

INVINCIBLE SOUTHERN EXTENSION PROJECT

FINAL LANDFORM OPTIONS FOR
SOUTHERN EXTENSION AREA

FINAL

June 2017



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FINAL LANDFORM OPTIONS FOR SOUTHERN
EXTENSION AREA

FINAL

Prepared by
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on behalf of
Castlereagh Coal

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	Name	Date	Name	Date
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1.0 Introduction

The conceptual final landform of the Southern Extension Area in the Environmental Assessment (EA) for the Southern Extension Project (shown in Figure 3.4 of the EA and reproduced as **Figure 1.1**) reflects rehabilitating this area to the pre-mining terrain to achieve a rehabilitated landform that has the same features as the pre-mining landform. The Department of Planning and Environment (DP&E) have identified the possibility of parts of the conceptual final landform in the Southern Extension Area (SEA) having slopes that may present difficulties for rehabilitation. The potential areas of concerns are shown in **Figure 1.1** and are based on DP&E's observations of past rehabilitation experience of the West Pit area (refer to **Figure 1.1**) in the north of the Invincible Open Cut mining area. The slope gradients in the Southern Extension Area associated with the EA Conceptual Final Landform are shown in **Figure 1.2**.

It is noted that the steep slopes which have been identified as being of concern to DP&E are not the deeply incised gullies associated with the pagoda formations to the west and north of Southern Extension Area. Unlike previous proposals for mining at Invincible, the Southern Extension Project does not involve mining into the incised gullies located between the pagodas and cliff lines.

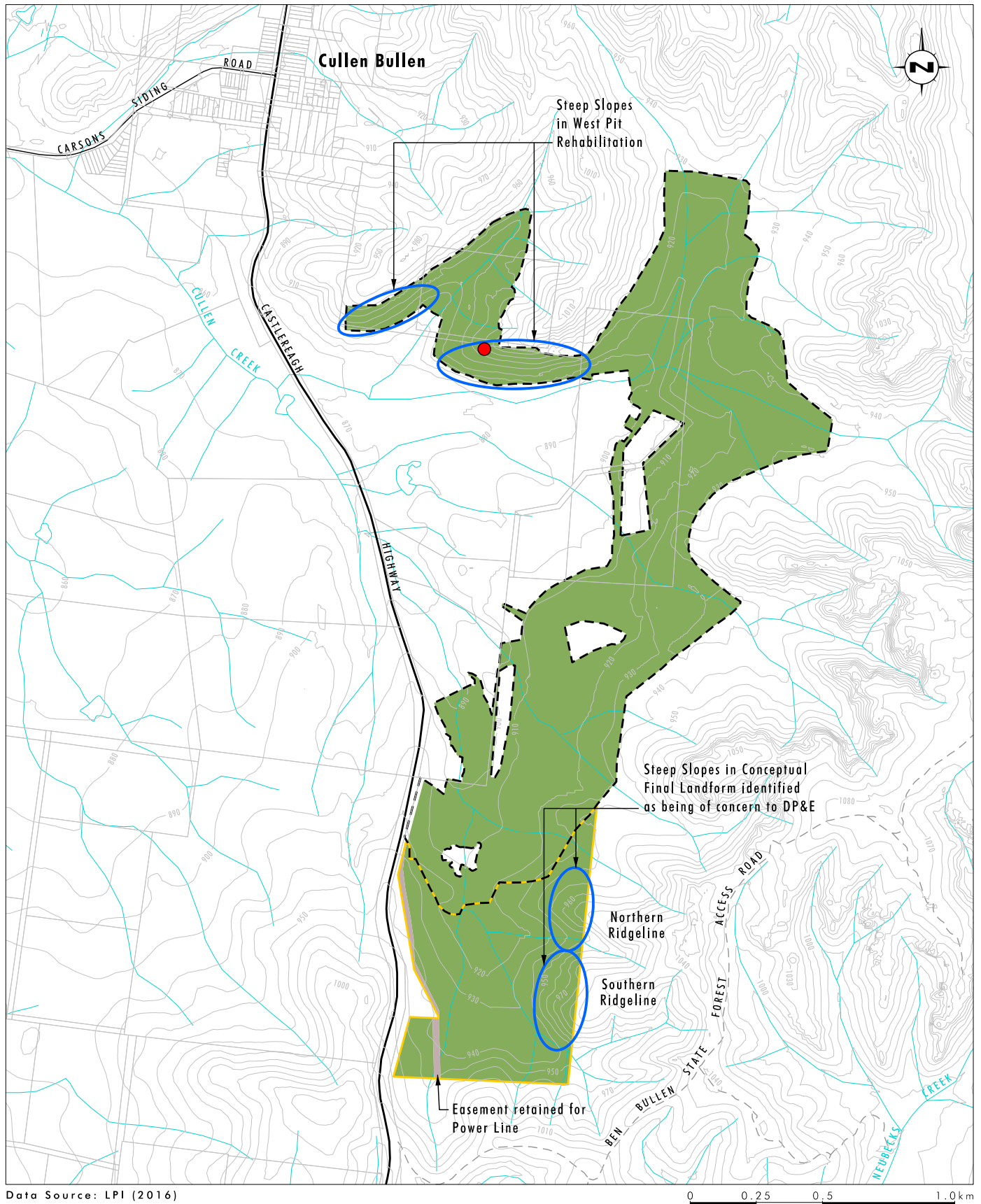
In response to the matters raised by DP&E in relation to areas of steeper slope in the proposed conceptual final landform as presented in the EA, a number of alternate final landform options have been identified for the Southern Extension Area for consideration. As requested by DP&E these alternate final landform options have been assessed and evaluated in this response, including (further detailed is provided in **Section 2.0**):

- Option 1: The proposed modification unchanged, including more justification about how the final landform could be achieved – this is referred to as the EA Conceptual Final landform in this response
- Option 2: No mining in the high slope areas at the eastern extent of the proposal – identified as Option 3 in this response; and
- Option 3: Other options (including highwall/s and/or options to reduce the gradient of slopes) – identified as Options 1 and 2 of this response.

In addition, relevant background and further discussion of the proposed conceptual final landform as presented in the EA, as well as other matters raised by DP&E including the overburden dump balance, is provided in response to the issues raised by DP&E.

1.1 Background to Rehabilitation of the West Pit Area

The West Pit was approved to be mined in 2008 under the current Project Approval, PA 07_0127 (Invincible Project Approval). The pre-mining terrain in this area was relatively steep and the mining resulted in a highwall height of up to 60 metres in places with associated horizontal distance of mining disturbance of as little as approximately 200-250m. **Plates 1.1** and **1.2** show rehabilitation (seeded in 2011 -12) in a section of the West Pit in 2017. The approximate locations of the photos are shown on **Figure 1.1**.



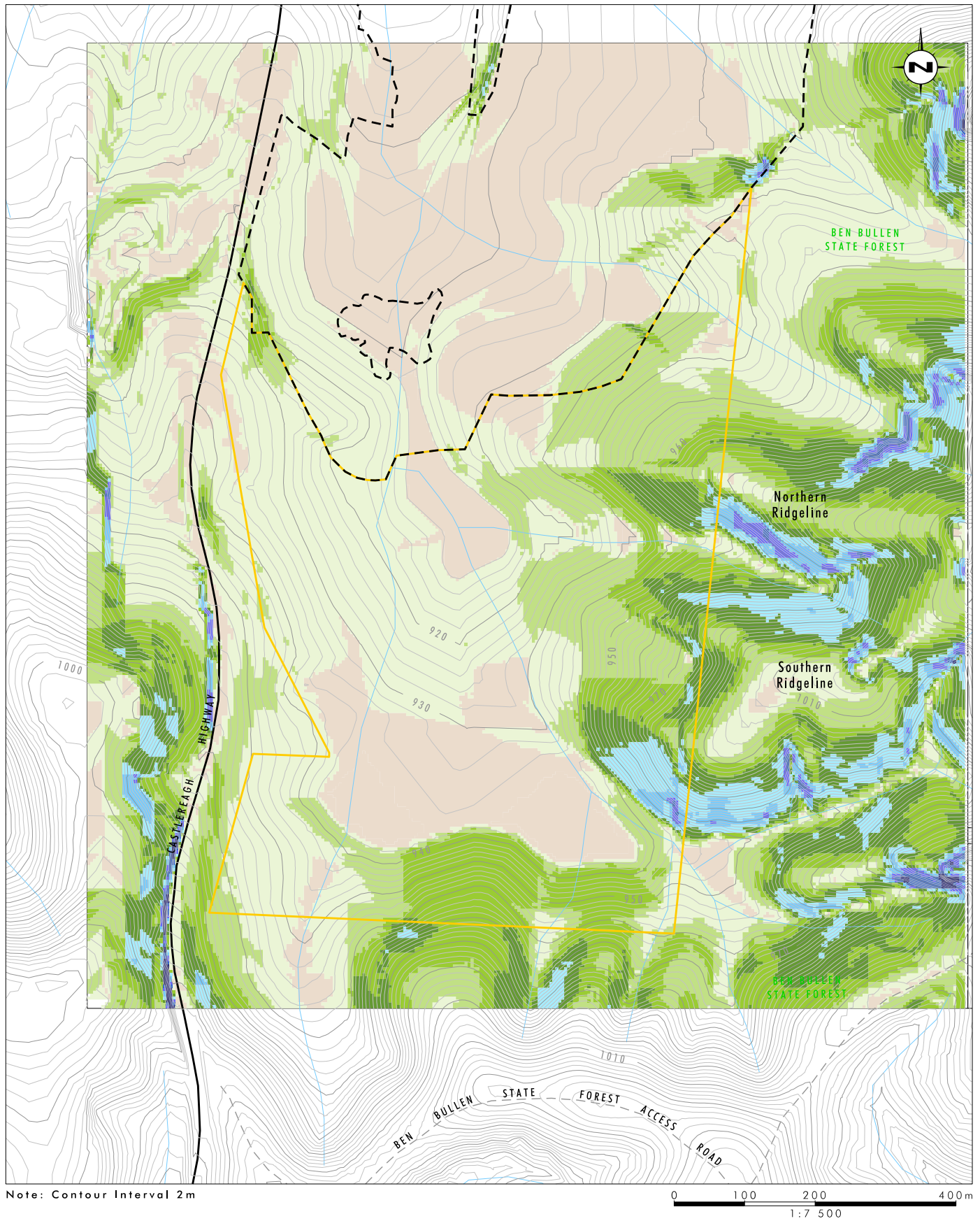
Data Source: LPI (2016)
Note: Contour Interval 10m

Legend

- Existing Approved Mining Disturbance Area
- Proposed Southern Extension Area
- Rehabilitation - Woodland/Forest
- Grassed Powerline Easement
- Location of Photographs (Plates 1.1, 1.2)

FIGURE 1.1

Environmental Assessment
Invincible Conceptual
Final Landform



Legend

Existing Approved Mining Disturbance Area	Range 30.00 - 35.00
Proposed Southern Extension Area	Range 35.00 - 40.00
Range 0.00 - 5.00	Range 40.00 - 45.00
Range 5.00 - 10.00	
Range 10.00 - 15.00	
Range 15.00 - 20.00	
Range 20.00 - 25.00	
Range 25.00 - 30.00	

FIGURE 1.2

EA Conceptual
Final Landform



Plate 1.1 Rehabilitation in West Pit (looking west)



Plate 1.2 Rehabilitation in West Pit (looking south-east)

The rehabilitated landform in the West Pit area has attempted to recreate the pre-mining terrain. **Figure 1.3** shows the rehabilitated West Pit Landform. Due to constraints presented by the offset area located to the immediate south of the West Pit area, the area to be rehabilitated was located in the mid slope area of the natural terrain which, in a natural concave/convex landform system meant that the area to be rehabilitated was located in the steepest area of the slope with limited or no ability to take advantage of less steep areas at the top and bottom of the slopes (refer to **Figure 1.4**) to improve slope design.

