SCT OPERATIONS PTY LIMITED

Strata Control Technology

WOLLONGONG COAL LTD

Russel Vale Colliery: Extraction Plan
Subsidence Assessment for PC27-34 (Stage 2) Mining

WCRV5385

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TITLE Russel Vale Colliery: Extraction Plan Subsidence Assessment for PC27-34 (Stage 2) Mining

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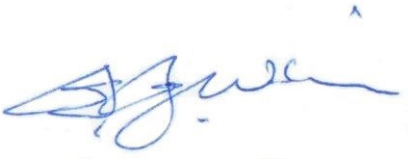

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SUMMARY

Wollongong Coal Limited (WCL) owns the Russell Vale Colliery (RVC) located approximately 9km north-northwest of Wollongong in the Southern Coalfield of New South Wales. In accordance with development consent MP09_0013 for the Russell Vale Revised Preferred Underground Expansion Project (RPUEP), WCL is preparing an extraction plan (EP) for the second stage of bord and pillar mining of the Wongawilli Seam in the multi-seam Russell Vale East (RVE) area of RVC. WCL commissioned SCT Operations Pty Ltd (SCT) to forecast the likely subsidence effects and assess impacts from the planned mining to and support the EP application for Stage 2, specifically, Conditions C10(e) and C10(f) of MP09_0013. This report presents our forecast of potential subsidence effects and assessment of subsidence impacts for the planned mining in the PC27-34 panels to inform other studies.

The scope of this assessment for the planned Stage 2 mining is limited to the PC27-34 panels that extend off existing Wongawilli Seam panel driveages. The PC27-34 layout is essentially the northern section of the approved RPUEP mining plan in a simpler (two seam rather than three seam) mining environment.

Vertical subsidence is expected to be generally less than 100mm and largely imperceptible over the majority of the EP Assessment Area for PC27-34. Unrelated to the planned mining, vertical subsidence of greater than 500mm is considered possible, but unlikely, in small, isolated areas within and near the edges of Bulli Seam goaf areas where remnant pillars not already collapsed may become unstable. These estimates of vertical subsidence are consistent with previous assessments (SCT 2019), peer reviews (Hebblewhite 2020) and other expert reviews (IAPUM 2020).

Subsidence impacts and environmental consequences from the planned bord and pillar mining are expected to be compliant with the subsidence impact performance measures in conditions of development consent MP09_0013, notwithstanding the input of other specialists.

No significant, additional impacts are expected to natural and built features.

Any impacts and consequences to natural, surface, and sub-surface features in the undeveloped bushland setting are expected to be negligible in the context of the existing condition and previous impacts.

Any impacts to built features are expected to be minor and repairable, without affecting safety and serviceability. No perceptible impacts are expected to the major regional infrastructure that is remote from the planned mining.

Additional risk to public safety is expected to be negligible. Overall, the potential for impacts to surface features affecting public safety for the Stage 2 mining are expected to be less than those assessed for Stage 1 EP.

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* with the required management plans and other risk control measures to manage risks to the health and safety of workers and other persons from subsidence.

The continued use and extension of the existing subsidence monitoring program and other subsidence management measures are recommended.

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1. INTRODUCTION

Wollongong Coal Limited (WCL) owns the Russell Vale Colliery (RVC) located approximately 9km north-northwest of Wollongong in the Southern Coalfield of NSW. In accordance with development consent MP09_0013 for the Russell Vale Revised Preferred Underground Expansion Project (RPUEP) and following the conditional approval of the Extraction Plan (EP) for panels PC07-08 and PC21-25 (Stage1), WCL is preparing an EP for the second stage of the bord and pillar mining of the Wongawilli Seam in the multi-seam Russell Vale East (RVE) area of RVC. To support the EP application for the Stage 2 mining, WCL commissioned SCT Operations Pty Ltd (SCT) to forecast the likely subsidence effects and assess impacts from the planned mining and prepare a subsidence assessment report. This report has been prepared to meet the requirements of Condition C10(e) and part of Condition C10(f) of MP09_0013 and provides revised predictions of potential subsidence effects and subsidence impacts for the planned bord and pillar mining in the PC27-34 panels of the Stage 2. These panels extend off existing gateroad driveages and the layout is essentially the northern section of the approved RPUEP mining plan. This report presents our estimates of subsidence effects and assessment of expected impacts to inform studies by other specialists and is structured to provide:

- Conclusions and recommendations including:
    - a review of subsidence forecasts since development consent MP09_0013 for the RPUEP was granted
    - assessment of expected compliance with subsidence impact performance measures in the MP09_0013 consent conditions
    - details of performance indicators
    - recommendations for subsidence monitoring and subsidence management.
- A brief overview of the site, including a general description of significant surface features within the EP assessment area (EP Area) including those identified during the subsidence risk assessment undertaken for the Stage 2 mining.
- Estimates of the subsidence effects expected within the EP Area as a result of the planned mining including a review of previous subsidence experience at RVE.
- A description of the subsidence impacts expected to the various surface and sub-surface features and surface infrastructure located across the EP Area resulting from the forecast subsidence movements for the planned mining.

Figure 1 shows a site plan of the existing workings in Wongawilli Seam and planned mining in PC27-34 with the EP Area for these panels superimposed onto a 1:25,000 topographic map of the area. Secondary extraction areas of the overlying Balgownie and Bulli Seams are also shown. The subsidence assessment presented is based on this layout for PC27-34 and planned mining height. Any variations to this geometry would require reassessment of the potential subsidence effects and impacts.

This subsidence assessment includes observations from a site inspection of the surface on 31 January 2022, considerations of a risk assessment conducted on 1 February 2022 for the planned mining in PC27-34, the "Guideline for Applications for Subsidence Management Approvals" and "Guidelines for the Preparation of Extraction Plans".

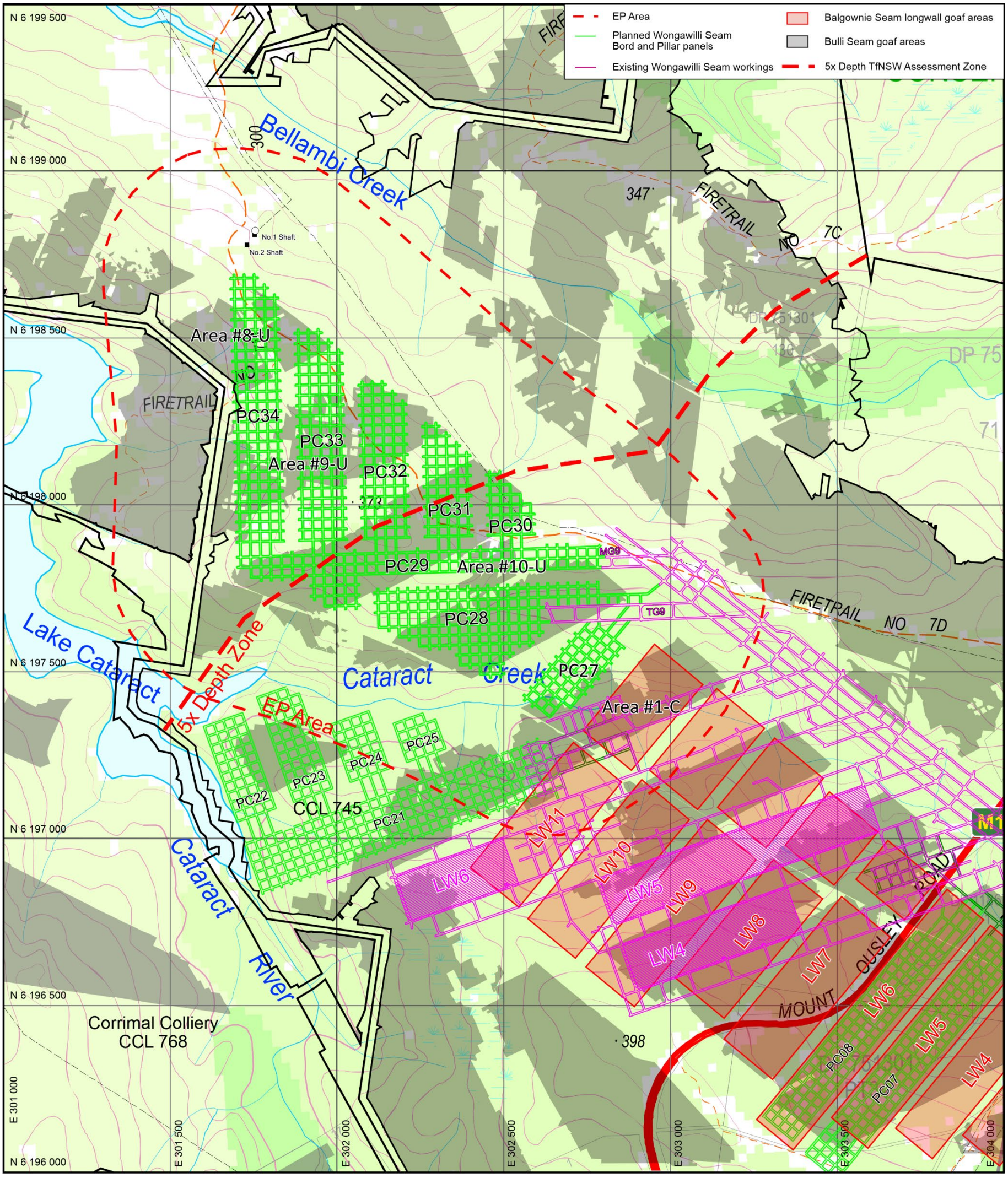

Figure 1: Site plan superimposed on 1:25,000 topographic map.

The subsidence effects 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 whether subsidence is or is not a principal hazard.
- 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.

Since the RPUEP development consent MP09_0013 was approved, SCT has conducted additional research and investigations for the preparation of Extraction Plans or modifications to the development consent. This research focused on the reliability of the Bulli Seam mine plan records and status of the goaf areas not yet confirmed as collapsed and includes additional information. The details of this research are presented as Appendix 3 of SCT Report WCRV5285 - Russell Vale Colliery: Subsidence Assessment for PC07-08 and PC21-25 Extraction Plan (SCT 2021b). This report is the subsidence assessment for the Stage 1 EP. The additional research and review of available data indicates the interpretations and assumptions made by SCT in previous assessments for the RPUEP were reasonable.

2. CONCLUSIONS AND RECOMMENDATIONS

The scope of this assessment for the planned Stage 2 mining is limited to the PC27-34 panels that extend off existing Wongawilli Seam panel driveages. The PC27-34 layout is essentially the northern section of the approved RPUEP mining plan in a simpler mining environment with only the Bulli Seam and Wongawilli Seam interactions to consider for the majority of the planned mining. The overburden depth is also deeper than over the Stage1 mining areas.

Estimates of subsidence effects, primarily vertical subsidence, for the planned bord and pillar mining for Stage 2 are consistent with previous assessments (SCT 2019) and peer reviews (Hebblewhite 2020).

Vertical subsidence is expected to be generally less than 100mm and largely imperceptible over the majority of the EP Area for PC27-34. IAPUM (2020) suggests allowance for subsidence of up to 300mm to cover possible reactivation of goafs in both the Bulli and Balgownie Seams. Vertical subsidence of greater than 500mm is considered possible, but unlikely. If such subsidence were to occur, it would be expected in small, isolated areas within and near the edges of Bulli Seam goaf areas where remnant pillars not already collapsed may become unstable.

Some possible remnant pillars have been identified during preparation of this EP assessment for Stage 2. Subsidence of up 300mm is considered possible but unlikely near these pillars. This potential for additional subsidence greater than 100mm exists irrespective of planned bord and pillar mining in the Wongawilli Seam.

Subsidence impacts and environmental consequences from the planned bord and pillar mining are expected to be compliant with the subsidence impact performance measures in conditions of development consent MP09_0013, notwithstanding the input of other specialists. No significant additional impacts are expected. Any impacts and consequences are expected to be negligible in the undeveloped bushland setting that exists over the EP Area.

Any impacts to natural, surface, and sub-surface features are expected to be negligible. No significant, additional impacts are expected to upland swamps, watercourses, sandstone formations and Aboriginal heritage sites. Impacts and consequences are expected to be negligible in the context of the existing condition and previous impacts.

Any impacts to built features are expected to be minor and repairable, without affecting safety and serviceability, with risk control measures in appropriate management plans. No perceptible impacts are expected to the Cataract Storage Reservoir.

The major regional infrastructure (Mount Ousley Road - M1 Princes Motorway - and high-voltage electricity transmission lines to the east) are remote from the EP Area and no perceptible impacts are expected to these built features.

Additional risk to public safety is expected to be negligible.

Overall, the potential for impacts to surface features affecting public safety for the Stage 2 mining are expected to be less than those assessed for Stage 1 EP.

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* with the required management plans and other risk control measures to manage risks to the health and safety of workers and other persons from subsidence.

2.1 Review of Subsidence Forecast Since Consent for RPUEP

The EP process provides an opportunity to update subsidence forecasts and assessment of impacts based on additional information and understanding gained since consent was granted. The subsidence effects forecast and assessment of impacts over the EP Area for PC27-34 has not changed significantly from those provided to the IPC for final determination of the RPUEP. Subsidence effects forecasts are consistent with previous assessments (SCT 2019) and other peer or expert reviews.

Impacts are expected to be negligible or minor and manageable consistent with the previous assessment for the planned bord and pillar mining geometry.

2.2 Subsidence Impact Performance Measures

Our assessment indicates that impacts from the planned bord and pillar mining, with the required management plans and associated risk control measures in place, are expected to be compliant with the subsidence impact performance measures detailed in Table 6 and Table 7 of MP09_0013, notwithstanding the input of other specialists.

Table 6 requires negligible or no impacts, consequences, and other changes to natural and heritage features. Table 7 requires infrastructure and built features to remain safe and serviceable and if damaged, repaired or compensated for and negligible additional risk to public safety. Table 1 summarises the subsidence impact performance measures of the development consent conditions for MP09_0013.

Table1: Subsidence impact performance measures of MP09_0013

Feature	Performance Measures
Watercourses	

Watercourses, including Cataract River, Cataract Creek and associated	• Negligible subsidence impacts or environmental consequences including
	  ○ Negligible diversion of flows or changes in the natural drainage behaviour of pools.
	  ○ Negligible increase in waters cloudiness.
	  ○ Negligible increase in bank erosion and
	  ○ Negligible increase in sediment load.

