Strata Control Technology

HV COKING COAL PTY LTD

Integra Underground Mine: Subsidence Assessment for Modification to PA 08_0101

INT4648

Mining Research and Consulting Group

SCT Operations Pty Ltd PO Box 824 Wollongong NSW 2520 Australia
Phone: +61 2 4222 2777 Email: sctnsw@sct.gs Website: www.sct.gs
ABN 23 078 328 953

REPORT TO Chloe Piggford
Environment and Community Manager
Integra Underground Operations
HV Coking Coal Pty Ltd
640 Middle Falbrook Road
Singleton NSW 2330

TITLE Integra Underground Mine:
Subsidence Assessment for Modification to PA08_0101

REPORT NO INT4648

PREPARED BY Stephen Wilson
Ken Mills

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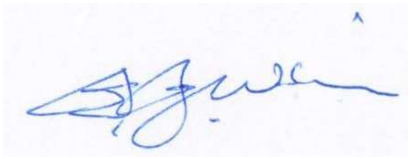

Stephen Wilson
Mine Planner

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Ken Mills
Principal Geotechnical Engineer

SUMMARY

HV Coking Coal Pty Ltd (HVCC), a wholly owned subsidiary of Glencore Coal Pty Ltd (Glencore), operates the Integra Underground Mine (IUG) at a site near Camberwell, approximately 12 km northwest of Singleton in the Hunter Valley of NSW. HVCC is proposing to modify the existing Project Approval (08_0101) for IUG to facilitate the continuation of longwall mining to the northwest within an area that is substantially owned by Glencore. HVCC commissioned SCT Operations Pty Ltd (SCT) to forecast the subsidence effects and impacts for two potential mining layouts, to inform an Environmental Assessment (EA) in support of a modification application. This report presents the results of our assessment based on a maximum footprint for two different longwall layouts.

Our assessment indicates that the impacts from the proposed extensions to mining are likely to be compliant with the subsidence performance measures for the existing Project Approval. Additional issues that are addressed in separate reports are potential for increased groundwater inflows and management of highwall stability in the Mt Owen North Pit. More detailed assessment of impacts to all surface features, including highwall stability, is expected during the development of Extraction Plans, based on an agreed final mining plan through consultation with Mt Owen mine.

Forecast maximum subsidence parameters for the two longwall width layout options considered in this report are shown in the table below. These forecasts are provided for ground that is not currently disturbed by open cut mining and for areas where waste rock fill, either in disused opencut voids or in emplacement areas, is present. The subsidence impacts from these movements are expected to be generally manageable through minor surface works or of no consequence.

Layout	Maximum Subsidence (m)	Maximum Tilt (mm/m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)
Undisturbed Ground (e.g. Rail Corridor and Loop)				
LW 15-20 (257m wide)	2.0	14	7	10
LW15-19 (330m wide)	2.2	15	8	11
Areas of Waste Rock Emplacement (e.g. TP1, TP2, West Pit, ERP, West Dump)				
LW 15-20 (257m wide)	2.8	14	14	20
LW15-19 (330m wide)	3.0	15	16	22

Major natural features in the Assessment Area are limited to Bettys Creek, small sections of remnant of the Ravensworth State Forest and a biodiversity offset area for the Mt Owen Complex. Impacts to Bettys Creek are expected to be manageable under the existing management plans. The impacts to the remnant Ravensworth State Forest and biodiversity offset areas are expected to be minor and manageable.

The subsidence impacts to the major rail and other Mine Infrastructure Area structures are expected to be manageable under existing management plans with some additional subsidence monitoring recommended.

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1. INTRODUCTION

HV Coking Coal Pty Ltd (HVCC), a wholly owned subsidiary of Glencore Coal Pty Ltd (Glencore), is proposing to modify the Underground Project Approval (08_0101) for longwall mining at the Integra Underground Mine (IUG). The mine is located near Camberwell, 12km northwest of Singleton in the Hunter Valley of NSW. IUG is adjacent to the Glencore Mt Owen Complex (MOC) which includes the Glendell, Ravensworth East and Mt Owen open cut mines. IUG and the open cut mines each operate under their own project approvals and development consents.

Since acquiring IUG in 2015, HVCC have invested in further exploration and are planning to optimise the resource recovery from the mining leases within the MOC. As part of this optimisation, the option of additional longwall panels and increasing the longwall face widths in the Middle Liddell Seam at IUG is being evaluated.

The Glennies Creek Underground Coal (GCUC) Project Approval 06_0213 authorises the mining of Longwalls 10 to 17 in the Middle Liddell Seam. Project Approval (08_0101) for the Integra Underground Coal Project (IUG Project) authorises mining in the Hebden and Barrett Seams in addition to Longwalls 10 to 17 in the Middle Liddell Seam. An Extraction Plan has been approved under PA08_0101 for Longwalls 13 and 14. Longwall 13 is currently in operation.

The scope of the proposed modification involves increasing the approved longwall mining footprint area of the Middle Liddell Seam and includes, but is not limited to:

- an extension of the Project Boundary
- change to the direction of main roadway development headings
- changes to the start and finish positions of currently approved Longwalls 15 to 17, to increase the length and resource recovery for these panels
- up to three additional longwall panels
- a potential change to longwall panel width.

HVCC commissioned SCT Operations Pty Ltd (SCT) to prepare an assessment to forecast the subsidence effects and impacts expected from the proposed extension to mining operations, to inform an Environmental Assessment (EA) being prepared by Hansen Bailey in support of a modification application.

Our assessment covers two proposed longwall panel layouts:

- 257m longwall panel void widths (246.2m coal face width with a 5.2m wide roadway at each end) consisting of Longwalls 15 to 20
- 330m wide longwall panel void widths (320m coal face width with a 5.2m wide roadway at each end) comprising Longwalls 15 to 19.

This assessment has been undertaken to evaluate the likely maximum impacts from underground mining associated with the two proposed longwall layouts on the surface features including the open cut mining operations and infrastructure.

The conceptual longwall layouts for the proposed modification are based on the geological information that is currently available. The longwall mining plan may be refined as further geological information becomes available however, the maximum subsidence footprint and impacts are expected to be within the predictions in this report. SCT understands that, prior to the commencement of longwall mining associated with the proposed modification, HVCC will prepare an Extraction Plan application in consultation with Mt Owen. The extraction plan process, is expected to include a detailed assessment of impacts to all surface features based on the potential interactions of the finalised mining plans including geometries and timings.

Figure 1 shows a site plan and void outlines of the proposed Longwalls 15 to 20 (257m wide panel voids) and Longwalls 15 to 19 (330m wide panels voids). The approved Longwalls 15 to 17 voids are also shown for reference. These outlines are superimposed onto an aerial photograph of the area from November 2016. The Assessment Area and surface features of relevance to this assessment are also shown, including the location of adjacent open cut mining operations and infrastructure.

This report presents the results of our assessment and is structured to provide:

- Conclusions and recommendations including:
  - a review of subsidence performance measures as outlined in the Project Approval conditions
  - a review and revision of predictions since the granting of Project Approval
  - recommendations for ongoing subsidence monitoring.
- A brief overview of the site, including a general description of significant surface features within the Assessment Area.
- A review of previous subsidence experience at IUG as an update of understanding gained since Project Approval was granted.
- Estimates of the subsidence expected as a result of the proposed mining.
- Comparisons with previous subsidence predictions for the longwall mining of the Middle Liddell Seam, as detailed in the Project EA.
- A description of the subsidence impacts expected as a result of the forecast movements on the various surface features and surface infrastructure located across the Assessment Area.

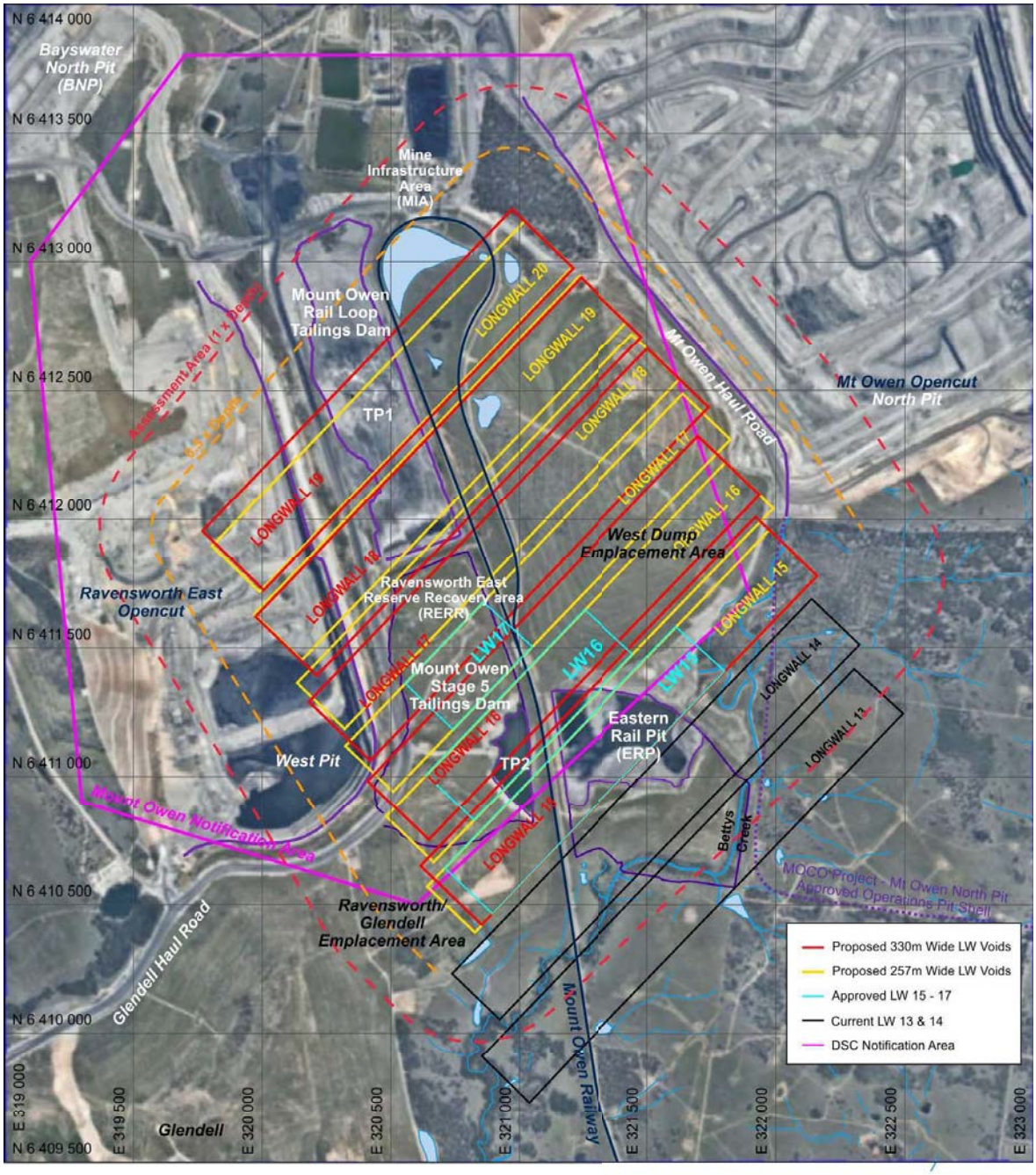

Figure 1: Site plan showing approved and proposed longwalls, Assessment Area and major surface features

2. CONCLUSIONS AND RECOMMENDATIONS

The subsidence impacts within the Assessment Area are expected to be compliant with the subsidence performance measures of the IUG Project Approval 08_0101 with the management plans and associated controls required for secondary extraction in place.

Further consideration for mine planning and associated management plans are recommended for:

- management of the potential for increased groundwater interactions with inflow from the Ravensworth East - West Pit into the overburden strata for the wider (330 m wide) longwall panel option (SCT understands this issue is included in the Groundwater Impact Assessment Report – AGE 2017).

- management of highwall instability for the Mt Owen North Pit, where panels extend to within a distance of 0.4 depth of the top of the highwall (addressed separately in SCT 2017a).

2.1 Performance Measures

Table 1 summarises the subsidence performance measures outlined in Table 10 of Section 17 in Schedule 3 (Environmental Performance Measures) IUG Project Approval 08_0101, and the status of compliance expected during the secondary extraction of the proposed longwall panels.

The subsidence performance measures should be considered in the context of the existing heavily modified surface environment and recent development consent approval for the Mt Owen Continued Operations (MOCO) Project (SSD-5850). The Mt Owen North Pit is approved to continue to the south above parts of Longwalls 9 to 15 at IUG. The Mt Owen North Pit open cut void is planned to consume part of the Bettys Creek Middle Diversion Channel (MDC), other minor drainage lines and areas of natural vegetation up to the southeast corner of the Eastern Rail Pit (ERP).

Table 1: Subsidence Performance Measures and the status of compliance expected during proposed mining

Subsidence Performance Measures			Status of compliance expected during proposed mining
Water	Glennies Creek alluvial aquifer	Negligible impacts	Compliance expected because the aquifer is remote from mining area (other specialists to assess impacts to water)
Water	Natural watercourses on site	No greater environmental consequences than predicted in the Underground Project EA	Compliance expected because no greater subsidence effects for natural ground compared to Underground Project EA (other specialists to assess impacts to water) Mt Owen North Pit approved to mine through some natural watercourses
Water	Mt Owen Bettys Creek Diversions	No greater environmental consequences than predicted in the Underground Project EA, unless the owner agrees in writing	Compliance expected because no greater subsidence effects for natural ground compared to Underground Project EA (other specialists to assess impacts to water) Mt Owen North Pit approved to mine through some sections of the Bettys Creek MDC
Water	Underground Project Creek Diversions	Remain hydraulically and geomorphologically stable	N/A (not built)
Water	Other water storages and drainage lines	No greater environmental consequences than predicted in the Underground Project EA	Compliance expected because no greater subsidence effects for natural ground compared to Underground Project EA (other specialists to assess impacts to water) Mt Owen North Pit approved to mine through some farm dams and drainage lines

Subsidence Performance Measures			Status of compliance expected during proposed mining
Biodiversity	Threatened species, populations, habitat, or ecological communities	Negligible impacts.	Compliance expected because no greater subsidence effects for natural ground compared to Underground Project EA (other specialists to assess impacts to biodiversity) Mt Owen North Pit approved to consume some areas of natural vegetation and endangered ecological communities
Built Features	All built features (except those fully covered by an operative contractual arrangement with another mine owner or other owner of the relevant built feature)	Safe, serviceable, and repairable unless the owner agrees otherwise in writing, including: • Serviceability should be maintained wherever practicable; • Loss of serviceability must be fully compensated; and • Damage must be fully repaired or replaced, or else compensated	Compliance expected (with management plans and controls in place) because no greater subsidence effects for natural ground compared to Underground Project EA
Public Safety	Public Safety	No additional risk due to mining	Compliance expected (with management plans and controls in place) and because no greater subsidence effects for natural ground compared to Underground Project EA Land largely owned by Glencore and is not readily accessible by the public

2.2 Subsidence Forecast

Table 2 summarises the subsidence forecast over the proposed longwall panels within the Assessment Area. Performance indicators should be based on a 20% increase in these values so natural variability does not trigger unnecessary reporting procedures for events of no practical consequence.

Table 2: Forecast Subsidence

Layout	Maximum Subsidence (m)	Maximum Tilt (mm/m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)
Undisturbed Ground (e.g. Rail Corridor and Loop)				
LW 15-20 (257m wide)	2.0	14	7	10
LW15-19 (330m wide)	2.2	15	8	11
Areas of Waste Rock Emplacement (e.g. TP1, TP2, West Pit, ERP, West Dump)				
LW 15-20 (257m wide)	2.8	14	14	20
LW15-19 (330m wide)	3.0	15	16	22
Previously Approved Values				
GCUC Project (06_0213)	1.6	12	6	9
IUG Coal Project (08_0101)	1.7[1] (4[2])	16[1] (40[2])	4[1] (10[2])	6[1] (13[2])

[1] Values for mining in the Hebden Seam only
[2] Values for mining in the Middle Liddell (reduced footprint) and Hebden Seams

These subsidence parameters are based on the ongoing subsidence monitoring at IUG, experience of mining below waste rock emplacements presented by Forrester and Whittaker (1976) and experience of mining below waste rock emplacements elsewhere in the Hunter Valley. They are considered suitable to provide an indication of expected subsidence behaviour over the proposed longwall layouts.

