Strata Control Technology

HUNTER VALLEY COKING COAL PTY LTD

Integra Underground Mine: Subsidence Assessment for LW17-20 Extraction Plan

INT5106

Mining Research and Consulting Group

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TITLE Integra Underground Mine:
Subsidence Assessment for
LW17-20 Extraction Plan

REPORT NO INT5106

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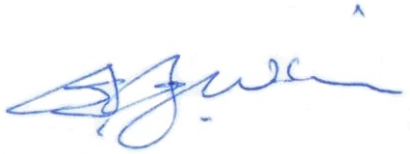

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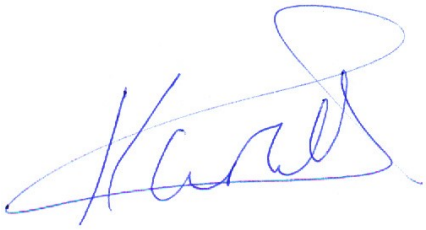

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SUMMARY

Integra Underground Mine (IUG) is an underground coal mine owned and operated by Hunter Valley Coking Coal Pty Ltd (HVCC) 12km northwest of Singleton in the Hunter Valley of NSW. In accordance with modified Project Approval 08_0101 for the Integra Underground Project, HVCC is preparing an Extraction Plan (EP) for secondary extraction of Longwalls 17-20 as part of its ongoing operations in the Middle Liddell Seam. HVCC commissioned SCT Operations Pty Ltd (SCT) to undertake a subsidence assessment to forecast the subsidence effects and impacts expected from mining these panels to support the EP application. This report presents the results of our assessment.

Conventional subsidence effects estimated for Longwalls 17-20 are shown in the table below. These estimates are the same as the maximum values forecast in the IUG Project MOD8 Environment Assessment (EA) for Longwalls 15-20 except for subsidence over waste rock emplacement which was 2.8m in the MOD8 EA to account for areas over Longwalls 15 and 16.

Longwalls	Subsidence (m)	Tilt (mm/m)	Tensile Strain (mm/m)	Compressive Strain (mm/m)
Natural/Undisturbed Ground				
LW17-20	2.0	14	7	10
Areas of Waste Rock Emplacement				
LW17-20	2.5	14	14	20

Impacts from proposed extraction of Longwalls 17-20 are expected to be compliant with the subsidence performance measures of PA08_0101 MOD8 with required management plans and related risk control measures in place.

Notwithstanding input from other specialists, impacts to sensitive or significant surface features identified in the IUG Project MOD8 EA are expected to be less than those forecast in the MOD8 EA. Changes to mining plans for both underground and surface mining and increased offset distances reduce the impacts to the Mt Owen - North Pit, Ravensworth East - West Pit and built features within the Mine Infrastructure Area at Mt Owen.

Impacts to natural features and surface infrastructure including infrastructure within the Mt Owen Railway Line corridor are expected to be consistent with or less than those forecast in the IUG Project MOD8 EA. All impacts are expected to be manageable with appropriate management plans in place.

Potential impacts from subsidence movements are not expected to constitute a principal hazard as defined by the *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014*.

We recommend subsidence monitoring of the surface and critical infrastructure in the vicinity of Longwalls 17-20. However, the need for additional monitoring and management measures at the Mt Owen - North Pit instigated for mining Longwalls 17–20 should be reviewed after mining the first section of Longwall 16.

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1. INTRODUCTION

Hunter Valley Coking Coal Pty Ltd (HVCC), a wholly owned subsidiary of Glencore Coal Assets Australia (Glencore), is planning to mine Longwalls 17-20 in the Middle Liddell (ML) Seam at the Integra Underground Mine (IUG) near Camberwell, 12km northwest of Singleton in the Hunter Valley of New South Wales. In accordance with modified Project Approval 08_0101 for the Integra Underground Project, HVCC is preparing an Extraction Plan (EP) addressing secondary extraction of these longwall panels. HVCC commissioned SCT Operations Pty Ltd (SCT) to undertake a subsidence assessment to forecast the subsidence effects and impacts expected from the proposed mining to support the EP application. This report presents the results of our assessment.

The report is structured to provide:

- Conclusions and recommendations in Section 2 including:
    - a review of subsidence performance measures as outlined in the IUG Project Approval conditions
    - a review of performance indicators
    - a review and revision of subsidence predictions since Project Approval
    - recommendations for ongoing subsidence monitoring and management.
- A brief overview of the site in Section 3, including a general description of significant surface features within the EP Assessment Area (EP Area) including those identified during the risk assessment undertaken for this EP application.
- Estimates of the subsidence effects expected within the EP Area as a result of the planned mining in Section 4. This section also includes:
    - A review of previous subsidence experience at IUG as an update of understanding gained since the original Project Approval was granted.
    - Comparisons with previous subsidence predictions for longwall mining in the ML Seam, as detailed in the Environmental Assessments (EAs) for the original Glennies Creek Underground Coal (GCUC) Project (06_0213) and updated in the recent Modification 8 (MOD8) to the IUG Project.
- A description of the subsidence impacts expected to the various surface features and surface infrastructure located across the EP Area as a result of the forecast subsidence movements in Section 5.

Figure 1 shows a site plan of the planned Longwalls 17-20 panel voids, relative to the existing longwalls panels, superimposed onto an aerial photo of the area taken in December 2019. The EP Area is also shown.

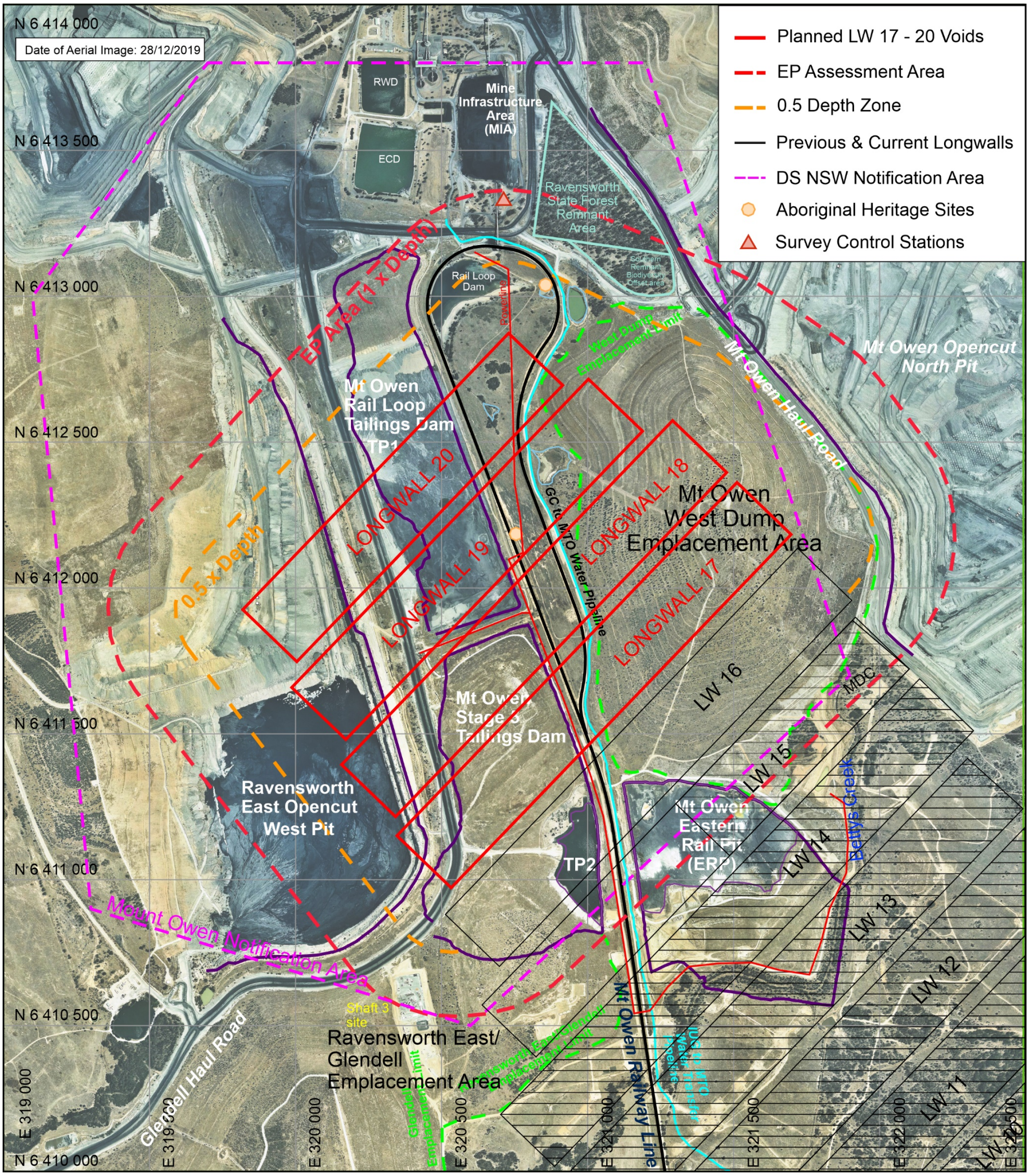

Figure 1: Site plan showing planned Longwalls 17-20, EP Area and major surface features.

Surface features of relevance to this assessment include the open cut mining operations and infrastructure at the Glencore owned Mt Owen Complex (MOC) mine infrastructure area (MIA).

The subsidence and impacts to surface features are assessed as required for an EP, but also in the context of the requirements under the *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014* to manage risks to health and safety associated with subsidence. The information presented is intended to assist in:

- Determination of subsidence as a principal hazard or not.
- Informing risk assessments and the development of control measures to manage or control risks to health and safety.
- Managing risks to health and safety associated with mining induced seismic activity.
- Improving co-operation and co-ordination of action, with respect to subsidence, between the mine operator and relevant persons conducting any business or undertaking that is, or is likely to be, affected by subsidence.
- Detailing the site characteristics, including relevant mining geometries, geological, hydrogeological or geotechnical conditions and potential impacts on relevant surface and sub-surface features to develop control measures to manage the risks from subsidence.
- Providing information about the land above or in the vicinity of the proposed mining that may be affected by subsidence.
- Managing the risks to the health and safety of workers and other persons from subsidence.

2. CONCLUSIONS AND RECOMMENDATIONS

Estimates of conventional subsidence effects for the Longwalls 17-20 EP are consistent with or less than the maximum values forecast in the IUG Project MOD8 EA for 257m wide longwalls and much less than forecast for 330m wide longwalls.

In general, impacts from mining Longwalls 17-20 are expected to be less than impacts described in GCUC Project EA and less than those detailed in the original IUG Project EA for the approved multi-seam mining. Impacts were assessed in the IUG Project MOD8 EA for additional surface features. These impacts are expected to be less than forecast in MOD8 for the 257m void width longwalls because longwall lengths and subsidence footprint have been reduced since that assessment. The impacts are much less than forecast for 330m wide longwalls.

Impacts to natural features and surface infrastructure are expected to be consistent with, or less than those forecast in the IUG Project MOD8 EA.

Surface features and infrastructure located within the active subsidence zone are expected to be included in new and revised management plans. All impacts are expected to be manageable with appropriate management plans.

In general, the consequences of subsidence impacts to surface features, largely owned by Glencore, within the substantially modified landform of the EP Area, are expected to be minor and insignificant for all practical purposes.

Since MOD8 to IUG PA08_0101 was approved, HVCC and Mt Owen Operations (MTO) changed the mine plans to reduce the potential subsidence impacts from underground longwall mining on surface mining operations at MOC. HVCC reduced the lengths of Longwalls 15-20 and MTO altered the mining sequence at Mt Owen North Pit to avoid mining directly above the active face line of Longwall 15. Together, these actions resulted in:

- a reduction in subsidence effects and impacts to built features within the MOC MIA

- a significant reduction in the potential for interactions of subsidence from Longwalls 17–20 with the Mt Owen North Pit, including impacts to the haul road and slope stability of the highwall.

Other interaction issues for the Mt Owen - North Pit identified for the MOD8 EA such as mining above longwall goaf areas have also been reduced or delayed by the changes made to the mining plan at each operation. There is potential to reduce the need for additional monitoring and management measures. We recommend these measures are reviewed once the monitoring data from mining the initial section of Longwall 16 is available and has been analysed.

Impacts to groundwater and potential for increased inflow into the underground workings from mining Longwalls 17-20 adjacent to the Ravensworth East - West Pit are not expected to be significant. The inflows are expected to be less than those forecast in the IUG Project MOD8 EA for the 257m wide longwalls and much less than the maximum impacts forecast for 330m wide longwall panels.

2.1 Revised Subsidence Forecast since Project Approval

Estimates of conventional subsidence effects for the Longwalls 17-20 EP are consistent with or less than the maximum values forecast in the IUG Project MOD8 EA for the 257m wide longwalls. Table 1 shows the estimates of primary subsidence parameters for conventional subsidence from the mining of Longwalls 17-20.

Maximum vertical subsidence from the mining of Longwalls 17-20 is expected to develop above Longwalls 17-19 with less subsidence over Longwall 20. Additional subsidence is expected over Longwalls 15 and 16 from the mining of Longwall 17 and subsequent panels. The values for Longwalls 15 and 16 are expected to increase to the maximum values forecast for these panels in the EP.

Table 1: Estimates of Primary Subsidence Parameters for the mining of Longwalls 17-20

Longwall	Maximum Subsidence (m)	Maximum Tilt (mm/m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)
Natural/Undisturbed Ground (e.g. Rail Loop Corridor)				
LW17	2.0	14	7	10
LW18	2.0	14	7	10
LW19	2.0	14	7	10
LW20	1.5	14	7	10
Areas of Waste Rock Emplacement (e.g. TP1, TP2, ERP, West Pit, West Dump)				
LW17	2.5	14	14	20
LW18	2.5	14	14	20
LW19	2.5	14	14	20
LW20	2.5	14	14	20

Greater vertical subsidence is expected in areas where the overburden has been modified by previous surface mining activities. Subsidence above areas filled with waste rock is expected to increase with increasing thickness of waste rock fill. The estimates of maximum vertical subsidence over waste rock emplacements within the EP Area for Longwalls 17-20 are less than those forecast in SCT (2017c) for the MOD8 EA. With changes to the mining plan, maximum waste rock thickness is less than the maximum over the larger Longwalls 15-20 Assessment Area considered in SCT (2017c) and subsidence is less as a result.

2.2 Subsidence Performance Measures

Our assessment indicates that the subsidence impacts from proposed mining of Longwalls 17-20 is likely to be compliant with the subsidence performance measures outlined in Table 10 of Section 17 in Schedule 3 (Environmental Performance Measures) of the modified IUG Project Approval 08_0101, assuming the required management plans and associated risk mitigation controls are in place.

Table 2 summarises the subsidence performance measures outlined in Table 10 of the modified IUG Project Approval 08_0101, and the status of compliance expected during the secondary extraction of Longwalls 17-20. Compliance with the subsidence performance measures should be considered in the context of the existing heavily modified surface environment, development consent approval (SSD-5850) for the Mt Owen Continued Operations (MOCO) Project, common ownership (Glencore) of built features, the location of the planned mining of Longwalls 17–20 relative to the position of significant surface features and the status of other proposed built features.

SSD-5850 provides consent for the Mt Owen North Pit to continue to the south above parts of Longwalls 9 to 15 at IUG. The North Pit open cut void is planned to mine through part of the Bettys Creek Middle Diversion Channel (MDC), other minor drainage lines with farm dams and areas of natural vegetation up to the southeast corner of the Eastern Rail Pit (ERP) excavation.

Table 2: Subsidence Performance Measures and status of compliance expected during proposed mining

Subsidence Performance Measures			Status of compliance expected during planned mining of Longwalls 17-20
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 IUG Project EA	Compliance expected because no greater subsidence effects for natural ground compared to IUG Project EA (other specialists to assess impacts to water). No natural watercourses above Longwalls 17–20. 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 IUG Project EA, unless the owner agrees in writing	Compliance expected because no greater subsidence effects for natural ground compared to IUG Project EA (other specialists to assess impacts to water). Mt Owen North Pit approved to mine through sections of the Bettys Creek MDC during next 5-10 years. Common ownership of assets (Glencore).
Water	Underground Project Creek Diversions	Remain hydraulically and geomorphologically stable	Not Applicable - Not built yet as these diversions are mitigation measures for Hebden Seam mining. Indicative construction date would be after mining LW20.
Water	Other water storages and drainage lines	No greater environmental consequences than predicted in the IUG Project EA	Compliance expected because no greater subsidence effects for natural ground compared to IUG Project EA. (other specialists to assess impacts to water). Mt Owen North Pit approved to mine through some farm dams and drainage lines.

Biodiversity	Threatened species, populations, habitat, or ecological communities	Negligible impacts.	Compliance expected because no greater subsidence effects for natural ground compared to IUG Project EA. (other specialists to assess impacts to biodiversity). Mt Owen North Pit approved to mine through 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 IUG Project EA. Common ownership of assets (Glencore).
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 IUG Project EA. Majority of land owned by Glencore and is not easily accessible by the public.

The Glennies Creek Alluvial aquifer is remote from the planned mining area and is not expected to be impacted by the proposed underground mining, although any potential impacts need to be assessed by other specialists.

The Underground Project creek diversions are not yet constructed. These are planned to be built in the future to mitigate or remediate the potential impacts of total vertical subsidence from approved multi-seam (ML and Hebden) mining.

Negligible impacts are expected to biodiversity items.

Built features, owned by Glencore, that may be impacted by the planned mining are expected to remain safe, serviceable and repairable unless agreed otherwise.

No additional public safety hazards are expected.

2.3 Performance Indicators

Condition 17 of Schedule 3 (Environmental Performance Measures) of the modified IUG Project Approval 08_0101 requires detailed performance indicators to be defined in the various management plans required under the approval for each of the subsidence performance measures in Table 10. Condition 20(d) requires detailed performance indicators be included in the EP for each of the subsidence performance measures in Table 10.

The provision of performance indicators in some categories falls within the domain of other specialists. However, the subsidence behaviour in the EP Area is expected to be generally consistent with the subsidence movements presented in the GCUC Project EA and less than those in the original IUG Project EA. Performance indicators were not required or presented in these previous assessments, but the subsidence effects forecast for this EP are generally consistent with forecasts in these previous EAs and less than those in the MOD8 EA.

To prevent triggering reporting processes for events that are of no practical consequence, we recommend setting performance indicators for conventional subsidence effects – maximum vertical subsidence, maximum tilt and maximum strain – at 20% above forecast values to account for expected natural variability of 15%. These performance indicators are then more suitable for setting levels in trigger action response plans (TARPS).

