APPENDIX P

Geological Structure Review

Dendrobium Mine Extension Project

Geological Structures Review

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1. Introduction

PSM was engaged by Illawarra Coal Holdings Pty Ltd (Illawarra Metallurgical Coal [IMC]), a wholly owned subsidiary of South32 Limited (South32) to undertake a review of geological structures within Area 5 of the proposed Dendrobium Mine Extension Project (the Project). The objective of this review was to assess the potential for geological structures with sufficient persistence and scale, such that they may have the potential to be mobilised by mine subsidence, thus affecting predicted subsidence movements. Specifically, this Geological Structures Review focussed on structures with continuity to potentially impact sensitive features such as the Avon Reservoir and dam wall. An overview of the study area is presented in Drawing 1.

It is understood this review is intended to be included as an appendix in IMC's Environmental Impact Statement (EIS) for the Project.

This review consists of a detailed assessment of existing geological and related data with limited field verification of identified structures. It is not possible to exhaustively identify the existence nor extent of all geological structures due to physical limitations on subsurface investigations. Hence, it is possible that some geological structures that occur at the surface have not been identified in this study, or their extent not fully realised.

2. Scope of Work

The scope of work for this review includes:

- Preparation of a Geological Structures Review including:
  - Addressing the Secretary's Environmental Assessment Requirements (SEARs).
  - A description of the exploration activities to date.
  - An explanation of the exploration and in-seam drilling that is ongoing throughout operations to inform and validate IMC's understanding of the geology (with the implementation of adaptive management where unexpected features are encountered).

A desktop review of the available literature including previous studies for relevant matters has been completed (this incorporates the reports and information outlined in the Previous Work section). Additionally, this review is to consider the relevant Project SEARs as issued by the NSW Govt, Department of Planning and Environment and specific requirements outlined in the "Agency Advice" from WaterNSW, including:

- Project SEARS – Key Issues (page 4).

  2. Subsidence – *including:*
  - *a review of the local and regional geological setting, including identification and characterisation of geological structures and lineaments within the proposed mining area;*
- Agency Advice – WaterNSW requirements of project SEARS, Attachment B (Page 7):
  - *the location, mapping and nature of any geological structures including faults, dykes, silts* [sic]*, and other intrusions*

3. Data Sources

Several key sources of information used in this review include:

- IMC provided data:
  - Report on the Geology, Quality and Mineral Resources of Dendrobium Area 2 (Reference 1).
  - Inspection of Surface Outcrops over Dendrobium Mine Area 1 (References 2 and 3).
  - Timing of brittle faulting and thermal event, Sydney region: association with the early stages of extension of East Gondwana (Reference 4).
  - An inspection of certain surface geological features in Area 5 of Dendrobium Mine (Reference 5).
  - Surface mapping of Dendrobium Area 3A and 3B (Reference 6 and 7).
  - Aerial photographs for Dendrobium Mine Area 5.

  - Topographic contour data (1 and 10 metres [m] contours).
  - Selected boreholes and core photographs for holes within Dendrobium Mine Area 5.
  - Selected acoustic televiewer logs.
  - Proposed mine plan.
  - Commonwealth Scientific and Industrial Research Organisation (CSIRO) interpretive plans:
    - Air photograph interpretation (Reference 8).
    - Landsat imagery interpretation (Reference 9).
    - Bedrock fracture trends (Reference 10).
    - Structural synthesis (Reference 11).
- Publicly available data:
  - Southern Coalfield 1:100k geological sheet (Reference 12).
  - Wollongong-Port Hacking 1:100k geological sheet (Reference 13).
  - NSW digital elevation model.
- 2020 Dendrobium Area 5 2D Seismic Survey (Reference 14).

Appendix A presents a full list of the data provided by IMC.

4. Previous Studies

Investigations conducted by IMC within the study area were considered by PSM to be directly relevant to this assessment. The subsections briefly describe relevant investigations conducted within Area 5.

4.1 IMC

The following sections summarise IMC's investigative work focused on Area 5 and the associated exploration of the Bulli Coal Seam.

4.1.1 Exploration

Exploration drilling began in the early 1990's, which included eleven boreholes to assess underground conditions within the study area. Since this time at least 93 boreholes have been drilled in Area 5 over the past 5 years. These boreholes are predominantly reverse circulation pre-collars with diamond cored "tails".

Since 1987, numerous aeromagnetic surveys and seismic programs have been conducted over the study area. These investigations are summarised in the following sub-sections.

4.1.2 Seismic Surveys

In 2020 extensive seismic interpretation was conducted utilising newly acquired and historical 2D seismic data sources covering the study area (Reference 14). This included interpretation/reinterpretation of data from 2005, 2008, 2009, 2010, 2016, 2018, 2019 and 2020.

The latest seismic interpretations indicate the following:

- Faulting:
  - No significant faulting identified within the Area 5 study area.
  - Four lower confidence normal style fault structures have been interpreted within the Area 5 study area, Drawing 2:
    - Fault D519PN002 and D519PN003 which appear to form a localised graben in the northwest of the study area.
    - Fault D519PN001.
    - Fault D520PN001.
- Igneous intrusions:

  - Extensive sill formation is known to occur in the Area 5 study area.
  - Seismic interpretations included assessment of the lateral extent of sill formation.
  - Numerous igneous sills have also been intersected in boreholes and inferred from airborne geophysics.

4.1.3 Aeromagnetic Surveys

Reinterpretation of previous aeromagnetic data in the study area has been completed with possible faults, dykes and sill locations interpreted (Drawing 3).

Interpreted features from the aeromagnetic surveys are not evident in exploration boreholes or from 2D seismic interpretations. Only one dyke appearing in this aeromagnetic interpretation has been confirmed (at borehole S2393) and this has been suggested to be at a different orientation.

Other features have been discounted by exploration drilling. Possible faults indicated in the 2018 interpretation are numerous and not supported by other investigations (Drawing 4). Therefore, it is suggested that the aeromagnetic interpreted structures are considered to have a low probability of existing in the field.

4.1.4 Surface Geological Features Inspection

BHP Billiton Illawarra Coal (BHP) (Reference 6 and 7) completed an inspection of geological features observed at the surface proximal to the proposed Area 5 and surrounds. The following points summarise the inspection report:

- Previously mapped structures:
  - The dominant joint set strikes between 290 and 310°.
  - Two dykes, oriented east-northeast with strike lengths of approximately 400 m and 1000 m, located near the Avon Dam structure were mapped by C. McElroy and Associates in 1975. They are inferred to intersect the reservoir only.
  - A series of geological structures along Avon Dam Road were mapped in 2012 by Doyle (Reference 7), these include:
    - Two dykes, 1.2 m and 0.25 m wide, oriented northwest-southeast. These two structures do not trend towards the dam structure or reservoir.
    - A 0.5 m thick dyke and minor fault structure 15 m long are located east of the Avon Dam Road. Both structures are oriented northwest-southeast.
- Geological Survey of NSW major structures inferred within Area 5 include:
  - Avon River Lineament.
  - Nepean Monocline.
  - Nepean River Lineament.
  - Cordeaux River Lineament.
  - Narellan Lineament.
  - Unnamed Fault 1.
- Boreholes drilled for exploration in Area 5 were placed away from potential geological structures to optimise the potential coal sample, however, structures have been intersected in numerous boreholes.
- Photographic, linear, residuals, and gradient analyses identified the following:
  - Dominant joint set trends 280 to 305 degrees (°).
  - Offset of lineaments was not observed.
  - Lineaments were probably a strong joint zone, possibly associated with dykes, and not fault related.
  - No evidence of faulting was noted within Area 5.
- A field inspection of geological anomalies was undertaken, with the following points noted:
  - Several dykes were identified which are presented in drawings with symbols displaying recorded orientations.

- No documented faults identified as potentially affecting the proposed mine plan were observable at the surface:
  - Reference 6 states this and supports the normal behaviour of faulting within the Southern Coalfield where faults typically diminish in displacement up sequence to the base of the Hawkesbury Sandstone.
- A fault, with approximately 15 m displacement, was reported east of the Avon Dam Road. The fault was noted as trending south east across Area 5.

The BHP report lists several recommendations to inspect potential geological structures in and around Area 5.

4.2 CSIRO Interpretative Studies

In 1983, the CSIRO conducted a fracture analysis of the Sydney Basin. This analysis resulted in the production of the following plans at 1:100k scale for the Wollongong-Port Hacking area:

- Air photograph interpretation (Reference 8).
- Landsat imagery interpretation (Reference 9).
- Bedrock fracture trends (Reference 10).
- Structural synthesis (Reference 11).

Lineaments based on the interpretation of air-photograph and Landsat imagery are presented in this report. The structural synthesis appears to be the basis for both the 1:100k geological sheets for Wollongong and Port Hacking, and the Southern Coalfield (References 12 and 13).

5. Geological Overview

5.1 Lithostratigraphy

The stratigraphy of proposed Area 5 is invariably documented as the well-recognised Sydney Basin sedimentary sequence. A detailed stratigraphy profile is presented in Figure 1. For the purpose of this review the stratigraphy has been simplified into seven units or intervals:

- Hawkesbury Sandstone (HBSS);
- Newport Formation (NPFM);
- Garie Formation (GRFM);
- Bald Hill Claystone (BACS);
- Bulgo Sandstone (BGSS);
- Stanwell Park Claystone (SPCS) to Wombarra Claystone (WBCS) interval. Where the SPCS is not recognised in sequence the entire sequence (Bulgo Sandstone to Scarborough Sandstone) is known as the Colo Vale Sandstone (SS); and
- Interbedded coal seams and beds from the Wombarra Claystone (WBCS), to the Wongawilli Coal (WWCO) and including the Bulli Coal (BUCO) and other coal units.

In summary, there are essentially two very thick, massive sandstone intervals of HBSS and BGSS which are each underlain by lower strength shale/claystone units (BACS and SPCS/WBCS). This is then underlain with a relatively thinly interbedded interval directly overlying the coal mining horizons (WWCO and BUCO).

The depths of cover above the proposed longwalls in Area 5 (BUCO coal mining horizons) vary between a minimum of 250 m in the southern part of the mining area and a maximum of 390 m in the north-eastern part of the mining area (Reference 15). The average depth of cover within the mining area is 360 m (Reference 15).

The uppermost units are HBSS and the Narrabeen Group comprising sandstones and claystones. Maximum thickness of HBSS is generally accepted to be approximately 160 m. Reference 5 states this thickness is generally less than this in the study area due to erosion and incision, being an average of only 110 m at Area 5.

GROUP		FORMATION	Thickness (m)
Hawkesbury Sandstone			Up to 120
Narrabeen Group		Newport Formation	10
		Garie Formation	3
		Bald Hill Claystone	12
		Bulgo Sandstone	95
		Stanwell Park Claystone	20
		Scarborough Sandstone	30
		Wombarra Shale	25
		Coalcliff Sandstone	15
Illawarra Coal Measures		BULLI COAL	1.5
	Eckersley Formation	Unnamed Member	10
		Balgownie Coal Member	1
		Lawrence Sandstone member	9
		Cape Horn Coal Member	0.3
		Unnamed Member	1
		Hargrave Coal Member	0.1
		Unnamed Member	3
		WONGAWILLI COAL	9.4
		KEMBLA SANDSTONE	14
	Allan's Creek Formation	American Creek Coal Member	3
		Unnamed Member	27
		APPIN FORMATION	
		TONGARRA COAL – Upper Split	2
		TONGARRA COAL – Lower Split	0.5
	Wilton Formation	Unnamed Member	15
		Woonona Coal Member	4
		Unnamed Members	26
		ERINS VALE FORMATION	
		PHEASANTS NEST FORMATION	
		Fig Tree Coal Member	0.5
		Unnamed Member	20
		Unanderra Coal Member	2
		Unnamed Member	>84

GRAPHIC

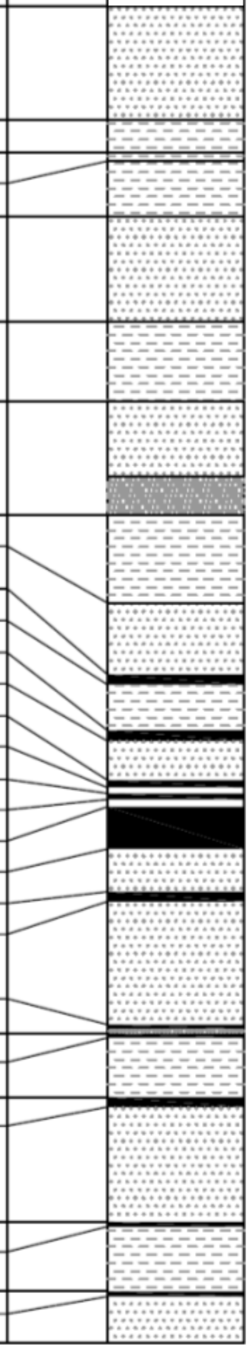


Figure 1: Stratigraphic profile (Reference 16)

5.2 Site Characteristics and Geomorphology

The Project underground mining area is situated on the Illawarra plateau and is located adjacent to the Avon Reservoir. There are a small number of access roads within and proximal to the Project underground mining area through natural bushland which are controlled by WaterNSW (i.e. access is restricted to the public). The study area is covered by dry sclerophyll forest and dense eucalypt bush.

