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HumeLink

Electric and Magnetic Field Study
EIS Technical Report 15

HumeLink

Technical Report 15.1 Transmission Lines Electric and Magnetic Fields (EMF) Assessment

Transgrid

June 2023

Bringing ideas to life

Executive summary

The Australian energy landscape is transitioning to a greater mix of low-emission renewable energy sources, such as wind and solar. To support this transition, meet our future energy demands and connect Australian communities and businesses to these lower cost energy sources, the national electricity grid needs to evolve.

Transgrid proposes to increase the energy network capacity in southern New South Wales (NSW) through the development of around 360 kilometres of new 500 kilovolt (kV) high-voltage transmission lines and associated infrastructure between Wagga Wagga, Bannaby and Maragle. This project is collectively referred to as HumeLink.

The scope of Aurecon's assessment relates to the transmission lines and is to encompass the following:

- Provision of a brief description of electric and magnetic fields (EMF) in relation to human health
- Calculating the EMF for the proposed lines at one metre above ground level, extending up to 200 metres on each side of their centrelines and covering the range of structure types, conductor configurations and other relevant parameters associated with the lines
- An assessment of the compliance of the anticipated field levels with the relevant national and international EMF guidelines
- An assessment of compliance of the proposed line with precautionary and prudent avoidance principles as defined in the relevant guidelines
- Preparation of a report covering the EMF assessment.

It should be noted that the scope of this assignment is confined to transmission lines EMF. The EMF assessment at the substations is addressed in a separate report.

The purpose of this assignment is to check the EMF levels of the proposed 500kV lines against the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) recommended International Commission on Non – Ionizing Radiation Protection (ICNIRP) public exposure guidelines. Aurecon has modelled the EMF associated with all of the proposed lines and based on the modelling results, has arrived at the following conclusions:

Magnetic fields

Whether in isolation, or in combination with the existing 132 and 330 kV transmission lines, the contribution of the proposed 500 kV lines at 500 kV and 330 kV operation to the magnetic field environment is predicted to be well within the ICNIRP Guideline Reference Level of 2,000 mG.

Under typical conditions:

- Directly beneath the proposed 500 kV lines, the highest predicted magnetic fields range from less than 3.5 per cent to 4.5 per cent of the ICNIRP Guideline Reference Level
- At the edge of the easements, the highest predicted magnetic fields of the proposed 500 kV lines range from less than 0.6 per cent to 1.7 per cent of the ICNIRP Guideline Reference Level
- Directly beneath the proposed Gugaa-Wagga line which would operate at 330 kV, the highest predicted magnetic field is 2.5 per cent of the ICNIRP Guideline Level
- At the edge of the easements, the highest predicted magnetic field of the proposed Gugaa-Wagga line which would operate at 330 kV is 0.5 per cent of the ICNIRP Guideline Reference Level.

Under normal peak load conditions:

- Directly beneath the proposed 500 kV lines, the highest predicted magnetic fields range from less than 9.5 per cent to 10.5 per cent of the ICNIRP Guideline Reference Level
- At the edge of the easements, the highest predicted magnetic fields of the proposed 500 kV lines range from 1.5 to 4 per cent of the ICNIRP Guideline Reference Level
- Directly beneath the proposed Gugaa-Wagga line which would operate at 330 kV, the highest predicted magnetic field is 6.8 per cent of the ICNIRP Guideline Reference Level
- At the edge of the easements, the highest predicted magnetic field of the proposed Gugaa-Wagga line which would operate at 330 kV is 1.3 per cent of the ICNIRP Guideline Reference Level.

Under emergency conditions, which would rarely occur during the life of the lines and would be of short duration:

- Directly beneath the proposed 500 kV lines, the highest predicted magnetic fields are less than 19 per cent of the ICNIRP Guideline Reference Level
- At the edge of the easements, the highest predicted magnetic fields of the proposed 500 kV lines range from less than 5 to 5.5 per cent of the ICNIRP Guideline Reference Level
- Directly beneath the proposed Gugaa-Wagga line which would operate at 330 kV, the highest predicted magnetic field is 15.8 per cent of the ICNIRP Guideline Reference Level
- At the edge of the easements, the highest predicted magnetic field of the proposed Gugaa-Wagga line which would operate at 330kV is 5.2 per cent of the ICNIRP Guideline Reference Level.

Notwithstanding the lines' proximity to existing 132 kV, 330 kV and 500 kV lines in some locations, there is little interaction with their magnetic fields, except at the undercrossings, where the field contributions from the two lines would interact. The extent to which one or other dominates would be governed by the relative heights of the two lines and their load currents. The highest resulting magnetic fields are very localised and the fields at the transmission line easement edges are substantially unchanged. Similar patterns could be expected in the event of future crossings by other lines.

Where the proposed transmission lines run parallel to existing transmission lines, or known future transmission lines, due to the relatively wide separation between them, there is little interaction between them and the fields associated with the respective transmission lines are much the same as under the individual transmission lines in isolation.

Electric fields

In all locations, under all conditions, the electric fields directly below the transmission lines will be less than 9.1 kV/m and, hence, would comply with the Basic Restrictions under the ICNIRP Guideline. The 9.1 kV/m value can be shown to meet the ICNIRP general public basic restriction as determined by Transgrid commissioned modelling.

At the edge of the transmission line easements, the highest predicted electric fields for 500 kV line operation would range from 0.2 to 0.6 kV/m, or 3 to 12 per cent of the ICNIRP Guideline Reference Level of 5 kV/m.

For the Gugaa - Wagga line which would operate at 330 kV, the highest predicted electric fields, at the edge of the transmission line easements would range from 0.15 to 0.3 kV/m, or 3 to 6 per cent of the ICNIRP Guideline Reference Level.

In practice, due to shielding by vegetation etc, the actual electric fields are likely to be considerably less than that predicted.

Where they cross existing high voltage lines, the field contribution from the proposed 500 kV transmission lines would interact with the existing fields from the undercrossing transmission lines, resulting in a complex field distribution with some increases in field levels at the crossing point below the transmission line and the increase dissipates away from the crossing point. The fields at the easement edges would be substantially unchanged with no discernible increase. Similar patterns could be expected in the event of future crossings by other transmission lines.

Where they run parallel to existing transmission lines, or known future high voltage transmission lines, the proposed transmission lines are not expected to cause any material increase to the existing electric fields associated with those lines.

Prudent avoidance

It is widely accepted that, given the inconclusive nature of the science, a prudent/precautionary approach continues to be the most appropriate response to health concerns regarding EMF. Under this approach, the operators of electricity infrastructure should design their facilities to reduce the intensity of the magnetic fields they generate, and locate them to minimise the fields that people, especially children, encounter over prolonged periods, provided this can be readily achieved without undue inconvenience and at reasonable expense, and be consistent with good engineering and risk minimisation practice.

In designing the lines, Transgrid and its consultants have:

- Adopted generous ground clearances throughout, thereby reducing the fields directly under the lines
- Used “vee” insulator strings, which enable the line design to be relatively compact, thereby reducing the electric and magnetic fields
- Arranged the phases of the two circuits to provide maximum field cancellation, both for new sections of the line and for the combination where the new line runs in parallel with the existing 500 kV double circuit line 5A6/5A7 Mt Piper to Bannaby.

In selecting the transmission line route, Transgrid has accorded a high importance to separating the route from residential dwellings and other occupied premises.

Due to the transmission line route being away from urban and semi-urban areas, it is unlikely that there would be any prolonged human exposure to EMF from the lines.

Due to the uncertainty as to the existence of adverse health effects, it cannot be said whether the above measures would result in any health benefit, but they are all appropriate and consistent with the principles of prudent avoidance.

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1 Introduction

1.1 Overview

The Australian energy landscape is transitioning to a greater mix of low-emission renewable energy sources, such as wind and solar. To support this transition, meet our future energy demands and connect Australian communities and businesses to these lower cost energy sources, the national electricity grid needs to evolve.

Transgrid proposes to increase the energy network capacity in southern New South Wales (NSW) through the development of around 360 kilometres of new 500 kilovolt (kV) high-voltage transmission lines and associated infrastructure between Wagga Wagga, Bannaby and Maragle. This project is collectively referred to as HumeLink. The project would be located across five Local Government Areas (LGAs) including Wagga Wagga City, Snowy Valleys, Cootamundra-Gundagai Regional, Upper Lachlan Shire and Yass Valley. The location of the project is shown on Figure 1-1.

HumeLink would involve construction of a new substation east of Wagga Wagga as well as connection to existing substations at Wagga Wagga and Bannaby and a future substation at Maragle in the Snowy Mountains (referred to as the future Maragle 500 kV substation). The future Maragle 500 kV substation is subject to a separate major project assessment and approval (reference SSI-9717, EPBC 2018/836).

The project would deliver a cheaper, more reliable and more sustainable grid by increasing the amount of renewable energy that can be delivered across the national electricity grid, helping to transition Australia to a low carbon future. It would achieve this by supporting the transfer of energy from existing renewable generation as well as facilitate development of new renewable generation in the Wagga Wagga and Tumut Renewable Energy Zones (REZs). The project would provide the required support for the network in southern NSW, allowing for the increase in transfer capacity between new renewable generation sources and the state's demand centres of Sydney, Newcastle and Wollongong. The project would also improve the efficiency and reliability of the current energy transfer in this part of the network.

Furthermore, HumeLink would form a key part of the transmission line infrastructure that supports the transfer of energy within the National Electricity Market (NEM) by connecting with other major interconnectors. The NEM incorporates around 40,000 kilometres of transmission lines across Queensland (QLD), NSW, Australian Capital Territory (ACT), Victoria (VIC), South Australia (SA) and Tasmania (TAS).

Construction of the project is targeted to commence in 2024, subject to the required planning and regulatory approvals. Once construction has commenced, the project is estimated to take approximately 2.5 years to build and would become operational by the end of 2026.

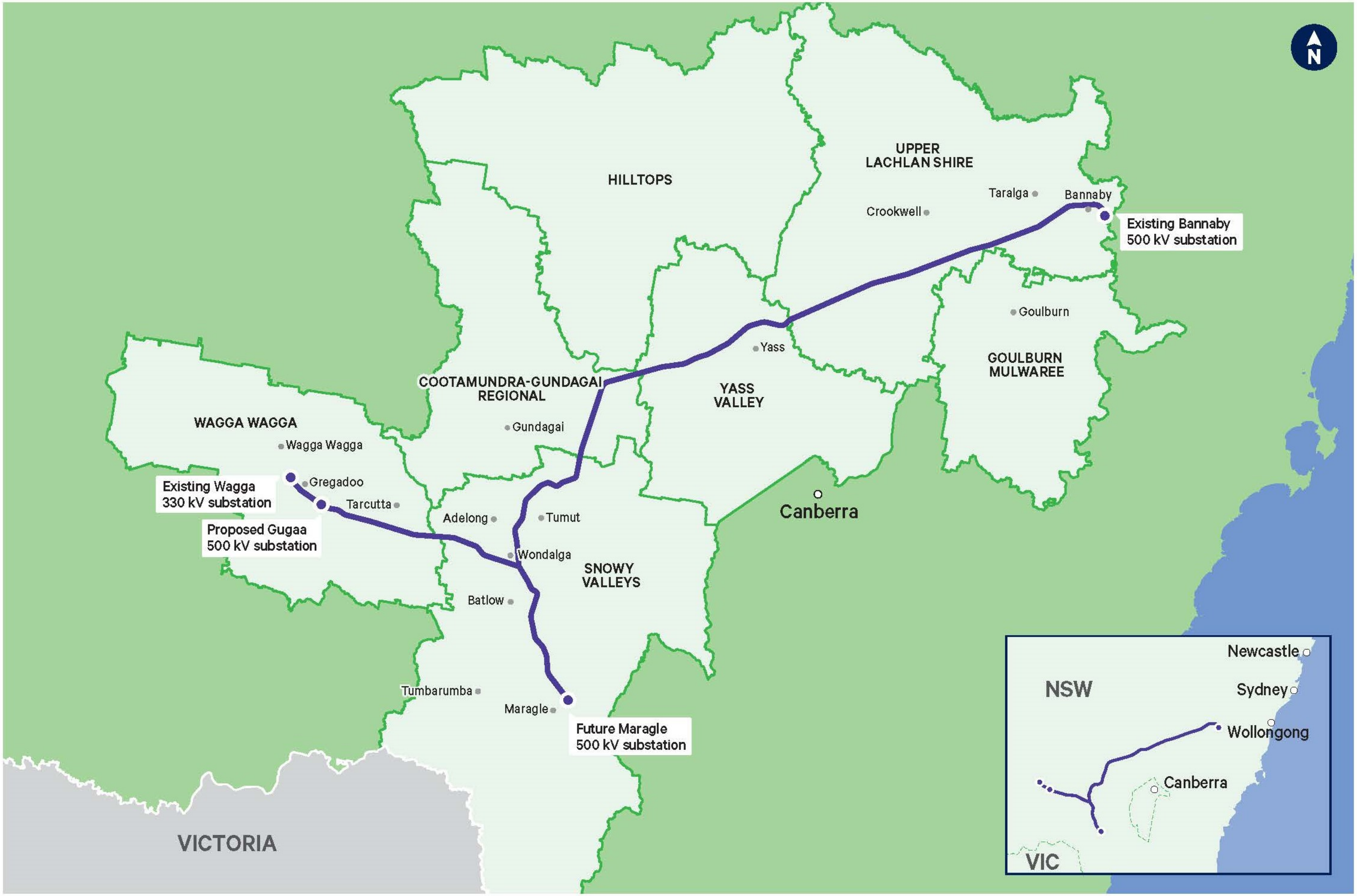
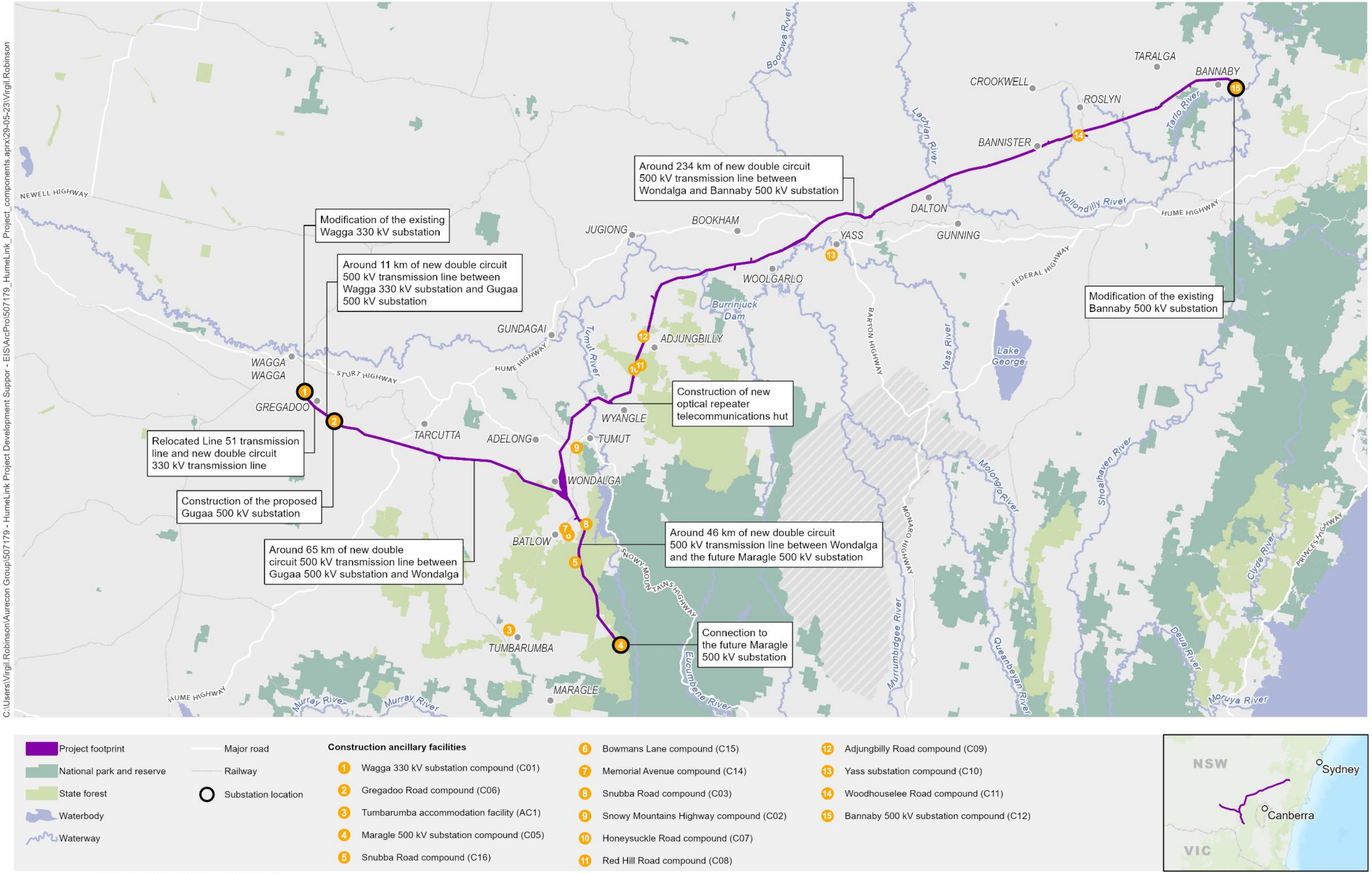


Figure 1-1 | Location of the project

1.2 Key components

The project includes the following key components (refer to Figure 1-2):

- construction and operation of around 360 kilometres of new double circuit 500 kV transmission lines and associated infrastructure between Wagga Wagga, Bannaby and Maragle
- construction of a new 500/330 kV substation at Gregadoo (Gugaa 500 kV substation) approximately 11 kilometres south-east of the existing Wagga 330/132 kV substation (Wagga 330 kV substation)
- demolition and rebuild of a section of Line 51 (around two kilometres in length) as a double circuit 330 kV transmission line connecting into the Wagga 330 kV substation
- modification of the existing Wagga 330 kV substation and Bannaby 500/330 kV substation (Bannaby 500 kV substation) to accommodate the new transmission line connections
- connection of transmission lines to the future Maragle 500/330 kV substation (Maragle 500 kV substation, approved under the Snowy 2.0 Transmission Connection Project (SSI-9717))
- provision of one optical repeater telecommunications hut and associated connections to existing local electrical infrastructure
- establishment of new and/or upgraded temporary and permanent access tracks
- ancillary works required for construction of the project such as construction compounds, worker accommodation facilities, utility connections and/or relocations, brake and winch sites, and helipad/helicopter support facilities.



Source: *Aurecon, Transgrid, Spatial Services (DCS), ESRI Basemap*

1:925,000

0 20 40km

Projection: GDA 1994 MGA Zone 55

HumeLink **Electric and Magnetic**

FIGURE 1-2: Key components of the project

The approximate lengths of the transmission line route sections are:

- Maragle-Wondalga line: 47 kilometres
- Wondalga-Gugaa line: 61 kilometres
- Wondalga-Bannaby line: 236 kilometres
- Gugaa-Wagga line: 11 kilometres.

A double circuit[1] 500 kV transmission line would be constructed along each of the above routes and electrical connections would be made at Wondalga to produce the following circuits:

- Maragle to Bannaby (5C1[2])
- Maragle to Gugaa (5C3)
- Gugaa to Bannaby (5C2)
- Gugaa to Wagga (6R/6P).

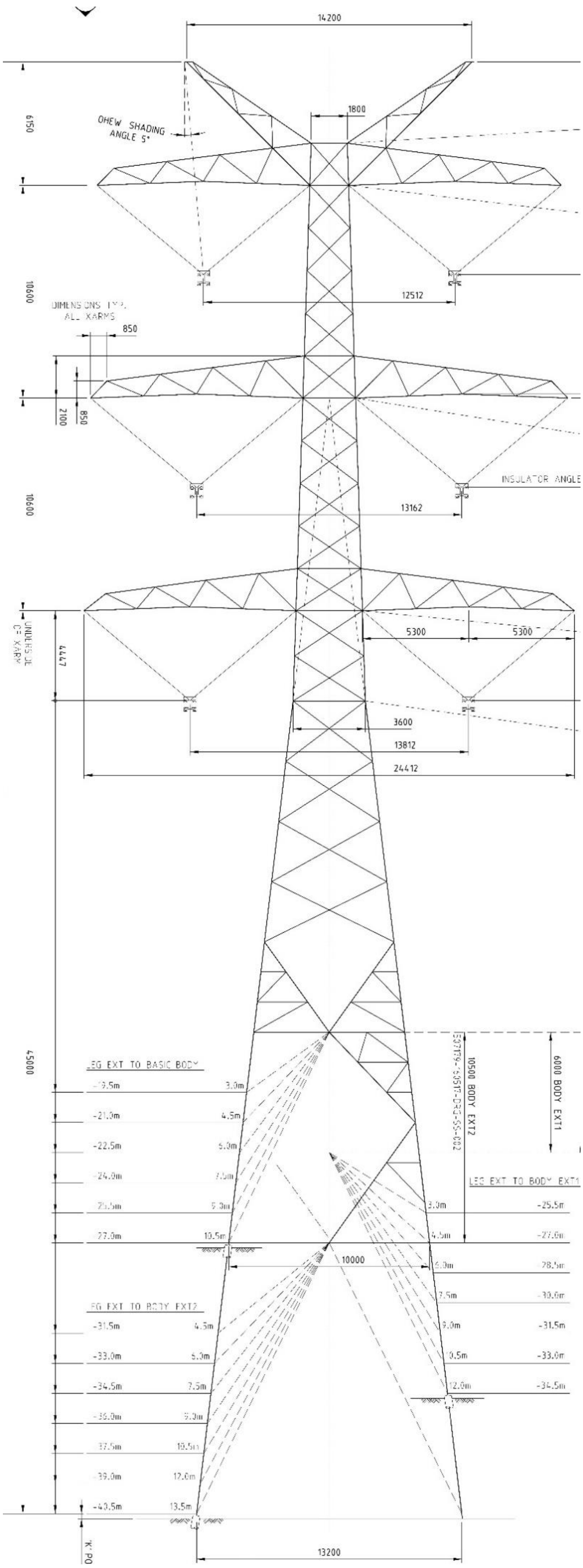
The above first three circuits would be formed by connecting the double circuit lines at Wondalga as shown in Table 1-1:

Table 1-1 | Composition of the various circuits

Circuit Name	Section to Wondalga	Section from Wondalga
Maragle to Bannaby	Eastern circuit of Maragle to Wondalga line	Southern circuit of Wondalga to Bannaby line
Maragle to Gugaa	Western circuit of Maragle to Wondalga line	Southern circuit of Wondalga to Gugaa line
Gugaa to Bannaby	Northern circuit of Wondalga to Gugaa line	Northern circuit of Wondalga to Bannaby line

An outline of a typical 500 kV double circuit structure is shown in Figure 1-3 below.