The subsidence parameters presented in Table 2 are different to the subsidence parameters presented in the EA for the GCUC Project (06_0213) and reflect the increased mining height proposed, changes to planned mining geometries, the changed overburden conditions and the influence of waste rock fill.

Maximum tilt levels forecast for the natural ground surface above proposed layouts are generally consistent with and only slightly greater than the predicted values for the GCUC Project EA reflecting the increased vertical subsidence forecast, but also the increased minimum overburden depth within the extended area of this approval modification proposal.

There is expected to be potential for greater subsidence, tilt and strains within landforms modified by mining, such as over emplacement areas, in and near the edges of the open excavations and at locations where interfaces of natural ground and fill material exist.

The forecast increases in subsidence parameters do not imply significantly greater subsidence impacts or greater environmental consequences from those previously predicted. None of the subsidence impacts anticipated are particularly sensitive to specific values of maximum vertical subsidence, tilt or strain. The consequences of these increases are likely to be insignificant in the substantially modified landform of the Assessment Area.

2.3 Recommendations for Subsidence Monitoring

Subsidence monitoring is recommended to enhance the existing IUG subsidence monitoring database, manage operational and personal safety risks and address the specific requirements of approval conditions.

IUG has undertaken two types of subsidence monitoring activities: subsidence monitoring required to meet regulatory commitments and strategic monitoring to inform understanding of subsidence behaviour at the mine site. A continuation of this approach is recommended. There may be opportunities for further strategic monitoring from time to time and it is anticipated that HVCC would take advantage of these opportunities as and when necessary to optimise their operational potential.

In addition to the subsidence monitoring recommended for Longwalls 13 and 14 (SCT Report INT4604A), SCT recommends the subsidence monitoring be extended to include:

- An extension to H Line, located alongside the Mt Owen Rail Line to the edge of the half depth zone within the Assessment Area and then further to the northwest, a series of isolated survey marks for far field monitoring.

- Strategic monitoring of the Mine Infrastructure Area structures within the Assessment Area.

- An array of survey points around the edge of the highwalls for both the Ravensworth East - West Pit and Mt Owen North Pit to monitor movements that may lead to instability in these areas.

- LIDAR data of the surface on a regular basis (at the end of each panel as a minimum).

Monitoring intervals should be dictated by the various management plans or technical committee requirements.

Ideally, ongoing monitoring would include survey control that uses the far-field GPS control points located on all sides of the mining area.

Pegs should be spaced at intervals of 1/20th of depth or 20m whichever is less. Survey control should be established to provide an absolute accuracy of better than about 30mm. Intermediate pegs should be surveyed with a nominal relative accuracy of better than ±10mm.

The aim of this monitoring is to:

- provide data to assist with the management of the risks associated with subsidence
- validate the subsidence forecasts
- provide a basis to analyse the relationship between the subsidence effects and impacts including any environmental consequences.

3. SITE DESCRIPTION

This section presents background to the status of mining approvals, a description of the site, the geometry of the Middle Liddell Seam mining horizon, mining geometries and the various surface features of significance to this assessment.

3.1 Approvals Context

The IUG was previously known as Glennies Creek Colliery.

The potential environmental impacts of the Glennies Creek Underground Coal Project (06_0213) were assessed in the Glennies Creek Colliery Longwalls 10 to 17 Part 3A Environmental Assessment (ERM 2007) and associated document titled Glennies Creek Part 3A Application – Longwall Panels 10-17 Middle Liddell Seam Response to Submissions dated February 2008 (ERM 2008).

This EA covers what are now known as IUG Longwalls 10-17 in the Middle Liddell Seam. Project 06_0213 (GCUC Project) was approved in June 2008. The predicted subsidence effects and impacts for the GCUC Project were presented in SCT Report GLEN2990A (SCT 2006) and included as Annexure B of the GCUC Project EA (ERM 2007).

A subsequent project application was made for the Integra Underground Coal Project (08_0101), which proposed longwall mining of the Hebden and Barrett Seams in addition to the approved Middle Liddell Seam longwalls. Additional first workings were also approved within the Hebden, Barrett and Middle Liddell Seams.

The potential environmental impacts of the Integra Underground Coal Project (08_0101) were assessed in the Proposed Integra Underground Coal Project Environmental Assessment (ERM 2009) and associated document titled Integra Underground Project Collated Response to Submissions dated March 2010 (ERM 2010). These documents are referred to as the IUG Project EA and relate to mining in the Middle Liddell, Hebden and Barrett Seams.

Approval for IUG Project 08_0101 was granted in November 2010. The predicted subsidence effects and impacts for the Underground Project were presented in SCT Report GLEN3253 (SCT 2009) and included as Annex E in the IUG Project EA (ERM 2009).

A number of modifications have been made to PA 08_0101 to facilitate the operation of the mines under the separate ownership structure. These modifications include separation of the underground and surface mining operations from a consolidated approval to two individual approvals (PA 08_0101 and PA 08_0102).

IUG was sold to HVCC (a wholly-owned subsidiary of Glencore). Many of the surface interaction issues that stemmed from separate ownership of the surface and underground mines are now no longer relevant under common ownership.

HVCC is seeking to modify the Underground Project Approval (PA 08_0101) to facilitate further longwall mining of the Middle Liddell Seam. Specialist reviews of the current subsidence and associated environmental impacts are to be included in the EA for this modification application. These reviews are understood to include a review of actual impacts against predictions made within previous environmental assessments including the IUG Project EA (ERM 2009) and the subsidence performance measures in PA 08_0101.

This subsidence assessment is presented with consideration of the standards of the Subsidence Performance Measures and environmental management plan requirements for secondary extraction contained in the conditions of PA 08_0101. These performance measures generally relate to multi-seam mining of overlying layouts geometries in the Middle Liddell and Hebden Seams.

3.2 Assessment Area

The Assessment Area for this proposed modification is determined as the area within a distance equal to the overburden depth from the outermost goaf edges of the maximum extent of each of the two panel layouts. An Assessment Area based on overburden depth is more reliably defined and is not subject to variations in survey tolerance. A horizontal distance equal to overburden depth from the nearest goaf edge is considered a conservative option for the identification of surface features and assessment of impacts to these features. Any subsidence related movements beyond this distance are likely to be insignificant for all practical purposes.

A 20mm vertical subsidence contour based on 0.5 times depth was previously used to define a Subsidence Management Plan or Extraction Plan assessment area. However, the actual position of this contour can vary significantly with survey tolerance and the effects of far-field horizontal movements.

3.3 Land Ownership and Land Use

The land within the Assessment Area is almost entirely owned by Glencore (or subsidiary companies). A small area of the Ravensworth State Forest adjacent to the Mt Owen Open Cut North Pit is owned by the NSW State Government.

The surface land above the Assessment Area owned by Glencore (and subsidiary companies) is used primarily for mining purposes. A small strip adjacent to Bettys Creek located above Longwalls 13 and 14 is used for grazing. All surface infrastructure is owned by Glencore.

3.4 Surface Features

Natural features within the Assessment Area include the highly modified catchment of Bettys Creek, a small section of the natural creek, small portions of natural vegetation mainly inside the Mt Owen Rail Line loop, remnant areas of the Ravensworth State Forest and remnant vegetation along the upper reaches of the middle diversion channel of Bettys Creek and ephemeral drainage lines over Longwall 15.

Most of the area above the proposed longwalls has been significantly modified by the mining activities associated with the MOC. These mining activities include Glendell, Ravensworth East and Mt Owen Open Cut Mines. The landform associated with the surface mining areas is, by nature of the mining process, a dynamic environment.

The main man-made features within or adjacent to the Assessment Area include the Mt Owen Rail Line (and loop) and part of the Mt Owen Mine Infrastructure Area (MIA). The MIA includes the coal handling and preparation plant, stockpiles, dams, coal handling and train loading infrastructure.

Other features include active or idle open cut pits, partially filled tailing dams, emplacement areas, rehabilitated areas and haul roads associated with the MOC.

The active Barret Pit at Glendell Mine is outside of the Assessment Area.

The Dams Safety Committee (DSC) notification area around the prescribed dam referred to as Mt Owen Rail Loop Tailings Dam (also known as TP1) extends across most of the Assessment Area although this tailings dam itself is almost completely backfilled. The location of this dam is shown on Figure 1.

3.5 Future Surface Mining

Surface mining is expected to continue throughout the period of proposed underground mining. The Mt Owen Open Cut (North Pit) is currently above the north-eastern extent of the Assessment Area for the proposed longwalls. Mining of the North Pit will progress from directly above the proposed Longwall 15 to the south over Longwall 14 and Longwall 13 adjacent to the ERP. The Mt Owen North Pit continuation is approved, under the MOCO Project, to extend open cut mining operations to the east above previously mined Longwalls 9-12 at IUG.

A further modification is proposed for the MOCO Project Approval (SSD-5850). This proposed modification, SSD-5850 MOD2 – Mt Owen Operation Southern Extension (MOOSE), includes deepening of the North Pit and extensions to the east of the pit shell.

The proposed eastern extension of the pit shell is outside the Assessment Area for the proposed longwalls. The potential interactions issues associated with the proposed MOOSE modification are considered in this report.

3.6 Middle Liddell Seam Geometry

Figure 2 shows contours of the overburden depth from the original surface landform to the current workings and proposed longwalls in the Middle Liddell Seam.

Figure 3 shows the seam thickness isopachs of the same area. Both Figure 2 and Figure 3 show the main existing subsidence monitoring lines (H and G line) with the recommended extension to monitoring for Longwalls 13 and 14.

3.6.1 Overburden Depth

The overburden depth varies through a combination of seam gradient, topographic variation and surface mining activities from about 270m to 590m.

Within the Application Area, the seam dips to the northeast ranging from moderate dip (around 1 in 20) in the south west and central parts before flattening and rising steeply (up to 1 in 1.5) to the north east as part of a localised syncline feature.

The original surface topography was gently rolling terrain generally dipping to the southwest towards Bettys Creek but this original topography has been significantly modified by mining activities. Surface mining activities have reduced the overburden depth in the vicinity of excavated pits and increased the overburden depth by back filling open cut voids and emplacement areas.

Examples of these excavations include the shallower TP1, TP2 and ERP (up to 35m deep) and much deeper Ravensworth East - West Pit and Mt Owen North Pit. Emplacement areas where the original surface has been raised include the West Dump (up to 65m higher) and the Glendell/Ravensworth emplacement area (up to 25m higher).

Natural ground that has not been disturbed by open cut mining activities is located along the Mt Owen Rail Line and loop area. The overburden depth in these areas ranges from 450m over Longwall 15 to approximately 490m over the northernmost panel.

The maximum depth of cover for the proposed longwalls is below the rehabilitated West Dump area where the total thickness of natural strata and emplaced material is approximately 590m.

The lower depths of cover are likely to be over the start and finish lines of the proposed longwall panels where surface excavations associated with the Mt Owen North Pit and Ravensworth East - West Pit are located. The minimum overburden thickness is likely to be below the West Pit highwall near the finish lines of Longwall 18 (or Longwall 17 in the 330m layout) where the overburden depth is approximately 270m.

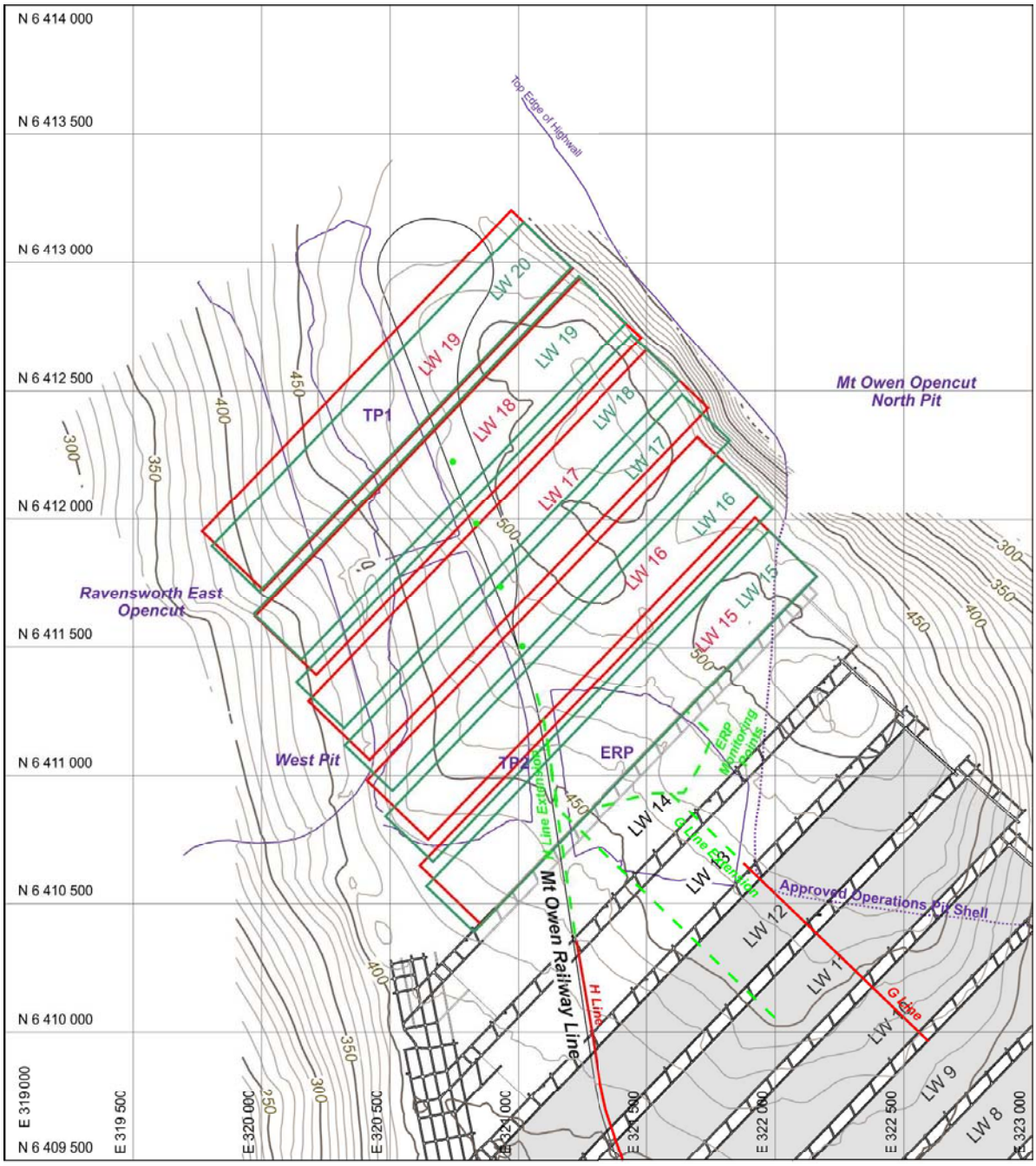

Figure 2: Overburden depths from original surface to current workings and proposed longwalls in Middle Liddell Seam

