Glass Sands Closure Plan
Sibelco Australia, Minjerribah

2419A | OCT 2024 | GEO-ENG

EXECUTIVE SUMMARY

Sibelco Australia and its predecessors have operated several mineral sand mining operations on North Stradbroke Island (Minjerribah) since the 1960s. All operations have closed and the sites have been, or are being, rehabilitated to native ecosystems.

Sibelco Australia is required to develop a Progressive Rehabilitation and Closure Plan (PRCP) to progress with surrender of the Glass Sands Mining Leases under the current Environmental Authority (EA).

Part of the PRCP is a Void Closure Plan demonstrating that any voids remaining will be in a safe and stable condition and are consistent with the post-mining land use (PMLU). The PMLU for all the voids is native ecosystems consistent with the local landscape.

A void closure plan has been developed for the Glass Sands Mining Area (ML1124 and ML7064), which provides a geotechnical and hydrogeological assessment to show that the landform created at the mine voids (on ML7064) are both geotechnically stable and will have minimal impact on the groundwater table and surface water bodies. It is assessed by GEO-ENG that the Glass Sands Void are consistent with the PMLU.

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1.0 PROJECT OVERVIEW

GEO-ENG has been appointed by Sibelco Australia to prepare a void closure plan for the Glass Sands Mine Deposit (Mining Leases [ML] 1124 and 7064) approximately 4.5km north-east of Dunwich on North Stradbroke Island (Minjerribah), Figure 1. The void closure plan assesses the geotechnical and hydrogeological state of the site. (Slope aspects and grades to meet the Environmental Management Plan (EMP) criteria are reported separately in the Progressive Rehabilitation and Closure Plan). The void closure plan is to be consistent with Section 3.6.3 of the Department of Environment and Science's (DES) progressive rehabilitation and closure plan guideline.[1]

1.1 Regulatory Conditions

Under the *Environmental Protection Act 1994* (EP Act), organisations carrying out mining in Queensland must rehabilitate the land (DES, 2020).[2] Proponents of new and existing large scale mining activities (that meet requirements for a site-specific Environmental Authority) need to submit a Progressive Rehabilitation and Closure Plan (PRCP) describing a) how and where activities will be carried out progressively over the life of a mine and b) the condition to which the land must be rehabilitated before the Environmental Authority for the activity may be surrendered (EP Act section 126B). The EP Act stipulates that land disturbed by mining must be progressively rehabilitated to a 'stable condition' after mining (EP Act section 111A). Land is in a stable condition if — (a) the land is safe and structurally stable; and (b) there is no environmental harm being caused by anything on or in the land; and (c) the land can sustain a post-mining land use (PMLU).

Sibelco is developing a Progressive Rehabilitation and Closure Plan (PRCP) for the sand mining operations on NSI. The PRCP must be consistent with the DES progressive rehabilitation and closure plan guideline requirements.[1]

Section 3.6.3 of the guideline requires Sibelco to include a "void closure plan" in the PRCP. The void closure plan must address the requirements outlined in this section of the guideline. The overall objective for the department is to ensure that the PRCP demonstrates that any voids remaining will be in a safe and stable condition and are consistent with the post-mining land use (PMLU). The PMLU for all Sibelco voids is native bushland consistent with the local landscape.

The Glass Sands Voids would not be filled with groundwater (being above the water table), and thus void groundwater modelling has not been undertaken.[3] The voids would occasionally hold surface run-off water due to underlying low permeability sands.