[1] *A double circuit transmission line comprises two 3 phase circuits, one on each side of the supporting lattice tower. Each of these circuits comprises three overhead conductor bundles which are arranged vertically as shown in* Figure 1-3*.*
[2] *For system control purposes, Transgrid allocates a code number (SCN) to each circuit on its high-voltage system.*

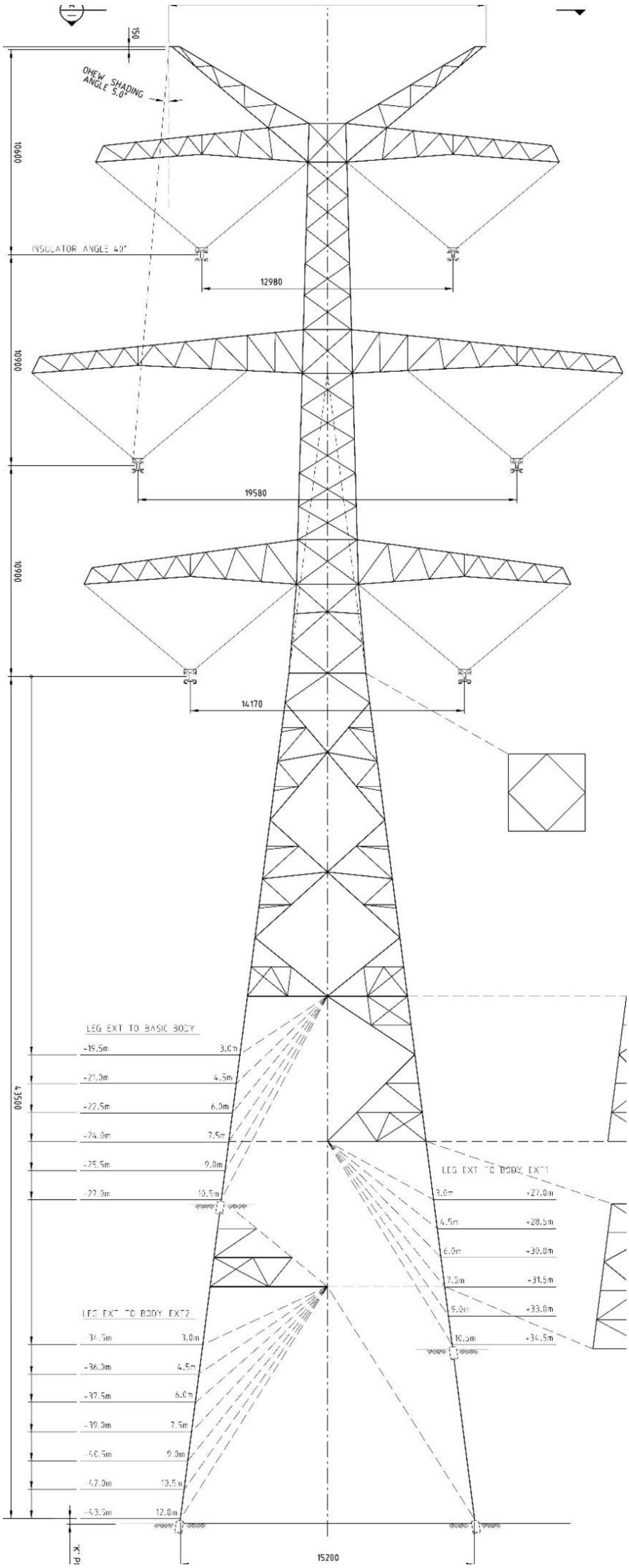


Tower type VSE
(extract from drawing TL-799081)

- Vertical phase separation = 10.6 m
- Circuit separation:
  - Top phase = 12.51 m,
  - Middle phase = 13.16 m and
  - Bottom phase = 13.81 m
- Shield wire separation = 14.2 m

Figure 1-3 | 500 kV double circuit structure (non-Alpine construction)

An outline of a 500 kV double circuit alpine structure is shown in Figure 1-4.



Tower type VSL
(extract from drawing TL-799084)

- Phase separation = 10.9 m
- Circuit separation:
  - Top phase = 12.98 m,
  - Middle phase = 19.57 m and
  - Bottom phase = 14.17 m
- Shield wire separation = 16.38 m

Figure 1-4 | 500 kV double circuit structure (Alpine construction)

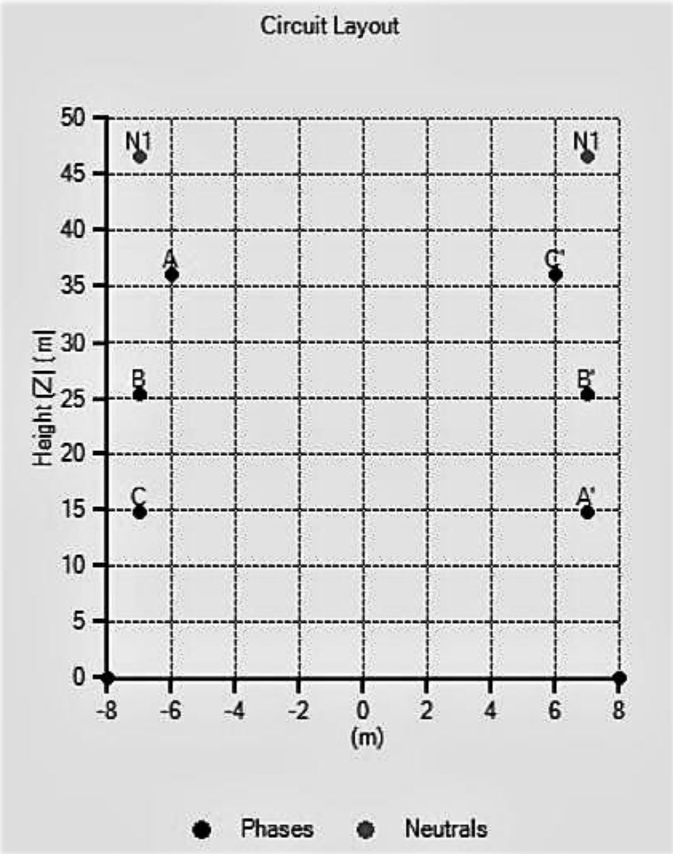


Figure 1-5 | Double circuit phasing arrangement

Aurecon has been engaged to calculate the electric and magnetic field (EMF) levels likely to be produced by the proposed lines and assess them against relevant health guidelines as part of the overall environmental impact assessment of the project.

1.3 Purpose and scope of this report

The scope of Aurecon's assessment relates to the transmission lines and is to encompass the following:

- provision of a brief description of EMF in relation to human health
- calculating the electric and magnetic fields for the proposed lines at one metre above ground level, extending up to 200 metres on each side of their centrelines and covering the suspension structure, conductor configurations and other relevant parameters associated with the transmission lines
- an assessment of the compliance of the anticipated field levels with the relevant national and international EMF guidelines
- an assessment of compliance of the proposed lines with precautionary and prudent avoidance principles as defined in the relevant guidelines
- preparation of a report covering the EMF assessment.

The EMF assessment for the purpose of the report has only been done for suspension structures of alpine (VSE) and non-alpine construction (VSL). It should be noted that tension structures would have larger circuit spacing than suspension structures and hence might result in higher Electric Field level. A worst-case scenario for tension structure has been modelled to check the compliance of electric field levels with the Basic Restrictions. However, further EMF assessment for tension structures would be carried out during detailed design.

The scope for this assignment is confined to transmission line EMF. The potential EMF and electrical phenomena at substations is addressed in the separate HumeLink Substation EMF Assessment, refer Table

1-2 . For radio interference and audible noise assessment, please refer to the HumeLink Audible Noise and Radio Interference Report as per Table 1-2.

1.4 Structure of this report

The structure and content of this report is as follows:

- Chapter 1 – Introduction: outlines the overview, key components and the purpose and scope of this report
- Chapter 2 – Project description summary: provides an outline and summary of the key components of the project
- Chapter 3 – Overview of electric and magnetic fields: provides a description of EMF and outlines the key guidelines relating to EMF
- Chapter 4 – Input information and aspects of field predictions: provides approach and assumptions used in the EMF modelling
- Chapter 5 – Field characterisation: presents the EMF modelling results
- Chapter 6 – Cumulative impacts - overcrossings and parallel sections: presents the cumulative EMF modelling results for representative cases of high voltage transmission line overcrossings and parallels
- Chapter 7 – Compliance with EMF guidelines and prudent avoidance principles: discusses compliance against the key guidelines relating to EMF and application of prudent avoidance.

1.5 HumeLink design documentation

Reference should be made to the below table for the Transgrid reference number associated with HumeLink design documents referenced within this report.

Drawings, spreadsheets, and models pertinent to the design are listed in full in Appendix A of the HumeLink Concept Design Report.

Table 1-2 | HumeLink design documentation

Document Title	Document Identifier
HumeLink Lines Safety in Design Report	TL-600228
HumeLink Concept Design Report	TL-799000
HumeLink Transmission Line Electrical and Magnetic Fields (EMF) Assessment *(this report)*	TL-799001
HumeLink Audible Noise and Radio Interference Report	TL-799002
Transmission Lines: Live Line Climbing - Electric and Magnetic Fields (EMF) Assessment	TL-799003
HumeLink Concept Design - Geotechnical Desktop Study	TL-799004
HumeLink Ice Loading Study Report	TL-799005
HumeLink Design Risk Report - Concept Design	TL-799006
Humelink Preliminary Conductor Selection and Structure Selection Report	TL-799007
HumeLink Substation EMF Assessment	TL-799008

2 Project description summary

The project description in this chapter is based on a concept design and indicative construction methodology for the project. The design and construction methodology would continue to be refined and confirmed during detailed design and construction planning by the construction contractors. Further details on the project are provided in Chapters 3 and 4 of the EIS.

2.1 Summary of key components of the project

Key components of the project are summarised in Table 2-1.

Table 2-1 | Summary of key components of the project

Component	Description
Transmission lines and supporting infrastructure	
Transmission lines and structures	The project includes the construction of new 500 kV transmission line sections between: ▪ Wagga 330 kV substation and Gugaa 500 kV substation (approximately 11 km) ▪ Gugaa 500 kV substation and Wondalga (approximately 65 km) ▪ Wondalga and Maragle 500 kV substation (approximately 46 km) ▪ Wondalga and Bannaby 500 kV substation (approximately 234 km). The transmission line section between the Wagga 330 kV substation and proposed Gugaa 500 kV substation would operate at 330 kV under HumeLink. The project also includes the rebuild of approximately 2 km of Line 51 as a new 330 kV transmission line between the Wagga 330 kV substation and around Ivydale Road, Gregadoo. This would be adjacent to the new transmission line between the existing Wagga 330 kV and proposed Gugaa 500 kV substations. The 500 kV transmission lines would be supported on a series of free-standing steel lattice structures that would range between around 50 m up to a maximum of 76 m in height and generally spaced between 300 to 600 m apart. The typical transmission line structure height would be around 60 m. Earth wire and communications cables would be co-located on the transmission line structures. The 330 kV structures for the rebuild of Line 51 would range between 24 m and 50 m in height and have a typical height of 40 m. Indicative configurations of transmission line structures that may be used as part of the project are shown in Figure 2-1. The type and arrangement of the structures would be refined during detailed design. The footings of each structure would require an area up to 450 m^2, depending on ground conditions and the proposed structure type. Additional disturbance at each structure site may be required to facilitate structure assembly and stringing.
Transmission line easements	The easements for the 500 kV transmission lines are typically 70 m wide. However, a number of locations may require wider easements of up to 110 m wide at transposition locations[3] and up to 130 m wide where the new transmission line would parallel the relocated section of Line 51. The easement provides a right of access to construct, maintain and operate the transmission line and other operational assets. The easement also generally identifies the zone of initial vegetation clearance and ongoing vegetation management to ensure safe electrical clearances during the operation of the lines. Vegetation management beyond the easement may also occur where nearby trees have the potential to fall and breach safety clearances.

[3] Transposition is the periodic swapping of positions of the conductors of a transmission line in order to improve transmission reliability.

Component	Description
Telecommunications huts	Telecommunications huts, which contain optical repeaters, would be required to boost the signal in the optical fibre ground wire (OPGW). One telecommunications hut would be required for the project. The telecommunications hut would be located adjacent to existing transmission line structures. Cables would be installed between the transmission line structure and the local power supply. The telecommunications hut would be surrounded by a security fence. A new easement would be established for the telecommunications hut power connection. The project also involves a telecommunications connection of OPGW between two proposed transmission line structures and the future Rye Park Wind Farm substation (SSD-6693). This removes the need for an additional telecommunications hut in this area of the project.
Substation activities	
Construction of the proposed Gugaa 500 kV substation	A new 500/330 kV substation would be constructed at Gregadoo, about 11 km south-east of the Wagga 330 kV substation. The substation would include seven new 500/330 kV transformers and three 500 kV reactors. The proposed Gugaa 500 kV substation is expected to occupy an area of approximately 22 hectares
Modification of the existing Bannaby 500 kV substation	The existing Bannaby 500 kV substation on Hanworth Road, Bannaby would be expanded to accommodate connections for new 500 kV transmission line circuits. The modification would include changes to the busbars, line bays, bench and associated earthworks, steelwork, drainage, external fence, internal/external substation roads, secondary containment dams, sediment containment dams, cabling, and secondary systems. All of the work would be restricted to the existing substation property.
Modification of the existing Wagga 330 kV substation	The existing Wagga 330 kV substation on Ashfords Road, Gregadoo would be reconfigured to accommodate new bays for two new 500 kV transmission line circuits within the existing substation property. This would include modifications to the busbars, line bays, existing line connections, bench and associated earthworks, relocation of existing high voltage equipment, drainage, external fence, internal substation roads, steelwork, cabling, and secondary systems.
Connection to the future Maragle 500 kV substation	The project would connect to the future Maragle 500 kV substation approved under the Snowy 2.0 Transmission Connection Project (SS1-9717). Construction of the Maragle substation is proposed to be undertaken between 2023 and 2026. Further detail on the Snowy 2.0 Transmission Connection project is available at the Department of Planning and Environment's Major Projects website: www.planningportal.nsw.gov.au/major-projects/project/10591.
Ancillary facilities	
Access tracks	Access to the transmission line structures and the substations would be required during construction and operation. Wherever possible, existing roads, tracks and other existing disturbed areas would be used to minimise vegetation clearing or disturbance. Upgrades to existing access tracks may be required. In areas where there are no existing roads or tracks, suitable access would be constructed. This may include waterway crossings.
Construction compounds	Construction compounds would be required during construction to support staging and equipment laydown, concrete batching, temporary storage of materials, plant and equipment and worker parking required to construct the various elements of the project. Fourteen potential construction compound locations have been identified. The proposed use of the construction compounds and their proposed boundaries/layout would be refined as the project design develops in consultation with relevant stakeholders and the construction contractors.

Component	Description
Worker accommodation facility	Existing accommodation facilities within towns adjacent to the project would provide temporary accommodation for the majority of the construction workers. However, a potential shortage in accommodation has been identified close to the project footprint. A potential option to provide additional temporary worker accommodation during the construction period is the establishment of a temporary worker accommodation facility at the corner of Courabyra Road and Alfred Street, Tumbarumba to accommodate about 200 construction workers. The worker accommodation facility would consist of demountable cabins and would be connected to existing utilities. All required amenities for the accommodation facility would be provided including services and worker parking for light and heavy vehicles. However, the ultimate delivery of the project may include multiple temporary worker accommodation facilities in various forms, which would be outlined in the Worker Accommodation Strategy for the project. The strategy will be developed in consultation with councils, and other relevant stakeholders. Any new or changed worker accommodation facility would be subject to additional environmental assessment, as required.
Helipad/helicopter facilities	To facilitate construction of the project, helicopters may be used to deliver materials/equipment and transfer personnel to construction areas particularly within high alpine regions. To enable helicopters to operate safely and allow easy access to the site, a helicopter landing pad would be required. The helipad is expected to occupy an area of around 30 m by 30 m and would be remediated after construction. These areas would typically be located on existing disturbed land not subject to inundation and a reasonable distance from waterways, sensitive receivers and drainage lines. Eight locations have been identified and assessed as potential helipad locations. The exact locations to be used would be confirmed during detailed design by the construction contractors. In addition to this, the existing facilities at the Wagga Wagga Airport and Tumut Airport may be used.
Utility connections, adjustments and protection	The project would require utility connections, adjustments and protection. Such works include interfaces with other transmission lines and connections to existing services for temporary facilities. Potential impacts to existing services and utilities would be confirmed during detailed design and any proposed relocation and/or protection works would be determined in consultation with the relevant asset owners.

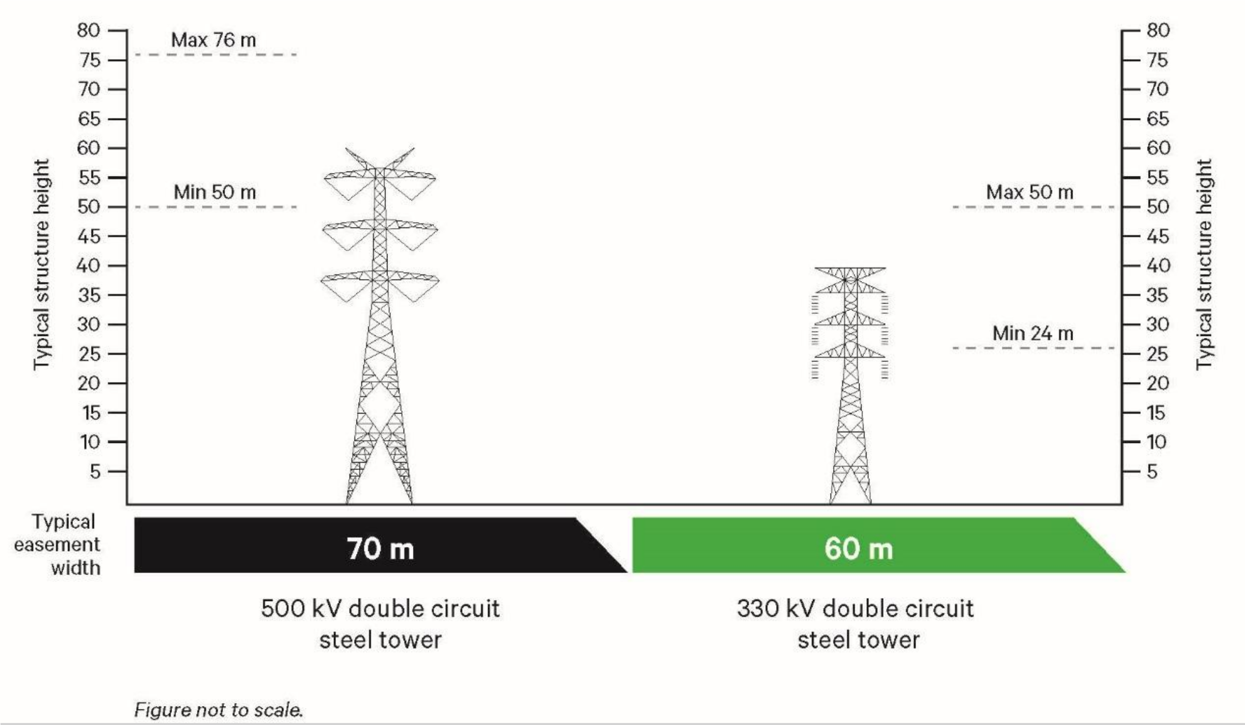


Figure 2-1 | Indicative transmission line structures

2.2 Construction of the project

2.2.1 Construction activities

- Key construction activities would generally include (but are not limited to):
  - site establishment work, such as:
  - clearing of vegetation and topsoil
  - establishment of construction compounds and helipad/helicopter facilities
  - utility relocations and/or adjustments
  - construction of new access tracks and waterway crossings and/or upgrade of existing access tracks to transmission line structures
  - road improvement work
  - establishment of environmental management measures and security fencing
  - construction of temporary worker accommodation
- construction of the transmission lines, including:
  - earthworks and establishment of construction benches and brake and winch sites for each transmission line structure
  - construction of footings and foundation work for the new transmission line structures including boring and/or excavation, steel fabrication works and concrete pours
  - erection of the new transmission line structures
  - stringing of conductors, overhead earth wires and OPGW
  - installation of associated transmission line structure fittings inclusive of all earthing below ground level
- relocation of a section of Line 51, including:
  - demolition of the existing section of Line 51

- erection of new transmission line structures for the rebuild of Line 51 in a new location
    - stringing of conductors, overhead earth wires and OPGW
    - installation of associated transmission line structure fittings inclusive of all earthing below ground level
- construction of the proposed Gugaa 500 kV substation, including:
    - bulk earthworks to form the substation bench, access roads, drainage and oil containment structures
    - installation of concrete foundations, bund walls, fire walls, noise walls and kerbs including excavation
    - installation of reinforced concrete and piled foundations for the electrical equipment and associated steel support structures
    - installation of electrical conduits, electrical trenches, site stormwater drainage, oil containment work and associated concrete pits, pipes and tanks including excavation
    - installation of new ancillary and equipment control buildings
    - erection of galvanised steel structures to support electrical equipment
    - installation of electrical equipment on foundations and/or steel support structures
    - installation of conductors, cabling, wiring, electrical panels and electrical equipment
    - erection of the substation site boundary security fencing, including site access gates
    - connection of the proposed transmission lines to the substation
- modification of the existing Wagga 330 kV substation to enable the proposed connection and operation of the new transmission lines, including:
    - demolition and removal of redundant electrical equipment, fencing and cabling
    - bulk earthworks to form the extended substation bench and modified drainage structures
    - installation of concrete foundations and kerbs including excavation
    - installation of reinforced concrete and piled foundations for the electrical equipment and associated steel support structures
    - erection of galvanised steel structures to support electrical equipment
    - installation of electrical equipment on foundations and/or steel support structures
    - installation of electrical conduits, electrical trenches, and modified site stormwater drainage including excavation
    - installation of conductors, cabling, wiring, electrical panels and electrical equipment
    - installation of fencing, lighting and other security features
    - testing and commissioning
    - connection of the proposed transmission lines to the substation
- modification of the existing Bannaby 500 kV substation to enable the proposed connection and operation of the new transmission lines, including:
    - bulk earthworks to form the extended substation bench, new access road, modified stormwater drainage, modified oil containment and modified sediment control structures
    - installation of concrete foundations, retaining walls, bund walls, fire walls and kerbs including excavation
    - installation of reinforced concrete and piled foundations for the electrical equipment and associated steel support structures
    - erection of galvanised steel structures to support electrical equipment
    - installation of electrical equipment on foundations and/or steel support structures

  - installation of electrical conduits, electrical trenches, site stormwater drainage, oil containment works and associated concrete pits, pipes and tanks including excavation
  - installation of conductors, cabling, wiring, electrical panels and electrical equipment
  - installation of fencing, lighting and other security features
  - demolish redundant fencing including footings and kerbs
  - testing and commissioning
  - connection of the proposed transmission lines to the substation
- connection of the proposed transmission lines to the future Maragle 500 kV substation, including:
  - stringing conductors between transmission line structures and the future Maragle 500 kV substation gantry (including overhead earth wire (OHEW) and OPGW)
  - installing droppers from the future substation gantry to the switchgear
- construction of the telecommunications hut, including:
  - bulk earthworks to form the pad for the hut
  - excavation and preparation for concrete foundations
  - installation of reinforced concrete and piled foundations
  - excavation and installation of electrical equipment conduits, trenches and general site drainage work
  - installation of the building, site wiring and electrical equipment
  - installation of security fencing and site access gates
- installation of buried cabling from the 500 kV transmission line structures to Rye Park Wind Farm substation
- testing and commissioning of new electrical infrastructure
- demobilisation and rehabilitation of areas disturbed by construction activities.