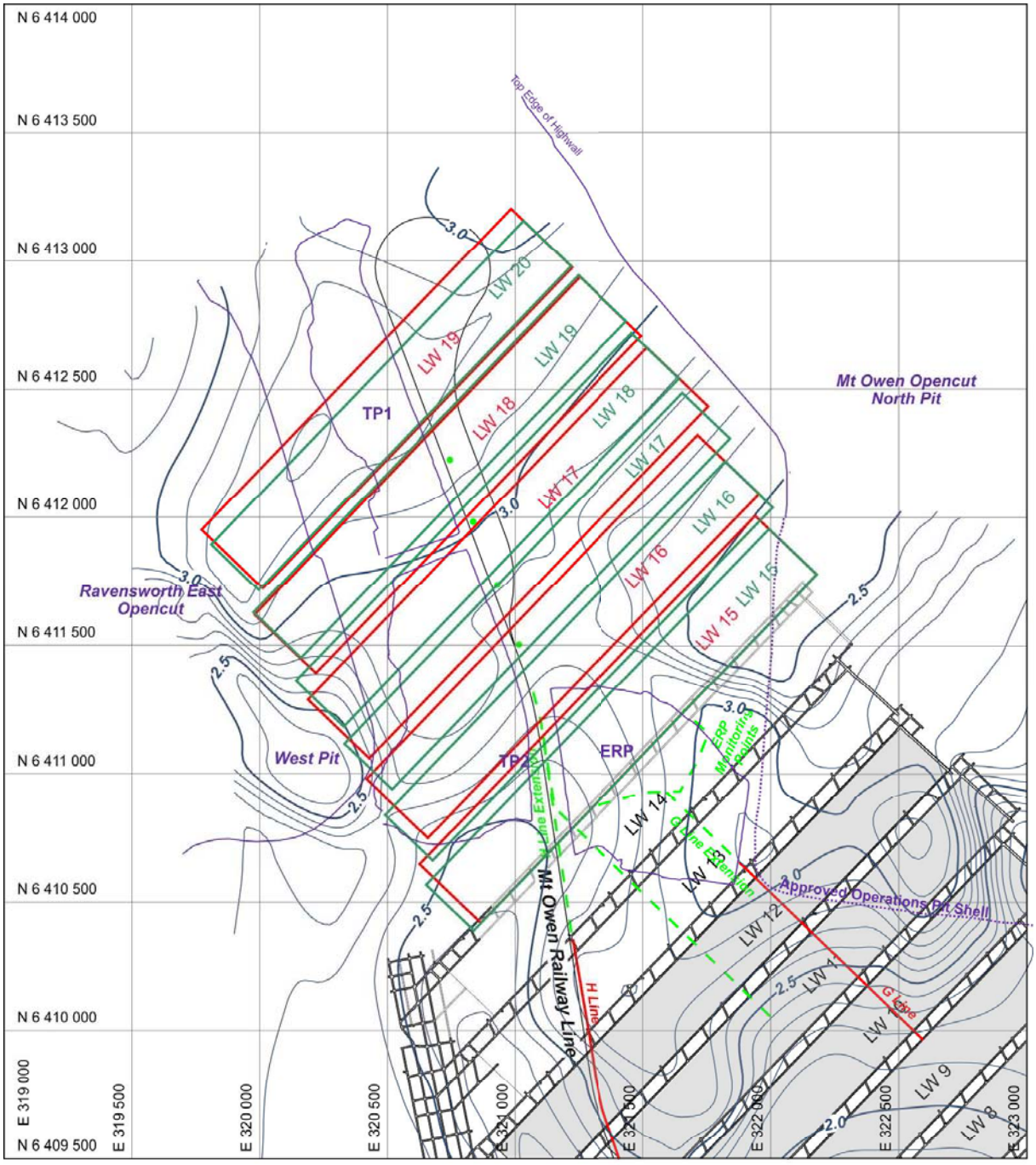

Figure 3: Seam thickness isopachs for Middle Liddell Seam

3.6.2 Geological Structure

A major regional geological feature known as the Hebden Thrust Fault is inferred to exist within the Assessment Area. This feature strikes in a northwest – southeast direction. The latest interpretation from October 2017 indicates that the thrust is an en echelon fault system which presents locally as a steeply dipping roll in the overburden strata between the north-eastern end of the proposed longwalls and the south-western highwall of the Mt Owen North Pit.

The Hebden Thrust has potential to limit the north-eastern extent of some of the proposed longwall panels as it appears the Middle Liddell Seam rises sharply in the northeast towards the Mt Owen North Pit and reaches a gradient that are unlikely to be suitable for longwall mining.

3.6.3 Seam Thickness

Seam thickness isopachs for the Middle Liddell Seam indicate that the seam thickness varies within the proposed longwall mining area from a low of 2.4m near the finish line of Longwall 15 up to a maximum of 3.3m near the north western panel edge of the last longwall panel.

The mining height is expected to range from 2.8m to 3.3m. This includes allowances for variations in seam thickness, minimum practical operating height for the mining equipment and any loss of immediate roof strata plies.

A maximum mining height of 3.3m is used for subsidence assessment in this assessment.

3.7 Mining Geometries

Two longwall layouts are assessed. Both layout options are a continuation of the existing series of parallel longwall panels (Longwalls 1-14) progressing to the northwest. The layouts are similar but with different face widths. The actual mining geometry will be determined based on market conditions at the time of first workings development.

As shown in Figure 1, both layouts involve extending the approved Longwalls 15 to 17 panel lengths with additional parallel panels to the northwest for a distance of approximately 900-1000m. A section of the approved Hebden Seam longwall layout is located below Longwalls 15 to 17 of the proposed layouts.

In the narrower panel layout, individual panels create voids that are approximately 257m wide (the same width as the currently approved Longwalls 15 to 17) separated by chain pillars with widths of around 48m. The panel lengths vary.

In the wider panel layout, panels create voids around 330m wide with 48m wide inter-panel chain pillars. The start and finish lines are slightly different to the narrower panel geometry.

Longwall panels are developed to the northeast from the main headings in the southwest. The direction of longwall retreat is then from the northeast, back towards the main headings.

The Longwall 14-15 inter-panel chain pillar is approximately 49m wide.

Table 3 shows the dimensions of the two layouts assessed.

Table 3: Assessed Longwall Layouts Panel Dimensions

Narrow Panel Option: Longwalls 15-20				
Panel	**Nominal Gateroad Width (m)**	**MG Chain Pillar Width Coal Rib to Rib (m)**	**LW Void Width (m)**	**LW Void Length (m)**
LW15	5.2	48	256.6	2272
LW16	5.2	48	256.6	2174
LW17	5.2	48	256.6	2138
LW18	5.2	48	256.6	2142
LW19	5.2	46	256.6	2117
LW20	5.2	45	256.6	2080
Wide Panel Option: Longwalls 15-19				
Panel	**Nominal Gateroad Width (m)**	**MG Chain Pillar Width Coal Rib to Rib (m)**	**LW Void Width (m)**	**LW Void Length (m)**
LW15	5.2	48	330.4	2241
LW16	5.2	48	330.4	2156
LW17	5.2	48	330.4	2084
LW18	5.2	48	330.4	2069
LW19	5.2	46	330.4	2029

3.8 Surface Features and Surface Infrastructure

In this section, surface features that have been identified with the Application Area are described. Figure 4 shows the locations of these various surface features.

These features were identified based on:

- two site inspections conducted on 12 April 2017 and 23 August 2017
- previous subsidence assessments (including the recent Longwalls 13 and 14 Extraction Plan risk assessment)
- information presented in the MOCO Project EA, MOCO Project MOD2 (MOOSE).

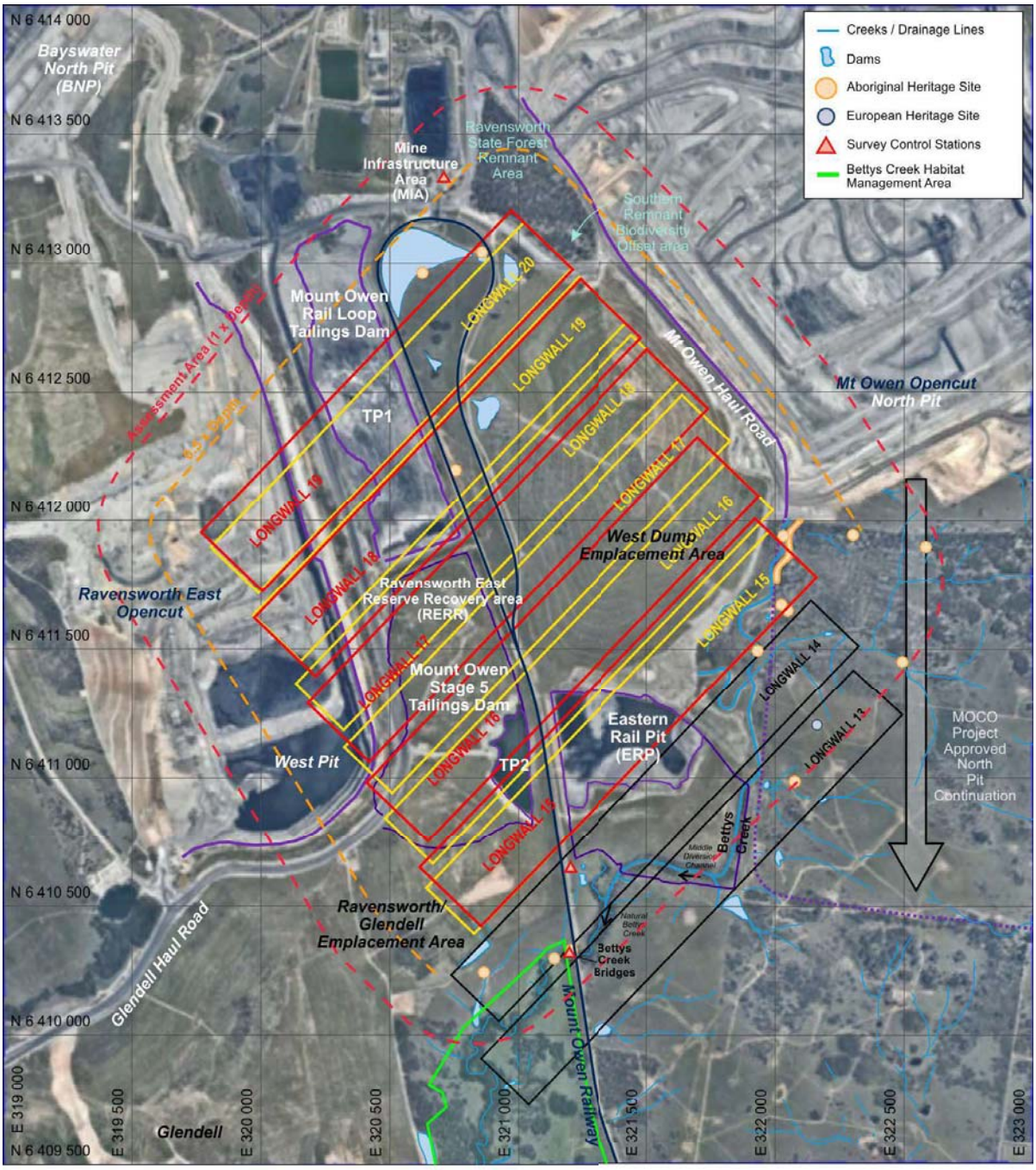

Figure 4: Locations of surface features

The NSW Department of Mineral Resource guidelines for Subsidence Management Plan (SMP) Applications also provide a comprehensive list of surface features to be considered in a subsidence assessment. There are only a few surface features from the SMP Application Guidelines list located within the Assessment Area, and fewer still that are sensitive to subsidence impacts.

3.8.1 Natural Features

The major natural feature within the Assessment Area is Bettys Creek located on the south eastern periphery of the area. Bettys Creek is a third order, ephemeral, meandering watercourse incised some 2-3m below the general floodplain. The channel extends above Longwalls 13 and 14 but does not extend over the proposed longwall panels. The upstream reaches of Bettys Creek have been diverted by the Middle Diversion Channel (MDC). The headwaters have been significantly modified by the Mt Owen Open Cut and will be entirely consumed as open cut operations continue to the south.

There are a small number of ponds (natural dams) also located on the south eastern edge of the Assessment Area above Longwalls 13 and 14. These are situated on the general floodplain and appear to be remnants of previous creek channels isolated where the main channel has cut down and changed course over time.

Isolated pockets of natural vegetation remain above Longwalls 13, 14, and the proposed Longwall 15 with the most substantial areas along the drainage lines of Bettys Creek in the south western corner of the Assessment Area. At this location, a section to the west of the Mt Owen Rail Line is set aside as a habitat management area.

Over the proposed longwall mining area, the majority of natural vegetation is located immediately adjacent to the Mt Owen Rail Line and the area inside the rail loop. There are some additional areas on the periphery and outside the proposed mining panel edges including a small section of the Ravensworth State Forest (Ravensworth remnant area) and southern remnant biodiversity offset area above the northernmost panel.

3.8.2 Non-Mining Man-Made Features

There are no known water bores or wells, other than those owned by Glencore within the Assessment Area.

A number of farm dams are located within the Assessment Area. These are located along the various drainage lines that make up the catchment of Bettys Creek and generally consist of insubstantial structures of less than 2-3m in height.

There are several water treatment/settlement ponds located within the Assessment Area. These are associated with the management of runoff from rehabilitated open cut areas.

A number of Aboriginal heritage sites comprising artefact scatters, isolated finds or open camp sites have previously been identified within the Assessment Area on the Bettys Creek floodplain and broader area. These are generally above Longwalls 13, 14 and the proposed Longwall 15. An additional five sites have recently been recorded within the Assessment Area. Three of these are adjacent to the Mt Owen Rail Line loop. There are no rock shelter sites within the Assessment Area.

There is only one European heritage site within the Assessment Area that has not already been disturbed by open cut mining. This site is located above Longwall 13.

Public utilities or amenities identified within the Assessment Area are limited to a number of permanent survey control marks.

3.8.3 Mining Related Features

The major man-made surface features located within the Assessment Area are all mining related and are all owned by Glencore.

The main features include the Mt Owen Rail Line (and loop) and part of the Mt Owen MIA. The section of the MIA in the Assessment Area includes a coal stockpile, dams, coal handling and train loading infrastructure. Also located within this rail corridor are a service road, bridges for the road and rail over Bettys Creek, signal cabling, overhead powerlines and a raw water supply pipeline.

Other features include the active or idle open cut pits, partially filled tailing dams, emplacement areas, rehabilitated areas and haul roads associated with the Mt Owen, Ravensworth East and Glendell Open cut Mines.

Active or idle open cut pits include the Mt Owen North Pit and the Ravensworth East - West Pit. The active Glendell Barret Pit is located to the southwest outside the Assessment Area.

The open or partially filled tailings dam excavations include TP1 (Mt Owen Rail Loop Tailings Dam), TP2 (Mt Owen Stage 5 Tailings Dam) and the ERP.

Emplacement and/or rehabilitated areas include the West Dump and the Ravensworth/Glendell emplacement area.

Minor surface infrastructure such as four wheel drive access roads, agricultural land and farm infrastructure, is also owned by Glencore to support either grazing activities and surface or underground mining operations.

Gas drainage boreholes and related installations associated with the IUG are located across the surface in the southeast of the Assessment Area. This infrastructure has been designed and installed to withstand subsidence impacts.

4. SUBSIDENCE BEHAVIOUR

In this section, the subsidence movements expected above the proposed longwall panels and more generally within the Assessment Area are forecast on the basis of site-specific monitoring at the IUG.

4.1 Forecast Subsidence Movements

Table 4 summarises the subsidence parameters expected in undisturbed ground within the Assessment Area for the two different layouts.

Table 4: Subsidence parameters forecast for the proposed longwall panels in areas undisturbed by open cut mining

Layout	Maximum Subsidence (m)	Maximum Tilt (mm/m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)
LW15-20 (257m)	2.0	14	7	10
LW15-19 (330m)	2.2	15	8	11

The subsidence forecasts presented take account of the increased seam thickness, proposed mining heights, mining geometry, physical dimensions and overburden characteristics. These are also based on additional information and understanding gained since the GCUC Project approval was granted.

Open cut mining has modified the overburden composition from natural conditions and subsidence behaviour in these areas is expected to be modified as a result of additional settlement of the fill and lateral spreading of stockpiles. Sections of the deeper open excavations (Ravensworth East-West Pit and Mt Owen North Pit) overlying the longwall layouts are also likely to experience greater subsidence effects as a result of the reduced natural overburden thickness.

Forrester and Whittaker (1976) provide a guide to the additional subsidence that may be expected with the formula (rearranged from that presented in the paper):

$$S_a = 2 * S_p H / d$$

where S_a is the additional subsidence, H is the depth of waste rock and d is the overburden depth to rock head (i.e. not including the waste rock). They also detail experience of how tilts, strains, cracking and horizontal movements are modified by waste rock fill. This experience has been found to be consistent with the limited experience available from other sites in the Hunter Valley where fill has been mined under. The approach outlined by Forrester and Whittaker is used to estimate the additional subsidence expected within the Assessment Area.