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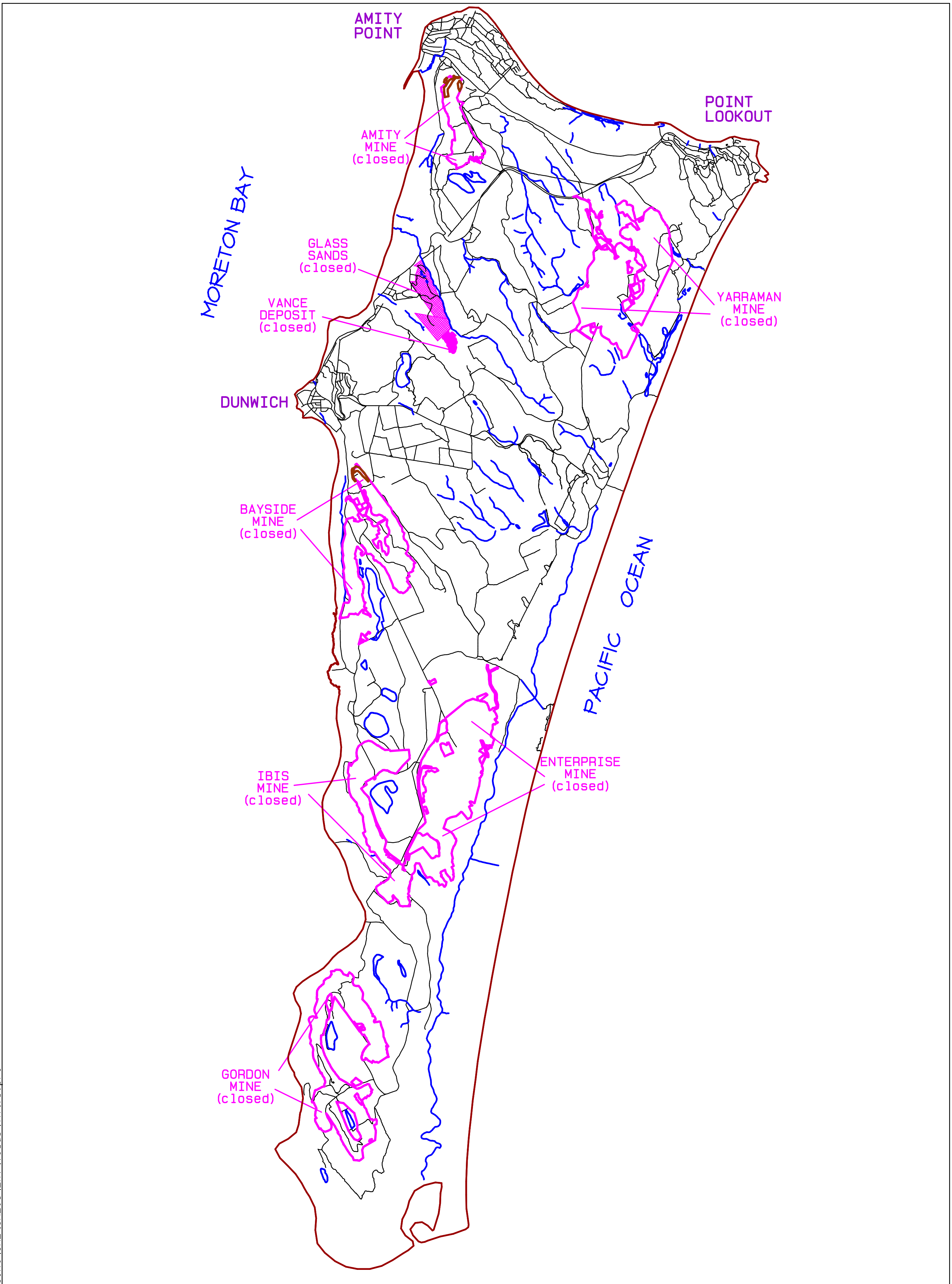
1. <environment.des.qld.gov.au/__data/assets/pdf_file/0026/95444/rs-gl-prc-plan.pdf>
2. DES (2020) *Information Sheet*, *Environmental Protection Act 1994 Non-Use Management Areas* (ESR/2019/4954), Version 1.00. Department of Environment and Science. Available at: https://environment.des.qld.gov.au/__data/assets/pdf_file/0023/95441/rs-is-numa-policy.pdf (Accessed: 16/03/2022).
3. Tomlin, J., Phillipson, K., Lenahan, M., Durick, A., Manewell, N., Newton, D., Briody, M., and Dunlop, J.(2023) *Approaches for leading practice modelling of residual mine voids for rehabilitation planning: Technical paper 2*. Brisbane. Office of the Queensland Mine Rehabilitation Commissioner.



19.5 x 26.41	North	Sibelco Australia			North Stradbroke Island Location Plan
Road/Track	Mine disturbance bdy	Surveyed: Sibelco	Plotted: Oct 14 2024	Design: n/a	Contour int: NA; A4 - 1 : 10000; Hor: na; Ver: NA; Figure 1

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1.2 Mining History

Sibelco Australia and its predecessors have operated several sand mining operations on North Stradbroke Island (Minjerribah) since the 1960s. Mining has ceased at all operations and the sites have been rehabilitated to native ecosystems, with some rehabilitation work currently continuing.

Glass Sands includes Mining Leases 1124 and 7064. Mining commenced on ML1124 in about 1973 moving from west to east, with mining at ML7064 starting in about 2001 (Figure 2). Mining ceased in November 2014. A void closure plan for the adjacent Vance deposit (ML1108) was completed in July 2024.[4]

The Glass Sands area was mined at a rate of about 180 tonnes per hour for 4 days per week (approximately 1 million tonnes per year). Mining was carried out using front-end loaders feeding a dry mining unit to slurry and pump the ore to a wash plant. The sand was washed and processed for saleable products. Excavation depths varied up to about 15 m.

The site has limited backfilling as most of the excavated sand was removed. The mined areas were re-contoured to form similar slopes to the original land surface, blending in with the surrounding topography. Overall final slopes are flatter than 18°. Stockpiled topsoil was spread across the mined area which was subsequently re-vegetated.