Water Supply	
Cataract Reservoir	• Negligible leakage from reservoir. • Negligible reduction in water quality of reservoir. • No connective cracking between the reservoir surface and the underground workings.
Land	
Cliffs, steep slopes and rock face features	• Negligible environmental consequences (including subsidence induced rockfalls, displacement or dislodgement of boulders or slabs or fracturing).
Swamps	
Upland swamps identified in the figure in Appendix 5	• Negligible environmental consequences including negligible change to the structural integrity of the bedrock base or any controlling rockbar of swamp.
Biodiversity	
Threatened species, threatened populations, or endangered ecological communities	• Negligible environmental consequences.
Heritage Sites	
Aboriginal heritage sites identified in the figure in Appendix 6	• Negligible subsidence impacts and environmental consequences. • Negligible loss of heritage value.
Historic heritage sites identified in the figure in Appendix 7	• Negligible subsidence impacts and environmental consequences. • Negligible loss of heritage value.

Feature	Performance Measures
Other Aboriginal and historic heritage sites	• Negligible subsidence impacts and environmental consequences. • Negligible loss of heritage value.
Mine workings	
First workings and Second workings	• To remain long-term stable and non-subsiding.
Key Public Infrastructure	
M1 Princes Motorway (formally known as Mount Ousley), electricity transmission lines and towers (330kV, 132kV, 2x33kV) and telecommunications line	• Always safe and serviceable. • Damage that does not affect safely or serviceability must be fully repairable and must be fully repaired.
Other Infrastructure	
Access roads, fire trails and other public infrastructure and built features	• Always safe. • Serviceability should be maintained wherever practicable. • Loss of serviceability must be fully compensated. • Damage must be fully repairable and must be fully repaired or else replaced or fully compensated.
Public Safety	
Public Safety	• Negligible additional risk.
Vertical Subsidence	
All areas of the site affected by the development	• Vertical subsidence limit of not more than 300mm.

2.3 Performance Indicators

Condition C10 (f) of MP09_0013 requires detailed performance indicators for each of the subsidence impacts performance measures in Tables 6 and 7. Notes for Conditions C1 and C7 required more detailed performance indicators and performance measures to be included in relevant subsidence management plans. Most of the categories of subsidence impacts performance measures that require performance indicators are outside SCT's areas of expertise and so need to be set by other specialists and presented in the various management plans/monitoring programs consistent with the forecast of subsidence effects.

Performance indicators for subsidence effects can be set. We recommend performance indicators for multi-seam mining are set at greater than 20% above forecast values. With this margin, it is envisaged that natural variability will not trigger unnecessary reporting procedures for events of no practical consequence. For a non-caving mining method where the forecast vertical subsidence levels are low, a performance measure of 300mm has been included in MP03-0013 and an upper limit of 300mm has been set as a performance measure for swamps by experts in this field (IAPUM 2020), values of 100mm and 250mm are considered appropriate to activate trigger action response plans (TARP) for the planned mining geometry in the EP for Stage 2. Similarly, 100mm additional closure from all mining in the Wongawilli Seam, including from Longwalls-4-6, is considered appropriate as a lower valley closure trigger with an upper level of 150mm following confirmation of the current measurement of valley closure from the August 2021 survey.

2.4 Recommendations

The continued use and extension of the existing subsidence monitoring program to cover the EP Area for PC27-34 is recommended to manage operational, personal, and public safety risks and to address specific requirements in the approval conditions of MP09_0013.

Full details of recommendations for the subsidence monitoring program are presented in Section 6.

The subsidence management plans/monitoring programs required by an EP under Condition C10 of MP09_0013 are expected to be suitable to manage the potential risks and impacts from subsidence effects expected for the planned bord and pillar mining shown in Figure 1.

Further recommendations for subsidence monitoring, the application of performance indicators for subsidence effects, and for risk control measures to mitigate or remediate potential subsidence impacts are made throughout this report. These are presented in the context of each relevant management plan.

3. SITE DESCRIPTION

This section presents a description of the surface features within the EP Area for PC27-34 as well as any other items of relevance to this subsidence assessment.

3.1 Site Overview

The surface within the EP Area for PC27-34 is located adjacent to Cataract Reservoir and over the ridgeline between the Cataract Creek and Bellambi Creek valleys as part of the catchment for the reservoir. The surface is mainly undeveloped bushland. Natural features include a section of the Full Supply Level (FSL) of the Cataract Reservoir along Cataract Creek, watercourses including the main channel of Cataract Creek and tributaries of Cataract Creek and Bellambi Creek, upland swamps and sandstone outcrop formations. In addition to Cataract Reservoir, built features or infrastructure are limited to fire trails/access roads and mining related infrastructure owned by WCL.

The major regional built features: Mount Ousley Road (M1 Princes Motorway) and the high-voltage electricity transmission lines to the east of Mount Ousley Road are approximately 700m to the east of the EP Area.

The mine workings of RVC (previously known as South Bulli Colliery and NRE No1 Colliery) in the Bulli, Balgownie and Wongawilli Seams and sections of Bulli Seam workings at the adjacent Corrimal Colliery exist within the EP Area. The Bulli Seam workings of South Bulli and Corrimal Collieries are separated by a 40m wide barrier of coal along the boundary of the mining leases.

Figure 2 shows the existing and planned workings in the Wongawilli Seam superimposed onto an aerial photograph with extent of undeveloped bushland, watercourses, and land ownership details.

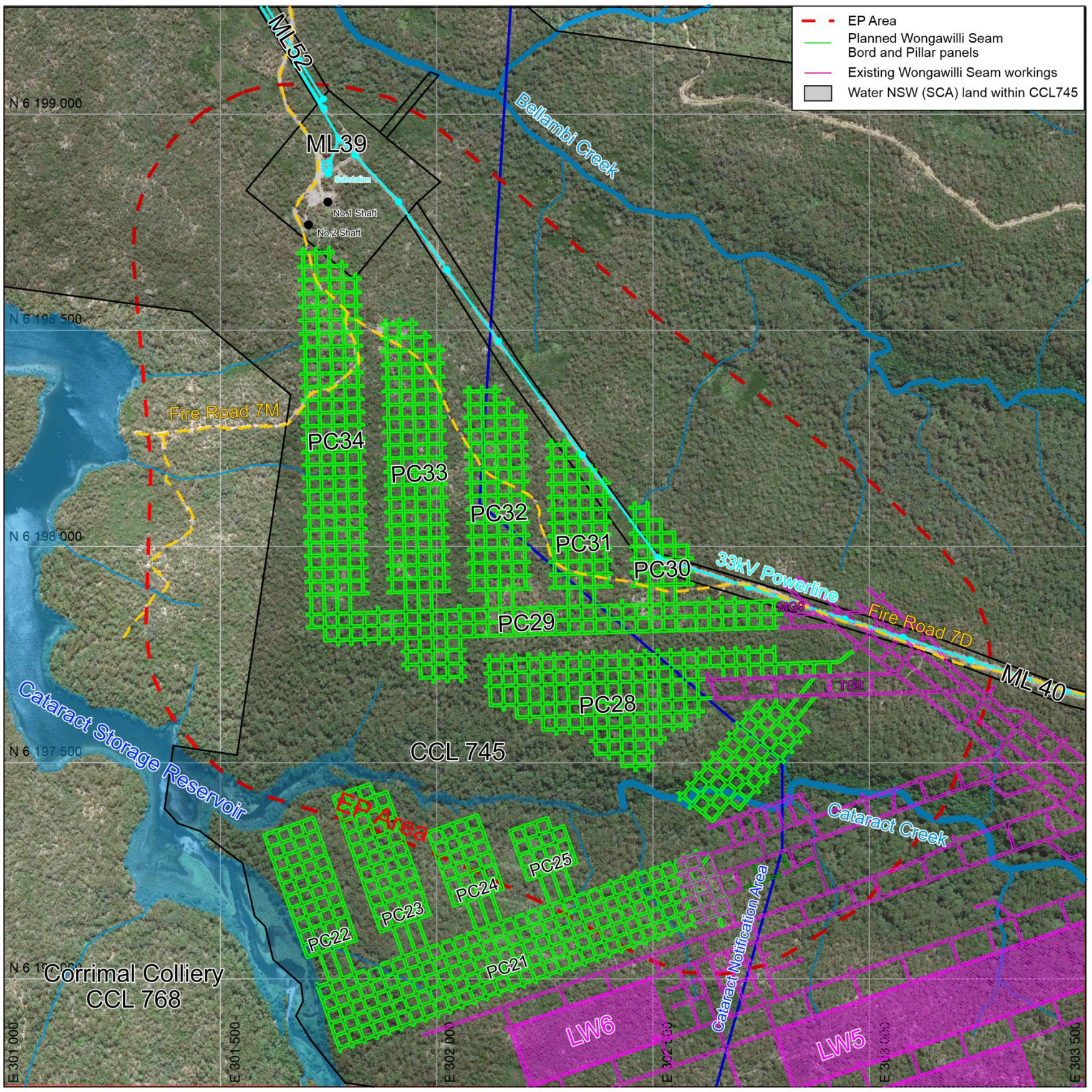

Figure 2: Site plan showing land ownership.

3.2 Extraction Plan Assessment Area

The EP Area for PC27-34 shown in Figure 1 is considered a conservative zone where all impacts from the planned mining would be expected to occur and are focus of the assessment of potential subsidence impacts.

The EP Area is determined based on a distance of 350m or a distance equal to overburden depth to the Wongawilli Seam, whichever is the greatest, which is equivalent to or greater than a 45° angle of draw, around the planned bord and pillar workings. This is greater than the 35° angle of draw traditionally used around secondary extraction panels in subsidence management plan applications for single seam mining in the Southern Coalfield of NSW. The 350m offset is used as the minimum dimension of the EP Area to satisfy the coastal upland swamp monitoring requirements for second workings (bord and pillar panels) in the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC) 2020/8702 conditions of approval (approved in August 2021) from Australian Government - Department of Agricultural, Water and the Environment (DAWE) for the RPUEP. The size of the EP Area also includes consideration of coal barriers remaining in the overlying Bulli and Balgownie Seam workings as a limit of angle of draw to 20mm subsidence.

Any subsidence effects beyond the boundary of the Assessment Area are expected to be generally imperceptible and insignificant for all practical purposes. In this situation, an EP Area of this size is considered a conservative option for the identification of surface features and for the purpose of assessment of impacts to these features.

3.3 Approvals Context

The planned mining of PC27-34 in the EP Area is wholly within Consolidated Coal Lease 745 (CCL745).

WCL was granted development consent MP09_0013 under of the Environmental Planning and Assessment Act 1979 (EP&A Act) for the Russell Vale Revised Preferred Underground Expansion Project (RPUEP) by the Independent Planning Commission (IPC) of NSW in December 2020. Condition C10, Part 3 of MP09_0013, requires WCL to prepare an EP for all second workings to the satisfaction of the Secretary of the Department of Planning, Industry and Environment (DPIE).

Second workings are defined as the workings in the bord and pillar panels. These workings are intended to be a non-caving and non-subsiding mining method. The conventional industry definition for second workings involves secondary extraction of first workings or other areas of the coal seam where caving of the immediate seam roof and overburden strata, with the potential for subsidence of the surface, may be intentional.

As part of the EP requirements, the EP must:

- "Provide revised predictions of the potential subsidence effects, subsidence impacts and environmental consequences of the proposed mining covered by the EP, incorporating any relevant information obtained since obtaining the development consent."

- Describe the performance indicators that would be implemented to ensure compliance with the subsidence impact performance measures and manage or remediate any impacts and/or environmental consequences to meet the rehabilitation objectives of MP09_0013.

This report specifically addresses Section C10(e) and part of Section C10(f).

In addition to a subsidence monitoring program, Condition C10 of MP09_0013 requires specific subsidence management plans and monitoring programs for Built Features, Water, Biodiversity, Swamps, Land, Heritage, Public Safety, as well as Trigger Action Response Plans and a Contingency Plan. These plans or programs provide for the management of potential subsidence impacts and/or environmental consequences caused by the planned mining.

SCT understands that assessment of the environmental consequences from the forecast of subsidence effects and impacts are being undertaken by specialists as supporting information for the EP application of the planned Stage 2 mining.

3.4 Land Ownership and Land Use

Figure 2 shows details of the land ownership in CCL745 within the EP Area.

The surface within the EP Area for PC27-34 is owned by Water NSW (previously Sydney Catchment Authority) as part of the Metropolitan Special Area for the Sydney water catchment. This catchment area is a restricted area with no access for the general public and limited access for other persons.

Sections of three mining leases held by WCL cross the EP Area. These leases provide rights to the surface and to certain depths for mining purposes. ML40 is a powerline easement from the Russell Vale pit-top to No1 and No2 Shaft site. ML39 is the surface area for the No1 and No2 ventilation shafts and associated installations. A small part of ML52; the powerline easement from the No1 Shaft site to the No3 Shaft site is also within the EP Area.

3.5 Mining Geometry

This section provides details of the previous multi-seam mining in the Bulli, Balgownie, and Wongawilli Seams at RVE relative to the planned mining of the Wongawilli Seam in the EP Area for PC27-34.

3.5.1 Previous Mining

Coal has previously been mined in three seams within the EP Area, the Bulli Seam, the Balgownie Seam and the Wongawilli Seam.

The Bulli Seam was mined extensively at RVE from the late 1800's until the 1950's. This seam is also referred to in historical records as the Top, Upper or No1 Seam. The Bulli Seam thickness and mining height is approximately 2.2m.

The early mining layouts of the Bulli Seam were irregular compared to later mining methods. The layouts include the full evolution of hand-working bord and pillar methods from the early 'Welsh bords' technique that resulted in very wide roadways and very narrow pillars in "worked out" areas through to complete pillar extraction by hand. Hand-working techniques were superseded with the introduction of mechanised mining from the 1950's. There are areas of completed pillar extraction and large areas of standing coal pillars remaining as first workings. Some of these areas are under and around the FSL of the Cataract Reservoir.

Reliable (accurate and complete) mine plan records (mine working plans and the record tracing copy) are available for areas of interest to the Stage 2 mining recognising that more detail is shown after 1931 when legislated standards required plans to be certified as accurate by a surveyor. Further detail of Bulli Seam workings is presented in Appendix 3 of SCT (2021b).