Subsidence above areas filled with waste rock increases with the thickness of waste rock fill. Table 5 summarises the additional subsidence that is expected above each of the various emplacements located within the Assessment Area.

Table 5: Subsidence parameters forecast for the proposed longwall panels in areas of waste rock back fill

Layout	Maximum Subsidence (m)	Maximum Tilt (mm/m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)
LW 15-20 (257m wide)	2.8	14	14	20
LW15-19 (330m wide)	3.0	15	16	22

Maximum tilts are expected to be of a slightly lower magnitude compared to those predicted for undisturbed ground.

Strains are expected to be approximately double the magnitude of strains in undisturbed ground, particularly in areas where there is a free surface available for horizontal movement. Tensile strains are expected to be particularly elevated at the top of steep slopes in the backfill material and at the interface between natural and backfilled ground.

Subsidence from the proposed longwall layouts is likely to represent typical subcritical width behaviour (excepting the small sections of the deeper open excavations) with the maximum subsidence controlled primarily by panel geometry consistent with consideration of the subsidence mechanics (Mills 1998).

Predictions of strains and tilts are based on the empirical relationships developed by Holla adjusted for the site-specific subsidence monitoring results. Previous monitoring experience provides a cross-check on the values determined and the approach appears to provide a reasonable basis for estimating the maximum values likely to occur.

Should the actual mining plan be a combination of the two longwall void widths assessed then subsidence effects would be expected to be within the parameters forecast and occur in slightly different locations. However, the subsidence impacts resulting from this flexibility in mine plan design is unlikely to be significant.

4.1.1 Vertical Subsidence

Figure 5 shows contours of subsidence that are expected over the Longwalls 15 to 20 layout at the completion of the proposed longwall mining in the Assessment Area. The maximum subsidence at the conclusion of mining Longwall 20 is forecast to be up to 2.0m.

Figure 6 shows contours of subsidence that are expected over Longwalls 15 to 19 layout with wider longwall panels. The maximum subsidence at the conclusion of mining Longwall 19 is forecast to be up to 2.2m. This value represents 65% of the assumed maximum mining height after consideration of the sag and strata compression components of the subsidence profile for the increased overburden depth and longwall panel widths.

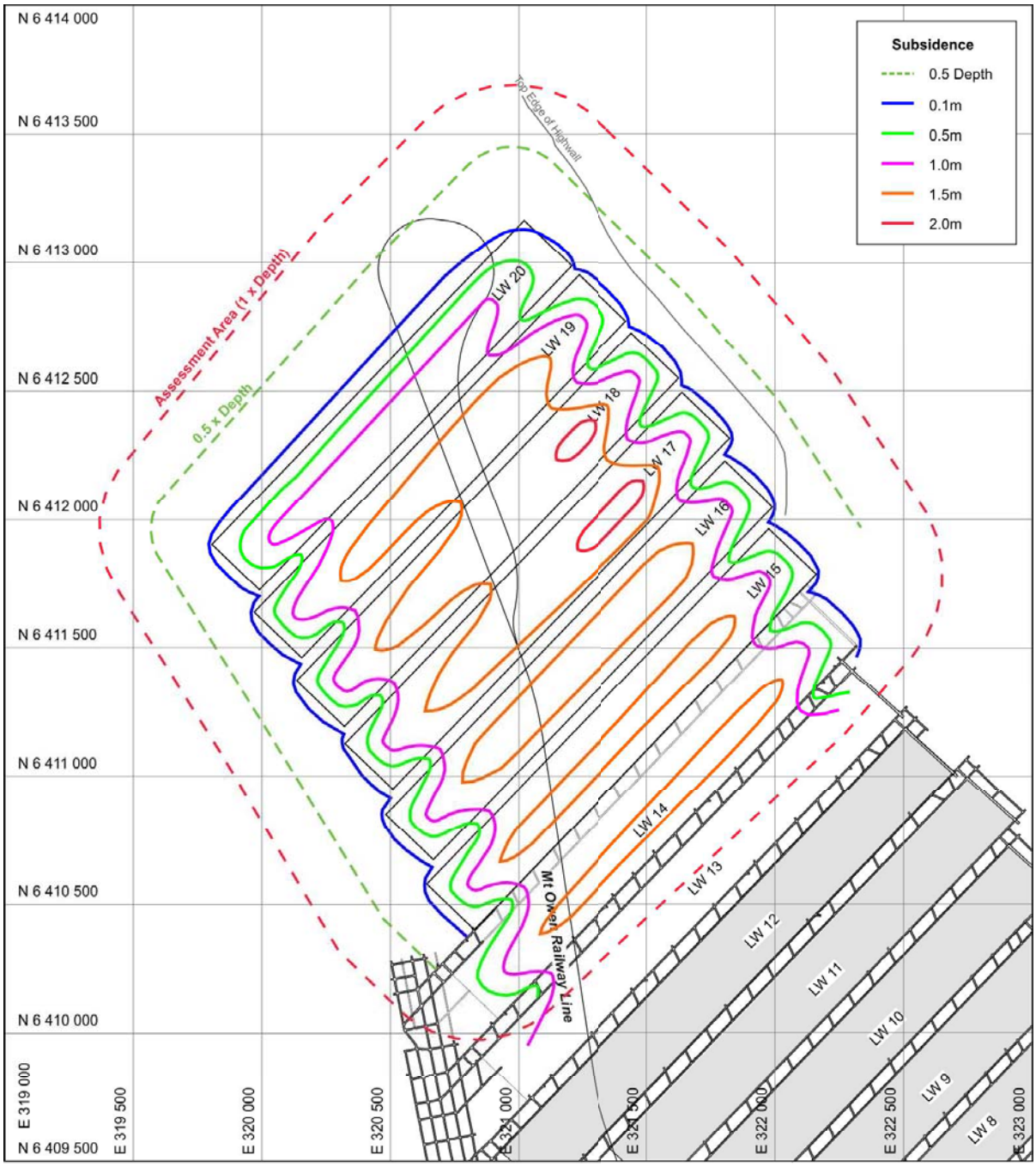

Figure 5: Subsidence contours forecast for Longwalls 15-20 (257m wide voids)

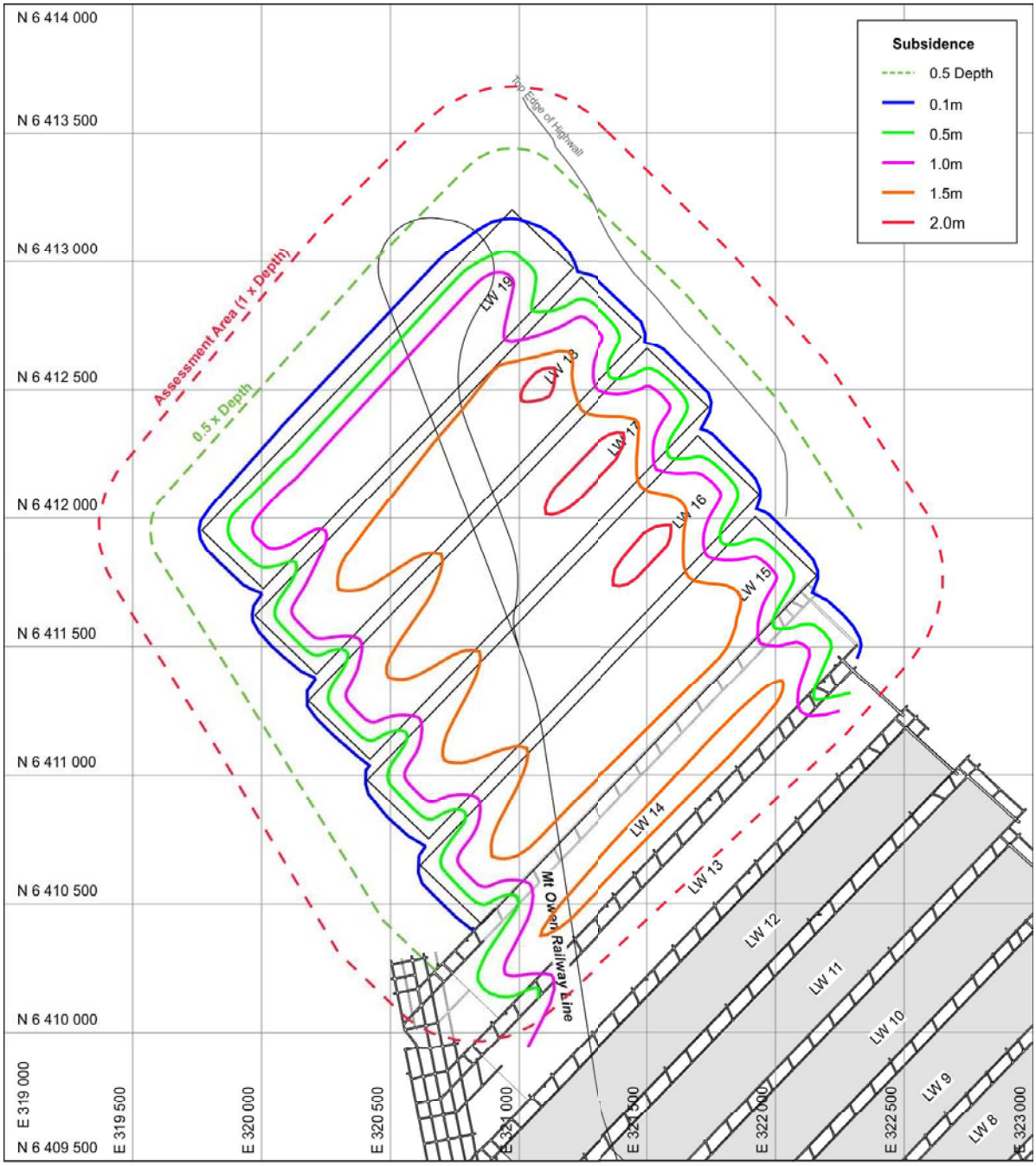

Figure 6: Subsidence contours forecast for Longwalls 15-19 (330m wide voids)

The outer subsidence contours are based on goaf edge subsidence profiles measured previously at the IUG.

Some differences in subsidence from that forecast may occur due to localised effects of topography, geology, and the modified mining surfaces. Variations between the measured and forecast vertical subsidence are not expected to be of any practical significance in this significantly modified surface environment.

Maximum vertical subsidence in a single seam situation is naturally variable by about ±15% for any given panel geometry and overburden depth. Subsidence contours shown should be regarded as indicative of the general level of subsidence rather than as precise indications of subsidence at a point. Any variations in cutting heights that may occur are expected to proportionally influence the maximum subsidence and other subsidence parameters.

As discussed in SCT Report INT4604A (SCT 2017) for Longwalls 13 and 14 Extraction Plan, the subsidence effects from mining Longwall 15, and subsequent panels, are expected to increase the vertical subsidence over Longwalls 13 and 14. The maximum subsidence over Longwall 14 is expected to be similar to that forecast for Longwall 13 at up to 1.9m.

4.1.2 Tilt

The Holla method adjusted for the site conditions indicates tilts of up to 15mm/m in the shallower areas of natural ground in the vicinity of the Mt Owen Rail Line and Rail Loop as a result of the proposed mining.

Over the centre of each longwall panel, tilt is likely to be transitory, although some low levels of residual tilt may remain. Tilt is likely to be permanent near the solid goaf edges and may be greater near the finish of each longwall panel. As each subsequent longwall panel is mined, and there is additional vertical subsidence over the inter-panel chain pillar between panels, a slight reduction in permanent tilt is likely near the panel edges of the inter-panel chain pillars.

4.1.3 Horizontal Movements

Horizontal subsidence movements of up to about 500mm are expected to occur in the Assessment Area as a result of the proposed mining. In general, horizontal movements are expected to occur in a direction toward the mined panel and once the longwall face has passed, in the direction of mining. Horizontal movements are expected to be larger in sloping terrain and adjacent to free surfaces such as open cut voids.

4.1.4 Strain and Surface Cracks

For the natural ground along the Mt Owen Rail Line above the proposed longwall panels, the maximum strains are forecast to be less than 8mm/m in tension and 11mm/m in compression as a result of proposed mining.

Tension cracks may occur in areas of tensile strain depending on the nature of the surface terrain. Cracks are expected to be generally less than about 20mm wide in flat or gently undulating land. Larger cracks may develop over the mining modified ground, particularly at the top of slopes.

Cracks may develop over the longwalls panels and remain in the vicinity of panel edges and along the tops of topographic highs once mining is complete. Permanent tension cracks are likely to be perceptible at the start of each panel. Transient tension cracks may also occur at regular intervals above the centreline of the panel typically just behind the progressing longwall face.

Permanent compression humps and associated low angle fracturing may become apparent at topographic lows such as drainage channels particularly where stream channels flow directly on bedrock. This is not expected to be significant within the Assessment Area.

4.1.5 Unconventional Subsidence Effects

Previous experience at the IUG indicates that unconventional subsidence effects may occur within the Assessment Area, but are unlikely.

Larger, non-systematic tilts and strains are possible as a result of surface topography and the surface expression of geological structure. These effects are difficult to forecast because bedding planes and geological structure are not typically apparent until they become mobilised by mining subsidence. At critical sites, unconventional subsidence movements are typically able to be detected by regular monitoring early on before they become significant.

Valley closure may also occur at topographic low points, but any such movements in the Assessment Area are expected to be of low magnitude and generally insignificant except at the bridges that cross Bettys Creek where they have potential to cause shortening of the bridge deck.

4.1.6 Multi-Seam Subsidence Effects

The multi-seam subsidence predictions for the Middle Liddell Seam and the planned Hebden Seam mining contained within the IUG Project EA were prepared in 2009. At that time no extensive database for multi seam mining in NSW (or Australian) conditions was available. The predictions of subsidence were made based on a conservative approach using the recommended method (Li et al 2007) of that time.

Since then, monitoring of multi-seam longwall mining in two seams has been undertaken and reported at the Ashton Underground Mine approximately 3-4 km to the southwest of IUG. This monitoring, conducted between 2012 and 2016, has advanced the understanding of the mechanics of multi-seam mining in a regular, offset longwall layout. The understanding of issues such as the recovery of latent subsidence from around pillar and goaf edges in the upper seam, the ground behaviour at stacked goaf edges and the influence of mining direction on subsidence movements has improved significantly as a result of the monitoring at Ashton Underground Mine. (Mills and Wilson 2017).

A review of the expected subsidence for the future multi-seam mining of the Hebden Seam (60m below the Middle Liddell Seam) within the Assessment Area indicates that the predicted maximum vertical subsidence value presented in the IUG Project EA is still reasonable, based on the assumptions made for mining height and panel geometries.

While the subsidence forecast for the proposed Longwalls 15 to 20 (or Longwalls 15 to 19) layout has increased since the IUG Project EA, the cumulative subsidence within the overlap area of the approved Middle Liddell Seam Longwall 15 -17 layout and the approved Hebden Seam longwall geometry is not expected to exceed the upper limit of 4.0m predicted in the IUG Project EA.

It is expected that a detailed multi-seam subsidence assessment would be undertaken, at the completion of the Middle Liddell Seam mining (when the actual subsidence is known), to satisfy Extraction Plan requirements within the PA 08_0101 conditions for the secondary extraction of the Hebden Seam.

4.2 Reliability and Accuracy of Subsidence Forecasts

The approach to estimating subsidence used in this assessment is based on a review of previous experience over the first 12 longwall panels at IUG. This approach provides a strong basis for estimating subsidence behaviour over natural ground within the Assessment Area. The forecast subsidence parameters are expected to provide an upper limit for most cases. Maximum subsidence forecasts may be exceeded in areas where the ground surface has been modified by open cut mining activities. Higher values of strain are also possible in some localised areas, particularly about the edges of backfilled open cut voids.