A number of activities are expected to commence in accordance with the project conditions of approval before the key construction activities outlined above. These activities are considered pre-construction minor work and would comprise low impact activities that would begin after planning approval but prior to approval of the Construction Environmental Management Plan.

2.2.2 Construction program

Construction of the project is targeted to commence in 2024 and is estimated to take about 2.5 years to complete. The project is expected to be fully operational by the end of 2026 (refer to Figure 2-2).

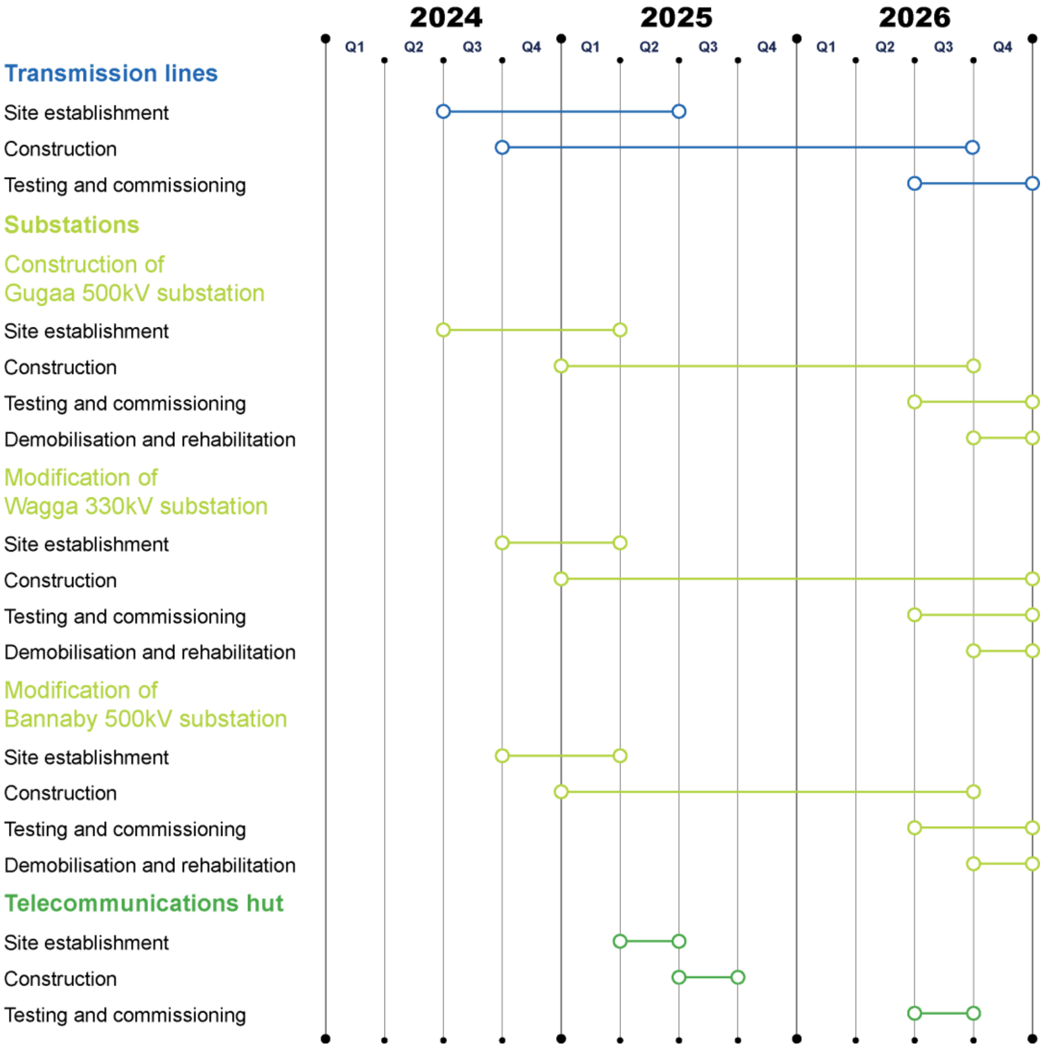


Figure 2-2 | HumeLink indicative construction program

2.2.3 Indicative duration of construction activities

Construction at each transmission line structure would be intermittent and construction activities would not occur for the full duration at any one location. Durations of any particular construction activity, and inactive/respite periods, may vary for a number of reasons including (but not limited to):

- multiple work fronts
- resource and engineering constraints
- work sequencing and location.

Figure 2-3 presents an indicative duration of construction activities associated with an individual transmission line structure.

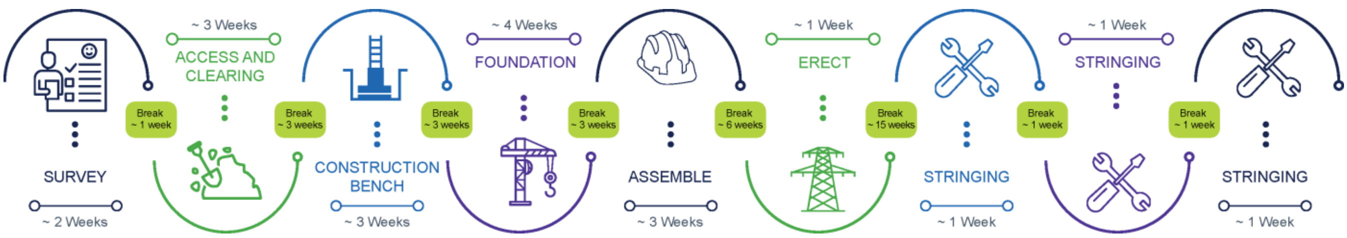


Figure 2-3 | Indicative duration and sequence of construction activities for transmission line structures

Construction of the proposed Gugaa 500 kV substation could take up to 2.5 years.

2.2.4 Construction hours

It is expected that construction activities would largely be undertaken during standard construction hours. However, there would be times when working outside of standard construction hours would be required (as defined by the *Interim Construction Noise Guideline* (DECC, 2009)), subject to approval. As the details of construction methodology and project needs are developed, these hours will be refined for certain activities.

Where extended hours are proposed for activities in proximity to sensitive receivers, additional measures would be implemented and the work would be managed through an out-of-hours work protocol.

A series of work outside the standard construction hours is anticipated to include (but is not limited to) the following:

- transmission line construction at crossings of a main road or railway as these locations are expected to have restricted construction hours requiring some night work for activities such as conductor stringing over the crossing(s)
- work where a road occupancy licence (or similar) is required, depending on licence conditions
- transmission line cutover and commissioning
- the delivery of equipment or materials outside standard hours requested by police or other authorities for safety reasons (such as the delivery of transformer units)
- limited substation assembly work (eg oil filling of the transformers)
- connection of the new assets to existing assets under outage conditions (eg modification and/or connection work at Bannaby 500 kV substation, Wagga 330 kV substation and Maragle 500 kV substation), which is likely to require longer working hours
- emergency work to avoid the loss of lives and/or property and/or to prevent environmental harm
- work timed to correlate with system planning outages
- situations where agreement is reached with affected sensitive receivers
- activities that do not generate noise in excess of the applicable noise management level at any sensitive receiver.

2.2.5 Construction plant and equipment

An indicative list of construction plant and equipment likely to be required during construction is provided below.

- air compressors
- backhoe
- bobcat
- bulldozers
- concrete agitator
- concrete pump
- cranes (various sizes up to 400 tonnes)
- crawler crane with grab attachments
- drill and blast units and associated support plant/equipment
- drones
- dumper trucks
- elevated working platforms
- excavators (various sizes)
- flatbed Hiab trucks
- fuel trucks
- generators
- graders
- helicopter and associated support plant/equipment
- mulchers
- piling rig
- pneumatic jackhammers
- rigid tippers
- rollers (10-15 and 12-15 tonnes)
- semi-trailers
- tilt tray trucks
- trenchers
- transport trucks
- watercarts
- winches.

2.2.6 Construction traffic

Construction vehicle movements would comprise vehicles transporting equipment, waste, materials and spoil, as well as workers' vehicles. A larger number of heavy vehicles would be required during the main civil construction work associated with the substations. Non-standard or oversized loads would also be required for the substation work (eg for transformer transport) and transportation of transmission line structure materials and conductors.

Hume Highway, Sturt Highway, Snowy Mountains Highway, Batlow Road and Gocup Road are the main national and state roads proposed to provide access to the project footprint. These roads would be supported by regional and local roads throughout the Local Government Areas (LGAs) of Wagga Wagga City, Snowy Valleys, Yass Valley, Cootamundra-Gundagai Regional and Upper Lachlan Shire that connect to the project footprint.

2.2.7 Construction workers

The construction worker numbers would vary depending on the stage of construction and associated activities. During peak construction activities, the project could employ up to 1,200 full time equivalent construction workers across multiple work fronts. It is expected that the maximum number of construction workers at any one location would not exceed 200.

2.2.8 Testing and commissioning

Prior to energisation of the infrastructure, a series of pre-commissioning activities would be conducted. This would include testing the new transmission lines and substation earthing, primary and secondary equipment.

2.2.9 Demobilisation and rehabilitation

Demobilisation and site rehabilitation would be undertaken progressively throughout the project footprint and would include the following typical activities:

- demobilisation of construction compounds and worker accommodation facility
- removal of materials, waste and redundant structures not required during operation of the project
- removal of temporary fencing and environmental controls.

2.3 Operation and maintenance

The design life of the project is 50 years, which can be extended to more than 70 years for some assets.

The substations and transmission lines would be inspected by field staff and contractors on a regular basis, with other operational activities occurring in the event of an emergency (as required). The project would require about five workers (in addition to Transgrid's existing workers) during operation for ongoing maintenance activities. Likely maintenance activities would include:

- regular inspection (ground and aerial) and maintenance of electrical equipment
- general building, asset protection zone and access road/track
- vegetation clearing/trimming within the easement
- fire detection system inspection and maintenance
- stormwater drainage systems maintenance.

It is expected that these activities would only require light vehicles and/or small to medium plant (depending on the work required).

3 Overview of electric and magnetic fields

3.1 General description

Whenever electrical equipment is in service, it produces an electric field and a magnetic field. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric wires. Being related to voltage, the electric fields associated with high voltage equipment remain relatively constant over time, except where the operating voltage changes. Conversely, being related to current, the magnetic field strength resulting from an electrical installation varies continually with time as the load on the equipment varies.

The electric and magnetic fields associated with electrical equipment, whilst interrelated, are not dependent on each other and as such can exist independently.

Further detail on EMFs can be found in Attachment A.

3.2 Electric and magnetic fields and health

It is known that EMFs at magnitudes much higher than those encountered in everyday life can interact with the central nervous system. In addition, the possibility of adverse health effects due to the much lower EMFs associated with electrical equipment has been the subject of extensive research throughout the world for more than 40 years.

To date, adverse health effects due to fields of the levels normally associated with electrical infrastructure, have not been established. However, due to a body of epidemiological evidence, the possibility that such effects may exist has not been ruled out.

3.2.1 Summary of health effects

While EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields. Nevertheless, high electric field strengths, such as those associated with the highest voltage transmission lines or high voltage equipment in major substations, can approach a level at which “nuisance shocks” can occur and this phenomenon needs to be managed. This can be done via easement and fencing guidelines and the adoption of the exposure guidelines described in the next section.

Magnetic fields are not readily shielded, are more ubiquitous and remain the subject of some debate. Accordingly, much of the health research has been directed towards magnetic fields.

A large number of studies have been conducted over many years to investigate the possibility of adverse health consequences from extremely low frequency electric and magnetic fields. These studies have addressed a wide range of end points including childhood leukaemia, other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease. The most recent scientific reviews by authoritative bodies are reassuring for most potential health end points. However, statistical associations between prolonged exposure to elevated magnetic fields and childhood leukaemia have persisted. This led the International Agency for Research on Cancer (IARC) (Ref. B-1) in 2002 to classify magnetic fields as a “possible carcinogen”, a categorisation used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals.

The fact that, despite over 30 years of laboratory research, no mechanism for an effect has been established, lends weight to the possibility that the observed statistical associations reflect some factor other than a causal relationship. This point is made in the 2001 report of the UK National Radiological Protection Board’s (NRPB) Advisory Group, chaired by eminent epidemiologist, the late Sir Richard Doll (Ref. B-2) *"in the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children." (page 164)*

Further discussion of the above including footnotes can be found in Attachment B.

3.3 Health guidelines

Since late 2015, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)[4] , has adopted the *Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz))* published by the International Commission on Non-Ionising Radiation Protection (ICNIRP) in 2010. In adopting the ICNIRP Guidelines ARPANSA noted:

"The ICNIRP ELF guidelines are consistent with ARPANSA's understanding of the scientific basis for the protection of the general public (including the foetus) and workers from exposure to ELF EMF." (Ref. C-2)

The ICNIRP Guideline sets 'Basic Restrictions', which are derived from the levels at which interactions with the central nervous system (CNS) are established, with a safety factor applied. The Basic Restrictions are expressed in terms of electric field levels within the human body but, as these levels can only be assessed by sophisticated computer modelling of the body, ICNIRP also sets 'Reference Levels', expressed in terms of kV/m and microtesla[5] for electric and magnetic fields respectively. These levels are conservatively set such that, provided they are met, the Basic Restrictions would also be met without the need for more comprehensive analysis. The ICNIRP 'Basic Restrictions' and 'Reference Levels' for the general public are reproduced in Attachment C and Table 3-1. As noted above, these criteria apply to both adults and children and are independent of duration of exposure.

Table 3-1 | ICNIRP Guideline levels (general public)

Parameter	Basic Restriction (Volts per metre)	Reference Level
Electric field	CNS tissue of the head: 0.02 All tissue of head and body: 0.4	5,000 Volts per metre (V/m)
Magnetic field		2,000 milligauss (mG)

In applying the ICNIRP Guideline, it is important to recognise that the numerical limits, eg 2,000 mG, are based on established health effects. In ICNIRP's fact sheet on the guidelines (Ref. C-3), it notes that:

"It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency Magnetic Fields is causally related with an increased risk of childhood leukaemia is too weak to form the basis for exposure guidelines. Thus, the perception of surface electric charge, the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes are the only well-established adverse effects and serve as the basis for guidance."

Being based on established biological effects (which occur at field levels much higher than those normally encountered in the vicinity of electrical equipment), the (numerical) exposure limits in the guidelines and standards cannot be said to define safe limits for possible health effects, should these exist, from magnetic fields at levels normally encountered in the vicinity of electrical equipment.

While the magnetic fields from high voltage transmission lines are normally well below the ICNIRP Reference Level, the electric fields may not be. It is Transgrid's policy to always comply with the ICNIRP Guidelines and to meet the general public Reference Level for electric fields (5 kV/m) where possible. However, as transmission lines of 330 kV and higher can exceed the Reference Level in some locations, it is necessary to assess them further to determine compliance with Basic Restrictions.

Accordingly, Transgrid commissioned a specialist consultant (Exponent Inc.) to undertake the sophisticated dosimetric analysis required to assess compliance with the Basic Restrictions. Based on this analysis

[4] *ARPANSA is the Australian government agency that is charged with the responsibility, inter alia, for protecting the health and safety of people and the environment from EMF.*

[5] *Magnetic fields are often expressed in units of milligauss, where 1 milligauss is equal to 0.1 microtesla. The units used for this report are milligauss.*

Transgrid has established that for large transmission lines (330 kV and 500 kV), compliance with the 0.02 V/m Basic Restriction is maintained where the electric field does not exceed 9.1 kV/m.

Accordingly, the principal compliance criteria used for this assignment are:

- magnetic fields: 2,000 milligauss (mG) being the ICNIRP Guideline 'Reference Level'
- electric fields: 9.1 kV/m, ensuring compliance with the ICNIRP Guideline 'Basic Restriction'.

3.4 Prudent avoidance

Given the inconclusive nature of the science regarding EMF at levels commonly associated with electrical equipment and human health, it is widely considered that a prudent approach is the most appropriate response under the circumstances. Prudent avoidance is a precautionary concept developed to address the possibility of health effects from prolonged exposure to field levels much lower than those for which effects have been established.

Under this approach, subject to modest cost and reasonable practicality, the owners of electric power infrastructure should design their facilities to reduce the intensity of the fields they generate in frequented areas where prolonged[6] exposure is possible. Further general discussion on this subject can be found in Attachment D and the implications for this assessment are discussed in Section 7.2.

3.5 Medical implants

In addition to direct interactions with the human body, EMFs also have the potential to interfere with active implanted medical devices (AIMDs) such as cardiac pacemakers, insulin pumps etc. A wide variety of devices are used in modern medicine and, due to the multiplicity of EMF sources in the modern environment, they are generally subject to standards regarding immunity from interference.

In Europe, the relevant European Directive (90/385/EEC) requires designers and manufacturers of AIMDs to make them immune to interference in "reasonably foreseeable" circumstances. The relevant European Standard (CENELEC 50527-1) interprets this as meaning that devices should be immune from interference up to the ICNIRP general public reference levels. Similar requirements apply in the UK. However, as the magnetic field reference level at the time of the European directive was 1000 mG, rather than the present 2,000 mG, it is customary to assume that AIMDs should be immune to interference from magnetic fields only up to 1000 mG.

The relevant Australian Standard (AS 45502-1: 2002), which was reproduced from a European Standard (EN 45502-1: 1997), stipulates that AIMDs be immune from risks connected with reasonably foreseeable environmental conditions such as magnetic fields, external electrical influences etc. In that context, as a first guide, the Australian Standard cites a magnetic intensity of 150 Amps/metre[7] (1,885 mG).

Accordingly, as the highest magnetic fields associated with 500 kV transmission lines are of the order of a 'few hundred mG', from a practical perspective, AIMDs which comply with the relevant Standards should be immune from transmission line interference. Nevertheless, concerned wearers of AIMDs should consult their treating physician for further information or advice.

In the case of hearing aids or cochlear implants, it is possible for audible interference ("buzzing") to be experienced within the transmission line easement or directly below the conductors, but this will not damage the devices or the ear (British Cochlear Implant Group, 2020).

[6] *In this context, prolonged exposure is taken as the time-weighted average exposure, measured over a period of months or years, rather than days or weeks*

[7] *In air or human tissue, a magnetic field intensity of 150 A/m is equivalent to a magnetic flux density of 1885 milligauss.*

3.6 Animals and plants

As well as potential effects on humans, the possibility of EMF effects on plants and various animals, including cows, sheep, pigs and horses has been studied over the years, particularly in the 1970s and 1980s. A smaller number of studies have also been reported since that time.

3.6.1 Gibbs Inquiry

In 1991, the late Sir Harry Gibbs, a former Chief Justice of the High Court of Australia published the findings of an extensive inquiry into community needs and high voltage transmission line development.

As part of the Inquiry, he reviewed the body of research on the possibility of effects on native flora and fauna, farm animals and plants and reported his conclusions in Chapter 6.6 of his report (Ref D-1) as follows:

> *'Bees in hives under or near transmission lines are adversely affected by shocks created by currents induced by the lines but the effect can be mitigated by shielding'*
>
> *'The Magnetic Fields created by power lines do not affect the health or reproductive capacity of farm animals or present a danger to native fauna.'*
>
> *'The growth of trees which are close to a transmission line may be reduced by the effect of corona[8]. In any case, the height of trees on a transmission line easement will be restricted when this is necessary in the interest of safety. Any loss which this causes to the landowner should be included in the compensation paid for the acquisition of the easement. …..'*
>
> *'From a practical point of view, the Electric Fields created by transmission lines have no adverse effects on crops, pasture grasses or native flora, other than trees growing under or near to the line.'*

His summary conclusion was:

> *'No reason exists for concern as to the effect of the fields on animals or plants.'*

3.6.2 United Kingdom EMF National Policy Statement

More recently than Sir Harry Gibbs, in July 2011, the UK Government adopted a National Policy Statement (NPS EN-5) for Electricity Networks Infrastructure. This NPS, taken together with the Overarching National Policy Statement for Energy (EN-1), provides the primary basis for decisions taken by the UK Infrastructure Planning Commission (IPC) on applications it receives for electricity networks infrastructure.