The Balgownie Seam is approximately 10m below the Bulli Seam. The seam thickness is 1.2-1.3m but anecdotal and survey plan evidence indicates the actual mining height in later panels and on the longwall faces was increased to 1.5m by including some seam floor material. Most of the Balgownie Seam workings in RVE were mined with continuous miners and longwall methods from 1968 to 1982. Eleven longwall panels of various lengths and widths were extracted from 1970 to 1982.

The floor of the Wongawilli Seam is approximately 25m below the Balgownie Seam. The seam is approximately 10m thick but only the bottom 2-3m is economic due to coal quality. Three short longwall panels (Longwalls 4, 5 and 6 – 520m, 840m and 340m in length, respectively), with voids widths of 150m, were extracted between April 2012 and July 2015. Main headings and gateroad panels were developed at 3.2-3.5m high with the longwall extracting a nominal 3.0-3.2m thick seam section.

3.5.2 Planned Mining

Figure 3 shows the planned mining layout for the Stage 2 EP assessed in this report, with contours of overburden depth to the mining horizon in the Wongawilli Seam. The planned mining is remote from the major infrastructure of Mount Ousley Road and high voltage power transmission lines, does not mine below the FSL of Cataract Reservoir, is almost entirely on the north side of Cataract Creek and is wholly to the northeast of Dyke D8.

The planned layout for PC27-34 is essentially the northern section of the approved RPUEP mining plan. This layout integrates with the existing Wongawilli Seam workings. Specifically, the first five pillars of Tailgate 9 (TG9) Panel and the initial driveages for Maingate 9 (MG9) Panel.

The planned mining consists of bord and pillar workings in:

- Two panels; PC27 off the side of TG9 and PC28 as an extension of TG9.
- One panel (PC29) as an extension of the MG9 driveages and 5 sub-panels (PC30, PC31, PC32, PC33 and PC34) to the north off PC29.

All workings under MP09_0013, (first workings and second workings – bord and pillar panels) are required to be designed to remain stable and 'non-subsiding'. In this context, long-term stability requires pillars with large width to height ratios and is taken to require factors of safety greater than 2.11 (UNSW 1999) where a factor of safety of 2.11 implies a probability of instability of 1 in 1,000,000.

It should be recognised, long-term stable and non-subsiding pillars are not necessarily conforming pillars as prescribed by *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014* with a minimum dimension of greater than one tenth of the thickness of cover (to the surface) and conforming pillars are not necessarily long-term stable and non-subsiding, due to mining height and multi-seam loading.

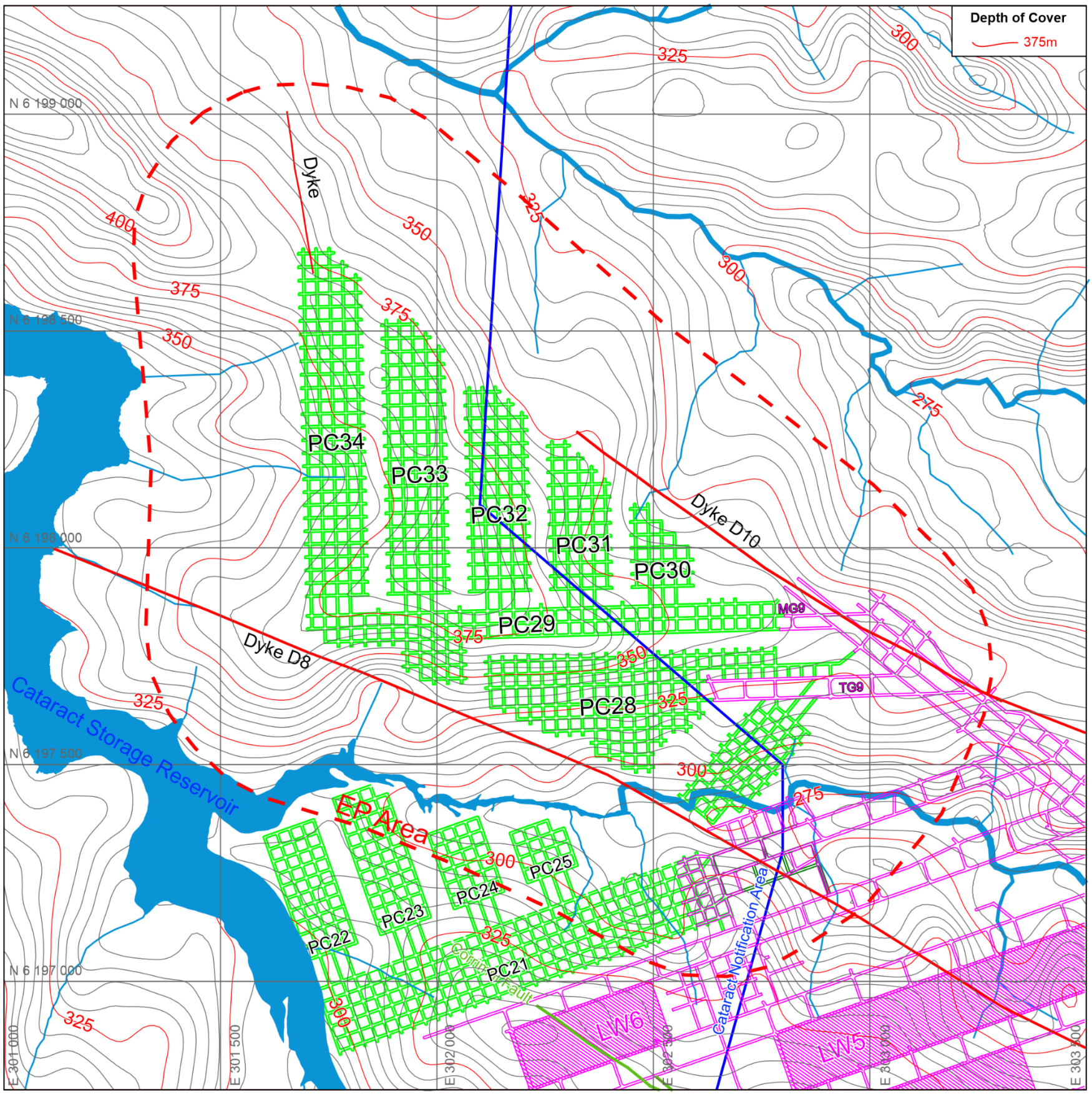

Figure 3: Contours of overburden depth to Wongawilli Seam mining horizon.

Only very minor changes to the approved RPUEP mining plan have been made for the planned layout in PC27-34. These changes involve slight increases to some pillar sizes in PC32-34 without reducing the barrier width between individual panels. A slight increase in pillar length is required to accommodate a small area of greater depth (up to 390m) and deliver a factor of safety of 2.11 for long-term stability consistent with the IAPUM (2020) assessment. Overall, the layout has extended marginally to the north. The PC32 Panel is about 10m longer, the PC33 Panel is about 20m longer and PC 34 Panel is about 10m longer than the approved layout in MP09_0013.

The planned mining in PC27-34 is in a simpler (two seam rather than three seam) mining environment. The majority of the PC27-34 panels are below first and second workings in the Bulli Seam only where no previous mining has taken place in the Wongawilli Seam. There are no Balgownie Seam secondary extraction areas above the planned mining in PC27-34. The last longwall in the Balgownie Seam (Longwall 11) is approximately 60m to the east of PC27. The remaining Balgownie Seam pillars above the planned mining in PC27-34 have large width to height ratios and are assessed as long-term stable.

Complete mine plan records for the Bulli Seam first workings and irregular goaf areas are available as original mine working plans and the record tracing copies. The Bulli Seam workings above PC27-34 consist of first workings from circa 1918 to around 1950. The second workings involve the extraction of pillars using what appears to be hand working methods dating from around 1928 to generally around 1950. However, there are some areas where machines may have been used including one area where secondary extraction of larger barriers of coal was attempted between earlier worked goafs. These trial workings are dated from about 1950 to 1956 and may coincide with the introduction of the first continuous miners. These trial workings form the central part of the larger area identified as Area#10 and unconfirmed as collapsed in SCT (2020a) which details Bulli Seam goaf areas confirmed or unconfirmed as collapsed and potentially subsided. The 'hit and miss' nature of these trial workings with single roadways and partial extraction may indicate difficult mining conditions from the abutments of the adjacent goaf areas, suggesting the earlier worked goaf areas were already collapsed.

In additional to Area#10, Area#1, Area#8 and Area #9 referenced in SCT (2020a) are above the planned mining in PC27-34. Of these, Area#1 above Balgownie seam longwalls is confirmed as collapsed, Area#8, Area#9 and the larger part of Area#10 are currently unconfirmed as collapsed because the edges of these areas are inaccessible, and no mining has recently taken place adjacent to or below these goaf areas. Only part of the southern edge of the three parts of Area#10 is confirmed as collapsed.

The layout for PC27-34 consists of coal pillars that are generally square in shape with a minimum plan dimension of 24.5m. The overall layout is designed with panels having a maximum of five headings separated by solid barriers with a minimum width of 40m of solid coal (without overdrive stubs into the barrier). This is to limit and isolate any subsidence that may occur from pillar and strata compression at the Wongawilli Seam horizon and to limit the extent of any subsidence from interactions with the overlying Bulli Seam workings.

Longer rectangular pillars are included in PC28 (a legacy of the TG9 gateroad panel configuration) and incorporated into the three heading entries to the PC30-33 sub-panels as part of the barrier between these panels.

Some longer pillars are included in PC29 as a result of the geometry for PC30-34 sub-panels and slightly longer pillars have also been included in the southern section of PC32, all of PC33 and the northern section of PC34 where the maximum overburden is located. Pillar widths have remained the same so as to not reduce the width of the barriers between panels.

The overburden thickness over the planned mining layout for PC27-34 ranges from a minimum of approximately 280m above PC27 up to the maximum of 390m above PC32 and PC33. The overburden depth is typically greater than 350m over the majority of the planned PC27-34 mining layout.

The planned mining height is 2.4m within a working section at the base of the Wongawilli Seam. It is recognised that pillar width to height ratio and pillar strength are sensitive to the mining height of the surrounding roadways. Where the width to height ratio is small, pillar strength and factors of safety for long-term stability reduce significantly with only small increases in mining height.

All roadways are assumed to be at the maximum prescribed width of 5.5m.

No significant geological structures have been mapped in the Bulli Seam workings above the planned mining in PC27-34. Dyke D8 is to the southwest and Dyke D10 is to the northeast of the planned mining in PC27-34. However, minor geological features may be intersected at the Wongawilli Seam horizon. Increasing pillar sizes, consistent with adaptive management measures, is recommended should any significant geological features or greater vertical abutment stress from Bulli Seam workings be encountered.

3.6 Surface Features and Surface Infrastructure

Figure 4 shows the locations of surface features identified within the EP Area for PC27-34 and discussed during a risk assessment conducted on 1 February 2022 for the planned mining in PC27-34. These features are described in this section.

The risk assessment team included environmental and subsidence specialists, and management personnel from WCL. 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* and other standards.

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. With no such equivalent list included in the draft Department of Planning & Environment, NSW Trade & Investment – Division of Resources and Energy – "Guidelines for the Preparations of Extraction Plans" for EP applications (Version 5 - unpublished), the Subsidence Management Plan list has been used as a guide instead. A complete list of these items is provided in Appendix 1.

3.6.1 Natural Features

The major natural features within the EP Area for PC27-34 are the parts of Cataract River, Cataract Creek and Bellambi Creek valleys and the peak on the ridgeline between these features.

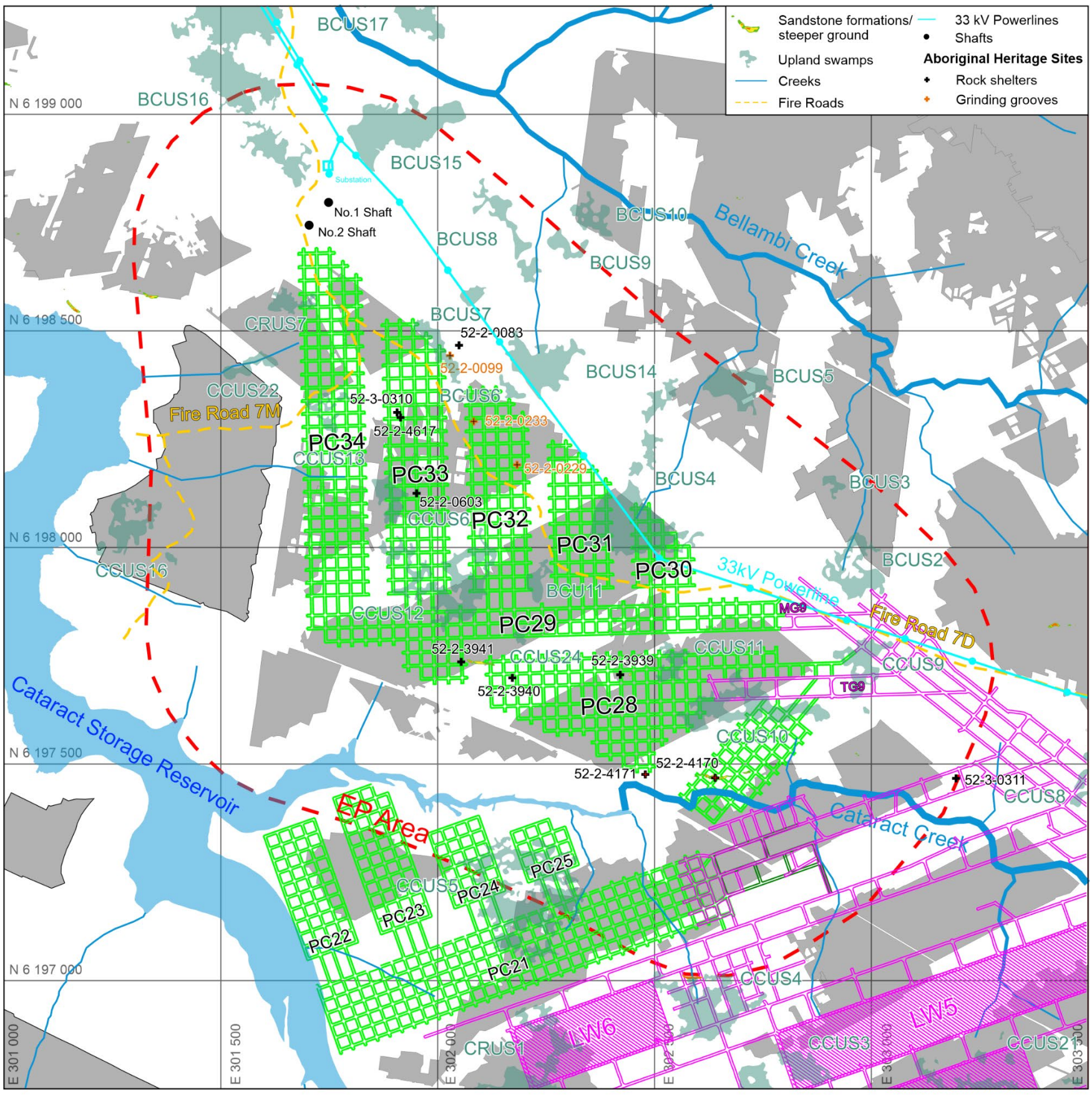

Figure 4: Surface features.