The method outlined in SCT 2006 for the GCUC Project (06_0213), and subsequent Longwalls 10-17 SMP predictions, has proven suitable for providing reasonable estimates of the upper limits of key subsidence parameters for Longwalls 6 to 12. This same methodology has been adopted for longwall panels beyond Longwall 12 in the Middle Liddell Seam.

The upper limit estimates of subsidence movements presented are used for assessment purposes. Actual subsidence is expected to be generally less than these upper limits, so the assessments are considered to be conservative.

Given that Glencore (and its subsidiaries) own almost all the surface land and infrastructure above the Assessment Area and have monitoring and management plans in place, the consequences of any variations from forecast of the maximum values of subsidence parameters are generally not expected to be significant in this extensively modified environment.

The Mt Owen Rail Line and structures within the MIA are the most sensitive infrastructure. The Rail Line has its own dedicated subsidence monitoring and a detailed management strategy including a hierarchy of review by a technical committee to manage any variations of subsidence behaviour from forecast.

This approach has effectively managed subsidence impacts on the rail corridor infrastructure for the extraction of Longwalls 7-12 and is expected to continue to be effective for the proposed mining layouts.

The results of this subsidence monitoring and implications for mining are presented in end of panel reports and compilation reports for previous longwall panels at the site. These results, together with comparison of predicted subsidence for the Longwall 10-17 SMP (SCT 2006) with actual subsidence measurement over Longwalls 10-12, are considered to provide a strong basis for forecasting the subsidence behaviour within the Assessment Area.

Subsidence profiles and estimates of maximum subsidence for this assessment are based on this previous subsidence monitoring using the methodology outlined in SCT 2006 (Mills 1998). Systematic strains and tilts are determined using the approach described by Holla (1985, 1987, 1991) for the Southern, Newcastle, and Western Coalfields of NSW. The forecast of these parameters is then made in consideration of the site-specific conditions and the results of previous measurements at the IUG.

Maximum subsidence parameters are forecast in the context of providing a best estimate of the most likely maximum subsidence. Forecast maximum subsidence values should not be used as performance indicators for subsidence because of the potential for natural variability.

Historically, it was accepted that there would be natural variability about these maxima either side of the best estimate. However, these best estimates can become the basis of triggers for fairly onerous exceedance reporting processes in the absence of specific alternatives even though the natural variability causes exceedances that are of no practical significance.

The intent of exceedance reporting is to identify circumstances when subsidence behaviour is outside the range of expected behaviour and expected natural variability. It is anticipated that specific performance measures will be developed during an Extraction Plan assessment to account for natural variability.

4.3 Review of Previous Subsidence Monitoring

The subsidence behaviour and general form of the subsidence movements at IUG up to Longwall 12 has been found to be consistent with experience at other sites given the site characteristics and mining geometries involved.

Subsidence monitoring has been conducted routinely at IUG since the commencement of longwall mining in 2002. Initially, only two dimensional monitoring surveys were undertaken.

Since the completion of Longwall 6, all the subsidence lines were resurveyed in three dimensions allowing improved insight into the horizontal movements associated with mining Longwalls 6-12. Additional monitoring lines were established along and parallel to the Mt Owen Rail Line to monitor the ground behaviour along this corridor.

Lower levels of subsidence over Longwalls 1-5 are consistent with the narrower panels in this area. Across all panels, chain pillars are clearly visible in the profile. The components of sag and strata compression subsidence are consistent with expectation based on panel and pillar widths and overburden depth.

Table 6 shows a summary of the main subsidence parameters measured on the existing monitoring lines. These include B Line (the main cross panel line) above Longwalls 1-11, G Line across Longwalls 10-12 and H Line adjacent to the Mt Owen Rail Line over Longwalls 7-12. The forecast values are compared with the actual measured values after mining of Longwalls 1-12. The maximum value at the completion of each panel may not necessarily be directly above that panel.

Table 6: Comparison of Predicted Subsidence Values with Measured Values (from SCT Report INT4604A)

LW	Predicted Maximum Subsidence (mm)	Measured Maximum Subsidence (mm)	Predicted Maximum Tilt in Flat Terrain (mm/m)	Measured Maximum Tilt (mm/m)	Predicted Maximum Strain Tens & Comp (mm/m)	Measured Maximum Strain (mm/m)
1	<30	N/A*	0	N/A*	0	N/A*
2	750	430	7	3-5	3.4 & 5.2	1-2
3	920	760	7	5-6	3.9 & 5.9	2-3.5
4	820	860	7	5-6	3.3 & 5.1	2-3
5	840	950	7	5-6	3.4 & 5.2	2-3
6	1470	970	10	6-9	5.7 & 8.8	2-3
7	1500	1270	10	6-9	6.0 & 9.3	2-3
8	1500	1310	10	6-9	5.9 & 9.1	2-3
9	1500	1400	10	6-9	5.5 & 8.5	2-3
10	1600	1350	12	6-9	6 & 9	3-4
11	1600	1410	12	8-11	6 & 9	4-6
12	1600	1500	12	8-10	6 & 9	4-6

*Not available – below survey tolerance

The subsidence behaviour of the natural ground surface for the proposed longwall panels is expected to be similar to the subsidence behaviour observed over previous longwall panels, particularly the subsidence behaviour in the most recently mined panels where the mining geometry, overburden depth and overburden characteristics are comparable.

Additional subsidence is expected in areas where unconsolidated waste rock has been placed in specific emplacement areas or in disused open cut voids.

4.3.1 Vertical Subsidence Parameters

The magnitude of the maximum vertical subsidence measured at the IUG is currently 1.5m. This is less than the value of 1.6m forecast in the Longwall 10-17 SMP assessment (SCT 2006). Individual panels are of subcritical width. Subsidence behaviour is primarily controlled by compression of the chain pillars and surrounding strata. In this circumstance, subsidence is only fully developed following extraction of two or more subsequent panels so that points on the surface experience a number of phases of subsidence as each panel is mined.

Although maximum subsidence is expected to increase over previously mined panels, as additional longwall panels are mined due to additional load and compression of the strata above and below the chain pillars, the total is expected to remain around the predicted maximum of 1.6m. Subsidence over the chain pillars is also expected to increase slightly with each additional panel and as the overburden depth increases. These effects in combination tend to smooth the vertical subsidence profile.

Maximum tilt measured on all the lines to the completion of Longwall 12 was 11mm/m over Longwall 11, with 8mm/m more typically the maximum over individual panels. This maximum value is consistent with the maximum 12mm/m tilts anticipated in flat terrain.

The maximum vertical subsidence recently forecast in Longwalls 13 and 14 Extraction Plan subsidence assessment (SCT 2017) is 1.9m. The increase from 1.6m to 1.9m is mainly a result of the increase in mining height due to changes in seam thickness and mining equipment. Maximum tilt for Longwalls 13 and 14 is forecast at 14mm/m to correspond with the increased vertical subsidence forecast.

4.3.2 Horizontal Subsidence Parameters

Horizontal movements have been observed at IUG since three dimensional monitoring was introduced at Longwall 6 in 2006. The horizontal movements measured at the IUG show characteristics that are similar to other sites. These movements typically comprise three identifiable components: a systematic component associated with vertical subsidence in flat terrain, a stress relief component causing horizontal movement toward the longwall void, and a component associated with sloping topography.

In flat terrain conditions, initial movements of typically less than 150mm occur toward the approaching longwall face followed by a reversal in direction once the longwall face has passed to give a final offset in the direction of mining of up to about 100mm. In the central section of the longwall panel, horizontal movements are predominantly transitory in nature with a permanent offset in the direction of mining. Near the panel edges, horizontal movements are predominantly toward the goaf and the offset in this direction is typically permanent.

Horizontal stress relief movements may extend some distance beyond the longwall panel goaf edge. Survey control for subsidence monitoring at the IUG has not been sufficiently strong to give high confidence measurement of horizontal stress relief movements.

The majority of maximum measured horizontal movements for Longwalls 7-12 have been in the range 200-400mm. This variation is consistent with the 300-400mm range anticipated.

Horizontal subsidence movements of up to about 500mm have been forecast for the mining of Longwalls 13 and 14. Horizontal movements are expected to be larger in sloping terrain and adjacent to free surfaces such as open cut voids.

Horizontal strains measured to date have typically been in the order of 1-4mm/m with localised peaks around 6mm/m. Maximum compressive strains are typically slightly greater than the maximum tensile strains. The strains are generally about half the maximum values anticipated for gently undulating terrain.

For Longwalls 13 and 14, the maximum strains were forecast to be less than 7mm/m in tension and 10mm/m in compression.

4.3.3 Unconventional Subsidence

Unconventional subsidence effects include:

- far-field horizontal movements outside the mining area
- horizontal movements associated with strata dilation in uneven topography
- shear movements on low strength bedding planes leading to the formation of ripples on the surface
- stepping in the ground surface associated with geological structure

The effects of unconventional subsidence movements tend to be localised along narrow zones so the impacts and consequences need to be considered in the context of sensitive features that may be in close proximity.

To date, there have been limited observations of unconventional subsidence movements. Some anomalous behaviour was observed on H Line at the finish line of Longwall 8 during the rail subsidence management program.

4.4 Comparisons with Previous Subsidence Predictions and Approval Performance Measures

This section focuses on the changes to the subsidence forecast for the Middle Liddell Seam mining made since the IUG Project EA (ERM 2009).

SCT 2006 informed the EA for both the GCUC Project 06_0213 and the IUG Project 08_0101. Both these projects include Longwalls 10-17 in the Middle Liddell Seam. The subsequent SMP for Longwalls 10-17 was also informed by SCT 2006. This report was prepared in 2006 when Longwall 6 was in progress. The GCUC Project 06_0213 was approved in 2008.

It was recognised in SCT 2006 that future surface mining proposals had potential to interact with the underground mining to alter the expected subsidence effects and impacts for natural ground surfaces from possibly Longwall 12 onwards. It was recommended at that time, that the subsidence behaviour be assessed in more detail once the mining geometries and timing of surface operations are more clearly defined.

The subsidence monitoring conducted since 2006 for the extraction of Longwalls 7-12 indicates that the subsidence behaviour has been largely within expectations with movements generally less than predictions contained in SCT 2006. Subsidence impacts and consequences have not generally exceeded the subsidence performance measures detailed in PA 08_0101.

The only variation to predictions is evident in the profile of vertical displacement along the Mt Owen Rail Line. Greater subsidence was observed above the finished end of Longwall 8 than was expected. The magnitude of subsidence was much less than the maximum subsidence predicted over subsequent longwalls, but the end effect of the panel near the finish line of the longwall was less than expected and the subsidence over the end of Longwall 8 was greater than predicted at this location.

The increased subsidence over Longwall 8 was of no consequence for the rail line. The rail line was managed effectively based on planned regular monitoring that provided early indication of all changes to predicted ground movements.

4.4.1 Basis for Subsidence Assessment

Considerations for the subsidence estimates in this assessment include:

- This assessment is specific to the Assessment Area and involves an extension to the Project Boundary that includes areas not previously assessed (the approved Longwalls 15 to 17 void area represents approximately 20% of the proposed longwall layouts void area).
- Two longwall width options have been assessed recognising that the actual mining geometry is yet to be determined, however it is assumed that the mine plan area and subsidence effects would be within the maximums forecast.
- The proposed longwall layouts are for the Middle Liddell Seam. Consideration of the multi-seam subsidence effects of the approved Hebden Seam longwall mining layout are included.
- The proposed seam mining height is expected to range from 2.8m to 3.3m compared to a range of 2.2m to 2.4m previously used for vertical subsidence estimates in GCUC Project EA and IUG Project EA.

- The proposed longwall mining area now extends below significant existing and proposed open cut mining excavations and emplacement areas.

- The overburden depth varies from that assumed for the GCUC Project EA in the extended area of this modification proposal.

- Longwall panel widths are proposed to be increased from those approved for the Middle Liddell Seam.

- Significant unconventional subsidence movements are not expected.

- A conservative approach to subsidence predictions has been adopted for the purpose of impact assessment and comparison with compliance thresholds.

4.4.2 Changes to Subsidence Parameters and Impacts since Project EA

For the Middle Liddell Seam mining, the predicted conventional subsidence parameters for natural ground above the proposed longwall layouts reflect the changes to planned mining geometries, the physical dimensions and ground characteristics since subsidence parameters were predicted for the GCUC Project EA.

Maximum vertical subsidence is forecast to increase from that predicted for the GCUC Project EA. The total increase includes additional sag over the centre of the panels from the increased mining height and more strata compression over chain pillars from the increasing overburden depth or increased longwall panel widths. For subcritical geometries, it is recognised that full subsidence effects only develop after a number of subsequent panels are mined. As a result, additional subsidence is expected over Longwalls 13 and 14 from the mining Longwall 15 and subsequent panels.

Maximum tilt and strain levels forecast for the natural ground surface above proposed layouts are generally consistent and only slightly greater than with those predicted in the GCUC Project EA. This reflects the increased vertical subsidence forecast, but also increased minimum overburden depth within the extended area of this approval modification proposal.

There is expected to be potential for greater subsidence, tilt and strains in the mining modified landform over emplacement areas, in and near the edges of the open excavations and at locations where interfaces of natural ground and fill material exist. Additional subsidence is considered likely over backfilled voids and on waste rock emplacements with locally elevated strains and tilts around the edges of the voids and at the top of steep slopes. However, other areas may experience reduced tilts and strains due to the softening effect of unconsolidated ground.

The forecast increases in subsidence parameters do not imply significantly greater subsidence impacts or greater environmental consequences from those previously predicted. None of the subsidence impacts anticipated are particularly sensitive to specific values of maximum vertical subsidence, tilt or strain. The consequences of these increases are likely to be insignificant in the substantially modified surface landform of the Assessment Area.

5. SUBSIDENCE IMPACT ASSESSMENT

In this section, the potential subsidence impacts for various surface features located within the Assessment Area are assessed in the context of the current surface landform and available mine planning information.

It is recommended that the interactions between underground and open cut mining are periodically reviewed as mining plans change.

As well as assessment of environmental impacts, the various features considered are assessed within the context of informing principal hazard management plans required under the Work Health and Safety (Mines and Petroleum Sites) Regulation 2014 to manage the risks to the health and safety of workers and other persons from subsidence.

5.1 Natural Features

Major natural features in the Assessment Area considered in this section include Bettys Creek, the Bettys Creek Diversion, natural dams, areas of natural vegetation and the groundwater system generally. The majority of these features are located over Longwalls 13 and 14. The subsidence effects and impacts from the mining of these panels are discussed in detail in SCT 2017.

5.1.1 Bettys Creek

Bettys Creek is an ephemeral watercourse that meanders across and is incised some 2-3m into the general flood plain in its natural state in the south eastern part of the Assessment Area above Longwalls 13 and 14. The overland flow paths to the northern part of Bettys Creek have been significantly altered by surface mining operations. Bettys Creek was diverted around and across the ERP above Longwalls 13, 14 and 15 in an engineered diversion channel called the MDC. The location of the natural and MDC sections of the creek are shown in Figure 4.

Subsidence impacts on the natural section of Bettys Creek and tributary drainage lines from mining the proposed longwall layouts are expected to involve some ponding following heavy rain. These impacts are not expected to be greater than impacts described in GCUC Project EA and those detailed in the IUG Project EA.

At the completion of both Longwalls 13 and 14, vertical subsidence along the natural section of Bettys Creek is expected to range over a distance of around 700m from around 1.2m at the end of the MDC to about 0.5m near the finish lines of Longwall 13 and Longwall 14.
Valley closure is expected to be less than 100mm from the mining of Longwalls 13 and 14.

The mining of Longwall 15, and subsequent panels, is expected to marginally increase the total subsidence along Betty's Creek to 1.4m. This 1.4m is less than the predicted maximum in the GCUC and IUG Project EA.

A part of the MDC to the north of Longwall 15 has already been consumed by the active Mt Owen North Pit mining operations with approval to continue to mine further to the south over the next few years as part of the MOCO Project.