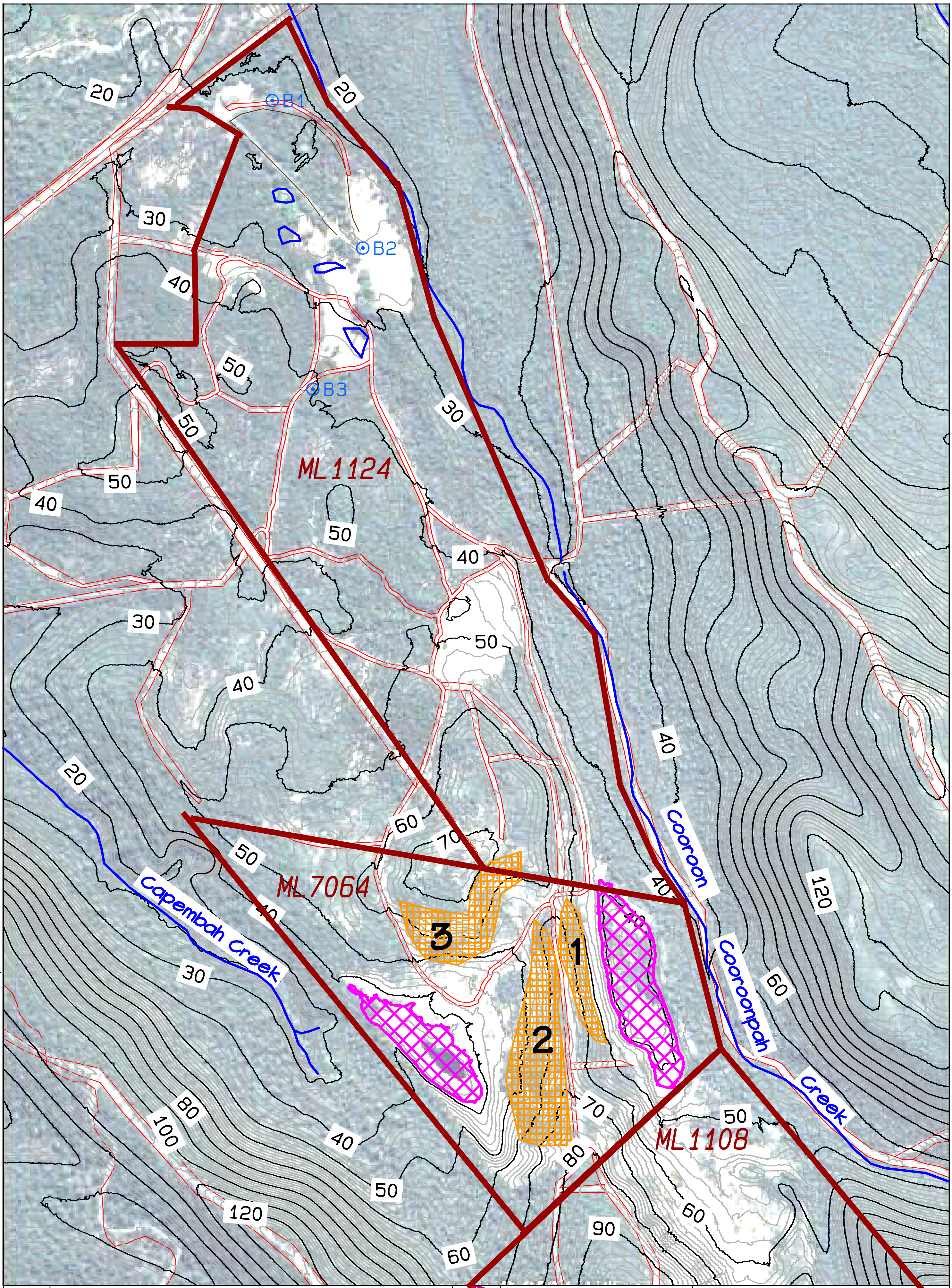
The following assessment considers slope geotechnical stability, hydrology, and hydrogeology.

1.3 Topography Data

The topography across ML1124 and ML7064 rises from 20mAHD in the northwest to 80mAHD in the southeast (Figure 2). Capembah Creek is located to the southwest and Cooroon Cooroonpah Creek is adjacent to the northeastern boundary. The most recent LiDAR and aerial photography were used to review the slope angles.[5] The steepest slopes (up to 18°) are located on ML7064 in Management Zones 1 and 2 (Figure 2). Most other areas have slopes less than 15°. Figure 3 indicates locations where local slopes are greater than 25° (blue dots), and 30° (red dots). The site inspection identified multiple causes of steep slopes (creek diversions, stockpiled materials, erosion gullies and vehicle track cuttings). External to the mine leases, it is noted that many natural/undisturbed slopes are stable at slopes steeper than 25°.

