally occurring salt crust several centimetres thick. Previous surface water salinities (based on limited data), indicated salinities range between 50,000 to 260,000 mg/L. The lake salinity typically decreases during flooding, with salinity levels decreasing below 50,000 mg/L. As the water levels recede, the lake becomes hypersaline with salinity levels exceeding 250,000 mg/L. **Table 3** shows the conductivity associated with water quality tests for the Lake Mackay aquatic macroinvertebrates sites (360 Environmental, 2017). The equivalent salinities range from 1,600 mg/L to 225,000 mg/L.

Table 3: Water quality for aquatic macroinvertebrate sites (Invertebrate Solutions, 2017).

Site	Description	Water Depth (cm)	Conductivity (µs/cm)
1A	Lake Mackay	<15	140,263
2A	Lake Mackay	<15	167,626
3A	Lake Mackay	<15	204,787
4A	Lake Mackay	<15	243,343
5A	Lake Mackay	<2	261,732
6A	Lake Mackay	<15	239,504
7A	4ha, claypan	<30	402
8A	0.1 ha, tiny claypan	8	2,255
9A	21 ha, large claypan	>50	3,326

METHODS

Floodwaters dissolve the naturally occurring salt crust, which extends across much of the surface of Lake Mackay. An assessment of the salt related impacts of the evaporation pond and salt piles post closure requires a comparison to the baseline inflows to Lake Mackay along with the background salinity levels, as summarised below.

The Mackay Basin has a theoretical catchment area of 87,000 km^2; however, due to the presence of internally draining areas, the surrounding dunes, and other factors, the effective catchment area is limited to approximately 10-20% of the total area (Stantec 2020). The effective catchment area varies by event.

Using an effective catchment area of 9,000 km^2, or approximately 10 to 20% of the catchment area, to represent typical annual flow conditions, the average annual rainfall depth of 300 mm yields an annual inflow volume of approximately 2,700 GL, including direct rainfall onto the lake surface area of approximately 3,400 km^2. This volume of runoff equates to a lake level of approximately 362.0 m AHD if the inflow occurred in a single event with saturated subsurface conditions (**Figure 3**). The corresponding maximum lake depth is approximately 2 metres; this level would cover an area of 2,800 km^2, which is equivalent to approximately 80% of the lake surface.

The external runoff enters the lake with a relatively low salinity and dissolves the salt crust as it ponds. Using an assumed, mid-range salinity of 50,000 mg/L for the total runoff that ponds in the lake at an elevation of 362.0m AHD (with an assumed specific gravity of approximately 1.1), the equivalent salt load present in the inundated portion of the lake is approximately 150 million tonnes (Mt).

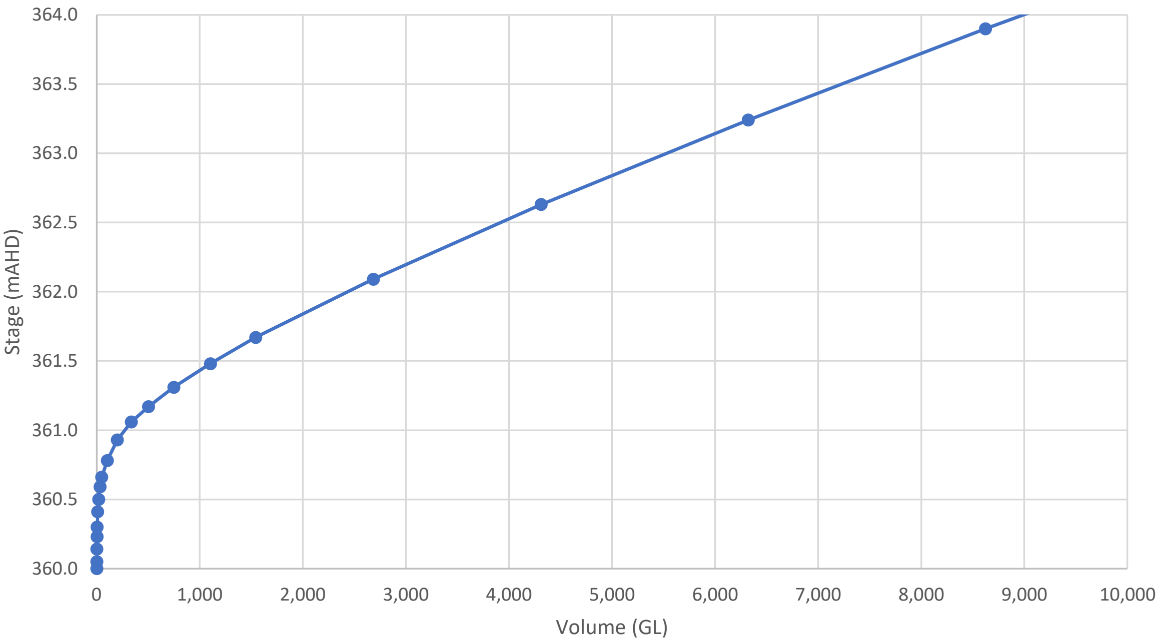

Figure 3: Lake Mackay Stage-Volume relationship.

RESULTS

Residual salts in the evaporation ponds will be more than the natural 150 Mt of salt that enters the lake during average annual rainfall as inflow (approximately 2,700 GL with a 2 m depth; during a major flood event, on average, once every 10 years). Following cessation of mining, salt accumulated within the evaporation ponds and salt piles will gradually dissipate and return to the playa through dissolution, over a period of approximately 400 years.