The surface terrain is mainly undeveloped bushland within the Metropolitan Special Area for the Sydney water catchment.

A section of Cataract Reservoir along Cataract Creek and a fourth order section of the main channel of this creek is within the EP Area. This section of the main channel crosses over the southern extent of PC27. First order tributaries of Cataract River, Cataract Creek and Bellambi Creek are located within the EP Area but do not extend very far, typically less than 100m, over the planned mining in PC27-34.

There are 24 upland swamps of various sizes associated with the drainage lines of Cataract River, Cataract Creek and Bellambi Creek. Some areas designated as swamps are two or more discontinuous areas. Of these 24 identified swamp areas, 12 are located above or partially above the planned mining in PC27-34.

There are a number of sandstone formations located within the EP Area. These are associated with the outcrop of the Hawkesbury Sandstone in the stratigraphic section. These formations host a number of Aboriginal heritage rock shelter sites. The sandstone formations are generally less than 5m in height and short in length. There are no sandstone formations located within the EP Area that would be described as cliffs by contemporary mining approval definitions. Longer sections of steeper ground are associated with the sandstone outcrops generally and in particular along the northern side of the Cataract Creek valley.

3.6.2 Man-Made or Built Features

Built features or infrastructure within the EP area for PC27-34 are limited to a section of the Cataract Reservoir, fire trails/access roads and mining related infrastructure owned by WCL. The major public utilities infrastructure of Mount Ousley Road, and the 300kV, 132kV and 33kV powerlines are more than 1km to the east of PC27-34 and not expected to be impacted by the planned mining.

Thirteen Aboriginal heritage sites of a type sensitive to subsidence impacts (e.g. rock shelters, grinding grooves), have also been identified within the EP Area with 11 of these sites above the planned mining in PC27-34.

No European or historical heritage features have been identified within the EP Area. The nearest survey control marks to the planned mining in PC27-34 are positioned 1km to the east along the edge of Mount Ousley Road.

The majority of the planned mining in PC27-34 is within the current Notification Area around the Cataract Storage Reservoir administered by Dams Safety NSW (previously NSW Dams Safety Committee). However, most of the planned mining is outside the 35° angle of draw (0.7 depth) marginal zone with no mining planned directly below the FSL of the Cataract Reservoir.

Fire roads 7D and 7M traverse the surface within the EP Area. These unsealed roads are owned by Water NSW and provide access for maintenance activities and during emergencies. Sections of Fire Road 7D are within the mining purposes lease covering the easement for the 33kV overhead powerline owned by WCL. In addition to 33kV powerlines, other WCL assets, include a substation/switchyard and ventilation installations and equipment at the No1 and No2 shaft site.

Sections of Fire Road 7D and 7M cross over the planned mining in PC27-34.

While within the EP Area, the installations at the No1 and No2 Shaft site are not above the planned mining and only two poles of a 33kV powerline are above or over the edge of the planned mining. However, none of these assets have been in use since 2019 with power to this infrastructure currently disconnected.

Historical heritage features at the Russell Vale pit-top area and the Cataract dam wall are more than 3km and 8km respectively from the planned mining and not expected to be impacted.

4. FORECAST SUBSIDENCE BEHAVIOUR

In this section, the subsidence movements expected above the planned PC27-34 bord and pillar panels and within the EP Area are estimated from experience of subsidence behaviour at RVC and elsewhere in the Southern Coalfield and NSW more generally.

4.1 Review of Previous Subsidence at RVE

This review is presented in the context of the advancements in understanding of the mechanics of multi-seam subsidence behaviour made since the last forecast for longwall mining at RVE was prepared in 2014. Back analysis of measured vertical subsidence profiles from mining in the Balgownie and Wongawilli Seams indicates behaviour consistent with this latest multi-seam subsidence understanding.

Mills and Wilson (2017) present measurements and observations of the incremental and cumulative subsidence effects from longwall mining in two seams in a regular, parallel, offset geometry at a site in NSW. More recent monitoring to 2020 at this site confirms these earlier observations and interpretation and includes additional learnings for multi-seam subsidence from longwall mining in three seams.

4.1.1 Vertical Subsidence

The only known records of subsidence effects associated with mining of the Bulli Seam are comments on historical plans regarding individual subsidence impacts. However, it is possible to estimate subsidence given the geometry of the panels mined, seam thickness/mining height and estimating the likely secondary extraction percentages.

The vertical subsidence for the Bulli Seam mining in RVE is estimated based on subsidence monitoring results and subsidence profiles from mining in the Bulli Seam further to the west above the T and W (200 and 300 Series) longwall panels at South Bulli Colliery and subsequent pillar extraction operations. Maximum vertical subsidence of up to 1.0m is estimated.

Monitoring of the subsidence from the Balgownie Seam longwalls was comprehensive for the period of mining. Each of the 11 longwalls mined between 1970 and 1982 had a longitudinal line along the whole length of the panel and three cross-panel lines were also installed perpendicular across Longwalls 1-11.

The incremental vertical subsidence was monitored at regular intervals during panel retreat above the initial panels and less frequently during mining of the last few panels. Ground strains were only measured during the last panel; Longwall 11. The last subsidence surveys for the Balgownie Seam longwalls were completed in 1983.

Longwall 7 mined directly below Mount Ousley Road in 1976-77 where maximum subsidence of approximately 1.0m was measured. Sections of Mount Ousley Road were realigned coincidental with the period of active longwall mining. Subsidence impacts were managed as part of the realignment construction activities.

Observations from the database of subsidence monitoring for the Balgownie Seam longwalls indicate:

- The chain pillars and other areas of coal not mined by the longwall are evident in the subsidence profile.
- Incremental subsidence of approximately 75% (generally 65-85%) of mining height is evident in areas where secondary extraction in both the Bulli and Balgownie Seams has been undertaken.
- Subsidence occurred primarily within the footprint of the Balgownie Seam longwall panels.
- Goaf edge subsidence is greater and extends further where there is overlying Bulli Seam goaf.
- Incremental subsidence of greater than 90% of the Balgownie Seam mining height is evident where latent (extra) subsidence is recovered. Latent subsidence in this context is the subsidence associated with Bulli Seam mining that did not occur during mining of the Bulli Seam because of proximity to the edge of the panel. Maximum incremental subsidence of 1.42m was measured above Longwall 10 where latent subsidence from the edges of Bulli Seam pillars is likely to have been recovered. This subsidence represents 95% of the nominal 1.5m mining height.

Conventional monitoring of survey lines for subsidence from longwall mining in the Wongawilli Seam indicated maximum incremental vertical subsidence of 1.8m occurred over Longwalls 4 and 5 after Longwall 5 was mined. Incremental vertical subsidence over the short section of Longwall 6 mined to date is estimated at 0.72m. These values are consistent with and less than the forecast for these longwalls based on the approach recommended by Li et al (2010) and provided in the subsidence assessment for the Preferred Project Report (PPR) longwall layout at RVE (SCT 2014).

Although mining has been conducted in three seams at RVE, there are only a few places where secondary extraction has occurred in all three seams at the same location. Total cumulative subsidence is not necessarily the addition of all the maximum increments. The maximum cumulative vertical subsidence for all three seams is approximately 3.7m above Longwall 4 in the Wongawilli Seam at a location below parts of Swamp CCUS6. Other swamps over RVE have currently experienced up to approximately 0. 6m where there is only secondary extraction in the Bulli Seam and 1.5-2.0m where secondary extraction of the Balgownie Seam was conducted below Bulli Seam goafs.

A comparison between the survey measurements of subsidence on conventional monitoring lines over Longwalls 4, 5 and 6 and subsidence derived from LiDAR surveys over the broader RVE area was recently undertaken (SCT 2022). The LiDAR surveys used in the comparison were flown in 2009, before longwall mining in the Wongawilli Seam commenced, and in 2021 after longwall mining was completed. The comparison indicated:

- The LiDAR generated subsidence over the longwall mining areas is consistent with the actual measured subsidence and within an accuracy expected for the technique.

- The pattern of subsidence is generally consistent with the contours of subsidence predicted but included areas of latent subsidence recovered from the chain pillars between Balgownie Seam longwall goafs, consistent with the expectations presented in Mills and Wilson (2017).

4.1.2 Tilt and Strain

Detailed measurements of tilt and strain effects on the ground surface from mining subsidence are not available for the Bulli Seam mining and most of the Balgownie Seam longwalls. Point to point, incremental strains were measured for the mining of Longwall 11 in the Balgownie Seam. Incremental tilts and strains were however, measured for the mining completed in Longwalls 4-6 in the Wongawilli Seam.

Maximum strains over Longwall 11 in the Balgownie Seam were measured at the northern end of the panel where there has been pillar extraction in the Bulli Seam. Strains ranged from 3-4mm/m along the panel to peaks of 13-14mm/m in compression across the topographic low point of Cataract Creek and 8-9mm/m in tension on the slope beyond from vertical subsidence of 1.3-1.4m.

The monitoring of incremental subsidence movements from the mining of Longwalls 4, 5 and 6 in the Wongawilli Seam indicate:

- Maximum tilt of 30mm/m in the RVE area was measured on the southern cross-panel line over Longwall 4 after mining Longwall 5. This maximum tilt was measured near the edge of Longwall 9 in the Balgownie Seam superimposed onto a goaf edge in the Bulli Seam. Maximum tilts measured elsewhere along Longwalls 4 and 5 were in the range of 10-25mm/m.

- Maximum tensile strain in the range 3-6mm/m.

- Maximum compressive strain of 12mm/m at the pillar and D8 Dyke over Longwall 5. Maximum compressive strains elsewhere along Longwalls 4 and 5 were in the range of 3-6mm/m.

Cumulative tilts and strains are not able to be derived, due to the limits of the database. However, Mills and Wilson (2017) present results that show that in areas remote from stacked goaf edges, the levels of permanent tilt and strain in multi-seam mining are similar or less than for single seam mining despite the greater vertical subsidence.

Cumulative values for tilt and strain are not necessarily the addition of the increments from each seam due to the general softening, or reduction in shear stiffness, of the overburden with each episode of subsidence. Transient and permanent levels of tilt and strain are much higher when a stacked goaf edge is formed and especially when the stacked edge is undercut. At RVE, there are no stacked goaf edges of any significant length due to the irregular mining layouts in the three seams.

These observations suggest that tensile ground strains from previous mining are likely to be less than about 60% of values estimated and forecast in SCT (2014) for longwall mining of the PPR layout in RVE. This reduction is significant when considering cumulative effects including those from the planned bord and pillar mining.

4.2 Forecast of Subsidence Effects

In this section, the maximum subsidence effects for the primary subsidence parameters are estimated for the planned geometry shown in Figure 1 as the basis for performance indicators for subsidence effects.

4.2.1 Vertical Subsidence

Figure 5 shows contours for the estimated vertical subsidence expected at the completion of the planned bord and pillar panels in the EP Area. Vertical subsidence from the planned mining within the EP Area is expected to be generally less than 100mm. This level of subsidence is expected to be imperceptible for all practical purposes.

However, vertical subsidence of greater than 500mm is considered possible, but unlikely. If such subsidence were to occur, it would be expected in small, isolated areas at RVE near Bulli Seam goaf edges or above goaf areas where any 'marginally stable' remnant pillars not already collapsed are destabilised. Some possible remnant pillars have been identified during preparation of this EP assessment. Subsidence of up 300mm is considered possible but unlikely near these pillars. The IAPUM (2020) identify the potential for subsidence up to 300mm in some areas. The potential for this greater vertical subsidence exists because of the previous mining in the overlying seam or seams. This potential exists irrespective of planned mining, but additional subsidence of this magnitude over large areas would be considered a significant departure from the low levels of subsidence expected. Any such subsidence would be identified from LiDAR monitoring and investigated to better inform subsequent mining layouts and applications.

4.2.2 Tilt and Strain

The approach to estimate incremental tilt and strain levels outlined in Holla and Barclay (2000) for single seam mining in the Southern Coalfield indicates that for 100mm of vertical subsidence at 280m depth the following maximum values can be estimated:

- Tilt of less than 2.0mm/m.
- Tensile strain of approximately 0.5mm/m.
- Compressive strain of approximately 1.0mm/m.