Pre-mining topography is based on measurement from 1968 aerial photography. Comparing the surface level measurements for undisturbed locations to the current LiDAR survey indicates the 1968 data generally over-estimated the ground level by about 5 m. Mine excavation depths are estimated to be up to about 15 m.

4. GEO-ENG (2024) *Vance Deposit Mine Void Closure Plan Sibelco Australia Limited North Stradbroke Island*, 2405A
5. The LiDAR data has a high resolution and can identify steep slopes over very small distances, with a ground sample distance on 0.15 m. The vertical accuracy is 0.15 m and the horizontal accuracy is 0.3 m.



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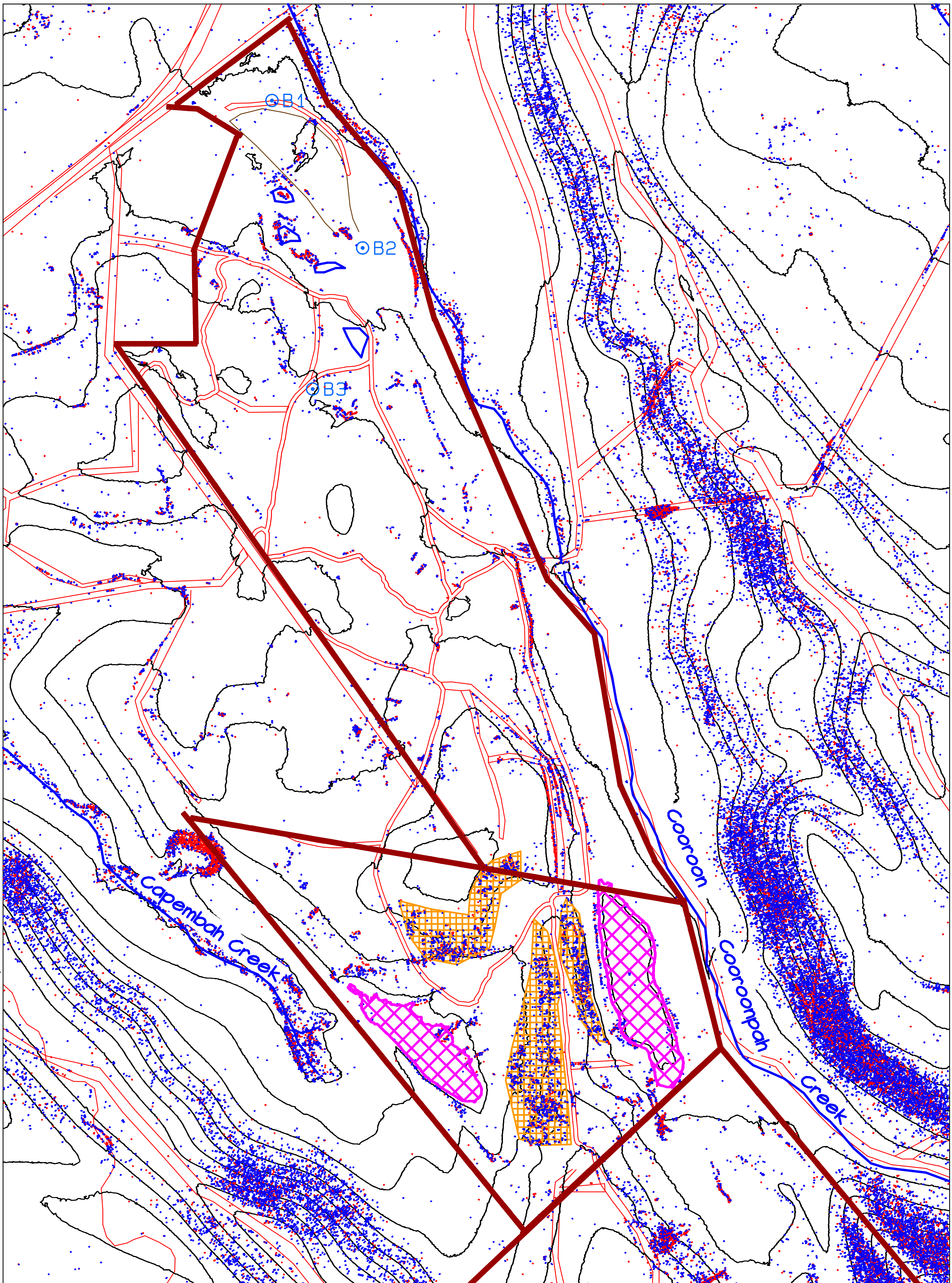
19.5 x 26.41	Google Earth Image July 2024	North	Sibelco Australia	Glass Sands Location Plan and Topography

Road/Track — Void — Lease Bdy — Erosion Zone

Surveyed:	Plotted:	Design:	Contour: 2m	A4 - 1 : 10000
Sibelco	Oct 28 2024	n/a	Hor: GDA Ver: A.H.D.	Figure 2



19.5 x 26.41	Local Slope: >25d >30d	North	Sibelco Australia Minjerribah		Glass Sands Steep Slopes
Road/Track Void Lease Bdy Erosion Zone		Surveyed: Sibelco	Plotted: Oct 24 2024	Design: n/a	Contour: 10m A4 - 1 : 10000 Hor: GDA Ver: A.H.D. Figure 3

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1.4 Geology

The geology of Minjerribah is primarily dune sands with some minor outcrops of basement rock. The sand dunes comprise mostly fine-grained quartz sand, which is chemically inert and permeable. The island's profile has formed over time from beach sand blowing inland to form dunes, which have been subsequently stabilised by vegetation.