Unconventional subsidence movements and ground movements in areas of mining modified terrain may locally exceed these performance indicators. Unconventional subsidence movements are easily identifiable and tend to be localised within narrow zones. The impacts and consequences of unconventional subsidence movements need to be considered in the context of sensitive features that may be close by. We recommend that exceedances associated with unconventional subsidence and ground movements in areas of mining modified terrain do not trigger formal exceedance reporting processes because their appearance is not an indication that subsidence behaviour is out of range or non-compliant with forecasts. Subsidence movements that exceed the performance indicators, not associated with unconventional subsidence behaviour or areas of mining modified landform, should trigger formal reporting processes.

The Glennies Creek alluvium aquifer referred to in Table 10 is remote from EP Area. There is no potential for impacts from the proposed mining. Notwithstanding the input of other specialists, the absence of perceptible impacts following the completion of mining in Longwalls 17–20 is considered likely to be an appropriate performance indicator at this stage.

The Underground Project Creek Diversions (to mitigate expected impacts from the approved multi-seam mining of the ML and Hebden Seams) are yet to be constructed. No compliance status or performance indicator is required at this stage.

The performance indicators for built features are required to confirm the features remain safe, serviceable or repairable, unless the owner agrees otherwise in writing. Under the common ownership of Glencore, an appropriate performance indicator for built features is compliance with expectations and performance measures in the various management plans for built features.

An appropriate performance indicator for public safety would be the occurrence of any public safety incident. Such an incident would be considered to represent an exceedance of the subsidence performance measure requiring no additional risk to public safety due to mining.

2.4 Recommendations

The recommendations found in the various sections of this report are summarised in this section.

2.4.1 Subsidence Monitoring

Full details of recommendations for subsidence monitoring are presented in Section 6. In summary, the recommended survey subsidence monitoring for Longwalls 17-20 includes:

- An extension of R Line (H Line replacement), the subsidence line located alongside the Mt Owen Railway Line, to 250m northwest of Longwall 20, as a series of isolated survey marks for far-field horizontal movement monitoring installed prior to the commencement of Longwall 17.

- Maintaining marks on R Line at 1/20th depth (or 20m) spacings to the north as far as 0.5 overburden depth beyond the northern goaf edge of each active longwall.

- Continuous, near real-time GNSS (GPS) monitoring of the train loading infrastructure within the MOC MIA or similar installed prior to the commencement of Longwall 17.

- LIDAR surveys of the surface at the end of each longwall panel.

- Ongoing surveys of survey pegs located around the top edge of the highwall of Ravensworth East - West Pit after each longwall until the completion of Longwall 19.

- Ongoing surveys of points around the Shaft 3 site boundary after each longwall until the completion of Longwall 19.

2.4.2 Subsidence Management

There are several existing management plans in place at IUG and MTO covering previous and existing longwalls to manage the potential risks and impacts from subsidence and surface mining.

In addition to recommendations regarding the application of performance indicators for subsidence effects and for subsidence monitoring, recommendations for measures to mitigate or remediate potential subsidence impacts are made throughout this subsidence assessment report.

Most of the recommendations are for management strategies and inclusions in built features, land, surface water or other asset management plans to manage the expected impacts to surface features. These features include infrastructure in the MOC MIA, Mt Owen Railway Line and associated infrastructure, surface drainage, powerlines, West Pit, Glendell and North Pit haul roads, TP1, TP2, ERP, emplacement areas, sediment control dams, Ventilation Shaft 3 and access roads and four-wheel drive tracks. Continuing use of the public safety management plan is also recommended.

3. SITE DESCRIPTION

This section presents a description of the surface features within the EP Area including the proposed mining geometry, overburden depth, mining section thickness and other parameters relevant to this subsidence assessment. An overview of the mining approvals context and a general overview of significant surface features likely to be impacted by mining are also included.

Figure 1 shows the EP Area and surface features of relevance to this assessment including the adjacent open cut mining operations and various infrastructure owned by Glencore. The locations of the longwall panels at IUG relative to these surface features are also shown. Longwalls 1-14 were mined previously and are completed. Longwall 15 started secondary extraction in September 2019 and is scheduled to be complete in May 2020.

Figure 2 shows views from a three-dimensional (3D) model of the site illustrating the relativity between the surface mining areas and the planned Longwalls 17–20 layout at the ML Seam horizon. The surface terrain and imagery for the model were captured on 28 December 2019.

3.1 Definition of Extraction Plan Area

The EP Area for Longwalls 17–20 is determined as the area within a distance equal to the overburden depth to the mining horizon (equivalent to a 45° angle of draw) around the outermost goaf edges of the planned panel voids.

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 expected to be insignificant for all practical purposes.

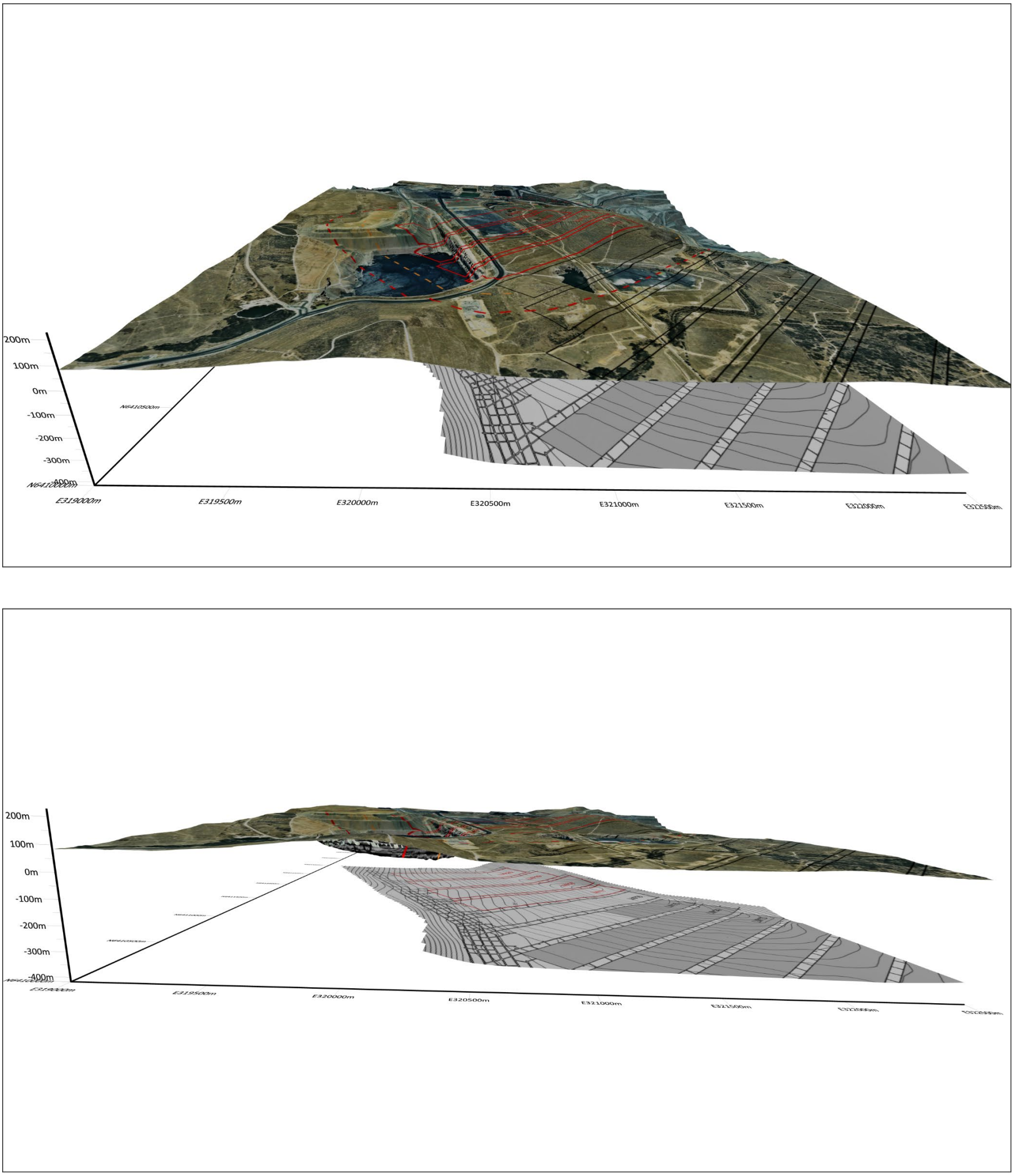

Figure 2: Views from the 3D model at natural scale showing relativity between surface and underground mining in Middle Liddell Seam.

The EP Area includes the surface above Longwall 16 and more than half the width of Longwall 15 so that the assessment includes the effects of additional subsidence from mining Longwalls 17-20 expected above these panels.

3.2 Approvals Context

Integra Underground Mine was previously known as Glennies Creek Colliery. Glennies Creek Underground Coal (GCUC) Project (06_0213) covers the general area now known as Integra Longwalls 10-17. The GCUC Project was approved in June 2008. Potential environmental impacts were assessed in the Glennies Creek Colliery Longwalls 10 to 17 Part 3A Environmental Assessment (ERM 2007) and associated documents. The predicted subsidence effects and impacts for the GCUC Project were presented in SCT Report GLEN2990A 'Subsidence Assessment for Longwalls 10-17 at Glennies Creek Colliery' (SCT 2006).

A subsequent project application was made for the site to include completion of mining in the ML Seam and provision for mining in the Hebden and Barrett Seams. This project, Integra Underground Project 08_0101, was approved in November 2010. The potential environmental impacts of this project were assessed in the Proposed Integra Underground Coal Project Environmental Assessment (ERM2009) and associated documents. The predicted subsidence effects and impacts for the IUG Project were presented in SCT Report GLEN3253 'Part 3A Subsidence Assessment for Mining in the Hebden, Barrett and Middle Liddell Seams at Integra Underground Mine' (SCT 2009).

Further modifications to the IUG Project Approval include separation of the underground and surface mining operations from a single approval to two individual approvals to facilitate separate ownership of the assets. Integra Underground Mine was subsequently sold to HVCC, a subsidiary of Glencore. Many of the surface interaction issues that stemmed from separate ownership of the underground and the surface mines in the vicinity of the MOC above the underground are no longer relevant under common ownership.

A recent modification (MOD8) to IUG PA08_0101, approved in April 2018, authorises extensions to the lengths of Longwalls 15-17 plus additional longwall panels in the ML Seam to the northwest beyond the area approved by GCUC PA06_0213. The EA for this modification "Integra Underground Mine - Longwall Extension Modification - Environmental Assessment", by Hansen Bailey Environmental Consultants, (HB 2017) was informed by SCT Report "Integra Underground Mine: Subsidence Assessment for Modification to PA08_0101" (SCT 2017c). MOD8 approves a combination of Longwalls 15-20 at 257m void width or Longwalls 15-19 at a coal width of 320m (330m void).

An approved Subsidence Management Plan (SMP) for PA06_0213 granted in October 2008 covering Longwalls 10-17 in the ML Seam expired in October 2015. As a result of the expiry of the SMP approval and in accordance with the requirements of Condition 20, Schedule 3 in PA08_0101, HVCC is required to prepare and gain approval of an EP prior to undertaking second workings (longwall extraction) for Longwalls 13 and subsequent panels.

The EP for Longwalls 13 and 14 was approved in April 2017 following the period the IUG was in 'care and maintenance'. The EP for Longwalls 15 and 16 with 257m void widths was approved in August 2019.

To support the EP development for Longwalls 17-20, this subsidence assessment provides:

- revised predictions of the conventional and non-conventional subsidence effects

- revised predictions of subsidence impacts and environmental consequences of the proposed second workings, incorporating any relevant information obtained since obtaining the Project Approval

- a comparison of predicted subsidence impacts against the subsidence performance measures described in Schedule 3, Condition 17 of PA08_0101 recognising that these subsidence performance measures generally relate to impacts and consequences from multi-seam mining.

The EP requirements of PA08_0101 include specific management plans for Built Features, Public Safety, Rehabilitation, Water, Biodiversity, Land and Heritage for features within the EP Area. These provide for the management of potential subsidence impacts and/or environmental consequences caused by the proposed second workings.

SCT understands that specialist reviews of the current subsidence and associated environmental impacts are to be included as supporting information within the current EP Application. These reviews are understood to include a review of actual impacts against predictions made within previous environmental assessments including the IUG Project EAs and the subsidence performance measures.

3.3 Land Ownership and Land Use

Most of the surface land within the EP Area is owned by Glencore or subsidiary companies and is used for mining purposes. These purposes include active surface mining associated with MOC and active gas drainage and ventilation installations for underground mining operations at IUG. All surface infrastructure within the EP Area is owned and maintained by Glencore or subsidiary companies.

There are no agricultural activities within the EP Area.

A small portion of the remnant Ravensworth State Forest is located in the north of the EP Area but outside half depth or 26.5° angle of draw from areas of underground mining. This remnant of the Ravensworth State Forest is owned by the NSW Government and managed by the Forestry Corporation of NSW.

3.4 Surface Features

Longwalls 17-20 are located below an area of the Glencore Mt Owen Complex (MOC) which includes the Glendell, Ravensworth East and Mt Owen open cut mines. Almost all the EP Area has been significantly modified by the MOC surface mining activities. The landform associated with the surface mining areas is, by nature of the mining processes, a dynamic environment.

The major features of significance to this subsidence assessment above, or in the vicinity of, the planned longwalls are:

- Some infrastructure associated with the MOC Mine Infrastructure Area (MIA).
- The Mt Owen - North Pit highwall and haul road to the northeast of the longwall start lines.
- The Mt Owen Railway Line loop and associated infrastructure crossing all longwalls.
- Glendell haul road traversing all longwalls.
- Rehabilitated emplacement areas (e.g. West Dump, Ravensworth East/Glendell).
- Open cut voids being capped (TP1 - Mt Owen Rail Loop Tailings Dam).
- Open cut voids being filled and used for tailings disposal (Ravensworth East - West Pit).
- Open or partially filled open cut voids (TP2 - Mt Owen Stage 5 Tailings Dam and Eastern Rail Pit).
- Powerlines.
- Surface water management installations.
- Gas drainage and ventilation installations and equipment.
- Access roads and four-wheel drive tracks.

Other surface features within the EP Area and adjacent areas include two Aboriginal heritage sites (isolated finds) within the rail loop and several survey control stations located within 3km of the planned mining that may be affected by far-field subsidence movements.

All the planned longwalls are located within the Dams Safety NSW notification area for Mt Owen Rail Loop Tailings Dam (also known as TP1). TP1 is a declared dam (previously referred to as a prescribed dam up until 2015) under the jurisdiction of Dams Safety NSW (previously the Dams Safety Committee). TP1 is almost completely full of tailings and in the process of being capped.

3.5 Future Surface Mining Activities and Infrastructure

Future mining activities at Mt Owen include the filling and capping of the ERP after the mining of Longwall 15 and ongoing filling and capping of Ravensworth East – West Pit and TP1. Further emplacement of waste rock material above the ERP to form a continuation of the West Dump is planned, but not scheduled until after underground mining in the area (Longwall16) is complete.

HVCC is planning to regular installations of goaf drainage boreholes and gas management infrastructure during mining of Longwalls 17-20.

MOD8 to IUG PA08_0101 allows HVCC to construct additional surface infrastructure over the northern ends of Longwalls 15-20. This additional infrastructure includes dewatering boreholes with pumping equipment and ventilation shafts with surface fans. The power supply for this infrastructure would require an extension of the existing 11kV overhead powerline that currently terminates above Longwall 14.

3.6 Middle Liddell Seam Geometry

Figure 3 shows the depth below natural ground surface to the ML Seam mining horizon and seam thickness isopaches with an outline of major surface features, the current workings and the planned Longwalls 17-20 layout.

3.6.1 Overburden Depth

The overburden depth within the EP Area varies through a combination of seam gradient, topographic variation and surface mining activities.

The seam dips to the northeast at a gradient of approximately 1 in 20 across most of the longwall panels. The seam rises steeply to the northeast at a gradient of up to 1 in 1.5 beyond the northeast end of the panels as part of a localised syncline feature associated with the Hebden Thrust Zone.

The depth of overburden between the original surface and ML Seam mining horizon ranges from 390m to 540m above Longwalls 17–20. The original surface has been modified by emplacements and excavations causing the overburden depth to change. This modification is ongoing. Up to 65m of waste rock is emplaced on the West Dump. The West Pit was mined to a maximum depth of approximately 130m at its southern end and is currently being backfilled with tailings and waste rock. Waste rock is higher than the original ground level in some areas. TP1, TP2 and the ERP were mined to depths of around 30m to 35m below surface and are being or have been back filled.

As a result of these modifications, maximum overburden depth to the Middle Liddell Seam mining horizon is now approximately 600m below the West Dump at the north-eastern end of Longwall 17. Minimum overburden depth is currently 340m below the southern end of the West Pit at the south-western end of Longwall 18. The overburden in this area comprises 270m of undisturbed rock and 70m of tailings.

The rail corridor above Longwalls 17–20 is located on or close to the natural ground surface. Overburden depth ranges 480-500m along this corridor.

