

# **Gregory Crinum Mine**

## **Rehabilitation Management Plan**

**Sojitz Gregory Crinum Pty Ltd**

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## 1 Introduction

GCM is located approximately 50km northeast of the township of Emerald, within the Bowen Basin coalfields. The site commenced operations under the ownership of BHP Mitsubishi Alliance (BMA) as a conventional open cut mining operation in 1979, with the addition of the Crinum underground longwall operation in 1993.

BMA placed open cut operations in care and maintenance in 2012. Underground operations ceased in 2015 and the remainder of the site placed in care and maintenance. On 28 March 2019, Sojitz Coal Mining Pty Ltd acquired ownership of GCM from BMA and has been progressively recommencing mining operations at the site since.

This Rehabilitation Management Plan (RMP) has been prepared in support of Gregory Crinum Mine's (GCM) Environmental Authority (EA) (Permit number EPML00945013) dated 15 May 2019).

GCM is required to rehabilitate all areas that have been significantly disturbed through its mining activities back to a stable landform with a self-sustaining vegetation cover. Further, progressive rehabilitation shall commence within two years as and when areas become available within site's mining leases. More than 2,400 ha of disturbed land is already rehabilitated, including 1,177 ha of subsidence area rehabilitation which was certified as progressively rehabilitated by the Department of Environment and Science (DES) in 2018.

The purpose of this RMP is to describe rehabilitation at GCM in accordance with the requirements of Condition F5 of the EA. The RMP shall be reviewed and updated every three years, or as industry or operational changes dictate.

The RMP addresses the requirements of EA Condition F5 as outlined in Table 1.

**Table 1 – RMP coverage of EA Condition F5 requirements**

EA Condition F5 requirement	Where addressed
The rehabilitation management plan must include, at a minimum:	
a) map existing areas of rehabilitation;	Appendix D
b) develop design objectives for rehabilitation of disturbed areas and post mining land uses across the mine;	Section 7 Appendix F, G
c) specify spoil characteristics, soil analysis, soil separation for use on rehabilitation;	Section 3 Appendix A, B
d) detail rehabilitation methods applied to areas;	Section 6
e) contain landform design criteria including end of mine design;	Section 6 Appendix F, G
f) detail how landform design will be consistent with the surrounding topography	Section 4 & 5
g) identify success criteria for areas and itemize revegetation criteria;	Section 6 Appendix F, G
h) explain planned native vegetation rehabilitation areas and corridors;	Section 5 Appendix E
i) identify at least a minimum of three (3) reference and three (3) rehabilitation sites to be used to develop rehabilitation success criteria;	Section 5.2 & 7

EA Condition F5 requirement	Where addressed
j) describe rehabilitation indicators and the monitoring program to be used;	Section 8
k) develop a contingency plan for rehabilitation maintenance or redesign;	Section 8
l) describe end of mine landform design plan and post mining land uses across the mine; and	Section 9 Appendix E
m) include a cost benefit analysis / triple bottom line assessment (or an alternative assessment method) of the proposed final landform design criteria and alternatives.	Section 9

## 2 General Rehabilitation Goals

The Queensland Government has four general rehabilitation goals that require areas disturbed by mining to be rehabilitated such that sites are safe, stable, non-polluting and able to sustain an agreed post-mining land use (DES, 2018).

The overall strategy that GCM has developed to meet these four rehabilitation goals takes into account the physical and biological characteristics of the site. The rehabilitation goals and respective strategies are outlined in Table 2.

**Table 2 – Rehabilitation goals and overall strategy**

Rehabilitation Goal	GCM's Overall Rehabilitation Strategy
Safe to humans and wildlife	<ul style="list-style-type: none"> <li>Spoil dumps will be reshaped to make safe for humans and wildlife.</li> <li>Provide backfill spoil to mine voids and unused ramps during operations, where practicable and cost effective.</li> <li>Upon mine closure, weathered highwall strata will be regraded, and low walls will be regraded, where required to form safe and stable slopes.</li> <li>Above ground tailings dams will be de-watered and capped to be geotechnically and erosionally stable.</li> </ul>
Non-polluting	<ul style="list-style-type: none"> <li>All spoil and waste materials classified as '<i>Hostile/potentially toxic</i>' or '<i>Extremely hostile</i>' (as per Section 3.4) are buried or capped with an adequate depth using competent and benign cover material.</li> </ul>
Stable	<ul style="list-style-type: none"> <li>All final landform slopes will be geotechnically and erosionally stable. Where required, areas of Tertiary sedimentary mine spoil will be covered fully or selectively using more competent Permian spoil or Tertiary basalt.</li> </ul>
Able to sustain an agreed post-mining land use	<ul style="list-style-type: none"> <li>Terrestrial features of the final landform will be formed and revegetated to achieve a mosaic of open woodland and areas suited to low-intensity cattle grazing, depending on slope and/or substrate suitability.</li> <li>Water storage features shall be stable and achieve relevant water quality requirements.</li> </ul>

## **3 Environmental Characteristics**

### **3.1 Pre-mining Landform and Land Use**

The land covered by GCM mining leases was previously used primarily for cattle grazing and dryland cropping. The landform was gently undulating with slopes less than 5%.

Identified pre-mining land systems, and their associated soil type, include:

- Oxford Land System: Downs with cracking clay soils on slightly weathered basalt;
- Daunia Land System: Lowlands with Brigalow and cracking clay soils on weathered and fresh Permian shale and lithic sandstone;
- Humboldt Land System: Blackbutt and Brigalow on weathered clay pans, with texture contrast and cracking clay soils;
- Kinsale Land System: Brigalow scrub on rolling basalt country, with cracking clay soils; and
- Waterford Land System: Undulating country, low hills, shallow cracking clay soils with silver-leafed ironbark on basalt.

### **3.2 Climate**

GCM is located in the warm subtropics. The region experiences moderate, yet variable rainfall, with high evaporation rates. Summers are generally hot, and winters moderate. Droughts are a common occurrence throughout the region.

The long-term averages for rainfall suggest that 71% of the 556mm of annual rainfall is received in between November and April of every year, with 46% of the annual total received in the summer months of December to February. The average number of rain days per year is 45, with 30 of these days occurring between November and April of every year, primarily in the form of cyclonic rain depressions or summer thunderstorms. A typical rainfall pattern for GCM includes:

- Thunderstorms during late spring/ early summer, (i.e. October – December) with erratic frequency and rainfall.
- Wet season rainfall, (typically through January – March) with heavy soaking falls for periods of up to several days.
- Dry season winter/ early spring, (i.e. April – September) with infrequent falls from passing cold fronts.

The annual evaporation rate is estimated to be 2,400mm per annum, greatly exceeding precipitation. This means that rehabilitation has to consider slope, appropriate substrates and species selection in order to ensure that the rehabilitated profile has sufficient plant available water to support vegetation.

### **3.3 Topsoil**

The soil types found at GCM comprise a range of media with variable suitability for placement on land rehabilitation. Most of the soil types are of basaltic origin (black Vertosols) which exhibit shrink/swell behaviour. These cracking clay soils and others on site all have the potential for use in rehabilitation, with due consideration given to slope, erosion risk and vegetation type. The soils in the area are generally suitable for grazing with varying limitations

to their use for pasture improvement. Topsoil depths range between 200-600mm, with the associated subsoils varying in depths. Topsoil is salvaged pre-mining and has valuable growth properties to support rehabilitation such as microbes and organic matter that allows establishment of long-term nutrient recycling processes. Topsoil may also contain seed of aggressive pasture species such as buffel grass.

A 2013 study analysing soil, spoils and mineral wastes across the GCM site (Emmertson & Burgess, 2013a) included Permian and basaltic derived natural soils that had been used in rehabilitation. These soils had the following characteristics:

- neutral pH and very low salinity;
- low ESP. Ca/ Mg ratio is moderate in the Permian derived soil and at good levels in the basaltic soil.
- R1 dispersion is elevated in the Permian derived soil, low in the basaltic derived soil
- generally marginal CEC (poor nutrient holding ability) and low clay activity in the Permian derived soils, (inactive soils) with high CEC and active clays present in the basaltic soils.
- Permian derived topsoil has marginal moisture holding capacity, while the basaltic soil has high moisture holding capacity.
- infiltration rates into the Permian derived soils would only be initially moderate, with resilience being moderate on natural slopes, (low where elevated on freshly topsoiled rehabilitation). Infiltration rates into the basaltic derived soils are initially high, but decrease with wetting, and resilience is relatively high.

Topsoil stripping and handling is managed in accordance with the Topsoil Management Plan (SGM, 2019). The key considerations in the management of topsoil include:

- All topsoil stripping requires an approved Permit to Disturb, based primarily on a topsoil stripping plan which includes:
- the extent of operations, depth of stripping and placement of stripped topsoil.
- Plans for the area to surveyed and appropriately demarcated, i.e. pegged out.
- Topsoil may be pushed into windrows with dozers for removal by truck/ loader or removed directly to rehabilitation or stockpiled with scrapers.
- Mine planning processes aim to prioritise direct placement onto regraded areas over stockpiling.
- Where stockpiling is unavoidable, stockpiles kept below 4m height and are trimmed / deep ripped to prevent erosion.
- Topsoil should not be stripped when it is damp or wet, as this can cause compaction and reduce the viability of the topsoil when used on rehabilitation.
- Any vegetation cleared is stockpiled separately from topsoil.
- Upon completion of the topsoil stripping, a survey of the area, including topsoil stockpile locations and volumes is completed.

### **3.4 Spoil Characteristics**

A wide range of spoil characterisation studies has been undertaken since the 1980's. These have identified that certain strata exhibit a range of unfavourable characteristics. The studies undertaken between 1984 and 2010 are summarised in Appendix A. The most comprehensive

characterisation study is that of Emmerton & Burgess (2013a) who analysed spoil and coal waste material from 248 locations over the full extent of GCM and classified them into 15 Spoil/Waste Mapping Categories (SWMC). The characteristics of each SWMC reflects the geological origin of the material and this is detailed in Appendix B.

The samples were further grouped by “Functional Material Ratings” into 5 groups with similar analytical and behavioural characteristics, and with broadly similar treatment recommendations (see Table 3). Much of the spoil material on site is saline and sodic and consequently, some hostile spoil types need to be isolated from the surface to improve rehabilitation outcomes. Carbonaceous material, coarse rejects and tailings are generally acid forming (pH 2.6 to 4.2) and typically generate high salinity when oxidised (Emmerton & Burgess, 2013a).

Hostile materials can be effectively managed by selective burial or cladding with more benign material (competent Permian sandstone (Pss) and Tertiary basalt ((Tbi, Btb)).

**Table 3 – Spoil and waste material characteristics**

Functional Material Rating	% of mapped area*	SWMC**	Recommended rehabilitation treatment***
Hostile / potentially toxic	15%	Pas, Pcb and Crt	Regarded as being potentially acid forming and where exposed, contribute elevated levels of contaminants to surface water flows. Undesirable as rehabilitation materials and should be preferentially buried (optimally in pit). Where exposed, capping to an adequate depth to account for acidity will be required to achieve effective rehabilitation.
Extremely hostile	16%	Bcz, Tci and Btc	Extremely poor physical characteristics and markedly undesirable as rehabilitation materials. Effective rehabilitation will require cladding with competent and/or resilient cover material.
Hostile/difficult	6%	Bqa, Btq and Pls	Relatively benign but difficult to rehabilitate at anything above low slope angles. Areas with steeper slope angles will most likely require some degree of cladding for effective rehabilitation.
Supportable	59%	Pss and Bpw	In conjunction with the use of topsoil and good rehabilitation methodology should result in adequate rehabilitation outcomes (involving passive land uses) at slope angles which are elevated above background/natural slope angles (but not at high slope angles).
Preferred	4.5%	Tbi and Btb	Effective rehabilitation is achievable on steeper slopes and in more elevated positions than with less competent spoil types. This is a more desirable waste group with a high proportion of resilient rock material present, and this material will have a role in providing cladding to stabilise steeper slopes on poorer spoil/waste types. The material should be salvaged and preserved for future use wherever it is encountered.

\* % of the spoil/waste material area (2,634ha) classified and mapped by Emmerton & Burgess (2013a)

\*\* Spoil/Waste Mapping Categories – see Appendix B for more detail.

\*\*\* For planning purposes only, individual areas should be assessed on a specific basis.

### 3.5 Contaminated Land

Records are maintained at GCM showing the type, location and extent of infrastructure and activities that has the potential to contaminate land. Area specific investigation and remediation action plans shall be developed as part of final rehabilitation and closure planning.

### 3.6 Flora and Fauna

GCM is located in the Brigalow Belt Bioregion, one of 13 bio-geographical areas of Queensland. The Brigalow Belt Bioregion extends from the Queensland – New South Wales border to Townsville. Encompassing approximately 3.6 million hectares, this bioregion consists of sub-humid and semi-arid environments and is contained almost entirely within the 500 to 750mm rainfall isohyets. Extensive clearing has occurred in the Brigalow Belt for agriculture. Remnant Brigalow (*Acacia harpophylla*) woodland and open poplar box woodland provide habitat for native flora and fauna species.

GCM has no current biodiversity offset obligations under Commonwealth or State legislation.

## 4 Bowen Basin Mine Rehabilitation Overview

This section examines the context in which rehabilitation of open-cut coal mines in the Bowen Basin, including the Gregory Crinum Mine, has occurred. It is based largely on Dr Bevan Emmerton's PhD thesis *Bowen Basin Coal Mine Spoil Classification for Improved Mine Rehabilitation Outcomes* (Emmerton, 2019) and an associated paper (Emmerton *et al.*, 2018). The research reviewed relevant literature on the relationship between geological origins, lithology, and weathering characteristics of individual strata within the Bowen Basin Coal Measures (and younger overlying weathered strata) and resultant natural landforms and then applied that knowledge to an assessment of the surface stability of major strata types when disturbed by mining. The research also looked at the relationship between landform, vegetation and erosion.

The relationship between lithology and resultant landform is well recognized. Natural landforms in the economic Bowen Basin coalfields are mostly associated with unconsolidated sediments and fine-grained or lithic substrates and large areas within the Basin occur as level to gently undulating plains and rises with slopes typically <3%. Steeper elevated natural landscapes with gradients >5% are associated with outcropping quartzose or micaceous Permian sandstones, relatively unweathered Cretaceous intrusives and Tertiary volcanics, duricrusted Tertiary sediments, and locally incised Quaternary alluvium.

Open-cut mining using draglines creates spoil piles elevated above the original surface, particularly so for box cut spoil. The increasing use of truck and shovel fleets to pre-strip overburden and place it on pre-existing dragline spoil creates even higher elevated landforms. The spoils on the surface of these constructed landforms are often weathered, sodic, and dispersive, often with high pH and salinity, poor combinations of clay, silt, and fine sand with low coarse sand and fragmental content, which contribute to poor levels of plant growth, low infiltration rates, and high levels of erosion. The side slope angles on these constructed landforms are typically in the range of 10 to 20%. Groundcover of > 70% on slopes > 12% is needed to lower erosion rates (Grigg *et al*, 2001).

Stabilisation of rehabilitated mined landforms in the Bowen Basin has traditionally been attempted through the establishment of protective vegetative cover. Two vegetative strategies have commonly been used. The first is an historical approach, involving the establishment of an improved pasture cover with a view to reinstating productive grazing. However, viable grazing can only take place on land of low slope that may be able to sustain the use into the future. This essentially restricts the grazing scenario for erodible fine-grained spoil types to reconstructed landforms that have low slopes equivalent to pre-mining landscapes.

A second strategy has become more commonplace in recent years and aims to re-establish a bushland ecosystem. However, the widespread presence and aggressive habit of introduced pasture species (such as buffel grass) and woody weeds has meant that the establishment of adequate numbers of woody species is difficult. Competition in the first few years following reshaping, ripping, and seeding is often extreme, resulting in substandard outcomes in terms of density and diversity of woody species. The resultant rehabilitation lacks sufficient structural and floristic diversity to realistically simulate any form of surrogate native ecosystem and is substantially different to unmined reference sites.

The physical and biological factors associated with rehabilitated spoil leads to the establishment of a “novel” rather than a native ecosystem (Doley & Audet, 2013; Erskine & Fletcher, 2013). In such circumstances, Doley & Audet (2013) conclude that it is not practicable to aim for restoration of historical, native ecosystems. However, “hybrid” or “novel” ecosystems comprising new combinations of physical and biological components (including native and non-native species) could provide acceptable levels of stability and functionality given suitable management (Doley & Audet, 2013).

The rehabilitation goals and strategies at GCM are based on an understanding of the regulatory requirements for acceptable rehabilitation as well as spoil and soil characteristics and constraints, climatic factors, mining program factors, and the results of site rehabilitation monitoring to date (Emmertson & Burgess, 2013a, 2013b).

## **5 Existing Disturbance and Rehabilitation**

### **5.1 Existing Disturbance**

When operations first commenced at GCM in 1979, most overburden was removed by draglines. At the time, the site’s lease conditions required that lands disturbed by mining should be “reinstated to no less than its former value for grazing”, thus rehabilitation efforts focused on the establishment of pasture based grazing systems.

Areas of rehabilitation have been completed on site since the early 1980s. Older (i.e. prior to the introduction of pre-stripping with truck and shovel) areas of rehabilitation have generally been constructed by regrading dragline spoil rows to an undulating landform, with slopes generally contoured to a gradient generally less than 15%. Typically 300mm to 400mm of black Vertosol topsoil was replaced and the final landform was then deep ripped, fertilised and seeded with improved pastures. Native tree seed was included in later years.

As spoil from the initial boxcut was placed, out of necessity, on the original land surface, the resultant spoil dump became significantly higher than subsequent spoil placed in the previously mined pit. This resulted in areas featuring longer slopes, higher gradients, and a capability to drain runoff away from the pit. Consequently, these areas require more intensive, or modified, approaches to achieve successful rehabilitation compared to internal spoil dumps.

Of over 7,000 ha of currently disturbed land across the GCM leases, more than 2,400 ha has been rehabilitated. This includes 1,177 ha of subsidence area rehabilitation which was certified as progressively rehabilitated by DES in 2018 (60% to beef cattle grazing PMLU and 40% to dryland cropping PMLU). It should be noted that this extent of dryland cropping rehabilitation is considered the only area likely to be suited to this PMLU, and future subsidence rehabilitation is likely to be cattle grazing PMLU.

Existing areas of disturbance and rehabilitation are summarised in Table 4 and mapped in Appendix C and Appendix D respectively.

**Table 4 – Summary of disturbance and rehabilitation**

Domain / Sub-domain	Area at March 2022 Forecast (ha)
<b>Voids (including pits and ramps)</b>	<b>675</b>
Active Pit	618
Ramps	57
<b>Spoil Area Domain</b>	<b>1,290</b>
Dragline Spoil – In pit	214
First Two Spoil Piles	22
Pre-strip Spoil – In pit	16
Pre-strip Spoil – Out of Pit	1
Spoil Dumps	959
Topsoil Stockpiles – In Pit	28
Topsoil Stockpiles - Rehab	49
<b>Coal Waste Emplacement Domain</b>	<b>207</b>
Rejects – In Pit	41
Rejects – Out of Pit	1
Tailing - Dam	84
Tailings – In Pit	81
<b>Water Management Domain</b>	<b>260</b>
Drains	31
Freshwater Dams	69
Licensed Stream Diversions	65
Mine Water Dams	95
<b>Infrastructure Domain</b>	<b>1,321</b>
Access roads	116
Cleared	260
Coal stockpiles	18
Excised land	13
Exploration	144
Hardstands	37
Haul roads	318
Industrial Area	90
Quarry	15
Structures, including CHPP	158
Topsoil stockpile – Out of Pit	92
Topsoil stripped	60
<b>Subsidence Area Domain</b>	<b>1,753</b>
Certified rehabilitation	1,175
Subsidence	578
<b>Other Rehabilitation (underway and completed) across Domains</b>	<b>1,572</b>
Established rehabilitation	1,226
Re-contoured	269
Seeded - Rehab	77
<b>TOTAL</b>	<b>7,080</b>

\*Data source is GCM\_PoO\_2021\_2022\_V2-MBlock.xlsx - Based upon reconciliation as at April 21 with a forecast out to March 22. M Block layout was captured September 21.

## **5.2 Historical Rehabilitation**

The initial revegetation approach at GCM involved seeding with improved pasture species. Native tree seed was included from time to time, and routinely from about 2000 onwards at rates of several kilograms per hectare. Rehabilitation monitoring commenced in the early 1980s. Systematic programs commenced in 1996 and over 10 monitoring campaigns were undertaken by various consultants up until, and including, 2013. In 2014 BMA placed the open-cut mine in care and maintenance.

Monitoring in 2010 and 2013 was undertaken in accordance with a standardised “One BMA Monitoring” methodology and those results, and others going back to 1996, are documented in Emmerton & Burgess (2013b). The “One BMA Monitoring” covered 17 conventional rehabilitation sites and four local unmined woodland sites. Plots were located in rehabilitation seeded between 1980 and 2002. Plots sizes were typically  $\leq 1,000\text{m}^2$ . Parameters measured included ground cover, tree cover, species counts, profile salinity, physical and chemical characteristics of substrate, and erosion.

Details of the monitoring sites are shown in Table 5 and locations in Figure 1.

The unmined woodland sites are located on plains adjacent to the elevated constructed post-mining landform. There are no unmined locations that are analogous to the rehabilitated spoil and which can be considered as reference sites. The constructed post-mining landform has quite different slopes, soil and substrate characteristics and profiles, resulting in quite different plant-soil-water relationships. It is not feasible to re-establish an ecosystem similar to the unmined sites.

**Table 5 – Rehabilitation monitoring locations**

Site	Easting	Northing	Year Rehabilitated
1	635421	7436984	1986
2	641285	7437897	1983
3	642194	7435658	1984
4	640531	7435902	1986
5	635682	7436253	1991
6	636086	7437759	1988
7	642098	7437814	1991
8	641078	7437186	1992
15	637179	7438200	2001
16	639838	7435102	2001
17	638799	7435869	2002
18	639909	7437925	2002
19	641489	7434816	2001
20	636844	7437294	2002
23	642223	7434806	1999
24	638762	7435564	1999
25	638025	7435257	1985
13	640432	7439084	Unmined (Brigalow-poplar box)
14	643017	7438770	Unmined (poplar box)
21	636342	7432388	Unmined (mountain coolabah)
22	641298	7439431	Unmined (poplar box)



**Figure 1 – Location of Historical Rehabilitation Monitoring Sites**

The key vegetation characteristics of the monitored sites are summarized in Table 6.

**Table 6 – Vegetation characteristics of monitoring sites**

Parameter	Rehabilitation Plot Mean (range)	Parameter Plot Mean (range)
Framework tree species (number)	1.2 (0 - 5)	3.8 (2 - 6)
Shrub species* (number)	3.2 (0 - 8)	6.9 (5 - 10)
Grass species* (number)	2.7 (0 - 6)	12.5 (11 - 15)
Tree canopy cover	8.5% (0 - 26%)	36% (26% - 45%)
Total groundcover (vegetation, litter, rock)	91% (80% - 100%)	84.5% (74% - 96%)

\*excludes weed species and competitive pasture species

The monitoring shows that once buffel grass is introduced, either from applied seed, topsoil seed reserves or natural dispersal, it inevitably becomes the dominant groundcover over time (Emmerton & Burgess, 2013b). While a high level of buffel grass cover assists with erosion control, it also severely suppresses the establishment of native trees and shrubs. This is illustrated by the low species diversity and low tree canopy cover evident in Table 6.

### 5.3 Mine Domains and Post-Mining Land Uses

Since commencement of coal mining and associated activities in 1979, more than 7,000 ha of land has been disturbed across the GCM leases, of which more than 2,400 ha has been rehabilitated. The degree of disturbance ranges from relatively minor (e.g. subsidence areas and areas cleared for exploration) to significant, such as pit voids and spoil piles.

Disturbed land is classified into mine domains, these being land management units with similar geophysical characteristics (e.g. spoil areas or subsidence areas). Different domains tend to contain elements that have different conditions, particularly topography (slope) and substrate characteristics, which make them suited to different post-mining land uses, and hence requiring different rehabilitation treatments to achieve the rehabilitation goals outlined above.

The key to planning for successful rehabilitation is the matching of these domains with the most appropriate post-mining land uses. The most suitable use for an individual area, and hence the required rehabilitation treatment, will be dependent on factors such as substrate characteristics, topography and availability of rehabilitation resources (e.g. topsoil, capping material).

The principal GCM mine domains and their compatible post-mining land use(s) (PMLU) are presented Table 7.

**Table 7 – Mine domains and compatible post-mining land uses (PMLU)**

	<b>Mine Domain</b>	<b>Description</b>	<b>PMLU</b>
<b>1</b>	Undisturbed	That area of the mining leases which remains largely unaffected by mining activity; includes areas historically cleared for grazing.	Low-intensity grazing
<b>2</b>	Spoil Areas	Completed historic rehabilitation (pre-Sojitz acquisition).	Grassy open woodland
		Includes unrehabilitated dragline spoil and pre-strip dumps, areas undergoing various stages of rehabilitation, post-Sojitz acquisition rehabilitation.	Open woodland
<b>3</b>	Coal Waste Emplacements	Tailings Dams: Fine coal waste deposited in above ground dams or in-pit voids.  Rejects Dumps: Coarse coal waste and carboniferous shales, sands and gravels in pit voids or out of pit emplacements.	Low-intensity grazing or open woodland
<b>4</b>	Voids	The open excavation – active or inactive mining voids, includes ramps and benches forward of the highwall.	Non-Use Management Area (NUMA) (see Section 6.6)
<b>5</b>	Water Management Areas	Dams	Water storage (subject to water quality)
		Licensed stream diversions.	Low-intensity grazing or open woodland
<b>6</b>	Infrastructure Areas	Footprint areas under buildings, plant, hardstands, stockpiles, roads and areas which have been stripped of soil (includes exploration tracks and pads).	Low-intensity grazing
<b>7</b>	Subsidence Areas	Areas affected by subsidence caused by underground mining activities.	Low-intensity grazing or dryland cropping

Note that the terminology of “grassy open woodland” PMLU has been used for rehabilitation established on spoil before Sojitz Coal Mining acquired the mine on 28 March 2019 and “open woodland” PMLU is any open woodland established thereafter.

In the existing grassy open woodland PMLU, grass swards may become moribund in the long-term and have reduced effectiveness for erosion control. In such areas, infrequent managed low-intensity grazing and/or infrequent cool burning is likely to be employed. Maintenance requirements for each PMLU are described in Section 8.2.

The projected conceptual PMLUs over the life of the mine are shown in Appendix E.

A description of the rehabilitation approach for each domain and PMLU is provided in Section 6.1.

## 6 Rehabilitation Methods

### 6.1 Rehabilitation Methods for each Domain

The rehabilitation methods aimed at achieving the relevant PMLUs applicable to each mine domain are presented in Table 8. The past rehabilitation practices for the grassy open woodland have been described in Section 5. Rehabilitation details for some domains are elaborated further in Sections 6.2 to 6.8 which follow.

**Table 8 – Rehabilitation methods**

Mine Domain / PMLU	Rehabilitation method
Spoil Areas  PMLU: Open woodland or low-intensity grazing	<ul style="list-style-type: none"> <li>• Pending spoil balance and basalt rock mulch stockpile location, spoil either (i) regraded to <math>\leq 25\%</math> and capped with 0.5 metres basalt rock mulch, or (ii) regraded to <math>\leq 10\%</math> and, if spoil not supportable (see Table 3), capped with 0.5 metres of competent Permian sandstone (Pss).</li> <li>• Reshaped-treated surfaces topsoiled, deep ripped</li> <li>• Slopes <math>&gt; 5\%</math> seeded with 'open woodland' PMLU seed mix</li> <li>• Slopes <math>\leq 5\%</math> seeded with a 'grazing PMLU' mix or 'open woodland' PMLU seed mix (selection may depend on PMLU of adjacent areas).</li> </ul>
Coal Waste Emplacements  PMLU: Low-intensity grazing or open woodland	<p>Tailings (includes Old Tailings Dam, I Block in-pit tailings, F Block in-pit tailings and potentially other future in-pit locations):</p> <ul style="list-style-type: none"> <li>• Cover tailings with 3m of benign spoil</li> <li>• Maximum 3% slope of final surface</li> <li>• Pending spoil balance and basalt rock mulch stockpile location, in-pit margins are either (i) regraded to <math>\leq 25\%</math> and capped with 0.5 metres basalt rock mulch, or (ii) regraded to <math>\leq 10\%</math> and, if spoil not supportable (see Table 3), capped with 0.5 metres of competent Permian sandstone (Pss).</li> <li>• Surfaces topsoiled and deep ripped</li> <li>• Slopes <math>\leq 5\%</math> seeded with a 'grazing PMLU' mix or 'open woodland PMLU seed mix (selection may depend on PMLU of adjacent areas).</li> <li>• Slopes <math>&gt; 5\%</math> seeded with 'open woodland' PMLU seed mix</li> </ul> <p>Rejects (includes H Block and Ramp 3 rejects and potentially other future in-pit locations):</p> <ul style="list-style-type: none"> <li>• Cover rejects with 3m of benign spoil</li> <li>• Maximum 3% slope of final surface</li> <li>• Pending spoil balance and basalt rock mulch stockpile location, margins are either (i) regraded to <math>\leq 25\%</math> and capped with 0.5 metres basalt rock mulch, or (ii) regraded to <math>\leq 10\%</math> and, of spoil not supportable (see Table 3), capped with 0.5 metres of competent Permian sandstone (Pss).</li> <li>• Surfaces topsoiled and deep ripped</li> </ul>

Mine Domain / PMLU	Rehabilitation method
	<ul style="list-style-type: none"> <li>Slopes &lt; 5% seeded with a 'grazing PMLU' mix or 'open woodland' PMLU seed mix (selection may depend on PMLU of adjacent areas).</li> <li>Slopes &gt; 5% seeded with 'open woodland' PMLU seed mix</li> </ul>
<p>Voids</p> <p>NUMA (see Section 6.6)</p>	<p>Low walls and weathered highwalls:</p> <ul style="list-style-type: none"> <li>Pending spoil balance and basalt rock mulch stockpile location, margins are either (i) regraded to <math>\leq 25\%</math> and capped with 0.5 metres basalt rock mulch, or (ii) regraded to <math>\leq 10\%</math> and, if spoil not supportable (see Table 3), capped with 0.5 metres of competent Permian sandstone (Pss).</li> <li>Reshaped-treated surfaces topsoiled, deep ripped</li> <li>All slopes seeded with 'open woodland' PMLU seed mix</li> <li>Safety fencing/bunding as required</li> </ul>
<p>Water management areas</p> <p>Dams PMLU: Water storage.</p> <p>Licensed stream diversion PMLU: Low-intensity grazing or open woodland</p>	<ul style="list-style-type: none"> <li>Pending water quality meeting ANZECC (2000) stock water guidelines, dams to be retained for stock water purposes, otherwise removed</li> <li>Licensed stream diversion rehabilitated following construction. Basalt rock mulch was applied where necessary</li> <li>Licensed stream diversions to be maintained as per <i>Water Act</i> licence conditions</li> </ul>
<p>Infrastructure Areas</p> <p>PMLU: Low-intensity grazing</p>	<ul style="list-style-type: none"> <li>Fixed plants and equipment and structures shall be removed. Certain building (e.g. workshops, offices) may be retained by agreement with future landholder to support grazing/ rural uses</li> <li>Refuelling areas to surveyed for contamination. Contaminated soil excavated and remediated as required</li> <li>Concrete slabs removed. Hardstands de-compacted by deep ripping, topsoil respread, ripped on contour</li> <li>Haul roads de-compacted by dozer ripping, topsoil respread, roadway ripped on contour</li> <li>Minor drainage works where required</li> <li>Infrastructure areas (slopes &lt; 5%) to be seeded with a 'grazing PMLU' seed mix</li> </ul>
<p>Subsidence Areas</p> <p>PMLU: Low-intensity grazing or dryland cropping</p>	<ul style="list-style-type: none"> <li>Re-establish graded erosion control banks on dryland cropping areas where function of existing banks affected by differential settlement</li> <li>Settlement cracks will be monitored and treated where required according to the intensity of the cracking. Deep rip crack zones if required (note, longwall mining has ceased and full settlement has occurred).</li> </ul>

## 6.2 Final Spoil Slopes and Surface Treatment

Spoil shall be either (i) regraded to  $\leq 25\%$  and capped with 0.5 metres basalt rock mulch, or (ii) regraded to  $\leq 10\%$  and, if underlying spoil is not “supportable” (see Table 3), capped with 0.5 metres of competent Permian sandstone (Pss).

Basalt and competent Permian sandstone have:

- a resilient coarse fragment content greatly contributing to surface erosion control by mechanical means;
- desirable characteristics for plant growth; and
- desirable infiltration and moisture retention characteristics.

Rock cladding provides a surface with high infiltration rates and a high level of surface roughness. As well as providing erosion resistance, rock cladding effectively acts as a sponge (the degree of which is partially dependent on cladding depth), minimizing surface runoff, increasing infiltration and limiting concentration of surface flow. Secondly, where a minor pipe structure has formed in underlying spoil, the cladding cover is largely resistant to erosive forces. Moisture captured during rainfall events, slowly drains from the cladding into the clayey spoil below and the moistened spoil is weakened and deforms and settles under the weight of the rocky overburden. This process assists in stabilizing/repairing erosional features that develop (Emmertson, 2019).

Basalt is highly resistant to erosion which is why it is suitable as rock mulch on slopes up to 25%. The surface treatments are designed to provide a substrate with physical properties that minimise erosion and optimise infiltration, rather than relying mainly on vegetation cover.

## 6.3 Open Woodland Revegetation Approach

Black Vertosols, the predominant topsoil resource at GCM, are high clay content soils exhibiting pronounced shrinking and swelling behaviour. This influences seed-soil contact and water uptake by small seeded native tree and shrub species and reduced germination.

Black Vertosol topsoil is replaced at a thickness of 100mm over the rock mulch cladding and deep ripped in such a way to bring rock to the surface. This produces a mosaic substrate which increases infiltration and creates multiple germination niches fed by runoff from individual rocks. It also ameliorates the shrink-swell behaviour of the topsoil. *Eucalyptus/Corymbia* and *Acacia* species germination and establishment is also enhanced because the thinner soil depth reduces the competitive advantage for moisture that introduced grass species, especially buffel grass, would otherwise have. The shrink/swell impacts on germination and establishment are also mitigated.

The topsoil is being utilized as an inoculation resource to ensure the development of an appropriate substrate for the ongoing propagation of soil microbial populations that are required for longer-term nutrient recycling processes.

The open woodland seed mix comprises a range of long-lived woody native species (subject to seed availability) (see Table 9 for an indicative list). A range of scarification treatments are applied to hard-seeded *Acacia* species so that all seed does not germinate in the same rainfall event or same season. Seeding is conducted in mid-year to take advantage of winter rainfall which competitive grass species don't respond to. The overall tree/shrub seeding rate is  $>12\text{kg/ha}$ , much higher than that previously used at GCM.

Table 9 – Indicative open woodland species seed list

Native open woodland species	
<i>Eucalyptus exserta</i>	<i>Lysiphylum hookeri</i>
<i>Eucalyptus populnea</i>	<i>Cassia brewsterii</i>
<i>Eucalyptus crebra</i>	<i>Casuarina cristata</i>
<i>Eucalyptus tereticornis</i>	<i>Atalaya hemiglauca</i>
<i>Eucalyptus cambageana</i>	<i>Acacia bancroftii</i>
<i>Eucalyptus coolibah</i>	<i>Acacia victoriae</i>
<i>Eucalyptus moluccana</i>	<i>Acacia coriacea</i>
<i>Eucalyptus melanophloia</i>	<i>Acacia salicina</i>
<i>Eucalyptus tessellaris</i>	<i>Acacia harpophylla</i>
<i>Corymbia citriodora</i>	<i>Acacia anuera</i>
<i>Corymbia erythrophloia</i>	<i>Dodonaea viscosa</i>

## 6.4 Low-Intensity Grazing

The low-intensity grazing areas will be seeded with improved pasture species and legumes, and a fertiliser regime applied which is appropriate for the particular soil type that has been replaced. The depth of replaced soil will typically be  $\geq 200\text{mm}$ . For black Vertosol soils, species of the Bluegrass (*Dichanthium* spp.) dominant grasslands of the Brigalow Belt Region shall be used as the main pasture species (subject to seed availability).

Infrastructure areas have < 5% slopes and are suited to a low-intensity grazing PMLU. Certain reshaped spoil areas will have < 5% slopes and will also be capable of supporting a low-intensity grazing PMLU. In accordance with the *Guidelines for Agricultural Land Evaluation in Queensland* (DSITI & DNRM, 2015), respective associated land capability classes are:

**Class VI:** Land that is not suitable for cultivation but is well suited to pastoral use and on which pasture improvement involving the use of machinery is practicable.

**Class VII:** Land that is not suitable for cultivation but on which pastoral use is possible only with careful management; pasture improvement involving the use of machinery is not practicable.

## 6.5 Coal Waste Emplacements

Current coal waste emplacements comprise tailings (Old Tailings Dam, in-pit I Block, in-pit F Block, H Block South) and rejects (H Block South, Ramp 3). In the future, tailings and rejects may also be placed in other voids. The locations of current emplacements are shown in Figure 2 and the rehabilitation method is presented in Table 8. Coal waste shall be covered with a 3m cover of benign spoil in order to isolate replaced topsoil from any capillary rise of acidity and salinity.



Figure 2 – Coal Waste Emplacement Locations

## 6.6 Final Voids

The approach to rehabilitation of final voids is presented in Table 8. A residual void investigation study has been undertaken in accordance with EA Condition F7 (SGM 2021). The study modelled void long-term water balances and long-term Total Dissolved Solids concentrations (TDS) (as an indicator of water quality) for the final voids. The void characteristics are summarised in Table 10. The TDS of water in the residual voids is predicted to become unsuitable for irrigation and for drinking water for stock within decades (ie TDS well above 4,000 mg/L). The voids would be unable to support a Post-Mining Land Use and would be Non-Use Management Areas. Serious environmental harm is not expected to be caused to any recognised groundwater aquifer. The maximum water level does not reach a level where any of the voids would spill and therefore adverse environmental impact is not expected to be caused to adjacent surface waters or adjacent land.

**Table 10 – Summary of final void characteristics**

Final Void	High Water Level* (mRL)	Surface Area** (ha)
M Block	188.2	16.3
J Block Ramp 7	191.9	12.1
J Block Ramp 8	173.8	9.3
J Block Ramp 9	167.8	27.5
F Block	193.8	8.2
ASE Block - A	176.3	7.2
ASE Block - B	176.3	12.3
ASE Block - C	176.3	3.6
ASE Block - D	176.3	7.3
ASE Block - E	176.3	2.8
G Block Central	167.5	45.6
ABG Block - West	176.2	0.7
ABG Block - East	176.2	31.2
G Block North - A	183.3	2.4
G Block North - B	183.3	0.7
Ramp 4	183.1	2.0
Liskeard	198.1	5.2
		Total 194.4

\* average of maximum daily level

\*\* at high water level

## 6.7 Water Storages

It is envisaged that some freshwater and mine water dams would be retained in support of grazing activities after mine closure. Any mine water dams to be retained shall be remediated to remove any contaminated material which may be present. Dams will only be retained if water quality meets ANZECC (2000) water quality guidelines for beef cattle.

The G North Wetland is a former void located adjacent to Crinum Creek that has been retained as a permanent water body. It receives catchment inflow from Boundary Drain catchment to the north-east as well as back flow from Crinum Creek during high flow events. Under the EA, water is able to be released from G North Wetland to Crinum Creek, subject to meeting downstream water quality criteria for pH and EC. G North Wetland water quality meets ANZECC (2000) water quality guidelines for beef cattle and has a water storage PMLU.

## 6.8 Licenced Creek Diversions

Sojitz Gregory Crinum Pty Ltd holds water licences under the *Water Act 2000* for the Crossbed Creek diversion (licence 45251F) and the Crinum Creek diversion (licences 41312F and 401300). The Crossbed Creek diversion was constructed in the 1980s to divert the creek to the west and south of its original alignment and enable the mining of J Block. Crinum Creek was diverted during the 1980s to allow for open cut mining beneath the original alignment. The diversion provides a connecting corridor for fauna between the upstream and downstream natural reaches of Crinum Creek.

The water licences require an on-going monitoring and evaluation program be carried out consistent with ACARP Project C9068 *Monitoring and Evaluation Program for Bowen Basin River Diversions* (ACARP 2001). The diversions must be maintained in accordance with the water licence conditions and the licences cannot be relinquished until the diversion is meeting or progressing towards:

- developing features (including geomorphic and vegetation) present in the landscape and in local watercourses;
- maintenance of a sediment transport regime that allows the diversion to be self-sustaining and not directly impact upstream or downstream reaches; and
- the diversion and associated structures maintain equilibrium and functionality and do not require ongoing maintenance.

Prior to relinquishment, a final evaluation report must be certified by a Registered Professional Engineer of Queensland.

## 7 Rehabilitation Objectives, Indicators and Completion Criteria

For each of the PMLUs (low-intensity grazing, dryland cropping, grassy open woodland, open woodland, water storage), specific rehabilitation objectives, indicators and completion criteria have been developed taking into account the four general rehabilitation goals set out in Section 2.

The rehabilitation objectives, indicators and completion criteria for subsidence area PMLUs are presented Appendix F. These are the same BHP (2018) criteria against which subsidence was certified as progressively rehabilitated by DES in 2018.

The rehabilitation objectives, indicators and completion criteria for PMLUs in all other areas are presented Appendix G.

The floristic completion criteria (species richness and tree canopy cover) for grassy open woodland and open woodland are interim criteria. Grassy open woodland criteria are based on mean data from historic rehabilitation monitoring (see Table 7), the last of which was carried out in 2013. A further round of monitoring is necessary before finalisation. The open woodland criteria assume improved species richness and tree canopy cover due to the recent adoption of rock mulching, higher native tree seeding rates and measures to reduce grass competition. The results from open woodland monitoring undertaken four years after establishment shall be used to validate these interim criteria.

## 8 Rehabilitation Monitoring and Maintenance

### 8.1 Monitoring Program

As new areas of rehabilitation are established, new monitoring locations shall be established in representative locations. Certain parameters measured at historical monitoring sites may be discontinued at some sites, or the locations themselves discontinued. For example, leaching behaviour of salts down the soil-spoil profile is now understood for the main spoil types (Emmertson & Burgess 2013b, Emmertson 2019) and such measurements are no longer routinely required at all sites.

The rehabilitation monitoring program is outlined in Table 11.

**Table 11 – Rehabilitation monitoring program**

Type of Disturbance	Type of Monitoring	Schedule
Rehabilitated spoil	Representative transects: - Groundcover (vegetative and non-vegetative) - Canopy cover - Species diversity - Gully and sheet erosion - Soil characteristics	Years 1, 2 and 4 post-establishment, then 4 yearly intervals
Final voids	- Geotechnical stability of walls (field inspections and aerial imagery).  - Water level and quality (pH, EC).	- At cessation of mining, then 5-yearly intervals until relinquishment - Annual sampling and analysis
Creek Diversions	Vegetation cover assessment and structural stability: - Inspect full length of diversions using high resolution aerial photogrammetry and/ or detailed ground observations.	Surveillance inspections as per Water Licence requirements.

In addition to continued rehabilitation monitoring based on discrete sampling locations, there is a need to gain broader, PMLU-wide, information about rehabilitation performance against completion criteria. Commencing with the gassy open woodland PMLU, a methodology shall be developed over the next three years to monitor rehabilitation at scales encompassing tens and hundreds of hectares. This is likely to involve a combination of high resolution multi-

spectral remote sensing imagery (e.g. obtained from aircraft, drones or satellite) in conjunction with some physical traverses to ground-truth and calibrate remotely collected data.

## **8.2 Maintenance**

Rehabilitated areas shall be regularly inspected to identify any areas in need of maintenance. Inspections shall be conducted after extreme rainfall events.

As a contingency in cases of sub-standard rehabilitation, a maintenance program shall be implemented. Rehabilitation maintenance activities include:

- Remediation of unstable and expanding gully erosion and repair of failing drainage works.
- Remediation of areas showing poor vegetation establishment. This may involve ripping, reseeding and/or fertilising, depending on the identified cause of the problem.
- Maintenance of graded banks in certified progressive rehabilitation (dryland cropping areas).
- Control of invasive weeds in rehabilitated areas (subject to the requirements of the *Biosecurity Act 2014*).

In older grassy open woodland rehabilitation, grass swards may become moribund in the long-term and have reduced effectiveness for erosion control. In such areas, managed infrequent low-intensity grazing and/or infrequent cool burning is likely to be employed in a manner which does not adversely affect long-term tree and shrub cover.

# **9 Final Landform Planning**

## **9.1 Final Landform Design**

A conceptual final landform design has been prepared for GCM based on the expected pit and dump surface configuration at the cessation of operations. Operational mine planning takes into account the need to take opportunities to progressively achieve the final landform design by providing backfill to existing residual voids and unused ramps.

The following assumptions have been made when designing the final landform:

- unrehabilitated spoil and low wall slopes greater than 25% shall be reshaped to a maximum slope of 25%;
- weathered highwalls shall be reshaped to a maximum slope of 25% and unweathered highwalls remain;
- slopes below long-term final void high water levels will be left at angle of repose;
- reshaped 25% slopes shall be capped with 0.5m of basalt rock mulch; and
- a 30m running surface shall be provided for basalt and topsoil haulage.

The conceptual final landform is shown in **Appendix H**.

## **9.2 Rehabilitation risks, costs and benefits**

GCM conducts risk assessments and budgeting for rehabilitation outcomes in coordination with Sojitz Green Pty Ltd (a contracted rehabilitation entity of Sojitz Coal Mining Pty Ltd).

GCM's assessment of the risks, costs and benefits pertaining to rehabilitation covers social, environmental and economic aspects. When critical decisions are being made, managers are required to look beyond the obvious risks and recognise all sources of uncertainty, including issues related to health, safety, environment and community.

In conjunction with the above, GCM carries out a regular environmental risk assessment, which includes the identification of major risks for closure and beyond. This risk assessment involves key site personnel, particularly long-term planners, environmental personnel, coal preparation and handling, and mine operations.

Considered to be an important inclusion in site's environmental risk assessment is landform stability and the adequacy of site's rehabilitation programs. These risks include:

- Rehabilitation Criteria: Company may not meet the performance criteria;
- Landform Stability: If inadequate or poor design parameters are used, inherent high erosion risks would result;
- Final Voids: Voids with incompetent wall and spoil materials may need substantial treatment;
- Community Pressure: Possible community objection if landforms fail;
- Tailings Dam Failure: Potential for wall failure due to erosion, seismic events, etc.;
- Water Management Criteria: If rehabilitation is ineffective, sediments and salts could migrate to creeks and rivers;
- Creek Diversions: If poorly designed or constructed, erosion of batters and siltation further downstream could occur;
- Out-of-Pit Reject Dumps: If insufficient capping is applied, possible potential for fires to establish; erosion of batters could expose rejects, etc.;
- Groundwater: Saline waters may impact regional aquifers;
- Contaminated Sites: Groundwater may be impacted by mobilisation of contaminants;
- Infrastructure CHPP/ROM, Haul Roads: Costs could be higher than expected;

GCM's risk assessments show that the most substantive risks which have the greatest potential impact the business relate to the erosional and geotechnical stability of the final landform, and the protection of surface and groundwater resources. Land disturbance is a major impact of open cut mining operations and represents by far the greatest element of the rehabilitation liability.

The risk assessments highlight the importance that final landform should not be considered as merely a consequence of an excavation program, but rather the outcome of a planned mining and spoil placement program by which a stable landform has been reinstated.

The most substantive costs for a large open cut mine site such as GCM are associated with stabilising large areas of elevated spoil and residual voids. These costs are generally significantly higher than for other mine disturbance domains. GCM is conscious that spoil placement is paramount when establishing a final landform in which spoil elevation is reduced as much as practicable, whilst allowing coal reserves to be extracted in an economically viable manner.

The life-of-mine planning at GCM recognises that conservative spoil treatments are required to improve the sustainability of constructed landforms on site. The strategies that have been developed take into account the costs of material movement and benefits of the final stable landform. The approaches taken include primary mine plan dumping to pits and ramps as part of the routine spoil placement activity and regrading of spoil slopes to modest grades or to

steeper grades, depending on underlying spoil characteristics and availability of capping material.

## 10 References

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## 11 Version Management

Version	Details	Contributors
1.0	November 2021	Rehabilitation Manager (R. Gooley)

## 12 Appendices

### Appendix A: Spoil Characterisation Studies 1984 - 2010

Spoil characterisation studies undertaken between 1984 and 2010 are briefly summarised below.

#### **Emmerton 1984** (E block trial characterisation and rehabilitation monitoring sites.)

Spoil analysis programs have been undertaken in association with various trials and monitoring programs since the early 1980's. In the early years of the mine, several trials were established to examine the beneficial effects of topsoil.

#### **Thomas 1992** (Thomas WJ, E block characterisation, 1992)

Wendy Thomas (1992) revisited the topsoil trial area at E Block (established by Emmerton). Soil cores were extracted to measure trends in pH and EC, which had also been monitored in 1987 and 1989. Results confirm that topsoiled areas have sustained robust vegetation cover with deep leaching of salts and pH reduction as opposed to adjoining bare spoil areas which have remained bare, saline and extremely alkaline. In addition, topsoil has significantly improved soil surface condition through increased infiltration potential and decreased potential to set hard and erode.

#### **CSIRO Investigation 1994** (Review of Research Investigations and Existing Data on the Characteristics of Coal Mining Spoil, Bowen Basin, Central Queensland, TPT McLannan, February 1994)

The CSIRO report reviews spoils work undertaken at Gregory Mine and refers to work undertaken by Evans and also Emmerton. The CSIRO report notes that the spoil is composed of two main units:

- 1 Strongly alkaline sandstone (up to pH 9.5), moderate to high soluble salts and high ESP (13%)
- 2 Strongly acidic shales (pH 4.7) with high soluble salts and very high ESP (46%). Evans et al., 1980; Evans, 1983; Emmerton, 1984)

The report also noted:

- Salinity studies carried out by Emmerton (1984) were continued by mine personnel to at least 1989. Significantly, EC results on 10yr old, topsoiled test sites highlight the flushing of salts down the profiles. However, bare spoil has remained saline; and
- Analyses by Evans indicated that shales are acidic, extremely sodic and Sulphur rich and quite saline, whilst sandstones were alkaline, but still quite saline and moderately sodic.