Iron and aluminium oxides are found coating the beach sand grains giving it a yellow-brown colour. Recharge of slightly acidic and oxygenated rainwater through the sand dunes has caused leaching and migration of the soluble iron and aluminium oxides from the upper layers (Podzol A–horizon: grey organic layer and E–horizon: completely leached white layer). Precipitation of the soluble components occurs further down the profile in the zone of accumulation (Podzol B— horizon), due to changes in pH (acidity) and pE (redox potential) conditions, as oxygen in the rainwater is lost to organic and inorganic reactions. Some fine silt and clay size grains (primarily silica) are also carried downwards by the rainwater, accumulating at the lower permeability B–horizon.

The B–horizon ranges in colour from orange to black, due to the oxidized iron and aluminium minerals (formed during precipitation) and is often described as indurated sand. The precipitation and clay/silt size particles form a cement of variable strength and a low permeability zone, which can result in perched groundwater tables. The profile of the B–horizon often mimics the topographic surface (past or present) and thus may be found at various levels in the profile. Podzol C–horizon is the un-leached sand below the B–horizon. Multiple combinations of Podzol profiles may exist where newer sand dunes have blown over previous dunes.[6]

1.5 Geotechnical

1.5.1 Slope Stability

For sand slopes, overall slope failures tend to be shallow planar failures (non-circular). The Factor of Safety (FOS) can be determined by comparing the slope angle to the residual angle of friction for the sand. The dune sand generally has an internal friction angle in the range of 32° to 36° and an in-situ density of 1.6 t/m^3.[7] Conservatively using the lower internal friction angle value of 32°, a slope of 25° would have a FOS of 1.34. The target FOS for stable sand slopes is greater than or equal to 1.3, based on well-accepted industry standards, and site experience. As shown in Figure 3 nearby undisturbed dune sand slopes have areas steeper than 25° and show no mass stability issues. Similar outcomes would be expected where any small areas with slopes steeper than 25° occur in the rehabilitation.

1.5.2 Erosion and Settlement

Due to its small grain size the sand is highly erodible under wind and water forces. Stabilisation of slopes is primarily achieved by vegetation. The development and subsequent exposure of B-horizons, can also reduce surface erosion. Once vegetation has established, erosion is generally limited to steeper slopes, and where rainfall run-off cannot infiltrate quickly due to shallow B-horizons.

Erosion pin monitoring at various mining areas has shown that rates of erosion in rehabilitated

6. Thompson, C.H., Genesis of Podzols on Coastal Dunes in Southern Queensland. I. Field Relationships and Profile Morphology, Aust. J. Soil. Res. (30):593–613, 1992.

7. Laboratory test data collated by GEO-ENG over 20 years of assessments for Sibelco Australia. In addition to laboratory testing, it has been observed that mine faces typically form at angles steeper than 35° and cyclone stacked clean sand form profiles of 33° to 34°.

areas are similar in undisturbed and rehabilitated areas and that the only difference is generally associated with isolated erosion features (personal communication, Sibelco Australia). However, as vegetation cover is established, these features gradually stabilise and where they do not, they are actively managed by Sibelco Australia.

No settling or subsidence would be expected to occur due to the low compressibility of the sand.

1.6 Hydrology and Hydrogeology

Apart from the indurated B-horizon sands, the dune sands are generally permeable and rainfall infiltrates into the ground to the water table. Small water bodies, both perched and groundwater table window lakes, are found across the island. Perched water bodies (e.g., Swallow Lagoon) are located where there is underlying low-permeability cemented sands.

As shown in Figure 2, Cooroon Cooroonpah Creek is located to the east of the mining area, and Capembah Creek is located to the west. Cooroon Cooroonpah Creek is supported by a perching layer above the prime water table for most of its length, until its northwestern end. Thus, it is usually dry, with flows only occurring after heavy rain. Capembah Creek intersects the groundwater table at about 24mAHD, about 10 m lower than the lowest point in the mining area, 200 m to the east.

Two long-term groundwater monitoring bore (79938 and 14400085) are located near to the Glass Sands Mining Area. Recorded water levels are shown in Figure 4.

