Transmission Connection Project for Snowy 2.0

Options report

Prepared for TransGrid November 2021

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Snowy 2.0 Shallow Connection

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Options Report

Snowy 2.0 Shallow Connection

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TransGrid

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Executive summary

ES1 Purpose of this report

In May 2020, Snowy Hydro Ltd (Snowy Hydro) obtained approval for Snowy 2.0 which will expand the current Snowy Mountains Hydro-electric Scheme's (Snowy Scheme) renewable energy generating capacity by almost 50%, providing an additional 2,000 megawatts (MW) of capacity to the National Electricity Market (NEM). A new connection is required to connect and provide the full generating capacity of Snowy 2.0 to the broader transmission network and NEM. NSW Electricity Networks Operations Pty Ltd, as a trustee for NSW Electricity Operations Trust (known as TransGrid) is seeking approval for the construction and operation of the Snowy 2.0 Transmission Connection Project (the Project) to enable the grid connection of Snowy 2.0 to the NEM.

In February 2021, TransGrid published an environmental impact statement (EIS) prepared by Jacobs Group (Australia) Pty Ltd (Jacobs) for the Project. The EIS considered the impacts of an approximately 9 kilometre (km), 330 kilovolt (kV), 2 x double circuit overhead connection from the Snowy 2.0 cable yard at Lobs Hole within Kosciuszko National Park (KNP) to a new 330/500 kV substation at Maragle within Bago State Forest. The Project is intended to connect with HumeLink, a separate 500 kV transmission connection, at Maragle to further enable the full 2,000 MW from Snowy 2.0 to enter the NEM.

Following exhibition of the EIS, and in response to submissions received, the NSW Department of Planning, Industry and Environment (DPIE) requested that TransGrid prepare an expanded options report, including different connection locations and methods of connecting to the NEM. EMM Consulting Pty Ltd (EMM) was subsequently engaged to prepare this Options Report.

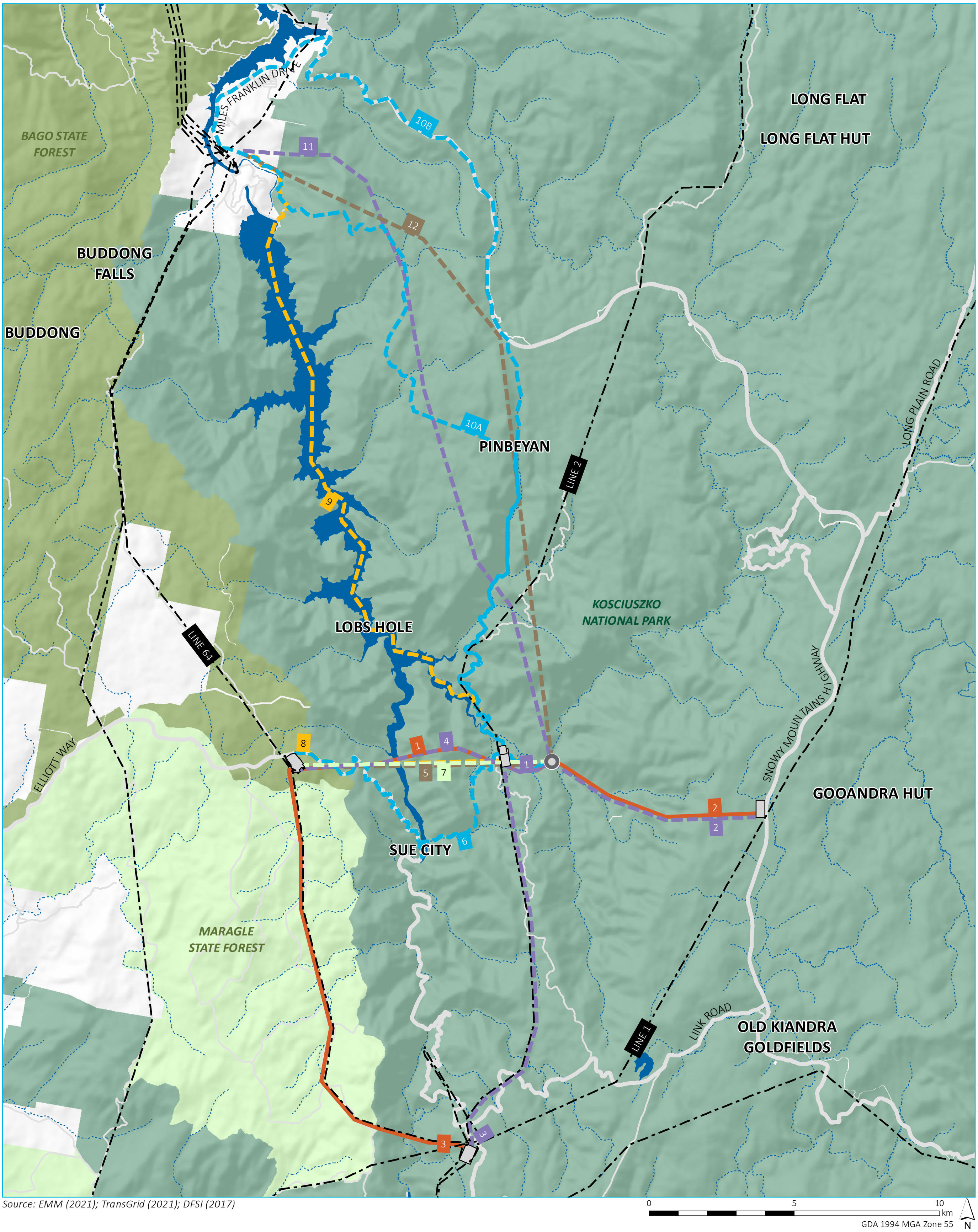
To inform the Options Report, and through engagement with Snowy Hydro, TransGrid has derived 12 options (refer to Figure ES1) to be assessed from investigations and studies carried out to inform Project development since its inception in 2017. Two engineering studies were also commissioned to further inform the analysis of the selected options.

Preparation of the Options Report was undertaken in consultation with DPIE and NSW National Parks and Wildlife Services (NPWS) encompassing several progress update meetings and separate information request deliverables.

ES2 Project and network requirements

The key aim of the Project is to transmit the 2,000 MW of power generated from Snowy 2.0 into the NEM so that it can be distributed effectively and efficiently to consumers. The point of transfer/connection between generation and transmission for this Project will be the Snowy 2.0 cable yard at Lobs Hole within KNP. When full Snowy 2.0 generation capacity is available it will increase the 'Tumut' locality generation density in excess of 4,000 MW. This is an increased concentration of power that needs to be managed appropriately through a risk-based approach to transmission development to maintain and improve system resilience and security, which can be achieved through the design of the connection of Snowy 2.0 to the NEM.

There are significant existing binding transmission constraint points both north and south of the Snowy Scheme even without the addition of Snowy 2.0 capacity. Maragle was chosen as the Snowy 2.0 HumeLink connection point as it is remote from other substations/switching stations that connect the existing Snowy Scheme generation and Victorian interconnector meaning that risks are reduced due to geographical separation and allows for greater control of power flows. To integrate the Snowy 2.0/HumeLink connection point with the existing Upper Tumut Switching Station (UTSS) or Lower Tumut Switching Station (LTSS), or southern NSW 330 kV lines (ie Line 2) would reduce system resilience gained though geographical diversity achieved by locating the Snowy 2.0 connection point



Source: EMM (2021); TransGrid (2021); DFSI (2017)

KEY

- Snowy 2.0 cable yard
- HumeLink options
- Substation footprint

Transmission connection options (by method)

- Overhead
- Deep cable
- Trench
- HDD
- Hybrid

- Existing electricity transmission line
- Major road
- Minor road
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest

Transmission connection options

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure ES.1

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\\emmsvr1\EMM3\2021\J210539 - Snowy 2.0 Shallow Connection Options Report\GIS\02_Maps\TCOR\TCOR017_OptionMethods_20210916_02.mxd 16/09/2021 at Maragle, and expose five key energy assets (Snowy 2.0, HumeLink, Southern NSW 330 kV network, Victoria to NSW Interconnector (VNI) and existing Snowy Hydro Scheme) to bushfire and extreme weather events at specific locations.

Given the criticality of the power generation from Snowy 2.0 to the stability, energy security and reliability for the NEM, as demonstrated through the Critical State Significant Infrastructure (CSSI) declaration of Snowy 2.0, including this Project, a key transmission connection design objective is to minimise the risk of losing the ability to transmit this power to consumers. Electricity network reliability standards govern how network infrastructure is designed, built and operated to avoid or manage interruptions to electricity supply which includes damage to network infrastructure. The level of redundancy specifies the number of backup arrangements (either 1, 2, or 3) that must be in place to support continued supply of electricity in the event that part of the transmission network fails. The redundancy requirement for Snowy 2.0 connection assets is n-1, referring to one back-up arrangement that must be in place.

Construction options for transmission lines include:

- overhead transmission lines;
- cables within tunnels;
- cables within trenches;
- submarine cables; and
- a combination of the above.

Each of these construction options have different design, construction, maintenance and safety requirements that mean that they are suited to particular terrain and environmental conditions.

KNP is one of Australia's sub-alpine national parks and also represents one of the most complex conservation reserves in Australia. The existing Snowy Scheme and assets have long been part of the KNP landscape and are a key feature in park recreation and visitation. There has been approximately 65 years of continuous operation since construction, with sustained water and environmental management allowing the Snowy Scheme's assets to operate within the natural and recreational areas of KNP. Several threatened ecological communities and populations are found in proximity to the area where Snowy 2.0 is being constructed. Impacts to biodiversity was a key assessment and regulatory matter for the Snowy 2.0 Main Works project. Consistent with the Snowy 2.0 Main Works project, minimisation of impacts to KNP and its values is a key project objective.

ES3 Project objectives and evaluation criteria

The method of option analysis undertaken included the identification of the Project's objectives, in consideration of the network and Project requirements, and development of Project evaluation criteria for assessment of the Project options.

The Project objectives that have been reviewed for the options analysis are presented in Figure ES2.

Figure ES3 presents the evaluation criteria that have been reviewed for the options analysis based on the Project objectives. The criteria are separated into three categories: technical; environment and planning; and safety. Criteria have also been separated into sub-categories where applicable.

PROJECT OBJECTIVES

- Provide a connection for renewable electricity generated by Snowy 2.0 (Critical State Significant Infrastructure) to the existing and future National Electricity Market (NEM).
- Provide a connection point to the NEM which facilitates the future reinforcement of the NSW Southern Shared Network, a priority project identified by the Australian Energy Market Operator (AEMO) and the Federal and NSW governments.
- Establish a point of connection to the NEM which increases the reliability, resilience and security of the future renewable power supply network to deliver affordable, safe and secure renewable energy across the NEM and to ACT and NSW electricity consumers.
- Provide a connection that minimises additional infrastructure within Kosciuszko National Park.
- Provides a connection that minimises environmental and socials impacts, particularly to the Kosciuszko National Park.
- Design, construct and operate the connection in a manner that is practicable and feasible and balances environmental and social impacts with safety impacts, cost and schedule.
- Provides a high level of safety for workers and the public during its construction and operation.
- Provides a connection that can be constructed and operational by the time renewable electricity is being generated by Snowy 2.0.

Figure ES2 Project objectives

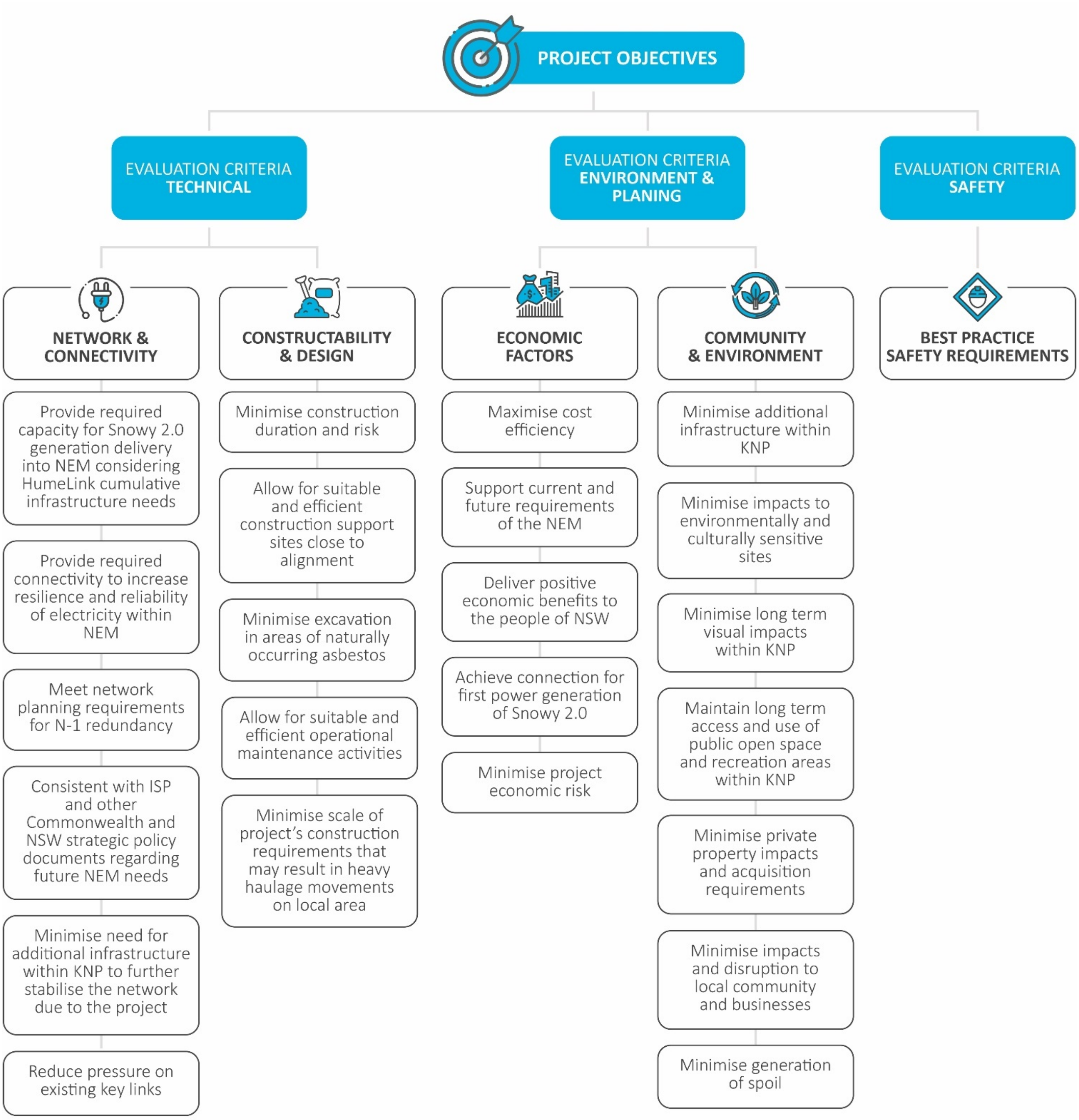

Figure ES3 Evaluation criteria

ES4 Option development and evaluation

The 12 options developed for the Project are shown in Figure ES1 and include:

- Option 1 – Overhead to Line 2;
- Option 2 – Overhead to Line 1;
- Option 3 – Overhead to UTSS;
- Option 4 – Overhead to Line 64 (the base case which is currently the subject of the EIS for the Project);
- Option 5 – Deep cable tunnel to Line 64;
- Option 6 – Trench to Line 64;
- Option 7 – Horizontal directional drilling (HDD) to Line 64;
- Option 8 – Hybrid trench/deep cable tunnel to Line 64;
- Option 9 – Hybrid trench/submarine cable to LTSS;
- Option 10 – Trench to LTSS;
- Option 11 – Overhead to LTSS; and
- Option 12 – Deep cable tunnel to LTSS.

The options are also shown in Table ES1 which shows the matrix of the different connection points to the transmission network and methods of transmission.

Table ES1 Options subject to screening assessment

Connection point	Method of transmission				
	Overhead	**Underground (deep)**	**Trench**	**HDD**	**Hybrid**
West of KNP (Line 64)	Option 4	Option 5	Option 6	Option 7	Option 8 (trench and tunnel)
Within KNP (Line 1 or 2 or UTSS)	Options 1, 2 and 3	-	-	-	-
North of KNP (LTSS)	Option 11	Option 12	Option 10	-	Option 9 (trench and submarine cable)

A screening assessment of the options was undertaken against the Project objectives and evaluation criteria. The results of the screening analysis indicated that eight options did not meet the set objectives and exceeded threshold issues relating to the assessment criteria. These included options that:

- require significant extra assets to be constructed within KNP (Options 1, 2 and 3);
- are not technically viable (Options 7 and 9); and/or
- do not enhance the resilience and reliability of the NEM (Options 10, 11 and 12).

The remaining four options (Options 4, 5, 6, and 8) were proposed to be considered further as part of the detailed assessment.

However, during engagement with DPIE and NPWS post the screening assessment, additional information was requested on Options 3, 5, 6, 8 and 9. As an outcome of these detailed information requests, it was resolved with DPIE and NPWS that Options 5, 6, 8 and 9 would not proceed to a detailed assessment because, primarily, they did not meet the evaluation criteria relating to economic factors. Specifically, they significantly increased the Project's economic risk. Project timeframes and disturbance areas were also a key consideration.

It was therefore resolved that Options 3 and 4 would proceed to the detailed assessment stage for selection of a preferred option for the Project.

ES5 Option details

ES5.1 Option 3 – Overhead to Upper Tumut Switching Station

Option 3 involves the connection of Snowy 2.0 to UTSS. It involves the construction of approximately 16 km of overhead transmission line with two x double circuit 330 kV lines within a 120 to 140 m wide easement from the Lobs Hole cable yard to UTSS. Predominantly the transmission line would be constructed adjacent to Line 2.

Option 3 would require the extension of HumeLink from its current proposed connection point at Maragle to UTSS within KNP. This would require the construction of approximately 17 km of one x double circuit 500 kV transmission line within 80 m wide easements from Maragle to UTSS. It would also require an extension to the existing UTSS to include the new 330/500 kV substation infrastructure or the construction of a new 330/500 kV substation adjacent to UTSS.

In addition, Option 3 would:

- require the construction of approximately 8 km of new access tracks or roads;
- require the disturbance of approximately 185 hectares (ha) of vegetation (not including vegetation removal required for extending HumeLink which would be an additional 133 ha);
- generate approximately 500,000 cubic metres (m^3) of spoil;
- take close to approximately 5 years (estimated time of 57 months) from feasibility phase to commissioning; and
- cost approximately $450 million (M).

During operations, overhead transmission lines have a failure incidence rate of approximately once every 10 years. The relative risk of damage to the transmission lines because of events like fires is high. However, the average time to repair a fault is low at < 2 weeks.

ES5.2 Option 4 – Overhead to Line 64

Option 4 involves the construction of an approximately 9 km overhead transmission line with two x double circuit 330 kV lines within a 120 to 150 m wide easement from Lobs Hole cable yard to the proposed Maragle substation and Line 64. At that point it will connect with the new 500 kV HumeLink. The connection point to Line 64, the Maragle substation, has been located close to the Elliot Way to reduce new access road construction and as directly west from Lobs Hole as possible to reduce the length of the connection as much as possible.

As part of this option, the only asset proposed within KNP is the transmission line. The substation and HumeLink connections are proposed outside of KNP and therefore removes the risk of future infrastructure being brought into the KNP to connect to the 330/500 kV substation.

Option 4 would:

- require the construction of approximately 7.5 km of new access tracks or roads;
- require the disturbance of approximately 118 ha of vegetation (71 ha fully cleared);
- generate an estimated approximately 364,800 m^3 of spoil;
- take approximately just under 4 years (estimated time of 45 months) from feasibility phase to commissioning; and
- cost approximately $290 M.

As stated above, during operations, overhead transmission lines have a failure incidence rate of approximately once every 10 years. The relative risk of damage to the transmission lines because of events like fires is high. However, the average time to repair a fault is low at < 2 weeks.

ES6 Assessment and selection of preferred option

A detailed assessment of Option 3 and Option 4 was undertaken against the evaluation criteria. Each criterion was weighted equally to determine the preferred option for the Project.

ES6.1 Option 3 – Overhead to Upper Tumut Switching Station

ES6.1.1 Network and connectivity

Option 3 meets the n-1 redundancy requirements but worsens the resilience and reliability within the NEM with connection at the UTSS rather than at Maragle as identified within the ISP (AEMO 2018). This option is anticipated to not achieve connection for first power generation for Snowy 2.0, based on the Project development commencement in 2017. However, Option 3 does not provide the required capacity for Snowy 2.0 generation delivery into the NEM unless HumeLink infrastructure is brought into KNP.

A new substation is required in the KNP along with future 500 kV lines for HumeLink.

Overall, this option does not adequately meet the required network and connectivity criteria.

ES6.1.2 Constructability and design

This option presents no significant constraints for constructability and design, given that:

- suitable construction support sites are available at UTSS through Snowy 2.0 (although the topography may prove challenging in some areas); and
- overhead lines are susceptible to fault/damage but are cost effective to fix and allow for more straightforward maintenance.

Connection into the existing Line 2 was investigated by TransGrid as part of the development of Option 3 route analysis. The single circuit for the existing Line 2 is fully utilised and cannot be used or combined with the transmission of Snowy 2.0. Any arrangement or use of Line 2 easement within Option 3 will need to maintain a single circuit for Line 2 and four circuits for Snowy 2.0.

It is also not possible to progressively replace the existing Line 2 to include the transmission of Snowy 2.0 generation to UTSS as Line 2 forms part of the existing Southern NSW 330 kV network.

Option 3 would take approximately 5 years to construct.

ES6.1.3 Economic factors

The cost of Option 3 is approximately $450 M. The construction costs for Option 3 are well in excess (in order of 50%) of those for Option 4. These costs are due to the length of line and the terrain. Operation costs are comparable to those of Option 4 due to the fact that damage to overhead transmission lines and structures are more cost effective to fix when compared to underground lines.

ES6.1.4 Community and environment

Option 3 would require the disturbance of approximately 185 ha of vegetation within KNP. An additional 133 ha of vegetation disturbance, 25 ha within KNP, would be required to extend HumeLink from the proposed Maragle substation location to UTSS.

The majority of the footprint of Option 3 and the HumeLink extension has not been surveyed, with the exception of the section of route between Lobs Hole cable yard and the existing Line 2 (which is identical for both Options 3 and 4). However, the footprint contains known areas of habitat (34.5 ha) and potential areas of habitat (107.7 ha) for Smoky Mouse which is listed as critically endangered under the NSW *Biodiversity Conservation Act 2016* (BC Act) and endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Given the large areas of potential habitat disturbance, and its critically endangered status, there is high potential for significant impacts to this species.

Aboriginal heritage surveys have not been undertaken for the majority of the Option 3 route. Notwithstanding this, based on the distribution of Aboriginal heritage sites recorded for Snowy 2.0, impacts on sites are likely.

For Option 3, the following visual elements will occur within KNP:

- approximately 16 km of two x double circuit 330 kV transmission lines (total permanent easement width of approximately 120 to 140 m), running from the Snowy 2.0 cable yard at Lobs Hole to Line 2, and then running adjacent along Line 2 to UTSS, with an estimated 106 transmission towers (53 pairs);
- expansion of UTSS with an additional disturbance area of approximately 22 ha; and

- approximately 13.4 km of single circuit 500 kV transmission lines (total additional permanent easement width of approximately 80 m), running from UTSS to the western edge of KNP for the future HumeLink project. This line congestion at UTSS would likely require significant realignment and cross-overs to accommodate Option 3, creating additional visual elements at this location.

Under Option 3, all other aspects of the future HumeLink project would occur outside of KNP.

Option 3 would likely require the removal and disposal of approximately 500,000 m^3 of spoil.

Overall, Option 3 will result in significant additional infrastructure and associated environmental impacts within the KNP.

ES6.1.5 Best practice safety requirements

Option 3 is able to meet best practice safety requirements during construction and operation.

ES6.2 Option 4 - Overhead to Line 64

ES6.2.1 Network and connectivity

Option 4 meets the n-1 redundancy requirements increasing the resilience and reliability within the NEM. It also achieves connection for first power generation for Snowy 2.0.

Another benefit is that Option 4 is able to provide the required capacity for Snowy 2.0 generation delivery into the NEM, without the need for HumeLink infrastructure to be brought into KNP. A new substation in Bago State Forest and 500 kV transmission lines associated with the HumeLink are outside the KNP. Line 64 is also seen as a better connection point into the 330 kV network as it is part of a less constrained cutset than Line 1 or Line 2 and the line is of lesser consequence than Line 1 or Line 2.

Overall, this option has no significant network and connectivity constraints.

ES6.2.2 Constructability and design

Option 4 presents no significant constraints for constructability and design, given that:

- suitable construction support sites are available at Lobs Hole and at the western extent at Line 64 through Snowy 2.0;
- overhead lines are susceptible to fault/damage but are cost effective to fix and allow for more straightforward maintenance; and
- construction footprint would be small and would, therefore, result in a smaller disturbance footprint.

Option 4 would take just under 4 years to construct, meeting requirements to connect for first power generation for Snowy 2.0, which is shorter than the 5 years to construct Option 3.

ES6.2.3 Economic factors

The cost of Option 4 is approximately $290 M. This is $160 M less than the cost of Option 3.

The construction costs associated with Option 4 are considerably less than those of Option 3 due to the short length of line and the terrain. Operation costs are comparable to those of Option 3 due to the fact that damage to overhead transmission lines and structures are more cost effective to fix when compared to underground lines.

ES6.2.4 Community and environment

Option 4 would require the disturbance of approximately 118 ha of vegetation. Of this, approximately 74 ha would be within KNP which is significantly less than the disturbance required for Option 3, particularly within KNP.

Option 4 requires the clearing of native vegetation which provides habitat for threatened species. However, no significant impacts are predicted, including on Smoky Mouse. As stated above, Option 3 is likely to have a significant impact on Smoky Mouse.

Option 4 will disturb three potential archaeological deposits (PADs), four Aboriginal heritage sites, one site of local heritage significance and five items with archaeological potential. However, no significant impacts to heritage are predicted.

For Option 4, the only infrastructure required to be constructed in KNP includes approximately 8 km of two x double circuit 330 kV transmission lines (total permanent easement width of approximately 120 to 140 m), running from the Snowy 2.0 cable yard at Lobs Hole to the western edge of KNP with 32 transmission towers (16 pairs). However, these transmission lines will need to be constructed in new easements and not adjacent to existing lines and easements like the Option 3.

Under Option 4, the 330/500 kV Maragle substation and HumeLink connections are outside of KNP.

Option 4 is estimated to require the removal and disposal of approximately364,800 m^3 of spoil which is less than the 500,000 m^3 of spoil required to be removed for Option 3.

While Option 4 will result in additional infrastructure and associated environmental impacts within the KNP, this infrastructure is significantly less than that required for Option 3. In addition, and as previously stated, the location of the Maragle substation and HumeLink connections outside of KNP for Option 4 removes the risk of future infrastructure being brought into the KNP to connect to the substation.

ES6.2.5 Best practice safety requirements

Option 4 is able to meet best practice safety requirements during construction and operation.

ES6.3 Comparison

Table ES2 provides a summary table of Options 3 and 4 with respect to the following characteristics:

- area of vegetation clearing, including areas required for HumeLink connections which are additional to current corridor extent;
- environmental considerations, such as visual and biodiversity impacts;
- spoil quantity;
- estimated construction cost;
- estimated construction and approvals time; and
- network resilience considerations including connection to HumeLink.

Table ES2 Summary table

Element	Option 3 – Overhead to UTSS	Option 4 – Overhead to Line 64
Vegetation disturbance		
• within KNP	185 ha plus HumeLink extension 25 ha	74 ha
• outside KNP	0 ha plus HumeLink extension 108 ha	44 ha
Total	*185 ha plus HumeLink extension 133 ha*	*118ha*
Visual amenity	Potential low to high impacts resulting from taller towers in new easement adjacent to existing lines. Due to connection to UTSS, any network expansions will have to come into the KNP in the future. These lines would also have additional visual impacts.	Low to high visual impacts given the new lines are not near existing electrical infrastructure and maintenance of easement.
Biodiversity	Approximately 142 ha of Smoky Mouse (critically endangered species listed under NSW and Commonwealth legislation) habitat cleared with additional indirect impacts. This is a significant impact that is unlikely to be tolerable. Additional future network expansion impacts due to HumeLink KNP connection.	Requires clearing of native vegetation which provides habitat for threatened species though no significant impacts are predicted.
Heritage	Potential Aboriginal and non-Aboriginal heritage impacts (disturbance area not surveyed).	Disturbance of 3 PADs, four Aboriginal heritage sites, one site of local heritage significance and five items with archaeological potential. No significant impacts to heritage are predicted.
Spoil quantity	~ 500,000 m^3	~ 364,800 m^3
Cost	~ $450 M	~ $290 M
Time	57 months	45 months
Network resilience considerations including HumeLink connection	Worsens. Additional assets and Snowy 2.0 connection at UTSS will lower system resilience when assessed using causal events (extreme weather and/or bushfire) due to worsened spatial and temporal factors in combination with the higher concentration of assets and localised power density. Threats at UTSS include loss of significant generation input capacity (2,660 MW and disruption of critical interconnection between Victoria and NSW.	Improved. New assets and Snowy 2.0 connection at Maragle will increase system resilience when assessed using causal threats of extreme weather and/or bushfire due to improved spatial and temporal factors in combination with overall reduced concentration of assets and localised power density (relative to the two proposed alternative connection point options). The choice of Maragle also creates a node on an alternative interconnection path to south-west NSW and Victoria relative to the existing single interconnection between Victoria and NSW. Threats at Maragle include loss of significant generation input capacity (2,000 MW) but avoids disruption of critical interconnection between Victoria and NSW.

Note: Impacts have not been subject to detailed impact assessments and are predicted based on existing area knowledge where available. Option 4 impacts are assessed as per the Transmission Project EIS (Jacobs 2021)

ES6.4 Preferred option

Table ES3 below summarises the outcomes of the comparative analysis for Options 3 and 4 for the Project. The analysis clearly demonstrates that Option 4, overhead transmission connection to the Maragle substation, is the preferred option. This option is the same as that proposed in the EIS for the Project.

Table ES3 Outcomes of comparative analysis for Option 3 and 4[1]

Evaluation criteria	Option 3	Option 4
Technical – network and connectivity		
Provide required capacity for Snowy 2.0 generation delivery into the NEM considering HumeLink cumulative infrastructure needs	✓	✓
Provide required connectivity to increase resilience and reliability of electricity within the NEM		✓
Meet network planning requirements for n-1 redundancy	✓	✓
Consistent with ISP and other Commonwealth and NSW strategic policy documents regarding NEM future needs		✓
Minimise need for additional infrastructure within KNP to further stabilise the network due to the project		✓
Reduce pressure on existing key transmission infrastructure links	✓	✓
Technical – constructability and design		
Minimise construction duration and risk		✓
Allow for suitable and efficient construction support sites close to alignment	✓	✓
Minimise excavation in areas of naturally occurring asbestos		✓
Allow for suitable and efficient operational maintenance activities	✓	✓
Minimise scale of project's construction requirements that may result in heavy haulage movements on local area		✓
Environment and planning – economic factors		
Maximise cost efficiency		✓
Support current and future requirements of the NEM		✓
Deliver positive economic benefits to the people of NSW		✓
Achieve connection for first power generation of Snowy 2.0	✓	✓
Minimise project economic risk		✓
Environment and planning – community and environment		
Minimise additional infrastructure within KNP		✓

Table ES3 Outcomes of comparative analysis for Option 3 and 4[1]

Evaluation criteria	Option 3	Option 4
Minimise impacts to environmentally and culturally sensitive sites		✓
Minimise long term visual impacts within KNP		✓
Maintain long term access and use of public open space and recreation areas within KNP	✓	✓
Minimise private property impacts and acquisition requirements	✓	✓
Minimise impacts and disruption to local community and businesses		✓
Minimise generation of spoil		✓
Safety		
Best practice safety requirements	✓	✓

1. Where both options equally satisfy sub-criteria, a tick is provided for both. Where one option satisfies sub-criteria more than the other option, only one tick is shown.

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Appendices

Tables

Figures

1 Introduction

1.1 The Project

In recognition of the need to manage the transition and future energy mix in the national electricity market (NEM), Snowy 2.0 was declared critical State significant infrastructure (CSSI) by the former New South Wales (NSW) Minister for Planning under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) in March 2018. It was declared to be critical for the energy security and reliability needs of NSW. At the time of the declaration the Minister stated that Snowy 2.0 was "essential for the future security of our energy system, the economy and the environment." The declaration signifies the critical role that Snowy 2.0, together with the upgrades to the NSW transmission network, will play in providing reliable on-demand energy and large-scale storage to NSW as it transitions to a low emissions economy.

The CSSI declaration included both the generation and transmission components of Snowy 2.0.

Snowy 2.0 is the largest committed renewable energy project in Australia. By expanding the current Snowy Mountains Hydro-electric Scheme's (Snowy Scheme) renewable energy capacity by almost 50%, the NEM will be served with an additional 2,000 megawatts (MW) of generating capacity.

In May 2020, Snowy Hydro Ltd (Snowy Hydro) obtained approval for Snowy 2.0 Main Works and construction has commenced.

A new connection is required to connect and provide the full 2,000 MW of electricity generated from Snowy 2.0 to the broader transmission network and NEM. NSW Electricity Networks Operations Pty Ltd, as a trustee for NSW Electricity Operations Trust (known as TransGrid), is seeking approval for the construction and operation of the Snowy 2.0 Transmission Connection Project (the Project) to enable the grid connection of Snowy 2.0 to the NEM.

In February 2021, TransGrid published an environmental impact statement (EIS) prepared by Jacobs Group (Australia) Pty Ltd (Jacobs) for the Project. The EIS considered the impacts of an approximately 9 kilometre (km), 330 kilovolt (kV), 2 x double circuit overhead connection from the Snowy 2.0 cable yard at Lobs Hole within Kosciuszko National Park (KNP) to a new 330 kV/500 kV substation at Maragle within Bago State Forest. In accordance with the assessment requirements for the EIS, it considered an analysis of a range of alternative options for connecting Snowy 2.0 to the electricity grid.

1.2 Purpose of this report

The EIS for the Project was publicly exhibited for 30 days between 23 February and 5 April 2021 and received a total of 40 submissions from government agencies, special interest groups and members of the public. A number of these submissions, most notably from the National Parks Association (NPA), a special interest group, raised concerns regarding the EIS. One of these was the lack of analysis demonstrating alternative solutions were developed and considered prior to the selection of the preferred option, which included:

- availability of alternative locations to connect to the broader NEM; and
- availability of different methods of transmitting electricity generated from Snowy 2.0 to the NEM.

Following the public exhibition period of the EIS, the NSW Department of Planning, Industry and Environment (DPIE) requested that TransGrid prepare an expanded and thorough options report that responds to the matters raised in the submissions, including those raised by the NPA, regarding different connection locations and methods of connecting to the NEM.

EMM Consulting Pty Ltd (EMM) has been engaged to lead and prepare the options report for the Project (ie this Options Report) on behalf of TransGrid. To inform this Options Report, and through engagement with Snowy Hydro, TransGrid derived 12 options to be assessed from investigations and studies carried out to inform project development since its inception in 2017. To support these options, TransGrid engaged two energy engineering consultancies to further inform the options analysis, namely:

- WSP Australia Pty Ltd (WSP) to prepare engineering analysis of options to transmit electricity from Snowy 2.0 to the NEM; and
- GHD Group Pty Ltd (GHD) to prepare analysis on network connection options for Snowy 2.0 and achieving reliability and stability within the NEM.

The preferred option recommended from this report will be the subject of detailed assessment and consideration in the Submissions Report and Amendment Report for the Project.

1.3 Option analysis method

The method of option analysis undertaken for the Project included the following steps:

- Identification of the Project's objectives.
- Development of Project evaluation criteria within the categories of technical, environment and planning, and safety.
- Option development based on key considerations that include a range of connection points to the transmission network and methods of transmission.
- Undertake a screening assessment of options against Project objectives and evaluation criteria.
- Undertake a more detailed post-screening assessment of a number of options.
- Selection and assessment of preferred option.

The Project's objectives and evaluation criteria are discussed in Chapter 5. A summary on the options developed for consideration are provided in Chapter 6. A summary of the results of the screening assessment is provided in Chapter 7. A summary of the engagement outcomes is provided in Chapter 8 with a more detailed assessment of the final two options presented in Chapter 9.

As described below, key government agencies were consulted at various stages of the option analysis. The results of this engagement also helped shape the detailed assessment phase of the options, particularly the more detailed post screening assessment of various options.

1.4 Engagement with government

This section provides an overview of the engagement process carried out with DPIE and NSW National Parks and Wildlife Services (NPWS) during the preparation of the options analysis report following public exhibition of the EIS. Engagement involved the presentation of information regarding options under consideration and information in response to requests for further information.

1.4.1 Initial meeting

On 18 June 2021, an initial meeting was held with DPIE and NPWS to discuss the requirements of the Submissions Report, including the proposed scope of this Options Report that will be appended to the Submissions Report.

It was resolved at the meeting that a subsequent meeting would be held with DPIE and NPWS to present the results of the screening assessment of options against the Project objectives and evaluation criteria.

1.4.2 Screening phase

In June and July 2021, EMM undertook a screening assessment of 12 options that were developed to provide a high voltage (HV) connection of Snowy 2.0 to the transmission network. These options included different connection points to the transmission network and methods of transmission, and these are described in Chapter 6. The purpose of the screening assessment was to screen out unviable options to enable a smaller number of options which would be subject to more detailed assessments.

The screening assessment was undertaken with consideration to the Project's objectives and the evaluation criteria within the categories of technical, environment and planning, and safety. Details on the objectives and evaluation criteria are provided in Chapter 5.

A figure showing the route of the 12 options can be seen in Figure 1.1.

The results of the screening assessment indicated that eight options did not meet the set objectives and exceeded threshold issues relating to the assessment criteria. These included options that:

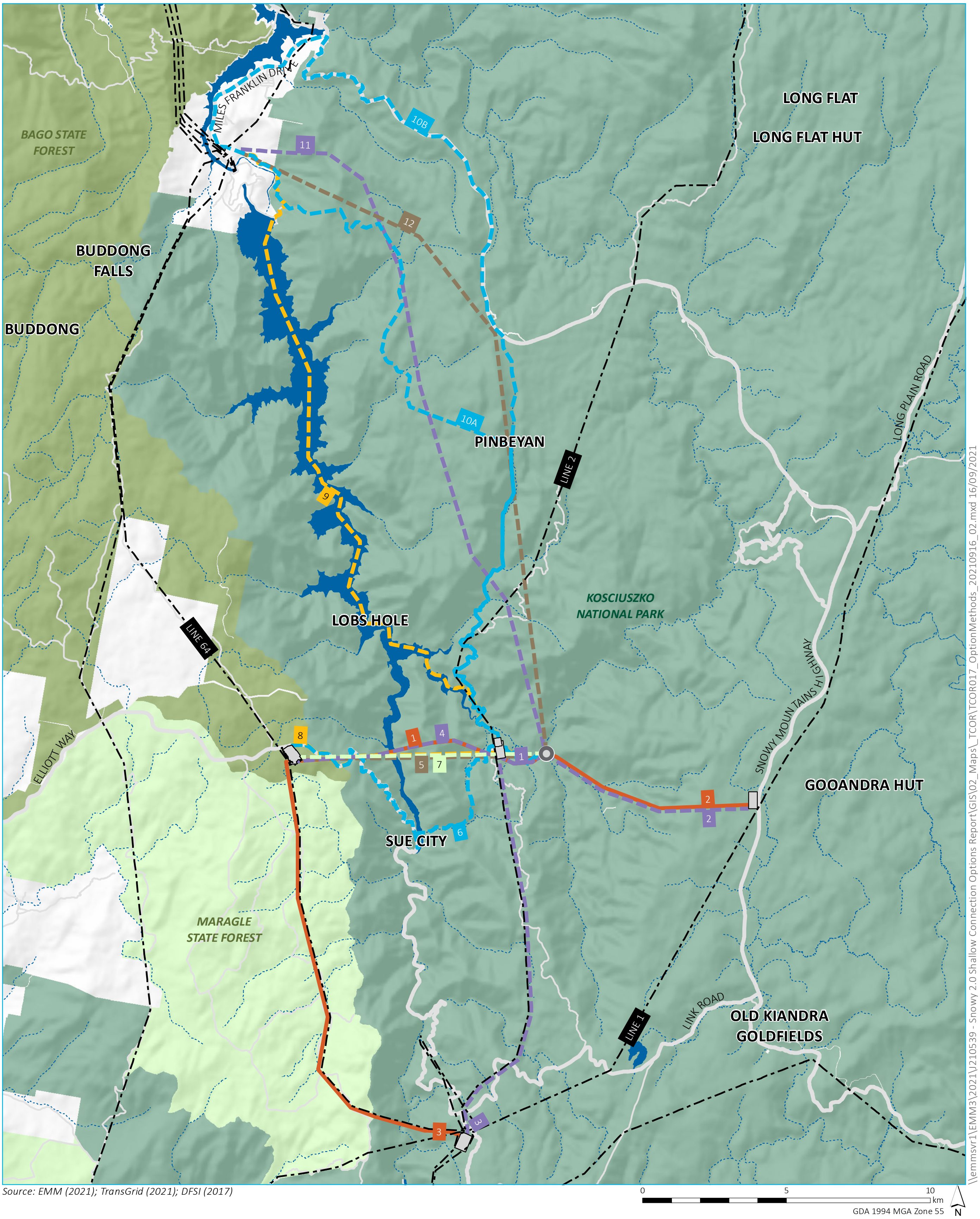
- require significant extra assets to be constructed within KNP;
- are not technically viable; and/or
- do not ensure the resilience and reliability of the NEM in the context of dramatically increased intermittent renewable generation.

The four options recommended to be considered further as part of detailed assessments include:

- Option 4 – Overhead to Line 64.
- Option 5 – Deep cable tunnel to Line 64.
- Option 6 – Trench to Line 64.
- Option 8 – Hybrid trench/deep cable tunnel to Line 64.

Further details of the screening phase assessment are provided in Chapter 7.

The results of the screening assessment were presented to DPIE and NPWS at a meeting on 16 July 2021.



Source: EMM (2021); TransGrid (2021); DFSI (2017)

KEY

- Snowy 2.0 cable yard
- HumeLink options
- Substation footprint

Transmission connection options (by method)

- Overhead
- Deep cable
- Trench
- HDD
- Hybrid
- Existing electricity transmission line
- Major road
- Minor road
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest

Transmission connection options

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 1.1

EMM
creating opportunities

1.4.3 Request for further information

Following the presentation of the results of the screening assessment, four requests for information (RFI) were issued by DPIE and four meetings held with DPIE and NPWS to discuss the responses to the RFIs.

The process for undertaking the options analysis inclusive of the engagement with DPIE and NPWS can be seen in Figure 1.2. The information requested by DPIE and where this has been included within this Options Report is provided in Table 1.1.

Further information is provided within Chapter 8 regarding the responses provided for the Project with consideration of the options assessment.

Table 1.1 DPIE and NPWS requested information during options assessment

Information requested	Where addressed in Options Report
RFI #1	
Option 5 • *justification of the technical feasibility and the grade limits (are proposed limits to transport tunnels applicable to transmission tunnels)* • *safety issues on vertical tunnels where these are being construction elsewhere (including Snowy generation)* • *justification of the need for 2 lines* • *justification of timing given timing for Snowy generation tunnels being significantly shorter*	Section 4.3.3i Section 4.4.2i Section 4.5.2 Section 8.3
Option 3 • *Justification of construction methodology and ability for dual construction a new line within same easement and progressively replacing existing to minimise need for wider easement*	Section 8.2
Options 8, 6 • *Can options 6 and 8 have lesser trenching impacts than described?*	Section 8.4 Section 8.5
• *One figure of the 5 options listed above on an aerial basemap including the proposed corridors for HumeLink* • *One table of the options above with the following information for each option:* – *Area of vegetation clearing* – *Spoil quantity* – *Cost* – *Time* – *Network resilience considerations including connection to HumeLink* • *Clarification of why other construction methodologies for Option 3 (i.e. underground / trenching / hybrid) have not been considered.*	Section 8.2 Table 8.3 Figure 1.1 Figure 4.5

Table1.1 DPIE and NPWS requested information during options assessment

Information requested	Where addressed in Options Report
RFI #2	
The Department requests an updated version of Table 3.1 Summary Table including:	Table 8.3
• *Vegetation clearing*	
– *breakdown of permanent vs temporary clearing / rehabilitated for each option*	
– *For Option 3 – for HumeLink - breakdown for within Park vs outside Park*	
• *Addition of consideration of other environmental – visual for each option*	
• *Add Option 9 to Table 3*	
Additional info:	Table 8.4
• *High level breakdown of costs*	Section 8.4
• *Further information on the design parameters for Option 6 to justify not progressing further opportunities to optimise and reduce footprint and spoil impacts (such as narrower corridor)*	Section 4.2
• *Further information on Note 1 to Table 3 regarding risk (in plain English)*	
RFI #3	
• *The benefits of locating the Maragle substation at its current proposed location, and if there were options closer to UTSS for connection under Option 3.*	Section 4.2.3i
• *Reasons for the number of electrical circuits required for transmission of Snowy 2.0, how these circuits are translated into transmission lines and easements and resultant clearance requirements for these easements over different types of terrain along the proposed route for Option 3 including any available cross-sections.*	Section 4.3.1
• *Impacts for Option 3 be separated into project only and cumulative (including HumeLink) inside and outside KNP.*	Table 8.1
RFI #4	
• *information on the number of circuits required for project, inclusive of two double circuit 330 kV lines or single circuit 500 kV*	Section 4.3.2i
• *a three circuit arrangement to UTSS for Option 3,*	Section 8.2.1
• *location of the proposed substation at Maragle with further details on the required easement widths for Option 3*	Section 8.2.2ii
• *Extent of reliance on timing of HumeLink construction*	Section 4.2.2
• *Further improvements to Option 4*	Refer to Amendment Report

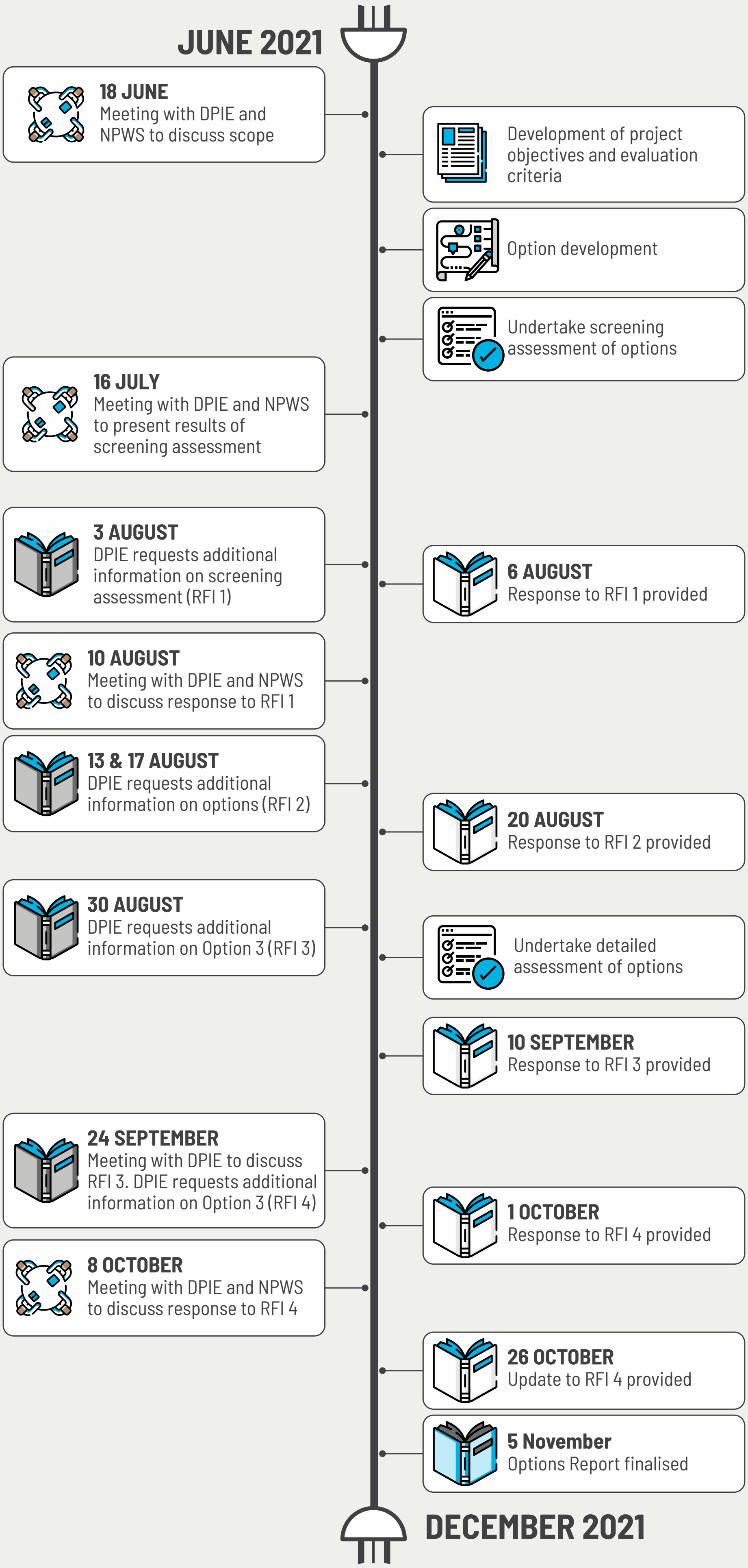


Figure 1.2 Process for development of options report

1.5 Structure of this report

This report is structured as follows.

- **Chapter 1** provides the background on the need for this options report, an overview of the method undertaken to develop the report and an overview of engagement with government agencies in developing this options report.
- **Chapter 2** provides an overview of the NEM and its current constraints and how Snowy 2.0 helps overcome some of those constraints, as well as an overview of the risks to the NEM should Snowy 2.0 not be able to transmit power.
- **Chapter 3** provides a summary of the classification of Snowy 2.0 and the upgrades required to the electricity network to transmit power from Snowy 2.0 as infrastructure that is deemed to be critical to NSW (ie CSSI).
- **Chapter 4** provides details on the Project and its requirements, including network resilience requirements, design requirements, construction requirements, maintenance requirements and safety requirements. It also provides details of electricity assets within KNP, including both existing and proposed assets.
- **Chapter 5** provides details on the Project's objectives and the evaluation criteria reviewed to guide the options analysis. The evaluation criteria have been identified for this options analysis based on the Project objectives. The criteria are separated into three categories: technical; environment and planning; and safety.
- **Chapter 6** provides a summary of each of the options developed for the options analysis. A total of 12 options were developed to include alternative connection points and transmission methods. For each option a summary of the route is provided as well as a summary of the construction methodology.
- **Chapter 7** provides the results of the screening assessment that was undertaken of the 12 identified options and presented to DPIE and NPWS on 16 July 2021. For each option an assessment is made against the Project's objectives and the evaluation criteria.
- **Chapter 8** provides details on the more detailed analysis of five options post the screening assessment. This analysis was undertaken to address information requests from DPIE as previously discussed.
- **Chapter 9** provides a detailed assessment of the preferred option for the transmission of the power generated by Snowy 2.0.
- **Chapter 10** provides a conclusion to the process carried out analysing the options for the Project.

2 National electricity market

2.1 Overview

The NEM involves the wholesale generation of electricity from coal, gas and renewable sources that is transported via HV transmission lines from generators to local distributors. From the distributors, it is converted to low voltage electricity and delivered to almost 10 million homes and businesses across the Australian eastern and south-eastern seaboard. The NEM delivers around 80% of all electricity consumption in Australia.

The NEM operates on one of the world's longest interconnected power systems and connects five regional market jurisdictions – Queensland, NSW (including the Australian Capital Territory (ACT)), Victoria, South Australia, and Tasmania (as shown in Figure 2.1). The NEM has over 300 registered industry participants which include market generators, transmission network service providers, distribution network service providers and market customers.

The NEM is a wholesale commodity exchange for electricity across the five regional markets. As electricity cannot currently be stored easily, the NEM works as a 'pool', or spot market, where power supply and demand across all jurisdictions is matched instantaneously in real time through a centrally coordinated dispatch process.

The spot market is managed by a set of procedures that is managed on a five-minute basis by the Australian Energy Market Operator (AEMO), where generators offer to supply the market with specified amounts of electricity and the AEMO decides which generators will be deployed to produce electricity, with typically the cheapest generator put into operation first. NEM operation is designed to meet electricity demand (or consumption) in the most cost-efficient way.

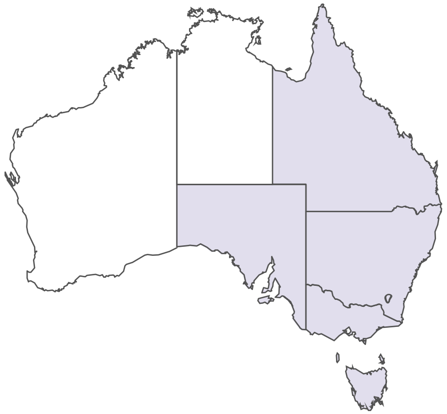
2.2 National electricity market requirements and constraints and need for Snowy 2.0 connection

Amongst the participants of the NEM, NSW is likely to have one of the greatest requirements for energy replacement and capacity. TransGrid's *2020 Transmission Annual Planning Report* notes that over 30% of the coal-fired generation capacity in NSW is scheduled to retire over the next decade. As the likelihood of new coal-fired power stations is considered to be low, much of the replacement of coal-fired generation will be from renewable sources, and to a lesser extent, gas.

Renewable generators, such as solar and wind farms, provide an intermittent source of electricity whereby the power produced is dictated by the availability of the renewable energy source. To reliably supply customer demand, wind and solar farms need to be coupled with energy storage such as pumped hydro-electric storages like Snowy 2.0. Snowy 2.0 allows excess renewable energy to be stored and used when required to supply major load centres like Sydney and Melbourne during periods of high demand. As Snowy 2.0 is a new asset, a new transmission connection is required for the electricity generated by Snowy 2.0 to be transmitted into the existing network, as proposed under the Project.

The energy generation and storage that will be provided by the Snowy Scheme and Snowy 2.0 is considered essential to maintaining reliable electricity supplies to the NEM as coal-fired power stations are closed. Supply is contingent on being connected to the NSW transmission system via high capacity, high availability transmission lines. If the transmission lines connecting the Snowy region and the NSW transmission system are constrained during periods of bushfire or high-power demands, this has the potential to impact supply reliability for NSW and ACT customers. The existing NSW transmission system is shown in Figure 2.2.

The NEM and how it works



There are over **300** registered participants such as generators, retailers & distributors in the NEM

States/Territories that form the NEM

40,000 km
of transmission lines and cables.

80%
of all electricity used in Australia is delivered via the NEM

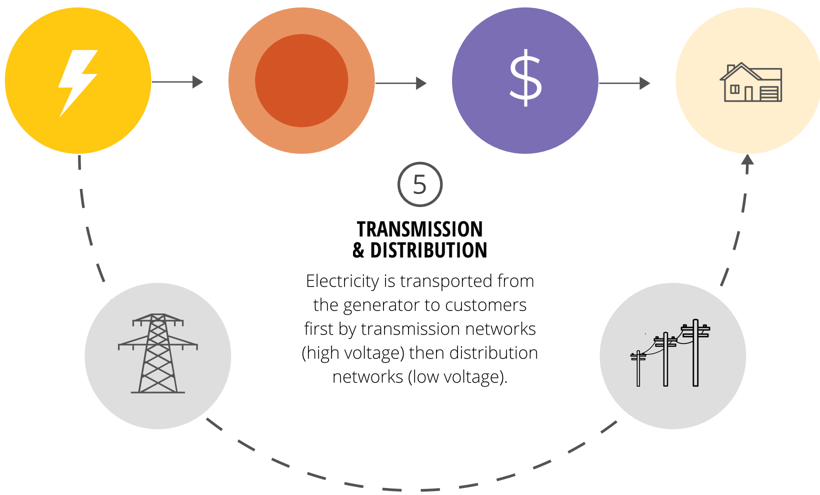
9 million
customers

1
GENERATORS
Generators within Qld, NSW, ACT, Vic, Tas & SA produce electricity from fuels, as well as via wind, solar and hydro.

2
'THE POOL'
Generators offer to supply the market with set amounts of electricity at set prices for set periods. All power available at any given time is referred to as 'the 'pool'.

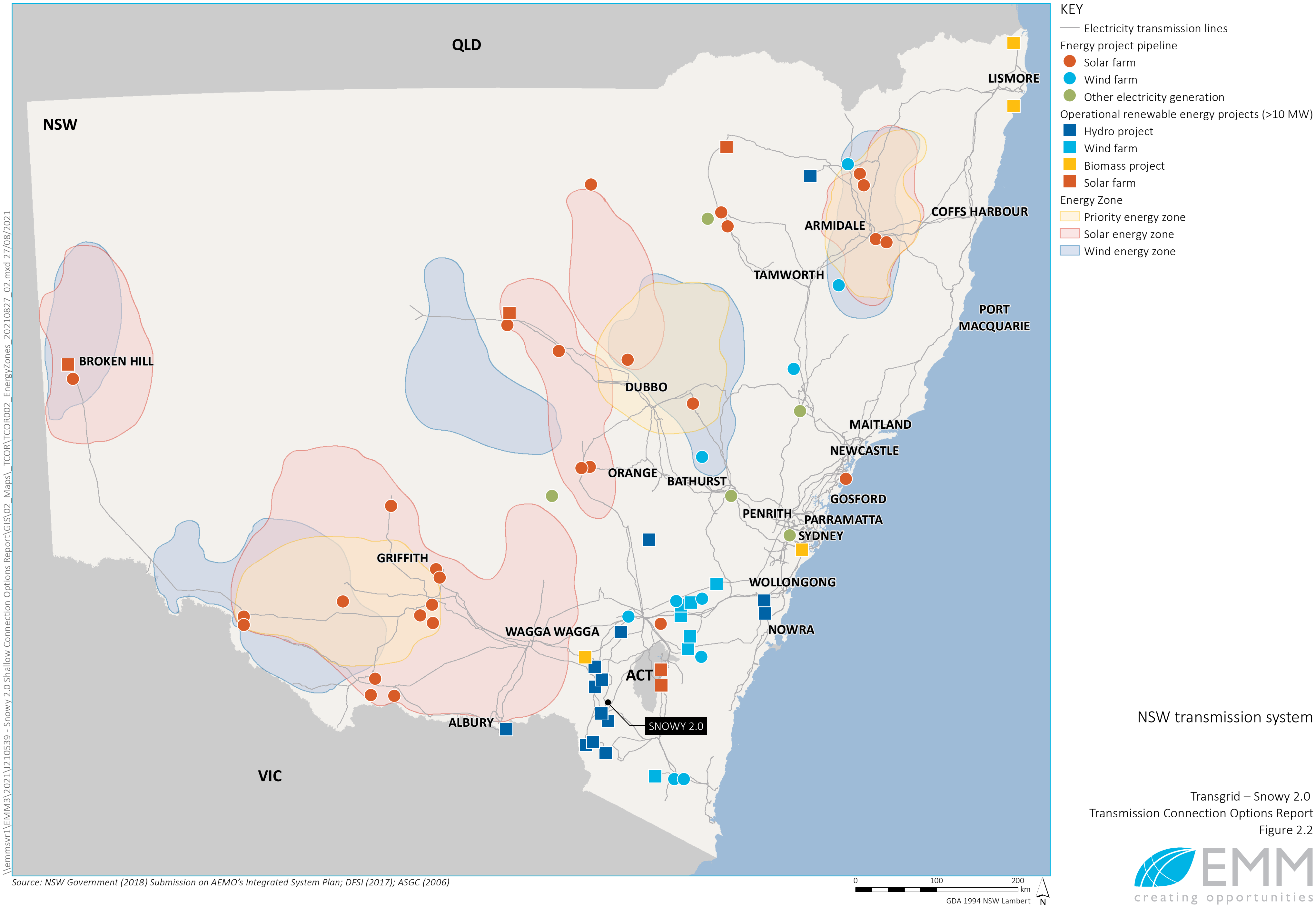
3
RETAILERS
Retailers buy electricity produced by generators from the pool and sell it to customers.