#### **Woodward Clyde 1993** (Gregory Mine Reject and Spoils Characterisation, September 1993)

The Woodward Clyde study mostly dealt with rejects but included chemical characterisation of two spoil samples in the G North Area. The consultants reported that both samples were highly saline and the results were reported for saturated paste as follows:

- pH: 6.8 and 7.6
- EC: 1,400 and 2,180 uS/cm\*

\*Note these results do not support a conclusion for high salinity. These are modest salinities if saturated pastes were used.

### **Land Reclamation Services Pty Ltd 1996**

In November 1996, Land Reclamation Services Pty Ltd (LRS) commenced baseline assessment of vegetation, soils and erosion at 14 sites across Gregory Mine (Elsol 1997, Emmerton 1997, Fletcher 1997).

### **CLMR 1998**

In December 1998, the Centre for Mined Land Rehabilitation (CMLR) took over the program which set out to:

- determine diversity, density and cover of vegetation and changes over time,
- determine pH and EC profiles,
- analyse media at each site for properties relevant to long-term success of rehabilitation and,
- measure erosion rates.

### **ACARP Projects 1629 & 4011, 1998**

These projects were co-ordinated by the University of Queensland (1998); set out to establish landform design parameters for erosional stability on rehabilitated spoil in the Bowen Basin. Field studies for this project at Gregory Crinum were conducted at Ramp 8. Results from rainfall simulation trials indicated that erosion rates for bare weathered and un-weathered Permian spoils did not significantly reduce until the slope gradient fell below 15%. Consequently, in situations such as ramp batters or low walls, flattening of batters from repose to 30% would not improve land suitability potential of the regraded slope and would reduce the amount of better performed, flatter adjoining areas which would be needed for cut back.

### **Spoil Profile Chemistry GTES Pty 2004** (GTES Pty Ltd, BMA Gregory Crinum Mine Rehabilitation Monitoring Soil Profile Chemistry, April 2004)

In 2004 Graham Tuck (GTES) undertook spoil profile monitoring at 10 older rehabilitation sites across Gregory Mine. Three levels of rehabilitation performance were used:

- Category 1: Sites which have reached a satisfactory steady-state chemically with little variation across the three profiles or with immediate past sampling trends. Six sites met these criteria.
- Category 2: Sites which have reached an unsatisfactory steady-state chemically with little variation across the three profiles or with the immediate past sampling trends. 3 sites met this criterion.
- Category 3: New sites, or sites having not reached a steady state with major variation either within the three sampled locations or with previous trends. They remain in an apparent dynamic chemical state. 1 site was placed in this category.

### **BR Emmerton 2010** (Preliminary Characterisation of Major Spoil and Waste Types Evident on Gregory Mine as a Guide to Contaminant Source Identification, Oct 2010)

In 2010, B. R. Emmerton Pty. Ltd. was commissioned to undertake a survey of spoil/waste materials on site and to classify the materials into broad categories which would have relevance in terms of physical attributes and possible elemental enrichment.

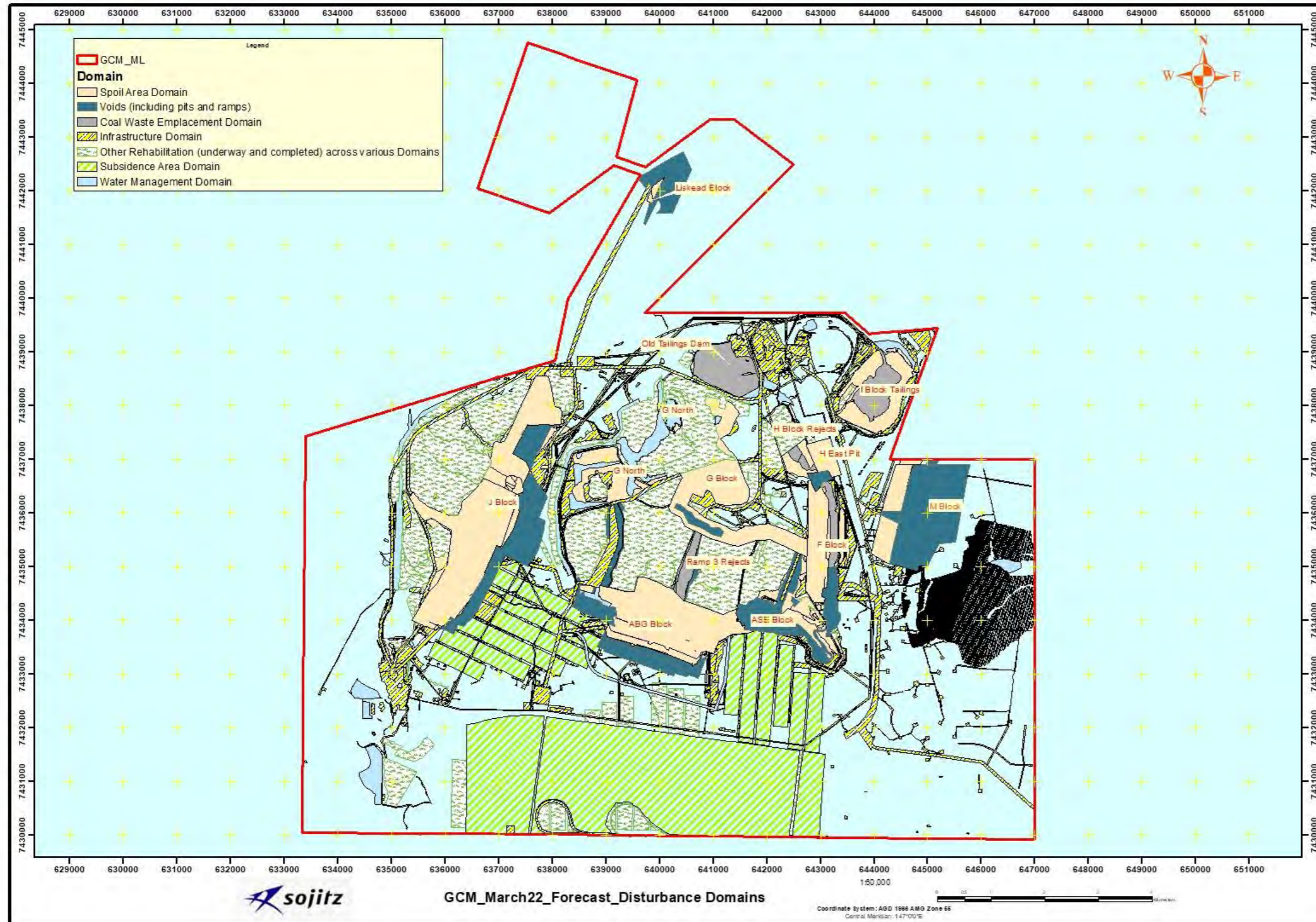
Emmerton classified spoil types present into broad categories and also appraised spoil quality of the materials which were present in areas disturbed to date. The investigation covered the full length of the mine. The study was a broad rapid assessment of the spoil and waste materials on site as an interim guide to potential spoil and coal waste contaminant sources. It examined spoil and coal waste material from 21 sites, which were considered to be the major spoil and waste types observed on site by the author to date. It classified the spoil/waste into ten Spoil/Waste Mapping Categories (SWMC's).

## Appendix B: Characteristics of Soil, Spoil and Waste Materials

Material type/ Strata	pH, EC, Cl & SO <sub>4</sub>	ESP & Ca/ Mg	R1 Dispersion	CEC & Clay Activity	Moisture holding capacity/ use	Resilience & Infiltration Characteristics
<b>Uncontaminated surface soil samples</b>						
<b>Permian derived soil</b>  <b>Basaltic derived soil</b>	pH is neutral and salinity is very low.	ESP is low. Ca/ Mg ratio is moderate in the Permian derived soil and at good levels in the basaltic soil.	Elevated in the Permian derived soil, low in the basaltic derived soil.	Generally marginal CEC (poor nutrient holding ability) and low clay activity in the Permian derived soils, (inactive soils) with high CEC and active clays present in the basaltic soils.	The Permian derived topsoil has marginal moisture holding capacity, while the basaltic soil has high moisture holding capacity.	Infiltration rates into the Permian derived soils would only be initially moderate, with resilience being moderate on natural slopes, (low where elevated on freshly topsoiled rehabilitation). Infiltration rates into the basaltic derived soils are initially high, but decrease with wetting, and resilience is relatively high.
<b>Quaternary silty/sandy alluvium</b>						
<b>Bqa</b>	pH was highly alkaline in the sample analysed. E.C., chloride and sulphate are low.	ESP was low in the leached sample analysed. Ca/Mg ratio is at a good level.	The material has extreme dispersion (R1 of 0.95).	Moderate CEC (reasonable nutrient holding ability), with moderate clay activity (0.78) in the sample analysed.	Relatively low (marginal) moisture holding capacity for shallow rooted species. The materials are better suited to the growth of more resilient deep rooted woody species.	The material has reasonable infiltration characteristics but is extremely erosive where vegetative cover is not present, with the low clay content and high sand content providing little aggregation and little resistance to erosion. The material is also prone to tunnel erosion and piping/slumping
<b>Unconsolidated Tertiary – Quaternary calcareous sediments</b>						
<b>Btq</b>	pH is alkaline to highly alkaline, with moderate salinity and chloride levels encountered in fresh samples.	ESP is elevated, (6 to 16%) but maybe reduced by exposure and leaching. Ca/ Mg ration is variable, (low/ imbalanced to non-limiting).	The material has elevated to extreme dispersion, (0.56 to 0.99, with a mean level of 0.82).	Generally moderate CEC, (reasonable nutrient holding ability) with low to moderate clay activity, (0.25-0.74) in the samples analysed.	Generally relatively low, (marginal) moisture holding capacity for shallow rooted species. The materials are better suited to the growth of more resilient deep rooted woody species.	The materials have variable infiltration characteristics, (higher infiltration where coarser materials are present) but are generally extremely erosive. The material type is also prone to tunnel erosion and piping/ slumping in an elevated landform.
<b>Unconsolidated Cainozoic sediments (sedimentary origins)</b>						
<b>Bcz</b>	Generally highly alkaline pH. High salinity and chloride levels which inhibit germination and growth. Sulphate is sometimes elevated.	High to extreme ESP, (19 to 36%, with a mean of 28%). Ca/ Mg ration is generally low to strongly imbalanced, indicating dispersion and poor infiltration characteristics.	Extreme dispersion, (0.78 to 0.99, with a mean level of 0.87).	Marginal to moderate CEC, with a moderate clay activity ration, (mean level of 0.52) indicating only very slight clay activity.	Moderate moisture holding capacity, (if water can infiltrate and salinity does not restrict plant use). The materials are considered very hostile and would only support a range of resilient salt tolerant ephemeral shrub or woody species. The materials are not a desirable subsoil and should be preferentially buried wherever possible.	Extremely poor infiltration characteristics dues to sodicity, dispersion, high fine sand and silt contents and moderate clay content, (with low activity). The materials are prone to capillary rise of salts. They are highly erosive, (by surface erosion, and also by piping in the unconsolidated landforms) and this is exacerbated by high runoff levels.
<b>In situ Tertiary sediments</b>						
<b>Tci</b>  <b>Btc</b>	Neutral to highly alkaline pH. Salinity and chloride are often extreme. Sulphate is sometimes elevated. The materials do not leach readily and are prone to capillary rise of salts where exposed.	Elevated to extreme ESP, (9 to 38% with a mean of 16%). Ca/ Mg ratio is generally strongly imbalanced indicating dispersion and poor infiltration characteristics.	High to extreme dispersion, (0.71 to 0.99, with a mean level of 0.86).	Generally low to marginal CEC, with a low clay activity ratio, (mean level of 0.23) indicating a lack of clay activity.	Low to moderate, (considered marginal) moisture holding capacity, (if water can infiltrate and salinity does not restrict plant use). The materials are considered very hostile and would only support a range of resilient salt tolerant ephemeral shrub or woody species. The materials are not a desirable subsoil and should be preferentially buried wherever possible.	Extremely poor infiltration characteristics due to sodicity, dispersion, high fine sand and silt contents and substantial inactive clay content. The materials are prone to capillary rise of salts. They are extremely erosive, (even on moderate slopes) and are also prone to piping in unconsolidated landforms.
<b>Tertiary basalt</b>						
<b>Tbi</b>  <b>Btb</b>	Alkaline to highly alkaline pH. Salinity and chloride are low.	Generally very low sodicity, (<1 to 8%, with a mean of <2%). Ca/ Mg ratio is very high and this will assist physical characteristics in the long term.	Low dispersion.	Good CEC level, strong nutrient holding ability, (although nutrition is often low) and active clays are indicated.	There is only marginal to moderate moisture holding ability in the fine fraction and the rock, (basalt) content present further lowers moisture storage for shallow rooted plants. The material is considered to be a desirable subsoil material, but is considered better suited to growth of woody species than pasture growth.	Good infiltration characteristics are present, due to the ability of the material to form a resilient surface rock mulch and due to other desirable physical characteristics. The materials are considered to be stable materials, with good erosion control characteristics.
<b>Permian sedimentary rocks (predominately fresh)</b>						
<b>Pis</b>	Alkaline to extremely alkaline material. Some high to extreme salinity and chloride levels, (with elevated sulphate) where leaching has not occurred.	Elevated sodicity, (11 to 16%, with a mean of 13%). Ca/ Mg ratio is strongly imbalanced.	Elevated to high dispersion, (0.58 to 0.77 with a mean of 0.67).	Moderate CEC level indicating a reasonable nutrient holding ability. The clays present have high activity, however their content is relatively low and the majority, (77 to 82%) of the material is fine sand and silt.	A moderate moisture holding ability is indicated, however the materials are not considered to be desirable materials where any slope is present as they are prone to erosion.	Poor infiltration characteristics and high erosion are evident from field observations. Although sodicity is not extreme, sediments are soft and labile, fine sand content is high and silt contents are very high. Coarse sand content, (which assists infiltration and hydraulic conductivity) is very low.
<b>Pss</b>	Neutral to highly alkaline	Elevated sodicity where exposure and	Elevated to extreme	The CEC level is marginal, indicating a limited nutrient	Clay content is often marginal, and only marginal to moderate	Dispersion and the presence of semi-active clays, (causing rock fretting) make the materials

Material type/ Strata	pH, EC, Cl & SO <sub>4</sub>	ESP & Ca/ Mg	R1 Dispersion	CEC & Clay Activity	Moisture holding capacity/ use	Resilience & Infiltration Characteristics
	material. Salinity and sulphate levels may be elevated where leaching has not occurred, (the material leaches readily in better seasonal/ rainfall conditions).	leaching has not occurred, (range of <1 to 15%). Ca/ Mg ratio is imbalanced to strongly imbalanced.	dispersion in the fine fraction, (0.56 – 0.99, with a mean of 0.81) but the material can be stabilised to a degree with rock armouring.	holding ability. The clays present appear to have slight activity, (mean activity ratio of 0.65) which would assist rock fretting.	moisture holding ability is indicated, (this is further lowered by the rock content present). The material is considered to have moisture and nutrient holding limitations and is considered better suited for woody species growth rather than pasture growth.	prone to breakdown in the short to medium term. Infiltration would initially be at good levels but would decline in the medium term in strata where high fine sand and silt is present. The bulk of the materials are considered to exhibit erosive characteristics, but the presence of some resilient rock materials slows erosion processes.
<b>Bpw</b>	Marginal/ low to extremely high pH range. Salinity, chloride and sulphate levels are sometimes elevated, and the more highly weathered materials do not leach as readily as the fresh Pss materials.	Elevated to high ESP where more weathered materials are present, (range of <1 to 25%). Ca/ Mg ratio is imbalanced to strongly imbalanced indicating dispersion and poorer infiltration characteristics than are desirable.	High to extreme dispersion in the fine fraction, (0.66 – 0.90, with a mean of 0.81). The less clayey materials show partial stability with rock armouring.	The CEC level is marginal, indicating a limited nutrient holding ability. The clays present appear to have very slight activity, (mean activity ratio of 0.56) which would assist rock fretting.	Clay content is sometimes marginal, and generally moderate moisture holding ability is indicated, (this is lowered by the rock content present in less weathered materials). The material is considered to be a reasonable subsoil material but has some nutrient and hydraulic conductivity limitations and is considered better suited to woody species growth than pasture growth.	The presence of dispersion and high fine sand and silt contents, (totals of 52 to 80%) along with the presence of moderate amounts of clay with only slight activity suggests that the materials have a moderate to poorer infiltration characteristic. The materials may occasionally be prone to capillary rise of salts in poorer seasonal conditions, (in the poorer of the materials approaching the Bcz spoil type).
<b>Pas</b>	Strongly acidic material which is below the range for effective plant cover. Salinity and sulphate are elevated or occasionally extreme.	Generally low ESP. Ca/Mg is imbalanced or at a reasonable level.	Elevated to extreme dispersion in the fine fraction (0.58-0.99, with a mean of 0.71), but the material rock armours to a degree.	CEC and clay activity were not measured, however CEC would be considered to be marginal and the clays present would be considered to have slight activity. A substantial proportion of the exchange complex would be occupied by aluminium and acidity.	Clay content is sometimes marginal, and moderate moisture holding ability is indicated. The materials are not a desirable subsoil (due to the low pH), and should be preferentially buried, as runoff will contain substantial levels of undesirable contaminants.	Infiltration would initially be at good levels but would decline in the medium term in strata where high fine sand and silt is present. The bulk of the materials are considered to exhibit erosive characteristics, but the presence of some resilient rock material slows erosion processes.
<b>Coal enriched materials</b>						
<b>Pcb</b> <b>Crt_c</b> <b>Crt_r</b> <b>Crt_t</b>	Extremely acidic pH which is below the range for effective plant cover. Salinity and sulphate levels are generally extreme.	Generally low (sometimes elevated) ESP. Ca/Mg level is imbalanced or at a reasonable level.	Generally elevated to extreme dispersion (0.56-0.99, with a mean of 0.78).	CEC and clay activity were not measured. A substantial proportion of the exchange complex would be occupied by aluminium and acidity.	Clay content is usually marginal, and marginal moisture holding ability is indicated. The materials are not a desirable subsoil (due to extremely low pH), and should be preferentially buried/capped, as runoff or drainage/leachate will contain substantial levels of undesirable contaminants.	Infiltration into coarse textured materials such as rejects is initially high and leads to the production of undesirable leachate. Runoff from both tailings and exposed/compacted rejects material also creates undesirable surface flows. Tailings materials have almost no plant cover, are totally dissociated and would have very little resistance to erosion if not contained in an impoundment.

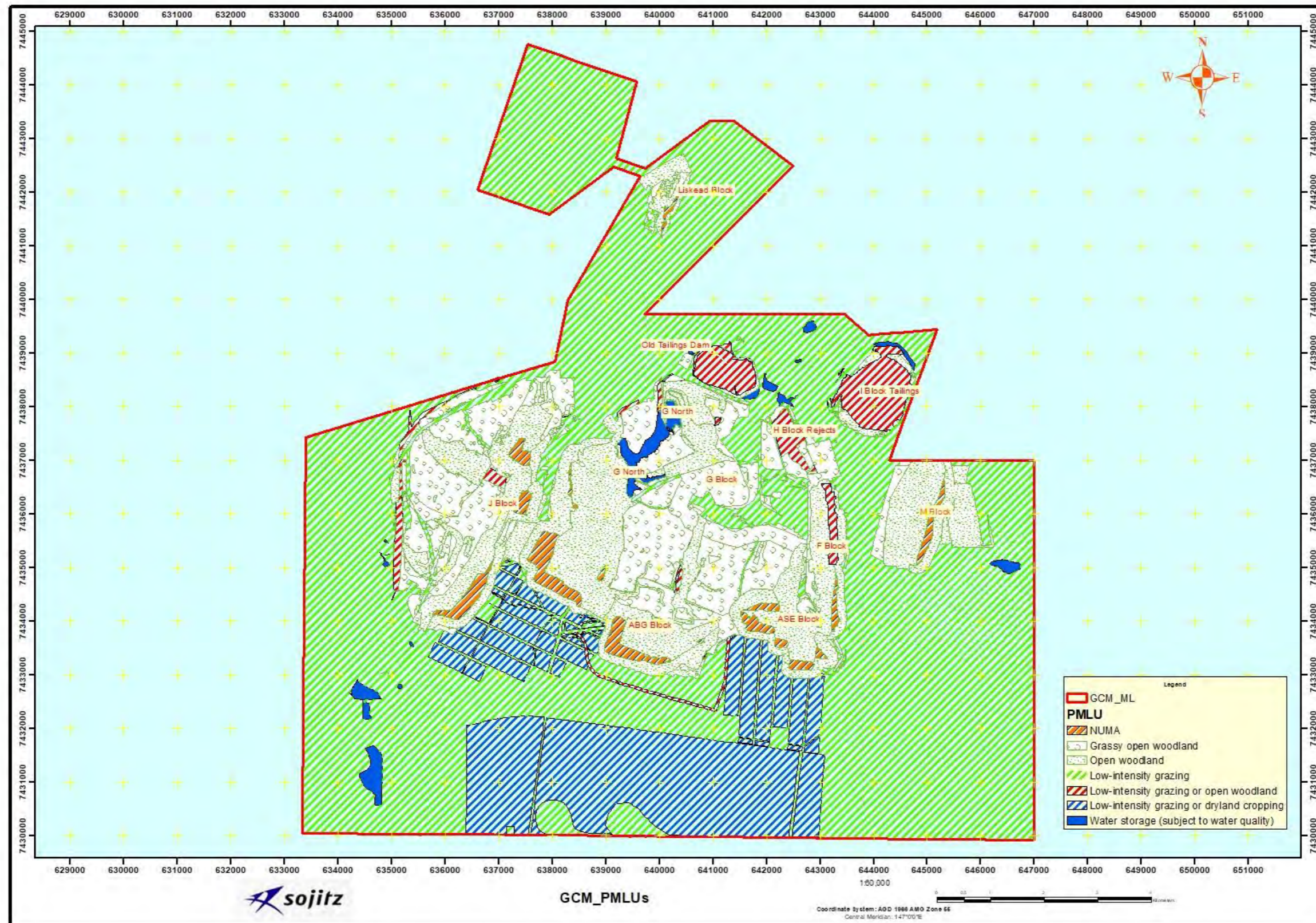
**Appendix C: Land Disturbance Domains (Forecast March 2022)**



**Appendix D: Current Land Rehabilitation**



**Appendix E: Conceptual Post Mining Land Uses**



## Appendix F: Subsidence – Rehabilitation Goals, Objectives, Indicators and Completion Criteria

Rehabilitation Goal	Rehabilitation Objective	Indicators	Completion Criteria
<b>Dryland Cropping</b>			
Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
Stable	Rehabilitation is geotechnically stable	Factor of safety	≥1.5
	Rehabilitation is erosionally stable	Percentage of cultivation at >1% slope gradient with functional contour banks	100%
Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to: a) the EPP (Water) schedule documents water quality objectives for relevant sub-basins; or, b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
	Deep drainage from rehabilitation achieves relevant water quality objectives for groundwater <sup>1</sup>	EC	Not significantly different to: a) the EPP (Water) schedule documents water quality objectives for relevant groundwater chemistry zones; or, b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
Able to sustain an agreed postmining land use	Rehabilitation is suitable for sustainable dryland cropping	Land suitability assessment for dryland cropping	Land suitability class ≤3
<b>Beef Cattle Grazing</b>			
Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference
Stable	Rehabilitation is geotechnically stable	Factor of safety	≥1.5
	Rehabilitation is erosionally stable	Groundcover	>50%
Non-polluting	Rainfall runoff from rehabilitation achieves relevant water quality objectives for receiving waters	pH EC Turbidity	Not significantly different to: a) the EPP (Water) schedule documents water quality objectives for relevant sub-basins; or, b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
	Deep drainage from rehabilitation achieves relevant water quality objectives for groundwater <sup>1</sup>	EC	Not significantly different to: a) the EPP (Water) schedule documents water quality objectives for relevant groundwater chemistry zones; or, b) local water quality objectives developed in accordance with the Queensland Water Quality Guidelines.
Able to sustain an agreed postmining land use	Rehabilitation is suitable for sustainable beef cattle grazing	Land suitability assessment for dryland cropping	Land suitability class ≤3

<sup>1</sup>Objectives, indicators and criteria that relate to groundwater are not assessed in certification of progressive rehabilitation. These criteria are to be assessed at the time of mine closure.

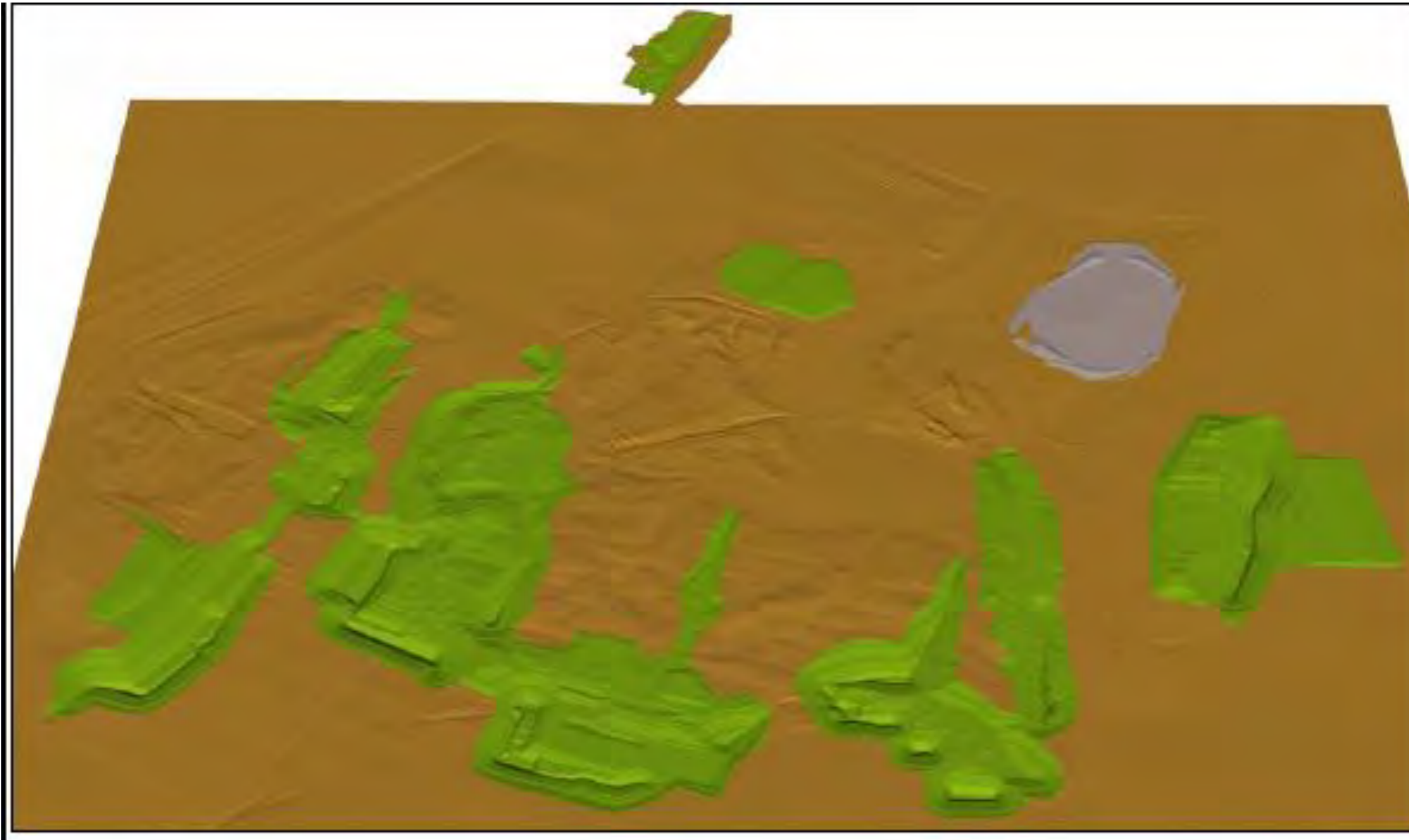
**Appendix G: Non-Subsidence Rehabilitation Goals, Objectives, Indicators and Completion Criteria**

PMLU	Rehabilitation Goal	Rehabilitation Objective	Indicators	Completion Criteria	
Low intensity grazing	Safe to humans and cattle	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference	
	Stable	Rehabilitation is geotechnically stable	Factor of safety	≥1.5 unless an alternative is justified by an appropriately qualified person	
		Rehabilitation is erosionally stable	Slope gradient	≤5%	
			Total groundcover	≥50%	
	Non-polluting	Maintenance of surface and groundwater quality	Licensed creek diversions are geotechnically and erosionally stable	Condition assessed by an appropriately qualified person	Final evaluation report certified by an RPEQ in accordance with <i>Water Act 2000</i> licence conditions
			Hostile material	Receiving water quality	Spoil and waste materials classified as ' <i>Hostile/potentially toxic</i> ' or ' <i>Extremely hostile</i> ' (as per Table 3 in RMP) are buried or capped with ≥ 3m of competent and benign cover material. Surface water and groundwater quality of receiving environments meets the requirements of Schedule W of the Environmental Authority.
Able to sustain the agree post-mining land use	Rehabilitation is suitable for sustainable beef cattle grazing	Land capability assessment for cattle grazing	Land capability class VI or VII as assessed in accordance with DSITI & DNRM (2015) <i>Guidelines for Agricultural Land Evaluation in Queensland (2<sup>nd</sup> Ed)</i> .		

PMLU	Rehabilitation Goal	Rehabilitation Objective	Indicators	Completion Criteria	
Grassy open woodland and open woodland	Safe to humans and wildlife	Safety hazards in rehabilitation are not significantly different to surrounding unmined landscapes subject to the same land use	Hazard assessment	No significant difference	
	Stable	Rehabilitation is geotechnically stable	Factor of safety	≥1.5 unless an alternative is justified by an appropriately qualified person	
		Rehabilitation is erosionally stable	Total groundcover	≥ 50% (slopes ≤12%) ≥ 70% (slopes >12%)	
		Licensed creek diversions are geotechnically and erosionally stable	Condition assessed by an appropriately qualified person	Final evaluation report certified by a Registered Professional Engineer of Queensland (RPEQ) in accordance with <i>Water Act 2000</i> licence conditions	
	Non-polluting	Maintenance of surface and groundwater quality	Hostile material	Receiving water quality	Spoil and waste materials classified as ' <i>Hostile/potentially toxic</i> ' or ' <i>Extremely hostile</i> ' (as per Table 3 in RMP) are buried or capped with ≥ 3m of competent and benign cover material. Surface water and groundwater quality of receiving waters meets the requirements of Schedule W of the Environmental Authority.
	Able to sustain the agree post-mining land use	Grassy open woodland characteristics (Interim Completion Criteria)	Species richness (per ha)		≥1 ≥3 ≥3
			Tree canopy cover		≥9%
		Open woodland characteristics (Interim Completion Criteria)	Species richness (per ha)		≥3 ≥5 ≥5
Tree canopy cover				≥16%	

PMLU	Rehabilitation Goal	Rehabilitation Objective	Indicators	Completion Criteria
Water storage	Safe to humans and wildlife	Safety hazards minimized.	Hazard assessment off access	No public access to highwalls/end walls (bundling/fencing as required)
	Stable	Dams are stable	Hydraulic function	Functioning bywash or spillway with adequate flow capacity provided for dams. Sign-off by post-mining landholder (for retained dams).
		Dams and final voids are geotechnically stable	Factor of safety	≥1.5 unless an alternative is justified by an appropriately qualified person
		Highwalls/endwalls/lowwalls of final voids are geotechnically stable	Condition assessed by an appropriately qualified person	Assessment report by a Registered Professional Engineer of Queensland (RPEQ) on the geotechnical stability of final voids.
	Non-polluting	Maintenance of surface and groundwater quality	Receiving water quality	Surface water and groundwater quality of receiving waters meets the requirements of Schedule W of the Environmental Authority.
	Able to sustain the agree post-mining land use	Water quality is suitable for beef cattle drinking water.	TDS Sulphate	≤4,000mg/L ≤1,000mg/L

Appendix H: Conceptual Final Landform



# **Residual Void Investigation Report**

## **Gregory Crinum Mine**

Version: 19 November 2021

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# 1 Introduction

The Gregory Crinum Mine (GCM) operates under Environmental Authority EPML00945013 which authorises residual voids to remain following mining provided that the void outcomes in Conditions F6 and F7 are met. Condition F6 of the Environmental Authority states that residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority.

Condition F7 of the Environmental Authority states that an investigation into residual voids which proposes acceptable landform design criteria is to be completed.

**Table 1** shows where this *Residual Void Investigation Report* addresses Conditions F6 and F7.

**Table 1 – Environmental Authority Conditions F6 and F7**

Condition F6 and F7	Addressed in
F6. Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to any other condition within this environmental authority.	Section 3
F7. Complete an investigation into residual voids and submit a report to the administering authority proposing acceptance criteria to meet the outcomes in F6 and landform design criteria. The investigation report must be reviewed and updated every three (3) years, commencing on <b>30 June 2008</b> .  The investigation must at a minimum include the following:	
(a) a study of options available for minimising final void area and volume;	Section 2
(b) develop design criteria for rehabilitation of final voids;	Section 2
(c) a void hydrology study, addressing the long-term water balance in the voids, connections to groundwater resources and water quality parameters in the long term;	Section 3
(d) a pit wall stability study, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events;	Section 4
(e) study of void capability to support native flora and fauna; and	Section 5
(f) a proposal/s for end of mine void rehabilitation success criteria and final void areas and volumes.	Section 6

# 2 Final Void Area and Volume

A conceptual final landform design has been prepared for GCM by 3D Data Guidance Pty Ltd based on the expected pit and dump surface configuration at the cessation of operations. Operational mine planning takes into account the need to take opportunities to progressively achieve the final landform design by providing backfill to existing residual voids and unused ramps.

The following design criteria have been adopted when designing the final landform:

- unrehabilitated spoil and low wall slopes greater than 25% shall be reshaped to a maximum slope of 25%;
- weathered highwalls shall be reshaped to a maximum slope of 25% and unweathered highwalls remain;

- slopes below long-term final void high water levels will be left at angle of repose;
- a 5m angle of repose batter will be left down to G North Wetlands water level;
- reshaped 25% slopes shall be capped with 0.5m of basalt rock mulch; and
- a 30m running surface shall be provided for basalt and topsoil haulage.

The final landform design report (3DDG, 2021) is attached as **Appendix A**.

The optimised final landform design results in 17 final voids, the areas and volumes of which are shown in . **The** void areas and volumes are measured at the modelled long-term average high water level (see Section 3.2 for details).

Table 2. The void areas and volumes are measured at the modelled long-term average high water level (see Section 3.2 for details).

**Table 2 – Final Void Area and Volume**

Final Void	Surface Area* (ha)	Void Volume* (Mm3)	Relevant Void Water Level (mRL)
M Block	16.3	2.24	188.2
J Block Ramp 7	12.1	1.30	191.9
J Block Ramp 8	9.3	0.87	173.8
J Block Ramp 9	27.5	5.04	167.8
F Block	8.2	0.90	193.8
ASE Block - A	7.2	0.99	176.3
ASE Block - B	12.3	2.11	176.3
ASE Block - C	3.6	0.61	176.3
ASE Block - D	7.3	1.50	176.3
ASE Block - E	2.8	0.15	176.3
G Block Central	45.6	10.89	167.5
ABG Block - West	0.7	0.03	176.2
ABG Block - East	31.2	5.30	176.2
G Block North - A	2.4	0.06	183.3
G Block North - A	0.7	0.00	183.3
Ramp 4	2.0	0.17	183.1
Liskeard	5.2	0.19	198.1
	Total 194.4		

\*subject to some change as design is refined and physical works progress

The final voids are shown in plan view in **Figure 1**. A three-dimensional representation of the final landform is shown in **Figure 1**. The green shading includes the highwall and low wall areas to be reshaped.

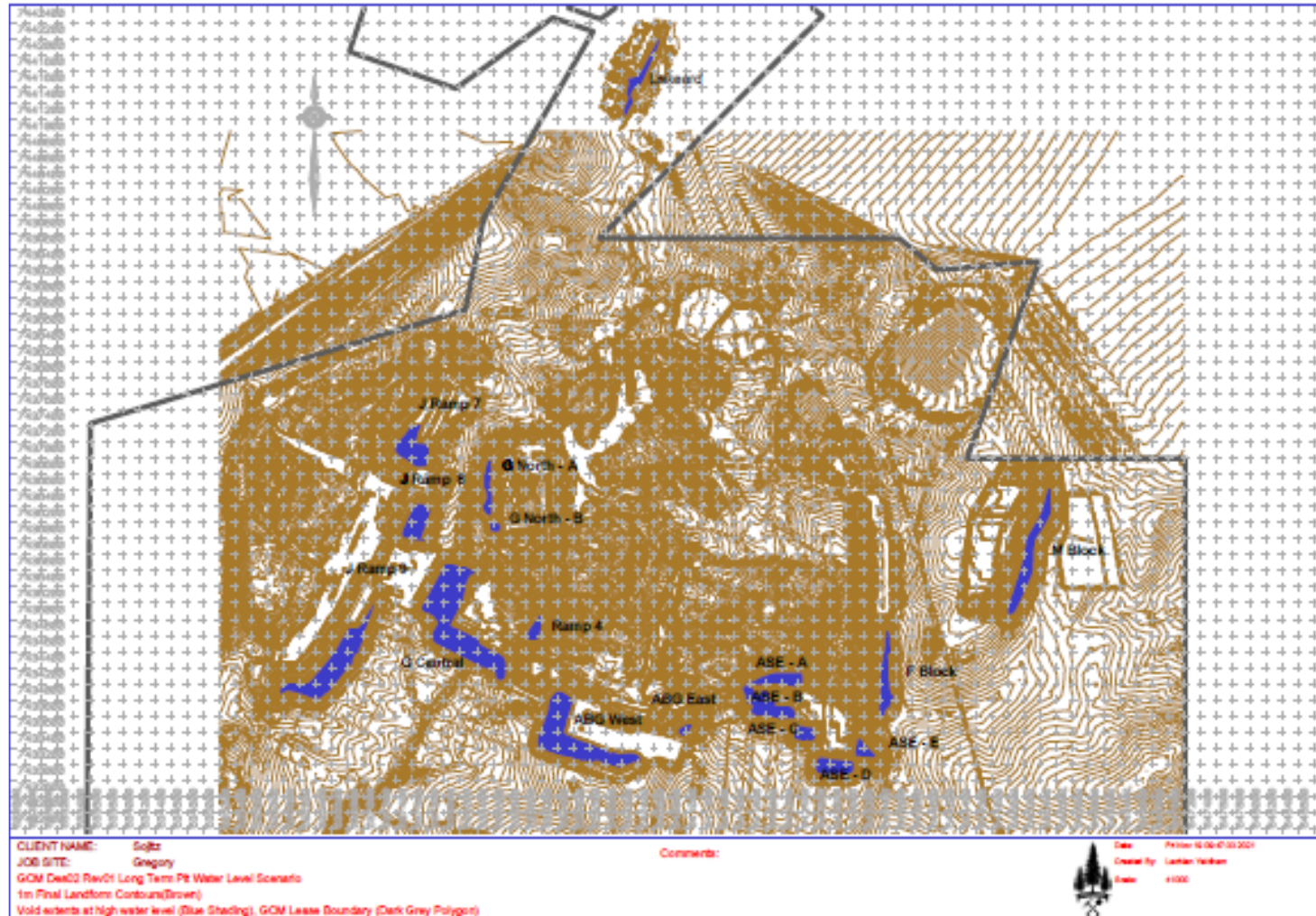


Figure 1 – Plan view of final void reshaping

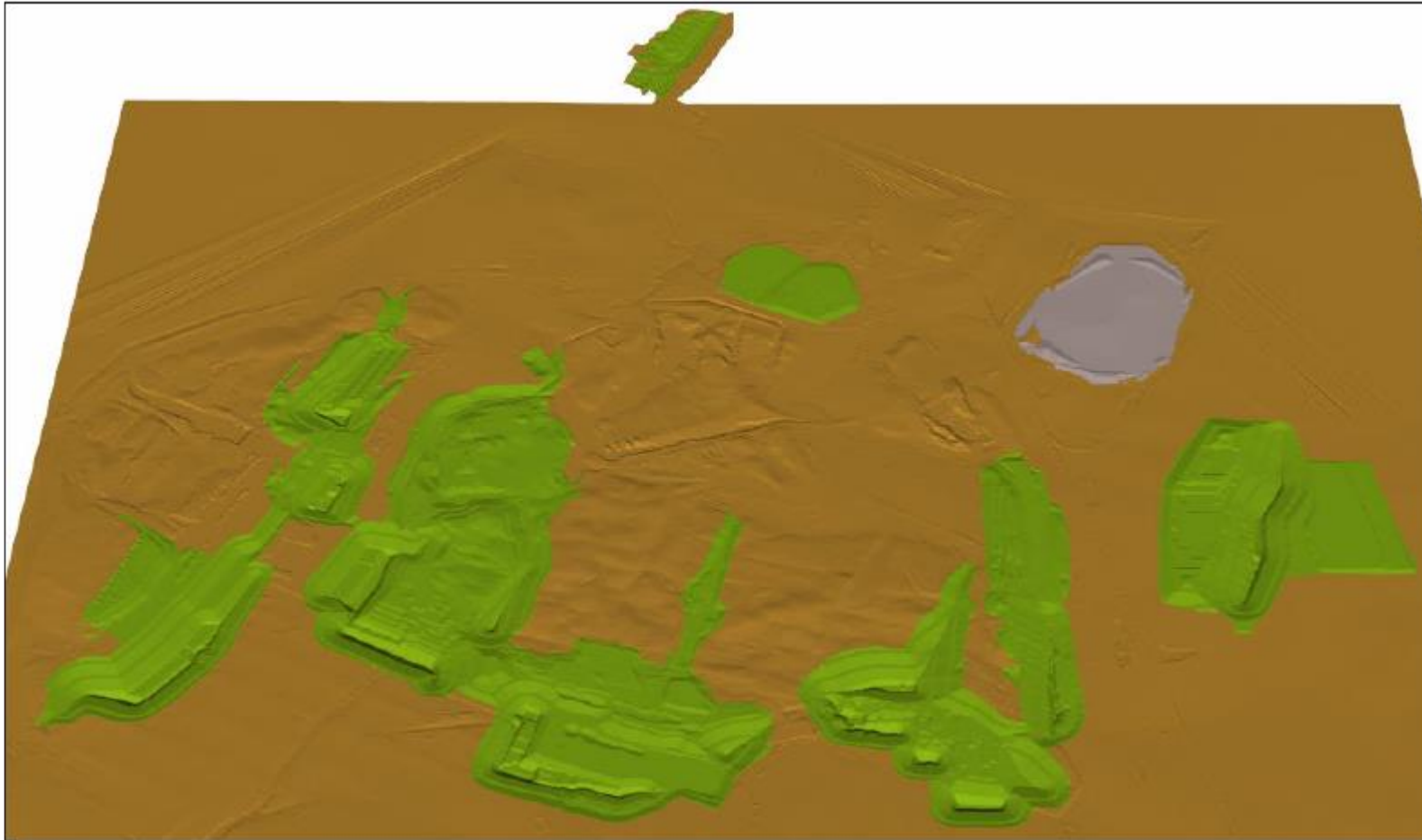


Figure 2 – 3D view of final void reshaping

## 3 Void Hydrology Study

Residual void hydrological studies have been undertaken to:

- calculate future groundwater inflow rates into residual voids;
- determine to long-term water balance in the voids (including the long-term equilibrium water level and potential interactions with surrounding aquifers); and
- estimate long-term void water quality.

These studies are summarised below and further details are presented in KCB (2021) (attached as **Appendix B** to this report).

### 3.1 Modelling Approach

KCB Australia Pty Ltd (KCB) were commissioned to prepare a joint three-dimensional numerical groundwater flow model using MODFLOW-USG for GCM and the neighbouring Kestrel Coal Mine. The model was developed to represent the key hydrogeological units within 15 model layers, covering an area of approximately 2,000 km<sup>2</sup>.

The physical structure of the groundwater model was based on the detailed geological models provided by Sojitz and Kestrel. Model development was supplemented by published geological maps, digital geology surfaces and information from mining operations near the project area and data from the DNRME groundwater database.

The groundwater flow model was initially calibrated to groundwater levels from 53 observation bores (steady-state) screened across a variety of hydro-stratigraphic units in the GCM and Kestrel mining areas. Groundwater inflow data from existing mining operations was also used as a target for model calibration.

The groundwater regime near the project area has varied over time due to the influence of historic and current mining activities. A two-stage transient (time-variant) calibration was performed, which considered the change in groundwater levels and flow from pre-mining conditions up to and including current (2021) conditions. The stage 1 calibration was from 1979 to 2009, and the stage 2 calibration was from 2009 to 2021. Stage 1 calibration included 37 observation bores. Stage 2 calibration included 80 monitoring bores.

The modelling approach included the simulation of subsidence-induced fracturing above the longwall panels in the historical areas (and approved future operations). Continuous cracking is expected to extend above mined longwall panels and into the overlying units within the Permian coal measures. Continuous cracking increases the vertical hydraulic conductivity throughout the affected zone, with the magnitude of the increase likely to be less with increasing height above the mined seam.

The calibration achieved a 4.7% scaled RMS error which is within acceptable 10% limit recommended by the Australian Groundwater Modelling Guidelines (Barnett *et al.* 2012). The calibrated groundwater levels, vertical gradients, flow patterns and mine inflows replicate measured data and groundwater trends. The model calibration is therefore robust.

The calibrated groundwater model was used to predict groundwater inflows and changes in groundwater levels in response to the planned closure landforms. An iterative approach to closure groundwater predictions was adopted to account for the interaction between surface hydrology and groundwater flows in the post-operational period.

The following approach was taken:

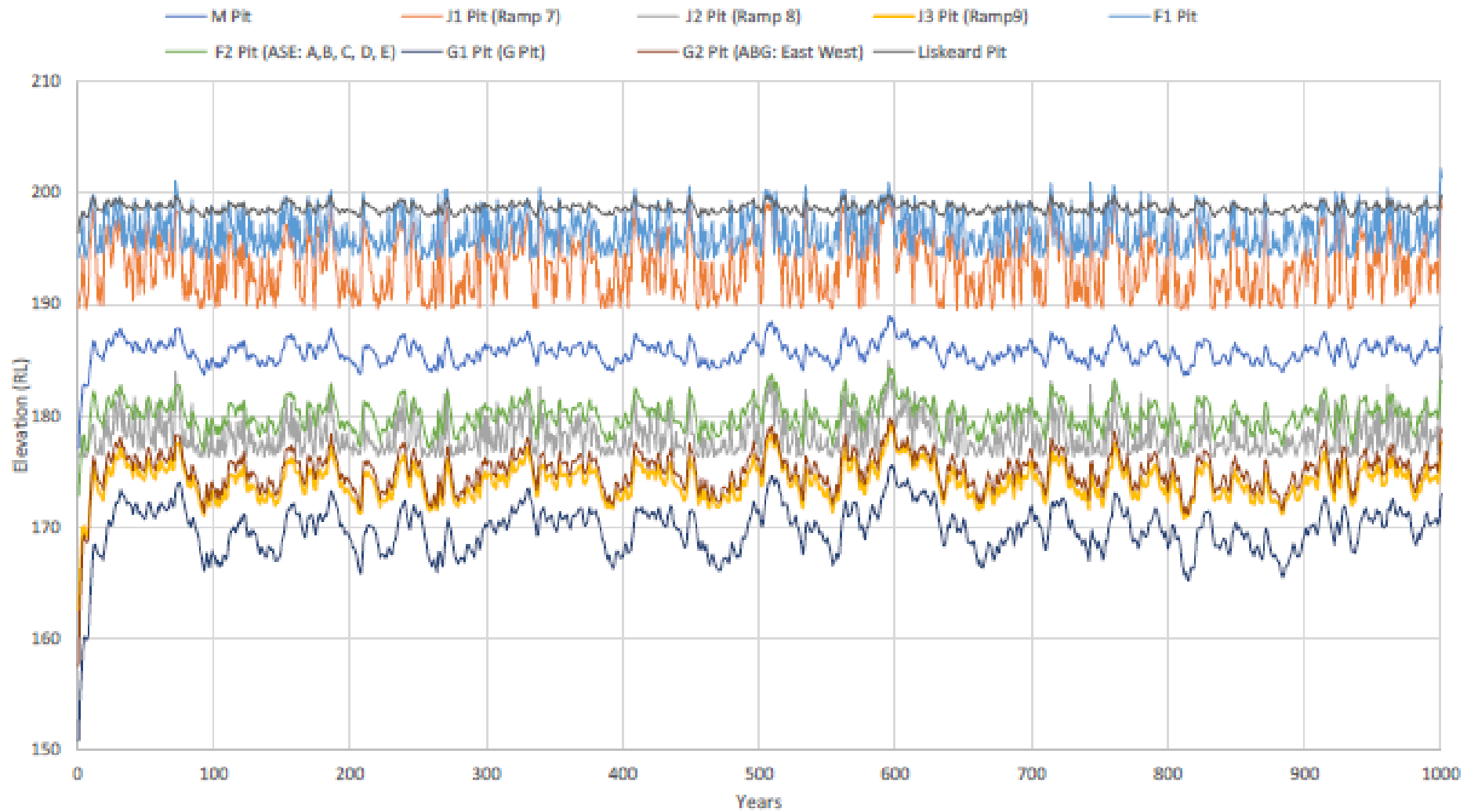
- The predicted groundwater condition at the end of GCM operations was adopted as the starting condition for the post-closure assessment.
- To provide initial estimates of potential groundwater inflow, groundwater rebound and the refilling of the voids was simulated. For this initial assessment, the only surface water / hydrology considerations included were direct rainfall to the final void and evaporation from the void. This allowed an initial assessment of the potential period to rebound and an indication of groundwater inflow to each void as a function of groundwater/void water level elevation.
- Once these initial estimates had been extracted from the groundwater model, additional assessment of the potential groundwater inflow rates as a function of groundwater elevations was obtained (within the range of the recovered groundwater table).
- From the two preceding steps, projected groundwater flow rates and the range of recovered/rebounded equilibrium groundwater elevations was provided to the surface hydrology consultants (Cardno) for inclusion in a long-term post-closure hydrology and void OPSIM water balance model.
- Stochastic modelling of the range of hydraulic conditions over a period of 1,000 years was undertaken by Cardno to provide the projected change in void water levels over time. These void water levels were, in turn, used as input to the post-closure groundwater model to assess the potential long-term post-closure groundwater conditions over a 600 year period.