The geomorphology of the area is described as deeply dissected plateaus. The plateaus are primarily HBSS, incised down to the claystones, such as the BHCS in parts of Wongawilli Creek and within Avon Reservoir. Most outcrops noted across the plateau in earlier investigations were HBSS. The geomorphology of the study area is likely controlled by the massively-bedded HBSS and joint sets. Figure 2 presents a long section with vertical exaggeration through Dendrobium Areas 1, 2, 3A and 3B to illustrate the surface profile and surficial units.

The arms of the Avon and Cordeaux Reservoirs and Wongawilli Creek form the main dissecting valleys across the study area as seen in Drawing 1.

Deep valleys and gorges are dominated by structure. Short, moderately spaced joints appear to control the shape and orientation of the valley edges.

5.3 Folding

Regionally, the Southern Coalfield consists of a broad syncline with a north-south to north northwest trending axis. Dips associated with this folding are commonly below 2° and rarely exceed 5°. The regional context indicates the stratigraphy above the Bulli Seam dips gently to the north-northwest, on average about 0.5 to 1° (References 17 and 18).

The study area is bounded by two fold axes: to the west by the Camden Syncline, and to the east by the Kemira Anticline, Drawing 5 (Reference 11). Although the site is close to several fold axes, folding of the basinal rocks is gentle and is typically less than 10°. The maximum bedding dip recorded during the PSM site visit was less than 3°.

The Nepean Monocline and Camden Syncline are projected to converge near the Avon Dam structure. A noticeable change in bedding orientation was not observed along the eastern edge of the northern portion of Avon Reservoir nor near the eastern abutment of the dam structure. The Nepean Monocline may project into Area 5, but no evidence of change in bedding orientation was observed by PSM.

5.4 Faulting

Regional faulting is dominated by normal faults trending sub parallel to the regional fold axes in a northwest to north-northwest orientation. Subordinate strike slip and reverse (low angle) thrust faults are also known to occur in the Southern Coalfield but occur less frequently than normal faulting.

The Lapstone Structural Complex, which includes the Lapstone Monocline, is a major north-trending association of monoclines and faults that forms the frontal ridge of the Blue Mountains Plateau (Reference 19). Faults associated with this complex are located less than 20 kilometres (km) to the west of the Project.

Large regional scale faults have been drawn across the study area in the Southern Coalfield 1:100k geological sheet (Drawing 5 and Reference 11).

Locally, faults and fault zones have been identified by IMC using a range of field exploration techniques such as surface boreholes, seismic surveys, and aeromagnetic surveys.

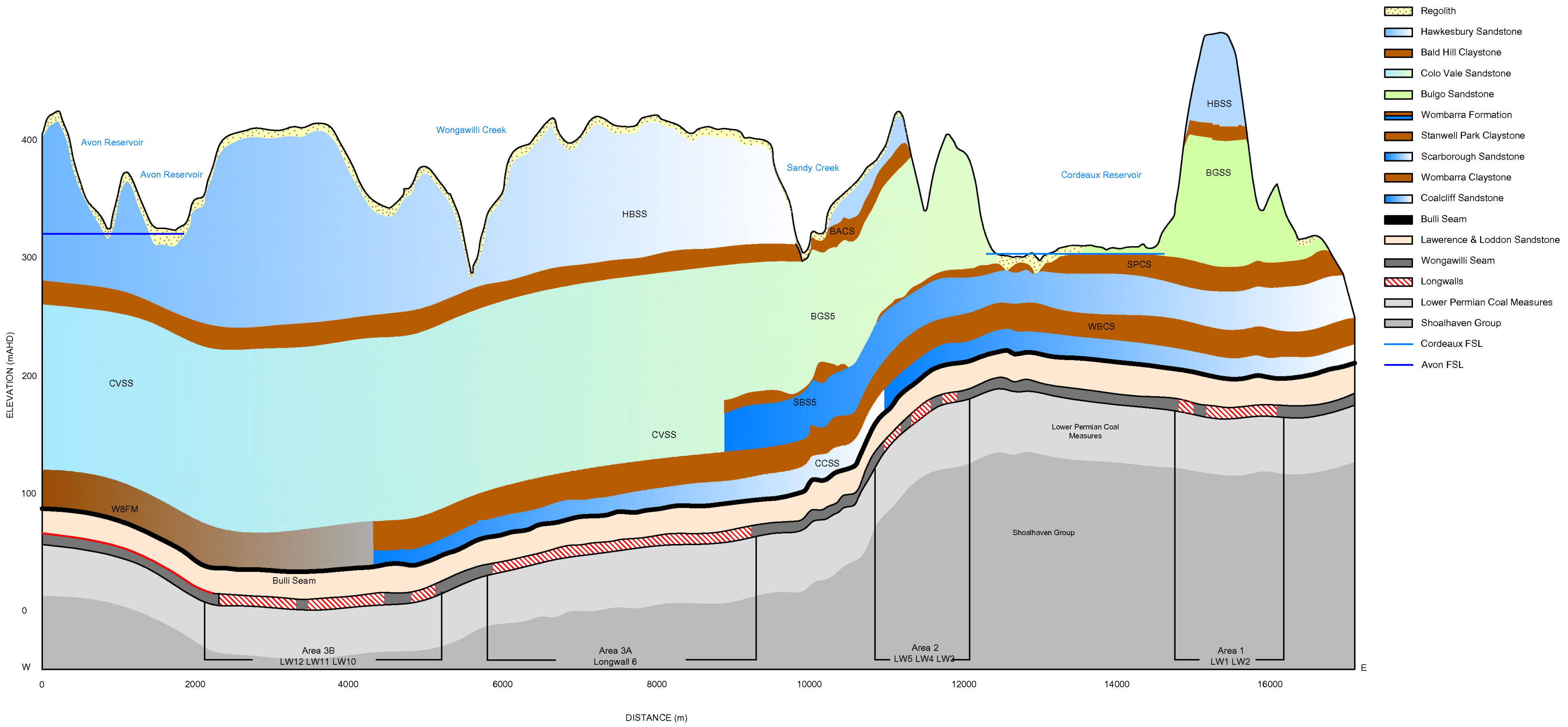
This section presents and discusses known faults that occur in the vicinity of Area 5 (Drawing 6).

6. Site Visit

PSM's Daniel Strang, Associate Engineering Geologist and Angela Mabee, Engineering Geologist, conducted a site visit on 19 February 2019. Drawing 7 presents the tracks covered and the locations of geological structures observed during the site visit. The purpose of the site visit was to inspect Area 5 and surrounding areas to identify and describe any geological structures along accessible tracks and trails at the surface.

Areas inspected during the site visit include:

- the northern portion of the Avon Reservoir (eastern edge) by drone;
- publicly accessible areas around Cordeaux Reservoir dam wall;
- cuttings along fire trails (6, 6b, and 6x);
- a 1.3 km portion of the disused Maldon-Dombarton Rail Line; and
- exposures of rock in creek beds along Fire Trail 6.



Regolith
Hawkesbury Sandstone
Bald Hill Claystone
Colo Vale Sandstone
Bulgo Sandstone
Wombarra Formation
Stanwell Park Claystone
Scarborough Sandstone
Wombarra Claystone
Coalcliff Sandstone
Bulli Seam
Lawerence & Loddon Sandstone
Wongawilli Seam
Longwalls
Lower Permian Coal Measures
Shoalhaven Group
Cordeaux FSL
Avon FSL
Avon Reservoir
Avon Reservoir
Wongawilli Creek
Sandy Creek
Cordeaux Reservoir
HBSS
BACS
BGS5
SBS5
CCSS
CVSS
CVSS
W8FM
Bulli Seam
SPCS
WBCS
HBSS
BGSS
Lower Permian Coal Measures
Shoalhaven Group
Area 3B
LW12 LW11 LW10
Area 3A
Longwall 6
Area 2
LW5 LW4 LW3
Area 1
LW1 LW2
ELEVATION (mAHD)
400
300
200
100
0
W
E
0
2000
4000
6000
8000
10000
12000
14000
16000
DISTANCE (m)

The bushland at the site is densely vegetated. Field observations were restricted to just a few metres either side of the trail where rock outcrops were observed.

Relevant photographs and figures derived from the site visit are presented throughout this report.

7. Geological Structure Review

7.1 General

PSM's review included examination of:

- borehole data for evidence of geological structure;
- known and inferred faulting;
- Igneous intrusions;
- lineaments; and
- jointing.

Data was collated from surface and underground mapping, drilling (both surface and in seam) as well as geophysical and LiDAR surveys. Each of the elements examined is discussed in more detail below.

7.2 Borehole Interceptions

Previous studies and field inspection reports completed by IMC (summarised in Section 4) identify multiple boreholes that have intersected geological structures of note, as summarised in Drawing 7. Structural data provided by IMC is summarised in Appendix A and Appendix B.

PSM has completed a high-level review of the structural borehole data provided by IMC whereby potential "major" structures were assessed prior to ground truthing. An initial filter by defect type for "fault" includes 612 records from 93 boreholes. Furthermore, major geological fault structures are typically characterised by a high strain fault core. As such, these can be expected to include significant zones of fault gouge or other lower strength infill such as clay. On this basis the structural data provided was assessed based on infill type and thickness to identify potential structures of interests.

Our assessment of the structural data indicates the following:

- 574 discrete structures had no infill.
- 37 structures had an infill thickness of 1 mm or more.
- 15 structures had an infill thickness of 5 mm or more.
- 10 structures had an infill thickness of 10 mm or more, the breakdown being:
  - S2358 had 6 structures.
  - S2370 had 2 structures.
  - S2353 had 1 structure.
  - S2324 has 1 structure (located between the mine and Avon Reservoir).
- 5 structures had an infill thickness of 20mm or more, the breakdown being:
  - S2358 had 4 structures.
  - S2353 had 1 structure (20 mm).
- The maximum infill thickness was 90mm (S2358).

Where available, borehole logs and borehole imaging records from the selected holes were reviewed for evidence of major structures. As mentioned above, major structures would be expected to incur an extended zone of disruption within the rock mass. No evidence of major structures (continuous zones of high strain faulted core) was identified in our review of the available borehole data with a single maximum infill thickness of 90 mm.

Core photographs, logs, or televiewer images were not available for all boreholes identified with structures. A list of these holes is summarised in Appendix A. PSM are unable to verify these structures nor comment on the potential for these to impact the surface during mine subsidence where this data is unavailable.

The only borehole with identified structure containing a defect infill of 10 mm or more was borehole S2324, located between the proposed Area 5 longwall footprint and the Avon Reservoir.

7.3 Faulting

7.3.1 Regional Faults

The regional faults described herein are based on published geological sheets (References 12 and 13). The basis for regional faults inferred in published maps is unknown as they could be informed by as little as desktop review and projection. One unnamed regional fault extends through Area 5 with no basis for interpretation or sense of movement provided in References 12 and 13. Therefore, confidence in these published structures is low. Drawing 5 presents the location and extent of published faults.

Unnamed Fault 1 strikes northeast across both Area 5 and the Avon Reservoir. The fault trace does not appear to align with depressions or ridges identified in the topographic surface, and the basis for the fault is unknown. IMC have conducted numerous seismic lines across this feature in order to prove its existence – no displacement has been observed. Therefore, this inferred structure is unlikely to be present and was consequently excluded from further assessment.