The gradual dissipation of NaCl salts to the playa may cause localised salinity increases in the south west portion of the lake during years with low seasonal rainfall. Under dry conditions, the discharge water would follow natural drainage paths which are not discernible in the available topographic data and may change over time as salts dissolve and reform. However, this is not expected to impact on the ionic composition of the lake during flooding. During major floods, which typically occur every five to ten years, the relative volume of discharge water is unlikely to have an appreciable influence on the overall water balance and hydrological function of Lake Mackay. In effect, NaCl salts will be returned to the environment in which they were previously stored prior to abstraction.

At closure, approximately 350 million tonnes of residual salt is expected to remain across an indicative footprint of 4,790 ha (although not all ponds will have salt left in them). If fully contained, the average annual rainfall of approximately 300 mm of freshwater would have the potential to pond and dissolve the salts to the point of complete saturation. The equivalent, volume of freshwater rainfall over the pond area is approximately 14 GL, or less than 1% of the annual inflow into Lake Mackay.

If only fully saturated brine were released from the pond area upon breaching, an annual load of approximately 5 Mt could be released into the receiving environment. At this dissolution rate, the residual salts would be dissolved within approximately 75 years. A fully saturated brine would have the potential of dropping the level of residual salt by approximately 100 mm per annum. However, the additional salt load would diminish over time, as the lower elevation salt piles are dissolved, leaving the higher elevation salt piles with a smaller exposed surface area.

Salt pile tests have confirmed the potential dissolution rate resulting from fully saturated brine (Knight Piesold, 2017). However, preferential flow paths would form over time as the pond walls are breached, leaving some of the salt crust with very low flow depths and times of ponding during runoff events. The probable "armouring" of salts over time is also cited in Knight Piesold (2017), suggesting a more realistic estimate for dissolution from rainfall events is approximately half saturation. This represents a reduction of residual salt by approximately 50 mm per year, assuming annual rainfall of 300 mm.

At this dissolution rate, the brine would contribute the equivalent of approximately 1.5% of the existing natural load contained in the system annually. This is during the initial closure period where salts within the entire 4,790 ha pond and salt pile areas are exposed to rainfall. Residual salts in the ponds with depths of less than 1 m would dissolve within a few years while the salt piles with heights of 20 metres would be present for a longer period of time.

Due to the combined effect of the differential depths and armouring processes, the dissolution of salt within evaporation ponds and salt piles is anticipated to take approximately 400 years, contributing approximately 1.5% of the salt load annually relative to the total salt load in the system during the initial years. This reduces to less than 0.3% of the total salt load near the end of the dissolution period where only the 500 ha salt piles remain.

The estimated extent of the potential area influenced by periodic pulsed discharge of salt from the evaporation ponds is subject to limitations in the available data. It does not account for wind forces and/or the presence of any salt scald associated with the discharge of the brine to the playa surface following rainfall events.

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SUMMARY

Lake Mackay has a high natural salinity level, with a natural salt crust that varies in thickness but is generally 5 to 10 mm thick. Additional salt will be received from the dissolution of salt piles at closure. The distribution of these salts may result in localised areas with higher salinity during years with low seasonal rainfall. During wet years, when the lake fills completely (approximately every 5-10 years) the additional salt deposits will dissolve and distribute across the lake as previous. Breaching of bunds in selected locations at mine closure will allow the salt piles to dissolve during rainfall events, distribute and reform across the playa as the lake dries. During flooding the salinity of surface water on the lake can range from less than 10,000 mg/L to more than 250,000 mg/L.

Dissolving residual salts from the evaporation ponds will add to the natural 150 Mt of salt that enters the lake during average annual rainfall as inflow (approximately 2,700 GL). This is considered equivalent to approximately 1.5% of the natural incoming salt loads from inflows annually during the initial closure period, diminishing to less than 0.3% near the end of the dissolution period. Potential impacts resulting from dissolution of salt from the evaporation ponds and salt piles post closure will have minor influence on the overall salt balance of the system. Mitigation measures to reduce the risk of these impacts will include the following:

- staged development of the evaporation ponds with an initial pond area of approximately 3,060 ha, increasing by 1,230 ha for a total pond area of approximately 4,290 ha at year 20;
- staged development of the salt piles comprising approximately 200 ha at year 2, and 500 ha at year 20;
- evaporation ponds and salt piles designed for a 1% AEP flood event, with a minimum bund height of 1.5 m and 1 m, respectively, providing sufficient freeboard (min. 0.5 m) to limit saline runoff into the lake during large rainfall events;
- location of evaporation ponds to have at least a 250 m buffer zone from surrounding riparian vegetation; and
- breaching of the evaporation ponds embankments at closure will allow periodic, pulsed flows and gradual dissipation of accumulated salt to return to the playa over a 400-year period.

Relative to the natural inflows from rainfall, the brine from the evaporation ponds will be substantially more saline. However, relative to the existing natural salt loads within the basin, the addition of salts is not significant and will not impact the overall salt balance. Residual salt loads may remain in the lake within the evaporation ponds and salt piles, until mobilised by infrequent, major flood events. Ongoing monitoring and hydrogeological investigations across the lake will continue to build knowledge on the natural spatial and temporal variability in surface water and groundwater quality and detect operational changes from the baseline condition.

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