4
CUSTOMERS
Customers (both business and residential) use the power.



5
TRANSMISSION & DISTRIBUTION
Electricity is transported from the generator to customers first by transmission networks (high voltage) then distribution networks (low voltage).

Figure 2.1 National Electricity Market



Source: NSW Government (2018) Submission on AEMO's Integrated System Plan; DFSI (2017); ASGC (2006)

NSW transmission system

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 2.2

creating opportunities

2.3 Risks to the national electricity market and Snowy 2.0 connection infrastructure

As the transition to renewables accelerates, reliable and stable energy supply cannot be achieved without large-scale storage and on-demand energy generation. Snowy 2.0 will provide large-scale energy storage and quick-start electricity generation at critical times of peak demand when energy supply is constrained and at times when intermittent renewable energy output is low.

It is important to understand the risks associated with establishing the required infrastructure to connect of Snowy 2.0 to the grid. Peak demand periods for electricity in NSW can occur during late summer when school holidays are over, when high temperatures coincide with high industrial and commercial business activity, a period when bushfire potential is also high. Therefore, it is a risk to have multiple transmission lines running in close proximity where they can be impacted by the same bushfire event. For this reason, having Snowy 2.0 generation connected via transmission lines running in the same corridor as existing 330 kV lines leaving existing switching stations at Upper and Lower Tumut could mean that a single bushfire event could disrupt power supply from the entire Snowy Scheme to NSW as well as significantly damage transmission assets.

Other potentially significant risks to the NEM include:

- transmission line outages due to extreme weather;
- congestion due to the sharing of power load between 500 and 330 kV circuits;
- exceedances of voltage stability limits, restricting the ability to securely transmit power to and from Snowy 2.0;
- unexpected outages of circuit transmission lines; and
- malicious attacks impacting critical switching stations and substations that connect generation to NSW or connect significant amounts of load.

3 Critical State significant infrastructure

3.1 Critical State significant infrastructure declaration

Snowy 2.0 is a critical project for NSW and the broader NEM. The Project, along with the existing Snowy Scheme, will underpin Australia's transition to a renewable energy future at the lowest cost to consumers. As the transition to renewables accelerates, reliable and stable energy supply cannot be achieved without large-scale energy storage and on-demand generation.

Snowy 2.0, inclusive of this Project, was declared State significant infrastructure (SSI) and CSSI in accordance with the provisions of the EP&A Act. The declaration of Snowy 2.0 as a CSSI project acknowledges that the project is critical to the State for environmental, economic or social reasons. The need, justification and environmental impact of Snowy 2.0, including the generation capacity and the transmission connection point being the Snowy 2.0 cable yard, is contained within the Snowy 2.0 Main Works EIS (EMM, 2019) which received planning approval from the NSW Minister for Planning and Public Spaces in May 2020.

The CSSI listing within Schedule 5, clause 9 of *State Environment Planning Policy (State and Regional Development) 2011* is provided below. It encompasses Snowy 2.0, this Project, HumeLink and other required transmission projects within the NSW Southern Shared Network to ensure the security and resilience of the NEM.

(3) Snowy 2.0

Development for the purpose of pumped hydro and generation works to be known as Snowy 2.0 on land between Tantangara Reservoir and Talbingo Reservoir that involves –

(a) the carrying out of exploratory geotechnical works or engineering investigations, and

(b) the construction and operation of an underground hydroelectric power and pump station capable of supplying approximately 2,000 megawatts of hydroelectric power, and

(c) the construction of water and access tunnels, surge tank and intake and outlet structures at and between the two reservoirs.

(4) Transmission works

Development that involves –

(a) the construction and operation of new electricity transmission lines and an electricity substation to the west of the Talbingo Reservoir to connect Snowy 2.0 to the existing electricity transmission network at Nurenmerenmong, east of Tumbarumba, and

(b) the construction and operation of new electricity transmission lines between the new substation at Nurenmerenmong and an existing substation at Bannaby, north of Marulan, and

(c) the construction and operation of new transmission lines between an existing substation at Khancoban and a location on the NSW-Victorian border generally south-west of Khancoban, and

(d) the augmentation of the existing substation at Bannaby.

The listing demonstrates the importance of connecting the generation from Snowy 2.0 to the major load centres such as Sydney, with transmission projects through to Bannaby (known as HumeLink), and Melbourne, with transmission projects to Khancoban (known as the Victoria to NSW Interconnector, or VNI) and substation works to support.

3.2 Snowy 2.0

Snowy 2.0 will provide large-scale energy storage and quick-start electricity generation at critical times of peak demand when energy supply is constrained and at times when intermittent renewable energy output is low. This is shown on Figure 3.1.

Energy storage helps build power system resilience to weather events (including wind and solar droughts) by storing surplus renewable generation for use at times when these resources are scarce and allowing more constant operation of less flexible existing generation. This, in turn, creates a more dispatchable and reliable power system, while helping to keep prices down for consumers.

Pumping water at times of low electricity demand (ie when there is excess supply) means that Snowy 2.0 will have water ready to use for energy generation at times when consumers need it most. Snowy 2.0 will make efficient use of our precious water resources to generate electricity without impacting on downstream water users and environmental flows for the Murray-Darling Basin.

Given the need to ensure future stability of the grid and reliability and security of energy supply to customers, it is fundamental that the energy generated from Snowy 2.0 is transmitted to the NEM with the Project that reflects its strategic importance.

3.3 HumeLink

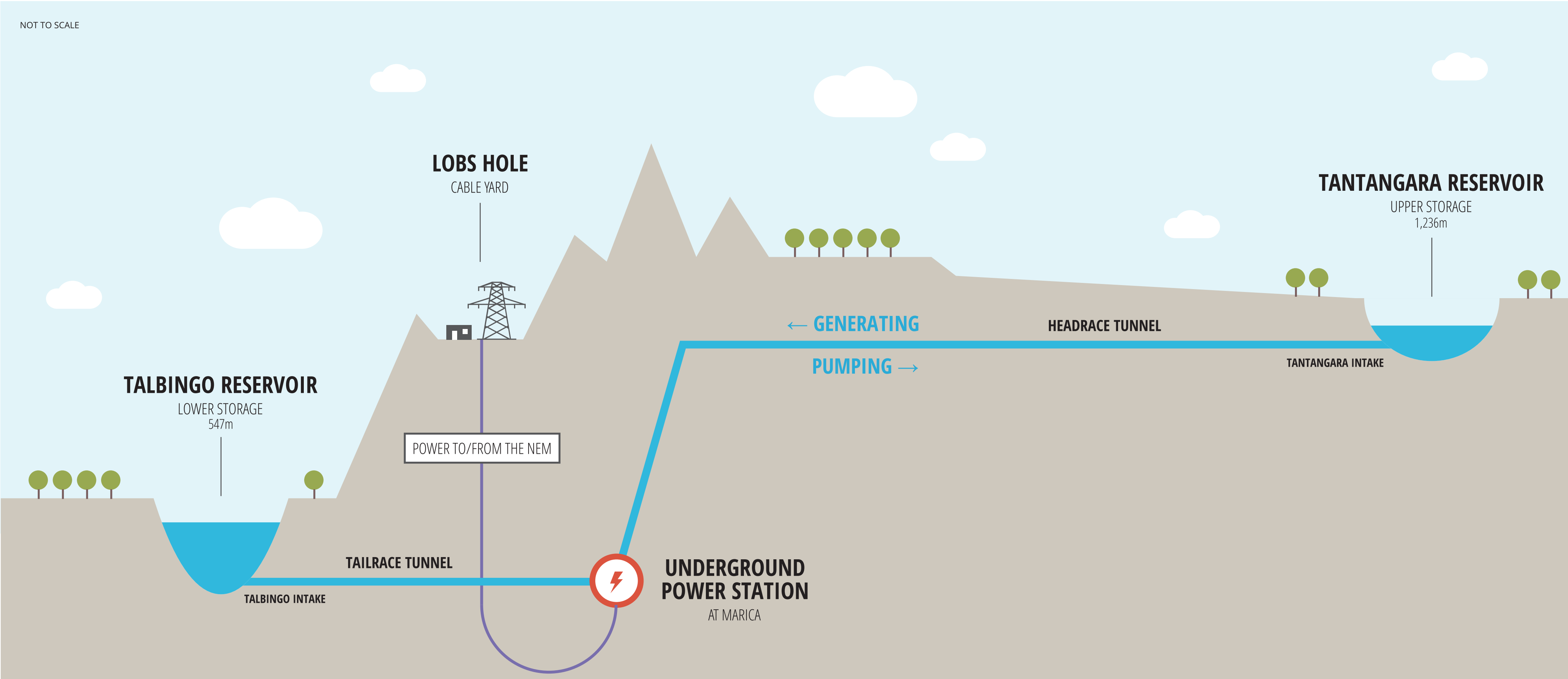
The main aim of the Project is to provide a direct connection between Snowy 2.0 and the southern shared network. HumeLink's purpose is to reinforce the NSW southern shared network of the NEM to increase transfer capacity to the primary load centre of NSW, Sydney. HumeLink has been identified as an actionable Integrated System Plan (ISP) project by AEMO since 2018. Actionable ISP projects are deemed to be critical to address cost, security and reliability issues.

AEMO modelled a triangular transmission connection between Wagga Wagga, Tumut (Maragle) and Bannaby, south of Sydney (refer to Figure 3.2), which provides access to Wagga Wagga and Southern NSW Tablelands Renewable Energy Zone (REZ).

In its latest ISP (2020), AEMO identified the following benefits for HumeLink:

- Increasing the transfer capacity and stability limits between the Snowy Mountains and major load centres of Sydney, Newcastle and Wollongong.
- Enabling greater access to lower-cost generation to meet demand in these major load centres.
- Facilitating the development of renewable generation in high quality renewable resource areas in southern NSW, which will further lower the overall investment and dispatch costs in meeting NSW demand whilst also ensuring that emissions targets are met at the lowest cost to consumers.

A key driver of the preliminary design and the benefits is the current known constraints of the network limiting access to the existing capacity and new capacity (for example, Snowy 2.0) around the Snowy Mountains with the 330 kV and 132 kV network between this area and Sydney.



Operation of Snowy 2.0 will involve the transfer of water through a series of newly established power waterway tunnels and the underground power station to provide for energy generation, as well as large scale energy storage that will be available as quick-start electricity generation at critical times of peak demand.

IN GENERATING MODE:

- The intake structure at Tantangara Reservoir allows water to flow into the headrace tunnel
- Water falls via gravity into the surge tank (the surge tank valves/gate are opened)
- Water flows through pressure tunnels and to the turbines in the machine hall, spinning the turbines and generators to create electricity
- Transformers located in the transformer hall of the underground power station convert the electricity to a higher-voltage current, and is then transmitted via cables to supply the NEM
- Water continues through the tailrace tunnel and is released into Talbingo Reservoir via the Talbingo gate shaft and intake structure

IN PUMPING MODE:

- Energy is sourced from the NEM which is transmitted into the Power station via the same electrical infrastructure used in generating mode
- Water from Talbingo Reservoir is drawn through the Talbingo intake and the tailrace tunnel toward the turbines
- The turbines in the machine hall, spinning in the reverse direction (as pumps), push the water up the inclined tunnel and through the headrace tunnel to Tantangara Reservoir where it can be stored and used again for energy generation when needed

Figure 3.1 **Principles of Snowy 2.0 Main Works**

HumeLink would involve the construction and operation of a 500 kV transmission network that would carry electricity to customers from new generation sources, including Snowy 2.0. This would allow sharing of energy between the eastern states and unlock the full capacity (2,000 MW) of Snowy 2.0.

As part of the Regulatory Investment Test for Transmission (RIT-T) process, TransGrid recently completed the *Project Assessment Conclusions Report* (PACR, July 2021) which concluded the preferred option is new 500 kV double circuit lines in an electrical loop between Maragle, Wagga Wagga and Bannaby. The analysis within the PACR showed this option is expected to:

- deliver net benefits of approximately $491 million (M) over the assessment period, in present value terms, which increases further if alternate scenario weighting are assumed, in-line with recent commentary by AEMO and Energy Security Board (ESB);
- reduce the need for new dispatchable generation investment to meet demand going forward;
- avoid capital costs that would otherwise be required associated with enabling greater integration of renewables within the NEM;
- lower the aggregate generator fuel costs required to meet demand in the NEM going forward; and
- provide significant competition benefits by increasing the efficiency of bidding in the wholesale market.

This preferred option identified within the RIT-T is consistent with the HumeLink described in the 2020 ISP (AEMO 2020). The PACR stated that all lines are to be constructed in a double circuit configuration to minimise a refinement of the ISP candidate option, reducing both investment cost and potential environmental impacts.

Consistent with the PACR and 2020 ISP, a 330/500 kV substation at Maragle is proposed as part of the Project. This would facilitate the transfer of the full capacity of Snowy 2.0 from the 330 kV circuits into the 500 kV circuits of HumeLink. HumeLink would run between Maragle and Bannaby via Wagga Wagga.

Combined, the Project, Snowy 2.0 and HumeLink would be able to dispatch electricity at virtually any time to meet energy demand and facilitate an orderly transition to a decarbonised and secure energy system for NSW and the broader NEM.

HumeLink is currently in initial project development phase, with community consultation and design and route option refinement underway. TransGrid would seek approval for HumeLink under the CSSI provisions of Part 5, Division 5.2 of the EP&A Act.

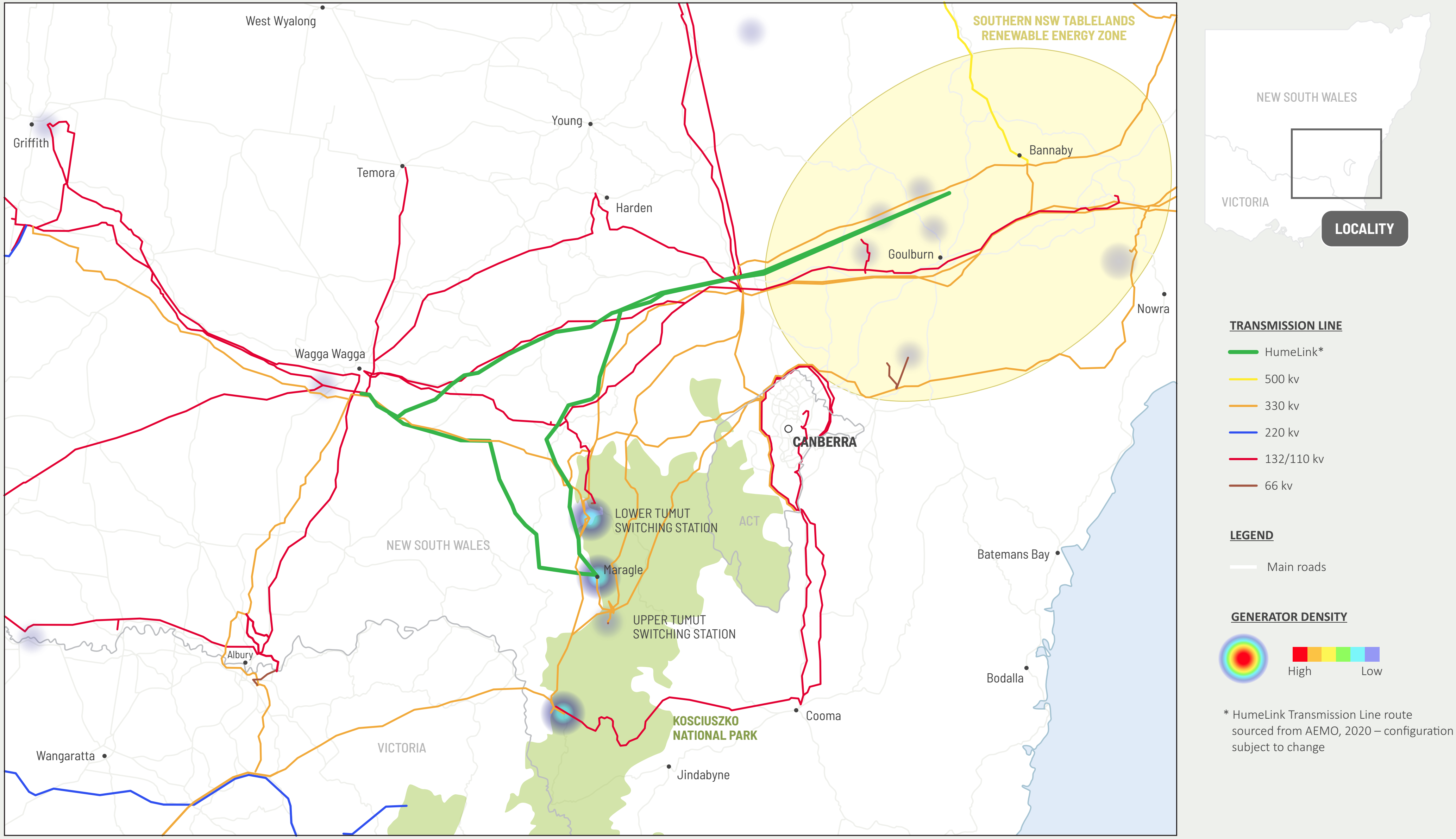


Figure 3.2 HumeLink Actionable ISP Project (AEMO 2020)

4 Project and network requirements

4.1 Requirements and considerations

The key aim of the Project is to transmit the 2,000 MW of power generated from Snowy 2.0 into the NEM so that it can be distributed effectively and efficiently to consumers. The point of transfer/connection between generation and transmission for this Project will be the Snowy 2.0 cable yard at Lobs Hole within KNP into the NEM.

The following sections describe the requirements and considerations for the Project with respect to:

- network resilience;
- design requirements to reliably and securely transmit the full power of Snowy 2.0 to customers ensuring the stability and security of the NEM;
- method of transmission and the construction requirements;
- ongoing maintenance requirements;
- safety requirements to ensure the safety of personnel and the public; and
- minimisation of environmental impacts including footprint and direct impacts to the sensitive surrounding environment of KNP, particularly biodiversity and amenity impacts.

These requirements and considerations were used to develop the options for the Project described in Chapter 6. These are described in the following sections with references made to known advantages and disadvantages.

4.2 Network resilience requirements

4.2.1 System resilience

AEMO oversees the operations and security of the NEM. AEMO provides the detailed, independent planning, forecasting and modelling information and advice that drives effective and strategic decision-making, regulatory changes and investment. This includes developing standards and frameworks, implementing necessary changes across markets and systems that will support a stronger, more effective energy system.

Figure 4.1 shows the existing generation density across the south-eastern section of the NEM with high density locations in the Hunter/Central Coast area, Tumut (Snowy Scheme) and La Trobe Valley[1].

When 2,000 MW Snowy 2.0 generation capacity is available it will increase the 'Tumut' locality generation density to approximately 3,800 MW. This will then be equivalent to the current La Trobe Valley locality when comparing generation density with only the Hunter/Central Coast node exceeding this generation density within the NEM with that node also spanning 100 km. This is an increased concentration of power that needs to be managed appropriately through a risk-based approach to transmission development to improve system resilience and security, which can be achieved through the design of the connection of Snowy 2.0 to the NEM.

[1] Refer to: https://www.aemo.com.au/aemo/apps/visualisations/map.html

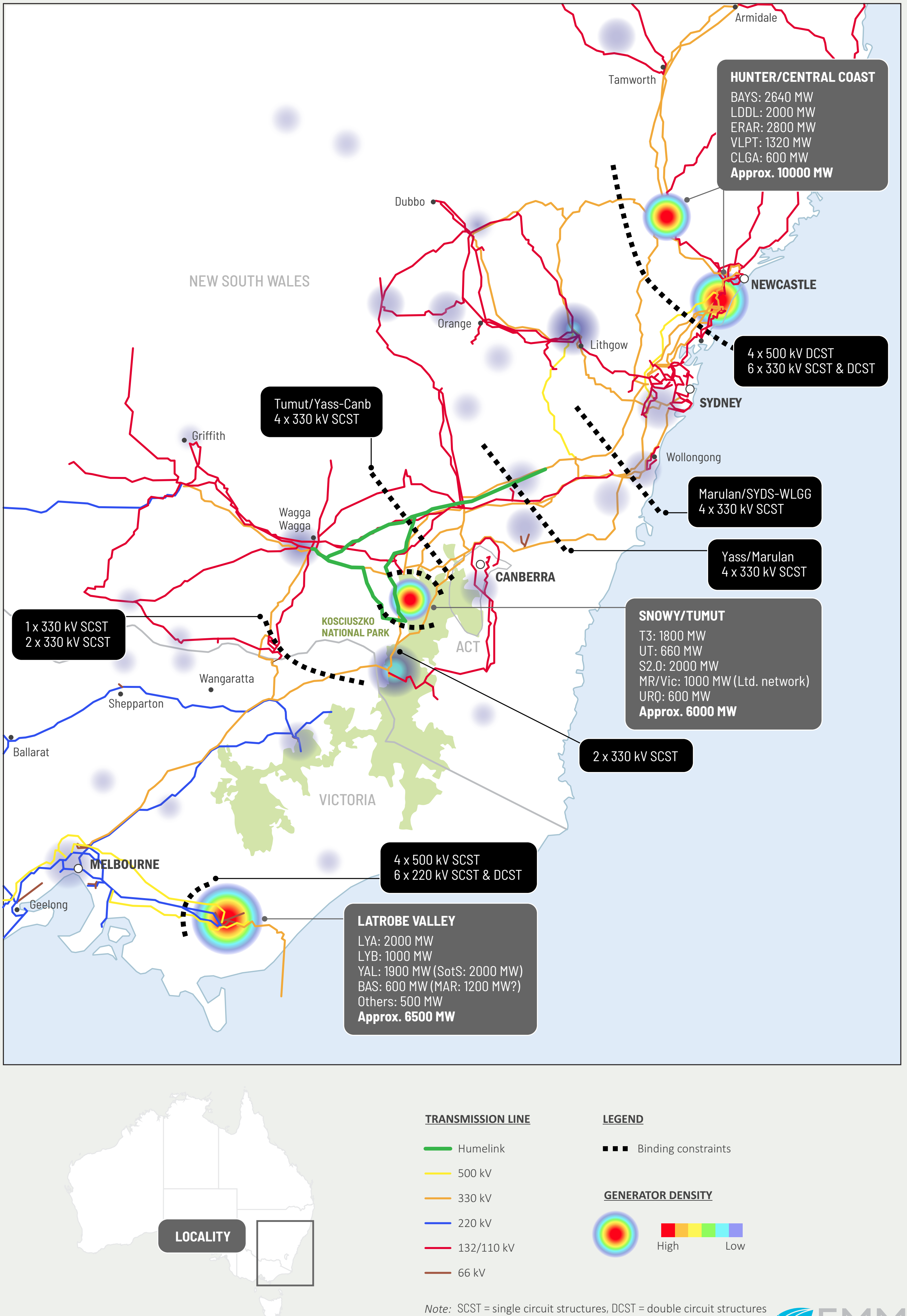


Figure 4.1 Power concentration and density in south eastern National Electricity Market

As can be seen from Figure 4.1 the Tumut node, with few 330 kV connections, is significantly deficit in transmission lines relative to the La Trobe node which has 4 x 500 kV and 6 x 220 kV transmission lines servicing the node, and similar for the NSW Hunter/Central Coast nodes north of greater Sydney.

There are significant existing binding constraint points both north and south of the Snowy Scheme even without the addition of Snowy 2.0 capacity. A binding constraint is when there is a direct and limiting impact on the dispatch of power generation, meaning that the dispatch (and therefore electrical flows across the network) could be more efficient if the constraint was removed. The constraints in the southern NSW network are shown on Figure 4.1 (black dotted lines).

i Resilience and reliance risks

It is considered that resilience and reliance risks to the NEM are low probability, however they have very high or catastrophic impact consequences when they occur. The outage impact is widespread, and a cascading failure will likely result in a state-wide blackout which will have a catastrophic consequence for NSW. This identified risk needs to be managed for Snowy 2.0 as it will provide a reliable source of electricity to the NEM as it transitions away from a long-standing reliance on coal-fired power stations to a reliance on renewable energy.

Understanding the risk is important in determining the preferred transmission arrangement. Typically, it is less common for experts to quantitatively define low probabilities (ie High Impact Low Probability (HILP) events) as they instead typically carry out resilience assessment of High Impact Low Frequency (HILF) events on the basis that probabilities cannot be meaningfully ascertained for quantitative calculations whilst impacts of events are becoming much easier to calculate. For example, power outages in Texas USA, due to the 2021 polar storm (>$20 billion (B) and 200 deaths), or the South Australia state-wide 8-hour blackout in 2016 ($500 M). Resilience studies more commonly consider vulnerability to low frequency occurrence events and are based on proximity, buffer zones and diversification of routes and fuels.

A potential quantitative measure of frequency is provided in the AEMO *Power System Reclassification Events* reports available at https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-events-and-reports/power-system-reclassification-events. The number of reclassifications by AEMO provides a record of the frequency in which non-credible contingency events are reclassified to credible contingency events and which are considered a threat to power system security.

Over the last five years, AEMO has performed a significant number of reclassification events (growing from approximately 800 per year to greater than 1,000 per year) which provides a clear indication that threats to power system security are regular and are increasing in number.

The proposed solution for the Project will need to deliver an as low as reasonably practicable (ALARP) solution in response to this outage risk along with achieving the other objectives of the Project.

> ***There is nil spare capacity in the existing southern NSW network for additional generation whether that be Snowy 2.0, Project Energy Connect or the SW-NSW REZ generators. The capacity constraints are historical and have existed since before the NEM started and has resulted in a long-term market inefficiency with under-utilisation of existing installed generation capacity.***

4.2.2 Need for HumeLink

During the *Snowy 2.0 feasibility study* (Snowy Hydro, 2017) it was determined that rebuilding the entire southern NSW 330 kV transmission system including major load substations[2] to relieve these existing constraints and allow additional capacity for Snowy 2.0, Project Energy Connect and any SW-NSW REZ generators would take decades to complete and would include extensive market and customer disruption periods.

Further, by relying on and upgrading existing flow paths and nodes, the increased energy capacity for the existing southern NSW network arrangement would reduce system resilience unless increased route and node geographical diversification was also introduced.

This is the basis of the HumeLink which, in conjunction with Project Energy Connect provides transmission capacity upgrades and geographical route and connection point diversity relative to the existing southern NSW transmission system and will increase system resilience and enable the renewables transition.

HumeLink is a new 500 kV transmission arrangement which will carry electricity to customers from new generation sources, including Snowy 2.0 and which is included in the AEMO ISP 2018 and 2020 as an Actionable ISP project. HumeLink geographical representation relative to the existing southern NSW network is shown in Figure 4.2.

AEMO[3] notes:

> A view to future climate risk resilience will also influence route selection, with projected increases in extreme weather events and bushfires increasing the value of route diversity.

In its 2018 ISP AEMO[4] recognised that:

> SnowyLink [now called HumeLink] provides route diversity to harden the grid against extreme climate conditions, and unlocks high quality renewable energy resources, reducing connection costs for new renewable generation needed once the majority of the coal fleet retires. Without this interconnection, AEMO's modelling indicates that more balancing services (such as gas powered generation or energy storage) would be required to address the lack of diversity that arises from concentrating renewable generation in clusters.

AEMO defines system resilience[5] in electrical networks as a characteristic arising from fuel diversity, geographic diversity (spatial diversity) and strategic redundancy. HumeLink provides geographic route diversity and new connection point locations to increase system resilience and provide the increased transmission network capacity to accommodate the renewable energy transition.

However, there are reductions in system resilience benefits when critical system nodes are grouped too close together as would be the case by locating the Snowy 2.0 connection point at either the existing LTSS or UTSS. These network resilience outcomes would need to be evaluated against other project objectives and evaluation criteria in the design development and evaluation of the preferred connection to the NEM.

[2] Major load substations in southern NSW include Yass 330 kV, Canberra 330 kV, Marulan 330 kV.

[3] AEMO 2018 | Integrated System Plan p.89

[4] AEMO 2018 | Integrated System Plan pp.9

[5] AEMO 2020 | 2020 Integrated System Plan pp. 26

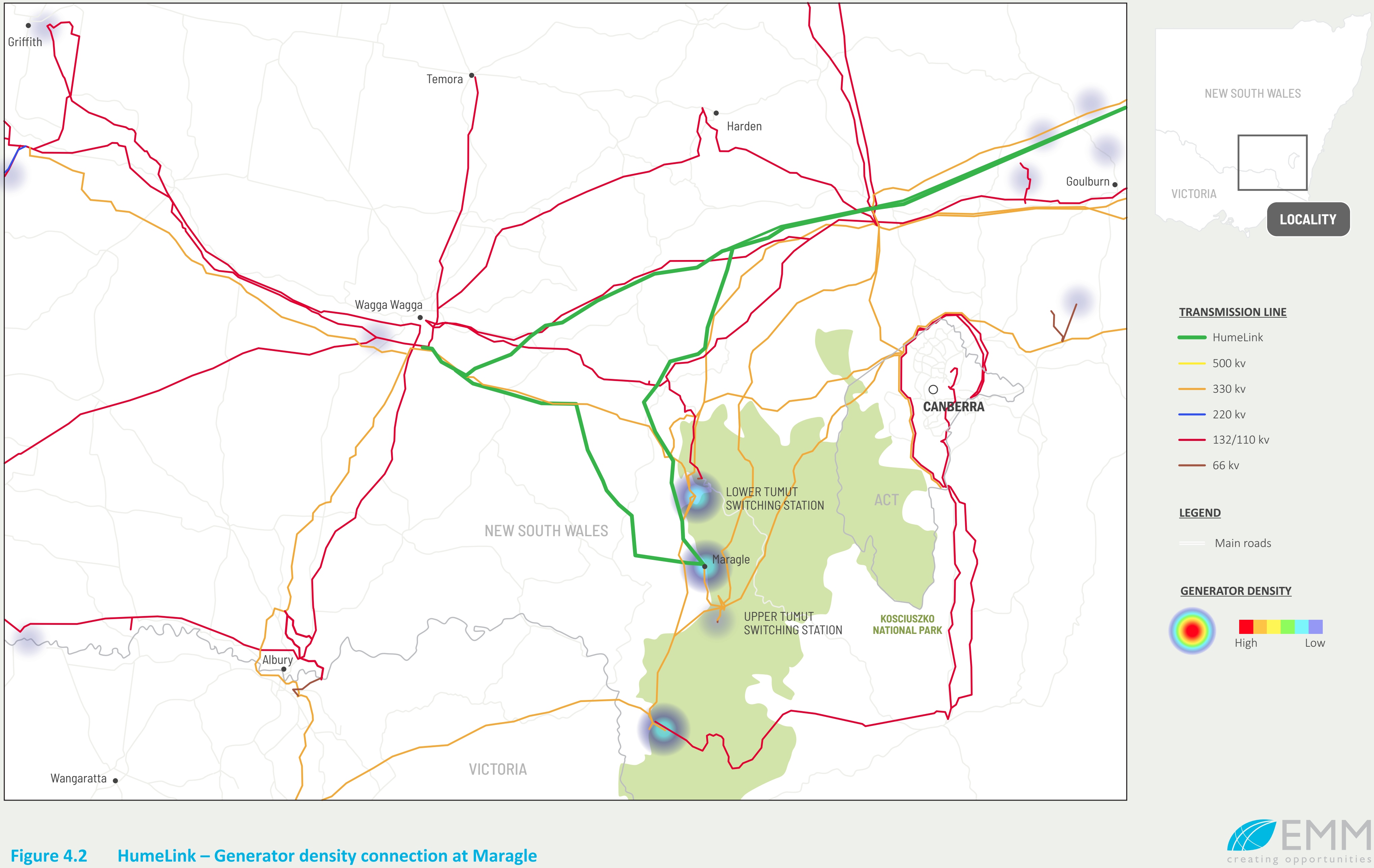


Figure 4.2 HumeLink – Generator density connection at Maragle

It should be noted that it is proposed for the Project to connect Snowy 2.0 to Line 64 initially by the Maragle 330 kV switching station until HumeLink is connected. This will allow for commissioning of the units and a generation or pumping capacity of about 600 MW (ie two units at a time). Snowy 2.0 expects back energisation of the connection assets in mid 2024/early 2025 under the current Snowy 2.0 timeline to allow for commissioning of the Snowy 2.0 330 kV GIS, extra-high voltage (EHV) cables and first two units later in 2025.

The initial HumeLink completion plan was for early 2025 to match the Snowy 2.0 dates; however as stated above, Snowy 2.0 will commission and operate up to two units consecutively into the Maragle 330 kV switching station/Line 64 prior to HumeLink connection.

4.2.3 Connection locations

The following sections provide summary information regarding the system resilience outcomes for the available connection points for HumeLink to the Project.

i Maragle substation

Connection at a newly constructed substation at Maragle, between Upper Tumut and Lower Tumut, is a connection location for the Project. New 500 kV circuits emanating from Maragle substation would transmit power between Snowy 2.0 and the NSW transmission network, via HumeLink and the existing 330 kV Line 64 (refer to Figure 4.2). This connection for HumeLink has been contemplated since the 2018 ISP (AEMO).

The site of the Maragle substation was chosen for the following reasons:

- **Network resilience and reliability** –
  - It is remote from the other substations/switching stations that connect the existing Snowy Scheme generation and Victorian interconnector meaning that risks are reduced due to geographical separation and allows for greater control of power flows. Having electrical separation between the new Maragle substation and the existing LTSS would provide for greater control over the power flow within the transmission grid. This separation enables better utilisation of the 500 kV lines, which is preferred over utilising the lower capacity 330 kV transmission system.
  - The Maragle connection option allows for the existing 330 kV transmission line (Line 64) running between LTSS and UTSS to be switched at the new 330/500 kV Maragle substation. Preliminary studies carried out by TransGrid indicated that switching the existing 330 kV line at Maragle improves the transient stability following the trip of one of the 500 kV circuits leaving Maragle.
  - Should connection at Maragle occur, but the existing 330 kV line (Line 64) is not switched at Maragle, the ability to export power from Snowy 2.0 would need to be restricted under particular dispatch scenarios to avoid transient instability following a 500 kV line fault. Under this scenario, the maximum generation from Snowy 2.0 may need to be reduced by 250 MW.
- **Reduce pressure on existing key links** - Line 64 is considered to be the optimal line to connect to because of lower usage and it allows for greater control of power flows.
- **Minimise infrastructure within KNP** - It allows for the shortest route for the transmission lines from the Lobs Hole cable yard out of KNP and any future network expansions will not need to enter the KNP.

- **Minimise construction duration and risk** –
  - It is a situated on reasonably flat ground which minimises the earthworks required to prepare the substation bench.
  - It is located just off Elliott Way allowing for limited road upgrade/construction works to allow for the construction of the substation and for the delivery of large plant such as the transformers and reactors (see below).

Having electrical separation between the new Maragle substation and the existing LTSS would provide for greater control over the power flow within the transmission grid. This separation enables better utilisation of the 500 kV lines, which is preferred over utilising the lower capacity 330 kV transmission system.

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Should connection at Maragle occur, but existing 330 kV line is not switched at Maragle, the ability to export power from Snowy 2.0 would need to be restricted under particular dispatch scenarios to avoid transient instability following a 500 kV line fault. Under this scenario, the maximum generation from Snowy 2.0 may need to be reduced by 250 MW.

It is technically challenging for the Maragle substation to be sited further south along Line 64 and analysis (refer to Section 8.2.2) indicates it is unlikely to meet key project objectives. Any location further south along Line 64 would likely need substantial road upgrades to be able to deliver the transformers and reactors due to the increased distance from Elliot Way, the main road in the area. The transformer delivery vehicle is expected to be at least 175 tonne (t) and 60 metres (m) long but could very well be heavier and longer. Refer Photograph 4.1 for an image of a similar transformer being delivered to TransGrid's Bannaby substation.

Photograph 4.1 Transformer delivery vehicle used for Bannaby substation

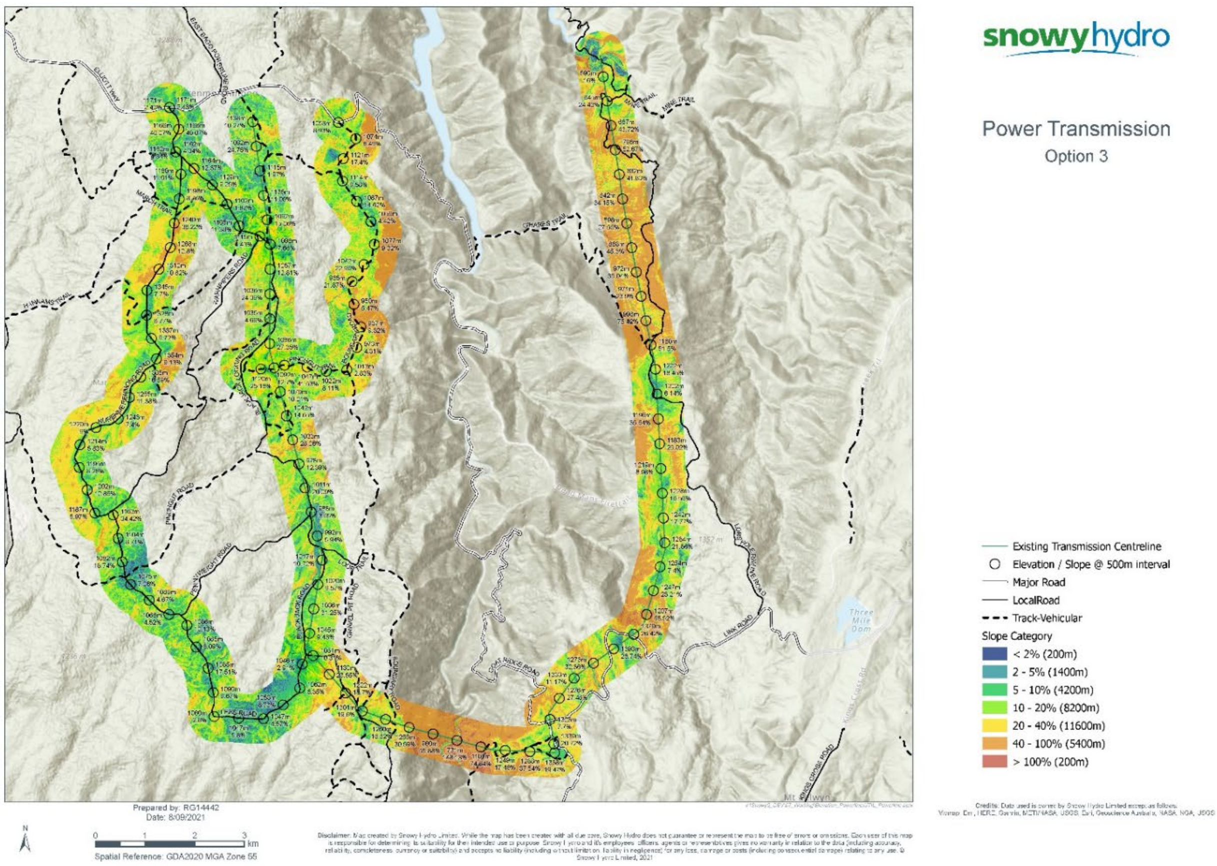


Figure 4.3 Slope mapping (Source: Snowy Hydro)

The slope of potential access routes south along Line 64 is shown in Figure 4.3. This shows that each road/track has a gradient over 12% (some over 40%) and so would require earthworks to construct a suitable access.

Alternate sites further south along Line 64 would also require HumeLink to be extended down through Bago State Forest to the new substation location with the likely route being a new easement adjacent to Line 64, that would pass the proposed Maragle substation location.

Connecting to sites further south would also require longer transmission lines and a larger footprint within KNP.

ii Lower Tumut Switching Station

Connection of Snowy 2.0 to LTSS, and therefore also bringing HumeLink into LTSS, will add to the existing high asset concentration and power density in this area. The following considerations are important with connection to this location:

- It is immediately below the Talbingo Dam wall and spillway;
- It is exposed to bushfire and weather events;
- It has congested transmission exit routes and already forms a critical node in the VNI, refer to Figure 4.1; and
- Exposes the power system to even higher disruption in extreme climate events.

Figure 4.4 illustrates the concentration of assets that would result in having the HumeLink Snowy 2.0 connection point at LTSS. The existing transmission assets are shown in yellow with the addition of HumeLink connection adjacent in blue.

Figure 4.4 Asset and energy concentration at Lower Tumut Switching Station for HumeLink connection (Source: Snowy Hydro)

iii Upper Tumut Switching Station

A potential connection for the Project is at the UTSS. Figure 4.5 shows existing transmission line congestion at the UTSS node which is within KNP in a heavily wooded ridge downward sloping to the west. Even before the addition of Snowy 2.0 lines and the HumeLink 330/500 kV substation, it is clear the substation is exposed to extreme weather events, and as noted previously, forms part of the existing VNI.

Should Snowy 2.0 access the UTSS location, new transmission lines from Lobs Hole to UTSS would be required (a distance of approximately 16 km). The route from Lobs Hole to UTSS would likely follow and extend the existing Line 2 easement which runs north-south from the Lobs Hole to UTSS in KNP with steep downward slopes to the west. This area is recorded habitat for the critically endangered species listed under NSW and Commonwealth biodiversity legislation, the Smoky Mouse. This is considered further in the Screening Assessment within Chapter 7.

The inset within Figure 4.5 shows the existing asset density at UTSS which has 8 x 330 kV lines terminating in the yard as well as an indicative footprint required for the infrastructure required – similar to the proposed Maragle 330/500 kV substation.

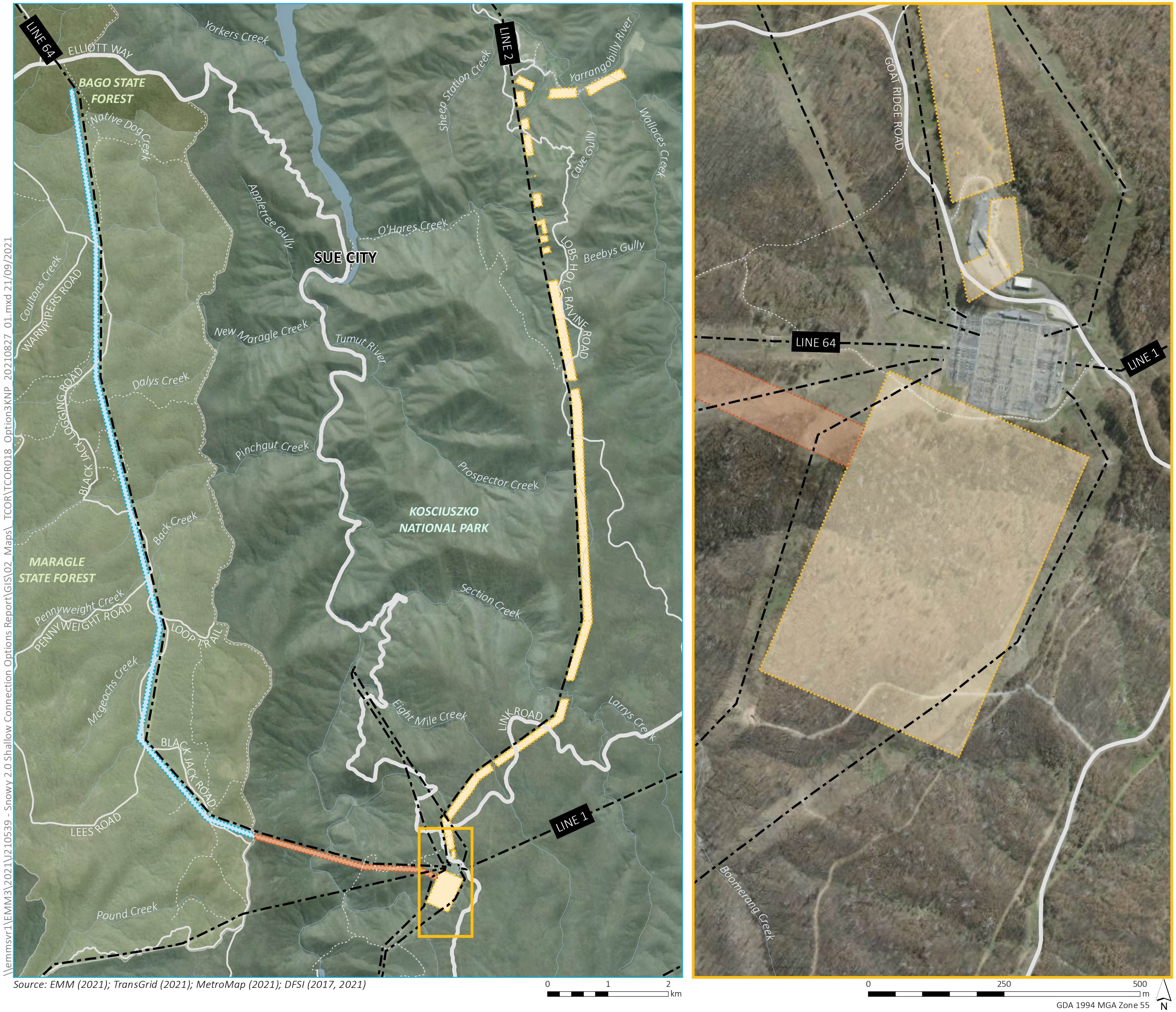
If the Snowy 2.0 connection lines followed the existing Line 2 route, then there would be 'exposure coupling[6]' between the existing Southern NSW 330 kV network and the Snowy 2.0 connection assets over approximately 16 km to UTSS. This would represent a vulnerability in terms of system resilience since Snowy 2.0, HumeLink, Southern NSW 330 kV network, VNI and existing Snowy Hydro Scheme would all be exposed over this distance (all having close spatial and temporal links) and thereby raising the event impact level (Risk Consequence) significantly. Therefore, this would worsen the level of resilience in this part of the NEM.

There may be other local factors which affect Risk Likelihood that are also applied at that specific location which are influenced by the engineering design and localised conditions such as terrain features. These Risk Likelihood reducing factors can be applied when assets are forced to co-locate in order to reduce the overall risk rating. Such mitigating factors may include increasing buffer zones and easement widths (both are used in Snowy 2.0 Main Works EIS options). These risk mitigating factors may introduce other considerations such as footprints and associated environmental impacts which need to be balanced in the selection of the preferred option.

To integrate the Snowy 2.0 HumeLink connection point with existing Upper Tumut or Lower Tumut switching stations, or southern NSW 330 kV lines (eg Line 2) (including the VNI lines), would reduce system resilience gained though geographical diversity achieved by locating the Snowy 2.0 connection point at Maragle, and expose five key energy assets (Snowy 2.0, HumeLink, Southern NSW 330 kV network, VNI and existing Snowy Hydro Scheme) to bushfire and extreme weather events at specific locations

The Snowy 2.0 connection point at Maragle has been a feature of HumeLink since the 2018 ISP when the project was determined to be an actionable ISP project (refer to Figure 4.2***). Maragle was chosen as this location provided a reasonable separation from UTSS, LTSS and the existing Southern NSW 330 kV network.***

[6] 'exposure coupling' simply means locations where assets with different purposes are co-located such that a hazard is capable of affecting all co-located assets at the same time (ie assets are exposed to the same hazard). As a result of co-location the Risk Consequence in that location is increased to account for potential loss of all assets.



Source: EMM (2021); TransGrid (2021); MetroMap (2021); DFSI (2017, 2021)

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KEY

- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest

Transmission connection - Option 3

- Widening of easement and substation footprint (within KNP)
- Hume Link - widening of existing easement (within KNP)
- Hume Link - widening of existing easement (outside KNP)

Option 3 – overhead connection to Upper Tumut Switching Station

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 4.5

creating opportunities

4.3 Design requirements

4.3.1 Circuits

Given the criticality of the power generation from Snowy 2.0 to the stability and energy security and reliability for the NEM, as demonstrated through the CSSI declaration of Snowy 2.0, including this Project, a key design objective is to minimise the risk of losing the ability to transmit this power to consumers.

Electricity network reliability standards govern how network infrastructure is designed, built and operated to avoid or manage interruptions to electricity supply. The level of redundancy specifies the number of backup arrangements (either 1, 2, or 3) that must be in place to support continued supply of electricity in the event that part of the transmission network fails. The redundancy requirement for Snowy 2.0 connection assets is n-1.

A single transmission circuit consists of three phases. Each phase is typically transmitted via a single conductor (wire) or set of conductors in close proximity (300 – 500 millimetres (mm)), though for very high voltages or currents, each phase may be transmitted via a bundle of two or four conductors (cable). The distance between phases is required to maintain their insulation and avoid flashover (a thermally driven fire event). Transmission towers are either a single circuit tower that holds one circuit or a double circuit tower that holds two circuits.

The transmission line arrangement for Snowy 2.0 with four circuits is driven by the need to have the lines separated on two sets of towers to allow for the n-1 in a loss of a single circuit plus the removal a single event that could take out the whole capacity (eg tower failure or lightening flashover). The most optional arrangement in terms of footprint, cost and risk is the current arrangement of two sets of double circuit towers as this allows for the n-1 capacity across the four circuits.

If Snowy 2.0 supplies the loads via a single set of double circuit lines with high-capacity conductors, a multiple contingency event on this section will result in an instantaneous loss of up to 2,000 MW Snowy 2.0 generation or pumping at that point of time. This is because the connection is in the radial configuration (meaning there is only one source of power transmission) and there is no other flow path for Snowy 2.0 generation during the outage.

Under this single set of double circuit lines scenario, this large generation loss will be larger than the current largest generator in the NEM of 750 MW and can lead to widespread loss of supply and load including the possibility of cascading tripping and system blackout. In addition, in the event of forced or planned outage of one circuit, Snowy 2.0 generation required to manage large generator trip events will be limited to approximately 750 MW and the pumping load to manage large load trip events would be limited to approximately 400 MW.

If Snowy 2.0 supplies the loads via two sets of double circuit lines with normal conductors, a multiple contingency event on one of these sets of lines, will likely result in a reduction of up to 400 MW Snowy 2.0 generation or pumping at that point of time, while the remaining set of double circuit lines will continue to transfer approximately 1,600 MW power. It is expected that this will mean that the network will remain stable with the generation gap able to be managed by re-dispatching generation in the other part of the network. Forced or planned outages on one line is also unlikely to constrain generation or pumping load from Snowy 2.0.

4.3.2 Overhead

There are several overhead structure options to carry the circuits required and these are shown in Figure 4.6, along with the typical easement widths required for each structure. These easement widths are required for electrical safety. A double circuit structure generally fits in the same footprint as a single circuit structure.

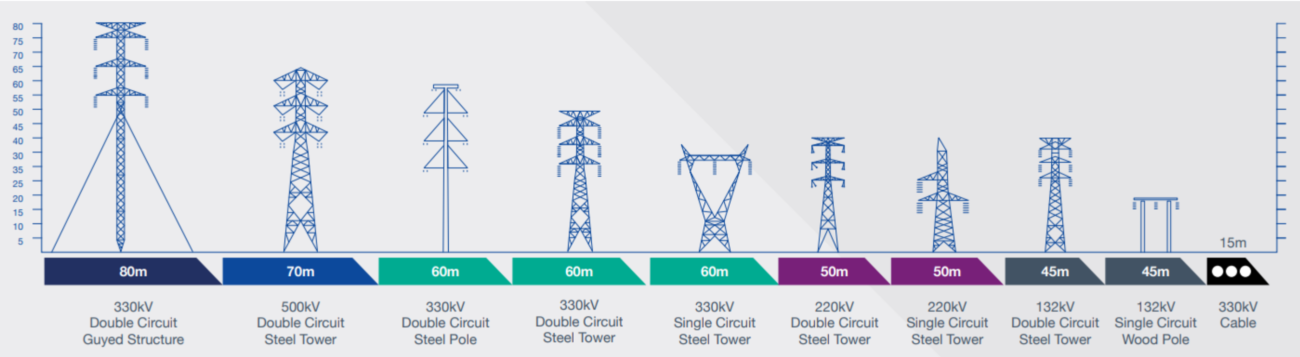


Figure 4.6 Overhead transmission tower and easements

Source: TransGrid 2021 https://www.transgrid.com.au/being-responsible/public-safety/Living-and-working-with-electricity-transmission-lines/Documents/High%20Voltage%20Transmission%20Line%20Fact%20Sheet.pdf

Selection of overhead structures (and resultant required easements) to carry the four circuits for Snowy 2.0 will balance several factors such as the reliability and continuity of power supply from the transmission network, minimum disruption to the power supply system following a fault, ease in operation and maintenance, personnel and public safety, risks and environmental impacts and footprint.

For example, as part of their role, AEMO[7] will assess bushfire threats to transmission assets using a threat weighting system which is based on a number of factors such as temperature, wind speed and direction, fire front characteristics, local terrain, local vegetation types, easement characteristics including adjacent vegetation, and circuit type (for example number of circuits, independent or shared towers etc).

In relation to circuit types, AEMO assigns twice the risk weighting to a double circuit 330 kV tower construction compared to two x single circuit construction when considering the risk of bushfire. This translates to a wider footprint (and likely greater environmental impact) to reduce the bushfire risk with two sets of single circuit structures. The development and evaluation of overhead options will consider the balance of environmental impacts and outage risks to bushfire.

[7] AEMO Power System Security Guidelines SO_OP 3715. Available at: https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/procedures/so_op_3715-power-system-security-guidelines.pdf?la=en

i Double circuit 330 kilovolt and single circuit 500 kilovolt considerations

Considering the broader southern NSW transmission capability level, the original feasibility studies for HumeLink and Snowy 2.0 (references: AEMO NTNDP 2018[8]; AEMO 2018 ISP[9]; TransGrid TAPR 2018[10]) identified the optimal integrated configuration for Energy Connect, SW-NSW REZ integration, Snowy 2.0 and ultimately VNI West, to be:

- 500 kV circuits between Maragle, Wagga Wagga and Bannaby;
- tie into the existing 330 kV network at Maragle to increase voltage stability and worst fault stability case (fault trip of the longest 500 kV line section); and
- the 330 kV connection at Maragle also provides significant market capacity benefits by releasing long stranded Snowy Scheme generation capacity (essentially Murray generation but also Victoria imports) due to the original (pre-NEM) southern NSW network development concept (dictated at that time by State ownership portions of Snowy Hydro rather than NEM benefits).

Not tying into the 330 kV network at Maragle would reduce the overall HumeLink benefits significantly as well as Snowy 2.0 generation and pumping capability.

Once the benefits of tying into the 330 kV network at Maragle were established from a system stability and technical perspective in 2018 (see above), the decision to utilise 330 kV for the Snowy 2.0 connection was essentially set and allowed the use of robust and mature 330 kV technology including the EHV cables and generator step-up transformers (GSUT) that must be housed in the limited space of the underground power station complex.

Changing from a 330 kV to 500 kV GSUT would be extremely disruptive to Snowy 2.0, requiring significant redesign of the underground cavern, the EHV cable system and surface GIS and possibly also the access roads and tunnels.

ii One double circuit connection and network considerations

Under the scenario of a Snowy 2.0 connection via a double circuit set of lines, it would be expected these lines will transfer up to 2,000 MW of power for both generation and pumping mode. When there is a double circuit outage, the Snowy 2.0 generator (ie power station) needs to be tripped since the connection is in radial configuration and there is no parallel flow path (ie generation cannot be redistributed elsewhere as it is only transferred by the double circuit).

Figure 4.7 and Figure 4.8 show the power flows under double circuit trips for HumeLink and Snowy 2.0, respectively. Figure 4.7 shows that a single set of double circuit lines for HumeLink can be developed with the power system remaining stable given the alternate power flows within the existing network via UTSS and LTSS should an outage be experienced (or predicted) on these lines.