### 3.2 Water Balance Modelling Results

The water balance model for the water level in each residual void is predicted to rise towards an equilibrium over a period of about 50 years (see **Figure 3**). Water level fluctuations within each void of about 5m over decades are expected. The modelled long-term high water level (ie the modelled average daily maximum water level) for each void is shown in **Table 2**. The maximum water level does not reach a level where any of the 17 voids would spill and therefore adverse environmental impact is not expected to be caused to adjacent surface waters or adjacent land.

The groundwater modelling results over simulation period indicate that:

- Groundwater inflows will continue to the voids, with the highest rates of groundwater flows in the first 50 years after operations have ceased.
- The groundwater system has recovered within 100 years.
- Over the entire 600-year simulation period, groundwater gradients remain toward the voids, with the voids acting as localised groundwater sinks.
- The modelling results suggest that it is unlikely that void water will migrate away from the voids to impact on the regional groundwater quality. Short period of outflow would occur in periods of very high rainfall when the void water levels are temporarily higher than the groundwater elevations but the general gradients towards the voids re-establish after these event.



**Figure 3 – Predicted long-term water levels in residual voids**

### 3.3 Water Quality Modelling

The Total Dissolved Solids (TDS) concentrations in the residual voids was estimated over time using a mass balance model (see **Appendix B** for details). The potential for secondary minerals to play a role in the long-term evolution of the final void water quality was assessed using the hydro-geochemical modelling code PHREEQC. The hydro-geochemical assessment found that no additional mineral saturations apart from those already present in the voids are likely to play an important role in limiting concentrations and salinity. The water quality assessment suggests that (a) the residual voids are expected to remain neutral to slightly alkaline, except for F void which is expected to be acidic, and (b) TDS is the key determinant of water quality.

The predicted TDS concentrations for the residual voids are shown in **Figure 4**.

The ANZECC (2000) water quality guidelines classifies irrigation water with a “high salinity rating” as having an electrical conductivity of between 2.9 dS/m and 5.2 dS/m (equivalent to 1,945 – 3,485 mg/L Total Dissolved Solids (TDS)). Adverse effects in beef cattle can be expected to begin when stock drinking water exceeds 4,000 mg/L TDS (ANZECC 2000).

In the long-term the salinity of water in the 17 residual voids is predicted to become unsuitable for irrigation and for drinking water for stock within decades (ie TDS typically above 10,000 mg/L). The voids would be unable to support a Post-Mining Land Use and would be Non-Use Management Areas.

The long-term groundwater simulations indicate that post-closure the voids will continue to act as local groundwater sinks. This will encourage flow toward the final voids and will act to prevent the high salinity water in the voids from migrating away from the mining area. Short-term transient reversals of flow will occur in periods of high rainfall/run-off into the voids when void water levels are temporarily higher than the equilibrated groundwater levels. During these short-lived periods, the higher salinity void water will be able to migrate into the groundwater immediately adjacent to each void, however, the gradients toward the voids will rapidly re-establish and the groundwater will again flow toward the voids. It can be expected that groundwater quality in the immediate vicinity will be poor over the period of several hundred years. Regional groundwater user are expected to be unaffected and serious environmental harm is not expected to be caused to any recognised groundwater aquifer.

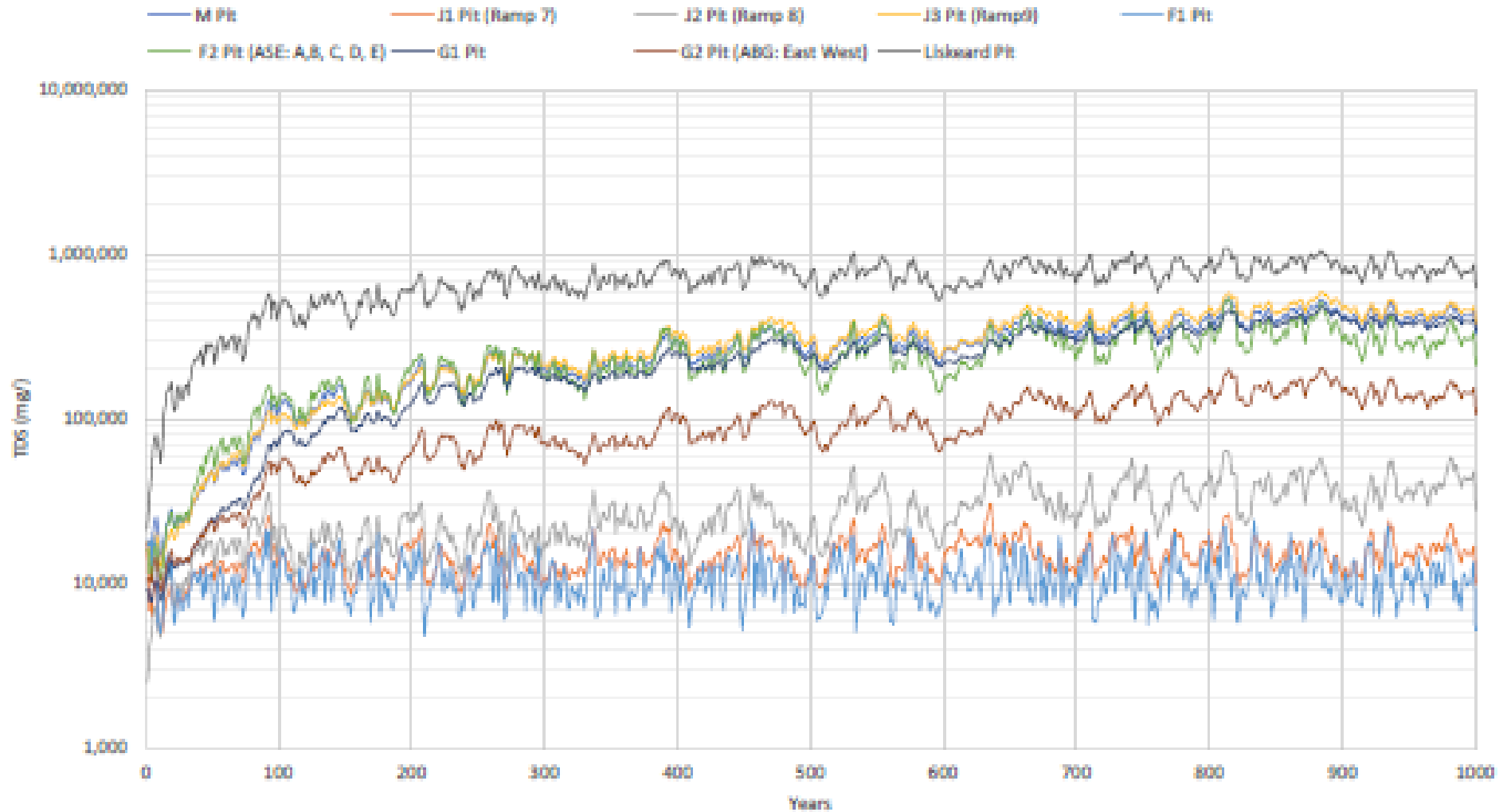


Figure 4 – Predicted TDS concentration in residual voids

## 4 Pit Wall Stability

Site-wide final landform modelling delineating the expected number and extent of final voids has only just been completed in November 2021 (see **Appendix A**). A geotechnical review and stability analysis of pit walls shall be undertaken before submission of the GCM Mine Progressive Rehabilitation and Closure Plan.

Studies of central Queensland pit wall erosion by have been undertaken under Australian Coal Industry Research Program Project C26019 (Henderson, 2018). The studies concluded that, based on prevalent conditions of rainfall, overburden and coal mining practice, over the long-term pit wall crests could retreat an average of 10m to 30m post-mining, depending on the erosivity of the near surface overburden. Individual gullies could extend about twice that if rainfall runoff was particularly concentrated. These findings shall be taken into consideration in the geotechnical review and stability analysis.

## 5 Void Flora and Fauna

The physical features of the residual voids are likely to restrict the development of diverse and productive aquatic flora and fauna communities. Steep pit walls mean that the littoral zone (depth <1m) would be very narrow and pit floor benthic habitats would be at great depth.

Such pit lakes have low abundance and diversity of structural features such as fallen timber, large rocks and emergent macrophytes (sedges and rushes) (Richardson *et al.* 2021). Richardson *et al.* (2021) found macroinvertebrate diversity in a saline coal mine pit lake was greatly reduced in comparison to a freshwater coal mine pit lake, although salt-tolerant blue green algae and diatoms were present. The absence of connectivity to watercourses would limit the opportunity for fish colonisation of the residual voids.

In an interim report for ACARP Project C27043 *Towards closure of potentially saline pit lakes: understanding biophysical processes for condition assessment and remediation*, Lund and Blanchette (2021) conclude that the main limitations to rehabilitating saline pit lakes are likely to be physical and related to the creation of littoral and riparian areas and developing strategies to enhance natural ecological successional processes.

The voids would be unlikely to support diverse and productive aquatic flora and fauna communities. The voids would not, however, result in adverse environmental impacts on surrounding aquifers as groundwater hydraulic gradients are expected to be maintained in the long term towards each of the 17 voids (see **Section 3.2**).

Residual void low walls shall be reshaped above the high water level as described in Section 2 and rehabilitated and revegetated in accordance with the GCM Mine *Rehabilitation Management Plan* (as required under Environmental Authority Condition F5).

## 6 Void Rehabilitation Criteria

The residual void completion criteria applicable to the residual voids are shown in **Table 3**.

**Table 3 – Residual Void Rehabilitation Criteria**

Objective	Indicator	Criteria
Safety hazards minimized	Hazard assessment of access	No public access to highwalls/end walls (bundling/fencing as required)
Final voids are geotechnically stable	Factor of safety	≥1.5 (unless an alternative is justified by an appropriately qualified person).
	Wall slope and area	Maximum slope in competent rock 275% (70 degrees)* Maximum slope in incompetent rock 65% (angle of repose). Maximum total void surface area 200ha (measured at high water level)
	Condition assessed by an appropriately qualified person	Assessment report by a Registered Professional Engineer of Queensland (RPEQ) on the geotechnical stability of final voids.
Maintenance of surface and groundwater quality	Water quality	Surface water and groundwater quality of receiving waters meets the requirements of Schedule W of the Environmental Authority.
		Voids have no adverse environmental impacts on surrounding aquifers
		Final voids do not spill to surface waters

\*subject to completion of geotechnical evaluation

## 7 References

3DDG (2021). *Gregory Final Landform. Summary of Long-Term Void Water Level Design*. Internal report for Sojitz Green Pty Ltd. 3D Data Guidance Pty Ltd. 16 November 2021.

ANZECC (2000). *Australia and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment and Conservation Council.

Barnet B, Townley LR., Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knappton A, and Boronkay A. (2012). *Australian Groundwater Modelling Guidelines*. National Water Commission, Canberra.

Henderson, S. (2018). *Prediction of Long Term Erosion at Pit Walls*. Australian Coal Industry Research Program Project C26019. Henderson Geotech.

KCB (2021). *Groundwater Model. Closure Scenarios Final Report*. Internal report for Sojitz Blue Pty Ltd. Klohn Crippen Berger, November 2021.

Lund, M.A and Blanchette, M.L. (2021). *Towards closure of potentially saline pit lakes: understanding biophysical processes for condition assessment and remediation*. ACARP Project C27043. Short Report 2020-03. 110pp.

Richardson, D.L., Bourke, G, and Swart, P. (2021). *Aquatic biodiversity values of two non-acidic pit lakes created by open-cut mining*. Life of Mine Conference Proceedings, Brisbane. AusIMM Publication 2/2021: p147-150.

## 8 Version Management

Version	Details	Contributors
1.0	November 2021	

## Appendix A

*Gregory Final Landform. Summary of Long-Term Void Water Level Design.* Internal report for Sojitz Green Pty Ltd. 3D Data Guidance Pty Ltd. 16 November 2021.

For the purposes of the PRC Plan, Appendix A has been updated with the following report:

3DDG (2023). *Gregory Final Landform 2023. Summary Report*, Sojitz. 3D Data Guidance Pty Ltd. 19 May 2023. (see Appendix C of PRC Plan)

## Appendix B

*Groundwater Model. Closure Scenarios Final Report.* Internal report for Sojitz Blue Pty Ltd. Klohn Crippen Berger, November 2021.

For the purposes of the PRC Plan, Appendix B has been updated with the following report:

KCB (2023). Sojitz Residual Void Modelling. Groundwater Model Update. Sojitz Gregory Crinum Pty Ltd. 26 May 2023. (see Appendix D of PRC Plan)

Sojitz

# Gregory Final Landform 2023 Summary Report



**3D Data Guidance Pty Ltd**

May 19, 2023

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Revised Imagery 19/09/2023

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*Figure 1 - 2031 pit/dump surface*

## **2 EXECUTIVE SUMMARY**

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- The report and designs cover the created designs for H, I, J, G, ABG, F, ASE, M, Liskeard, Boundary pit and TSF
- 2023.03.22 Final Landform Tailing v5 pit/dump surface was used as the start surface for design of any active mining areas.
- 2022 June LiDAR was used for the remaining areas that are outside active pits.
- This design iteration reshapes down to the modelled long term void water levels. Below this level no reshaping takes place within voids.
- The design extent covers 2,279 ha.
- Design Scenario Volumes: 73.3M BCM of dozer and truck reshaping
- A total of 5.6 million cubic metres of basalt rock mulch is required to cap reshaped batter slopes.
- 3D Views with contours of designs are included within this report.
- Full list of Plans and DTMs are available for Download via Dropbox.

# 3 PROJECT OVERVIEW

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## 3.1 PROJECT BACKGROUND AND DESCRIPTION

To create a cost-effective and conforming landform designed to the required specifications as detailed by the client, with considerations learnt from previous constructed landforms. To provide on-going monitoring and guidance throughout the entire construction phase to achieve a successful and efficient outcome for the client.

## 3.2 PROJECT SCOPE REV 01

To create a final landform design for the Gregory site based on expected pit and dump profiles to end of mine life.

The LOM pit/dump surface data was received from Sojitz, as well as a scope document outlining the project work area and design constraints. Modelled long term void water levels were provided for each of the voids.



*Figure 2 - LOM surface*

3D Data Guidance have available to for client evaluation:

- Comparison report containing; Analysis Summary and Contour Plans images. (report.pdf)
- Mass Haul Analysis of final landform designs. (report.pdf)
- Contour Plans of Designs and Cut Fill mapping. (Plans.pdf)
- TIN models of each Landform as designed by 3DDG. (tin\_design.dxf)
- Tabulated Mass Haul results (MHA.xlsx)

# 4 LANDFORM DESIGN

---

## 4.1 SCENARIO:

- 25% reshape with 30m wide running surface every 100m of slope length, all >10% batter slopes to be capped with 0.5m of basalt rock mulch. Reshaping to stop at the modelled long term void water levels within void areas.

### 4.1.1 Assumptions:

- No swell for dumped material.
- 1.2 swell for highwall cut.
- No highwall cut below base of weathering.
- 25% maximum grade for reshaped batters.
- 30m running surface every 100m of slope length required for basalt/topsoil haulage.
- No material to be pushed into G North Wetlands.
- A 5m angle of repose batter will be left down to G North Wetlands water level.
- Min 3m free draining capping surface over any tailings or rejects.
- 0.5m thick rock mulch capping layer on all reshaped 25% batter areas.
- 0.1m of topsoil to be applied on top of the design surface

### 4.1.2 Cost assumptions:

- Dozer productivity estimated using internal production model and an overall efficiency factor of 50% of dozer capability.

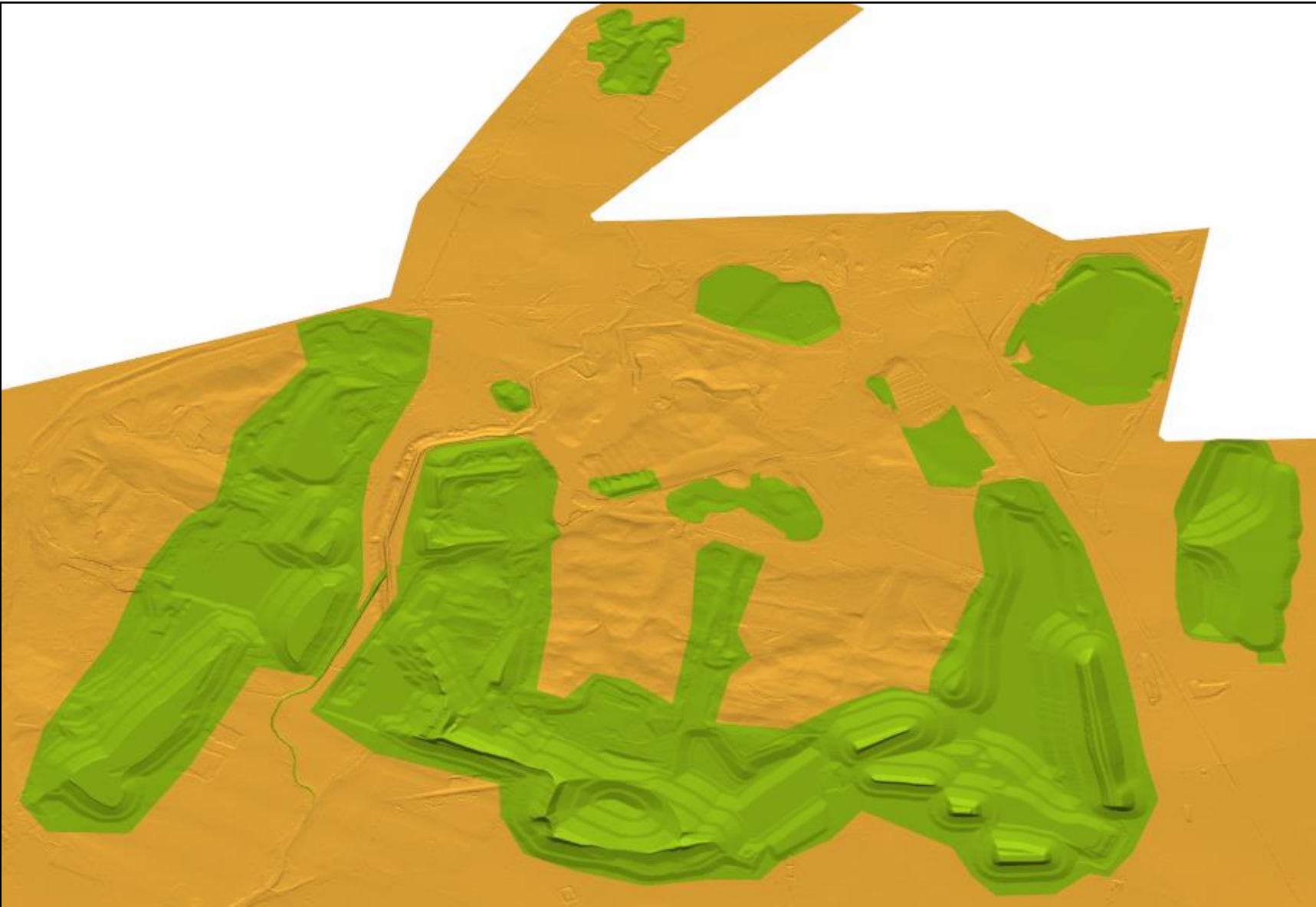
### 4.1.3 Void water level assumption

Below table shows the modelled long term water level information utilised to create the design surfaces for this iteration.

Final Void	Water Level (mRL)
M Block	215.8
J Block Ramp 7	205
J Block Ramp 8 - A	173.8
J Block Ramp 8 - B	173.8
J Block Ramp 9	167.8
F Block	193.9
ASE Block - A	176.3
ASE Block - B	176.3
ASE Block - C	176.3
ASE Block - D	176.3
G Block Central - A	167.5
G Block Central - B	167.5
G Central/ABG	167.5
G Block North - A	183.3
G Block North - B	183.3
Ramp 4	183.1
Liskeard	198.1

The water level for each void was used as the reshaping cut-off for any reshaped low-wall or high-wall batters that extend into each of these voids. Below this level no reshaping is to occur and any fill is left at angle of repose (37 degrees).

**4.2 DESIGN OVERVIEW**



*Figure 3 - 3D Image of Final Landform*

## 4.2.1 Void Map

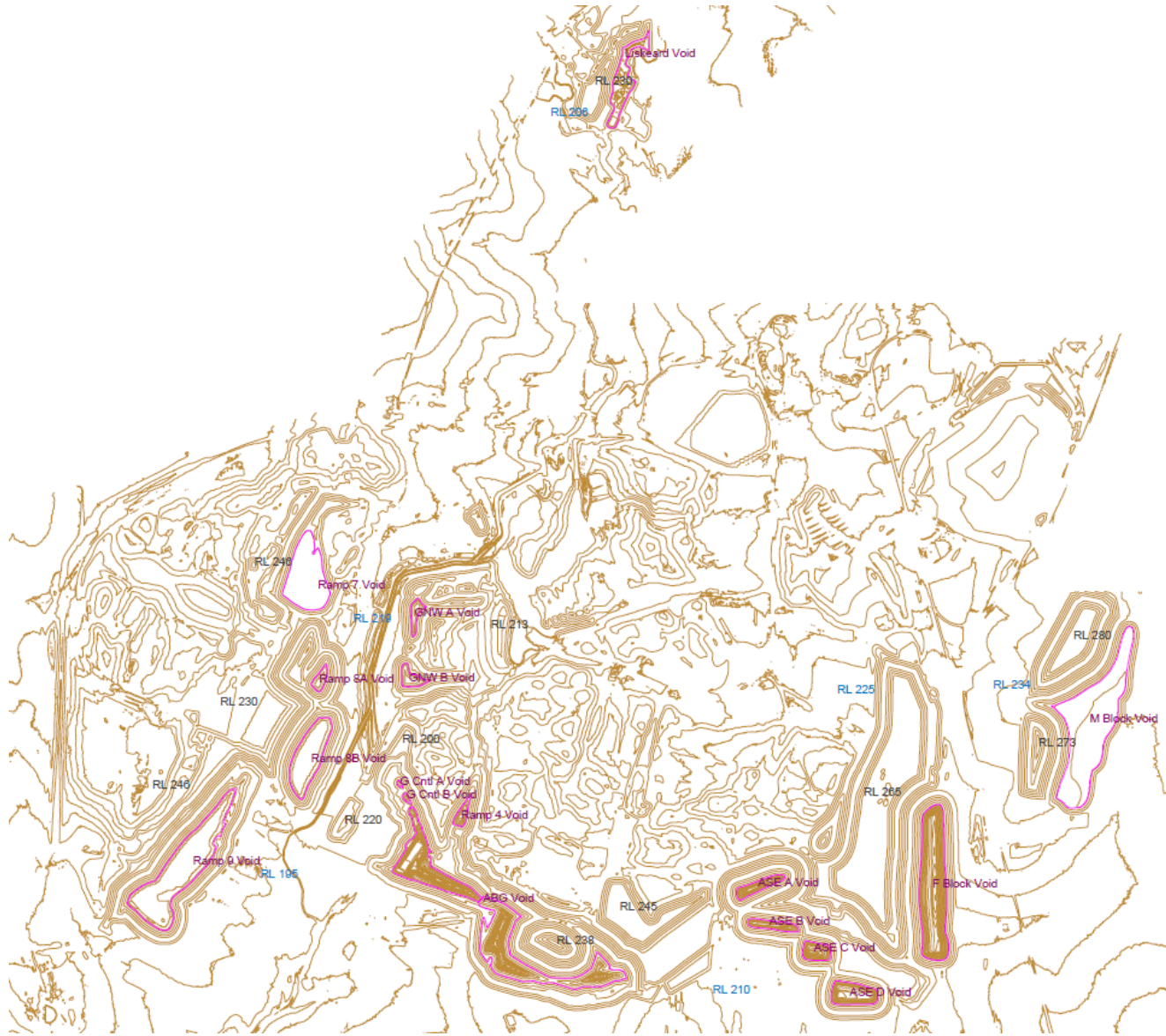


Figure 4 - Void locations and dump heights (5m Contours)

#### 4.2.2 Void water levels table

Final Void	Water Level (mRL)	Surface Area (ha) (at High water level)	Pit Volume (Million m3) (at High water level)	Number of pits	Figure
M Block	215.8	57.4	3.1	1	4.4.8
J Block Ramp 7	205	21.0	0.3	1	4.4.6
J Block Ramp 8 - A	173.8	2.1	0.2	1	4.4.6
J Block Ramp 8 - B	173.8	16.2	1.2	1	4.4.6
J Block Ramp 9	167.8	38.5	2.7	1	4.4.6
F Block	193.9	33.0	11.7	1	4.4.4
ASE Block - A	176.3	4.2	0.6	1	4.4.4
ASE Block - B	176.3	3.7	0.5	1	4.4.4
ASE Block - C	176.3	4.1	0.9	1	4.4.4
ASE Block - D	176.3	8.1	2.0	1	4.4.4
G Block Central - A	167.5	0.2	0	1	4.4.2
G Block Central - B	167.5	0.4	0	1	4.4.2
G Central/ABG	167.5	35.2	6.8	1	4.4.2
G Block North - A	183.3	2.3	0.2	1	4.4.2
G Block North - B	183.3	2.9	0.3	1	4.4.2
Ramp 4	183.1	2.1	0.2	1	4.4.2
Liskeard	198.1	10.0	0.6	1	4.4.10

### 4.2.3 Tailings & Rejects Capping - 3D

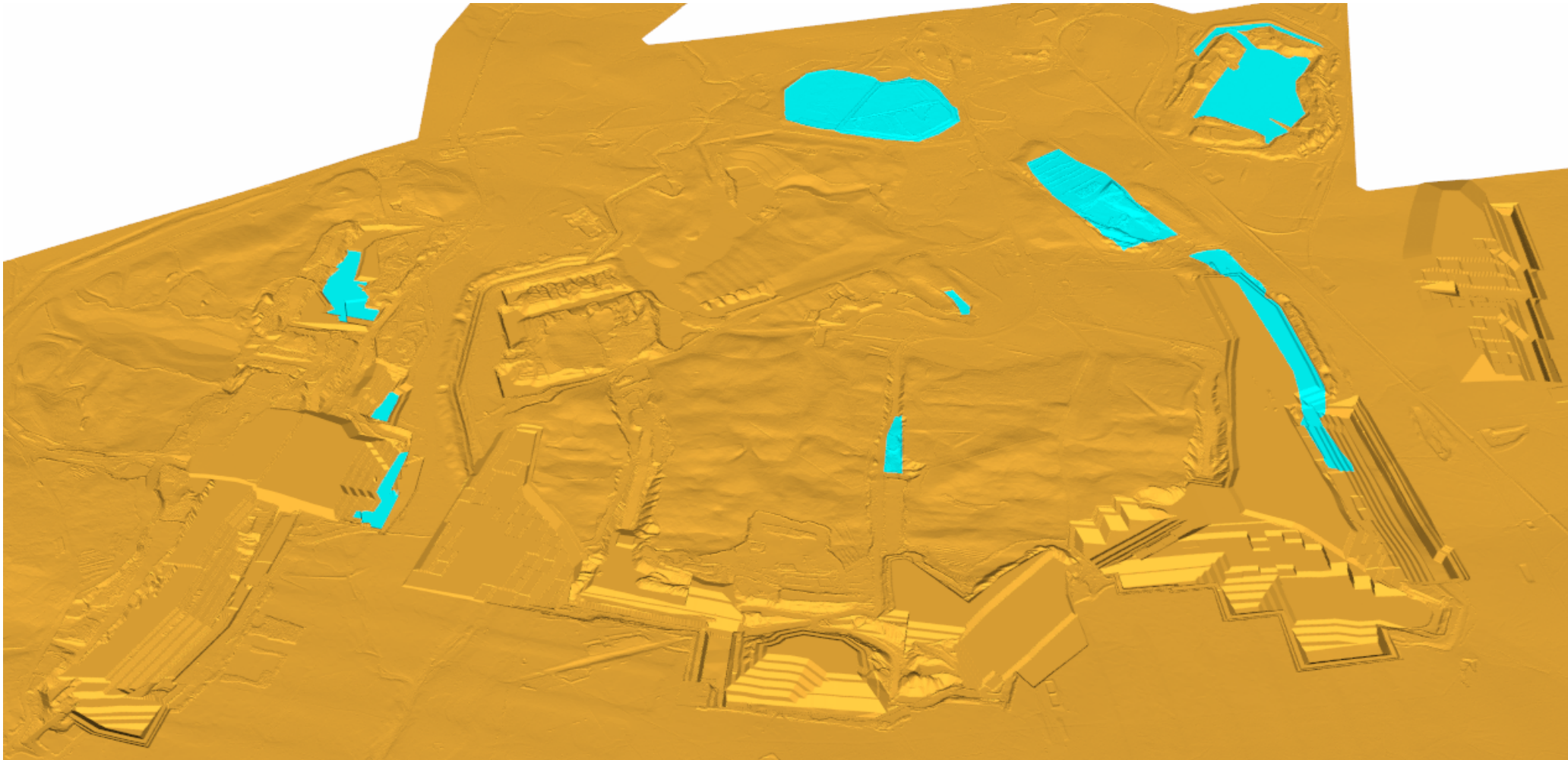


Figure 5 - Tailings and rejects locations (LOM)

Locations highlighted in blue where tailings and rejects exposed in the LOM surface have been capped with minimum 3m of material in the FLF surface.

#### 4.2.4 Tailings and Rejects Capping - Plan

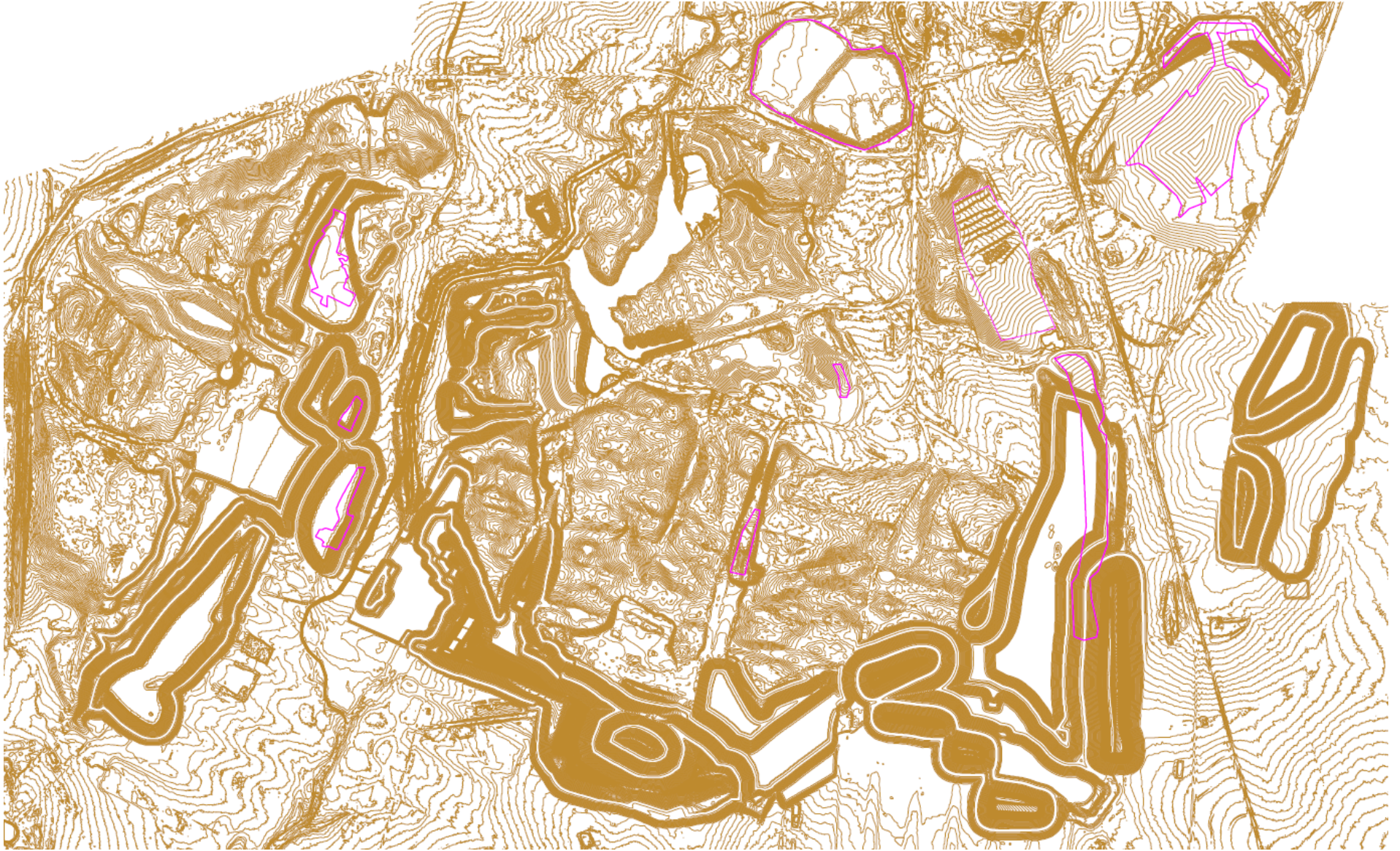


Figure 6 - Tailings and rejects capping locations (FLF) on 1m Contours

Locations where tailings and rejects exposed in the LOM surface have been capped with minimum 3m of material in the FLF surface.

## 4.3 DESIGN ANALYSIS

### 4.3.1 Design Volumes

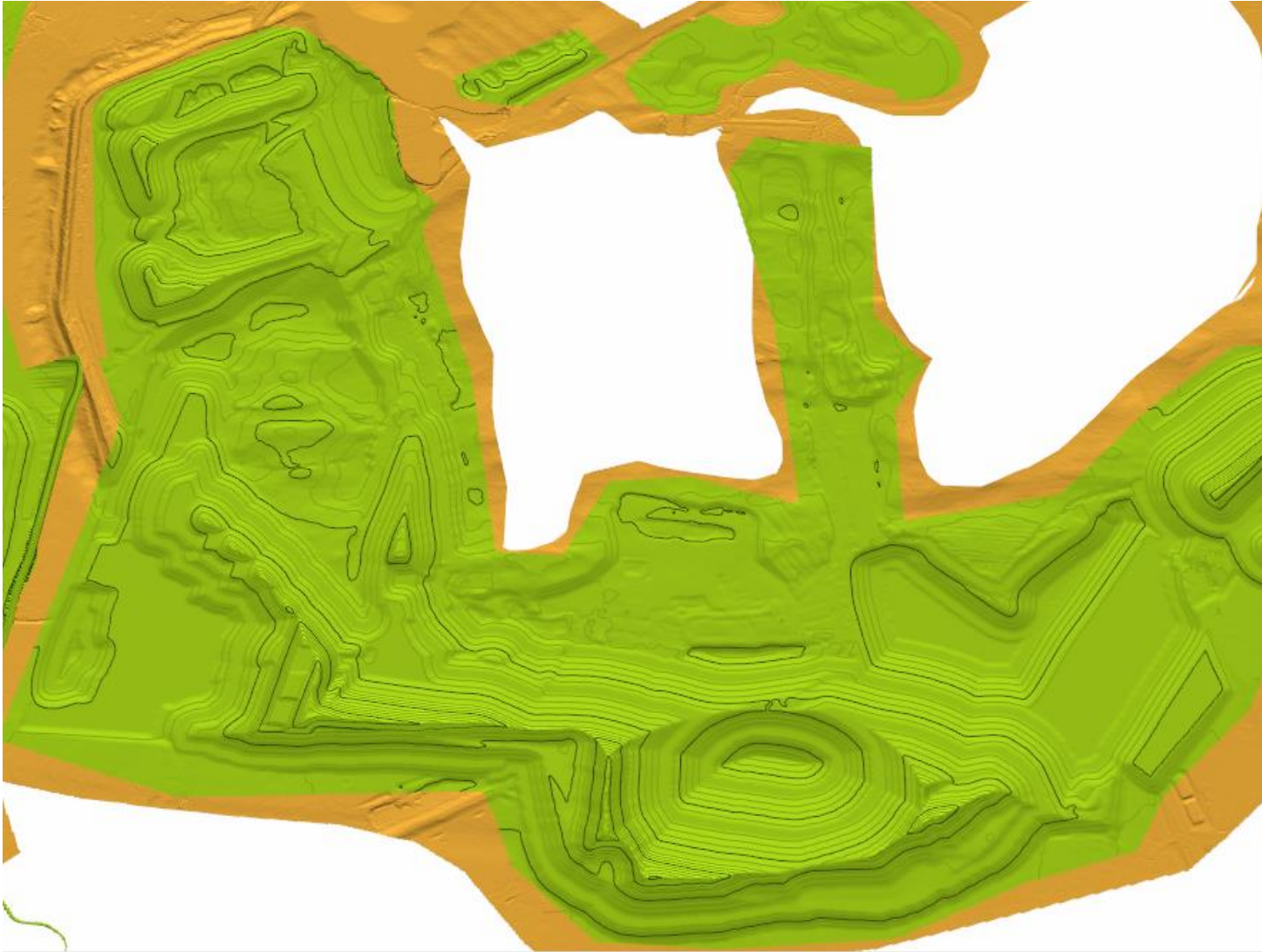
Design Description	Area (ha)	Cut Volume BCM	Swelled Volume LCM	Fill LCM	Net	Notes
ABG - Total	281.72	10,311,166.17	10,913,361.78	10,866,910.70	- 46,451.07	
G Cntl - Total	182.97	3,427,883.97	3,559,956.52	3,598,403.95	38,447.44	
Ramp 3 - Total	49.92	351,786.51	351,786.51	339,952.15	- 11,834.36	
Ramp 4 - Total	32.31	628,960.11	628,960.11	653,968.22	25,008.11	
G NW - Total	125.82	2,514,176.36	2,622,124.44	2,581,787.70	- 40,336.74	
GN Misc 1 - Total	7.05	64,835.92	64,835.92	64,869.09	33.17	
GN Misc 2 - Total	9.96	85,124.65	85,124.65	83,811.48	- 1,313.16	
ASE - Total	293.60	9,814,468.20	10,369,309.47	8,797,142.79	- 1,572,166.67	Excess goes to F
F Block - Total	187.77	4,059,296.67	4,352,471.39	5,993,664.94	1,641,193.55	Source from ASE
I Block - Total	183.42	9,929,381.53	9,929,381.53	8,050,172.78	- 1,879,208.75	Excess goes to TSF
J Block' - Ramp 7 Total	131.15	2,131,895.10	2,159,254.91	2,146,959.25	- 12,295.67	
J Block' - Ramp 8 Total	174.18	6,681,323.69	7,070,329.72	7,104,796.61	34,466.89	
J Block' - Ramp 9 Total	195.83	7,890,204.80	8,393,914.14	8,435,879.03	41,964.89	
Liskeard - Total	68.99	1,557,487.10	1,587,756.26	1,582,469.00	- 5,287.25	
M Block' - Total	181.40	12,822,538.39	13,214,757.84	13,194,768.01	- 19,989.83	
Boundary Pit - 10p' - Total	47.21	445,703.91	445,703.91	438,847.19	- 6,856.72	
TSF - Total	81.99	35,988.63	35,988.63	1,953,815.10	1,917,826.47	Source from I Block
H - Total	43.30	517,388.82	484,464.43	459,489.49	- 24,974.94	
<b>Gregory FLF Total</b>	<b>2,278.60</b>	<b>73,269,610.51</b>	<b>76,269,482.15</b>	<b>76,347,707.50</b>	<b>78,225.36</b>	

### 4.3.2 Construction Volumes

Summary		Reshaping		Topsoil		Rock Mulch	
Design Description	Area (ha)	Doze Volume (BCM)	Truck Volume (BCM)	Topsoil Area (m <sup>2</sup> )	Topsoil Vol (m <sup>3</sup> )	Rock Mulch Area (m <sup>2</sup> )	Rock Mulch Vol (m <sup>3</sup> )
ABG - Total	282	10,278,488	13,246	2,491,884	249,188	1,331,901	665,950
G Cntl - Total	183	3,413,103	30,613	1,633,414	163,341	1,075,264	537,632
Ramp 3 - Total	50	342,794	8,174	499,124	49,912	283,426	141,713
Ramp 4 - Total	32	628,101	-	302,024	30,202	239,733	119,867
G NW - Total	126	2,449,811	23,114	1,206,951	120,695	702,355	351,177
GN Misc 1 - Total	7	64,748	-	70,458	7,046	66,145	33,072
GN Misc 2 - Total	10	83,409	-	99,662	9,966	89,987	44,993
ASE - Total	294	9,781,276	50,335	2,734,579	273,458	1,839,727	919,864
F Block - Total	188	4,036,207	3,197	1,547,774	154,777	999,820	499,910
I Block - Total	183	8,050,784	-	1,789,608	178,961	299,422	149,711
J Block' - Ramp 7 Total	131	2,101,522	23,312	1,103,775	110,378	621,341	310,670
J Block' - Ramp 8 Total	174	6,412,834	277,751	1,557,451	155,745	988,490	494,245
J Block' - Ramp 9 Total	196	7,855,608	28,267	1,573,636	157,364	1,017,420	508,710
Liskeard - Total	69	1,516,176	40,283	590,242	59,024	474,553	237,277
M Block' - Total	181	12,591,918	209,056	1,324,014	132,401	1,027,284	513,642
Boundary Pit - 10p' - Total	47	438,806	-	470,525	47,053	-	-
TSF - Total	82	19,354	1,953,337	818,937	81,894	180,377	90,188
H - Total	43	473,551	-	433,853	43,385	-	-
<b>Gregory FLF Total</b>	<b>2,278</b>	<b>70,538,490</b>	<b>2,660,686</b>	<b>20,247,911</b>	<b>2,024,791</b>	<b>11,237,244</b>	<b>5,618,622</b>

## 4.4 3D IMAGES

### 4.4.1 G/ABG 3D Image with 5m Contours



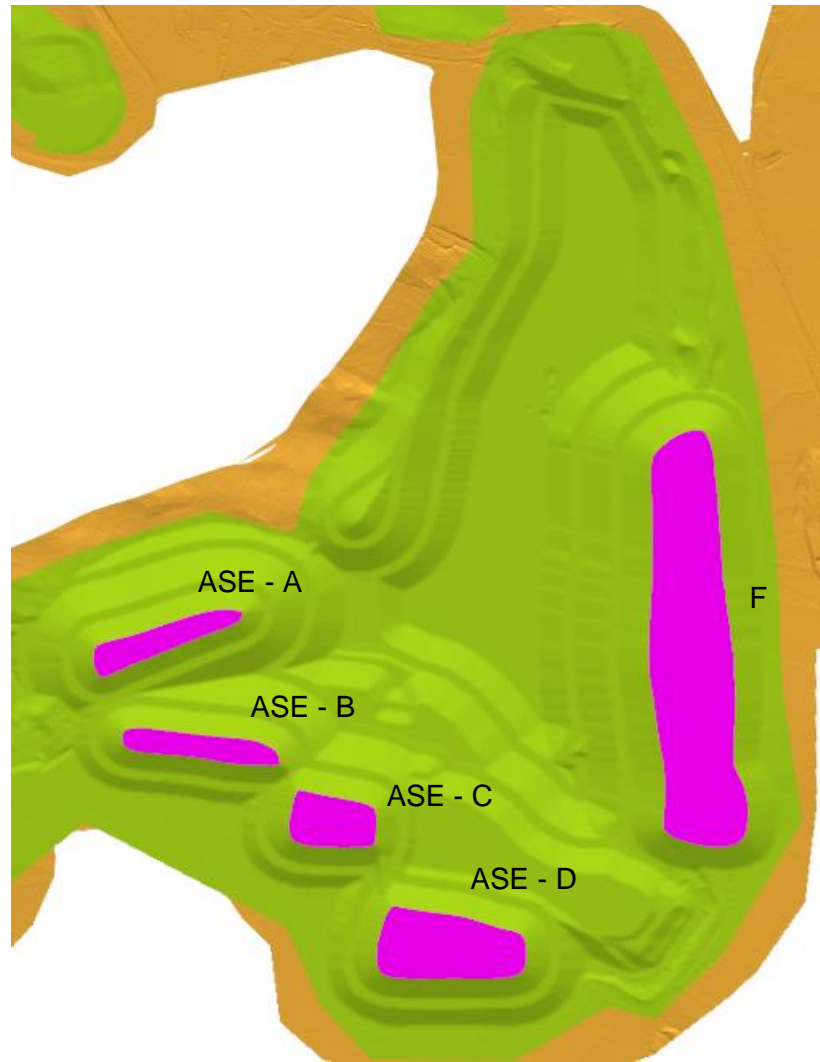
#### 4.4.2 G/ABG Void locations



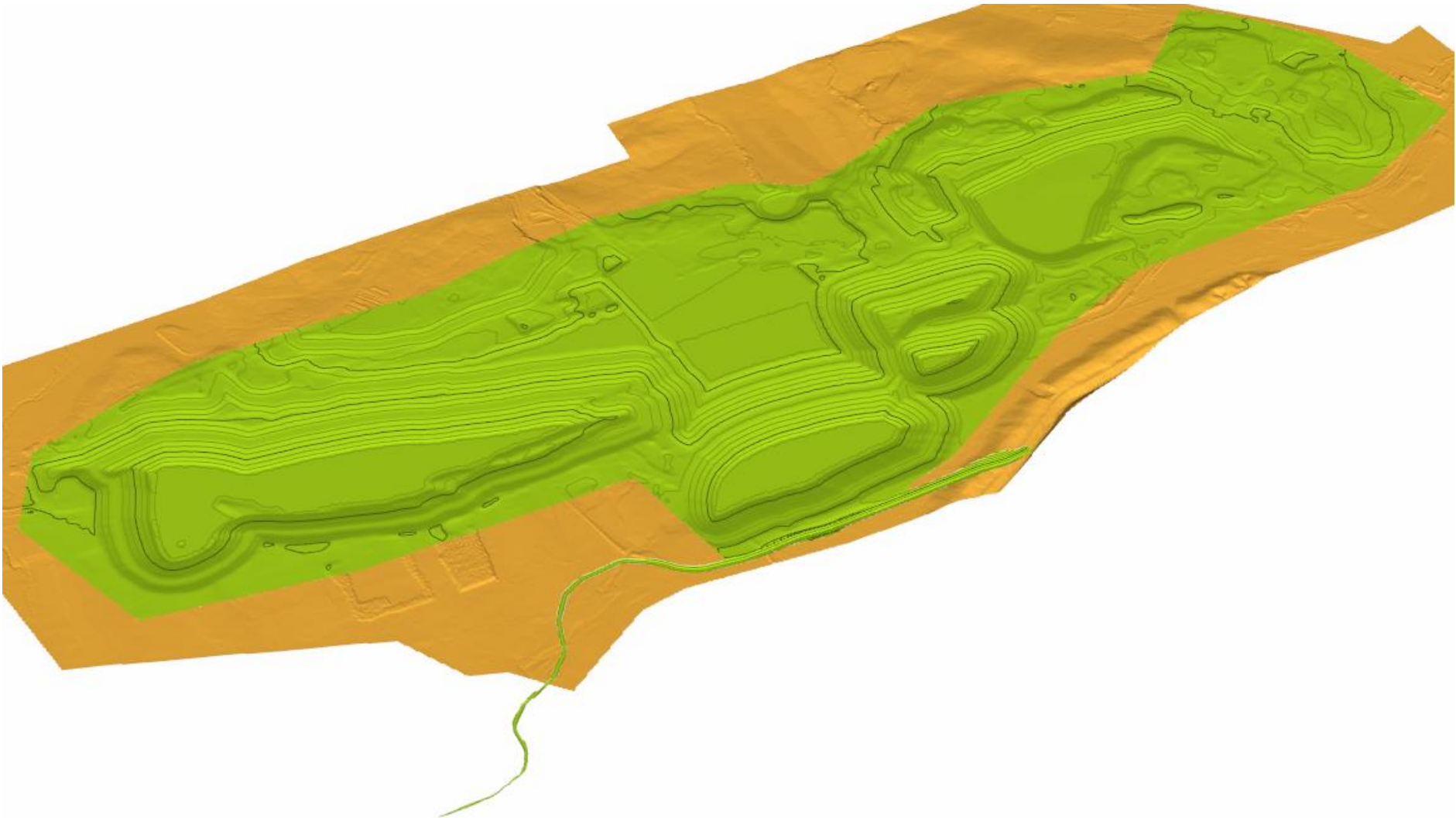
**4.4.3 F/ASE 3D Image with 5m Contours**