By the completion of mining both Longwalls 13 and 14, the maximum vertical subsidence along the MDC is forecast to be around 1.9m. This maximum subsidence is expected over the centre of Longwall 13 in the section of the channel above the backfilled ERP, with approximately 1.4m over Longwall 14. The mining of Longwall 15 and subsequent panels is expected to increase the maximum subsidence from 1.4m to 1.9m over Longwall 14.

Impacts to the MDC and tributary drainage lines from mining the proposed longwall layouts are expected to be consistent with impacts described in GCUC Project EA and those detailed in the IUG Project EA for the approved multi-seam mining.

5.1.2 Natural Dams (Ponds)

There are a number of natural ponds located in the southeast of the Assessment Area. These ponds are located on the general floodplain of Bettys Creek and appear to be remnants of old meander channels.

The estimated subsidence effects are expected to slightly increase the volume of each pond. The increased ponding is expected to be accommodated within the existing drainage lines and would not appear out of character with the current or previous water storage capacities at these locations.

Impacts on natural dams from mining the proposed longwall layouts are expected to be less than impacts described in GCUC Project EA and those detailed in the IUG Project EA for the approved multi-seam mining.

5.1.3 Natural Vegetation

There are isolated sections of natural vegetation above Longwalls 13, 14 and Longwall 15 adjacent to Bettys Creek, along the Mt Owen Rail Line (and loop), in the Ravensworth State Forest remnant area and in the Southern Remnant Biodiversity Offset Area above the northwest corner of last longwall panel. The areas are shown in Figure 4.

Parts of the combined Ravensworth State Forest remnant area and the Southern Remnant Biodiversity Offset Area overlie the north-western corner of the proposed longwall panels. Vertical subsidence of less than 0.3m with low level tilt and strains are expected. There is some potential for minor surface cracking to become evident, but in general the impacts to native bushland are expected to be imperceptible for all practical purposes.

There are no very large trees present in any of the areas. The potential for root damage caused by shear movements in the overburden strata is considered likely to imperceptible.

The majority of the area adjacent to Bettys Creek is set aside in the Mt Owen Bettys Creek Habitat Management Area west of the Mt Owen Rail Line. This area is managed under the Mount Owen Biodiversity Offset Management Plan and IUG's Land Management Plan and Biodiversity Management Plan.

The impacts to natural vegetation from mining the proposed longwall layouts are expected to be minor and no greater than impacts described in GCUC Project EA and those detailed in the IUG Project EA for the approved multi-seam mining.

Areas of native grassland remain adjacent to the southern section of the Mt Owen Rail line and within the rail loop. No significant impacts are expected to these sections of vegetation from the proposed longwall mining.

5.1.4 Groundwater

Assessment of the groundwater impacts from the proposed longwall mining has been undertaken independently by groundwater specialists (AGE 2017).

In this section, an overview of the longwall impacts is presented based on previous groundwater monitoring experience at IUG and published empirical data that appears to correlate closely with the IUG experience. Interactions with adjacent open cut operations are considered.

Groundwater monitoring using vibrating wire piezometers at IUG indicates that for 257m wide panels the height of depressurisation (the top of zone above the mining horizon where the pore pressure is zero) extends upward approximately 190m from the Middle Liddell Seam for a 2.3m mining height.

Tammetta (2012) presents an empirical relationship that allows the height of depressurisation above the mining horizon to be estimated from a broad database of hydrogeological experience in single seam mining situations from around the world as a linear function of panel width and exponential functions of seam thickness mined and overburden depth. The IUG experience is consistent with the Tammetta (2012) approach for calculating the height of depressurisation.

The height of depressurisation represents the point at which downward vertical flow within the overburden strata can occur under the influence of gravity without the need for additional pressure. The inflow rate is governed by the vertical hydraulic conductivity of the fracture network above the depressurised zone and the availability of a source of recharge.

To date at IUG, the groundwater monitoring indicates that the hydraulic conductivity of the subsided overburden strata is low enough for rainfall recharge to maintain the surface groundwater at close to pre-mining levels despite the disturbances and fracturing caused by subsidence.

Within the Assessment Area, the maximum seam thickness is nominally 3.3m, the two layout options considered create 257m and 330m wide voids and overburden depth, particularly the thickness of natural ground, is generally much less than over previous panels. These differences are expected to significantly affect the height of depressurisation that can be expected.

For the 257m panel option, the height of depressurisation is expected to be about 260m (220-300m) above the mining horizon based on the Tammetta approach For the 330m panel option, the height of depressurisation is expected to extend to about 330m (290-370m) above the mining horizon.

With the overburden depth generally in the 400-450m range, there is likely to be about 140-190m between the top of the zone of depressurisation and the surface for the 257m panels and 30-80m for the 330m wide panels.

In the Ravensworth East - West Pit, the depth to the Middle Liddell Seam mining horizon is approximately 270m due to the depth of the excavation so there is potential for the zone of depressurisation to extend through to the surface. This interaction represents a change to the groundwater system at this location.

Although such interaction does not imply uncontrolled inflow from the surface into the mine, it does indicate the potential for increased inflow compared to previous site experience. Further assessment is recommended at the Extraction Plan stage.

5.2 Heritage Sites

The current MOC heritage database is used as the basis to update the IUG heritage database. The positions of the Aboriginal and European heritage sites within the Assessment Area considered in the subsidence assessment are shown in Figure 4.

While there are no specific subsidence related performance measures for heritage items in the environmental performance conditions of the PA 08_0101, there are requirements for a Heritage Management Plan. Since the assessments for the GCUC and IUG Project EAs were prepared, ongoing heritage management monitoring surveys and investigations for the MOCO Project EA have identified new sites and several existing sites have been repositioned.

Potential impacts from surface cracking are considered in this section.

5.2.1 Aboriginal Heritage

The locations of the remaining Aboriginal heritage sites within the Assessment Area are shown on Figure 4. There have been a total of 24 sites identified, all of which are open camp sites, artefact scatters or isolated finds in open terrain. Most are located in areas likely to be impacted by the approved MOCO open cut mining.

Subsidence movements are not expected to have any practical effect on open camp sites, artefact scatters and isolated finds in open terrain. There is a slight possibility of subsidence cracks causing disturbance to artefact sites located close to the edge of or directly over mining areas. However the magnitude and frequency of previous surface cracking at the IUG is so small that the potential for change at these sites is considered to be insignificant for all practical purposes.

A total of 19 Aboriginal heritages sites were previously identified within the Assessment Area generally over Longwalls 13, 14 and 15. These were identified and assessed in the GCUC or IUG Project EAs.

Of the 19 sites, nine have been destroyed (or partially destroyed) in accordance with Section 87 or 90 collection or excavation permits. Seven of the remaining 10 sites will be consumed by the Mt Owen North Pit continuation approved under the MOCO Project. The three sites not in the path of the future Mt Owen North Pit are all isolated finds located over the southwest section of Longwall 14 or the Longwalls 13 to 14 chain pillar.

An additional five isolated find or artefact scatter sites have recently been recorded as part of investigations for the MOCO Project EA. Three of these are isolated finds positioned adjacent to the Mt Owen Rail Line loop with an isolated find and artefact scatter site located adjacent to the MDC of Bettys Creek. The two sites adjacent to the MDC will be consumed by the North Pit continuation to the south. Of the three isolated finds adjacent to the rail line, two are located near the western limit of the proposed mining and positioned where only low level subsidence is expected and the other is positioned over the centre of Longwall 18 (or19).

Subsidence movements are not expected to have any practical effect on open camp sites, artefact scatters and isolated finds in open terrain. There is a slight possibility of subsidence cracks causing disturbance to artefact sites located close to the edge of or directly over mining areas. However the magnitude and frequency of previous surface cracking at the IUG is so small that the potential for change at these sites is considered to be insignificant for all practical purposes.

No perceptible impacts are expected to the remaining Aboriginal heritage sites in the Assessment Area, that are not planned to be disturbed by the North Pit extension, due to the type of site, the nature of the terrain and the magnitude of subsidence movements forecast

5.2.2 European Heritage

The Assessment Area for the proposed longwall layouts originally contained seven European heritage sites identified and assessed in the GCUC and IUG Project EAs or recent MOCO Project EA. Only one of these sites, MOH6, remains. The location of this site is shown on Figure 4.

The MOH6 site comprises a former house/dairy site assessed as being of no significance. No perceptible impacts to this site are expected as a result of mining Longwall 13 and 14 or the longwalls of this modification proposal. This site will be consumed by the approved Mt Owen North Pit continuation.

Sites MOH1, MOH2, MOH3, RE31, RE32 and RE33 were assessed to comprise heritage value of local significance and identified as likely to be destroyed by the planned surface mining activities of the West Dump, ERP, TP2 and TP1. As a result, approval for the removal of these sites was previously granted by the Heritage Council of NSW for the Mt Owen Mine operations.

5.3 Public Utilities and Public Amenities

The only public utilities or amenities identified within the Assessment Area are three state survey stations identified as SS_94779, SS_94780 and SS_96126. Two are positioned over Longwalls 13 and 14 adjacent the Mt Owen Rail Line as shown in Figure 4. The third mark (SS_96126) is located in the MIA adjacent to the reclaim conveyor for the train loading storage bin. The proposed mining layouts are expected to cause all three marks to move.

A process to inform the Department of Land and Property Information and re-survey these marks is well developed. The impacts of mining are expected to be manageable through the IUG Built Features Management Plan (BFMP).

The BFMP should include the following processes:

- notifying the asset owner (Land and Property Information) to temporarily 'decommission' a mark that is located within the extent of far-field effects around current mining by removing its coordinates from the database during the period of active mining

- re-establishing the horizontal and vertical position once subsidence is complete

- returning the mark to service with revised coordinate and height valves

This approach is considered a practical way to manage the subsidence impacts on state survey marks from longwall mining and one that is regularly used.

Based on the subsidence monitoring and measurements of far-field movements from underground mining at the IUG, it is likely that SS_94779 and SS_94780 have already undergone horizontal movement as a result of previous mining up to Longwall 12.

The proposed mining layouts are expected to add to any previous horizontal movements with vertical displacement at these marks. SS_96126 is expected to experience increasing horizontal movements as the proposed longwall mining encroaches with the potential for minor vertical displacement during Longwall 20 (or Longwall 19).

As observed at other sites, permanent survey control marks within about 2-3km radius around longwall mining should be considered vulnerable to far-field effects.

5.4 Mine-Owned Infrastructure

Mine-owned surface infrastructure is not typically required to be assessed for subsidence impacts. However, there are some significant surface infrastructure that need to be managed to be compliant with Work Health and Safety obligations including those associated with subsidence. A subsidence assessment of mine-owned surface infrastructure is presented in this section.

The major mine-owned infrastructure located within the Assessment Area includes:

- parts of the MIA including coal stockpile, dams, coal handling and train loading (conveyor and storage bin) infrastructure
- Mt Owen Rail Line and associated infrastructure including the single spur line and loop, the rail and road bridges over Bettys Creek, the adjacent maintenance road, buried raw water supply line, buried communication cables and powerlines
- Mt Owen - North Pit Open cut
- Ravensworth East Open Cut – West Pit
- Glendell haul road
- the ERP, TP1 and TP2 tailings dams
- emplacement areas (overburden dumps) and rehabilitated areas adjacent to Glendell, Ravensworth East and Mt Owen open cut mines (Ravensworth/Glendell and West Dump).

Other infrastructure is located within the Assessment Area, but unlikely to be significantly affected by the proposed longwall mining includes infrastructure related to gas drainage and agricultural activities. A brief description and forecast of subsidence effects and impacts are provided in the following sections for each of the items.

5.4.1 Mine Infrastructure Area

A section of the MIA is located within the Assessment Area as shown in Figure 4. This section includes dams, part of the product coal stockpile, reclaim conveyor, storage bin and train loading infrastructure.

Major impacts to this infrastructure are not expected from the proposed longwall mining. With the exception of a series of run-off dams, most of this infrastructure is located in areas where vertical and horizontal movements are expected to be less than 50mm. Tilts and strains are also expected to be small.

The train loading structures are a critical piece of infrastructure for all three mines at the MOC. As such, including this infrastructure in the Mt Owen Rail Line Management Plan and monitoring the structures as the longwall panels approach is recommended.

The main dam within the rail loop is not expected to be significantly impacted by increased tilt and any minor cracks from increased strain of the ground adjacent to edge of the storage. The subsidiary dams that feed the main dam may experience temporary changes due to transient tilting of the surface as the planned longwalls undermine these features. Minor remedial work may be required to adjust gradients and restore flow paths.

5.4.2 Mt Owen Rail Line

A single line section and loop of the Mt Owen Rail Line and associated infrastructure traverse the Assessment Area.

Figures 7 and 8 show the estimated incremental subsidence profiles along the rail corridor for both the 257m and 330m panel width options.

A management plan for this infrastructure has recently been independently prepared by Mine Subsidence Engineering Consultants Pty Ltd (MSEC 2016) for the mining of Longwalls 13 and 14. The management plan involves regular monitoring of rail stresses with oversight from a technical committee. A similar program of rail monitoring and occasional re-stressing was used to successfully manage the dynamic impacts on the rail line during previous periods of undermining. The rail line was directly mined under by Longwalls 7, 8, 9, 11 and 12. Longwall 10 stopped short of the rail line. Longwalls 7 and 11 only mined under the rail line in one corner.

This management plan is expected to be effective for managing the dynamic subsidence impacts on the rail line loop and associated infrastructure. Rail lines including with curved sections have been successfully mined under by longwall panels elsewhere in NSW in recent years. The rail stresses are kept within tolerance by cutting and restressing the track from time to time as required.

MSEC's subsidence estimates are intended to be used for day to day management of the rail line. These estimates are not necessarily consistent, nor intended to be consistent, with the more general forecasts of maximum subsidence parameters presented in this subsidence assessment report.

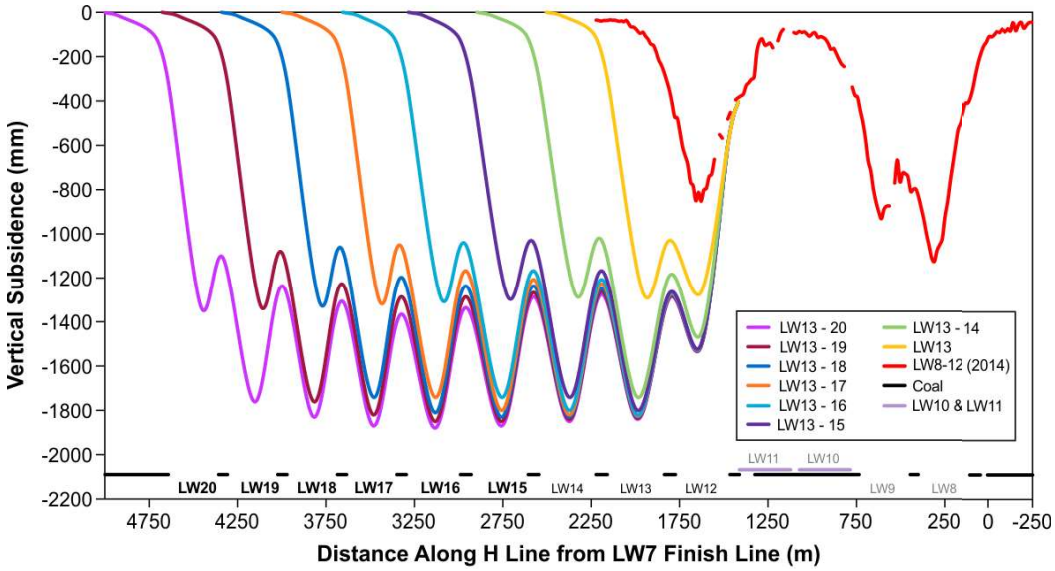

Figure 7: Estimated subsidence profile along rail corridor for 257m layout

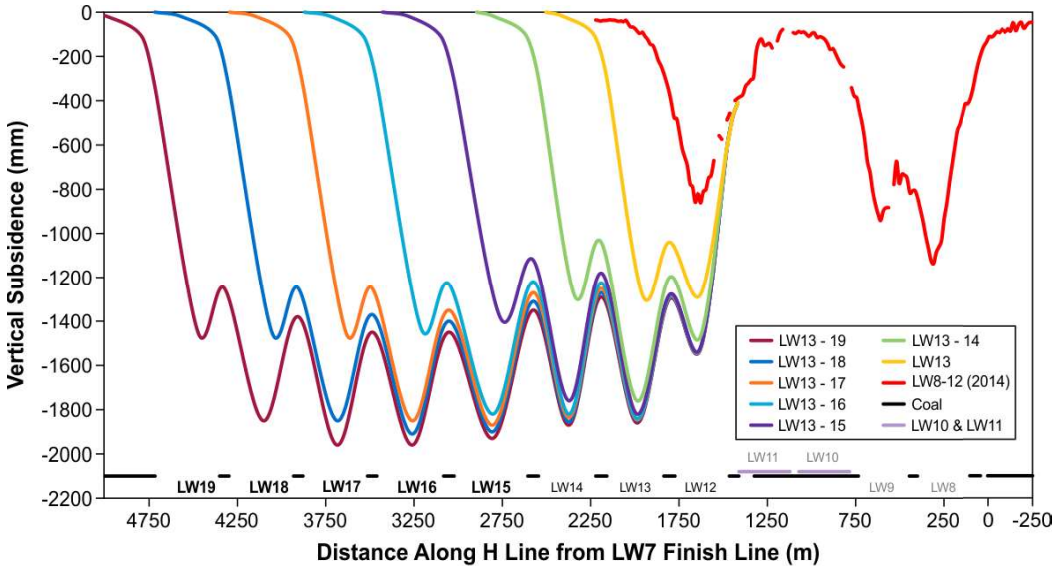

Figure 8: Estimated subsidence profile along rail corridor for 330m layout

A section of the Mt Owen Rail Line between the bridge over Bettys Creek and the start of the loop is currently at maximum gradient. This section is located on an embankment. Subsidence is expected to cause the grades to locally increase when subsidence occurs at the bottom part of the slope. Some significant earthworks are likely to be required to build up the embankment sufficiently to manage the grades during the period of mining and once mining is complete. This work would need to be scheduled ahead of mining.