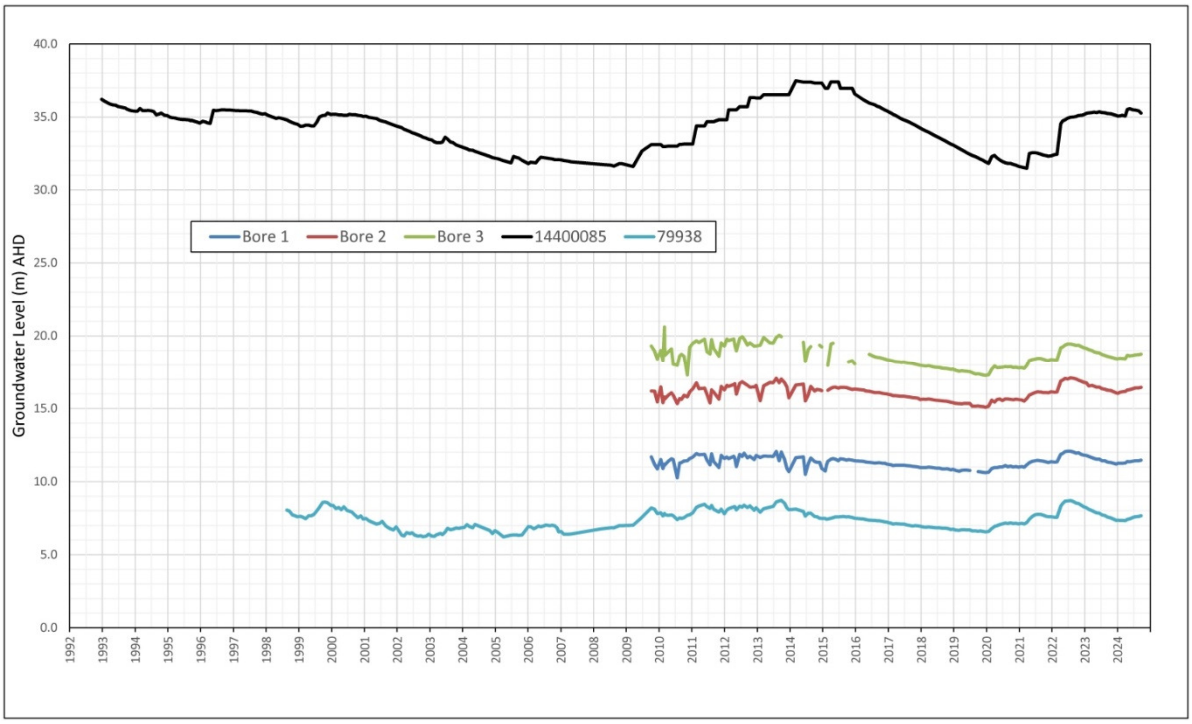


Figure 4 Groundwater Monitoring Levels

Water supply bores B1-B3 are located at the northwestern end of ML1124. Water level monitoring records are available from 2009 (Figure 4). Bore pumping ceased in 2015, as is evident by the smoother hydrograph after this date. As most of the water used for pumping and washing of the sand was returned to the aquifer via infiltration, the bore pumping would not have had a significant long-term impact on the groundwater table level. This is confirmed by comparing the groundwater monitoring levels before and after 2015 for the bores to the nearby monitoring bore 79938.

The Glass Sands area is not within a floodplain and thus flooding is not expected to be an issue. The residual mine voids on ML7064 are elevated above the natural water table level.

1.7 Groundwater Chemistry

The groundwater is generally acidic due to the presence of naturally occurring organic acids (humic and fulvic acids) released form the soils. The total dissolved solids (TDS) are generally less than 100 mg/L and the ion chemistry is similar to the rainfall. Of the metals tested, generally, only iron, manganese and zinc are detected, which reflects the process of weathering and induration of the 'giant' podsol soils present (URS, 2007)[8].

No chemicals were used in the sand extraction process. Therefore, the groundwater quality in the aquifer is relatively unchanged, from the pre-mine state. Based on the above, mine voids are expected to be geochemically stable, with no risk to the environment.

2.0 FINAL VOIDS

The mining removed a maximum depth of up to 13 m of sand from the western side of the central ridge in ML7064 and about 8 m from the eastern side, forming two shallow depressions (voids) as shown on Figure 2. The intervening ridge crest was left at about its pre-mining level. To the west the lowest ground level is about 34mAHD. On the east the lowest point is about 35.6mAHD. As discussed below these voids are located above the groundwater table range, and thus would not directly interact with the groundwater regime.

2.1 Hydrology

The direct catchments of the void areas are 21.8 ha on the west and 15.5 ha on the east (Figure 5). Surface runoff appears to be higher than usual due to shallow cemented sand layers that limit infiltration. During the site visit of 21/10/24 about 20 mm of surface water was noted at the eastern void. The depth of water in the western void pond was about 0.5 m (Photo 1–Appendix A).