As a result, there was limited ability for dozers working on the rehabilitation to operate across the slope and topsoil material had to be pushed from the bottom to the top of the slope. In addition, the general steepness of the rehabilitated terrain presented difficulties for dozers working horizontally across the slope in some areas which limited contour drain installation. In areas the slopes were so steep that dozers could not operate on the slope at all and the final landform represents the natural angle of repose (approximately 37 degrees); in these areas, top soil was spilled down the dump face prior to seeding. Approximately 6 hectares of the West Pit area has slopes in excess of 25° with around half of this exceeding 30° (refer to **Figure 1.5**). As can be seen in **Plate 1.2** (which is indicative of the areas with poorer rehabilitation outcomes in the West Pit Area), these difficulties limited the ability to effectively spread topsoil material and retained timber across the entire rehabilitated area. The steepness also presented difficulties for the installation and maintenance of contours drains in the steeper areas. As can be seen in the foreground of **Plate 1.2**, there is some minor erosion developing in areas with less vegetation however there are no significant erosion concerns in this area (due largely to the relatively small catchment area of disturbed areas).

Despite these constraints on rehabilitation, as can be seen from **Plates 1.1** and **1.2**, revegetation of the west pit area is progressing.

The slow uptake of rehabilitation in the West Pit Area has resulted in extended visual impacts associated with past mining within the West Pit Area (partly exacerbated by the generally pale colour of topsoil material). As the West Pit Area is visible from the Castlereagh Highway for vehicles travelling north the visual impacts are prominent for this section of the Highway. The former mining within the West Pit Area is an example of past open cut mining within the gully formations within the areas surrounding the Invincible mine. As outlined above, mining within these areas has been specifically avoided as part of the Southern Extension Project.

As shown in **Plates 1.1** to **2.1**, vegetation has now started to take in parts of the area, including the steepest sections of the rehabilitation. The 2016 Invincible Annual Report (Umwelt 2017) contains a detailed assessment of the status of rehabilitation across the Invincible site and, while there are areas where infill plantings and additional revegetation efforts are required, the rehabilitation in the West Pit area is trending towards completion criteria despite the limitations presented by the terrain in this area.

1.2 Commitments in the Southern Extension Project EA

Section 6.18 of the EA details the rehabilitation strategy for Invincible as the Southern Extension Project. The overall objective is to rehabilitate the entire Invincible Mine site, including the Southern Extension Area, to create a final landform with no voids, consistent with the pre-mining landform and integrated with the surrounding terrain.

The key commitment regarding slope design is identified in the Secondary Domain (Post – Mining) rehabilitation objections (Table 6.37 in the EA) which provide:

Disturbed landform to be graded and shaped to reflect natural landforms and drainage contours. Revegetation to be undertaken through seeding and/or tube stock planting compatible with the surrounding land use.

Post mining landforms to be geotechnically stable and non-polluting consistent with the proposed post-mining land use suitability.

A conceptual Final Landform for the Project is shown in Figure 3.4 of the EA (refer to **Figure 1.1**) and rehabilitation strategy is shown in Figure 6.34 of the EA.

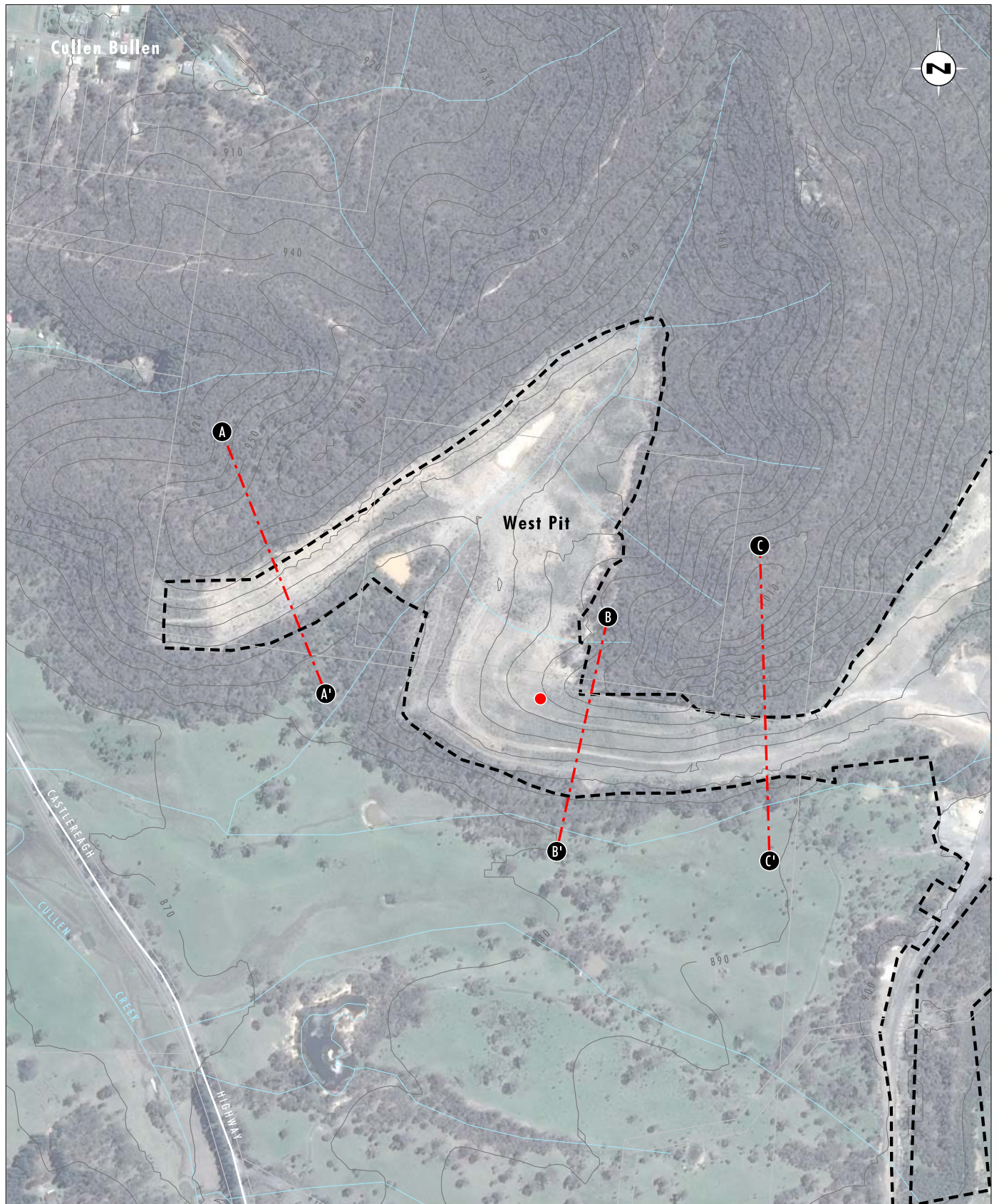


Image Source: Google Earth/CNES/Airbus (Oct 2016)

Data Source: LPI (2016)

Note: Contour Interval 10m

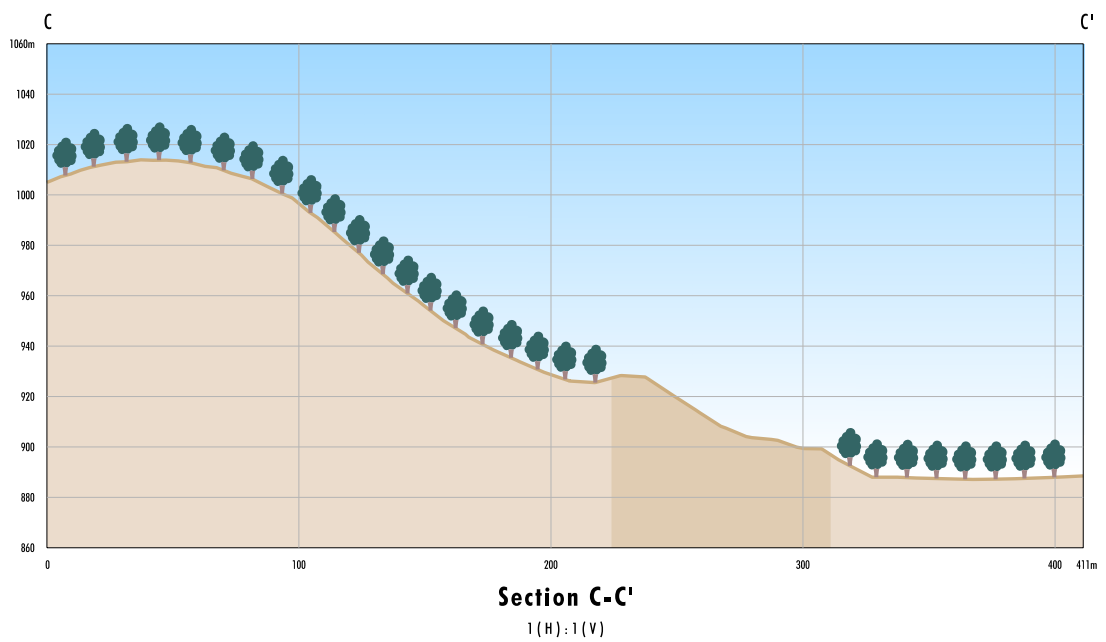
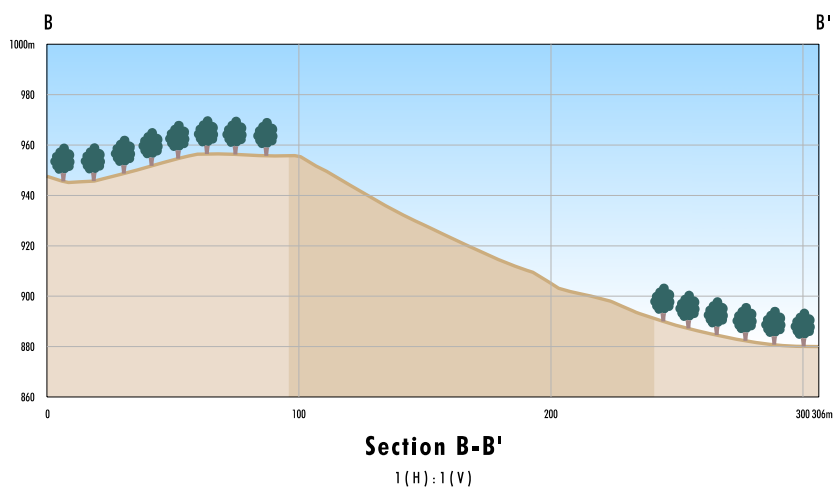
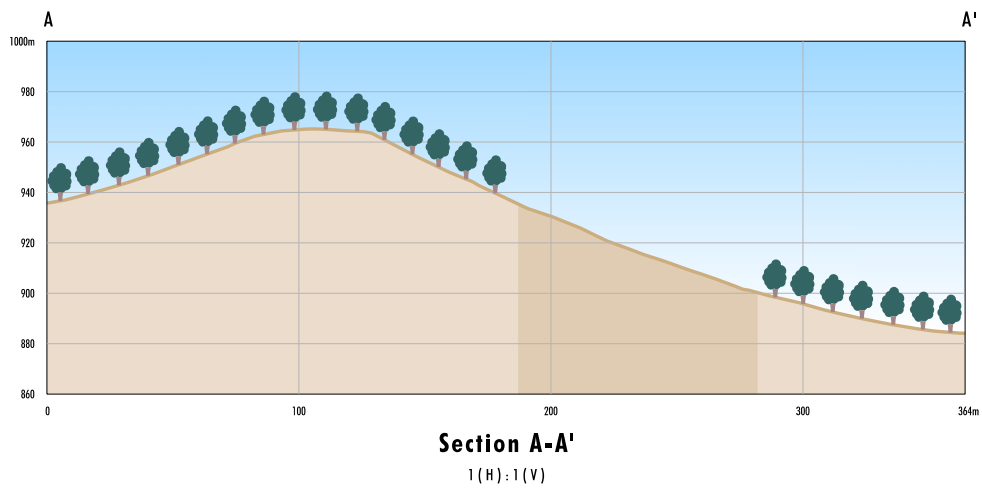
0 100 200 400m
1:7 500