Unnamed Fault 2 strikes north-northwest east of Cordeaux Reservoir. Similarly, oriented dykes have been found in this location.

The fault trace for Unnamed Fault 3 terminates on the western bank of Avon Reservoir, however this fault trace may be extended across the reservoir to the east bank.

These three regional faults were not observed during the PSM site visit, nor do they align with structures mapped at the surface by others.

7.3.2 Mine Scale Faults

Several mine scale faults have been identified across the study area and their existence is considered to be more reliable than the regional scale faults inferred in published geological sheets. Numerous small structures have also been identified in exploration drill core. Drawing 6 present mine scale faults inferred by IMC for Area 5.

No evidence of major faulting has been identified within the Area 5 study area and is relatively unstructured in comparison to the Elouera area to the south. This is supported by seismic interpretation, exploration drilling and surface to inseam (SIS) exploration holes. These have shown indications of elevation changes but no obvious faulting. Many of the elevation changes and variations are caused by sills and intrusions.

Fault characteristics described below were largely provided by IMC.

DF20

> *Dendrobium Fault 20 (DF20) is interpolated from indications in the Wongawilli underground mapping, faulting in borehole S0705 and from changes in elevation in one of the branches of borehole S2112 SIS. It is also drawn parallel to the projected dyke DD27. The large change in strata elevation around borehole S2483* are also likely related to this structure. The main change is likely due to the intrusions in that area. However, faulting is also likely involved as suggested by scanner interpretations strongly favouring this general orientation.*

DF40

> *Dendrobium Fault 40 (DF40) is interpreted from seismic data. The interpretation is of lower confidence with minimal orientation confidence. This fault is located on the edge of a seam floor slope which may be related to the sill DS6 or the dyke DD33. The strike of this fault is variable, as it is only picked up in one seismic line. It has been drawn to best highlight the case orientation for the project.*

DF41

> *Dendrobium Fault 41 (DF41) is interpreted from seismic data comprised of two structures forming a localised graben. This structure was not observed on adjacent seismic lines providing minimal orientation confidence. On this basis it is assumed a small scale feature and of low confidence.*
>
> *The details in the seismic line may be related to a sill rather than a fault, however, no intrusions are indicated in the surrounding boreholes S2414, S2325 for this area.*

7.4 Igneous Intrusions

The Southern Coalfield is known to have igneous rocks intruded into the basinal sedimentary rocks such as dykes, sills, plugs and diatremes.

Dykes are the most commonly observed volcanic intrusion and are generally coincident with the orientation and frequency of regional faults and fold axes. They are typically sub vertical, around 3 m in width, but known to reach up to 15 m wide, and reach up to 5 km in length (Reference 17).

The following sources of information were assessed for the occurrence of igneous intrusions:

- Published Maps:
  - One dyke is shown on the published 1:100k geological sheet (Reference 11), which is a north or northwest trending dyke between 4 km and 5 km long and about 3 km northeast of Area 5.
- Surface Mapping:
  - Dykes and plugs have been identified at the surface over the last 100 years of exploration and land development (Reference 6 and 7).
- IMC Investigations:
  - IMC have conducted airborne aeromagnetic and radiometric surveys of the site to identify geological structure.
  - Exploration drilling has intersected several sills and dykes.

Drawings 8 and 9 present the location, extents, and orientations of known igneous intrusions. Evidence for these intrusions was derived from one or a combination of the above sources of information as presented and discussed below.

7.4.1 Dykes

Several dykes are inferred and/or proven to exist within the project area and are presented in Drawing 8 along with dyke interpretations from airborne magnetometers. Dyke interpretations from airborne magnetometers has had limited success in identifying a contrast between the host rock and the igneous intrusions. This is further complicated in Area 5 where widely spread sills are present.

Apart from dyke DD33, large persistent dykes identified within the study area do not align with regional or PSM derived lineaments indicating the identified dykes may not extend to the surface.

Dykes identified with associated character descriptions as provided by IMC within the Area 5 study area are summarised below in italics and are presented in Drawing 8, denoted with the prefix 'DD'.

DD9

DD9 is an extensive dyke series extending across from Areas 3B/3C, where it has been laterally drilled and mined through. This dyke series can be relatively stiff and thick in some areas. Within the project area it is interpreted to terminate at the bottom eastern edge of the proposed mine design. The last indication of this dyke was in boreholes S2381 and S1796. There are no other indications.

DD22

DD22 is projected across the South, from evidence captured in Wongawilli underground drilling. This dyke lines up with intrusions logged in the WW/American Creak seams of borehole S2425, however these are more likely to be sills than dykes. This dyke is low confidence in direction and size with minimal supporting evidence.

DD25

DD25 is an extensive dyke series crossing Areas 3C/3B, where it parallels or originates from DD9. This dyke can also be relatively stiff and thick in some areas. In the project area it is inferred to have been intersected in drift drilling (borehole S2483) together with numerous other contacts in this area. The direction and size heading into the project area to the west is unclear with no further indications.*

DD27

> *DD27 is mapped in Wongawilli TG9 and projected through borehole S0705 to the north. This dyke may be part of a larger dyke or sill upwelling surrounding the eastern boundary of the proposed Area 5 mine design. This dyke is also interpreted to be part of a dyke mapped in Wongawilli underground workings and shown to the east and also connected to DD33 further to the north. There are no other indications within the project area.*

DD33

> *Dyke DD33 is projected along the eastern boundary of the proposed Area 5 mine design. This dyke has been inferred from aeromagnetic interpretations as a very strong feature and may have acted as a feeder to the intrusive bodies (Reference 20). It is not indicated further to the west, however, it may relate to other faulting and seam elevation changes along this eastern boundary.*

This dyke also aligns with the regional scale Narellan Lineament and associated valley, PSM derived lineament and the eastern edge of Area 5, Drawings 5 and 10.

Photo 1 shows a 200 mm wide dyke, located 380 m east of DD33 of which the minor dyke parallels. These are strong indicators the dyke shown in Photo 1 extends from seam to surface.

Photo 1: Dyke, approximately 200 mm wide, observed by PSM during site visit.

DD35

This is a low confidence dyke suggested from the high angle of intercept of intrusions in borehole S2397. The intrusions were intersected in the lower Wongawilli coal seam and are likely sills.

No other indications of the dyke are noted in the data provided.

DD36

DD36 is striking east/west in the centre. It has been intersected in borehole S2391 in the American Creek seam and has reasonable confidence in the east/west orientation gained from scanner interpretation.

There is no indication of thickness of this dyke from the borehole log.

DD37

DD37 is to the north of DD36 and striking east/west in the centre of the project. This dyke has multiple vertical intersections in borehole S2393 and has been intersected in the SIS hole S2480. In this SIS drilling, the dyke was around 3 m thick and of moderate strength (greater than 70 MPa based on testing). This dyke was previously inferred to be related to DD9. However, since the SIS drilling was undertaken DD9 has been found to be a separate feature trending more east/west. Intrusion intersections found in borehole S2370 may be related to this dyke. The eastern extent is uncertain, with no clear intersections from boreholes drilled inline (i.e. borehole S2348).

DD40

No clear evidence of DD40 was found in borehole data, suggesting the existence of this dyke is based entirely on aeromagnetic interpretation.

DD41 and DD42

Dykes DD41 and DD42 originate from NSW Geological Survey 1:100,000 Southern Coalfield Geological Sheet 1999 and projections from mapped exposures. Dyke DD41 appears to correspond with indications in aeromagnetic imagery.

Dyke labelled DD42 is based on a 2 m wide dyke mapped 2 km north of Area 5. IMC have projected the dyke along strike intersecting the corner of Area 5 based on the single mapping point only. No secondary evidence at this stage has been found from either drilling or seismic interpretations. Therefore, confidence in the existence, strike length and orientation of these dykes within Area 5 and near Avon Dam is low.

A6DEW1 and A6DEW2

East-west striking dykes (A6DEW1 and 2) are based on IMC mapped underground intersection in the Corrimal workings.

Photo 2 presents a typical dolerite dyke intersected in a vertical borehole. The dolerite appears fresh with a sharp contact with the surrounding sandstone. Basaltic lavas are generally under pressure when being emplaced, which, if sufficiently high, can generate its own fracture network within the host rock (Reference 16). More commonly, magma exploits existing fractures such as faults and joints, which is likely in the case of the Bulli Fault.

Photo 2: Example of a dolerite dyke intersected in borehole S2393 at approximately 340 m depth.

7.4.1 Sills

Area 5 is affected by several large mostly doleritic sills that have been identified by numerous vertical exploration boreholes. Most of the sills occur within the Illawarra Coal Measures, stratigraphically below the level of the Bulli Seam. However, there are at least three known locations of sills within the Bulli Seam.

There are significant sills underlying the Bulli Seam in the Balgownie, Cape Horn, Wongawilli, American Creek and Tongarra Seams or the interburden between these seams. Some of these sills are significant in both thickness and extent, with one borehole intersecting particularly thick and pervasive sill between the American Creek and Tongarra Seams having a thickness in excess of 40 m (Reference 7).

Intersected sills present with variably levels of alteration, generally, thinner sills (less than 3 m thick) are completely altered to clay, and thicker sills (greater than 3 and up to 40 m thick) are fresh (Reference 7). Photo 3 presents an example of the “Bulli Sill” (less than 3 m thick at this location) as intersected in borehole S2368.

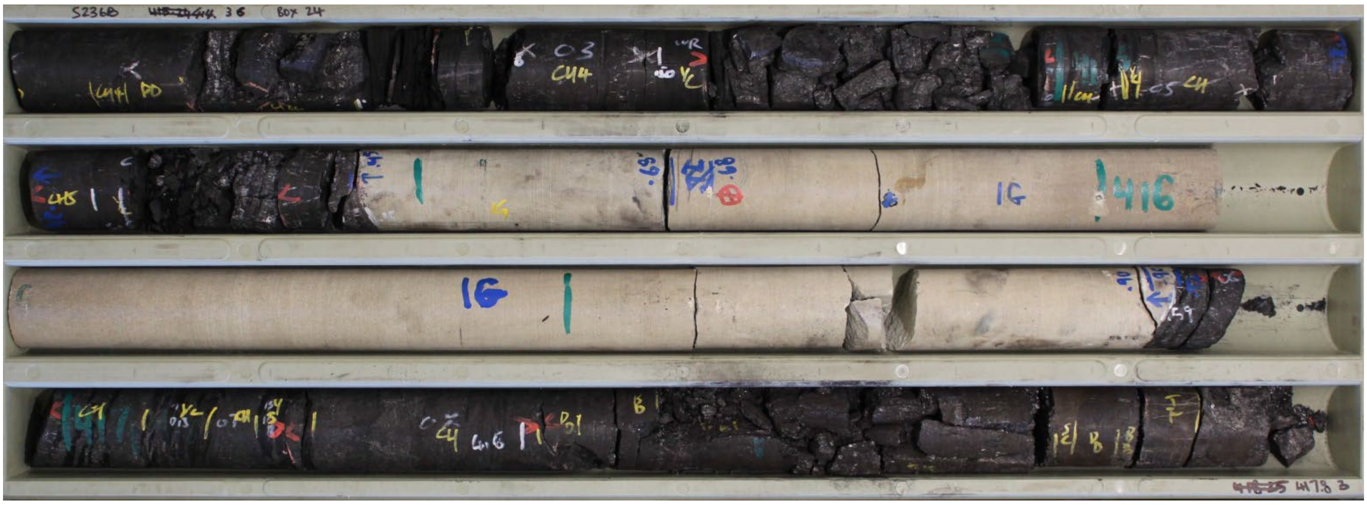


Photo 3: Example fresh dolerite sill in borehole S2368 at approximately 416 m.

Sills identified by IMC within the Area 5 study area are summarised below and are presented in Drawing 9, denoted with the prefix ‘DS’. The characteristics of sills summarised below were provided by IMC.

DS5

Dendrobium Sill 5 (DS5) was first indicated with seismic interpretation and later intersected in borehole S2344. There are numerous indications above and below the Bulli Seam in the surrounding holes S2348, S2449, S2347 and S2467.

DS6

Dendrobium Sill 6 (DS6) is interpreted to be a single large sill within the Bulli Seam, intersected by numerous boreholes and interpreted from several seismic lines.