8 AEMO – National Transmission Network Development Plan for the National Electricity Market, December 2018 (https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/ntndp/2018/2018-ntndp.pdf?la=en&hash=E50823D922F67FF9D4A5103898C8E14C)

9 AEMO – Integrated System Plan for the National Electricity Market, July 2018 (https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/isp/2018/integrated-system-plan-2018_final.pdf?la=en&hash=40A09040B912C8DE0298FDF4D2C02C6C)

10 TransGrid, Transmission Annual Planning Report 2018 (https://www.transgrid.com.au/media/0q1dau2w/transmission-annual-planning-report-2018.pdf

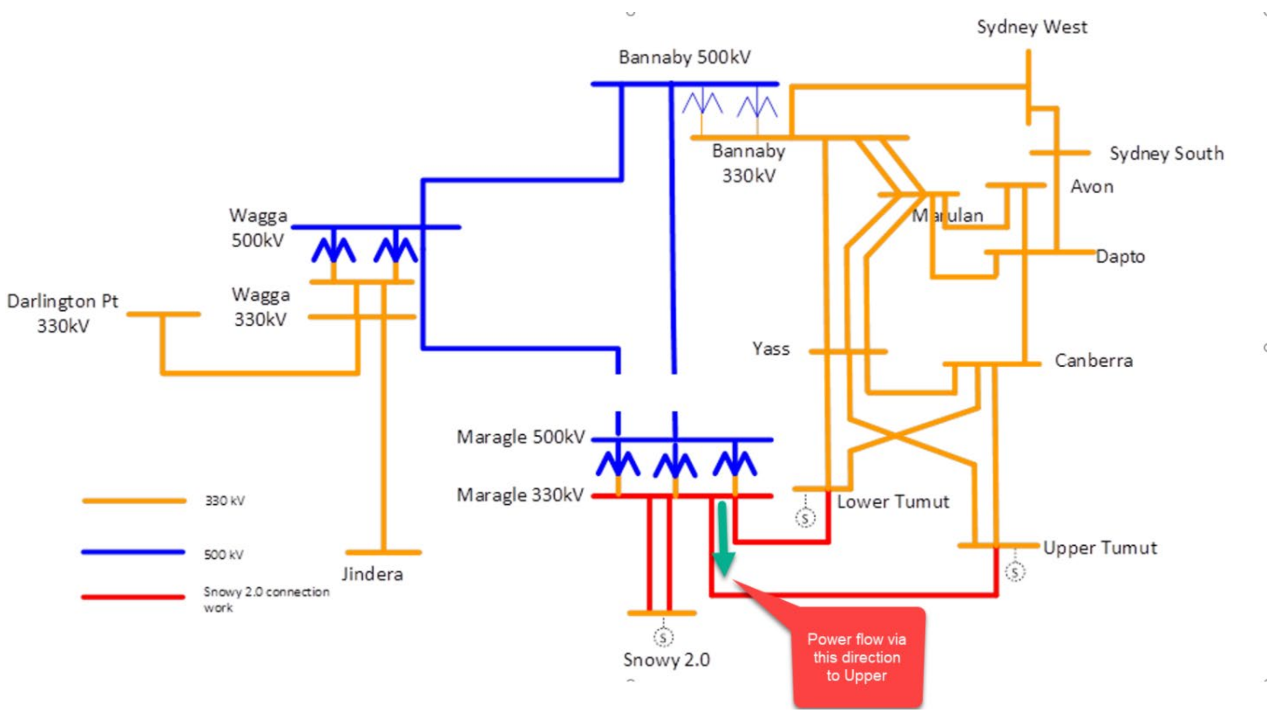


Figure 4.7 HumeLink – one double circuit trip scenario

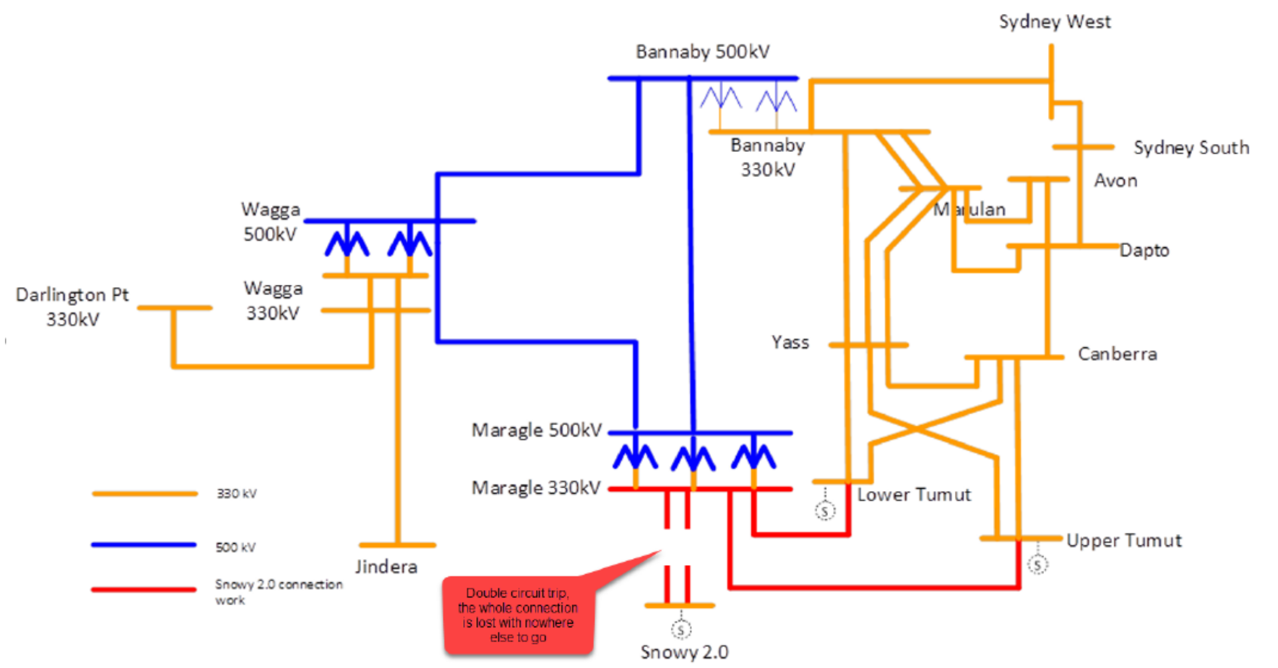


Figure 4.8 Snowy 2.0 Connection - one double circuit trip scenario

Under the double circuit arrangement for Snowy 2.0 shown in Figure 4.8, the following HILP events are possible:

- If Snowy 2.0 was generating at 2,000 MW for the NEM at the time of the loss of the double circuit and the power station was tripped, around the equivalent load to the generation will need to be tripped within less than ~100 milliseconds (ms) to maintain the voltage stability of the network and avoid the widespread loss of supply and load. The result is a likely NSW-wide blackout.

- If Snowy 2.0 was pumping at 2,000 MW with the loss of the double circuit and trip of the pumping load, around an equivalent load elsewhere will need to be tripped within less than ~100 ms to maintain the voltage stability of the network and avoid the widespread loss of supply and load. The result is a likely NSW-wide blackout.

Typically TransGrid has determined these types of schemes are not viable due to the speed, complexity, geographical spread and critical nature of the schemes. This scheme would have to be able to operate in the longer term and may not be viable in this form due to changing nature of the NEM and loss of large generators and possible loads that would be required.

For the double circuit set of lines for Snowy 2.0, individual loads and generation equivalent to the 2,000 MW of Snowy 2.0 generation would need to be found for this HILP event. Loads to be determined for inclusion in the scheme need to be made available for tripping at all times, including at times of minimum system load conditions. Loads that participate in AEMO's Reliability and Emergency Reserve Trade (RERT) function are considered unavailable for use in the scheme at load conditions higher than average demand. Other operational issues (ie possible local over-voltage issues) are considered when selecting the loads. Further considerations of the risk of maloperations include, but are not limited to:

- false operation of the scheme;
- failure to trip the correct amount of load or generator when required; and
- unavailability of the scheme.

Under the scenario of a double circuit outage of HumeLink 500 kV lines, up to 1,350 MW will be able to flow via the parallel 330 kV network (Lower Tumut/Upper Tumut – Yass/Canberra – Marulan/Dapto – Sydney South/West) while the power system can still remain stable. Depending on the flow on the HumeLink lines at the time of the double circuit outage event, a reduction of up to 1,150 MW flow (roughly up to 650 MW of Snowy 2.0 generation and up to 500 MW of existing Snowy Scheme generation) will be required from southern NSW to the major load centres.

The probability of double circuit outage event for HumeLink will be managed by improved design performance and parameters to reduce a double flashover event (eg improving ground resistance, increasing insulation levels, installation of surge arrestors etc). The reduction of power flow under the double circuit outage of HumeLink is significantly lower than the reduction of power flow under double circuit outage of Snowy 2.0 connection lines.

4.3.3 Underground

Transmission of power underground requires consideration of different design and constructability factors than those in overhead. These include close evaluation of the ground conditions and immediate environment to the cables themselves.

i Deep cable tunnel

Installation of the HV cables requires special consideration in deep vertical shafts. The weight of these cables is approximately 42 kilograms per metre (kg/m) and in deep vertical shafts the force of gravity can cause internal slippage between the copper core and surrounding insulation material potentially leading to failure of the cable.

Within the tunnel, cables would be configured in a flat arrangement by means of regularly spaced cleats as shown in Figure 4.9. The cable bundle would be placed on steel supports affixed to the tunnel lining, with allowance for snaking between supports to accommodate thermal movements. Cables would be pulled into the tunnel using rollers, winches, and pushing machines to reduce tension during the cable pulling. A bespoke crane would be developed to fit the tunnel size and would be used to hoist the cables on to the support arms.

Cables used in the tunnel would be specially chosen to have low smoke and zero halogen properties to minimize risk of fire and safety of personnel entering the tunnel for maintenance. Whilst there are fire retardant products that would be applied to the cables to impede the spread of flame along the cable surface in a fire scenario, it remains a design risk.

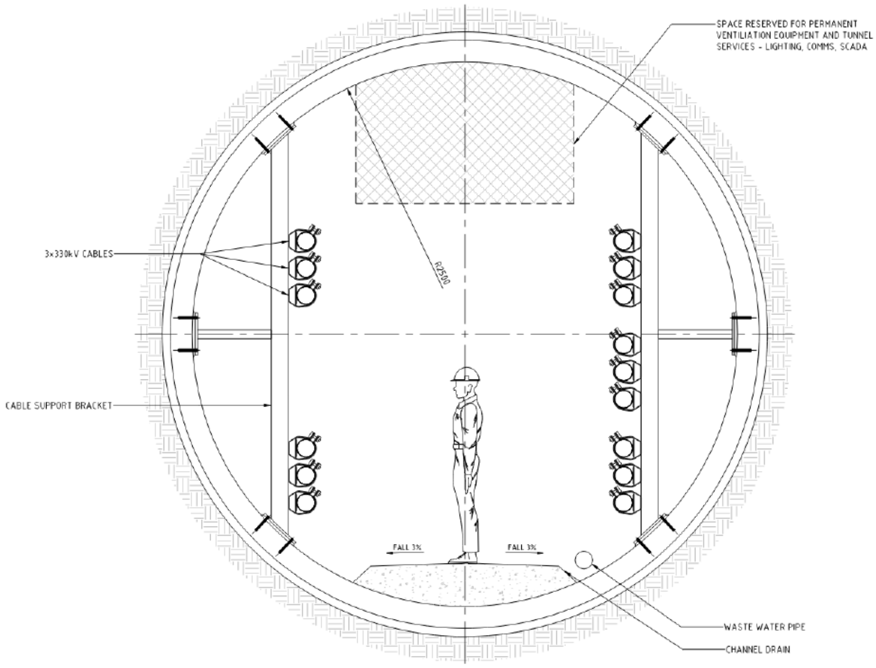


Figure 4.9 Tunnel indicative cross section

ii Trench

Sensitivity studies considering changes in cable arrangement, increased spacing between cables and lower native soil thermal resistivity values were undertaken to assess the feasibility of using two double circuits. It was determined that the required power transmission could not be achieved with four circuits without exceeding the cables' maximum conductor temperature (90 degrees Celsius (°C)) or increasing trench size and thermal separation between circuits to impractical values. As such, a fifth circuit needed to be introduced to provide the n-1 rating capacity of 2,550 megavolt amps (MVA). For five circuits, each circuit would need to be rated for 637.5 MVA. This equates to approximately 1,116 amps (A).

The choice of distance between circuit groups was driven by the thermal separation requirements (based on CYMCAP modelling using assumed thermal resistivity values). There is no relationship between the location of the road and the separation of the circuits. The thermal requirements dictate the width required between circuits not the road. Without this width the cables do not provide the required ratings.

A road has been placed across this separation width between circuits but the road could be located over the cables (refer to Figure 4.10). If the road was moved to sit across the cables the separation of the cables would remain the same and hence the overall width of the corridor is unaffected by the location of the access road.

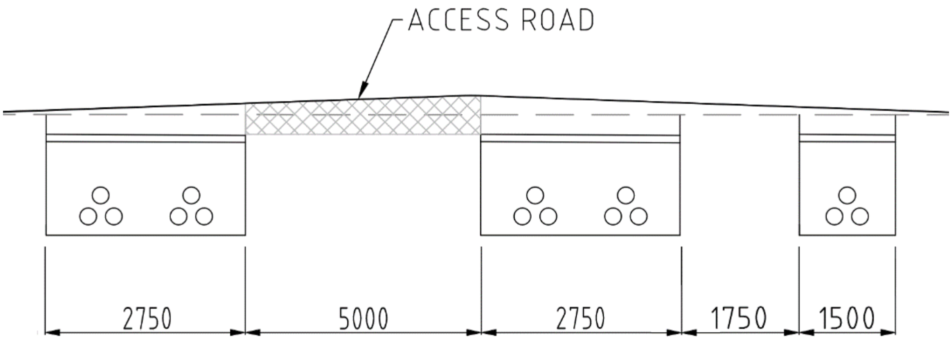


Figure 4.10 Surface trenched cable: typical cross section

4.4 Construction requirements

Transmission connections can be constructed in a variety of ways either overhead or underground. Submarine cables can also be constructed within waterbodies. Each construction method has different positives and negatives.

Electrical transmission connections require easements over the land where the connection is placed. Easements protect the safety of people living, working, or playing near electricity infrastructure by controlling activities under or near the network. They also provide the electricity provider with the right to safely access, operate, maintain, and upgrade the network. Vegetation within easements is often maintained to prevent bush fire hazards and to protect the transmission infrastructure from being damaged.

The width of easements varies depending upon the operating voltage, design of the transmission line, the length of the conductor span between structures, and the local terrain. As shown in Figure 4.6 there are different easement widths for different transmission structures. Generally, the higher the voltage, the wider the easement required.

4.4.1 Overhead

Overhead lines are the most common form of transmission connection. An overhead transmission line consists of a series of conductors (metal wires) supported by transmission structures to maintain a safe electrical clearance to the ground. The structures may be lattice towers or poles made of steel, concrete or wood, with varying designs depending on the number of conductors, the voltage and local environment. An example of a transmission tower for overhead lines is provided in Figure 4.11.

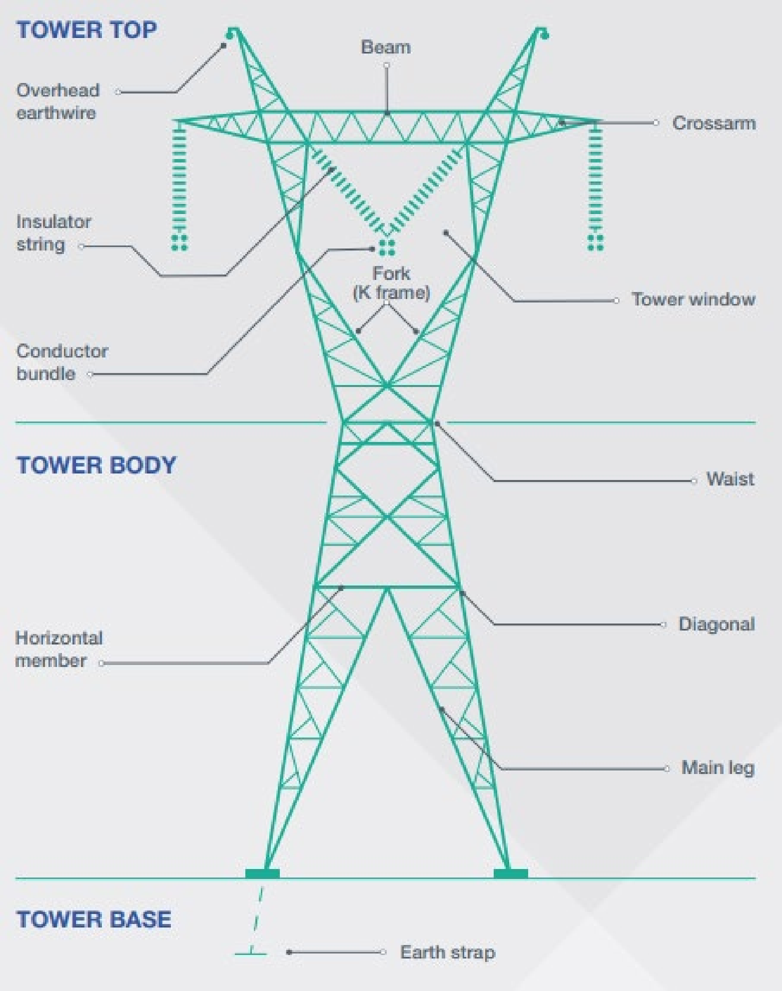


Figure 4.11 Example transmission tower for overhead lines

Source: TransGrid 2021 https://www.transgrid.com.au/being-responsible/public-safety/Living-and-working-with-electricity-transmission-lines/Documents/High%20Voltage%20Transmission%20Line%20Fact%20Sheet.pdf

A transmission line consists of one or two circuits. Each transmission line also has one or two earth wires. The earth wires are designed to protect the circuits from lightning strike, help to reduce the earth potential rise, and assist in ensuring that the circuit breakers turn the voltage off as soon as possible, if there is a fault. Earth wires may contain optic fibre for communications data, which enable real-time monitoring of the network and can identify faults.

At the base of transmission line structures, there are buried earth straps which extend for up to 15 m from the footings. On poles, standard earthing is buried under the butt of the pole, but where soil conditions are poor, there may be additional earthing extending from the base of the pole up to 8 m in any direction.

Structures may also be supported by guy wires, which extend out from the pole to provide additional strength and support. Guy wires also have a buried earth strap which extends toward the pole for approximately 2-3 m. Guy wires are connected to the pole earthing system and can generate earth potential rise under fault conditions. The tower leg or pole butt is encased in a concrete footing which can be anywhere from 3-10 m deep.

Transmission structures are required to be constructed on a level, cleared area. Construction benches are typically constructed using an excavator utilising a cut-and-fill approach to establish the levelled area. The amount of bulk earthworks required to form the level bench would be dependent on the slope of the terrain at the bench location. Access tracks are also required to each structure location. These access tracks must be of a grade and width suitable for the equipment required for construction and maintenance.

Foundation design, including depth of excavation required for a foundation, is dependent on the geotechnical features of the structure location. Foundation types include concrete pile, rock anchor or mass concrete style foundations. Concrete pile type foundations involve boring four boreholes at each structure leg location, followed by backfilling with concrete. Rock anchors are high tensile steel rods which would be grouted into pre-drilled holes at each structure leg location to provide the anchor point for each leg. Mass concrete type foundations generally involve establishing an open excavation, followed by the installation of steel framework and backfilling with concrete. Blasting can be required for foundation construction, should rock be encountered.

The steel lattice structures of the transmission towers are generally transported in parts to each structure location via heavy vehicle and assembled on-site. Mobile cranes are generally used to move steel members and structure sections around the worksite and position the structure section to allow work crews to manually bolt the sections together. The base of each structure is secured to the foundations via holding down bolts at each structure leg.

A process called 'tension stringing' is used to string the conductors and overhead earth wires between the transmission line structures using hydraulic tensioning and pulling equipment. This process ensures that the conductors and earth wires remain above the ground during the stringing of each section.

4.4.2 Underground

Installation of underground cabling can be undertaken as an alternative to overhead lines. Construction costs for underground transmission are substantially higher than overhead due to the higher amounts of civil works (materials, equipment and labour) required and the cable types and installation requirements to achieve the required thermal rating. Therefore, it is generally only considered in areas where overhead construction is not possible.

Further information on the construction requirements for transmission tunnels (deep tunnels and micro tunnels) and trenches is provided below.

i Deep tunnels

Deep tunnels for transmission cables can be constructed using a tunnel boring machine (TBM) for excavation of the ground. Precast concrete segments are placed to form a full circular lining as the TBM is advanced. It is desirable to have the TBM operating in an uphill direction to allow water ingress during tunnel construction to drain back away from the TBM head. A deep tunnel requires the construction of an entry portal as well as access and ventilation shafts/adits. Vertical or steep access shafts require construction of stairwells or lifts for movement of personnel.

The TBM is required to be designed for the specific ground conditions of the chosen alignment which requires the collection of geotechnical information through drilling. The purchase of the TBM typically takes 24 months including procurement, design, manufacturing, testing and transport to site (as experienced with Snowy 2.0). The typical tunnelling rate estimated for Snowy 2.0 using a TBM is 12 metres per day (m/day).

Limits are placed on the maximum gradient of deep tunnels based on their intended use. A gradient of 4.5% is the normal industry practice for spoil handling and segment delivery trains and the typical practical limit without consideration of specialist designs such as rack and pinion rail for TBMs. Tunnels with higher gradients can present safety issues, particularly for heavy vehicles where steeper grades increase the likelihood of brake-related issues and the potential for vehicle runaway to occur. In addition, these tunnels form part of the 'path to safety' for construction and maintenance persons in the event of an emergency and lower gradients support higher travel speeds (less physical exertion) which means less time is required to reach a place of safety. There are also benefits for safety-critical systems, such as ventilation, as the path of smoke is easier to control on shallower grades as it has less 'effective' self-buoyancy which makes it easier to ensure that the path it will take is not the same as occupants attempting to egress. Where a gradient above 5% is proposed, there is likely to be a need for specialist engineering studies to be undertaken in relation to smoke management in the event of fire to ensure that people will always have a feasible path to safety.

For Snowy 2.0, a maximum limit of 10% was adopted for tunnels intended for permanent access by people and vehicles and gradients of between 10 and 12% for temporary construction tunnels. Higher gradients are only proposed for waterway tunnels, such as the inclined pressure shaft at Snowy 2.0 which will be constructed at a grade of 46.73% or 25°. However, these tunnels are not designed for access and will be filled with water once constructed.

Deep tunnel transmission cables require consideration of additional safe work practices. The key issues for safety in tunnels and underground construction are:

- frequency of required access;
- dimensions to facilitate retrieval of persons in medical emergency;
- atmosphere control;
- evacuation is required in an upwards movement; and
- use of lifts for deep shafts which can trap personnel during a fire if their power supplies are not protected (ie single point failure avoidance, fire proof critical supplies and mineral-insulated metal sheath (MIMS) cabling etc).

One of the most significant risks during construction of a TBM tunnel is an event causing blockage of the single escape path. Methods for management of these events typically involve establishing alternate exits or a refuge chamber or other place of safety to await rescue. Typically, such chambers are an integrated part of the TBM. These are typically equipped with fire doors, air supply and other items to allow for workers to remain safe until it is safe to exit. The intermediate shaft could also be used for emergency egress once excavation has reached that point.

The installation of electrical cables in deep vertical shafts requires special consideration. The weight of cables and the force of gravity in deep vertical shafts can cause internal slippage between the copper core and surrounding insulation material potentially leading to failure of the cable. Frequently spaced cable supports using bespoke cleats and use of cable with a high coefficient of friction between its internal layers are used to assist in managing the forces exerted on the cable. In addition, the cables can be snaked to partially relieve the vertical forces and mitigate the effects of thermomechanical expansion. The deepest known vertical shaft for 330 kV cables is 280 m. the viability of manufacturing a cable that is suitable for installation and long-term operation at greater depths than this is unknown.

Photograph 4.2 shows photographs of cable replacement in a vertical shaft at an underground power station in New Zealand in 2003. This installation was of 220 kV cables with a 180 m vertical drop. As can be seen in the photographs, the installation methodology used pulling socks attached to a steel rope. Pulling socks were placed at regular intervals along the rope so that each one supported a short section of cable. Winches placed at intervals down the shaft and controlled with synchronised variable speed drives let out the rope and thus the HV cables in a controlled manner. It is unknown if the vertical shaft shown in Photograph 4.2 would comply with contemporary safe access requirements for personnel.

Photograph 4.2 Vertical cable installation[11]

ii Micro tunnels

Micro tunnels to carry cables can be constructed through horizontal directional drilling (HDD), which is the process of using a small diameter boring machine to advance the tunnel with pre-made concrete segmental lining segments jacked into position behind as the excavation progresses. Micro tunnels can be up to approximately 4 m in diameter, although typically are in the range of 1 – 2.5 m. They are usually used to overcome local obstructions over short distances such as roads, rivers, or built-up areas where overhead line routes and surface cable installations are not practical.

11 Courtesy Meridian Energy Limited, 2003

The excavation is progressed by pumping a slurry mixture to the cutting head of the boring machine. The resulting spoil, comprising slurry and soil/rock particles is pumped to the surface where the water is separated out and then recycled back into the process. When the cutting head has advanced sufficiently, a new segment is lowered into position behind the previously installed segment and the entire tunnel is jacked forward using hydraulic rams. The resistance between the concrete segment and the ground is reduced by using a bentonite-based lubricant around the annulus. Micro-tunnels are usually installed in straight lines although some curvature is possible; however, this reduces the distance that can be achieved.

The location of launch and receive shafts along the route is based on several considerations, including:

- alignment – the tunnel would be advanced as a series of straight sections;
- the maximum distance the lining can be jacked;
- length of cables between joints; and
- topography.

iii Trenches

The installation of cables in a surface trench is typically done using a cut and cover technique. Transmission cables are installed in an engineered thermal backfill, with the location of the buried cables marked by cable marker slabs. In some places the cable is contained within conduits or concrete ducts or cable bridges. Communications cabling may also be laid in the same trench.

Lengths of cables are joined together in reinforced concrete joint bays. Joint bays often have other associated assets such as pits for earth bonding, insulation oil monitoring and communications fibre splice boxes. Joint bays can have the same earth potential rise risks as overhead line earth straps and guy wires.

An example of this technique is shown in Photograph 4.3.

Photograph 4.3 Example of cable installed in a surface trench using a cut and cover excavation method

The process for construction of a trench to lay cables generally involves the following steps:

1. Site establishment – easement surveyed, cleared and prepared for construction with the corridor established with access roads, laydown areas and workforce amenities.

2. Trench and bench excavation – plant and equipment used to excavate materials from the trench. Where possible, excavated materials can be stored to be used in later stages as backfill over the thermally stable backfill. Excess materials require disposal. On undulating land, excavation is required by benching into the natural slope to construct the flat corridor required to accommodate the cable trenches and access roads.

3. Conduit installation – conduits installed with thermally stable backfill (TSB) used to fill and reinstate the trench.

4. Joint bays – joint bays, link boxes and fibre pits are installed and backfilled.

5. Cable installation – cables are delivered to the site in drums. The cables are progressively pulled through the conduits from joint bays. Testing is then completed prior to backfilling and reinstatement of joint bays.

6. Commissioning – cable system is tested and commissioned.

Typical cross sections of a surface bench and trench on flat terrain and steep land are shown in Figure 4.12 and Figure 4.13, respectively. As can be seen, the steeper the terrain the more excavation is required to construct the surface trench and the wider the disturbance footprint. Once construction is complete, remaining infrastructure includes access roads for ongoing maintenance and drainage swales for surface water runoff.

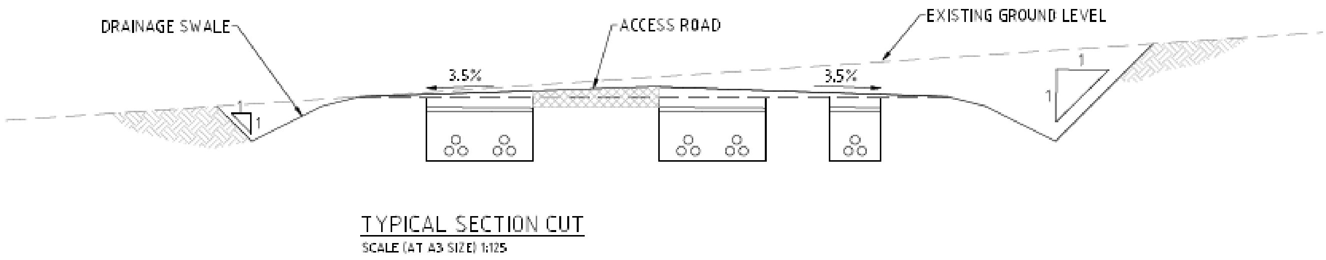


Figure 4.12 Typical cross section of surface trench on flat terrain

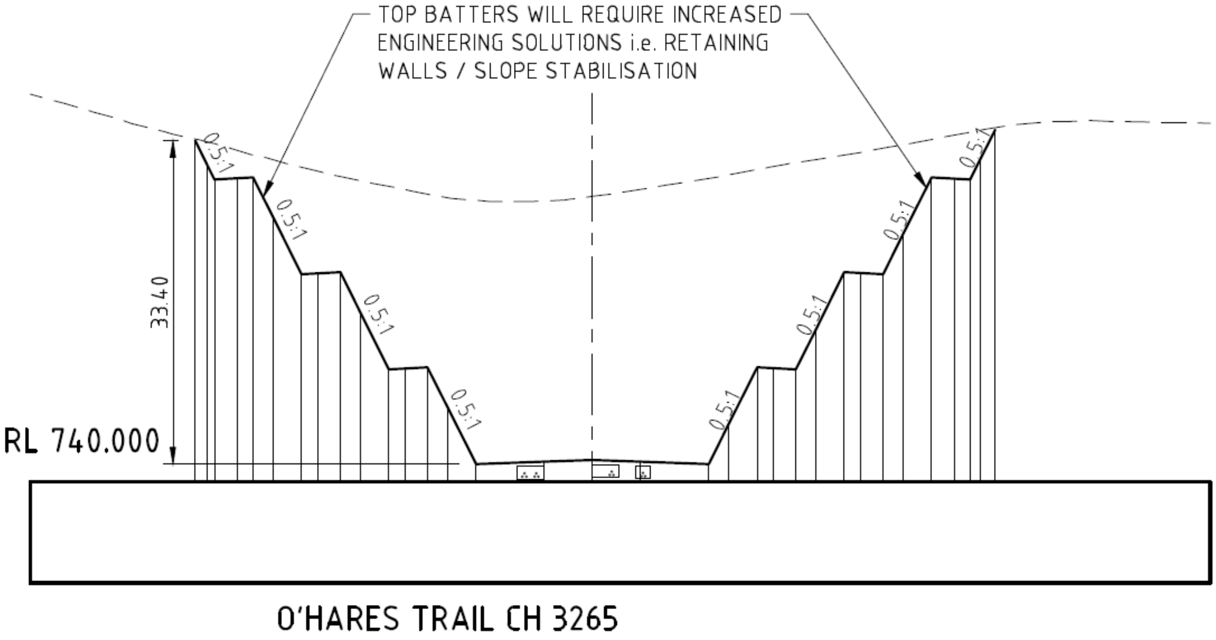


Figure 4.13 Typical cross section of surface trench on steep terrain

4.4.3 Submarine

Submarine transmission cables can be placed on the floor of waterbodies. This requires a cable system to be specifically designed to meet the conditions of the selected path. Cables are often buried in a trench and covered with sediment, rocks or artificial coverings. Submersible equipment is required to dig trenches and lay and bury the cables, sometimes with the assistance of divers.

The high costs of submarine cable installation due to the associated complex construction and technical requirements means that it is generally only considered in areas where overhead or underground construction is not possible, ie crossings of wide waterbodies.

Submarine cables are generally manufactured in high volumes (ie very long runs). This is because the complexity of jointing submarine cables and joint repair drives a need to minimise the number of joints. To reduce the number of joints the submarine cable would need to be manufactured at a waterside factory and run directly onto cable laying vessels (such as bespoke barges). Generally, construction of a submarine cable manufacturing facility and suitably sized transport vessel on site would also be impractical and cost prohibitive.

4.5 Maintenance requirements

The quality of transmission lines can be controlled by ensuring the cables or conductors are designed and manufactured to an adequate standard. Various tests are involved both at the factory and after installation to check the cable or conductor meets the minimum requirements.

Similarly, there are several checks and tests made throughout the installation process to check the integrity of the installation and quality of the materials used. However, the installation environment can impact the condition of the cable and associated infrastructure (ie towers, tunnel, trench, easements, access roads) over time and ongoing maintenance during the life of the transmission line is required.

Maintenance requirements specific to overhead, underground and submarine cables are detailed below.

4.5.1 Overhead

For overhead lines, conductors are well-separated from contact with the ground or each other; however, there is greater chance of exposure to external environmental factors such as bushfire smoke or wind-blown objects.

For a permanent fault on an overhead line circuit, such as a fallen conductor, the repair time is likely to be between one to two weeks. This relativity fast repair time is mainly due to the conductors being visible (and therefore the fault can be quickly identified) and accessible from the ground.

4.5.2 Underground

Surface trench and deep tunnel transmission lines have a natural resilience to adverse weather conditions and bushfires as they are located below ground.

Cables in surface trench are installed in conduits and, therefore, do not have a direct contact with the external environment. However, moisture migration from the native soil, increases in soil temperatures, vegetation encroachment or physical changes to the soil make up can have a detrimental impact to the cable condition which in turn may lead to premature failure.

The mean time to repair for cables in a trench could take between one to six months depending on where the fault is located and ease of access. Faults would most likely occur at a joint, and these would be easily accessed via a pit and therefore relatively quickly fixed. If the fault is located on a cable between pits, any repair would take longer as the cable would have to be carefully excavated, repaired, tested and commissioned before backfilling.

To protect the cable system from vegetation growth and to allow for future cable maintenance access, vegetation clearance and ongoing maintenance is required on either side of the trench.

For the deep tunnel option, the natural background temperature in the tunnel is maintained at a consistent level due to its depth below the surface. Changes to the physical environment and moisture levels do not vary and, therefore, the likelihood of cable failure due to changes in environmental conditions is greatly reduced.

The repair time for a cable in a tunnel would depend on its location and distance from the nearest access point. Safety protocols such as purging the air using the ventilation system, planning for emergency evacuation and requirement to use specialist equipment would mean that any repair could take between one month to four months. A significant failure event such as a tunnel fire, flood or seismic event may take much longer to undertake the required repair activities although the likelihood of these events is relativity low.

Significant maintenance of the tunnel and shafts themselves would also be required. This would include maintenance of the excavation support systems, ventilation systems, power supply systems, security and communication systems, lifts and access, drainage and water management systems (constant pumping would be required to drain tunnel/shaft seepage and potentially treat and discharge it). Ongoing maintenance of access roads, surface infrastructure and vegetation around shafts/adit portals as well as regular program of leak detection and plugging (or combination of both) and sump management would be required for the deep tunnel option.

4.5.3 Submarine cable

Submarine cables require physical protection against natural hazards or human activity. The main threats to submarine transmission cables are external impacts due to anchors or fishing gear. Cable protection zones can be established along a cable's path where activities that might damage the cables are regulated.

Cables must be periodically checked and maintained in order to prevent deterioration. Maintenance requirements include:

- survey of the cable to identify possible wear and tear;
- survey of the cable path to check bed stability; and
- replacement of cable components where signs of wear are identified of when components are approaching their lifetime.

These maintenance tasks require specialised vessels with appropriate equipment and so are often costly and technically complex. Divers can be used for inspection and to assist with maintenance at certain depths. If required, replacement of a section of cable placed at depth will result in omega jointing with extensive lengths of excess cable having to be accommodated on the reservoir floor in the future.

4.6 Safety

A core premise of all designs investigated is that of safety during construction and operation and maintenance. It is fundamental that any design and construction activities minimise risks to people, property and the environment using 'so far as is reasonably practicable' (SFAIRP) principles.

This will likely influence fundamental features of the options developed; for example, a relatively shallow tunnel gradient to allow a safer working environment for personnel fitting out the tunnel and then operating and maintaining it in the future, as well as the principle that evacuation procedures should be considered in a similar way to a publicly accessible tunnel rather than the principles used in the construction stage carrying over into operation.

4.7 Kosciuszko National Park

As discussed in Chapter 2, Snowy 2.0 is being constructed within KNP, one of Australia's sub-alpine national park. The KNP covers approximately 690,000 ha in the alpine region of NSW and is used recreationally for fishing, mountain biking, skiing, horse riding and camping.

Several threatened ecological communities and populations are found in proximity to the area where Snowy 2.0 is being constructed. Impacts to biodiversity was a key assessment and regulatory matter for the Snowy 2.0 Main Works project. Minimisation of impacts to KNP and its values is a key project objective.

Notwithstanding the above, areas of KNP contains prominent and functionally important overhead electricity infrastructure built with the construction of the Snowy Scheme. This infrastructure plays a critical role in delivering the existing electricity generated from the Scheme to customers in the main load centres of Sydney and Melbourne. In the northern section of the KNP, where the Project is, the Tumut 3 power station comprises a network of transmission assets to deliver up to 1,800 MW of electricity to the NEM.

The following sections describe the long-term management framework of KNP and its relevance to electricity assets as well as describing the existing electricity assets within KNP and those already approved and under construction as part of Snowy 2.0. This is important context in the design development and evaluation of the Project and its connection to the grid.

4.7.1 Plan of Management

The *Kosciusko National Park Plan of Management* (KNP PoM) is a framework which outlines objectives, principles, and policies to guide the long-term management of KNP. The KNP PoM recognises that HV power lines that transmit electricity produced by the Snowy Scheme traverse KNP. Section 12.6.1 of the KNP PoM outlines that management objectives related to telecommunication and electricity infrastructure services, namely:

> Telecommunication and electricity infrastructure are managed in ways that minimise adverse impacts on the values of the park and other users.

The policies and actions of the KNP PoM require that additional telecommunication and transmission lines be located underground.

As described in the EIS for the Project (Jacobs 2021), transitional measures ahead of amendments to the KNP POM are in place, clause 7 of Schedule 4 to the NSW *Snowy Hydro Corporatisation Act 1997* (SHC Act) provides that for a period of three years from the first Snowy 2.0 approval (7 February 2019 for Exploratory Works for Snowy 2.0), section 81(4) does not operate to prohibit operations being undertaken in relation to Snowy 2.0 (which includes transmission) that are not in accordance with the KNP PoM. Nevertheless, it is understood that amendments to the KNP PoM will be made by NPWS to reflect the requirement to connect Snowy 2.0 to the grid.

4.7.2 Existing electricity assets

Existing electricity assets within, or in close proximity to, KNP are shown in Figure 4.14 and detailed below:

- Tumut 3 power station, a pumped storage hydroelectric power station generating up to 1,800 MW below Talbingo Dam which is part of the Snowy Scheme and is connected to the NEM via the LTSS;
- LTSS at the northern end of Talbingo Reservoir outside of KNP, an existing hub for eight x 330 kV transmission lines;
- UTSS south of Talbingo Reservoir near Cabramurra, an existing hub for eight x 330 kV transmission lines. UTSS provides a critical NEM connection point for existing Snowy generation, pumped storage capacity at

Tumut 3 power station, and a NEM connection point for generation from Upper Tumut and Murray power stations;

- TransGrid's Transmission Line 1 (Line 1) which forms a 330 kV connection between UTSS and Canberra substation;
- TransGrid's Transmission Line 2 (Line 2) which forms a 330 kV connection between UTSS and Yass substation;
- TransGrid's Transmission Line 64 (Line 64), a 330 kV line which currently runs between UTSS and LTSS; and
- other 330 kV transmission lines within, or in close proximity to, KNP.

In addition to the above larger electricity assets, Snowy Hydro retains smaller existing overhead 66 kV easements throughout KNP as part of the existing Snowy Scheme. Some of these easements are proximate to UTSS and eastern parts of Snowy 2.0 and include:

- Providence Portal to Cabramurra transmission line generally south-west of the Snowy Mountains Highway and Link Road route to Cabramurra;
- Providence Portal to Tantangara Reservoir, west of Tantangara Road; and
- Eucumbene to Happy Jacks near the Tolbar Trail.

There are no existing 500 kV assets in proximity to Snowy 2.0.

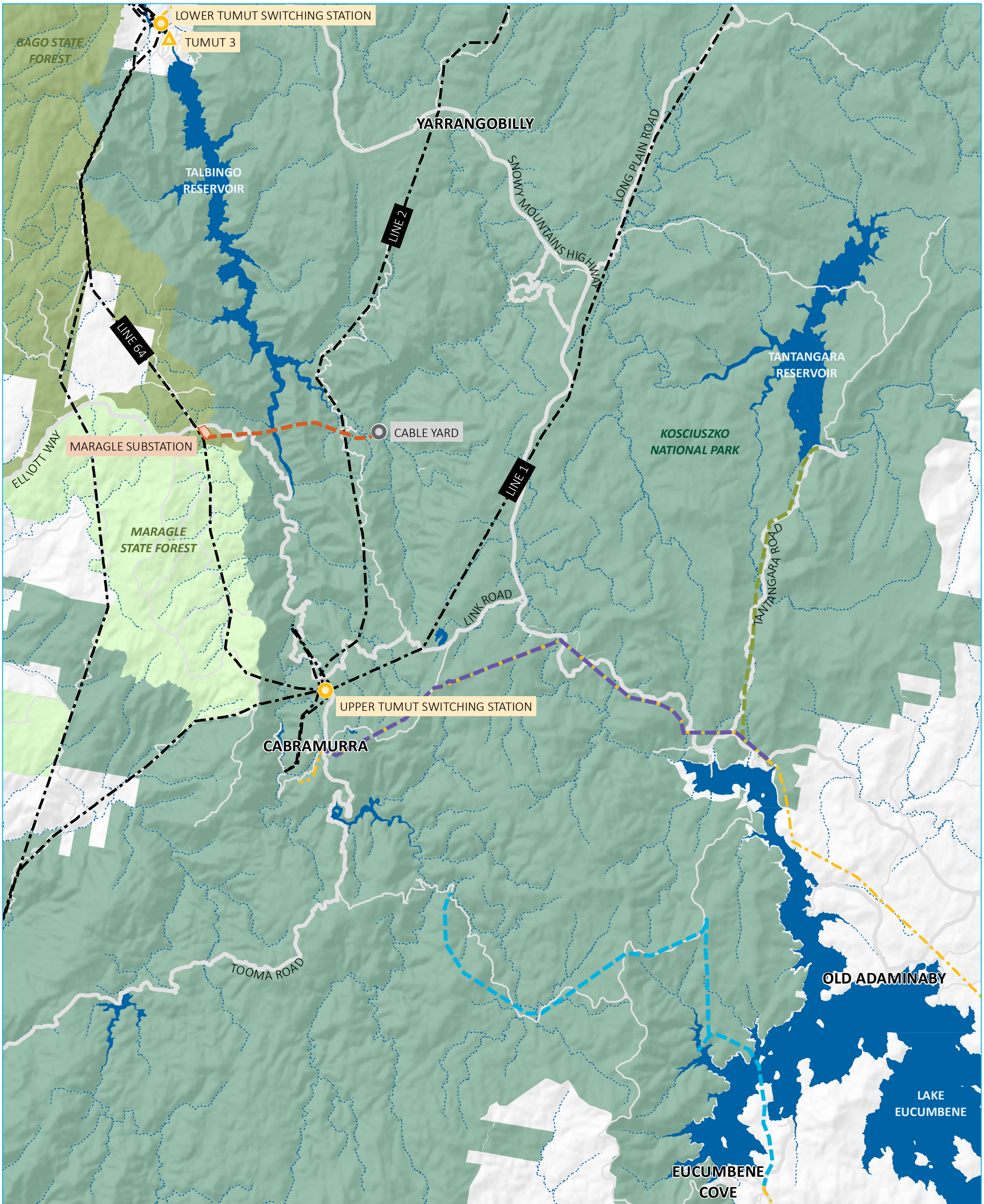
4.7.3 Under construction and proposed electricity assets

In addition to the existing assets described above, there are a number of assets that are being proposed or are under construction within KNP as shown in Figure 4.14 and detailed below:

- Under construction – Snowy 2.0's underground hydro-electric power station, battery storage and cable yard and buried electrical infrastructure to support the construction and operation of Snowy 2.0;
- Proposed within the EIS for the Project – 500/330 kV Maragle substation within Bago State Forest, adjacent to Line 64 and Elliot Way; and
- Proposed within the EIS for the Project – transmission line from Snowy 2.0 to the proposed Maragle substation and to Line 64.

As discussed in Section 3.3, in addition to the Project, HumeLink is proposed to reinforce the transmission network in southern NSW through the construction and operation of a new 500 kV transmission line between the project's proposed substation, Wagga Wagga and Bannaby. HumeLink will be subject to a separate CSSI application and is currently within the initial project development phase. It will allow new energy sources to come online, enable greater sharing of energy between the eastern states, and also unlock the full 2,000 MW capacity of Snowy 2.0.

To achieve efficiencies in the approval process, the Project includes two connection points: one for Snowy 2.0 and the other for the HumeLink project. Both connection points are to be collocated within the new substation and a 330 kV yard and 500 kV yard, for Snowy 2.0 and HumeLink respectively, will be constructed on a single bench with integrated drainage and common or integrated ancillary features.



Source: EMM (2021); TransGrid (2021); DFSI (2017)

0 5 10 km
GDA 1994 MGA Zone 55
N

KEY

- Major road
- Minor road
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest

Proposed electricity assets

- Snowy 2.0 Lobs Hole cable yard
- Transmission line (Option 4)
- Maragle substation

Existing electricity assets

- Tumut 3
- Switching station
- 330 kV transmission line
- 66 kV transmission line
- Providence to Cabramurra transmission line (66 kV)
- Eucumbene to Happy Jacks transmission line (11 kV)
- Providence to Tantangara transmission line (11 kV)

Kosciusko National Park electricity assets

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 4.14

5 Project objectives and evaluation criteria

5.1 Introduction

In consideration of the Project and network requirements that were identified and described in Chapter 4, Project objectives and evaluation criteria of Project options were developed. The analysis of options, to determine the preferred Project option, have been undertaken against the evaluation criteria and in consideration of the Project objectives.

5.2 Project objectives

The Project objectives that have been reviewed for the options analysis are presented in Figure 5.1.

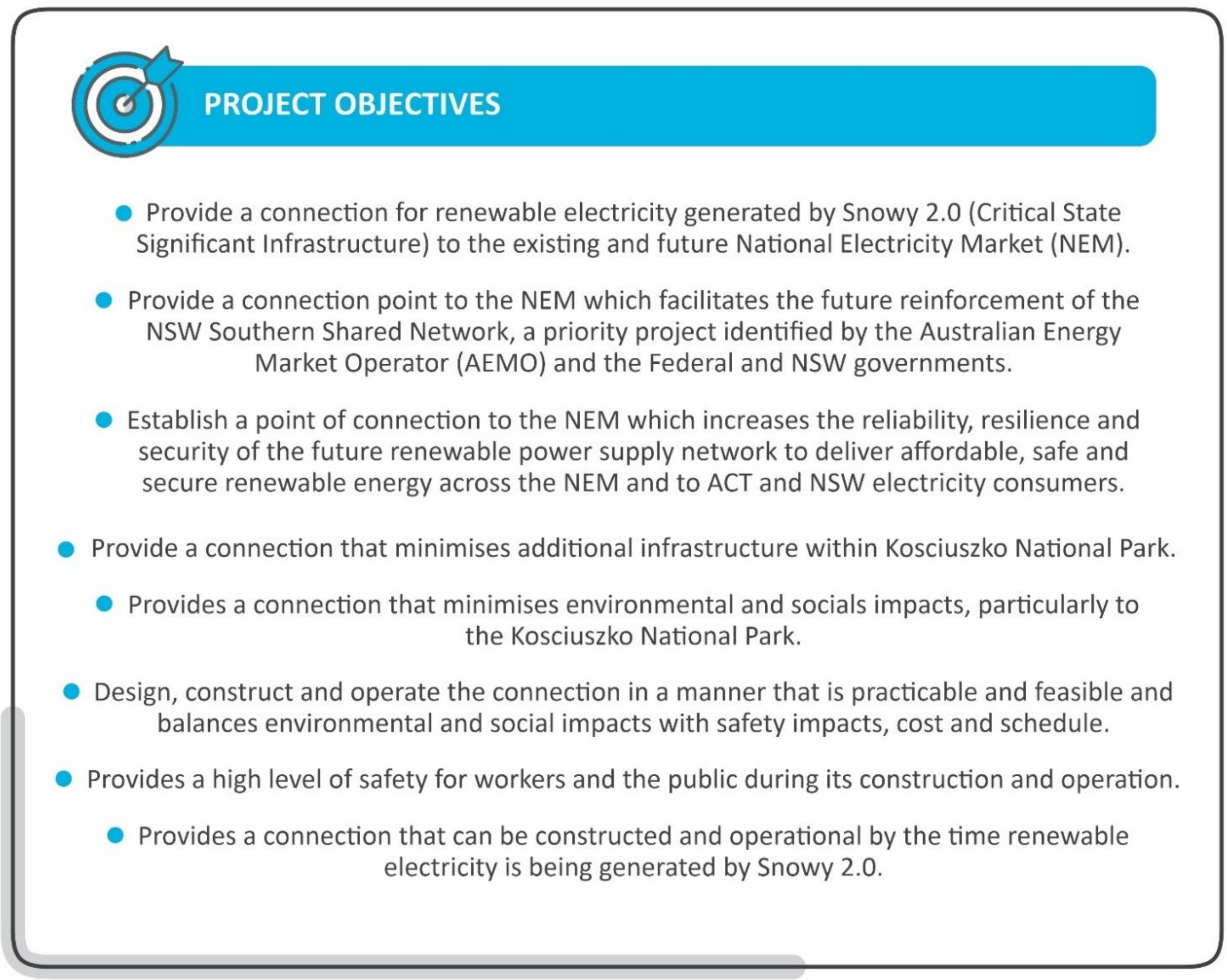


Figure 5.1 Project objectives

5.3 Evaluation criteria

Figure 5.2 presents the evaluation criteria that have been reviewed for this options analysis based on the Project objectives. The criteria are separated into three categories: technical; environment and planning; and safety. Criteria have also been separated into sub-categories where applicable. Criteria categories and sub-categories have been given equal weighting in this options assessment, with the exception of where threshold exceedances have been met.

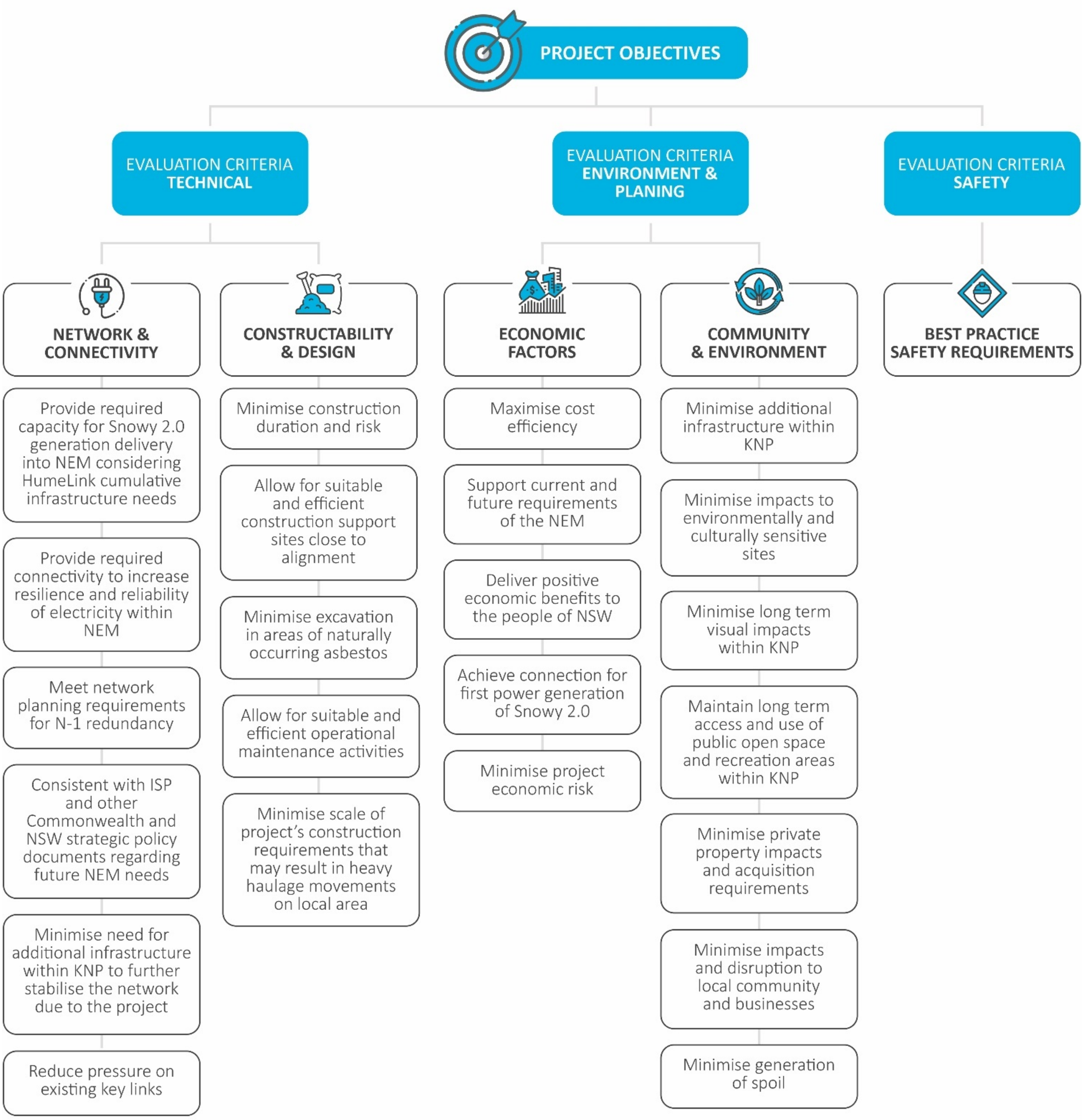


Figure 5.2 Evaluation criteria

6 Option development

6.1 Introduction

Options for transmission network connection for Snowy 2.0 were developed by TransGrid and Snowy Hydro. A total of 12 options were identified (refer to Figure 1.1) to include alternative connection points and transmission methods. Connection to both the 330 kV (through a new 330 kV switching station) and future 500 kV network (through a new 500 kV substation) is required as described in Section 4. The alternative connection points include connection to existing transmission assets and the future 500 kV network as follows:

- 330 kV transmission lines, being Line 1, Line 2 and Line 64;
- Switching stations being UTSS and LTSS; and
- Future 550 kV line and 500 kV substation.

Connection points also included points to the north, east, south and west of the Lobs Hole cable yard and connections within and external to KNP. The connection point to the north is LTSS. The connection to the east is Line 1. The connection point to the south is UTSS. And the connection points to the west are Line 2 and Line 64.

Connection points inside KNP include Line 1, Line 2 and UTSS. Connection points outside of KNP include LTSS and Line 64.

The alternative transmission methods include:

- overhead transmission lines;
- cables within tunnels;
- cables within trenches;
- submarine cables; and
- a combination of the above.

Based on the above, the 12 options developed included:

- Option 1 – Overhead to Line 2;
- Option 2 – Overhead to Line 1;
- Option 3 – Overhead to UTSS;
- Option 4 – Overhead to Line 64 (the base case which is currently the subject of the EIS for the Project);
- Option 5 – Deep cable tunnel to Line 64;
- Option 6 – Trench to Line 64;
- Option 7 – HDD to Line 64;

- Option 8 – Hybrid trench/deep cable tunnel to Line 64;
- Option 9 – Hybrid trench/submarine cable to LTSS;
- Option 10 – Trench to LTSS;
- Option 11 – Overhead to LTSS; and
- Option 12 – Deep cable tunnel to LTSS.

The options are also shown in Table 6.1 which shows the matrix of the different connection points to the transmission network and methods of transmission.

Table 6.1 Options subject to screening assessment

Connection point	Method of transmission				
	Overhead	**Underground (deep)**	**Trench**	**HDD**	**Hybrid**
West of KNP (Line 64)	Option 4	Option 5	Option 6	Option 7	Option 8 (trench and tunnel)
Within KNP (Line 1 or 2 or UTSS)	Options 1, 2 and 3	-	-	-	-
North of KNP (LTSS)	Option 11	Option 12	Option 10	-	Option 9 (trench and submarine cable)

Further detail on each of the options is given below.

6.2 Option 1 – Overhead to Line 2

Option 1 involves the connection of Snowy 2.0 to Line 2 which is the closest connection point to the transmission network from the Lobs Hole cable yard. Line 2 is approximately 1.6 km west of the cable yard.

Line 2 in an existing single circuit 330 kV overhead transmission line that runs between UTSS and Yass 330 kV substation. Line 2 is already constrained as it is part of a constrained cutset (the 'Tumut-Yass/Canberra' cutset), which includes Lines 1, 2, 3 and 7. This existing constraint is the first constraint on the existing Snowy Hydro Scheme making Line 2 already a relatively highly consequential line.

Option 1 involves the construction of a 1.6 km overhead transmission line with two x double circuit 330 kV lines within a 120 m easement from the Lobs Hole cable yard to Line 2.

Line 2, or any other existing 330 kV lines, does not have the capacity to transmit the full 2,000 MW of generating capacity of Snowy 2.0 to the network as is proposed by HumeLink. Snowy 2.0 requires connection into both the 330 kV network and the future 500 kV network. Therefore, Option 1 would require the extension of HumeLink from its current proposed connection point at Maragle at Line 64 to Line 2. This would require the construction of approximately 6 km of one x double circuit 500 kV transmission line within 80 m wide easements from Maragle to Line 2. It would also require the expansion or replacement of the Lobs Hole substation to a 330/500 kV substation.

During operations, overhead transmission lines have a failure incidence rate of approximately once every 10 years. The relative risk of damage to the transmission lines because of events like fires is high. However, the average time to repair a fault is low at < 2 weeks.

Option 1 was evaluated as not being viable due to a range of reasons, particularly given the need to bring HumeLink infrastructure into KNP. It would be expected that more generators will connect to HumeLink (the 330/500 kV substation) in the future. Locating this substation in Lobs Hole would therefore draw future connection infrastructure into the KNP. Accordingly, technical calculations such as the area of vegetation clearance, spoil volumes, construction schedule and construction costs were not undertaken.

A plan showing Option 1 can be seen in Figure 6.1.

6.3 Option 2 – Overhead to Line 1

Option 2 involves the connection of Snowy 2.0 to Line 1 which is the second closest connection point to the transmission network from the Lobs Hole cable yard. Line 1 is located approximately 8 km to the east of the cable yard adjacent to the Snowy Mountains Highway.

Line 1 is an existing single circuit 330 kV overhead transmission line that runs between Upper Tumut and Yass. Line 1 is already constrained as it is part of a constrained cutset, which includes lines 1, 2, 3 and 7. This existing constraint is the first constraint on the existing Snowy Hydro Scheme making Line 1 already a relatively highly consequential line.

Option 2 involves the construction of an 8 km overhead transmission line with two x double circuit 330 kV lines within a 120 m easement from the Lobs Hole cable yard to Line 1.