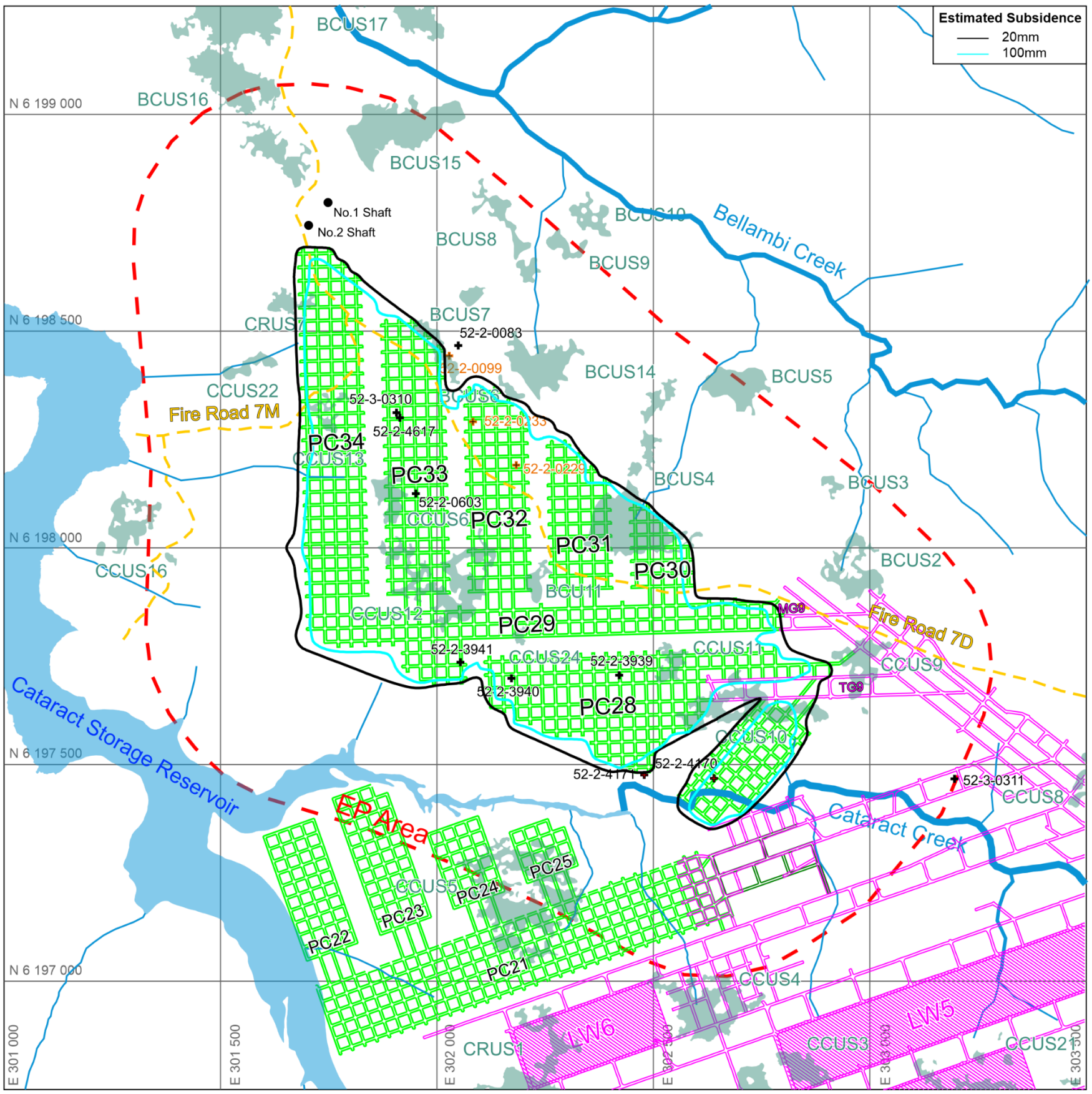

Figure 5: Contours of estimated subsidence and surface features.

Mills and Wilson (2017) found that in areas of multi-seam mining remote from stacked edges, incremental tilt and strain are not necessarily increased by greater vertical subsidence, so the Holla and Barclay (2000) approach is likely to give a greater and conservative estimate of the strains and tilts.

Changes to the surface from these low-level values of tilt and strain are expected to be generally imperceptible.

Any changes in the small areas where additional subsidence does develop are also expected to be generally imperceptible and less than the tilt and strain levels already experienced at the site over a wider area.

4.2.3 Horizontal Movements

Systematic horizontal ground movements from vertical subsidence are expected to be generally imperceptible. However, ongoing low-level horizontal movements of the southern slope down to Cataract Creek are expected to continue irrespective of the planned mining.

These movements are a legacy of the previous mining at the site, including early Bulli Seam mining, the Balgownie Seam longwalls and the mining of Longwalls 4 and 5 in the Wongawilli Seam more recently.

These horizontal movements are expected to continue to cause horizontal strains that increase cracking at the top of the ridge line between Cataract River and Cataract Creek, cause minor cracks in the slope and cause minor compression or valley closure effects at the Cataract Creek.

4.2.4 Unconventional Subsidence Effects

No significant unconventional subsidence movements are expected from the planned mining. Valley closure movements are expected but significant far-field movements from stress relief in the overburden strata are not envisaged.

Ongoing low-level valley closure movements are expected irrespective of the planned mining.

The current incremental closure at Cataract Creek from the Wongawilli Seam mining is approximately 60mm. This incremental closure is expected to remain well below the 150mm threshold set for the previously approved longwall mining in the Wongawilli Seam.

Any far-field horizontal movements from stress relief in the overburden strata are expected to have already occurred from the previous secondary extraction mining in the Bulli and Balgownie Seams and to a lesser extent, in the Wongawilli Seam. The planned mining in the Wongawilli Seam involves a non-caving method so additional far-field horizontal movements are not expected.

4.2.5 Risk of Pillar Instability

In this section, the existing coal pillars at RVE and pillars to be formed by the planned mining in Stage 2 are assessed for stability and convergence at seam level that may result in subsidence at the surface.

The basis of the assessment is the University of NSW pillar design formulae (UNSW 1999) and consideration of width to height ratios, roof and floor properties, potential loading scenarios in the multi-seam environment and factors of safety. The Australian and South African failed pillars database developed by UNSW does not contain any cases of pillar failure where the factor of safety is greater than 1.5 for a width to height ratio of 5. Both these parameters are less than for the planned pillars in Stage 2 layout.

The UNSW approach recognises that:

- Stable bord and pillar workings result in minimal surface subsidence.
- The design of stable pillars requires consideration of the strength of the 'pillar system' and the load that will be acting on the pillar system.

Generally, with the pillar system parameters remaining constant, vertical subsidence decreases as the width to height ratios of pillars increases. For pillars with width to height ratios of greater than about 8 in strong roof and floor strata, the load bearing capacity of the pillars can increase beyond the nominal strength, so the pillars become 'stronger' by a process referred to as 'strain hardening'. Some small convergence or deformation of the pillar at the mining horizon occurs during this process.

IAPUM (2020) suggests the adoption of a maximum probability of instability of 1 in 1,000,000 for all mine workings as this minimises (almost eliminates) the likelihood of pillar instability developing. A probability of failure of 1 in 1,000,000 equates to a factor of safety of 2.11 using UNSW (1999) pillar design methodology.

Figure 6 shows the details of the existing Bulli and Balgownie Seam workings as well as the existing and planned mining in the Wongawilli Seam relative to the EP Area.

4.2.5.1 Wongawilli Seam Pillars

The planned Wongawilli Seam pillars are assessed as long-term stable.

It is recognised that pillar width to height ratio and pillar strength are sensitive to the mining height of the surrounding roadways. Where the width to height ratio is small, pillar strength and factors of safety reduce significantly with only small increases in mining height.

The coal pillars in the PC27-28 panels are planned to have a minimum width of 24.5m and to be 24.5m or longer in length. SCT understands that the mining height is planned to be a maximum of 2.4m with a maximum roadway width of 5.5m. These pillars have a width to height ratio of greater than 10. Pillar stability is assessed on this basis.

Strong roof and floor conditions typical of the Wongawilli Seam are expected. Assuming full tributary overburden load, these pillars have a factor of safety of 2.11 or greater at depths up to 390m. There is no experience in Australia or South Africa of pillars in this geometry failing when the factor of safety is 2.11 or greater.

The potential for perceptible subsidence, should pillars become overloaded and deform over time, is significantly reduced by limiting the panels to five headings and incorporating a barrier of solid coal greater than 40m wide (without overdrive stubs into the barrier) between panels. This strategy isolates individual panel width to approximately 125m at depths of 280-390m.

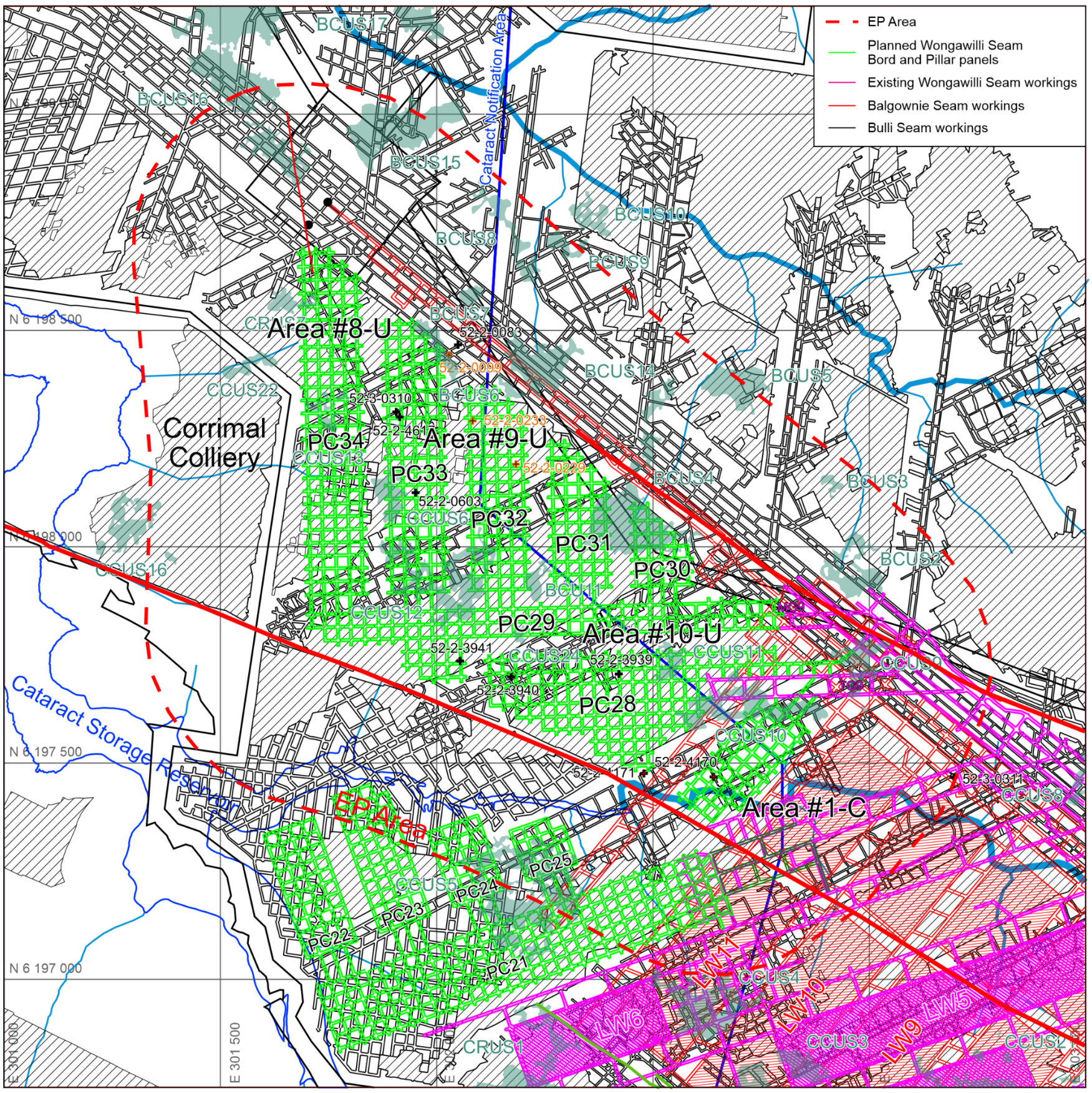

Figure 6: Workings in Bulli and Balgownie Seams with existing and planned workings in Wongawilli Seam.

4.2.5.2 Balgownie Seam Pillars

The existing Balgownie Seam coal pillars above the planned mining in PC27-34 are assessed as long-term stable after consideration of their status and the potential for interactions from the planned Wongawilli Seam mining.

The existing Balgownie Seam coal pillars above the planned mining are generally first workings within longwall gateroads panels where the longwall block has not been extracted. These pillars typically range in width from a minimum of 33m to 40m or larger. These pillars have width to height ratios of 22 to greater than 26 for a mining height of 1.5m and greater than 25 to greater than 30 for a seam thickness of 1.3m.

4.2.5.3 Bulli Seam Pillars

The majority of the planned mining in PC27-34 is below Bulli Seam workings only. The boundary of the planned mining in PC27-34 is below the 'worked out' area on the south side of the main headings in the Bulli Seam. This 'worked out' area consists of five larger goaf areas formed by the secondary extraction of first workings, separated by remaining sections of first workings that were presumably for transport (labour, materials, coal) and ventilation. Parts of these workings are likely to be flooded. The overburden here has not been disturbed for a second time like the eastern areas where secondary extraction in the Balgownie Seam was undertaken. Although expected to be collapsed, the goaf areas are currently unconfirmed as collapsed and subsided.

Detailed mine plan records for the Bulli Seam first workings and goaf areas are available as original mine working plans and record tracing copies. These Bulli Seam records are considered to be accurate and complete with the only remaining uncertainties being the percentage extraction in the goaf areas shown by the drafting standards and status of these goaf areas. This uncertainty is common for all historical mine plans for this mining method and reflects the 'artistic licence' of the surveyors and draftsmen of the day. IAPUM (2020) suggests allowance for subsidence of up to 300mm to cover possible reactivation of goafs.

The potential for instability of the remaining first workings pillars and the potential for any remnant pillars within goaf areas or at goaf edges of the Bulli Seam workings to become destabilised and result in additional subsidence has been identified and considered in the forecast of subsidence effects.

The potential for additional subsidence from the Bulli Seam cannot be eliminated, but this potential exists irrespective of the planned mining and the planned mining is not expected to cause a significant change at the Bulli Seam mining horizon.

Vertical subsidence of greater than 500mm is considered possible, but unlikely. If such subsidence were to occur, it would be expected in small, isolated areas within and near the edges of Bulli Seam goaf areas where any "marginally stable" remnant pillars not already collapsed become unstable.

Some remnant pillars have been identified within and at the edges of goaf areas. These pillars have lower width to height ratios and are expected to have collapsed at the time of secondary extraction in the Bulli Seam because of the high abutment loads generated by the secondary extraction process. In the unlikely event that these remnant pillars are still standing and were to collapse, additional subsidence is expected to be less than 300mm over an area with a radius of approximately 50m.