DS7

Dendrobium Sill 7 (DS7) is intersected by boreholes S2431 and S2430, with an indication of size/extent from seismic interpretation.

DS8

Dendrobium Sill 8 (DS8) surrounds the project area to the north, to the west and to the south. There are numerous boreholes that intersect the sill. The extent is poorly defined and only a coarse interpretation of the boundary.

7.5 Lineaments

Lineaments are linear topographic features, such as defined breaks in slope, linear ridges and valleys that may represent an intersection with major structures such as faults, shear zones, dykes, or joints.

Drawings 10 and 11 present the regional lineaments (based on published geological sheets) and lineaments identified by PSM.

7.5.1 Regional Lineaments

Regional lineaments are based on published lineaments, namely the Southern Coalfield 1:100k geological sheet (Reference 12), as presented in Drawing 10. Lineaments crossing the study area include:

- Narellan Lineament – aligns with the eastern edge of Area 5.
- Cordeaux River Lineament – traverses the middle of Area 5.
- Avon River Lineament – located west of Area 5.

All three regional lineaments strike north-south and align with valleys at the surface.

7.5.2 PSM Lineament Assessment

A lineament assessment has been conducted over the study area to identify potential geological structures not identified in other data sources, Drawing 10. The lineament assessment was based on topographic surface interpretation only, this being a resolution of 1 m contours. The topographic surfaces were rotated in 3D and viewed from different angles to ensure that major lineaments were identified, and any potential bias was minimised.

The common lineament orientations were found to trend northwest, north, and northeast. Some identified lineaments align with identified faults, dykes, and regional lineaments.

7.5.3 CSIRO Lineaments

The CSIRO conducted lineament assessment of aerial photographs (Reference 8) and Landsat imagery (Reference 9). These plans have been scanned, digitised, and presented in Drawing 10. The accuracy of the lineaments is questionable due to the digitising process.

Some inferred structures align with lineaments identified by PSM and structures inferred by IMC. This may indicate structures that are persistent from seam to surface.

7.5.4 Comparison of Lineament Interpretations with Identified Structures

Table 1 presents the structures that align with lineaments.

Table 1: Summary of Structures and Aligning Surficial Lineaments

Structure	Aligning Lineament
A5FW3	PSM
	CSIRO Air Photo Interpretation
DD33	PSM
DD41	CSIRO Landsat Imagery Interpretation

7.6 Jointing

Jointing was observed at several exposures across the site as part of this review. The orientations correspond to the two major joint sets, namely sub vertical joints striking northwest and north (Reference 10). This is consistent with joints mapped in Area 3B to the south of the study area (Reference 16), where northwest striking joints are considered the master joint set, with the north-south striking set being the conjugate set.

The joints observed within the study area were typically planar and often terminated against bedding partings, see Photo 4. Generally, the persistence of joints was no greater than 10 m (Photo 5).

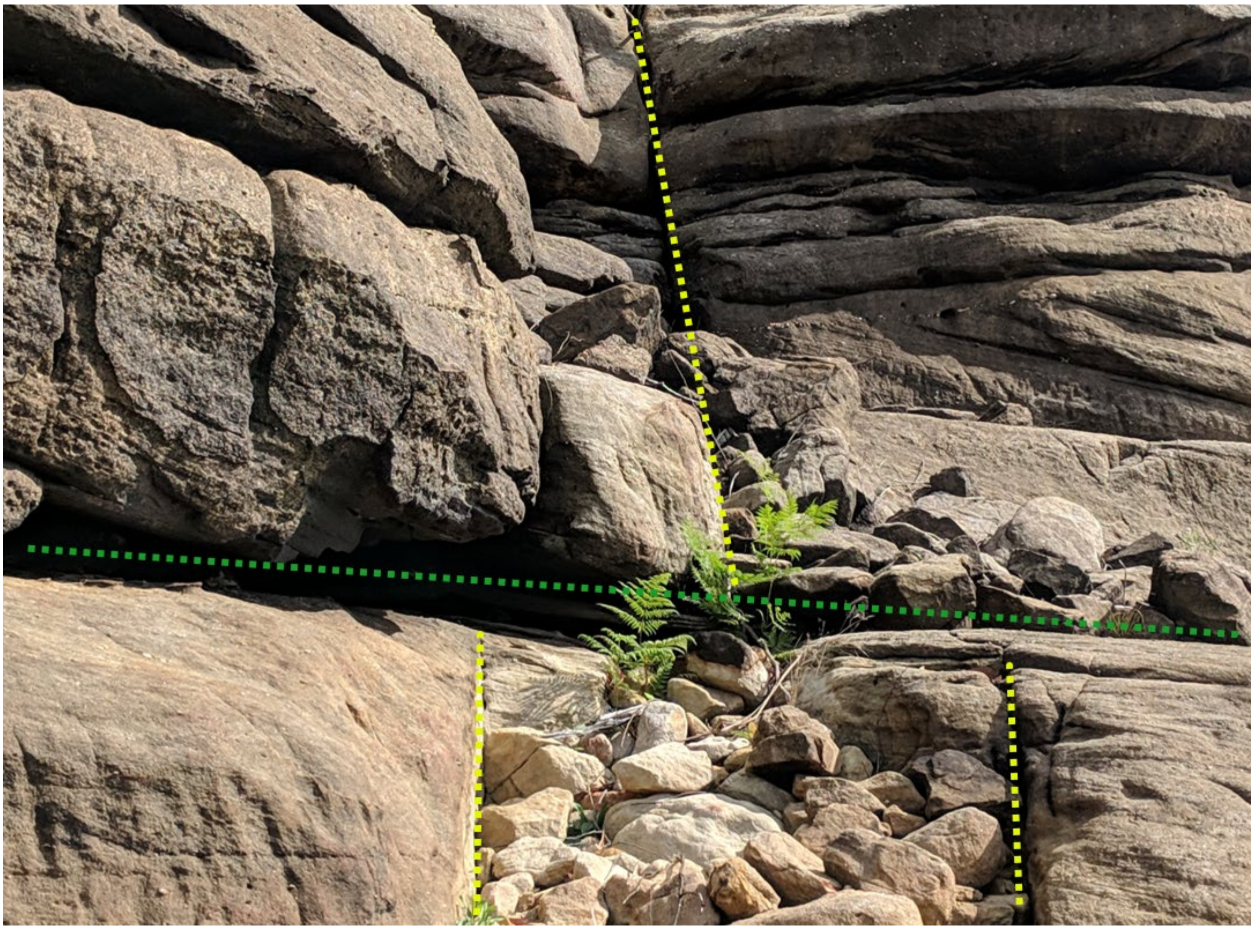


Photo 4: **Example of typical sub-vertical joints (yellow) terminating against a horizontal bedding parting (green) near northeast shore of Cordeaux Reservoir.**

Photo 5: **Joints (indicated by yellow arrows) striking northwest spaced approximately 3 m on northwest shore of Avon Reservoir.**

PSM consider it is unlikely that the joints observed at the surface persist to seam level.

8. Potential Interaction between Dams and Mine Subsidence

This section presents the geological structures identified within the study area that could lead to interaction between Area 5 mine subsidence and the Avon Reservoir and associated dam wall. This section aims to satisfy the relevant Project SEARs and the requirements of WaterNSW, these being:

- Project SEARS – Key Issues (page 4).

  2. Subsidence *– including:*

  – *a review of the local and regional geological setting, including identification and characterisation of geological structures and lineaments within the proposed mining area;*
- Agency Advice – WaterNSW requirements of project SEARS, Attachment B (Page 7):
  – *the location, mapping and nature of any geological structures including faults, dykes, silts* [sic]*, and other intrusions*

8.1 Assessed potential

Drawing 11 presents all identified and inferred geological structures and mapping points. The following structures cross from the mining area to the dam or reservoir:

- IMC inferred dyke DD42 near Avon Dam – if projected further, or with an easterly deviation may cross the proposed Area 5 footprint and Avon Reservoir.
- PSM derived lineaments:
  – A5LNE1 (possible extension of regional scale Unnamed Fault 3).
  – A5LNE2 (crosses Avon Reservoir and immediately south of Area 5).
  – A5LNE3 (if trend projected may cross into the Avon Reservoir).
  – A5LNE4 (crosses Avon Reservoir and area immediately adjacent to proposed Area 5 mine design).

Dyke DD42 inferred across Area 5 is based on a solitary mapping point 2 km north of Area 5. There is no evidence supporting the inference of this dyke across Area 5 or extending to Avon Dam or Reservoir. The structure was not observed in cuttings where the dyke is projected during the site inspection undertaken as part of this assessment. Based on the lack of direct evidence, the dyke is unlikely to project into the Avon Dam or reservoir from seam to surface.

The PSM derived lineaments are based on topographic expressions. No evidence has been identified suggesting these are major geological structures persistent from seam to surface.

Based on the information provided, there is no strong evidence suggesting there are geological structures persistent from seam to surface which would be affected by Area 5's mine subsidence.

9. Discussion

In order to provide certainty for mine planning, IMC has undertaken surface-based exploration, including boreholes, 2D seismic surveys, and aerial magnetic surveys. The surface-based exploration techniques are used to infer or identify faults, dykes, and sills as a basis for mine planning. The exploration techniques define areas of relatively undisturbed ground suitable for longwall mining, and the location of major structures which delineate mining domains but do not necessarily identify whether structures are hydraulically charged.

In addition to surface-based exploration, the Dendrobium Mine operation relies on in-seam exploration to collect information on the character of geological structures. This exploration activity is conducted during operations; therefore, the information is not available prior to approval for the Project and development of roadways (i.e. approval of the Project would be a prerequisite for the development required to conduct in-seam exploration).

In-seam drilling is routinely undertaken between development roadways and the reservoirs within the Dams Safety NSW Notification Area and exploration is used to define:

- Geological structure extent and character - the location (margin and extent) of a geological structure that was not detected by the surface exploration techniques (e.g. sills or dykes with no magnetic signature or faults smaller than the resolution of the surface exploration techniques).
- Pore water pressure due to geological structure - whether the area in advance of the development is hydraulically charged due to a geological structure. In-seam drilling is undertaken through standpipes to control high pressures should a zone of high pore water pressure be intersected.

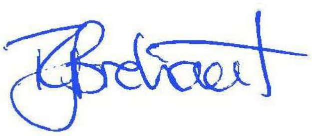
After in-seam drilling has been completed, newly inferred structures are identified and added to the geological model prior the mining of development roadways. The roadways allow access for geological and geotechnical mapping of structures as well as recording water inflow. The mapping enables the extent of the longwall to be further refined by adding additional detail such as fault displacement, sense of movement, or geotechnical instability due to associated jointing.

10. Recommendations

Recommendations for post Project approval exploration activities for identifying potential structures linking the mining area and reservoirs include:

- Area 5 and Avon Reservoir and dam wall:
  - Future exploration boreholes should be inclined towards possible structures and drilled diamond core from surface with televiewer conducted over the entire borehole. This is especially relevant to any drilling undertaken within proximity of the following boreholes identified to contain defect infills of greater than 10 mm thickness, these boreholes being:
    - S2358.
    - S2370.
    - S2353.
    - S2324.
  - Undertake UIS drilling from underground workings, similar to current Dams Safety NSW requirements between Lake Avon and Area 3B. This in seam exploration is more likely to identify previously unidentified structures traversing Area 5 and the Avon Dam Wall structure and Reservoir.
  - Mapping of geological structures at the Avon Reservoir full supply level, and around the Avon Dam Wall structure to provide additional confidence of the persistence of projected structures identified within this assessment. This would be particularly relevant for structures such as DD24 (Drawings 8 & 11) that are shown to cross the Avon Reservoir but not projected to continue toward the Area 5 footprint. Confirmation of the features termination would increase confidence.