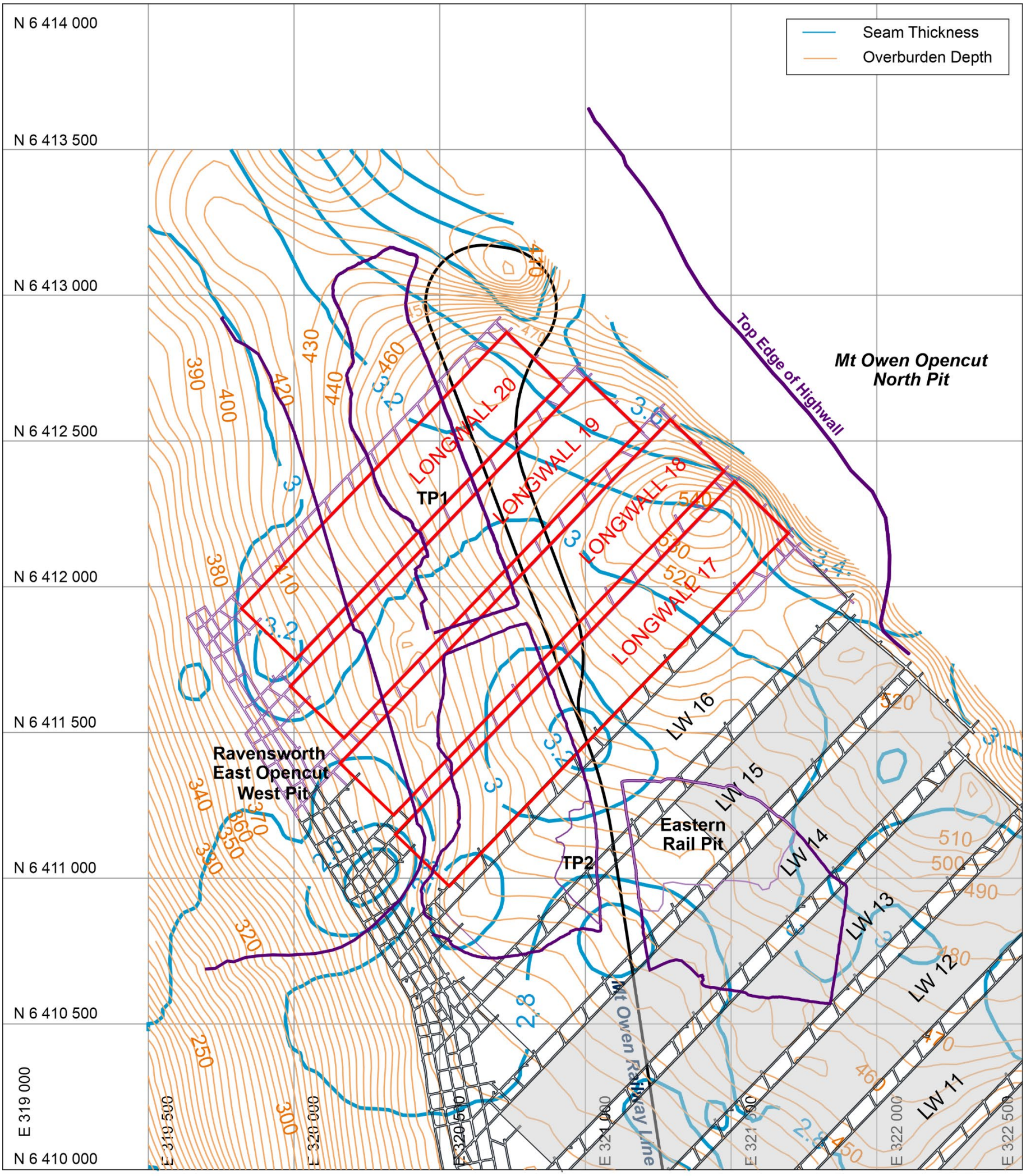

Figure 3: Overburden depths from original surface to current workings and Seam thickness for planned Longwalls 17-20 in Middle Liddell Seam.

3.6.2 Geological Structure

The north-eastern extent of the longwall panels within the EP Area is limited by a major geological structure called the Hebden Thrust Fault. This feature is interpreted as an en echelon fault system aligned in a northwest-southeast orientation and presenting locally as a steep roll in the strata rather than as an offset fault structure. Recent exploration drilling and verification from underground mining proved seam gradients close to the Hebden Thrust are up to 1 in 2 and unsuitable for longwall mining. As a result, the lengths of Longwalls 15-20 are reduced from those approved in MOD8 and the Longwalls 15 and 16 EP. The start lines for Longwalls 17-20 are positioned where the seam gradients become too steep for conveyors.

3.6.3 Seam Thickness

Exploration drilling indicates the ML Seam thickness in the area of Longwalls 17-20 ranges 2.6-3.4m but is more typically 2.8-3.2m. The maximum and minimum thicknesses occur at the ends of panels. Mining height is expected to range 2.8-3.2m allowing for variations in seam thickness and the minimum practical operating height for mining equipment. A maximum mining height of 3.2m is used to forecast the estimated subsidence parameters specific to Longwalls 17-20.

3.7 Proposed Mining Geometry

Longwalls 17-20 are a continuation of the series of longwall panels mined sequentially at IUG from the southeast to the northwest.

Development roadways for longwall panels are driven to the northeast from the main headings in the southwest. Individual longwall panels retreat mined from the northeast toward the main headings. Longwalls 17-20 are immediately adjacent to the current development for Longwall 16.

The voids for Longwalls 17-20 are planned to be nominally 257m wide, separated by chain pillars that are 49m wide measured coal rib to coal rib.

The planned lengths of Longwalls 17-20 are all significantly shorter than approved in MOD8. The influence of the Hebden Thrust caused a reduction in length of between 175m to 405m at the north-eastern ends. The panels are also marginally shorter at southwestern ends for practical reasons related to development of the panel entries in the underground layout.

Table 3 details the planned mining geometry including the total longwall lengths as approved by MOD8 for the 257m wide longwall layout in brackets.

The shortening of Longwalls 17-20 has increased the horizontal offset distance to 300-600m between longwall mining and features assessed for MOD8 including the haul road and south-western highwall at Mt Owen – North Pit. This increased offset is expected to significantly reduce the potential for interactions with Mt Owen - North Pit, including impacts to the haul road and to the stability of the highwall.

Longwall 17 start line is approximately 300m horizontally from the top edge of the highwall. Longwall 20 is approximately 600m from the highwall.

Table 3: Planned mining dimensions for Longwalls 17-20

Panel	Nominal Gateroad Width (m)	MG Chain Pillar Width Coal Rib to Rib (m)	LW Void Width (m)	LW Void Length (m) (length approved by MOD8)
LW17	5.2	49	257.1	1681 (1897)
LW18	5.2	49	257.1	1637 (1882)
LW19	5.2	49	257.1	1467 (1824)
LW20	5.2	49	257.1	1315 (1752)

3.8 Surface Features and Surface Infrastructure

In this section, surface features identified within the EP Area are described. Figure 4 shows the locations of these features.

Surface features in the EP Area were identified based on:

- multiple site inspections over recent years including:
    - on 25 June 2019 for a review of the subsidence assessment for multi-seam mining approved in PA 08_0101
    - on 9 October 2019 for the Longwall 14 End of Panel subsidence report
    - on 4 March 2020 for this subsidence assessment.
- previous subsidence assessments including those for the Longwalls 13 and 14 Extraction Plan, Longwalls 15-20 in PA08_0101 MOD8 and the Longwalls 15 and 16 Extraction Plan
- review of historical satellite imagery for the site
- information presented in the Mt Owen Continued Operations (MOCO) Project Environmental Impact Statement (UM 2015) and MOCO Project MOD2 Statement of Environmental Effects (UM 2018).

A risk assessment for the planned mining of Longwalls 17-20 was conducted on 4 March 2020. The risk assessment team included environmental specialists, a railway subsidence specialist, and management personnel from both IUG and the MOC. The risks associated with subsidence impacts to the features identified within the EP Area were considered in the context of the subsidence management requirements under the *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014*.

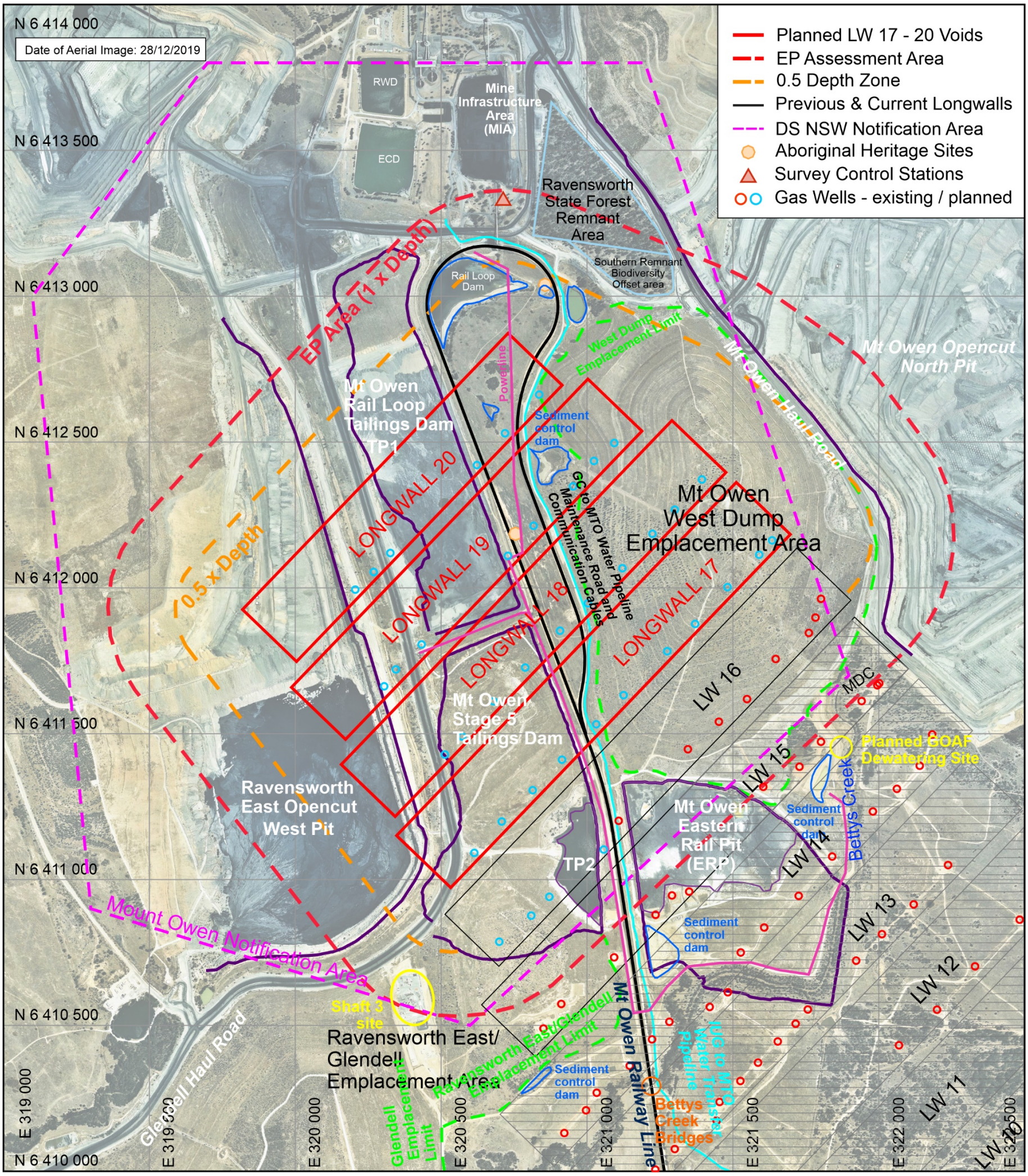

Figure 4: Site plan showing planned Longwalls 17-20, EP Area and surface features.

The NSW Department of Mineral Resources "Guideline for Applications for Subsidence Management Approvals" provides a comprehensive list of surface and sub-surface features to be considered in a subsidence assessment. This list has been used as a guide. A complete list of these items is provided in Appendix 1 at the end of this report but few surface features from this list are located within the EP Area, and fewer still are sensitive to subsidence impacts.

3.8.1 Natural Features

Natural features within the EP Area include:

- small sections of natural ground surface and vegetation adjacent to and within the Mt Owen Railway Line loop
- a small section of the Ravensworth State Forest (Ravensworth remnant area) and the neighbouring southern remnant biodiversity offset area to the north of Longwall 19
- a small section of natural vegetation adjacent to the MDC of Bettys Creek above Longwall 15.

Only small areas of natural ground and natural vegetation (grassland) remain on the surface above Longwalls 17-20. These areas are located adjacent to and within the Mt Owen Railway Line loop. A small section of a natural watercourse, a tributary of Swamp Creek, flows into the Rail Loop Dam to the north of Longwall 20.

Areas of natural vegetation within the EP Area include a small section of natural vegetation adjacent to the Bettys Creek MDC, small sections of the Ravensworth State Forest (Ravensworth remnant area) and the Southern Remnant Biodiversity Offset Area. All these areas are located beyond half depth (26.5^0 angle of draw) from the edges of Longwalls 17-20.

3.8.2 Non-Mining Man-Made Features

The only public utilities and public amenities identified within the EP Area or adjacent areas likely to be impacted by the planned mining are some permanent survey control marks located within 3km of the planned mining.

There is no privately-owned land, no privately-owned infrastructure, no agricultural land and no known privately-owned water bores or wells within the EP Area.

Two Aboriginal heritage sites remain within the EP Area. These are isolated find sites located within the rail loop. There are no Aboriginal rock shelter sites within the EP Area.

There are no significant historical heritage sites within the EP Area that have not already been disturbed by open cut mining.

There are some water treatment/settlement ponds located within the EP Area. These are associated with management of surface water run-off from existing or planned rehabilitated open cut mining areas.

3.8.3 Mining Related Infrastructure or Built Features

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

The main features include:

- Some infrastructure associated with the MOC MIA
- Mt Owen Rail Line loop and associated infrastructure.
- Mt Owen - North Pit and haul road.
- Ravensworth East - West Pit.
- Glendell haul road.
- TP1.
- Eastern Rail Pit (ERP).
- West Dump.
- Ravensworth/Glendell emplacement area (including TP2).
- Surface water management installations.
- Gas drainage and ventilation installations and equipment.
- Access roads and four-wheel drive tracks.
- Powerlines.

The section of the MIA within the EP Area includes dams, a conveyor, a coal bin, train refuelling shed and other train loading infrastructure.

Infrastructure within the rail corridor includes the rail loop, a maintenance/service road, signal cabling, overhead powerlines, water treatment dams, raw water supply and wastewater transfer pipelines.

The Mt Owen Railway spur line upward from the east to the eastern edge of Longwall 17 at the beginning of the rail loop. The western incoming rail line in the loop then dips to the northwest with the grade of the trackwork controlled by a series of cuttings and embankments. There are several culverts through the embankments.

The surface water in the rail loop area drains either to the north into the rail loop dam or to the lowest point in the rail loop. The low point in the rail loop is adjacent to northern edge of the filled section of TP2 near the southern end of TP1. Surface water flows west from this low point towards the West Pit and then south around the rim of the West Pit.

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 south-western highwall and haul road of the North Pit are within the EP Area but offset from the planned longwalls. The southern end of the West Pit is currently used for tailings disposal. The north end of West Pit is being filled with waste rock.

The Glendell haul road traverses the surface above Longwalls 17–20. The active Barret Pit at Glendell is approximately 2km southwest of the EP Area.

The open or partially filled tailings dam excavations within the EP Area include:

- TP1 (Mt Owen Rail Loop Tailings Dam)
- the ERP.

TP1 is almost completely full and in the process of being capped from north to south. TP2 (Ravensworth East Tailings Pit or Mt Owen Stage 5 Tailings Dam) was filled with waste rock rather than tailings and a large section has been rehabilitated. A small section of TP2 above Longwalls 15 and 16 remains open and in use for surface water storage as part of the site water management system. The ERP is located above Longwalls 15 and 16 but may experience some subsidence as Longwalls 17 and 18 are mined.

Emplacement and/or rehabilitated areas include:

- the West Dump with contour drains and drop structures
- part of the Ravensworth/Glendell emplacement area.

Minor surface infrastructure such as surface water management installations with dams, powerlines, pipelines, pumping equipment and four-wheel drive access roads, is also owned by Glencore to support surface or underground mining operations.

Gas drainage boreholes and related installations associated with the gas management systems at IUG are located across the surface and construction of these systems will continue as part of on-going operations.

A new surface to seam ventilation shaft (Shaft 3) for IUG is located to the west of Longwalls 15 and 16. The surface installations for the shaft, including main fans and service boreholes, are located beyond the finish line of Longwall 16 on the southern edge of the EP Area.

All this gas drainage and ventilation infrastructure has been designed and installed to withstand subsidence impacts.

4. FORECAST SUBSIDENCE BEHAVIOUR

In this section, the subsidence movements expected above Longwalls 17-20 and more generally within the EP Area are forecast based on site specific subsidence monitoring at IUG.

4.1 Forecast Subsidence Movements

Table 4 summarises primary conventional subsidence parameters expected over natural, undisturbed ground within the EP Area for Longwalls 17–20.

Table 4: Primary subsidence parameters forecast above Longwalls 17-20 in areas undisturbed by surface mining activities.

Longwall	Maximum Subsidence (m)	Maximum Tilt (mm/m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)
Natural/Undisturbed Ground (i.e. Rail Loop Corridor)				
LW17	2.0	14	7	10
LW18	2.0	14	7	10
LW19	2.0	14	7	10
LW20	1.5	14	7	10

The EP process provides an opportunity to update subsidence forecasts and assessment of impacts based on additional information and understanding gained since project approval.

The subsidence forecasts presented for Longwalls 17-20 take account of the increased seam thickness, proposed mining heights, mining geometry, increasing overburden depth and overburden characteristics. These forecasts include additional information and improved understanding gained since the project was approved.

In general, subsidence movements above Longwalls 17–20 are expected to be typical of subcritical width subsidence behaviour with maximum subsidence controlled primarily by a combination of sag subsidence above individual panels and strata compression above the chain pillars (Mills 1998). Subsidence over individual panels is expected to occur incrementally when adjacent panels are mined.

Predictions of strains and tilts are based on the empirical relationships developed by Holla (1991) and calibrated for IUG based on site-specific subsidence monitoring results. Comparison with previous monitoring experience indicates that this approach provides a reasonable estimate of maximum values likely to occur.

In areas where open cut mining has modified the overburden characteristics through excavation or emplacement, subsidence behaviour is expected to be modified. Sections of deeper open excavations overlying the longwall panels are expected to experience greater subsidence effects as a result of the reduced natural overburden thickness. Emplacements are expected to experience greater subsidence as a result of settlement and lateral spreading of emplaced material.

Forrester and Whittaker (1976) provide a guide to the additional subsidence that may be expected on colliery spoil heaps. They also detail experience of how tilts, strains, cracking and horizontal movements are modified by waste rock fill. Subsidence movements in areas with waste rock filled material increase with increasing thickness of waste rock fill. This experience has been found to be consistent with the limited experience available from other sites in the Hunter Valley of NSW where fill material has been mined under. The approach outlined by Forrester and Whittaker is used to estimate the additional subsidence expected within the EP Area for Longwalls 17-20.

Table 5 summarises the total subsidence forecast for areas where fill material is emplaced within the EP Area (e.g. TP1, TP2, ERP, West Pit, West Dump).

Table 5: Primary subsidence parameters forecast above Longwalls 17-20 in areas of waste rock fill material.

Longwall	Maximum Subsidence (m)	Maximum Tilt (mm/m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)
Areas of Waste Rock Emplacement (e.g. TP1, TP2, ERP, West Pit, West Dump)				
LW17	2.5	14	14	20
LW18	2.5	14	14	20
LW19	2.5	14	14	20
LW20	2.5	14	14	20

Maximum tilts are expected to be less than those predicted for undisturbed ground due to the softening effects of the backfill.