Like Line 2, Line 1 does not have the capacity to transmit the full 2,000 MW of generating capacity of Snowy 2.0 to the network as is proposed by HumeLink. Therefore, Option 2 would require the extension of HumeLink from its current proposed connection point at Maragle at Line 64 to Line 1. This would require the construction of approximately 16 km of one x double circuit 500 kV transmission line within 80 m wide easements from Maragle to Line 1.

It would also require the construction of a new 330/500 kV substation at the connection point adjacent to the Snowy Mountains Highway.

As stated above, during operations, overhead transmission lines have a failure incidence rate of approximately once every 10 years. The relative risk of damage to the transmission lines because of events like fires is high. However, the average time to repair a fault is low at < 2 weeks.

Option 2 was evaluated as not being viable due to a range of reasons, particularly given the need to bring HumeLink infrastructure into KNP. It would be expected that more generators will connect to HumeLink (the 330/500 kV substation) in the future. Locating this substation in Lobs Hole would therefore draw future connection infrastructure into the KNP. Accordingly, technical calculations such as the area of vegetation clearance, spoil volumes, construction schedule and construction costs were not undertaken.

A plan showing Option 2 can be seen in Figure 6.2.

6.4 Option 3 – Overhead to Upper Tumut Switching Station

Option 3 involves the connection of Snowy 2.0 to UTSS which is located approximately 16 km from the Lobs Hole cable yard.

UTSS was established in 1959 and connects eight hydro-electric generation units to the NEM which total 616 MW. It forms part of the wider southern NSW network which supports renewable energy zone development and allows flow paths between the Snowy Mountains, Canberra and Sydney.

Option 3 involves the construction of approximately 16 km of overhead transmission line with two x double circuit 330 kV lines within a 120 m easement from the Lobs Hole cable yard to UTSS. Predominantly the transmission line would be constructed adjacent to Line 2 which, as previously discussed, runs between UTSS and Yass 330 kV substation. The line would require an estimated 106 transmission towers (53 pairs).

Like options 1 and 2, Option 3 would require the extension of HumeLink from its current proposed connection point at Maragle at Line 64 to UTSS. This would require the construction of approximately 16.6 km of one x double circuit 500 kV transmission line within 80 m wide easements from Maragle to UTSS. It would also require an extension to the UTSS to include the new 330/500 kV substation infrastructure or the construction of a new 330/500 kV substation adjacent to UTSS.

In addition, Option 3 would:

- require the construction of approximately 8 km of new access tracks or roads;
- require the disturbance of approximately 185 hectares (ha) of vegetation (not including vegetation removal required for extending HumeLink which would be an additional 133 ha);
- generate approximately 500,000 cubic metres (m^3) of spoil;
- take close to approximately5 years (estimated time of 57 months) from feasibility phase to commissioning; and
- cost approximately $450 M.

As stated above, during operations, overhead transmission lines have a failure incidence rate of approximately once every 10 years. The relative risk of damage to the transmission lines because of events like fires is high. However, the average time to repair a fault is low at < 2 weeks. Option 3 would also bring HumeLink infrastructure into KNP. It would be expected that more generators will connect to HumeLink (the 330/500 kV substation) in the future. Locating this substation in Lobs Hole would, therefore, draw future connection infrastructure into KNP.

A plan showing Option 3 can be seen in Figure 6.3.

6.5 Option 4 – Overhead to Line 64

Option 4 involves the construction of a 9 km overhead transmission line with two x double circuit 330 kV lines within a 120 m wide easement from Lobs Hole cable yard to the proposed Maragle substation and Line 64. At that point it will connect with the new 500kV HumeLink. The connection point to Line 64, the Maragle substation, has been located close to the Elliot Way to reduce new access road construction and as directly west from Lobs Hole as possible to reduce the length of the connection as much as possible.

Line 64 is an existing single circuit 330 kV overhead transmission line that runs between Upper Tumut and Lower Tumut. Line 64 is not part of the constrained cutset that Line 1 and 2 are part of ('Tumut-Yass/Canberra') and therefore is less constrained and less consequential.

As part of this option, the only asset proposed within KNP is the transmission line. The line consists of 32 transmission towers (16 pairs). The substation and HumeLink connections are proposed outside of KNP and therefore removes the risk of future infrastructure being brought into the KNP to connect to the 330/500 kV substation.

Option 4 would:

- require the construction of approximately 7.5 km of new access tracks or roads;
- require the disturbance of approximately 118 ha of vegetation (71 ha fully cleared);

- generate approximately an estimated 364,800 m^3 of spoil;
- take approximately just under 4 years (estimated time of 45 months) from feasibility phase to commissioning[12]; and
- cost approximately $290 M.

As stated above, during operations, overhead transmission lines have a failure incidence rate of approximately once every 10 years. The relative risk of damage to the transmission lines because of events like fires is high. However, the average time to repair a fault is low at < 2 weeks.

A plan showing Option 4 can be seen in Figure 6.4.

This option is the base case which is currently the subject of the EIS for the Project.

6.6 Option 5 – Deep cable tunnel to Line 64

Option 5 involves the construction of a 9 km tunnel between the Lobs Hole cable yard and the proposed Maragle substation and Line 64.

The tunnel would have an internal diameter of approximately 5 m. The tunnel would be excavated by a TBM launched and retrieved from underground chambers at each end (launched at Lobs Hole and retrieved at Maragle). These chambers require significant plant and equipment such as gantry cranes to lift all the machine modules into place.

The launch chamber at Lobs Hole would be at the bottom of a 30 m deep shaft. Based on an industry standard design gradient of 4.5%, the retrieval chamber at Maragle would be at the bottom of a 530 m deep shaft. Intermediate shafts would also likely be required for ventilation and emergency ingress/egress purposes, with at least one 170 m deep shaft, and possibly three shafts with the deepest at 500 m.

The tunnel would be required to be lined with concrete segmental linings. The tunnels and shaft would require significant ongoing maintenance and operation of support systems like power supply, ventilation, drainage/water management, lifts, lighting, communications and security.

As part of this option, the only assets proposed within KNP is the transmission line from the Lobs Hole cable yard to the tunnel and the tunnel itself. The substation and HumeLink connections are proposed outside of KNP and therefore removes the risk of future infrastructure being brought into the KNP to connect to the 330/500 kV substation.

Option 5 would:

- require the construction of new access tracks or roads (distance unknown);
- require the disturbance of approximately 35 ha of vegetation;
- generate approximately 770,000 m^3 of spoil;

[12] This 45 month timeframe includes 6 months of feasibility investigation and approvals and 12 months of project planning approvals. It should be noted that these activities have already been completed or are close to completion. Therefore, actual construction timeframe for Option 4 from the date of this report would be significantly shorter (around 30 months). However, to provide equal comparison between options, these activities have been included within the timeframe.

- take just under 7 years (estimated time of 82 months) from feasibility phase to commissioning; and
- cost approximately $1,393 M.

During operations, cables located in tunnels have a failure incidence rate of approximately once every 32 years. The relative risk of damage to cables because of events like fires is rare. However, the average time to repair a fault is very high at between four to 16 weeks.

A plan showing Option 5 can be seen in Figure 6.5.

This option is presented as Alternative A (with tunnel construction) in NPA's submission.

6.7 Option 6 – Trench to Line 64

Option 6 involves the construction of an approximately 16 km trench between the Lobs Hole cable yard and the proposed Maragle substation and Line 64.

The terrain between Lobs Hole and Maragle is challenging, and it is difficult to find a route that is safe and practical to construct. A maximum gradient of 10% was assumed based on the limitations of construction equipment needed to construct the trench and lay the cables, however it is noted that approximately 20% of route has a gradient of > 10% as a result of the terrain.

The shortest continuous route for the trench was identified, following the use of a combination of existing access roads, fire trails, new routes and a short water crossing over the Talbingo Reservoir.

The trench would have a minimum excavated depth of 2 m and a minimum corridor width of 25 m on flat terrain to house the required five 330 kV circuits. On steeper terrain, the corridor would be required to be wider to account for cutting into the upper slope. The steeper the gradient of the terrain, the wider the corridor would need to be. Initial modelling and design determined the corridor would be up to 80 – 90 m wide in parts with up to 75 m high cuts.

Option 6 would also require approximately four x 1 ha laydown areas along the route. In addition, 36 m long x 5.2 m wide x 2 m deep cable joint bays would be required every 1 km along the route.

Once laid, the cables would need to be covered with a thermally stable backfill which would need to be batched in batching plants close to the route.

Option 6 would require a bridge or tunnel to cross Talbingo Reservoir. If a bridge, it would need to be approximately 200 m in length to span the reservoir. If a tunnel, it would need to have a finished internal diameter of approximately 5 m and would require access shafts approximately 50 m deep at either end.

As part of this option, the only assets proposed within KNP is the transmission line from the Lobs Hole cable yard to the tunnel and the tunnel itself. The substation and HumeLink connections are proposed outside of KNP and, therefore, removes the risk of future infrastructure being brought into the KNP to connect to the 330/500 kV substation.

Option 6 would:

- require the construction of approximately 15 to 20 km of new access tracks or roads;
- require the disturbance of approximately 110 ha of vegetation;
- generate approximately 4,228,527 m^3 of spoil (refer Table 8.2);

- take approximately 6 years (estimated time of 74 months) from feasibility phase to commissioning; and
- cost approximately $1,087 M.

During operations, cables located in trenches have a failure incidence rate of approximately once every 22 years. The relative risk of damage to cables because of events like fires is low. However, the average time to repair a fault is high at between four to 26 weeks.

A plan showing Option 6 can be seen in Figure 6.6.

This option is similar to Alternative B in NPA's submission, though it proposes a route further south that utilises existing access tracks where possible to minimise vegetation clearance and spoil disposal volumes.

6.8 Option 7 – Horizontal directional drilling to Line 64

Option 7 involves HDD over a distance of approximately 9 km from the Lobs Hole Cable yard to the proposed Maragle substation and Line 64. It generally follows the same route as Option 5.

To enable the installation of the required cables for the Project, it is estimated that between four to 12 individual 'tunnels' would need to be drilled side-by side. The requirement for this many 'tunnels' would lead to a high probability of 'tunnel drift' and, therefore, it was estimated that a launch site for the drilling rig would be required every 200 to 300 m along the route. Accordingly, Option 7 would require the construction of a large number of access roads.

Option 7 is unsuitable for steep terrain so it would likely require the switch to an alternative transmission method at Sheep Station Ridge and over Talbingo Reservoir, such as tunnelling or overhead transmission.

As part of this option, the only assets proposed within KNP is the transmission line from the Lobs Hole cable yard to the HDD tunnels and the tunnels themselves. The substation and HumeLink connections are proposed outside of KNP and therefore removes the risk of future infrastructure being brought into the KNP to connect to the 330/500 kV substation.

Option 7 was evaluated as not being technically viable due to:

- its unsuitability for steep terrain; and
- the high probability of cable drift.

Accordingly, technical calculations such as the area of vegetation clearance, spoil volumes, construction schedule and construction costs were not undertaken.

A plan showing Option 7 can be seen in Figure 6.7.

This option is presented as Alternative A (with HDD) in NPA's submission.

6.9 Option 8 – Hybrid trench/deep cable tunnel to Line 64

Option 8 involves the construction of a hybrid trench/deep cable tunnel from the Lobs Hole Cable yard to the proposed Maragle substation and Line 64. It is a combination of options 5 and 6 as described above.

The eastern section of the route at Lobs Hole and the western section of the route at Maragle are relatively flat and therefore can be trenched. The steep sections would be tunnelled. The total route would be approximately 10 km with 4 km of trench and 6 km of tunnel.

The trench and tunnel would both hold five x 330 kV circuits.

Like Option 6, the trenched sections would have a minimum excavated depth of 2 m and a minimum corridor width of 25 m on flat terrain to house the required five x 330 kV circuits. The trenched sections would require a 1 ha laydown areas along the route, and 36 m long x 5.2 m wide x 2 m deep cable joint bays would be required every 1 km.

Once laid, the cables would need to be covered with a thermally stable backfill from material batched at nearby batch plants.

Like Option 5, the tunnel would have an internal diameter of approximately 5 m and would be excavated by a TBM launched and retrieved from chambers at each end. From the transition from trenching to tunnelling, and vice versa, the launch chamber on the eastern end would have a depth of 40 m. Based on an industry standard design gradient of 4.5%, the chamber at Maragle would be required to be 550 m deep. An intermediate shaft would also be required to be constructed for ventilation and emergency ingress/egress.

The tunnel would be required to be lined with concrete segmental linings.

As part of this option, the only assets proposed within KNP is the transmission line from the Lobs Hole cable yard to the trenches/tunnel and the trenches/tunnel itself. The substation and HumeLink connections are proposed outside of KNP and therefore removes the risk of future infrastructure being brought into the KNP to connect to the 330/500 kV substation.

Option 8 would:

- require the construction of new access tracks or roads (distance unknown);
- require the disturbance of approximately 40 ha of vegetation;
- generate approximately 1,750,000 m^3 of spoil;
- take approximately 6.5 years (estimated time of 78 months) from feasibility phase to commissioning; and
- cost approximately $1,304 M.

During operations, cables located in trenches have a failure incidence rate of approximately once every 22 years. The relative risk of damage to cables because of events like fires is low. However, the average time to repair a fault is high at between four to 26 weeks.

During operations, cables located in tunnels have a failure incidence rate of approximately once every 32 years. The relative risk of damage to cables because of events like fires is rare. However, the average time to repair a fault is very high at between four to 16 weeks.

A plan showing Option 8 can be seen in Figure 6.8.

Option 8 is a combination of Alternative A and B in NPA's submission.

6.10 Option 9 – Hybrid trench/submarine cable to Lower Tumut Switching Station

Option 9 involves the construction of a hybrid trench and submarine cable connection from the Lobs Hole cable yard to LTSS.

LTSS at the northern end of Talbingo Reservoir outside of KNP, an existing hub for eight x 330 kV transmission lines.

The land-based sections of the route at Lobs Hole and LTSS are relatively flat and, therefore, can be trenched. The total route would be approximately 30 km with 9.5 km of trenching and 20.5 km of submarine cable.

The trench would hold five 330 kV circuits between Lobs Hole and Talbingo Reservoir where it would then transition to a submarine connection with the cables placed on the bed of Talbingo Reservoir. The connection would then transition back to a trench design from Talbingo Reservoir to LTSS.

Within the reservoir, six cables would be required to be laid with a 5 m separation to meet the n-1 security of supply standard. This would require a clear 25 m wide cable corridor on the bed of the reservoir, which would likely need to be wider at depths greater than 50 m.

The Yarrangobilly and Tumut River valleys were not cleared of vegetation prior to flooding in the early 1970s for the Snowy Scheme. As a result, there are many areas of submerged trees and boulders, together with a variable terrain. Since the reservoir was filled a significant but variable thickness of silt is likely to have built up on the floor of the reservoir. The cable route would need to be free of these hazards which would require underwater tree removal, dredging and rock removal.

Option 9 would require significant wharf/marine access structures to be constructed and maintained on the northern end of the reservoir (ie UTSS end). During construction, it would also require large laydown and construction areas.

Joints are weak areas in any cable system, particularly in submarine cables. To minimise joints, a cable manufacturing facility would be required to be established next to the reservoir.

If this could not be achieved, the cables would need to be sourced externally, and most likely from overseas. Assuming a 100 t limit, the length of a cable on a drum would be around 600 m, thus the submarine section would require approximately 35 joints for each circuit. The joints would have to be connected on a barge or on land before laying on the reservoir bed. There would be over 200 submarine joints which would introduce a significant risk to power supply.

Maintenance would be expected to be slow and costly due to the planning required to identify the fault and carry out the repairs.

Water level fluctuations and velocities in the reservoir through power generation at T2 and T3 power stations would also make construction and maintenance difficult.

This option would require construction of a new 330/500 kV substation at a site near to LTSS or the expansion of LTSS to a 330/500 kV substation. As previously discussed, LTSS is outside KNP.

Option 9 was evaluated as not being viable due to a range of reasons. Accordingly, technical calculations such as the area of vegetation clearance, spoil volumes, construction schedule and construction costs were not undertaken.

A plan showing Option 9 can be seen in Figure 6.9.

This option is presented as Alternative C in NPA's submission. This option is also similar to Alternative E2 in NPA's submission.

6.11 Option 10 – Trench to Lower Tumut Switching Station

Option 10 involves the construction of a trench from the Lobs Hole cable yard to LTSS. Two routes were considered for this option, including:

- Option 10A which is approximately 35 km in length and predominantly uses fire trails where possible; and

- Option 10B which is approximately 44 km in length and uses fire trails and public roads such as the Snowy Mountains Highway and Mile Franklin Drive.

Accordingly, both options have been designed to utilise existing trails and roads where possible.

Notwithstanding the above, both options would be required to traverse seep gradients, including a gradient of 61% for Option 10A.

Like Option 6, the trench would have a minimum excavated depth of 2 m and a minimum corridor width of 25 m on flat terrain to house the required five 330 kV circuits. On steeper terrain, the corridor would be required to be wider to account for cutting into the upper slope.

It would require a number of 1 ha laydown areas along the route as well as the provision of 36 m long x 5.2 m wide x 2 m deep cable joint bays every 1 km along the route.

Once laid, the cables would need to be covered with a thermally stable backfill that would need to be batched in a batching plant and delivered by agitators.

This option would require construction of a new 330/500 kV substation at a site near to LTSS or the expansion of LTSS to a 330/500 kV substation. As previously discussed, LTSS is located outside KNP.

During operations, cables located in trenches have a failure incidence rate of approximately once every 22 years. The relative risk of damage to cables because of events like fires is low. However, the average time to repair a fault is high at between four to 26 weeks.

Option 10 was evaluated as not being viable due to a range of reasons. Accordingly, technical calculations such as the area of vegetation clearance, spoil volumes, construction schedule and construction costs were not undertaken.

A plan showing Option 10 can be seen in Figure 6.10.

Option 10 is similar to Alternative D in NPA's submission, though it proposed a trench rather than tunnel.

6.12 Option 11 – Overhead to Lower Tumut Switching Station

Option 11 involves the construction of a 26 km overhead transmission line with two x double circuit 330 kV lines within a 120 m wide easement from the Lobs Hole cable yard to LTSS.

This option would require construction of a new 330/500 kV substation at a site near to LTSS or the expansion of LTSS to a 330/500 kV substation. As previously discussed, LTSS is located outside KNP.

During operations, overhead transmission lines have a failure incidence rate of approximately once every 10 years. The relative risk of damage to the transmission lines because of events like fires is high. However, the average time to repair a fault is low at < 2 weeks.

Option 11 was evaluated as not being technically viable due to a range of reasons. Accordingly, technical calculations such as the area of vegetation clearance, spoil volumes, construction schedule and construction costs were not undertaken.

A plan showing Option 11 can be seen in Figure 6.11.

6.13 Option 12 – Deep cable tunnel to Lower Tumut Switching Station

Option 12 involves the construction of a 26 km tunnel between the Lobs Hole cable yard and LTSS.

The tunnel would have an internal diameter of approximately 5 m. The tunnel would be excavated by a TBM launched at each end (Lobs Hole and LTSS). The launch chambers at Lobs Hole and LTSS would both have a depth of 30 m. Approximately three intermediate shafts would also likely be required for ventilation and emergency ingress/egress purposes with depths of approximately 20 m, 320 m, and 420 m, respectively.

The tunnel would be required to be lined with concrete segmental linings. The tunnels and shaft would require significant ongoing maintenance and operation of support systems like power supply, ventilation, drainage/water management, lifts, lighting, communications and security.

This option would require construction of a new 330/500 kV substation at a site near to LTSS or the expansion of LTSS to a 330/500 kV substation. As previously discussed, LTSS is located outside KNP.

During operations, cables located in tunnels have a failure incidence rate of approximately once every 32 years. The relative risk of damage to cables because of events like fires is rare. However, the average time to repair a fault is very high at between four to 16 weeks.

Option 12 was evaluated as not being technically viable due to a range of reasons. Accordingly, technical calculations such as the area of vegetation clearance, spoil volumes, construction schedule and construction costs were not undertaken. Notwithstanding this, initial estimates indicate that this option would generate more than 1,000,000 m^3 of spoil and take more than 7 years to construct.

A plan showing Option 12 can be seen in Figure 6.12.

Option 12 is similar to Alternative D in NPA's submission.

Source: EMM (2021); Transgrid (2021); MetroMap (2021); DFSI (2017)

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KEY

- Existing electricity transmission line
- Minor road
- Vehicular track
- Named watercourse
- Kosciuszko National Park
- Snowy 2.0 cable yard

Transmission connection – Option 1

- Overhead twin double circuit 330 kV line to Line 2
- Project footprint

Option 1 – overhead to Line 2

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.1

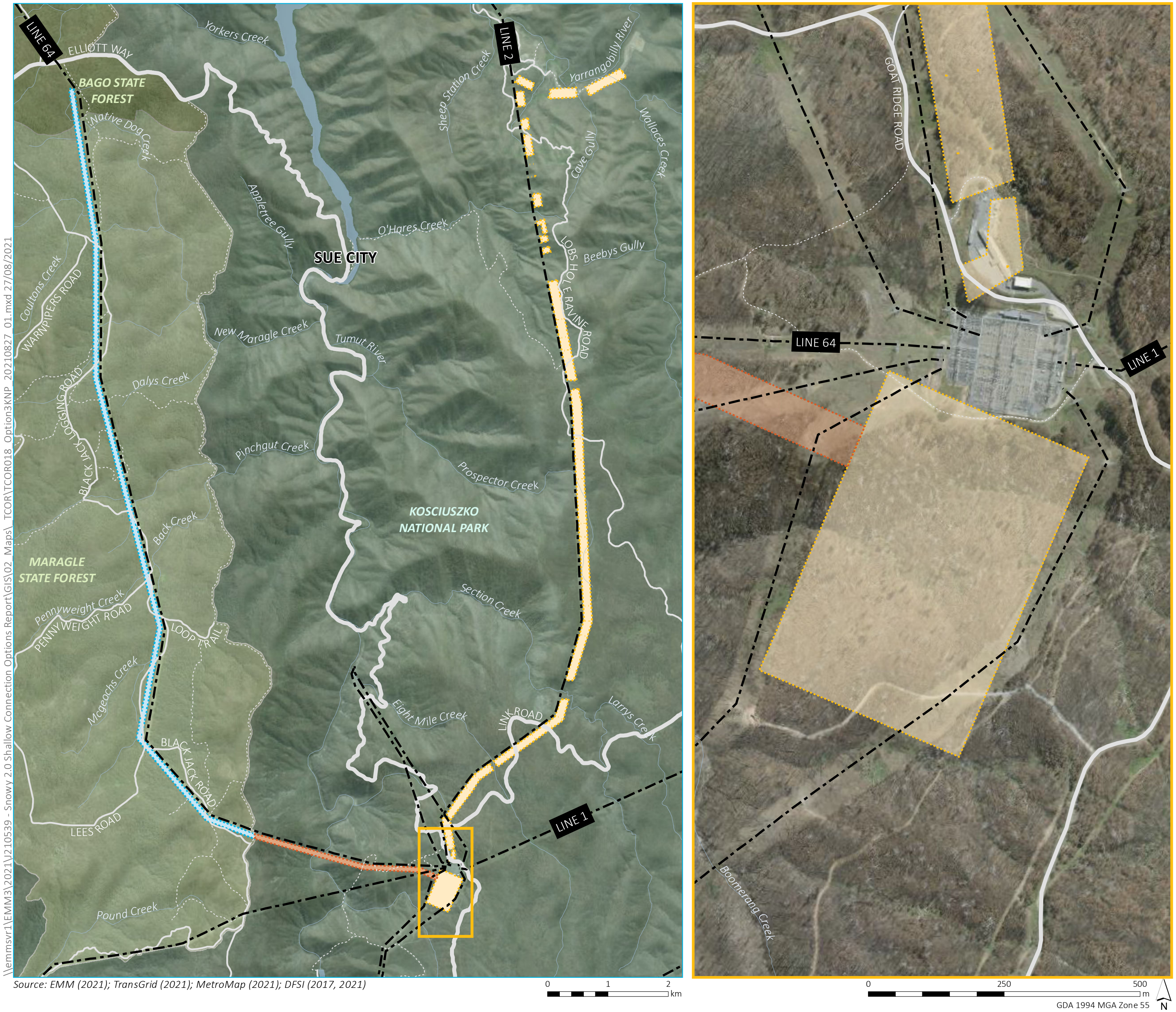
EMM
creating opportunities

Source: EMM (2021); Transgrid (2021); MetroMap (2021); ESRI (2021); DFSI (2017; 2021)

Option 2 – overhead to Line 1

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.2

EMM creating opportunities



Source: EMM (2021); TransGrid (2021); MetroMap (2021); DFSI (2017, 2021)

KEY

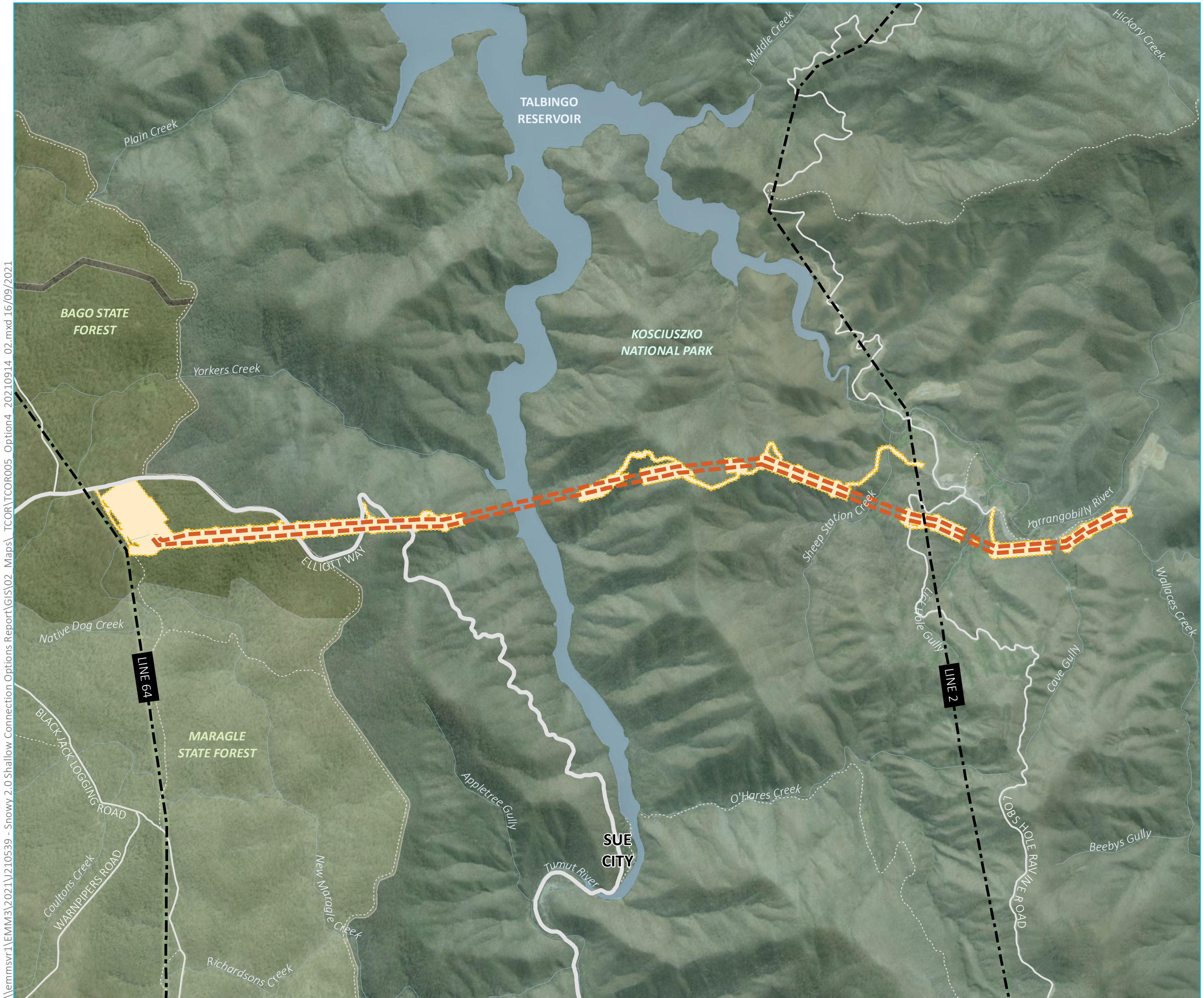
- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest

Transmission connection - Option 3

- Widening of easement and substation footprint (within KNP)
- Hume Link - widening of existing easement (within KNP)
- Hume Link - widening of existing easement (outside KNP)

Option 3 - overhead to Upper Tumut Switching Station

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.3



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Source: EMM (2021); TransGrid (2021); MetroMap (2021); DFSI (2017, 2021)

0 1 2 km
GDA 1994 MGA Zone 55
N

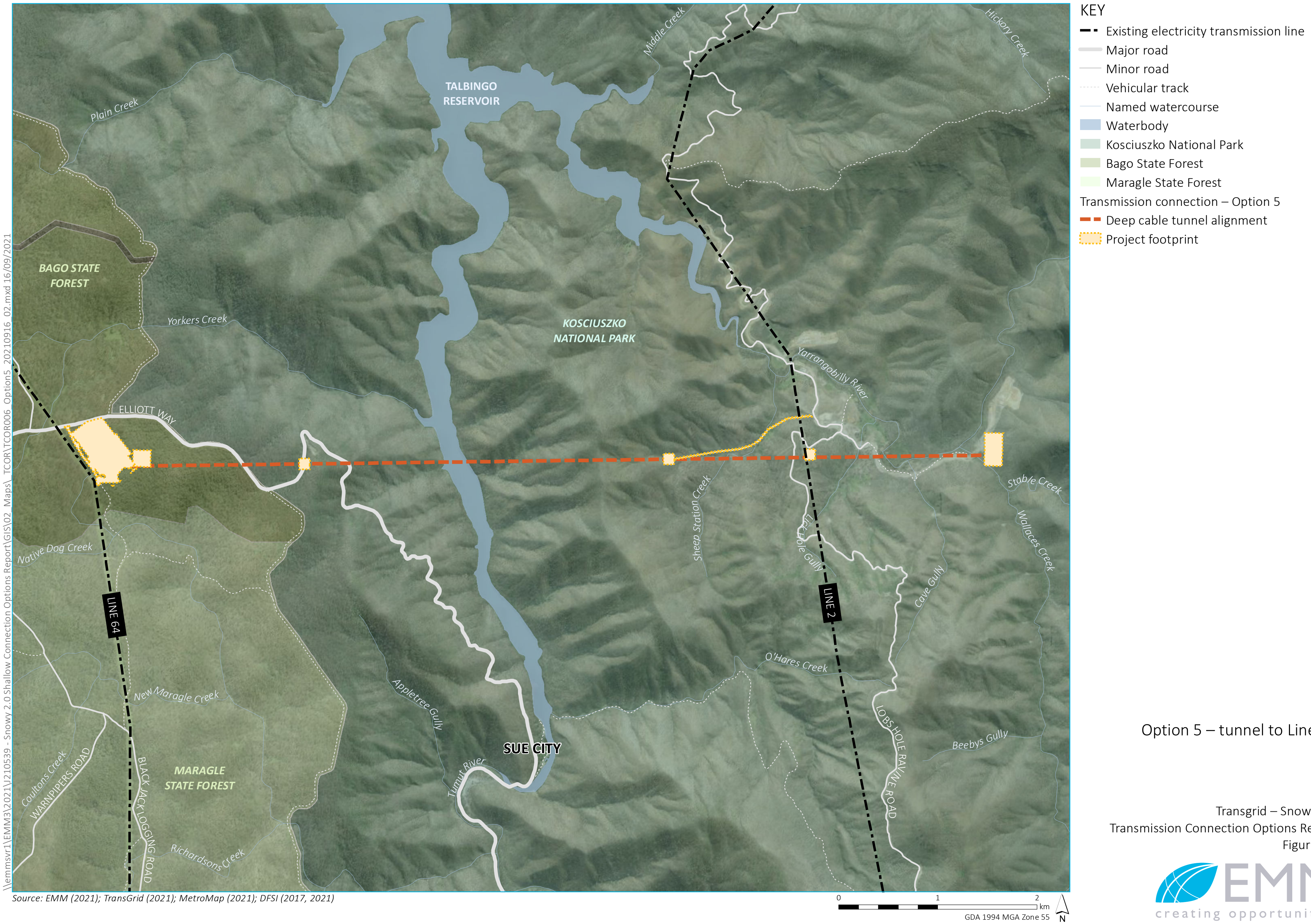
KEY
- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest

Transmission connection – Option 4
- Proposed electricity transmission line
- Project footprint

Option 4 – overhead to Line 64

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.4

creating opportunities

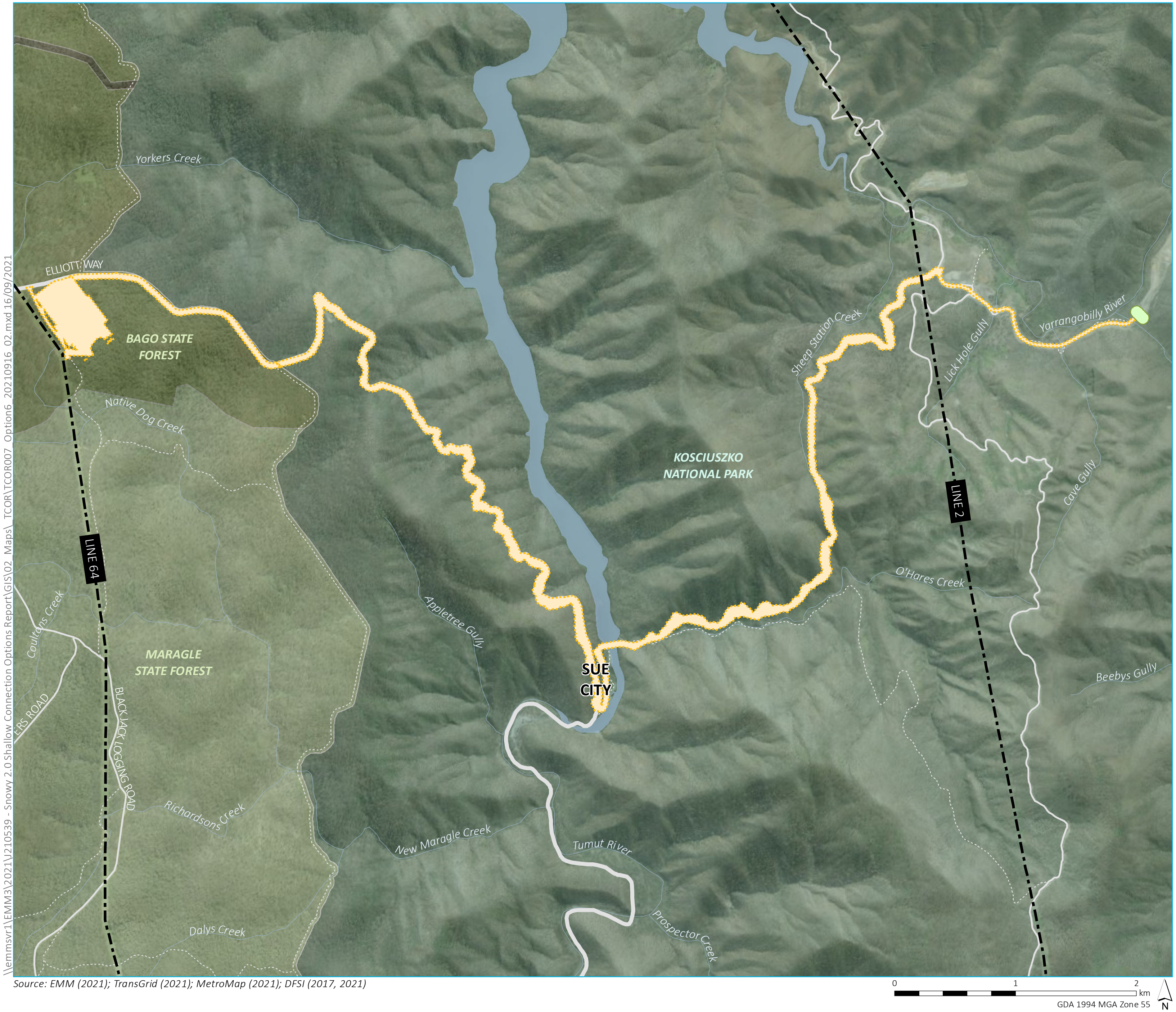


Source: EMM (2021); TransGrid (2021); MetroMap (2021); DFSI (2017, 2021)

Option 5 – tunnel to Line 64

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.5

EMM creating opportunities



KEY

- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest
- Snowy 2.0 cable yard

Transmission connection – Option 6

- Project footprint

Source: EMM (2021); TransGrid (2021); MetroMap (2021); DFSI (2017, 2021)

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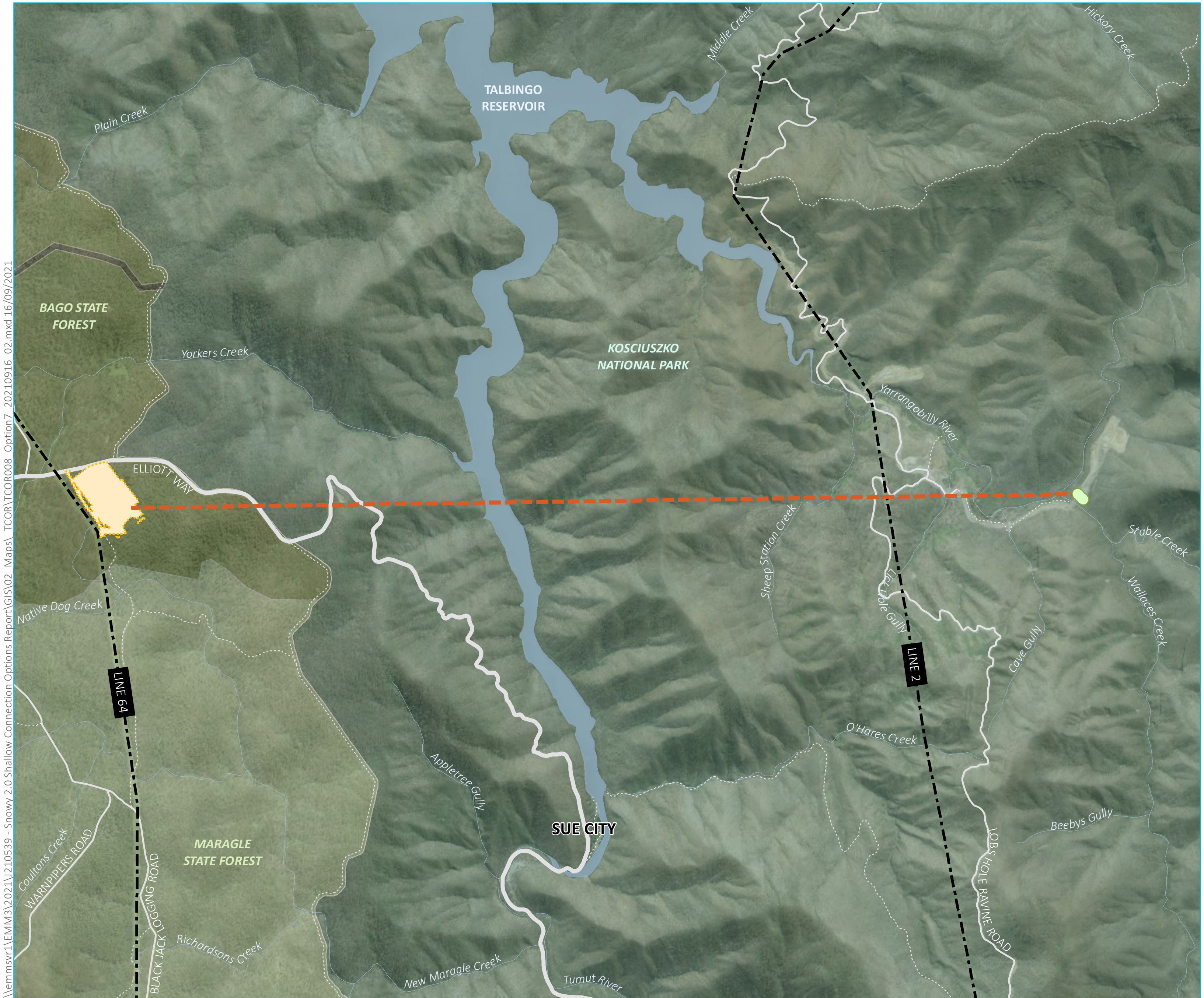
Option 6 – trench to Line 64

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.6

creating opportunities



KEY

- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest
- Snowy 2.0 cable yard

Transmission connection – Option 7

- Underground five 330 kV circuits to Line 64 (horizontal directional drill)
- Project footprint

Option 7 – HDD to Line 64

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.7

Source: EMM (2021); Transgrid (2021); MetroMap (2021); DFSI (2017)

0 1 2 km
GDA 1994 MGA Zone 55
N

EMM
creating opportunities

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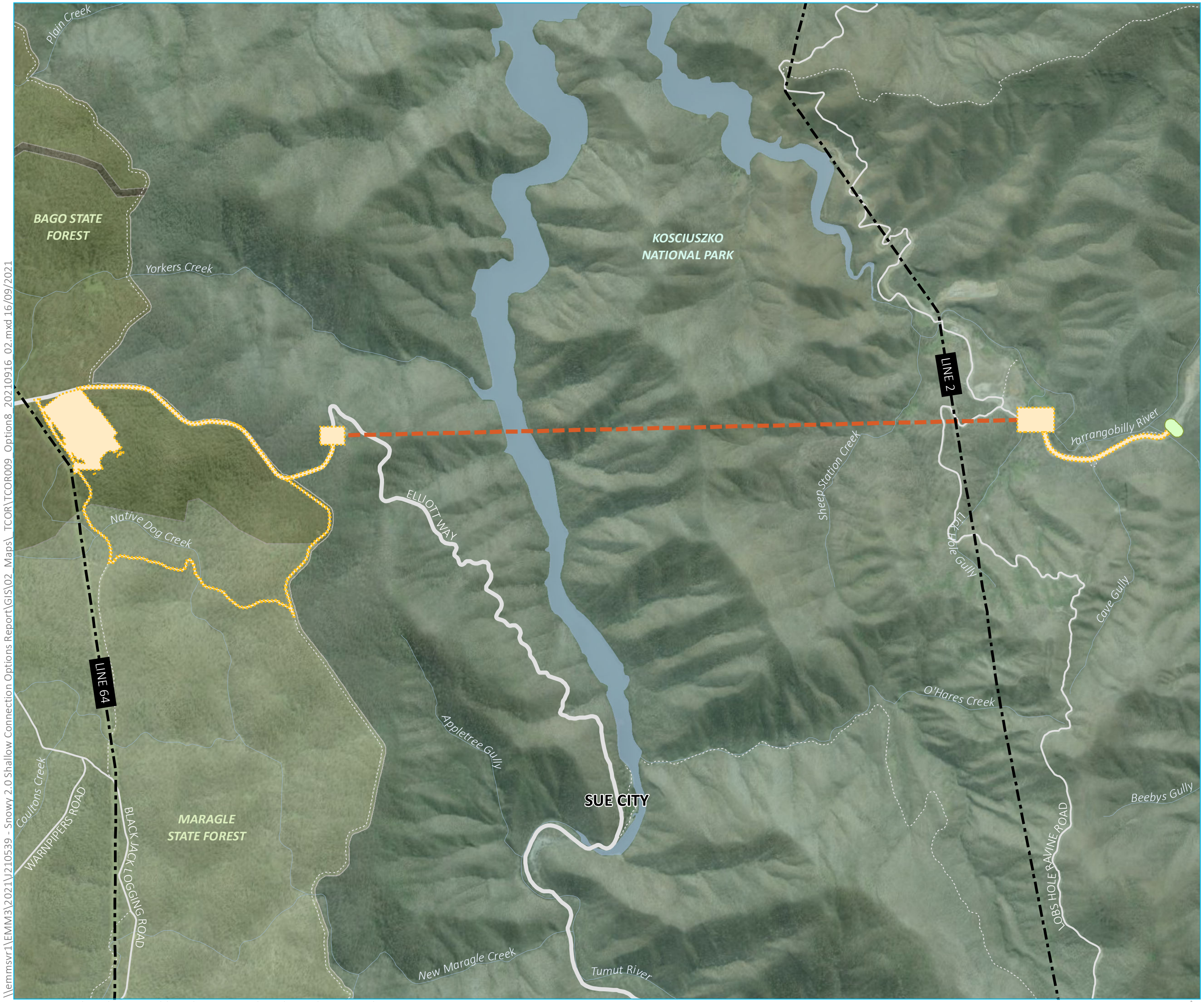

Source: EMM (2021); TransGrid (2021); MetroMap (2021); DFSI (2017, 2021)

0 1 2 km

GDA 1994 MGA Zone 55

N

KEY

- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest
- Snowy 2.0 cable yard

Transmission connection – Option 8

- Cable tunnel alignment
- Project footprint

Option 8 – hybrid trench/tunnel to Line 64

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.8

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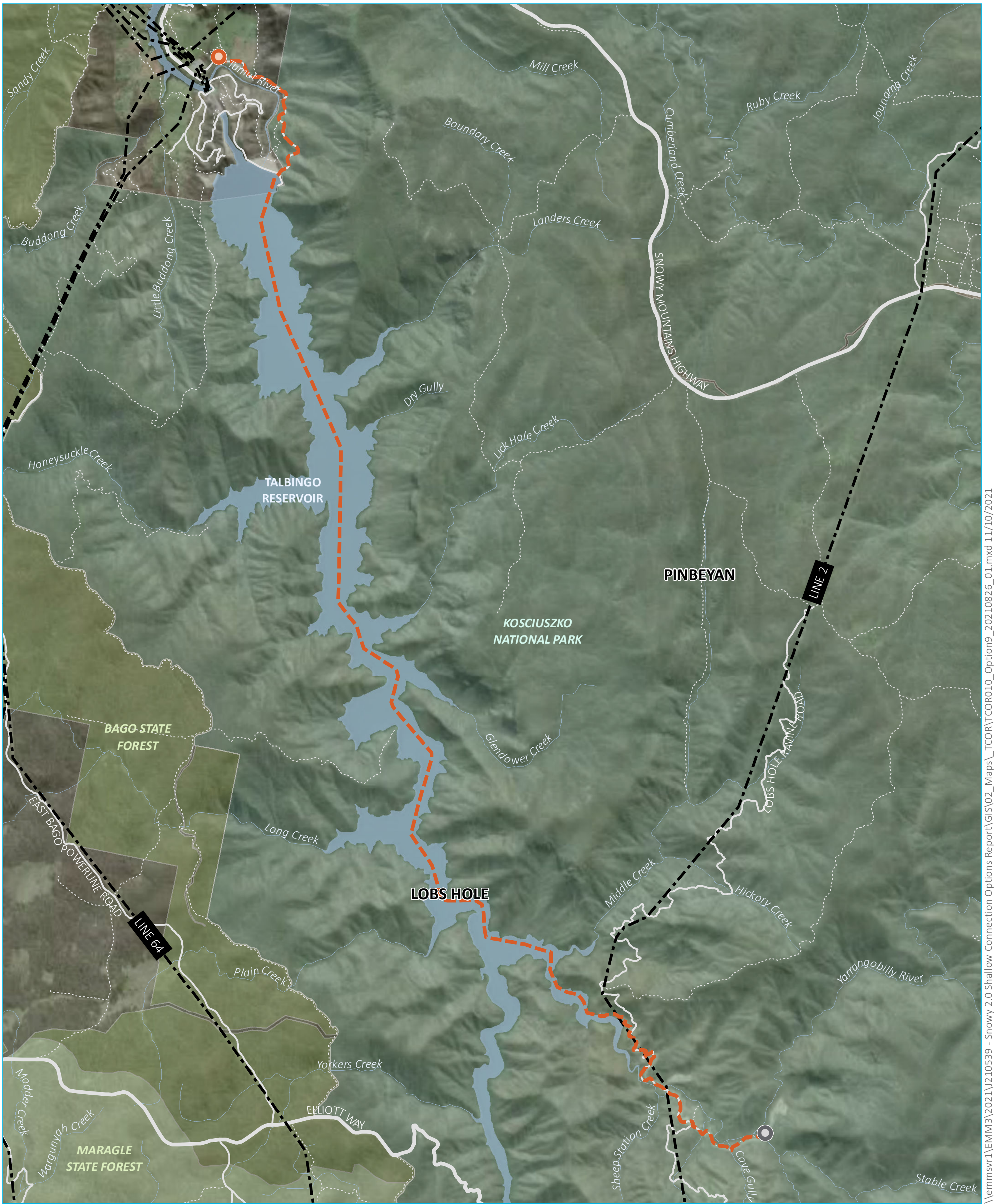


Source: EMM (2021); Transgrid (2021); MetroMap (2021); DFSI (2017, 2021)

KEY

- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest
- Snowy 2.0 cable yard

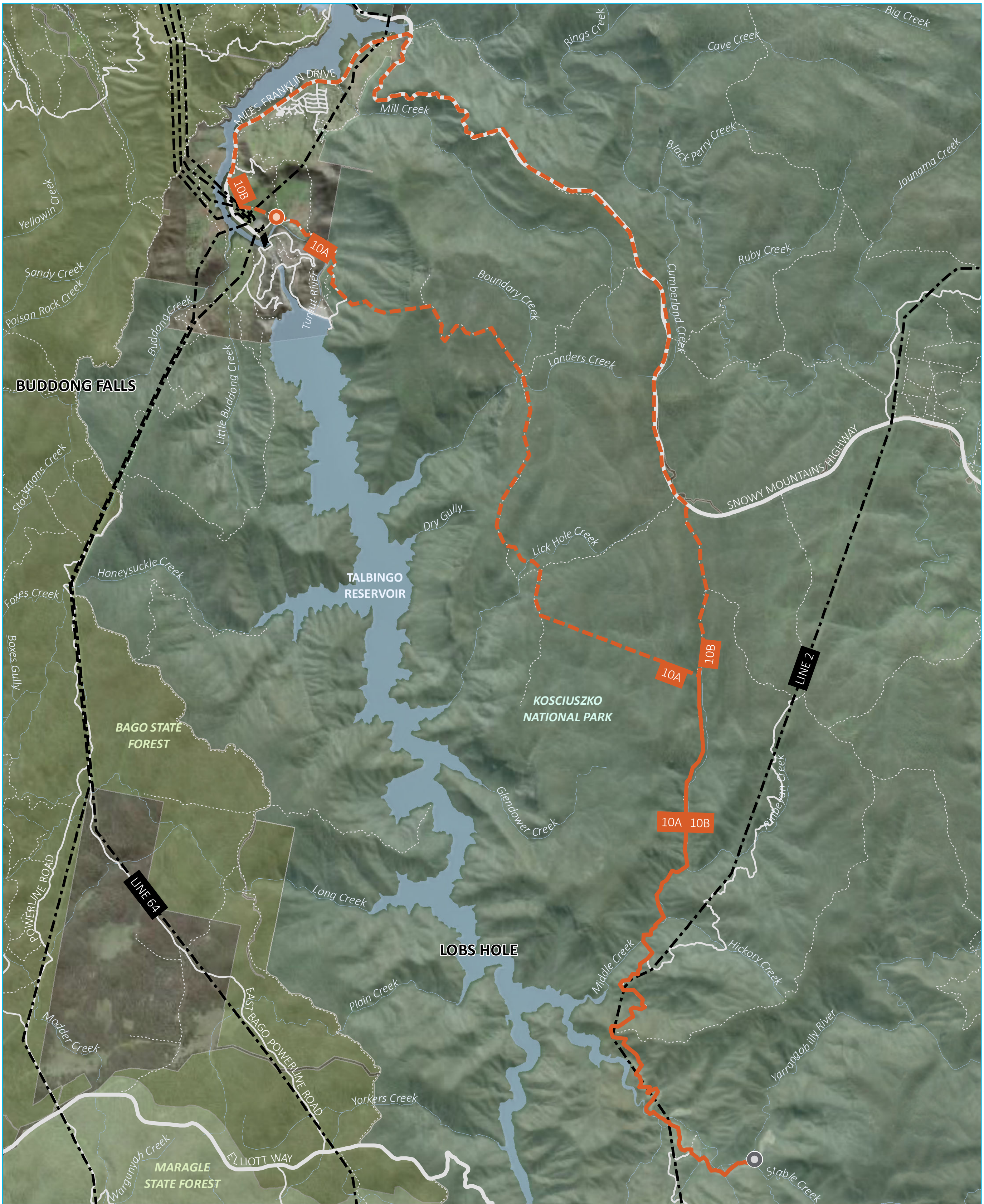
Transmission connection – Option 9

- New substation or expansion of Lower Tumut Switching Station
- Hybrid of submarine cable and trench

Option 9 – hybrid trench/submarine cable to Lower Tumut Switching Station

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.9

EMM
creating opportunities



Source: EMM (2021); Transgrid (2021); MetroMap (2021); DFSI (2017, 2021)

0 2 4
km
GDA 1994 MGA Zone 55
N

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KEY

- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest
- Snowy 2.0 cable yard

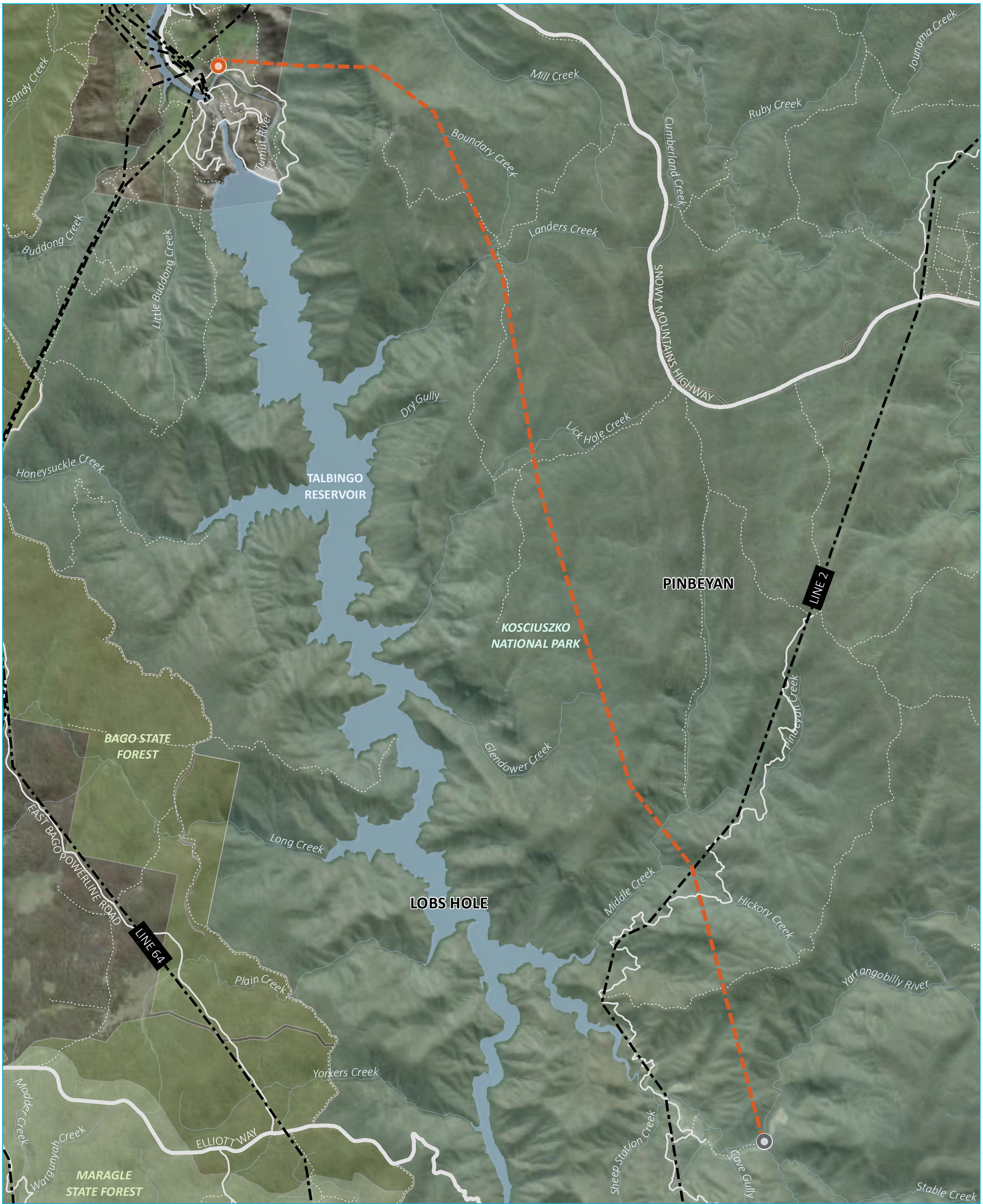
Transmission connection – Options 10a/10b

- New substation or expansion of Lower Tumut Switching Station
- Trenched five 330 kV circuits to Lower Tumut Switching Station

Option 10 – trench to Lower Tumut Switching Station

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.10

EMM
creating opportunities



Source: EMM (2021); Transgrid (2021); MetroMap (2021); DFSI (2017, 2021)

0 2 4 km
GDA 1994 MGA Zone 55
N

KEY

- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest
- Snowy 2.0 cable yard

Transmission connection – Option 11

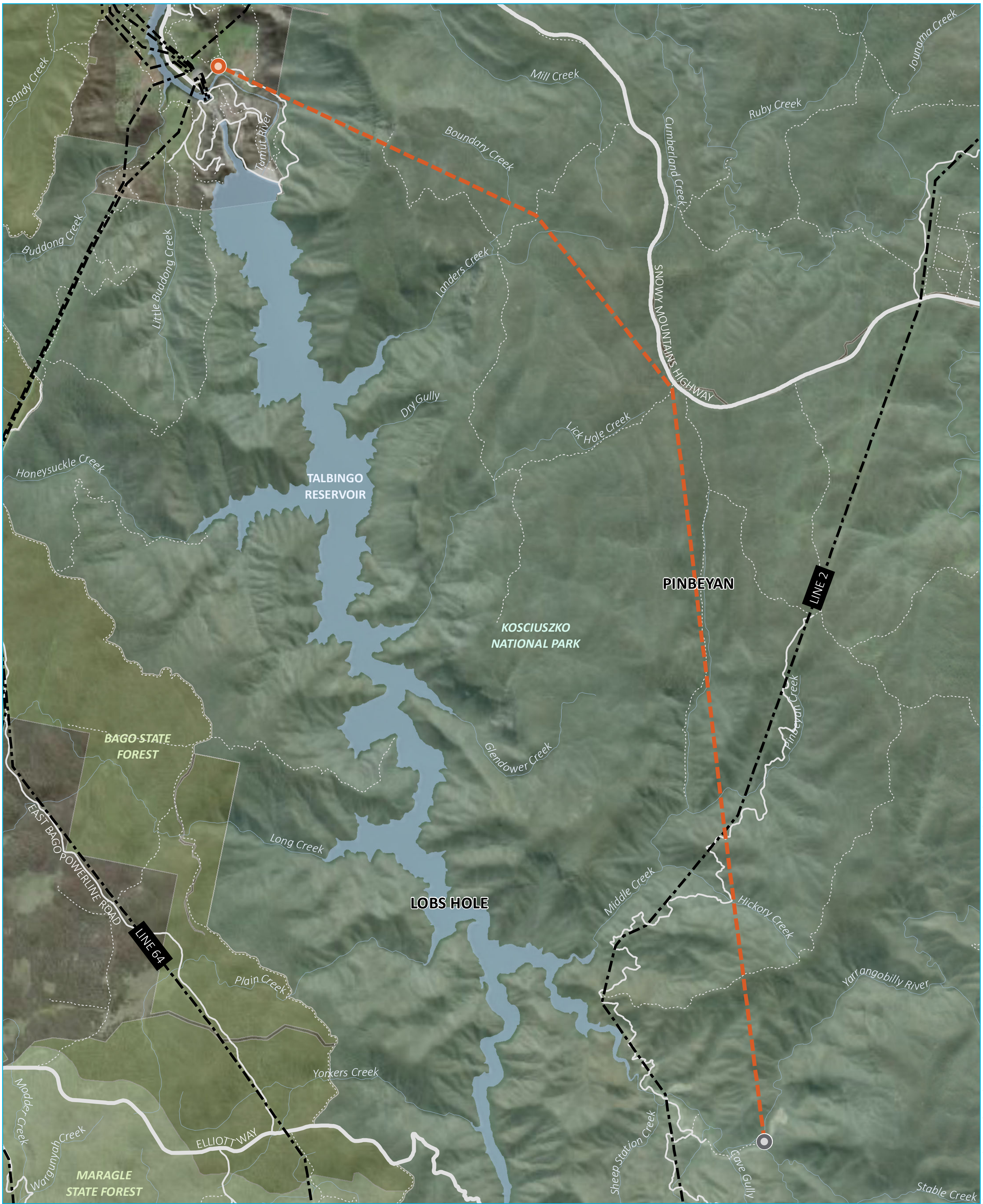
- New substation or expansion of Lower Tumut Switching Station
- Overhead twin double circuit 330 kV to Lower Tumut Switching Station

Option 11 – overhead to Lower Tumut Switching Station

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.11

EMM
creating opportunities

\\emmsvr1\EMM3\2021\J210539 - Snowy 2.0 Shallow Connection Options Report\GIS\02_Maps_TCOR\TCOR012_Option11_20210916_02.mxd 16/09/2021



Source: EMM (2021); Transgrid (2021); MetroMap (2021); DFSI (2017, 2021)

0 2 4 km

GDA 1994 MGA Zone 55

N

KEY

- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest
- Snowy 2.0 cable yard

Transmission connection – Option 12

- New substation or expansion of Lower Tumut Switching Station
- Underground five 330 kV circuits to Lower Tumut Switching Station (deep cable tunnel)

Option 12 – tunnel to Lower Tumut Switching Station

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 6.12

EMM
creating opportunities

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7 Screening assessment

7.1 Introduction

A screening assessment of the 12 options was completed differentiating the positive and negative features of each. This assessment was informed by technical information provided by TransGrid (and their technical advisers – GHD and WSP), Snowy Hydro and EMM. The below summaries highlight the key findings of each option, based on the evaluation criteria. The full evaluation is provided in Appendix A.