Yours Sincerely



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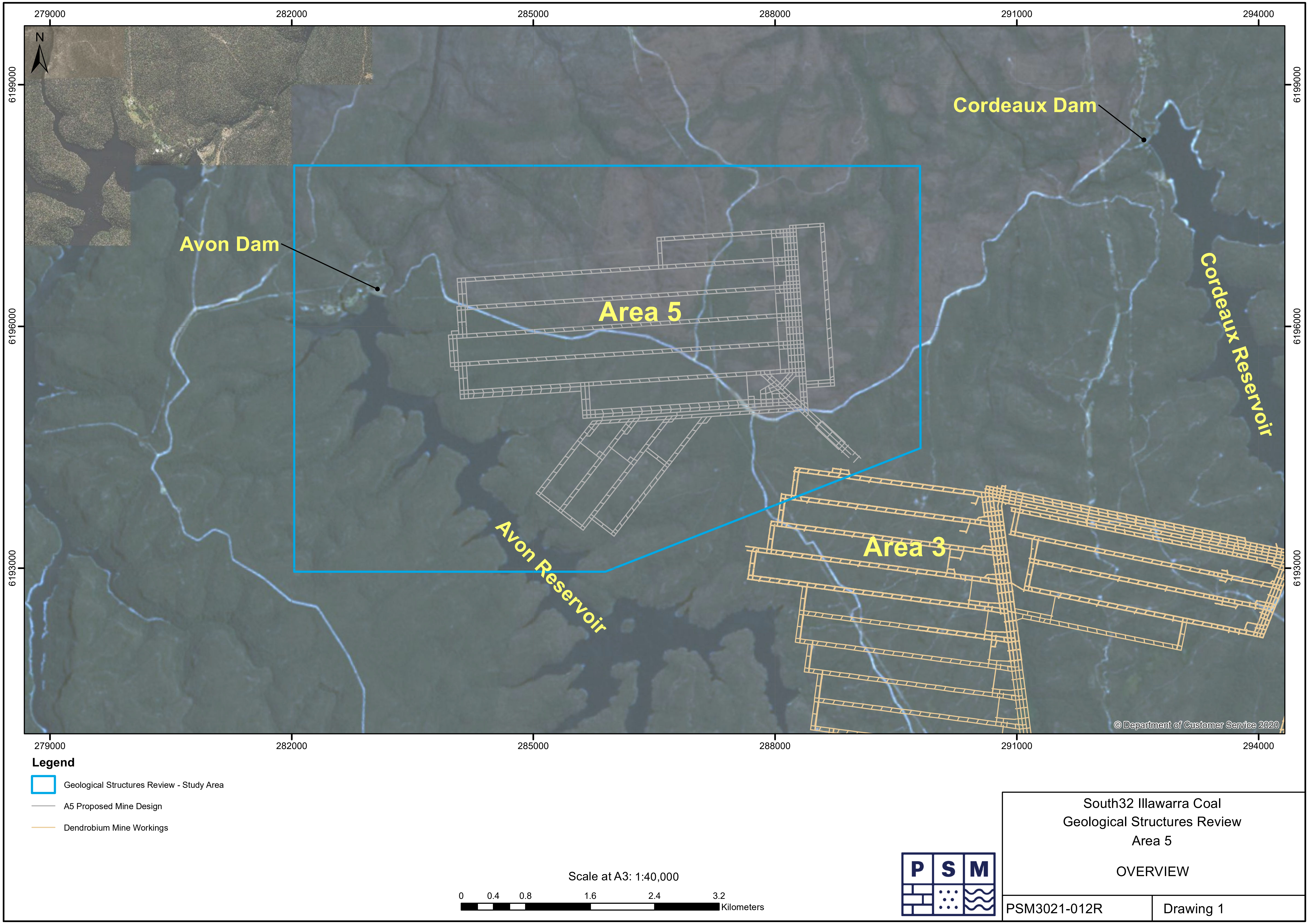
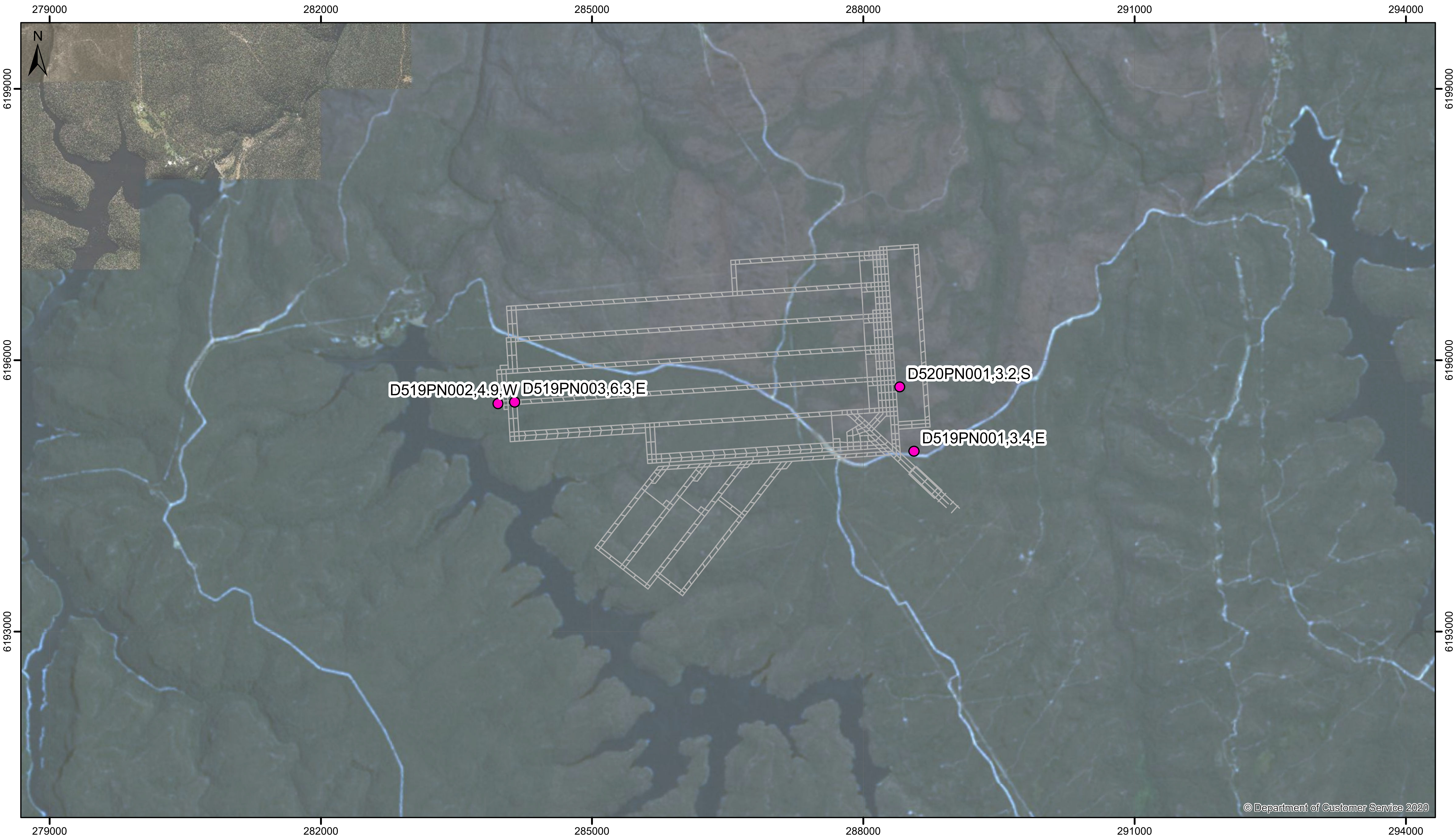


South32 Illawarra Coal
Geological Structures Review
Area 5

OVERVIEW

PSM3021-012R	Drawing 1



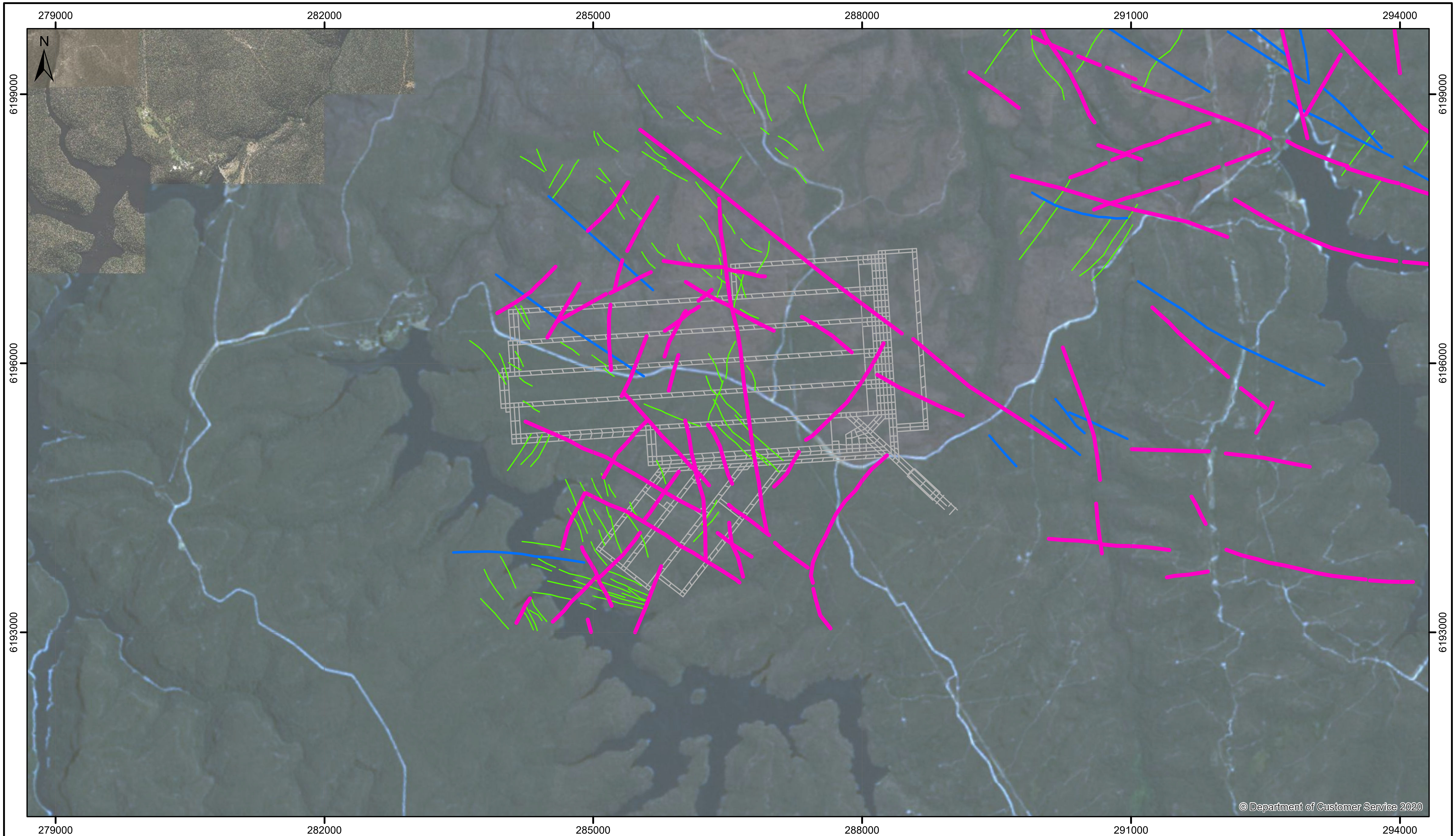
Legend

2020 Area5 Seismic Interpretation - Fault Locations

Scale at A3: 1:40,000

0 0.4 0.8 1.6 2.4 3.2 Kilometers

South32 Illawarra Coal Geological Structures Review Area 5 FAULT LOCATIONS 2020 SEISMIC INTERPRETATION	
PSM3021-012R	Drawing 2