Legend

- Existing Approved Mining Disturbance Area
- Section Locations
- Location of Photographs (Plates 1.1, 1.2)

FIGURE 1.3

West Pit Landform



Legend

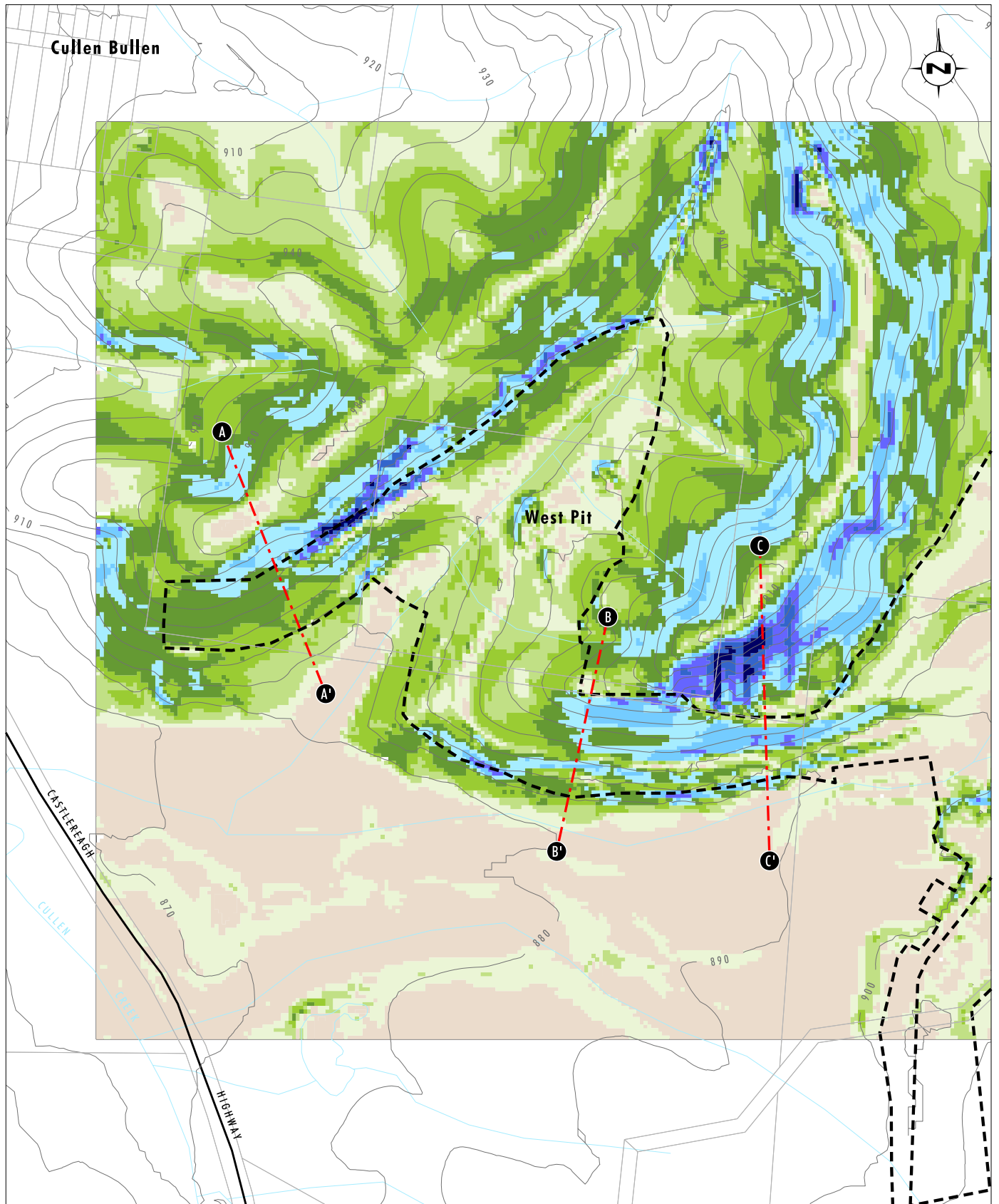
- Existing Surface
- Existing Vegetation

0 50 100 150 m
1 : 3000

File Name (A4): R13/3622_165.dgn
20170614 10.54

FIGURE 1.4

Rehabilitated Landform in
West Pit Area



Data Source: LPI (2016)
Note: Contour Interval 10m

0 100 200 400m
1:7 500

Legend

- | | |
|---|---------------------|
| Existing Approved Mining Disturbance Area | Range 30.00 - 35.00 |
| Section Locations | Range 35.00 - 40.00 |
| Range 0.00 - 5.00 | Range 40.00 - 45.00 |
| Range 5.00 - 10.00 | |
| Range 10.00 - 15.00 | |
| Range 15.00 - 20.00 | |
| Range 20.00 - 25.00 | |
| Range 25.00 - 30.00 | |

FIGURE 1.5

West Pit Landform
Slope Classification

This landform is the same as the pre-mining landform in all areas except the very lower parts of the drainage line flowing north which has been reshaped due to this area being subject to significant gully erosion. The EA identified that detailed rehabilitation strategy for each domain and parts of each domain will be developed as part of the MOP approval process for the Southern Extension Project under the *Mining Act 1992*. The MOP will include detailed considerations of dump balance (refer to **Section 1.3** below), slope design, water management, topsoil spreading, revegetation strategies and ongoing monitoring and maintenance, and will be subject to further detailed review and approval from the Department of Resources and Energy (DRE). It is noted that DRE have not provided any objection to, or raised any issues, in relation to the proposed conceptual final landform for the Southern Extension Project in its submissions.

As discussed in **Section 1.3**, the dump balance indicates that, on the proposed mining strategy, there is sufficient overburden available to further revise final slopes in the detailed final landform design process. In areas where the reinstatement of the pre-mining landform would result in slopes which may pose difficulties for successful rehabilitation in those areas, the landform design can be revised to reduce slope lengths or incorporate benches through the use of the overburden to be sourced from the proposed mining in the Southern Extension Area. These options are discussed and evaluated further in **Section 2.0**.

1.3 Available Material for Rehabilitation

Appendix 1 of the Response to Submissions Report A includes a dump balance for the Southern Extension Project based on developing a landform consistent with the conceptual final landform shown in the EA (refer to **Figure 1.1**).

Table 1.1 Dump Balance

Conceptual Mine Plan Year	Scheduled Volume of Overburden from Southern Extension Area (Mbcm)	Available Overburden from Southern Extension Area for Rehabilitation (Mm ³)	Dump Room Required to Rehabilitate Site to EA Conceptual Final Landform (Mm ³)
1	3.6	4.5	4.6
2	3.8	4.8	4.8
3	3.8	4.8	5.1
4	3.8	2.1	2.2
Total	1.7	16.2	16.7 (15.8*)

*Number in parentheses excludes capacity of Northern Void (see Table 1.2 below). The majority of the Northern Void can be filled and rehabilitated to the EA Conceptual Final Landform design using existing overburden stockpiled around the Northern Void and does not rely on Overburden from the Southern Extension Area. The rehabilitation of the Northern Void using this overburden would require only minimal re-disturbance of existing rehabilitated areas.

The bulking factor associated with the removal of overburden from the Southern Extension Area means there is sufficient material to fill all voids in the existing Invincible open cut disturbance area (North Pit, East Pit and Renown/South Pit) and to complete the proposed rehabilitation of the Southern Extension Area back to a landform consistent with the pre-mining landform. The 'capacities' in each of the voids shown in **Table 1.2** reflects the volume of material required to create the conceptual landform design shown in **Figure 1.1**. In the case of the Southern Extension Area, this landform is largely identical to that which existed pre-mining.

Table 1.2 Void Areas to be Filled/Shaped

Area	Dump Capacity (Mm ³)	Comment
Southern Extension Area	14.0	Based on returning landform to that shown in Figure 3.4 of the EA (refer to Figure 1.1).
Renown/South Pit Void	1.3	
Northern Void	0.9*	Majority can be pushed from existing emplaced overburden around Northern void area.
Eastern Void	0.5	
Total	16.7	

*This capacity can be met through existing stockpiles of overburden around the Northern Void.

As can be seen from **Table 1.1**, there is approximately 0.4 million m³ more overburden material generated by the Southern Extension Project than is required to develop the conceptual final landform identified in **Figure 1.1**. This additional material provides flexibility for improving slope design in different areas of the final landform and improves the 'tie-in' with the undisturbed areas upslope from the areas to be rehabilitated. These improvements can be in areas where this additional overburden can be used to reduce risks to rehabilitation success and improve final landform design area the areas of concern shown in **Figure 1.1** and the Northern Void area. Due to the relatively flat basin to the west of the northern and southern ridgelines (refer to **Figure 1.1**), there is scope to extend the foot of these slopes westwards through additional overburden emplacement to lessen the slopes associated with these features in the proposed conceptual final landform.

As discussed in Section 3.7.1.1 of the EA, the existing Invincible voids can be rehabilitated without overburden from the Southern Extension Areas however this would require disturbance of rehabilitated areas and significant earthworks. This would further extend the time to rehabilitate the existing disturbance area and the re-disturbance of existing rehabilitation presents risks to successful reuse of topsoil material from re-disturbed areas which would again need to be stripped, stockpiled and respread. Typically, it is considered that additional handling on this scale would result in poorer rehabilitation outcomes due to rehandle and disturbance of seed bank material that may be present.

2.0 Consideration of Final Landform Options for Southern Extension Area

The concerns raised by DP&E relate to the steeper south, south western facing slopes on the ridgelines in the eastern parts of the conceptual final landform proposed for the Southern Extension Area (refer to **Figure 1.1**). DP&E's focus on these areas is understood to relate to concerns that the rehabilitation of these areas may be subject to similar constraints as those which applies to the West Pit area. As noted in **Section 1.2**, the landform shown in **Figure 1.1** (see also Figure 3.4 from the EA) is conceptual only and is subject to detailed rehabilitation design considerations to be incorporated into the MOP. As discussed in **Section 1.3**, the surplus overburden generated by the Southern Extension Project provides the flexibility in revising the landform to achieve long term stable landforms across the Southern Extension Area and the remaining areas of the Invincible Open Cut disturbance area yet to be fully rehabilitated. The following sections discuss different options regarding possible landforms and evaluate the merits and disadvantages of each of the potential rehabilitation options, including the avoidance of mining of steeper slopes as requested by DP&E.