The first workings pillars in the remaining coal barriers are expected to remain stable however, similar to the goaf areas, there is a low risk of additional low magnitude subsidence at some time regardless of the planned mining. It is recognised some of the first workings pillars in the remaining coal barriers may be at limiting or unstable equilibrium. Some deformation of pillars and convergence at seam level is expected to have occurred at the time of secondary pillar extraction with low-level surface subsidence before reaching the current state of equilibrium. The mining geometry is expected to remain stable due to large width to height ratios of remaining pillars and factors of safety against instability.

First workings pillars in the coal barriers between the goaf areas typically consist of two heading panels with narrow chain pillars and wider flanking pillars. The chain pillars are 10m wide and generally rectangular in shape. The pillars on each side are generally 30m to 50m in width and typically rectangular in shape with some much longer in length than their width. There are also some narrower pillars flanking the chain pillars. These are 20m wide and more than 100m long. The seam thickness/mining height is approximately 2.2m, roadways are 6m wide and the overburden depth ranges from approximately 300m to 350m. The irregular goaf areas are approximately 200m wide.

The pillars have width to heights ratios ranging from 4.5 for the 10m pillars to 22 for the 50m pillars but are typically 10 or greater. A number of different loading scenarios are considered from full tributary loading for the 10m pillars, to side abutment from one goaf and double abutment loading for the stiffer flanking pillars as the mining progressed. Strong roof and floor conditions typical of the Bulli Seam are assumed.

In the unlikely scenario where the narrow chain pillars are subject to full tributary loading but are unable to carry any load, the tributary load of the overburden above these narrow pillars would then be required to be carried by the larger flanking pillars to maintain equilibrium. In this scenario, the factor of safety for say 24m square flanking pillars at 350m is estimated as greater than 2.3. A greater stability is derived for the 10m wide pillars flanked by pillars greater than 24m in width.

In a scenario where a 30m X 60m pillar is under a side abutment load from a goaf area, this pillar has a width/height of greater than 13 and at maximum depth, has a factor of safety of approximately 2.

For a 50m X 60m pillar subject to double abutment loading, this barrier pillar has a width/height of greater than 22 and at maximum depth has a factor of safety of approximately 3.

There is one area identified where the first continuous miners may have been used between two goaf areas. This area could be described as partial extraction. This mining was conducted approximately 20 years after the adjacent goaf areas were formed. It is likely some deformation of pillars occurred at the time of mining from the abutment loads resulting in convergence at seam level and potentially low-level subsidence of the surface before equilibrium was achieved. The remaining mining geometry is expected to be stable after the passage of 60-70 years since this partial extraction was undertaken.

Some of the Bulli Seam workings located above the planned mining in PC27-34 are likely to be flooded. Assessment of pillar stability for the remaining geometry in the Bulli Seam indicates that the pillars are expected to remain stable without any reduction in load due the minimal buoyancy effects of the water. That is, if the water is removed to render the inrush hazard harmless, overall stability of pillars in the overlying seams is unlikely to be affected.

4.3 Reliability and Accuracy of Subsidence Forecasts

Maximum vertical subsidence in a single seam mining environment is naturally variable by about 15% for any given panel geometry and overburden depth. In a multi-seam situation, the variability is somewhat greater particularly given the sensitivity of subsidence to the interaction between mining geometries in each seam. For multi-seam mining, performance indicators of 20% greater than maximum forecast values are recommended to provide an alert that subsidence is not tracking as expected while avoiding unnecessary triggering of insignificant events associated with natural variation.

Guidelines for Subsidence Management Approvals recommend assessing impacts at 1, 1.5, 2 or 2.5 times the maximum values forecast for subsidence parameters or 5 times where subsidence is forecast at less than 150mm.

The limited extraction and limited width of individual panels relative to overburden depth makes it difficult for instability in the Wongawilli Seam to cause greater than 100mm of surface subsidence. Maximum convergence at seam level would be approximately 450mm before the roadways became filled (assuming no bulking). The limited panel width and significant depth means that maximum subsidence at the surface from the Wongawilli Seam mining would be less than 100mm if these pillars were to totally collapse.

Instability of the overlying Bulli Seam would be possible in those areas where no subsidence has occurred previously. There is potential for up to 1m of subsidence from instability in the overlying Bulli Seam, this potential exists irrespective of any further mining activity. The surface terrain in the general vicinity has historically experienced subsidence of this magnitude and greater following mining in the overlying Bulli and Balgownie Seams. In a bushland environment, such levels of subsidence are barely perceptible.

The main surface features likely to be impacted are upland swamps. The probability of such an event causing loss of a swamp is assessed as "very rare" using the National Emergency Risk Assessment Guidelines (SCT 2020a) and "extremely rare" once Bulli Seam pillars are confirmed as having previously collapsed during the period of active mining. SCT understands that the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) considers these risks to be tolerable.

4.4 Comparisons with Previous Subsidence Forecasts and Consent Subsidence Performance Measures

Condition C10, Part 3 of MP09_0013, requires WCL to prepare an EP for all second workings. The EP must:

- "Provide revised predictions of the potential subsidence effects, subsidence impacts and environmental consequences of the proposed mining covered by the EP, incorporating any relevant information obtained since obtaining the consent."

- "Describe in detail the performance indicators that would be implemented to ensure compliance with the performances measures in Tables 5 and 6 (sic) and manage or remediate and impacts and/or environmental consequences to meet the rehabilitation objectives in Table 4 (sic)."

We note that Tables 4, 5 and 6 referred to above have been renumbered in the document as Tables 5, 6 and 7.

This section provides details of:

- The scope of the subsidence assessment for Stage 2 mining.

- Changes to the subsidence effects forecast since the subsidence assessment (SCT 2019) for the RPUEP was prepared.

- Recommendations for performance indicators for subsidence effects consistent with the subsidence performance measures of the consent conditions.

4.4.1 Basis for Subsidence Assessment

The mining plan layout for Stage 2 is essentially the northern section of the mining plan assessed and approved by development consent MP09_0013. This subsidence assessment is for the mining layout shown in Figure 1 and described in detail in Section 3.5.2.

A conservative approach to subsidence forecasts has been adopted for the purpose of impact assessment and compliance thresholds.

4.4.2 Changes to Subsidence Parameters Since RPUEP Subsidence Assessment

The subsidence assessment for the RPUEP was presented in SCT (2019). This assessment was peer reviewed (Hebblewhite 2019a and 2019b). Since then, further information on potential subsidence impacts was sought by the IPC, NSW Department of Planning Industry and Environment (DPIE) and the Australian Government Department of Agricultural, Water and the Environment (DAWE). Advice was also sought from the IESC and the IAPUM to inform the NSW and Federal Government approval processes for the proposed mining.

The IESC (2019) advice to DPIE concluded further assessment was required to quantify the potential risk to coastal upland swamps from pillar failure. SCT (2020a) responded to this assessment of risk requirement. IAPUM (2020) responded to a request for advice from the IPC on the assessment of risk to upland swamps and the forecast of subsidence effects more generally with reference to estimated subsidence effects at upland swamps presented in SCT (2014) for the longwall mining proposed at that time.

IAPUM (2020) suggests an allowance for greater subsidence from reactivation of goafs and an upper limit of 300mm for vertical subsidence as a threshold for significant impact to swamps as compared to the more conservative 100mm subsidence used by SCT (2020a) for the quantitative risk assessment. The IPC has included 300mm as a subsidence performance measure in the consent conditions for MP09_0013.

SCT's assessment of the likely maximum subsidence of less than 100mm over the majority of the mining area has not changed, but the maximum subsidence considered tolerable by upland swamps has increased from 100mm to 300mm based on the expert advice from the IAPUM. However, the EPBC 2020/8702 approval from DAWE sets a subsidence limit of 100mm at swamps.

4.4.3 Recommendation for Performance Indicators

Most of the categories of subsidence impacts performance measures that require performance indicators are outside the SCT's area of expertise and need to be determined by other specialists.

For subsidence effects, SCT typically recommends performance indicators that are generally 20% above the maximum values forecast so that natural variability does not trigger unnecessary reporting procedures for events of no practical consequence. For the non-caving mining method planned where the forecast vertical subsidence levels are low and the upper limit of 300mm has been set as a performance measure, values of 100mm and 250mm are considered appropriate to activate trigger action response plans (TARPs) for the planned mining geometry in Stage 2.

Similarly, 100mm additional closure from all mining in the Wongawilli Seam, including from Longwalls 4-6, is considered appropriate as a lower valley closure trigger with an upper level of 150mm consistent with the EPBC 2014/7259 approval conditions for the first 400m of Longwall 6. These trigger levels seem appropriate following the measurement of valley closure from the August 2021 survey.

5. SUBSIDENCE IMPACT ASSESSMENT

In this section, the potential subsidence impacts are assessed for the various surface features located within the EP Area for PC27-34.

5.1 Natural Features

Natural features considered in this section comprise upland swamps, watercourses, sandstone outcrop formations and steep slopes, surface landform and groundwater more generally. Figure 4 shows the locations of these surface features.

5.1.1 Upland Swamps

There are 24 upland swamps located partially, or wholly, within the relatively steep terrain of the EP Area for PC 27-34, with 12 of these swamps above, partially above or near the edge of the planned bord and pillar panels. No significant additional impacts are expected to any of these features from the planned mining based on expert advice from the IAPUM (2020) review. Consequences are expected to be negligible in the context of previous impacts.

The 12 swamps are of various sizes with some swamps made up of two or more discontinuous areas and others covering larger (200-300m) areas. The average surface gradients over swamp areas are relatively steep at typically steeper than 1 in 10.

The swamps over Bulli Seam goaf areas confirmed as collapsed and subsided are likely to have already experienced vertical subsidence of up to 600mm with associated maximum tensile strain of 3.3mm/m and maximum tilt of up to 11mm/m. An additional 100mm of vertical subsidence would theoretically result in incremental tensile strain of approximately 0.5mm/m and tilt of less than 2mm/m but the cumulative tilt and strain parameters are not necessarily the simple addition of the incremental estimates for each seam of mining.

Each of the 12 swamps has been individually assessed for additional subsidence effects and impacts expected from the planned mining in PC27-34. The assessment involved examination and comparison of the various original mine working plans and the record tracing copies of these plans to identity any remnant pillars within the goaf areas and the geometry of the pillars at the goaf edges. The conclusions of the status of the previous mined areas after consideration of the likely mining methods and drafting standards of the time are the basis of assessment.

Overall, only low-level subsidence effects are expected with vertical subsidence of generally less than 100mm over most of the planned mining with potential for greater vertical subsidence and up to 300mm in small, isolated areas at or adjacent to swamps over goaf areas or edges.

Changes in tensile stain that may result in additional cracking in the base or rockbar of swamps are expected to be small, consistent with the estimates of low-level vertical subsidence and the latest understanding of strain magnitudes likely from multi-seam mining. Any changes to the surface from the low-level subsidence effects expected are unlikely to result in flow patterns that would significantly increase erosion within a swamp.

The 12 swamps assessed (in alphanumeric order not in order of significance or at risk from subsidence from the planned mining) are:

- BCUS4, BCUS6, BCUS7, BCUS11, CCUS9, CCUS10, CCUS11, CCUS12, CCUS13, CCUS24, CRUS6 and CRUS7.

The majority of the largest part of BCUS4 is located over goaf formed by secondary extraction in the early 1930's. This goaf is the northern section of the currently unconfirmed as collapsed Area#10. In this position, some of this part of BCUS4 is expected to have already experienced up to 600mm of vertical subsidence from the previous mining. Based on the records of the existing mining geometry, the probability for additional subsidence to exceed 100mm over BCUS4 from the planned mining in PC30-31 is considered to be low. No significant, additional impacts to this swamp are expected.

The majority of BCUS6 is located above the solid coal pillars of the main headings in the Bulli and Balgownie Seams. The smaller western part of this swamp is near a goaf edge formed during the 1940's and above the edge of the planned mining in PC32. This goaf is the currently unconfirmed as collapsed Area#9. In this position, the majority of this swamp is expected to have already undergone less than 100mm of vertical subsidence from the previous mining. The probability for additional subsidence to exceed 100mm over parts of this swamp from the planned mining in PC32 is considered to be low. No significant, additional impacts are expected.

BCUS7 is located over solid coal pillars and along the edge of goaf where secondary extraction occurred during the early 1940's. This goaf is the eastern part of the currently unconfirmed as collapsed Area#8. In this position, some sections of this swamp are expected to have already undergone approximately 100mm of vertical subsidence from the previous mining. The probability for additional subsidence to exceed 100mm over the northern half of this swamp from the planned mining in PC33 is considered to be low. No significant, additional impacts are expected.

BCUS11 is located above goaf formed in the 1930's where up to 600mm of vertical subsidence is expected to have already occurred from the previous mining. This goaf is the northern section of the currently unconfirmed as collapsed Area#10. The probability for additional subsidence to exceed 100mm from the planned mining in PC29, 31 and 32 is considered to be low. No significant, additional impacts are expected.

CCUS9 is located on the edge of the planned mining, similar to BCUS6, and included in this assessment for completeness. CCUS9 is located over the main headings in the Bulli, Balgownie and Wongawilli Seams. In this position, some of this swamp is expected to have already undergone approximately 100mm of vertical subsidence from the previous mining. Additional vertical subsidence from the planned mining in PC27-34 is expected to be less than 100mm. No significant, additional impacts are expected.

The southern part of CCUS10 is located over solid coal pillars with the northern part crossing over a goaf where secondary extraction was conducted from about 1928-1935. This goaf is the southern section of the larger Area#10. The goaf is confirmed as collapsed locally by the high vertical stress conditions observed during the mining of 3 cut-through in TG9 Panel and recent vertical drilling in this panel for inrush prevention. In this position, the northern part of this swamp is expected to have already experienced up to 400mm of vertical subsidence from the previous mining. The probability for additional subsidence to exceed 100mm from the planned mining in PC27-28 is considered to be low. No significant, additional impacts are expected.

CCUS11 is located mainly over the goaf but also at the northern edge of the southern goaf area of the currently unconfirmed as collapsed Area#10. The goaf below CCUS11 was formed in the 1930's. In this position, some of this swamp is expected to have already experienced up to 600mm of vertical subsidence from the previous mining. The probability for additional subsidence to exceed 100mm from the planned mining in PC28-29 is considered to be low. No significant, additional impacts are expected.