Ponding of water at the western void is evident in Google Earth photographs since the locality was mined in 2017. It is expected that the ponding would fully evaporate during extended dry periods, given its shallow depth. Hand auger drilling near the water body indicated a water holding perching layer of dark sand within 1 m of the surface. As discussed in Section 2.2, there may be multiple perching layers beneath this area. The historic photos also indicate significant past rainfall-runoff erosion from the slope to the east. The area is being colonized by aquatic plants and is expected to develop into an intermittent wetland.

The eastern void had about 20 mm of water at the lowest point, and is not expected to host surface water for long periods of time, due to the high evaporation rate (Photo 2–Appendix A).

8. URS (2007) *Final Environmental Studies Report for Vance Mining Lease (ML1108) North Stradbroke Island, Queensland*, ESR-151007.

2.2 Hydrogeology

The Sibelco Groundwater Model[9] was refined with more accurate topography, especially to reflect the creeks near to Glass Sands. Estimated groundwater contours from the model for a near average groundwater table are shown in Figure 5. The model estimates the groundwater table to be within eight meters of the local ground level at the two voids (Table 1).

Table 1 Void Levels (m) AHD

	West	East
Lowest surface level (m) AHD	34	35.6
Groundwater level range (m) AHD	26.5–30.5	29.9–34.9
Depth to groundwater (m)	3.5–7.5	0.7–5.7

A standpipe piezometer (GP01) was installed within the western void to investigate the groundwater levels (Figure 5). The piezometer was installed to a depth of 3.3 m and intersected water at 2.8 m (approximately 32.3 mAHD), about 1.7 m below the nearby perched pond level. This confirms that the ponded water is not a window lake of the groundwater table. The water level in the piezometer is higher than the expected groundwater table level of about 27.5mAHD[10], and may reflect a second, lower perching layer.

Perching layers are a common feature of the geological profile, as discussed in Section 1.4, and multiple perched layers have been observed at several location, such as Lake Kounpee.

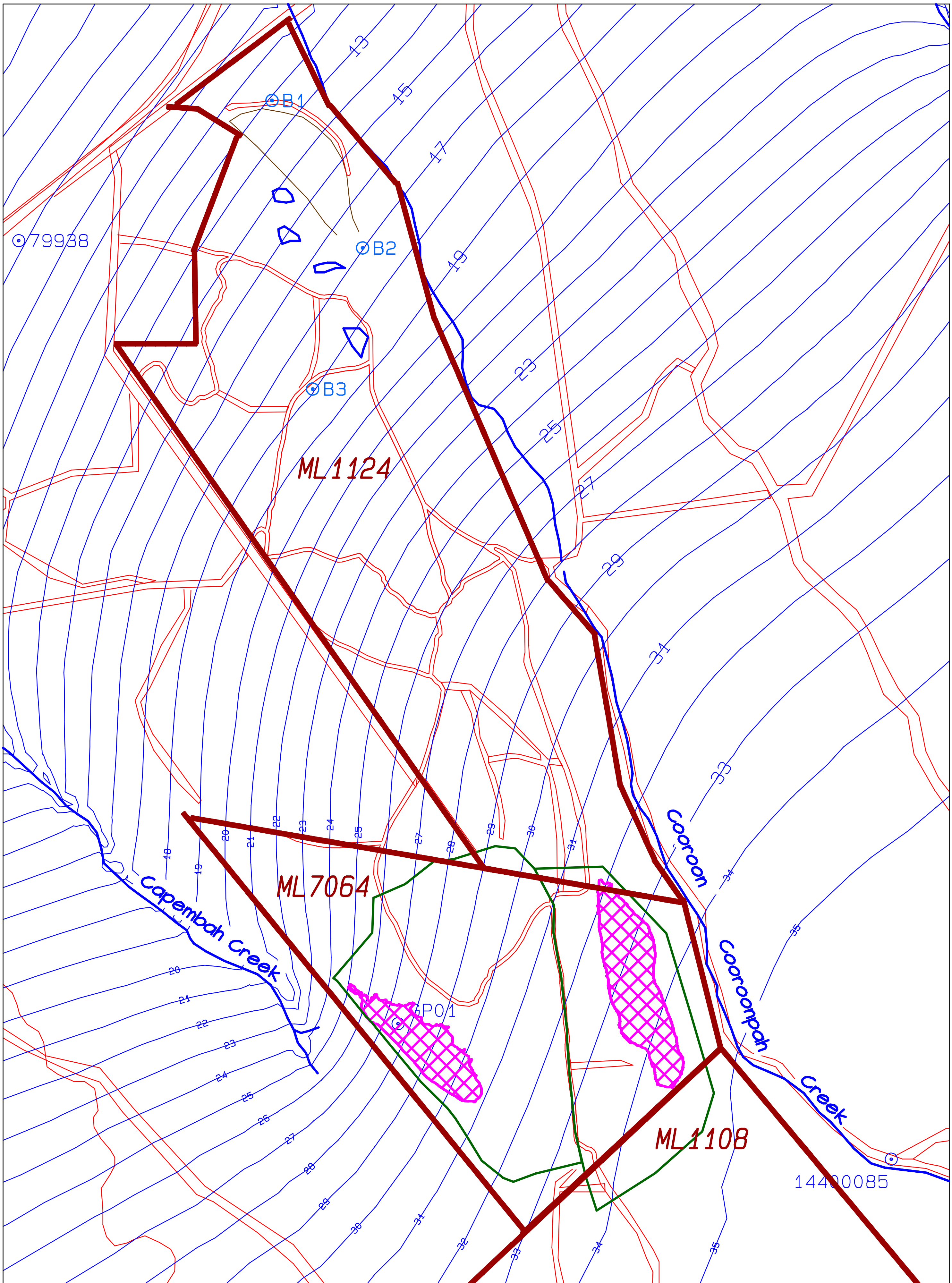
The local groundwater gradient flows to the west (Figure 5), with an estimated average gradient of about 1V:80H, steepening near to Capembah Creek. The estimated throughflow rate across the site is about 40 L/s.