Legend

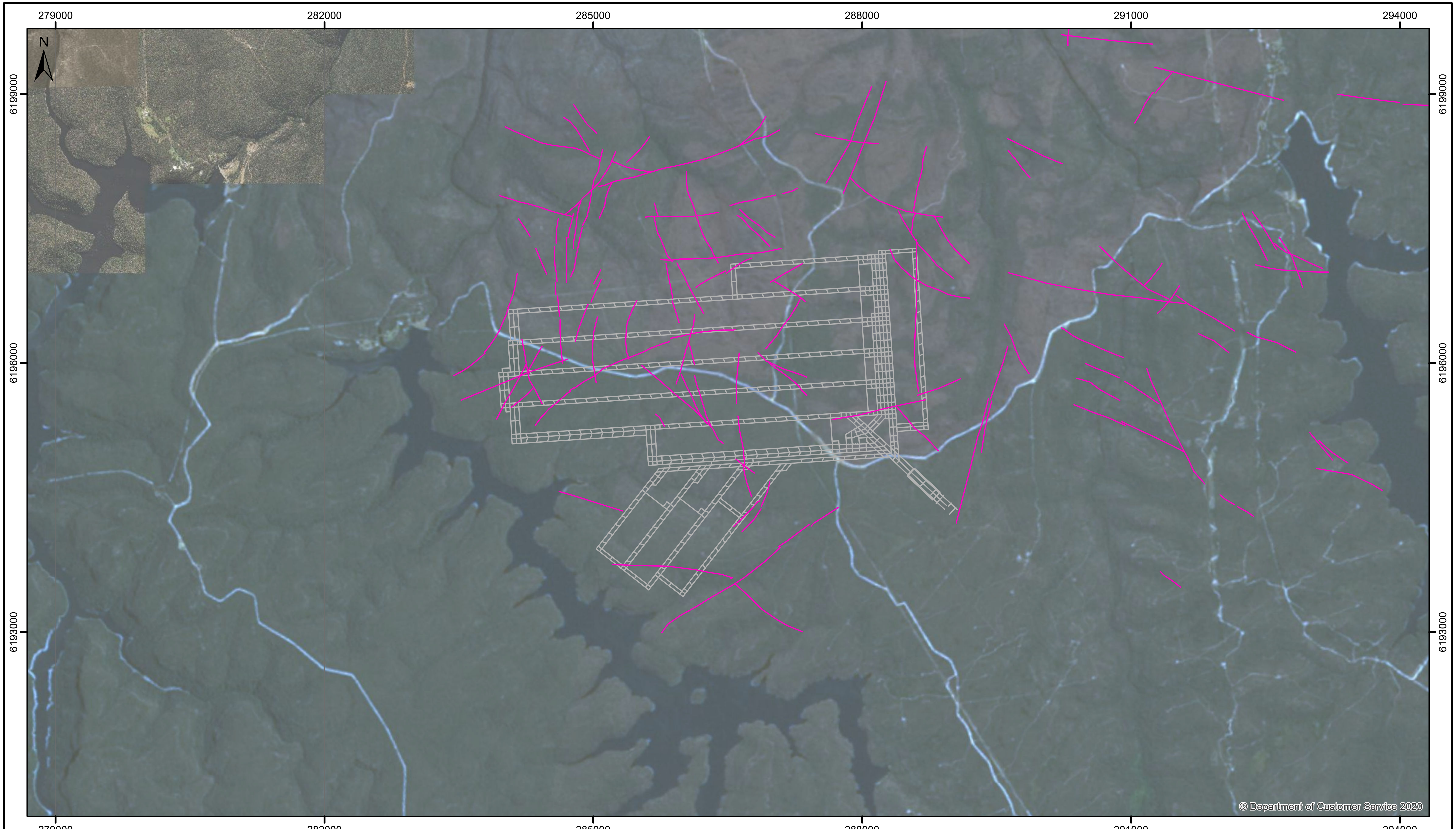
- Faults
- Joints
- Bedding

Scale at A3: 1:40,000

0 0.4 0.8 1.6 2.4 3.2 Kilometers

South32 Illawarra Coal
Geological Structures Review
Area 5
INFERRED STRUCTURS
2020 AEROMAGNETIC INTERPRETATION

PSM3021-012R	Drawing 3



Legend

Possible Faults 2018 Interpretation

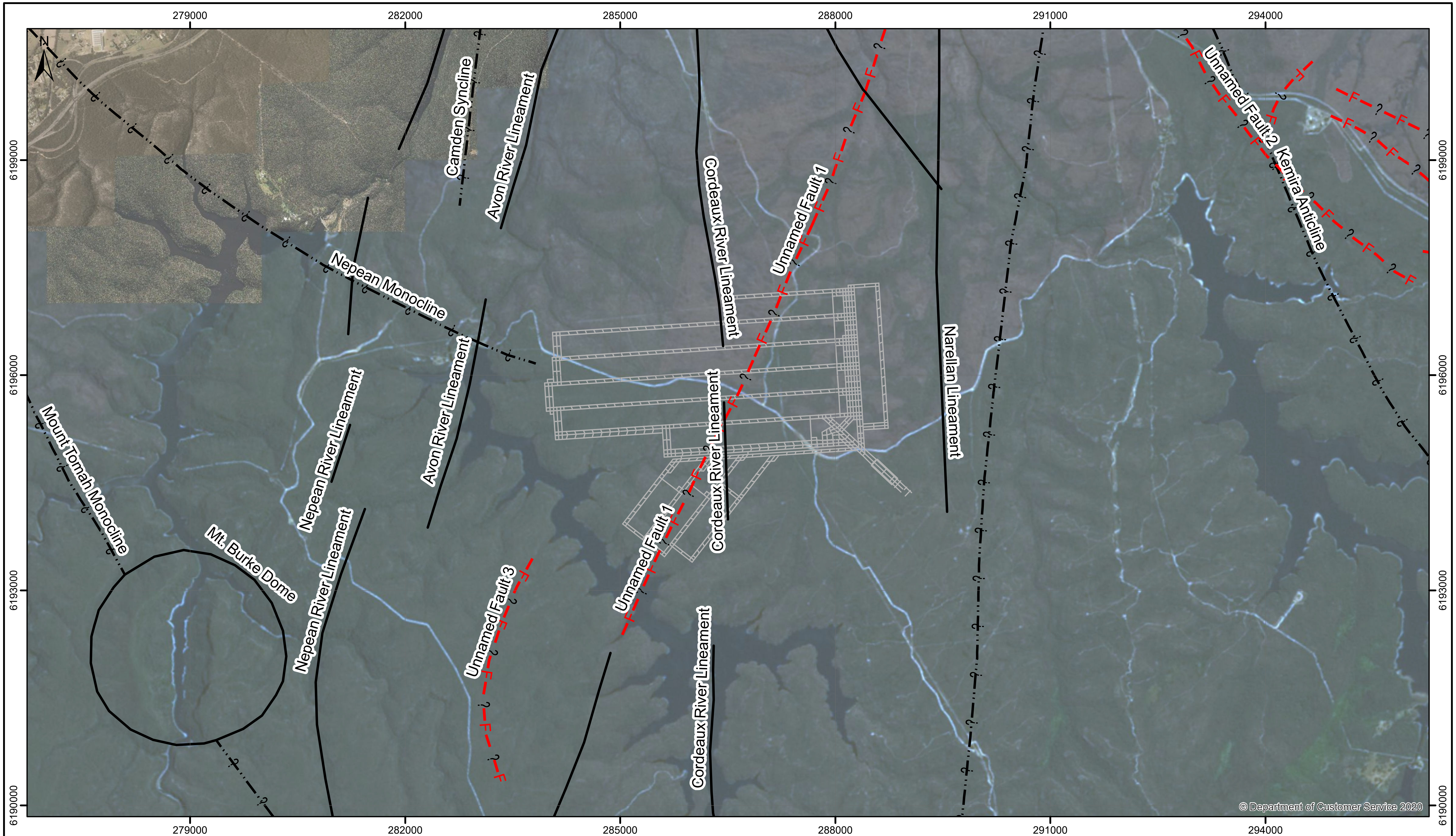
Scale at A3: 1:40,000

0 0.4 0.8 1.6 2.4 3.2 Kilometers

PSM

South32 Illawarra Coal
Geological Structures Review
Area 5
INFERRED STRUCTURS
2018 AEROMAGNETIC INTERPRETATION

PSM3021-012R	Drawing 4



Legend

A5 Proposed Mine Design

Published Lineaments

F Published Faults

? Published Fold Traces

Scale at A3: 1:50,000

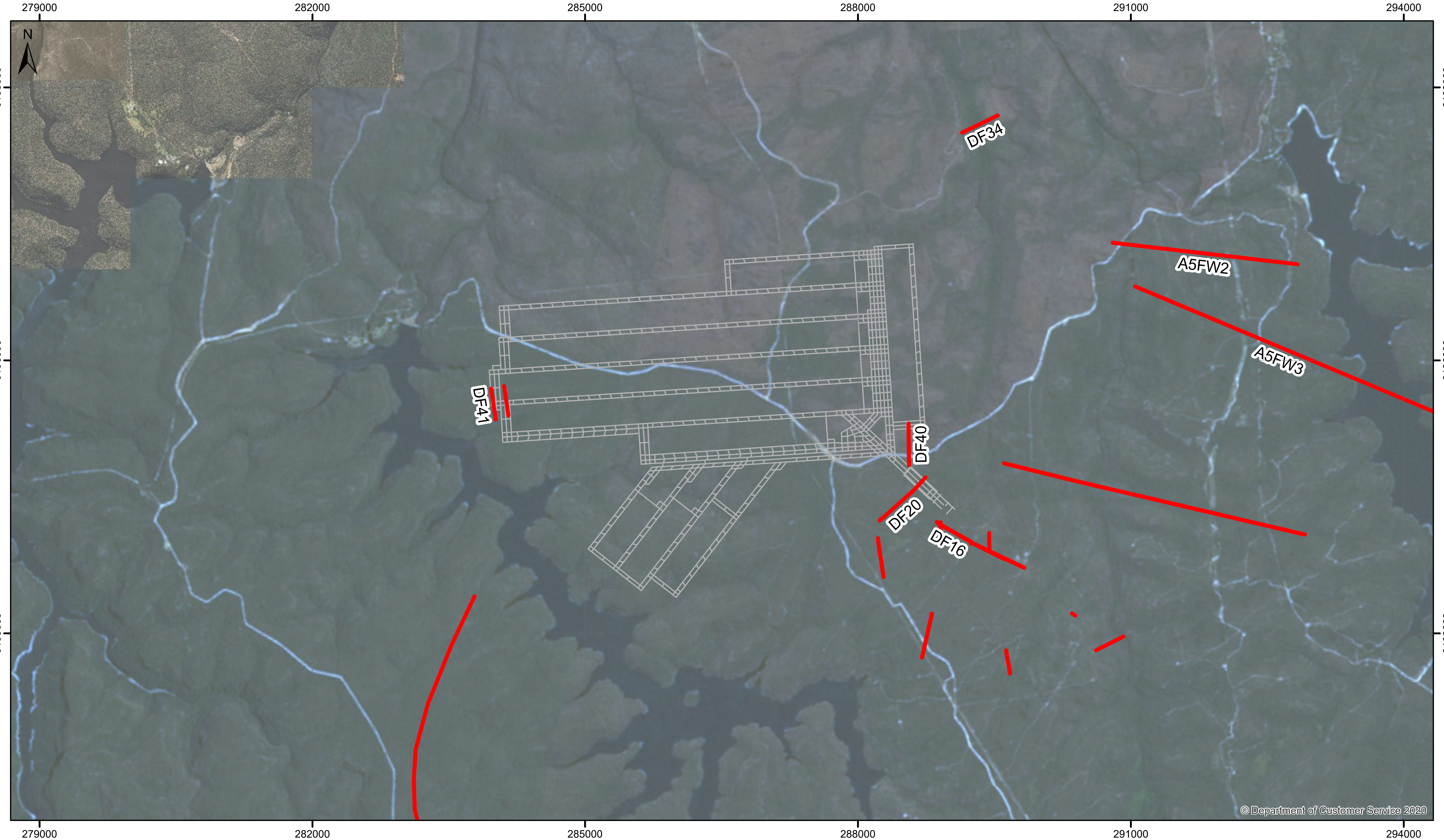
0 0.5 1 2 3 4 Kilometers

PSM

South32 Illawarra Coal
Geological Structures Review
Area 5

PUBLISHED FOLD AND FAULT TRACES

PSM3021-012R	Drawing 5



Legend

A5 Proposed Mine Design

A5_Faults (Inferred by South32)