In Clause 2.10.8, the NPS states:

> *'There is little evidence that exposure of crops, farm animals or natural ecosystems to transmission line EMFs has any agriculturally-significant consequences.'*

3.6.3 Birdlife

While birds often perch on the conductors of lower voltage lines, they do not perch on 100 kV or higher voltage transmission line conductors, but some species perch or nest on the supporting structures. Perhaps for this reason, over the years, there have been numerous studies on potential effects of EMF on a number of avian health endpoints. In 2005, Fernie and Reynolds (2005) published a review of bird studies, both under aviary conditions and free ranging. They found that

> *"most studies indicate that EMF exposure of birds generally changes, but not always consistently in effect or direction, their behaviour, reproductive success, growth and development, physiology and endocrinology, and oxidative stress under EMF conditions."*

---

[8] *For this to happen, the leaves have to be sharp and pointy eg as on conifers, rather than rounded. Due to the nature of Australian vegetation and easement clearing practices, leaf-tip corona has not been an issue in Australia.*

3.6.4 Australian Government National Standard for Organic and Bio-Dynamic Produce

The Australian Government National Standard for Organic and Bio-Dynamic Produce (Edition 3.7, 2016) does not mention powerlines, electric or magnetic fields (Department of Agriculture and Water Resources, 2016). Section 1.25.2 of the Standard states:

> *"Bio-dynamic Preparations[9] are to be stored in a suitable container away from fumes, electricity, contamination sources."*

The project is not located within proximity of any known storage areas and is therefore not considered to impact on organic or bio-dynamic certification[10].

[9] *Bio-dynamic preparations are for the purpose of improving soil fertility and are regulated by Australian Government National Standard for Organic and Bio-Dynamic Produce. Bio-dynamic preparations are designed to work directly with the dynamic biological processes and cycles which are the basis of soil fertility. However, they are not fertilisers themselves.*

[10] *Procedures by which an approved certifying body under Department of Agriculture, Fisheries and Forestry provides written assurance that an operator has been determined to conform to the Australian Government National Standard for Organic and Bio-Dynamic Produce and allows biodynamic practices.*

4 Input information and aspects of field predictions

4.1 Input information

The input data required for the calculations on which this assessment is based has been obtained from various sources, as follows:

Transgrid

- Transmission line routes
- Easement widths
- Transmission line loadings
- Details of other Transgrid assets in proximity to the proposed transmission lines

Aurecon

- Construction types
- Structure details
- Conductor details and ground clearances.

The transmission line has been divided into various sections for analysis. The type of construction for the various sections of the transmission line routes shown in Figure 1-1 are described separately below:

- Maragle-Wondalga line: The transmission line between Maragle and Wondalga would be of double circuit 500 kV construction, situated on a 70-metre-wide easement. The structures in this section of transmission line would be lattice towers to an alpine design for the first 47 kilometres towards Wondalga, with the remaining 4 kilometres being of non-alpine construction.
- Wondalga-Gugaa line and Wondalga-Bannaby line: Each of these two transmission lines would be of non-alpine double circuit 500 kV construction, situated on a 70-metre-wide easement.
- Gugaa-Wagga line: The transmission line between Gugaa and Wagga would be of non-alpine double circuit 500 kV construction, situated on a 70-metre-wide easement. The 500 kV transmission line would operate at 330 kV. Any future energisation at 500 kV would be subject to further assessment and approval.

4.2 Approach

To gain a comprehensive understanding of the EMF contributions of the proposed transmission lines, the predicted EMF levels associated with the various sections of the HumeLink transmission lines have been modelled separately as follows:

- Maragle-Wondalga line (alpine construction)
- Wondalga-Gugaa line (non-alpine construction)
- Wondalga-Bannaby line (non-alpine construction)
- Gugaa-Wagga line (non-alpine construction).

The EMF produced by a double circuit transmission line is influenced, inter alia, by the magnitudes and directions of the currents in the two circuits. In selecting the load conditions to be modelled for this assessment, Aurecon has examined the various possible combinations of load currents and directions for each transmission line and, for the purposes of reporting, has selected the case which results in the highest magnetic fields.

In all cases, fields have been modelled at a height of one metre above ground level in accordance with international standards.

In addition to the individual transmission lines, custom modelling has been undertaken in four selected locations where a proposed transmission line crosses an existing major transmission line or runs parallel to it. This modelling is sufficient to provide a broad understanding of the effect of parallels and undercrossings and demonstrate that it is relatively insignificant. If necessary, or if requested by a stakeholder, custom modelling could be undertaken at a later date, when all relevant transmission line details are finalised. Table 4-1 and Table 4-2 set out the total listing of undercrossings and parallels.

Table 4-1 | List of undercrossing assets

Proposed HumeLink line section	Undercrossing asset
500 kV double circuit alpine Maragle-Wondalga	330 kV single circuit Lower Tumut-Murray 66
500 kV double circuit alpine Maragle-Wondalga	330 kV single circuit Lower Tumut-Upper Tumut 64
500 kV double circuit alpine Maragle-Wondalga	330 kV single circuit Lower Tumut-Wagga 51
500 kV double circuit Wondalga-Gugaa	330 kV single circuit Lower Tumut-Wagga 51
500 kV double circuit Wondalga-Bannaby	132kV single circuit Tumut-Gadara 99P
500 kV double circuit Wondalga-Bannaby	132kV single circuit Wagga-Yass 990
500 kV double circuit Wondalga-Bannaby	132kV single circuit Yass-Murrumburrah 99M
500 kV double circuit Wondalga-Bannaby	132kV single circuit Cowra-Yass 973
500 kV double circuit Wondalga-Bannaby	132kV single circuit Yass-Cowra 999
500 kV double circuit Wondalga-Bannaby	330 kV single circuit Bannaby-Crookwell Wind Farm 61
500 kV double circuit Wondalga-Bannaby	330 kV single circuit Crookwell-Gullen Range Wind Farm 3H
500 kV double circuit Wondalga-Bannaby	330 kV single circuit Gullen Range Wind Farm-Yass 3J

Table 4-2 | List of parallel assets

Proposed HumeLink line section	Parallel asset
500 kV double circuit alpine Maragle-Wondalga	330 kV single circuit Lower Tumut-Upper Tumut 64
500 kV double circuit alpine Maragle-Wondalga	330 kV single circuit Lower Tumut-Murray 66
500 kV double circuit alpine Maragle-Wondalga	330 kV single circuit Lower Tumut-Wagga 51
500 kV double circuit alpine Maragle-Wondalga	330 kV single circuit Lower Tumut-Yass 3
500 kV double circuit Wondalga-Gugaa	330 kV single circuit Lower Tumut-Wagga 51
500 kV double circuit Wondalga-Bannaby	330 kV single circuit Lower Tumut-Yass 3
500 kV double circuit Wondalga-Bannaby	330 kV single circuit Bannaby-Crookwell 61
500 kV double circuit Wondalga-Bannaby	330 kV single circuit Crookwell-Gullen Range 3H
500 kV double circuit Wondalga-Bannaby	330 kV single circuit Gullen Range-Yass 3J
500 kV double circuit Wondalga-Bannaby	500 kV double circuit Mt. Piper-Bannaby 5A6 & 5A7
500 kV double circuit Gugaa-Wagga	330 kV single circuit Lower Tumut-Wagga 51

As noted in Attachment A while EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields.

Accordingly, while electric field levels have been calculated and assessed, the magnetic fields are addressed in more detail. In particular, it has been possible to group some of the transmission line sections having similar electric field characteristics together and model two operating scenarios for each whereas, for the magnetic fields, four or five different loading scenarios have been modelled separately for each section of transmission line.

4.3 Data and assumptions for modelling

The following assumptions have been made in undertaking the EMF modelling:

- Where future load forecasts have been provided in megawatt (MW), Transgrid has advised that this can be treated as megavolt-ampere (MVA).

- Ground clearances have been taken as mid-span values, where the maximum conductor sag typically occurs. This is a conservative assumption. The ground clearances taken for modelling the fields in the report are shown in the table below. The clearance at emergency peak is a minimum clearance, increased over the Transgrid standard 11 metre design ground clearance, that would ensure compliance with the required 9.1 kV/m E field limit. The remaining ground clearances are calculated from the conductor characteristics and design tensions for a typical span (450 metre for non-alpine and 380 metre for alpine), where the conductor temperature is set to 105°C at emergency peak, 62°C at system normal peak and 39°C at time-weighted average. (The emergency peak ground clearance is lower than the design ground clearance, which has additional allowances for modelling methods included).

Table 4-3 | Assumed ground clearances for different load condition

Load condition	Ground clearance (m)		
	Non-alpine construction	*Alpine construction*	*Tension structure*
Time-weighted average (TWA)	14.5	14.2	13.9
System normal peak	13.6	13.4	13
Emergency peak	12	11.9	11.7

- The transmission lines are designed to have a low reactance phasing arrangement in accordance with Transgrid's policy of prudent avoidance. The phasing arrangement used to model field levels in the report is shown in Figure 1-5.
- The loadings in the existing transmission lines have been taken as the average and system normal peak values as applicable, derived from comprehensive load records provided by Transgrid.
- The projected loadings, spanning the period 2024/5 to 2044/5, and used for modelling of the proposed 500 kV transmission lines have been provided separately by Transgrid. These are summarised in Table 4-4.

Table 4-4 | 500 kV circuit loadings (in Amps) provided by Transgrid

Circuit	TWA[12] 2024/5 (A)	Peak 2024/5 (A)	TWA 2044/5 (A)	Peak 2044/5 (A)	Emergency (A)
Maragle to Gugaa	257	830	773	1,559	2,680
Maragle to Bannaby	297	1,482	767	1,909	3,450
Gugaa to Bannaby	382	1,468	773	1,971	3,450

- The projected loadings used for modelling of the proposed 500 kV transmission line operating at 330 kV have been provided separately by Transgrid. These are summarised in the table following. Note that the intention would be to uprate the transmission lines to 500 kV operation after 2030/31.

Table 4-5 | 330 kV circuit loading (in Amps) provided by Transgrid

Circuit	TWA 2030/31 (A)	Peak 2030/31 (A)	Emergency (A)
Gugaa to Wagga	788	1,923	3,847

Fields are calculated based on the midspan conductor geometry between a pair of suspension towers according to Figure 1-3 and Figure 1-4. Other towers used less frequently on the transmission line such as tension towers and transpositions may give rise to different results, depending on how they are used. We have assumed the differences are negligible for the purposes of this report. Conductor geometries that can give rise to higher fields shall be analysed and checked for compliance during the detailed design phase.

[12] *TWA is the Time Weighted Average and can be regarded as a typical load for transmission lines.*

5 Field characterisation

5.1 Approach

Based on the available design and loading information, the electric and magnetic fields in the vicinity of the proposed transmission lines have been modelled using the CDEGS software package. CDEGS is an internationally recognised software package pioneered by Safe Engineering Services & Technologies (SES) to provide grounding and electromagnetic and conductive interference analysis involving electrical networks. The software has undergone extensive scientific validation using field tests and comparisons with analytical or published results for over twenty years[13].

In all cases, the fields cited apply at a height of one metre above ground, in accordance with international practice.

5.2 Magnetic field results

The results obtained from the magnetic field modelling of the proposed transmission lines are shown in the following sections and are presented in the form of profiles indicating the magnetic fields along a transmission line perpendicular to the proposed 500 kV overhead conductors. In the case of emergency loads, it is often the case that one circuit of a double circuit transmission line is out of service. This skews the field profiles to that side of the transmission line and, accordingly, the field is lower on the side of the de-energised circuit. To take account of the fact that either circuit could be the one energised, the field profiles have been calculated for both cases, and the profiles presented in this report are a composite of the two worst cases, depending on which circuit is carrying the higher load.

As the proposed 500 kV transmission lines could run parallel to, or cross over, existing high voltage transmission lines in various locations, the contribution of the adjacent or overcrossing transmission line has the potential to influence the total field. As noted previously, calculations have also been done for two representative samples of each. These are covered in Section 6.

All profiles are presented as seen by an observer looking along the respective 500 kV transmission lines in the following directions.

- Maragle-Wondalga line: Towards Wondalga
- Wondalga-Gugaa line: Towards Gugaa
- Wondalga-Bannaby line: Towards Bannaby
- Gugaa-Wagga line: Towards Wagga.

5.2.1 Maragle-Wondalga line (alpine construction[14])

The calculated magnetic field along the Maragle-Wondalga 500 kV line (feeders 5C1 and 5C3) is shown in Figure 5-1.

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[13] *Safe Engineering Services & Technologies Ltd (SES): CDEGS Software Validation http://www.sestech.com/products/softwarevalidation.htm*
[14] *Only the alpine construction has been modelled as it represents over 90% of the route length and results in slightly higher fields than the non-alpine construction*

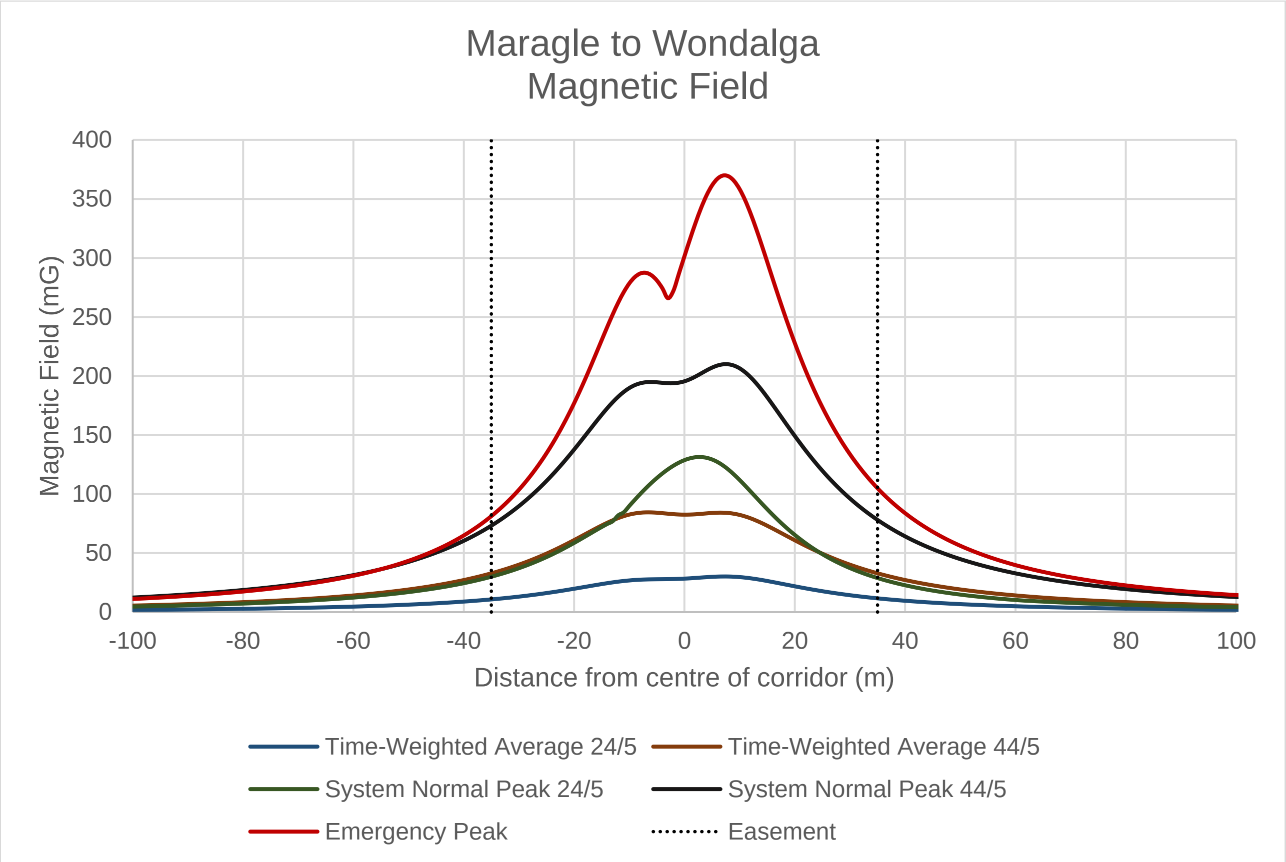

Figure 5-1 | Calculated magnetic field profile – Maragle-Wondalga 500 kV line

The predicted magnetic fields depicted in Figure 5-1, under the various load conditions, are summarised in Figure 5-2.

Table 5-1 | Calculated magnetic fields – Maragle-Wondalga 500 kV line

Loading condition	Directly under line (mG)	Easement edge – 35 m (mG)	100 m from line (mG)
2024/5			
Average load	30	12	2
Peak (system normal) load	131	29	5
2044/5			
Average load	85	34	6
Peak (system normal) load	210	78	13
Peak (emergency) load	370	105	14

5.2.2 Wondalga-Gugaa line

The calculated magnetic field along the Wondalga-Gugaa 500 kV line (feeders 5C2 and 5C3) is shown in Figure 5-2 following.

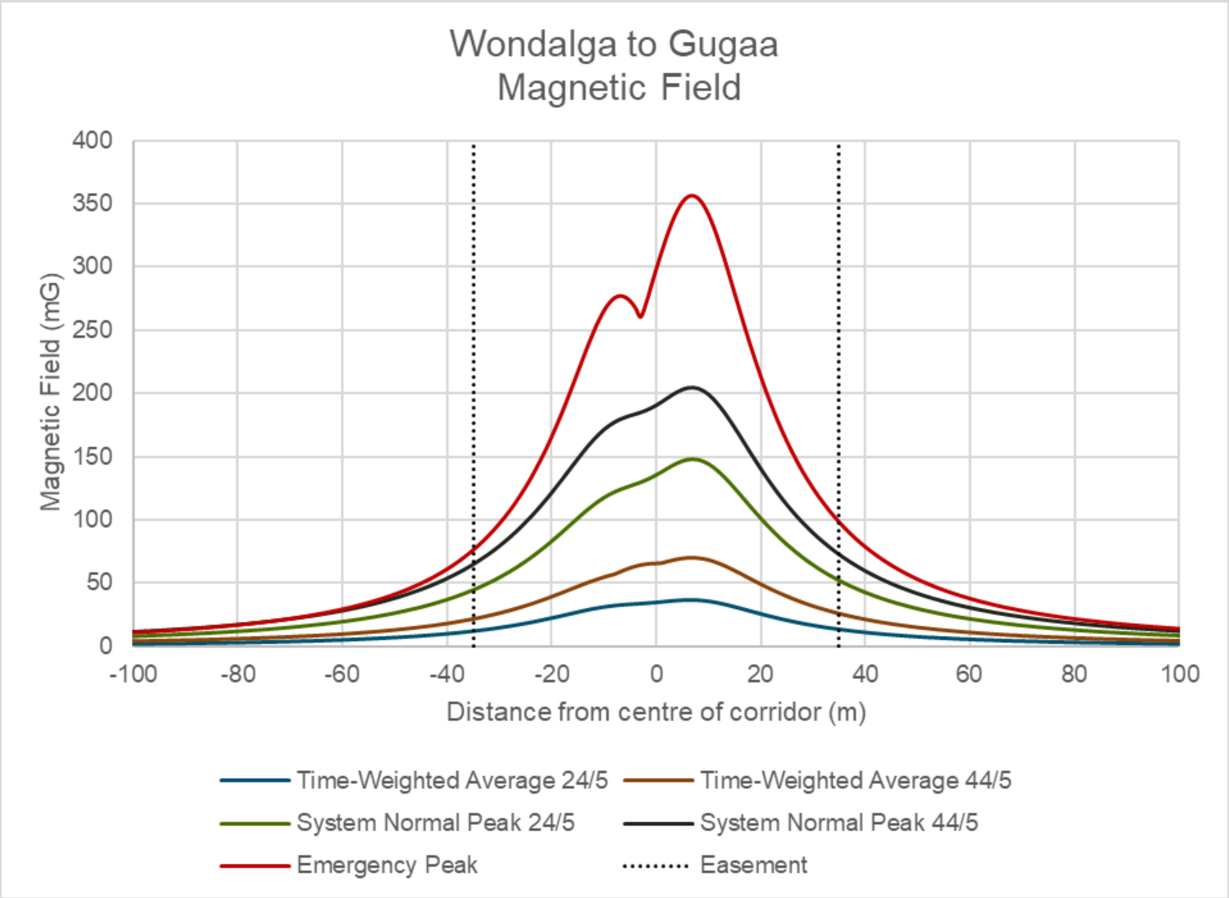

Figure 5-2 | Calculated magnetic field profile – Wondalga-Gugaa 500 kV line

The predicted magnetic fields depicted in Figure 5-2 under the various load conditions, are summarised in Table 5-2.

Table 5-2 | Calculated magnetic fields – Wondalga-Gugaa 500 kV line

Loading condition	Directly under line (mG)	Easement edge – 35 m (mG)	100 m from line (mG)
2024/5			
Average load	37	14	2
Peak (system normal) load	148	52	8
2044/5			
Average load	70	26	4
Peak (system normal) load	205	72	12
Peak (emergency) load	356	98	14

5.2.3 Wondalga-Bannaby Line

The calculated magnetic field along the Wondalga-Bannaby 500 kV line (feeders 5C1 and 5C2) is shown in Figure 5-3.