As discussed in Section 1.4, the results of the screening assessment were presented to DPIE and NPWS at a meeting on 16 July 2021.

7.2 Option 1 – Overhead to Line 2

The key features of Option 1 are shown in Figure 7.1.

7.2.1 Network and connectivity

Option 1 meets the n-1 redundancy requirements increasing the resilience and reliability within the NEM. It also has the benefit of achieving connection for first power generation for Snowy 2.0, based on the Project development commencement date of 2017[13]. However, Option 1 does not provide the required capacity for Snowy 2.0 generation delivery into the NEM unless HumeLink infrastructure is brought into KNP.

A new substation is required in the KNP along with future 500 kV lines for HumeLink.

Overall, this option does not adequately meet the required network and connectivity criteria.

7.2.2 Constructability and design

This option presents no identifiable constraints for constructability and design, given that:

- suitable construction support sites are available at Lobs Hole through Snowy 2.0;
- while overhead lines are susceptible to fault/damage, they are cost effective to fix and allow for more straightforward maintenance; and
- construction footprint would be very small (compared to other options) and would therefore result in the lowest heavy vehicle movements.

7.2.3 Economic factors

Commensurate with a screening assessment, a high-level review of the construction costs associated with Option 1 indicates they are unlikely to be prohibitive due to the short length of line and the terrain.

Similarly, operation costs are also unlikely to be prohibitive due to the fact that damage to overhead transmission lines and structures are more cost effective to fix when compared to underground lines.

[13] Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen at this stage of approvals process, approvals and associated assessments of achieving connection for first power generation would need to be redone.

7.2.4 Community and environment

Vegetation clearance associated with this option, particularly the requirement for the construction of the HumeLink assets within KNP, has the reasonable potential to impact State and Commonwealth listed threatened species habitat (noting, however, that the Smoky Mouse has not been identified in this area).

Due to the short length of the line and terrain to connect the Lobs Hole cable yard to Line 2, around 80,000 m^3 of excavated material is expected. The volume of material required to be excavated for the HumeLink assets is unknown.

This option would also result in additional infrastructure within the KNP resulting in amenity impacts with expansion or replacement of the existing Ravine substation, additional transmission lines (330 and 500 kV) and associated easement and access tracks. This would represent a potential land use conflict with future potential recreational land uses in this area following the completion of Snowy 2.0 construction.

Overall, Option 1 will result in significant additional infrastructure and associated environmental impacts within the KNP.

7.2.5 Best practice safety requirements

Option 1 is able to meet best practice safety requirements during construction and operation.

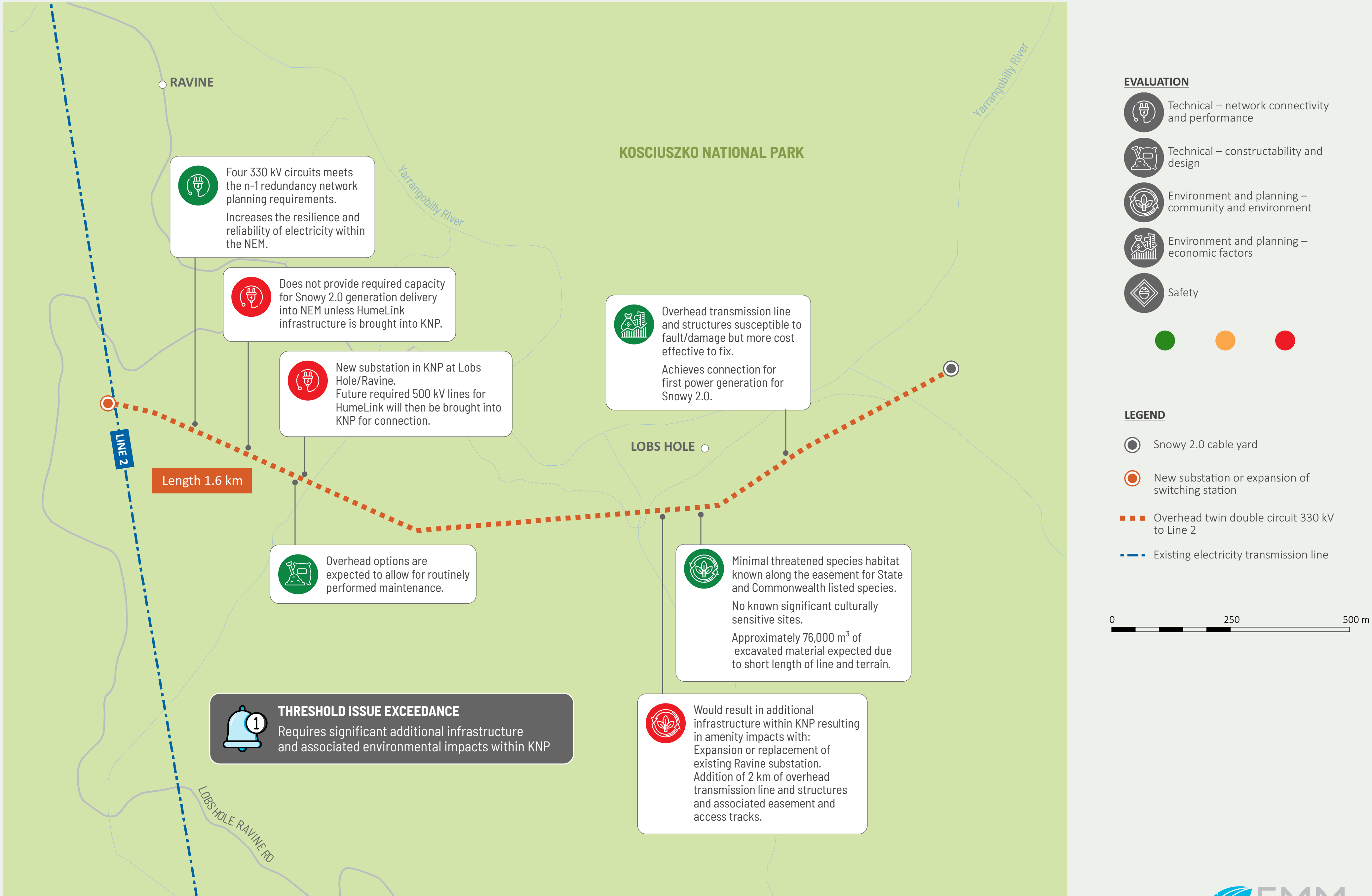


Figure 7.1 Option 1 – Overhead to Line 2

7.3 Option 2 – Overhead to Line 1

The key features of Option 2 are shown in Figure 7.2.

7.3.1 Network and connectivity

Option 2 meets the n-1 redundancy requirements increasing the resilience and reliability within the NEM. It also achieves connection for first power generation for Snowy 2.0, based on Project development commencement date of 2017[14]. However, Option 2 does not provide the required capacity for Snowy 2.0 generation delivery into the NEM unless HumeLink infrastructure is brought into KNP.

A new substation is required in the KNP along with future 500 kV lines for HumeLink.

Overall, this option does not adequately meet the required network and connectivity criteria.

7.3.2 Constructability and design

This option presents no significant constraints for constructability and design, given that:

- suitable construction support sites are available through Snowy 2.0 (although the topography may prove challenging in some areas);
- overhead lines are susceptible to fault/damage but are cost effective to fix and allow for more straightforward maintenance; and
- construction footprint would be small and would therefore result in a smaller disturbance footprint.

7.3.3 Economic factors

Commensurate with a screening assessment, a high-level review of the construction costs associated with Option 2 indicates they are unlikely to be prohibitive due to the relatively short length of line and the terrain. Similarly, operation costs are also unlikely to be prohibitive since damage to overhead transmission lines and structures are more cost effective to fix when compared to underground lines.

7.3.4 Community and environment

Vegetation clearance associated with this option has reasonable potential to impact State and Commonwealth listed threatened species habitat, including the Smoky Mouse.

Approximately 320,000 m^3 of excavated material is expected to connect the Lobs Hole cable yard to Line 1. The volume of material required to be excavated for the HumeLink assets is unknown.

Option 2 would result in additional infrastructure within KNP resulting in amenity impacts with:

- addition of new substation and associated access; and
- addition of 330 and 500 kV overhead transmission lines and structures and associated easements and access tracks.

[14] Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen at this stage of approvals process, approvals and associated assessments of achieving connection for first power generation would need to be redone.

The new substation would need to be constructed on the plateau adjacent to the Snowy Mountains Highway resulting in visual impacts of users of that section of KNP.

Overall, Option 2 will result in significant additional infrastructure and associated environmental impacts within the KNP.

7.3.5 Best practice safety requirements

Option 2 is able to meet best practice safety requirements during construction and operation.

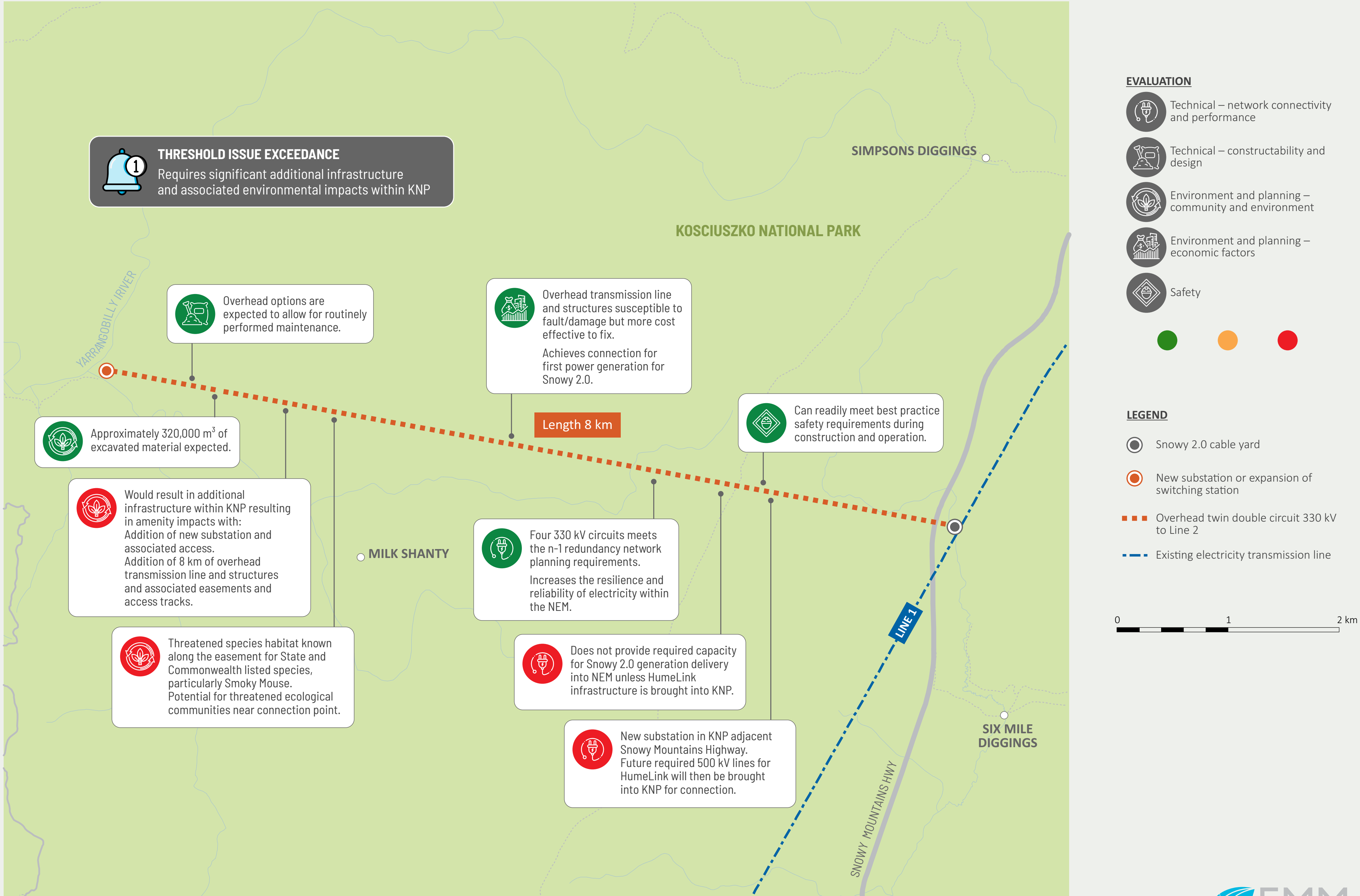


Figure 7.2 Option 2 – Overhead to Line 1

7.4 Option 3 – Overhead to Upper Tumut Switching Station

The key features of Option 3 are shown in Figure 7.3.

7.4.1 Network and connectivity

Option 3 meets the n-1 redundancy requirements but worsens the resilience and reliability within the NEM with connection at the UTSS. It also achieves connection for first power generation for Snowy 2.0, based on Project development commencement date of 2017[15]. However, Option 3 does not provide the required capacity for Snowy 2.0 generation delivery into the NEM unless HumeLink infrastructure is brought into KNP. A new substation is required in the KNP along with future 500 kV lines for HumeLink.

Overall, this option does not adequately meet the required network and connectivity criteria.

7.4.2 Constructability and design

This option presents no significant constraints for constructability and design, given that:

- suitable construction support sites are available at UTSS through Snowy 2.0 (although the topography may prove challenging in some areas); and
- overhead lines are susceptible to fault/damage but are cost effective to fix and allow for more straightforward maintenance.

7.4.3 Economic factors

Commensurate with a screening assessment, a high-level review of the construction costs associated with Option 3 indicates they are unlikely to be prohibitive due to the short length of line and the terrain. Similarly, operation costs are also unlikely to be prohibitive due to the fact that damage to overhead transmission lines and structures are more cost effective to fix when compared to underground lines.

7.4.4 Community and environment

Vegetation clearance associated with this option has reasonable potential to impact State and Commonwealth listed threatened species habitat, including the Smoky Mouse.

Approximately 500,000 m^3 of excavated material is expected to be generated.

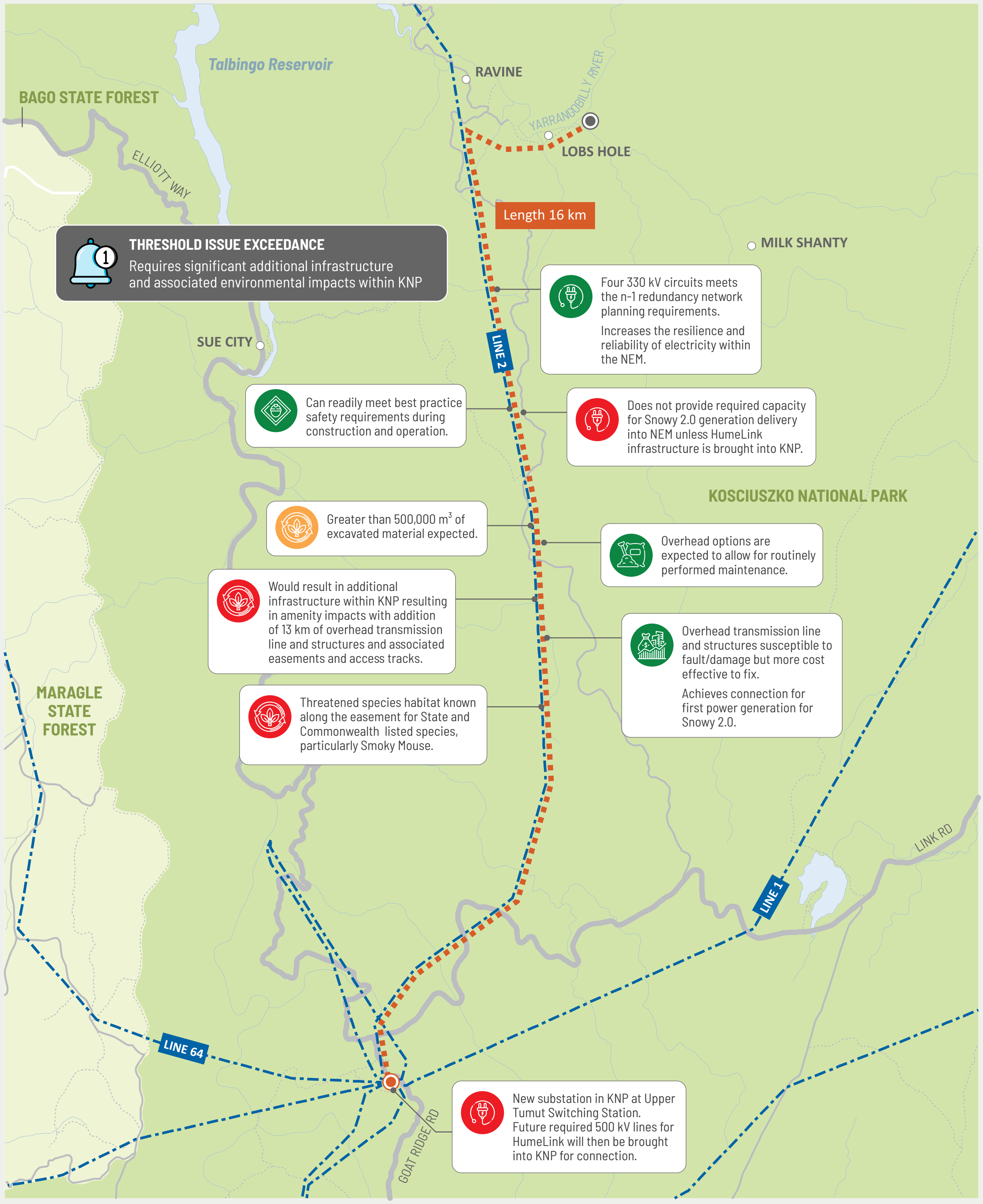
Option 3 would result in additional infrastructure within KNP resulting in amenity impacts with the addition of two new sets of 330 kV lines adjacent to Line 2 and 500 kV overhead transmission lines (HumeLink) and structures and associated easements and access tracks.

Overall, Option 3 will result in significant additional infrastructure and associated environmental impacts within the KNP.

7.4.5 Best practice safety requirements

Option 3 is able to meet best practice safety requirements during construction and operation.

[15] Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen at this stage of approvals process, approvals and associated assessments of achieving connection for first power generation would need to be redone.



EVALUATION

- Technical – network connectivity and performance
- Technical – constructability and design
- Environment and planning – community and environment
- Environment and planning – economic factors
- Safety

LEGEND

- Snowy 2.0 cable yard
- New substation or expansion of switching station
- Overhead twin double circuit 330 kV line to Upper Tumut Switching Station
- Existing electricity transmission line

0 1 2 km

EMM creating opportunities

Figure 7.3 Option 3 – Overhead to Upper Tumut Switching Station

7.5 Option 4 - Overhead to Line 64

The key features of Option 4 are shown in Figure 7.4.

7.5.1 Network and connectivity

Option 4 meets the n-1 redundancy requirements increasing the resilience and reliability within the NEM. It also achieves connection for first power generation for Snowy 2.0.

Another benefit is that Option 4 is able to provide the required capacity for Snowy 2.0 generation delivery into the NEM, without the need for HumeLink infrastructure to be brought into KNP. A new substation in Bago State Forest and 500 kV transmission lines associated with the HumeLink are outside the KNP. Line 64 is also seen as a better connection point into the 330 kV network as it is part of a less constrained cutset than Line 1 or Line 2 and the line is of lesser consequence than Line 1 or Line 2.

Overall, this option has no significant network and connectivity constraints.

7.5.2 Constructability and design

This option presents no significant constraints for constructability and design, given that:

- suitable construction support sites are available at Lobs Hole and at the western extent at Line 64 through Snowy 2.0;
- overhead lines are susceptible to fault/damage but are cost effective to fix and allow for more straightforward maintenance; and
- construction footprint would be small and would therefore result in a smaller disturbance footprint.

7.5.3 Economic factors

Commensurate with a screening assessment, a high-level review of the construction costs associated with Option 4 indicates they are unlikely to be prohibitive due to the short length of line and the terrain. Similarly, operation costs are also unlikely to be prohibitive since damage to overhead transmission lines and structures are more cost effective to fix when compared to underground lines.

7.5.4 Community and environment

Vegetation clearance associated with this option has the reasonable potential to impact State and Commonwealth listed threatened species habitat (noting, however, that the Smoky Mouse has not been identified in this area).

Around 364,800 m^3 of excavated material is expected.

Option 4 would result in additional infrastructure within KNP resulting in amenity impacts with the addition of 9 km of overhead transmission line and structures and associated easements and 7.5 km of access tracks.

Overall, Option 4 will result in additional infrastructure and associated environmental impacts within the KNP.

7.5.5 Best practice safety requirements

Option 4 is able to meet best practice safety requirements during construction and operation.

EVALUATION

- Technical – network connectivity and performance
- Technical – constructability and design
- Environment and planning – community and environment
- Environment and planning – economic factors
- Safety

LEGEND

- Snowy 2.0 cable yard
- New substation or expansion of switching station
- Overhead twin double circuit 330 kV to Line 64
- Existing electricity transmission line

0 1 2 km

EMM creating opportunities

Figure 7.4 Option 4 – Overhead to Line 64

7.6 Option 5 – Tunnel to Line 64

The key features of Option 5 are shown in Figure 7.4.

7.6.1 Network and connectivity

Option 5 meets the n-1 redundancy requirements increasing the resilience and reliability within the NEM.

Based on Project development commencement date of 2017[16], this option has a very high risk of achieving connection for first power generation of Snowy 2.0 given the risk profile of using single TBM for tunnel excavation and the estimated timeframe of 82 months from feasibility phase to commissioning.

Option 5 is able to provide the required capacity for Snowy 2.0 generation delivery into the NEM, without the need for HumeLink infrastructure to be brought into KNP.

A new substation in Bago State Forest associated with the HumeLink is outside the KNP.

Overall, this option has no significant network and connectivity constraints.

7.6.2 Constructability and design

Option 5 has the following constructability and design attributes:

- suitable construction support sites are available at Lobs Hole through Snowy 2.0 and Maragle via Elliot Way;
- the construction footprint would be relatively small and would therefore result in a smaller disturbance footprint; and
- the design is constrained by the presence of underground lines which are more difficult to access for maintenance, compared to overhead. Option 5 will also require intermediate shafts for ventilation and emergency access.

Other significant constructability and design risks include:

- the tunnel would also pass-through areas of high potential asbestos and a fault with potential connection to the Tumut River above; and
- suspension of the cables in a deep shaft.

7.6.3 Economic factors

The construction cost of Options 5 may be prohibitively high due to the need to deep tunnel through rock for approximately 9 km.

Similarly, any damage to underground cables is likely to result in failure of transmission with high economic risk outcomes due to probable time and cost needed to recommence transmission of Snowy 2.0 generation.

16 Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen at this stage of approvals process, approvals and associated assessments of achieving connection for first power generation would need to be redone.

7.6.4 Community and environment

Vegetation clearance associated with this option has a reasonable potential to impact State and Commonwealth listed threatened species habitat (noting, however, that the Smoky Mouse has not been identified in this area).

Approximately 770,000 m^3 of excavated material is expected to be generated.

Option 5 would result in additional infrastructure within the KNP resulting in amenity impacts with addition of entry portal and shafts/adits with associated access tracks at designated points along the length of the underground deep cable tunnel.

Overall, Option 5 has reasonable potential to impact the environment within the KNP.

7.6.5 Best practice safety requirements

As Option 5 requires underground excavation activities in a remote area, it results in a higher safety risk than other methods, both during construction and for operations and maintenance.

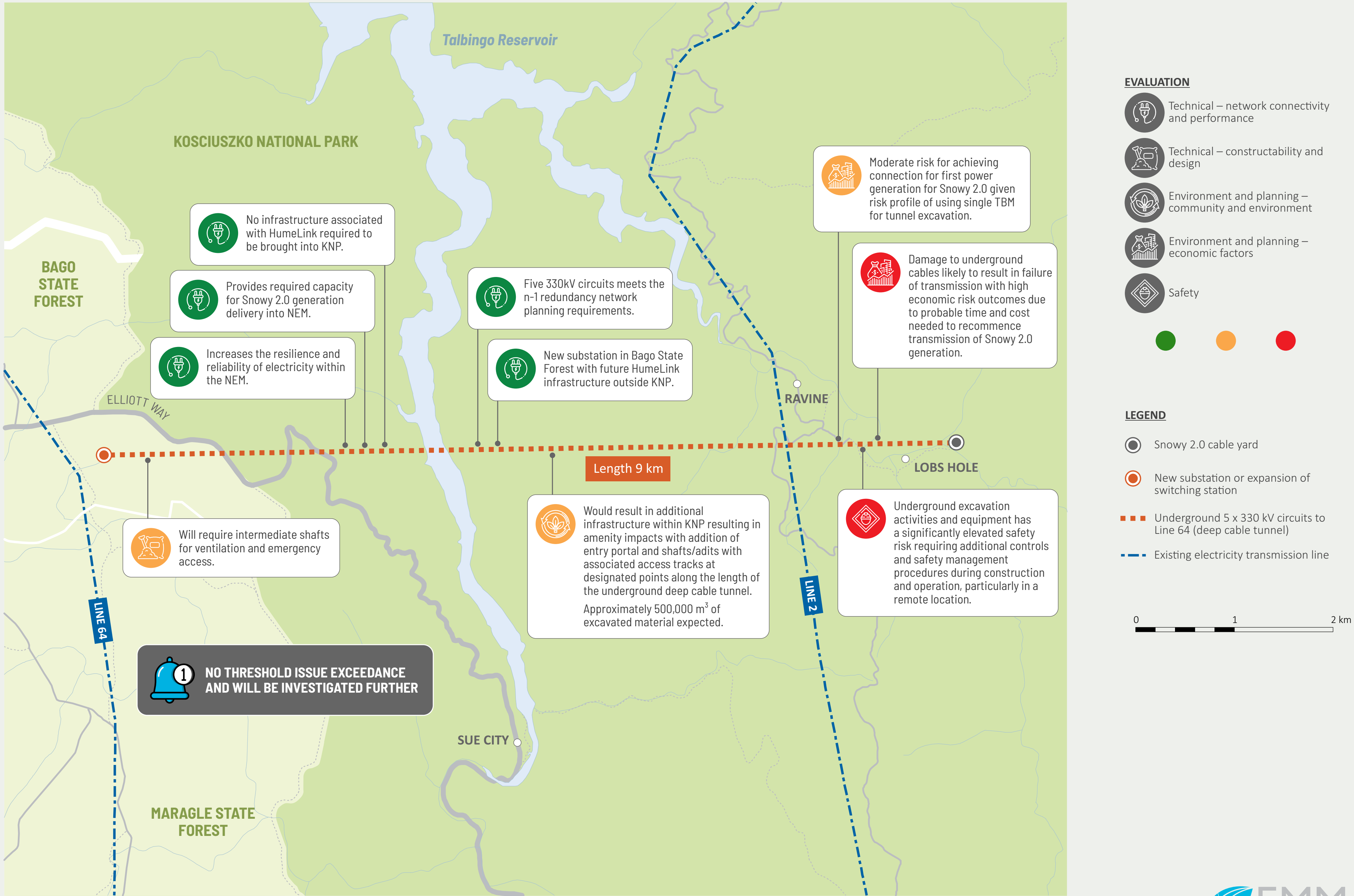


Figure 7.5 Option 5 – Tunnel to Line 64

7.7 Option 6 – Trench to Line 64

The key features of Option 6 are shown in Figure 7.6.

7.7.1 Network and connectivity

Option 6 meets the n-1 redundancy requirements increasing the resilience and reliability within the NEM. It also achieves connection for first power generation for Snowy 2.0, based on Project development commencement date of 2017[17].

Another benefit is that Option 6 is able to provide the required capacity for Snowy 2.0 generation delivery into the NEM, without the need for HumeLink infrastructure to be brought into KNP.

A new substation in Bago State Forest associated with the HumeLink is outside the KNP.

Overall, this option has no significant network and connectivity constraints.

7.7.2 Constructability and design

Option 6 has the following constructability and design benefits:

- suitable construction support sites are available in along the route through the Snowy 2.0 Main Works project; and
- allows for replacement faulted cables or joints in sections.

However, it also has the following disadvantages:

- because of the need for excavation within steep terrain, the construction footprint would be large, and the volume of excavated materials would be significant and would require disposal; and
- the constructability and design are constrained by the presence of underground lines which are more difficult to access for maintenance, compared to overhead.

7.7.3 Economic factors

The construction cost of Option 6 may be prohibitively high due to the need to trench through a significant volume of excavations required to establish the trench required within challenging topography for approximately 16 km.

Similarly, any damage to underground cables is likely to result in failure of transmission with high economic risk outcomes due to probable time and cost needed to recommence transmission of Snow 2.0 generation. The considerable timeframe also presents a risk to achieving connection prior to power generation of Snowy 2.0.

A trenched cable along a maintained access road is unlikely to be prone to damage but can be difficult to fix should it be damaged.

17 Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen at this stage of approvals process, approvals and associated assessments of achieving connection for first power generation would need to be redone.

7.7.4 Community and environment

Vegetation clearance associated with this option has reasonable potential to impact State and Commonwealth listed threatened species habitat (noting, however, that the Smoky Mouse has not been detected in this area).

Approximately 4,000,000 m^3 of excavated material is expected to be generated.

Option 6 would result in additional infrastructure within the KNP resulting in amenity impacts with additional widening of existing O'Hares Track and Elliott Way to allow for trenching activities and easement.

Overall, Option 6 has reasonable potential to impact the environment within the KNP.

7.7.5 Best practice safety requirements

As Option 6 involves significant excavation volumes as well as works along public roads, it presents some safety challenges that will need to be overcome to achieve the required criteria and standards.

Figure 7.6 Option 6 – Trench to Line 64

EMM creating opportunities

7.8 Option 7 – Horizontal directional drilling to Line 64

The key features of Option 7 are shown in Figure 7.7.

7.8.1 Network and connectivity

Option 7 meets the n-1 redundancy requirements increasing the resilience and reliability within the NEM. It also achieves connection for first power generation for Snowy 2.0, based on Project development commencement date of 2017[18].

Another benefit is that Option 7 is able to provide the required capacity for Snowy 2.0 generation delivery into the NEM, without the need for HumeLink infrastructure to be brought into KNP.

A new substation in Bago State Forest associated with the HumeLink is outside the KNP.

Overall, this option has no significant network and connectivity constraints.

7.8.2 Constructability and design

Option 7 is technically not viable as it is unsuitable for steep terrain, has a high probability for cable drift and requires transitions to overhead transmission over Talbingo Reservoir or tunnelling under the reservoir. It also has no suitable construction support sites.

7.8.3 Economic factors

Directionally drilled cable along public road is unlikely to be prone to damage but can be difficult to fix should it be damaged.

7.8.4 Community and environment

Impacts to the community and the environment associated with this option are likely to be generally manageable. Vegetation clearance associated with this option has reasonable potential to impact State and Commonwealth listed threatened species habitat (noting, however, that the Smoky Mouse is not recorded in this area).

Volumes of excavated material were not calculated as this option is not considered viable.

7.8.5 Best practice safety requirements

As Option 7 involves surface works and drilling in remote locations and challenging terrain with technical difficulties, it does not meet the required safety criteria.

18 Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen at this stage of approvals process, approvals and associated assessments of achieving connection for first power generation would need to be redone.

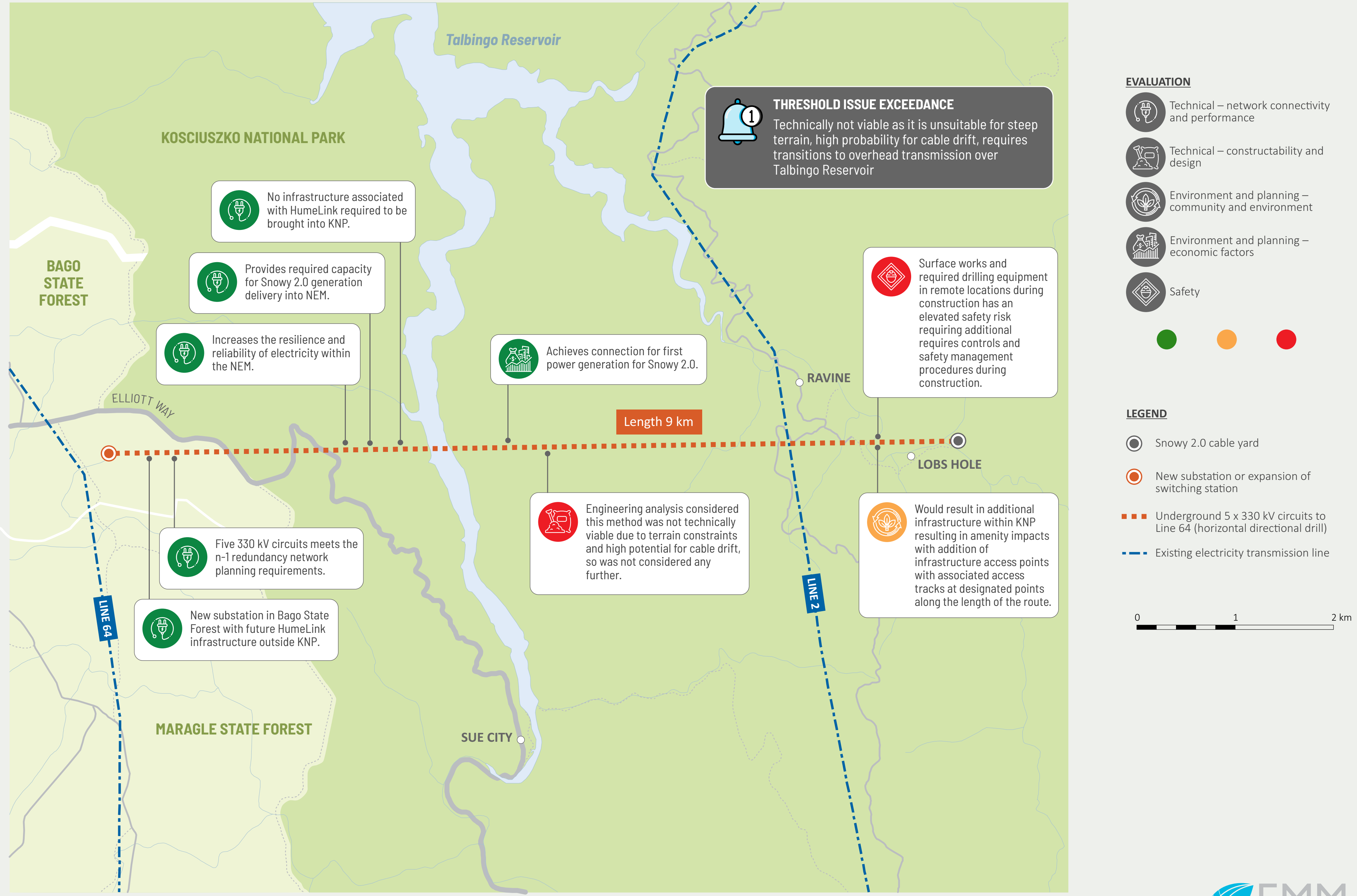


Figure 7.7 Option 7 – HDD to Line 64

7.9 Option 8 – Hybrid trench/tunnel to Line 64

The key features of Option 8 are shown in Figure 7.8.

7.9.1 Network and connectivity

Option 8 meets the n-1 redundancy requirements increasing the resilience and reliability within the NEM.

This option is able to provide the required capacity for Snowy 2.0 generation delivery into the NEM, without the need for HumeLink infrastructure to be brought into KNP.

A new substation in Bago State Forest associated with the HumeLink is outside the KNP.

Based on Project development commencement date of 2017[19], this option has a very high risk of achieving connection for first power generation of Snowy 2.0 given risk profile of using single TBM for tunnel excavation and the estimated timeframe of 78 months from feasibility phase to commissioning.

Overall, this option has no significant network and connectivity constraints.

7.9.2 Constructability and design

Option 8 has the following constructability and design benefits:

- suitable construction support sites are available in along the route through Snowy 2.0;
- the construction footprint would be smaller and would therefore result in a smaller disturbance footprint, however there are likely to be significant volumes of excavated materials requiring disposal from both the tunnelling and trenching activities.; and
- allows for replacement faulted cables or joints in sections.

However, the design is constrained by the presence of underground lines which are more difficult to access for maintenance, compared to overhead. Also, Option 8 will require intermediate shafts for ventilation and emergency access.

7.9.3 Economic factors

The construction cost of Options 8 is prohibitively high due to the need to trench and deep tunnel through rock for approximately 10 km.

Potential damage to underground cables is likely to result in failure of transmission with high economic risk outcomes due to probable time and cost needed to recommence transmission of Snow 2.0 generation.

A trenched cable along a maintained access road is unlikely to be prone to damage but can be difficult to fix should it be damaged.

[19] Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen at this stage of approvals process, approvals and associated assessments of achieving connection for first power generation would need to be redone.

7.9.4 Community and environment

Vegetation clearance associated with this option has reasonable potential to impact State and Commonwealth listed threatened species habitat (noting, however, that the Smoky Mouse is not detected in this area).

Approximately 1,750,000 m^3 of excavated material is expected to be generated.

Option 8 would result in additional infrastructure within the KNP resulting in amenity impacts with addition of entry portal and shafts/adits with associated access tracks at designated points along length of the underground deep cable tunnel component. Amenity impacts would also result from access points and widening of Elliott Way component.

7.9.5 Best practice safety requirements

As Option 8 involves surface works and drilling in remote locations, it does meet the required safety criteria.

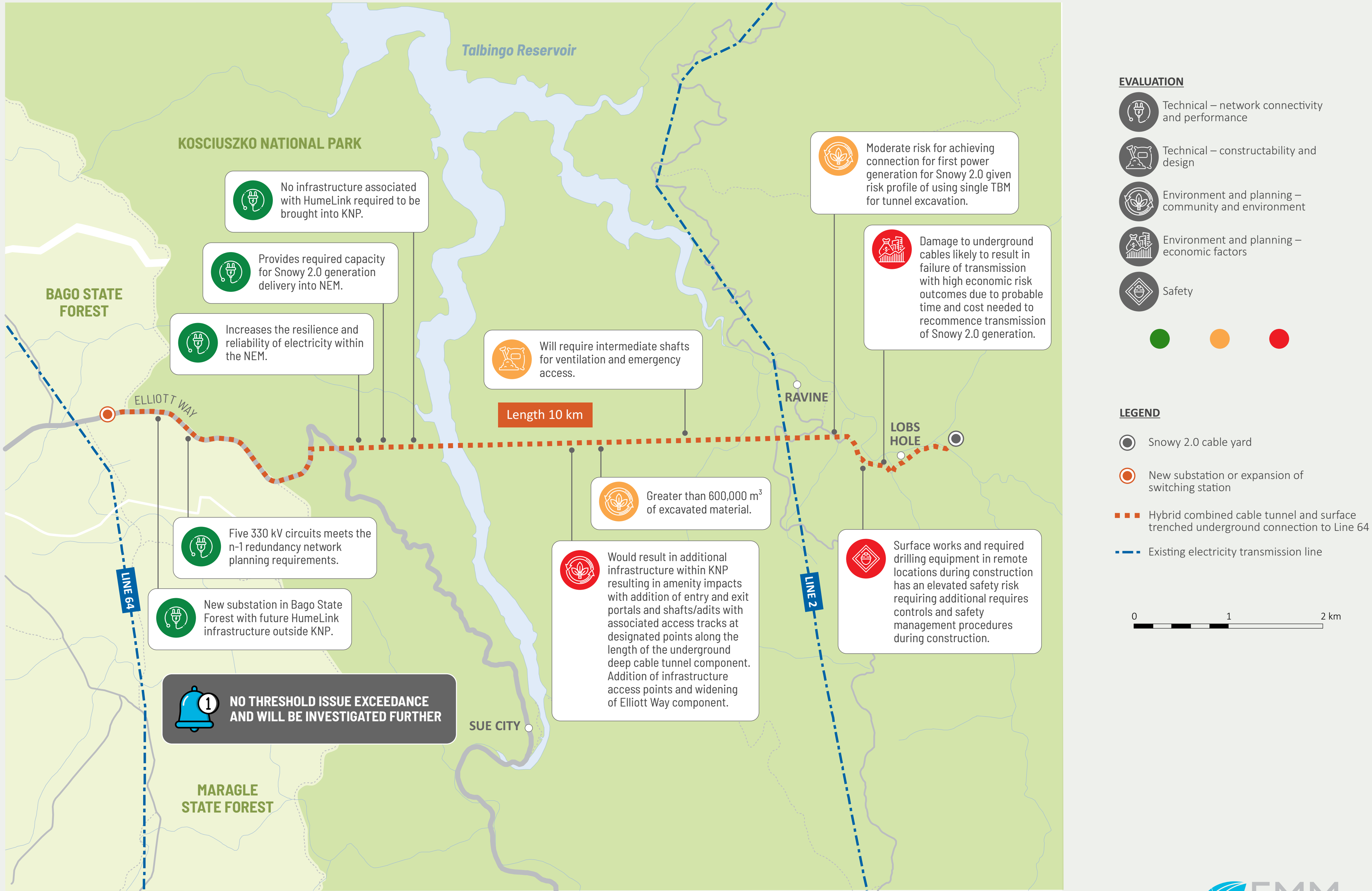


Figure 7.8 Option 8 – Hybrid trench/tunnel to Line 64

EMM creating opportunities

7.10 Option 9 – Hybrid trench/submarine cable to Lower Tumut Switching Station

The key features of Option 9 are shown in Figure 7.9.

7.10.1 Network and connectivity

Option 9 meets the n-1 redundancy requirements increasing the resilience and reliability within the NEM.

This option is able to provide the required capacity for Snowy 2.0 generation delivery into the NEM, without the need for HumeLink infrastructure to be brought into KNP.

A new substation is required at the existing LTSS location along with a single set of double circuit 500 kV lines.

Based on Project development commencement date of 2017[20], this option will not achieve connection for first power generation for Snowy 2.0 due to the construction timelines.

Option 9 will decrease the resilience and reliability of electricity within the NEM as it leads to an overconcentration of generation capacity in a single location.

Overall, this option is not viable in terms of network and connectivity constraints.

7.10.2 Constructability and design

Option 9 has significant constructability and design constraints:

- no suitable construction support sites are available in along the route;
- underground lines in the trenches will be more difficult to access for maintenance, compared to overhead;
- the construction footprint would be large and would therefore result in a large disturbance footprint; and
- repairs to submarine cable requires divers to detect fault and specialised equipment to repair fault.

7.10.3 Economic factors

Commensurate with a screening assessment, a high-level review of the construction costs associated with Option 9 indicates they are prohibitive due to the large disturbance footprint and plant and equipment required to establish the construction activities for dredging the reservoir bed, cable manufacturing facilities for the cable laying and the operational facilities required to be able perform maintenance and monitoring activities on the submarine cable.

Similarly, operation costs are also prohibitive due to the fact that any damage to submarine cables is likely to result in failure of transmission with high economic risk outcomes due to probable time and cost needed to recommence transmission of Snow 2.0 generation.

7.10.4 Community and environment

Vegetation clearance associated with this option has significant potential to impact State and Commonwealth listed threatened species habitat (noting, however that the Smoky Mouse is not detected in this area). Laying submarine

[20] Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen at this stage of approvals process, approvals and associated assessments of achieving connection for first power generation would need to be redone.

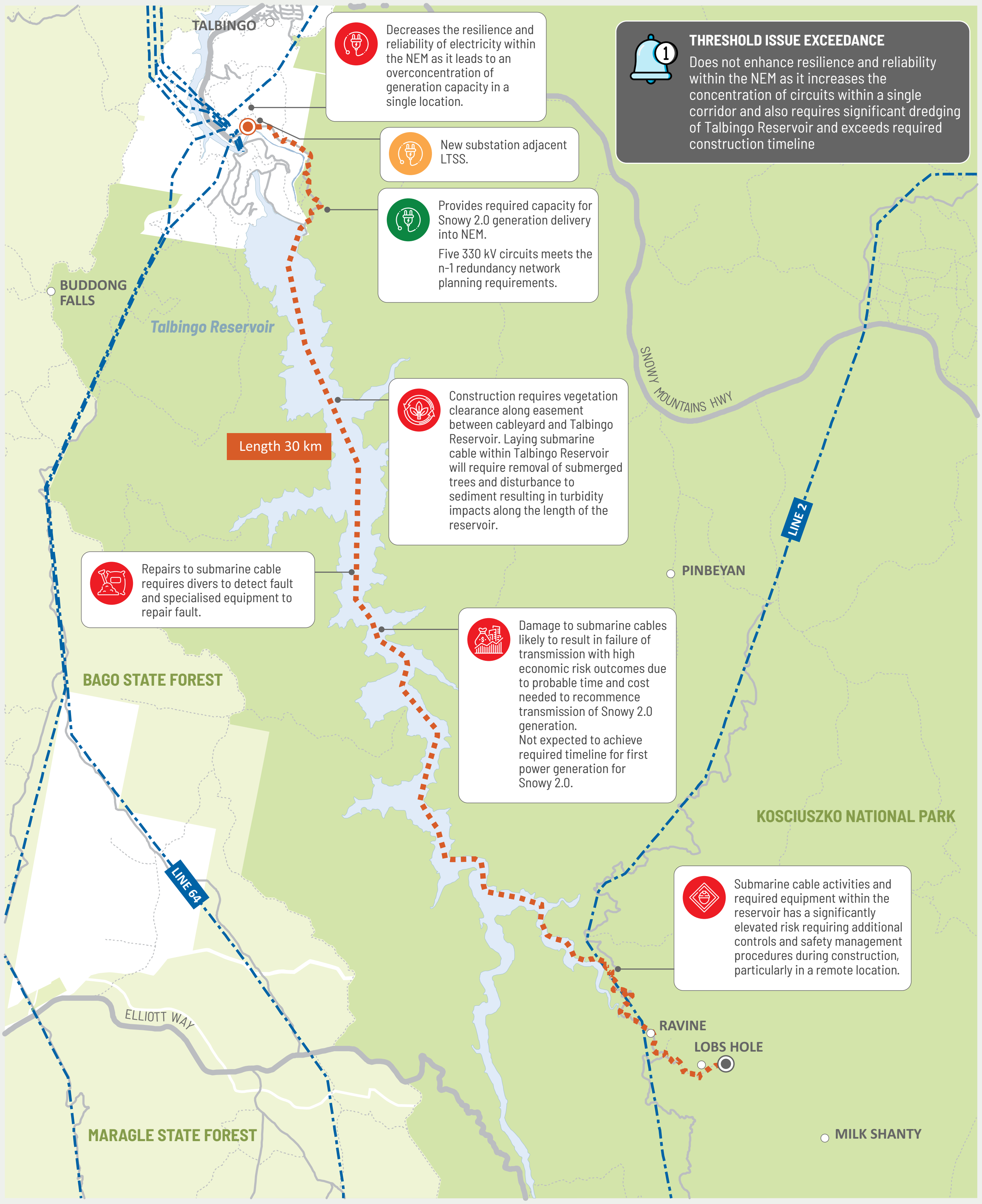
cable within Talbingo Reservoir will require removal of submerged trees and rocks, and disturbance of sediment resulting in turbidity impacts along the length of the reservoir.

Significant volumes of excavated material are expected particularly dredging volumes required for the 17 km route within Talbingo Reservoir to lay cable.

Option 9 would result in additional infrastructure within the KNP resulting in amenity impacts with the addition of infrastructure access points with associated access tracks at designated points along the length of the route between the cable yard and Talbingo Reservoir.

7.10.5 Best practice safety requirements

As Option 9 involves submarine cabling within the reservoir in a remote location, it does meet the required safety criteria.



EVALUATION

- Technical – network connectivity and performance
- Technical – constructability and design
- Environment and planning – community and environment
- Environment and planning – economic factors
- Safety

LEGEND

- Snowy 2.0 cable yard
- New substation or expansion of switching station
- Underground 5 x 330 kV circuits to Line 64 (hybrid of deep able and trench)
- Existing electricity transmission line

0 2 4 km

EMM creating opportunities

Figure 7.9 Option 9 – Hybrid trench/submiaring cable to Lower Tumut Switching Station

7.11 Option 10 - Trench to Lower Tumut Switching Station

Option 10 has two routes that were investigated, 'a' and 'b'. The key features of these two routes are shown in Figure 7.10 and Figure 7.11, respectively.

Note Option 10 in this section refers to both Option 10a and 10b.

7.11.1 Network and connectivity

Option 10 meets the n-1 redundancy requirements.

These options are able to provide the required capacity for Snowy 2.0 generation delivery into the NEM, without the need for HumeLink infrastructure to be brought into KNP.

A new substation is required at the existing LTSS location along with five sets of 330 kV cables.

Based on Project development commencement date of 2017[21], these options are unlikely to achieve connection for first power generation for Snowy 2.0.

Option 10 will decrease the resilience and reliability of electricity within the NEM as it leads to an overconcentration of generation capacity in a single location.

Overall, Option 10 is not viable in terms of network and connectivity constraints.

7.11.2 Constructability and design

Option 10 has significant constructability and design constraints, namely:

- no suitable construction support sites are available in along the route;
- underground lines are more difficult to access for maintenance, compared to overhead, with Option 10b more accessible than Option 10a given it runs adjacent to large sections of the Snowy Mountains Highway and Miles Franklin Drive;
- the construction footprint would be large and would therefore result in a large disturbance footprint and significant excavated material volumes requiring disposal; and
- trenched cable along public road is unlikely to be prone to damage but can take a long time to repair should it be damaged.

7.11.3 Economic factors

Commensurate with a screening assessment, a high-level review of the construction costs associated with Option 10 indicates they are likely to be prohibitive due to trenching and clearance works over a significant distance (33 – 45 km), with substantial costs for trenching equipment, covering the completed trench, disposal of excess materials excavated from trenches, and upgrades (and establishment) of access roads.

[21] Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen at this stage of approvals process, approvals and associated assessments of achieving connection for first power generation would need to be redone. .

In the event that cables are damaged, the substantial time required to identify and repair damaged cables for Option 10 would result in sustained disruption to Snowy 2.0 generation and have significant associated economic impacts.

7.11.4 Community and environment

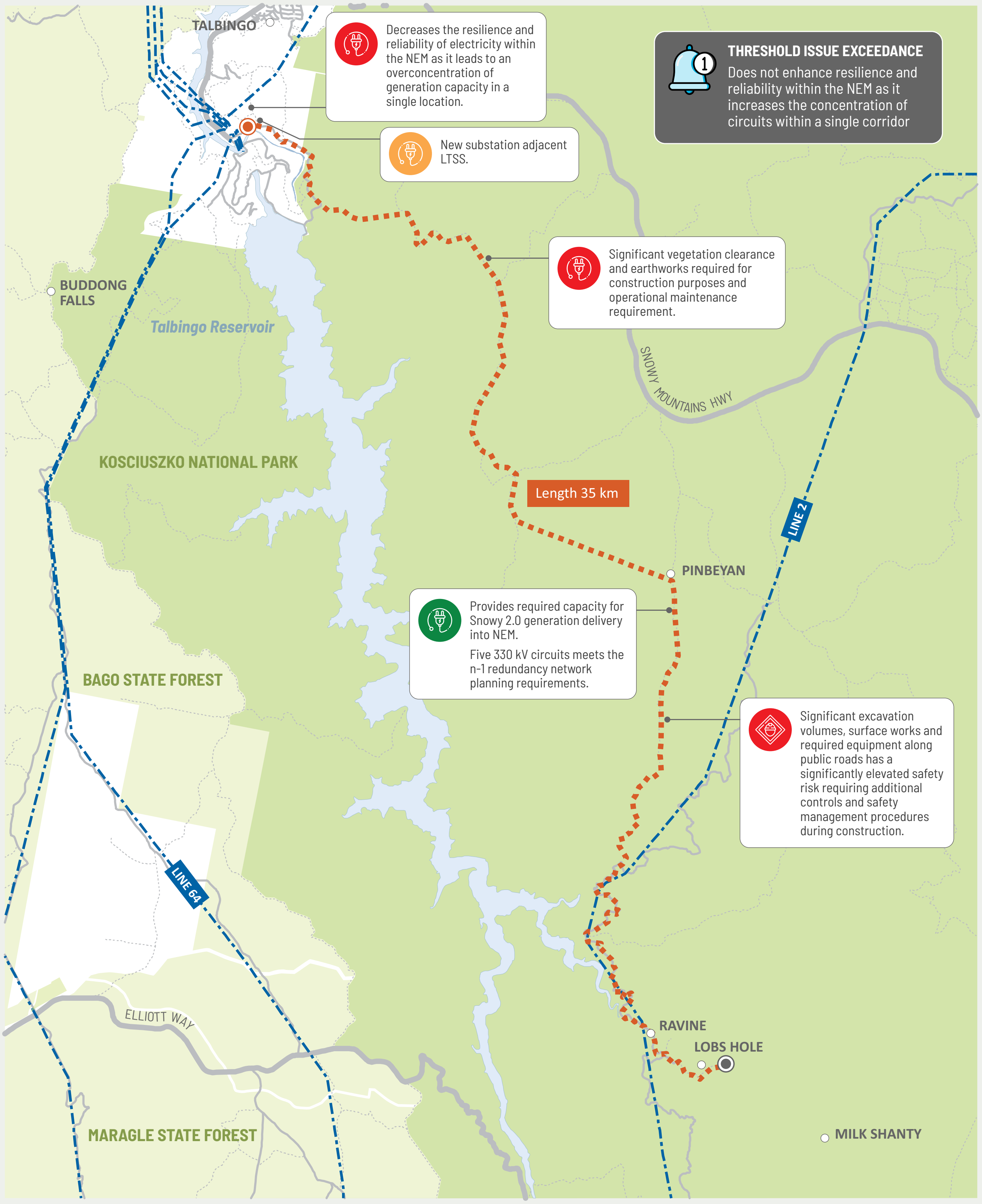
Vegetation clearance associated with these options has significant potential to impact State and Commonwealth listed threatened species habitat.

A significant volume of excavated material is expected to be generated.

Option 10 would result in additional infrastructure within KNP resulting in amenity impacts with the addition of new easements within KNP, infrastructure access points with associated access tracks at designated points along the length of the route.

7.11.5 Best practice safety requirements

As Option 10 involve significant excavation volumes and work along a public road, there are elevated safety risks requiring additional safety controls and management procedures during construction.