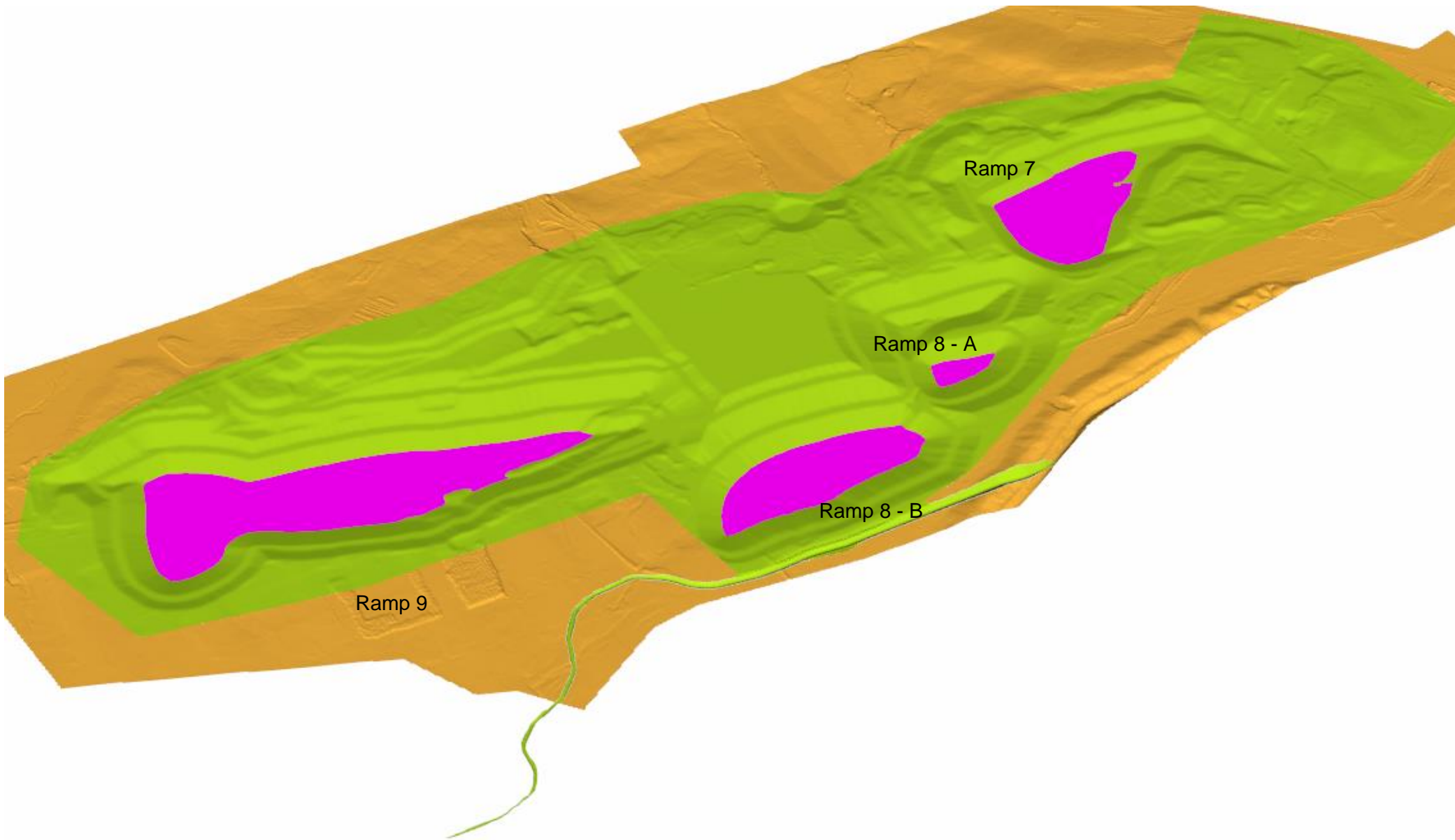
#### 4.4.4 F/ASE Void Locations



**4.4.5 J Block 3D with 5m contours**



#### 4.4.6 J Block Void Locations



4.4.7 M Block 3D with 5m contours



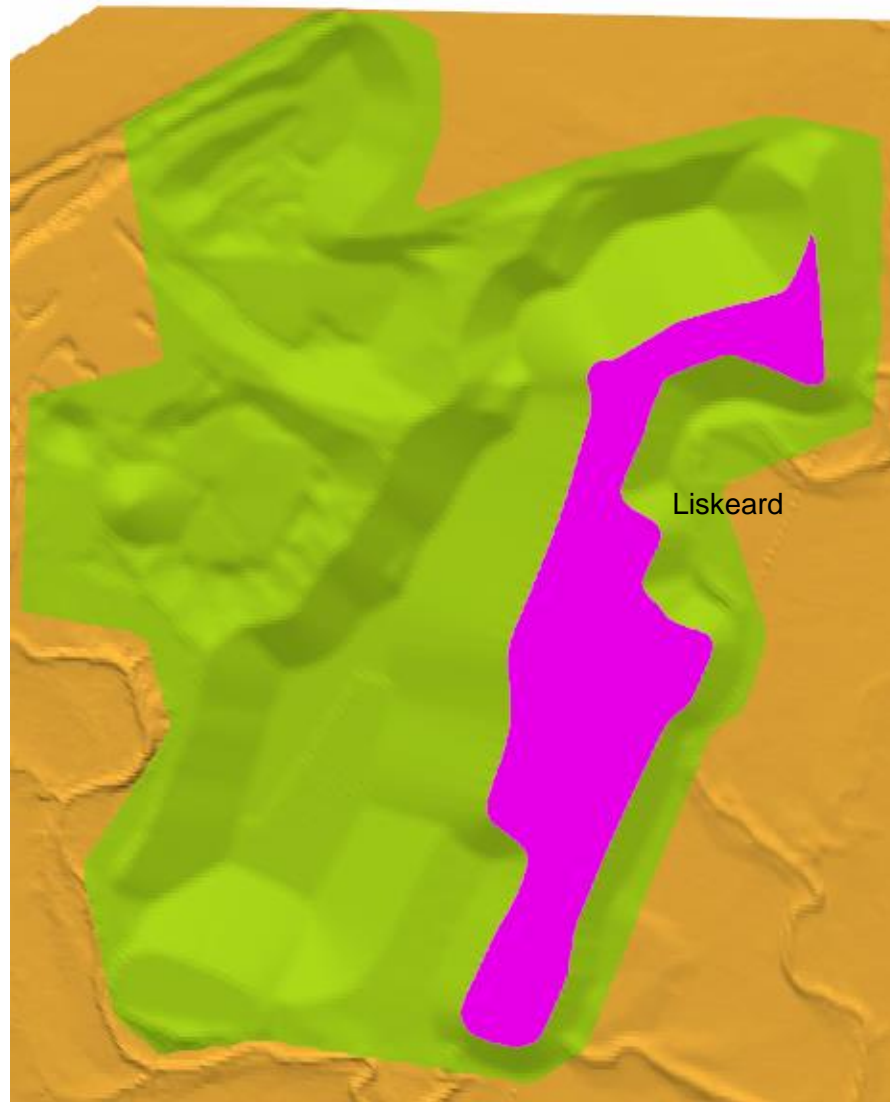
**4.4.8 M Block Void Locations**

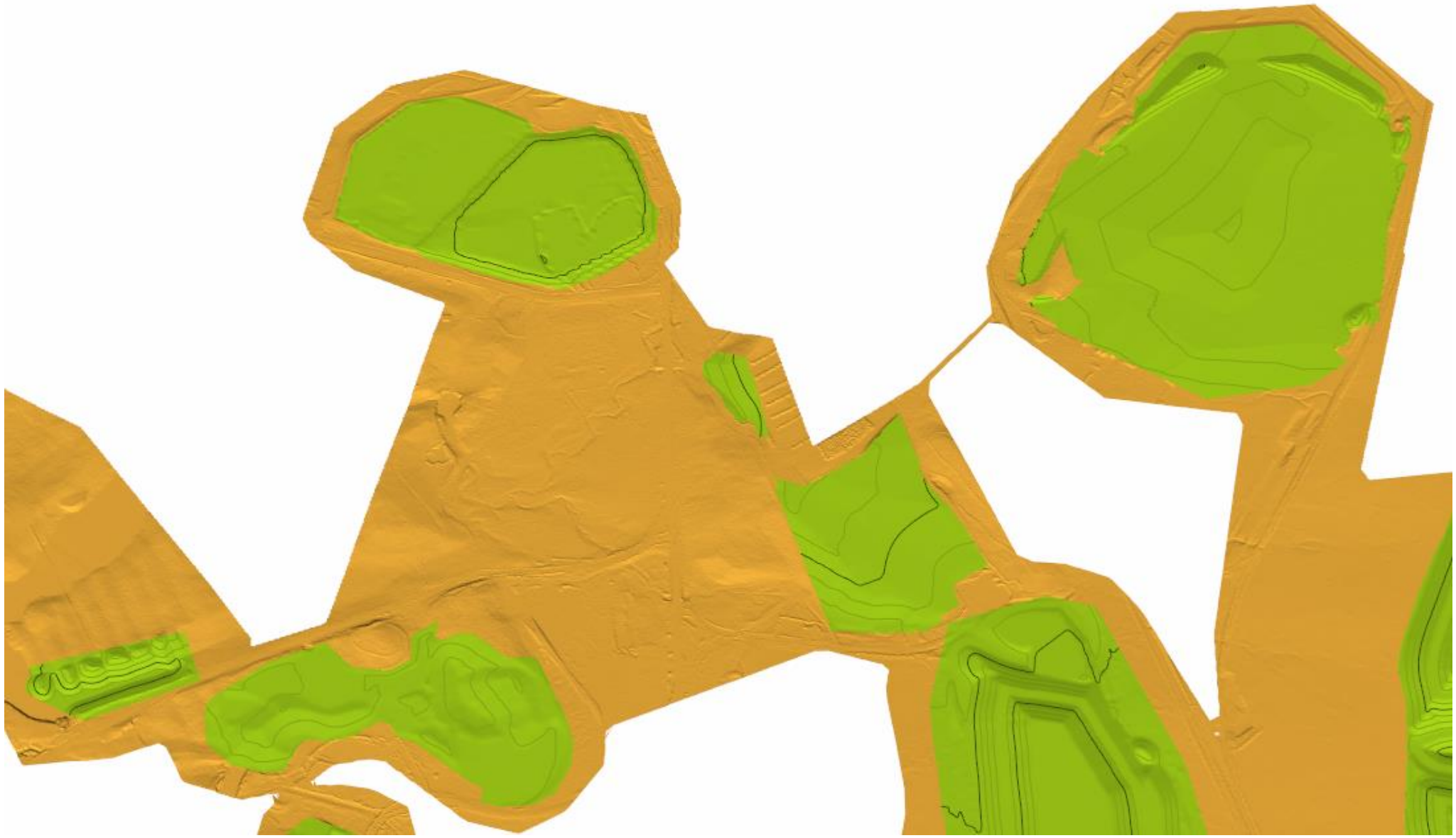


**4.4.9 Liskeard 3D with 5m contours**



**4.4.10 Liskeard Void Locations**



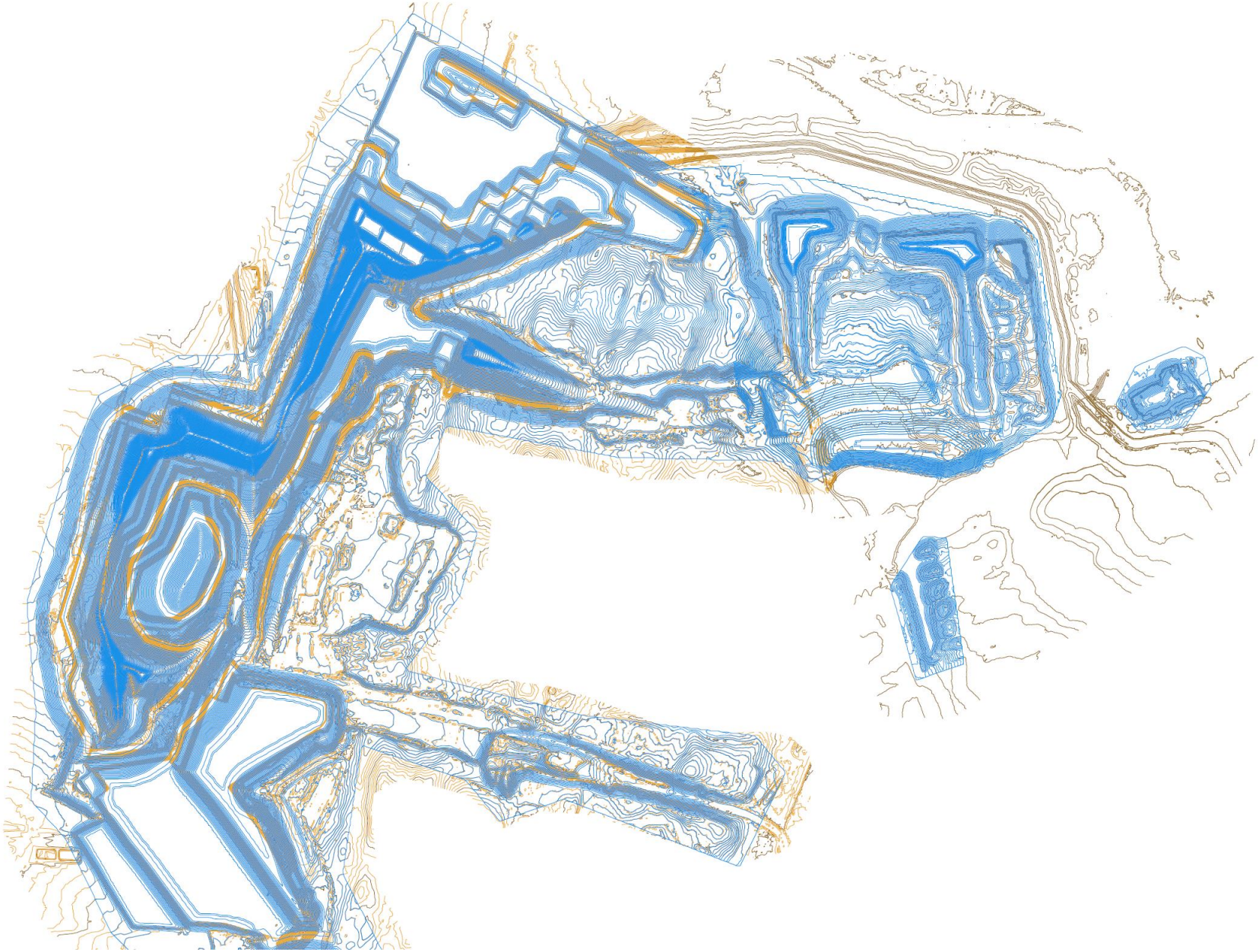


# 4.5 CONTOUR PLANS

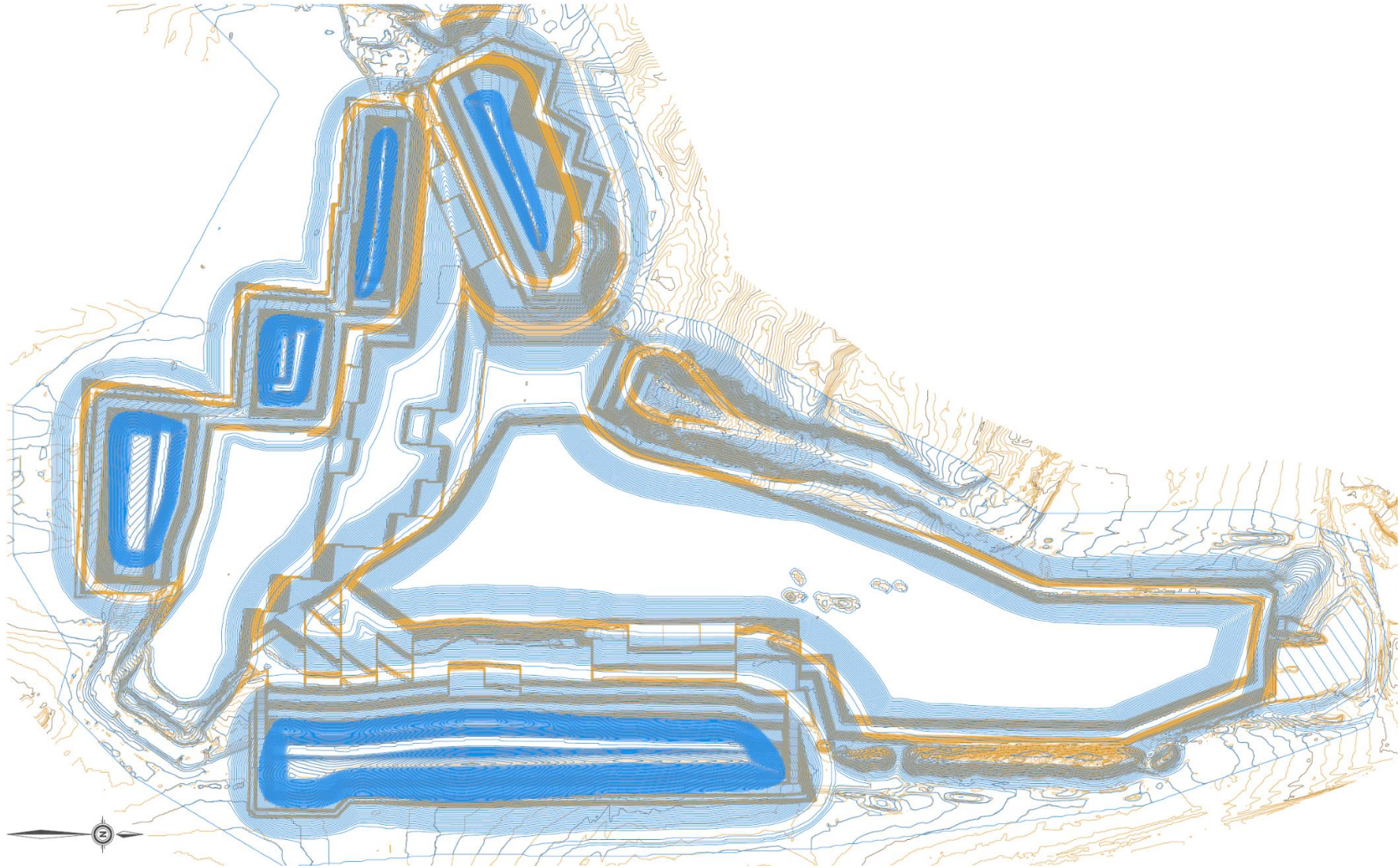
## 4.5.1 Full Site (1m Contours)



4.5.2 G/ ABG 1m Contours



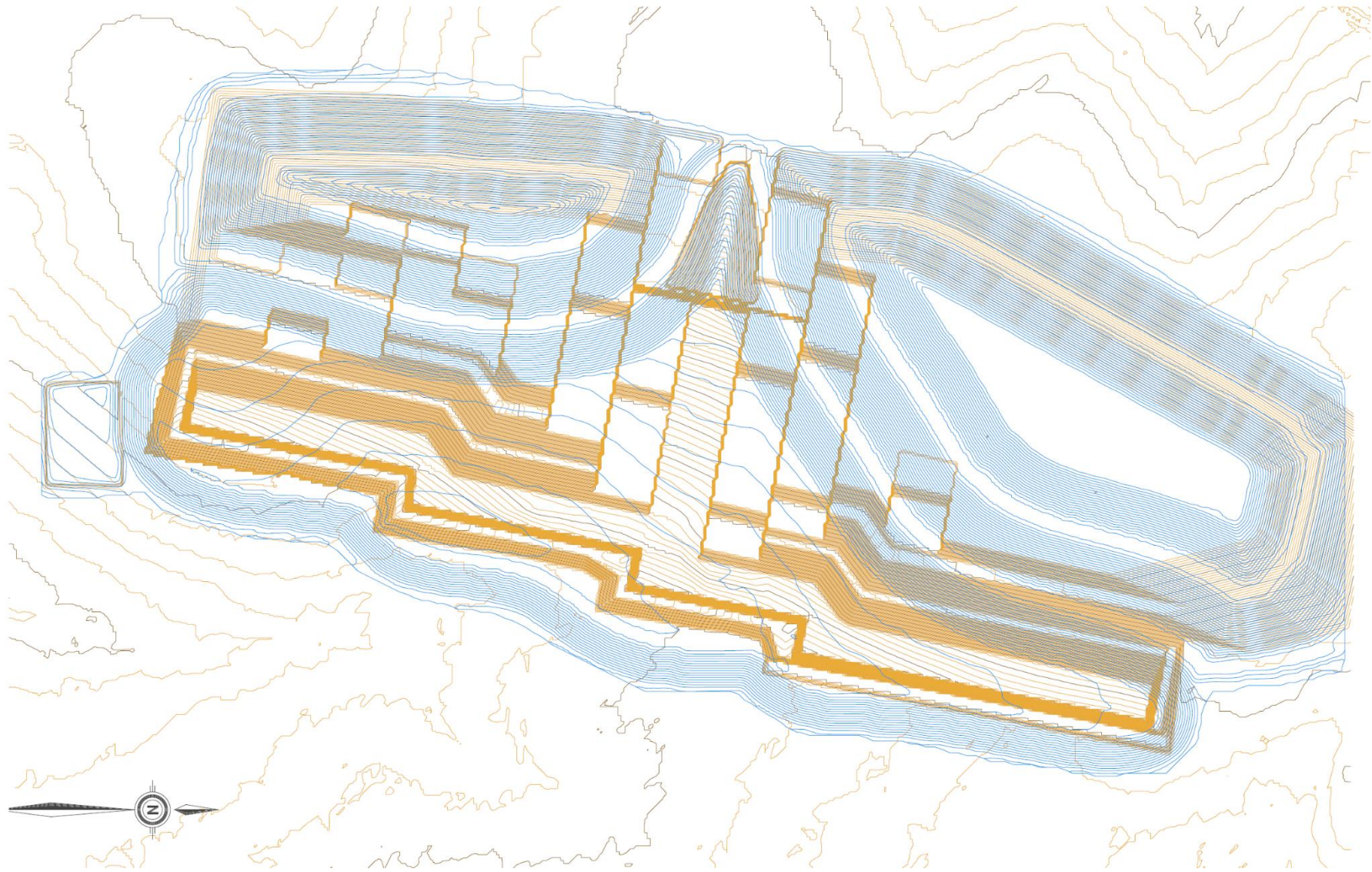
### 4.5.1 F/ASE 1m Contours



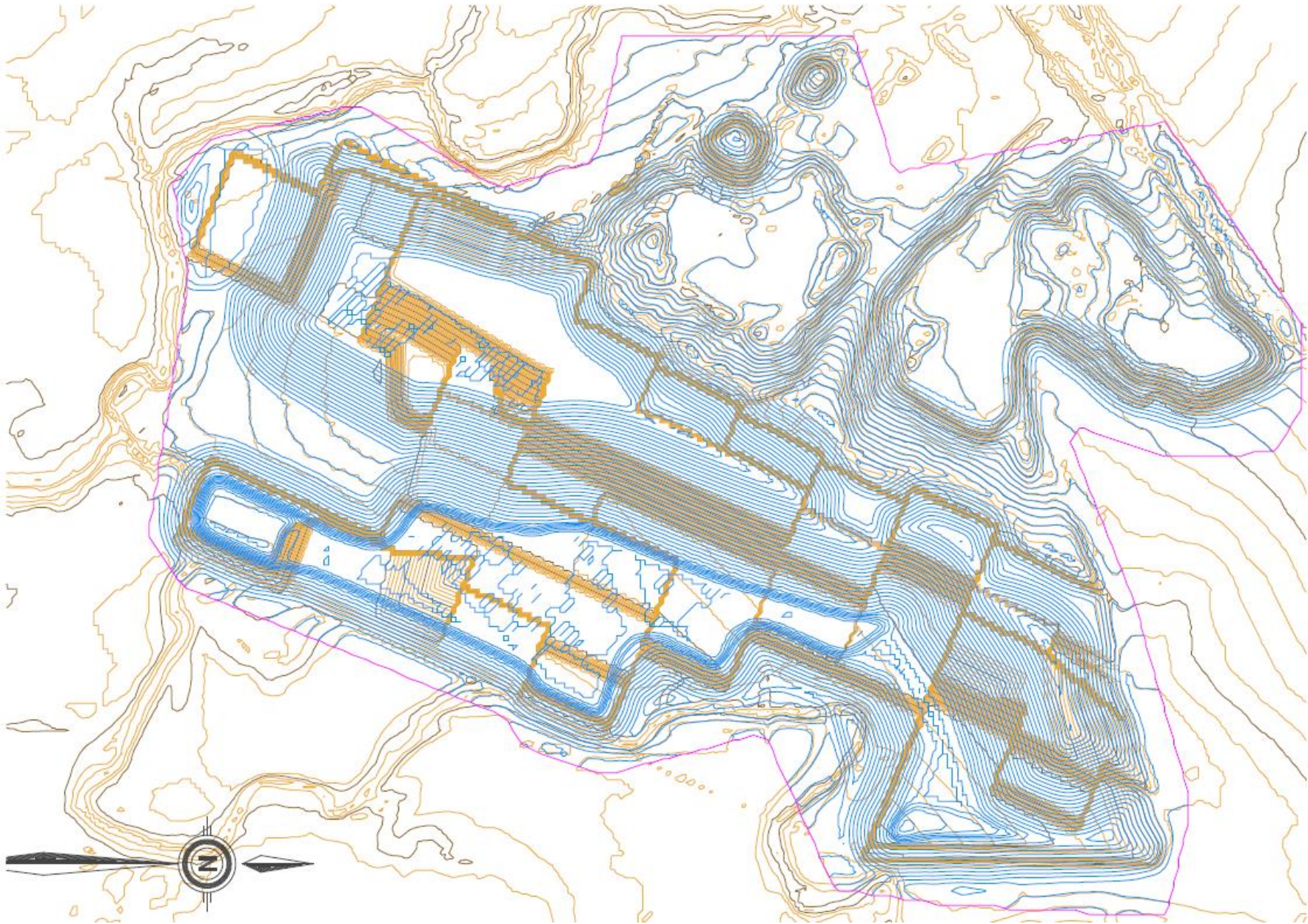
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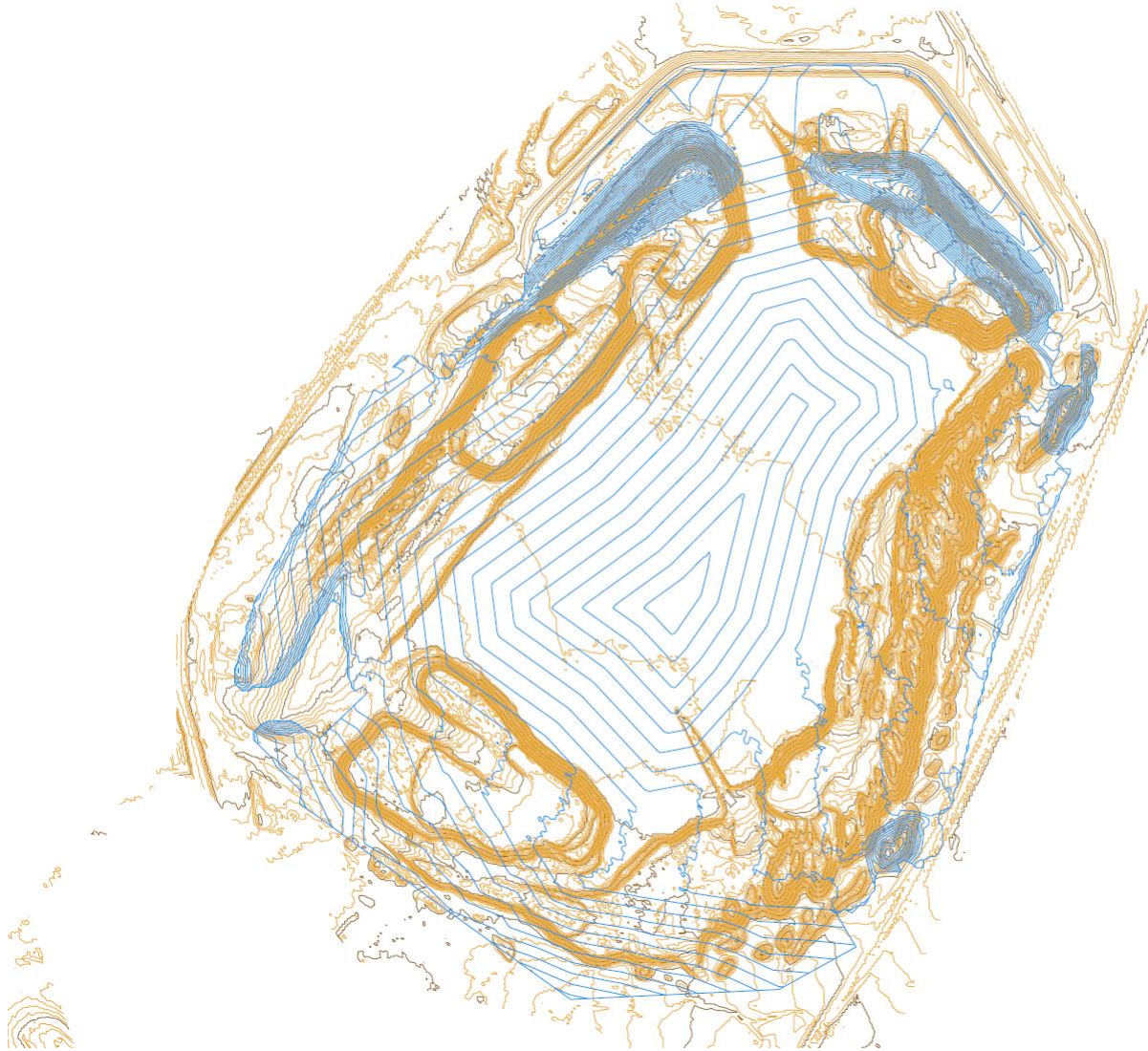


#### 4.5.1 M Block 1m Contours



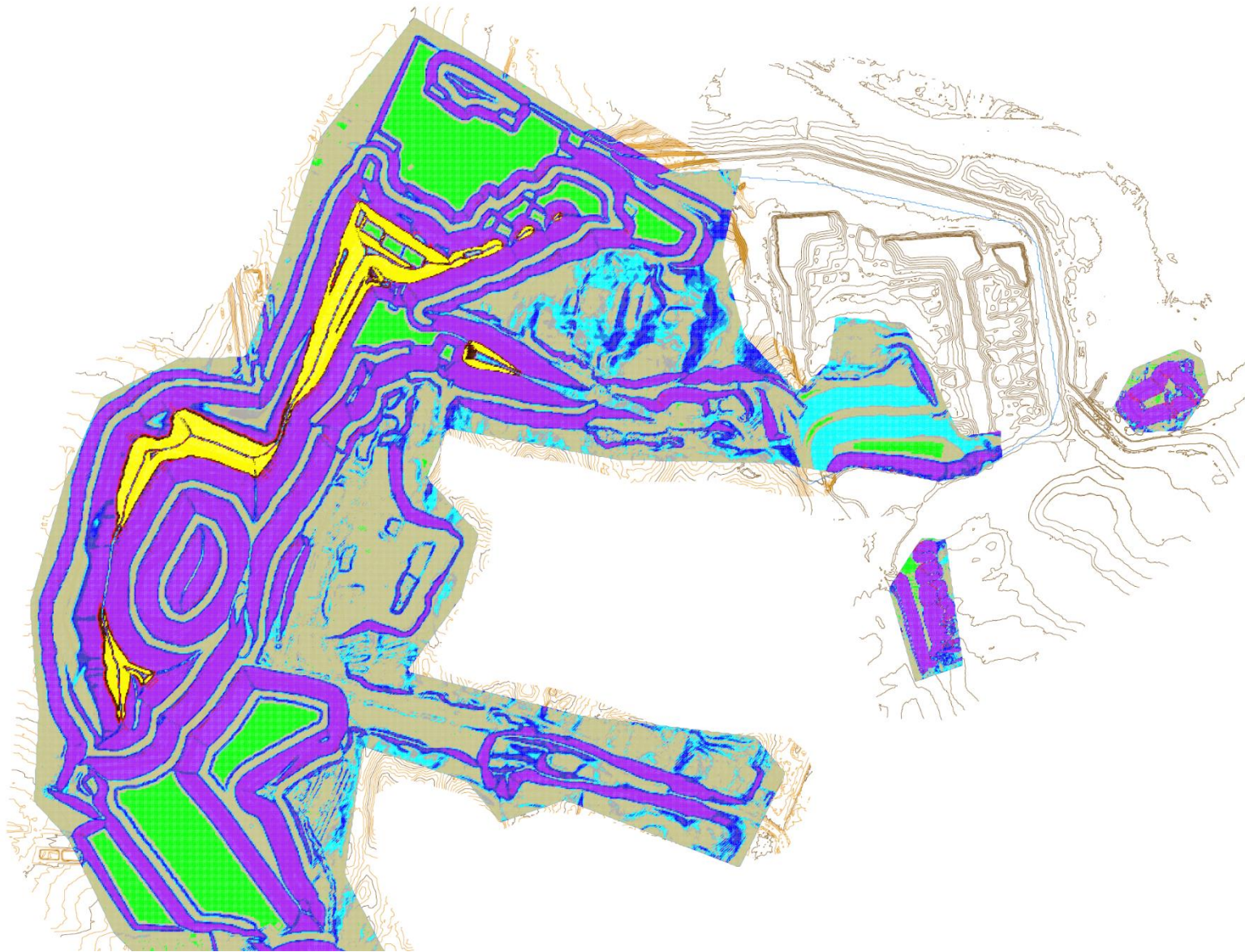
**4.5.1 Liskeard 1m Contours**





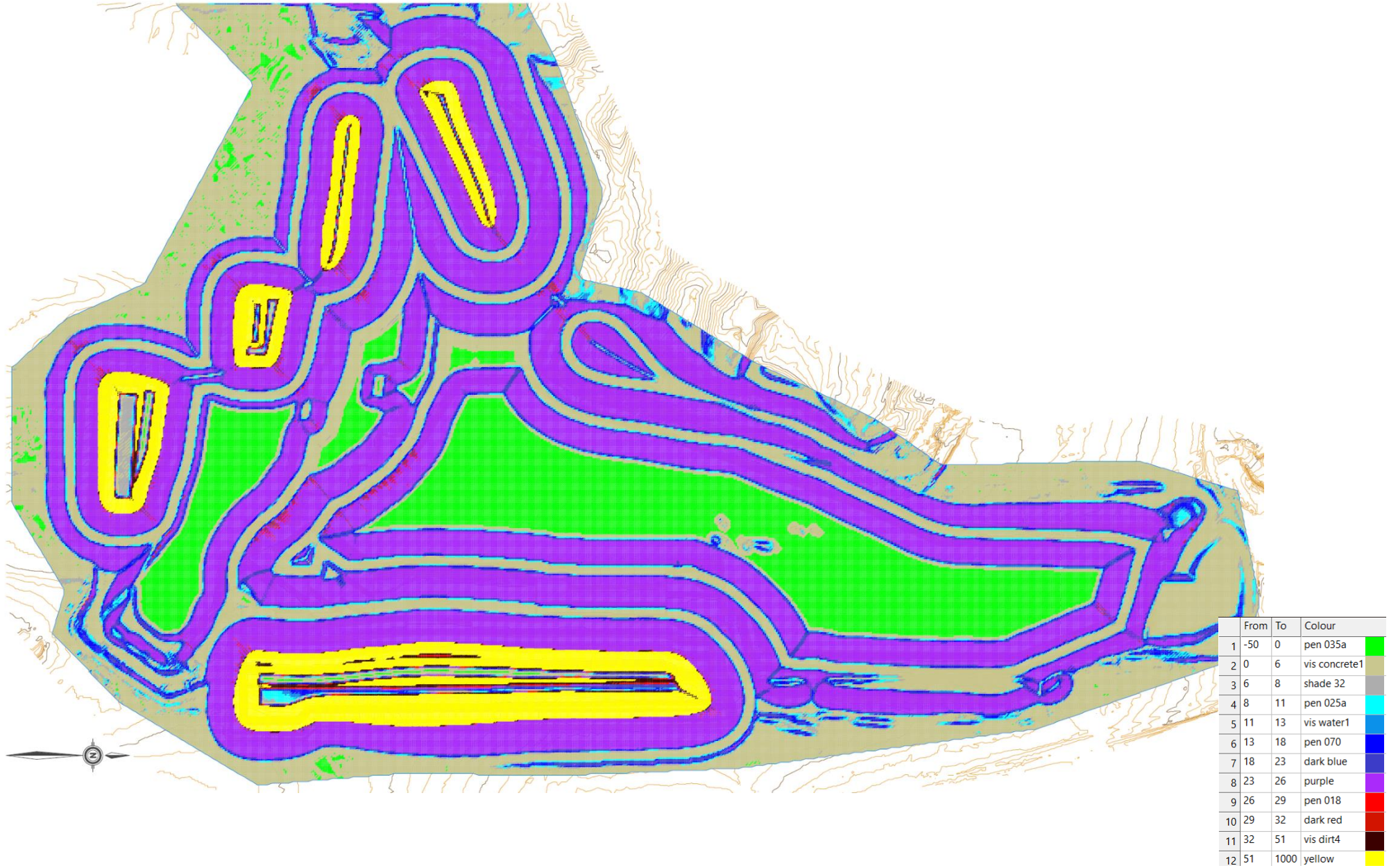
## 4.6 SLOPE PLANS

### 4.6.1 G/ ABG Slope

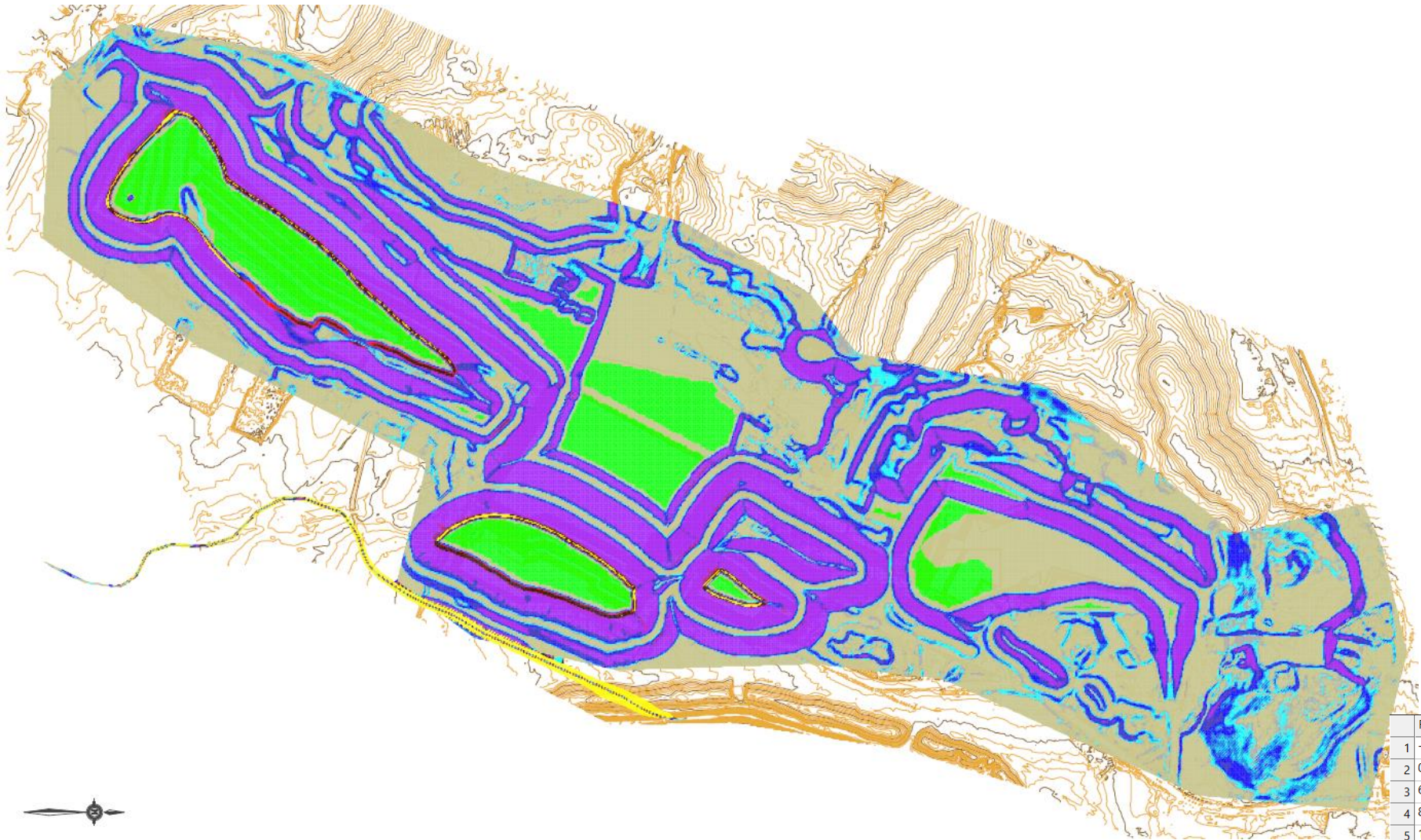


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2	0	6	vis concrete1
3	6	8	shade 32
4	8	11	pen 025a
5	11	13	vis water1
6	13	18	pen 070
7	18	23	dark blue
8	23	26	purple
9	26	29	pen 018
10	29	32	dark red
11	32	51	vis dirt4
12	51	1000	yellow

#### 4.6.2 F/ASE 1m Slope

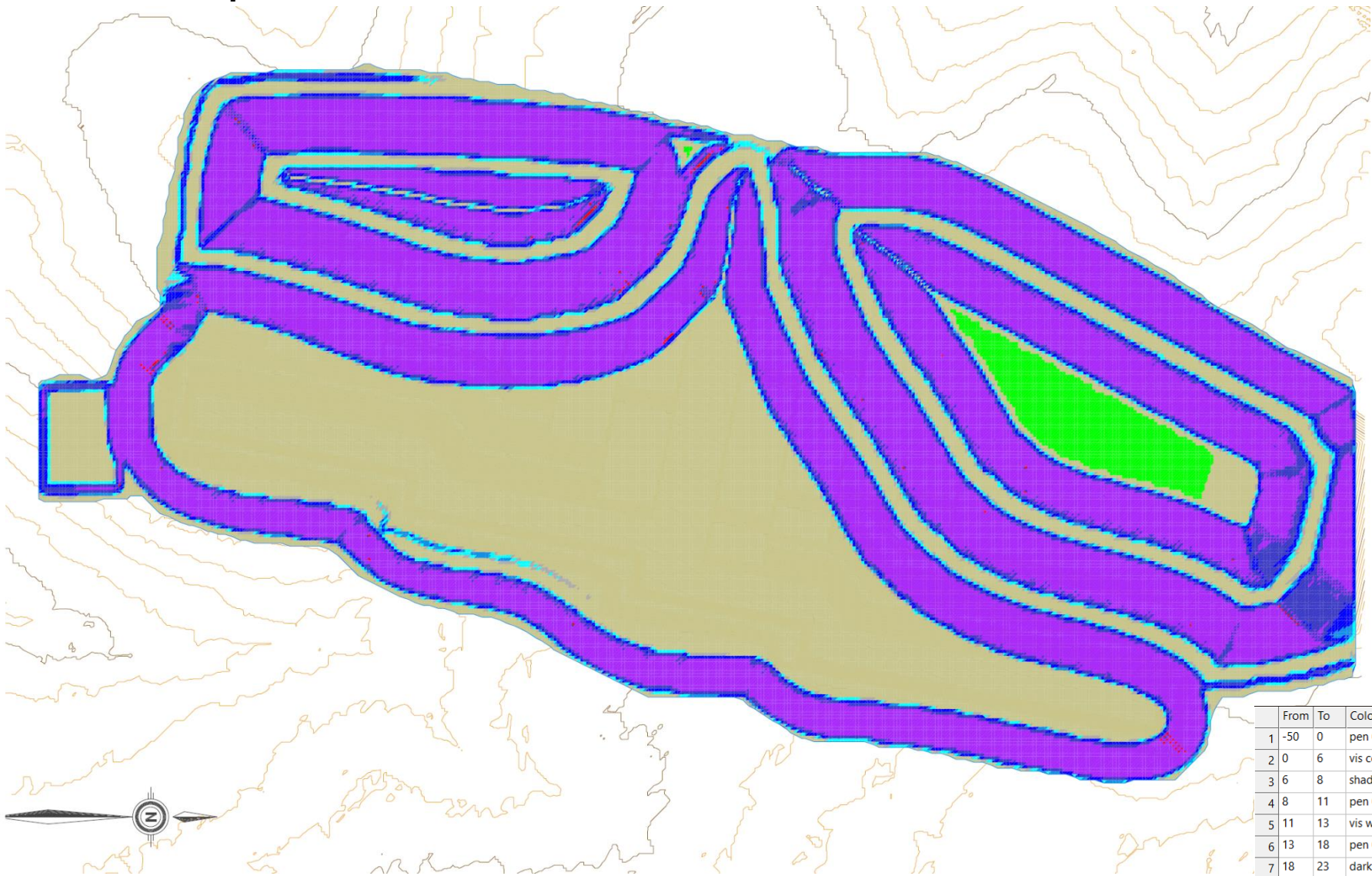


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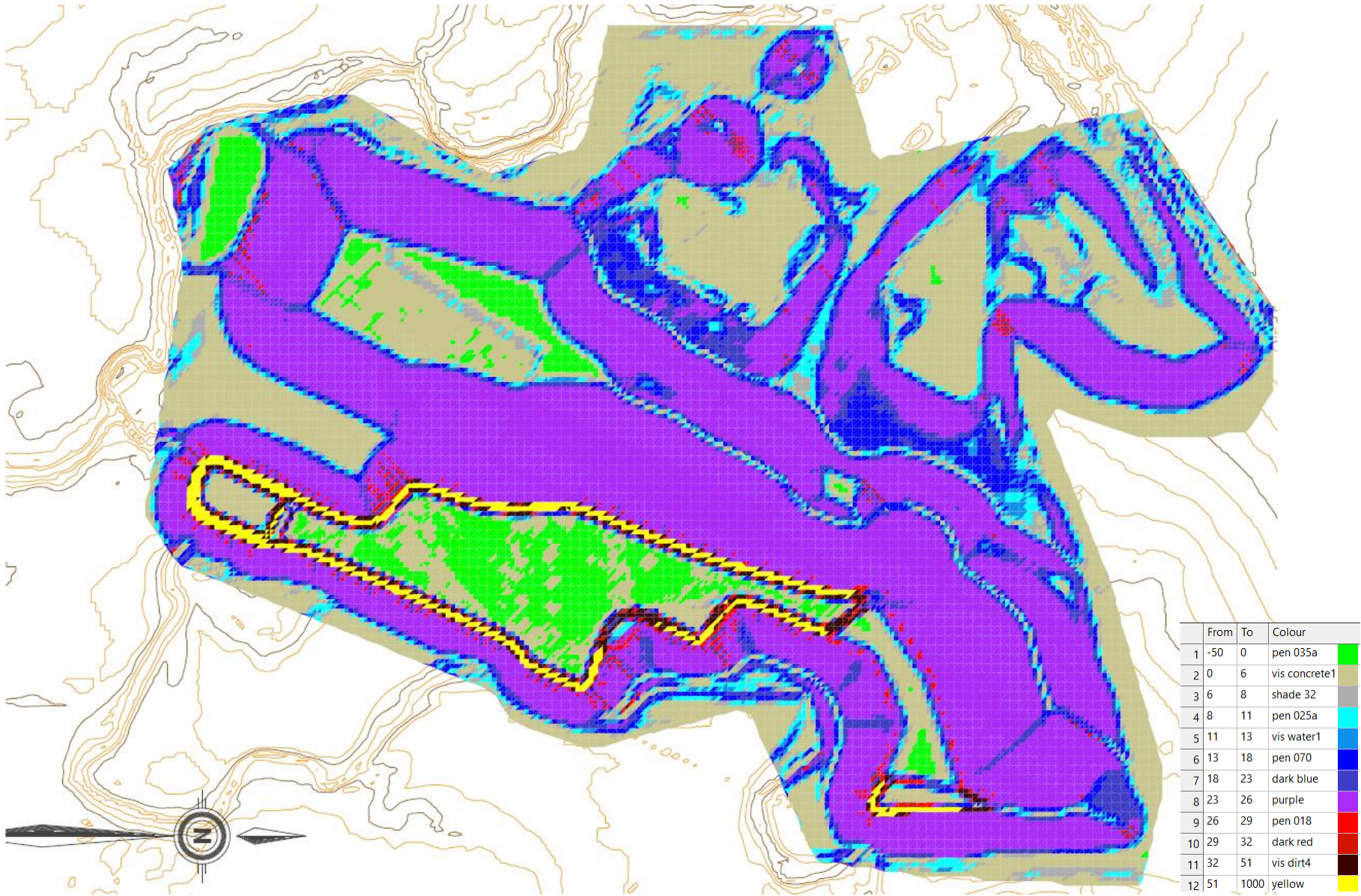
	From	To	Colour
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2	0	6	vis concrete1
3	6	8	shade 32
4	8	11	pen 025a
5	11	13	vis water1
6	13	18	pen 070
7	18	23	dark blue
8	23	26	purple
9	26	29	pen 018
10	29	32	dark red
11	32	51	vis dirt4
12	51	1000	yellow