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

4.1.1 Vertical Subsidence

Figure 5 shows contours of conventional subsidence for natural ground that are expected over Longwalls 17-20 at the completion of mining. The subsidence contours are based on goaf edge subsidence profiles measured previously at IUG and consideration of sag and strata compression components of the subsidence profile in subcritical panel geometries.

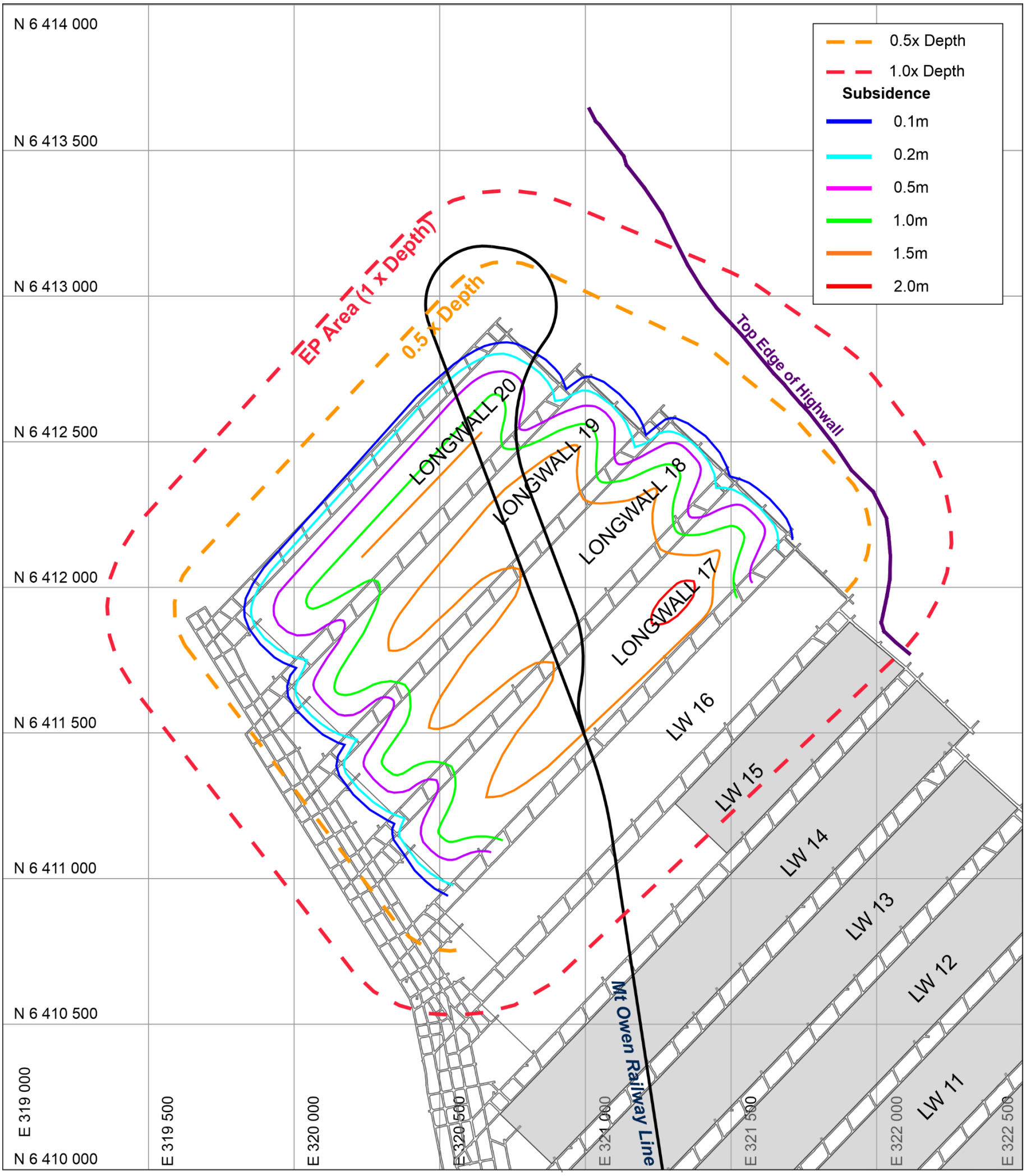

Figure 5: Estimated subsidence contours forecast for Longwalls 17-20.

Maximum 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 mining heights that may occur are expected to proportionally influence the maximum subsidence and other subsidence parameters.

Some variations in subsidence may occur due to localised effects of topography, geology, and the modified mining surfaces. Variations between the forecast and greater measured vertical subsidence are not expected to be of any practical significance in the highly modified surface environment above Longwalls 17-20.

Maximum subsidence over natural ground at the conclusion of mining Longwalls 17-20 is forecast to be 2.0m. Maximum subsidence over each panel is initially expected to reach about 1.5m when that panel finishes. Mining of subsequent panels is expected to further increase this initial subsidence with small increases possible during mining of the next four or five longwall panels.

Figure 6 shows an estimate of vertical subsidence profile along the alignment of Mt Owen Railway Line at the completion of Longwalls 17-20.

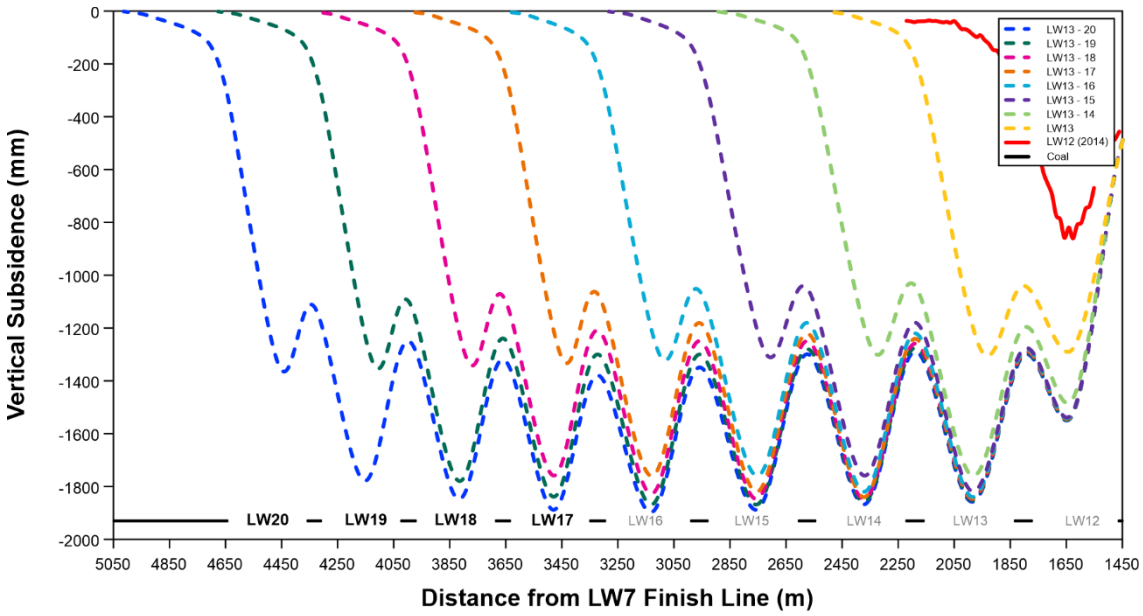

Figure 6: Forecast Subsidence over Natural Ground along Mt Owen Railway Corridor.

4.1.2 Tilt

Maximum tilt of 14mm/m is forecast above Longwall 17-20. This maximum tilt is expected in shallower areas of natural ground located in the vicinity of the Mt Owen Railway Line loop. These levels of tilt are expected to be imperceptible except possibly along linear features such as the rail line and some fence lines.

Tilt is likely to be transient over the centre of each longwall panel, although some low levels of residual tilt may remain in the centre of the panel after mining. Tilt is expected to be permanent near the goaf edges and may be greater near the start and finish of each longwall panel. As each subsequent longwall panel is mined, additional vertical subsidence over the chain pillars is likely to cause some variations in tilt.

Maximum tilts in areas of modified overburden are expected to be of similar or slightly lower magnitude compared to tilts predicted for natural, undisturbed ground.

4.1.3 Horizontal Movements

Horizontal subsidence movements of up to about 500mm are expected to occur in the EP Area as a result of mining Longwalls 17-20. In general, horizontal movements over panels are expected to occur initially in a direction toward the mining face and once the longwall face has passed, in the direction of mining.

Horizontal stress relief movements (far-field movements) of typically less than 200-300mm may extend some distance beyond the longwall panel goaf edge. These far-field horizontal movements and those near the panel edges due to draping of the strata into the void created by mining, are expected to be permanent and predominantly in a direction toward the goaf. Horizontal movements are expected to be larger in sloping terrain adjacent to free surfaces such as open cut voids and areas of fill material or waste rock emplacements.

4.1.4 Strain and Surface Cracks

Maximum mining-induced strains in natural ground are forecast to be less than 7mm/m in tension and 10mm/m in compression. Strains in disturbed ground are expected to be approximately double these magnitudes.

In areas of natural ground, tension cracks up to 50mm wide may occur in areas of tensile strain depending on the nature of the surface terrain. Cracks are expected to be generally less than about 25mm wide and barely perceptible in flat or gently undulating land. Cracks are most likely to develop above the longwall panels in the vicinity of panel edges and along the tops of topographic highs. Cracks along permanent goaf edges are likely to remain 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 retreating longwall face. These cracks may remain permanently open near the finish line of each panel.

Larger cracks may develop over the mining modified ground, particularly at the top of slopes in the backfill material and at the interface between natural and backfilled ground. These cracks may be approximately 100-200mm wide in localised areas depending on the degree of compaction and settlement of the fill material.

Permanent compression humps and associated low angle fracturing may become apparent at topographic lows such as drainage channels particularly where bedrock is exposed. These effects are not expected to be significant within the EP Area.

4.1.5 Unconventional Subsidence Effects

Previous experience at the IUG indicates that unconventional subsidence effects may occur within the EP Area, but the potential is low because of the amount of disturbance caused by previous mining and the relatively flat lying nature of the surface terrain.

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

Valley closure horizontal movements and upsidence may also occur at topographic low points but any such movements in the vicinity of Longwalls 17–20 are expected to be of low magnitude and generally insignificant.

4.2 Reliability and Accuracy of Subsidence Forecasts

The experience of mining at IUG provides a strong basis for estimating subsidence behaviour within the EP Area for Longwalls 17-20. The forecast subsidence parameters are expected to provide an upper limit of subsidence behaviour in most cases. Forecasts of maximum subsidence and strain may be exceeded locally in areas where the ground surface has been modified by open cut mining activities.

The approach to estimating subsidence used in this assessment is based on a review of previous experience over the first 14 longwall panels at IUG.

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 6-14. This same method has been adopted for estimating subsidence behaviour over Longwalls 17-20.

The upper limit estimates of subsidence movements presented are used for impact assessment purposes. Actual subsidence is expected to be generally less than these upper limits. The forecast values are intended to be conservative.

A common method of assessing potential consequences of subsidence is to double and treble the maximum subsidence. At IUG, it is not credible that the magnitude of maximum subsidence could exceed forecast maxima by 100% or 200% because double the forecast subsidence is much greater than the proposed mining height.

Given that Glencore owns all the surface and surface infrastructure above Longwalls 17-20 and has monitoring and management plans in place, the consequence of any variations from forecast subsidence is not expected to be significant.

The Mt Owen Railway Line is the most subsidence sensitive infrastructure above Longwalls 17–20. This rail line and associated infrastructure has dedicated subsidence monitoring and a detailed management plan in place including a hierarchy of review by a technical committee of specialists. Subsidence impacts on the rail corridor infrastructure have been managed effectively for the extraction of Longwalls 7-15 using this approach. This strategy is expected to be effective as a strategy to manage subsidence impacts to the rail line during mining of Longwalls 17-20 including any variations of subsidence behaviour that may occur locally.

4.3 Review of Previous Subsidence Monitoring

The subsidence behaviour and general form of the subsidence movements at IUG up to Longwall 14 is consistent with experience at other sites recognising the influence of the mining geometries involved.

Subsidence monitoring has been conducted routinely at IUG since the commencement of longwall mining in 2002. Cross panel (transverse) and long panel (longitudinal) monitoring lines have been installed and regularly surveyed. Additional monitoring lines were established to monitor the ground behaviour along and parallel to the Mt Owen Railway Line.

Two-dimensional monitoring surveys were undertaken up until the completion of Longwall 5. Since then, all subsidence lines are resurveyed in three dimensions allowing improved insight into horizontal movements.

Table 6 summarises the primary 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 Railway Line over Longwalls 7-12. P Line over Longwalls 12-14 and G Line extension over Longwall 13. The forecast values are compared with the actual measured values after mining of Longwalls 1-12. The maximum values recorded at the completion of each panel are not necessarily directly above that panel.

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

The subsidence monitoring recommended in EP assessments for Longwalls 13 and 14 and Longwalls 15 and 16 was aimed at capturing measurements of subsidence behaviour of the fill material emplaced over the ERP and enhancing the database of the extent and magnitude of horizontal (far-field) movements at IUG.

Table 6: Comparison of Predicted Subsidence Parameters with Measured Values

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
13	*1400*	*700*	*14*	*5*	*7 & 10*	*4-4*
14	*1400*	*750*	*14*	*12***	*7 & 10*	*4-4*

*Not available – below survey tolerance

** Unconventional effect - typically 4

This data is expected to assist in estimating impacts to sensitive infrastructure at the MOC MIA and below larger waste rock emplacements. The survey monitoring on subsidence lines over Longwalls 13 and 14 indicates that subsidence behaviour is generally consistent with expectations and the levels of primary subsidence effects are less than forecast and less than the maxima recorded over Longwalls 1-12. These lower values of subsidence parameters apply to both the natural ground surface and areas of disturbed ground with waste rock fill material.

Only marginally greater subsidence movements are measured at the interface between natural ground and fill material in the ERP over Longwall 13. These measurements, and measurements over the remainder of the fill material, show subsidence effects less than forecast for natural ground and much less than forecast for the fill material. The absence of significantly greater subsidence over the fill material may be a result of compaction when the material was placed and consolidation of the emplaced material over the approximately eight years since emplacement.

4.3.1 Vertical Subsidence Parameters

Maximum vertical subsidence at IUG is currently 1.5m above Longwall 7. This was measured on B Line after Longwall 12 was mined.

As individual panels are of subcritical width, subsidence behaviour is primarily controlled by compression of the chain pillars and surrounding strata with subsidence only fully developing after extraction of two or more subsequent panels. As a result, points on the surface experience additional subsidence as each panel is mined and overburden weight is redistributed.

Subsidence over previously mined panels is expected to increase as additional longwall panels are mined. Maximum subsidence is expected to remain around 1.6m above panels to Longwall 12 and increase to 1.9-2.0m over for Longwalls 13-14 and Longwalls 15-16 respectively as forecast in SCT (2017a) and SCT (2018c) after the mining of Longwalls 17-20. Subsidence over the chain pillars is also expected to increase slightly with each additional panel and as the overburden depth increases.

Maximum tilt measured on all the lines to the completion of Longwall 14 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.

Maximum tilt for Longwalls 13-14 and Longwalls 15-16 was forecast at 14mm/m in SCT (2017a) and SCT (2018c) to correspond with the increased vertical subsidence forecast as a result of an increase in mining height due to changes in seam thickness and mining equipment and increasing overburden depth.

A peak tilt of 12mm/m was measured during the end of panel surveys for Longwall 14. This measurement was at a localised uplift zone associated with the outcrop of a low strength bedding plane above Longwall 14. This unconventional subsidence impact is discussed further in Section 4.3.3.

4.3.2 Horizontal Subsidence Parameters

Horizontal movements have been observed at IUG since three-dimensional monitoring was introduced at Longwall 6. The horizontal movements measured at IUG show characteristics similar to those at 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
- 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 normally permanent.

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

The majority of maximum measured horizontal movements for Longwalls 7-14 have been in the range 200-400mm. These measurements are consistent with the 300-400mm range anticipated.

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 typically about half the maximum values anticipated for gently undulating terrain.

4.3.3 Unconventional Subsidence

Unconventional subsidence effects include:

- horizontal movements associated with strata dilation in uneven topography including valley closure causing upsidence
- 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 close to these zones once they are identified.

To date, there have been few observations of unconventional subsidence movements at IUG. These observations are limited to anomalies on the rail line.

Low level valley closure was measured at the bridge where the rail line crosses Bettys Creek. The effects were expected and the impacts on the bridge structure were managed through some engineering works designed to accommodate the movement. Significant upsidence was not observed.

Some anomalous behaviour was observed on H Line, above the finished end of Longwall 8, during the Mt Owen Railway Line subsidence monitoring program. A localised uplift zone above Longwall 14 was measured along the rail line during the mining of both Longwalls 13 and 14. The uplift is limited in magnitude and extent and is likely a result of shear movements on a low strength bedding plane outcropping at this location. The uplift is estimated to rise and fall approximately 75mm over 40m. In both cases, the impacts of these movements were successfully managed through the asset management plan for this infrastructure.

4.3.4 Interactions with Open Cut Mining

Survey measurements and visual inspections for subsidence effects and potential impacts from longwall mining to open cut surface mining operations at Mt Owen – North Pit were undertaken during Longwall 14 and initial mining in Longwall 15. The start lines of both Longwall 14 and 15 are below the haul road at the rim of the North Pit as shown in Figure 1. The monitoring started in November 2018 soon after the start of Longwall 14 and continued to the completion of this panel in August 2019. Monitoring was also conducted for the start-up of Longwall 15 and mining approximately 500m of this panel.

Monitoring in the vicinity of Longwall 14 start line included:

- GNSS (GPS) point surveys of the haul road and benches
- drone based aerial photogrammetry of the haul road, bench and highwall areas
- fixed prism shots to strategic points
- weekly visual inspections of these areas.

Radar surveys complemented by fixed prism monitoring were used to monitor ground movement and highwall stability during the initial stage of mining Longwall 15.

The Geotechnical Engineer at the Mt Owen – North Pit did not observe any behaviour out of character with normal operations at Mt Owen Operations (MTO) related to subsidence effects or impacts from the mining of Longwall 14. No measurement or observations of movements beyond normal levels or survey tolerance were recorded.

Monitoring of highway stability during the initial stages of mining Longwall 15 to 450m of retreat, indicates no perceptible impacts to slope stability. The radar data indicates low levels of horizontal movement at the base of the slope towards the open cut void and away from the open cut at the top of the slope; effectively at slight tilting of the highwall, in favour of stability. These movements are in the order of 30mm and are consistent with the balancing of systematic horizontal movements, horizontal movements generated by the dilation of fractured ground and horizontal stress relief movements towards a void.