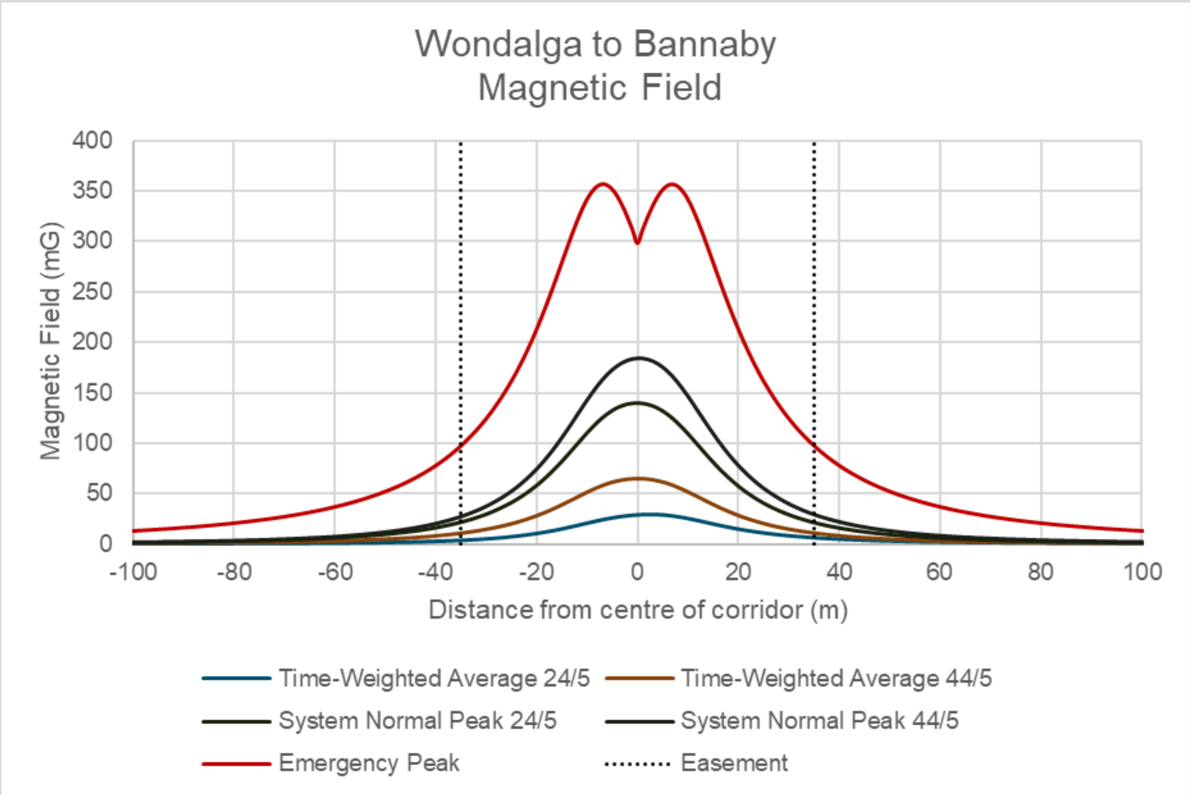

Figure 5-3 | Calculated magnetic field profile – Wondalga-Bannaby 500 kV line

As explained previously, the curve for the emergency peak condition is a composite of two conditions that involve either the left or the right circuit carrying all of the load. This composite reflects the highest possible magnetic field on each side of the transmission line whereas in reality only one or other circuit could carry all of the load at any particular time. Even then it is an extreme case which would be rare and of short duration.

The predicted magnetic fields depicted in Figure 5-3, under the various load conditions, are summarised in Table 5-3.

Table 5-3 | Calculated magnetic fields – Wondalga-Bannaby 500 kV line

Loading condition	Directly under line (mG)	Easement edge – 35 m (mG)	100 m from line (mG)
2024/5			
Average load	30	6	1
Peak (system normal) load	141	22	2
2044/5			
Average load	66	11	1
Peak (system normal) load	185	30	2
Peak (emergency) load	357	98	14

5.2.4 Gugaa-Wagga line

The calculated magnetic field along the Gugaa-Wagga line which would operate at 330 kV is shown in Figure 5-4.

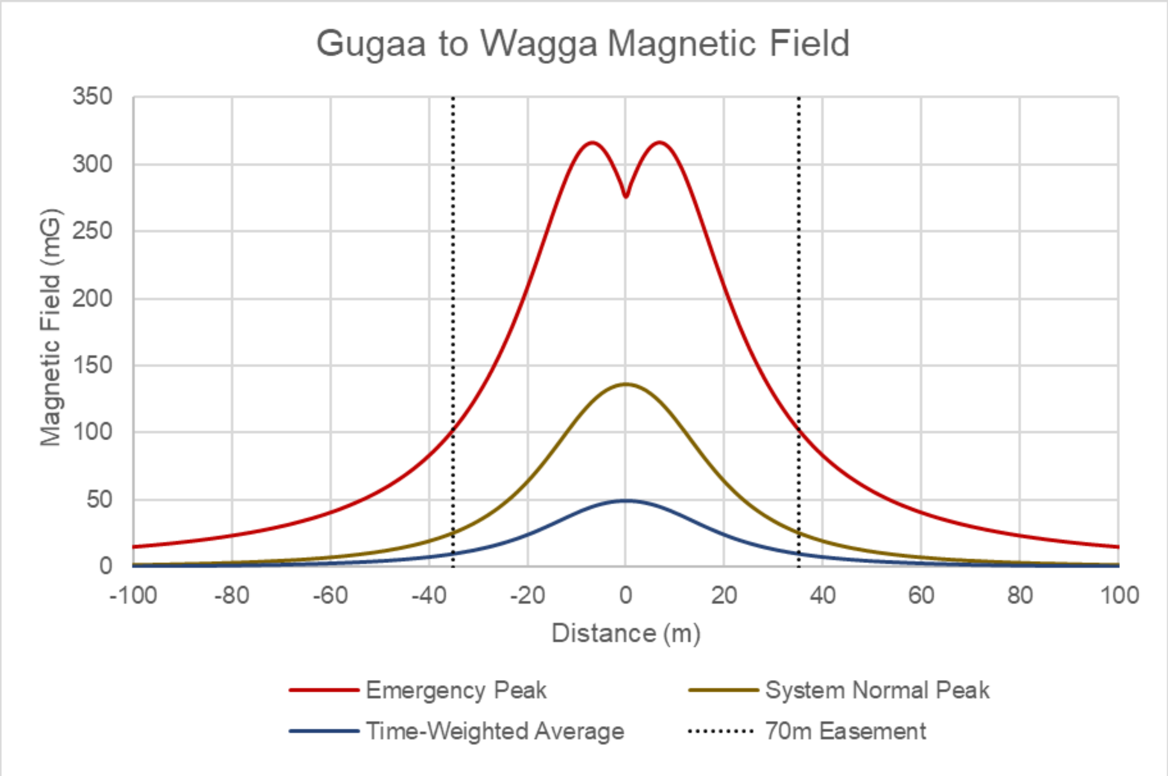

Figure 5-4 | Calculated magnetic field profile – Gugaa-Wagga line at 330 kV operation

The predicted magnetic fields depicted in Figure 5-4, under the various load conditions, are summarised in Table 5-4.

Table 5-4 | Calculated magnetic fields – Gugaa-Wagga line at 330 kV operation

Load condition	Directly under line (mG)	Easement edge – 35 m (mG)	100 m from line (mG)
Average load	50	10	0.8
Peak (system normal) load	136	26	2
Peak (emergency) load	316	103	15

5.3 Magnetic fields experienced in everyday life

In considering the fact that the magnetic fields associated with the proposed transmission lines are quite localised and, due to their location in an easement, are unlikely to be experienced by people, other than intermittently, it is useful to recognise that life in the modern world involves moving from one source of magnetic fields to another. To put this into perspective, the Energy Networks Association published a series of typical magnetic field levels associated with particular appliances and infrastructure at normal user distance[15]. These are set out in Table 5-5.

Table 5-5 | Typical ELF magnetic field levels associated with appliances and infrastructure [15]

Appliance	Typical Measurement (mG)	Typical range of measurements (mG)[16]
Electric Stove	6	2 – 30
Refrigerator	2	2 – 5
Electric Kettle	3	2 – 10
Toaster	3	2 – 10
Electric Blanket	20	5 – 30
Hair Dryer	25	10 – 70
Pedestal Fan	1	0.2 – 2
Substation - Substation Fence	 5	 1 – 8
Distribution Line - Under line - 10 m away	 10 -	 2 – 30 0.5 – 10
Transmission Line - Under line - Edge of easement	 20 10	 10 – 200 2 – 50

From the above range of fields, it can be seen that the predicted average magnetic field contributions associated with the proposed transmission lines (in the range 5 to 90 mG under the line) are within the range of fields normally encountered around transmission lines. The predicted peak magnetic field contributions at the easement edges (in the range 22 to 80 mG) are generally within the ’normal’ range but the peak values directly under the transmission lines are higher. This is to be expected due to the size and voltages of the transmission lines involved and it is noted that the levels in Table 5-5 are typical only and fields may vary from the ranges shown. It is also noted that the transmission line would be within an easement and human interaction with magnetic fields would therefore be intermittent and transitory in nature.

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[15] *Electric and Magnetic Fields - What we know*, Energy Networks Association (n.d)
[16] *Levels of magnetic fields may vary from the range of measurements shown. Appliance measurements at normal user distance.*

5.4 Electric field results

The results obtained from the electric field modelling of the proposed transmission lines are shown in the following sections and are presented in the form of profiles indicating the electric fields along a transmission line at right angles to the proposed 500 kV overhead conductors. As noted in Section 3.1, electric fields are primarily governed by the transmission line voltage[17] and, accordingly, are less variable than magnetic fields. This level of stability is reflected in the lesser number of electric field profiles shown.

5.4.1 Maragle-Wondalga line (alpine construction)

The calculated electric field associated with the Maragle-Wondalga 500 kV line is shown in Figure 5-5. It can be seen from the curves that, under average conditions, the field directly under the transmission line is slightly less than at normal peak load, but there is no difference beyond the easement edge.

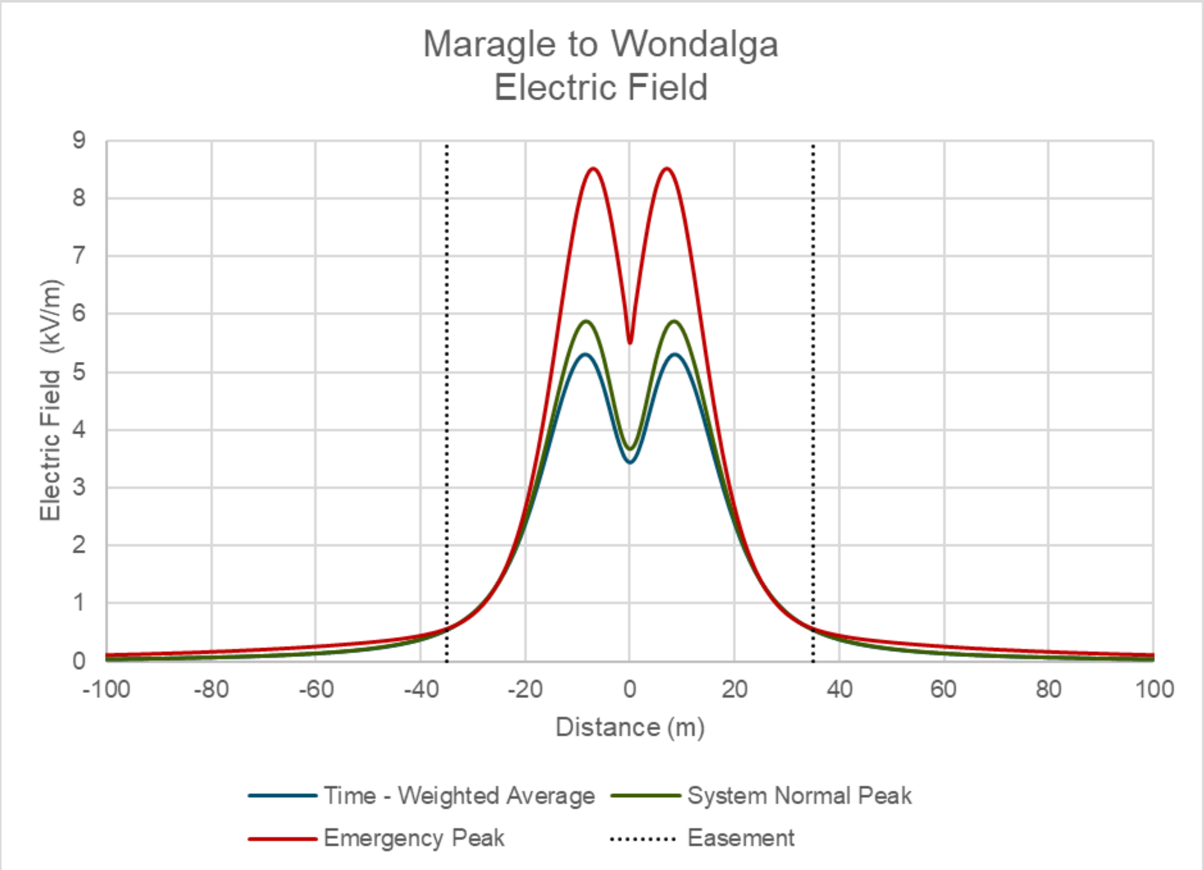

Figure 5-5 | Calculated electric field profile – Maragle-Wondalga 500 kV line

The predicted electric fields depicted in Figure 5-5, under peak load conditions, are summarised in Table 5-6.

Table 5-6 | Calculated electric fields – Maragle-Wondalga 500 kV line

Load condition	Directly under line (V/m)	Easement edge – 35 m (V/m)	100 m from centreline (V/m)
Peak (system normal) load	5,870	552	43
Peak (emergency) load	8,522	570	115

[17] *Load current has a secondary influence on electric fields directly under the line, due to its influence on conductor sag.*

5.4.2 Wondalga-Gugaa and Wondalga-Bannaby lines

The calculated electric field associated with the Wondalga-Gugaa and Wondalga-Bannaby 500 kV lines, is shown in Figure 5-6. As with the Maragle-Wondalga line, it can be seen from the curves that, under average conditions, the field directly under the transmission line is slightly less than at normal peak load, but there is little difference beyond the easement edge.

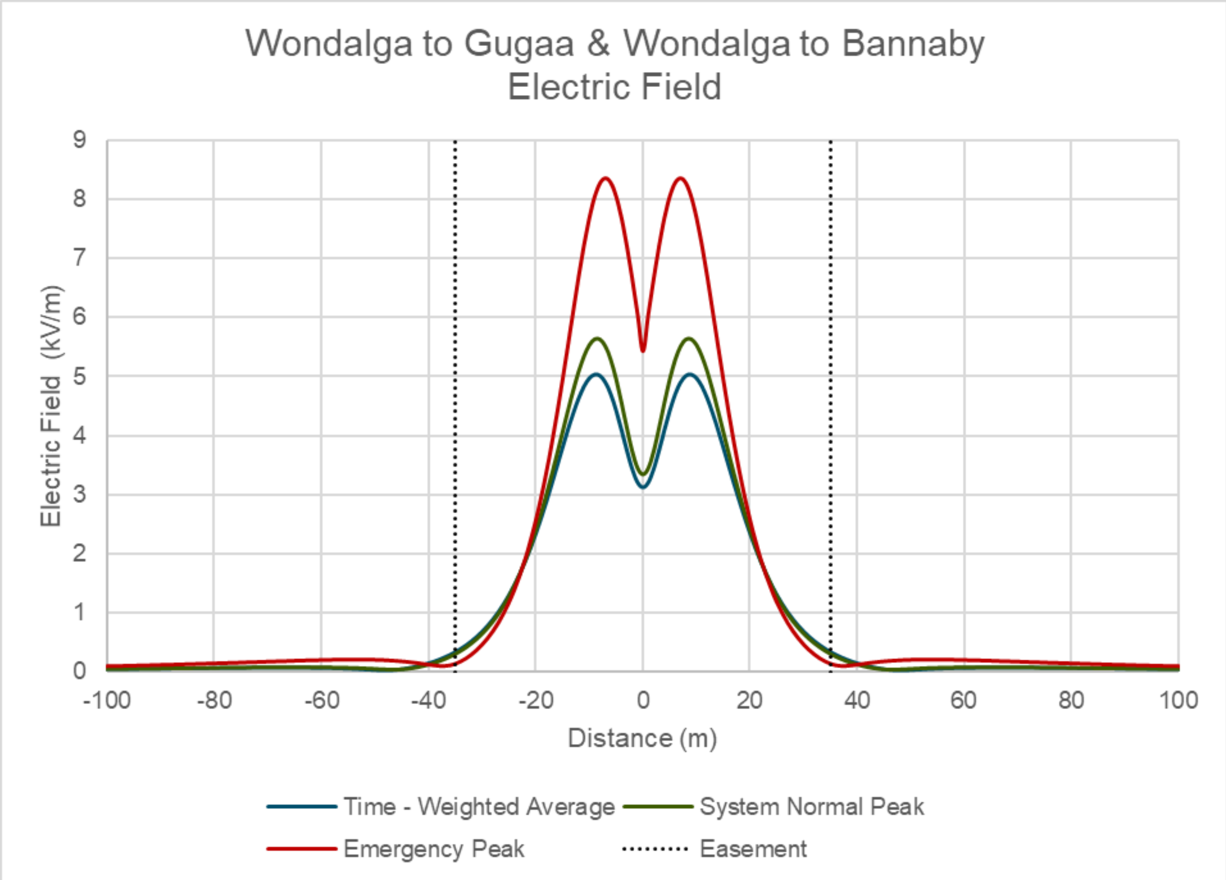

Figure 5-6 | Calculated electric field profile – Wondalga-Gugaa and Wondalga-Bannaby 500 kV lines

The predicted electric fields depicted in Figure 5-6 are summarised in Table 5-7.

Table 5-7 | Calculated electric fields – Wondalga-Gugaa and Wondalga-Bannaby 500 kV lines

Load condition	Directly under line (V/m)	Easement edge – 35 m (V/m)	100 m from centreline (V/m)
Peak (system normal) load	5,638	301	47
Peak (emergency) load	8,352	152	111

5.4.3 Gugaa-Wagga line

The calculated electric field profile along the Gugaa-Wagga line which would operate at 330 kV is shown in Figure 5-7.

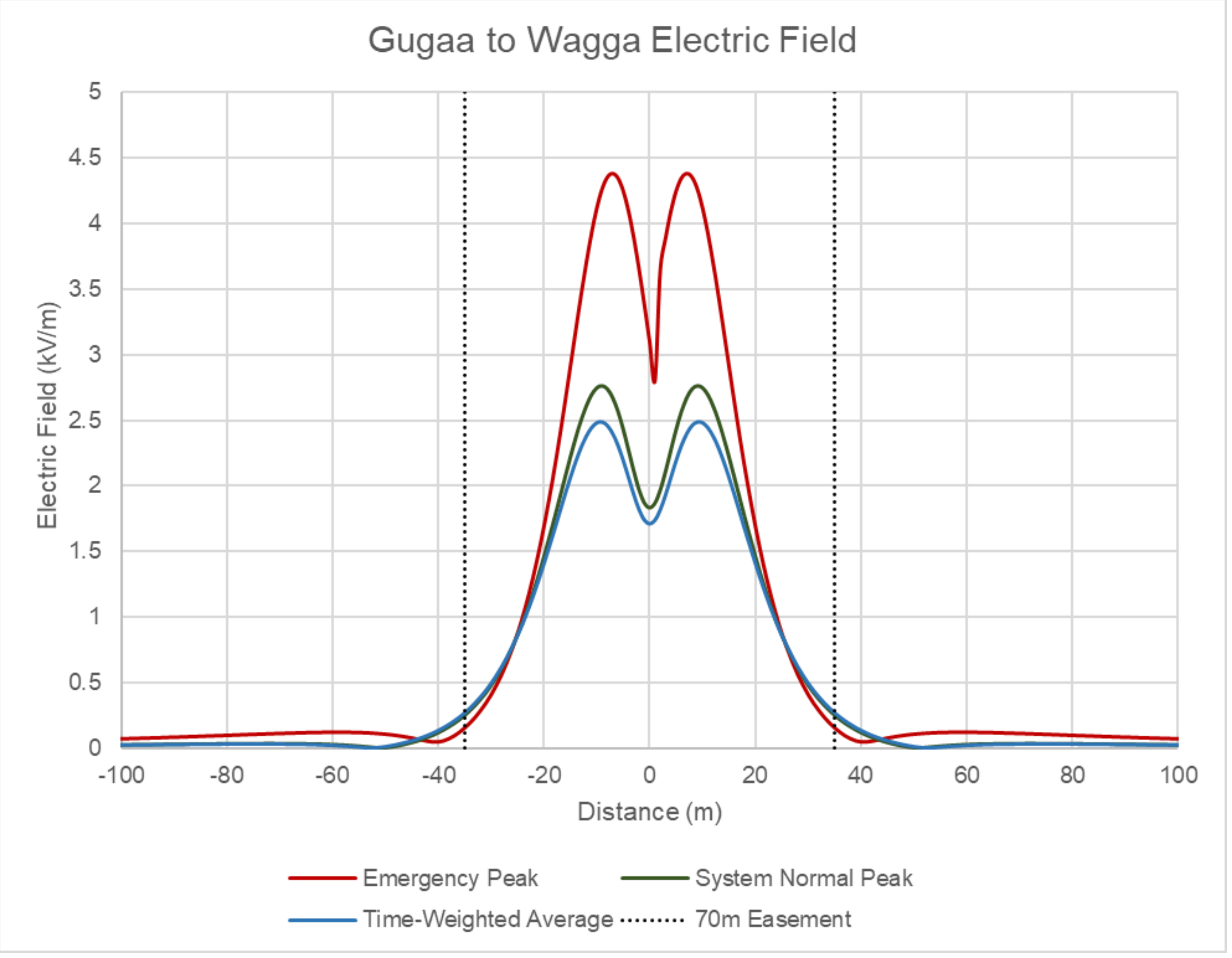

Figure 5-7 | Calculated electric field profile – Gugaa-Wagga line at 330 kV operation

The predicted electric fields depicted under the various load conditions, are summarised in Table 5-8.

Table 5-8 | Calculated electric fields – Gugaa-Wagga line at 330 kV operation

Load condition	Directly under line (V/m)	Easement edge – 35 m (V/m)	100 m from line (V/m)
Average load	2,486	273	28
Peak (system normal) load	2,766	254	28
Peak (emergency) load	4,378	153	70

5.4.4 Tension structure

Tension structures have larger circuit spacing than suspension structures, hence, might result in higher electric field level. To assess the compliance of electric field of tension structures with the Basic Restrictions level of 9.1 kV/m, the worst-case scenario with straight line tension span, minimum ground clearance and alpine construction has been modelled.

The calculated electric fields associated with the worst-case tension structure (VTL), under TWA, system normal peak and emergency peak conditions are shown in Figure 5-8.