#### 4.6.4 M Block Slope

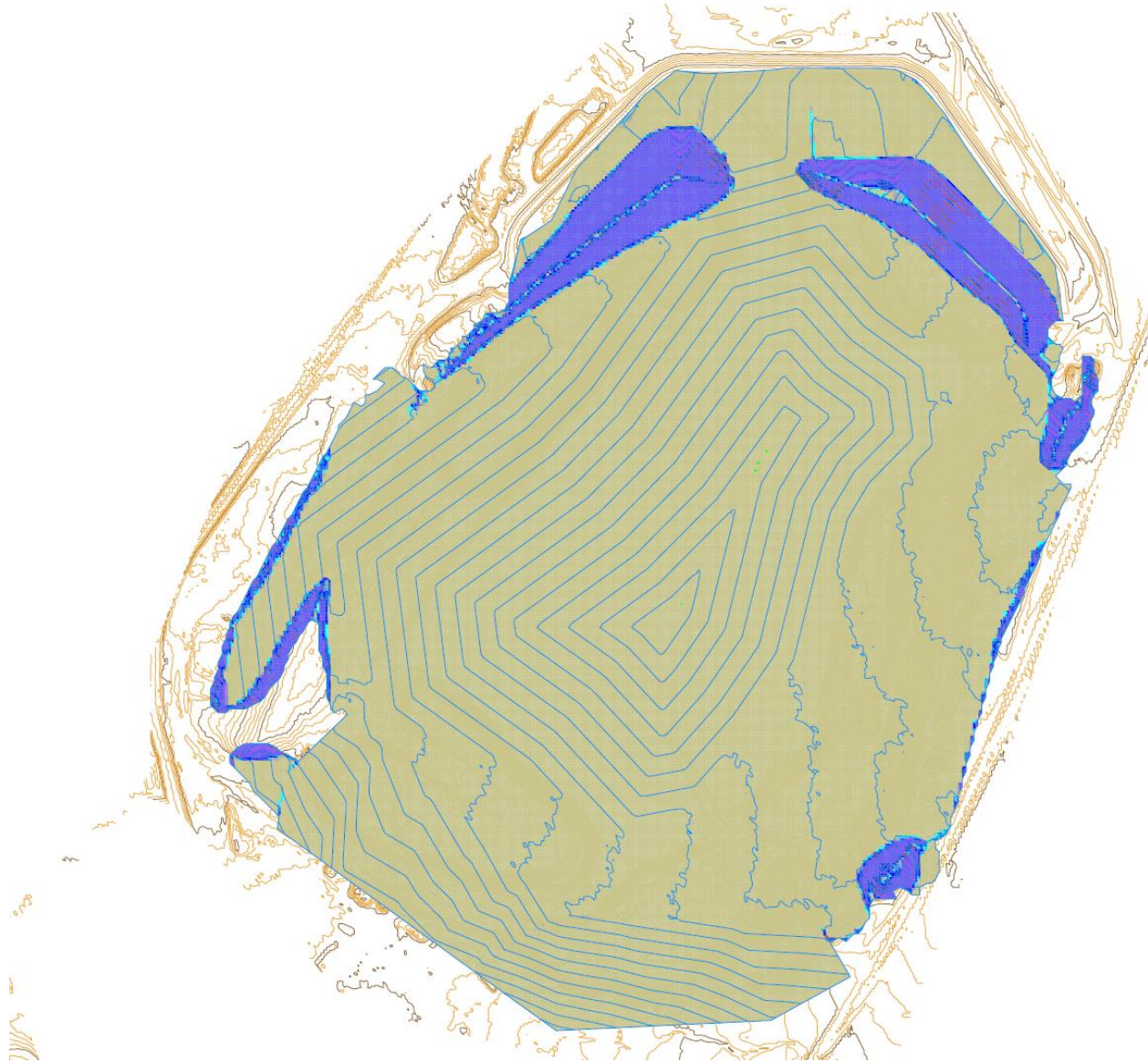


	From	To	Colour
1	-50	0	pen 035a
2	0	6	vis concrete1
3	6	8	shade 32
4	8	11	pen 025a
5	11	13	vis water1
6	13	18	pen 070
7	18	23	dark blue
8	23	26	purple
9	26	29	pen 018
10	29	32	dark red
11	32	51	vis dirt4
12	51	1000	yellow

## 4.6.5 Liskeard Slope



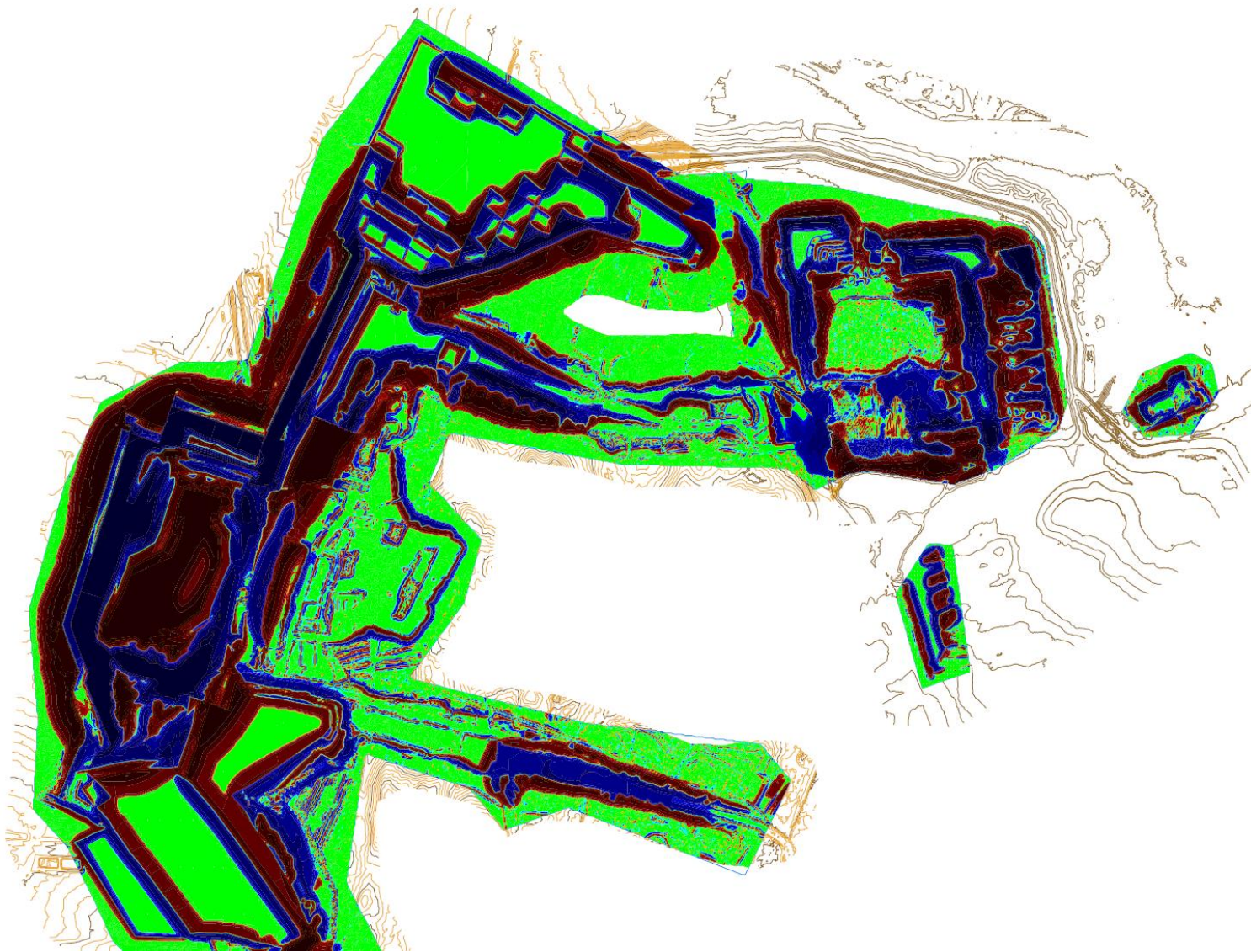
## 4.6.6 | Block Slope



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4	8	11	pen 025a	cyan
5	11	13	vis water1	light blue
6	13	18	pen 070	dark blue
7	18	23	dark blue	blue
8	23	26	purple	purple
9	26	29	pen 018	red
10	29	32	dark red	dark red
11	32	51	vis dirt4	black
12	51	1000	yellow	yellow

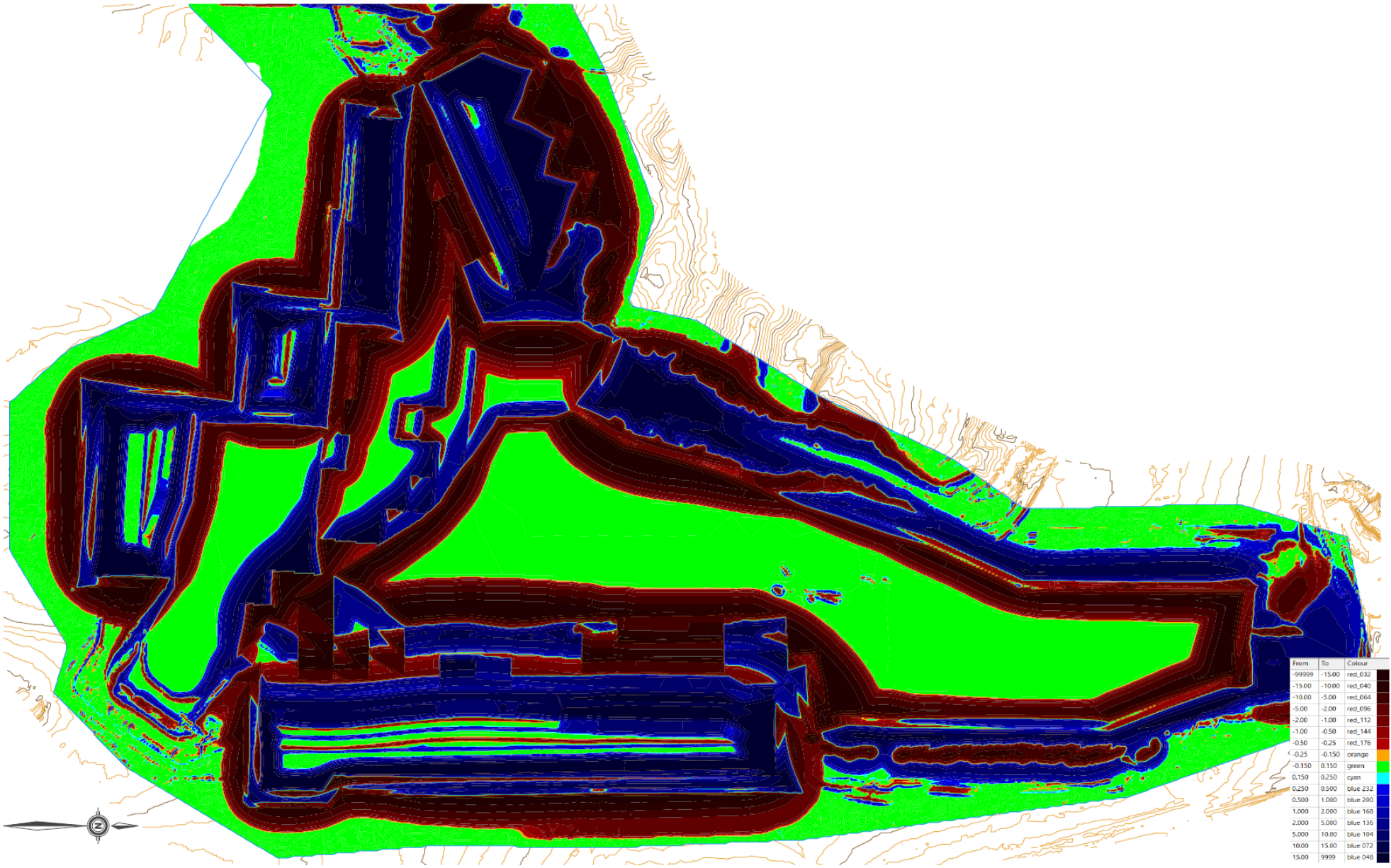
## 4.7 CUT/FILL PLANS

### 4.7.1 G/ ABG Cut/Fill

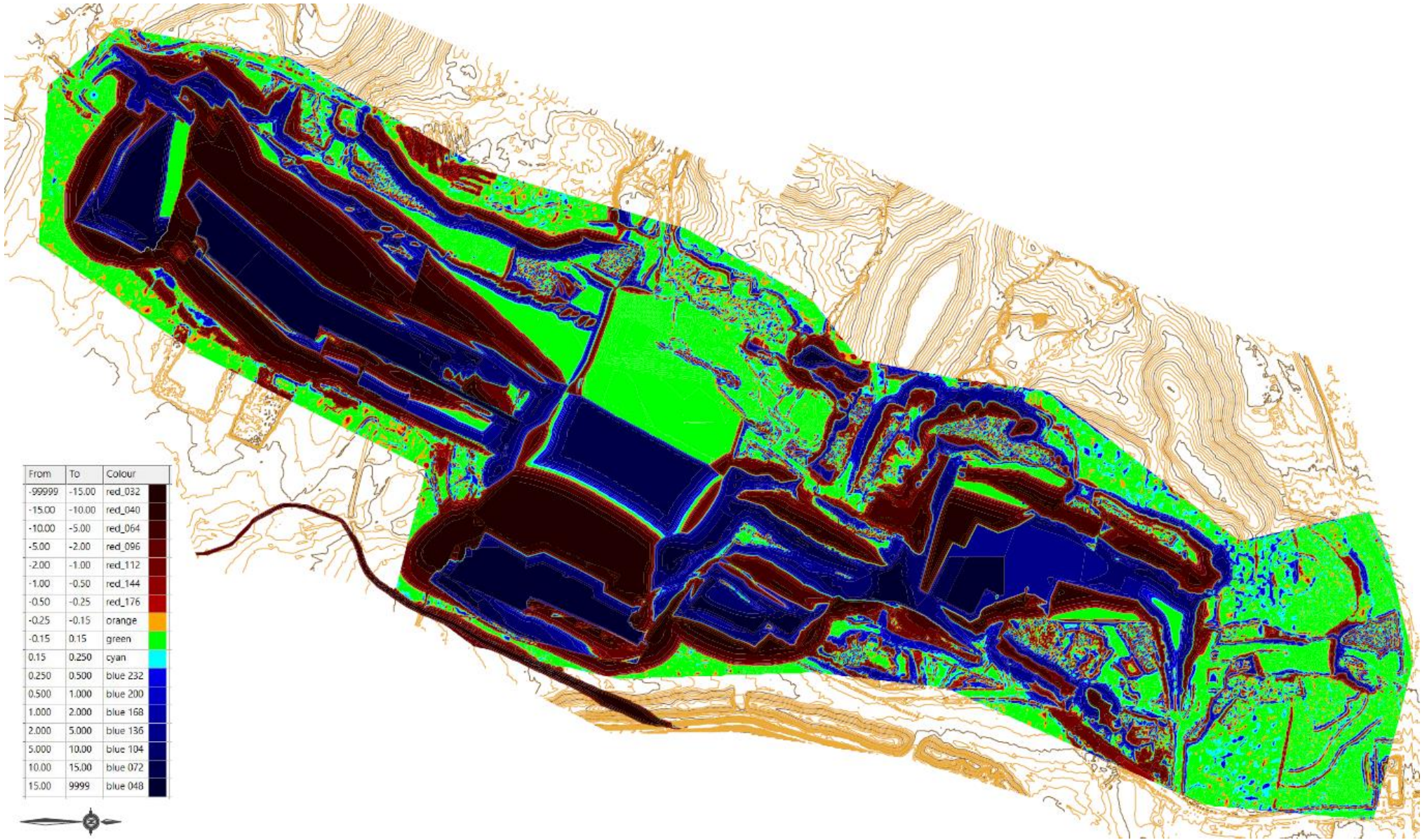


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-10.00	-5.00	red_064
-5.00	-2.00	red_096
-2.00	-1.00	red_112
-1.00	-0.50	red_144
-0.50	-0.25	red_176
-0.25	-0.150	orange
-0.150	0.150	green
0.150	0.250	cyan
0.250	0.500	blue_232
0.500	1.000	blue_200
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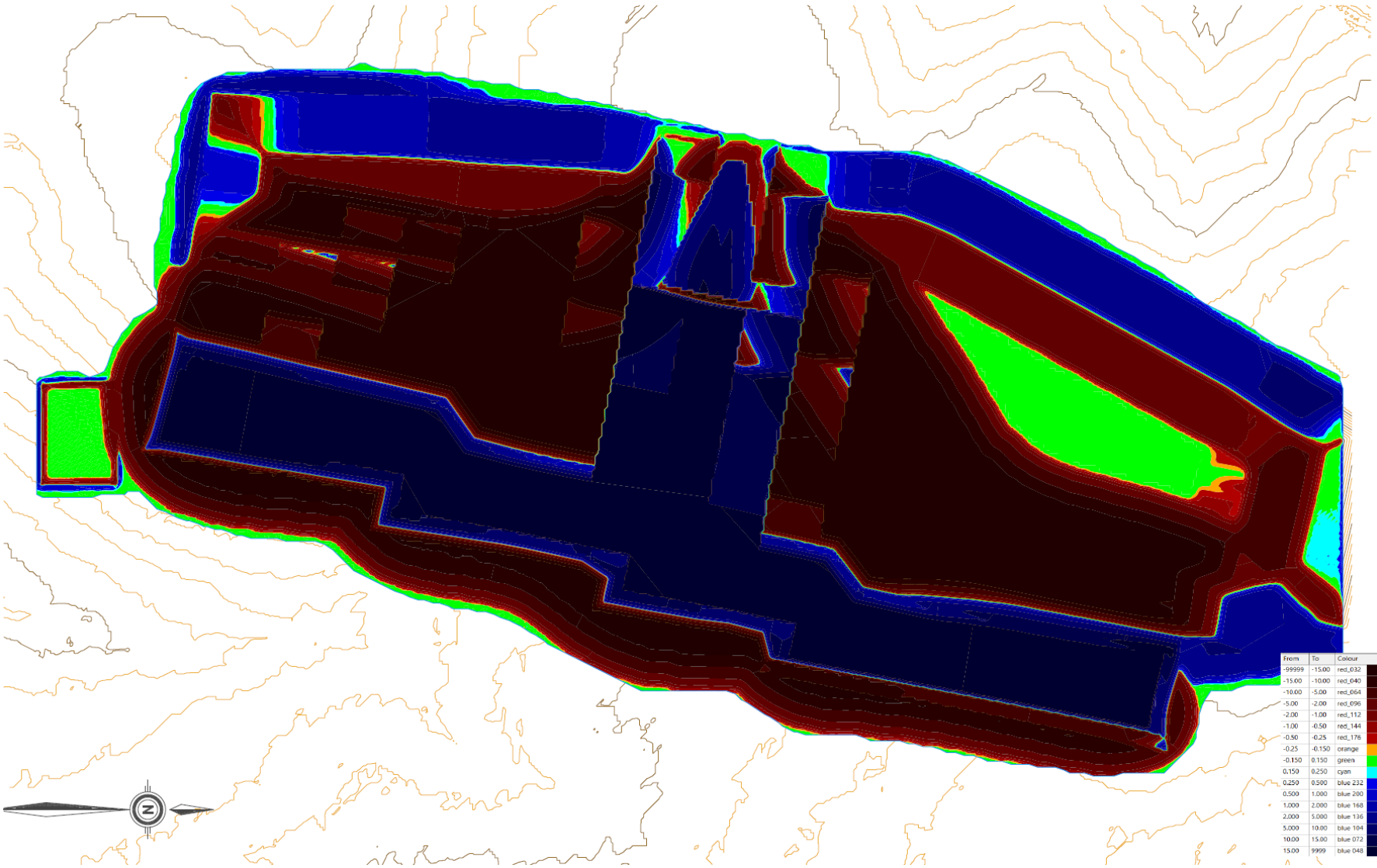
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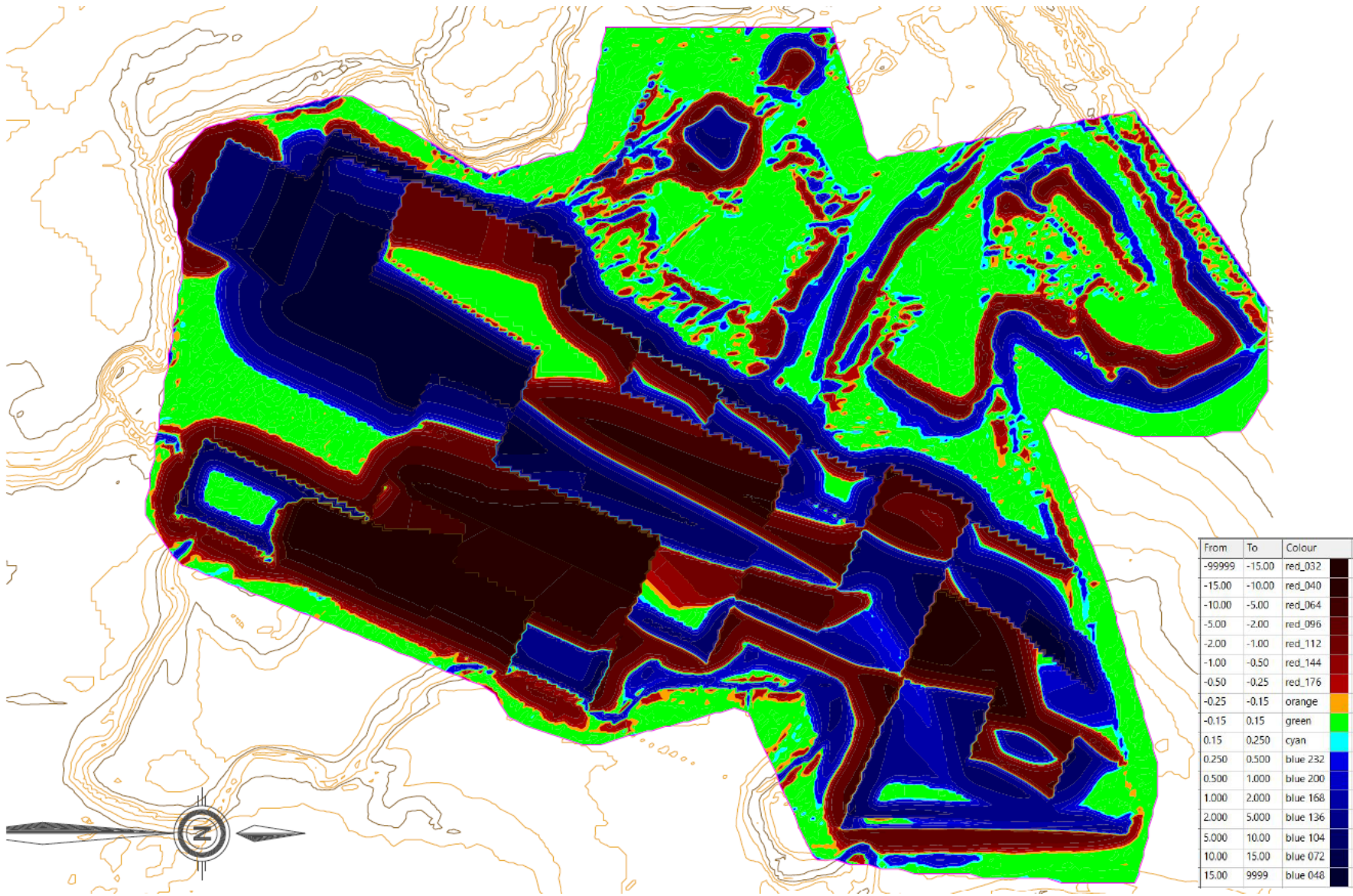
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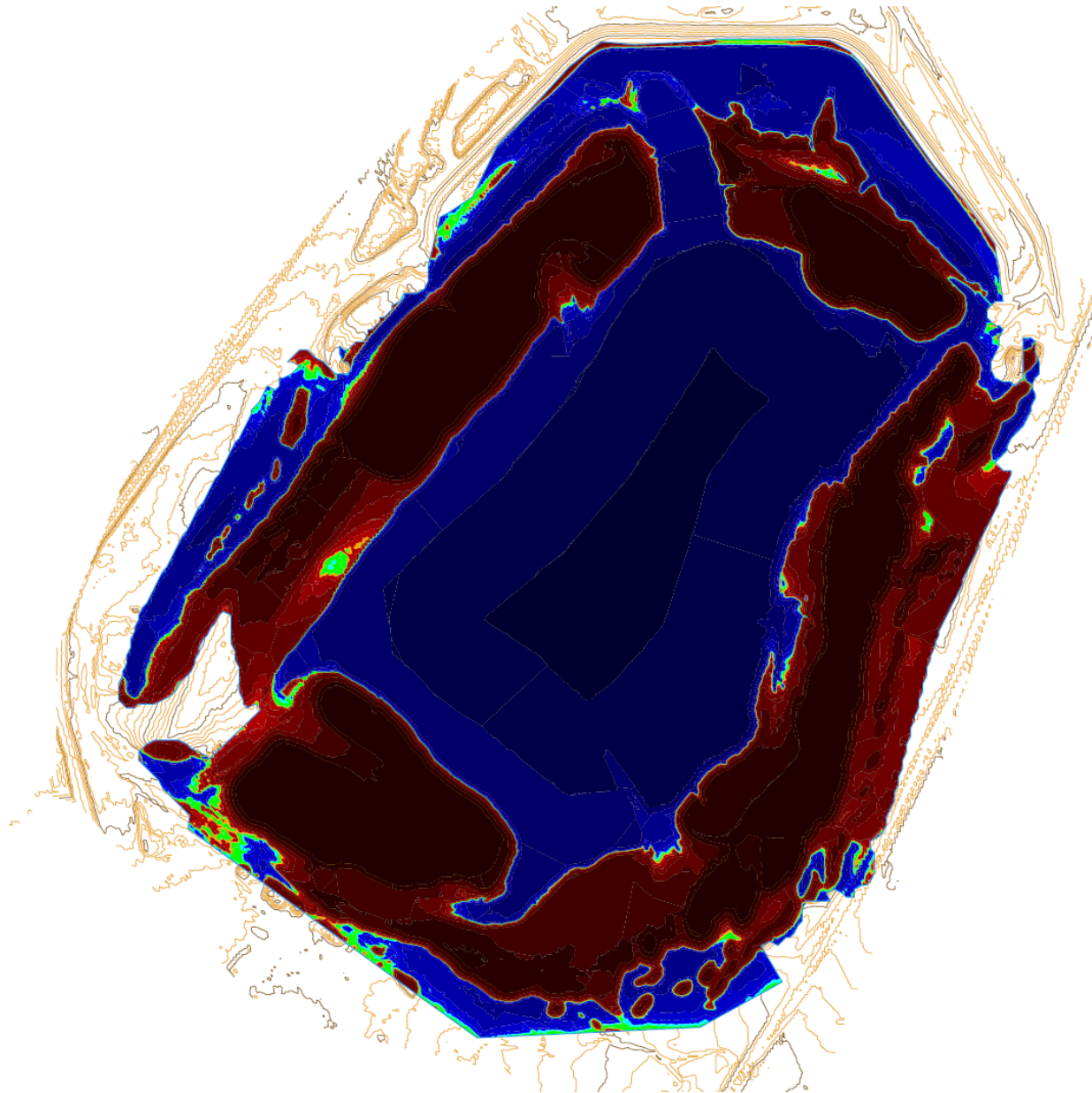
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#### 4.7.5 Liskeard Cut/Fill

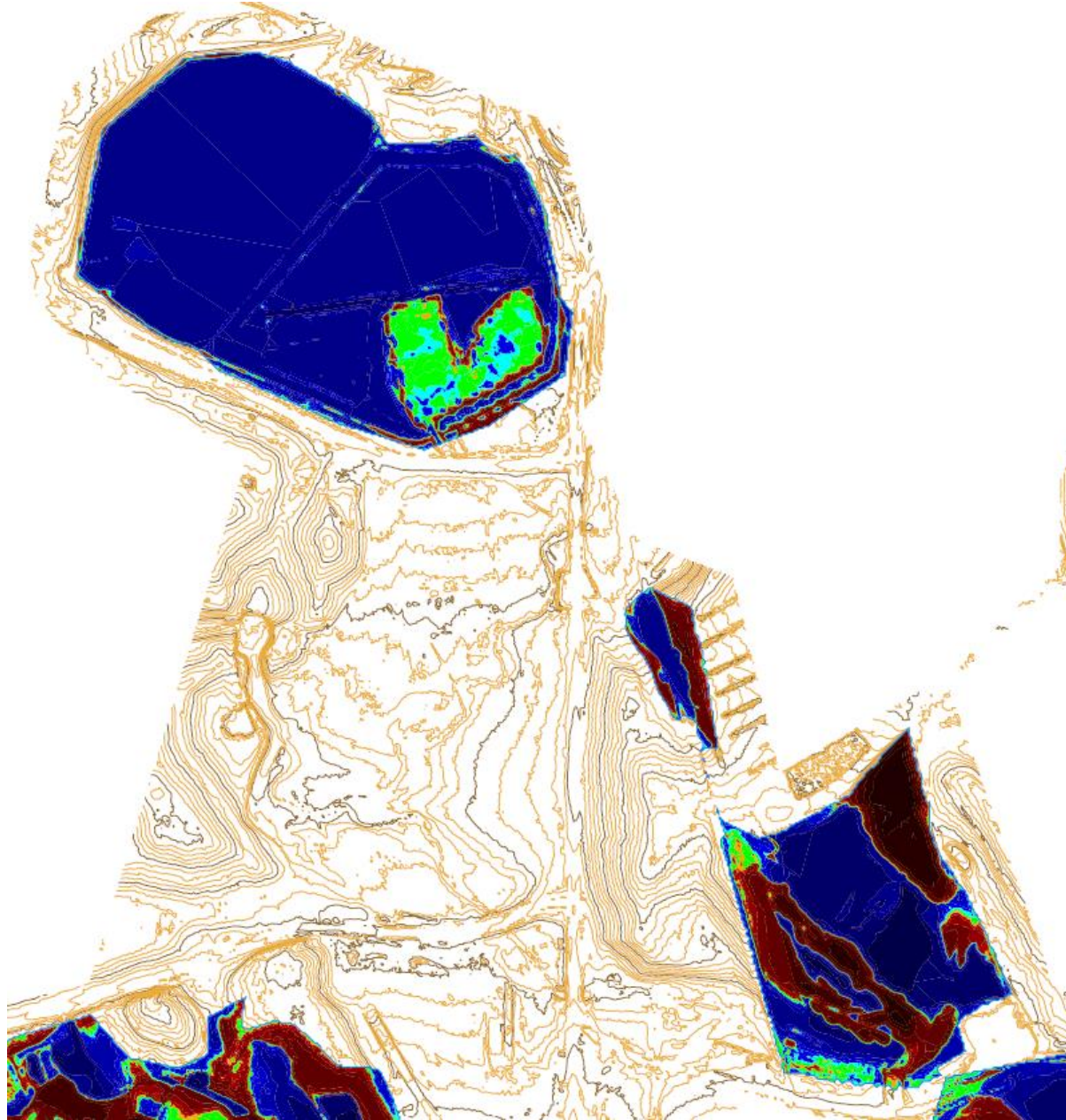


## 4.7.6 I Block Cut/Fill



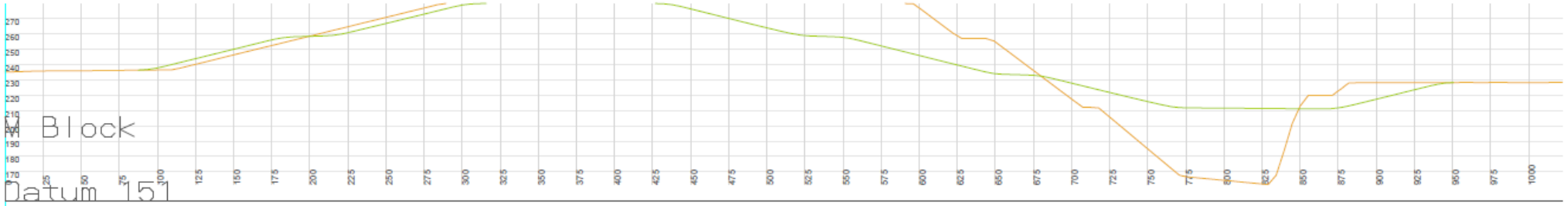
From	To	Colour
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-15.00	-10.00	red_040
-10.00	-5.00	red_064
-5.00	-2.00	red_096
-2.00	-1.00	red_112
-1.00	-0.50	red_144
-0.50	-0.25	red_176
-0.25	-0.150	orange
-0.150	0.150	green
0.150	0.250	cyan
0.250	0.500	blue 232
0.500	1.000	blue 200
1.000	2.000	blue 168
2.000	5.000	blue 136
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**4.7.7 TSF Old and H Block Cut/Fill**

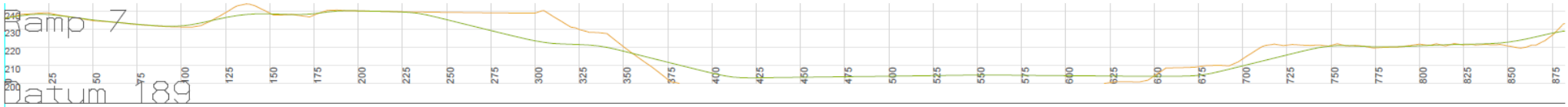


# 4.8 CROSS SECTIONS

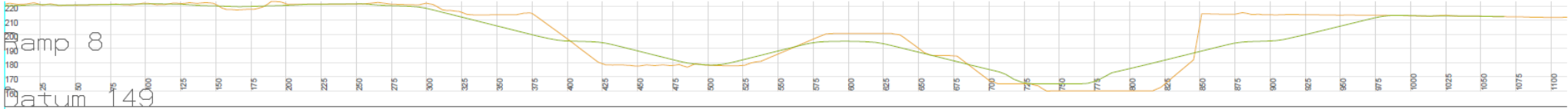
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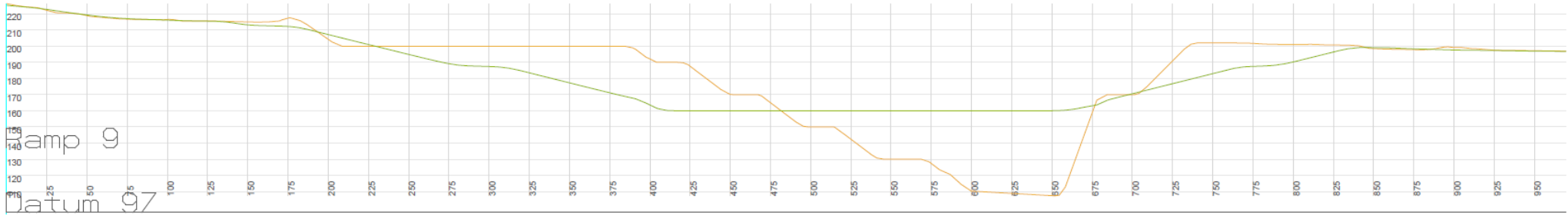
## 4.8.2 Ramp 7



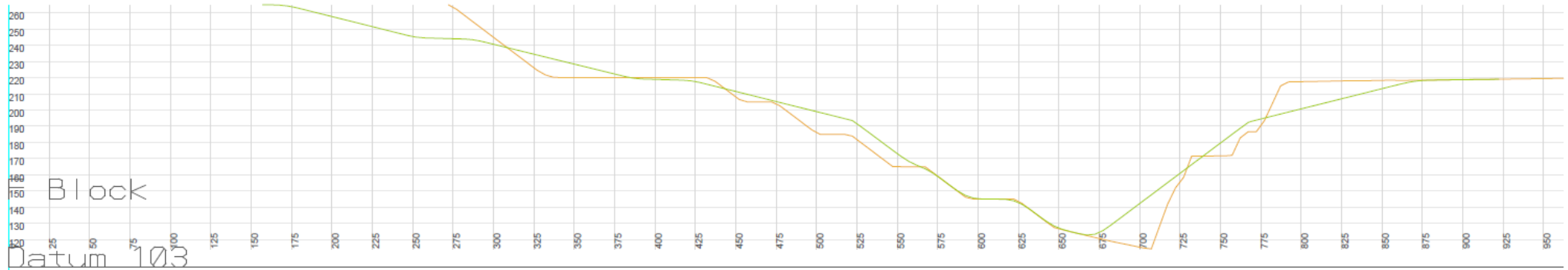
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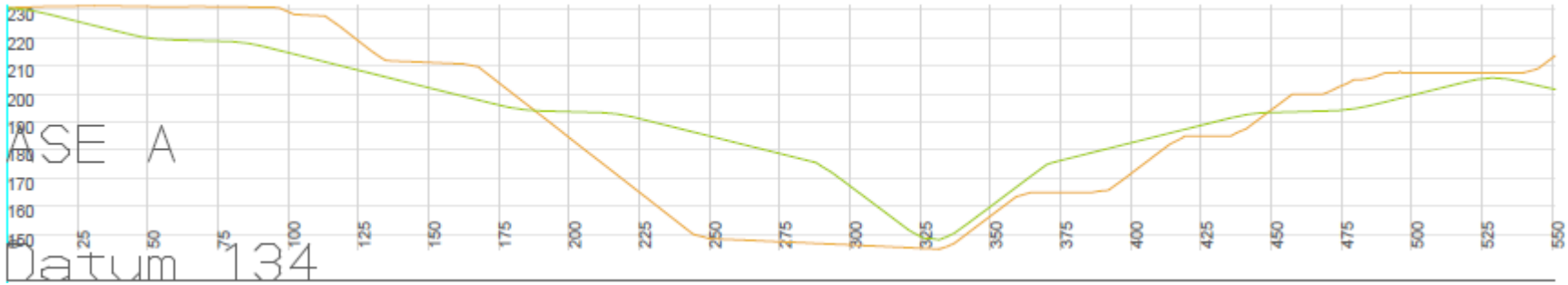
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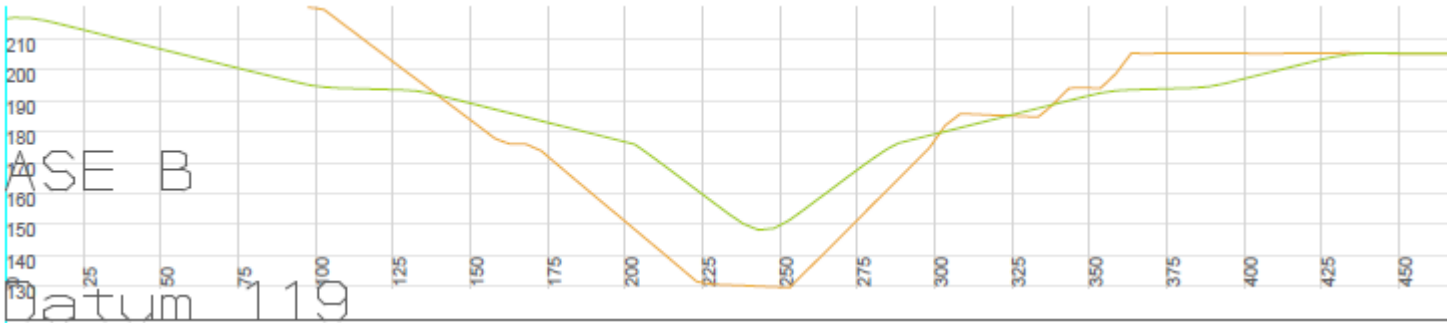
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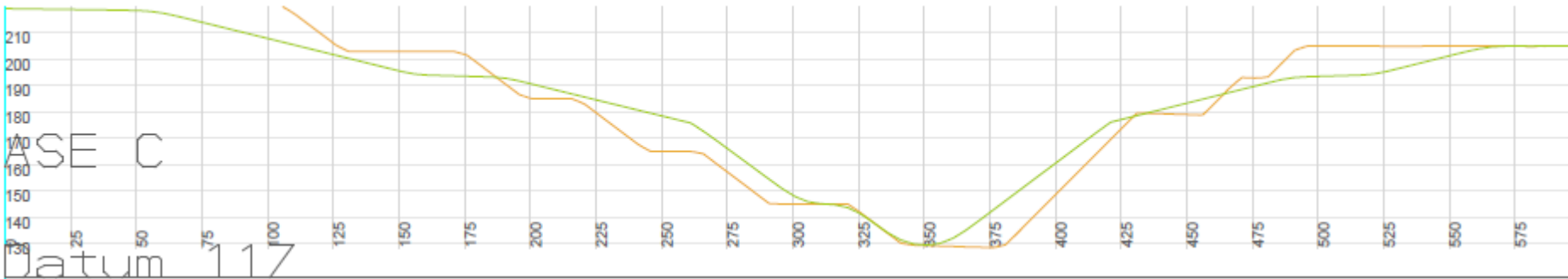
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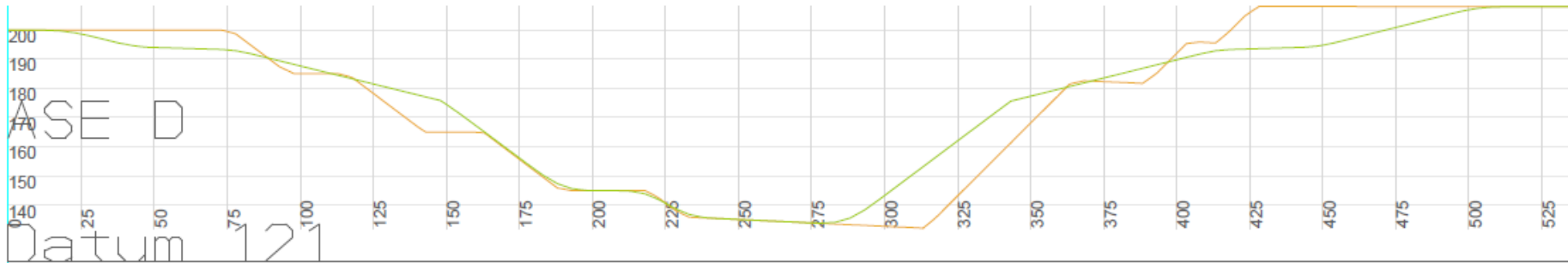
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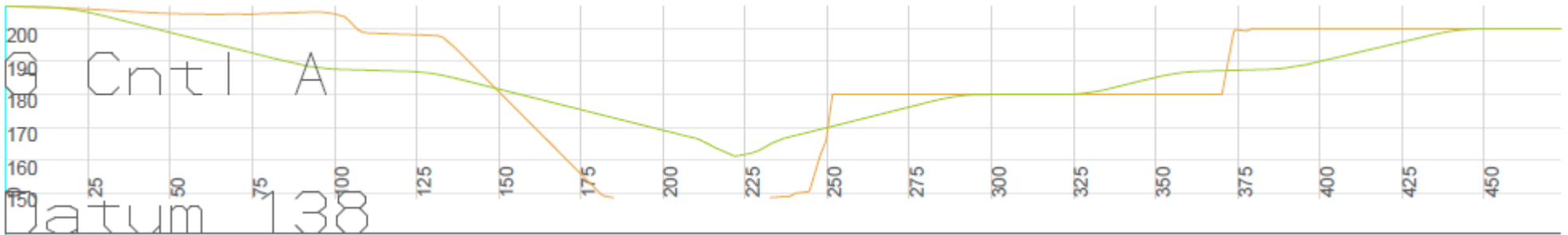
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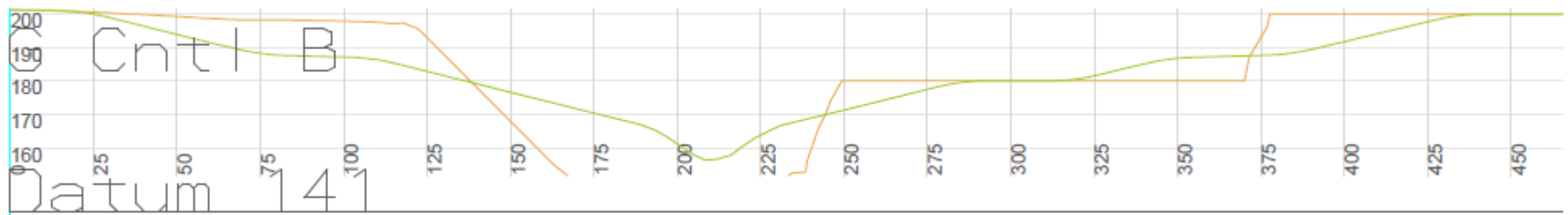
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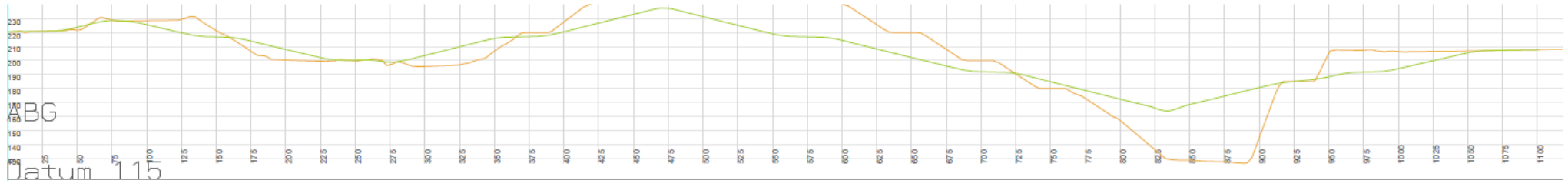
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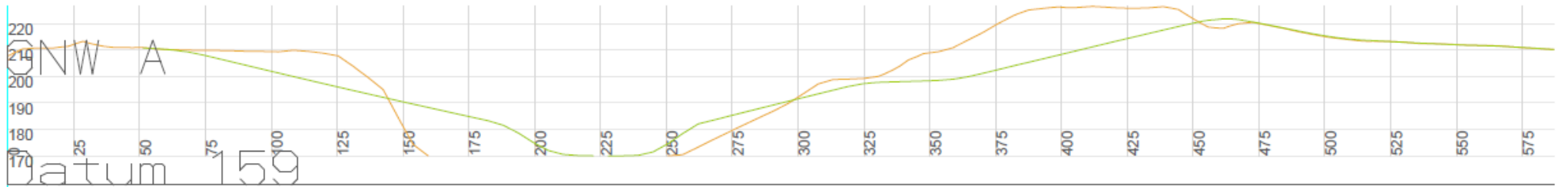
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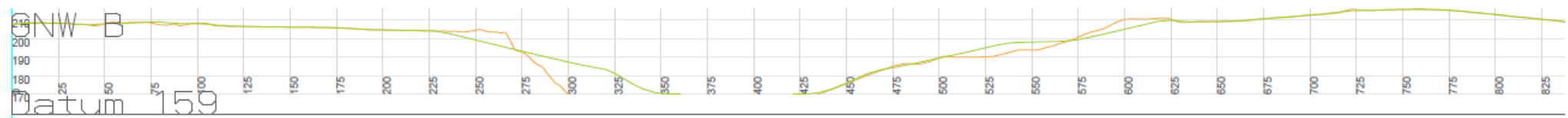
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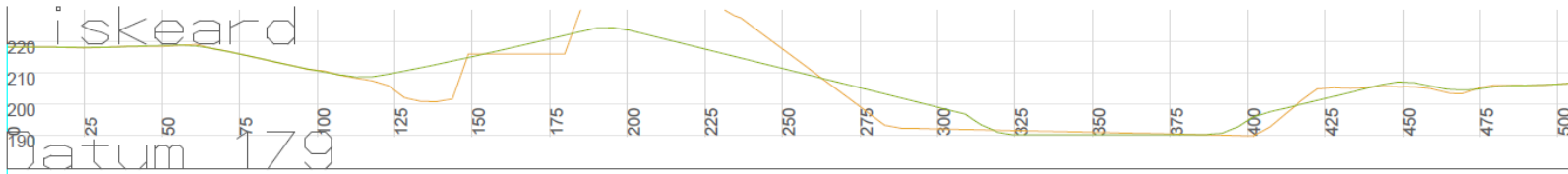
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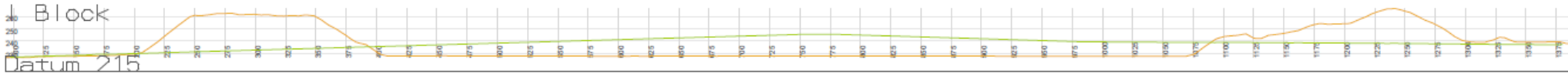
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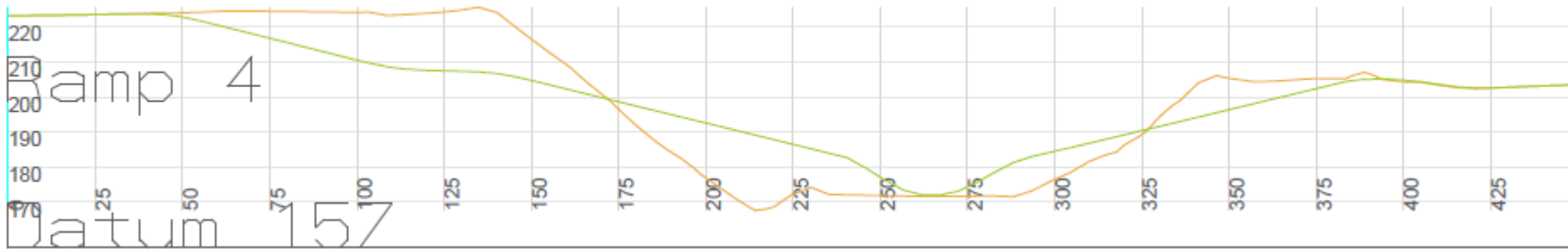
### 4.8.15 Liskeard



### 4.8.16 I Block



### 4.8.17 Ramp 4



# 5 DISCLAIMER

- Designs have been created and analysed using Topographical Data supplied by the Client. 3DDG cannot be held responsible for any differences between the Digital Topographical data and actual field positions, or any problems occurring from these differences. It is advised that data validation of the area be undertaken prior to project commencement.
- Reported Volumes, Lengths and areas are calculated using the Authors modelling Techniques and Procedures; others may use different techniques which may produce different results. 3DDG utilizes multiple CAD packages for redundancy checks of calculated workings and model analysis.
- 3D takes no responsibility for issues arising from errors in third party data that may have been supplied such as topographic data, design limits, erosion studies, base of weathering surfaces, blasting data, toe limits etc
- Design has been created to balance using the cut fill ratio listed in the design report, 3DDG waives liability if material Cut/Fill factors differ in the field.
- The Final Landform Design has been created using Design Criteria in accordance of the Clients recommendations. If design criteria do not work as expected, the Client carries the responsibility. Refer to report for list of criteria.
- 3D Data has not conducted the following to validate the clients design criteria: Soil sampling, Erosion modelling, flood modelling, geo tech analysis, catchment analysis.
- 3DDG provides no guarantee that the provided design meets the sites regulatory requirements for rehabilitation nor any warranty against erosion or failure of the constructed landform.
- The mass haul analysis construction costs are calculated with assumed production statistics, dozer hourly rates and average fuel burn rates. Production statistics dozers are obtained from a mix of OEM and field data. While the costs may not be the same as what is found to be on site, the percentages in savings can still be used to compare the cost benefit of the alternate designs by 3DDG. 3DDG provides no guarantee that the client will achieve these production rates in the field due to the variability of dozing material. The client should utilize their own historic production rates where available.