A 250m long conventional subsidence monitoring line was installed by IUG from the start line of Longwall 15 along the centreline of the panel. This line was surveyed three times until the longwall face had retreated more than 500m. Analysis of the ground movements indicates only low-level movements consistent with conventional subsidence behaviour. The vertical and horizontal movements, tilt and strain measured on the subsidence line over the goaf area are consistent with monitoring over Longwalls 13 and 14.

4.4 Comparisons with Previous Subsidence Predictions and Approval Performance Measures

Table 7 summaries the approved maximum predicted values from previous assessments for single seam longwalls with a 257m void width and the forecast for Longwalls 17-20 EP. Compliance with the subsidence performance measures should be considered in the context of the MOCO Project Approval (SSD-5850), common ownership of built features (by Glencore), the location of the planned mining of Longwalls 17-20 relative to the position of significant surface features and the status of other proposed built features.

Table 7: Comparison of previously predicted subsidence parameters with those forecast for Longwalls 17-20 EP

Assessment	Maximum Subsidence (m)	Maximum Tilt (mm/m)	Maximum Tensile Strain (mm/m)	Maximum Compressive Strain (mm/m)
Natural or Undisturbed Ground				
GCUC (SCT 2006)	1.6	12	6	9
IUG MOD8 (SCT 2017c)	2.0 (2.2*)	14 (15*)	7 (8*)	10 (11*)
LW 15 &16 EP	2.0	14	7	10
LW 17–20 EP	2.0	14	7	10
Disturbed or Modified Overburden (fill material or emplacement areas)				
GCUC (SCT 2006)	-	-	-	-
IUG MOD8 (SCT 2017c)	2.8 (3.0*)	14 (15*)	14 (16*)	20 (22*)
LW 15 &16 EP	2.5	14	14	20
LW 17–20 EP	2.5	14	14	20

* approved for Longwalls 15-19 with 330m wide voids

Condition 20, Schedule 3 of PA08_0101 (MOD8) requires HVCC to provide revised predictions of the potential subsidence effects, subsidence impacts and environmental consequences of the proposed second workings, incorporating any relevant information obtained since this approval.

This section focuses on the changes to the original subsidence predictions for ML Seam longwalls made in GCUC Project EA (SCT 2006) for Longwalls 10-17 and the updated forecasts for Longwalls 15-20 presented in SCT (2017c) for the PA08_0101 MOD8. The subsidence performance measures of PA08_0101 are also discussed.

It was recognised in SCT (2006) prepared for the GCUC Project EA that future surface mining proposals had potential to interact with underground mining from about Longwall 12 onwards and expected subsidence effects and impacts would need to be updated to accommodate these interactions. SCT (2006) recommended that the subsidence behaviour be assessed in more detail once the mining geometries and timing of surface operations were more clearly defined. No predictions of subsidence movements for areas of disturbed or modified overburden were included in SCT (2006) or SCT (2009) prepared for the original IUG Project EA. No formalised table of performance measures was included in GCUC PA.06_0213 for the single seam mining of Longwalls 10-17.

The primary subsidence parameters estimated in the Longwalls 17-20 EP assessment are only marginally greater than those predicted in SCT (2006) and consistent with or less than the maximum forecast for the 257m wide longwall void layout in SCT (2017c) for PA08_0101 MOD8. The subsidence performance measures of PA08_0101 generally refer to the impacts from multi-seam longwall mining (i.e. ML and Hebden Seams).

The impacts from mining Longwalls 17-20 as planned, are not expected to be greater than those outlined in the subsidence performance measures in PA08_0101. Maximum primary subsidence effects forecast for natural ground are much less than the maxima predicted in the original IUG Project EA for multi-seam mining.

SSD-5850 provides consent for the Mt Owen - North Pit to continue to the south through the Bettys Creek MDC, other minor drainage lines and areas of natural vegetation, to the southeast corner of the ERP.

Glennies Creek Alluvial aquifer is remote from the planned mining area and is not expected to be impacted, although this needs to be assessed by other specialists.

The Underground Project creek diversions are not yet built. These are planned to be built in the future to mitigate or remediate the potential impacts of total vertical subsidence from the approved multi-seam (ML and Hebden Seams) mining.

Negligible impacts are expected to biodiversity items.

Built features, owned by Glencore, that may be impacted by the planned mining are expected to remain safe, serviceable, and repairable unless agreed otherwise.

No additional public safety hazards are expected.

4.4.1 Basis for EP Subsidence Assessment

This assessment is specific to the planned mining of Longwalls 17-20 with 257m wide voids in the ML Seam in a single seam mining environment. Differences in subsidence effects are expected compared to the original GCUC Project EA because of differences in mining geometry. These differences include:

- The mining height is expected to range from 2.8m to 3.2m compared to a range of 2.2m to 2.4m previously used for vertical subsidence estimates in the original GCUC Project EA.

- The longwall panels now extend further than the area assessed in the GCUC Project EA.

- The longwall panels are below significant open cut mining excavations and emplacement areas.

- The overburden depths vary from those assumed for the GCUC Project EA because the mining area has changed.

Furthermore, a more conservative approach to subsidence predictions has been adopted for the purpose of impact assessment and setting of compliance thresholds and significant unconventional subsidence movements are not expected.

4.4.2 Changes to Subsidence Effects and Impacts Since Project EA

Maximum vertical subsidence forecast is increased from that predicted for the GCUC Project EA. The total increase includes additional sag over the centre of the panels due to increased mining height and more strata compression over chain pillars due to increasing overburden depth. Forecast subsidence has also been increased to allow for further subsidence to develop as additional panels are mined.

Maximum tilt and strain levels forecast for the natural ground surface above proposed layouts are generally consistent with and only slightly greater than those predicted in the GCUC Project EA. The changes reflect the increased vertical subsidence forecast and greater overburden depths within the extended area of the approved MOD8 longwall layouts.

There is expected to be potential for greater subsidence, tilt and strains in the mining modified landform over waste rock 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. Other areas may experience reduced tilts and strains due to the softening effect of unconsolidated ground.

The consequences of any small increases in subsidence parameters are not expected to be significant in the substantially modified surface landform of the EP Area. 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.

5. SUBSIDENCE IMPACT ASSESSMENT

In this section, the potential subsidence impacts are assessed for various surface or sub-surface features located within the EP Area for Longwalls 17-20 and considered in a risk assessment conducted on site on 4 March 2020. An overview of these features is presented in Section 3.4.

In general, impacts from mining Longwalls 17-20 are expected to be less than impacts described in GCUC Project EA and much less than those detailed in the original IUG Project EA for the approved multi-seam mining. Impacts from mining Longwalls 17-20 are also expected to be less than forecast in the IUG Project MOD8 EA for 257m wide panels because of the reduced longwall panel lengths and much less than forecast for 330m wide panels because of the narrower panel widths.

With each longwall panel there is a period of active subsidence movements when most of the subsidence movements occur and within which most mitigation and monitoring effort should be focussed. At any given point, active subsidence occurs when the longwall face approaches within about 100m from the site and continues until the longwall face is approximately one times depth or 500m past. A second period of active subsidence occurs when the adjacent longwall panel passes.

5.1 Natural Features

Major natural features in the EP Area considered in this section include areas of natural ground and vegetation within or adjacent the mining area, adjacent to a section of Bettys Creek MDC and the groundwater system generally.

5.1.1 Natural Vegetation

Details of the vegetation communities are outlined in the Integra Underground Biodiversity Management Plan.

Impacts to natural vegetation from the planned mining of Longwalls 17-20 are expected to be minor, no greater than those described in the GCUC Project EA, less than those detailed in the original IUG Project EA for the approved multi-seam mining and less than forecast in the EA for MOD8.

The only substantial areas of natural vegetation (native grassland) located above Longwalls 17–20 are located adjacent to and within the Mt Owen Railway Line loop area. These features are likely to experience the full range of subsidence movements forecast for the planned mining, but they are not expected to be significantly impacted by these movements.

A small section of the Ravensworth State Forest (Ravensworth remnant area) and the neighbouring southern remnant biodiversity offset area to the north of Longwall 19 are within the EP Area but beyond half depth from Longwalls 17-20. Subsidence effects to these areas are expected to be limited to low-level vertical and horizontal movements of less than 100mm and most likely less than 20-30mm. Impacts to these features are likely to be less than those forecast in SCT (2017c) for MOD8 to PA08_0101 and imperceptible for all practical purposes.

Small sections of natural and planted vegetation remain adjacent to the MDC of Bettys Creek above Longwall 15. Approximately 600m of the MDC has already been mined through by the Mt Owen - North Pit reducing the catchment of this watercourse. The section of the MDC above Longwall 15 is within the EP Area but beyond half depth from Longwall 17. Any subsidence impacts in addition to those forecast for the MDC and adjacent natural vegetation presented for the mining of Longwalls 15 and 16 in SCT (2018c) are expected to be imperceptible for all practical purposes.

5.1.2 Groundwater

An independent assessment of the groundwater impacts from the planned Longwalls 15-20 was undertaken by Australian Groundwater Environmental Consultants Pty Ltd in November 2017 (AGE 2017) as part of the EA for MOD8 to the IUG Project Approval 08_0101. SCT understands a surface and groundwater impact assessment will be completed by specialist consultants for the Longwall 17-20 EP.

AGE (2017) includes assessment of groundwater impacts for Longwalls 15-20 with 257m wide voids and for a layout with one less panel but 330m wide voids (Longwalls 15-19). The assessment indicates that the 330m wide layout has the greater increase in groundwater flow into the underground mine workings compared to the 257m wide panels due to the increased "*height of cracking*".

The planned layout for Longwalls 17-20 (as well as Longwalls 15 and 16) has shorter panel lengths than assessed in (AGE 2017). This shortening increases the offset to the Mt Owen - North Pit and reduces the distance the longwall panels extend below the Ravensworth East - West Pit where overburden depth is shallower. As a result, the mining footprint is smaller, both in area and perimeter.

On this basis the groundwater impacts are expected to be similar or less than those forecast in AGE (2017) for the 257m wide longwall voids in the MOD8 EA.

5.2 Heritage Sites

Two Aboriginal heritage sites remain within the EP Area for Longwalls 17–20. These remaining sites are isolated finds located over solid coal north of Longwall 20 and above Longwall 19 as shown on Figure 4. Mining Longwalls 17–20 is not expected to cause perceptible impacts to these sites consistent with the expectations presented in SCT (SCT 2017c) for MOD8 to PA08_0101.

Site 37-3-1173 (MOCO IF-4) is approximately 200m beyond the northwest corner of Longwall 20. Vertical subsidence at this location is expected to be less than 50mm and imperceptible for all practical purposes.

Site 37-3-1175 (MOCO IF-6) is over Longwall 19 where up to 1.8m of vertical subsidence is forecast at the completion of Longwall 20.

Subsidence movements are not expected to have any practical effect on 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 IUG is so small that the potential for change at Site 37-3-1175 is likely to be insignificant for all practical purposes.

No perceptible impacts to artefacts at Sites 37-3-1173 and 37-3-1175 are expected from the planned mining of Longwalls 17-20, due to the type of site, the nature of the terrain and the magnitude of subsidence effects and impacts forecast.

The current MOC heritage database is used as the basis to update the IUG heritage database in conjunction with environmental assessments completed for the IUG Project. There are no Aboriginal rock shelter sites within the EP Area. All other heritage sites in the vicinity of the planned mining of Longwalls 17-20 have already been disturbed by surface mining activities.

Since the assessments for the original GCUC Project EA and IUG Project EA were prepared, ongoing heritage management monitoring surveys and investigations for the MOCO Project EA have identified new sites. Several previously recorded sites were repositioned. The most recent surveys were undertaken by OzArk Environmental and Heritage Management Pty Ltd (OzArk 2017) as part of the assessment of impacts to Aboriginal and Historical Heritage from the proposed mining of Longwalls 15-20 in the EA for MOD8 to the IUG Project Approval.

The existing Aboriginal Heritage Management Plan is expected to be effective in protecting Aboriginal heritage items from any potential impacts of mining Longwalls 17-20. There are no specific subsidence related performance measures for heritage items in the environmental performance conditions of the PA08_0101.

5.3 Public Utilities and Public Amenities

The only public utilities or amenities identified as likely to be impacted by the mining of Longwalls 17–20 are survey control stations. The section of Forest Road accessible to the public is outside the EP Area.

There are several state survey, permanent mark and trigonometrical stations within 3km of Longwalls 17–20 over the MOC site and surrounding area. The only control point within the EP Area is SS_96126 positioned as shown in Figure 4 adjacent to the elevator conveyor for the train loadout bin.

Some of these marks are likely to have already undergone significant horizontal and vertical movements as a result of previous underground mining up to Longwall 15 and from nearby open cut excavations. The planned mining of Longwalls 17-20 is expected to cause additional movements at these marks.

A process to inform NSW Land Registry Services 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 (NSW Land Registry Services) 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 subsidence
- 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.

Permanent survey control marks within 2-3km radius around longwall mining should be considered vulnerable to far-field subsidence movements.

5.4 Mine Owned Infrastructure

In this section, mine-owned surface infrastructure within the EP Area is assessed for subsidence impacts. The intent is to inform the management of this infrastructure compliant with Work Health and Safety and other regulatory obligations. A brief description of each item is provided together with forecast of subsidence effects and expected impacts.

5.4.1 MOC Mine Infrastructure Area

A section of the MOC MIA is located within the EP Area as shown in Figure 4. This section includes dams, haul roads, reclaim and elevator conveyor, coal storage bin and train refuelling shed and other minor train loading infrastructure. The rail line is discussed separately in Section 5.4.2. Figure 7 shows the train shed, coal bin and conveyor, and Rail Loop Dam.

No significant impacts to this critical infrastructure are expected from the planned mining of Longwalls 17-20 once appropriate monitoring and asset management plans are in place. Impacts are likely to be less than the maximum forecast in SCT (2017c) for MOD8 to PA08_0101 for the 257m wide longwalls.

Except for the series of dams, most of this infrastructure is located in areas of low vertical subsidence, typically less than 30mm, and very low levels of tilt and tensile strain. Although the far-field effects monitoring database at IUG is not strong, absolute horizontal movements at the train shed and coal bin are expected to be around 100mm. These movements are expected in a southerly direction towards the longwalls. Differential horizontal movements along the conveyor between the coal bin and reclaim tunnel are expected to be less than 50mm.

a) Distant view of Rail Loop Dam, Train Shed, Coal Bin and Conveyor - looking northwest.

b) Looking northeast - Train Shed, Conveyor, Coal Bin and Rail Loop Dam.

Figure 7: Built features of MOC Mine infrastructure Area within EP Area.

The Rail Loop Dam and subsidiary dams, that feed this dam, are not expected to be significantly impacted. These dams are located above solid coal outside the planned longwall panels. Vertical subsidence at the Rail Loop Dam including the dam wall (the railway embankment) is expected to be generally less than 50mm. The corresponding low levels of tilt and strain are expected to be generally imperceptible. No significant impacts are expected to the dam walls and culverts through the railway embankments.

No significant impacts are expected to the coal bin and conveyor. Any minor impacts are expected to be manageable.

Horizontal movements may result in some minor tilting of the bin structure and minor cracking of the concrete foundation/sump area. The load cells may also be affected by the very small differential movements across the footings requiring recalibration to maintain operational accuracy.

Horizontal movements are expected to be most detectable along the length of the conveyor from the top of the bin to the entrance of the reclaim tunnel below the coal stockpile area. Inspection of the conveyor indicates that the differential movements are likely to be accommodated along the conveyor belt structure and any small extension is not expected to affect the gradient, vertical curve or operation of this installation.

No significant impacts from horizontal movements are expected at the train shed. Far-field horizontal movement from stress relief are mass movements with only very low rate of change or differential movement likely across the width and over the length of the shed.

The train loading facilities are a critical piece of infrastructure for all three mines at MOC. It is recommended that this infrastructure is included in the asset management for Mt Owen Rail Line and subsidence movements are reviewed periodically by the technical committee responsible for the rail line.

Continuous GNSS (GPS) units provide an excellent means to monitor potential subsidence impacts. These high precision units monitor position in three dimensions. They can provide early indication and warning of subsidence movement. The units could also provide 'floating' control for engineering surveys of the conveyor/bin, train shed and rail geometry that might be conducted to maintain operational integrity and safety.

In the absence of high confidence information suitable to characterise far-field subsidence movements at IUG, it is recommended that continuous GNSS units are installed on key infrastructure prior to the commencement of Longwall 17 to ensure that any movements associated with mining Longwalls 17-20 are captured.

5.4.2 Mt Owen Railway Line

The EP Area includes the loop of the Mt Owen Railway Line and a section of the single line as well as infrastructure associated with the rail. The rail switch (point blades or turnout) at the end of the loop is located above the eastern edge of Longwall 17. Longwalls 17–20 mine under most, but not all, of the rail loop.

Impacts on the rail corridor are expected to be less than impacts described in GCUC Project EA and less than those detailed in the original IUG Project EA for the approved multi-seam mining. The magnitudes of subsidence effects and impacts are expected to be consistent with those described in SCT (2017c) for MOD8 to PA08_0101 but over a smaller area.

All impacts to the Mt Owen Railway Line and associated infrastructure are expected to be manageable (albeit with two sections of trackwork to be impacted in quick succession) with a similar asset management plan to that currently in place at IUG for this infrastructure.

The overburden depth along the railway line corridor from Longwall 17 to Longwall 20 ranges from 480m to 500m. Maximum subsidence parameters forecast for the railway corridor during mining of Longwalls 17-20 are:

- vertical subsidence: 1.9m
- tilt: 12mm/m
- tensile strain: 5mm/m
- compressive strain: 8mm/m.

Subsidence impacts to the Mt Owen Railway Line, associated infrastructure and Bettys Creek Bridges are managed by a comprehensive assessment management plan. This plan was prepared independently by Mine Subsidence Engineering Consultants Pty Ltd (MSEC). The subsidence management process and actions are overseen by a technical committee that includes specialists, rails operators, infrastructure owners and management representatives from IUG and MOC.

The Mt Owen Railway and Bettys Creek Bridges Asset Management Plan includes engineering works to mitigate the expected subsidence effects, continuous, real-time and periodic monitoring and inspections in detailed longwall action plans with trigger action response plans. The monitoring includes surveys of ground movements for the railway, track geometry and rail stress measurements.

The procedures within this management plan have been successful in maintaining the railway and associated infrastructure in a safe and serviceable condition to avoid operating restrictions during mining below the railway infrastructure from Longwall 7 to Longwall 14. The current version of the management plan for Longwalls 15 and 16 is in operation.