5.4.3 Bettys Creek Bridges

The road and rail bridges across Bettys Creek are located above the chain pillar between Longwalls 13 and 14. The bridges are planned to be mined under for the first time by Longwall 13. The management of the expected subsidence impacts to these bridges is included in the Mt Owen Rail Line Management Plan and subject to the review of a technical committee.

The bridges are expected to undergo vertical subsidence of less than 300mm by the end of Longwall 13 and less than 1.1m by the end of Longwall 14. The mining of Longwall 15 and subsequent panels is expected to increase the vertical subsidence at the bridges to around 1.3m. The effects of vertical subsidence are not expected to be significant. The bridges are however expected to be vulnerable to horizontal closure that may occur across Bettys Creek. Valley closure of less than about 100mm is considered possible as a result of mining Longwalls 13 and 14. The mining of Longwall 15 is not expected to significantly increase closure movements.

SCT understands that a program involving a review of the structural design of the bridge and modification of the nib walls to provide more freedom for horizontal movements is underway. The mitigation work is expected to be effective in managing the subsidence effects including tilt, strains and valley closure for the planned mining in to the future.

5.4.4 Communication Cables

Communication cables for signalling and other purposes are laid alongside the rail line. It is understood from the Australian Rail Track Corporation that the cables are most likely to be direct buried, possibly in sand, covered by at least a danger marking tape and possibly a "Vinedex" type barrier. Depth of burial could range from approximately 0.5m to greater than 1m. All of the cables are understood to be of the PVC insulated copper type.

During mining of the proposed longwall panels, these communications cables are expected to experience the full range of subsidence movements forecast in Table 4. These cables are expected to be tolerant to expected movements consistent with experience over previous panels. There are failsafe monitoring systems within the communications systems that notify a central control centre and prevent train movements in the unlikely event of a communications cable failure.

Any impacts are expected to be are manageable under the provisions of the Mt Owen Rail Line Management Plan and review of a technical committee.

5.4.5 Maintenance Road

The maintenance road that services the Mt Owen Rail Line runs from the main northern railway to the MIA. This road is located immediately to the east of the rail line. It is a single lane, unsealed road. It is not a public road, and public access is restricted by locked gates.

The road is expected to experience the full range of subsidence movements forecast in Table 4. There is not expected to be any significant change in the condition of the road as a result of subsidence movements.

There is some potential for minor cracks, compression humps and local changes in grade, both along and across the road. There is also some increased potential for ponding across the road in the centres of longwall panels following heavy rain. Any changes are not expected to significantly impact on the serviceability of the road although some increased maintenance may be required over the current and previous longwall panels during the period of active mining, particularly given there is likely to be increased traffic volume during these periods.

The use of warning signs, regular inspections, and timely remediation of any impacts are considered appropriate measures to manage potential impacts.

5.4.6 Embankments and Cuttings

Within the Assessment Area, the Mt Owen Rail Line is constructed using a series of minor cuttings and embankments up to about 5m in height.

Mining subsidence may cause some minor cracking on the rail embankments and sides of the cuttings, but it is not expected to cause any significant instability of the rail formation. Subsidence monitoring and regular inspections undertaken as part of the Mt Owen Rail Line Management Plan are expected to be effective in identifying any significant stability issues. These regular inspections should include the monitoring of any culverts through embankments. There is potential for culverts to become elongated allowing fines migration from the embankment fill through pipe joints that may no longer be sealed.

The Mt Owen Rail Line crosses a causeway formed in the natural ground between the TP2 and ERP open cut voids. This causeway is about 30m high, 110m wide and 500m long. It is located over the proposed Longwalls 15 and 16. While the causeway is expected to experience the full range of subsidence movements from the proposed mining layouts, the stability of the causeway is not expected to be significantly affected.

5.4.7 Water Supply Pipeline

A buried raw water supply pipe that services Glendell and the Mt Owen coal handling and preparation plant runs alongside the rail line. The pipeline is understood to be welded polyethylene pipe with an outside diameter of 355mm buried to a nominal depth of 0.7m.

During mining of the proposed longwall panels, the pipeline is expected to experience the full range of subsidence movements forecast in Table 4. The pipeline is expected to be tolerant to these movements consistent with experience over previous panels.

Any impacts are expected to be manageable under the provisions of the Mt Owen Rail Line Management Plan and review of a technical committee.

5.4.8 Powerlines

Single pole overhead electricity transmission lines are located above the proposed longwall layouts. These powerlines are positioned inside and adjacent to the Mt Owen Rail Line loop running from the MIA to the western extent of the ERP and across to the Ravensworth East – West Pit. These powerlines supply water management installations for the TP1, TP2 and ERP dams as well as the current West Pit water lodgement.

These powerlines are expected to experience the full range of subsidence movements forecast.

Experience from other sites indicates that single pole powerline structures are generally tolerant of subsidence movements. Subsidence monitoring of individual poles during mining indicates that maximum ground tilts and strains do not necessarily transfer fully to the pole structures. However, prior to undermining, a review should be undertaken to ensure the poles are spaced closely enough such that ground clearances to conductors are not likely to be compromised as a result of the subsidence movements expected.

A program of regular visual inspection and appropriate remediation as required is considered a satisfactory way to manage any potential impacts.

5.4.9 Mt Owen - North Pit

The proposed longwalls are being assessed on the basis of the geometries shown in Figure 1.

A major regional geological feature known as the Hebden Thrust Fault is inferred to strike northwest – southeast across the Assessment Area near the north-eastern ends of the proposed longwall panels. The latest interpretation (October 2017) indicates that, within the area of interest, the thrust is not a fault (offset) or series of faults but rather a steeply dipping roll in the overburden strata. The steepest section of this roll is between the north-eastern end of the proposed longwalls and the current position of the south-western highwall at the North Pit.

This roll has potential to limit the north-eastern extent of some of the proposed longwall panels as it appears the Middle Liddell Seam rises rapidly in the northeast direction and reaches a gradient that is unlikely to be suitable for longwall mining.

Figure 9 show a cross-section along the line of the Longwall 17-18 chain pillar edge (for the 257m layout).

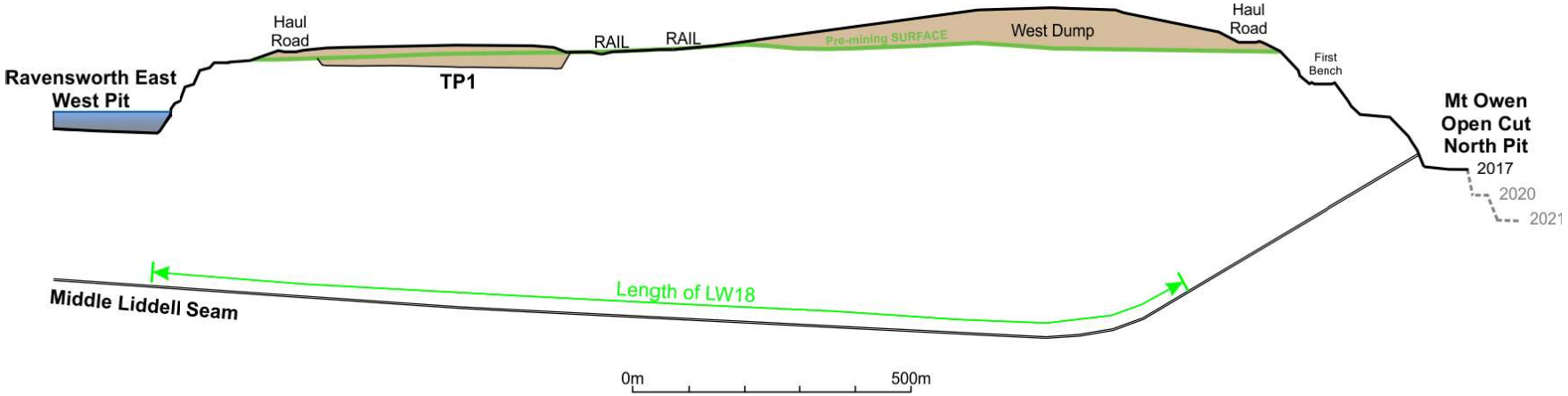

Figure 9: Generalised cross section between Longwall 17-18 at natural scale

The rim of the North Pit or top edge of the Mt Owen south-western highwall is assumed to be the edge of the haul road at the toe of the West Dump slope. For this assessment, the panels are assumed to extend as shown in the proposed layouts in Figure 1. The overburden thickness from the North Pit to the Middle Liddell Seam at the start line of the proposed longwalls and the angle of draw for interactions are largely dependent on the length of the longwall panel and the relative timing of the surface and underground mining operations.

For the geometries assessed, a number of potential interactions between the open cut and the longwall panels are possible. These include:

- highwall and slope instability in the open cut on slopes directly mined under or within a distance of 0.4 times depth to the underground mining
- potential for floor heave in the floor of the open cut
- potential for blasting efficiency of the surface mining to be decreased by subsidence fracturing
- potential for blast vibration to affect the underground
- increased potential for surface inflows into the underground mine and methane emissions into the open cut.

Based on the 2017 Mt Owen Life of Mine - End of Year mining plans it would appear that only Longwall 15 would mine below an active highwall of the North Pit. The geometry for 2019 is shown on the cross section along the centre of Longwall 15 in Figure 10.

5.4.9.1 Slope Instability

A high level geotechnical assessment of the potential highwall or slope instability at the North Pit from the proposed longwall layouts was completed recently. This is based on the experience of mining in proximity to natural cliff formations. SCT Letter Report INT4738_Rev2 (SCT 2017a) presents the assessment.

The assessment indicates that the top 60m section of the south-western highwall between the haul road and the first bench has potential to be impacted by subsidence from all the proposed longwall panels.

For all panels except Longwall 15, these impacts are likely to be relatively minor and mainly associated with the formation of tensile cracks. The cracks may lead to potential for increased water ingress into the slope at times of high rainfall and potential for slope instability as a result. Minor earthworks to control inflow of surface water are likely be to effective controls.

Longwall 15 is planned to mine directly below a 45m high section of highwall in 2019. There is considered to be potential for rock falls to occur along this section of highwall soon after the longwall starts (scheduled for commencement in March 2019).

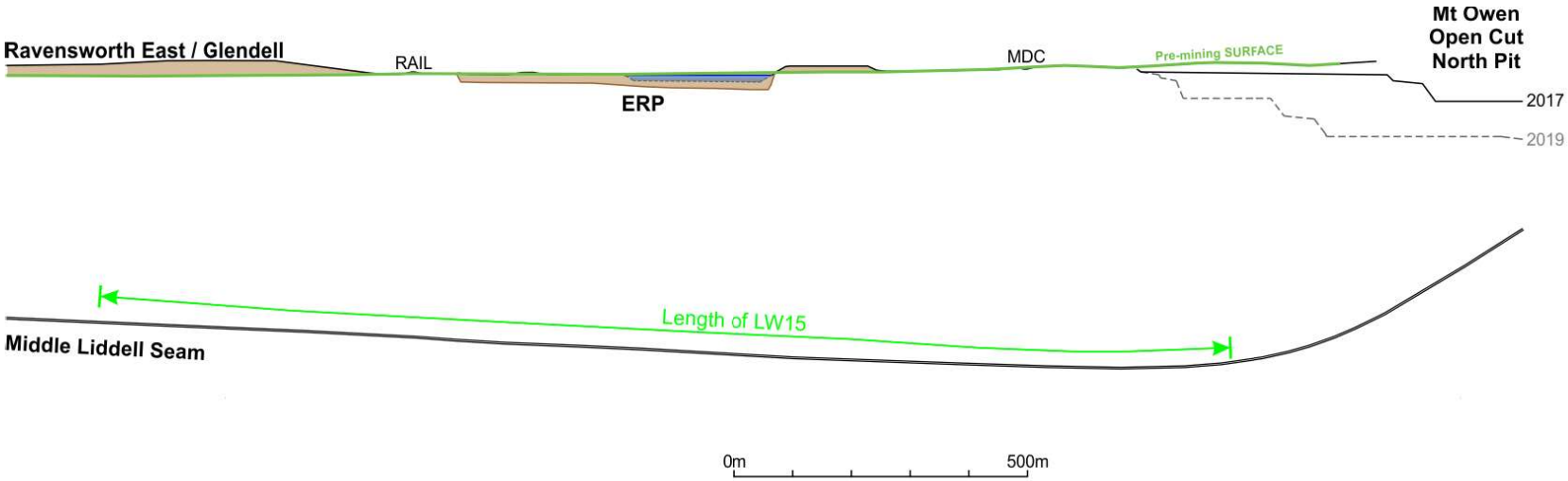

Figure 10: Generalised cross section along Longwall 15 at natural scale

The development of an Extraction Plan application, in consultation with Mt Owen mine, is expected to provide effective mitigation measures for these potential hazards. The Extraction Plan process is expected to involve:

- Further investigation of the Hebden Thrust and overburden stratigraphy to confirm the geometries and material properties of these features.
- Further detailed geotechnical assessments for each longwall at a time when the mining plans for both the surface and underground operations are more fully developed.
- Determination of appropriate stand-off distances as part of a risk assessment process.
- Development of a Management and Monitoring Plan

The experience of mining under the highwalls of active open cut operations is relatively limited. Mining under natural cliff formations has been studied at numerous locations, particularly in the Western and Southern Coalfields of NSW and this understanding provides a basis to assess the likely stability of the open cut highwalls. The mechanics of the processes that cause mining subsidence impacts to cliff formations are relatively well understood.

Based on the experience of mining under natural cliff lines:

- The proposed longwall mining directly below the North Pit open cut void would have potential to cause rock falls on up to about 10% of the length of highwall directly mined under (depending on overburden depth and highwall height).
- Perceptible cracking would also be expected on up to about 50% of the length of highwall directly mined under. Cracking would also be expected to be perceptible to a distance of up to about 0.4 times overburden depth beyond the start of extracted longwall panels.
- Open cracks would increase the potential for ingress of surface run-off into the cracks to contribute further to slope instability.
- Any slope instability may also impact the haul road atop the edge of the southwestern highwall and the toe of the adjacent West Dump slope.