The northern half of CCUS12 is located over solid coal pillars whereas the southern half is located over goaf where secondary extraction occurred from around 1939 to 1944. This goaf is the northern edge of the northern section of the currently unconfirmed as collapsed Area#10. The northern half of CCUS12 is expected to have already experienced up to 100mm and the southern half up to 600mm of vertical subsidence from the previous mining. Additional vertical subsidence from the planned mining in PC29 and PC32-33 is expected to be less than 100mm over the northern half and the probability for additional subsidence to exceed 100mm over the southern half of CCUS12 is considered to be low. No significant additional impacts are expected.

CCUS13 is located over solid coal pillars and along the edge of goaf where secondary extraction occurred during the early 1940's. This goaf is the western part of the currently unconfirmed as collapsed Area#8. In this position, the northern edge of the northern part of this swamp is expected to have already undergone approximately 100mm of vertical subsidence from the previous mining. The probability for additional subsidence to exceed 100mm over the northern parts of this swamp from the planned mining in PC34 is considered to be low. No significant, additional impacts are expected.

CCUS24 is a small swamp (covering an area of approximately 35m by 45m) located above goaf formed in the 1930's where up to 200-300mm of vertical subsidence is expected to have already occurred. This goaf is the northern section of the currently unconfirmed as collapsed Area#10. However, an inspection of impacts to the nearby sandstone outcrop formation that hosts Aboriginal heritage rock shelter site 52-2-3941 suggests that the goaf at the site location has already collapsed. This site is in a similar position relative to the goaf edge as CCUS24. The probability for additional subsidence to exceed 100mm from the planned mining in PC29 is considered to be low. No significant, additional impacts are expected.

CRUS6 is primarily located above a goaf area and goaf edge where secondary extraction was undertaken around 1948-1950. This goaf is the currently unconfirmed as collapsed Area#9. Up to 300mm of vertical subsidence is estimated to have occurred within the swamp boundary due to the previous mining. Several small remnant pillars have been identified within the goaf including two small (10m by 10m) pillars just outside the swamp boundary. These are likely to have crushed (failed or collapsed) at the time of mining. However, in the unlikely event that these remnant pillars are still standing and were to collapse, additional subsidence is expected to be less than 300mm over an area with a radius of approximately 50m. The probability for additional subsidence over the majority of CRUS6 to exceed 100mm from the planned mining in PC33-34 is considered to be low. No significant, additional impacts are expected.

The majority of CRUS7 is located over goaf where secondary extraction occurred circa 1950. Only the eastern part of CRUS7 extends over the goaf edge and where PC34 would mine below. This goaf is the western part of the currently unconfirmed as collapsed Area#8. In this position, the majority of this swamp is expected to have already experienced between 100-200mm of vertical subsidence from the previous mining. The probability for additional subsidence to exceed 100mm from the planned mining in PC34 is considered to be low. Any additional subsidence is expected over the eastern part of this swamp. No significant additional impacts are expected.

5.1.2 Watercourses

A section of Cataract Reservoir along Cataract Creek, a fourth order section of the main channel of Cataract Creek and first order tributaries of Cataract River, Cataract Creek and Bellambi Creek are within the EP Area. However, the main body of the reservoir along Cataract River and the main channel of Bellambi Creek are outside the EP Area.

The fourth order section of the main channel of Cataract Creek crosses over the southern extent of PC27 but elsewhere first order tributaries of Cataract River, Cataract Creek and Bellambi Creek but do not extend very far, over the planned mining in PC27-34.

No significant, additional subsidence impacts are expected to these watercourses. Impacts and consequences are expected to be negligible in the context of previous impacts.

The fourth order main channel of Cataract Creek above PC27 is just upstream of where the creek flows in the surface expression of Dyke D8 in the outcrop of the Bald Hill Claystone. The creek crosses a Bulli Seam goaf edge three times above PC27. The valley closure measurement site CC3 is located here. There is a sandstone outcrop formation and associated steeper ground parallel to the watercourse but the stream gradient here is quite flat, having been reduced by subsidence from the previous mining in the Bulli Seam and immediately upstream, Longwall 11 in the Balgownie Seam. The cumulative magnitude of previous subsidence at this location is estimated at 0.2m near the Bulli Seam goaf edge to approximately 1.5m over Longwall 11.

The probability for additional subsidence to exceed 100mm, with corresponding low-level increases in tilt or strain, along this section of the creek from the planned mining in PC27, is considered to be low. No significant impacts are expected to this watercourse from any additional cracking, ponding and erosion from the low levels of subsidence effects forecast however, stream monitoring just downstream of PC27 is recommended.

A first order tributary of each of Cataract River, Cataract Creek and Bellambi Creek extends over the planned mining in PC27-34. The Cataract River tributary extends about 100m over PC34. A Cataract Creek tributary extends for about 60m over PC27 and the Bellambi Creek tributary extends over PC30 for about 50m into Swamp BCUS4. These tributaries, and others within the EP Area but not above the planned mining, cross over goaf areas.

All first order tributaries are expected to experience generally less than 100mm vertical subsidence with low probability to experience 100-200mm if there are any marginally stable remnant pillars that become destabilised by the planned mining.

Vertical subsidence of this magnitude is not expected to result in any significant additional impacts to these watercourses. The gradients are quite steep at between 1 in 4 to 1 in 10 with any reduction in grade due to subsidence of up to 100mm generally and up to 200mm in small areas is expected to be imperceptible. No significant additional impacts or consequences are expected from any cracking, ponding or erosion from the low levels of subsidence effects forecast.

5.1.3 Sandstone Formations

There are no definitions for cliffs, rock face features and steep slopes included in the consent conditions of MP09_0013. For the purposes of this assessment, cliffs are defined as sandstone formations or rock faces greater than 10m high, consistent with contemporary approval definitions and steep slopes are defined as extended slopes, that are not sandstone outcrop formations, with an average slope of greater than 1 in 1 (45°).

There are several sandstone formations within the EP Area. These are all less than 10m high. There are no sandstone formations greater than approximately 5-6m in height above the planned mining in PC27-34. There are no areas above PC27-34 considered to be steep slopes.

No significant, additional impacts to sandstone outcrop formations (including Aboriginal heritage rock shelter sites) or instability of steeper ground is expected from the low-level subsidence effects forecast. Impacts and consequences are expected to be negligible in the context of previous impacts.

Including the use of subsidence warning signs, restricting access where possible, and regular inspections before and after active mining in Land and Heritage Management Plans are considered appropriate measures to monitor and limit exposure to potential subsidence impacts.

The cliff line at Brokers Nose on the Illawarra Escarpment is remote from the EP Area and more than 3.0km from PC27. The 7m high battered road cuttings for Mount Ousley Road located on the northern side of the Cataract Creek are outside the EP Area and more than 1200m from PC27. No perceptible impacts to these features are expected from the planned mining.

5.1.4 Surface Landform

Ongoing low-level horizontal movements of the slope on the south side of Cataract Creek, a legacy of the previous mining on site, are expected to continue irrespective of the planned mining. This movement is likely to result in small increases in tensile cracking along the topographic high point, the crest/ridgeline between the Cataract River and Cataract Creek valleys, minor cracks on the slope, and valley compression closure across Cataract Creek.

Inspection of the main channel of Cataract Creek indicates that there is almost no physical disturbance to the rock strata in the bed of the creek despite previous mining activity in three seams. Geological mapping indicates that this section of the creek flows across outcrops of the Bald Hill Claystone and Bulgo Sandstone immediately below it. These strata units appear more tolerant of valley closure movement than Hawkesbury Sandstone.

This level of impact to the creek may change in the future regardless of any further mining. The basal shear plane is at limiting equilibrium (on the verge of moving) as a legacy of previous longwall mining. Only very small changes, such as changes in pore pressure caused by high intensity rainfall events, are required to cause further movement.

The main impacts from this ongoing movement are closure of the pavement, compression of the culverts at Cataract Creek and stretching at the top of the ridge to the south. These impacts and management measures are discussed in Section 5.3.

5.1.5 Groundwater

The planned first workings and bord and pillar mining in the Wongawilli Seam below existing Bulli Seam workings are not expected to significantly alter the current groundwater regime as no substantial additional caving of the overburden is likely.

The overburden strata is already depressurised to various heights from the previous secondary extraction in the Bulli, Balgownie and Wongawilli Seams.

Groundwater levels are expected to respond more to weather patterns than to the planned mining.

Any additional impacts to groundwater are expected to be negligible and limited to only in the immediately vicinity of the Wongawilli Seam within the area of the planned mining.

5.2 Heritage Sites

In this section, the potential subsidence impacts to Aboriginal heritage features located within the EP Area for PC27-34 are assessed. There are no historical heritage items in or within the vicinity of the EP Area.

Figure 4 shows the locations of 13 Aboriginal heritage sites of the type susceptible to subsidence impacts, identified within the EP Area. These comprise 10 rock shelter sites (52-2-0083, 52-2-0603, 52-2-3939, 52-2-3940, 52-2-3941, 52-2-4170, 52-2-4171, 52-2-4617, 52-3-0310, 52-3-0311) and three grinding grooves sites (52-2-0099, 52-2-0229, 52-2-0233). Some types of Aboriginal heritage sites (e.g. Artefact scatter and isolated finds) are considered less sensitive to subsidence movements. No impacts to the artefacts themselves are likely and the probability of impacts (cracking) intersecting the artefact location is considered to be low.

The locations of some of these rock shelter and grinding groove sites has changed from previous assessments and substantially different to those shown in Appendix 6 of MP09_0013.

Some of these sites were previously inspected and assessed in SCT (2014) for potential subsidence effects and impacts from the longwall mining proposed at that time. Impacts from the previous Bulli Seam mining were observed at some of the sites or along adjacent sandstone outcrop formations indicating that Bulli Seam goaf areas below these locations were collapsed and subsided. Rock falls from natural causes were also observed at some locations along sandstone formations.

Overall, only low-level subsidence effects are expected with vertical subsidence of approximately 100mm over most of the planned mining with potential for up to 300mm in small, isolated areas at or adjacent to sites. Changes in tensile and compressive strain that result in perceptible impacts (cracking and rockfalls respectively) are expected to be small consistent with the estimates of low-level vertical subsidence. No significant additional impacts are expected to the sites within the EP Area from the planned mining in PC27-34. Impacts and consequences are expected to be negligible in the context of the existing condition and previous impacts.

It is recognised that some impacts from previous mining pre-date the original recording of the sites.

Of these 13 sites within the EP Area, two rock shelter sites (52-2-0083, 52-3-0311) are outside the boundary of the planned mining in PC27-34 and located above solid coal pillars where no secondary extraction in the Bulli or Balgownie Seam has occurred. No impacts from the previous mining have been recorded at these two sites and no perceptible impacts are considered likely from the planned mining.

The 11 sites above the boundary of the planned mining in PC27-34 and either Bulli Seam goaf areas or first workings are assessed for the potential of impacts in the form of perceptible cracking and rockfalls.

Site 52-2-0603 is a rock shelter site with art and artefact near Swamp CRUS6 above PC33. This site is located on a sandstone outcrop formation that extends over the Bulli Seam goaf Area#9 that is currently unconfirmed as collapsed. Previous subsidence at this site is estimated at 300mm. No impacts from the previous mining were observed at this site but a more recent rockfall (last 10-20 years) that may be from natural processes was apparent on a nearby section of the sandstone formation. This is not clear evidence that goaf Area#9 is fully collapsed and subsided but, nevertheless adds credence to the assumption that this area is collapsed.

The potential for additional subsidence at this site to exceed 100mm from the planned mining in PC33 is considered to be low. However, the site is adjacent to where two remnant pillars have been identified within goaf Area#9. In the unlikely event that these remnant pillars are still standing and were to collapse, additional subsidence is expected to be less than 300mm over an area with a radius of approximately 50m some of which could include Site 52-2-0603. The probability of perceptible cracking at the site is considered to be low and the probability of rockfalls at the site is low.

Site 52-2-3939 is a rock shelter site with deposit and artefacts above PC28. The site is located at point that protrudes from the general line of the sandstone outcrop formation. The site is located just over the southern part of Bulli Seam goaf Area#10 where an estimated 200mm of subsidence is likely to have occurred. The probability for additional subsidence to exceed 100mm from the planned mining in PC28 is considered to be low. The probability of perceptible cracking at the site is considered to be low and the probability of rockfalls at the site is low.

Site 52-2-3940 is a rock shelter site with deposit and artefacts above PC28. The site is located on a longer sandstone outcrop formation where previous rock falls have occurred either due to mining impacts or natural decay. The site is located over solid coal pillars where an estimated 100mm of subsidence is likely to have occurred. Additional subsidence at this site from the planned mining in PC28 is expected to be less than 100mm. The probability of perceptible cracking at the site is considered to be very low and the probability of rockfalls at the site is very low.

Site 52-2-3941 is a rock shelter site with deposit and artefacts above PC29. The site is located just over the northern part of Bulli Seam goaf Area#10 where an estimated 200mm of subsidence is likely to have occurred. The site is adjacent to a section of sandstone outcrop formation with rock fall from the previous Bulli Seam mining which suggests the goaf at this location is collapsed and subsided. The site itself is below a detached boulder from the main line of the sandstone outcrop and as such not expected to be vulnerable to further rock falls. The probability for additional subsidence to exceed 100mm from the planned mining in PC29 is considered to be low. The probability of perceptible cracking at the site is considered to be low and the probability of rockfalls at the site is low.

Site 52-2-4170 is a rock shelter site with deposit and artefacts above PC27. The site is along the larger sandstone outcrop formation adjacent to Cataract Creek and located over solid coal pillars near a goaf edge where approximately 100mm is likely to have occurred. Additional subsidence at this site from the planned mining in PC27 is expected to be less than 100mm. The probability of perceptible cracking at the site is considered to be low and the probability of rockfalls at the site is low.

Site 52-2-4171 is a rock shelter site with stone arrangement above the edge of PC28. The site is at the end of the larger sandstone outcrop formation adjacent to Cataract Creek and located over solid coal pillars near a goaf edge where approximately 100mm is likely to have occurred. Additional subsidence at this site from the planned mining in PC27 is expected to less than 100mm. The probability of perceptible cracking at the site is considered to be low and the probability of rockfalls at the site is low.