The above applies to any future revisions of the design, analysis and construction guidance that may occur during the project duration.

Name	Title	Signature	Date
Richelle Griffiths	Design Technician	<i>RJGriffits</i>	19/09/2023
Lachlan Yeldham	General Manager	<i>Ch L</i>	08/09/2023

Revised Imagery 19/09/2023





**Klohn Crippen Berger**

# **Sojitz Gregory Crinum Pty Ltd**

## **Sojitz Residual Void Modelling**

*Groundwater Model Update*

*Final*

26 May 2023

Sojitz Gregory-Crinum Pty Ltd  
[AWard@sojitzblue.com.au](mailto:AWard@sojitzblue.com.au)

**Toni Ward**  
**Manager – Environment, Rehabilitation & Community**

Dear Ms. Ward:

**Sojitz Residual Void Modelling**  
**Groundwater Model Update**  
**Final**

KCB Australia Pty Ltd (KCB) is pleased to provide Sojitz Blue Pty Ltd (Sojitz) with the updated closure groundwater modelling outputs for the Gregory-Crinum Mine to inform the Progressive Rehabilitation and Closure Plan (PRCP) required under the Queensland Environmental Protection Act 1994 (State of Queensland 2021a).

Yours truly,

**KCB AUSTRALIA PTY LTD.**



Jaco Nel  
Senior Hydrogeologist

AD:JN:BU:JJ

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## 1 INTRODUCTION

KCB Australia Pty Ltd (KCB) was commissioned by Sojitz Blue Pty Ltd (Sojitz) to provide updated closure-related groundwater modelling outputs for the Gregory-Crinum Mine (the Mine) to inform their Progressive Rehabilitation and Closure Plan (PRCP) required under the Queensland Environmental Protection Act 1994 (State of Queensland 2021a).

Groundwater model outputs for this project have been prepared using a calibrated numerical model of the Gregory-Crinum Mine. The detailed model setup and calibration are discussed in KCB (2022), with only the components relevant to the closure simulations repeated here.

### 1.1 Numerical Model Background

In 2021 KCB Australia Pty Ltd (KCB) was commissioned by Kestrel Coal Resources (Kestrel) and Sojitz Blue Pty Ltd (Sojitz) to conduct a joint groundwater model for the Kestrel Coal Mine, owned by Kestrel, and the neighbouring Gregory-Crinum Mine, owned by Sojitz.

The numerical groundwater model was commissioned for development, with mining operations from both mines incorporated due to the proximity of the operations and the historical interaction between the two sites. Following the development of the base model, the model has been used separately by Kestrel and Sojitz to allow mine-specific scenarios to be simulated. Closure scenarios have been simulated as part of Sojitz PRCP preparation.

An initial closure scenarios groundwater model was carried out for the Gregory-Crinum Mine (KCB 2021), the closure model updated the joint Kestrel and Sojitz groundwater operational model (KCB 2022). Post-operational modelling was conducted for 600 years taking into account the residual voids expected in the final landform after closure.

Since the 2021 closure assessment was undertaken (KCB 2021), the landforms have been updated as part of the PRCP process. The revised final landform design was provided by Sojitz in May 2023. A high-level comparison of the landforms suggested that the difference in the 2021 and 2023 landforms may change the water balance and/or final pit water levels, hence the need for an update to the groundwater model as well as associated surface water balance modelling.

### 1.2 Scope of Work

Based on KCB's proposal, the scope of work is to:

- Update the groundwater model to provide inflow rates as inputs into a long-term post-closure void equilibrium water level model and a TDS mass balance model. Sojitz will engage Cardno to complete the surface water balance modelling component, using the site OPSIM water balance model that was created for the 2021 work.
- KCB will incorporate the output of Cardno's long-term, post-closure void equilibrium water level modelling into the updated post-closure groundwater model, assessing the potential groundwater conditions over 600 years.
- A technical report on the modelling results will be produced.

### 1.3 Closure Plan and Final Voids

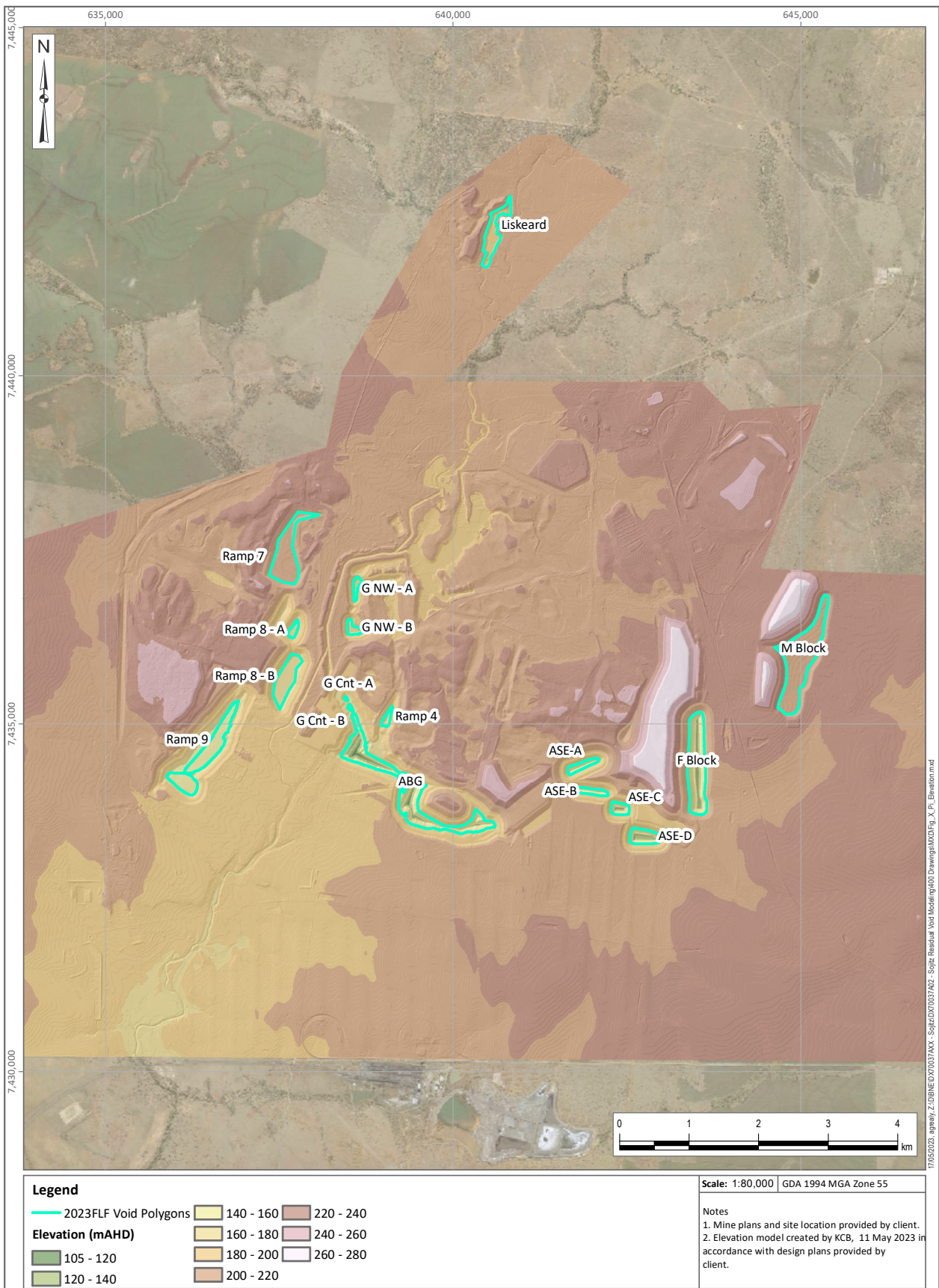
Sojitz has commenced closure planning activities for the existing Gregory-Crinum Mine and the proposed M-Block extension. A conceptual final landform design was prepared for Gregory-Crinum Mine by 3D Data Guidance Pty Ltd based on the expected pit and dump surface configuration at the cessation of operations. Operational mine planning considers opportunities to progressively achieve the final landform design by scheduling backfill of existing voids and unused ramps.

The following design criteria have been adopted in designing the final landform:

- Unrehabilitated spoil and low wall slopes greater than 25% shall be reshaped to a maximum slope of 25%;
- Weathered highwalls shall be reshaped to a maximum slope of 25% and unweathered highwalls remain;
- Slopes below long-term final void high water levels will be left at the angle of repose; and
- Reshaped 25% slopes shall be capped with competent material.

The proposed final landform includes several pit voids across the existing Gregory-Crinum Mine as residual voids. The final landform design (2023\_FLF\_230511\_Design) provided to KCB includes 17 final voids (Figure 1.1).

Final voids proposed to remain as non-use management areas (NUMAs) include Liskeard, J-Block – Ramp 7, J-Block – Ramp 8 (A and B), G NW (A and B), J-Block – Ramp 9, G Central (A and B), ABG Block (including Ramp 4), ASE Block (A, B, C, D), F-Block and M-Block.



**Figure 1.1    Voids in proposed Final Land Form**

## 2 HYDROGEOLOGICAL CONCEPTUAL MODEL

This section provides a summary of the hydrogeological conceptual model, relevant to the numerical model and closure scenarios. The complete groundwater model conceptualisation and calibration is covered in the KCB (2021) report.

### 2.1 Climate

The climate of the area is classified as semi-arid and characterised by mild, relatively dry winters and hot summers with high rainfall, using the modified Köppen classification system (BOM 2005).

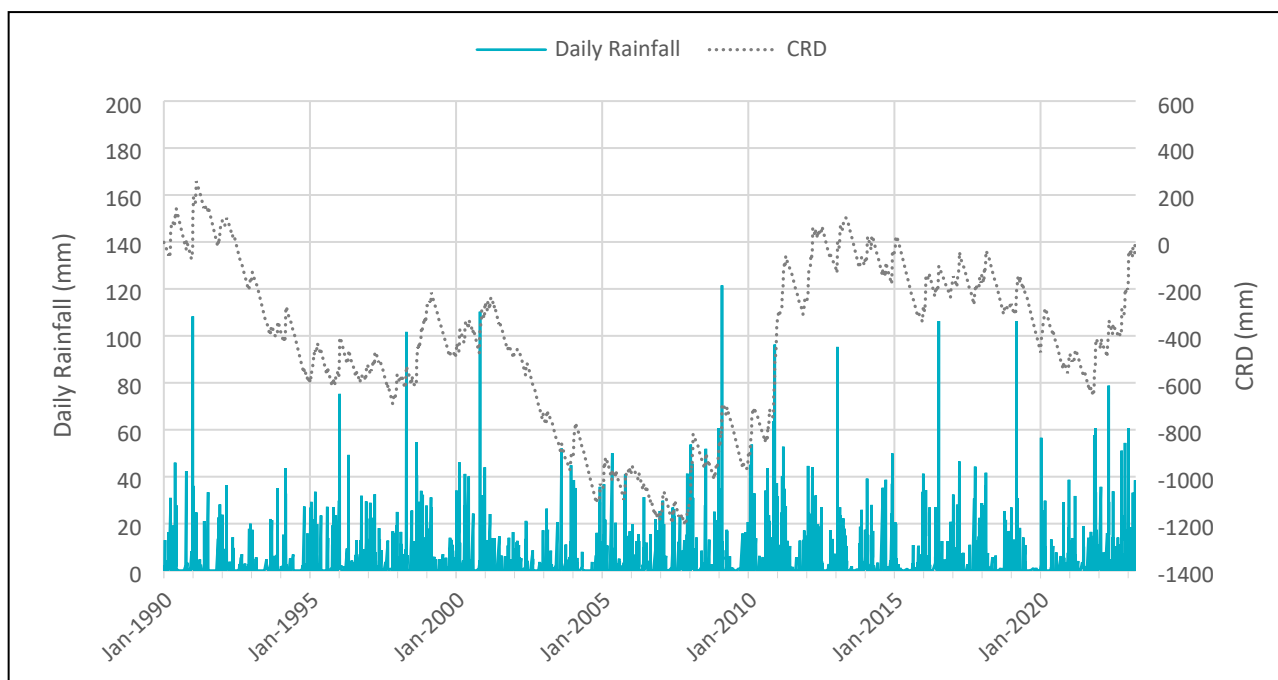
Climate statistics sourced from SILO are presented in Table 2.1 (DES 2023). Mean maximum temperatures range between ~34.3°C in the summer months and ~23.5°C in the winter months. Mean minimum temperatures range between ~22.1°C in the summer months and ~8.7°C in the winter months. Daily evaporation rates are generally high and exceed rainfall throughout the year. The highest rainfall occurs from December to February, with the lowest rainfall occurring from May to September.

**Table 2.1 Climate Statistics (SILO Data Drill for -23.25, 148.35)**

Statistic Element	Mean Min Temp (°C)	Mean Max Temp (°C)	Mean Daily Evaporation (mm)	Mean Daily Rainfall (mm)	Mean Monthly Rainfall (mm)
Period of record	1990 to 2022	1990 to 2022	1990 to 2022	1990 to 2022	1990 to 2022
January	22.1	34.3	7.5	2.8	86.6
February	22.0	33.7	6.8	2.6	73.5
March	20.4	32.6	6.3	1.8	57.1
April	17.0	29.8	5.0	1.0	29.6
May	13.1	26.4	3.8	0.7	20.6
June	10.1	23.5	3.1	0.8	23.0
July	8.7	23.5	3.4	0.5	16.9
August	9.8	25.6	4.4	0.6	18.3
September	13.4	29.0	5.9	0.6	18.8
October	17.0	31.8	7.1	1.3	40.8
November	19.4	33.3	7.8	1.7	49.7
December	21.2	34.2	7.9	2.6	79.9
<b>Annual</b>	<b>16.2</b>	<b>29.8</b>	<b>5.8</b>	<b>1.4</b>	<b>506.9</b>

Figure 2.1 presents the daily rainfall and cumulative rainfall departure (CRD) for the period of January 1990 to March 2023. CRD trends are used to depict seasonality and long-term rainfall trends. They are based on actual rainfall comparison to long-term averaged conditions. CRD trends are useful for comparison against groundwater level hydrographs for groundwater systems, which show a strong correlation to rainfall recharge.

For the period presented, the data highlights the wet-dry season cycle in the climate. Between the periods of 1990 and 2007, there is a general decline in the cumulative rainfall. An increasing trend is observed between 2008 and 2013, a slight decline was noted between 2014 and 2021, and a sharp increase was observed between 2022 and the current period.



**Figure 2.1 Daily Rainfall and CRD (SILO Data Drill for -23.25, 148.35), January 1990 to March 2023**

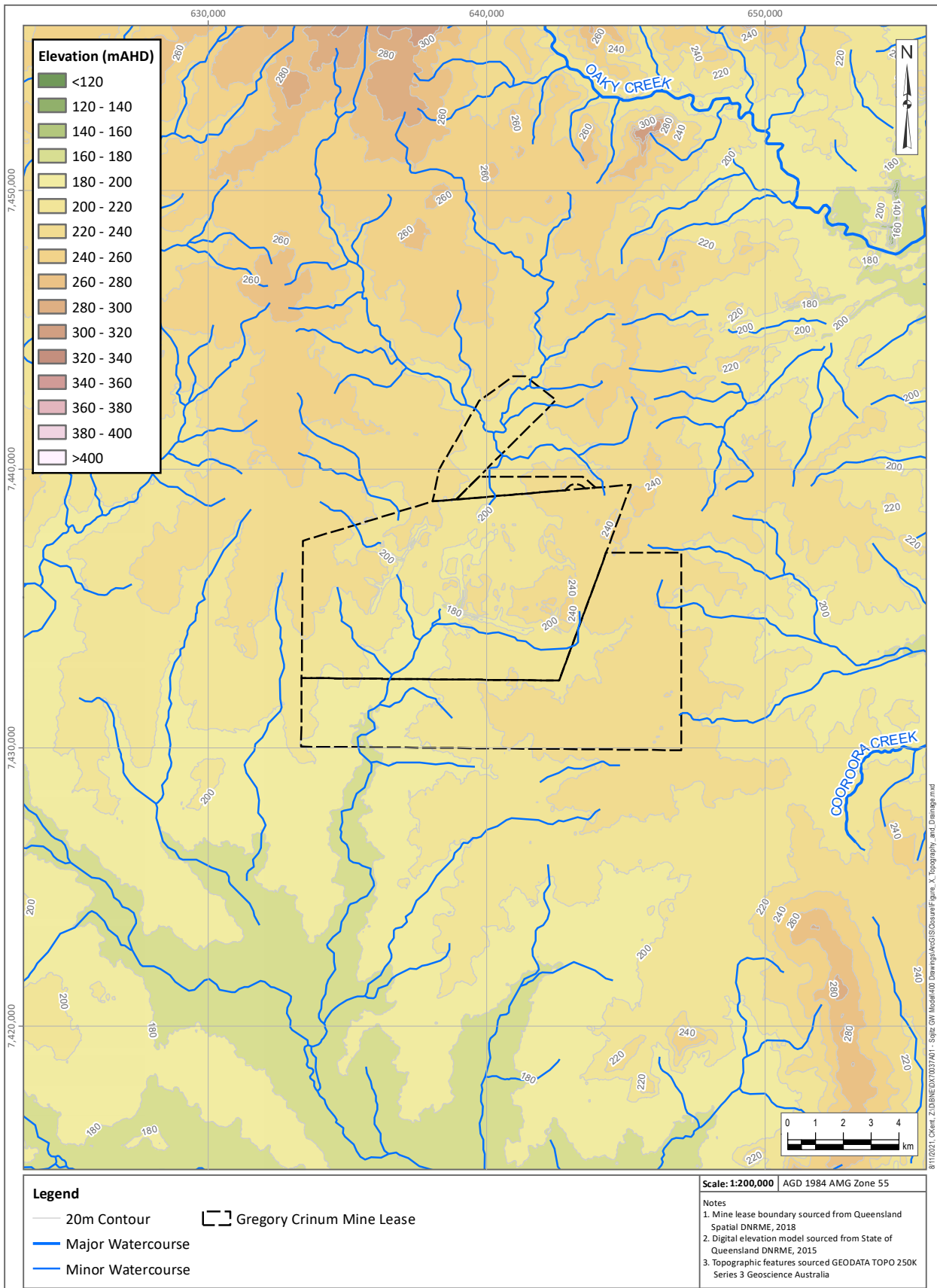
## 2.2 Topography and Drainage

The Mine is located within the Nogoia River sub-basin, which is part of the Fitzroy River Basin. The Fitzroy River Basin is the second largest externally drained basin in Australia and the largest on the eastern coast of the continent. Covering an area of 150,000 km<sup>2</sup>, the basin contains several significant tributaries, including the Nogoia, Comet, Mackenzie and Dawson Rivers. The basin discharges into the Coral Sea east of Rockhampton.

Topography within the vicinity of the Mine is shown in Figure 2.2. Ground elevations generally range between 240 and 180 mAHD, with lower topography associated with the area of Crinum Creek. Watercourses in the vicinity of the Mine include:

- The Nogoia River is situated ~25 km south, flowing southeast and discharges to the Mackenzie River following the confluence of the Nogoia River with Comet River approximately 42 km south east.
- Cooroora Creek is located 7 km east, flowing towards the southeast.
- The Crinum Creek flows from north to south through the Gregory-Crinum Mine and continues for ~50 km before joining with Belcong Creek, draining into Bridge Creek, and discharging to the Nogoia River ~17.5 km southwest. Crinum Creek has been artificially modified to divert around the Gregory-Crinum Mine.

Watercourses within the area are all ephemeral. These watercourses will typically only experience surface water flow during or immediately after heavy or sustained rainfall events (i.e. summer wet season). Following periods of flow surface water will persist in the form of non-flowing, disconnected pools separated by dry/exposed stream bed. Surface water (flowing or non-flowing) is only present for a small part of the hydrological cycle (Kennard et al. 2010).



**Figure 2.2 Topography and Drainage**

## 2.3 Regional Geology

The regional geology comprises sediments from the Early Permian to Middle Triassic age Bowen Basin. The Bowen Basin is an elongated, north to south trending basin extending over 160,000 km<sup>2</sup> from central Queensland, south beneath the Surat Basin, and into New South Wales, where it connects with the Gunnedah and Sydney basins (OGIA 2016). The Bowen Basin contains up to 10 km (thickness) of terrestrial and shallow-marine sediments (Green 1997; R. Korsch and Totterdell 2009).

The Bowen Basin contains up to 10 km of terrestrial and shallow-marine sediments (Green 1997; R. Korsch and Totterdell 2009). The southern Queensland and northernmost New South Wales portion of the basin is overlaid by up to 2.5 km of Early Jurassic to Early Cretaceous Surat Basin sedimentary sequences (Fielding et al. 2000; R. Korsch and Totterdell 2009). In the vicinity of the Mine, sediments from the Surat Basin have been eroded and the Bowen Basin units reside under Cenozoic cover.

Regionally, Cenozoic sedimentary deposits overlay the Bowen Basin units, formed through subsidence-related faulting and erosion, in conjunction with fluvial sedimentary depositional processes (Laronne and Shlomi 2007; Nichols and Fisher 2007; R. J. Korsch et al. 2009). Crustal thinning due to extensional tectonic events resulted in magma upwelling and intermittent volcanism, expressed as basaltic lava flows in the vicinity of the Mine as well as interbedded tuff and volcanolithic fragments within the Cenozoic sedimentary sequences (R. Korsch and Totterdell 2009).

The mapped surface and solid geology within the vicinity of the Mine are presented in Figure 2.3 and Figure 2.4.

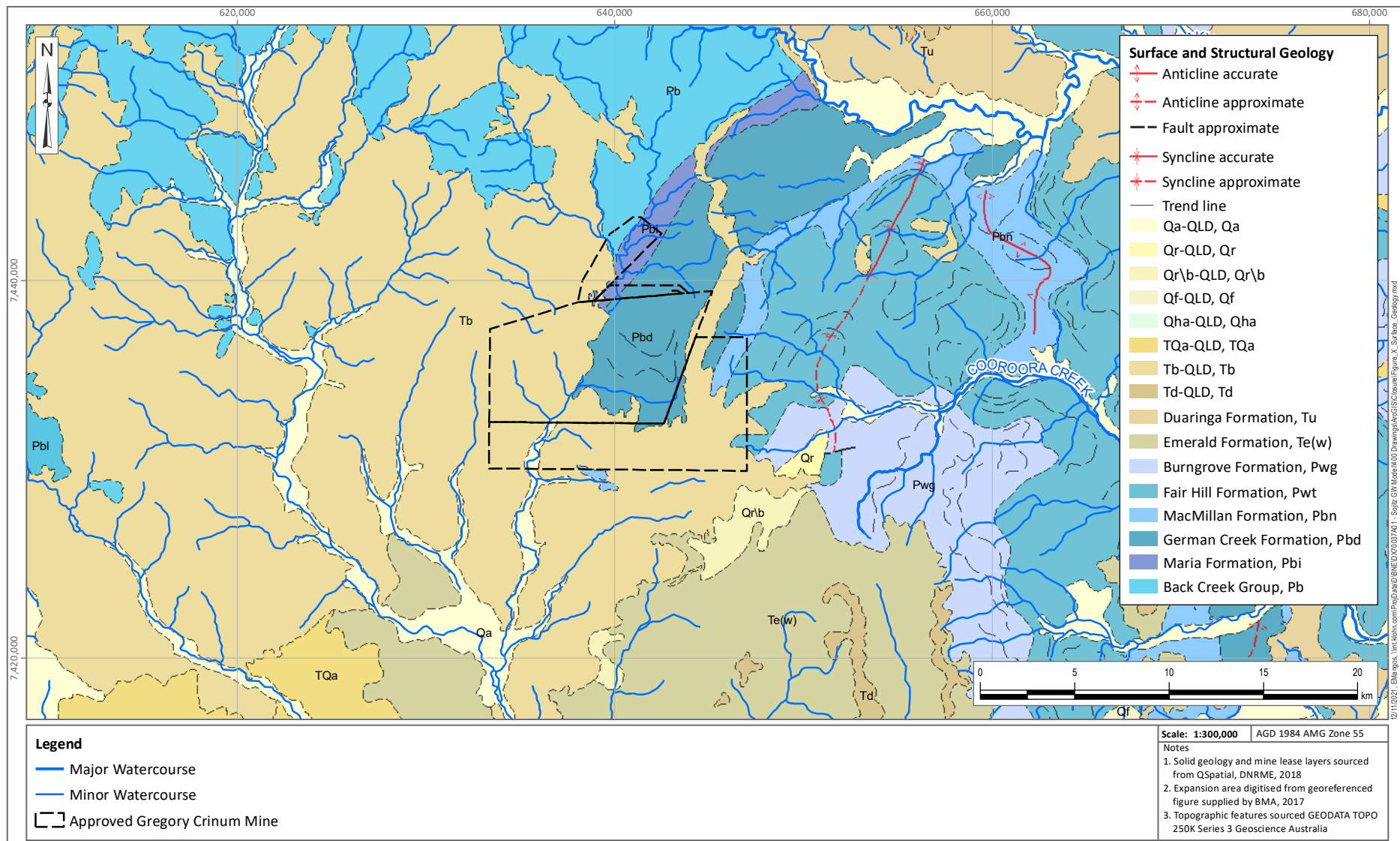
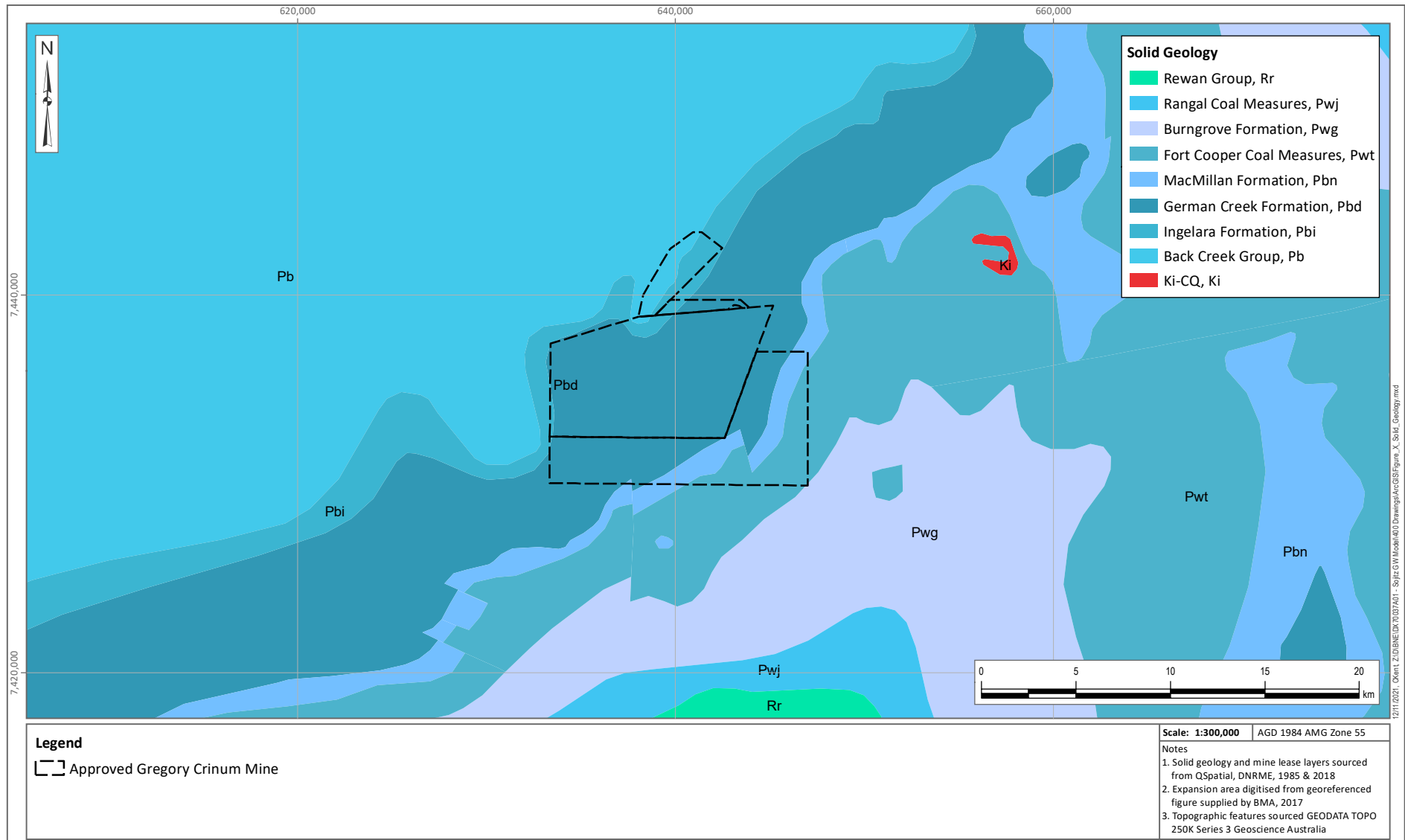


Figure 2.3 Surface Geological Map



**Figure 2.4 Solid Geological Map**

The lithology associated with the geological units at the project is summarised in Table 2.2.

**Table 2.2 Summary of Regionally Mapped Geology**

Age	Unit		Map Code	Lithological Summary
Quaternary	Alluvium		Qa	Clay, silt, sand, and gravel; floodplain alluvium
Tertiary	Basalt		Tb	Mostly olivine basalt flows and some plugs
	Tertiary Sediments		Td	Duricrusted palaeosols at the top of deep weathering profiles, including ferricrete and silcrete; duricrusted old land surfaces
	Emerald Formation		Te(w)	Deeply weathered fluvial and lacustrine claystone and siltstone, quartzose sandstone, pebbly sandstone, gravel, lignite, oil shale, interbedded basalt
Triassic	Rewan Group		Rr	Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanolithic pebble conglomerate (at base)
Permian	Blackwater Group	Rangal Coal Measures	Pwj	Calcareous sandstone, calcareous shale, mudstone, coal, concretionary limestone
		Burngrove Formation	Pwg	Mudstone, siltstone, sandstone, coal, tuff
		Fair Hill Formation	Pwt	Lithic and feldspathic labile sandstone, quartzose sublabile sandstone, siltstone, mudstone, calcareous and tuffaceous sandstone, volcanic conglomerate, carbonaceous mudstone, coal
	Back Creek Group	Macmillan Formation	Pbn	Mudstone, siltstone, sandstone
		German Creek Formation	Pbd	Quartzose to sublabile, locally argillaceous sandstone, lithic and feldspathic sandstone, siltstone, mudstone, carbonaceous mudstone, and coal
		Maria Formation	Pbi	Siltstone, mudstone, shale, feldspathic sublabile to labile sandstone, calcareous sandstone
		Back Creek Group	Pb	Quartzose to lithic sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite

Source: (DNRME 2018)

## 2.4 Conceptual Model Summary

A schematic of the hydrogeological conceptual model is provided in Figure 2.5 and can be summarised as follows:

- Kestrel and Gregory-Crinum mines are located in an area where sediments from the Early Permian to Middle Triassic age Bowen Basin occur.
- The relevant hydrogeological units comprise:
  - ◆ Quaternary-age alluvium, which includes localised deposits associated with minor ephemeral creeks such as Cooroora Creek and Crinum Creek.
  - ◆ Tertiary basalt comprises multiple basalt flows with separate flow events separated by clay horizons representing weathered material between events; Tertiary clay is occasionally present underlying the basalt and forms an aquitard.
  - ◆ Tertiary basal sand is occasionally present and comprises highly weathered sandstone that, where laterally continuous, can form a productive aquifer.
  - ◆ Permian interburden includes sandstone, siltstone and mudstone that are typically 'tight' and low yielding; and Permian coal seams which form low to moderate-yielding aquifers confined by overlying interburden units.

Mining operations at both mines have been undertaken since 1979, which has significantly changed the hydrogeological system. Open cut mining through excavation and backfilling of voids has been completed at Gregory-Crinum in the north, where the German Creek seam is closer to surface. Where voids remain, these have been used for water storage. Limited data exists for the accurate sequence of open cut mining.

Underground longwall mining was completed to the south of the open cut, as the coal seam deepens. Dewatering was undertaken progressively as each area was mined, with groundwater levels allowed to recover once mining in that area has ceased. Limited data exists for the accurate sequence of longwall mining historically.

Goafing has developed above the mining longwall panels, with breakthrough into the Tertiary units observed in areas where the interburden between the coal seam and Tertiary units thins. Fracture development is estimated to have a height of 115 m above the mined coal seam. The goaf area has modified the hydraulic properties and will induce a connection with the overlying Tertiary units in some areas.

Groundwater within the Project area has been monitored through an extensive network at Kestrel and Gregory-Crinum, with monitoring records available since 1979. The groundwater elevations monitored in the Permian strata have been significantly altered by mining activities, particularly in the area of the Kestrel LW100/200/300 series, which have the longest records for the Permian. Records show drawdown in preparation and during mining, then the recovery post-mining. Through comparison of the mining sequences and monitoring records, it is evident that the two operations (Kestrel and Gregory-Crinum) have influenced the other operation (across the lease boundary line).

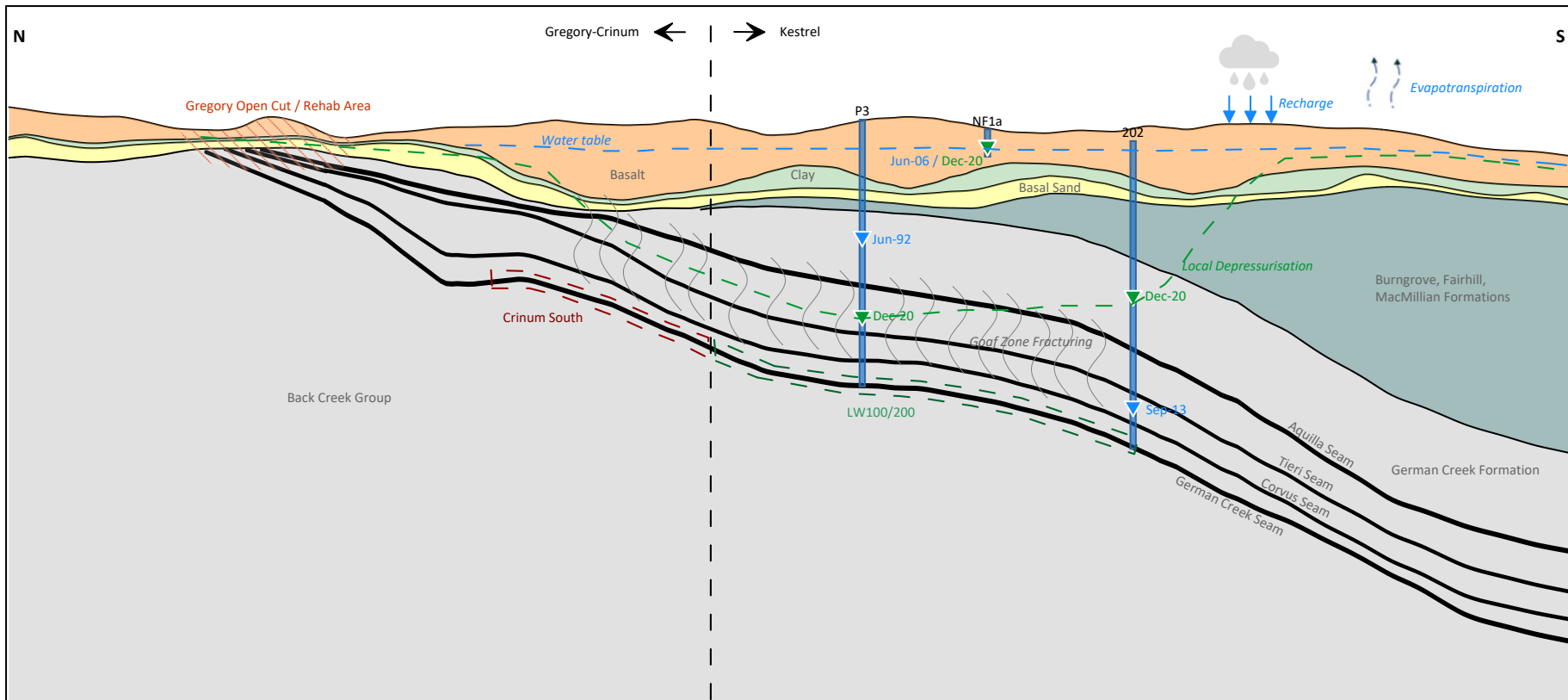


Figure 2.5 Hydrogeological Conceptual Model Summary

### 3 CLOSURE MODELLING

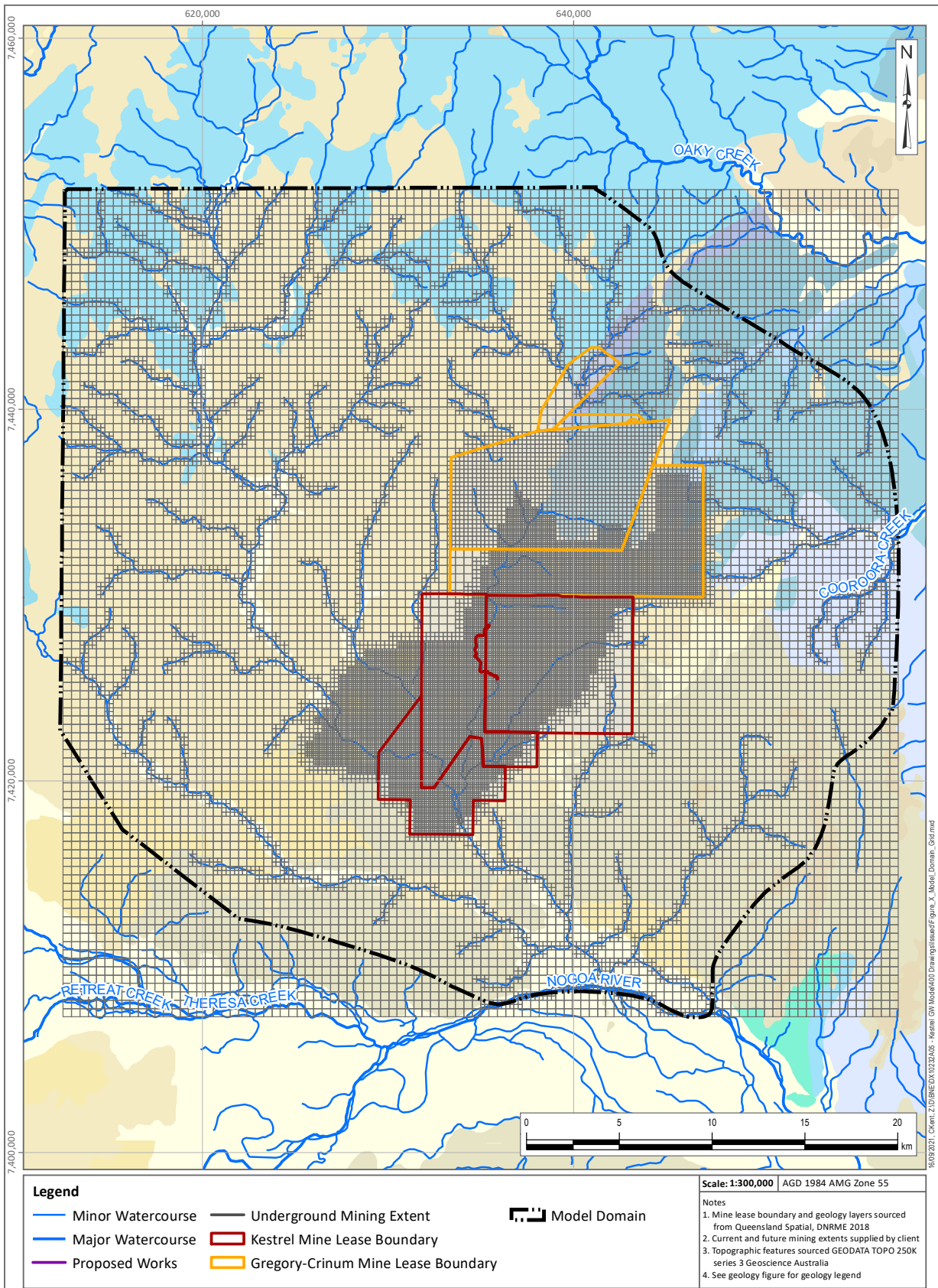
#### 3.1 Model Construction and Calibration

The model was developed using MODFLOW-USG to represent the key hydrogeological units within 15 model layers, covering an area of approximately 2,000 km<sup>2</sup>. The domain (Figure 3.1) was developed based on a combination of surface, solid and structural geology, as well as consideration is given to topography as far as groundwater divide boundaries could be inferred. The proposed model boundary also allows for adequate representation of local mining operations for inclusion in cumulative impact assessments. Furthermore, the model boundary is interpreted to be sufficiently far enough away from future operations such that the predicted drawdown is not influenced by numerical boundary effects.

The Australian Groundwater Modelling Guidelines (Barnett et al. 2012) were used to frame the calibration process. The groundwater flow model was initially calibrated to groundwater levels from 53 observation bores (steady-state) screened across a variety of hydrostratigraphic units in the Gregory-Crinum and Kestrel Mining areas; groundwater inflow data from existing mining operations were also used as a target for model calibration. The modelling approach included the simulation of subsidence-induced fracturing above the longwall panels in the historical areas (and approved future operations).

A preliminary steady-state model simulation (which excluded mining operations) was used to establish initial groundwater levels for the transient calibration. The steady-state calibration was considered appropriate for large-scale optimisation of hydraulic parameters and boundary conditions. The transient calibration approach considered the period from January 1979 to December 2021 to account for the influence of existing mining operations on the current groundwater system. The transient calibration was divided into two separate stages (based on the availability and reliability of monitoring and mine sequencing data) with seasonal and monthly stress periods based on available time-variant data (mine inflows and monitoring data) to be replicated in the numerical groundwater model. The mine development sequence was also simultaneously replicated in the calibration. The calibration process was iterative, with the transient calibration sequence as follows:

1. Initial calibration of Transient 1 period (1979 to 2009) using available data.
2. Parameters and conditions established in Transient 1 used as initial parameters / conditions for Transient 2 period (2009 to 2021). Complete calibration of Transient 2 period.
3. Parameters established during Transient 2 period, then applied to Transient 1 period and calibration target across entire transient period assessed, with implementation of further minor changes to Transient 2 calibrated parameters until an appropriate calibration achieved.



**Figure 3.1 Model Grid**

### 3.2 Model Classification

Barnett et al. (2012) developed a system to classify the confidence level of groundwater flow models based on the calibration process used and the predictive capability of the model. Three classes of model were developed: Class 1, Class 2, and Class 3. A Class 3 model has the greatest confidence level, and a Class 1 model has the least. Factors that are considered when determining model confidence level are:

- Data availability;
- Calibration procedures;
- Consistency between calibration and predictive analyses; and
- Stresses varied on the model.

The model used for the predictions in this report is considered a Class 2 model on based on the following:

- Over 350 exploration and monitoring bores are distributed within the model domain and were available for updating the local geological model. 80 groundwater monitoring bores were available for transient calibration, with the majority of monitoring bores within the mine leases, or in the close vicinity of the mine leases (in Class 3).
- Key calibration statistics (SMRS <5%;  $R^2$  > 90%) were acceptable and met agreed targets in Tr2 (Class 2-3).
- Detailed transient calibration was undertaken over 13 years (second stage calibration), and the long-term trends were replicated in three major hydrostratigraphic units (basalt, basal sand and Permian) around the mine sites.
- Seasonal fluctuations are adequately simulated for the key shallow bores (e.g., 84515B and 84514B) (Class 3).
- The transient calibration covered the most recent period (from the year 2009 and 2021), and 80 monitoring bores and data observed over this period are used in the calibration (Class 3).
- Abstraction data (mine dewatering rate from the previous studies) were available for model calibration (Class 2-3).
- Water dams and in-pit water levels are used in calibration (Class 2-3).
- Model parameters were calibrated within the ranges of conceptualisation (Class 2-3).
- Model water balance error is less than 0.5% (Class 3).
- The predictive model duration is approximately three times that of the calibration period (Class 2-3) (reported separately).

The calibration model meets the criteria for a Class 2 model. The calibrated model is therefore deemed to be a suitable tool for assessing the regional depressurisation impacts from proposed and approved mining.

Furthermore, this calibration went through a robust, multi-staged review process which included peer review from an independent external groundwater modeller. The independent peer review concluded that the model is exceptionally well-calibrated and that the model was fit for purpose to be able to function as a reliable predictor of future mining effects.

### 3.3 Model Update for Closure

The closure prediction model has retained the same calibration as the previous model. Updates to the model included the following:

- Spatially assigned backfill and open void properties according to the final land form provided;
- Spatially assigned hydraulic and storage properties for the underground mine areas and goafing/fracturing where the updated backfill voids are likely to interact with the underground workings; and
- Confirm positions of surface water streams and diversions that are likely to influence/be influenced by the updated landform.

### 3.4 Closure Prediction Scenario Approach

An iterative approach to closure groundwater predictions was adopted to account for the interaction between surface hydrology and groundwater flows in the post-operational period.

An outline of the approach is summarised below:

- The predicted groundwater levels at the end of operations were adopted as the starting condition for the post-closure assessment.
- Initial water balance estimates of the voids consisting of the potential groundwater inflow rates during groundwater rebound, and the refilling levels of the voids were simulated. For this initial assessment, the only surface water/hydrology considerations included were direct rainfall to the final void and evaporation from the void. This allowed an initial assessment of the potential period to rebound and an indication of groundwater inflow rate to each void as a function of groundwater/void water level elevation.
- From the two preceding steps, projected groundwater flow rates and the range of recovered/rebounded equilibrium groundwater elevations were provided to the surface hydrology consultants (Cardno) for inclusion in the post-closure long-term hydrology and void water balance model constructed in OPSIM. Cardno undertook predictive modelling to consider the range of hydraulic conditions, rainfall run-off and evaporation over 1,000 years to provide the projected change in void water levels and TDS over time.
- The time series OPSIM void water level simulations were, in turn, used as input to the post-closure groundwater model to assess the potential long-term post-closure groundwater conditions and flow directions.

## 3.5 Closure Prediction Scenario Results

### 3.5.1 Pit Water Level Predictions

The OPSIM pit water level modelling results over the 1000-year simulation period for the various pit voids (Figure 3.2) indicate that:

- The highest rates of recovery of pit water levels occur within the first 50 years after operations have ceased.
- Within the first 100 years after operations, the pit water levels have reached an equilibrium level, with temporary fluctuations due to rainfall increases and evaporative losses in the pit void.
- The water level within Ramp 7 is very stable and the void often runs dry during periods of low rainfall.
- There are small variations in the water level within M-Block partially backfilled residual void, driven by rainfall and evaporation.

The time series OPSIM void water level simulations were used as input to the post-closure groundwater model to assess the potential long-term post-closure groundwater conditions and flow directions.

### 3.5.2 Water Table Contours

Groundwater flow in the closure simulations was assessed for a period of 600 years post-operations. Snapshots of the groundwater contours over time have been provided in Figure 3.3. For the first 50 to 100 years after operations, groundwater gradients are strongly toward the voids as the general groundwater levels recover and re-establish a post-closure equilibrium. Thereafter the groundwater pattern is generally stable, but the persistence of groundwater lows associated with the voids in Liskeard, J-Block Ramp9, ABG, ASE and M-Block areas (Figure 3.3) are significant features in the groundwater system.