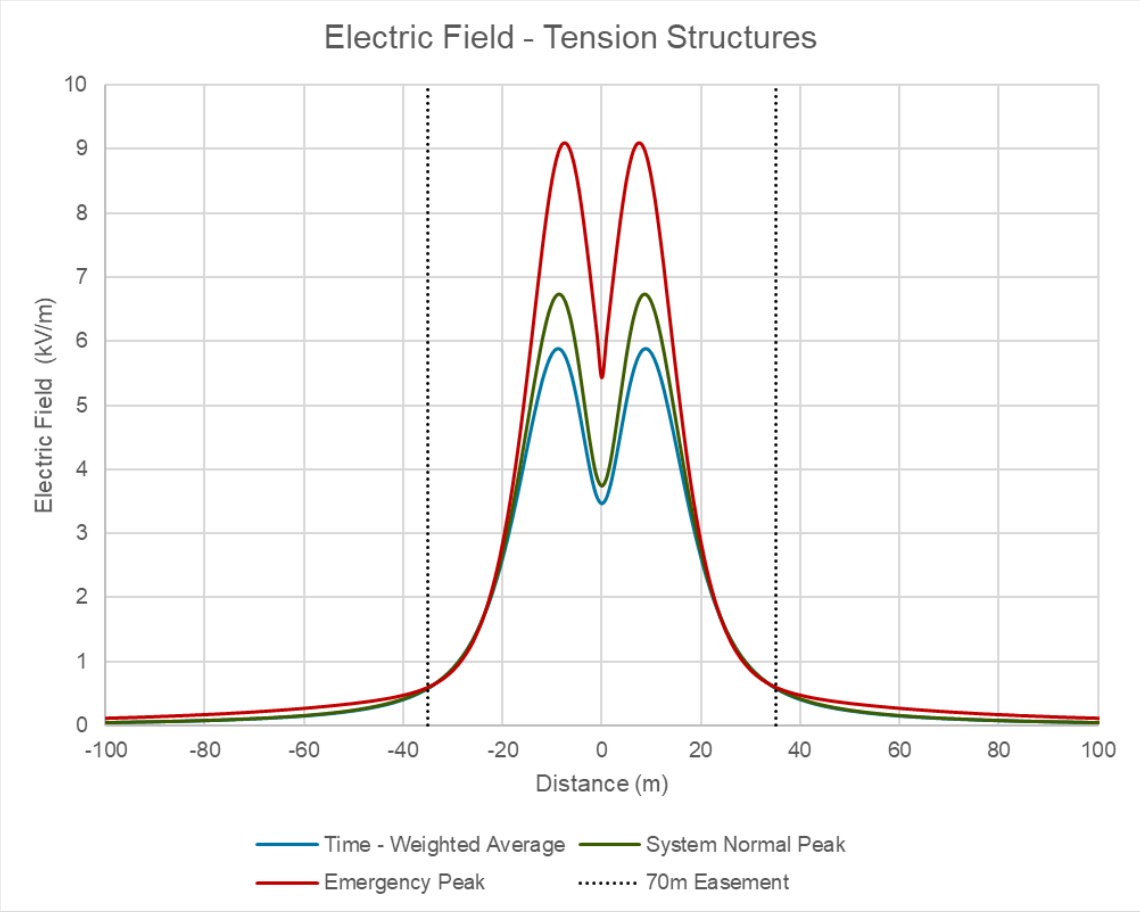

Figure 5-8 | Calculated electric field profile – tension structure (VTL)

It can be seen from the curves that the fields directly under the transmission line under all three load conditions are below the 9.1 kV/m limit used to show compliance with the Basic Restrictions. Since the calculated electric field is for the worst-case tension span scenario, the electric field associated with all tension structures would be below the Basic Restriction level of 9.1 kV/m.

The predicted electric fields for tension structures depicted under the various load conditions, are summarised in Table 5-9.

Table 5-9 | Calculated electric fields – tension structure

Load condition	Directly under line (V/m)	Easement edge – 35 m (V/m)	100 m from line (V/m)
Average load	5,879	580	45
Peak (system normal) load	6,725	588	46
Peak (emergency) load	9,084	605	118

6 Cumulative impacts - overcrossings and parallel sections

6.1 General

As noted in Table 4-1 and Table 4-2, a number of locations have been identified where one of the proposed transmission lines would either cross over or run parallel to existing high voltage transmission lines. In either case, although the electric and magnetic fields of the two transmission lines would interact cumulatively in rather complex ways, depending on the transmission line separation details[18] and electrical phase relationships, for known transmission line configurations and loading conditions, the cumulative effect can be calculated. This has been done in Sections 6.2 and 6.3 for representative cases of high voltage transmission line overcrossings and parallels respectively.

Where a 500 kV transmission line is located in proximity to a lower voltage distribution line, the field from the 500 kV line would dominate and the distribution line would have little effect.

6.2 Overcrossings

The proposed 500 kV transmission lines would also cross over existing high voltage transmission lines in some locations. When transmission lines cross one another, their electric and magnetic fields interact and result in a field distribution which tends to be dominated by the larger transmission line and can be quite variable across the area of the crossing. The resulting fields for a selection of these situations (one crossing of a 330 kV transmission line and one crossing of a 132 kV transmission line) have been calculated and, due to the complexity of the field distribution, the results are presented as contour plans covering the area around the crossing.

The indicative concept design has been used for the assessment of overcrossings.

6.2.1 Maragle-Wondalga line: overcrossing of Lower Tumut-Wagga single circuit 330 kV line

The magnetic fields present where the Maragle-Wondalga 500 kV line crosses over the Lower Tumut-Wagga 330 kV line are shown as a contour plan in Figure 6-1. The transmission line from Maragle to Wondalga is operating at system normal peak 2044/45 and the 330 kV line from Lower Tumut to Wagga is operating at its system normal peak (1,185 A). The 500 kV line runs vertically through the plan.

[18] *Separation details* comprise the centreline separation between the proposed line and the adjacent parallel line.

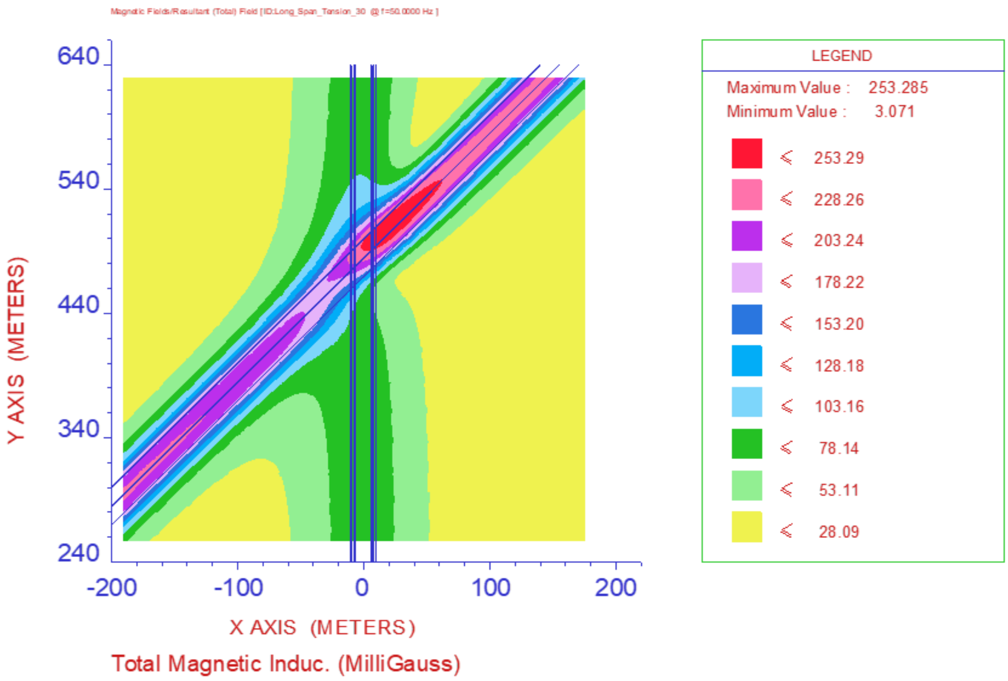

Figure 6-1 | Magnetic fields: Maragle-Wondalga overcrossing of Lower Tumut-Wagga 330 kV line

It can be seen that the field distribution at the overcrossing is quite complex and is dominated by the 330 kV transmission line, partly due to its lower ground clearance. The highest magnetic field, which occurs directly under the crossing point, is about 30 per cent higher than that under the 330 kV transmission line elsewhere. The fields at the easement edges are substantially unchanged.

The electric fields where the Maragle-Wondalga line crosses over the Lower Tumut-Wagga 330 kV line are shown as a contour plan in Figure 6-2. The 500 kV line runs vertically through the plan.

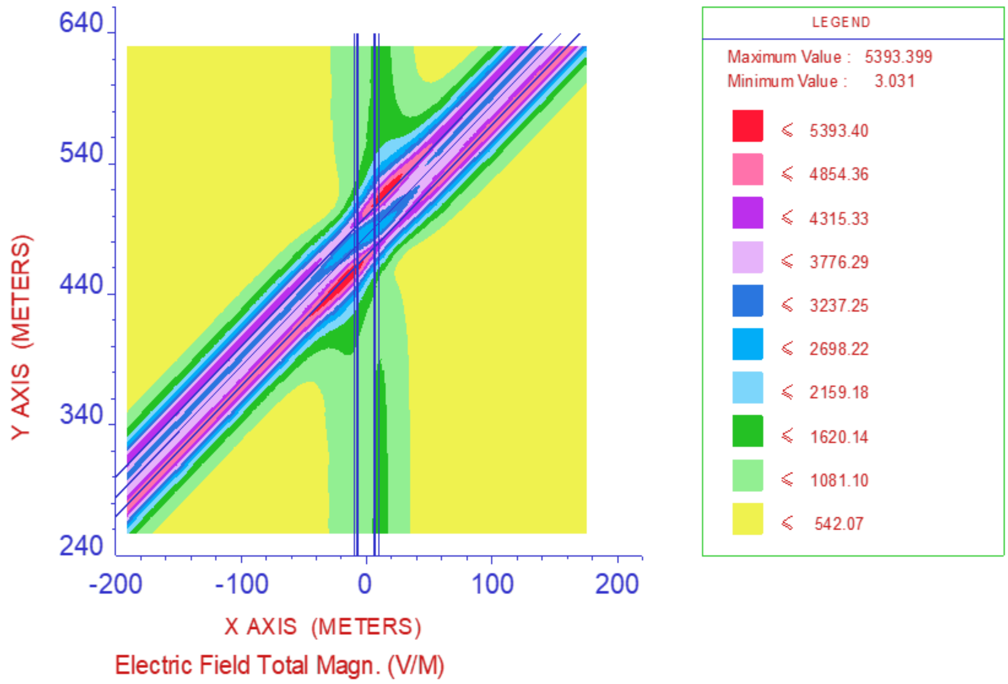

Figure 6-2 | Electric fields: Maragle-Wondalga overcrossing of Lower Tumut-Wagga 330 kV line

As with the magnetic fields, it can be seen that the field distribution at the overcrossing is quite complex and, again, is dominated by the 330 kV transmission line, partly due to its lower ground clearance. The highest electric field, which occurs directly under the crossing point is about 25 per cent higher than that under the 330 kV transmission line elsewhere. The fields at the easement edges are substantially unchanged.

6.2.2 Wondalga-Bannaby line: overcrossing of Wagga-Yass single circuit 132kV line

The magnetic fields where the Wondalga-Bannaby line crosses over the 132kV single circuit Wagga-Yass line are shown in Figure 6-3. The transmission line from Wondalga to Bannaby is operating at system normal peak 2044/45 and the 132kV line from Wagga to Yass is operating at its system normal peak (395 A). The 500 kV line runs vertically through the plan.

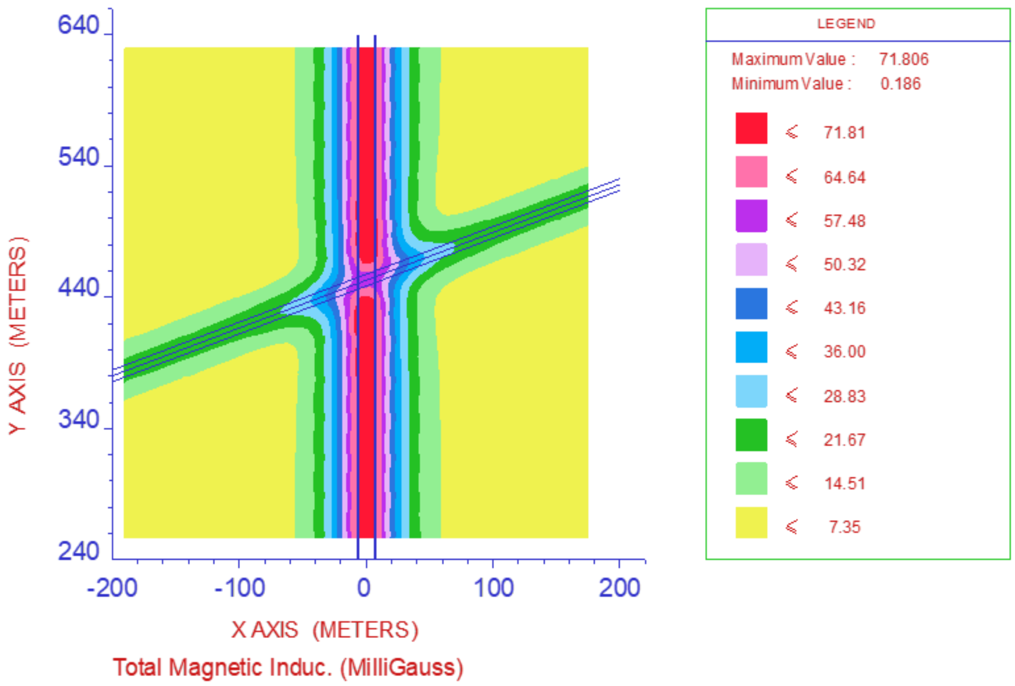

Figure 6-3 | Magnetic fields: overcrossing of Wagga-Yass 132 kV line

As in the previous case, the field distribution at the overcrossing is quite complex but, in this case, it is dominated by the 500 kV transmission line, partly due to its much higher load than the 132 kV transmission line. The highest magnetic field, which occurs directly under the crossing point is up to three times that under the 132 kV transmission line elsewhere. The fields at the easement edges are substantially unchanged.

The electric fields present where the single circuit section of the Maragle-Bannaby line crosses over the Yass-Wagga 132 kV line are shown as a contour plan in Figure 6-4. The 500 kV transmission line runs vertically through the plan.

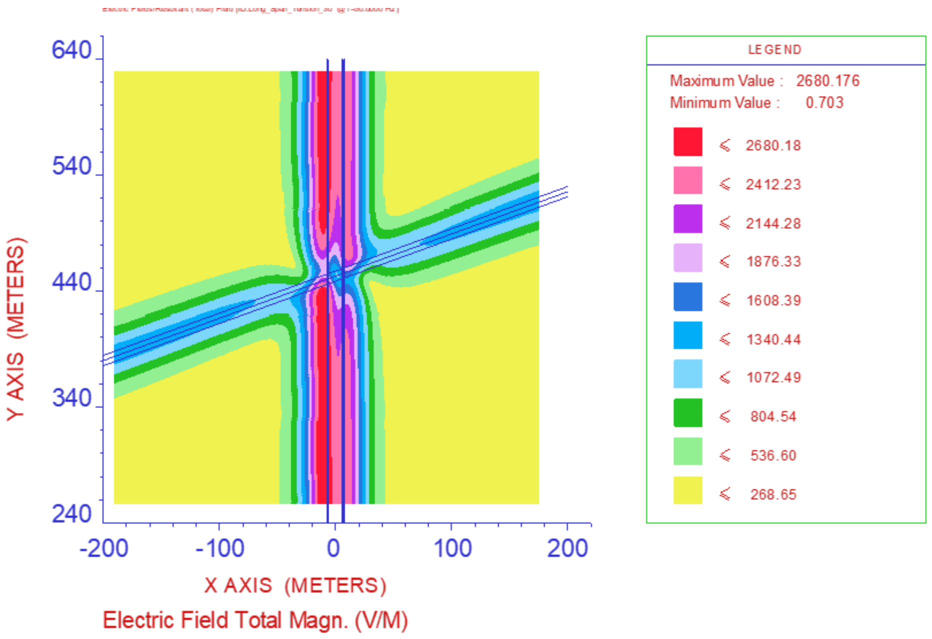

Figure 6-4 | Electric fields: overcrossing of single circuit Wagga-Yass 132 kV line

The electric field distribution at the overcrossing is again quite complex and is mainly dominated by the 500 kV transmission line. The highest electric field, which occurs directly under the crossing point, is about twice that under the 132 kV transmission line elsewhere. The fields at the easement edges are substantially unchanged.

6.3 Parallel sections

As the proposed 500 kV transmission lines are expected to run parallel to existing high voltage transmission lines in various locations, where the contribution of the adjacent line has the potential to influence the total field, electric and magnetic field profiles for two representative parallel sections for 500 kV transmission line and two representative parallel sections for 330 kV operation of Gugaa-Wagga line have been produced and are shown below.

The indicative concept design has been used for the assessment of parallel.

6.3.1 Maragle-Wondalga line: parallel with Lower Tumut-Wagga single circuit 330 kV line

The magnetic fields where the Maragle-Wondalga line parallels the Lower Tumut-Wagga 330 kV line are shown as a profile across the easement in Figure 6-5. Both the lines operate at their system normal peak and the centreline separation between the transmission lines is 64.7 metres.

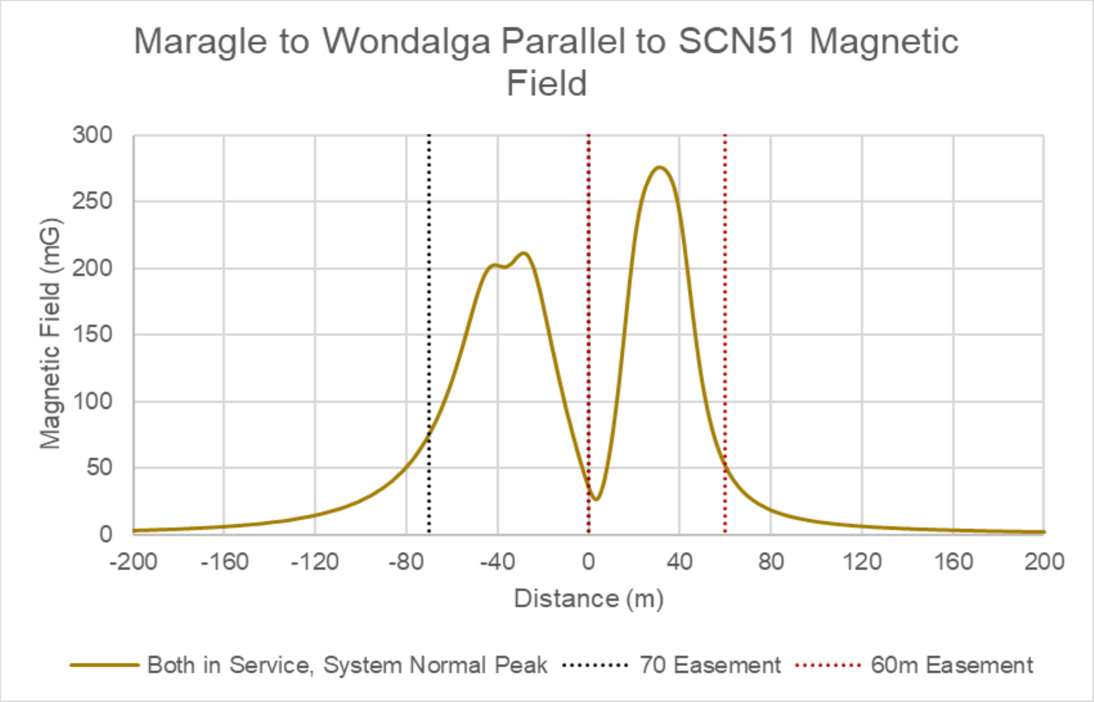

Figure 6-5 | Magnetic Fields: Maragle-Wondalga line parallel with Lower Tumut-Wagga 330 kV line (500 kV line on the left)

The electric fields where the Maragle-Wondalga line parallels the Lower Tumut-Wagga 330 kV line are shown as a profile across the easement in Figure 6-6.

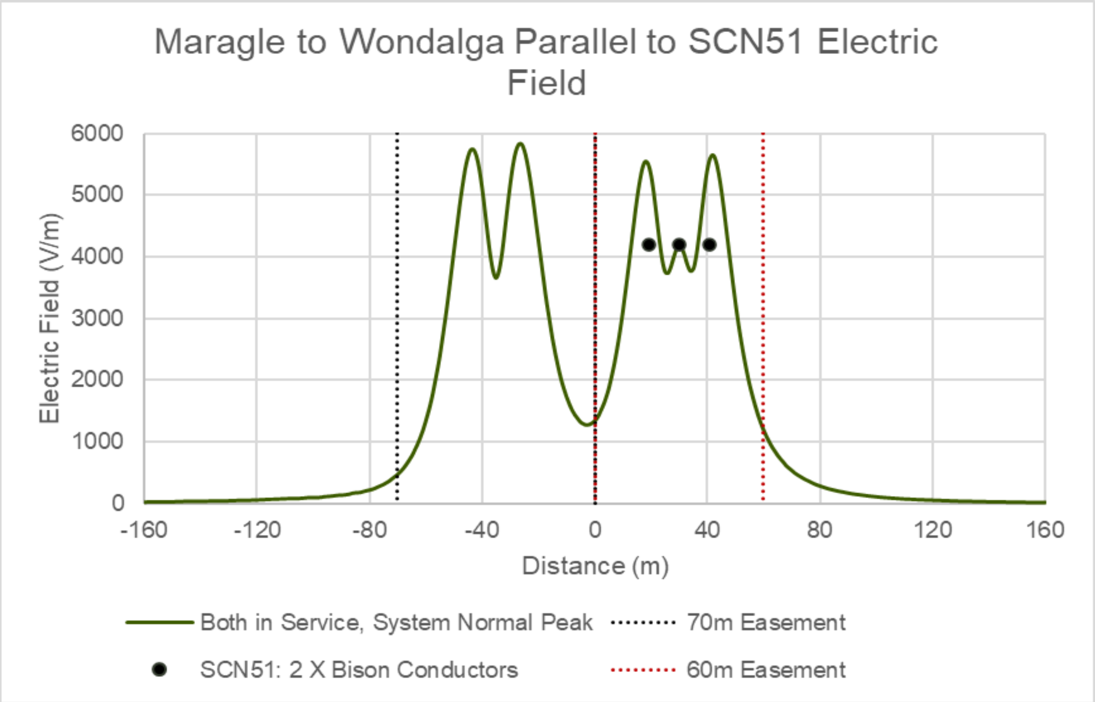

Figure 6-6 | Electric fields: Maragle-Gugaa line parallel with Lower Tumut-Wagga 330 kV line (500 kV line on the left)

6.3.2 Wondalga-Bannaby line: parallel with Mt Piper-Bannaby double circuit 500 kV line

The magnetic fields where the Wondalga-Bannaby line parallels the Mt Piper-Bannaby double circuit 500 kV line are shown as a profile across the easement in Figure 6-7. The line on left side of the graph is Wondalga-Bannaby line while the line on right is the Mt Piper-Bannaby 500 kV line, with 70 metres centreline separation between them.