Site 52-2-4617 is a rock shelter site with art located above PC33. This site is in proximity to Site 52-3-0310 on the same sandstone formation. The site is located over a solid coal pillar near a goaf edge where less than 150mm is estimated to have occurred. Additional subsidence at this site from the planned mining in PC33 is expected to be approximately 100mm. The probability of perceptible cracking to the site including intersecting the art wall is considered to be low and the probability of rockfalls at the site is low.

Site 52-3-0310 is a rock shelter site with deposit, art and grinding grooves above PC33. This site is adjacent to Site 52-2-4617. The site is located over solid coal pillars near a goaf edge where approximately 100mm is likely to have occurred. Additional subsidence at this site from the planned mining in PC33 is expected to be approximately 100mm. The probability of perceptible cracking to the site including intersecting the art walls and grinding grooves is considered to be low and the probability of rockfalls at the site is low.

Site 52-2-0099 is a grinding grooves site at the edge of Swamp BCUS7 to the east of PC33. This site comprises three grooves on a small sandstone outcrop. The site is located above solid coal pillars where previous subsidence estimated at less than 100mm and would not be directly mined under by PC33. Additional vertical subsidence from the planned mining is expected to be less than 100mm at this site. No perceptible impacts are expected at this site.

Site 52-2-0229 is a grinding groove site above PC32. This site comprises a single groove on a sandstone outcrop and a recent attempt to relocate the site has been unsuccessful. The site is above Bulli Seam goaf Area#9 currently unconfirmed as collapsed. The potential for additional subsidence at this site to exceed 100mm from the planned mining in PC32 is considered to be low. The probability of cracking impacting the sandstone outcrop and intersecting the grinding groove at this site is very low.

Site 52-2-0233 is a grinding grooves site above PC32. This site comprises two grooves on a sandstone outcrop. The site is above Bulli Seam goaf Area#9 currently unconfirmed as collapsed. The potential for additional subsidence at this site to exceed 100mm from the planned mining in PC32 is considered to be low. The probability of cracking impacting the sandstone outcrop and intersecting the grinding grooves at this site is very low.

The use of subsidence warning signs, restricting access where possible, and inspections before and after active mining as detailed in the Heritage Management Plan (HMP) are considered appropriate measures to monitor impacts and consequences and limit exposure to potential mining related hazards during the planned mining in the EP Area for PC27-34

5.3 Built Features and Infrastructure

Built features are shown in Figure 4. Public utilities identified within the EP Area or in positions with potential to be affected by the planned mining include: the Cataract Storage Reservoir and minor infrastructure including Fire roads and survey control stations. There are no public amenities, farmland and facilities, industrial, commercial and business establishments, residential establishments, or items of architectural significance.

The major regional infrastructure of Mount Ousley Road and 300kV, 132kV and 33kV overhead electricity transmission lines are outside the EP Area and no direct impacts from the planned mining are expected to be perceptible at these built features. As shown on Figure 1, Mount Ousley Road is outside the EP Area, about half of the planned mining is within the 5 X Depth zone (up to 1.8km) used by TfNSW (RMS) to assess risk to their assets. As such, a formal risk assessment of the potential impacts on Mount Ousley Road and associated structures from the planned mining would be expected to be required.

However, a formal risk assessment was conducted for this critical infrastructure during preparation of the current Built Features Management Plan (BFMP) for Stage 1 mining. The TfNSW Technical Committee (TC) that manages the monitoring of and impacts to Mount Ousley Road, has determined that a formal risk assessment is not considered necessary and the existing BFMP, with additional monitoring for Stage 2 mining, is suitable to manage any potential impacts from the planned mining in PC27-34.

5.3.1 Cataract Storage Reservoir

The majority of the planned mining in PC27-34 is within the current Notification Area around the Cataract Storage Reservoir administered by Dams Safety NSW (previously NSW Dams Safety Committee). However, most of the planned mining is outside the 35° angle of draw (0.7 depth) marginal zone with no mining planned directly below the FSL of the reservoir.

Subsidence effects and impacts to the FSL from the planned mining are expected to be imperceptible for all practical purposes. No perceptible changes to the extent of the FSL are expected. No changes to water quality in the reservoir are expected. Any changes to water quantity flowing into the mine are expected to be negligible and no additional conductive cracking is expected.

The mining plan for the EP is expected to require consent from Dams Safety NSW (DSNSW) and the approval of the Chief Inspector of Coal Mines. The expected subsidence effects and impacts from the planned mining within the Notification Area are expected to be tolerable to DSNSW. The requirements for DSNSW consent may involve detailed risk and engineering assessments and the implementation and maintenance of a detailed underground mine water balance measurement system.

5.3.2 Fire Roads

Fire Roads 7D and 7M traverse the EP Area for PC27-34 as shown on Figure 4. These unsealed, four-wheel drive tracks cross over the planned mining in PC30-PC34. These roads are owned and maintained by Water NSW with entry to the roads controlled by locked gates as part of access restrictions to the Metropolitan Special Area of the Sydney water catchment. These roads are used for bushfire control purposes and by WCL for access to their mining infrastructure on mining purposes leases.

The access gates to Fire Road 7D on Mount Ousley Road and the Bellambi Creek Crossing on Fire Road 7D are well outside the EP Area. No perceptible impacts are expected to these features.

The southern section of Fire Road 7D has a creek crossing over exposed bedrock and some steeper sections. These features are located over a goaf area in the Bulli Seam workings of Corrimal Colliery to the west of PC34 near the western edge of the EP Area. This goaf area formed in the 1950's is isolated from the Bulli Seam workings above PC27-34 by a 40m wide barrier of solid coal. Subsidence effects and impacts to these features are expected to be imperceptible.

In general, no additional subsidence effects or impacts are expected to be perceptible from the planned mining. Any impacts are not expected to be of out of context with the existing conditions of these roads and easily repairable for safety of users. Regular inspections during active mining, and timely remediation are considered appropriate management measures in the unlikely event of any impacts or changes to the surface being observed. Including these measures in the Land and Public Safety Management Plan is recommended.

5.3.3 Survey Control Stations

There are no survey control stations within the EP Area for PC27-34 but there six state survey or permanent marks along the edge of Mount Ousley Road approximately 1km to the east of the planned mining in PC27.

These include permanent marks PM173136, PM173135 and state survey mark SS165830 within the EP Area for PC07-08 in the Stage 1 EP and three additional marks PM173728, PM173137 and SS165831.

Survey marks within 1km of the planned mining are likely to susceptible to ongoing low-level far-field subsidence movements from the multi-seam environment at RVE. Including the additional marks in the existing BFMP for survey control stations is recommended to manage the potential subsidence impacts to these additional public utilities.

5.3.4 Mining Related Infrastructure

Mining related infrastructure within the EP Area for PC27-34, owned by WCL, is located on mining purposes lease areas. This infrastructure includes 33kV overhead powerlines and a substation/switchyard and ventilation fan installations and equipment at the No1 and No2 shaft site.

While within the EP Area, the installations at the No1 and No2 Shaft site are not above the planned mining and only two poles of a 33kV powerline are above or over the edge of the planned mining in PC30-31.

However, these assets have not been in service since 2019 with power to this all infrastructure currently disconnected and substation partially dismantled.

Impacts to this infrastructure from the planned mining are expected to be imperceptible. Any impacts are expected to manageable, repairable and of no consequence.

The pole at the change of direction on 33kV powerline above the goaf area over PC30 is not expected to be impacted however, reducing the tension of guy wires during the period of active mining is recommended as this pole was observed to be in a poor state of repair.

5.4 Public Safety

The potential risk to public safety from the planned mining in the Stage 2 EP is expected to be less than that for the Stage 1 EP. The potential risk to public safety associated with impacts to Mount Ousley Road and the electricity transmission lines are likely to be less as these surface features are remote from the planning mining in PC27-34.

The fire roads are the only built features where there is potential for public safety to be affected but any impacts to the fire roads are expected to be imperceptible, so additional risk to public safety is expected to be negligible. This expectation assumes that the existing BFMP, developed in consultation with the asset owners for Mount Ousley Road and the powerlines for Stage 1 EP, is reviewed and continues to be used during the planned mining in PC27-34.

Revising the existing Public Safety Management Plan (PSMP) with references to the risk control measures for public safety in the BFMP and Land and Heritage Management Plan is recommended.

6. SUBSIDENCE MONITORING

Continued use and extension of the existing subsidence monitoring program (SMP) is recommended to manage operational, personal, and public safety risks and to address the specific requirements in the approval conditions of MP09_0013. The monitoring detailed in this section relates to surveying of the ground surface or structures and other observations but excludes the environmental monitoring for subsidence impacts to natural features as required by MP09_0013 and EPBC 2020/8702.

The aim of this monitoring is to:

- Provide data to assist with the management of the risks associated with subsidence.
- Confirm the status of Bulli Seam goaf areas.
- Validate subsidence forecasts.

- Provide a basis to analyse the relationship between the forecast and actual subsidence effects and impacts including any environmental consequences.
- Ensure compliance with MP09_0013 including subsidence performance measures.
- Inform adaptive management process for compliance with performance measures.
- Collect sufficient baseline data for future mining applications.
- Ensure compliance with the approval conditions of EPBC 2020/8702.
- Enhance general understanding of subsidence behaviour at RVE.

The full details are provided in the existing SMP required by Condition C10 (g) (i) of MP09_0013, relevant guidelines and legislated standards. An overview of the recommended monitoring approach to satisfy these aims is presented here.

Given the low-levels of subsidence effects expected over the bushland environment and steep terrain above RVE, the basis of the monitoring is an array of monitoring points with continuous, near real-time, high-accuracy ground-based GNSS (GPS) units at strategic locations combined with remote monitoring (LiDAR) surveys of the broader-area. Also included are the existing systems of closure monitoring across Cataract Creek including closure slot monitoring on the Mount Ousley Road pavement, culvert surveys and survey closure measurements at four cross-section locations, a monitoring line along the edge of Mount Ousley Road and additional monitoring by the asset owners of the major infrastructure.

The high-accuracy ground-based GNSS points are located at suitable locations above the planned mining and in or on specific natural or built features including critical infrastructure (Mount Ousley Road and electricity transmission powerlines) to confirm the low-level ground movements expected. Broad-area remote monitoring (LiDAR) across the entire area is to check for unexpected movements, particularly any that may be associated with instability of remnant pillars in or in the vicinity of Bulli Seam goaf areas.

The LiDAR coverage area for RVE already includes the area of the planned mining in PC27-34. Extending the GNSS unit network to cover strategic points over the planned mining in PC27-34 using the same logic as used for the existing SMP is recommended.

The GNSS measurements and LiDAR surveys are expected to be able to identify the subsidence effects in all areas above and adjacent to the planned mining in the Wongawilli Seam, including Bulli Seam goaf areas yet to be confirmed as collapsed and subsided.

Regular underground geotechnical mapping of changes to the observed vertical and horizontal stress conditions, around the edges of the areas shown as goaf on the original Bulli Seam mine working plans and record tracing copies, is expected to be a strong indicator of the status of Bulli Seam goafs. There are currently seven Bulli Seam goaf areas that are likely to have collapsed and subsided but there is no substantial evidence to confirm this collapse. Underground observations of roadway condition in the Wongawilli Seam are considered a reliable technique to confirm these areas have collapsed and subsided.

The proposed mining method is flexible compared to longwall mining and easily adaptable to unexpected or unfavourable mining conditions. Adaptive management practices, including TARPs as part of contingency plans, allow for immediate changes to the mining layout in response to changes in mining conditions, risk profiles, potential impacts and compliance with the conditions of MP09_0013.

In addition to incident reporting (e.g. a TARP exceedance), the 'Guidelines for the Preparation of Extraction Plans' requires subsidence impact reporting on a bi-monthly (every two months), six-monthly and annual basis. Subsidence effects monitoring results are required in the annual report.

The subsidence monitoring program includes, amongst other things, provisions to ensure the mine operator manages risks to health and safety associated with subsidence as required by Clause 67 of *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014.*

Clause 67 (2), requires:

b) monitoring of subsidence to be conducted, including monitoring of its effects on relevant surface and subsurface features

c) any investigation of subsidence and any interpretation of subsidence information is carried out only by a competent person.

On this basis, it is envisaged that subsidence effects will be measured as required by the Survey and Drafting Directions for Mining Surveyors 2020 (S&DD 2020) and impacts will be reviewed and validated for compliance with forecast and MP09_0013 by a competent person (subsidence specialist) at a regular frequency. The reporting of these requirements is expected at the end of a panel (or significant milestone in mining of the underground layout) and/or annually as a minimum.

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

Table A1: The 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;	**Y**	***3.1, 3.4***
2) Rivers and creeks;	**Y**	***3.6.1, 5.1.2***
3) Aquifers, known groundwater resources;	**Y**	***3.6.1, 5.1.5***
4) Springs;	**N**	
5) Sea/lake;	**N**	
6) Shorelines;	**N**	
7) Natural dams;	**N**	
8) Cliffs / pagodas;	**N**	***3.6.1, 5.1.3***
9) Steep slopes;	**N**	***3.6.1, 5.1.3***
10) Escarpments;	**N**	
11) Land prone to flooding or inundation;	**N**	
12) Swamps, wetlands, water related ecosystems;	**Y**	***3.6.1, 5.1.1***
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;	**N**	
17) Natural vegetation;	**Y**	***3.1, 3.6.1***
18) Areas of significant geological interest, and	**N**	
19) Any other feature.	**N**	
Public Utilities		
1) Railways;	**N**	
2) Roads (all types);	**Y**	***3.6.2, 5.3.2***
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;	**Y**	***3.6.2, 5.3.1***
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	**Within EP Area**	**Relevant Section**
8) Bowling greens	**N**	
9) Ovals and cricket grounds	**N**	
10) Racecourses	**N**	
11) Golf courses	**N**	
12) Tennis courts	**N**	
13) Any other amenities considered significant	**N**	
Farm Land and Facilities		
1) Agricultural utilisation or agricultural suitability of farmland;	**N**	
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**	
11) Any other feature.	**N**	
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;	**N**	
8) Mine infrastructure including tailings dams and emplacement areas, and	**Y**	***3.6.2, 5.3.4***
9) Any other feature considered significant.	**N**	
Areas of Archaeological and/or Heritage Significance	**Y**	***3.6.2, 5.2***
Items of Architectural Significance	**N**	
Permanent Survey Control Marks	**Y**	***3.6.2, 5.3.3***
Residential Establishments	**N**	
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**	

*Assessment by other specialist