EVALUATION

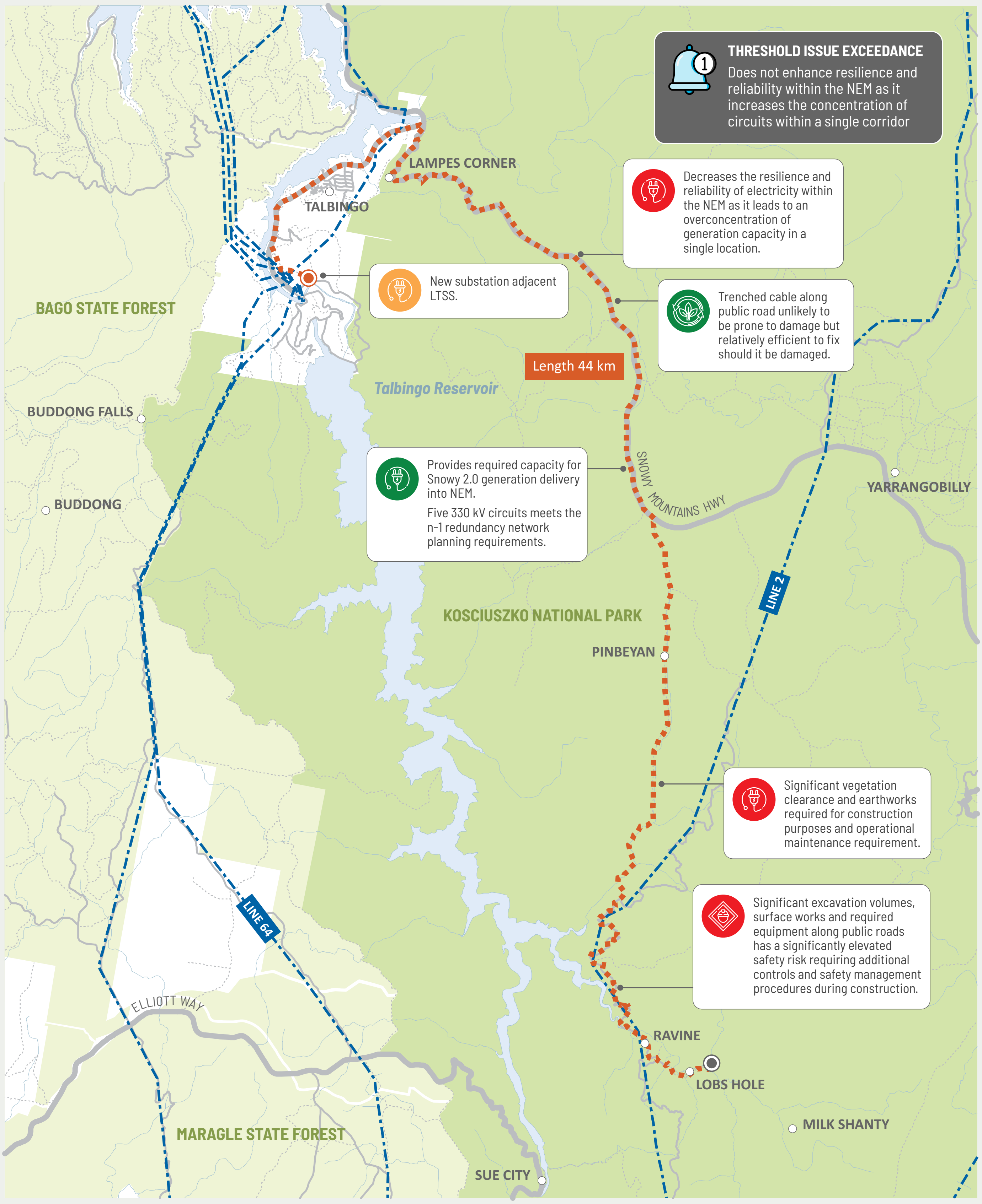
- Technical – network connectivity and performance
- Technical – constructability and design
- Environment and planning – community and environment
- Environment and planning – economic factors
- Safety

LEGEND

- Snowy 2.0 cable yard
- New substation or expansion of switching station
- Trenched 5 x 330 kV circuits to Lower Tumut Switching Station
- Existing electricity transmission line

EMM creating opportunities

Figure 7.10 Option 10a – Trench to Lower Tumut Switching Station



EVALUATION

- Technical – network connectivity and performance
- Technical – constructability and design
- Environment and planning – community and environment
- Environment and planning – economic factors
- Safety

LEGEND

- Snowy 2.0 cable yard
- New substation or expansion of switching station
- Trenched 5 x 330 kV circuits to Lower Tumut Switching Station
- Existing electricity transmission line

0 2 4 km

EMM creating opportunities

Figure 7.11 Option 10b – Trench to Lower Tumut Switching Station

7.12 Option 11 – Overhead to Lower Tumut Switching Station

The key features of Option 11 are shown in Figure 7.11.

7.12.1 Network and connectivity

Option 11 meets the n-1 redundancy requirements.

This option is able to provide the required capacity for Snowy 2.0 generation delivery into the NEM, without the need for HumeLink infrastructure to be brought into KNP. A new substation is required in the KNP along with two new double circuit lines.

This option is likely to achieve connection for first power generation for Snowy 2.0, based on Project development commencement date of 2017[22].

Option 11 will decrease the resilience and reliability of electricity within the NEM as it leads to an overconcentration of generation capacity in a single location (ie at LTSS).

Overall, this option is not viable in terms of network and connectivity constraints.

7.12.2 Constructability and design

Apart from the significant route length, Option 11 has no significant constructability and design constraints. The overhead lines are susceptible to fault/damage but are cost effective to fix and allow for more straightforward maintenance; and there are suitable construction support sites are available outside of KNP.

7.12.3 Economic factors

Commensurate with a screening assessment, a high-level review of the construction costs associated with Option 11 indicates they are likely to be prohibitive due to large amounts of clearing and length of overhead lines required.

Operational and maintenance costs, however, are unlikely to be prohibitive as, even though the overhead transmission line and structures are more susceptible to fault/damage, they are more cost effective to fix should damage occur.

7.12.4 Community and environment

Vegetation clearance associated with this option has reasonable potential to impact State and Commonwealth listed threatened species habitat (noting, however, that critically threatened species such as the Smoky Mouse have not been identified in this area).

Approximately 1,000,000 m^3 of material is expected to be excavated for Option 11.

Option 11 would result in additional 24 km of overhead transmission lines and associated easement and access tracks within the KNP which is likely to have amenity impacts to users of the Park.

[22] Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen at this stage of approvals process, approvals and associated assessments of achieving connection for first power generation would need to be redone.

7.12.5 Best practice safety requirements

Option 11 is able to meet best practice safety requirements during construction and operation.

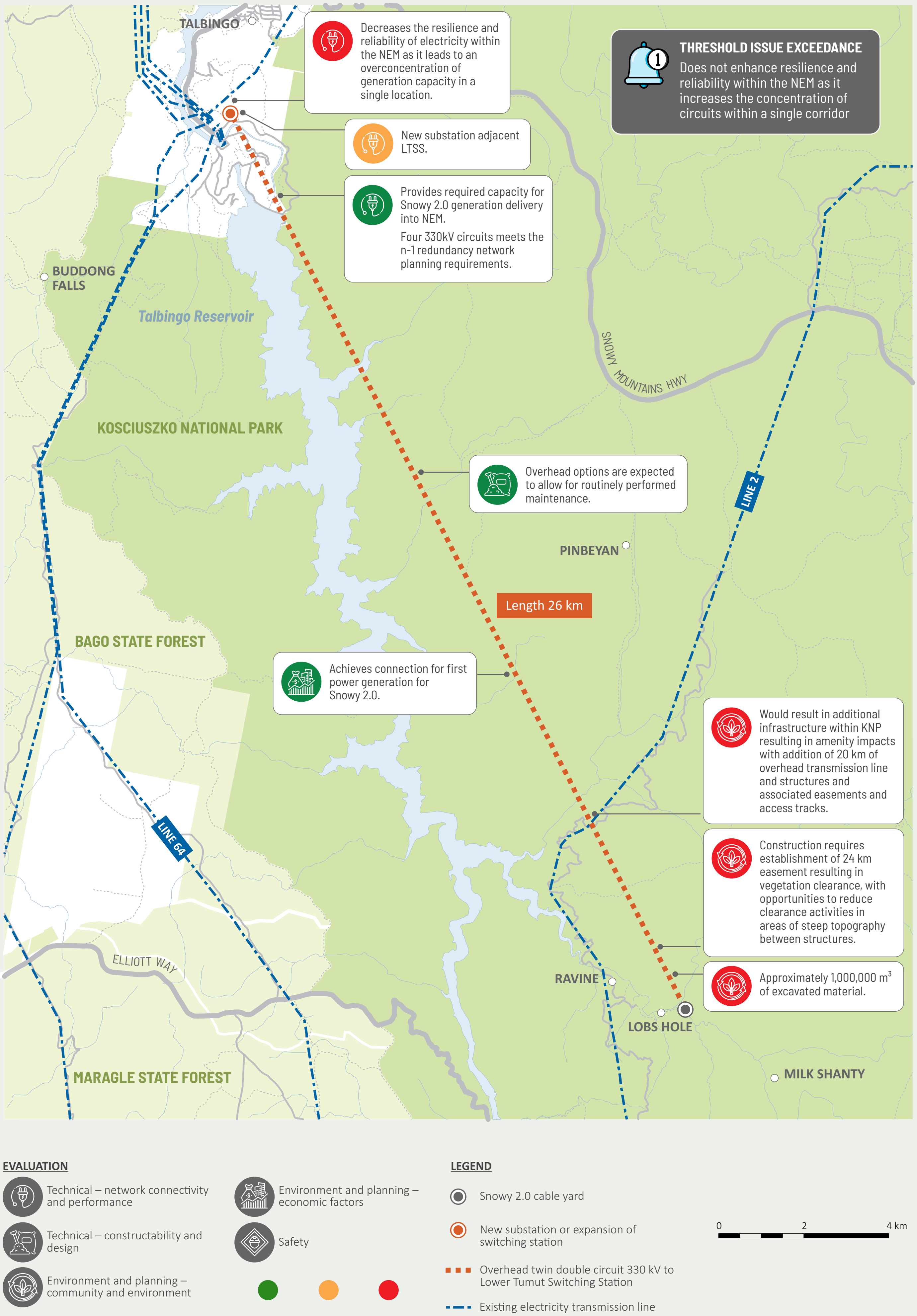


Figure 7.12 Option 11 – Overhead to Lower Tumut Switching Station

7.13 Option 12 – Tunnel to Lower Tumut Switching Station

The key features of Option 12 are shown in Figure 7.13.

7.13.1 Network and connectivity

Option 12 meets the n-1 redundancy requirements.

This option is able to provide the required capacity for Snowy 2.0 generation delivery into the NEM, without the need for HumeLink infrastructure to be brought into KNP.

A new substation is required in KNP along with five sets of cables within the tunnel.

Based on Project development commencement date of 2017[23], this option has a very high risk of achieving connection for first power generation of Snowy 2.0 given risk profile for tunnel excavation, even though two TBMs are proposed.

Option 12 will decrease the resilience and reliability of electricity within the NEM as it leads to an overconcentration of generation capacity in a single location (LTSS).

Overall, this option is not viable in terms of network and connectivity constraints.

7.13.2 Constructability and design

Although Option 12 would have access to suitable construction support sites outside of KNP, overall it has significant constructability and design constraints, namely:

- underground lines will be more difficult to access for maintenance, compared to overhead;
- the construction footprint would be large and would therefore result in a large disturbance footprint;
- high degree of uncertainty of tunnelling through rock types with naturally occurring asbestos; and
- will require intermediate shafts for ventilation and emergency access.

7.13.3 Economic factors

The construction cost of Options 12 is likely to be prohibitively high due to the need to trench and deep tunnel through rock for approximately 25 km.

In the event that damage to underground cables occurs, this is likely to result in failure of transmission of Snowy 2.0 generation with high economic risk outcomes due to probable time and cost needed to recommence transmission.

7.13.4 Community and environment

Vegetation clearance associated with this option has significant potential to impact State and Commonwealth listed threatened species habitat, particularly at the portals within KNP adjacent to Snowy Mountains Highway.

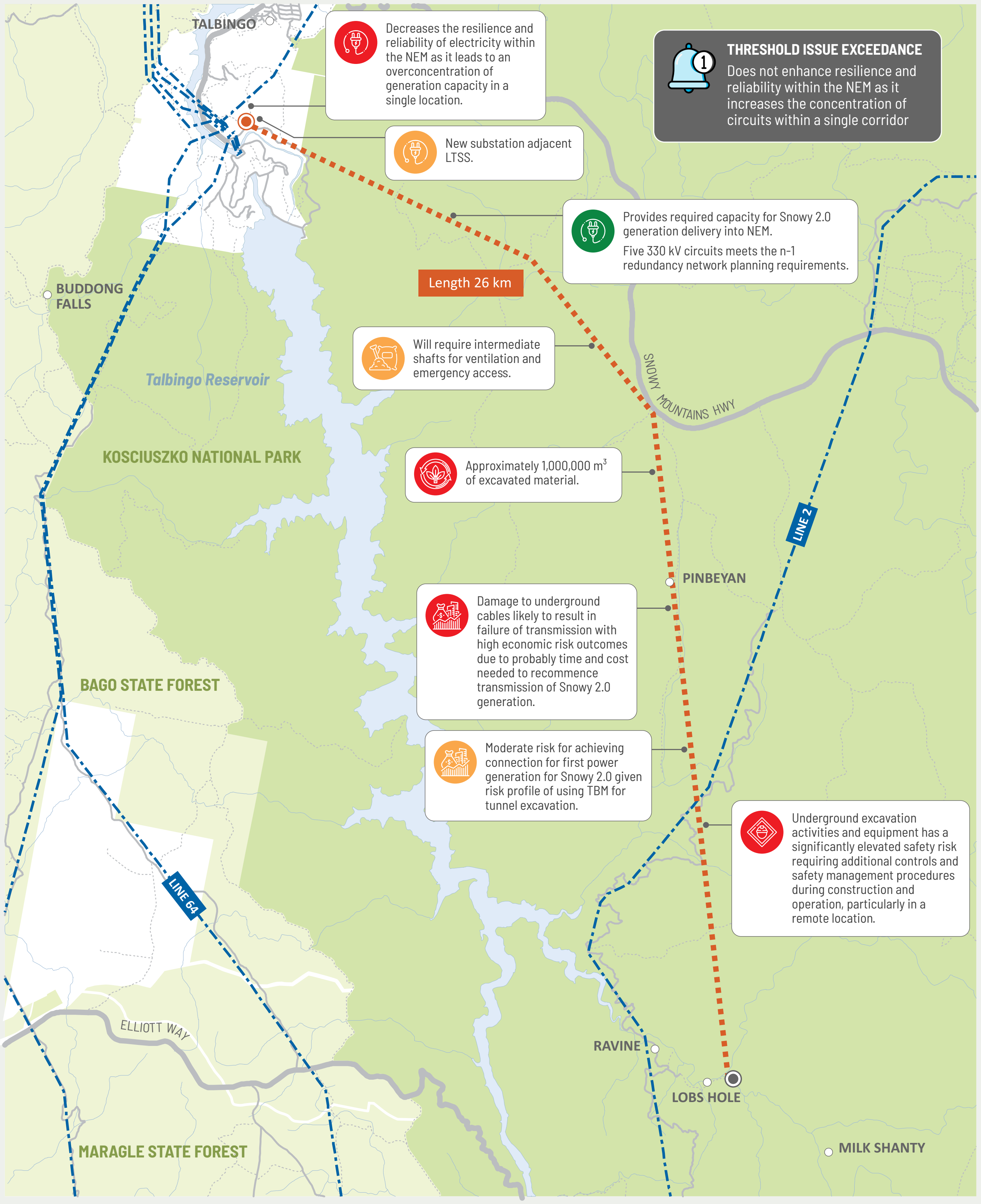
[23] Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen at this stage of approvals process, approvals and associated assessments of achieving connection for first power generation would need to be redone.

More than approximately 1,000,000 m^3 of material is expected to be excavated.

Option 12 would result in additional infrastructure within KNP with the addition of entry portal and shafts/adits with associated access tracks at designated points along the length of the underground deep cable tunnel. The additional infrastructure is likely to have amenity impacts to users of KNP.

7.13.5 Best practice safety requirements

As Option 12 requires underground excavation activities in a remote area and at significant depths (up to 420 m), it has a significantly elevated safety risk requiring additional safety controls and management procedures during construction and operation.



EVALUATION

- Technical – network connectivity and performance
- Technical – constructability and design
- Environment and planning – community and environment
- Environment and planning – economic factors
- Safety

LEGEND

- Snowy 2.0 cable yard
- New substation or expansion of switching station
- Underground five 330 kV circuits to Lower Tumut Switching Station (deep cable tunnel)
- Existing electricity transmission line

0 2 4 km

EMM creating opportunities

Figure 7.13 Option 12 – Tunnel to Lower Tumut Switching Station

7.14 Screening analysis outcomes

The results of the screening analysis indicated that eight options did not meet the set objectives and exceeded threshold issues relating to the assessment criteria. These included options that:

- require significant extra assets to be constructed within KNP;
- are not technically viable; and/or
- do not enhance the resilience and reliability of the NEM.

The options that require significant additional assets to be constructed within KNP include:

- Option 1 – Overhead to Line 2;
- Option 2 – Overhead to Line 1; and
- Option 3 – Overhead to UTSS.

These options all necessitate the addition of HumeLink infrastructure within KNP, including a new substation and 500 kV lines.

The options that are not technically viable include:

- Option 7 – HDD to Line 64; and
- Option 9 – Hybrid trench/submarine cable to LTSS.

Option 7 was deemed to be technically unviable because it is unsuitable for steep terrain, has a high probability of tunnel drift during drilling, and requires the transition to overhead transmission over Talbingo Reservoir.

Option 9 was deemed to be technically unviable because of the required construction methodology within Talbingo Reservoir and the construction schedule. Further, it does not enhance the resilience and reliability of the NEM as it increases the concentration of transmission circuits within a single corridor north of LTSS. It would also likely have significant environmental impacts associated with dredging within the reservoir.

In addition to Option 9, the options that do not enhance the resilience and reliability of the NEM include:

- Option 10 – Trench to LTSS;
- Option 11 – Overhead to LTSS; and
- Option 12 – Deep cable tunnel to LTSS.

As a result of the screening assessment, four options were proposed to be considered further as part of the detailed assessment, including:

- Option 4 – Overhead to Line 64;
- Option 5 – Deep cable tunnel to Line 64;
- Option 6 – Trench to Line 64; and
- Option 8 – Hybrid trench/deep cable tunnel to Line 64.

As stated in Chapter 1, the results of the screening assessment were presented to DPIE and NPWS at a meeting on 16 July 2021. After this meeting, DPIE requested additional information on four occasions (RFI 1, RFI 2, RFI 3 and RFI 4) on several options, including Option 3.

At a subsequent meeting with DPIE and NPWS on 10 August 2021, Options 5, 6 and 8 were screened from the assessment, primarily on the basis they would not be economically feasible to construct. Option 3 was returned to the assessment and was the focus of RFI 2, RFI 3 and RFI 4. Therefore, the two options selected to go through to the detailed assessment phase were Option 3 and Option 4.

Details of the post screening analysis of the options in accordance with DPIE's RFIs are provided in Chapter 8. The detailed assessment of Options 3 and 4 is provided in Chapter 9.

8 Post screening analysis

8.1 Meetings and additional information requests

The results of the screening assessment were presented to DPIE and NPWS at a meeting on 16 July 2021. Following this meeting, additional detailed information was requested in correspondence from DPIE received on 3 August 2021 (RFI 1), 13 and 17 August 2021 (RFI 2), and verbally at a meeting on 30 August 2021 (RFI 3) which are discussed in Section 1.4. The purpose of these additional information requests was to further understand the design considerations and significance of impacts associated with three of the four options that had been proposed to move forward to detailed analysis from the screening assessment (Options 5, 6 and 8) and to further consider Options 3 and 9.

Four detailed memorandums addressing the information requests were prepared by EMM, in collaboration with Snowy Hydro and TransGrid, and provided to DPIE on 6 August 2021, 20 August 2021, 10 September 2021 and 26 October 2021. The memorandum responding to RFI was first provided to DPIE on 1 October 2021 and then updated and provided again on 26 October 2021.

A summary of the information provided to DPIE and NPWS, that has not been previously detailed elsewhere in this report, is given in the following sections. Technical information contained within this section is based on a Cable Options Study prepared by WSP in 2021 for the Project on behalf of TransGrid.

8.2 Option 3 – Overhead to Upper Tumut Switching Station

8.2.1 Number of circuits

Transmission lines have two key aspects that determine the capacity of the line. The first is the thermal rating. The second is the stability limit.

The thermal rating is defined as the maximum temperature that the conductors can withstand and still achieve the required clearance to the ground. This is because as the conductors lengthen they heat up. It is also based on real-time operating conditions and based on specified time periods, such as continuous, 15 minute or 30 minute periods. This thermal rating is relatively slow to change and generally allows for 15 minute or 30 minute ratings after a network issue (eg adjacent line trip).

The stability limit is the maximum capacity of the line in which the power system is safe to operate at when subjected to a contingency event. A contingency event (such as an outage of a circuit or generator), occurs with very high speed with action (ie generator trip) generally required in the order of 100 milliseconds (ms).

Building Option 3 with only three circuits does not work due to stability limits. The actual thermal capacity of the line/s is not the limiting factor. The stability limit is estimated to be between 700 and 1,000 MW with detailed network modelling normally required to determine stability limits for configurations.

The loss of the double circuit line when pumping or generating (up to 2,000 MW) would mean that up to 1,300 MW of load or generation would be lost and is well above the estimated stability limit. This size of loss of generation or load is significant to the security of the NEM and will be larger than the existing biggest generation in the network and can lead to widespread loss of supply and load. In contrast, the configuration with four circuits would only lose about 700 MW and is within the current operating parameters of the NEM.

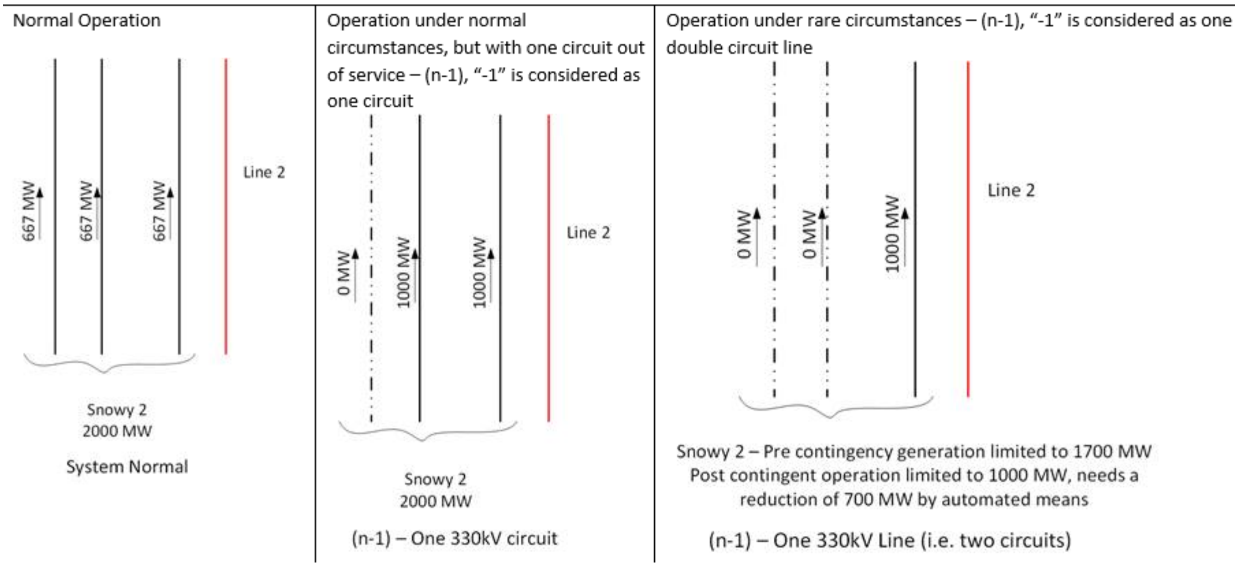


Figure 8.1a Figure 8.1b Figure 8.1c

Figure 8.1 Suggested three circuit arrangement for Option 3 (Figures 8.1a, 8.1b and 8.1c)

Additionally, the above proposal (Figure 8.1a and 8.1b) only considers the "case" for Snowy 2.0 import/export and does not consider the loss of capacity to greater NSW that would result from an outage of the Line2/S2Line 3 double circuit single tower (DCST) line. This Line 2/S2Line 3 line is shown as the far right DCST lines in Figures 8.1a, 8.1b and 8.1c. Such an outage or reclassification as per Figure 8.1c would significantly impact NSW with both existing Snowy Scheme (Snowy 1)/Vic import capacity and Snowy 2.0 capacity effectively doubling the overall impact on NEM supply reliability (~1,000 MW on existing Snowy Scheme" and ~1,000 MW on Snowy 2.0 = -2,000 MW) under a three circuit arrangement for Snowy 2.0.

The following figure (Figure 8.2) is adapted from the operation under "rare" circumstances case above (Figure 8.1c) to include the greater NSW impacts from sharing structures on steady-state dispatch (as an example).

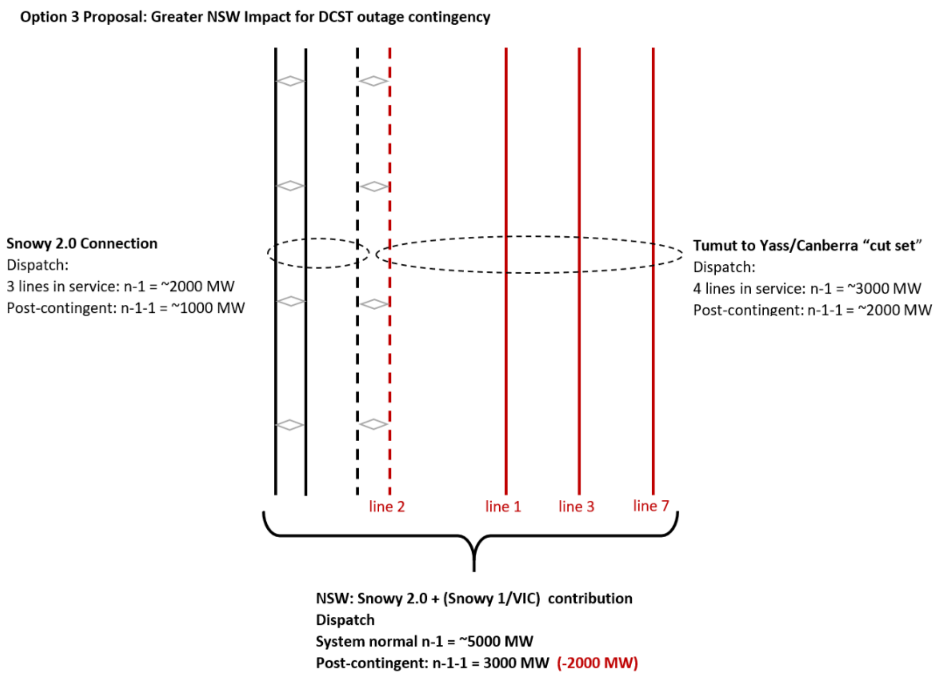


Figure 8.2 Three-circuit arrangement for Option 3 under 'rare' circumstances and NSW impacts

The Option 3 arrangement above (in any of its forms but more so for the proposal in Figure 8.1a and Figure 8.1b with circuits and sharing structures on steady state dispatch) does not provide for resilience benefits given there is no geographic separation of the Snowy 2.0 connection lines from the existing Southern NSW 330 kV lines and instead creates a more vulnerable 30 km corridor with ~2,800 MW capacity on wooded slopes, as opposed to the Option 4 alternative which has a 9 km corridor with 2,000 MW capacity (both relative to the base case existing system).

8.2.2 Construction options

i Replacement of existing line

As presented in the EIS (Jacobs 2021), TransGrid's Line 2 presents the closest connection into the existing transmission network being approximately 1.6 km west of the Snowy 2.0 cable yard**.** Line 2 runs generally north-south to the east of Talbingo Reservoir, providing a single 330 kV connection between UTSS and Yass 330 kV substation.

Connection into the existing Line 2 was investigated by TransGrid. The single circuit for the existing Line 2 is fully utilised and cannot be used or combined with the transmission of Snowy 2.0. Any arrangement or use of Line 2 easement within Option 3 will need to maintain a single circuit for Line 2 and four circuits for Snowy 2.0.

It is also not possible to progressively replace the existing Line 2 to include the transmission of Snowy 2.0 generation to UTSS because Line 2 forms part of the existing Southern NSW 330 kV network. Key issues around Line 2 are explained below:

- Line 2 connects UTSS to Yass and is one of four existing 330 kV transmission lines of the existing 'Tumut-Yass/Canberra' cutset (which are made up of Line 1, Line 2, Line 3 and Line 7) which forms an integral part of the existing Southern NSW 330 kV network.

- The “Tumut-Yass/Canberra” cutset is already a binding constraint on the network which currently limits full Snowy scheme output to NSW loads by at least 1,000 MW (as identified in the ISP and HumeLink RIT-T).
- To demolish Line 2 and repurpose the easement for Snowy 2.0 duty would reduce existing Snowy Scheme transmission access by a further ~1,000 MW (based on the n-1 capability of the ’Tumut/Yass/Canberra‘ cutset) effectively restricting NSW customer access to ~2,000 MW of existing renewable generation.

Further:

- Snowy 2.0 output (and supply) requires new supply paths which do not interact with the existing 330 kV network as the Southern NSW 330 kV network has constraint points at all cutsets on the route to Sydney (Tumut-Yass/Canberra – Lines 1, 2, 4 and 7) (Yass/Marulan – Lines 4 and 5), (Marulan-Avon/Dapto Lines 8 and 16), (Bannaby-SYDW 39). This was investigated within the Snowy 2.0 Feasibility Study (Snowy Hydro 2017) which identified these constraints within the network – refer to Figure 4.1. The Southern NSW 330 kV network is severely limiting further development of renewable energy zones in southern and south-west NSW.
- It was identified in the Snowy 2.0 Feasibility Study (Transmission – Chapter 10) that significant connection into the existing 330 kV network would require rebuild of the entire southern 330 kV network from Snowy 2.0 to Sydney.
- Rebuilding of just Line 2 requires outages for periods of time which would have unacceptable impacts on the market and costs for NSW electricity consumers and would simply move the constraint point to the Yass/Marulan cutset or the Southern Sydney/Wollongong cutsets. The construction period would be drawn out to account for stoppages over winter months due to sections in alpine areas. The length of this rebuild and additional 60 m easement required is shown in Figure 8.4.
- It is not possible to upgrade the voltage rating of an existing 330 kV line to 500 kV. The old 330 kV line must be demolished and a new line (or lines) with the increased clearances for the higher voltage built in its place. Notwithstanding, the requirement to connect Snowy 2.0 to both the 330 kV network and the 500 kV network remains. Therefore, any upgrade that changes Line 2 from a 330 kV line to 500 kV would mean the requirement to connect to both networks couldn’t be met.
- A shorter replacement of Line 2 from Lobs Hole to UTSS is not considered feasible as there would be five circuits required in the arrangement across three sets of towers hence a minimum 180 m wide easement including the existing Line 2 easement. The simplest solution in this situation would be to leave Line 2 in its current configuration and build the two sets of towers as double circuits towers adjacent to Line 2. It may be feasible to rebuild Line 2 on a tower with one Snowy 2.0 circuit however the four Snowy circuits would be spread across three sets of towers rather than two and the easement width would remain the same at 180 m. The configurations of circuits and towers for Option 3 is shown below in Figure 8.3 with Line 2 shown on the right as a single circuit tower with the proposed Snowy 2.0 towers shown as four circuits in the middle and left-hand side.

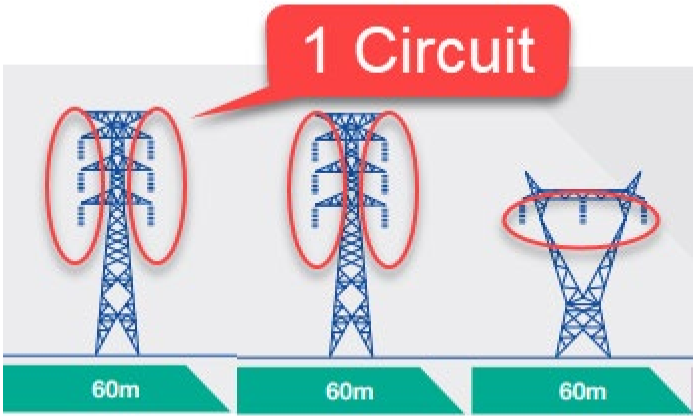


Figure 8.3 Circuits and structures for Option 3

An important additional consideration is that it is recognised that outages for Line 2 also cause substantial market impacts that have indirect costs for NSW consumers. Therefore, long-term outages are required to be minimised.

ii Alternative Maragle options closer to Upper Tumut Switching Station

Alternative locations for the Maragle substation were investigated for Option 3 where the connection length could be reduced by bringing the proposed substation closer to UTSS. However, no suitable alternative was found that met key project objectives. In summary, these alternative locations would increase the footprint, cost and risk of the option with a relatively large footprint in the KNP.

From a Snowy 2.0 perspective, changing the location of Maragle 330/500 kV substation from the current location (Line 64-Elliot Way intersection) to a nominal location (as suggested above) would increase the length of the connection assets from 9 km to approximately 30 km.

Integrating the Snowy 2.0 connection lines with Line 2 in 2 x DCST configuration would also reduce the number of Snowy 2.0 connection circuits from four (2 x DCST) to three (1.5 X DCST). The increase in circuit length and decrease in circuit numbers would increase the connection impedance and, therefore, increase generator steady state power angles, leading to reduced transient stability for the Snowy 2.0 power station. Further, the generator reactive power delivery at the connection point would also be affected and may require additional reactive power capability which could in-turn increase footprint. The increased lengths of the connection lines would also increase their exposure the extreme weather and bush-fire risk thereby compounding the reduced transient stability arising from the higher impedance connection.

Additionally contingency plans are in-place for commissioning of individual units and pairs of units with just the 330 kV Maragle connection, or with staged HumeLink commissioning. Changing the location of Maragle 330/500 kV substation will not accelerate HumeLink and may actually further delay it, having the opposite effect and exacerbating the given potential differences in delivery times. Section 4.2.2 provides further information on timing relationship between Snowy 2.0 and HumeLink.

Figure 4.3 shows an assessment of terrain where locations west of UTSS (on the western side of the gorge) for large substation development would be particularly difficult. Terrain mapping was undertaken for areas west of the UTSS to understand the engineering challenges for substation and structure construction. The areas west of UTSS are particularly challenging for structure construction adjacent to the existing Line 2 as well as substation construction.

iii Widening easement

On the basis it is not feasible to integrate the existing Line 2 into the Project, a possible technical solution would be to retain the existing Line 2 and widen the existing easement to accommodate a new set of Snowy 2.0 overhead transmission lines between the Lobs Hole and UTSS to the south. However, this easement widening also presents several challenges.

- A length of approximately 16 km where the easement is to be widened by some 120 m equating to a footprint of approximately 185 ha.
- Line 2 easement widening would occur in areas of known and recorded habitat of Smoky Mouse, listed as critically endangered under both the NSW *Biodiversity Conservation Act 2016* (BC Act) and Commonwealth *Environment Protection and Biodiversity Conservation Act 2000* (EPBC Act).
- The additional footprint for the HumeLink connection from its proposed connection point at Maragle to the UTSS, equating to approximately 133 ha.

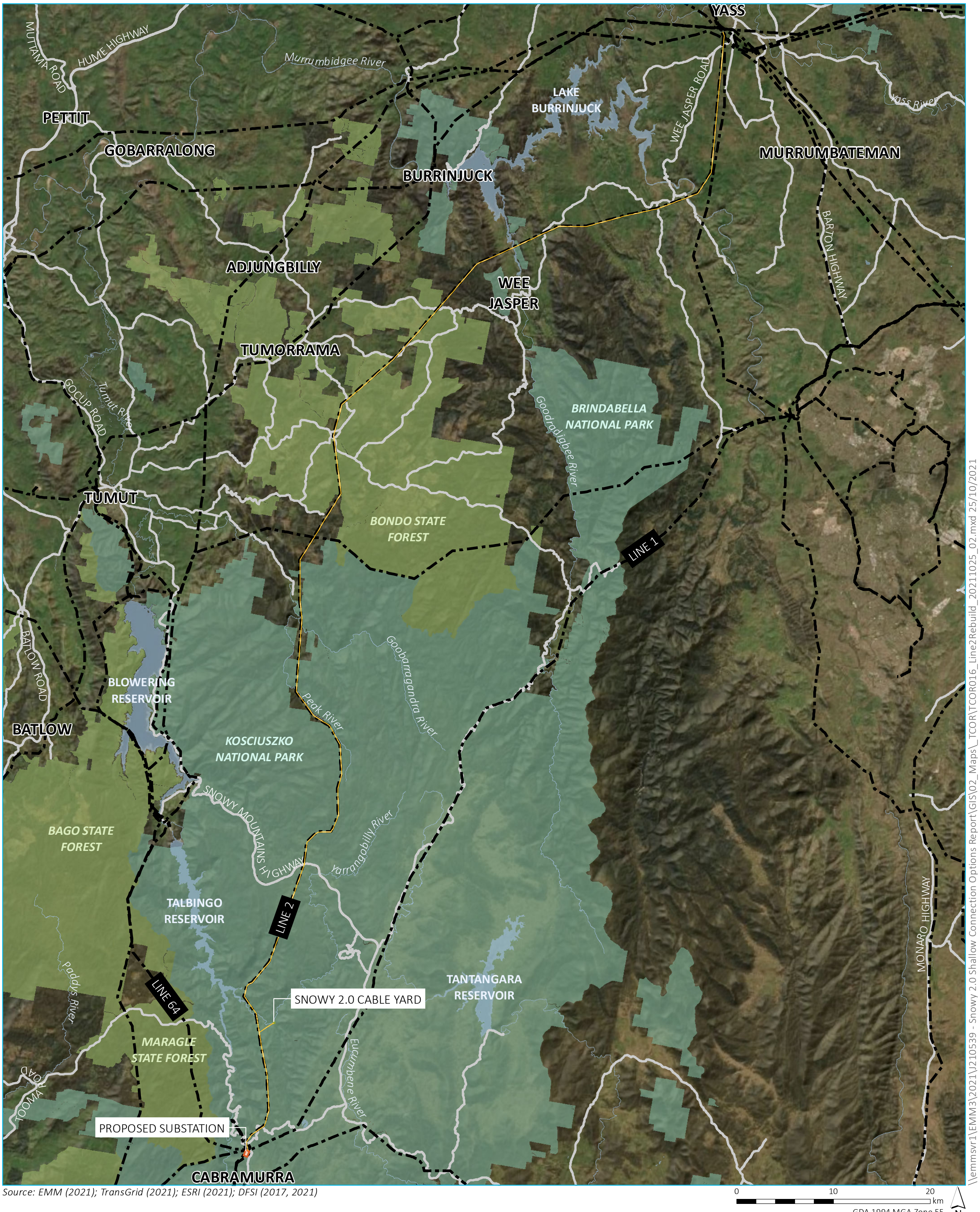
iv Other construction methods

Other construction methods were initially investigated for Option 3 (connection to UTSS), with these being:

- deep cable tunnel; and
- surface trenching.

High level investigations were carried out before concluding these methods did not meet identified project objectives so were not pursued any further as overhead transmission for Option 3 was the preferred connection method.

Key elements of these high-level investigations are described below.



Source: EMM (2021); TransGrid (2021); ESRI (2021); DFSI (2017, 2021)

KEY

- Existing electricity transmission line
- Major road
- River
- Waterbody
- NPWS reserve
- State forest
- Snowy 2.0 cable yard

Transmission connection – rebuild of Line 2

- Substation footprint
- Widening of existing easement (additional easement width of 60 m required)

Rebuild of Line 2 for Snowy 2.0 connection

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 8.4

EMM creating opportunities

a Deep cable tunnel

Two routes from Lobs Hole to UTSS were identified and initially investigated with these routes shown in Figure 8.5 below. Option A is shown in purple with Option B in blue.

Option A has an approximate total tunnel length of 13.3 km with a deep shaft at Upper Tumut of approximately 400 m required for sufficient depth of cover beneath the terrain features shown in the cross-section below (Figure 8.6). The likely construction method would be a single TBM commencing from the Lobs Hole end.

This option presented the following challenges:

- significant spoil volumes exiting the tunnel requiring disposal;
- significant timing considerations to gather and evaluate geotechnical information to understand the sub surface geological conditions to inform tunnelling specifications;
- concern regarding construction timeframes enabling timely connection to Snowy 2.0; and
- challenges in constructing necessary intermediate shafts for ventilation and emergency access.

Option B has an approximate total tunnel length of 16.5 km with 30 m shafts at either end. This is shown in the cross-section in Figure 8.7 below.

The length and route were determined through a requirement to maintain 4.5% gradient. The construction method assumed two TBMs boring from each end to meet at an approximate right angle near Three Mile Dam Campground. A cavern would need to be created at this location to allow the cables to traverse the angles in the tunnel. This may be able to be achieved through an excavation technique that allows the spoil to be brought out of the portals as the depth of cover at 375 m likely precludes dropping a shaft for cavern excavation.

This option presented the following challenges:

- significant spoil volumes exiting the tunnel at Three Mile Dam Campground requiring disposal;
- significant timing considerations to gather and evaluate geotechnical information to understand the sub surface geological conditions to inform tunnelling specifications;
- concern regarding construction timeframes enabling timely connection to Snowy 2.0; and
- challenges in constructing necessary intermediate shafts for ventilation and emergency access.

The identified challenges with tunnelling from Lobs Hole to UTSS were evaluated to not satisfy the project objectives and were not pursued any further as a reasonable construction method for connection of Snowy 2.0.

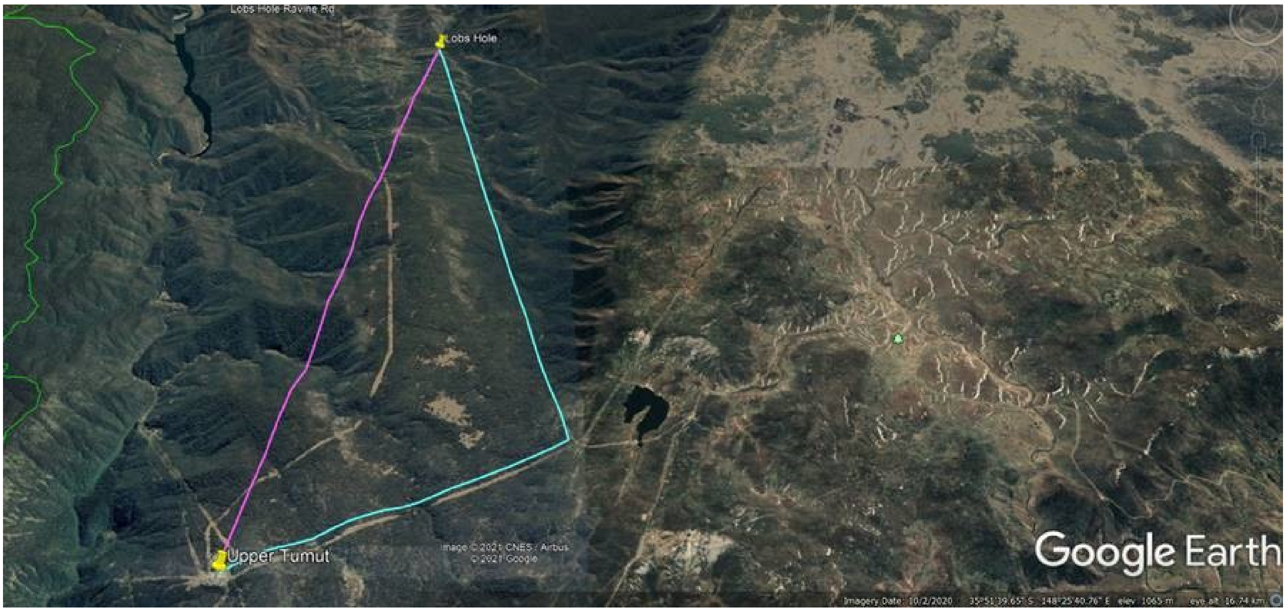


Figure 8.5 Deep cable tunnel routes from Lobs Hole to UTSS

Figure 8.6 Cross-section for Option A – deep cable tunnel to UTSS

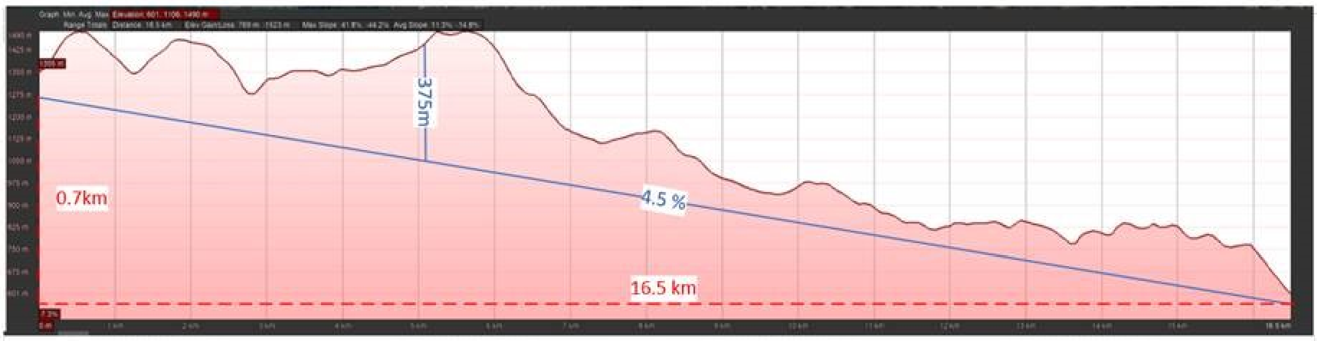


Figure 8.7 Cross-section for Option B – deep cable tunnel to UTSS

b Surface trench

A high-level review of the routes for a surface trench from Lobs Hole to UTSS concluded:

- use of existing easement of Line 2:
  - significant quantities of excavated material generated and requiring disposal;
  - areas of known and recorded habitat of Smoky Mouse, listed as critically endangered under both the BC Act and EPBC Act; and
  - due to terrain, severe technical challenges and unlikely to be possible in some areas.
- use of Lobs Hole Ravine Road:
  - areas of known and recorded habitat of Smoky Mouse, listed as critically endangered under both the BC Act and EPBC Act;
  - unacceptable disruption to the construction phase of Snowy 2.0 with use and occupation of Lobs Hole Ravine Road to establish trench and lay cable; and
  - significant quantities of excavated material generated and requiring disposal.

The identified challenges with trenching a route from Lobs Hole to UTSS were evaluated to not satisfy the project objectives and were not pursued any further as a reasonable construction method for connection of Snowy 2.0.

Additionally, for the reasons outlined for both trenching and tunnelling, a hybrid method was not pursued.

8.2.3 Clearance requirements

i Option 3 – Overhead to Upper Tumut Switching Station

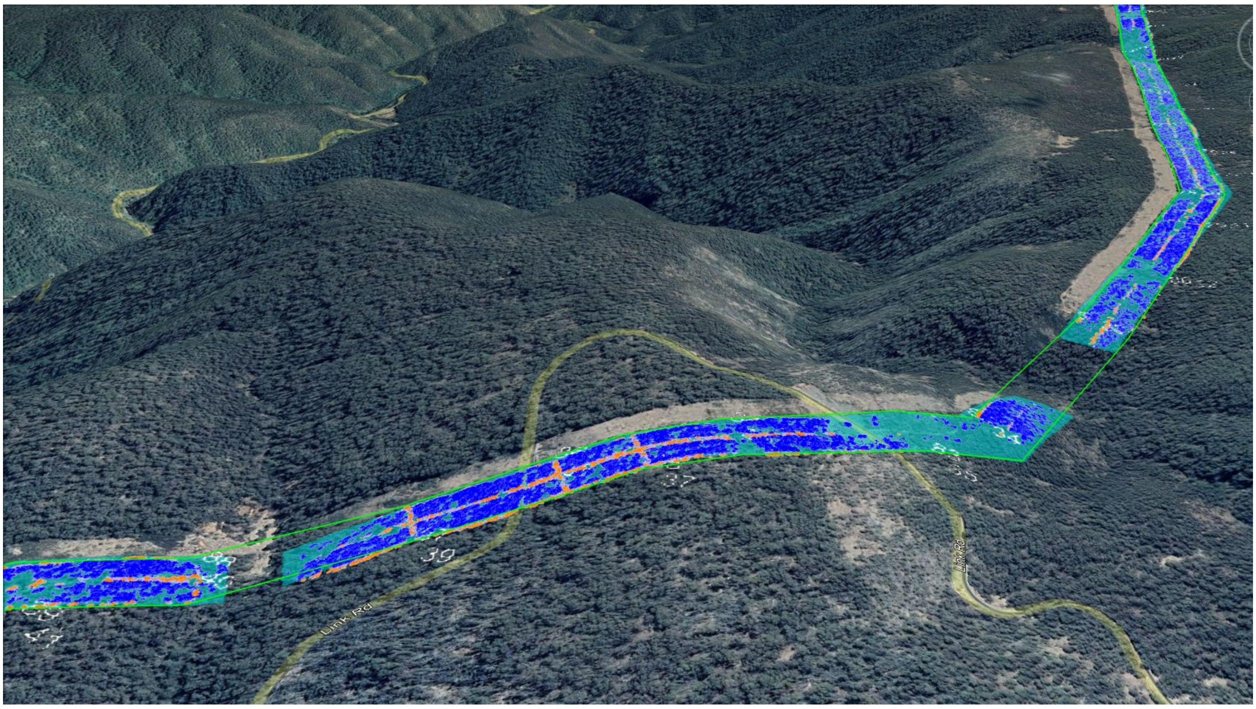
For any overhead line option for Snowy 2.0 that meets the n-1 redundancy standard, the arrangement of four circuits requires at least two new sets of double circuit towers to be built. As shown in Figure 8.3, the typical easement requirements for a double circuit 330 kV transmission tower are 60 m. For Option 3 the easement width would be a minimum 120 m for two sets of double circuit 330 kV transmission towers and up to 140 m in sections where terrain is challenging.

To determine the likely clearance requirements for Option 3, the terrain adjacent to Line 2 was examined using lidar data and web-based mapping. The terrain mapping can be seen in Figure 4.3.

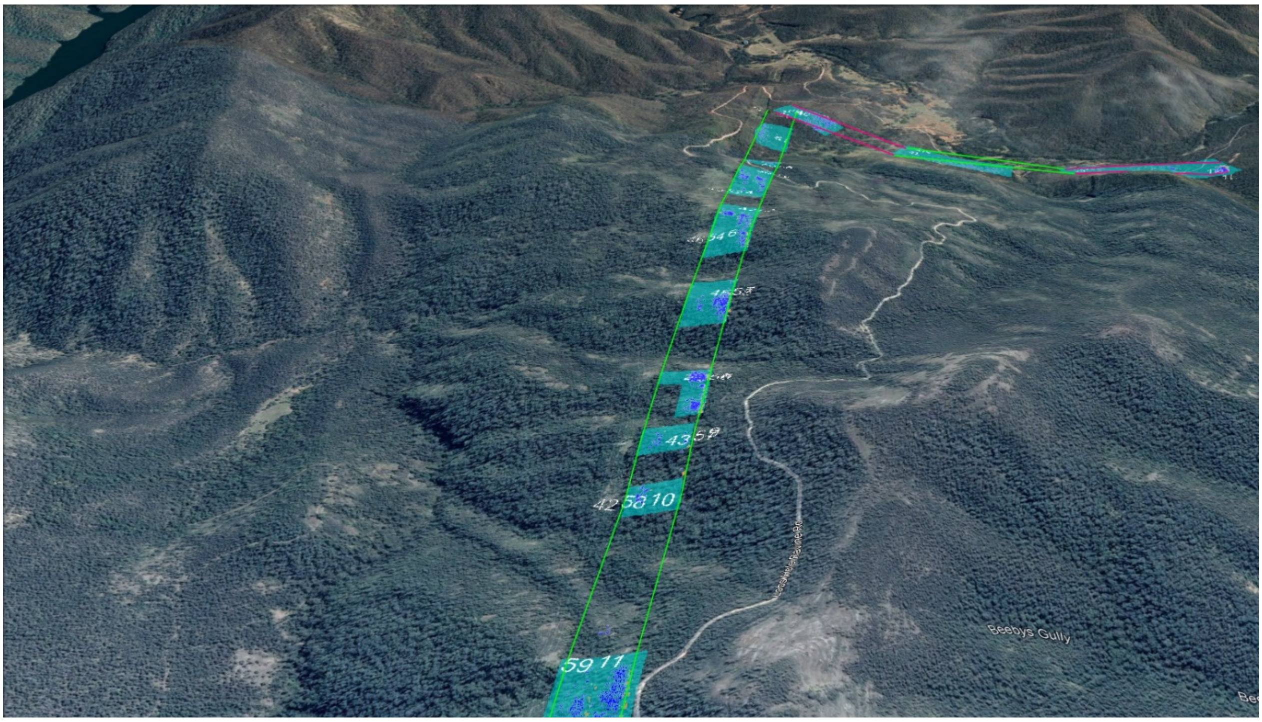
The eastern side of Line 2 provides more suitable terrain for construction. An estimated 106 towers (53 pairs) would be required along the approximately 16 km route. Transmission structures are required to be constructed on a level, cleared area. The volume of bulk earthworks required to form the level bench is dependent on the slope of the terrain at the bench location.

An example of the tower locations and clearance area estimations are provided in Photograph 8.1 and Photograph 8.2, respectively. The route for Option 3 consists of large sections of elevated flat terrain. This means that there are limited areas for lines to span across depressions in the terrain, and more clearance is required within the easement. An example of where this can be achieved is at the northern end of Option 3 as shown in Photograph 8.3.

Photograph 8.1 Tower locations for Option 3 – approximately 6 km section of the total route



Photograph 8.2 Clearance areas for Option 3 – approximately 6 km section of the total route



Photograph 8.3 Clearance areas for Option 3 – approximately 5 km section at northern end of route

ii HumeLink - Upper Tumut Switching Station to Maragle

To extend the HumeLink connection to UTSS adjacent to Line 64 in Option 3, a single set of 500 kV transmission towers is currently proposed. An easement width up to 80 m is anticipated under this scenario based on the existing easement characteristics of Line 64.

To determine the likely clearance requirements for HumeLink for Option 3, the terrain adjacent to Line 64 and its existing clearance was examined using lidar data and web-based mapping. For example, it is assumed that HumeLink will replicate existing spans of Line 64 such as the span over the Tumut River west of UTSS. In total, the anticipated clearance for HumeLink from Maragle to UTSS is approximately 133 ha, with 25 ha of this area within KNP.

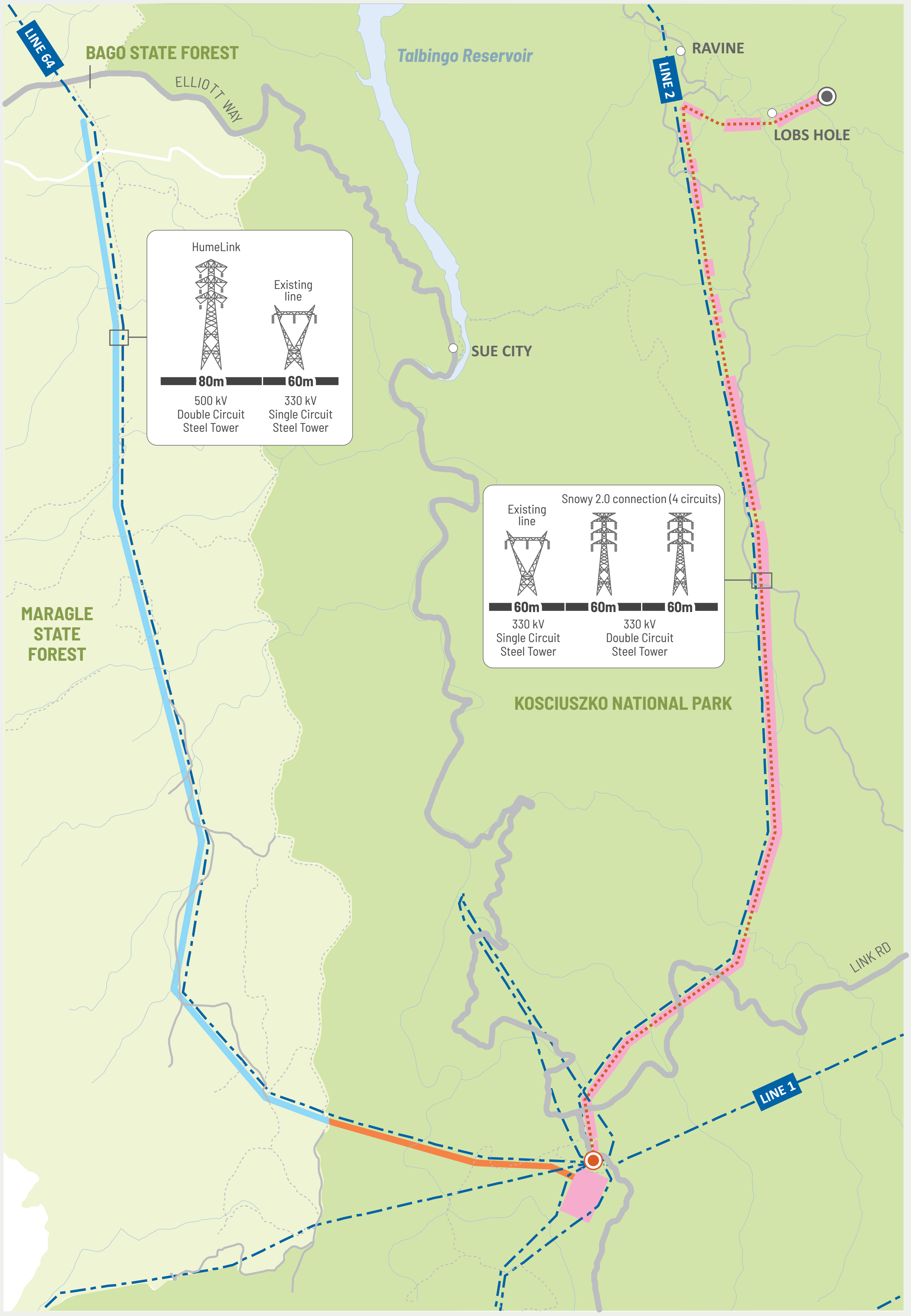
8.2.4 Potential impacts

i Vegetation clearing

Option 3 would involve the construction of approximately 16 km of overhead lines and associated easements within KNP. An expansion of the UTSS, or construction of a new substation, and the construction of HumeLink infrastructure would also be required within KNP. The Option 3 route of the overhead lines is also adjacent to existing infrastructure in KNP.