As detailed further below avoidance of mining of areas of the Southern Extension Area have been previously evaluated in response to previous issues raised by DP&E (refer to Additional Information Response dated 10 May 2017). This assessment clearly indicated that there would be a substantial impact on the volume of target nut coal, and other coal resources, within the Southern Extension Area which impacts the viability of the Southern Extension Project. As detailed in this additional information response, and extensively throughout the EA and previous Response to Submissions reports, the Southern Extension Project has been designed to avoid (where possible) and to incorporate measures to minimise and mitigate potential environmental impacts; this design has considered issues raised regarding previously proposed more extensive mining proposals at Invincible. Notwithstanding, the option of avoiding mining on existing steeper slope areas in the Southern Extension Area (which would require a more extensive area of exclusion of mining than contemplated in the 10 May 2017 Additional Information Response) has been evaluated in accordance with the DP&E request.

2.1 Final Landform Options Considered

Following discussions with the DP&E, three final landform options for the Southern Extension Area have been considered in addition to the Conceptual Final Landform as proposed in the EA.

EA Landform Conceptual Final Landform based on reinstating the pre-mining landform. This landform is shown in **Figure 1.1**.

Option 1 This is the EA Conceptual Final Landform with landforms developed to reduce slope gradients on the eastern side of the Southern Extension Area through the use of surplus overburden from the Southern Extension Project (refer to **Section 1.3**). The landform in the south and west of the Southern Extension area will be reinstated to a landform similar to the pre- mining landform. This option is shown in **Figure 2.1**.

Option 2 As per Option 1 however the rehabilitation of the southern ridge area would incorporate a 15-20 m high cliff line feature in the final landform which would be created through the retention of a section of highwall in this area. The inclusion of a cliff feature will reduce the vertical height of the slopes in to the east and south of this ridgeline which also results in these slopes having a reduced gradient.

The cliff feature is developed through retention of an upper section of the highwall in the final landform; this option does not result in any void being retained. The cliff line would be similar in height to canopy height for the proposed rehabilitation vegetation, meaning the mature rehabilitation vegetation will largely screen the cliff line. This option is shown in **Figure 2.2**.

Option 3a As per Option 1 but with mining of steeper sections of the southern-most ridge avoided. Due to constraints associated with mining in a constrained pit shell, avoiding mining in this area would also limit the efficacy of mining the area immediately south of the steep slope, resulting in the sterilisation of coal resources in this area. This Option is shown in **Figure 2.3**.

Option 3b As per Option 3a but mining of the steeper sections of both the northern and Southern ridgelines is avoided. Due to the constraints associated with mining the northern section (discussed in Part B of the Response to Submissions Report in relation to incorporating a 300m setback from pagodas and cliff lines), this option would result in the sterilisation of coal resources along the Eastern edge of the Southern Extension Area. This option is shown in **Figure 2.3**.

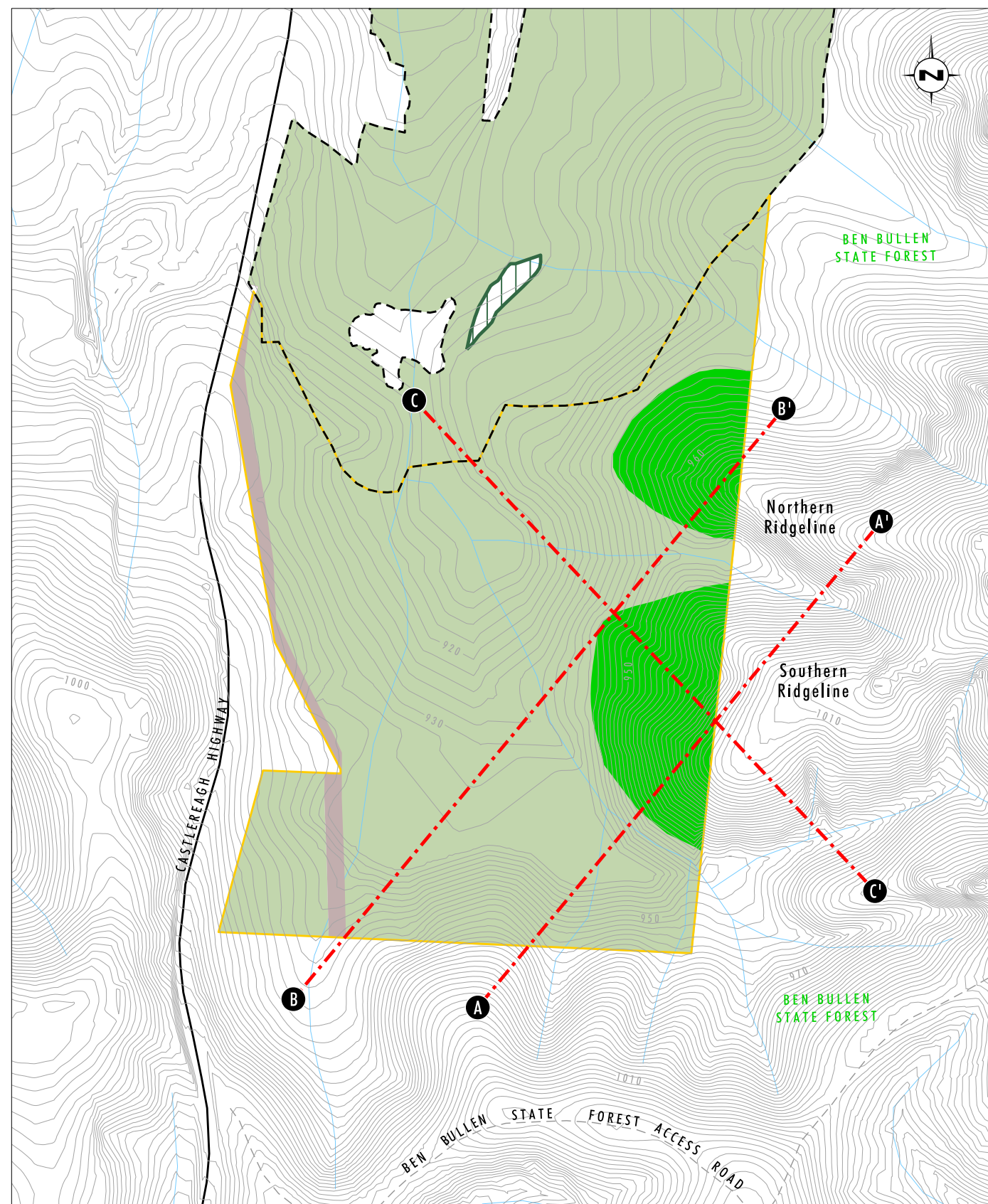
The slope gradients associated with each of the rehabilitated landform options are also shown in **Figures 2.1 to 2.3**.

Figures 2.4, 2.5 and 2.6 show landform cross sections for each option through the steeper sections of the northern and southern ridgelines in the Southern Extension Area. The sections from the EA Conceptual Final Landform (which are the same as the Pre-mining landform) are shown for reference.

As can be seen from **Figure 1.2** the slopes in the EA Conceptual Final Landform range up to 20° to 25° in places on the southern side of the northern ridgeline and the northern face of the southern ridgeline. The southern slope of the southern ridgeline includes short sections which exceed 25° however the majority of these slopes are less than 25° in slope. The slope length (top to bottom – ground length) in the steepest section of the northern ridgeline is less than 50 metres while the slope length on the northern and southern sections are each approximately 100m in length. The gradient of these slopes is consistent with those in the immediate area with many areas immediately east being significantly steeper than the conceptual final landform within the Southern Extension Area (refer to **Figure 1.2**). As noted earlier, these slopes represent the existing (pre-mining) slope gradient in these areas.

As discussed in **Section 1.3**, there is approximately 0.4 Mm³ of overburden available to modify the EA Conceptual Final Landform to create a safe and stable landform and reduce the gradients of the northern and southern ridgeline areas. Consistent with current regulatory practice, this modification always contemplated the detail regarding the final landform being developed as part of the detailed MOP approval process for the Southern Extension Project under the *Mining Act 1992*. Option 1 reflects the landform likely to have been developed as part of this detailed MOP rehabilitation planning process.

Option 2 reflects a variation of this utilising a retained cliff line feature similar to that found in the surrounding landform (there is a similar sized natural cliff line (refer to **Plate 2.1**) located approximately 200m east of the Southern Extension Area (refer to **Figure 2.2**) which is lower in the landform than the proposed cliff line ; there are also numerous cliff lines in the surrounding area associated with pagoda formations or escarpment features. As can be seen from **Figures 2.2 and 2.4**, the retention of the cliff feature in the final landform for Option 2 allows the slopes in the rehabilitated landform below the cliff line to be reduced below 20°. The slopes created in Options 1 and 2 in the eastern parts of the Southern Extension Area are less than occurred in the pre-mining landform or occur immediately adjacent to the areas but the slopes remain similar to those in the southern and western parts of the Southern Extension Area and the north-facing slope of the northern ridgeline.



Note: Contour Interval 2m

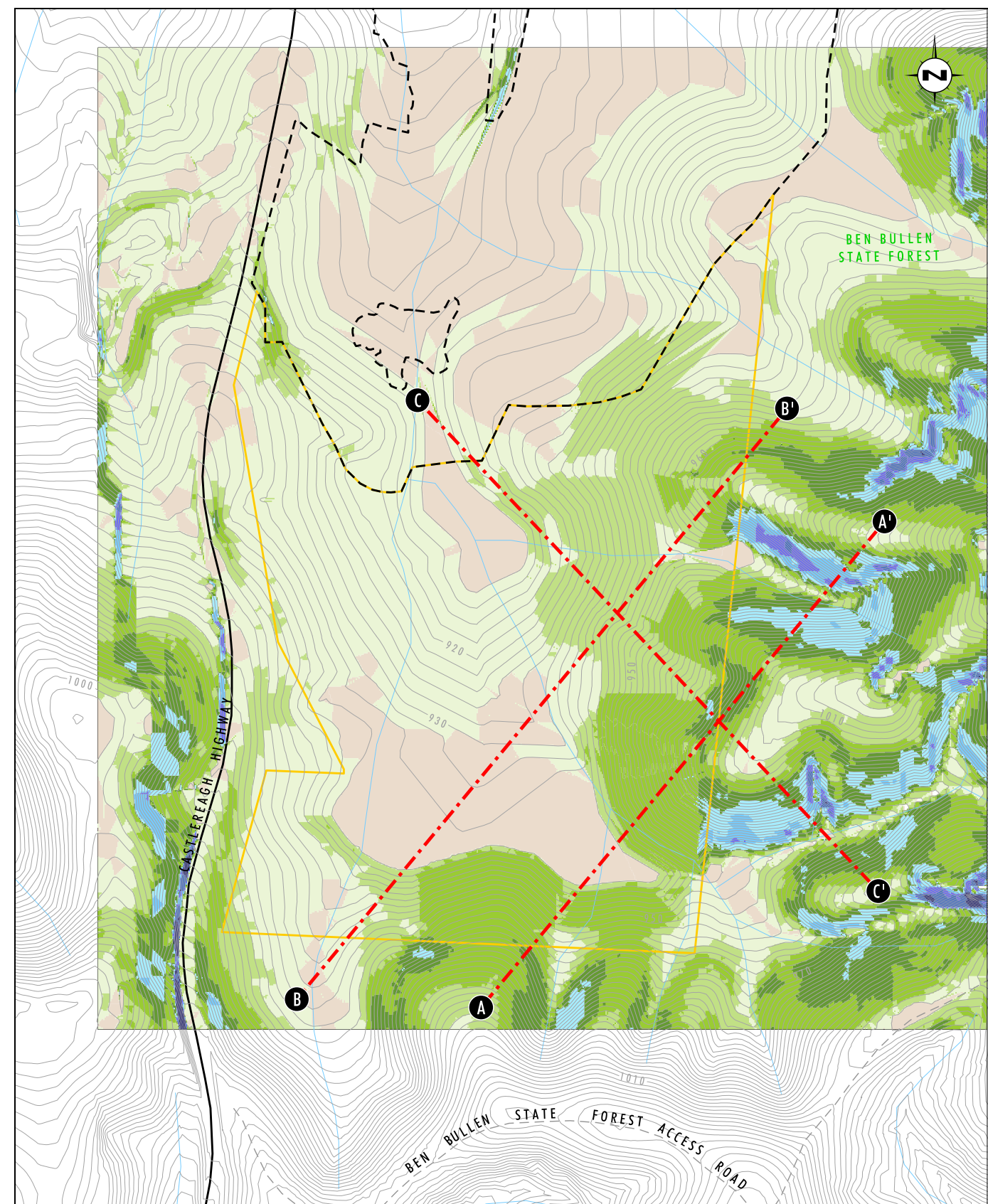
Legend

- Existing Approved Mining Disturbance Area
- Proposed Southern Extension Area
- Tableland Gully Mountain Gum Broad Leaved Peppermint Grassy Forest
- Exposed Blue Mountains Sydney Peppermint - Silvertop Ash Shrubby Woodland
- Grassed Powerline Easement
- 2012 Established Rehabilitation