A revised version of this management plan appropriate for Longwalls 17–20 is expected to be effective in managing the dynamic subsidence impacts on the railway and associated infrastructure during the mining of these panels.

The subsidence effects estimated by MSEC are intended to be used for day to day management of the railway line and associated infrastructure. These estimates are not necessarily consistent, nor intended to be consistent, with the more general forecasts of maximum subsidence parameters presented for impact assessment in this report. Subsidence predictions by MSEC are less than those presented in this assessment and much less than the values provided as performance indicators for mandatory compliance reporting purposes across the site.

The rail and road bridges over Bettys Creek are located above the inter-panel chain pillar between Longwalls 13 and 14 outside the EP Area. Subsidence effects and impacts to these features are expected to be substantially complete after the mining of Longwall 16. No additional impacts are expected from the mining of Longwalls 17-20.

5.4.3 Communication Cables

Communication cables for signalling and other purposes are laid alongside the Mt Owen Railway Line. It is understood from the Australian Rail Track Corporation that the cables are most likely to be directly 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 the cables are understood to be PVC insulated copper cables.

These power and communications cables are expected to experience the full range of forecast subsidence movements during the mining of Longwalls 17-20.

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. Uncovering the cable would remove any potential for further impacts should this prove necessary.

The provisions of the Mt Owen Railway Asset Management Plan are expected to be suitable to manage any impacts to the buried cables from the forecast subsidence effects.

5.4.4 Maintenance Road

The maintenance road that services the Mt Owen Railway Line is located immediately to the east of the railway line. This road is a single lane, unsealed road not accessible to the public. Public access is restricted by locked gates. This road provides a connection between the MOC MIA and Forest Road along the rail corridor.

The road is expected to experience the full range of subsidence movements forecast for the mining of Longwalls 17-20 but 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. A culvert located under the rail embankment in the centre of Longwall 14 is expected to be effective in managing ponding in this area.

Any changes are not expected to significantly impact on the serviceability of the road although some increased maintenance may be required during the period of active subsidence of each panel and the subsequent panel, 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. The provisions of the Mt Owen Railway and Bettys Creek Bridges Asset Management Plan and IUG Built Features Management Plan are expected to be suitable to manage any impacts to the maintenance road from the forecast subsidence effects.

5.4.5 Cuttings and Embankments

Within the loop the rail passes through and over series of cuttings and embankments. The cuttings are generally less than 5-6m deep with embankments generally less than 2-3m high. There are several culverts through the embankments as part of the surface water management system.

No significant impacts are expected to the cuttings and embankments in the rail loop from the mining of Longwalls 17–20.

Above the longwalls, the longer cuttings are over Longwalls 17, 18 and 19 and the main embankment is over Longwall 19. There is a culvert through this low embankment positioned above the chain pillar between Longwalls 19-20. This culvert allows overflow from the western sediment dam for the West Dump run-off to flow to the main rail loop dam via another dam within the loop. The cuttings and emplacements are expected to experience the full range of subsidence effects forecast.

No significant impacts are expected in the cuttings, but some cracking and minor slumping may be evident. Subsidence movements may cause some low magnitude lateral spreading and minor cracking of the rail embankments, but it is not expected to cause any significant instability of the rail foundation. No significant impacts are expected to the culvert.

Subsidence monitoring and regular inspections undertaken as part of the asset management plan for this infrastructure are expected to be effective in identifying any significant stability issues. These regular inspections should include the monitoring of any culverts through embankments and impacts to drainage.

5.4.6 Surface Drainage

SCT understands a surface water impact assessment will be completed by specialist consultants for the Longwall 17-20 EP.

The drainage of the surface within the rail loop is likely to be impacted by the forecast vertical subsidence and tilt for the mining of Longwalls 17-20. However, impacts are expected to be minor in nature, repairable and manageable within provisions of the surface water management system for the site.

The lowest point in the rail loop is on the western incoming track adjacent to the northern edge of the filled section of TP2 near the southern end of TP1. This point is above Longwall 18 and is expected to be lowered by up to 1.8m at the completion of mining Longwalls 18–20. This change in reduced level may affect drainage to the west and around the rim of the West Pit to the dam above the south-western corner of this pit. If a suitable gradient cannot be re-established, pumping equipment in conjunction with the adjacent TP1 and TP2 installations may need to be installed at the low point to avoid temporary ponding.

It is recommended that drainage features and associated infrastructure for the low point in the rail loop are included within the BFMP and regular inspections are conducted during the period that the area is affected by active subsidence from each longwall panel.

As discussed in Section 5.4.1 dams to the north of Longwall 20 including the Rail Loop Dams are not expected to be significantly impacted by the planned mining in Longwalls 17–20. As discussed in Section 5.4.16, other dams that flow to the Rail Loop 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.

5.4.7 Water Pipelines

There are several 300mm+ diameter, flexible polyethylene pipelines delivering water across the EP Area as part of the surface water management system. The sections of pipelines positioned above ground are unlikely to be impacted by subsidence movements from the mining of Longwalls 17-20.

A buried raw water supply pipe that services Mt Owen and Glendell Mines runs alongside Mt Owen Railway Line. The pipeline extends from Glennies Creek to the Mt Owen CHPP within the MIA. The pipe is understood to be welded polyethylene pipe buried to a nominal depth of 0.7m.

This pipeline is expected to experience the full range of forecast subsidence effects during the mining of Longwalls 17-20 but 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 asset management plan for the Mt Owen Railway Line and associated infrastructure and are unlikely to pose an environmental risk due to the quality of the water.

A new polyethylene water pipeline was recently constructed between the mine infrastructure areas of IUG and Mt Owen. The pipeline traverses Longwall 13 and then parallels the buried raw water supply pipeline adjacent to the Mt Owen Railway Line over Longwalls 14-20 as shown in Figure 4. This pipeline transfers waste mine water from IUG Pit-top to Mt Owen MIA for reuse as part of the Greater Ravensworth Area Water and Tailings Scheme.

This water transfer pipeline is generally above ground except at road crossings and some watercourse crossings. The pipeline has been mined under by Longwalls 13, 14 and 15 without being impacted. No impact expected from planned mining of Longwalls 17–20.

Other above-ground pipelines are installed over the EP Area as part of the surface water management system for the site. These pipelines allow water to be pumped between sumps (e.g. TP1, West Pit, TP2, ERP). These pipelines are not expected to be impacted by the mining of Longwalls 17–20.

5.4.8 Powerlines

A single pole overhead 11kV electricity transmission line traverses the EP Area from north to south. The sections of this powerline above Longwalls 17-20 are positioned on natural ground surface. These sections are not expected to be significantly impacted by mining Longwalls 17-20 consistent with the expectations described for MOD8 in SCT (2017c).

As shown in Figure 4, the 11kV powerline runs from the MOC MIA to the southern extent of the ERP through the centre of Mt Owen Railway Line loop and then generally adjacent to the rail line across the causeway between TP2 and the ERP. The line also runs across to the Ravensworth East – West Pit.

In addition to surface water management installations at TP1, TP2, ERP and West Pit, this powerline now also supplies the pumping equipment at the sediment and stormwater dams recently constructed above Longwalls 14 and 15 to treat run-off from the West Dump and any future overflow from the ERP.

The powerline is expected to experience the full range of subsidence movements forecast for natural ground over Longwalls 17-20.

Experience at IUG and 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 because the point of maximum tilting occurs when the ground is being stretched around the foundation of the poles.

Placing conductors in roller sheaves and managing guy wire and stay tensions at changes of direction during the period of active subsidence is recommended. Sheaves should be in place prior to the longwall face approaching within half depth of each pole. A review of conductor clearances along the line should be undertaken prior to mining to ensure the poles are spaced closely enough to maintain conductors ground clearances throughout the period of mining.

A program within the BFMP for regular visual inspection during the period of active subsidence and appropriate remediation as required is considered suitable to manage any potential impacts.

5.4.9 Mt Owen - North Pit

The Mt Owen – North Pit is referred to as the North Pit in this section. As shown in Figure 4, the south western highwall and haul road around the rim of North Pit extend into the EP Area. The highwall and the haul road are largely beyond half depth from the edges of Longwalls 17–20. Figure 8 shows views from a 3D model of the site showing the relative positions of the North Pit and the start lines of Longwalls 17–20.

Impacts to the North Pit from the planned mining of Longwalls 17-20 are expected to be insignificant and much less than those outlined for MOD8 in SCT (2017c).

Notwithstanding the input of other specialists, any potential impacts from subsidence movements are not expected to constitute a principal hazard as defined by the *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014*.

Subsidence effects and impacts are expected to be reduced from the maxima forecast in SCT (2017c) due to the reduced panel lengths for Longwalls 15-20 and a smaller subsidence footprint. The mine plan changes are expected to result in a significant reduction in the potential for interactions with Mt Owen operations (MTO) at the North Pit, including impacts to the haul road and stability of the highwall.

SCT understands that there is good communication between the IUG and MTO sites, and awareness of the risks from potential subsidence impacts. Any impacts are expected to be manageable through management plans for both the surface and underground mining operations and the ongoing communication protocols between sites.

The highwall and almost all the haul road are located beyond half depth from Longwalls 17-20. Vertical subsidence is expected to be less than 30mm at the small section of the haul road above the corner of Longwall 17 located within half depth of Longwalls 17-20. Horizontal movement at this location are expected to be less than 100mm. These low-level subsidence movements are expected to be imperceptible and of no practical consequence for the highwall and haul road. No significant impacts to the haul road or highwall are expected. However, the potential for impacts to the highwall should be assessed by a highwall stability specialist.

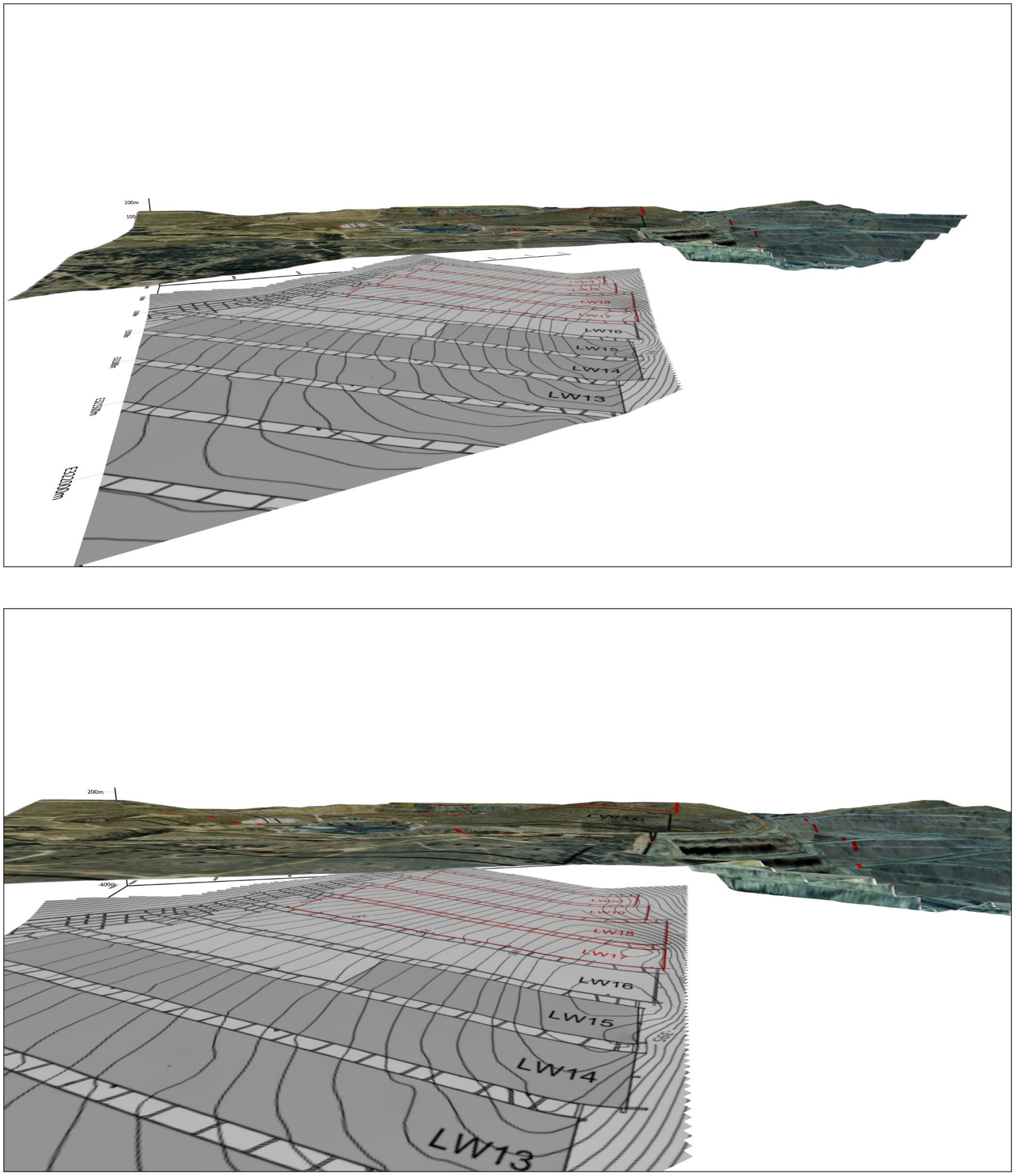

Figure 8: Views from the 3D model at natural scale showing relative positions of North Pit operations and start lines of Longwalls 17-20.

Subsidence and stability monitoring of the highwall and haul road by MTO during the first 500m of Longwalls 15 and 16 was recommended in the subsidence assessment for Longwalls 15 and 16 EP SCT (2018c). With the shortening of Longwalls 17-20 from the Longwalls 15-20 layout assessed in SCT (2017c) and the experience now available from monitoring Longwalls 14 and 15, the need for ongoing subsidence and stability monitoring post Longwall 16 should be reviewed. SCT does not have expertise in geotechnical assessments of high wall stability and review by an open cut slope stability specialist familiar with North Pit is recommended.

SCT understands that as part of their "*Principal Hazard Management Plan, Ground or Strata Failure*" MTO have day to day site management of geotechnical risk with geotechnical observations and surveillance reporting undertaken by independent specialists on a regular basis. These processes are expected to be suitable to manage any residual risk associated with subsidence related impacts from Longwalls 17-20 without the need for further monitoring.

Although not expected, any impacts to the haul road from Longwall 17 are likely to be minor and more likely to affect light vehicle traffic rather than significantly impact serviceability of the road for the haul truck fleet. A BFMP that includes the use of warning signs, regular inspections during the period of active subsidence as part of a monitoring plan and timely remediation of any impacts is recommended as an appropriate management measure.

The subsidence assessment for PA08_0101 MOD8 presented in SCT (2017c) identified several potential interactions between the open cut mining and underground longwall panels. These include:

- highwall and slope instability in the open cut on slopes directly mined under or within 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 workings
- increased potential for methane emissions into the open cut.

For the mining of Longwalls 17–20 most of these potential interaction issues are no longer valid due the shortening of Longwalls 15-20 which increases the offset to the North Pit. Changes to the MTO mining schedule has also meant that surface mining has not yet progressed to areas above the goaf areas of Longwall 15 to Longwall 9 as approved in the MOCO Project (SSD-5850).

From the list of potential interaction issues, blast vibration is likely to be the most significant impact in the short-term for IUG. Management systems and monitoring of the interactions between surface blasting vibration from MTO and underground impacts at IUG are already in place and have proven to be effective.

The potential issues of blasting efficiency, surface water inflow to the underground mine workings and methane emissions are not directly applicable to the planned mining of Longwalls 17–20 because of MTO timing and greater offset distances provided by shortening of these panels.

Investigations into the potential hazards to MTO from subsidence induced fracturing of the overburden strata above extracted IUG longwall panels, including a decrease in blasting efficiency and possible methane emissions are issues that need to be managed by MTO, as recommended in SCT (2017c), but they are not relevant to Longwalls 17-20 or this EP subsidence assessment.

5.4.10 Ravensworth East - West Pit

The Ravensworth East - West Pit is referred to as the West Pit in this section. Figure 4 shows the southern section of West Pit relative to the EP Area. Figure 9 shows the relative locations of the West Pit and the finish lines of Longwalls 17–20 at natural scale in three dimensions.

The southern end of the West Pit is currently being used for tailings emplacement and water storage. A section of the exposed southern and eastern highwall is within the EP Area. Further to the north and still within the EP Area, the pit is being filled with waste rock overburden material.

The main impacts from mining Longwalls 17-20 are expected to be the potential for instability of the exposed highwalls, potential for backfill instability and increased potential for water ingress to the underground workings because the overburden thickness is reduced by the depth of the West Pit.

5.4.10.1 Highwall Stability

Impacts to the West Pit highwall from the planned mining of Longwalls 17–20 are expected to be less than those presented in SCT (2017c) for MOD8 for the 257m void width layout. The extent of mining below the West Pit has been reduced by the shortening of each longwall panel.

Furthermore, back filling in the West Pit is expected to reduce the consequences of any rock falls and cracking to low levels. The maximum height of the eastern highwall was 130m when the pit was operating but the exposed highwall is currently about 60m high after 70m of tailings have been emplaced against it. Current planning indicates that tailings are to be deposited at a rate of up to 8-9m per year for the next few years so by the time Longwalls 18 and 19 are mined, the potential for rock falls on the West Pit highwall are expected to be further reduced.