The inset within Figure 8.8 shows the existing asset density at UTSS which has 8 x 330 kV lines terminating in the yard as well as an indicative footprint required for the infrastructure required – similar to the proposed Maragle 330/500 kV substation.

Outside of KNP, Option 3 would require the construction of approximately 13.4 km of overhead lines and associated easements as a result of extending HumeLink further south than currently planned. From the edge of KNP, an additional approximately 3.2 km of overhead lines and associated easement would be required to the UTSS.



LEGEND

- Snowy 2.0 cable yard
- New substation or expansion of switching station
- Overhead twin double circuit 330 kV line to Upper Tumut Switching Station
- Existing electricity transmission line
- Widening of easement and substation footprint (within KNP)
- HumeLink – widening of existing easement (within KNP)
- HumeLink – widening of existing easement (outside KNP)

0 1 2 km

EMM creating opportunities

Figure 8.8 Op on 3 – Easement requirements

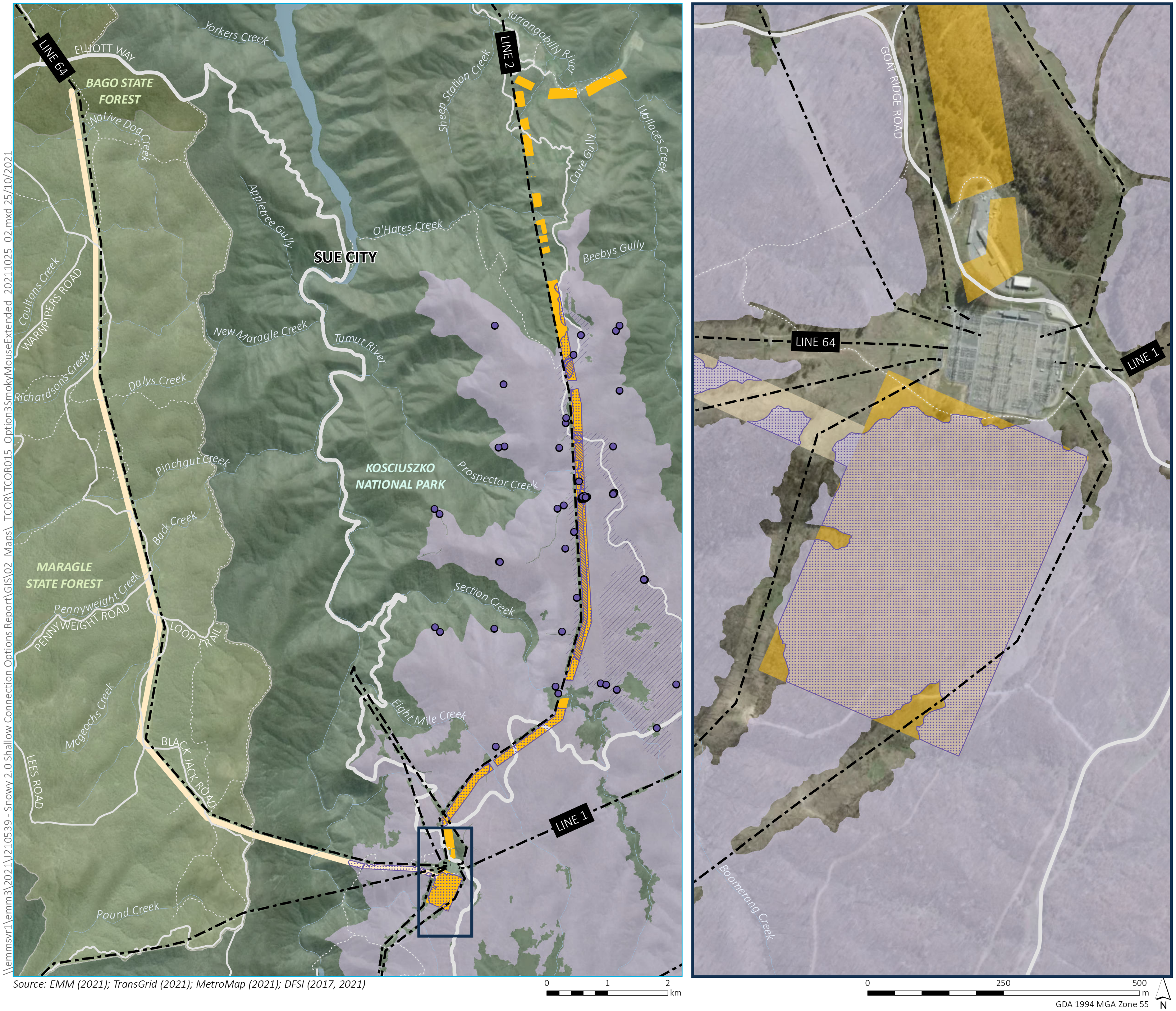
The amount of clearing required for Option 3 can be seen in Table 8.1. This shows the amount of clearing within and outside of KNP, and for the Project alone and cumulatively with HumeLink.

Table 8.1 Clearing required for Option 3

	Project alone	HumeLink	Total
Inside KNP	185 ha	25 ha	*210 ha*
Outside KNP	Nil	108 ha	*108 ha*
Total	***185 ha***	***133 ha***	***318 ha***

8.2.5 Biodiversity impacts

The majority of the footprint of Option 3 has not been surveyed, with the exception of the section of route between Lobs Hole cable yard and the existing Line 2 (which is identical for both Options 3 and 4). However, the footprint contains known areas of habitat (34.5 ha) and potential areas of habitat (107.7 ha) for Smoky Mouse (Figure 8.9). Smoky Mouse is listed as critically endangered under the BC Act and endangered under the EPBC Act. Given the large areas of potential habitat disturbance, and its critically endangered status, there is high potential for significant impacts to this species. Significance of impacts to this species, and other threated species and ecological communities, would require further survey and assessment.



Source: EMM (2021); TransGrid (2021); MetroMap (2021); DFSI (2017, 2021)

KEY

- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest

Transmission connection - Option 3

- Widening of easement and substation footprint
- Hume Link - widening of existing easement

Smoky Mouse (*Pseudomys fumeus*)

- Smoky Mouse record
- Smoky Mouse habitat
- Disturbance to Smoky Mouse habitat (34.5 ha)
- Potential Smoky Mouse habitat
- Potential additional disturbance to Smoky Mouse habitat (107.7 ha)

Option 3 – Smoky Mouse habitat and potential disturbance

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 8.9

EMM
creating opportunities

8.2.6 Visual impacts

The route proposed for Option 3 is adjacent to the existing Line 2, which is currently a single circuit transmission line with a predominantly cleared 60 m wide easement. Option 3 proposes an additional twin set of double circuit transmission lines with a minimum additional 120 m of easement required.

Photographs of the existing Line 2 at Lobs Hole are provided below.

For Option 3, the following visual elements will occur within KNP:

- Approximately 16 km of two x double circuit 330 kV transmission lines (total permanent easement width of approximately 120 to 140 m), running from the Snowy 2.0 cable yard at Lobs Hole to Line 2, and then running adjacent along Line 2 to UTSS, with an estimated 106 transmission towers (53 pairs).
- Expansion of UTSS with an additional disturbance area of approximately 22 ha.
- Approximately 3.2 km of single circuit 500 kV transmission lines (total additional permanent easement width of approximately 80 m), running from UTSS to the western edge of KNP for the future HumeLink project.

Under Option 3, all other aspects of the future HumeLink project would occur outside of KNP.

Photograph 8.4 Line 2 at Lobs Hole looking north

Photograph 8.5 Line 2 near Lobs Hole Ravine Road looking south to Upper Tumut Switching Station

Photograph 8.6 Line 2 from Goats Ridge Road

Photograph 8.7 Line 2 crossing Link Road

8.3 Option 5 – Deep cable tunnel to Line 64

8.3.1 Technical feasibility

The deep cable tunnel option is conceived as a single continuous tunnel drive from the Lobs Hole cable yard to the Maragle substation, with vertical shafts at either end. The construction method would be by TBM for excavation of the ground and for placing of precast concrete segments to form a full circular lining as the TBM is advanced. A minimum finished internal diameter of 5 m for the tunnel is estimated to be required based on preliminary modelling of the cooling requirements for the 330 kV cables, the need for physical separation between cable clusters, and the overall air flow requirements within the tunnel.

i Tunnel alignment

The principal constraints which set the tunnel alignment are as follows:

- Horizontal alignment:
  - Start and finish points as close as reasonably practicable to the start and finish points for the transmission option (Lobs Hole cable yard and Maragle 330/500 kV substation, respectively).
  - Ideally as a straight line between the start and finish points, or up to two large radius bends if needed to navigate geological features;

- Vertical alignment:

  - Topography: specifically, ensuring that a sufficient distance is achieved between the floor of the Talbingo Reservoir and the head of the tunnel. A minimum depth of four times the tunnel diameter (approximately 20 m) has been determined. As a bed level survey of Talbingo Reservoir, or a bathymetric survey of the flooded reservoir, had not been undertaken, a conservative depth of 45 m beneath the reservoir top water level has been assumed in setting the low point of the tunnel alignment.

  - Tunnel gradient: for the transmission project, the tunnel would be accessed by vehicles and personnel and, therefore, suitable gradients that meet safety requirements are required. For the approximately 3 km section of the tunnel between Talbingo Reservoir and Maragle Substation two gradient options were considered:

    - a gradient of 4.5% which is the normal industry practice for spoil handling and segment delivery trains and the typical practical limit without consideration of specialist designs such as rack and pinion rail for TBMs (resulting in a 530 m deep shaft at Maragle); and

    - a gradient of 11.5% which is the gradient that would be required from the low point beneath the reservoir to reach a 300 m deep shaft at Maragle Substation, and thus be feasible for installing vertical cables.

The long section in Figure 8.10 below shows the potential arrangement and location of vertical shafts as well as the gradients required to clear below the Talbingo Reservoir for a deep cable tunnel.

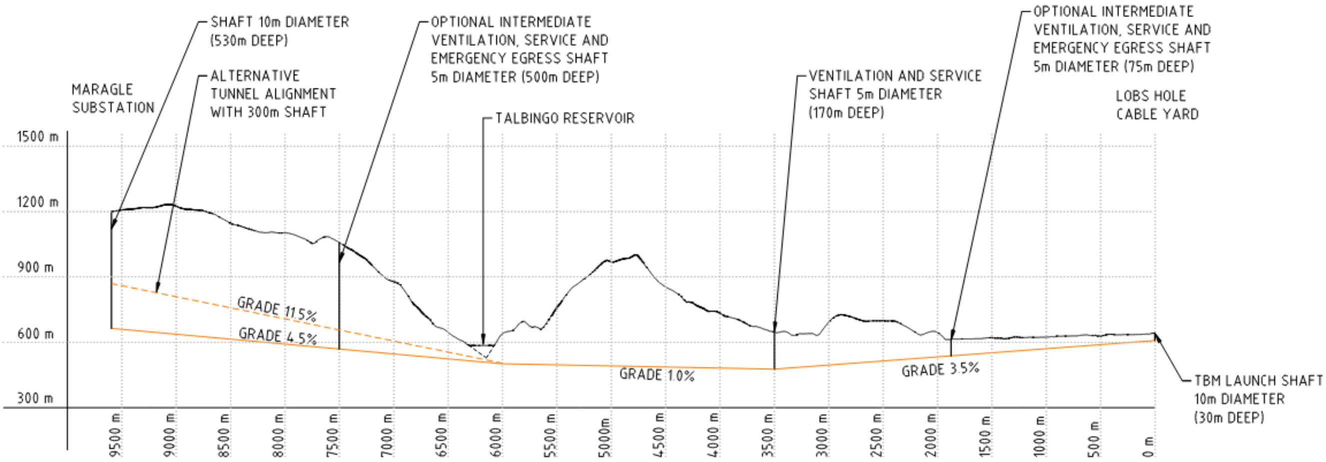


Figure 8.10 Option 5 – Deep cable tunnel long section

ii Standard tunnel gradient scenario

For the 4.5% tunnel gradient scenario, and for minimum depth of approximately 20 m rock cover beneath low points including the Talbingo Reservoir, the deep cable tunnel option is likely to require a minimum of three shafts for operational reasons:

- one shaft 30 m deep at Lobs Hole cable yard (start point);
- an intermediate shaft for permanent ventilation requirements; and
- one shaft approximately 530 m deep at Maragle Substation (end point).

These depths are tentative based on broad assumptions for known topography. Further studies could assess the benefits of constructing a 'decline tunnel' from the surface at the Lobs Hole end instead of a vertical shaft, however the overall concept and surface land take would likely be similar.

Construction of the shafts, particularly the end point shaft, would involve considerable construction effort. The start-point and end-point shafts would need to be constructed to a sufficient width to provide egress for maintenance and also accommodate the 330 kV cables. Egress options for the end point shaft are limited to a lift as a 530 m high stairwell would not be feasible. Further design work incorporating safety requirements may identify the need for additional shafts and/or alternative access at the Maragle end of the tunnel.

There are also major uncertainties with regards to the feasibility of installing HV cables in such a deep shaft. While there are known precedents for vertical cable runs of up to 280 m, these runs would be almost twice as high and proving, or disproving, the feasibility of manufacturing a cable designed for such conditions would require a cable manufacturer to undertake a preliminary design.

In addition to the operational shafts, the addition of one or more intermediate shafts would likely yield benefits for the operational phase as it would improve the efficiency of the ventilation system for cooling the cables, allow personnel entry for inspection and maintenance, and for emergency egress. Figure 8.10 above shows indicative locations for two optional shafts. As can be seen in the figure, the additional shaft to the east of the reservoir is relatively shallow but the shaft to the west of the reservoir is some 500 m high which would involve considerable construction effort and spoil disposal. Notwithstanding this, consideration would need to be given to the safety risk of an escape point with a vertical climb of approximately 500 m (see Section 4.4.2).

iii Non-standard tunnel gradient scenario

The maximum gradient for spoil handling and segment delivery trains is limited by rolling stock and safety considerations, and not the TBM itself. For gradients steeper than 4.5% the locomotives used for transporting materials inbound and spoil outbound would have to have sufficient power and breaking ability to manage the loads; beyond this limit represents a steep change in the locomotive power requirements. Alternatively, a rack and pinion rail system could be used for delivery of materials and potentially a conveyor system for spoil removal.

A gradient of approximately 11.5% would be required from the low point beneath the reservoir to reach a 300 m deep shaft at Maragle Substation, and thus be feasible for installing vertical cables. However, fit-out of such a steep tunnel over approximately 3 km and installation of large HV cables would be challenging, as would access by personnel for routine maintenance and inspection in the future.

Where a gradient above 5% is proposed, there is likely to be a need for specialist engineering studies to be undertaken in relation to smoke management in the event of fire to ensure that people will always have a feasible path to safety. For grades of 5% (and greater) it is unlikely that it will be suitable to locate dedicated (fire/smoke separated) points of egress further apart than 500 m.

8.3.2 Timing

Construction of Option 5 is estimated to take approximately 64 months, excluding lead time for TBM construction which can be a further 18 to 24 months depending on the specifications needed based on geotechnical investigations. This timeframe includes the following aspects which have been compared to Snowy 2.0 construction time where relevant:

- Geotechnical investigation required to design the TBM for the specific ground conditions of the chosen alignment. Snowy 2.0 was able to progress some of the TBM purchasing in tandem with approvals as drilling was conducted through non-CSSI, Part 5 (of the EP&A Act) approvals which are not available to the Project (see below for further detail) over a period of approximately 18 months prior to lodgement of the Scoping Report for Snowy 2.0 Main Works in June 2019.

- Duration for completing, submitting and determination of a preferred infrastructure report (PIR) which would be required if the preferred option were to change from overhead to underground (estimated as 450 days which is the average of the days that Snowy 2.0 Early Works and Main Works approvals required). The PIR would be required to assess all impacts associated with Option 5 if progressed.

- Duration for the purchase of the TBM of 24 months (including procurement, design, manufacturing, testing and transport to site) which is consistent with the time it took the first TBM on Snowy 2.0 to complete these tasks from procurement to site delivery.

- Tunnelling rate of 12 m/day is assumed which is the typical rate used on Snowy 2.0.

As stated above, Option 5 would require a substantial amount of geotechnical investigation to inform the tunnel and TBM specifications required for procurement. There is currently limited geotechnical information covering the ground through which Option 5 is proposed. A drilling program would be required to obtain this information, initially focusing on three critical target areas:

- proposed vertical access/vent shafts along the tunnel alignment;

- significant geomorphological and construction features along the tunnel alignment; and

- significant geological features along the tunnel alignment.

The above would require the drilling of a minimum 12 boreholes with a total length of between 5,800 and 7,000 m. The boreholes would require the establishment off new access tracks and a number of the boreholes would have to be drilled in areas of very steep terrain and difficult access potentially requiring a helicopter rig to access. Like the Snowy 2.0 drilling program, the potential program is subject to potential delays due to the weather or very poor ground conditions. There is also the potential that initial investigations will require additional boreholes to be drilled. The drilling program is estimated to take approximately 8 months, including analysis and interpretation of results to inform tunnel design and then specifications required for the TBM.

The overall project duration, including approvals, procurement, geotechnical investigations, design and construction is estimated to be approximately 82 months (approximately 7 years).

8.4 Option 6 – Trench to Line 64

8.4.1 Route selection

Option 6 involves the installation of cables in a surface trench from the Snowy 2.0 cable yard to the proposed Maragle substation using a cut and cover technique.

Given the undulating terrain in the project area, the main challenge to the surface trench option was identifying a route that is safe and practical to construct. A maximum average gradient of 10% was assumed as a constraint in finding a viable cable route from the Snowy 2.0 cable yard to the Maragle substation. This gradient is based on limitations of construction plant using common construction techniques.

The shortest continuous route identified follows a combination of existing access roads, fire trails, new routes and a short water crossing at Talbingo Reservoir – refer to Figure 8.11.

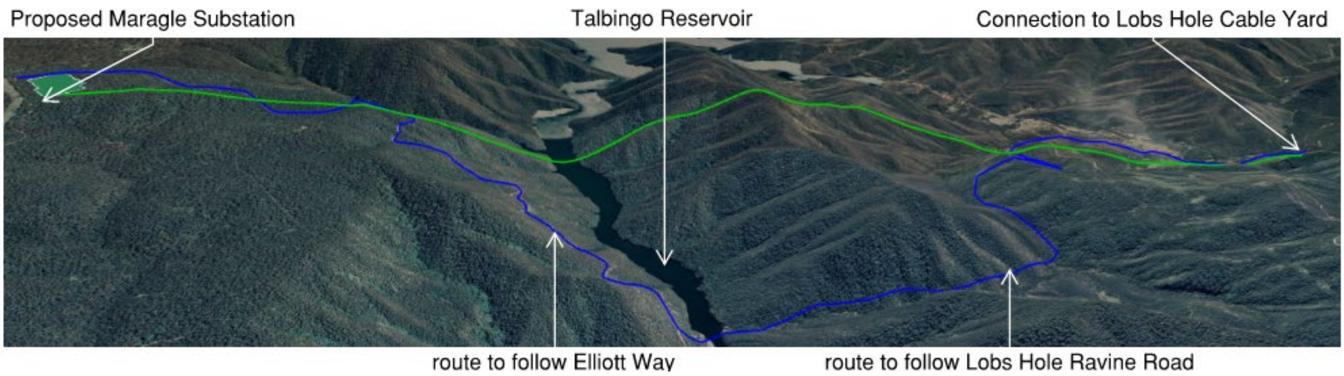


Figure 8.11 Route for surface trenched cables option

The route of the surface trench is shown in blue in Figure 8.11. The route in green is the route of the overhead transmission lines proposed for Option 4 which is currently the subject of the EIS for the Project.

The length of Option 6 is approximately 16 km and generally evenly split on the eastern and western sides of the Talbingo Reservoir.

From the Snowy 2.0 cable yard the route follows Lobs Hole Ravine Road before diverting to a new route over remnant bushland and then running parallel to O'Hares Trail to Talbingo Reservoir. West of the reservoir crossing, the cable route would join and follow Elliott Way, a paved public road, before terminating at Maragle substation.

8.4.2 Design considerations

i Trench parameters and considerations

WSP (2021) provides further details of the electrical cable study parameters and considerations.

The choice of distance between circuit groups was driven by the thermal separation requirements (based on CYMCAP modelling using assumed thermal resistivity values). Without this separation width the cables do not provide the required ratings. A road has been located across this separation width between circuits but the road could be located over the cables (refer to Figure 4.10). If the road was moved to sit across the cables the separation of the cables would remain the same and hence the overall width of the corridor is unaffected by the location of the access road within that corridor.

In addition to key elements referenced in the previous section, further key design considerations investigated to optimise the footprint of the buried cable trench included:

- ampacity ratings;
- cable type;
- installation conditions; and
- electromagnetic fields (EMF).

These are briefly described in the following sections.

a Ampacity ratings

The total power requirement is 2,550 MVA at an n-1 security of supply standard. A preliminary cable study identified that to maintain practical cable trench and tunnel sizes and ensure that the maximum conductor sizes are not exceeded due to overheating, five circuits (rated at 638 MVA each) are needed.

All ampacity ratings would have a load profile of 1 per unit (p.u) over 24 hours and have a steady state rating.

b Cable type

Typical cables used by TransGrid for projects of this nature are a 330 kV 2,500 square millimetres (mm^2) cable with a weight of 42 kilograms per metre (kg/m) and diameter of 160 mm. These cables are usually provided in drums of 1,000 m weighing 45 t.

c Installation conditions

The cable would be installed in conduits to provide flexibility in installation sequencing during the construction phase and to allow for future maintainability. The selected internal diameter of the conduits is proposed to be 214 mm which allows for the anticipated thermal expansion of the cable within the conduit and reduce pulling tensions during installation.

The current carrying capacity of the cable can be greatly affected by the environment immediately surrounding it. The greater the thermal resistivity of this environment, the harder it is for heat to dissipate away from the cable. This directly affects the power transferability of the circuit.

No thermal resistivity testing has been carried out for the trenching route (Option 6), with assumptions used to guide trench and cable design. A thermal resistivity value of 2 degrees Kelvin-meter per watt (K.m/W) at 3% moisture content has been used for the design. The construction method for the trenched cable has also assumed that the thermal resistivity value for thermally stable backfill is 1 K.m/W at 0% moisture content with fluidised needed to provide a stable thermal environment given these are HV cables.

d Electromagnetic fields

Underground cables will produce electromagnetic fields (EMF). There are no current specific limits on the level of EMF from electrical infrastructure in Australia; however, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) provides advice around exposure levels and associated time limits for working within particular EMF levels.

The design of the cable layout considers EMF mitigation with the EMF significantly reduced by arranging the cables in trefoil formation (bundle of three phases).

ii Trench design

For most of its length the surface trench option would be constructed as a linear work site, with an access road running alongside the trench. This road would be used for direct access to the trench, for removal of spoil, for construction of the trench and for installation of the cables.

It was determined that the required power transmission could not be achieved with four circuits without exceeding the cables' maximum conductor temperature or increasing trench size and thermal separation between circuits to impractical values. Therefore, a fifth circuit needed to be introduced to provide the n-1 rating capacity of 2,550 MVA. For five circuits, each circuit would need to be rated for 637.5 MVA. This equates to approximately 1,116 amps (A).

A trefoil circuit configuration was selected for the trench to minimise cost and environmental impacts from the civil excavations and ground reinstatement and rehabilitation. The trefoil arrangement allows a reduction in trench width with only a marginal increase in depth with an overall reduction of excavation quantities and construction footprint.

The proposed layout of the cable trench is shown in Figure 4.10, which has two double circuit trenches separated by a minimum distance of 5 m and a fifth circuit at the side of one of the double circuits. The fifth circuit is positioned at a minimum distance of 1,750 mm from the double circuit trench to maintain the minimum level of thermal separation. An access road is above the required separation width between the two double circuits.

An allowance of 5 m was made from the side of the outer trenches to the cleared area for construction activities and to restrict vegetation growth which would otherwise adversely impact the cable system. This area would have to remain cleared to allow for future access to the trench if required for maintenance. The road width between trenches shown in Figure 4.10 of 5 m was chosen to accommodate typical construction vehicles.

The minimum cable corridor width would be approximately 25 m in relatively flat terrain, which would increase in steeper terrain as some 20% of the route has a longitudinal gradient of greater than 10%. This is particularly the case along Elliot Way where existing deep slope cuttings for the road would need to be widened to create space for the trench requiring significant civil works. Therefore, this option would require a significant civil undertaking to prepare the alignment for cable installation.

iii Construction method

To achieve the safe and practical construction of Option 6, whilst meeting the project objectives, a geometrical gradient objective of less than 10% was established. The natural undulation in the topography of this section of KNP limited the available options for route selection. The route selected adjacent to existing access tracks and public roads is some 15 km long and approximately 80% of this length with a longitudinal slope of less than 10%.

Further details on the civil works required to construct the surface trench is provided in Section 8.4.3.

iv Joint bays

Cable joint bays would likely be needed every 1,000 m along the route. This is based on limitations on cable manufacturing and cable drum transportation restrictions. Joint bay structures would most likely comprise of large prefabricated concrete sections or modules.

The footprint of a double circuit 330 kV joint bay was assumed to be 10 m long x 5.2 m wide x 2 m deep. A further length of 13 m was added on each side of the joint bay to allow for snaking to mitigate the effects of thermo-mechanical expansion of the cables. Therefore, a total footprint of 36 m x 5.2 m is assumed for each double circuit. The width of the joint bay was reduced to 2.6 m for a single circuit arrangement.

Photograph 8.8 shows a typical cable joint bay in Australia.

Photograph 8.8 Typical joint bay being installed in Australia

v Reservoir crossing

The crossing of Talbingo Reservoir would most likely either require a cable bridge or a section of underground tunnel beneath the reservoir.

The tunnel option would require construction of a single large tunnel of approximately 5 m diameter. Shafts approximately 50 m deep would be required either side of the reservoir to allow sufficient rock cover over the reservoir for the tunnel. This option would be complicated by the need to provide a sump to pump out groundwater ingress that is likely to accumulate between routine maintenance inspections. However, this option has the advantage that it would have a relatively low visual impact, although a cleared area around each shaft would be required to allow for maintenance access.

The bridge option would need to be approximately 200 m in length to span the Talbingo Reservoir. Common types of utility bridges include steel or concrete simply supported or steel truss bridges with the cables placed on the deck or beneath a grated pedestrian walkway or trafficable surface. The advantages of a bridge would be:

- significantly lower cost compared with a tunnel;
- easier to construct and to install cables;
- provides future amenity to cross the reservoir (design could accommodate pedestrian only or include vehicles);
- allows easier and safer maintenance of cables; and
- less maintenance compared with tunnel.

However, a disadvantage of the bridge would be its visual impact and potential impact on recreational users of the reservoir.

vi Thermally stable backfill

Following the placement of the cables in the trenches, a TSB is required to be placed in the trenches. TSB is a fluidised material transported via agitator truck as required. An example of TSB being installed at a cable installation site is shown below in Photograph 8.9.

Photograph 8.9 TSB being poured over conduits

As this option relies on a considerable amount of TSB, there is likely a need for multiple batching plants to be located along the route at various intervals depending on space constraints and number of work fronts. It is expected that each batching plant would require an area of approximately 1,000 square metres (m^2). These sites could be co-located with laydown areas used for other materials and equipment.

8.4.3 Spoil

As previously discussed, to construct the corridor required to accommodate the cable trenches, excavation is required by benching into the natural slope. To understand the extent of excavation, 3D computer modelling was undertaken by WSP (2021) using the following parameters:

- 25 m wide alignment to accommodate trenches and access roads;
- Maximum gradient of 10% to accommodate large construction vehicles;
- Maximum cutting batter height of 10 m between benches of 4 m width; and
- Slope of 1 vertical (V) in 0.5 horizontal (H).

The model outputs shows that significant sections of the route require large benched cuts extending up to 100 m in height. Accordingly, the lateral extent of vegetation clearance at these locations is approximately 100 m.

Table 8.2 below sets out the modelled excavation volumes generated and the bulk volume of spoil to be removed for Option 6. It shows that over 3.5 million cubic metres (Mm^3) of spoil would need to be excavated as part of this option and 4.3 Mm^3 of spoil would need to be transported and disposed of (based on a swell factor of 1:1.35). It is noted that less than 10% of the excavated material is needed for fill on the alignment or for access areas, meaning almost all excavated material must be disposed of.

Table 8.2 Estimated spoil disposal volumes

Element	In situ excavated volume (m^3)	Assumed volume to be reused on site (m^3)	Volume of spoil to be disposed[1] (m^3)
Platform (west of reservoir) – 8 km of route	1,430,791	143,079	1,738,411
Platform (east of reservoir) – 7 km of route	1,909,478	190,948	2,320,016
Cable trenches[2]	178,500	52,500	170,100
Total	**3,518,769**	**386,527**	**4,228,527**

Notes: 1. Based on a swell factor of 1:1.35

Because of the significant volumes of material to be removed, large capacity off-road articulated haul trucks would be required. The working assumption for WSP (2021) is that the material could be dumped locally and not transported on major public roads. This would require identification of an area in which to place the spoil, which will add to the area of vegetation disturbance. If this is not possible the longer haul distances would increase the required haul truck fleet size, number of vehicle movements and program duration.

8.5 Option 8 – Hybrid trench/deep cable tunnel to Line 64

8.5.1 Overview

Option 8 is a hybrid surface trench and deep cable tunnel that connects to Line 64 as shown in Figure 8.12.

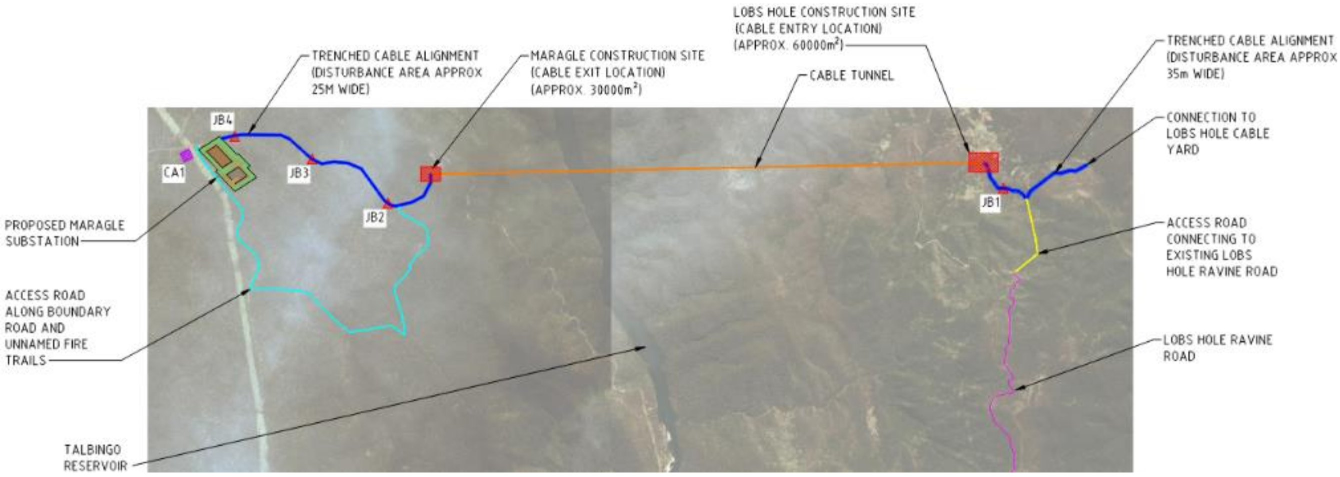


Figure 8.12 Option 8 hybrid trench/tunnel alignment

Option 8 combines elements of Options 5 (tunnel only) and 6 (trench only). The objective of developing this option is to consider whether there are benefits of only using shafts and tunnels where terrain is more difficult to traverse and using trenched construction in less challenging terrain.

Given the topography of the area between Lobs Hole and Line 64, trenching is better suited to the sections at each end, ie the initial sections from part of the Option 6 alignment. This configuration results in an approximately 1.4 km long trench from the Snowy 2.0 cable yard where the terrain is not too steep, a 5.8 km long deep cable tunnel under the steep terrain and the Talbingo Reservoir, then reverting to an approximately 3 km long trench to connect with the Maragle substation. A long section of the route is provided in Figure 8.13.

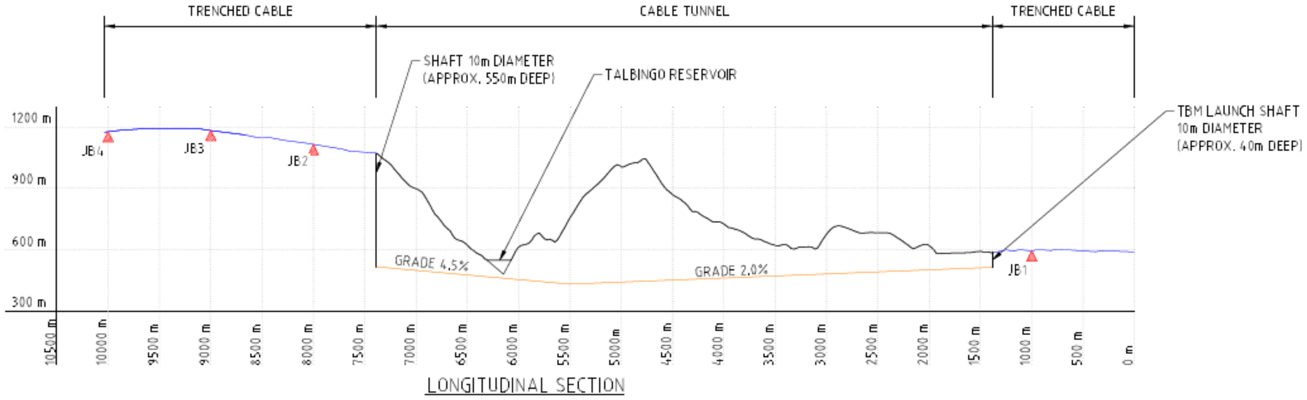


Figure 8.13 Option 8 hybrid trench/tunnel long section

The design considerations for Option 8 are very similar to the relevant sections of Options 5 and 6 described above.

There are no material design differences specifically related to the hybrid option, other than dividing up the alignment to suit the terrain advantages best suited to the hybrid techniques. Other combinations of preferential trench distances may emerge if Option 8 were to be progressed to the detailed design phase. However, it is unlikely that this would progress over Option 5 as, once tunneling equipment is established then the effort to continue tunneling for the full length (as per Option 5) would be incremental particularly if a TBM is used. Option 5 also has the benefits of less surface disturbance for a full tunnel compared to the hybrid trench/deep cable tunnel.

8.5.2 Spoil

As previously discussed, to construct the corridor required to accommodate the cable trenches, excavation is required by benching into the natural slope. To understand the extent of excavation, 3D computer modelling was undertaken by WSP (2021) using the following parameters:

- 25 m wide alignment to accommodate trenches and access roads;
- Maximum gradient of 10% to accommodate large construction vehicles; and
- Maximum cutting batter height of 10 m between benches of 4 m width.
- Slope of 1V in 0.5H.

As Option 8 proposed that a tunnel would be constructed in the sections of the route with challenging terrain, the maximum benched cuts are not as high as for Option 6. This, coupled with the smaller trench lengths, mean that the amount of spoil generated is significantly less that Option 6 with an estimated 1,750,000 m^3 of material requiring disposal.

8.6 Option 9 – Hybrid trench/submarine cable to Lower Tumu Switching Station

Option 9 involves a combination of underground terrestrial and submarine cable sections. The cable route extends from Lobs Hole cable yard and travels through the Talbingo Reservoir to the LTSS.

This option was not progressed to costing and scheduling stages of investigations due to an evaluation at the screening phase of options analysis where it did not satisfy key project objectives of being practical and feasible to design, construct and operate and balancing environmental and social impacts with safety, cost and schedule.

The trenched sections totalling approximately 9 km are relatively straight-forward to construct, which is facilitated by the existing access roads and low to moderate gradients. Substantial bulk excavation is likely to be required at the northern section to widen the existing road by at least 20 m to accommodate the cable trenches plus the extent of the cutting, whereas the southern section access road is generally in less steep terrain and requires significantly less cutting and bulk excavation by comparison.

A number of aspects make the reservoir section very complex to construct and to maintain and, therefore, feasibility has not been established. The below challenges were identified by WSP (2021):

- Logistics of transportation of large components to a remote site with steep terrain and over a large distance including barges, wharf materials and cable drums.
- Mobilisation to site of tugboats or otherwise construct boats at the site.
- Construction of large dock and wharf facility with capability to be used as a dry dock.
- Maximum size of cable drum allows relatively short lengths of cable to be used, thus a significant number of joints are required which dramatically reduces reliability because of the increased risk of failure with consequential loss of power supply.
- Reprofiling the reservoir bed across a width of 25 m for 21 km in water ranging up to 120 m deep; requires excavation and clearing of silt, clays, rock, boulders, and vegetation including submerged trees. In addition, bedding material is likely to be required to prevent sections of the cable from impinging on sharp objects, sudden changes in terrain and also to prevent the cable from spanning across old ravines, creeks, large boulders and the like. Areas of stress on the cable are likely to lead to failures. At this stage it is not considered to be feasible.
- Significant works including dredging over a long period of time would cause mobilisation of sediment into the reservoir with a high risk of adversely impacting on the flora and fauna, including threatened Murray Crayfish, and the recreational amenity of the reservoir.
- Logistics of laying multiple cables at precise separation in very deep water may not be feasible.
- Operation and maintenance of the cables is very high risk due the likelihood that divers will be required for inspection and to assist with maintenance including raising and lowering cables. Maintenance would also be expected to be slow and costly due to the planning required to identify the fault and carry out the repairs. Repairs would also be reliant on having reasonably good weather as extreme cold, wind, rain, fog or bush fire threat would potentially hamper this work.
- While a cost estimate has not been carried out, the significant issues raised would suggest Option 9 would be very high cost.

Given this, Option 9 would not be practically feasible to construct and maintain.

8.7 Option comparison

8.7.1 Summary

Table 8.3 below provides a summary table of the options as requested by DPIE as part of RFI 2 with respect to the following characteristics:

- area of vegetation clearing, including areas required for HumeLink connections which are additional to current corridor extent;
- spoil quantity;
- estimated construction cost;
- estimated construction and approvals time;
- network resilience considerations including connection to HumeLink; and
- other environmental considerations, such as visual and biodiversity impacts.

Table 8.3 Summary table

Element	Option 3 – UTSS (overhead)	Option 4 – Line 64 at Maragle (overhead)	Option 5 – Line 64 at Maragle (cable tunnel)	Option 6 – Line 64 at Maragle (trenched cable)	Option 8 – Line 64 at Maragle (hybrid trench/tunnel)	Option 9 – LTSS hybrid trench/submarine cable
Area of vegetation disturbance						
Note: vegetation disturbance areas are not based on detailed design with the exception of Option 4 with areas sourced from the Project Amendment Report (Jacobs 2021b)						
Within KNP	185 ha	74 ha (37 ha fully cleared, 37 ha partially cleared)	8 ha	77 ha	5 ha	8a
Outside KNP	Nil	44 ha (34 ha fully cleared, 10 ha partially cleared)	27 ha	33 ha	35 ha	4 ha
Max. disturbance total	***185 ha*** *(not including HumeLink disturbance)*	***118 ha*** *(71 ha fully cleared, 47 partially cleared)*	***35 ha***	***110 ha***	***40 ha***	***12 ha***
Other environmental considerations						
Note: impacts have not been subject to detailed impact assessments and are predicted based on existing area knowledge where available. Option 4 impacts are assessed as per the EIS (Jacobs 2021a)						
Visual amenity	Potential low to high impacts resulting from taller towers in new easement adjacent to existing lines. Due to connection to UTSS, any network expansions will have to come into the KNP in the future. These lines would also have additional visual impacts.	Low to high visual impacts given the new lines are not near existing electrical infrastructure and maintenance of easement.	Likely low impacts given minimal surface infrastructure.	Likely low to moderate visual impacts due to the required excavation works, particularly large cuts required within KNP (O'Hares Track) and along Elliot Way and maintenance of grassed easement. Visual impacts of reservoir bridge crossing if proposed.	Likely low to moderate visual impacts due to required excavation works and maintenance of grassed easement for trench component.	Likely low to moderate impacts permanent shipyards required to be built and barges stored for maintenance. Likely low to moderate visual impacts for trench component due to required excavation works and maintenance of grassed easement.

Table 8.3 Summary table

Element	Option 3 – UTSS (overhead)	Option 4 – Line 64 at Maragle (overhead)	Option 5 – Line 64 at Maragle (cable tunnel)	Option 6 – Line 64 at Maragle (trenched cable)	Option 8 – Line 64 at Maragle (hybrid trench/tunnel)	Option 9 – LTSS hybrid trench/submarine cable
Waste	Moderate volumes of spoil requiring disposal off site. Significant oil volumes in the park due to substation location at UTSS.	Low volumes of spoil requiring disposal off site.	Moderate volumes of spoil requiring disposal off site.	High volumes of spoil requiring disposal off site.	High volumes of spoil requiring disposal off site.	Significant volumes of spoil and excavated materials (submerged trees and dredged material) requiring disposal off site.
Biodiversity	Approximately 142 ha of Smoky Mouse (critically endangered species listed under NSW and Commonwealth legislation) habitat cleared with additional indirect impacts. This is a significant impact that is unlikely to be tolerable. Additional future network expansion impacts due to HumeLink KNP connection.	Requires clearing of native vegetation which provides habitat for threatened species though no significant impacts are predicted.	Disturbance footprint has been largely surveyed. Significant impacts to biodiversity are unlikely.	Potential biodiversity impacts (disturbance area not surveyed).	Potential biodiversity impacts (disturbance area not surveyed for trench component).	Potential biodiversity impacts (disturbance area not surveyed). Potentially significant impacts on the threatened Murray crayfish from dredging.
Heritage	Potential Aboriginal and non-Aboriginal heritage impacts (disturbance area not surveyed).	Disturbance of 3 potential archaeological deposits (PAD), four Aboriginal heritage sites, one site of local heritage significance and five items with archaeological potential. No significant impacts to heritage are predicted.	Disturbance footprint has been largely surveyed. Significant impacts to Aboriginal heritage, and non-Aboriginal heritage are unlikely.	Potential Aboriginal and non-Aboriginal heritage impacts (disturbance area not surveyed).	Potential Aboriginal and non-Aboriginal heritage impacts (disturbance area not surveyed for trench component).	Potential Aboriginal and non-Aboriginal heritage impacts (disturbance area not surveyed).

Table 8.3 Summary table

Element	Option 3 – UTSS (overhead)	Option 4 – Line 64 at Maragle (overhead)	Option 5 – Line 64 at Maragle (cable tunnel)	Option 6 – Line 64 at Maragle (trenched cable)	Option 8 – Line 64 at Maragle (hybrid trench/tunnel)	Option 9 – LTSS hybrid trench/submarine cable
Water	Erosion and sediment impacts during construction.	Erosion and sediment impacts during construction.	Potential interaction with groundwater. Groundwater information in the area is poorly understood. Unlikely to impact nearby groundwater users. Potential impacts to groundwater dependent ecosystems (GDEs). Erosion and sediment impacts during construction.	Erosion and sediment impacts during construction.	Potential interaction with groundwater for tunnel component. Groundwater information in the area is poorly understood. Unlikely to impact nearby groundwater users. Potential impacts to GDEs. Erosion and sediment impacts during construction.	Significant turbidity impacts due to dredging required. Likely downstream impacts to water users.
Transport	Temporary impacts on traffic and access during construction.	Temporary impacts on traffic and access during construction.	Temporary impacts on traffic and access during construction.	Temporary impacts on traffic and access during construction.	Temporary impacts on traffic and access during construction.	Temporary impacts on traffic and access during construction.
Spoil quantity to be disposed of off-site (Shallow connection only)	~ 500,000 cubic metres (m^3) of material.	~ 364,800 m^3 of material.	~ 770,000 m^3 of material.	~ 4,228,527 m^3 of material.	~ 1,750,000 m^3 of material.	Unable to quantify however likely to be in the range of several million m^3.
Cost (refer to Section 8.7.2 for further detail)	~ $450 M	~ $290 M	~ $1,393 M	~ $1,087 M	~ $1,304 M	Unable to quantify however likely to be >$1,000 M
Time						
• Feasibility investigation planning approvals	12 months	6 months	9 months	8 months	8 months	-
• Project planning approvals	12 months	12 months	15 months	12 months	12 months	-
• Construction and rehabilitation	30 months	24 months	64 months	50 months	54 months	-

Table 8.3 Summary table

Element	Option 3 – UTSS (overhead)	Option 4 – Line 64 at Maragle (overhead)	Option 5 – Line 64 at Maragle (cable tunnel)	Option 6 – Line 64 at Maragle (trenched cable)	Option 8 – Line 64 at Maragle (hybrid trench/tunnel)	Option 9 – LTSS hybrid trench/submarine cable
• Commissioning	3 months	3 months	3 months	4 months	4 months	-
Total	**57 months**	**45 months**	**82 months**	**74 months**	**78 months**	***N/A***
Network resilience considerations including HumeLink connection	Worsens See Note 1	Improved See Note 2	Improved See Note 2	Improved See Note 2	Improved See Note 2	Worsens See Note 1

Note:

1. Additional assets and Snowy 2.0 connection at UTSS will lower system resilience when assessed using causal events (extreme weather and/or bushfire) due to worsened spatial and temporal factors in combination with the higher concentration of assets and localised power density. Threats at UTSS include loss of significant generation input capacity (2,660 MW and disruption of critical interconnection between Victoria and NSW (VNI1). Threats with connection at LTSS are even higher with loss of extreme generation input capacity of 3,800 MW and similar disruption of critical interconnection between Victoria and NSW. See Section 6 for more detail.
2. New assets and Snowy 2.0 connection at Maragle will increase system resilience when assessed using causal threats of extreme weather and/or bushfire due to improved spatial and temporal factors in combination with overall reduced concentration of assets and localised power density (relative to the two proposed alternative connection point options). The choice of Maragle also creates a node on an alternative interconnection path to south-west NSW and Victoria relative to the existing single interconnection between Victoria and NSW (VNI1). Threats at Maragle include loss of significant generation input capacity (2,000 MW) but avoids disruption of critical interconnection between Victoria and NSW.

8.7.2 Detailed breakdown of costs

i Costing principles

The option development process investigated high level quantification of the estimated costs as it is a critical project objective to ensure that it is designed, constructed and operated in a manner that is practicable and feasible and balances environmental and social impacts with safety impacts, cost and schedule.

Given Snowy 2.0 is under construction, cost estimates used were based on current contractor rates for relevant items like tunnelling costs and advance rates. The cost estimates have also used the principles of *ACCE International Recommended Practice No 18R-97* classification system to identify the level of effort required. This system provides a range of classes on the levels of maturity appropriate to the design level, with Class 5 least mature and Class 1 most mature. For the purposes of this option development and evaluation process, Class 5 was deemed appropriate.

ii Primary costed elements

Benchmark rates used in similar projects relative to the options developed were used, including reference projects verified by Tier 1 contractors such as those relevant to Snowy 2.0. The sections below identify key items included within these reference projects and provide an appropriate for use in costing the options for the Project.

a Civil costs

Items include:

- TBM constructed tunnel with concrete segmental lining (this item has been costed using rates from the Snowy 2.0 contract);
- several access shafts of various diameters and construction methodology of comparable depth to this project;
- several construction sites including a main site for spoil removal, materials supply and segment production;
- access road upgrades of existing fire trails in steep terrain;
- new access roads through forested and steep terrain;
- bridges for construction access;
- remote location including within KNP;
- alignment crossing below a reservoir;
- trenched services route; and
- TBM production rates in hard rock.

b Cable and substation costs

Items include:

- long extra HV transmission cable project in Australia installed in a greenfield environment;
- cables installed in underground conduits in trefoil arrangements;
- use of multiple cable circuits within a single transmission corridor;
- challenging installation conditions with a number of spatial constraints, undulating topology and sections of steep terrain;
- several construction sites including multiple laydown areas, batch plants sites and access tracks along the cable;
- alignment using existing access tracks where available;
- use of multiple installation crews;
- access road upgrades of existing access tracks in steep terrain;
- equivalent cable type, voltage and conductor size; and
- supply of cable within NSW.

8.7.3 Cost breakdown

Table 8.4 below provides a summary cost breakdown of Options 3, 4, 5, 6 and 8. Costs for Option 9 are not included as it is considered not technically feasible and accurate quantification of costing was not possible.

Table 8.4 Cost breakdown summary

Element	Option 3 - UTSS (overhead)	Option 4 – Line 64 at Maragle (overhead)	Option 5 – Line 64 at Maragle (cable tunnel)	Option 6 – Line 64 at Maragle (trenched cable)	Option 8 – Line 64 at Maragle (hybrid trench/tunnel)
Civil works	$69,129,000	$38,885,000	$653,872,000	$350,439,000	$574,731,000
Cable supply and integration	$69,329,000	$38,998,000	$142,127,000	$217,758,000	$152,432,000
Ancillary civil works	-	-	$13,440,000	$24,511,000	$19,228,000
Substation associated costs	$162,650,000	$162,650,000	$178,175,000	$178,175,000	$178,175,000
Direct costs sub-total	*$301,108,000*	*$240,536,000*	*$987,614,000*	*$770,883,000*	*$924,565,000*
Indirect costs sub-total	$37,328,000	$29,818,000	$246,903,000	$192,721,000	$231,141,000
Owner's costs sub-total	$24,395,000	19,487,000	$158,018,000	$123,341,000	$147,930,000
Additional HumeLink costs	*~ $75,000,000*	*Nil*	*Nil*	*Nil*	*Nil*
Total	**~ $443,246,000**	**~ $290,000,000**	**$1,392,535,000**	**$1,086,945,000**	**$1,303,637,000**

8.7.4 Engagement outcomes

A second meeting was held on 10 August 2021 to discuss the first memorandum provided by EMM on 6 August 2021. At this meeting it was resolved that Options 5, 6 8 and 9 would not proceed to a detailed assessment as, primarily, they did not meet the evaluation criteria relating to economic factors, specifically they significantly increased the Project's economic risk. Timeframes and disturbance areas were also a key consideration.

It was resolved that options 3 and 4 would proceed to the detailed assessment stage for selection of a preferred option for the Project. This detailed assessment is presented in the following chapter.

9 Detailed assessment and preferred option

9.1 Introduction

A detailed assessment of the remaining options – Option 3 and Option 4 – was undertaken against the evaluation criteria. Each criterion was weighted equally to determine the preferred option for the Project.

9.2 Evaluation criteria – technical

9.2.1 Network and connectivity

The network and connectivity criteria have six sub-criteria:

1. Provide required capacity for Snowy 2.0 generation to be delivered into the NEM considering cumulative infrastructure needs for HumeLink.
2. Provide required connectivity to increase the resilience and reliability of electricity within the NEM.
3. Meet network planning requirements for n-1 redundancy.
4. Consistent with AEMO ISP and other Commonwealth and NSW strategic policy documents regarding the future NEM needs.
5. Minimise need for additional infrastructure within KNP to further stabilise the network due to the project.
6. Reduce pressure on existing key links.

The designs of both Option 3 and Option 4 provide the required capacity for Snowy 2.0 generation to be delivered into the NEM. However, Option 3 is dependent on additional HumeLink infrastructure being brought into KNP to connect with UTSS. Option 4 proposes to construct a new substation at Maragle, outside of KNP, and then connect to the NEM through Line 64 and HumeLink. Assuming that HumeLink infrastructure is brought into KNP to connect at UTSS, then **both options equally satisfy the network and connectivity sub-criteria (1)**.

As demonstrated in Section 4.2.3, connectivity of Snowy 2.0 generation at UTSS (Option 3) would reduce system resilience gained through the geographical diversity achieved by locating the Snowy 2.0 connection point at Maragle. This is because, having the Snowy 2.0 connection lines following the existing Line 2 route, would result in 'exposure coupling' between the existing Southern NSW 330 kV network and the Snowy 2.0 connection assets over approximately 16 km to UTSS.

Option 4 would provide reasonable separation between the new Maragle substation, UTSS, LTSS and the Southern NSW 330 kV network. This separation and would allow greater control over the power flow within the transmission grid and enables better utilisation of the 500 kV lines, which is preferred over utilising the lower capacity 330 kV transmission system. The Maragle connection option allows for the existing 330 kV transmission line running between LTSS and UTSS to be switched at the new 330/500 kV Maragle substation.

Therefore, it is considered that **Option 4 satisfies the network and connectivity sub-criteria (2) more than Option 3**.

The designs of both Option 3 and Option 4 have considered the requirement for n-1 redundancy. Both options have double circuit overhead lines so that, in the event that there was a failure on one line, generation from Snowy 2.0 would still be available to the NEM. Therefore, **both options equally satisfy the network and connectivity sub-criteria (3)**.

Option 4 is consistent with AEMO ISP and other Commonwealth and NSW strategic policy documents regarding the future NEM needs. The Snowy 2.0 connection point at Maragle has been a feature of HumeLink since the 2018 ISP when the project was determined to be an Actionable ISP project (refer to Figure 3.2). This is because, Maragle provides a reasonable separation from UTSS, LTSS and the existing Southern NSW 330 kV network. Option 3 is not consistent with the AEMO ISP as its connection point is at UTSS and does not provide reasonable separation from the existing 330 kV network. Therefore, **Option 4 satisfies the network and connectivity sub-criteria (4) more than Option 3**.

Both options would involve construction of additional infrastructure in KNP.

Option 4 would involve construction of approximately 9 km of overhead lines within KNP. Though it is noted that the route of these overhead lines is moving away from existing infrastructure in KNP. Option 4 would also involve construction of the Maragle substation outside of KNP.

Option 3 would involve construction of approximately 16 km of overhead lines within KNP. Upgrade of the UTSS, or construction of a new substation, and HumeLink infrastructure would also be required within KNP, potentially drawing additional connections into KNP in the future. The Option 3 route of the overhead lines is also adjacent to existing infrastructure in KNP. The easement requirements for Option 3 are shown in Figure 4.5.

Therefore, it is considered that **Option 4 satisfies the network and connectivity sub-criteria (5) more than Option 3**, as it would involve construction of less infrastructure, away from existing infrastructure, in KNP.

UTSS is an existing key link in the NEM. To reduce pressure on this key link, Option 3 would require expansion of UTSS and HumeLink infrastructure to connect at UTSS. Option 4 would involve construction of a new substation (Maragle) and connection with HumeLink infrastructure to reduce pressure on existing key links in the NEM. Assuming that HumeLink infrastructure is brought into KNP to connect at UTSS, and that the UTSS is expanded or a new substation is constructed at that location, then **both options equally satisfy the network and connectivity sub-criteria (6).**

In summary, a comparison of Options 3 and 4 concludes that they equally satisfy three out of the six network and connectivity criteria. **Option 4 satisfies the remaining three criteria more than Option 3.**

9.2.2 Constructability and design

The constructability and design criteria have five sub-criteria:

1. Minimise construction duration and risk.
2. Allow for suitable and efficient construction support sites close to the alignment.
3. Minimise excavations in areas of Naturally Occurring Asbestos.
4. Allow for suitable and efficient operational maintenance activities.
5. Minimise scale of project's construction requirements that may result in heavy haulage movements on local area.

Project timeframes for Options 3 and 4 are presented in Table 8.3. Both options have similar timeframes for planning approvals, and commissioning. The feasibility investigations planning approvals and construction works duration for Option 3 are both longer than Option 4 by six months due to the additional length overhead line required to be constructed.

Generation from Snowy 2.0 is expected to be available in 2025. If feasibility investigation and planning approvals for Option 3 had commenced at the time these commenced for Option 4, then the construction of Option 3 could feasibly have been completed by 2025. However, this timeframe does not provide an appropriate buffer in construction planning to allow for unseen delays and presents a significant risk to achieving connection for first power generation of Snowy 2.0. Therefore, it is considered that **Option 4 satisfies the constructability and design sub-criteria (1) more than Option 3.**

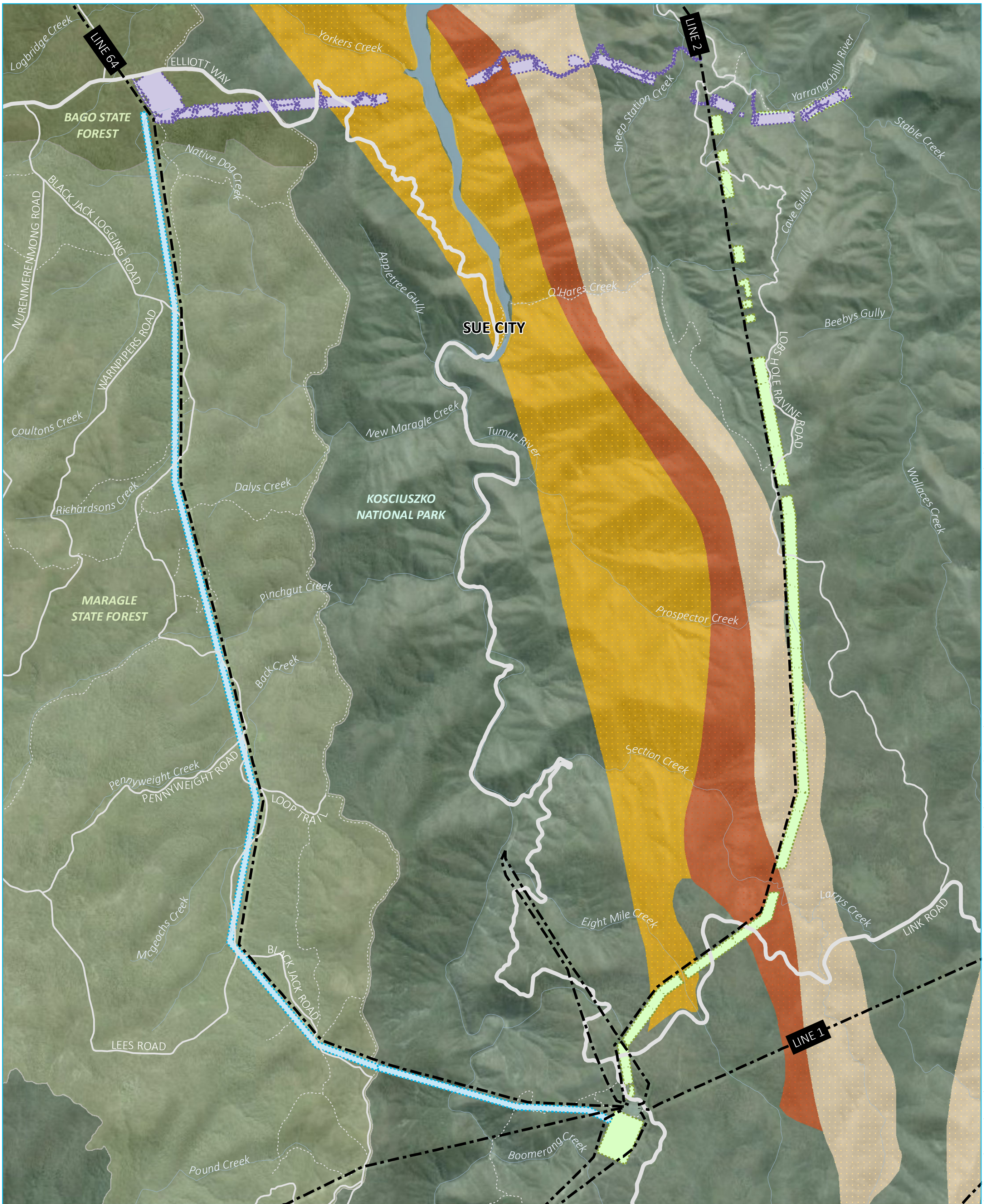
Option 4 has suitable construction support sites available at Lobs Hole and at the western extent at Line 64. Option 3 has suitable construction support sites available at Lobs Hole and at UTSS. Therefore, it is considered that **both options equally satisfy the constructability and design sub-criteria (2).**

Mapping for the region (NSW Trade & Investment, Division of Resources and Energy, 2015) indicates the there is a risk of encountering NOA around Sheep Station Ridge in geology associated with the Gilmore Fault Zone, Gooandra Volcanics and the Tumut Ponds Group. The NOA mapped areas within the disturbance footprint for Option 3 and Option 4 are shown in Figure 9.1 and detailed in Table 9.1.