--- Section Location

- Range 0.00 - 5.00
- Range 5.00 - 10.00
- Range 10.00 - 15.00
- Range 15.00 - 20.00
- Range 20.00 - 25.00
- Range 25.00 - 30.00

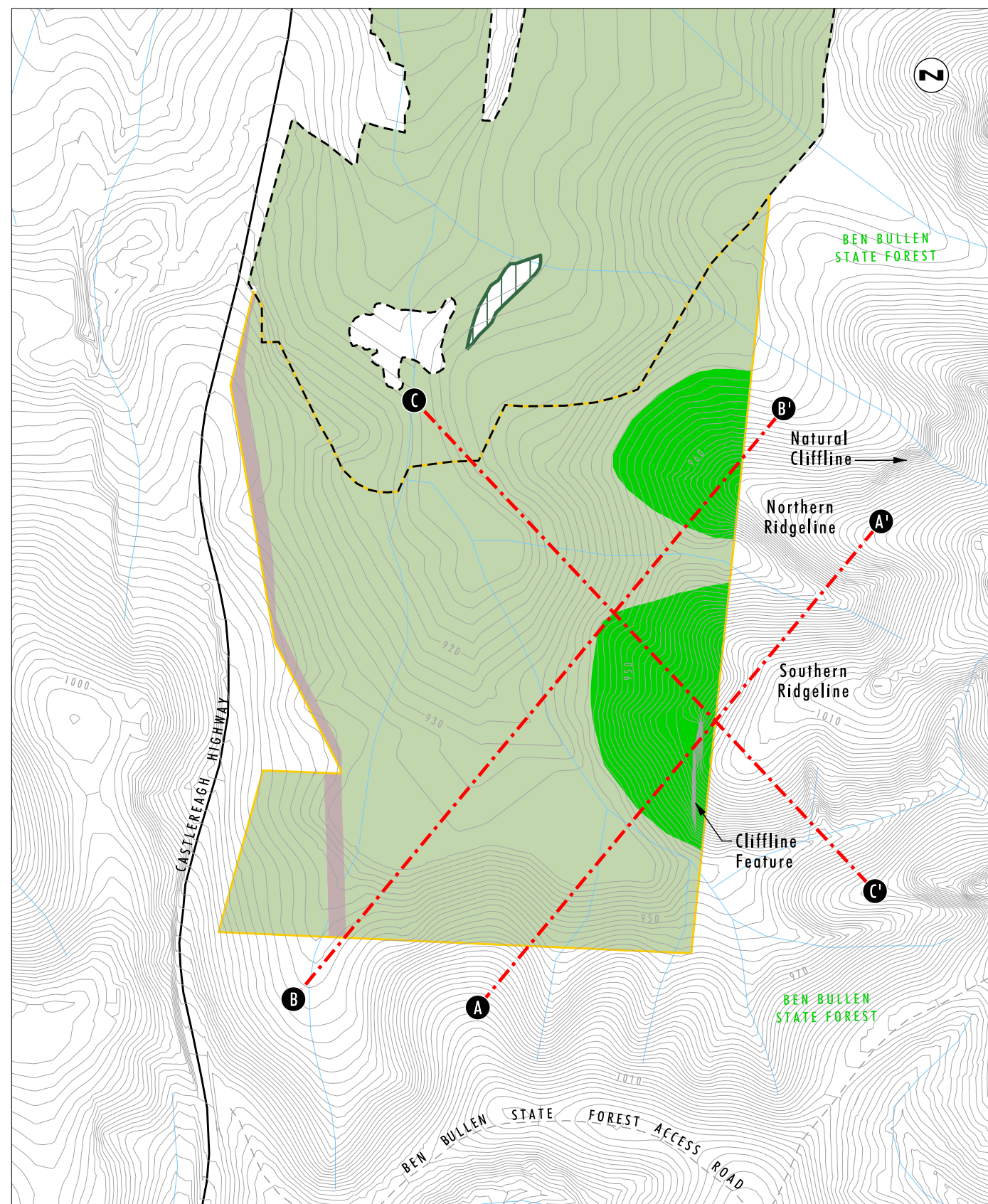
- Range 30.00 - 35.00
- Range 35.00 - 40.00
- Range 40.00 - 45.00



0 100 200 400m
1:7 500

FIGURE 2.1

Conceptual Final Landform
Option 1: Reduced Slope Treatment



Note: Contour Interval 2m

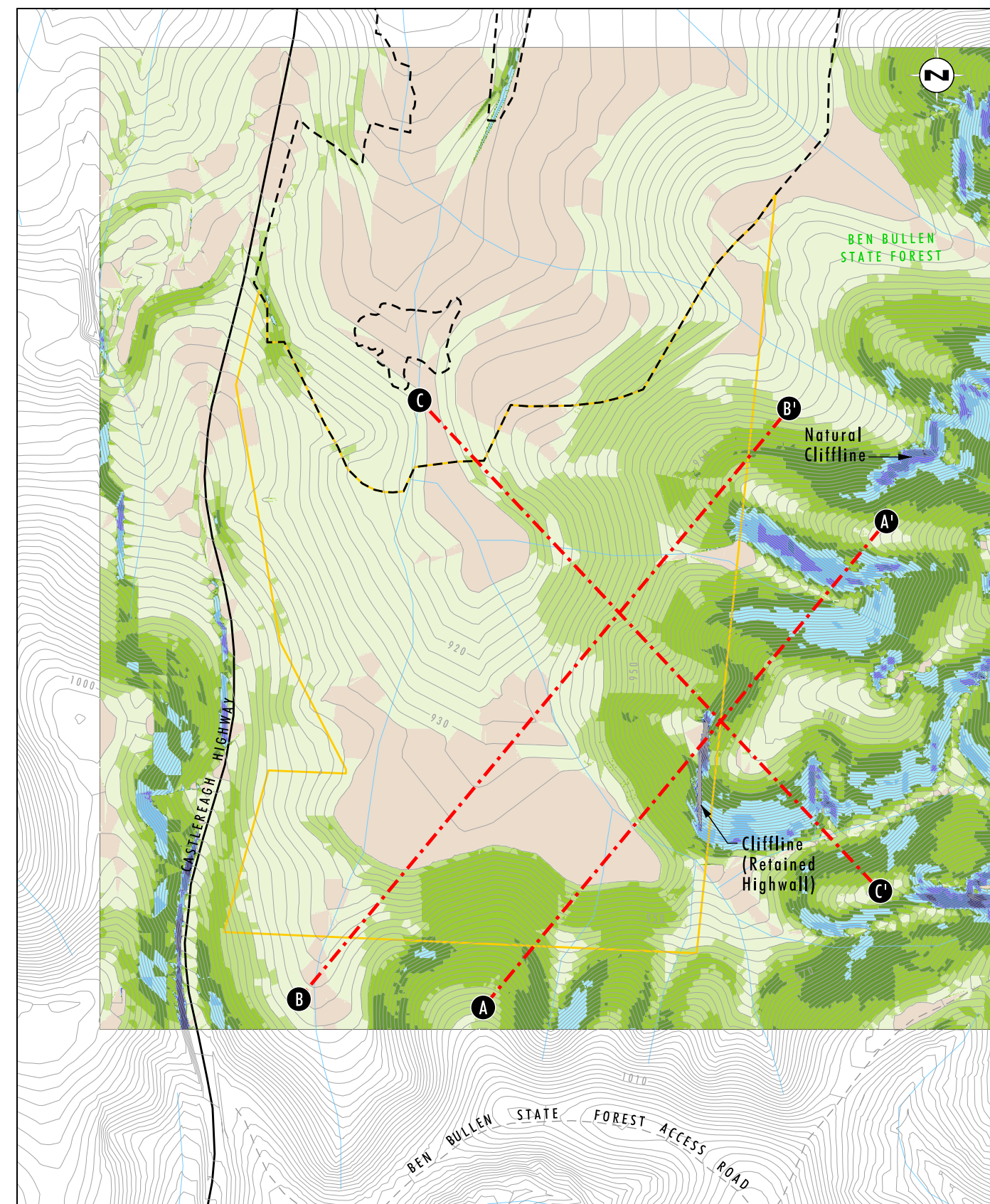
Legend

- Existing Approved Mining Disturbance Area
- Proposed Southern Extension Area
- Tableland Gully Mountain Gum Broad Leaved Peppermint Grassy Forest
- Exposed Blue Mountains Sydney Peppermint - Silvertop Ash Shrubby Woodland
- Grassed Powerline Easement
- 2012 Established Rehabilitation

Section Location

- Range 0.00 - 5.00
- Range 5.00 - 10.00
- Range 10.00 - 15.00
- Range 15.00 - 20.00
- Range 20.00 - 25.00
- Range 25.00 - 30.00