The reduction in ground level and the loss of evapotranspiration due to vegetation clearing would likely result in an increased potential for rainfall infiltration to the groundwater table. Evapotranspiration would be the primary control on rainfall infiltration and evapotranspiration would increase as the vegetation cover increases. The net effect of changes to infiltration to the water table is expected to be small and not significant compared to the estimated natural fluctuations in water table levels of about 4 m to 5 m at the void locations.

2.3 Slope Stability

The slopes around the voids are gentle, with a maximum slope of about 18°. Local erosion on tracks leading down to the voids has been repaired and silt fences installed to control rainfall-runoff.

9. Yarraman Groundwater Model (GEO-ENG 2023). Model Run 1858a, October 2024.
10. The modelled groundwater levels reflect the control of the potential seepage level of 26mAHD at the nearby Capembah Creek.



19.5 x 26.41	Groundwater Contours	Catchment	North	Sibelco Australia Minjerribah	Glass Sands Groundwater
Road/Track	Void	Lease Bdy	Bore	Surveyed: Sibelco	Plotted: Oct 28 2024	Design: n/a	Contour int: 0.5m	DATUMS: Hor: GDA Ver: A.H.D.	A4 - 1 : 10000 Figure 5

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The steepest overall slope of 18°, is calculated to have a FOS of about 2.0. The landform is assessed to be stable and as vegetation develops the mine voids will become an indistinguishable part of the local sand dune landform, with intermittent perched water wetlands

3.0 SITE EROSION

Three areas of significant past erosion were identified on ML7064 (Figure 2).

Erosion Zone 1 has been recontoured to a slope angle of about 18°, re-vegetated and protected with fencing. Ongoing maintenance would be required until the vegetation cover has developed (Photo 3–Appendix A).

Erosion Zone 2 has many deep erosion gullies down to the cemented sand layer, which is limiting infiltration (Photo 4–Appendix A). Ripping of the cemented sand would improve the ground condition, but would destroy the thick vegetation cover. It is recommended to backfill the erosion gullies with hay bales and brush cutting to trap run-off and prevent sand erosion

Erosion Zone 3 is similar to Zone 2, but has sparser vegetation (Photo 5–Appendix A). This area could also be treated with hay bales, brush cutting and mulching to encourage better vegetation growth.

Other smaller areas of steep slopes across both mining leases were found to be stable with good vegetation growth and ground cover (Photos 6 to 8–Appendix A).

4.0 VERIFICATION AND AUDITING

Verification of the landform construction is achieved by comparison of post-construction surveys to the EMP requirements as discussed in the PRCP.

5.0 CONCLUSION

The local sand is a strong, stable material suitable for constructing final void slopes. The Glass Sands slopes are generally flatter than 18° and have a FOS of greater than 2.0. Steeper locations indicated by the survey data are related to vehicle tracks and erosion gullies which will stabilise over time as vegetation develops. Ongoing maintenance is to be used to limit erosion until the vegetation is well established. The overall slopes of the mine voids are assessed to be safe and geotechnically stable over the long-term.

The voids are expected to have similar rainfall infiltration rates to the pre-mining condition and thus would have minimal effect on the groundwater regime.

The landform is unlikely to cause any long-term environmental harm and is consistent with the PMLU.

Appendix A—Glass Sands Photos

Photo 1 Western Void

Photo 2 Eastern Void

Photo 3 Erosion Zone 1

Photo 4 Erosion Zone 2

Photo 5 Erosion Zone 3

Photo 6 Drainage gully Diversion Bank Northwest ML1124

Photo 7 Drainage gully Northwest ML1124

Photo 8 Drainage gully Southeast ML1124