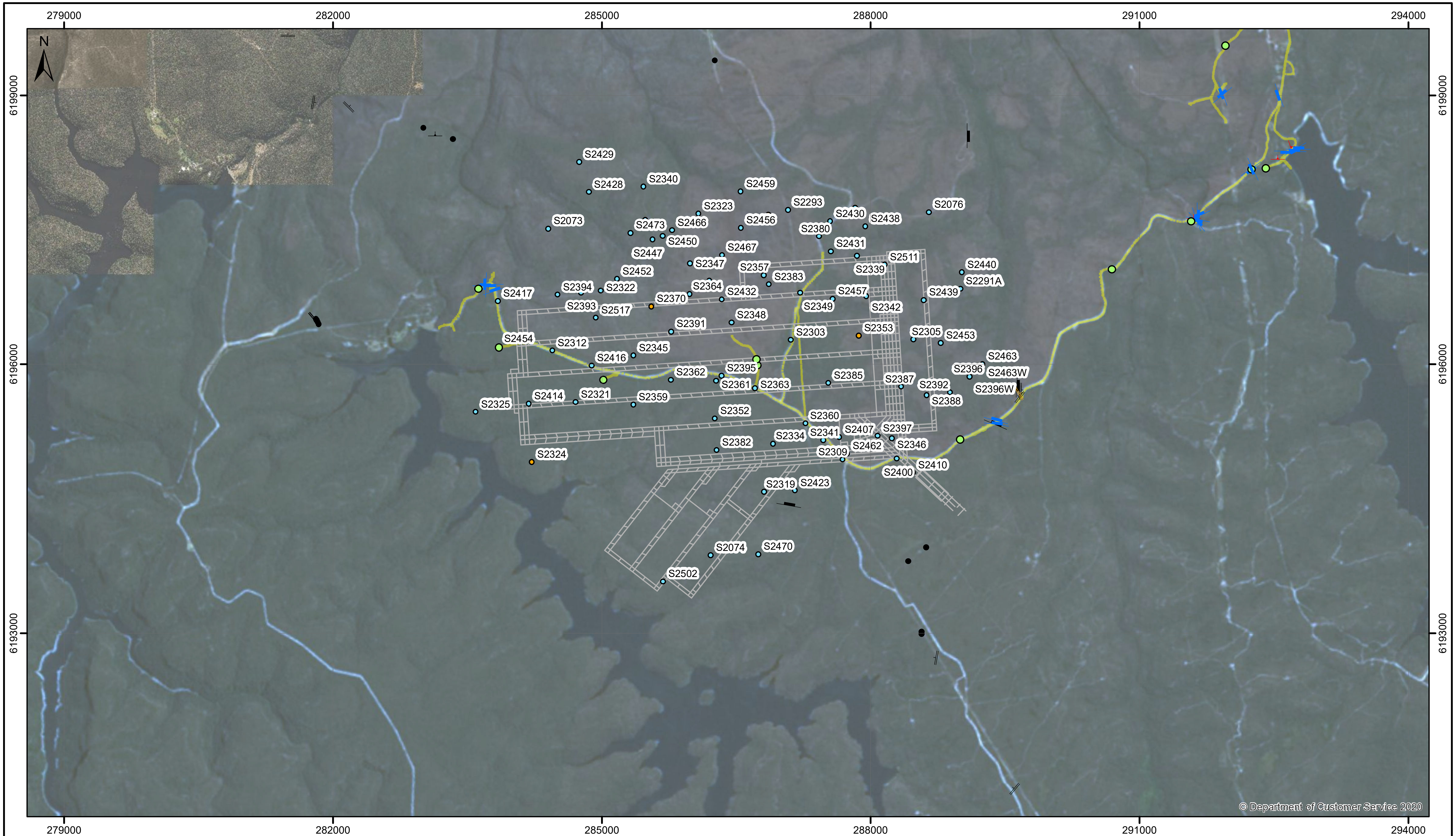
Scale at A3: 1:40,000

0 0.4 0.8 1.6 2.4 3.2 Kilometers

South32 Illawarra Coal
Geological Structures Review
Area 5

FAULTS

PSM3021-012R | Drawing 6



Legend

PSM Mapping Points	Mapping Points by Others	
Observation	Observation	A5 Boreholes with Structure (Identified by South32)
Dyke	Dyke	Borehole structure (identified by PSM)
Fault	Fault	PSM Site Inspection Tracklog
Joint	Joint	A5 Proposed Mine Design

Scale at A3: 1:40,000

0 0.4 0.8 1.6 2.4 3.2 Kilometers

South32 Illawarra Coal
Geological Structures Review
Area 5
STRUCTURE MAPPING POINTS & BOREHOLES WITH STRUCTURE

PSM3021-012R | Drawing 7

Legend

A5 Proposed Mine Design

Known Dyke Occurrences

Possible Dykes from Aeromagnetic Interpretation

PSM Mapping Points

Dyke

Mapping Points By Others

Dyke

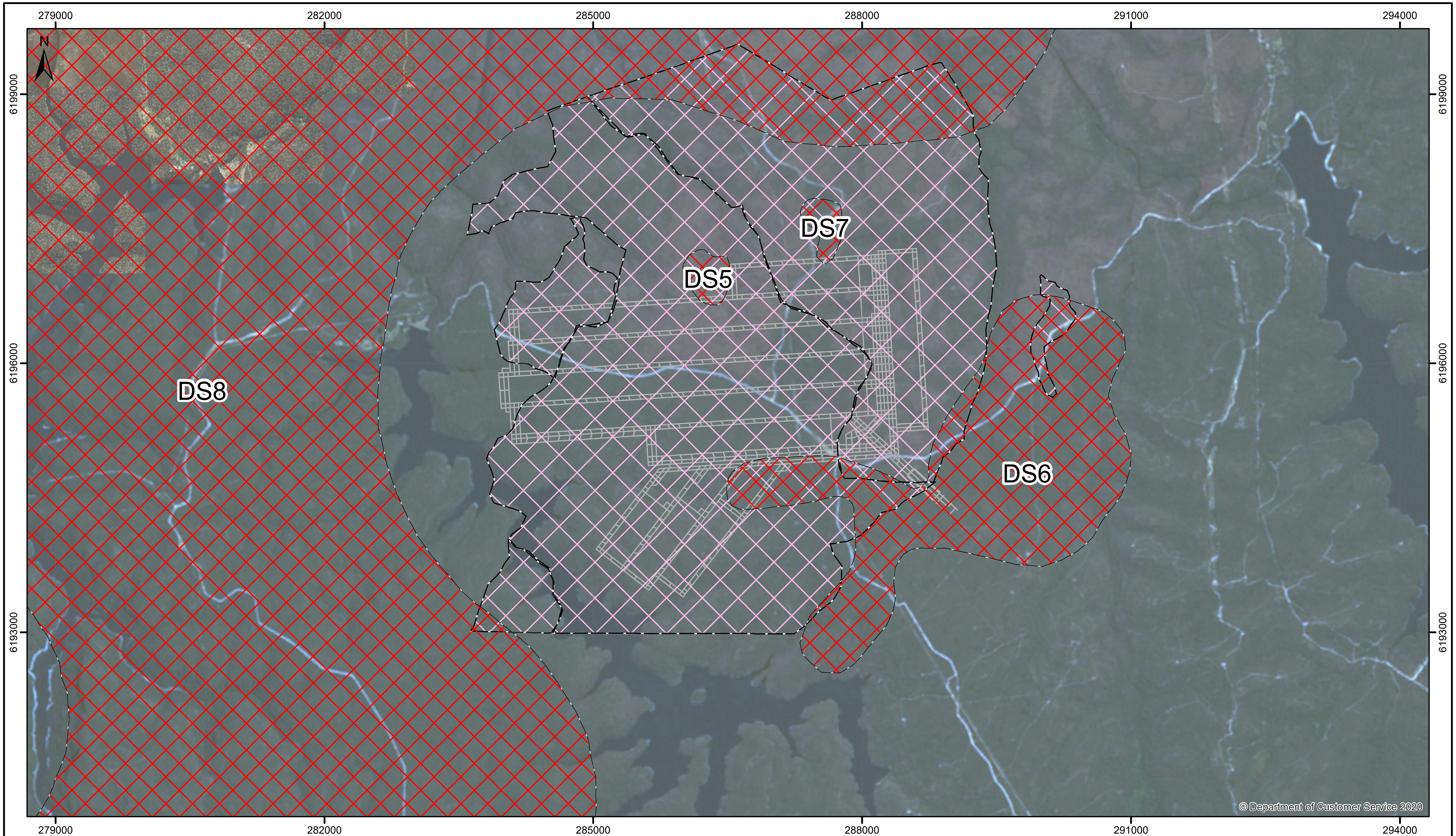
Scale at A3: 1:40,000

0 0.4 0.8 1.6 2.4 3.2 Kilometers

PSM

South32 Illawarra Coal
Geological Structures Review
Area 5
IGNEOUS INTRUSIONS
DYKES

PSM3021-012R	Drawing 8



Legend

- A5 Sills (Identified by South32)
- Possible Sill Region from Aeromagetic Interpretation
- A5 Proposed Mine Design

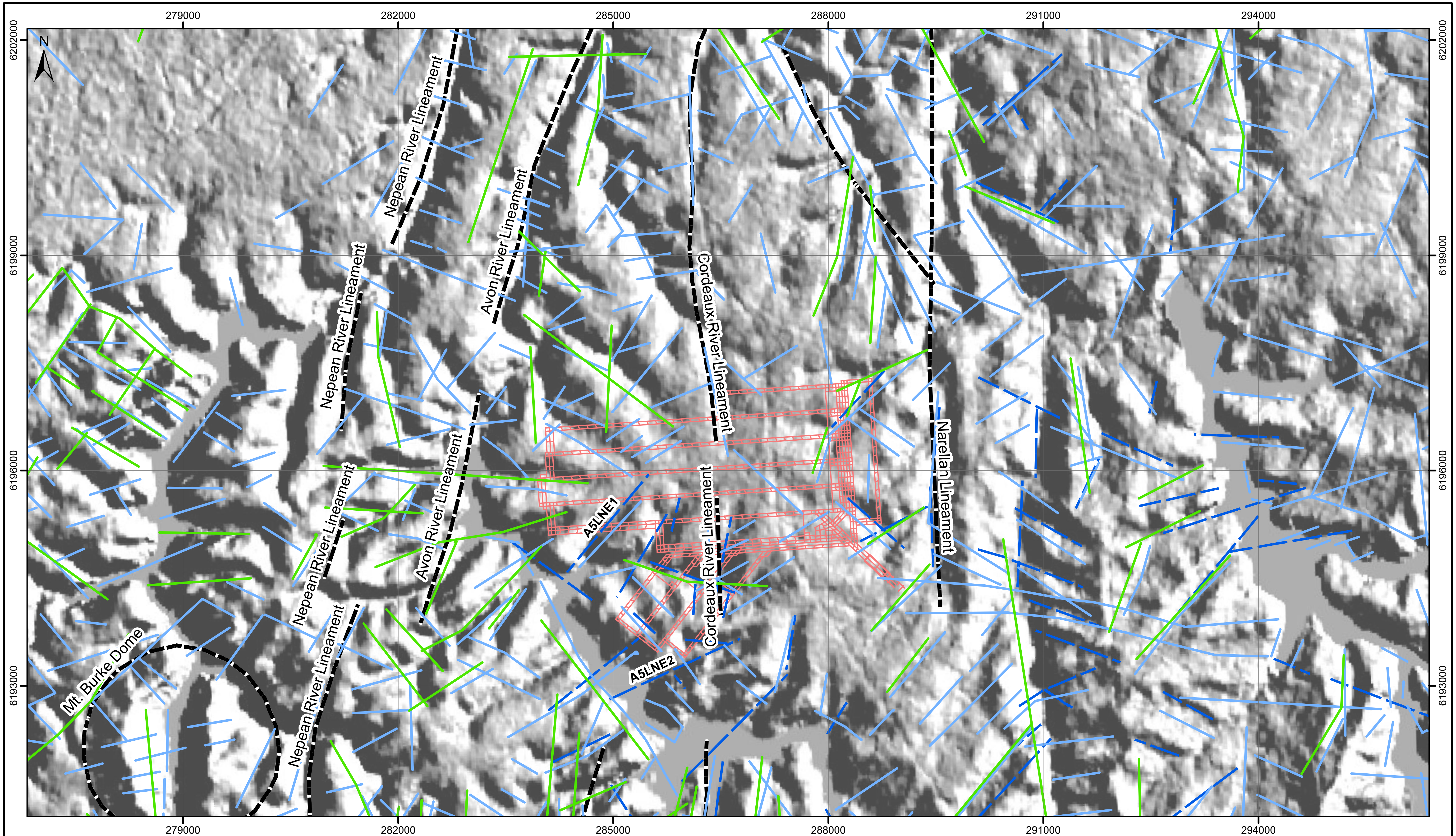
Scale at A3: 1:40,000

0 0.4 0.8 1.6 2.4 3.2 Kilometers

PSM

South32 Illawarra Coal
Geological Structures Review
Area 5
IGNEOUS INTRUSIONS
SILLS