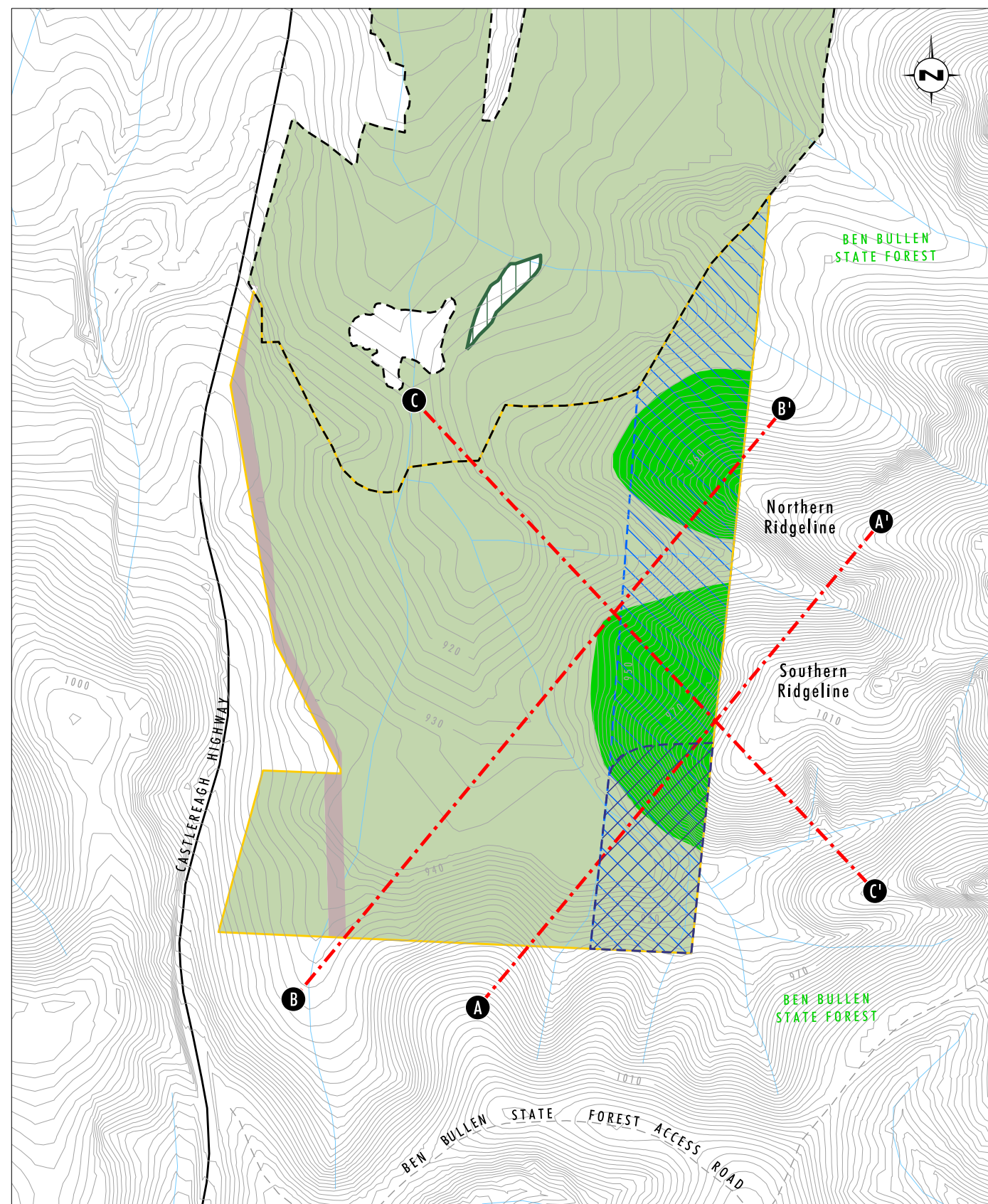
- Range 30.00 - 35.00
- Range 35.00 - 40.00
- Range 40.00 - 45.00



0 100 200 400m
1:7 500

FIGURE 2.2

Conceptual Final Landform
Option 2: Reduced Slope Treatment with Cliff Line Feature



Note: Contour Interval 2m

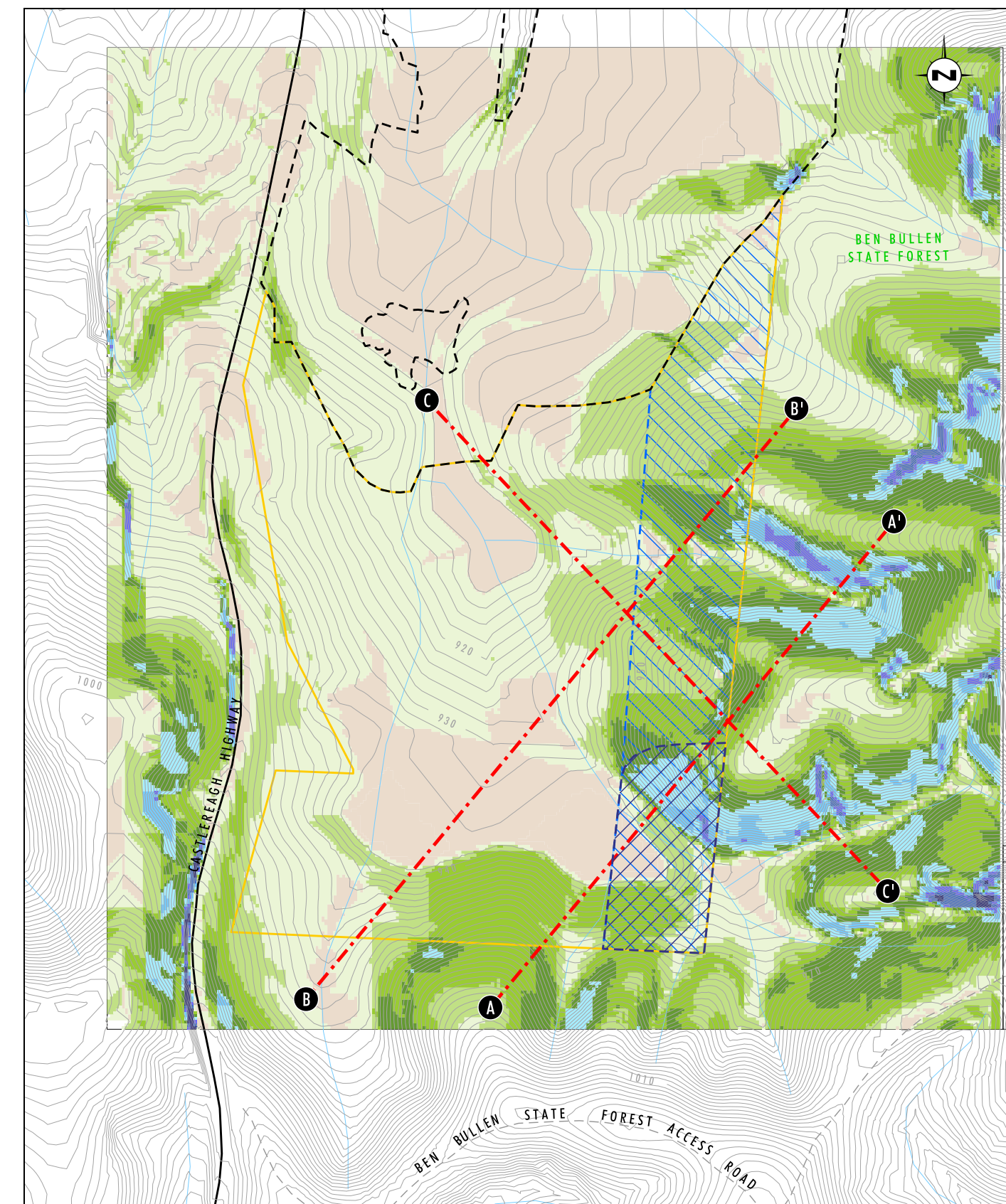
Legend

- Existing Approved Mining Disturbance Area
- Proposed Southern Extension Area
- Tableland Gully Mountain Gum Broad Leaved Peppermint Grassy Forest
- Exposed Blue Mountains Sydney Peppermint - Silvertop Ash Shrubby Woodland
- Grassed Powerline Easement
- 2012 Established Rehabilitation

- Un-mined Area Option 3a
- Un-mined Area Option 3b
- Section Location

- Range 0.00 - 5.00
- Range 5.00 - 10.00
- Range 10.00 - 15.00
- Range 15.00 - 20.00
- Range 20.00 - 25.00
- Range 25.00 - 30.00

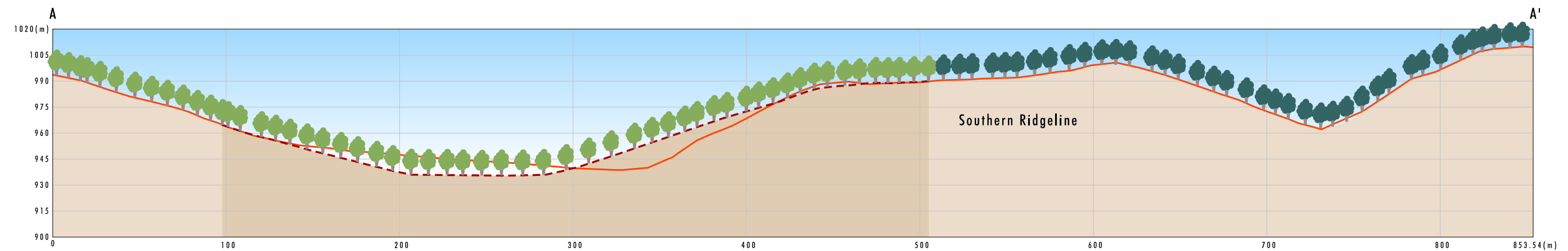
- Range 30.00 - 35.00
- Range 35.00 - 40.00
- Range 40.00 - 45.00



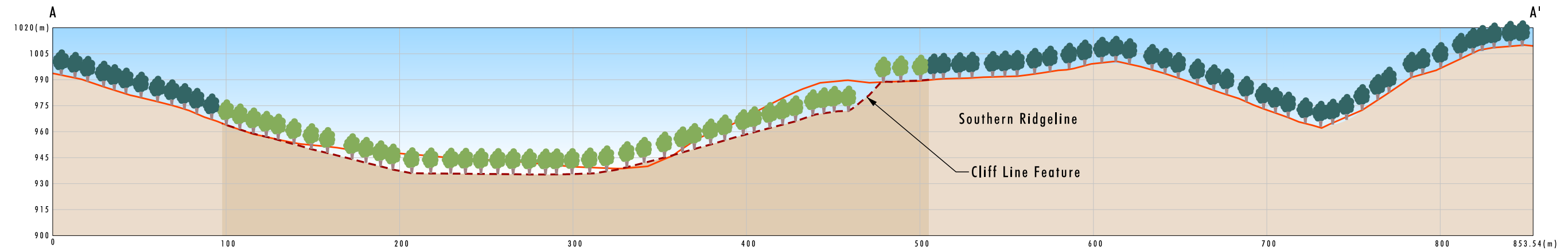
0 100 200 400m
1:7 500

FIGURE 2.3

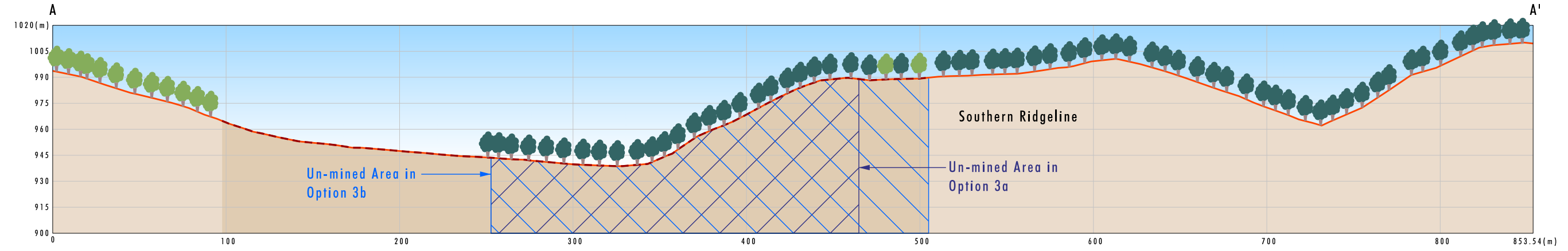
Conceptual Final Landform
Options 3a and 3b: Reduced Mining Options



Section A-A' Option 1
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Section A-A' Option 2
1(H):1(V)