The final phasing of the proposed 500kV transmission line has been arranged to provide maximum field cancellation when in combination with the existing 500kV double circuit Mt Piper-Bannaby line.

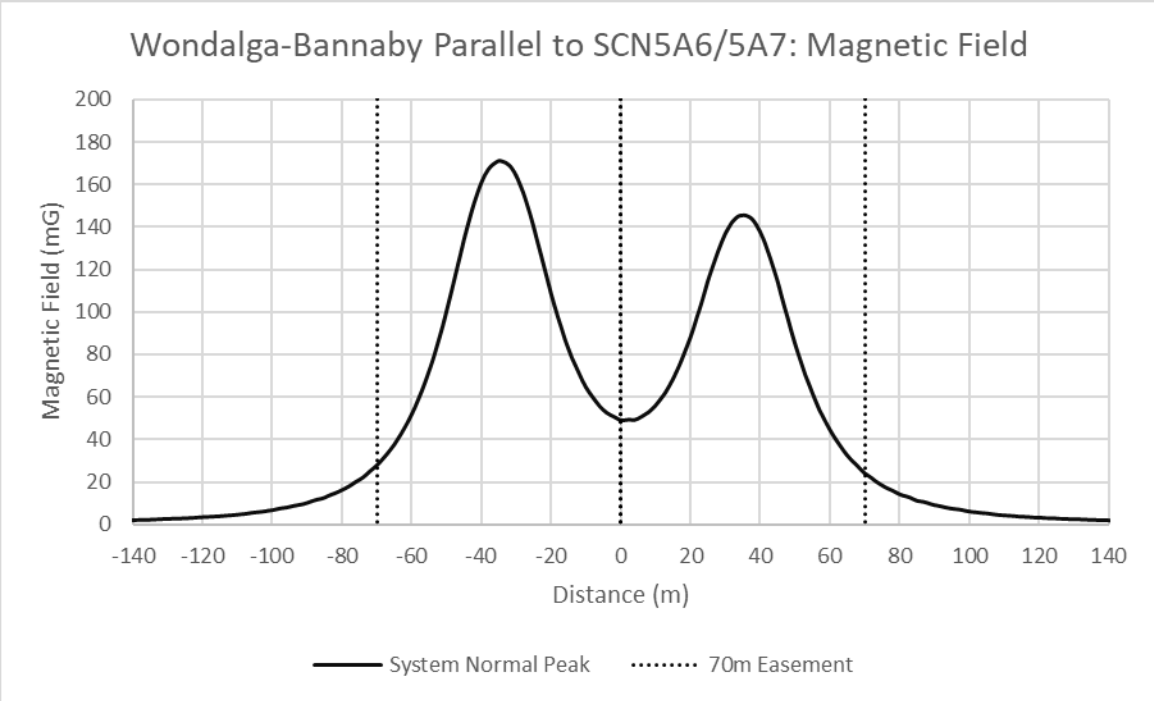

Figure 6-7 | Magnetic fields: Wondalga-Bannaby line parallel with Mt Piper-Bannaby 500 kV line (500 kV HumeLink line on the left)

The electric fields where the Wondalga-Bannaby line parallels the Mt Piper-Bannaby double circuit 500 kV line are shown as a profile across the easement in Figure 6-8. As for the magnetic field, both phasing arrangements are shown but the differences are considered immaterial.

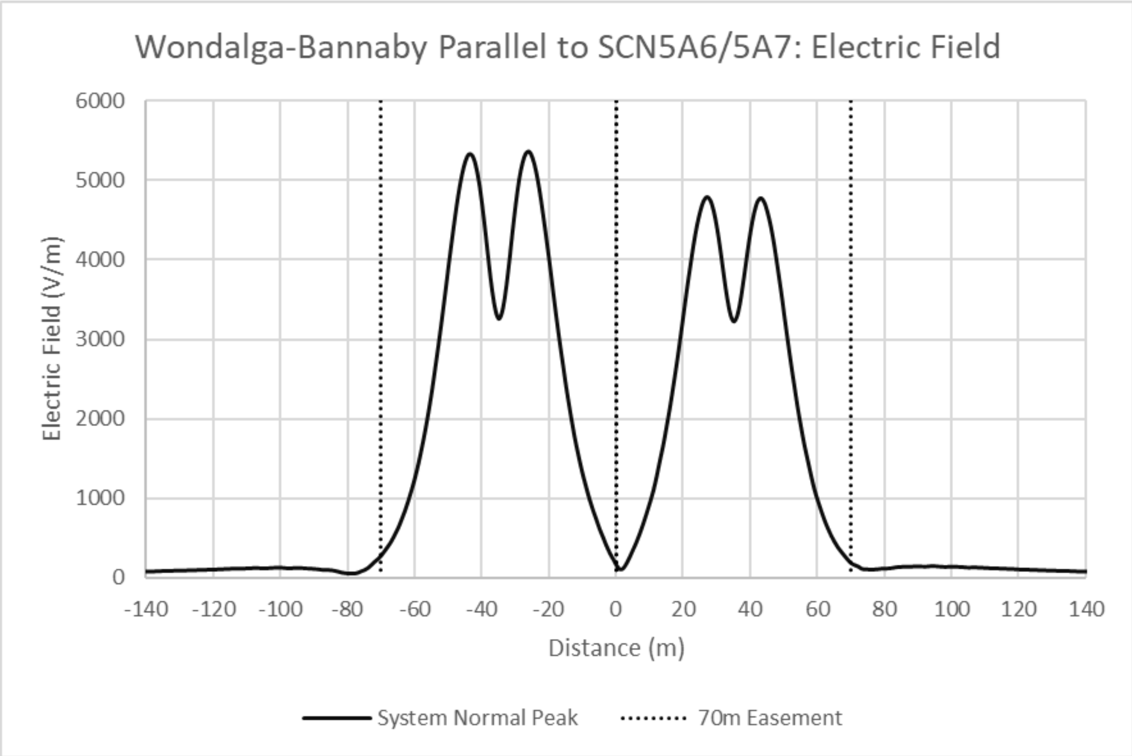

Figure 6-8 | Electric fields: Wondalga-Bannaby line parallel with Mt Piper-Bannaby 500 kV line (500 kV HumeLink line on left)

It can be seen from Figure 6-5 to Figure 6-8 that for parallels with both 330 kV and 500 kV transmission lines, the resulting magnetic and electric field profiles on the respective outer sides of the parallel are similar to those associated with the nearer line to that side. In the area between the transmission lines, the profiles are similar to those which would exist in the absence of the parallel, until they intersect in the centre of the easement in the region where the fields have reduced to some 30 per cent or less of their peak values.

6.3.3 Gugaa-Wagga line: parallel with Lower Tumut-Wagga single circuit 330 kV line

The magnetic fields where the Gugaa-Wagga line parallels the Lower Tumut-Wagga 330 kV line are shown as a profile across the easement in Figure 6-9. Both the transmission lines operate at their system normal peak and the centreline separation between the transmission lines is 63 metres. The 500 kV line from Gugaa to Wagga is operating at 330 kV.

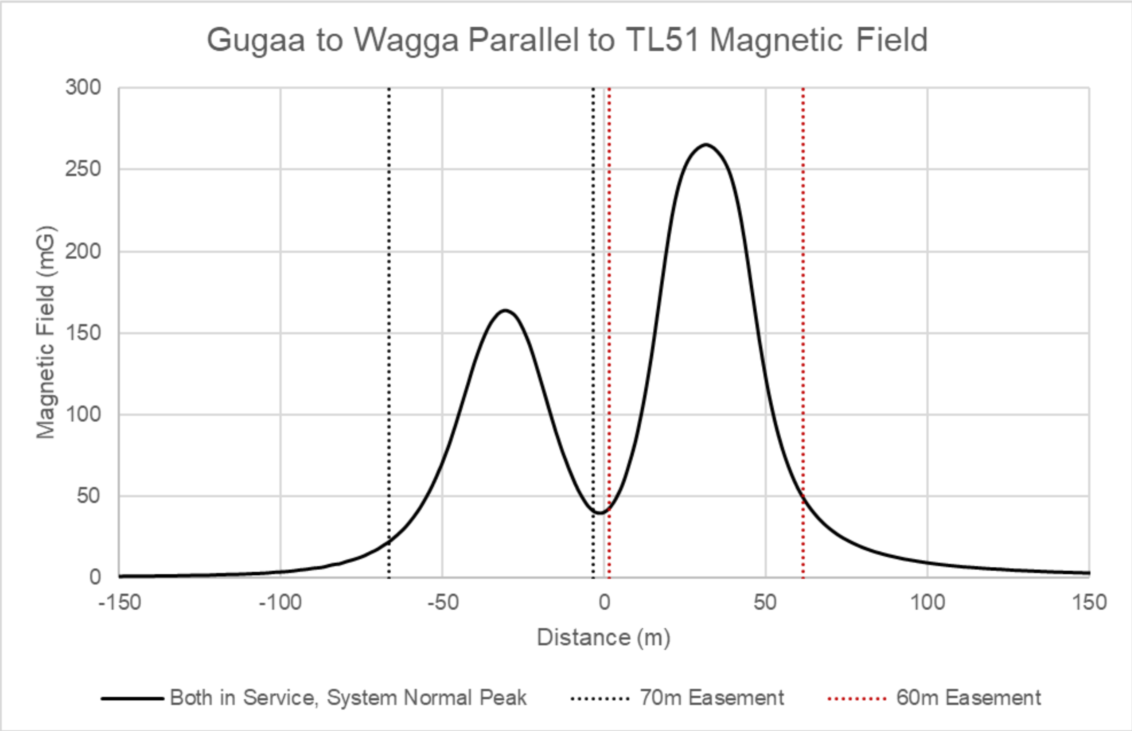

Figure 6-9 | Magnetic fields: Gugaa-Wagga line parallel with Lower Tumut-Wagga single circuit 330 kV line (500 kV proposed line on the left)

It can be seen from Figure 6-9 that the profiles for the individual transmission lines are of similar shape and magnitude to those expected from either one in isolation. In the space between the transmission lines, where profiles are influenced by both lines, the field decrease to about 15per cent of the peak value.

The magnetic fields where Lower Tumut-Wagga 330 kV line is rebuilt on new double circuit tower of DSP tower type and is parallel for part of the proposed route between Gugaa and Wagga are shown as a profile across the easement in Figure 6-10. Both the transmission lines operate at their system normal peak and the centreline separation between the transmission lines is 43 metres.

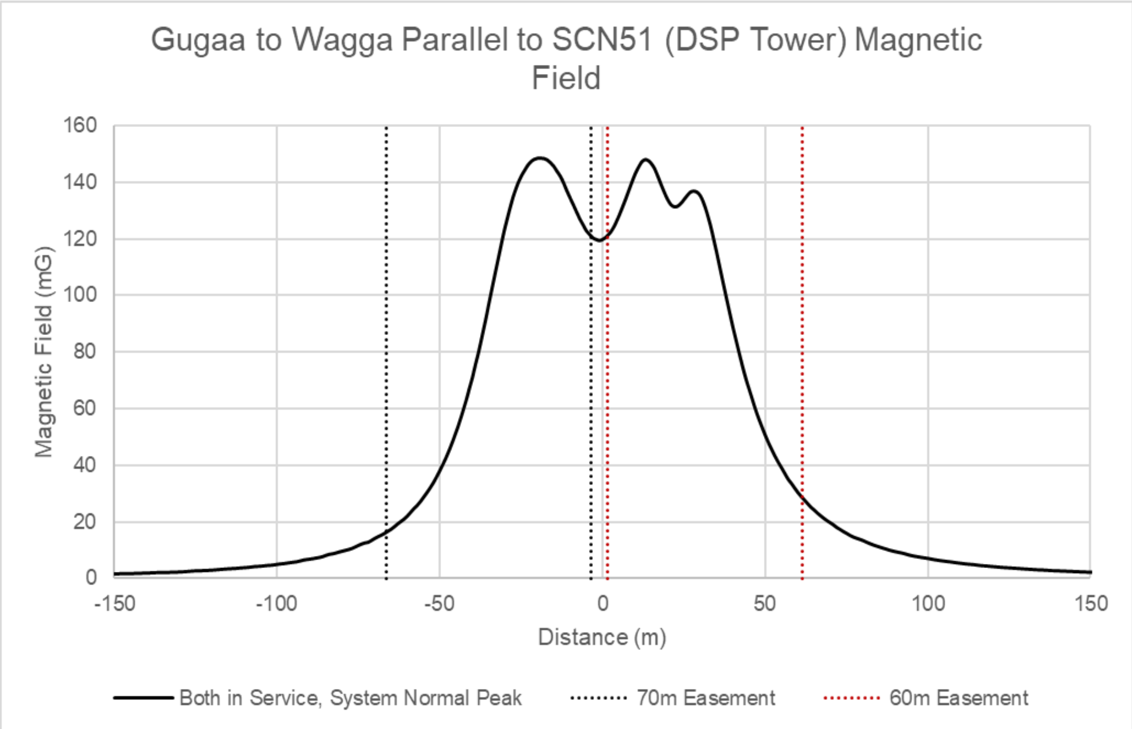

Figure 6-10 | Magnetic fields: Maragle-Wondalga line parallel with Lower Tumut-Wagga double circuit 330 kV line DSP Tower type (500 kV line on the left)

The electric fields where the Gugaa-Wagga line parallels the Lower Tumut-Wagga 330 kV line are shown as a profile across the easement in Figure 6-11.

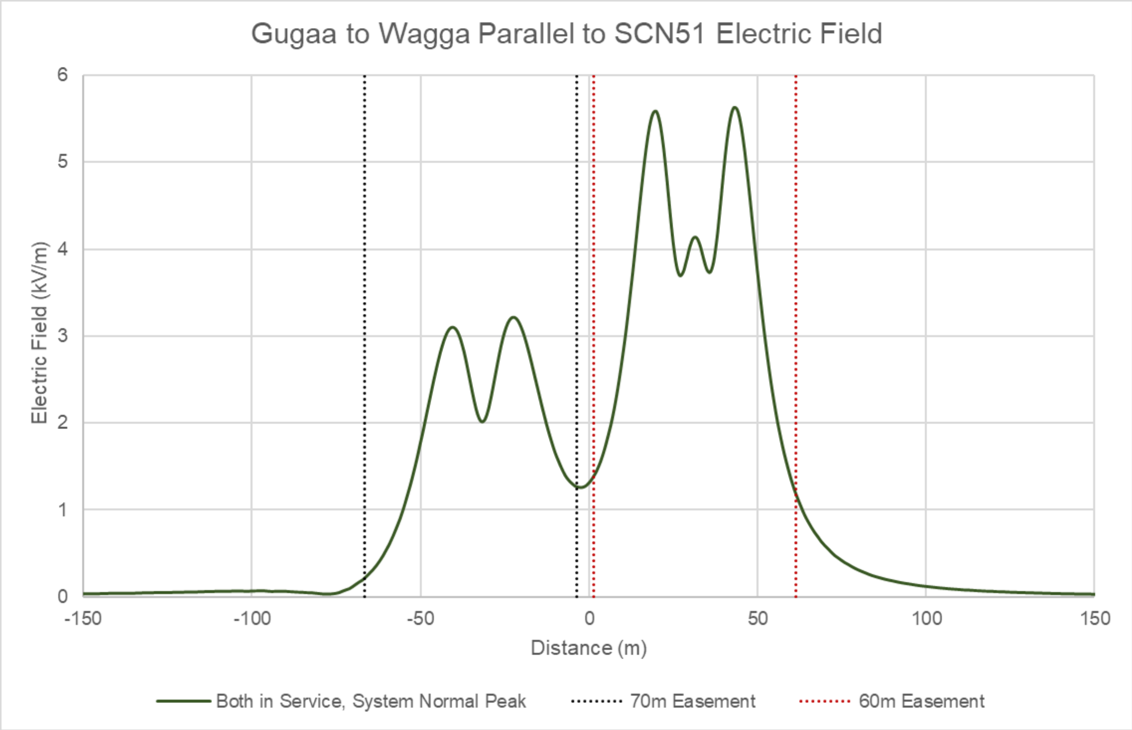

Figure 6-11 | Electric fields: Gugaa-Wagga line parallel with Lower Tumut-Wagga single circuit 330 kV line (500 kV line on the left)

The electric fields where Lower Tumut-Wagga 330 kV line is rebuilt on new double circuit tower of DSP tower type and is parallel for part of the proposed route between Gugaa and Wagga are shown as a profile across the easement in Figure 6-12.

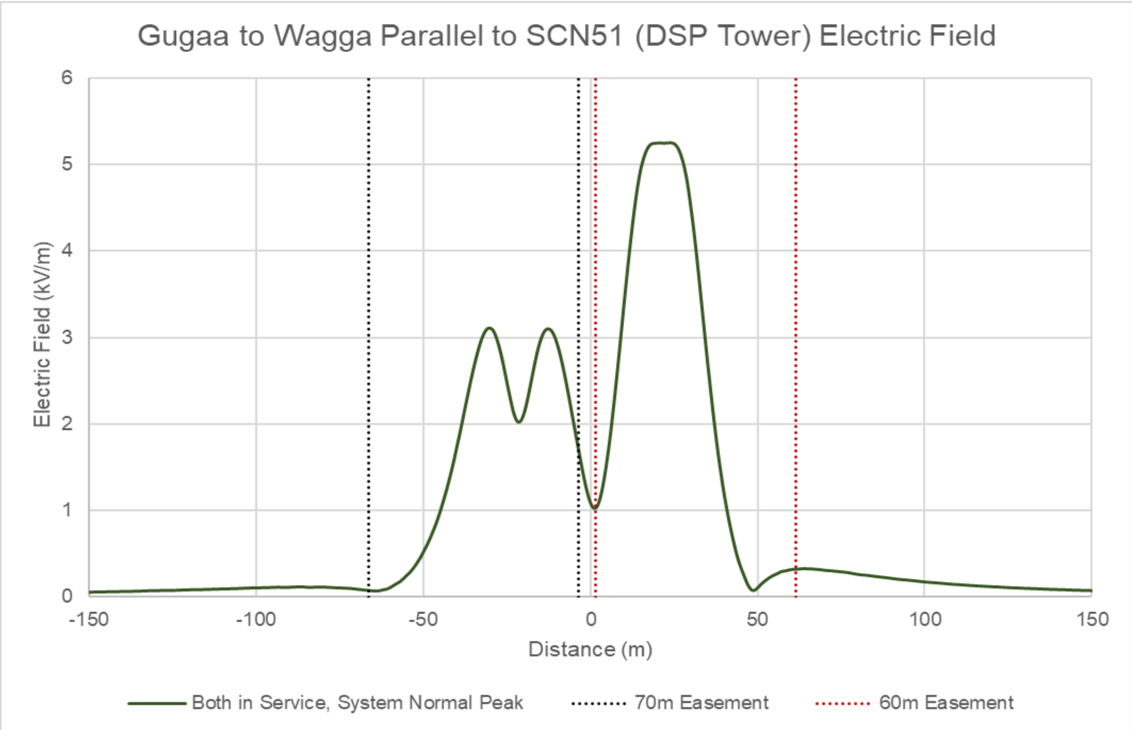

Figure 6-12 | Electric fields: Gugaa-Wagga line parallel with Lower Tumut-Wagga double circuit DSP 330 kV line (500 kV line on the left)

6.4 Potential overcrossings and parallels with future transmission lines

As well as the overcrossings and parallels with existing transmission lines identified in Table 4-1 and Table 4-2, a search of all known future projects with the potential to cross or closely parallel one or other of the Humelink transmission lines has been undertaken. Of these projects, only two have been identified as having such potential:

- Jeremiah Wind Farm: based on the assumption that the wind farm would connect to an existing 330 kV transmission line with new substation or switching station there is the possibility of two crossings of the Wondalga-Bannaby line with future 132kV or 330 kV transmission lines.
- Victoria to NSW Interconnector West: depending on location of the substation it is possible that there could be one span or landing span parallel to the Wondalga-Gugaa line.

Although there is insufficient information to undertake modelling of these identified possible future interactions, the field patterns will be similar to those already modelled and the general findings outlined in Section 6.1 and Section 6.3 would be equally applicable. Nevertheless, it would be appropriate to consider them further during the environmental assessment phase of the respective future projects.

7 Compliance with EMF guidelines and prudent avoidance principles

7.1 Compliance with health guidelines

7.1.1 Magnetic fields

Whether in isolation, or in combination with the existing 132 and 330 kV transmission lines, the contribution of the proposed 500 kV transmission lines at 500 kV and 330 kV operation to the magnetic field environment is predicted to be well within the ICNIRP Guideline Reference Level of 2,000 mG.

Under **typical conditions:**

- directly beneath the proposed 500kV lines, the highest predicted magnetic fields range from less than 3.5 per cent to 4.5 per cent of the ICNIRP Guideline Reference Level
- at the edge of the easements, the highest predicted magnetic fields of the proposed 500 kV lines range from less than 0.6 per cent to 1.7 per cent of the ICNIRP Guideline Reference Level
- directly beneath the proposed Gugaa - Wagga line which would operate at 330 kV, the highest predicted magnetic field is 2.5 per cent of the ICNIRP Guideline Level
- at the edge of the easements, the highest predicted magnetic field of the proposed Gugaa-Wagga line which would operate at 330 kV is 0.5 per cent of the ICNIRP Guideline Reference Level.