Table 9.1 Naturally Occurring Asbestos mapping for Options 3 and 4

NOA potential	Area (ha) within disturbance footprint	
	Option 3	Option 4
High	9.28	5.74
Medium	9.56	12.10
Low	34.40	12.56
Total area (ha)	***53.24***	***30.40***

Marc Hendrickx and Associates Pty Ltd (2020) were engaged by TransGrid to assess the potential for NOA within the Option 4 disturbance footprint. On the basis of the assessment and observed geology of the project area the project areas mapped as having a low to high risk of NOA have been re-classed with a very low potential to contain NOA. The assessment observed the local geology and while the risk is very low, there is potential that NOA may be within the disturbance area at locations associated with the Gooandra Volcanics Tumut Ponds Group geological units, and may present a risk to human health during construction. Further assessment would be required to be carried out to verify the presence/absence of NOA within the NOA risk zones.



Source: EMM (2021); Transgrid (2021); MetroMap (2021); DFSI (2017, 2021); DRE (2015)

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KEY

Transmission connection - Option 3
- Widening of easement and substation footprint
- Hume Link - widening of existing easement

Transmission connection – Option 4
- Project footprint

Naturally occurring asbestos potential
- High
- Medium
- Low

- Existing electricity transmission line
- Major road
- Minor road
- Vehicular track
- Named watercourse
- Waterbody
- Kosciuszko National Park
- Bago State Forest
- Maragle State Forest

Naturally occurring asbestos mapping

Transgrid – Snowy 2.0
Transmission Connection Options Report
Figure 9.1

creating opportunities

Additional investigation has not been undertaken for the Option 3 disturbance footprint. However, it is reasonable to assume that a similar finding would apply and that the risk of NOA is very low within the footprint. The EIS for the Project proposed that a NOA management plan would be prepared and, should NOA be detected, the plan would be implemented to guide the handling, transport and disposal of the material. The same management measures could be applied for Option 3.

Both options minimise excavation in areas of potential NOA through the design of an overhead transmission line which has a reduced amount of excavation compared to underground transmission methods. Regardless, the estimated amount of excavated spoil for Option 3 (~500,000 m^3 of material) is more than Option 4 (~364,800 m^3 of material) due to the extra 7 km of line required to be constructed and differences in terrain between the two options.

Option 4 would impact less area within potential NOA mapped land and would extract significantly less spoil. Therefore, it is considered that **Option 4 satisfies the constructability and design sub-criteria (3) more than Option 3**.

The design of both Options 3 and 4 have included the use of existing and construction of additional access roads to allow for operational maintenance activities to occur over the length of the route. Overhead transmission lines are more susceptible to fault/damage than underground options; however, fault/damage points are quicker to identify for overhead transmission and are more cost effective to fix. Overhead transmission lines also allow for more straightforward maintenance than underground options. Therefore, it is considered that **both options equally satisfy the constructability and design sub-criteria (4)**.

Maximum daily heavy vehicle movements for Option 4 were estimated in the EIS for the Project as 75 movements for the substation construction and 75 movements for the construction of the transmission lines and access tracks. Traffic movements for Option 3 have not been estimated; however, similar daily heavy vehicle movements can be expected. As the construction of Option 3 would take an additional 6 months than Option 4, then the impacts of heavy haulage movements on the local area would occur for longer. Therefore, it is considered that **Option 4 satisfies the constructability and design sub-criteria (5) more than Option 3.**

In summary, a comparison of Options 3 and 4 concludes that they equally satisfy two out of the five constructability and design criteria. **Option 4 satisfies the remaining three criteria more than Option 3.**

9.3 Evaluation criteria – environment and planning

9.3.1 Economic factors

The economic factors criteria have five sub-criteria:

1. Maximise cost efficiency.
2. Support current and future requirements of the NEM.
3. Deliver positive economic benefits to the people of NSW.
4. Achieve connection for first power generation of Snowy 2.0.
5. Minimise project economic risk.

The relative costs for the construction of Option 3 and Option 4 are $450 M and $290 M, respectively. As both options are overhead transmission lines, the capital cost items are similar (noting Option 3 is 50% more primary due to the longer route) with primary construction costs being clearance of vegetation, creation of access tracks, construction of structures and stringing of line across steep topography.

The route length for Option 3 is longer than that proposed in Option 4 (approximately 16 km compared to 9 km), with higher fixed costs anticipated as a result. In addition, anticipated biodiversity compensatory costs should be considered in the cost efficiency evaluation of these options. As shown in Section 9.2.2, Option 3 will require clearance of known habitat for EPBC Act and BC Act critically endangered species (Smoky Mouse) which will require large biodiversity offset costs. Notwithstanding, Option 4 will also incur biodiversity offset costs through predicted impacts but these would likely be substantially less than those likely for Option 3. Therefore, **Option 4 satisfies the economic factors sub-criteria (1) more than Option 3**.

The designs of both Option 3 and Option 4 provide support for the future needs of the NEM. However, as discussed in Section 9.1, Option 3 is dependent on additional HumeLink infrastructure being brought into KNP to connect with UTSS and provides for sub-optimal network resilience outcomes given the increased concentration of power density at the connection location. Therefore, **Option 4 satisfies the economic factors sub-criteria (2) more than Option 3**.

Both options will deliver positive economic benefits to the people of NSW, with integration of n-1 redundancy requirements and two sets of double circuit lines to reduce risk of failure and availability of Snowy 2.0 energy generation. However, the connection at Maragle substation provides for less risk to network instability and greater control over the power flow within the transmission grid, thereby providing for more consistent and available positive economic benefits to NSW. Therefore, **Option 4 satisfies the economic factors sub-criteria (3) more than Option 3**.

Both options would be able to be constructed within an acceptable timeframe to achieve connection for first power generation of Snowy 2.0, based on the Project development commencement date of 2017[24]. Therefore, **both options equally satisfy the economic factors sub-criteria (4).**

As discussed in Chapter 4, overhead transmission line and structures are susceptible to fault/damage, but are more cost effective to fix than underground installations. Therefore, designs for Option 3 and 4 provide for comparatively less economic risk in times of outage. However, project economic risk requires consideration of the risk to the transmission of the full energy generation of Snowy 2.0 to the NEM.

As previously discussed, connection at UTSS for Option 3 presents a sub-optimal network resilience outcome with increased risk to reduced transmission of Snowy 2.0 energy generation. Connection at Maragle for Option 4 provides reasonable separation between the new Maragle substation, UTSS, LTSS and the Southern NSW 330 kV network. This separation and would allow greater control over the power flow within the transmission grid. Therefore, **Option 4 satisfies the economic factors sub-criteria (5) more than Option 3.**

In summary, a comparison of Options 3 and 4 concludes that they equally satisfy one out of the five network and connectivity criteria. **Option 4 satisfies the remaining four criteria more than Option 3.**

24 Assessment of connection timelines for first power generation from Snowy 2.0 was based on Project development commencement in 2017. Should an option other than Option 4 be chosen, approvals and associated assessments of achieving connection for first power generation would need to be redone.

9.3.2 Community and environment

The community and environment criteria have seven sub-criteria:

1. Minimise additional infrastructure within KNP.
2. Minimise impacts to environmentally and culturally sensitive sites.
3. Minimise long term visual impacts within KNP.
4. Maintain long term access and use of public open space and recreation areas within KNP.
5. Minimise private property impacts and acquisition requirements.
6. Minimise impacts and disruption to local community and businesses.
7. Minimise generation of spoil.

Both options would involve construction of additional infrastructure in KNP. Option 4 would involve construction of approximately 9 km of overhead lines within KNP, with disturbance of approximately 74 ha of vegetation within KNP. Option 3 would involve construction of approximately 16 km of overhead lines within KNP, with disturbance of approximately 185 ha of vegetation. Option 3 would also require the upgrade of the UTSS, or construction of a new substation, and HumeLink infrastructure within KNP. Therefore, it is considered that **Option 4 satisfies the environment and community sub-criteria (1) more than Option 3**.

The footprint of Option 4 has been surveyed for environmentally and cultural sensitivity sites as part of the preparation of the EIS for the Project. Option 4 will require disturbance of approximately 118 ha of native vegetation which contains habitat for State and Commonwealth listed threatened species (endangered and vulnerable). These impacts have been assessed for the EIS which determined that the clearance would not have significant impacts on these species.

Cultural heritage surveys (Aboriginal and non-Aboriginal) were also undertaken as part of the preparation of the EIS. Option 4 would result in the disturbance of three potential archaeological deposits (PADs) and one Aboriginal site which were assessed to have low to moderate significance. No non-Aboriginal heritage items were identified within the disturbance footprint, in addition to those already recorded and assessed as part of Snowy 2.0.

The majority of the footprint of Option 3 has not been surveyed, with the exception of the section of route between Lobs Hole cable yard and the existing Line 2 (which is identical for both Options 3 and 4). However, the footprint contains known areas of habitat (34.5 ha) and potential areas of habitat (107.7 ha) for Smoky Mouse which are not within the Option 4 footprint. Smoky Mouse is listed as critically endangered under the BC Act and endangered under the EPBC Act. Given the large areas of potential habitat disturbance, and its critically endangered status, there is high potential for significant impacts to this species. Significance of impacts to this species, and other threated species and ecological communities, would require further survey and assessment.

In summary, Option 3 will have a much higher impact on biodiversity than Option 4. Option 3 will result in a 270% increase in clearing of native vegetation (inclusive of HumeLink) and will include clearing of an estimate 142 ha of habitat for the critically endangered Smoky Mouse (compared to zero clearing for the preferred option – refer to Table 9.2).

Option 3 is likely to impact on a similar suite of threatened species as Option 4, including *Caladenia montana*, Gang-gang Cockatoo, Eastern Pygmy-possum, Yellow-bellied Glider endangered population on the Bago Plateau and Masked Owl, but with a predicted higher level of impacts.

Table 9.2 Estimated biodiversity impacts from clearance for Option 3

	Option 4	Option 3
Native vegetation	118 ha	318 ha
Smoky Mouse habitat	0	142 ha

Overall, the biodiversity impacts of Option 3 are much higher than Option 4 and include impacts to critically endangered Smoky Mouse which do not arise from Option 4.

Option 3 would also result in the disturbance of two of the three PADS and the one Aboriginal site that would be disturbed under Option 4, as they occur within the section of route between Lobs Hole cable yard and the existing Line 2. There is also potential for further Aboriginal sites to be located within the remainder of the disturbance footprint. Sites of non-Aboriginal heritage may also be present.

Of the two options, Option 3 has the greater potential for significant impacts to environmentally sensitive sites. The two options likely have an equal potential for significant impacts to culturally sensitive sites, although the footprint for Option 3 has not been fully surveyed. Therefore, it is considered that **Option 4 satisfies the environment and community sub-criteria (2) more than Option 3.**

Visual impacts of Option 4 were assessed in the EIS. The addition of 9 km of overhead transmission line and associated easements and access tracks would result in low to high levels of long-term visual amenity impacts, the majority of which are within KNP. This will result in visual impacts at publicly accessible locations such as Talbingo Reservoir, Elliott Way and Lobs Hole.

For Option 4, the following visual elements will occur within KNP:

- approximately 8 km of two x double circuit 330 kV transmission lines (total permanent easement width of approximately 120 to 140 m), running from the Snowy 2.0 cable yard at Lobs Hole to the edge of KNP at Bago State Forest; and
- approximately 7.5 km of new access track outside of the transmission line easement.

For Option 4, the following visual elements will occur outside of KNP:

- approximately 1 km each for two x double circuit 330 kV transmission lines, running parallel (total permanent easement width of approximately 120 to 140 m) within Bago State Forest;
- a new 330/500 kV substation located at the Line 64 cut-in occupying a footprint of approximately 600 x 300 m; and
- all aspects of the 500 kV transmission lines for the future HumeLink project.

The transmission line will be suspended by approximately 42 steel lattice towers (21 pairs) approximately every 400–500 m along the route. The towers will be approximately 75 m high.

The base of each tower will require a cleared work site of approximately 40 x 60 m, as well as an access track to facilitate construction and ongoing maintenance. Where the transmission line structures of the two x double-circuit 330 kV lines are located directly side-by-side, the 40 x 60 m cleared areas around the structure sites would overlap. The majority of the access tracks will be contained within the disturbed easement area with approximately 7.5 km of new access track constructed outside of the easement corridor.

For Option 3, the following visual elements will occur within KNP:

- approximately 16 km of two x double circuit 330kV transmission lines (total permanent easement width of approximately 120 to 140 m), running from the Snowy 2.0 cable yard at Lobs Hole to Line 2, and then running adjacent along Line 2 to UTSS;
- expansion of UTSS with an additional disturbance area of 22 ha; and
- approximately 13.4 km of 500 kV lines transmission lines for the future HumeLink project.

Under Option 3, all other aspects of the future HumeLink project would occur outside of KNP.

Figure 9.2 provides an indicative visualisation of Option 3 from Lobs Hole Ravine Road looking west towards the existing Line 2 infrastructure with the additional 120 m easement for Option 3.

Figure 9.3 and Figure 9.4 provide indicative visualisations for Option 3 (painted green structures) and Option 4 (no mitigation) from a vantage point at Lobs Hole, a prominent recreational area in the vicinity of the Project. The existing electricity infrastructure of Line 2 is visible with the proposed additional infrastructure for the Project also shown.

Whilst no visual assessment of Option 3 has been undertaken, visual impacts of this option are expected to be greater than Option 4 for the following reasons:

- the Option 4 route runs through rough low-lying terrain whilst Option 3 route runs along elevated terrain;
- tall vegetation would provide visual screening of Option 4 from surrounding vantage points such as the Wallaces Creek Lookout whilst Option 3 is on a similar elevation only 1.5 km to the west, and may potentially be visible above the tree line;
- Option 3 would be adjacent to the existing line 2 easement and so would have a greater total easement width that would be more visually dominant than the easement for Option 4;
- the structures required for the two sets of double circuits are taller than the existing single circuit Line 2 structures and would create additional visual impacts;
- Line 2 is currently visible from public vantage points including Lick Hole Gully and on Lobs Hole Ravine Road (see Photograph 8.4, Photograph 8.5 and Figure 9.2);
- under Option 3 the expansion to UTSS would be within KNP whereas under Option 4 the Maragle substation would be outside of KNP; and
- Option 3 requires additional 500 kV transmission lines to enter KNP and connect to UTSS.

It is considered that **Option 4 satisfies the environment and community sub-criteria (3) more than Option 3**.

Both options would impact access and use of public open space and recreation areas within KNP during construction. However, these impacts would not be long term and once operational, the transmission lines would have no impacts. Therefore, **both options equally satisfy the environment and community sub-criteria (4).**

Both Option 3 and Option 4 are entirely within State Forest or KNP with no impacts to private property or need for acquisition. Therefore, **both options equally satisfy the environment and community sub-criteria (5).**

Neither Option 3 nor Option 4 would impact on private land. Heavy vehicle movements during construction may potentially have transport and access impacts to the local community and businesses. This impact would be greater for Option 3 as the construction period would be longer by approximately 6 months. Therefore, it is considered that **Option 4 satisfies the environment and community sub-criteria (6) more than Option 3.**

The estimated amount of excavated spoil for Option 3 (~500,000 m^3 of material) is more than Option 4 (~364,800 m^3 of material) due to the extra 7 km of line required to be constructed and differences in terrain between the two options. Therefore, it is considered that **Option 4 satisfies the environment and community sub-criteria (7) more than Option 3.**

In summary, a comparison of Options 3 and 4 concludes that they equally satisfy two out of the seven constructability and design criteria. **Option 4 satisfies the remaining five criteria more than Option 3.**

Figure 9.2 Lobs Hole Ravine Road (VP7 from EIS) - looking west to south

Figure 9.3 Lobs Hole (V12 from EIS) – looking east to south

Figure 9.4 Lobs Hole (VP12 from EIS) – looking south to west

9.4 Evaluation criteria – safety

9.4.1 Best practice safety requirements

Both Option 3 and 4 are likely to have very similar safety requirements during construction and operation.

Key hazards during construction and operation would include:

- falling from height causing serious injury/death;
- electrocution during operational maintenance of the transmission connection and substation; and
- vegetation clearing (mechanical and manual) resulting in personnel being struck by falling timber.

Such risks that could cause significant harm or death to construction staff or operational maintenance personnel could be controlled to a level that is ALARP through the application of the hierarchy of controls. These requirements are considered manageable and can achieve best practice safety requirements. Therefore, **both options equally satisfy safety sub-criteria (1)**.

9.5 Preferred option

Table 9.3 below summarises the outcomes of the comparative analysis for Option 3 and 4 for the Project. The analysis demonstrates that Option 4, overhead transmission connection to the Maragle substation, is the preferred option. This option is the same as that proposed in the EIS for the Project.

Table 9.3 Outcomes of comparative analysis for Option 3 and 4[1]

Evaluation criteria	Option 3	Option 4
Technical – network and connectivity		
Provide required capacity for Snowy 2.0 generation delivery into the NEM considering HumeLink cumulative infrastructure needs	✓	✓
Provide required connectivity to increase resilience and reliability of electricity within the NEM		✓
Meet network planning requirements for n-1 redundancy	✓	✓
Consistent with ISP and other Commonwealth and NSW strategic policy documents regarding NEM future needs		✓
Minimise need for additional infrastructure within KNP to further stabilise the network due to the project		✓
Reduce pressure on existing key links	✓	✓
Technical – constructability and design		
Minimise construction duration and risk		✓
Allow for suitable and efficient construction support sites close to alignment	✓	✓
Minimise excavation in areas of naturally occurring asbestos		✓

Table 9.3 Outcomes of comparative analysis for Option 3 and 4[1]

Evaluation criteria	Option 3	Option 4
Allow for suitable and efficient operational maintenance activities	✓	✓
Minimise scale of project's construction requirements that may result in heavy haulage movements on local area		✓
Environment and planning – economic factors		
Maximise cost efficiency		✓
Support current and future requirements of the NEM		✓
Deliver positive economic benefits to the people of NSW		✓
Achieve connection for first power generation of Snowy 2.0	✓	✓
Minimise project economic risk		✓
Environment and planning – community and environment		
Minimise additional infrastructure within KNP		✓
Minimise impacts to environmentally and culturally sensitive sites		✓
Minimise long term visual impacts within KNP		✓
Maintain long term access and use of public open space and recreation areas within KNP	✓	✓
Minimise private property impacts and acquisition requirements	✓	✓
Minimise impacts and disruption to local community and businesses		✓
Minimise generation of spoil		✓
Safety		
Best practice safety requirements	✓	✓

1. Where both options equally satisfy sub-criteria, a tick is provided for both. Where one option satisfies sub-criteria more than the other option, only one tick is shown.

10 Conclusion

This report was prepared in response to submissions received on the EIS for the Project (Jacobs 2021) that raised concerns regarding the lack of analysis demonstrating alternative solutions were developed and considered prior to the selection of the preferred option for the Project. TransGrid, through engagement with Snowy Hydro, derived 12 options for the Project to be assessed in the options report.

The method of option analysis undertaken for the Project included several steps:

- identification of the Project's objectives;
- development of Project evaluation criteria within the categories of technical, environment and planning, and safety;
- option development based on key considerations that include a range of connection points to the transmission network and methods of transmission;
- undertake a screening assessment of options against Project objectives and evaluation criteria;
- undertake a more detailed post-screening assessment of a number of options; and
- selection and assessment of preferred option.

As a result of the screening assessment, the four options recommended to be considered further as part of detailed assessments included:

- Option 4 – Overhead to Line 64 (the base case);
- Option 5 – Deep cable tunnel to Line 64;
- Option 6 – Trench to Line 64; and
- Option 8 – Hybrid trench/deep cable tunnel to Line 64.

During engagement with DPIE and NPWS post the screening assessment, DPIE also requested that Options 3 and 9 be considered further.

After consultation with DPIE and NPWS, it was resolved that Options 5, 6, 8 and 9 would not proceed to a detailed assessment as, primarily, they did not meet the evaluation criteria relating to economic factors, specifically they significantly increased the Project's economic risk. Timeframes and disturbance areas were also a key consideration. It was resolved that Options 3 and 4 would proceed to the detailed assessment stage for selection of a preferred option for the Project.

Detailed comparison of Options 3 and 4 against the evaluation criteria determined that Option 4 is the preferred option for the Project as it:

- provides more support for the current and future requirements of the NEM as it:
  - would increase resilience and reliability within the NEM;

- is more consistent with the ISP and other strategic policy documents regarding future NEM needs; and
- has a shorter construction duration resulting in reduced risks to connecting Snowy 2.0 to the NEM;

- has less infrastructure overall and within KNP that would involve:
  - less excavation in areas of NOA;
  - less impacts to environmentally sensitive sites, particularly Smoky Mouse habitat;
  - less long term visual impacts within KNP; and
  - requires significantly less excavated spoil to be disposed
- would have less construction requirements and associated heavy vehicle movements that would impact the local community and businesses; and
- would be more cost efficient, thereby delivering positive economic benefits to the people of NSW and reducing project economic risk.

References

Jacobs 2021a, *Environmental Impact Statement – Snowy 2.0 Transmission Connection Project*, prepared for TransGrid

Jacobs 2021b, *Amendment Report – Snowy 2.0 Transmission Connection Project*, prepared for TransGrid

WSP Australia Pty Ltd (WSP) 2021, *Snowy 2.0 Transmission Connection Project – Cable Options Study*, prepared for TransGrid

GHD Group Pty Ltd (GHD) 2021, *Snowy 2.0 Connection Option – Review of Power System Risks*, prepared for TransGrid

Abbreviations

Amp	A
Australian Capital Territory	ACT
Australian Energy Market Operator	AEMO
Australian Radiation Protection and Nuclear Safety Agency	ARPANSA
Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*	EPBC Act
Critical State Significant Infrastructure	CSSI
cubic metres	m^3
environmental impact statement	EIS
electromagnetic fields	EMF
EMM Consulting Pty Limited	EMM
GHD Group Pty Ltd	GHD
groundwater dependent ecosystems	GDE
hectare	ha
high voltage	HV
horizontal	H
horizontal directional drilling	HDD
Integrated System Plan	ISP
Jacobs Group (Australia) Pty Ltd	Jacobs
Kelvin-meter per watt	K.m/W
kilograms per metre	kg/m
kilometre	km
kilovolt	kV
Kosciuszko National Park	KNP
Kosciusko National Park Plan of Management	KNP PoM

Lower Tumut Switching Station	LTSS
megawatt	MW
metre	m
metres per day	m/day
mineral-insulated metal sheath	MIMS
millimetre	mm
million	M
million cubic metres	Mm^3
million volt amp	MVA
National Electricity Market	NEM
National Parks Association	NPA
naturally occurring asbestos	NOA
New South Wales	NSW
NSW Electricity Operations Trust	TransGrid
NSW Department of Planning, Industry and Environment	DPIE
NSW National Parks and Wildlife Service	NPWS
NSW *Biodiversity Conservation Act 2016*	BC Act
NSW *Environmental Planning and Assessment Act 1979*	EP&A Act
per unit	p.u
percentage	%
potential archaeological deposit	PAD
Preferred infrastructure report	PIR
Project Assessment Conclusions Report	PACR
Renewable Energy Zone	REZ
requests for information	RFI
regulatory investment test – transmission	RIT-T

Snowy Hydro	Snowy Hydro Ltd
Snowy Mountains Hydro-electric Scheme	Snowy Scheme
so far as is reasonably practicable	SFAIRP
square metres	m^2
square millimetres	mm^2
State Significant Infrastructure	SSI
thermally stable backfill	TSB
tonne	t
tunnel boring machine	TBM
Upper Tumut Switching Station	UTSS
vertical	V
Victoria to NSW Interconnector	VNI
WSP Australia Pty Ltd	WSP

Appendix A

Options evaluation

Table 1 – Summary of options

	OPTION 1 Overhead to Line 2	OPTION 2 Overhead to Line 1	OPTION 3 Overhead to Upper Tumut Switching Station	OPTION 4 Overhead to Line 64	OPTION 5 Tunnel to Line 64	OPTION 6 Trenched to Line 64	OPTION 7 Horizontal Directional Drill to Line 64	OPTION 8 Hybrid trench and tunnel to Line 64	OPTION 9 Hybrid trench and submarine cable to Lower Tumut Switching Station	OPTION 10a + 10b Trenched to Lower Tumut Switching Station	OPTION 11 Overheard to Lower Tumut Switching Station	OPTION 12 Tunnel to Lower Tumut Switching Station
Start point	Snowy 2.0 cable yard											
Connection point	Line 2	Line 1	Upper Tumut Switching Station	Line 64	Line 64	Line 64	Line 64	Line 64	Lower Tumut Switching Station	Lower Tumut Switching Station	Lower Tumut Switching Station	Lower Tumut Switching Station
Line capacity	330 kV											
No. of circuits	Twin double	Twin double	Twin double	Twin double	5	5	5	5	5	5	Twin double	5
Method	Overhead	Overhead	Overhead	Overhead	Tunnel	Trench	Horizontal Directional Drill	Trench and tunnel	Trench and submarine cable	Trench	Overhead	Tunnel
Line length (approximate)	1.9 km	8 km	16 km	9 km	9 km	15.4 km	9 km	9.8 km	30 km	44 km	23.5 km	23.5 km
Substation location	In KNP at Lobs Hole/Ravine	In KNP near Snowy Mountains Highway	In KNP at Upper Tumut Switching Station	In Bago State Forest	In Bago State Forest	In Bago State Forest	In Bago State Forest	In Bago State Forest	In Talbingo township at Lower Tumut Switching Station	In Talbingo township at Lower Tumut Switching Station	In Talbingo township at Lower Tumut Switching Station	In Talbingo township at Lower Tumut Switching Station
WSP reference (2021)	No	No	No	Baseline	Option 3 'deep cable tunnel' ($857 M)	Option 2 'surface trenched cables' ($673 M)	No	Option 4 'hybrid surface trench and deep cable tunnel' ($793 M)	No	No	No	No
GHD reference (2021)	No	No	No	No	No	No	No	No	Option 4 or preferred option used	Option 4 or preferred option used	Option 4 or preferred option used	Option 4 or preferred option used

Notes

Options 1, 2, 3 could be overhead or tunnel. For the evaluation, we have assumed it will be overhead.

Table 2 – Evaluation matrix

Green text = advantage / positive differentiating feature

Orange text = neutral

Red text = disadvantage / negative differentiating feature

	OPTION 1 Overhead to Line 2	OPTION 2 Overhead to Line 1	OPTION 3 Overhead to Upper Tumut Switching Station	OPTION 4 Overhead to Line 64	OPTION 5 Tunnel to Line 64	OPTION 6 Trenched to Line 64	OPTION 7 Horizontal Directional Drill to Line 64	OPTION 8 Hybrid trench and tunnel to Line 64	OPTION 9 Hybrid trench and submarine cable to Lower Tumut Switching Station	OPTION 10a + 10b Trenched to Lower Tumut Switching Station	OPTION 11 Overhead to Lower Tumut Switching Station	OPTION 12 Tunnel to Lower Tumut Switching Station
Technical - network connectivity and performance												
Provides required capacity for Snowy 2.0 generation to be delivered into the NEM considering cumulative infrastructure needs for HumeLink	No Unless HumeLink is brought into the KNP.	No Unless HumeLink is brought into the KNP.	No Unless HumeLink is brought into the KNP.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Provide required connectivity to increase the resilience and reliability of electricity within the NEM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No Leads to a concentration of 5 circuits within one corridor creating bushfire exposure risk that could cause damage to multiple circuits. Connection concentrates generation capacity up to 6,800 MVA at any one point in the network.	No Leads to a concentration of 5 circuits within one corridor creating bushfire exposure risk that could cause damage to multiple circuits. Connection concentrates generation capacity up to 6,800 MVA at any one point in the network.	No Leads to a concentration of 5 circuits within one corridor creating bushfire exposure risk that could cause damage to multiple circuits. Connection concentrates generation capacity up to 6,800 MVA at any one point in the network.	No Leads to a concentration of 5 circuits within one corridor creating bushfire exposure risk that could cause damage to multiple circuits. Connection concentrates generation capacity up to 6,800 MVA at any one point in the network.
Meet network planning requirements for N-1 redundancy	Yes Four 330kV circuits meets the n-1 redundancy	Yes Four 330kV circuits meets the n-1 redundancy	Yes Four 330kV circuits meets the n-1 redundancy	Yes Four 330kV circuits meets the n-1 redundancy	Yes Five 330kV circuits meets the n-1 redundancy	Yes Five 330kV circuits meets the n-1 redundancy	Yes Five 330kV circuits meets the n-1 redundancy	Yes Five 330kV circuits meets the n-1 redundancy	Yes Five 330kV circuits meets the n-1 redundancy	Yes Five 330kV circuits meets the n-1 redundancy	Yes Four 330kV circuits meets the n-1 redundancy	Yes Five 330kV circuits meets the n-1 redundancy
Consistent with AEMO ISP and	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	OPTION 1 Overhead to Line 2	OPTION 2 Overhead to Line 1	OPTION 3 Overhead to Upper Tumut Switching Station	OPTION 4 Overhead to Line 64	OPTION 5 Tunnel to Line 64	OPTION 6 Trenched to Line 64	OPTION 7 Horizontal Directional Drill to Line 64	OPTION 8 Hybrid trench and tunnel to Line 64	OPTION 9 Hybrid trench and submarine cable to Lower Tumut Switching Station	OPTION 10a + 10b Trenched to Lower Tumut Switching Station	OPTION 11 Overhead to Lower Tumut Switching Station	OPTION 12 Tunnel to Lower Tumut Switching Station
other Commonwealth and NSW strategic policy documents regarding the future NEM needs									Although this option is less resilient outcome than other options.	Although this option is less resilient outcome than other options.	Although this option is less resilient outcome than other options.	Although this option is less resilient outcome than other options.
Minimise need for additional infrastructure within KNP to further stabilise the network due to the project	New substation in KNP at Lobs Hole/Ravine. Future required 500kV lines for HumeLink will then be brought into KNP for connection.	New substation in KNP adjacent Snowy Mountains Highway. Future required 500kV lines for HumeLink will then be brought into KNP for connection.	New substation in KNP at Upper Tumut Switching Station. Future required 500kV lines for HumeLink will then be brought into KNP for connection.	New substation in Bago State Forest. Will provide connection point for future HumeLink augmentation project.	New substation in Bago State Forest. Will provide connection point for future HumeLink augmentation project.	New substation in Bago State Forest. Will provide connection point for future HumeLink augmentation project.	New substation in Bago State Forest. Will provide connection point for future HumeLink augmentation project.	New substation in Bago State Forest. Will provide connection point for future HumeLink augmentation project.	New substation at Lower Tumut Switching Station. Requires two new single circuit 500 kV lines by reusing space created by demolition of 330 kV towers supporting Line 51.	New substation at Lower Tumut Switching Station. Requires two new single circuit 500 kV lines by reusing space created by demolition of 330 kV towers supporting Line 51.	New substation at Lower Tumut Switching Station. Requires two new single circuit 500 kV lines by reusing space created by demolition of 330 kV towers supporting Line 51.	New substation at Lower Tumut Switching Station. Requires two new single circuit 500 kV lines by reusing space created by demolition of 330 kV towers supporting Line 51.
Reduce pressure on existing key links	Yes	Yes Likely to increase upgrade requirements at Canberra substation due to increased fault levels	Yes	Yes	Yes	Yes	Yes	Yes	No As above – creates additional pressure on Lower Tumut Switching Station.	No As above – creates additional pressure on Lower Tumut Switching Station.	No As above – creates additional pressure on Lower Tumut Switching Station.	No As above – creates additional pressure on Lower Tumut Switching Station.
Technical - constructability and design												
Minimise construction duration and risk	~2 years construction period	~2.5 - 3 years construction period	~2-3 year construction period	2.5 years construction period	4.5 years construction period (excluding lead time for TBM construction)	3 years construction period	Not technically viable. Method not considered safe or feasible on the steep sloping inclines on either side of Sheep Station Ridge or the slope up to the substation site on the western side of the Talbingo Reservoir. Also, cable drift could extend beyond the	~4.3 years construction period (excluding lead time for TBM construction)	6.5 years construction period (excluding lead time for barge construction)	~3-4 years construction period	3 years construction period	5+ years construction period

	OPTION 1 Overhead to Line 2	OPTION 2 Overhead to Line 1	OPTION 3 Overhead to Upper Tumut Switching Station	OPTION 4 Overhead to Line 64	OPTION 5 Tunnel to Line 64	OPTION 6 Trenched to Line 64	OPTION 7 Horizontal Directional Drill to Line 64	OPTION 8 Hybrid trench and tunnel to Line 64	OPTION 9 Hybrid trench and submarine cable to Lower Tumut Switching Station	OPTION 10a + 10b Trenched to Lower Tumut Switching Station	OPTION 11 Overhead to Lower Tumut Switching Station	OPTION 12 Tunnel to Lower Tumut Switching Station
							intended easement corridor.					
Allow for suitable and efficient construction support sites close to the alignment	Yes Suitable support sites available at Lobs Hole	Yes However, topography from Lobs Hole to Marica is steep and likely to prove challenging in some areas where structures are required.	Yes However, topography from Lobs Hole to Upper Tumut Switching Station is steep and likely to prove challenging in some areas where structures are required.	Yes Suitable sites available at Lobs Hole and at the western extent at Line 64.	Yes Two main support sites at Lobs Hole and Maragle.	A number of support sites required along alignment.	No	Two main support sites at Ravine and east of Maragle substation – both in KNP. A number of support sites for trenching required along alignment.	A number of support sites for trenching required along alignment. Wharves and dry dock required at Ravine and at Talbingo boat ramp.	A number of support sites required along alignment.	Two main support sites at Lobs Hole and Talbingo, north of reservoir outside of KNP.	Two main support sites at Lobs Hole and Lower Tumut Switching Station, outside of KNP.
Minimise excavations in areas of Naturally Occurring Asbestos	No naturally occurring asbestos expected.	No naturally occurring asbestos expected.	No naturally occurring asbestos expected.	No naturally occurring asbestos expected. However, will span over mapped NOA.	High degree of uncertainty of tunnelling through rock types with naturally occurring asbestos requiring specific management.	Unlikely	High degree of uncertainty of tunnelling through rock types with naturally occurring asbestos requiring specific management.	High degree of uncertainty of tunnelling through rock types with naturally occurring asbestos requiring specific management.	Unlikely	Unlikely	No naturally occurring asbestos expected.	High degree of uncertainty of tunnelling through rock types with naturally occurring asbestos requiring specific management.
Allow for suitable and efficient operational maintenance activities	Yes Overhead options are expected to allow for routinely performed maintenance.	Yes Overhead options are expected to allow for routinely performed maintenance.	Yes Overhead options are expected to allow for routinely performed maintenance.	Yes Overhead options are expected to allow for routinely performed maintenance.	Intermediate shafts for ventilation and emergency access.	Allows for replacement faulted cables or joints in sections.	Not considered due to option not being technically viable.	Intermediate shafts for ventilation and emergency access.	Repairs to submarine cable requires divers to detect fault and specialised equipment to repair fault. Allows for replacement faulted cables or joints in trenched sections.	Allows for replacement faulted cables or joints in sections.	Overhead options are expected to allow for routinely performed maintenance.	Intermediate shafts for ventilation and emergency access.
Minimise scale of project's construction requirements that may result in heavy haulage movements on local area	Yes Construction footprint would be the smallest of all options and therefore would result in the lowest heavy	Yes Up to 150 heavy vehicle movements during peak construction. Similar construction footprint	Yes Larger footprint than Option 1,2 and 4 resulting in a higher quantum of oversize truck movements, but	Yes Up to 150 heavy vehicle movements per day during peak construction.	Oversize truck movements for tunnelling equipment. Large number of truck movements transporting concrete tunnel	Large number of truck movements on public roads transporting aggregate, sand and cement for batching plants, cables and	Not considered due to option not being technically viable.	Oversize truck movements for TBM and other excavation equipment (eg road header, diesel locomotives and cars).	Oversize truck movements for barges and dredges. Likely disruption within Talbingo township road network.	Large number of truck movements on public roads - aggregate, sand and cement for batching plants, cables and	Likely disruption within Talbingo township road network.	Oversize truck movements for tunnelling equipment. Large number of truck movements transporting

	OPTION 1 Overhead to Line 2	OPTION 2 Overhead to Line 1	OPTION 3 Overhead to Upper Tumut Switching Station	OPTION 4 Overhead to Line 64	OPTION 5 Tunnel to Line 64	OPTION 6 Trenched to Line 64	OPTION 7 Horizontal Directional Drill to Line 64	OPTION 8 Hybrid trench and tunnel to Line 64	OPTION 9 Hybrid trench and submarine cable to Lower Tumut Switching Station	OPTION 10a + 10b Trenched to Lower Tumut Switching Station	OPTION 11 Overhead to Lower Tumut Switching Station	OPTION 12 Tunnel to Lower Tumut Switching Station
	vehicle movements.	compared to Option 4.	generally achievable.		segments that would utilise local road network (likely to be from Cooma to KNP).	associated materials. Removal of excavated material on Elliot Way. Minimum 297 one-way truck movements per day (594 two-way movements) with significant proportion of traffic using Elliott Way.		Large number of truck movements transporting concrete tunnel segments and aggregate, sand and cement for batching plants, cables and associated materials. Minimum 297 one-way truck movements per day (594 two-way movements) with significant proportion of traffic using Elliott Way.	Large number of truck movements on public roads within Talbingo township transporting aggregate, sand and cement for batching plants, cables and associated materials.	associated materials. Likely disruption within Talbingo township road network, particularly on Miles Franklin Drive.		concrete tunnel segments. Likely disruption within Talbingo township road network.
Environment and planning - community and environment												
Minimise additional infrastructure within KNP	Expansion or replacement of existing Ravine substation. Addition of 2 km of overhead transmission line and structures and associated easement and access tracks.	Addition of new substation and associated access. Addition of 8 km of overhead transmission line and structures and associated easements and access tracks.	Addition of 13 km of overhead transmission line and structures and associated easements and access tracks.	Addition of 9 km of overhead transmission line and structures and associated easements and access tracks.	Addition of entry portal and shafts/adits with associated access tracks at designated points along the length of the underground deep cable tunnel.	Additional widening of existing O'Hares Track and Elliot Way to allow for trenching activities and easement. Additional overhead transmission line over Talbingo Reservoir.	Addition of infrastructure access points with associated access tracks at designated points along the length of the route.	Addition of entry and exit portals and shafts/adits with associated access tracks at designated points along the length of the underground deep cable tunnel component. Addition of infrastructure access points and widening of Elliott Way component.	Addition of infrastructure access points with associated access tracks at designated points along the route between the cableyard and Talbingo Reservoir.	Addition of new easement along the edge of Talbingo Reservoir above full supply level, infrastructure access points with associated access tracks at designated points along the length of the route.	Addition of 20 km of overhead transmission line and structures and associated easements and access tracks.	Addition of entry portal and shafts/adits with associated access tracks at designated points along the length of the underground deep cable tunnel.
Minimise impacts to environmentally and culturally sensitive sites	Construction requires establishment of 2 km easement resulting in vegetation clearance, with occasional	Construction requires establishment of 8 km easement resulting in vegetation clearance, with opportunities to	Construction requires establishment of 13 km easement resulting in vegetation clearance, with opportunities to	Construction requires establishment of 9 km easement resulting in vegetation clearance, with opportunities to	Construction requires vegetation clearance at entry and exit portals for TBM. Clearance will also be required	Construction requires establishment of 9 km easement adjacent to existing O'Hares track and Elliott Way resulting in	Construction requires vegetation clearance at entry and exit points of directional drill activities.	Construction requires vegetation clearance at entry and exit portals for TBM and directional drill. Clearance	Construction requires vegetation clearance along easement between cableyard and Talbingo	Construction requires establishment of an easement requiring vegetation	Construction requires establishment of 24 km easement resulting in vegetation clearance, with opportunities to	Construction requires vegetation clearance at entry and exit portals for TBM. Clearance will also be required

	OPTION 1 Overhead to Line 2	OPTION 2 Overhead to Line 1	OPTION 3 Overhead to Upper Tumut Switching Station	OPTION 4 Overhead to Line 64	OPTION 5 Tunnel to Line 64	OPTION 6 Trenched to Line 64	OPTION 7 Horizontal Directional Drill to Line 64	OPTION 8 Hybrid trench and tunnel to Line 64	OPTION 9 Hybrid trench and submarine cable to Lower Tumut Switching Station	OPTION 10a + 10b Trenched to Lower Tumut Switching Station	OPTION 11 Overhead to Lower Tumut Switching Station	OPTION 12 Tunnel to Lower Tumut Switching Station
	opportunities to reduce clearance activities in areas of steep topography between structures. Minimal threatened species habitat known along the easement for State and Commonwealth listed species. No known significant culturally sensitive sites.	reduce clearance activities in areas of steep topography between structures. Threatened species habitat known along the easement for State and Commonwealth listed species, particularly Smoky Mouse. Potential for threatened ecological communities near connection point. No known significant culturally sensitive sites.	reduce clearance activities in areas of steep topography between structures. Threatened species habitat known along the easement for State and Commonwealth listed species, particularly Smoky Mouse. No known significant culturally sensitive sites.	reduce clearance activities in areas of steep topography between structures. Threatened species habitat known along the easement for State and Commonwealth listed species. No known significant culturally sensitive sites.	for shafts / adits and associated access tracks along the length of the underground deep cable tunnel. Threatened species habitat known to occur at these locations. No known significant culturally sensitive sites.	vegetation clearance along the entire length. Threatened species habitat known to occur along the easement for State and Commonwealth species. No known significantly culturally sensitive sites.	Clearance will also be required for pipe laying areas at these locations and associated access tracks. Threatened species habitat known to occur along the easement for State and Commonwealth species. No known significantly culturally sensitive sites.	will also be required for shafts / adits and associated access tracks along the length of the underground deep cable tunnel. Clearance will also be required for pipe laying areas at directional drill locations and associated access tracks. Threatened species habitat known to occur at these locations. No known significant culturally sensitive sites.	Reservoir. Laying submarine cable within Talbingo Reservoir will require removal of submerged trees and disturbance to sediment resulting in turbidity impacts along the length of the reservoir. Threatened species habitat known to occur within the reservoir. No known significant culturally sensitive sites.	clearance along its entire length. Threatened species habitat known to occur along the easement for State and Commonwealth species. No known significantly culturally sensitive sites.	reduce clearance activities in areas of steep topography between structures. Threatened species habitat known along the easement for State and Commonwealth listed species. No known significant culturally sensitive sites.	for shafts / adits and associated access tracks along the length of the underground deep cable tunnel. Threatened species habitat known to occur at these locations. No known significant culturally sensitive sites.
Minimise long term visual impacts within KNP	New easement, overhead lines and structures for 2 km with some visual change for users of Lobs Hole. Expansion or replacement of existing substation with some visual change for users of Lobs Hole.	New easement overhead lines and structures for 8 km with some areas of visual change for users of Snowy Mountains Highway. New substation with high visibility from Snowy Mountains Highway and other tracks.	New easement, overhead lines and structures for 13 km with some areas of visual change for users of Ravine Road, Elliot Way and Cabramurra Expansion or replacement of existing substation with high visibility for users of Cabramurra	New easement, overhead lines and structures for 9 km with some areas for users of Talbingo Reservoir, Elliott Way and Lobs Hole where there is likely to be visual change.	New portal for TBM entry including areas for TBM construction with visual change for users of Lobs Hole. It is likely that spoil disposal within Snowy 2.0 spoil emplacement areas would occur, with additional volumes likely to result in further visual change for users of Lobs Hole.	Wider easement adjacent to O'Hares Track and Elliott Way with visual change for users of these accesses. New easement, overhead lines and structures either side of Talbingo Reservoir crossing with high visibility for users of Elliott Way and Talbingo Reservoir.	New cleared areas enabling the direction drills including pipe laying and associated access tracks with likely minimal visual change for users of Talbingo Reservoir and Elliott Way.	New portal for TBM entry with visual change for users of Lobs Hole. New cleared areas enabling the direction drills including pipe laying and associated access tracks with likely minimal visual change for users of Talbingo Reservoir and Elliott Way. It is likely that spoil disposal within Snowy 2.0	Minor infrastructure at edge of reservoir for entry and exit points with some visual change for users of Talbingo Reservoir.	Wider easement adjacent to full supply level of Talbingo Reservoir with visual change for users of the reservoir.	New easement, overhead lines and structures for 24 km with some areas of visual change for users of Ravine Road and Talbingo Reservoir.	New portal for TBM entry including areas for TBM construction with visual change visibility for users of Lobs Hole. New portal for TBM exit with visual change for some areas of Talbingo. It is likely that spoil disposal within Snowy 2.0 spoil emplacement areas would occur, with

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								spoil emplacement areas would occur, with additional volumes likely to result in further visual change for users of Lobs Hole.				additional volumes likely to result in further visual change for users of Lobs Hole. Additional spoil disposal location at Lower Tumut Switching Station would also be required.
Maintain long term access and use of public open space and recreation areas within KNP	Yes. Expanded substation will have minor impacts on available public open space and its use around Lobs Hole.	Yes New substation will impact on available public open space and its use in the plateau area near Eucumbene River.	Yes Expanded substation will have minor impacts on available public open space and its use around Upper Tumut Switching Station.	Yes	Yes	Yes	Yes	Yes	Yes Impacts on access to reservoir associated with marine facilities required for maintenance.	Yes Likely to improve access along eastern side of reservoir.	Yes	Yes
Minimise private property impacts and acquisition requirements	Line length is relatively short at around 1.9 km. Footprint is within state forest or KNP (no private land).	Line length is around 8 km. Footprint is within state forest or KNP (no private land).	Line length is 13 km. Footprint is within state forest or KNP (no private land).	Line length is around 9 km. Footprint is within state forest or KNP (no private land).	Line length I around 9 km. Footprint is within state forest or KNP (no private land).	Line length is around 15 km. Footprint is within state forest or KNP (no private land) and within road reserve.	Line length is around 9 km, Footprint is within state forest or KNP (no private land).	Line length is around 9.8 km. Footprint is within state forest or KNP (no private land).	Line length of around 30 km. Potential to impact on private property from Talbingo township.	Line length of around 44 km. Potential to impact on private property around Talbingo township.	Line length of around 23.5 km. Potential to impact on private property around Talbingo township.	Line length of around 23.5 km. Potential to impact on private property around Talbingo township.
Minimise impacts and disruption to local community and businesses	No private land impacted.	No private land impacted.	No private land impacted.	No private land impacted.	No private land impacted. Impacts to community through large number of track movements on public roads.	No private land impacted. Impacts to community through large number of track movements on public roads.	No private land impacted.	No private land impacted. Impacts to community through large number of track movements on public roads.	Potential impacts to private property owners around Talbingo township. Impacts to community through large number of truck movements on public roads. Impacts to recreational	Potential impacts to private property owners around Talbingo township. Impacts to community through large number of truck movements on public roads.	Potential impacts to private property owners around Talbingo township.	Potential impacts to private property owners around Talbingo township. Impacts to community through large number of truck movements on public roads.

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									users of reservoir.			
Minimise generation of spoil	Minimal generation of spoil due to short length of line and terrain.	Approximately 320,000 m3 of material expected.	Greater than 500,000 m3 of material expected.	Approximately 360,000 m³ of material.	Greater than 500,000 m3 of material expected.	Approximately 1,800,000 m³ of material expected.	Not considered due to option not being technically viable.	Greater than 600,000 m3 of material.	Greater than 500,000 m3 of material expected. (excluding considerable dredging volumes required for 17 km of Talbingo Reservoir to lay cable)	Approximately 2,000,000 m3 of material.	Approximately 1,000,000 m3 of material.	Approximately 1,000,000 m3 of material.
Environment and planning – economic factors												
Maximise cost efficiency	Construction: Unlikely to be prohibitive construction costs due to short length of line and terrain. Operation: Unlikely to be prohibitive operational costs.	Construction: Primary construction costs include clearance of vegetation, creation of access tracks, construction of structures and stringing of line across steep topography. Requires construction of new substation. Operation: Unlikely to be prohibitive operational costs.	Construction: Primary construction costs include clearance of vegetation, creation of access tracks, construction of structures and stringing of line across steep topography. Operation: Unlikely to be prohibitive operational costs.	Construction: Primary construction costs include clearance of vegetation, creation of access tracks, construction of structures and stringing of line across steep topography. Requires construction of new substation. Operation: Unlikely to be prohibitive operational costs.	Construction: Primary construction costs include deep tunnel excavation equipment (such as TBM), materials tunnel infrastructure (such as concrete segmental lining) and shaft construction, ancillary equipment required for spoil material management and disposal, construction access requirements (road upgrades). Requires construction of new substation. Operation: Primary additional operational	Construction: Primary construction costs include the trenching equipment and activity, covering the completed trench, disposal of excess materials excavated from trenches, and upgrades (and establishment) of access roads. Requires construction of new substation. Operation: Unlikely to be prohibitive operational costs.	Construction: Primary construction costs include the drilling equipment and activity, covering the completed trench, disposal of excess materials excavated from trenches, and upgrades (and establishment) of access roads. Requires construction of new substation. Operation: Unlikely to be prohibitive operational costs.	Construction: Primary construction costs include deep tunnel excavation equipment (such as TBM) and activity, materials tunnel infrastructure (such as concrete segmental lining) and shaft construction, ancillary equipment required for spoil material management and disposal, construction access requirements (road upgrades). Requires construction of new substation. Operation: Primary additional	Construction: Primary construction costs include activities associated with preparation of the reservoir bed such as removal of submerged vegetation and construction and operation of barges for cable laying activity. Requires upgrade/replacement of existing substation. Operation: Unlikely to be prohibitive operational costs.	Construction: Primary construction costs include the trenching equipment and activity, covering the completed trench, disposal of excess materials excavated from trenches, and upgrades (and establishment) of access roads. Requires upgrade/replacement of existing substation. Operation: Unlikely to be prohibitive operational costs.	Construction: Primary construction costs include clearance of vegetation, creation of access tracks, construction of structures and stringing of line across steep topography. Requires upgrade/replacement of existing substation. Operation: Unlikely to be prohibitive operational costs.	Construction: Primary construction costs include deep tunnel excavation equipment (such as TBM), materials tunnel infrastructure (such as concrete segmental lining) and shaft construction, ancillary equipment required for spoil material management and disposal, construction access requirements (road upgrades). Requires construction of new substation. Operation: Primary additional operational

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					costs include maintenance of safety protocols and equipment monitoring.			operational costs for tunnelling include maintenance of safety protocols and equipment monitoring. Unlikely to be prohibitive operational costs for directionally drilled component.				costs include maintenance of safety protocols and equipment monitoring.
Minimise project economic risk	Overhead transmission line and structures susceptible to fault/ damage but more cost effective to fix.	Overhead transmission line and structures susceptible to fault/ damage but more cost effective to fix.	Overhead transmission line and structures susceptible to fault/ damage but more cost effective to fix.	Overhead transmission line and structures susceptible to fault/ damage but more cost effective to fix.	Damage to underground cables is likely to result in failure of transmission with risk (due to remote location) of requiring significant time and cost to identify the underground issue and fix to recommence transmission of Snowy 2.0 generation.	Trenched cable along public road unlikely to be prone to damage but relatively efficient to fix should it be damaged.	Directionally drilled cable along public road unlikely to be prone to damage but relatively efficient to fix should it be damaged.	Damage to underground cables is likely to result in failure of transmission with risk (due to remote location) of requiring significant time and cost to identify the underground issue and fix to recommence transmission of Snowy 2.0 generation.	Trenched cable along public road unlikely to be prone to damage but relatively efficient to fix should it be damaged. Damage to submarine cable is likely to result in failure of transmission with risk (due to remote location) of requiring significant time and cost to identify the issue and fix to recommence transmission of Snowy 2.0 generation.	Trenched cable along reservoir edge unlikely to be prone to damage but relatively efficient to fix should it be damaged.	Overhead transmission line and structures susceptible to fault/ damage but more cost effective to fix should it be damaged.	Damage to underground cables is likely to result in failure of transmission with risk (due to remote location) of requiring significant time and cost to identify the underground issue and fix to recommence transmission of Snowy 2.0 generation.
Support current and future requirements of the NEM	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Deliver positive economic benefits to the people of NSW	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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Achieve connection for first power generation of Snowy 2	Yes	Yes	Yes	Yes	Likely, however the construction method of significant tunnelling length with a single TBM raises the risk profile of timely completion of construction for first power out.	Yes	Yes	Likely, however the construction method of significant tunnelling length with a single TBM raises the risk profile of timely completion of construction for first power out.	No	Yes	Yes	Likely, however the construction method of significant tunnelling length with a single TBM raises the risk profile of timely completion of construction for first power out.
Safety												
Meet best practice safety requirements during construction and operation	Achievable.	Achievable	Achievable	Achievable	Achievable, however underground excavation activities and equipment has a significantly elevated safety risk requiring additional controls and safety management procedures during construction and operation, particularly in a remote location.	Achievable, however significant excavation volumes, surface works and required equipment along public roads has a significantly elevated safety risk requiring additional controls and safety management procedures during construction.	Achievable, however surface works and required drilling equipment in remote locations during construction has an elevated safety risk requiring additional requires controls and safety management procedures during construction.	Achievable, however underground excavation activities and equipment has a significantly elevated safety risk requiring additional controls and safety management procedures during construction and operation, particularly in a remote location. Surface works along public roads has an elevated safety risk also requiring additional requires controls and safety management procedures during construction.	Achievable, however laying submarine cable activities and required equipment within the reservoir has a significantly elevated risk requiring additional controls and safety management procedures during construction, particularly in a remote location.	Achievable, however surface works and required equipment along Talbingo Reservoir and public roads has an elevated safety risk requiring additional controls and safety management procedures during construction.	Achievable	Achievable, however underground excavation activities and equipment has a significantly elevated safety risk requiring additional controls and safety management procedures during construction and operation, particularly in a remote location.
Hazards systematically identified and controlled	Key hazards during construction and	Key hazards during construction and	Key hazards during construction and	Key hazards during construction and	Underground tunnelling provides for a higher safety risk	Trenching activities can be managed through	Directional drilling activities can be managed through	Underground tunnelling provides for a higher safety risk	Trenching activities can be managed through	Trenching activities can be managed through	Key hazards during construction and	Underground tunnelling provides for a higher safety risk

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applying the hierarchy of controls	operation would include: -falling from height causing serious injury/death -Electrocution during operational maintenance of the transmission connection and substation -Vegetation clearing (mechanical and manual) resulting in personnel being struck by falling timber Such risks that could cause significant harm or death to construction staff or operational maintenance personnel could be controlled to a level that is ALARP through the application of the hierarchy of controls.	operation would include: -falling from height causing serious injury/death -Electrocution during operational maintenance of the transmission connection and substation -Vegetation clearing (mechanical and manual) resulting in personnel being struck by falling timber Such risks that could cause significant harm or death to construction staff or operational maintenance personnel could be controlled to a level that is ALARP through the application of the hierarchy of controls.	operation would include: -falling from height causing serious injury/death -Electrocution during operational maintenance of the transmission connection and substation -Vegetation clearing (mechanical and manual) resulting in personnel being struck by falling timber Such risks that could cause significant harm or death to construction staff or operational maintenance personnel could be controlled to a level that is ALARP through the application of the hierarchy of controls.	operation would include: -falling from height causing serious injury/death -Electrocution during operational maintenance of the transmission connection and substation -Vegetation clearing (mechanical and manual) resulting in personnel being struck by falling timber Such risks that could cause significant harm or death to construction staff or operational maintenance personnel could be controlled to a level that is ALARP through the application of the hierarchy of controls.	which requires significantly more stringent safety controls and management procedures during construction and operation, particularly in a remote location.	standard safety procedures to a level that is ALARP through the application of the hierarchy of controls.	standard safety procedures to a level that is ALARP through the application of the hierarchy of controls.	which requires significantly more stringent safety controls and management procedures during construction and operation, particularly in a remote location.	standard safety procedures to a level that is ALARP through the application of the hierarchy of controls. Marine activities provides for a higher safety risk which requires significantly more stringent safety controls and management procedures during construction and operation, particularly in a remote location.	standard safety procedures to a level that is ALARP through the application of the hierarchy of controls.	operation would include: -falling from height causing serious injury/death -Electrocution during operational maintenance of the transmission connection and substation -Vegetation clearing (mechanical and manual) resulting in personnel being struck by falling timber Such risks that could cause significant harm or death to construction staff or operational maintenance personnel could be controlled to a level that is ALARP through the application of the hierarchy of controls.	which requires significantly more stringent safety controls and management procedures during construction and operation, particularly in a remote location.

Appendix B

Photographs of Line 2

Photograph B.1 Line 2 at Lobs Hole looking north

Photograph B.2 Line 2 near Lobs Hole Ravine Road looking south to Upper Tumut Switching Station

Photograph B.3 Line 2 from Goats Ridge Road

Photograph B.4 Line 2 crossing Link Road






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