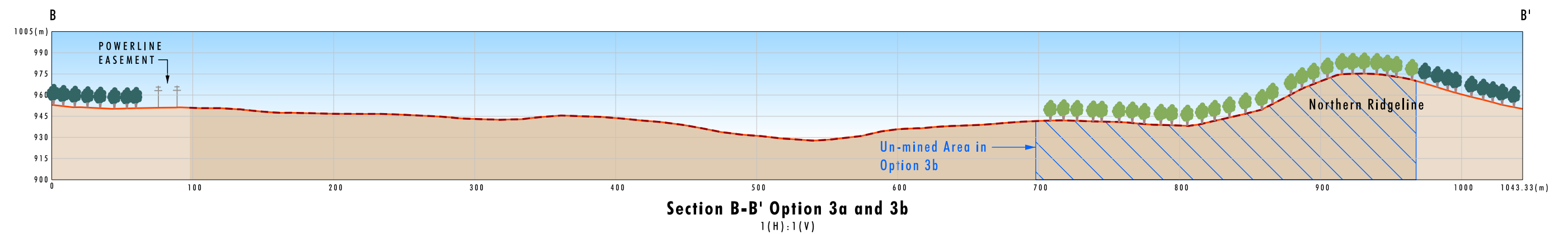
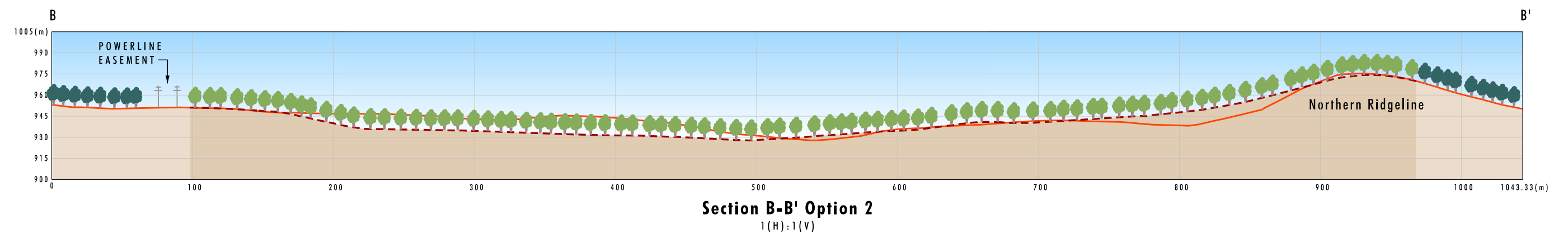
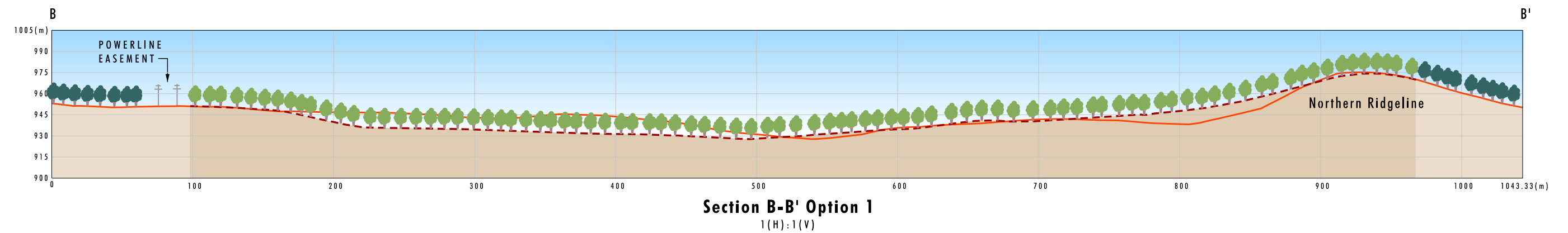


Section A-A' Option 3a and 3b
1(H):1(V)

- Legend**
- Existing Surface/EA Conceptual Final Landform
 - - - Proposed Surface
 - Existing Vegetation
 - Rehabilitated Vegetation
 - ▨ Un-mined Area Option 3a
 - ▩ Un-mined Area Option 3b

0 25 50 100m
1:2500

FIGURE 2.4
Comparison of Landform Options
Section A-A'

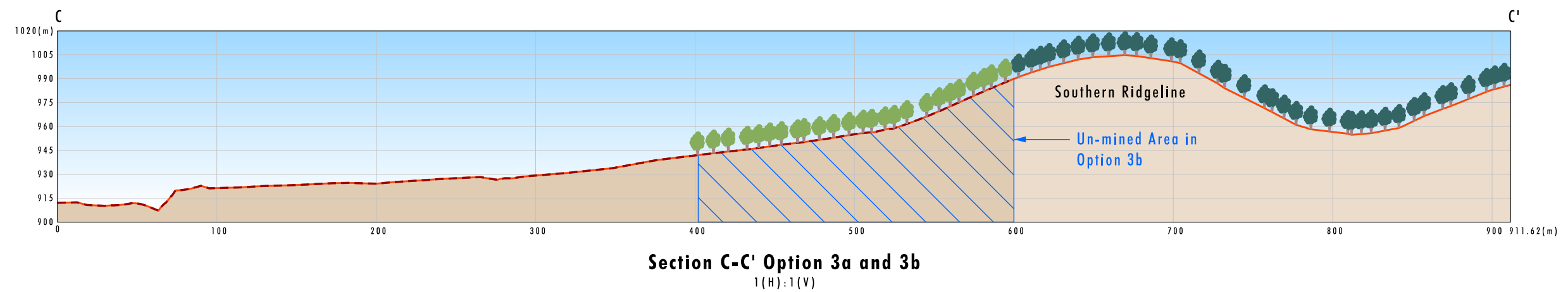
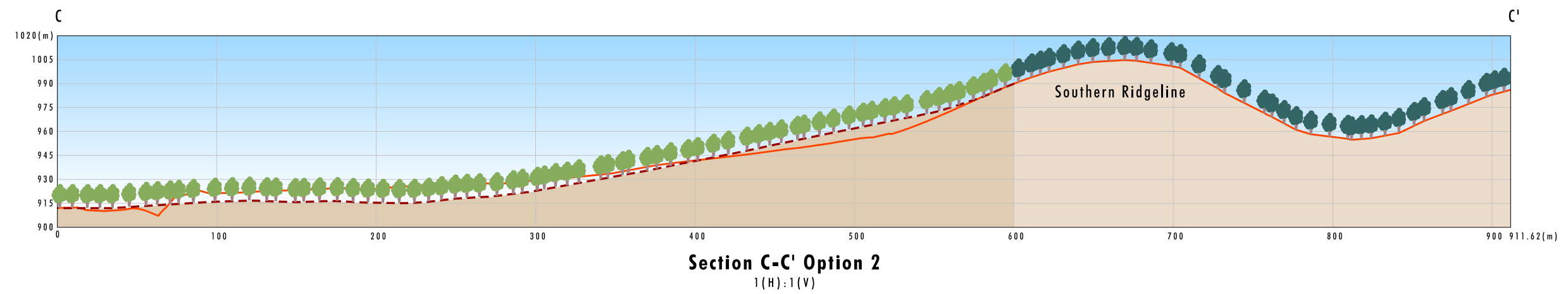
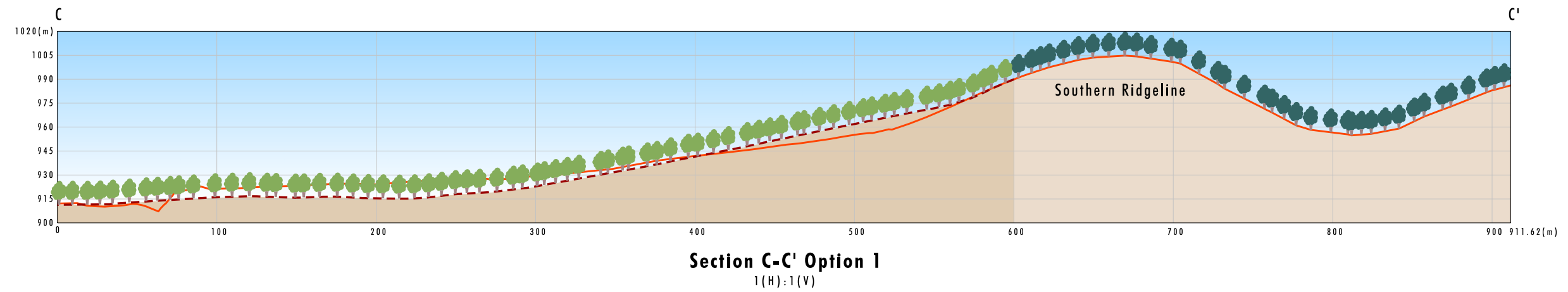


Legend

- Existing Surface/EA Conceptual Final Landform
- - - Proposed Surface
- Existing Vegetation
- Rehabilitated Vegetation
- ▨ Un-mined Area Option 3b

0 50 100 150m
1:3000

FIGURE 2.5
Comparison of Landform Options
Section B-B'



Legend

- Existing Surface/EA Conceptual Final Landform
- - - Proposed Surface
- Existing Vegetation
- Rehabilitated Vegetation
- ▨ Un-mined Area Option 3b

0 50 100 150m
1:3000

FIGURE 2.6
Comparison of Landform Options
Section C-C'



Plate 2.1 Natural cliff line to east of Southern Extension Area

Figure 2.3 identifies the areas that would need to be sterilised if the parts of the Southern Extension Area with natural slopes in excess of 20° are not mined (Options 3a and 3b). While the non-mining of these areas would avoid the need to rehabilitate steep slopes in the final landform, as is shown in Options 1 and 2, similar outcomes can be achieved through improved slope design without and impacts on resource recovery. As discussed in 10 May 2017 Additional Information Response), these non-mining options also come at the cost of reduced overburden volumes which poses constraints for the filling of the final voids associated with past mining at Invincible.

2.2 Differences to Rehabilitation in West Pit

Figure 1.5 shows the slope gradients for the West Pit area. The slopes in the steepest areas of the West Pit Area where there have been difficulties with rehabilitation include slopes of in excess of 35° in places. Slope lengths are limited to up to 140-150 metres. **Figure 1.4** shows cross sections of the rehabilitated areas within the West Pit area. Despite the steep slopes in the West Pit area, there has been limited erosion of these areas due to both the installation of contour drains and a catch drain above the rehabilitated areas which directs run-off from up slope away from the rehabilitated area (refer to **Figures 1.3** and **1.4**). As discussed in **Section 1.1**, the difficulties associated with rehabilitating the West Pit areas is largely associated with the inability to effectively spread topsoil across the steeper slopes. These difficulties were associated with the limitations posed by the terrain immediately uphill and downslope from the mined area (refer to **Figure 1.3**) which prevented different landform designs which could have reduced the slopes in the rehabilitated areas. Revegetation outcomes were also hindered through the limitations on spreading topsoil and logs and rocks across the final landform in steeper areas.

The EA Conceptual Landform is also shown for comparison purposes on each of the sections for Options 1, 2 and 3 in **Figures 2.4 to 2.6**. As can be seen by comparing **Figures 1.2 and 1.3**, with **Figures 2.1 and 2.2**, the slopes created in the Option 1 and 2 final landforms are significantly less steep than the landform created in the rehabilitation of the West Pit and the existing slopes in the Southern Extension Area (as reflected in the EA Conceptual Final Landform).

The rehabilitation of the areas of higher slopes associated with the ridgelines in the Southern Extension Area are not limited by the same practical difficulties that applied to the West Pit area. The areas to be rehabilitated in both the northern and southern ridgelines include both the upper slope and ridge cap itself as well as foot-slopes and flatter gully areas below the steeper slope sections. The additional area above and below the slope sections enable the emplacement of additional overburden material in the foot slope areas which enables the overall slope gradient to be reduced. The effect of this is shown in the Option 1 and 2 landform sections shown in **Figures 2.4 to 2.6**. The ability to emplace material below the slope and reduce slope gradients was not available for the West Pit area.