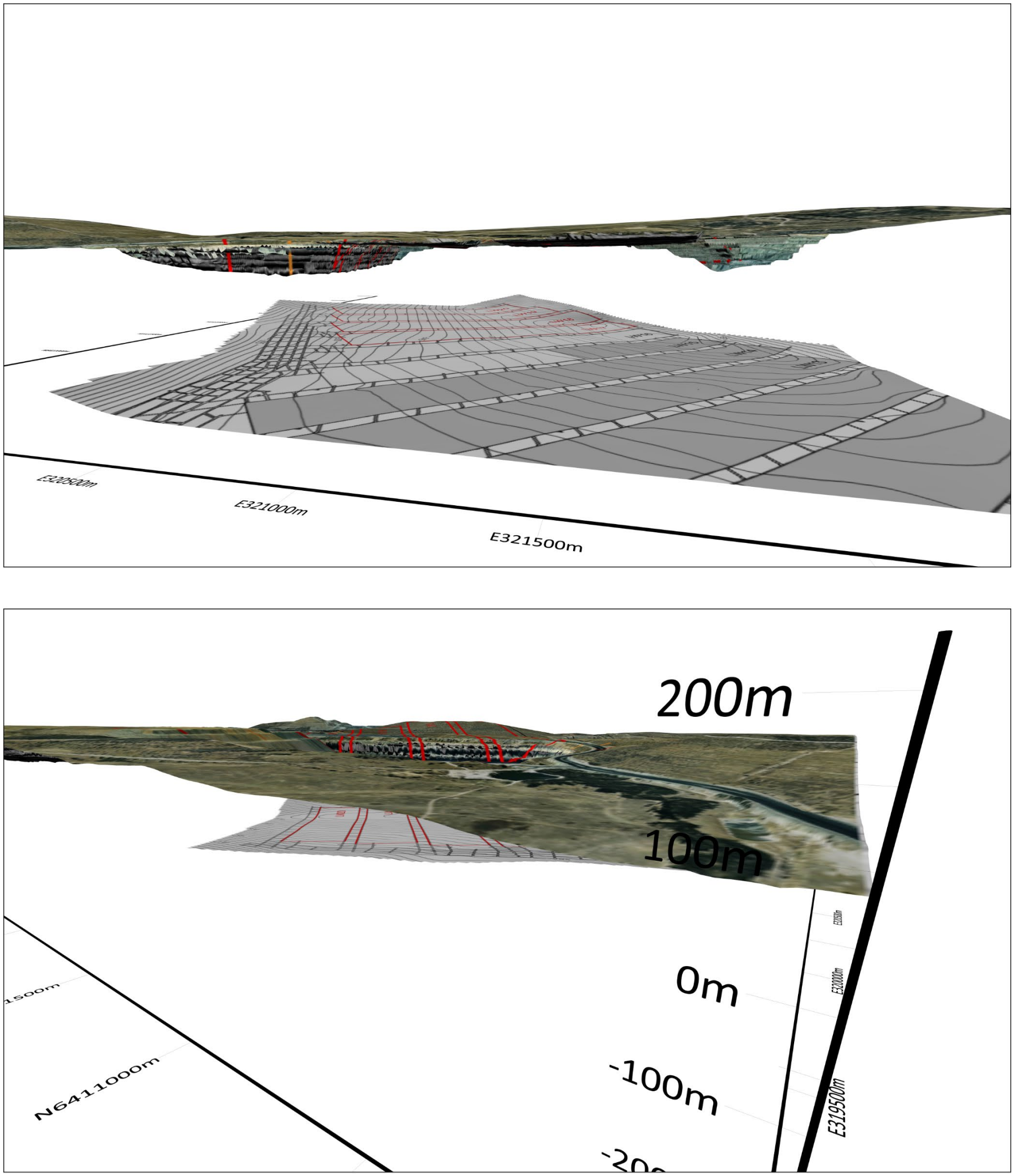

Figure 9: Views from the 3D model at natural scale showing relative positions of West Pit and finish lines of Longwalls 17-20.

Subsidence effects are likely to be greatest over Longwalls 18 and 19 because these panels extend furthest under the highwall. Subsidence of up to 1.6m is possible with horizontal movements up to 0.5m likely in a direction towards the centre of the panel. The overburden depth from the base of the West Pit to the mining horizon is approximately 300m and more than one panel width.

Impacts are likely to involve fracturing at the base of the highwall in the centre of each panel. This fracturing may lead to rock falls on the highwall. Fracturing is likely to be predominantly horizontal bedding plane separation. Experience of mining under natural cliff features indicates rock falls are possible on up to 20% of the sections of the highwall that are directly mined under and perceptible cracking may become evident on up to 70% of the length of highwall directly mined under. The consequences of any rock falls and cracking are not expected to be significant in the context of the current usage of the pit and position of the Glendell haul road and other access roads. Back filling in the West Pit is expected to reduce these consequences.

A BFMP that includes warning signs, restricted access to the bottom and top edge of the highwall during the periods of active subsidence in each panel and consideration of stand-off distances and windrows in-pit is considered an appropriate measure to manage subsidence impacts from Longwalls 17–20.

Monitoring the subsidence movements from a safe distance around the top edge of the exposed highwall is recommended for Longwalls 17-19 to provide context for any impacts observed.

5.4.10.2 Waste Rock Emplacement Stability

Waste rock emplacements within the West Pit may be mined under by Longwalls 19 and 20. Depending on the geometry of these emplacements at the time Longwalls 19 and 20 are mined, there is the potential for cracks to develop, particularly at the top of slopes with potential for ingress of surface water and possible slope instability. For the current emplacement geometry, this potential is greatest during the mining of the last 400m of Longwall 20. In an area where active material emplacement is occurring, the development of cracks is expected to be easily remediated. If the emplacement has been rehabilitated as a final landform, remediation may involve additional work, but would still be expected to be relatively minor.

5.4.10.3 Water Ingress

The potential for increased inflow from the West Pit into IUG mine workings has been assessed in an independent study by groundwater specialists (AGE 2017) for Longwalls 15-20, as part of the EA for MOD8 to the IUG Project Approval.

The West Pit was originally excavated to a maximum 130m depth near the finish line of Longwall 18. The minimum overburden thickness of original rock strata from the base of the open cut void to the ML Seam mining horizon is approximately 270-280m in the area where Longwall 18 extends out beyond the highwall and under the pit.

The height of groundwater depressurisation above the end of Longwall 18 is estimated to be up to 220m above the mining horizon using the approach described by Tammetta (2012) assuming 270m overburden depth, 257m panel void width and 2.8m mining height. Further to the northeast, below the Glendell haul road, where full caving is expected, the overburden depth is 440m and the height of depressurisation is estimated at up to 240m.

The height of depressurisation indicates the top of the zone where inflow to the mine occurs under the action of gravity alone without the need for additional pore pressure. There is a separation between the height of depressurisation and the bottom of the West Pit and an expectation of reduced inflows as a result. However, in both areas the fracture zones developed above individual longwall panels are expected to cause increased vertical and horizontal conductivity within the overburden above the panels that extend out under the West Pit.

On balance, the overall rate of surface water inflow into the underground mine workings resulting from the mining of Longwalls 17-20 is expected to increase compared to the rate experienced previously at IUG. However, despite this expectation of increased inflow, there is no potential for flow from the West Pit to constitute an inrush hazard to IUG.

5.4.11 Glendell Haul Road

The Glendell haul road extends from the active Barrett Pit to the southern ROM stockpile at the MOC CHPP. This haul road crosses the EP Area as shown in Figure 4. No significant impacts to the haul road are expected from the mining of Longwalls 17-20.

The haul road traverses around the West Pit, over the filled section of TP2 and alongside TP1, crossing the longwalls panels from the south eastern corner of Longwall 17 to near the centre of Longwall 20.

Above the corner of Longwall 17 the thickness of the fill material in TP2 is estimated at 15-20m. Other sections of the haul road have been constructed with fill material to approximately 10-15m above the natural ground level.

The haul road is likely to experience up to 1.6m of vertical subsidence with corresponding tilts and strains. The maximum effects are expected primarily over Longwall 19. Increased tilt and strains from vertical and horizontal movements may cause perceptible cracking on the hard surface of the road with local changes in grade, both along and across the haul road that could affect drainage. 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 subsidence.

The impacts of vertical subsidence may also be evident at the interface of natural ground and fill material in TP2 over Longwalls 17 and 18. A crack or small step may form across the haul road above Longwall 17. A similar crack may form along the edge of the haul road above Longwall 18.

A BFMP that includes the use of warning signs, regular inspections especially during the period of active subsidence in each panel and timely remediation of any impacts are recommended as appropriate measures to manage any potential impacts.

5.4.12 Mt Owen Rail Loop Tailings Dam / TP1

The location of Mt Owen Rail Loop Tailings Dam, also known as TP1, is shown in Figure 4. This dam is a tailings dam that is now being capped and rehabilitated. TP1 is a declared dam under the jurisdiction of Dams Safety NSW (DSNSW). Longwalls 17-20 mine within the DSNSW Notification Area for TP1 and Longwalls 18, 19 and 20 are planned to mine directly under the dam.

The subsidence effects from the planned mining are not expected to have any practical or significant impacts to the tailings, capping or any exposed highwall edges and pit surrounds. TP1 is not expected to have any practical impacts or pose an inrush risk to the mining of Longwalls 17-20.

TP1 was formed as an open cut pit to a depth of around 30m. Earth embankments at the southern end form the dam wall. The dam storage is almost completely full of tailings with only a small section of ponded water at the southern end. No significant highwalls are exposed. The capping process has started from the northern end of this dam with around 30% of the surface area capped to date. The capping is currently outside half depth from the edge of Longwall 20 but is likely to extend into the area of active subsidence by the time Longwall 20 is mined.

TP1 is expected to experience the full range of subsidence effects forecast. Minor impacts may include cracking of the surface of the tailings and capping material if the capping has advanced to be above the longwalls at the time of mining these panels and changes in level that may affect where water ponds and can drain.

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

The minimum overburden depth between the floor of TP1 and the mining horizon is approximately 450m. The height of depressurisation is estimated using the approach described by Tammetta (2012) to be 280m above the mining horizon for an assumed mining height of 3.2m. The base of the open cut void is approximately 170m above the top of the zone of depressurisation. There is expected to be very limited potential for significant inflow from TP1 through this interval. There is no potential for flows of a magnitude sufficient to constitute an inrush hazard to IUG.

To reduce the potential for overflow from TP1 due to surface tilting, it is recommended that, as part of the BFMP, the area is regularly inspected, any ponded water in TP1 is drawn down to a low-level during periods of active subsidence for each panel mining directly below TP1 and potential overflow points are reviewed following the completion of each panel.

The earth embankment that forms the lower end of TP1 is approximately 5m high. The ground strains expected in this area are less than 4mm/m. The earth embankment is expected to be able to accommodate this level of ground strain without perceptible impact.

Consent from Dams Safety NSW and approval from the Chief Inspector of Coal Mines are expected to be required for the mining of both development roadways and longwall extraction within the Mt Owen Notification Area whilst ever TP1 remains a declared dam.

5.4.13 Ravensworth East Tailings Pit / Mt Owen Stage 5 Tailings Dam / TP2

The Ravensworth East Tailings Pit / Mt Owen Stage 5 Tailings Dam, also referred to as TP2, is located adjacent to the Mt Owen Railway Line between TP1 and the ERP. The position of TP2 relative to Longwalls 17-20 is shown in Figure 4.

The sections of TP2 above Longwalls 17 and 18 are expected to experience the full range of subsidence effects forecast.

Impacts to TP2 from planned mining of Longwalls 17-20 are expected to be generally insignificant and not expected to have any significant consequence. The only potential impacts relate to minor differential subsidence that may become apparent on the Glendell haul road as discussed in Section 5.4.11.

TP2 was originally mined to a depth of approximately 35m. TP2 is filled with waste rock from Glendell Mine. There are no tailings in this pit. The section of TP2 above Longwalls 17 and 18 has been substantially backfilled, capped and largely rehabilitated to a height of approximately 15m above the original ground level. A small area of the void above Longwalls 15 and 16 is still open and used as part of surface water management system to store and filter water. Infrastructure for pumping from the southeast corner of the storage was recently upgraded. One side of the open void, approximately 25m deep, forms the western side of the railway line causeway with the ERP forming the other side.

Longwall 15 mined below part of this area. Additional subsidence movements are expected to occur at the open void above Longwalls 15 and 16 when Longwall 17 and subsequent panels are mined.

Forecast subsidence movements are likely to result in further settlement of the fill material and may induce cracking particularly at the crest of steeper sections of fill material. Impacts in the form of cracks, steps and potholes may form along the interface between fill material and natural ground surface around the buried perimeter of the TP2 pit. The additional settlement and impacts are generally not expected to have any significant consequence other than minor differential subsidence that may become apparent on the Glendell haul road. Other potential impacts include cracking and rock falls on the exposed highwall, slope instability in steeper parts of the emplaced material and potential for increased inflow to the underground mine workings.

The subsidence impacts are expected to be minor and manageable using the existing BFMP for Longwalls 15 and 16. Updating the section in the BFMP for TP2 to include regular inspections during the period of mining Longwalls 17 and 18 is recommended.

The rate of inflow from TP2 into IUG mine workings has been assessed for Longwalls 15-20 in an independent study by groundwater specialists (AGE 2017) as part of the EA for MOD8 to the IUG Project Approval. Any increase groundwater flow between the surface and underground workings from the mining of Longwalls 17-20 is not expected to be at a rate sufficient to constitute an inrush hazard for IUG.

5.4.14 Eastern Rail Pit

The section of the ERP, within the EP Area, is shown on Figure 4. The ERP does not extend over Longwalls 17–20. ERP has been partly filled and capped. The remaining open section is located above Longwalls 14, 15 and 16. Any additional impacts to the ERP from the planned mining of Longwalls17 – 20 are expected to be minor and manageable.

The corner of the ERP where the exposed northern and western highwalls meet is closest to Longwall 17 and approximately 180m from the panel edge. The highwalls at this location are currently 15m high following emplacement of approximately 15m of tailings. Most of the open void was recently mined under by Longwall 15 without significant impact.

Some additional subsidence movements are expected at the north west corner of the open void above Longwalls 15 and 16 from the mining of Longwall 17 and subsequent panels, but these will be small by comparison to the movements associated with Longwalls 15 and 16.

Impacts associated with mining Longwalls 17-20 are expected to be minor and manageable under the existing BFMP for Longwalls 15 and 16. Revising the section of BFMP for the ERP to include inspections for the period of planned mining in Longwalls 17 and 18 is recommended.

The potential for increased inflow from the ERP into IUG mine workings has been assessed for Longwalls 15-20 in an independent study by groundwater specialists (AGE 2017) as part of the EA for MOD8 to the IUG Project approval. Any increase in groundwater flow between the surface and underground workings from the mining of Longwalls 17-20 is not expected to be at a rate sufficient to constitute an inrush hazard for IUG.

5.4.15 Waste Rock 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 EP Area. The major emplacements are the West Dump, the Glendell/Ravensworth East area and the Glendell area. Other minor emplacements include those associated with the rehabilitation of TP2 and the ERP. The positions of these areas relative to planned mining in Longwalls 17-20 are shown in Figure 4.

The emplacement areas located above Longwalls 17–20 include parts of the West Dump and TP2. The Glendell/Ravensworth East and Glendell emplacement areas are further than half depth from Longwalls 17–20 and unlikely to be perceptibly impacted by mining these longwall panels.

Total vertical subsidence of up to 2.5m with strains up to 14mm/m in tension and 20mm/m in compression are forecast.

Cracking may develop along the crest of topographic high points allowing water ingress during periods of heavy rain. This ingress has potential to contribute to minor instability on steeper sections between contour drains on the West Dump, but such instability is not expected to be significant. The drop structure on the western slope of the West Dump is not expected to be significantly impacted. Some minor remediation work may be required to the contour drains, drop structure and sediment control dams, but overall, any subsidence impacts to this modified landform are expected to be manageable.

Regular inspections over the areas of active subsidence during mining in each panel in conjunction with the provisions of the Land Management Plan and BFMP are expected to provide satisfactory management of any subsidence impacts to the waste rock emplacements and associated features.

5.4.16 Sediment Control Dams

The main sediment control or run-off filtering dam located within the EP Area is located at the base of the drop structure on the western slope of the West Dump as shown on Figure 4. Other similar dams for the Ravensworth East/Glendell emplacement area, stormwater collection on the eastern slope of the West Dump (Dam 4) and sediment control dams for the ERP are located to the east of Longwall 15 and outside the EP Area.

The run-off dam for the West Dump is located adjacent to the rail line and overflows to feed a smaller dam on natural ground within the rail loop via culverts under the maintenance road and rail line embankment. The water from these dams then flows into the Rail Loop Dam.

These two dams are expected to experience the full range of subsidence movements forecast for the planned mining of Longwalls 17-20.

Minor surface cracking and changes in level are expected due to transient tilting of the surface as the planned longwalls mine under these features. These impacts are expected to be temporary. Minor remedial work may be required at the Longwalls 19-20 chain pillar and Longwall 20 goaf edge to adjust gradients and restore flow paths. No significant impacts to the culverts are expected.

Regular inspections over the areas of active subsidence as part of the provisions of the Land Management Plan and BFMP are recommended. These measures are expected to provide satisfactory management of any subsidence impacts to these features.

5.4.17 Gas Drainage Infrastructure

Components of the IUG gas management system either already exist or are proposed within the EP Area for Longwalls 17-20. Existing operational installations are currently located above Longwalls 15 and 16. The system comprises surface to seam boreholes with collar installations and surface pipeline networks for either flaring the gas or delivery to a central gas drainage plant for power generation. The existing gas management system is expected to be extended to cover areas above Longwalls 17-20 wherever surface access is possible and practical.

This equipment is expected to experience the full range of subsidence effects forecast. 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 in the event of any failure.

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 since initial commissioning of the plant some 10 years ago. Ongoing use of the current risk control measures within the IUG Ventilation Control Plan are expected to be effective for managing potential consequences from any impacts of subsidence from Longwalls 17-20.

5.4.18 Ventilation Shaft 3 and Associated Infrastructure

A new surface to seam ventilation shaft for IUG known as Shaft 3 has recently been commissioned. The surface installations for the shaft, including main fans and service boreholes, are located beyond the finish line of Longwall 16 on the southern edge of the EP Area as shown in Figure 4.

The shaft and associated infrastructure, including service boreholes are beyond half depth from the finish line of Longwall 17. No significant impacts from the planned mining in Longwalls 17–20 are expected.

Subsidence effects at the shaft site, in addition to those from mining in Longwalls 15 and 16, are expected to include small additional horizontal movements. Impacts are expected to be limited to additional shearing on bedding planes that may intersect the shaft and adjacent service boreholes.

SCT understands that the shaft infrastructure has been designed to accommodate the forecast subsidence movements with provision for minor adjustments to equipment during the mining of each longwall and that a BFMP including subsidence monitoring is in place for the mining of Longwalls 15 and 16.

Revising the BFMP and subsidence monitoring program to include inspections for the periods of mining the last 500m in Longwalls 17 and 18 and surveys is recommended.

5.4.19 Access Roads and Four-Wheel Drive Tracks

There are unsealed access roads and four-wheel drive tracks for light vehicles located across the EP Area. The impacts from the planned mining of Longwalls 17–20 on the tracks or roads are expected to be similar to impacts previously observed over earlier longwall panels. These previous impacts have all been minor and easily managed.

There is some potential for cracks, compression humps and local changes in grade, both along and across the road that may result in minor ponding. These impacts would not be significantly out of context with the general nature of the terrain and other hazards that may exist unrelated to subsidence impacts. Some minor repair work may be required to smooth out irregularities, fill any open cracks that may form and restore drainage.