PSM3021-012R	Drawing 9



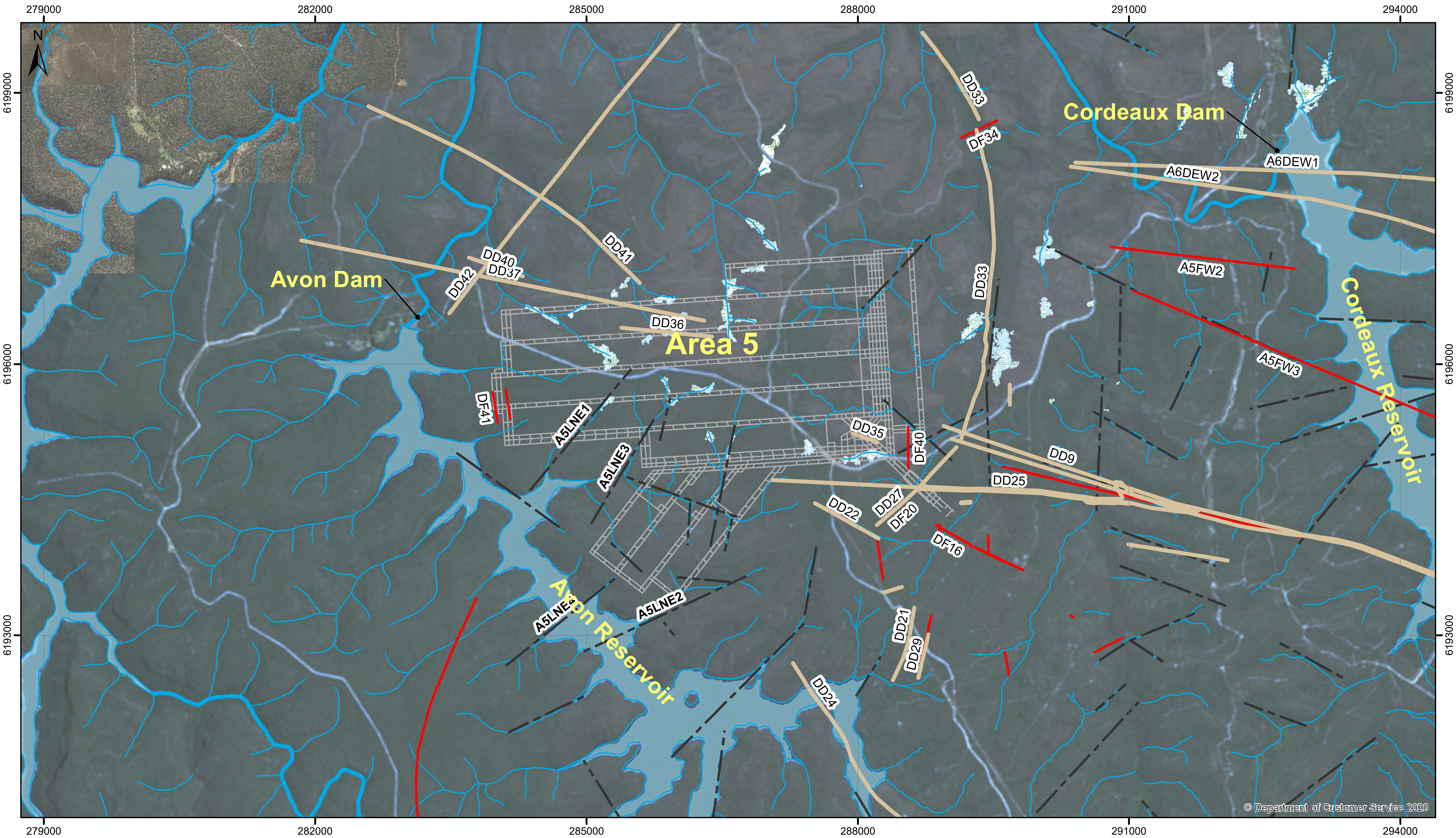
Legend

- CSIRO_Landsat_Lineaments
- CSIRO_Aerial_Lineaments
- Published Lineaments
- PSM Derived Lineaments
- A5 Proposed Mine Design

Scale at A3: 1:50,000

0 0.375 0.75 1.5 2.25 3 Kilometers

South32 Illawarra Coal Geological Structures Review Area 5 LINEAMENTS	
PSM3021-012R	Drawing 10



Legend

- Known Dyke Occurrences
- A5_Faults (Inferred by South32)
- PSM Derived Lineaments
- Rivers
- Tributaries
- Swamps
- Reservoirs
- A5 Proposed Mine Design

Scale at A3: 1:40,000

0 0.4 0.8 1.6 2.4 3.2 Kilometers

PSM

South32 Illawarra Coal
Geological Structures Review
Area 5
POTENTIAL GEOLOGICAL STRUCTURE INTERACTION WITH DAMS/RESERVOIRS

PSM3021-012R	Drawing 11

Appendix A
Data Provided by South32

Area 5 Aeromagnetic Survey Shape Files

- Bedding_Trend_Eureka_MGA94_polyline.shp
- Dykes_Eureka_MGA94_point.shp
- Dykes_Eureka_MGA94_polyline.shp
- Dykes_Eureka_MGA94_region.shp
- Faults_Eureka_MGA94_polyline.shp
- Faults_Eureka_MGA94_region.shp
- Joints_Eureka_MGA94_polyline.shp
- Maghaemite surface deposit_Eureka_region.shp
- Plugs_Eureka_MGA94_region.shp
- Possible Sill_region.shp
- Possible_Faults_polyline.shp

Dendrobium 2020 Area 5 2D Seismic Survey

- VP21-1027-South32_2020_DendrobiumArea5_3D_processing-interp-report.pdf
- 2020_South32_Dendrobium_Area5_2D_FaultSticks_150321.xlsx
- 2020_South32_Dendrobium_Area5_2D_Structures_150321.xlsx
- 2020_South32_Dendrobium_Area5_2D_Interpreted_SILLS_150321.xlsx
- 2020_BUSM_Sills.shp
- 2020_Wonga_Sills.shp
- 2020_P_BUSM.shp

Dendrobium Area 2 Geology report

Dendrobium Reservoir Mapping

Dendrobium Surface Mapping 1.2

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- consultation-info-guideline-characterisation-modelling.pdf

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Overburden geology of Dendrobium 5 and 6 ver 1.0

Shape Files DND rpt

South32 Mafic Intrusions consultancy report Part A March 2018

South32 Mafic Intrusions consultancy report Part B S2309 petrography 2018

South32 Mafic Intrusions consultancy report Part C (2)

South32 Mafic Intrusions consultancy report Part D

South32 2021 Memo - Area 5 Features Update

- 2106_A5_update note.docx

South32 Area 5 Borehole Data

- a5_faults_summary.xlsx
- A5_faults_logged.xlsx

South32 Area 5 Proposed Mine Design

- DEN-01-10543_Rev A_Proposed DND Adapt EIS Mine Plan 300m.dwg

South32 Area 3 Underground Mapping

- dend_mapping.dxf
- bulli_floor.dxf

South32 Structural Interpretation

- a5_sills.dxf
- a5_faults.dxf
- a5_dykes.dxf

SRK Consulting (Australasia). Geological Structures Comparison Investigation. STH055, June 2020

- STH055_Geological Structures Comparison Investigation_Rev1.pdf

Borehole Data with Evidence of Faulting Provided by IMC			
Site ID	**Borehole Imaging Interpretation**	**Bore Logs and Core photos**	**Infilled Fault**
S2073	Y	Y	
S2074		Y	
S2076		Y	Y
S2082		Y	Y
S2291A		Y	Y
S2293	Y	Y	
S2303		Y	
S2305	Y	Y	
S2309		Y	
S2312		Y	Y
S2319	Y	Y	
S2321	Y	Y	
S2322		Y	
S2323	Y	Y	
S2324	Y		Y
S2325			
S2334	Y	Y	Y
S2339	Y	Y	
S2340	Y	Y	
S2341	Y	Y	
S2342	Y	Y	
S2344	Y	Y	
S2345	Y	Y	
S2346			
S2347	Y	Y	
S2348	Y	Y	
S2349	Y	Y	

S2352	Y	Y	
S2353	Y	Y	Y
S2356		Y	
S2357	Y	Y	
S2358	Y	Y	Y
S2359		Y	
S2360		Y	
S2361	Y	Y	
S2362	Y	Y	
S2363	Y	Y	
S2364	Y	Y	
S2369	Y	Y	
S2370		Y	Y
S2380	Y	Y	
S2382	Y	Y	Y
S2383	Y	Y	
S2385		Y	
S2386		Y	
S2387		Y	
S2388		Y	
S2389		Y	
S2391		Y	Y
S2392		Y	Y
S2393		Y	Y
S2393W		Y	Y
S2394		Y	
S2395		Y	
S2396		Y	Y
S2396W		Y	
S2397			
S2400		Y	
S2407		Y	Y
S2410		Y	
S2414		Y	
S2415		Y	
S2416		Y	
S2417		Y	
S2419		Y	
S2423		Y	
S2428			
S2429			Y
S2430			Y
S2431			
S2432			
S2438			
S2439			

S2440			
S2447			
S2450			
S2452			
S2453			
S2454			
S2456			
S2457			
S2459			
S2462			
S2463			Y
S2463A			Y
S2463W			
S2466			
S2467			Y
S2470			
S2473			
S2502			
S2511			
S2517			Y

Appendix B
Area 5 Borehole Structural Data Summary

Identified Boreholes with Faults Containing Infill Thickness of 1 mm or More				
Site ID	Depth (m)	Defect Length (mm)	Infill Primary Type	Infill Thickness (mm)
S2076	357.72	20	CL	1
S2076	452.82	10	CA	1
S2082	413.985	5	CA	1
S2291A	508.26	NULL	CA	1
S2312	432.78	NULL	CA	1
S2312	457.24	NULL	CA	2
S2312	457.28	NULL	CA	2
S2312	457.3	NULL	CA	2
S2324	318.07	30	CO	10
S2334	393.26	460	CO	5
S2353	383.05	NULL	CB	20
S2358	3.4	12	PU	12
S2358	3.75	25	PU	10
S2358	4.44	90	PU	90
S2358	13.59	60	PU	60
S2358	31.9	20	PU	20
S2358	32.12	30	CL	30
S2358	53.51	NULL	CL	5
S2358	61.5	NULL	CL	3
S2370	310.33	10	PU	10
S2370	310.49	30	PU	8
S2370	310.68	10	PU	10
S2382	384	90	CA	1
S2382	388.35	60	CA	1
S2391	406.54	100	CA	1
S2392	423.36	200	CA	1
S2393	352.68	NULL	PU	3
S2393W	349.05	NULL	CA	1
S2396	403.44	200	CA	1
S2407	405.34	220	CA	3
S2429	418.95	50	CA	3
S2429	421.61	24	PU	9
S2430	442.42	40	CA	1
S2463	383.55	120	CA	1
S2463A	403.1	12	CL	5
S2467	380.32	30	CL	1
S2517	402.12	40	CA	1

Selected Borehole Data for Review					
Site ID	**Depth (m)**	**Defect Length (mm)**	**Infill Primary Type**	**Infill Thickness (mm)**	**PSM Assessment**
S2358	3.4	12	PU	12	Weathered Seam
S2358	3.75	25	PU	10	Weathered Seam
S2358	4.44	90	PU	90	Weathered Seam
S2358	13.59	60	PU	60	Weathered Seam
S2358	31.9	20	PU	20	Weathered Seam
S2358	32.12	30	CL	30	Siltstone clast
S2358	53.51	NULL	CL	5	Seam
S2358	61.5	NULL	CL	3	Seem
S2370	310.33	10	PU	10	Weathered Claystone
S2370	310.49	30	PU	8	Weathered Claystone
S2370	310.68	10	PU	10	Weathered Claystone
S2353	383.05	NULL	CB	20	Sample taken - no evidence of faulting
S2324	318.07	30	CO	10	No data available