The availability of flat areas at the top and the bottom of the slope also provides greater flexibility for dozer movement up and down the slope than was available in the steepest areas of the West Pit. The reduced slopes in Option 1 and 2 also enable dozer movement across the slope which enables greater control over the construction of drainage structures. This flexibility also enables topsoil to be spread more effectively across the steeper sections.

The steep slope (greater than 20°) areas in the EA Conceptual Final Landform for both the northern and southern ridgelines in the Southern Extension Area are significantly smaller in size than the West Pit area. The most prominent steep slope area in West Pit covers an area of approximately 6 to 7 hectares; whereas in the Southern Extension Area these areas range from less than 0.5 hectares to approximately 1.1 hectares. The largest of these areas is the southern face of the southern ridgeline. Additionally, the steeper slope areas in the Southern Extension Area have little to no upslope catchment. These differences are significant in terms of rehabilitation outcomes as the reduced surface area means reduced run-off potential and therefore lower erosion risk. These small areas are also more practicable to target for specific rehabilitation treatment to manage erosion risks such as hydro-mulching.

Coupled with the overall lower gradients, the steeper slope areas in the Southern Extension Area EA Conceptual Landform are significantly easier to manage from a rehabilitation perspective than was the case for the West Pit. Notwithstanding the small sections of slope greater than 25°, the EA Conceptual Final Landform is able to be successfully rehabilitated even with the steep slopes retained due to the relatively smaller areas of steep slope and the availability of the flat areas above and below these slopes which would facilitate dozer movement up and down the slope.

2.3 Comparison of Options

Table 2.1 compares the different options being evaluated in relation to the key matters raised by DP&E including slope, opportunities to further improve the landform, resource recovery and visual impact.

Table 2.1 Comparison of Options

Option	Maximum slope in rehabilitated areas	Total Area > 20° (Ha)	Opportunities to further improve slope in detailed design phase	Consistent with surrounding landform	Impact on resource recovery of proposed Southern Extension Project	Impact on financial Viability of the Project	Visibility of areas with slopes > 15°	Comments
EA Conceptual Landform	30-35° in parts of south facing slope on southern ridgeline. Up to 25° in small sections on south facing slope on northern ridgeline and northern part of southern ridgeline.	Approx. 2.5 hectares	Yes. Opportunities to increase slope length and reduce gradient in all steep areas through final landform design and use of surplus overburden. Areas where this could be utilised include the southern face of the northern ridgeline, northern parts southern ridgeline and southern face of southern ridgeline.	Yes. Conceptual Final Landform is similar to existing terrain (refer to Figure 2.4). 'Tie-in' areas adjacent to steep slopes have gradients in excess of that proposed in final landform.	Nil	Nil. As per Economic Assessment in EA.	Southern facing slopes not visible from Castlereagh Highway. Would be visible from Ben Bullen State Forest Access Road where powerline easement crosses road. Limited visibility of upper slope of northern face of southern ridgeline from Castlereagh Highway at distance of approximately 2.7 kilometres (refer to visual montage in Figure 6.33 of the EA).	The Conceptual Final Landform would return the landform in the Southern Extension Area consistent with the pre mining landform. While the steeper slopes retained in the landform would present technical challenges for rehabilitation, there are no significant practical issues limiting the rehabilitation of these areas and outcomes similar to that experienced in the West Pit area would not be expected.
Option 1 Revised Conceptual Final Landform.	<20°	Nil	Incorporated into revised Conceptual Final Landform Design and further detailed as part of the MOP process.	Yes. Conceptual Final Landform is similar to existing terrain (refer to Figure 2.4). 'Tie-in' areas adjacent to steep slopes have gradients in excess of that proposed in final landform.	Nil	Nil. As per Economic Assessment in EA. The different final landform will have little to no impact on the cost of undertaking the Southern Extension Project as it can be achieved through use of overburden from the Southern Extension Area.	Rehabilitated areas would be visible from the Castlereagh Highway however the reduced slopes in the southern ridgelines would mean that much of the rehabilitated southern ridgeline would be obscured by the northern ridgeline from vehicles traveling south on the Castlereagh Highway	Together with Option 2, represent an option that addresses the issues raised by DP&E in relation to the EA conceptual final landform whilst avoiding impacts on resource recovery. Consistent with EA Conceptual final landform, Option 1 also ensures final landform can be rehabilitated across the entire project site without disturbance of existing rehabilitation areas.

Option	Maximum slope in rehabilitated areas	Total Area > 20° (Ha)	Opportunities to further improve slope in detailed design phase	Consistent with surrounding landform	Impact on resource recovery of proposed Southern Extension Project	Impact on financial Viability of the Project	Visibility of areas with slopes > 15°	Comments
Option 2 – Revised Conceptual Final Landform with cliff line feature	<20° + small cliff line	Cliff line only	Yes. Incorporated into revised Conceptual Final Landform Design and further detailed as part of the MOP process.	Yes. Conceptual Final Landform is similar to existing terrain (refer to Figure 2.5). Slopes in rehabilitated landform are similar to pre-mining slopes in southern and western parts of Southern Extension Area. 'Tie-in' areas have gradients in excess of that proposed in final landform. Cliff line feature is similar to the cliff line present to the northeast of the Northern Ridgeline (refer to Plate 2.1). Cliff lines are prevalent in the local area.	Nil	Nil to slightly positive. Any changes are unlikely to be noticeable in overall project financials	Southern facing slopes not visible from Castlereagh Highway. Southern slope on northern ridge and cliff line would be visible from Ben Bullen State Forest Access Road where powerline easement crosses road (refer to Figure 2.3), however this is not inconsistent with other features to the east Limited visibility of upper slope of northern face of southern ridgeline from Castlereagh highway at distance of approximately 2.7 kilometres. Upper section of cliff line feature will be visible from Castlereagh Highway at a distance of approximately 2.7 kilometres. As the cliff line is between 15 and 20 metres in height, views of the cliff line will be ultimately screened by vegetation growing below the cliff line similar to that which occurs at the cliff line shown in Plate 2.1 .	As with Option 1,

Option	Maximum slope in rehabilitated areas	Total Area > 20° (Ha)	Opportunities to further improve slope in detailed design phase	Consistent with surrounding landform	Impact on resource recovery of proposed Southern Extension Project	Impact on financial Viability of the Project	Visibility of areas with slopes > 15°	Comments
3a	20-25° Southern facing slope in northern ridgeline	Approx. 1 ha.	Limited. Non-mining of eastern sections of Southern Extension Area reduces stripping ratios and reduces the volume of overburden available for landscaping.	Yes. Conceptual Final Landform is similar to existing terrain (refer to Figure 2.4). 'Tie-in' areas adjacent to steep slopes have gradients in excess of that proposed in final landform.	Not mining the steeper south-facing slope of the southern ridgeline is likely to constrain mining in the south eastern corner of the Southern Extension Area. This would result in the sterilisation of resources in the approximately 5 hectare shaded area shown in Figure 2.2 . Estimated loss of between 10 and 20kt Nut coal Estimated loss of thermal coal of approximately 100 to 160kt.	The reduction in coal recovery will have significant flow-on effects for Shoalhaven Starches.	Areas not mined under this option are not visible from the Castlereagh highway. Southern facing slope of northern ridgeline not visible from Castlereagh Highway. Would be visible from Ben Bullen State Forest Access Road where powerline easement crosses road. Limited visibility of upper slope of northern face of southern ridgeline from Castlereagh highway at distance of approximately 2.7 kilometres.	Reduced mining area represents a substantial reduced economic benefit for Shoalhaven Starches and reduced economic benefits for the State and local region.
3b	<20°	Nil.	Limited. Non-mining of eastern sections of Southern Extension Area reduces stripping ratios and significantly reduces the volume of overburden available. Northern and Eastern Voids in existing open cut area will have greater reliance on dozer push and disturbance of existing rehabilitated areas to remove voids.	Yes. Conceptual Final Landform for areas outside the non-mining area are as per the pre mining landform.	Avoiding mining the steeper sections of the Northern Ridgeline would also result in sterilisation of coal north of the Northern Ridgeline due to mining constraints. This Option would sterilise more than 30kt of nut coal (product) and over 250kt of thermal coal.	The reduction in coal recovery will have significant flow-on effects for Shoalhaven Starches.	Under this option, there would be minimal views of the Southern Extension Project from the Castlereagh Highway. As outlined in the visual assessment presented in the EA, the level of visual impacts associated with the Southern Extension Area are not considered significant.	The impact of this option on resource recovery is more significant than the impacts associated with implementing a 300m setback from all pagodas (discussed in the 10 May 2017 response to DP&E providing additional Assessment Information). The reduced mining area would result in significantly reduced economic benefits for Shoalhaven Starches and reduced economic benefits for the State of in excess of \$6.5 million dollars in NPV terms.

2.4 Discussion

Options 3a and 3b are not considered viable due to the resulting loss in nut coal, and other coal production and the significant impacts this has on the viability of the Southern Extension Project which would be greater than that associated with the incorporation of the 300m exclusion area discussed in the 10 May 2017 Additional Assessment Information. Option 3b in particular would have reduced benefits for the state of in excess of \$6.5 million (in NPV terms). Both of these options also have implications for the successful rehabilitation of the remainder of the Invincible site due to the reduced stripping ratios and volume of overburden available to fill existing voids. As both Options 1 and 2 both result in final landforms that have slopes which address the issues raised by DP&E; in particular avoiding the rehabilitation constraints present in the West Pit area, and enable full extraction of coal resources from within the Southern Extension Area, the benefits afforded by Options 3a and 3b are not considered to outweigh the loss of nut coal resources associated with these non-mining options.

There is little difference between Options 1 and 2 in terms of rehabilitation outcomes with Option 2 resulting in lower slopes in the southern parts of the Southern Extension Area than Option 1 due to the benefits associated with the retained cliff line.

Option 1 achieves the benefits of full resource recovery and acceptable final landform slopes without the retention of a cliff line feature. Relative to Option 2, Option 1 has similar rehabilitation outcomes but will have a larger area with slopes between 15° and 20°. These slope gradients are however similar to slopes in the surrounding landform and similar slopes have been successfully rehabilitated at Invincible in the past. In addition, as detailed in this response the retention of these lower gradients is not expected to present any significant practical limitations to achieving this final landform, particularly when compared to the issues of rehabilitating the existing West Pit area. In this way Option 1 addresses the issues raised by DP&E whilst also retaining resource recovery in the Southern Extension Area. Option 1 is considered to be the preferred final landform option relative to the other options considered due to the full recovery of nut coal resources and overall net public and private benefits.

While Option 2 includes a retained section of the highwall as a cliff line feature, the cliff line would be similar to natural cliff lines in the local area in terms of height and shape. The cliff line would be similar in height to the mature height of vegetation to be recreated in the rehabilitated area below the cliff line meaning views of the cliff itself would be largely obscured in the medium term (approximately 15-20 years). There is no formal policy regarding the retention of highwalls however there has been a general movement away from highwalls being retained in the final landform where possible. While this has merit in most circumstances, the Southern Extension Project is distinguishable from most other mining projects in that the nature of the surrounding environment means cliff lines are not inconsistent with the surrounding terrain. Additionally, the benefits that the retained cliff line provides in terms of slope and landform variability are positive (although noting that this is not essential in terms of rehabilitation success). The design of this cliff line feature means that there is limited visibility of the cliff from highly trafficked areas and the vegetation to be planted below the cliff line will obscure much, or all, of the cliff from view in the medium term. It is also noted that the cliff line is only being proposed in a small section of the final landform and is not a default rehabilitation option proposed for other areas.



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