A BFMP that includes warning signs, regular inspections, and timely remediation of any impacts is considered appropriate to manage potential impacts.

5.4.20 Planned Dewatering and Ventilation Infrastructure

MOD8 to IUG PA08_0101 provides consent for HVCC to construct additional surface infrastructure near the northern ends of Longwalls 15-20. This additional infrastructure includes a dewatering borehole with pumping equipment and ventilation shafts with exhaust fans supplied by an 11kV powerline.

The goaf dewater borehole collar is proposed to be located near the recently constructed stormwater dam over the northern section of Longwall 14/15 development roadways. The exact positions of the dewatering infrastructure and planned bleeder shafts, exhaust fan installations and powerline extension are yet to be finalised.

In the event of this infrastructure being installed, a detailed assessment of potential subsidence impacts is recommended. Subsidence effects and impacts to the planned infrastructure are expected to be manageable with appropriate assessment and design considerations.

5.5 Public Safety

The extraction plan condition of PA08_0101 requires a public safety management to ensure public safety at the site. The IUG Public Safety Management Plan (PSMP) is in place to safeguard members of the public from the hazards of subsidence impacts induced by underground mining.

These hazards include surface cracking or changes in grade that might affect traffic safety on public roads. More generally the PSMP addresses hazards associated with the potential for flooding, impacts relating to ponding and general subsidence remediation, ERP and TP2, Mt Owen Railway Line and Bettys Creek Bridges, roads and tracks, farm dams and fences (including escape of livestock onto Forest Road).

The subsidence performance measure for public safety requires that there be no additional risk (to the public) due to mining (in U/G mining area).

Current measures to manage these risks include controlling access, the use of warning signage and prompt remediation of any impacts. These measures are expected to be effective during the mining of Longwalls 17–20 where access can be controlled. Continuing use of the PSMP is recommended.

6. SUBSIDENCE MONITORING

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. 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 they become available.

Subsidence monitoring is recommended to manage operational, personal and public safety risks and address the specific requirements of PA08_0101 conditions including those detailed in the subsidence monitoring program.

The aim of this monitoring is to:

- provide data to assist with the management of the risks associated with subsidence
- validate subsidence forecasts
- provide a basis to analyse the relationship between the subsidence effects and impacts including any environmental consequences
- collect sufficient baseline data for future EP applications
- enhance general understanding of subsidence behaviour at IUG.

Subsidence monitoring recommended for Longwalls 17-20 is generally consistent with recommendations in SCT (2017c) for Longwalls 15-20. This monitoring includes an extension to R Line, continuous GNSS monitoring of key MOC MIA infrastructure (similar to the Mt Owen Railway Line and associated infrastructure), LIDAR surveys of the surface and continuation of surveying distributed arrays of points around the Ravensworth East – West Pit and Shaft 3.

Figure 10 shows the arrangement of recommended monitoring lines and subsidence marks.

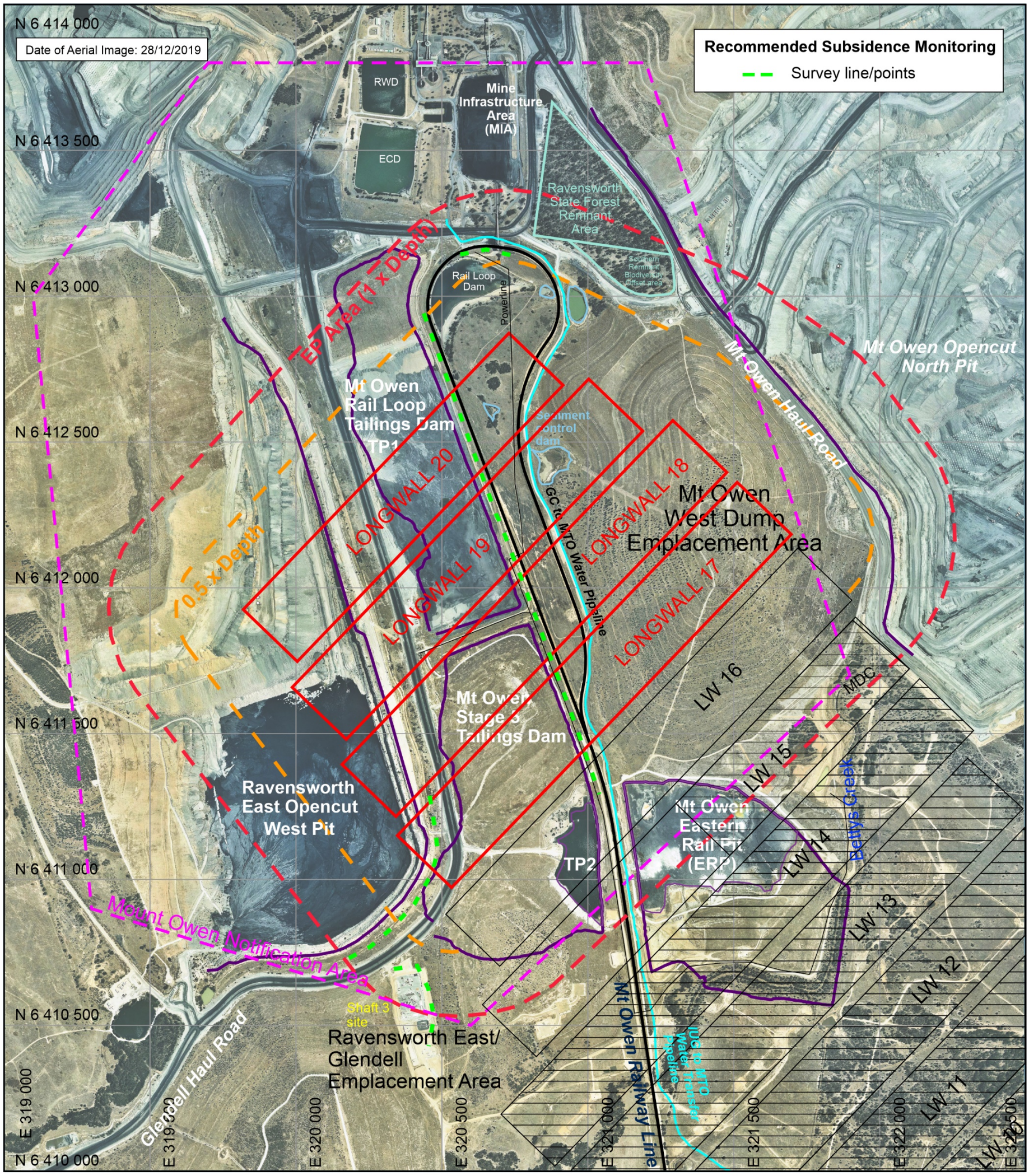

Figure 10: Recommended Locations of Subsidence Monitoring for Longwalls 17-20.

6.1 R Line

R Line currently extends as a subsidence line to midway across Longwall 17 and as a series of isolated points for 750m from the edge of Longwall 16 to Longwall 19. An extension of R Line alongside the Mt Owen Railway Line is recommended with each longwall panel. R Line is the main monitoring line at IUG and the only line suitable to demonstrate compliance with subsidence predictions. The rail corridor is the only area of natural ground suitable for a subsidence line.

It is recommended that the isolated marks are maintained to more than 1km ahead of the active longwall and "infilled" with marks at 20m spacing. Infilling to at least 250m beyond the edge of the active longwall panel is considered a minimum for compliance monitoring. Infilling to 500m ahead of the active longwall panel would improve the reliability of measurements of angle of draw and other horizontal subsidence parameters to generally enhance the understanding of subsidence behaviour at IUG.

6.2 GNSS Monitoring

There is currently no reliable information on far-field subsidence movements at IUG. These movements are observed at other sites at distances up to 3km in advance of longwall mining. Although typically only a few tens of millimetres in magnitude until closer to active mining, such movements nevertheless have potential to affect alignment sensitive infrastructure. Installation of at least one continuous, near real-time GNSS (GPS) monitoring unit at or adjacent to the train loading infrastructure at the MOC MIA is recommended.

An initial unit would monitor far-field movements in three-dimensions and provide advance warning of movement that any critical infrastructure might experience from Longwalls 17-20. Additional units could be installed subsequently on other infrastructure as required. The system has the ability to be reviewed in near real time and can be set to alarm if trigger levels are exceeded. Without any monitoring of far-field movements, there can be no reliable confirmation that infrastructure is not being impacted. This monitoring is considered necessary for management of critical infrastructure.

6.3 LIDAR Surveys

LIDAR surveys of the surface at the end of each panel are recommended to provide control on the magnitude and nature of subsidence movements in areas remote from the main subsidence lines. LIDAR surveys conducted routinely for MTO would only need to be extended slightly to cover the area of Longwalls 17-20. These surveys provide confirmation of subsidence movements across the entire site. Their accuracy is less than conventional subsidence lines, but the context they provide enables much more effective control and management of subsidence impacts. LIDAR surveying is considered a necessary part of contemporary subsidence monitoring systems.

6.4 Distributed Array Monitoring

Surveys of distributed survey pegs around the around the top edge of the highwall of Ravensworth East - West Pit and Shaft 3 are recommended to confirm the magnitude of any ground movements that may lead to subsidence impacts to the highwall and the ventilation shaft. Monitoring would be most useful through to the completion of Longwall 19.

This monitoring would be primarily to confirm the magnitude and nature of ground movements in the event of subsidence related impacts to the opencut void and the ventilation shaft. The information gained is not critical to the ongoing operation, but it would allow more informed decisions in relation to predicting future impacts and potential remedial activities.

6.5 Mt Owen - North Pit Monitoring

Subsidence and stability monitoring of the highwall and haul road by MTO during the first 500m of each of Longwalls 15-20 was recommended in the MOD8 subsidence assessment (SCT 2017c) and Longwalls 15 and 16 EP (SCT 2018c). With the shortening of Longwalls 17-20 and the experience now available from monitoring Longwalls 14 and 15, ongoing subsidence monitoring post Longwall 16 appears unlikely to be necessary. SCT does not have expertise in highwall slope stability and the advice of specialists with relevant experience should be sought as to whether further subsidence monitoring is necessary.

6.6 General Considerations

Pegs on conventional subsidence lines should be spaced at intervals of 1/20th of depth or 20m whichever is less. For an array of survey points, the points should generally be spaced at intervals of 50-100m.

Monitoring frequencies should be dictated by the various management plans and technical committee requirements. Surveys should be timed to capture maximum subsidence movements where practical.

Ongoing monitoring should include survey control for each survey based on GNSS (GPS) control points (including those maintained by the NSW Government) located well outside the far-field effects zone on all sides of the mining area. This 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.

Engineering survey monitoring undertaken as part of the asset management plan for the Mt Owen Railway Line is not included in these recommendations on the assumption that it will be managed independently by the Mt Owen Rail technical committee.

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APPENDIX 1 - EP/SMP APPLICATION GUIDELINES LIST OF SURFACE FEATURES TO BE CONSIDERED IN A SUBSIDENCE ASSESSMENT

Natural Features	Within EP Area	Relevant Section
1) Catchment areas and declared Special Areas;	**N**	
2) Rivers and creeks;	**Y**	*5.1.1*
3) Aquifers, known groundwater resources;	**Y**	*3.8.2, 5.1.2*
4) Springs;	**N**	
5) Sea/lake;	**N**	
6) Shorelines;	**N**	
7) Natural dams;	**N**	
8) Cliffs / pagodas;	*N*	
9) Steep slopes;	*N*	
10) Escarpments;	*N*	
11) Land prone to flooding or inundation;	*N*	
12) Swamps, wetlands, water related ecosystems;	**N**	
13) Threatened and protected species;	**Y**	
14) National parks;	**N**	
15) State conservation areas;	**N**	
16) State forests particularly areas zoned FMZ 1, 2 and 3;	**Y**	*3.8.1, 5.1.1*
17) Natural vegetation;	**Y**	*5.1.1*
18) Areas of significant geological interest, and	**N**	
19) Any other feature – Endangered Ecological Communities.	**Y**	
Public Utilities		
1) Railways;	**N**	
2) Roads (all types);	**N**	
3) Bridges;	**N**	
4) Tunnels;	**N**	
5) Culverts;	**N**	
6) Water/gas/sewerage pipelines;	**N**	
7) Liquid fuel pipelines;	**N**	
8) Electricity transmission lines (overhead/underground) and associated plants;	**N**	
9) Telecommunication lines (overhead/underground) and associated plants;	**N**	
10) Water tanks, water and sewage treatment works;	**N**	
11) Dams, reservoirs and associated works;	**N**	
12) Air strips,	**N**	
13) Any other infrastructure items.	**N**	
Public Amenities		
1) Hospitals	**N**	
2) Places of worship	**N**	
3) Schools	**N**	
4) Shopping centres	**N**	
5) Community centres	**N**	
6) Office buildings	**N**	
7) Swimming pools	**N**	
Public Amenities		
8) Bowling greens	**N**	
9) Ovals and cricket grounds	**N**	
10) Race courses	**N**	
11) Golf courses	**N**	
12) Tennis courts	**N**	
13) Any other amenities considered significant	**N**	

Natural Features	Within EP Area	Relevant Section
Farm Land and Facilities		
1) Agricultural utilisation or agricultural suitability of farm land;	**N**	*3.8.2*
2) Farm buildings / sheds;	**N**	
3) Gas and / or fuel storages;	**N**	
4) Poultry sheds;	**N**	
5) Glass houses;	**N**	
6) Hydroponic systems;	**N**	
7) Irrigation systems;	**N**	
8) Fences;	**N**	
9) Farm dams;	**N**	
10) Wells, bores, and	**N**	*3.8.2*
11) Any other feature – Access tracks.	**Y**	*5.4.19*
Industrial, Commercial and Business Establishments		
1) Factories;	**N**	
2) Workshops;	**N**	
3) Business or commercial establishments;	**N**	
4) Gas and / or fuel storages and associated plants;	**N**	
5) Waste storages and associated plants;	**N**	
6) Buildings, equipment and operations that are sensitive to surface movements;	**N**	
7) Surface mining (open cut) voids and rehabilitated areas;	**Y**	*5.4*
8) Mine infrastructure including tailings dams and emplacement areas, and	**Y**	*5.4*
9) Any other feature considered significant	**Y**	*5.4.8*
Railways;	**Y**	*5.4.2*
Bridges;	**N**	
Roads;	**Y**	*5.4.4*
Water/gas/sewerage pipelines;	**Y**	*5.4.7*
Communication Cables (underground);	**Y**	*5.4.3*
Areas of Archaeological and/or Heritage Significance	**Y**	*5.2.1*
Items of Architectural Significance	**N**	
Permanent Survey Control Marks	**Y**	*5.3.1*
Residential Establishments		
1) Houses;	**N**	
2) Flats / Units;	**N**	
3) Caravan parks;	**N**	
4) Retirement/aged care villages;	**N**	
5) Associated structures such as workshops, garages, on-site waste water systems, water or gas tanks, swimming pools and tennis courts, and	**N**	
6) Any other feature considered significant.	**N**	

APPENDIX 2 - GLOSSARY OF TERMS

The terms as defined in this glossary are used in this report.

Angle of Draw	The angle between a vertical line from the goaf edge to the surface and a direct line from the goaf edge to a point on the surface where subsidence is no longer regarded as significant, usually taken to be 20mm. An angle of draw of 26.5° is equivalent to a distance from the goaf edge equal to half the overburden depth. An angle of draw of 35° is equivalent to 0.7 times depth and 45° degrees is equal to the depth.
Chain Pillar	The block of coal left unmined between access roads for each longwall panel and eventually between two fully extracted longwall panels.
Conductivity	The terms conductivity and hydraulic conductivity describe the rate of water flow through the rock mass, usually measured in m/s or m/day.
Critical Panel Width	The panel width that equates to the minimum panel width that produces full subsidence in the centre of an extracted longwall panel i.e. maximum subsidence does not increase for panel widths greater than critical width. Critical panel width is usually in the range 1-1.4 times overburden depth.
Goaf	The area left when longwall goaf is extracted and into which the overlying strata collapses. The term is sometimes used to describe the collapsed strata above the mining horizon more generally.
Height of Depressurisation	Height of depressurisation is the maximum height above the mining horizon where there is zero pore pressure above the goaf and downward flow can proceed under the action of gravity alone i.e. no additional pore pressure is required to drive downward flow at the rate flow is occurring. The height of depressurisation does not imply zero flow into the mine from above this height or the strata is fully drained or necessarily even unsaturated below this height.
Horizontal Movements	Horizontal ground movements occur at the surface in response mining subsidence. There are three main components of horizontal movement, a systematic component that occurs because of vertical subsidence, a topographic component that occurs as a result of sloping terrain and a stress relief component associated with relief of horizontal stresses in the overburden rock strata.
Overburden Depth	The thickness of strata between the surface and the coal seam mining horizon.
Panel Width (void width)	The shortest distance across a longwall panel including the width of the coal extracted by the longwall and the width of the two access roadways on either side of the panel.
Primary Subsidence Effects	The three main subsidence parameters – subsidence, tilt and strain.
Secondary Subsidence Effects	Subsidence parameters such as: angle of draw, chain pillar subsidence, panel edge subsidence, horizontal movements.
Strain	The change in horizontal distance caused by subsidence divided by the original horizontal distance between two points. Strain is usually measured in mm/m. Strain may be either tensile (stretching) or compressive (squashing) in nature.

Subcritical Panel	A panel width less than critical width for which maximum subsidence is less than the subsidence that would be generated if the panel were wider.
Subsidence Effects	Ground movements caused by mining including vertical and horizontal displacement, tilt, strain and curvature.
Subsidence Impacts	Consequences of any subsidence effects for the ground, surface features and any communities affected in any way by subsidence effects.
Subsidence	Subsidence is the change in the level of the ground surface caused by mining.
Supercritical Panel Width	A panel width that is wider than critical width and one where maximum subsidence occurs in the central part of each panel.
Tilt	The difference in vertical subsidence between two points caused by mining subsidence divided by the horizontal distance between the two points. Tilt is usually measured in mm/m.
Unconventional Subsidence Effects and Impacts:	
Valley closure	The phenomenon whereby subsiding rock strata on either side of a valley moves together.
Upsidence	A localised reduction in background subsidence typically associated with valley closure.
Movements associated with geological features - bedding plane shears, compression overrides (ripples), and steps	A variety of subsidence related movements are observed in special circumstances where ground movements are locally concentrated. These types of movements are commonly caused by shear movements on low strength horizons that express themselves as a linear zone of deformation. These phenomena are difficult to predict in advance of mining, typically cause locally high strains and tilts but occur only infrequently.