The consequences of these impacts require consideration in mine planning and management of any residual risks. It is anticipated that the potential consequences would be considered during the Extraction Plan process in consultation with Mt Owen mine.

5.4.9.2 In-Pit Floor Heave

The mining of Longwall 15 below the highwall of the North Pit has potential for valley closure effects to generate floor heave in the base of the open cut. For the proposed mining geometry and planned timing, the magnitude of any such effects is expected to be small and result in no more than an operational inconvenience, if it is perceptible at all. Any floor heave events are not expected to present a safety hazard.

5.4.9.3 Decrease in Blasting Efficiency

Subsidence induced fracturing is recognised to develop in the overburden strata above extracted longwall panels. The fracture volume indicated by surface extensometers is of the order of 1% of the total volume (Mills and O'Grady 1998). The effect of this fracturing on the efficiency of overburden blasting is not known but the blast efficiency is expected to decrease.

The proposed modification to the MOCO Project approval SSD-5850 (MOD2 or MOOSE) includes mining deeper seams in the areas over IUG Longwalls 9 to 15. This modification proposal is expected to increase the potential for interactions between the planned surface and underground operations with potential to reduce the open cut blasting efficiencies above Longwalls 9 to 15 at IUG.

There is potential for free methane to be present within the subsidence induced fracture network. It is not anticipated that this free methane would present a specific hazard, but seeking of specialist advice on this issue is recommended.

5.4.9.4 Blast Vibrations

There is potential for open cut blasting to cause vibrations in the underground workings. SCT understands that a management plan to coordinate surface blasting activities and appropriate underground responses is currently in place. Refinement of this plan as mining continues is expected to provide an effective basis to manage these interactions.

5.4.9.5 Increase in Surface Inflows and Methane Emissions

The reduced septum between the base of the open cut and the top of the zone of depressurisation above each longwall panel is expected to increase the potential for downward flow of surface water into the underground mine workings and the upward flow of methane from the underground into the opencut.

These potential interactions are most likely to occur in areas where the open cut is mining directly over an existing goaf. The current mining plan geometry, relative timing and presence of the Hebden Thrust mean that only Longwall 15 is likely to mine directly above the active open cut operations. The North Pit is planning to mine directly above the goaf areas of Longwalls 9 to 15 at IUG.

SCT understands that the potential for increased inflow into IUG has been assessed in an independent groundwater study (AGE 2017).

The potential for methane emissions into the Mt Owen open cut to present a safety hazard needs to be assessed for areas where this potential exists.

5.4.10 Ravensworth East - West Pit

The position of the Ravensworth East - West Pit is shown on Figure 4. The southern end of the West Pit is currently idle and used for tailings emplacement and water storage. Further to the north the pit is being filled with overburden material. A section of the southern and eastern highwall is still exposed.

The main impacts from proposed longwall mining is expected to be the potential for instability of the exposed eastern highwall and the increased potential for water ingress to the underground workings from the reduced overburden thickness. Both these impacts are likely to reduce as the open cut void is back filled.

The maximum depth of the pit near the finish lines of the proposed longwall layouts is approximately 130m. This overburden depth to the base of the open cut void is approximately 270-280m where Longwalls 18 extends out below the eastern highwall. The exposed highwall here is around 80m high.

Subsidence effects are likely to be limited by the distance the proposed longwall panels extend out beyond the highwall. Full caving and disturbance of the overburden strata is unlikely to develop and extend through to the open cut void wherever the longwall face is less than about half depth (150m) past the highwall.

Rock falls and perceptible cracking are expected along sections of the highwall that are directly mined under. Rock falls are expected on up to about 20% of the length of highwall directly mined under. Perceptible cracking is expected on up to 70% of the length of highwall directly mined under.

The consequences of this instability are not considered significant in the context of the current usage of the pit and position of haul or access roads above the highwall or in-pit. However, this situation may change before the planned longwall mining is complete. This hazard is expected to be manageable using warning signs and restricted access during the periods of active undermining. A management plan similar to that current for the ERP and TP2 during the mining of Longwalls 13 and 14 is recommended.

There is the potential for minor cracking and slope instability to occur to the waste rock stockpiles as a result of the longwall mining operations.

With a minimum overburden thickness of around 270m, there is considered to be potential for increased ingress of water from the West Pit to the underground workings in areas directly above the proposed longwall panels.

Using the Tammetta approach, the estimations of height of depressurisation is a function of overburden depth, panel width and seam thickness mined. For 257m wide panels, the height of depressurisation is estimated to be in the range of 170-300m for mining heights of 2.8-3.3m. For the 330m wide panels, the height of depressurisation is estimated to be in the range of 210-340m for mining heights of 2.8-3.3m.

The zone of depressurisation above each 330m wide longwall panel is therefore likely to interact with the surface. The rate of surface inflow into the mine is expected to be increased compared to the rate experienced at IUG to date.

Management of the increased inflows is expected to involve increased pumping requirements for IUG.

The potential for increased inflow into IUG mine workings for both longwall layouts has been assessed in an independent groundwater study (AGE 2017).

5.4.11 Glendell Haul Road

The haul road from the active Glendell Barrett Pit to the Mt Owen Coal Handling Preparation Plant southern ROM stockpile crosses the proposed longwall area as shown in Figure 4.

The haul road is likely to experience up to 1.6m of vertical subsidence with corresponding tilts and strains. Perceptible cracking is expected on the hard surface with local changes in grade, both along and across the road. There is also some potential for minor compression humps. These potential changes are more likely to affect light vehicles rather than significantly impact on the serviceability of the road for the haul truck fleet. Some increased maintenance may be required over the current and previous longwall panels during the period of active undermining.

The use of warning signs, regular inspections, and timely remediation of any impacts are considered appropriate measures to manage potential impacts.

5.4.12 Eastern Rail Pit

The position of the ERP is shown on Figure 4. The ERP was mined after preparation of the GCUC Project EA and IUG Project EA. This shallow pit was mined to a maximum depth of about 35m. The ERP is currently being filled and capped, with only a small area of open void located above Longwalls 14-16. Sections of the northern and western highwalls are still exposed but these are of low height.

The backfilled open cut excavation extends over the full width of Longwalls 13 and 14. The Bettys Creek MDC above Longwall 13 and 14 is located in part on the rehabilitated ground of the ERP.

The ERP is expected to experience the full range of subsidence movements forecast for mining of the proposed longwall panels. The main impacts from these subsidence movements are the potential to cause minor instability of the exposed highwalls as they will be directly mined under, and settlement of filled areas, adding to the total subsidence forecast.

The consequences of any rock falls from the exposed highwalls are not likely to be significant in the context of ongoing backfilling of the void. Highwalls that have already been backfilled and capped are not expected to be affected by mining subsidence, although there may be increased potential for cracking particularly at the interface between fill material and natural ground surface.

As a precaution, access to any roads positioned close to the edge of highwall should be restricted during the period of active undermining. It is suggested that a management plan similar to the existing ERP Management Plan for the mining of Longwalls 13 and14 is developed and implemented.

There is some potential for additional subsidence movements to develop as a result of further settlement of unconsolidated backfill material both ongoing from natural consolidation and from disturbance caused by subsidence. This additional subsidence is not expected to be of any consequence.

The potential for spontaneous combustion of coal fines due to changes to the water level in the filled material and overflow of the material in the ERP as a result of subsidence movements should be considered in the BFMP.

The overburden depth from the floor of the ERP to the Middle Liddell Seam horizon is estimated to be 430m. For the 257m wide layout, the height of depressurisation is estimated to be about 240m and for the 330m wide around 300m. This suggests there is likely to be a minimum 130m of lower vertical hydraulic conductivity overburden strata above the zone of depressurisation. This overburden strata is expected to restrict vertical flow.

There is considered to be limited potential for increased vertical groundwater flow between the surface and underground workings and no potential for flows of a magnitude sufficient to constitute an inrush hazard.

The potential for increased inflow into IUG mine workings has been assessed in an independent groundwater study (AGE 2017).

Maintaining the pit water at a low level during periods of active undermining is recommended. This reduces any potential for overflow from the pit due to transient tilting of the surface that may pose an environmental risk.

5.4.13 TP1 / Mt Owen Rail Loop Tailings Dam

TP1, also known as the Mt Owen Rail Loop Tailings Dam, is located directly above the proposed longwall panels. TP1 is a prescribed dam under the NSW Dams Safety Committee jurisdiction. The position of TP1 is shown on Figure 4.

This open cut pit was mined to around 30m deep and has now been almost completely filled with tailings. TP1 is in the process of being capped. No significant highwalls are exposed. TP1 currently only has a small section of ponded water at its southern end.

The subsidence effects from the proposed longwall layouts are not expected to have any significant impacts to the tailings and capping or any exposed highwall edges.

The minimum overburden depth below the floor of this pit to the mining horizon is around 450m. The height of depressurisation for the 257m wide panels is estimated be around 260m above the mining horizon and for the 330m wide panels around 330m above the mining horizon.

These observations indicate that the base of the open cut void would be approximately 120m above the top of the zone of depressurisation. Although disturbed by mining, this septum is expected to significantly reduce the potential for vertical flow from the surface into the mine workings. It is considered to be no potential for flows of a magnitude sufficient to constitute an inrush hazard.

The potential for increased inflow into IUG mine workings has been assessed in an independent groundwater study (AGE 2017).

Maintaining the pit water at a low level during periods of active undermining is recommended. This reduces any potential for overflow from the pit due to transient tilting of the surface that may pose an environmental risk.

5.4.14 TP2 / Mt Owen Stage 5 Tailings Dam

TP2, also referred to as the Ravensworth East Resource Recovery (RERR) area, is located adjacent to the Mt Owen Rail Line and opposite the ERP. This pit was originally mined to a depth of around 35m. The position of TP1 is shown in Figure 4.

While the pit has been substantially backfilled, capped and largely rehabilitated, a small area of void is still open. This void appears to be currently in use for water quality management purposes. The maximum depth of the open void is around 25m where a section of the eastern highwall is still exposed. The open section would be directly above the proposed Longwalls 15 and 16 where the full range of subsidence movements would be expected.

The main impacts from these subsidence movements are the potential to cause minor instability of the exposed highwall as it will be directly mined under and settlement of filled areas.

The consequences of any rock falls from the exposed highwall are not likely to be significant in the context of the current use and exposure of persons and equipment to the top and bottom of the highwall. It is suggested that a management plan similar to the existing TP2 Management Plan for the mining of Longwalls 13 and14 is developed and implemented for the proposed longwall mining.

The forecast subsidence movements are likely to result in further settlement of the fill material and induce cracking particularly at the top of the filled areas and the interface between fill material and natural ground surface along the buried highwall. This additional settlement is not expected to be of any consequence.

The overburden depth from the floor of the open void of TP2 to the Middle Liddell Seam horizon is estimated to be 435m. For 257m wide panels, the height of depressurisation is estimated to be about 240m and, for the 330m wide panels, about 300m. An estimated 135m of strata between the floor of the open cut and the top of the zone of depressurisation is expected to be sufficient to reduce the vertical conductivity to low levels.

In this situation, there is considered to be potential for increased vertical groundwater flow between the surface and underground workings but not of a magnitude sufficient to constitute an inrush hazard.

The potential for increased inflow into IUG mine workings has been assessed in an independent groundwater study (AGE 2017).

The longer-term mining plan for the RERR indicates that the existing TP2 capping and fill is to be removed and the area mined again to a greater depth. This is planned for around 5-10 years' time after the North Bayswater Pit at Ravensworth East is complete. Further assessment of the potential interaction issues of the proposed longwall panels with the approved RERR surface mining is recommended during the Extraction Plan process, once the relative timings are better defined.

5.4.15 Overburden Emplacement Areas

There are several areas of rehabilitated waste rock fill from the Glendell, Ravensworth East and Mt Owen open cut mines located within the Assessment Area. The major emplacements are the West Dump and the Glendell/Ravensworth East area. Other minor emplacements include the in pit stockpiles of the idle Ravensworth East - West Pit and the active Mt Owen North Pit as well as those associated with the rehabilitation of TP2 and the ERP. The position of these areas is shown in Figure 4.

The major emplacements are expected to experience higher levels of subsidence than those forecast for natural ground areas due to additional settlement of the fill material. Cracking may develop at the topographic high points and at the base of the steeper sections inducing water ingress during periods of heavy rain contributing to minor instability. Some minor remediation work may be required, but overall any subsidence impacts to this modified landform are expected to be manageable.

There are two run-off dams associated with the main emplacement areas. The dam for the Ravensworth East/Glendell area, which drains to Bettys Creek, is expected to experience minor additional subsidence to that forecast for Longwalls 13 and 14. Any additional impacts are expected to be manageable under the current arrangements for this dam outlined in the existing Surface Water Management Plan.

The run-off dam for the West Dump is located adjacent to the rail line and overflows to feed a smaller natural dam via culverts under the maintenance road and rail line. This water then flows into the rail loop dam. These two dams are expected to experience the full range of subsidence movements from the proposed longwall layouts. Any changes in level or surface cracking are expected to be temporary in nature and easily repairable.

Regular inspections over the areas of active longwall mining in conjunction with the provisions of the Land Management Plan and BFMP are expected to provide satisfactory management of any subsidence impacts to these features.

5.4.16 Gas Drainage Infrastructure

Components of the IUG gas management system are present or proposed within the Assessment Area. The existing installations are mainly above Longwall 13. The system comprises surface to seam boreholes with collar installations and surface pipeline networks for either flaring the gas to reduce greenhouse gas emissions or delivery to a central gas drainage plant for power generation. It is anticipated that the existing gas management system will be extended to cover areas above the proposed longwall layouts where surface access is possible.

SCT understands that this gas drainage equipment is designed to accommodate the anticipated subsidence movements and effective management measures are in place. These measures include systems to monitor the gas flow composition with provision for alarm and safety shut-off.

A regular network inspection regime is also included in the control measures. These installations and systems were validated through risk assessment processes and have been successfully used over previous longwall panels for the eight years since initial commissioning. The current control measures are expected to be effective within the Assessment Area as well.

5.4.17 Agricultural Land

Some of the land located within the Assessment Area is used for grazing purposes. Subsidence impacts to this type of land are insignificant for most practical purposes and cracks are easily remediated if they occur.

The mining of the proposed longwall layouts is not expected to have any greater impact to agricultural utilisation or agricultural suitability of farm land than those outlined in the GCUC Project EA or IUG Project EA.

A program of regular visual inspection and appropriate remediation is considered a satisfactory way to manage any impacts.

5.4.18 Access Roads and Four Wheel Drive Tracks

There are unsealed access roads and four wheel drive tracks for light vehicles located throughout the Assessment Area. The impacts of mining subsidence on the tracks or roads are expected to be essentially similar to impacts previously observed over the previous longwall panels, all of which have been managed successfully in the past.

There is some potential for cracks, compression humps and local changes in grade, both along and across the road. The impact of these would not be significantly out of context with the general nature of the terrain and other hazards that might exist. Some minor repair work may be required to smooth out irregularities and close up any open cracks that may form.

The use of warning signs, regular inspections, and timely remediation of any impacts are considered appropriate measures to manage potential impacts.

5.4.19 Farm Dams

There are several small farm dams located along the south eastern portion of the Assessment Area. These are positioned on ephemeral drainage lines tributary to Bettys Creek.

The dam walls are generally insubstantial structures of less than 2-3m high. Minor impacts from subsidence are expected. These impacts are expected to be consistent with previous experience of undermining similar features.

Experience of mining below these types of dams indicates that the water losses are too small to be of significance from a downstream safety perspective, even if all the water was released in a short timeframe. They certainly do not pose an operational risk to underground mining.

The mining of the proposed longwall layouts is not expected to have any greater impact to farm dams than those outlined in the GCUC Project EA or IUG Project EA.

A small amount of remediation may be required to restore any impacted dam to its pre-mining condition. If undermining occurs when the dams are full, then consideration may need to be given to emptying the dams to reduce the potential for scour of the dam wall so as to avoid the requirement for more substantial remediation.

A BFMP that includes regular inspections during the period of active mining and consideration of remediation works is thought to be a satisfactory way to manage any potential impacts from subsidence effects.

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