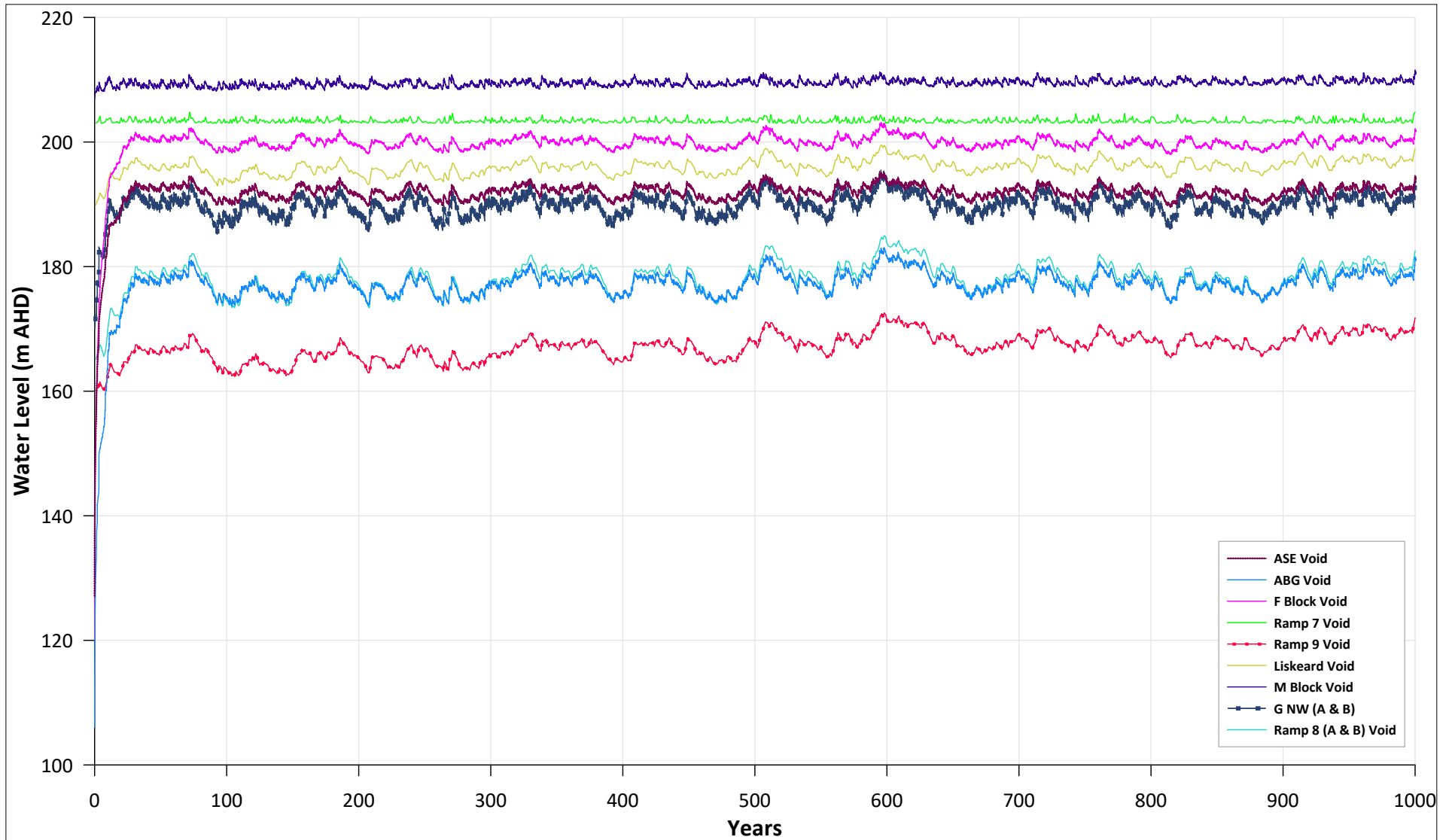
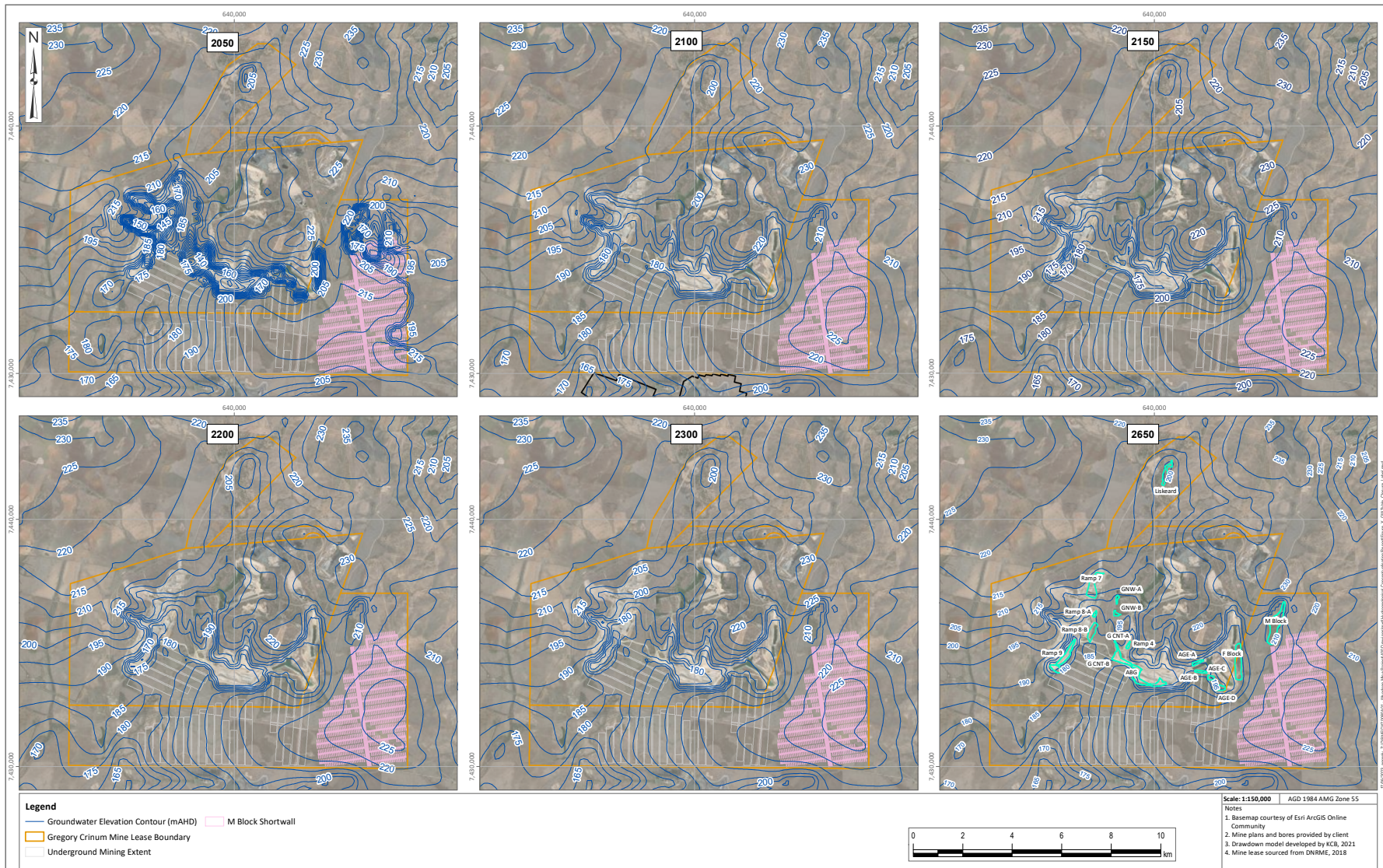


Figure 3.2 Projected Closure Void Water Levels (Data Provided by Cardno, 2023)



**Figure 3.3 Post-Closure Unconfined Shallow Groundwater Table Contours (2050, 2100, 2150, 2200, 2300, 2650)**

### 3.5.3 Void Water Quality Evolution

Final void water and salt balance modelling has been conducted by Cardno using OPSIM to supplement this report. The model has considered a range of final void configuration options and has provided a likely indication of the water quality behaviour of the residual voids. The initial water quality of the voids for the water contained at the end of operations is based on the measured water quality in each void as provided by the Mine’s surface water monitoring.

The 1,000-year model run for all the voids has used several key inputs based on-site monitoring and the inflow rates from the groundwater modelling (summary provided in Table 3.1).

**Table 3.1 Inputs to OPSIM Water Quality Model**

Block/Area	Initial Voids TDS (mg/L)	Surface Water TDS (mg/L)	Baseflow TDS (mg/L)	Groundwater TDS (mg/L)
M-Block	1500	800	1,600	800
J-Block Ramp 7	29000			
J-Block Ramp 8 (A and B)	1200			
J-Block Ramp 9	7600			
F Block	800			
ASE Block (A, B, C, D)	800			
ABG Block	900			
Ramp 4				
G NW (A &B)	1300			
Liskeard	1100			

The salinity results from this long-term water and salt balance provide an indicative assessment of void water quality undertaken using the range of groundwater qualities, potential groundwater inflows and run-off salinities in the Sojitz voids. The site-wide OPSIM water and salinity balance indicates that extremely high TDS values can be expected in these voids after closure, as a result of evaporation exceeding inflows, except during short periods of consecutive rainfall events.

The OPSIM result from the continuous input of salt and negative water balance due to evaporation, produces continuously increasing salinity in the majority of the voids in the 1000 years after closure (See Figure 3.4; note log scale for TDS). Based on the OPSIM modelling results (performed by Cardno), it is expected that:

- M-Block TDS will exceed 100,000 mg/L;
- Ramp 9, G NW, Liskeard and ABG void will reach 100,000 mg/L;
- Ramp 8 and ABG are likely to exceed 10,000 mg/L;
- F Block is expected to slowly rise over time and likely to reach a TDS of > 5,000 mg/L; and
- The TDS of the water in Ramp 7 is expected to fluctuate due to its shallow nature, with TDS of below 100 mg/L expected during wet periods and TDS exceeding 10,000 mg/L due to evapo-concentration in dry periods.



Figure 3.4 Projected Salinity in the Post-Closure Voids (Provided by Cardno, 2023)

## 4 FINAL VOID WATER LEVELS

A total of 17 residual voids are planned. The main void areas, volumes, and the expected equilibrium water levels are presented in Table 4.1. It is expected that all of the voids would have reached equilibrium by year 50 post-operation, with sufficient freeboard above the maximum predicted pit water levels to prevent any likely spills to the surrounding environment.

A total of nine cross-sections have been selected to provide a visual presentation of the final landform within the mined area and the range of expected water levels within the voids. The orientation of cross-sections relative to the final landforms is shown in Figure 4.1 while the cross-sections through respective residual voids are shown in Figure 4.2 to Figure 4.10.

Generally, these cross-sections are oriented such that they align with the inferred groundwater flow direction. The following information are presented on the cross-sections:

- May 2023 final landform surface elevation;
- Inferred subsurface geology and backfilled areas;
- The minimum and maximum water levels for the various pit areas calculated from the OPSIM model results for each pit (Table 4.1). Predicted void water levels (minimum, average, and maximum) between 50 and 1000 years are shown on the cross-sections;
- Crest full level; and
- Groundwater levels for the unconfined shallow aquifers at year 600 post-operation, extracted from the groundwater model.

**Table 4.1 Long-Term Pit Water Levels and Freeboard for 2023 FLF**

Final Void	Crest Full Level (m AHD)	Water Level (m AHD)			Freeboard Above Maximum Water Level (m)
		Minimum	Average	Maximum	
M-Block	222.0	208.2	209.5	211.6	10.4
J-Block Ramp 7	218.0	203.0	203.4	204.8	13.8
J-Block Ramp 8 (A and B)	195.0	173.4	178.3	185.0	10.0
J-Block Ramp 9	195.0	162.4	167.2	172.5	22.5
F Block	213.0	198.0	200.0	203.1	9.9
ASE Block (A, B, C, D)	205.0	189.6	192.1	195.1	9.9
ABG Block Ramp 4	190.0	173.7	177.5	183.1	6.9
G NW (A and B)	203.0	185.5	190.0	195.2	7.2
Liskeard	204.0	192.9	196.0	199.5	4.5
<b>Total</b>					

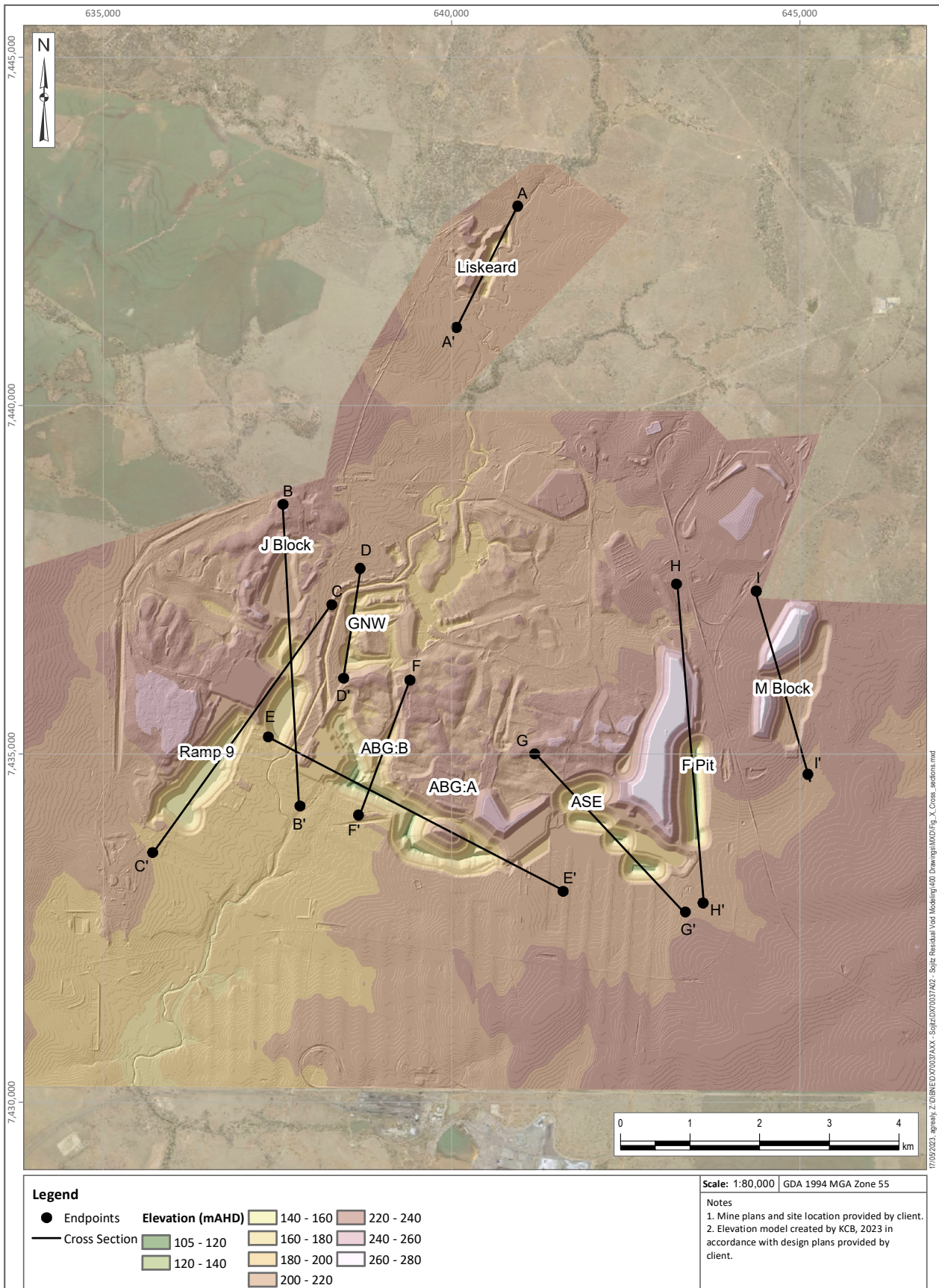


Figure 4.1 Cross-sections orientation in relation to voids

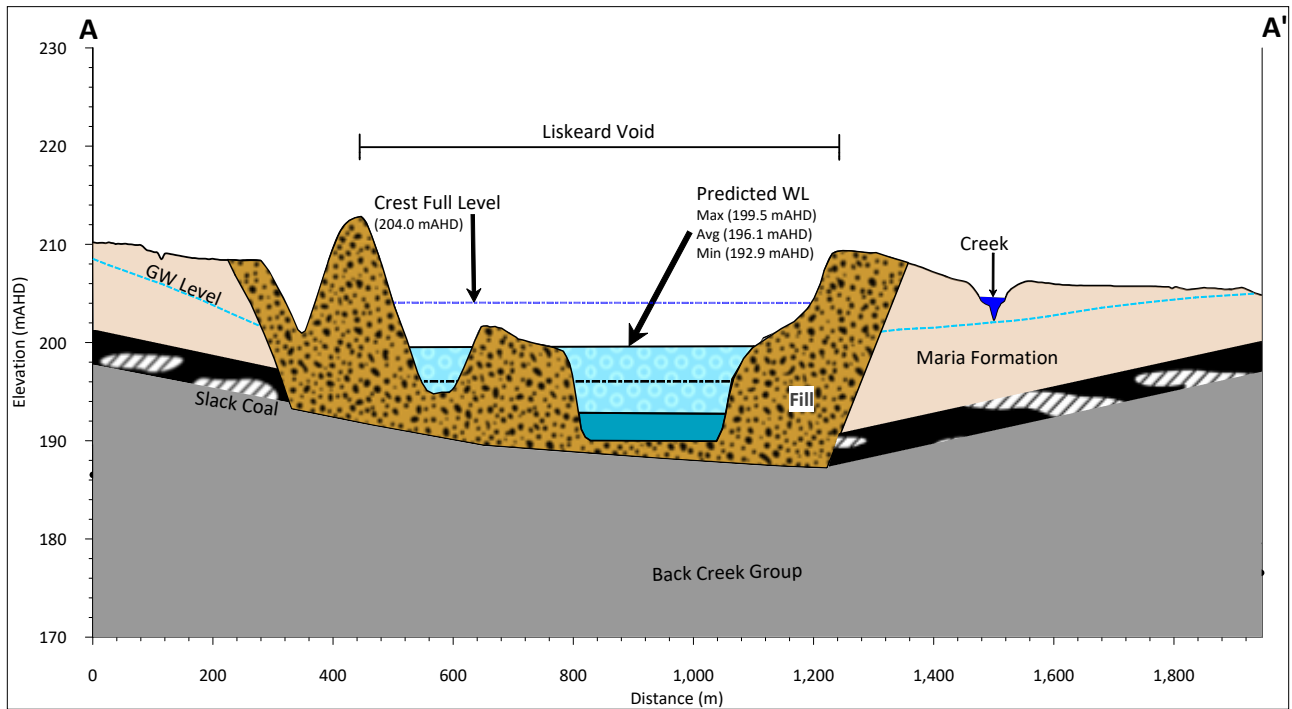


Figure 4.2 A-A': Liskeard residual void cross-section in NNE-SSW orientation

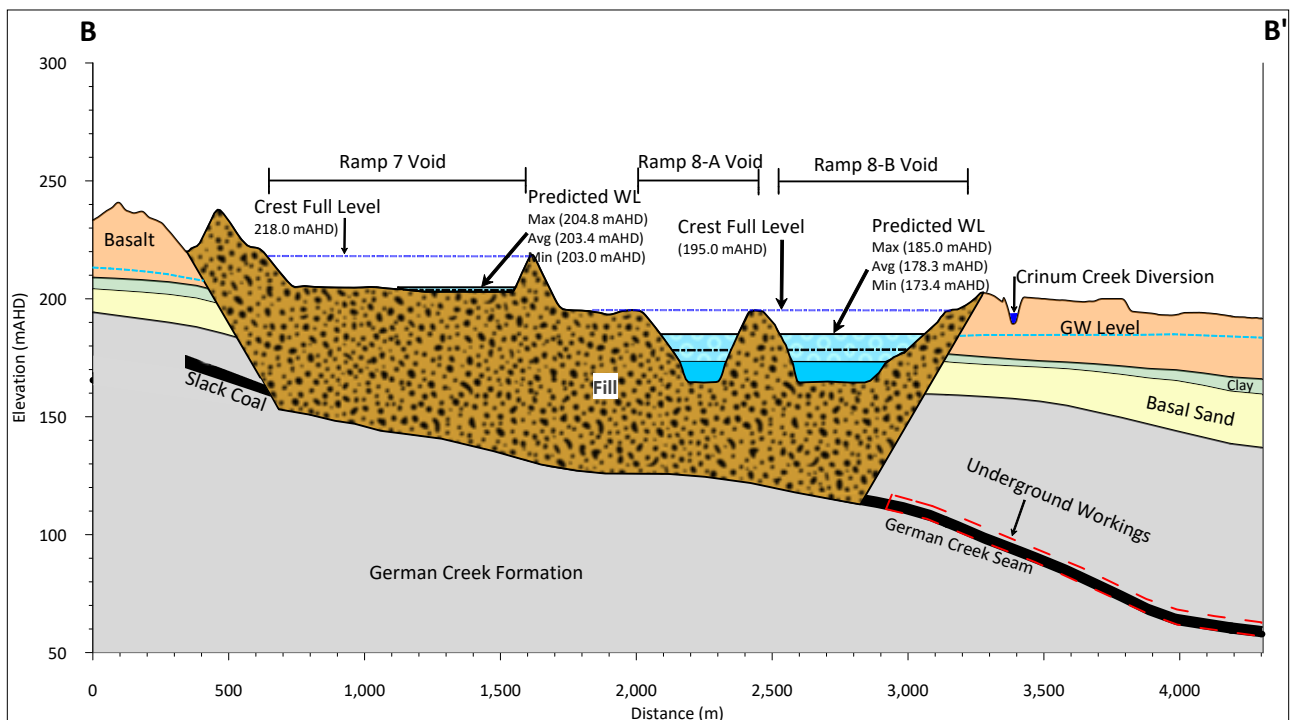
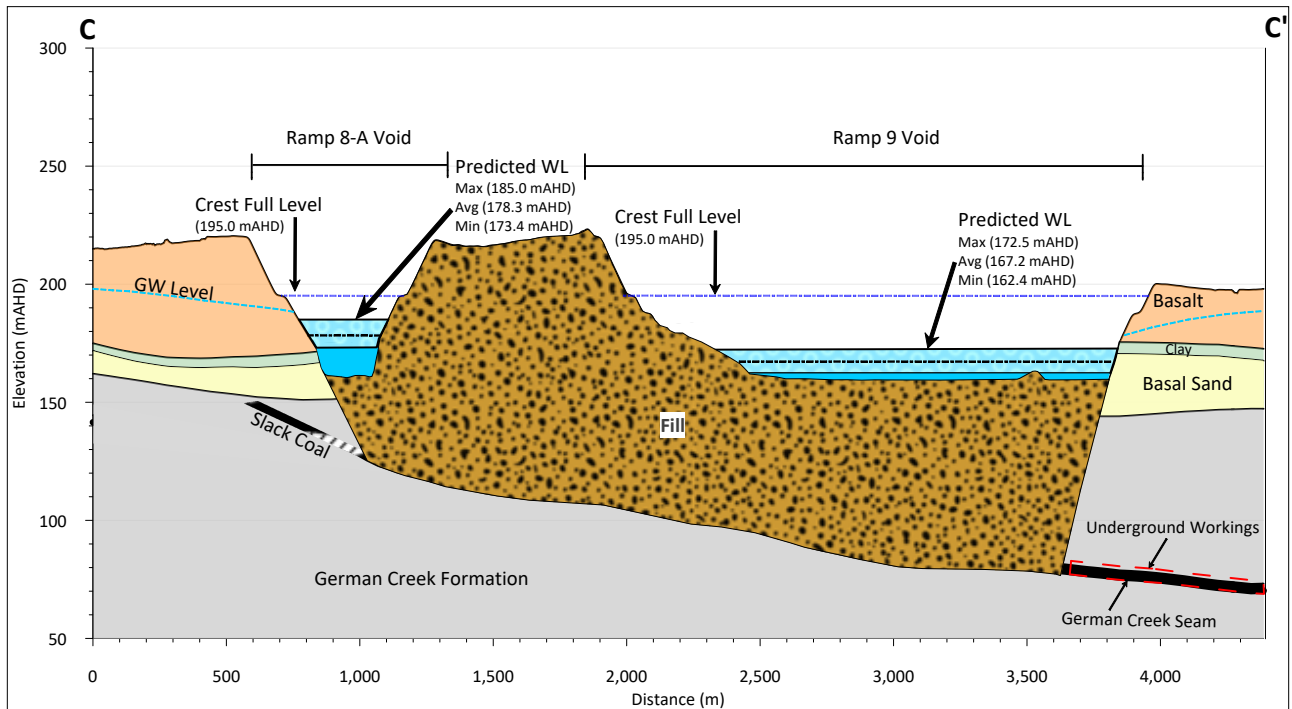
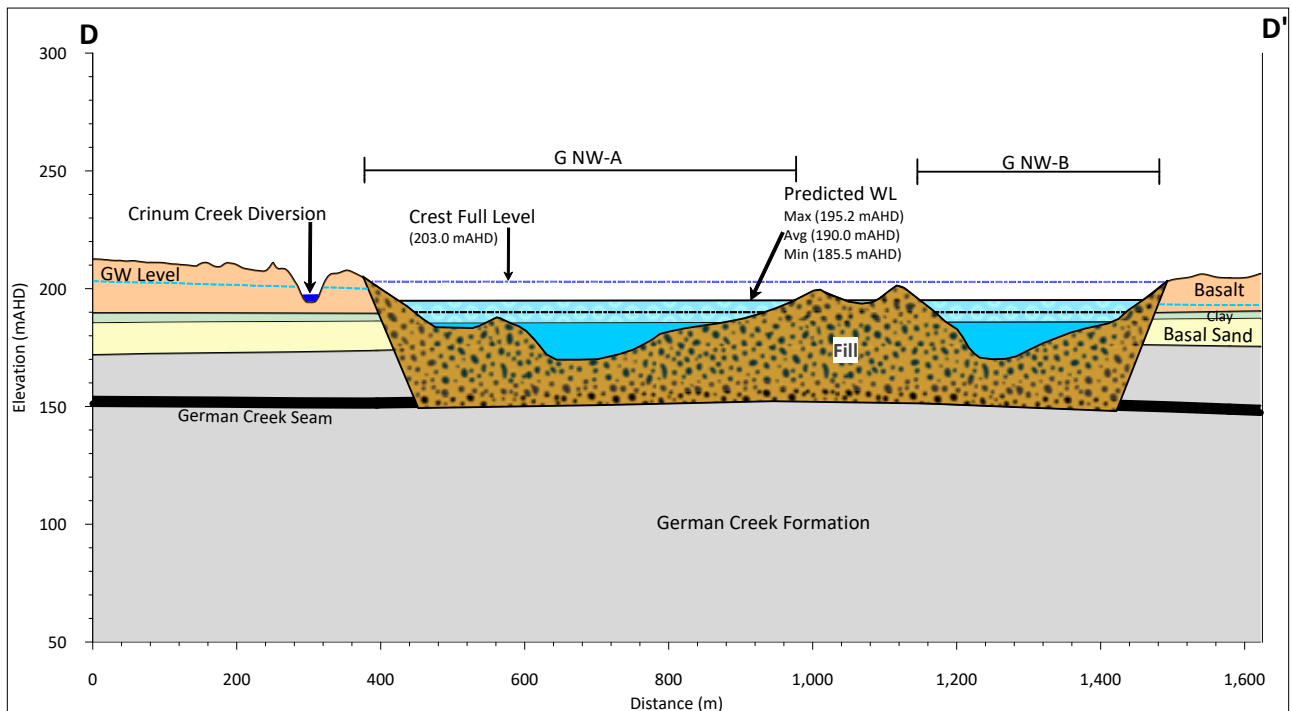


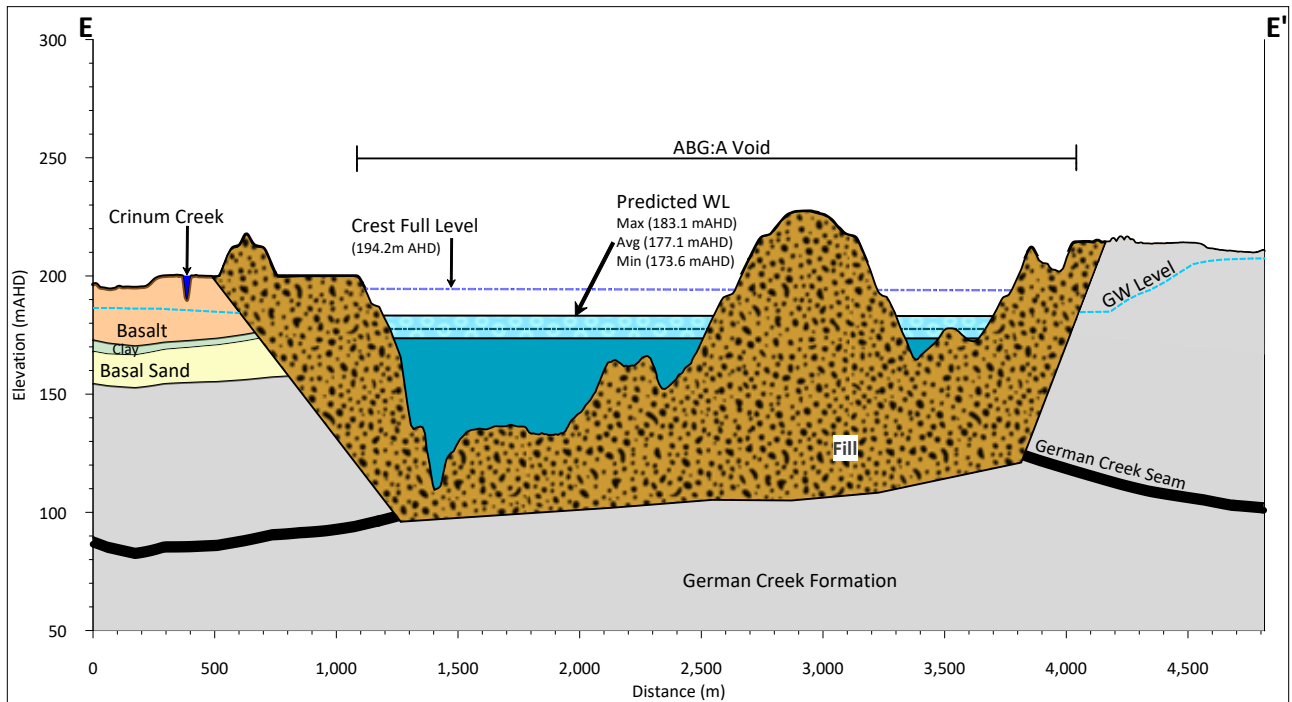
Figure 4.3 B-B': J-Block cross-section through Ramp 7 void and Ramp 8 void in NNW-SSE orientation



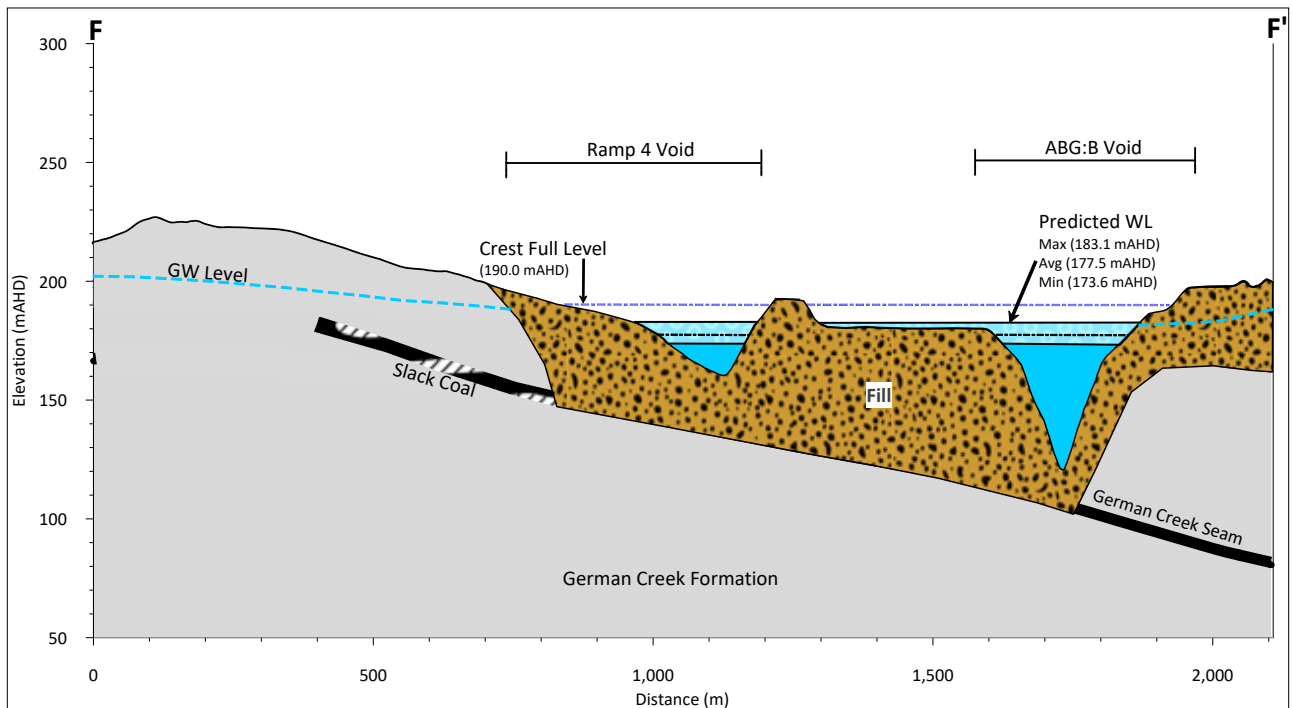
**Figure 4.4 C-C': J-Block cross-section through Ramp 8 (A) and Ramp 9 voids in NE-SW orientation**



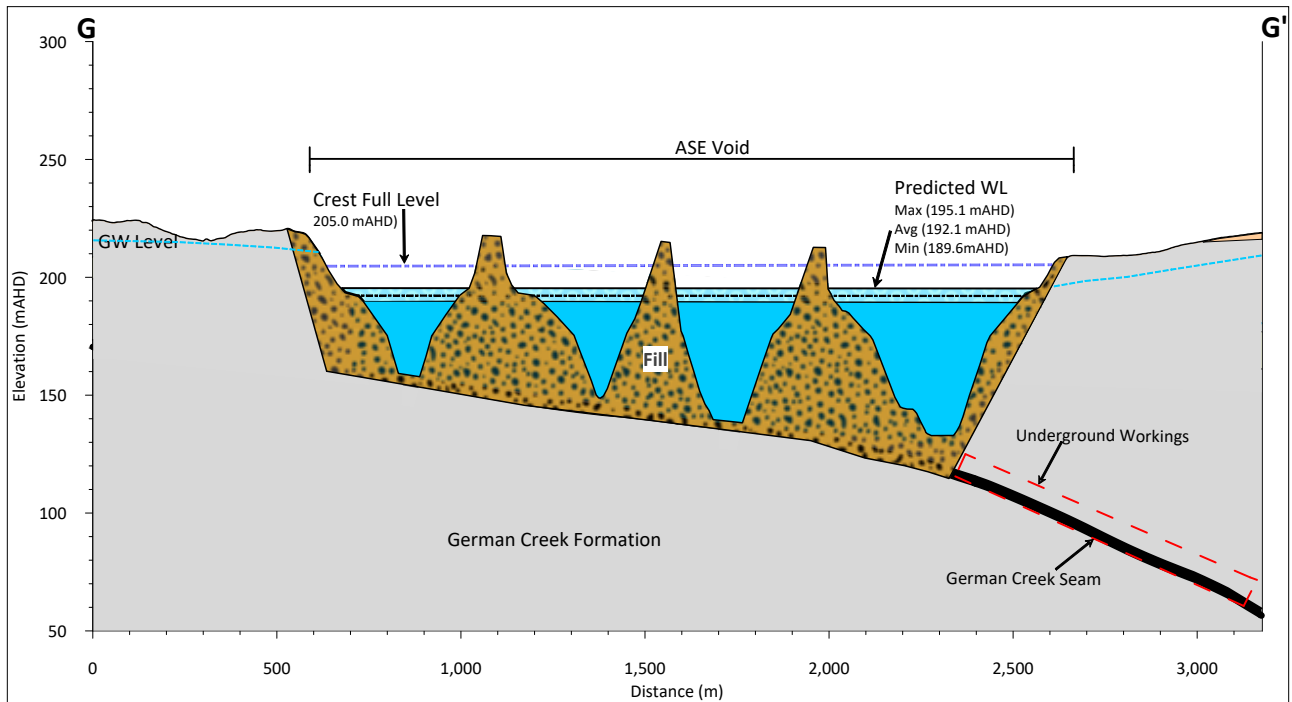
**Figure 4.5 D-D': G NW cross-section through GNW-A and GNW-B voids in N-S orientation**



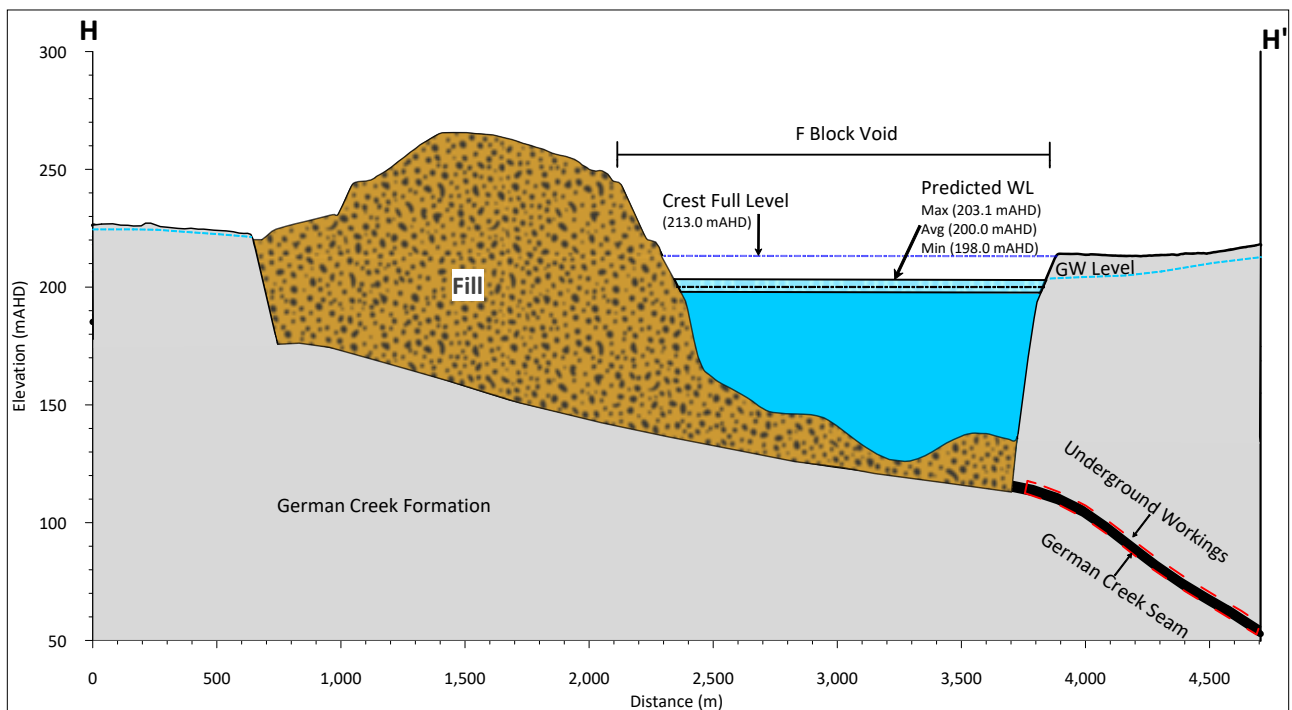
**Figure 4.6 E-E': ABG void cross-section in NW-SE orientation**



**Figure 4.7 F-F': Cross-section through Ramp4 void and ABG: B void in NNE-SSW orientation**



**Figure 4.8** G-G': ASE (A, B, C, D) void cross-section in NW-SE orientation



**Figure 4.9** H-H': F Block cross-section in N-S orientation

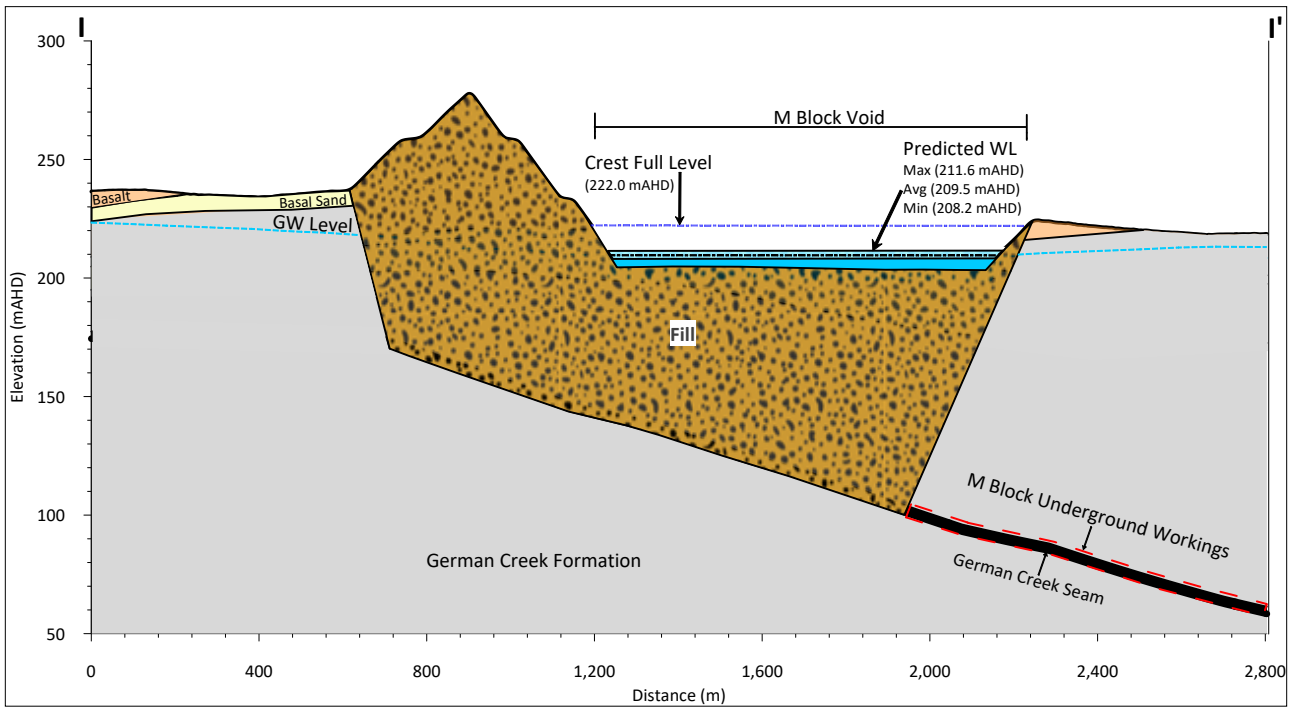


Figure 4.10 I-I': M-Block void cross-section in NNW-SSE orientation

## 5 IMPACT ASSESSMENT

### 5.1 The Potential of Void Spill Events

Once mining is complete, groundwater levels will recover (i.e. increase in elevation) from at or below the base of mining. The surface run-off, recharge from rainfall and evaporation from the open water body will contribute to the inflow/outflow within the residual voids. Over time, a balance will develop between the groundwater and surface inflow/outflow into the mine voids. The water level within the void will continue to rise until it reaches equilibrium (rates of inflow are balanced by rates of water loss).

The residual void modelling indicates that the expected maximum water levels for each of the final voids are below the crest full levels for the voids. The high salinity water in the voids will therefore not decant onto surface and flow into the surrounding streams.

### 5.2 Potential for Voids to Contaminate Surrounding Aquifers

The long-term groundwater simulations indicate that post-closure, the voids will continue to act as local groundwater sinks. This will encourage flow toward the final voids, as shown in Figure 3.3. These gradients, towards the voids, will prevent the high salinity water in the voids from migrating away from the mining area. The long-term void water equilibrium levels are lower in elevation than the surrounding groundwater levels and saline water seepage away from the pit voids is not expected to occur.

Short-term transient reversals of flow will occur in periods of high rainfall/run-off into the voids; these periods will allow the void water levels to temporarily be higher than the equilibrated groundwater levels. During these short-lived periods, the higher salinity void water will be able to migrate into the groundwater immediately adjacent to each void, however, the gradients toward the voids will rapidly re-establish and the groundwater will again flow toward the voids.

It can be expected that groundwater quality in the immediate vicinity of the voids will be poor over several hundred years. The simulations indicate that the void water quality is unlikely to impact regional groundwater users.

### 5.3 Potential for Agricultural / Stock Water Use

The range of TDS values (and the indicative ionic concentrations for the major ions) is predicted based on the current void water quality, the current groundwater quality and the long-term water balance that is largely dominated by evaporation from the voids.

In the TDS range, the current void water quality is already exceeding or is at the upper end of suitability for beef cattle, horses, pigs, and sheep (Figure 5.1). All of the pit areas are expected to exceed 5,000 mg/L over the 1000-year prediction period. Ramp 7 is expected to fluctuate drastically over time due to its shallow nature. TDS exceeding 10,000 mg/L is expected in dry periods making it unsuitable for cattle watering in dry periods.

Livestock	Total dissolved solids (mg/L)		
	No adverse effects on animals expected	Animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production	Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually
Beef cattle	0–4000	4000–5000	5000–10 000
Dairy cattle	0–2500	2500–4000	4000–7000
Sheep	0–5000	5000–10 000	10 000–13 000 <sup>b</sup>
Horses	0–4000	4000–6000	6000–7000
Pigs	0–4000	4000–6000	6000–8000
Poultry	0–2000	2000–3000	3000–4000

a From ANZECC (1992), adapted to incorporate more recent information  
 b Sheep on lush green feed may tolerate up to 13 000 mg/L TDS without loss of condition or production

**Figure 5.1 Tolerances of Livestock to Total Dissolved Solids (Salinity) in Drinking Water (ANZECC & ARMCANZ 2000)**

## 6 CONCLUDING COMMENTS

The Sojitz numerical groundwater model was used to provide projected post-mining groundwater conditions. The groundwater model was used to iteratively inform the corresponding surface water assessment and to consider the projected final void water level elevations from the surface water modelling in the long-term post-closure modelling.

The modelling results over the 600-year simulation period indicate that:

- Groundwater inflows will continue to flow towards the voids, with the highest rates of groundwater flows in the first 50 years after operations have ceased.
- Within the first 100 years after operations, the groundwater system has recovered.
- Over the entire 600-year period groundwater gradients remain toward the voids, with the open voids acting as localised groundwater sinks due to evaporation.
- Long-term modelled water levels show the maximum predicted void water levels are not expected to reach the pit crest full levels and therefore not expected to contribute to the surrounding surface water systems.
- The modelling results suggest that it is unlikely that saline void water will migrate away from the voids to impact on the regional groundwater quality or seep to surface waters. Short periods of outflow would occur in periods of very high rainfall when the void water levels are temporarily higher than the groundwater elevations but the general gradients towards the voids re-establish after these events. The post-closure groundwater simulations indicate that the void water quality would be unlikely to impact on regional groundwater users.
- The water quality assessment suggests that the voids will be unsuitable for stock watering or irrigation purposes after closure. It can be expected that with the voids acting as groundwater sinks that the water quality will become saline due to evaporative processes causing the salts to concentrate in the voids.

## 7 CLOSING

KCB is pleased to provide this report on the post-closure groundwater modelling at Sojitz. Should you have any queries, please do not hesitate to contact us at [jnel@klohn.com](mailto:jnel@klohn.com).

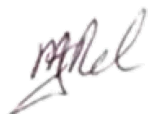
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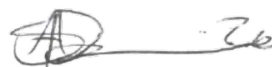
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### KCB AUSTRALIA PTY LTD.



Jaco Nel, PhD, PrSciNat  
Senior Hydrogeologist, Groundwater Modeller



Andile Dlamini, MSc  
Hydrogeologist

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## Landholder statement for the retention of infrastructure

### Background:

1. Sojitz Gregor Crinum Pty Ltd is the registered owner of the following lots (Property)

Real Property Description	
11 SP258266	7 RP849020
11 SP266093	42 CP864579
14 RP855491	10 RP848962
5 RP615803	11 SP258266
25 CP883753	14 FP855491
101 SP260668	45 CP883753
4 RP616357	101 SP260668
3 RP616357	101 SP260668
1 SP258941	100 SP260668

2. Mining Leases ML 1978, ML1923, ML7007, ML70061 (MLs) overlap the property
3. The MLs and associated environmental authority EPML00945013 (EA) are also held by Landowner.

### Infrastructure

4. The following infrastructure has been constructed on the Property within the area of the MLs:
  - (a) access roads;
  - (b) Selma Weir raw water supply pipeline;
  - (c) Water storage dams and associated stock water infrastructure;
  - (d) site administration facilities and bath houses;
  - (e) workshops and sheds, including hardstand areas;
  - (f) services associated with these buildings, including electricity connections and water and sewage;
  - (g) communications tower (infrastructure owned by Telstra); and
  - (h) basalt quarry.

(Collectively referred to as the Infrastructure).

5. Further details of the Infrastructure, including a map showing its general location and photos of the Infrastructure, are included in the Schedule.

### Landowner's acceptance of responsibility

6. The Landowner:
  - (a) consents to the Infrastructure remaining on the Property; and
  - (b) accepts it will have ownership of, and responsibility and liability for the Infrastructure, once mining has ceased.

## Benefits of retained Infrastructure

7. The Infrastructure will continue to be used in connection with grazing and agricultural activities conducted both on the Property and on immediately adjacent parcels. It will allow for increased efficiencies in that ongoing productive use of the Property once mining has ceased, without cost to the Landowner. The retained infrastructure will also ensure a raw water supply from the Selma Weir is maintained to neighbouring landholders that rely on the water for agricultural activities.
8. There is opportunity for adjoining properties through appropriate arrangements with the landholder to utilise these facilities thus strengthening relationships with neighbouring landowners.

### Signed by

Sojitz Gregory Crinum Pty Ltd

ABN 55 626 424 048

on 31/ 05 /2022

by its duly authorised officer in the presence of:

Signature of Authorised Officer: 杉浦知実

Full Name of Authorised Officer: Tomomi Sugiura

Position in the company: Director

Signature of witness: 

Name of witness (print) Jacob Sorenson

## Schedule

### Part A: Description

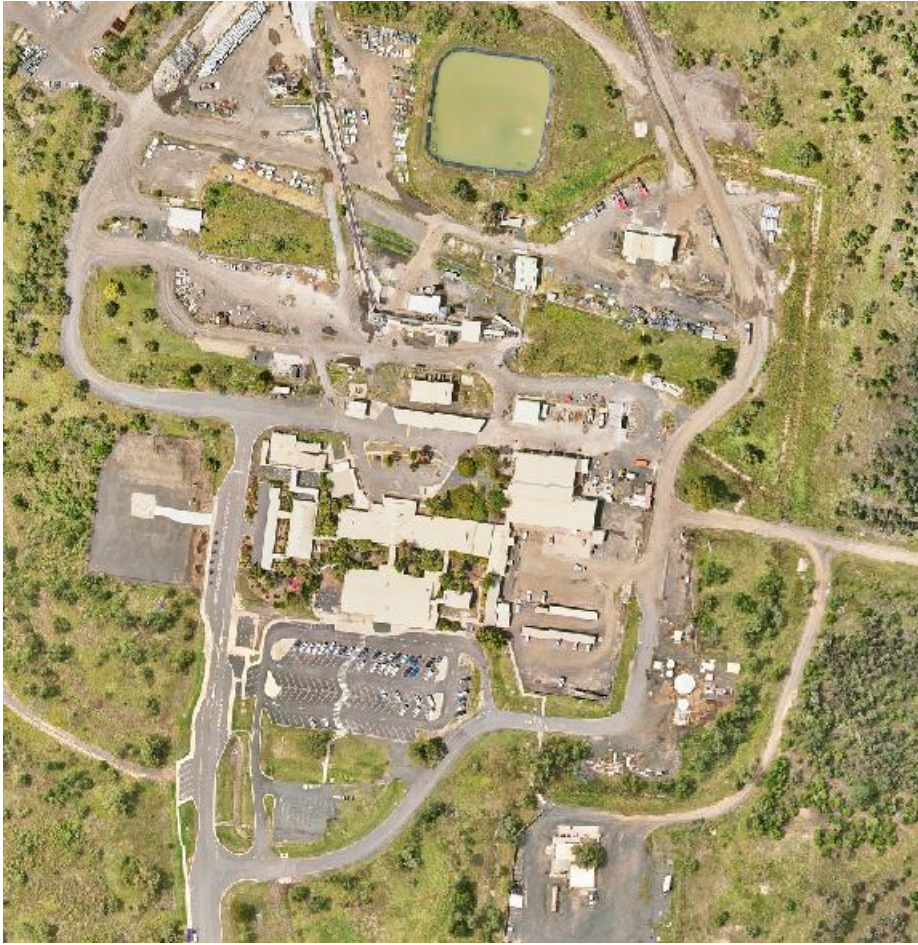
Description of Infrastructure	Location of Infrastructure	Landowner's proposed use
Access roads, vehicle parking and associated agricultural hardstand areas, as generally shown in the pictures Part C.	As generally shown in the map at Part B.	General access.
Dams as generally shown in the pictures Part C, with associated Selma Weir pipeline.	As generally shown in the map at Part B.	Stock watering.
Gregory and Crinum site administration facilities including bathhouses, as generally shown in the pictures Part C.	As generally shown in the map at Part B.	Homesteads.
Workshops and associated sheds, as generally shown in the pictures Part C.	As generally shown in the map at Part B.	Work sheds, hay sheds, storage sheds, horse stables.
Communications Tower	As generally shown in the map at Part B.	Providing communication services to the Lilyvale/Tieri area.

Appendix 1 – Map



## Appendix 2 – Images of Infrastructure

### Crinum Mine Infrastructure Area



### Gregory Mine Infrastructure Area



**Water Storages**

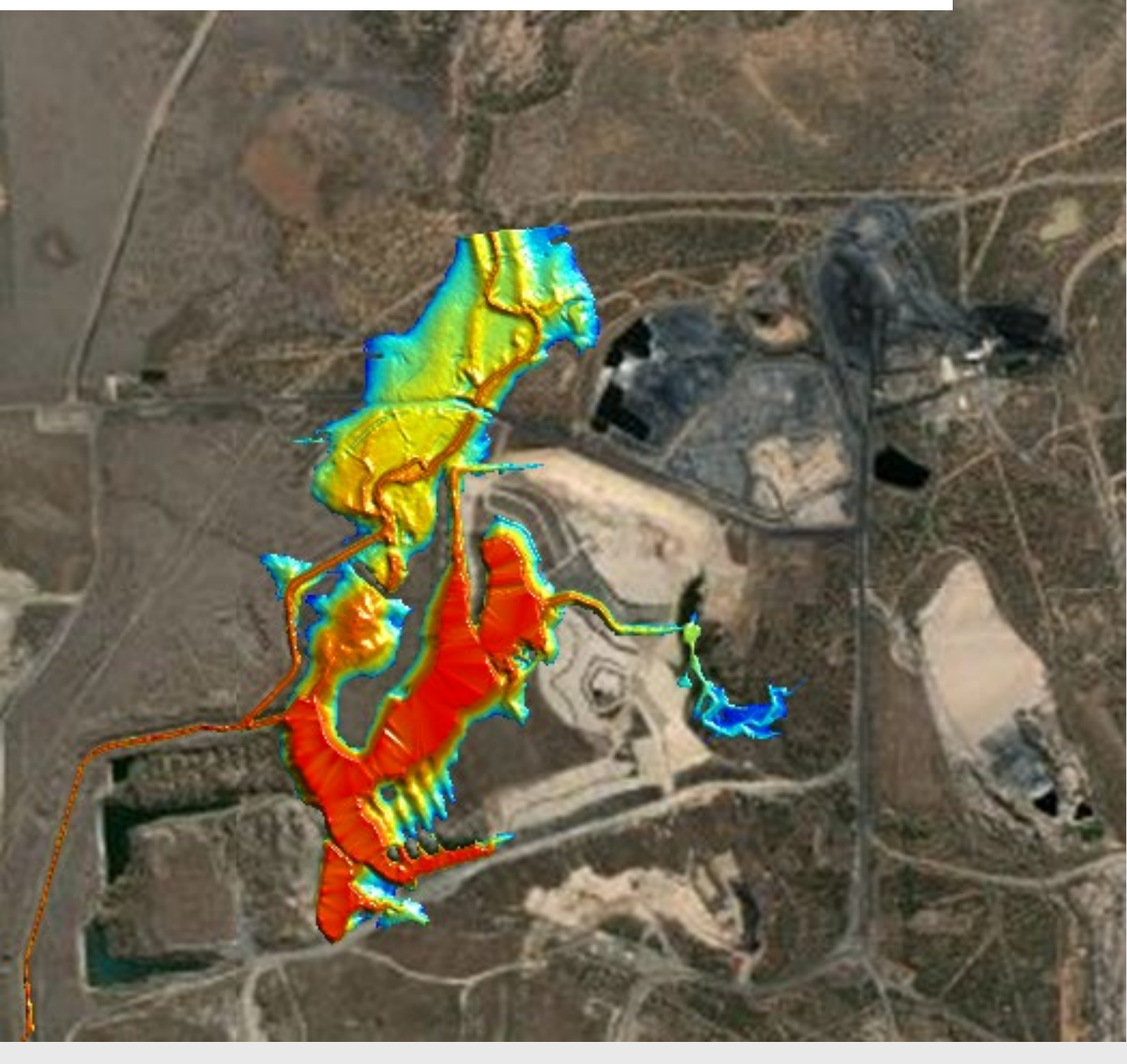




# North Wetland Quality Review

Prepared for [Sojitz Gregory Mining Pty Ltd](#)

Reference no. 300203764 | 27 April 2023





# North Wetland Quality Review

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Prepared for Sojitz Gregory Mining Pty Ltd

Reference no. 300203764 | 27 April 2023



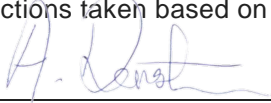
# North Wetland Quality Review

Prepared for Sojitz Gregory Mining Pty Ltd

Reference no. 300203764 | 27 April 2023

Revision	Date	Description	Author	Quality Check	Independent Review
1	27/04/2023	Final	AD	ZMC	ZMC

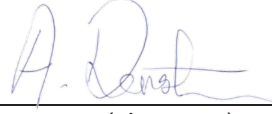
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**Anthony Densten**

Reviewed by   
 (signature)

**Zac McCosker**

Approved by   
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**Anthony Densten**



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# 1 Project Overview

The Gregory Crinum Mine (GCM) in central Queensland has been operating since the mid 1980's and has recently in 2019 been re-opened after a period of care and maintenance by Sojitz.

The North Wetland is an old mining pit that has been reshaped and operated as an off-stream detention storage for the Crinum Creek diversion channel. The storage forms a significant component of the diversion and receives inflow from approximately 227km<sup>2</sup> of upstream catchment.

The North Wetland area also appears to have a significant local catchment contribution of 1,600ha that includes industrial areas, operational rejects storage, spoil and rehabilitated areas.

In recent years the old Boundary Creek Diversion has been reshaped and rehabilitated and an alternative flow path established to direct upstream catchment into the wetland area.

A recent bathymetric survey of the area has identified that the wetland has a maximum depth of 20m (base at 172mAHD and spillway at 194.4mAHD) and is connected to the adjacent Crinum Creek Diversion via a 20m wide channel.

A general locality plan for the area is presented in Figure 1. Review of the locality indicates the following:

- A connection between the existing Crinum Creek Diversion and the North Wetlands.
- The general flow paths from local eastern catchments reporting to the North Wetlands storage.



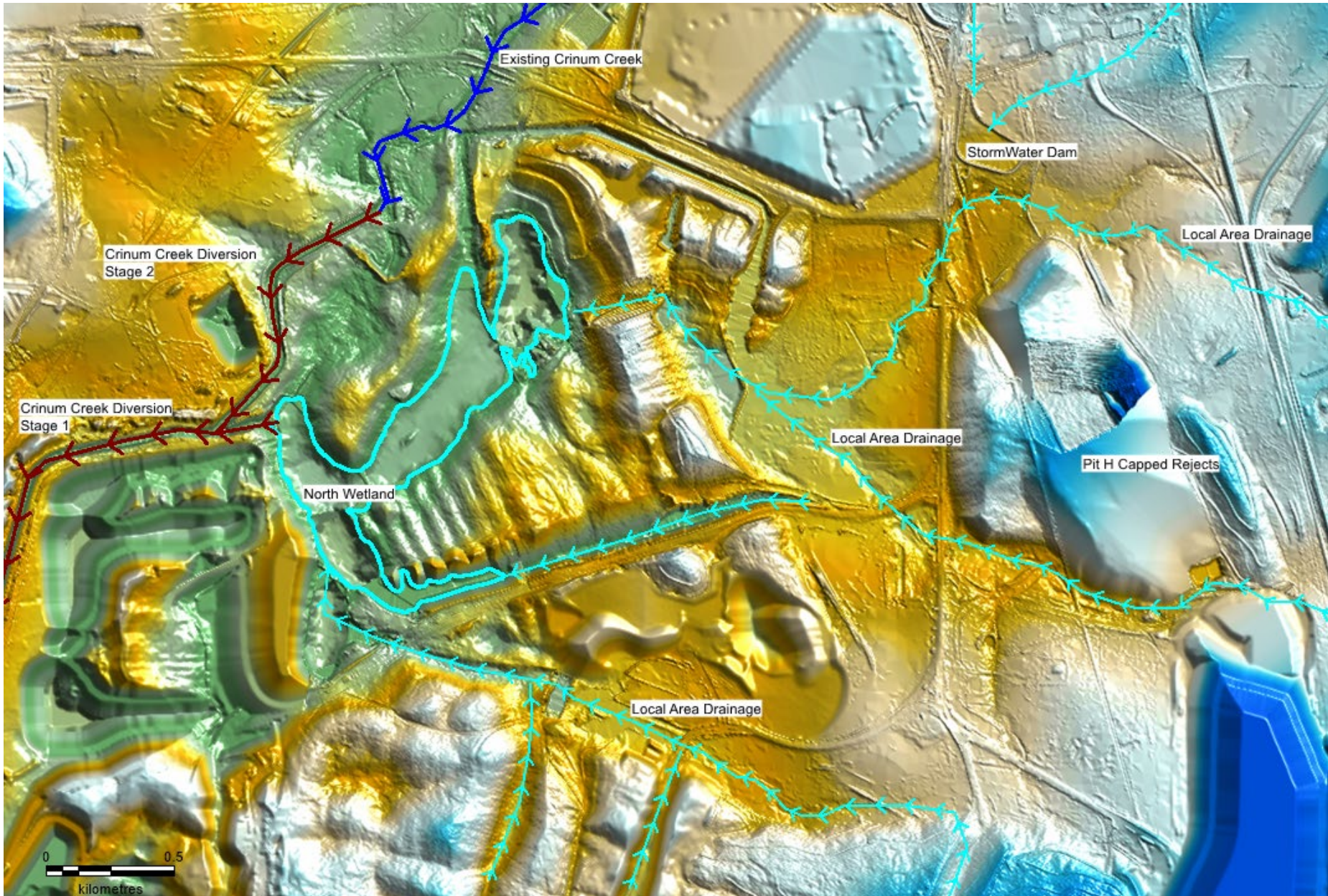


Figure 1 – North Wetland Locality and Overview

## 2 Project Information

### 2.1 North Wetland History and Progression

Based on discussions with GCM and review of historical LiDAR and site experience the following timeline has been developed for the operation of the existing North Wetland area

- G North area (G Seam) mined out in the late 1980's
- The development of the Crinum Creek Diversion Stage 1 and Stage 2 in 1997 and 1998 (Water license 41312F and 404300) and inclusion of G North as part of the diversion system for off stream storage and flow routing.
- Rehabilitation of the upstream spoil area followed by surface operations care and maintenance.
- Ongoing operation of the North Wetland to date
- Recommencement of surface operations in 2019
- Decommissioning of Boundary Creek Diversion and spoil reshaping to more stable final landform in 2020.
- Capping of H Block rejects area in 2021 to date.
- Ongoing reshaping and rehabilitation of spoil area within the catchment continues.
- Continuous pumping of water from Storm Water dam to the OTD at 50L/s to keep this drawn down and minimise discharge.

The key operational characteristic of the system remains the Crinum Creek Stage 1 Diversion established in the early 1990's where the upstream channel width of 30m decreases to a nominal 15m wide channel just downstream of the connection to the North Wetland. For conveyance of the 1% AEP event and higher the wetland is required to allow for containment of all flow within the downstream reduced width channel that was dragline constructed with a base width of 15m.

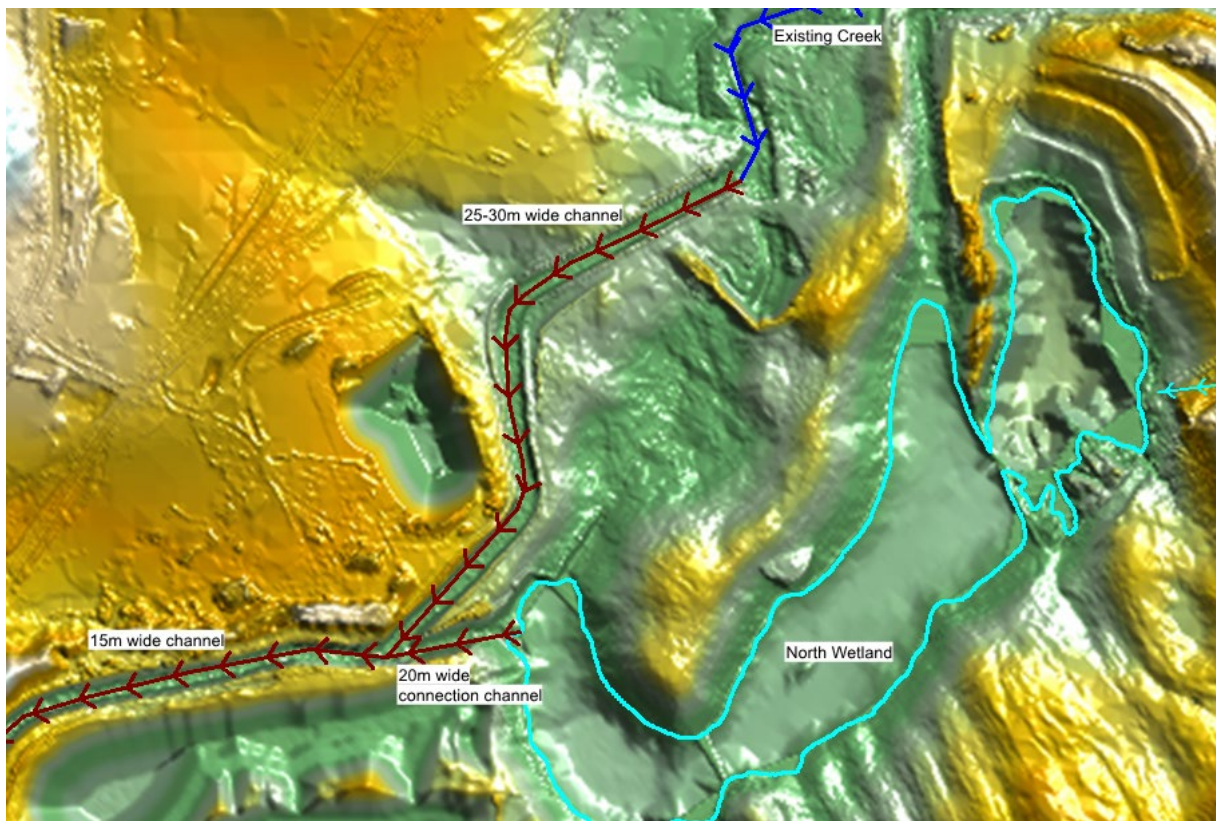


Figure 2 – North Wetland Connection Details

## 2.2 North Wetland Bathymetry

Site has provided detailed bathymetry for the wetland area with details of storage and spillway levels shown below:

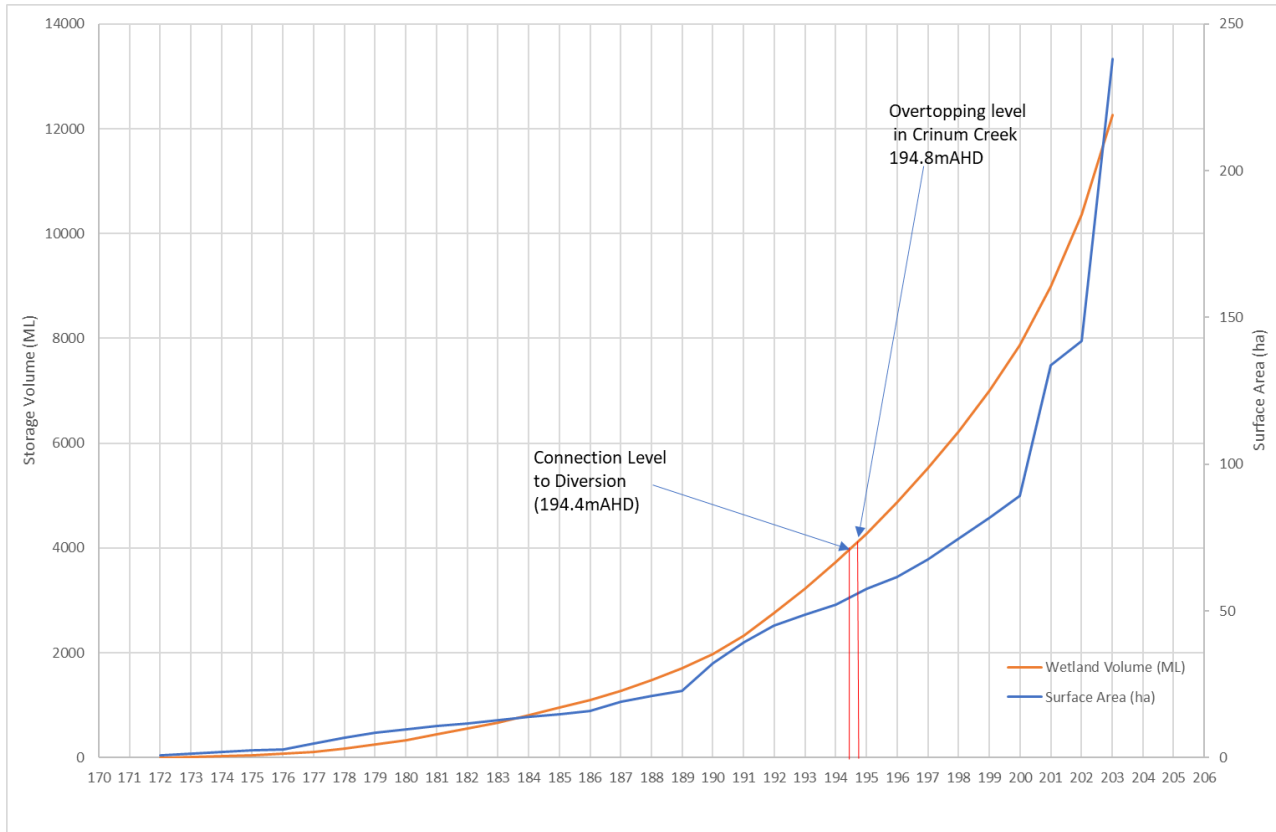


Figure 3 – Stage Storage and Overflow Characteristics

Review of provided topography for the area and the bathymetry indicates the following:

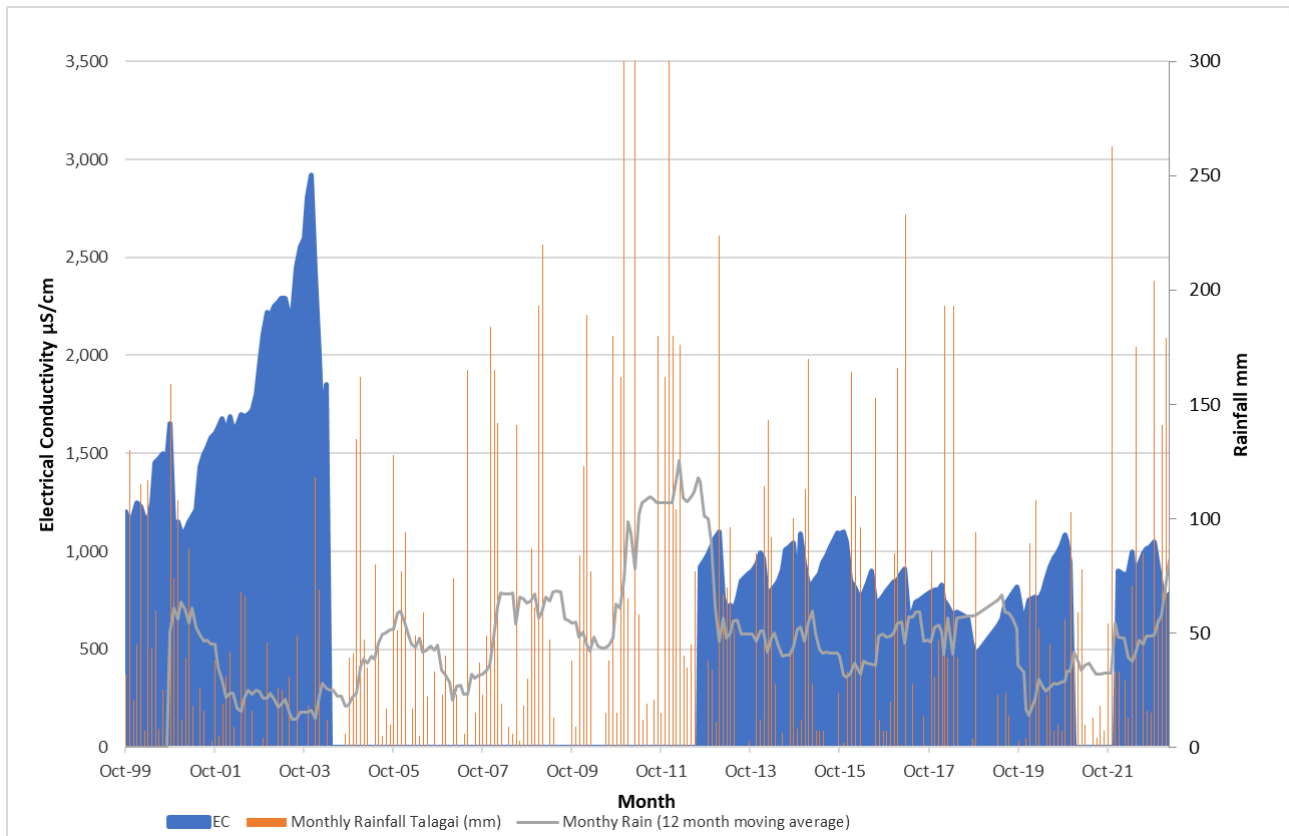
- Storage area can hold 4000ML of water to overflow level to diversion at 194.4m AHD.
- The minimum level in the diversion for flow to progress downstream is 194.8m AHD.
- When the diversion flows more than 400mm deep water is conveyed into both the wetland and down the diversion.
- The peak 1% AEP water level in the diversion has been estimated at greater than 204m AHD which would create significant volume of storage (>8000ML) that would flow into and then eventually flow out of the wetland. This flow volume is twice the capacity of the storage and means that large flows have the potential to significantly flush and replace all water in the storage.

## 2.3 Historical Quality and Level Data

Water quality data has been provided for the period October 1999 to January 2004 and from September 2011 to date. Long-term monthly rainfall data was sourced from the Bureau of Meteorology rainfall monitoring station at “Talagai”, which is approximately 10 km east of GCM. There is no long-term rainfall monitoring data available from GCM.

Summary data for Electrical Conductivity (EC) and rainfall over this period is presented in Figure 4.





**Figure 4 – Recorded EC Water Quality and Rainfall Data**

Review of the above indicates the following:

- In the period 2000 to 2004 the low rainfall generally resulted in the majority of inflow coming from the local catchment which may have been heavily disturbed and unrehabilitated. This may have been the reason for the higher recorded values (>2,500µS/cm).
- Since October 2012 the maximum EC levels in the wetland have not exceeded 1,100 µS/cm and there has been a general tendency for EC to decline after summer rainfall and then rebound.
- There are gaps in water level and salinity throughout 2021, however the EC levels appears to oscillate around a long-term average of 850 µS/cm since 2012.
- Current investigations have aimed to calibrate the model to the observed water levels and quality data from 2012 to date as this generally represents the status of the rehabilitation and current salinity generation of the catchment (see Section 3).

The minimum level of around 500 µS/cm occurred after a particularly wet period in February-April 2018.

This may represent the dominance of Crinum Creek stormwater inflows with relatively low salinity.

Some limited monthly water level data has also been provided for the period 2012 to date however these are monthly values and only represent the trend in the system over time and may not represent the maximum and minimum water levels in the storage over this period (see Figure 5). Large inflow events would not necessarily be reflected in monthly water levels.

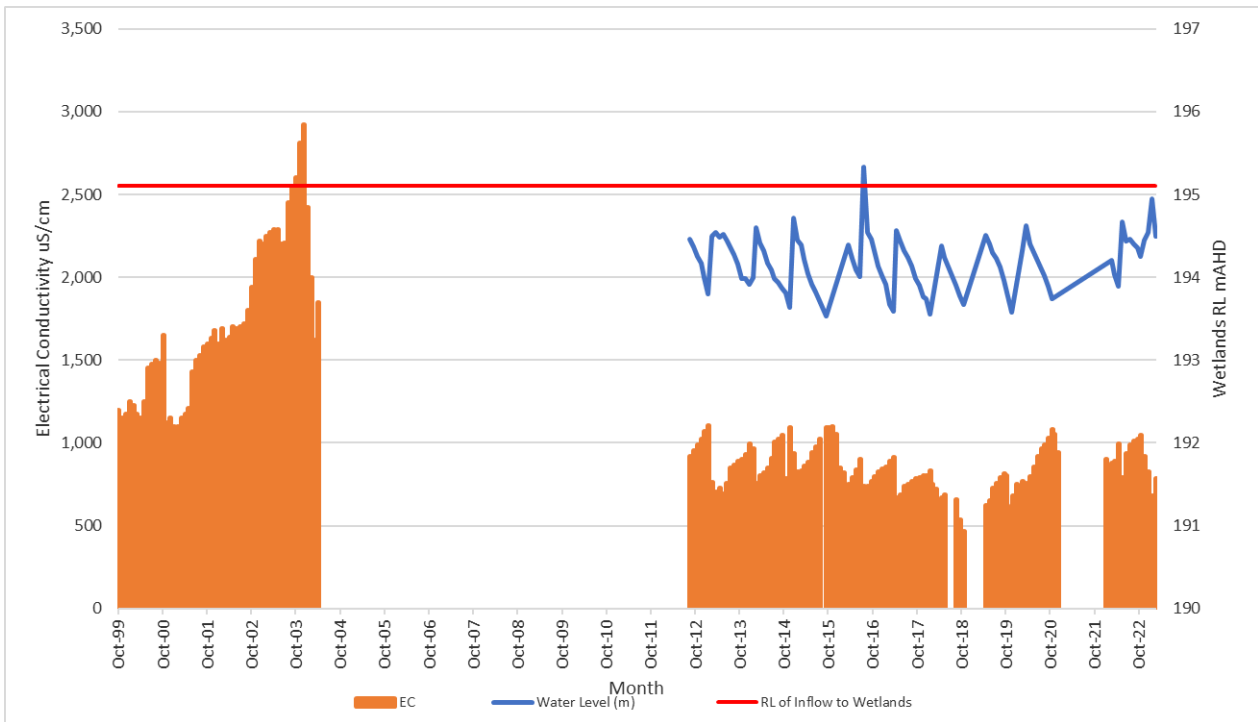


Figure 5 – Recorded EC Water Quality and Water Level

# 3 Model Development

## 3.1 Previous Model

A previous long term water balance model for the entire GCM site has been generated and calibrated for use in mine water management and assessment. This model has been amended to consider the North Wetland and associated catchment reporting to the storage and the adjacent creek.

## 3.2 Crinum Creek Performance

The performance of the North Wetland and especially assessment of long-term water quality will always be heavily linked to the inflows that are generated from the adjacent creek system and the rainfall/runoff response for this area.

Although a set of rainfall/runoff loss and catchment characteristics have been adopted the appropriateness of these has yet to be confirmed or calibrated against actual recorded flows. The only gauge data for Crinum Creek appears to be at the downstream Lilyvale waterhole which has flood data from 1976 through to 2012. The hydrological performance of this system has been influenced in the early 1990's by the development and connection of the North Wetland which potentially reduces the yields to the downstream area.

The rainfall runoff parameters defined as part of previous assessment has continued to be used for current investigations as they appear to represent the overall expected catchment yield however may not accurately always represent the yield on an event basis as rainfall can vary across the catchment.

## 3.3 Assigned Salinity and Catchment Breakdown

Current investigations have considered the following catchment areas and associated salinity generation rates for the different land use types as outlined in Table 1.

**Table 1 Catchment and Land Use Salinity**

Location	Land Use	Area (ha)	Salinity Concentration (mg/L)
Crinum Creek	Creeks/Natural	22722	Factor = 600* Exponent = -0.3 Limit = 900
North Wetland	Hardstand	124	1000
	Spoil (Surface)	754	1000
	Natural/Rehab (Surface)	630	800
	Natural/Rehab (Baseflow)	630	1600
	Industrial	100	3000

Note: Concentration = Factor \* Runoff Depth ^ Exponent

Note that the above rates for salinity load are based on the salt load being continually available however salt loads within the system have been continually flushed out of the G North system by the diversion and overflow and there is an expectation that the loads may continuously reduce in future due to the following:

- Capping and rehabilitation of industrial areas
- Reduced salt load from Natural/Rehabilitated Spoil surface and baseflow as loads are removed.
- Reduced salt load from surface runoff from Spoil area as load is removed and flushed.

Outcomes and modelling have also not assumed any loss to groundwater systems or significant inflows from groundwater.



### 3.4 Long Term Rainfall and Evaporation Data

Long term rainfall and Evaporation data was sourced from DataDrill online for the regions for the last 132yrs.

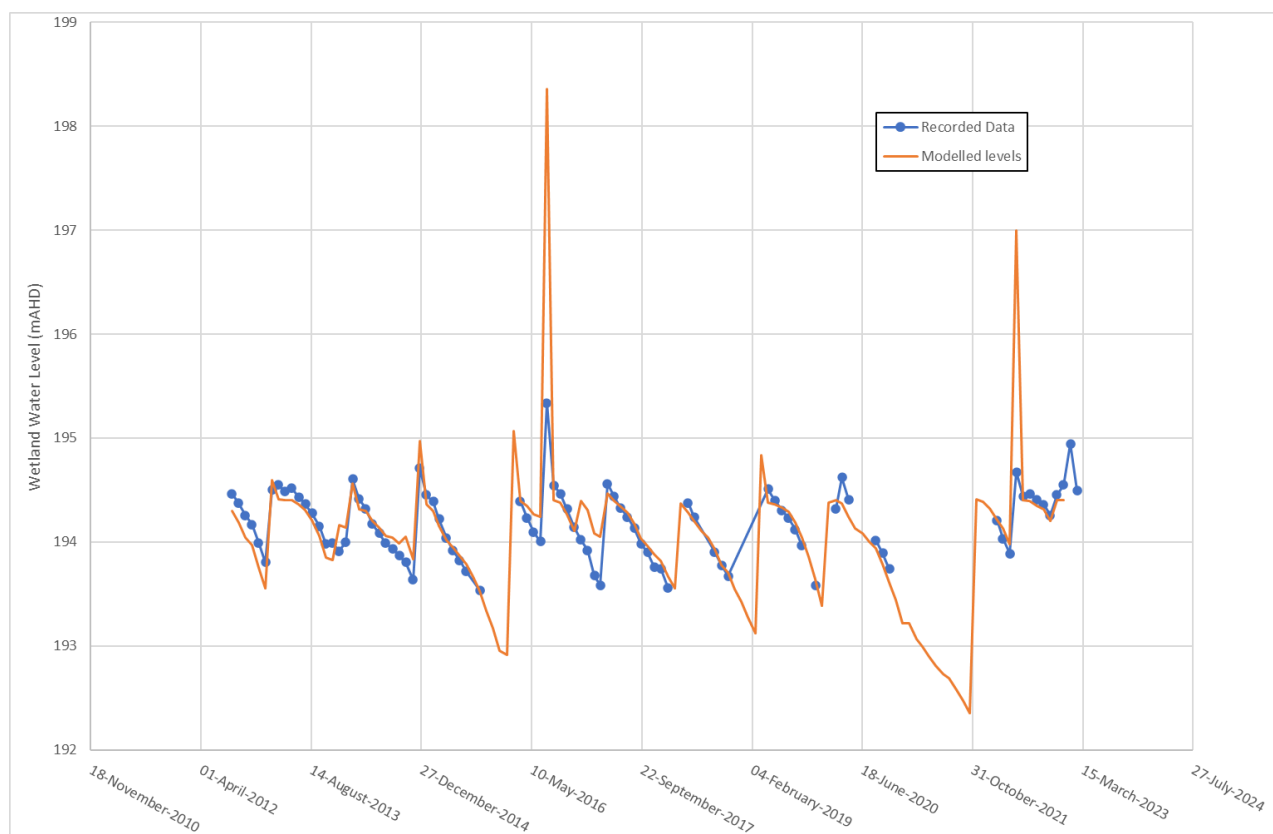
Daily site rainfall was also used from 2012 to date to calibrate and assess model against recorded data and confirm the suitability of the catchment rainfall/runoff parameters and the catchment salinity rates adopted in Section 3.2.

Assessment has also considered and generated a stochastic 1000yr rainfall data set based on the provided 132yr recorded data set to assess the North Wetland long term water quality performance.

### 3.5 Model Calibration and Assessment

Water balance modelling was undertaken for the period October 2012 to date to assess the performance of the system and to calibrate the model by replicating recorded water levels and water quality.

The current model outcomes compared to recorded water level data over the period are presented in Figure 6.



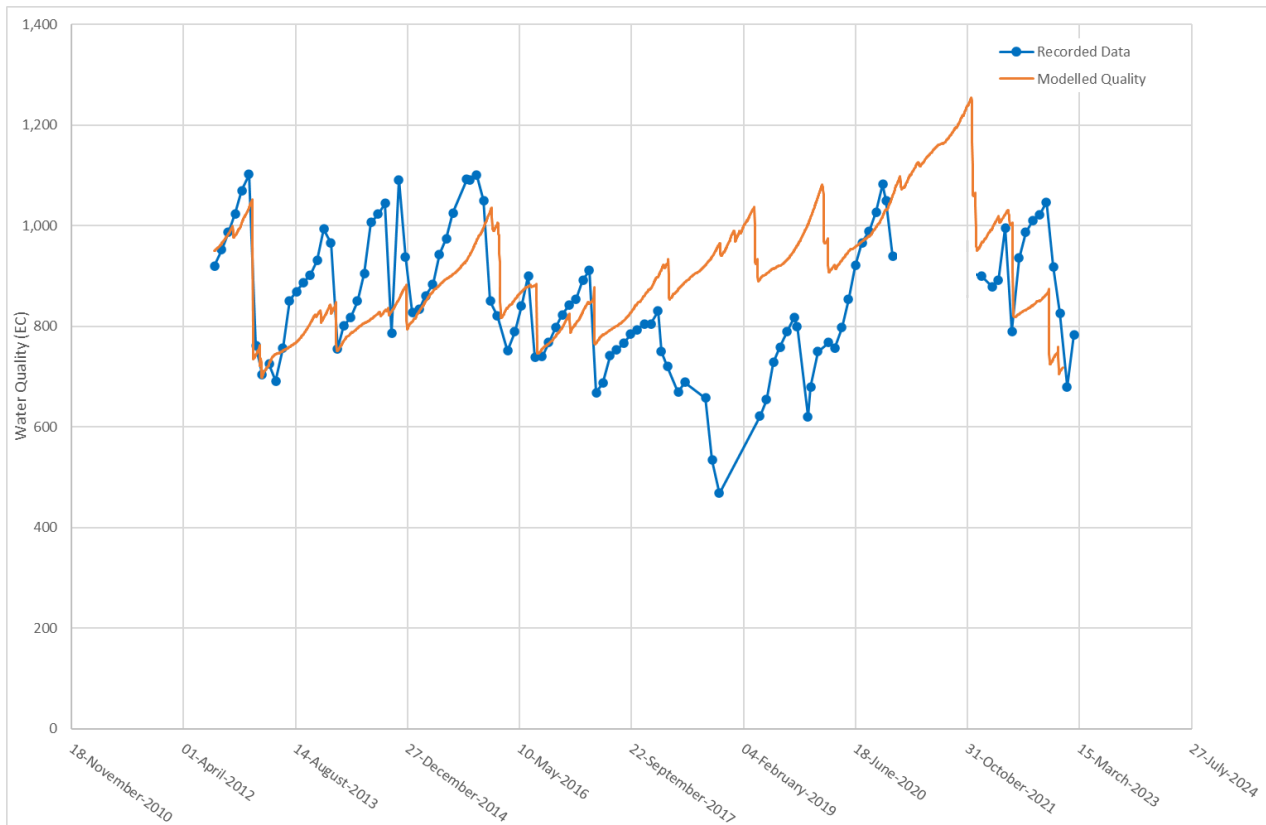
**Figure 6 – Recorded and Modelled Wetland Water Levels**

Review of the outcomes indicates the following:

- Good correlation between most peak levels on the date of level recording (18<sup>th</sup> of each month).
- Some variation in larger events where we expect inflows from Crinum creek temporarily is routed through the system.
- Good observed draw down of the storage after events. This generally indicates that there may be limited groundwater interaction at these storage levels.

Associated salinity estimates for the storage are presented below in Figure 7.





**Figure 7 – Recorded and Modelled Wetland Water Quality**

Review of the above generally indicates the following:

- Good start and finish concentration over the 12 year period with some replication of peaks and troughs prior to 2018.
- Modelled EC exceeds recorded EC during 2018 and 2019. The source of the difference could be attributed to the location of the “Talagai” rainfall monitoring station, being approximately 10 km east of GCM and outside of the Crinum Creek catchment area. Some significant storm inflows may be missed or underestimated.
- A modelled highest EC of 1,250 $\mu$ S/cm occurs during a period where there is a gap in the recorded EC data.

Based on the above modelled replication of recorded water levels and storage salinity a long-term assessment of the performance of the system has been undertaken using the generated 1000yr rainfall data set.

# 4 Modelling Outcomes

Long Term Modelled Outcomes for the North Wetland have been generated using the model defined from calibration assessment. The model has been run on a sub daily timestep (1hr) to allow for the volumetric mixing and movement of water through the North Wetland to be better estimated.

Long term (1000yr) EC modelled outcomes for the basin are presented in Figure 8.

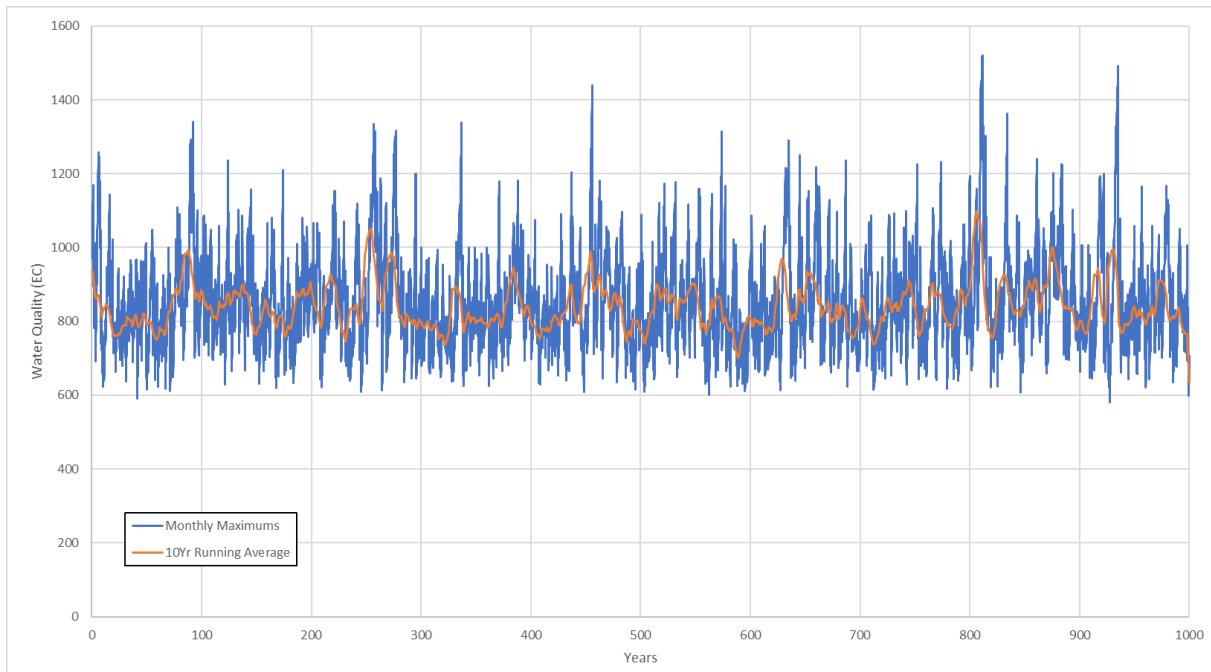


Figure 8 – Long Term Modelled North Wetland Water Quality

Review of the above generally indicates that the modelled water quality in the North Wetland would fluctuate between 600µS/cm to nearly 1500µS/cm over the 1000yr of climatic assessment.

In general, there is a 1% AEP of the EC levels being above 1,350µS/cm in any year and an median (50% AEP) water quality of 900 µS/cm in any year. The overall AEP assessment of water quality is presented below.

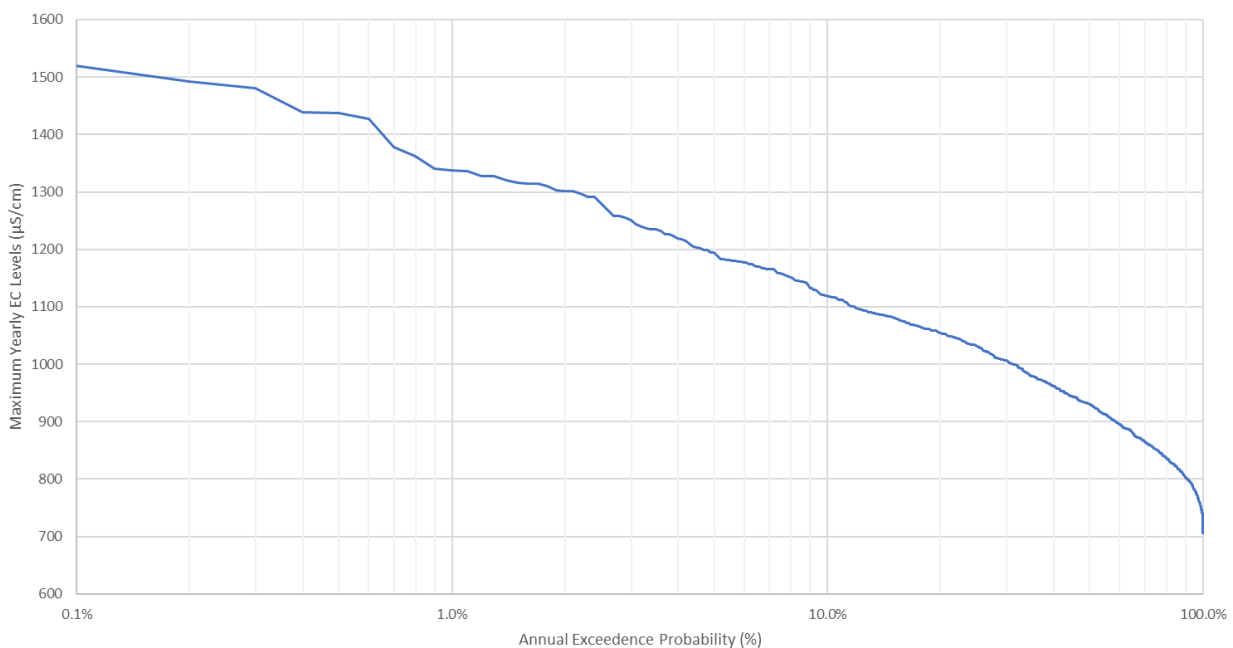


Figure 9 – AEP of North Wetland Water Quality



## 5 Conclusions

Based on the current assessment and the continued performance of the North Wetland, modelling has generally indicated that the water quality in the wetland is generally influenced as follows:

- Continuous flushing and contribution of significant inflows from Crinum Creek generally reduces the EC levels in the wetland during events.
- The initial increasing salinity recorded (i.e. years 1999 – 2004) is primarily due to local catchment (non-Crinum Creek) inflows and small first flush creek flows that may have elevated salinity levels. However the salt loading from the upstream direct catchment may continue to reduce over time as salt is transported out of the system and the catchment is further rehabilitated.
- Outcomes presented are based on the upstream catchment not being further disturbed or there being introduced another source of potential salinity to the wetland area.
- Modelled outcomes generally indicate that 95% of the time (daily basis) the wetland water quality EC level will be below 1,200  $\mu\text{S}/\text{cm}$  and that EC levels will remain stable over the modelled 1000year timeframe.





## Stantec Australia

515 St Pauls Terrace  
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Communities are fundamental. Whether around the corner or across the globe, they provide a foundation, a sense of place and of belonging. That's why at Stantec, we always design with community in mind.

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**Design with community in mind**

13 October 2023

Ms Juliana McCosker  
Manager, Environmental Services Regulation  
Coal Business Centre  
PO Box 3028 Emerald Qld 4720  
Via email: [CRMining@DES.qld.gov.au](mailto:CRMining@DES.qld.gov.au)

Dear Juliana,

**Re: Resubmission of Gregory Crinum Mine Progressive Rehabilitation and Closure Plan (PRCP)**

Gregory Crinum Mine is the holder of Environment Authority EPML00945013.

I refer to your letter dated 14 June 2023 in relation to further information required to assess an application for a PRCP Schedule. Gregory Crinum Mine has reviewed the request and updated the attached PRCP to address the queries. Individual responses to the information request are provided in **Table 1** below, with references to the relevant sections of the PRCP.

Please contact me if you would like to discuss this resubmission.

Yours Sincerely,



Ann Houston  
Head of Environment, Social and Governance  
Sojitz Blue Pty Ltd  
Ph: 0407 020 310  
E: [ann.houston@sojitzblue.com.au](mailto:ann.houston@sojitzblue.com.au)

Attachments:

*Gregory Crinum Mine Progressive Rehabilitation and Closure Plan, Version 2. 13 October 2023*

**Table 1 – Response to DES Information Request**

Item	DES Information Request	Gregory Crinum Response
1	The Rehabilitation Planning Part does not state the extent to which each proposed Post Mining Land Use (PMLU) is consistent with the outcome of consultation with the community in developing the plan as required by section 126C of the Environmental Protection Act 1994 (EP Act).	Section 4.1 Open Woodlands, 4.2 Grassy Open Woodlands, 4.3 Low Intensity Grazing and 4.4 Water Storage updated with reference to community feedback in relation to the PMLUs.
2	The Rehabilitation Planning Part does not state the extent to which each proposed non-use management area (NUMA) is consistent with the outcome of consultation with the community in developing the plan or strategies as required by section 126C of the EP Act.	Section 5 Non-use Management Areas updated with reference to community feedback in relation to the NUMAs.
3	The Rehabilitation Planning Part does not state the extent to which each proposed non-use management area (NUMA) is consistent with plans for the land of a local government, the State or the Commonwealth as required by section 126C of the EP Act.	Section 4.6 Strategies and Plans updated to provide the NUMAs alignment to Local, State or Commonwealth plans.
4	The rehabilitation planning part does not state how the total area of each NUMA will be minimized or how the location of each NUMA minimises risks to the environment. The area and location of proposed NUMAs is not identified in a LOD, hence this information is required pursuant to section 754(4) of the EP Act.	The area and locations of the proposed 17 residual voids were included within a LOD (Appendix A of Gregory Crinum Mine Residual Void Investigation Report. Sojitz Gregory Crinum Pty Ltd. Version 1.0, 19 November 2021) that was accepted by DES in 2021. Updated areas and locations are presented in Table 11 and Figure 17 of Version 2 of the PRCP. Section 5.1 Residual Voids discusses minimising the surface area of the residual voids as part of the final landform design process, with highwall shaping required for landform stability. The proposed residual voids are located outside the 0.1% AEP floodplain to minimise potential for floodwater ingress, except Liskeard residual void (see Section 6.2 Flooding).
5	The application is required to include the other information the administering authority reasonably considers necessary to decide whether to approve the PRCP schedule for the plan pursuant to section 126C(1)(j). As prescribed under section 550 of the EP Act, this includes information specified in the 'Guideline Progressive Rehabilitation and Closure plans (PRC	Geotechnical characterisation of tailings is being undertaken for tailings samples from I Block, F Block and the Old Tailings Dam. The samples are currently being analysed by a laboratory and the results from the

Item	DES Information Request	Gregory Crinum Response
	<p>plan) (ESR/2019/4965 – version 2)' (the PRCP Guideline). The Proposed PRC plan does not include specific information required by the PRCP Guideline as follows:</p> <ul style="list-style-type: none"> <li>a) Geotechnical characterisation of tailings as required by section 3.6 of the PRCP Guideline.</li> <li>b) Final landform design for ex-pit tailings emplacement (i.e. Old Tailings Dam) as required by section 3.6 of the PRCP Guideline.</li> </ul>	<p>testing will be provided to DES once they have been received from the laboratory.</p> <hr/> <p>a) PRCP Appendix C Revised Final Landform Model (Figure 5) has been updated to include the final landform profile of the Old Tailings Dam.</p>