Under **normal peak load conditions**:

- directly beneath the proposed 500 kV transmission lines, the highest predicted magnetic fields range from less than 9.5 to 10.5 per cent of the ICNIRP Guideline Reference Level
- at the edge of the easements, the highest predicted magnetic fields of the proposed 500 kV transmission lines range from 1.5 to 4 per cent of the ICNIRP Guideline Reference Level
- directly beneath the proposed Gugaa-Wagga line which would operate at 330 kV, the highest predicted magnetic field is 6.8 per cent of the ICNIRP Guideline Reference Level
- at the edge of the easements, the highest predicted magnetic field of the proposed Gugaa-Wagga line which would operate at 330 kV is 1.3 per cent of the ICNIRP Guideline Reference Level.

Even **under emergency conditions**, which would rarely occur during the life of the transmission lines and would be of short duration:

- directly beneath the proposed 500 kV transmission lines, the highest predicted magnetic fields are less than 19 per cent of the ICNIRP Guideline Reference Level
- at the edge of the easements, the highest predicted magnetic fields of the proposed 500 kV transmission lines range from less than 5 to 5.5 per cent of the ICNIRP Guideline Reference Level
- directly beneath the proposed Gugaa-Wagga line which would operate at 330 kV, the highest predicted magnetic field is 15.8 per cent of the ICNIRP Guideline Reference Level
- at the edge of the easements, the highest predicted magnetic field of the proposed Gugaa-Wagga line which would operate at 330 kV is 5.2 per cent of the ICNIRP Guideline Reference Level.

Notwithstanding the lines' proximity to existing 132, 330 and 500 kV transmission lines in some locations, there is little interaction with their magnetic fields, except at the undercrossings, where the field contributions from the two transmission lines would interact. The extent to which one or other dominates would be governed by the relative heights of the two transmission lines and their load currents. The highest resulting magnetic fields are very localised and the fields at the easement edges are substantially unchanged. Similar patterns could be expected in the event of future crossings by other lines.

Where the proposed transmission lines run parallel to existing lines, or known future lines, due to the relatively wide separation between them, there is little interaction between them and the fields associated with the respective transmission lines are much the same as under the individual transmission lines in isolation.

7.1.2 Electric fields

In all locations, under all conditions, the electric fields directly below the transmission lines would be less than 9.1 kV/m and, hence, would comply with the Basic Restrictions under the ICNIRP Guidelines.

At the edge of the easements, the highest predicted electric fields for transmission lines operating at 500 kV would range from 0.2 to 0.6 kV/m, or 3 to 12 per cent of the ICNIRP Guideline Reference Level.

For the Gugaa-Wagga line which would operate at 330 kV, the highest predicted electric fields, at the edge of the easements would range from 0.15 to 0.3 kV/m, or 3 to 6 per cent of the ICNIRP Guideline Reference Level.

In practice, due to shielding by vegetation etc, the actual electric fields are likely to be considerably less than that predicted.

Where they cross existing high voltage transmission lines, the field contribution from the proposed 500 kV transmission lines would interact with the existing fields from the undercrossing lines, resulting in a complex field distribution with some increases in field levels at the crossing point below the transmission line and the increase dissipates away from the crossing point. The fields at the easement edges would be substantially unchanged. Similar patterns could be expected in the event of future crossings by other transmission lines.

Where they run parallel to existing high voltage transmission lines, or known future lines, the proposed lines are not expected to cause any material increase to the existing electric fields.

7.2 Assessment against prudent avoidance principles

As noted in Section 3.4, given the inconclusive nature of the science, it is considered that, in the circumstances, a prudent/precautionary approach continues to be the most appropriate response to health concerns regarding EMF. Under this approach, the operators of electricity infrastructure should design their facilities to reduce the intensity of the magnetic fields they generate, and locate them to minimise the fields that people, especially children, encounter over prolonged periods, provided this can be readily achieved without undue inconvenience and at reasonable expense, and be consistent with good engineering and risk minimisation practice.

In designing the transmission lines, Transgrid and its consultants have:

- adopted generous ground clearances throughout, thereby reducing the fields directly under the transmission lines
- used “vee” insulator strings, which enable the design to be relatively compact, thereby reducing the electric and magnetic Fields
- arranged the phases of the two circuits to provide maximum field cancellation, both for new sections of the transmission line and for the combination where the new transmission line runs in parallel with the existing Mt Piper-Bannaby 500kV double circuit line.

In selecting the corridors, Transgrid has accorded a high importance to separating the alignments from residential dwellings and other occupied premises.

Due to their locations being away from urban and semi-urban areas, it is unlikely that there would be any prolonged human exposure to EMF from the transmission lines.

Due to the uncertainty as to the existence of adverse health effects, it cannot be said whether the above measures would result in any health benefit, but they are all appropriate and consistent with the principles of prudent avoidance.

8 References

British Cochlear Implant Group. (n.d.). *Safety & MRI*. Retrieved April 7, 2022, from https://www.bcig.org.uk/safety/

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Attachments

Attachment A

General description of electric and magnetic fields

The electric and magnetic fields associated with electrical equipment, whilst interrelated, are not dependent on each other and can exist independently. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric wires.

An **electric field** is a region where electric charges experience an invisible force. The strength of this force is related to the voltage, or pressure, which forces electricity along wires. Electric fields are strongest closest to their source, and their strength diminishes rapidly with distance from the source, in much the same way as the warmth of a fire decreases with distance. Many common materials – such as brickwork or metal – block electric fields, so they are readily shielded and, for all practical purposes, do not penetrate buildings. They are also shielded by human skin, such that the electric field inside a human body will be at least 100,000 times less than the external field (Ref A-1). Being related to voltage, the electric fields associated with high voltage aerial lines and electrical substations remain relatively constant over time, except where the operating voltage changes.

A **magnetic field** is a region where magnetic materials experience an invisible force produced by the flow of electricity (known as electric current and measured in Amperes). The strength of a magnetic field depends on the size of the current and decreases as distance from the source increases. The magnetic field strength resulting from an electrical installation varies continually with time and is affected by a number of factors including:

- total electric load
- size and nature of the equipment
- design of the equipment
- layout and electrical configuration of the equipment and its interaction with other equipment.

While electric fields are blocked by common materials, this is not the case with magnetic fields. This is why locating equipment in enclosures or underground will eliminate any external electric field but not the magnetic field.

Alternating electric and magnetic fields are produced by any electric wiring or equipment carrying alternating current (AC). This current does not flow steadily in one direction but oscillates backwards and forwards at a frequency[19] of 50Hz and hence the fields produced by AC systems oscillate at the same frequency. This frequency falls into a range referred to as **extremely low frequency** (ELF), so the electric and magnetic fields are referred to as ELF fields.

Electromagnetic radiation

It is not uncommon for the ELF EMF associated with electrical equipment to be confused with electromagnetic radiation (EMR). The fact that, in many jurisdictions, agencies which regulate the various forms of EMR are also involved in the setting of guidelines/standards for EMF tends to add to this confusion.

Electromagnetic radiation is a term we use to describe the movement of electromagnetic energy through the propagation of a wave. This wave, which moves at the speed of light in a vacuum, is composed of electric and magnetic waves which oscillate (vibrate) in phase with, and perpendicular to, each other. This is in contrast to EMF, where the electric and magnetic components are essentially independent of one another.

Electromagnetic radiation is classified into several types according to the frequency of its wave; these types include (in order of increasing frequency): radio waves, microwaves, terahertz radiation, infra-red radiation,

[19] *Frequency is a measure of the number of times per second a wave oscillates or vibrates. The most common unit of measurement of frequency is the Hertz (Hz) where 1 Hz is equal to 1 cycle per second.*

visible light[20], ultraviolet radiation, x-rays and gamma rays. Whereas EMR causes energy to be radiated outwards from its source e.g. light from the sun or radio-frequency signals from a television transmitter, EMFs cause energy to be transferred along electric wires.

In the context of EMF and health, the distinction between EMF and EMR is addressed by the New Zealand Ministry of Health in its public information booklet "Electric and Magnetic Fields and Your Health" (Ref A-2) as follows:

"The electric and magnetic fields around power lines and electrical appliances are not a form of radiation. The word "radiation" is a very broad term, but generally refers to the propagation of energy away from some source. For example, light is a form of radiation, emitted by the sun and light bulbs. ELF fields do not travel away from their source, but are fixed in place around it. They do not propagate energy away from their source. They bear no relationship, in their physical nature or effects on the body, to true forms of radiation such as x-rays or microwaves."

References

A-1. World Health Organisation: *Environmental Health Criteria Vol. 238*: Extremely low frequency fields. (2007).

A-2. New Zealand Ministry of Health: *Electric and Magnetic Fields and Your Health*. (2008).

[20] *Visible light is a group (spectrum) of frequencies which can be sensed by the eyes of humans and various other creatures.*

Attachment B

Overview of EMF and health

Research into EMFs and health is a complex area involving many scientific disciplines – from biology, physics and chemistry to medicine, biophysics and epidemiology. Many of the health end points of interest to researchers are quite rare. In this context, it is well accepted by scientists that no study considered in isolation will provide a meaningful answer to the question of whether or not EMFs can contribute to adverse health effects. In order to make an informed conclusion from all of the research, it is necessary to consider the science in its totality. Over the years, governments and regulatory agencies around the world have commissioned independent scientific review panels to provide such overall assessments.

Extremely low frequency (ELF) fields

The possibility of adverse health effects due to the ELF EMFs at levels commonly associated with electrical equipment has been the subject of extensive research throughout the world. To date, while adverse health effects have not been established, the possibility that they may exist cannot be ruled out.

While EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields. Nevertheless, high electric field strengths, such as those associated with the highest voltage transmission lines or high voltage equipment in major substations, can approach a level at which "nuisance shocks" can occur and this phenomenon needs to be managed.

Magnetic fields are not readily shielded, are more ubiquitous and remain the subject of some debate. Accordingly, much of the remainder of this section is directed towards magnetic fields.

The most recent scientific reviews by authoritative bodies are reassuring for most potential health end points. However, statistical associations[21] between prolonged exposure to elevated magnetic fields and childhood leukaemia have persisted. This led the International Agency for Research on Cancer (IARC) (Ref. B-1) in 2002 to classify magnetic fields as a "possible carcinogen"[22].

The fact that, despite over 30 years of laboratory research, no mechanism for an effect has been established, lends weight to the possibility that the observed statistical associations reflect some factor other than a causal relationship. This point is made in the 2001 report of the UK National Radiological Protection Board's (NRPB) Advisory Group, chaired by eminent epidemiologist, the late Sir Richard Doll (Ref. B-2).

"in the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children." (page 164)

Corona ions

Although not strictly ELF fields per se, the phenomenon known as corona ions has been raised in some quarters as an alternative explanation for possible health effects attributed to EMF.

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[21] *It should be noted that a statistical association does not necessarily reflect a cause and effect relationship*

[22] *IARC publishes authoritative independent assessment by international experts of the carcinogenic risks posed to humans by a variety of agents, mixtures and exposures. These agents, mixtures and exposures are categorised into 4 groups, namely:*

- *Group 1 – the agent is carcinogenic to humans – 121 agents are included in the group, including asbestos, tobacco and ultraviolet radiation*
- *Group 2A – the agent is probably carcinogenic – 89 agents have been included in this group, including diesel engine exhaust, creosotes and PCBs*
- *Group 2B – the agent is possibly carcinogenic to humans – 315 agents have been included in this group, including gasoline, lead, nickel, petrol engine exhaust and extremely low frequency Magnetic Fields*
- *Group 3 – the agent is not classifiable as to carcinogenicity – 497 agents have been included in this group, including caffeine, coal dust, extremely low frequency electric fields and static electric and Magnetic Fields*

When high voltage conductors are surrounded by air, they can cause some of the air molecules to become electrically charged. In the mid to late 1990s, it was hypothesised by a group at Bristol University that these charged molecules can attach to pollutant particles, which may also be present in the air. It was further hypothesised that, especially downwind of high voltage power lines, the charged pollutant particles are more likely to be deposited on the skin or in the lungs, thereby increasing the risk of pollution related health effects.

In considering this issue, it is important to note that it is customary to design transmission lines to limit the conductor surface gradients under normal weather conditions to prevent the inception of corona.

The hypothesis has been examined by various independent health authorities over the years as discussed below.

World Health Organisation (WHO)

WHO addressed the corona ion hypothesis in its 2007 monograph on extremely low frequency fields (Ref B-3) as follows:

"High-voltage power lines produce clouds of electrically charged ions as a consequence of corona discharge. It is suggested that they could increase the deposition of airborne pollutants on the skin and on airways inside the body, possibly adversely affecting health. However, it seems unlikely that corona ions will have more than a small effect, if any, on long term health risks, even in the individuals who are most exposed."

(UK) National Radiological Protection Board (NRPB)

In 2004, after having reviewed the issue, the NRPB's Ad Hoc Group on Corona Ions released a report "Particle deposition in the vicinity of power lines and possible effects on health" (Ref B-4). The report concluded that:

"The effects of external fields on deposition of particles in the respiratory tract, if any, are likely to be very small";

"Any health risks from the deposition of environmental particulate air pollutants on the skin appear to be negligible."
and

"…it seems unlikely that corona ions would have more than a small effect on the long-term health risks associated with particulate air pollutants, even in the individuals who are most affected. In public health terms, the proportionate impact will be even lower because only a small fraction of the general population live or work close to sources of corona ions."

References

B-1. World Health Organisation, International Agency for Research on Cancer, Lyon, France: IARC Monographs on the evaluation of carcinogenic risks to humans. Non-Ionising Radiation Part 1: Static and Extremely Low Frequency (ELF) Electric and Magnetic Fields. (2001)

B-2. National Radiological Protection Board, (UK), ELF ElectroMagnetic Fields and the Risk of Cancer, Report of an Advisory Group on Non-Ionising Radiation, Chairman, Sir Richard Doll, NRPB Vol. 12 No. 1, 2001.

B-3. World Health Organisation: Environmental Health Criteria Vol. 238: Extremely low frequency fields. (2007).

B-4. National Radiological Protection Board, (UK), Particle Deposition in the Vicinity of Power Lines and Possible Effects on Health: Report of an independent Advisory Group on Non-ionising Radiation and its Ad Hoc Group on Corona Ions. Volume 15, No. 1, 2004

Attachment C
Health guidelines

Health guidelines for extremely low frequency electric and magnetic fields

The World Health Organisation recognises two international EMF/health guidelines:

- the *Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz) produced by the International Commission on Non-Ionising Radiation Protection (ICNIRP)* Ref C-1)
- the *IEEE Standard C95.1*, produced by the International Committee on Electromagnetic Safety, Institute of Electrical and Electronics Engineers (IEEE) in the USA.

In July 2015, the relevant Australian regulator (ARPANSA) officially adopted the more conservative of the above two, the ICNIRP 2010 Guidelines, in full, stating:

"The ICNIRP ELF guidelines are consistent with ARPANSA's understanding of the scientific basis for the protection of the general public (including the foetus) and workers from exposure to ELF EMF." (Ref. C-2)

In line with the regulator's advice, Aurecon has applied the provisions of the current international ICNIRP Guidelines to this assessment.

The 'Basic Restrictions' and 'Reference Levels'[23] for both electric and magnetic fields, contained in the current ICNIRP Guidelines' are summarised in the table below.

Table C-1: ICNIRP Guideline levels

Parameter	Basic Restriction (Volts per metre)	Reference Level
Electric field – general public	CNS Tissue of the head: 0.02 All tissue of head & body: 0.4	5,000 Volts per metre (V/m)
Magnetic field – general public		2,000 milligauss (mG)
Electric field – occupational	CNS Tissue of the head: 0.1 All tissue of head & body: 0.8	10,000 Volts per metre (V/m)
Magnetic field – occupational		10,000 milligauss (mG)

In applying the guidelines, it is to be noted that, unlike earlier versions, the various limits are now independent of duration of exposure.

In applying the ICNIRP Guidelines, it is also important to recognise that the numerical limits, eg 2,000 mG, are based on established health effects. In ICNIRP's fact sheet on the guidelines (Ref. C-3), it notes that:

"It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency Magnetic Fields is causally related with an increased risk of childhood leukaemia is too weak to form the basis for exposure guidelines. Thus, the perception of surface electric charge, the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes are the only well-established adverse effects and serve as the basis for guidance."

Being based on established biological effects (which occur at field levels much higher than those normally encountered in the vicinity of electrical equipment), the (numerical) exposure limits in the guidelines and standards cannot be said to define safe limits for possible health effects, should these exist, from magnetic fields at levels normally encountered in the vicinity of electrical equipment.

[23] *The "Reference Levels" set out in the guideline are derived from the levels at which interactions with the central nervous system are established, with a safety factor applied and a further adjustment to simplify compliance measurement.*

It is in this context that precautionary measures for ELF magnetic fields such as prudent avoidance have arisen (see Attachment D).

References

C-1 International Commission on Non-Ionising Radiation Protection (2010: Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz): *Health Physics* 99(6):818-836; (2010).

C-2 ARPANSA: *Extremely Low Frequency Electric and Magnetic Fields* – 2015, accessed 10 May 2016.

C-3. ICNIRP Fact Sheet on the guidelines for limiting exposure to time-varying electric, and Magnetic Fields (1Hz-100kHz) published in *Health Physics* 99(6): 818-836; 2010, accessed 10 May 2016, <http://www.icnirp.org/cms/upload/publications/ICNIRPFactSheetLF.pdf>.

Attachment D
Prudent avoidance

Extremely low frequency magnetic fields

Regarding the potential health effects from ELF magnetic fields, while compliance with the relevant guideline is important in protecting people from established health effects, it does not necessarily address possible health effects, should they exist, from fields at levels normally encountered in the vicinity of electrical equipment. The possibility of such effects has been comprehensively studied over several decades worldwide but, to this day, there is no clear understanding of how ELF electric or magnetic fields at low levels could pose a threat to human health.

Since the late 1980s, many reviews of the scientific literature have been published by authoritative bodies. There have also been several inquiries such as those by Sir Harry Gibbs in NSW (Ref. D-1) and Professor Hedley Peach in Victoria (Ref. D-2). These reviews and inquiries have consistently found that:

- adverse health effects have not been established for fields at levels commonly found around electrical equipment and infrastructure
- the possibility cannot be ruled out
- if there is a risk, it is more likely to be associated with the magnetic field than the electric field.

Both Sir Harry Gibbs and Professor Peach recommended a policy of prudence or prudent avoidance, which Sir Harry Gibbs described in the following terms:

"… [doing] whatever can be done without undue inconvenience and at modest expense to avert the possible risk …"

In 1999, the (US) National Institute of Environmental and Health Sciences (NIEHS) (Ref. D-3) found:

"In summary, the NIEHS believes that there is weak evidence for possible health effects from ELF-EMF exposures, and until stronger evidence changes this opinion, inexpensive and safe reductions in exposure should be encouraged." (page 38)

The practice of prudent avoidance has been adopted by the (Australian) Energy Networks Association (ENA) and most Australian power utilities.

The World Health Organisation has also addressed the notion of prudence or precaution on several occasions, including in its 2007 publication *Extremely low frequency fields. Environmental Health Criteria, Vol. 238* (Ref. D-4), which states:

"…the use of precautionary approaches is warranted. However, it is not recommended that the limit values in exposure guidelines be reduced to some arbitrary level in the name of precaution. Such practice undermines the scientific foundation on which the limits are based and is likely to be an expensive and not necessarily effective way of providing protection."

It also states:

"Provided that the health, social and economic benefits of electric power are not compromised, implementing very low-cost precautionary procedures to reduce exposure is reasonable and warranted."

Given the inconclusive nature of the science, it is considered that a prudent approach continues to be the most appropriate response in the circumstances. Under this approach, subject to modest cost and reasonable convenience, power utilities and transport authorities should design their facilities to reduce the intensity of the fields they generate, and locate them to minimise the fields that people, especially children, encounter over prolonged periods. While these measures are prudent, it cannot be said that they are essential or that they will result in any benefit.

In the Australian context, ENA's position, as adopted in their *EMF Management Handbook* (Ref. D-5), states:

"Prudent avoidance does not mean there is an established risk that needs to be avoided. It means that if there is uncertainty, then there are certain types of avoidance (no cost / very low cost measures) that could be prudent."

It also states:

"Both prudent avoidance and the precautionary approach involve implementing no cost and very low cost measures that reduce exposure while not unduly compromising other issues."

References

D-1. Gibbs, Sir Harry, Chairman, *Inquiry into Community Needs and High Voltage Transmission Line Development, Submission to the NSW Government*, February 1991.

D-2. Peach HG, Bonwick WJ and Wyse T (1992). *Report of the Panel on ElectroMagnetic Fields and Health to the Victorian Government (Peach Panel Report)*. Melbourne, Victoria: September 1992.

D-3. National Institute of Environmental Health Sciences, National Institutes of Health, (USA), *NIEHS report on health effects from exposure to power-line frequency electric and Magnetic Fields*, NIH Publication No. 99-4493, 1999.

D-4. World Health Organisation*: Environmental Health Criteria* Vol. 238: Extremely low frequency fields. (2007).

D-5. Energy Networks Association: *EMF Management Handbook*. (2016).

Attachment E

Comparison between fields produced by quad orange and triple paw paw conductors

Transgrid has advised that it may elect to use ‘triple paw paw’ conductor instead of the ‘quad orange’ conductor upon which the modelling reflected in this report has been based. Accordingly, as well as studying the quad orange cases, Aurecon has undertaken a complete set of field calculations for the triple paw paw conductors. The purpose of this attachment is to outline the EMF implications of using the triple paw paw Conductor in lieu of the quad orange.

In summary the choice between these conductors makes little difference to the EMF outcomes.

- The magnetic fields from the triple paw paw conductors are up to a few percent higher than those from the quad orange conductors.
- Conversely, the electric fields from the quad orange conductors are up to a few percent higher than those from the triple paw paw conductors.

The differences between the fields associated with the respective conductors under system normal peak load conditions are illustrated[24] in more detail in Figure E-1 (magnetic fields) and Figure E-2 (electric fields).

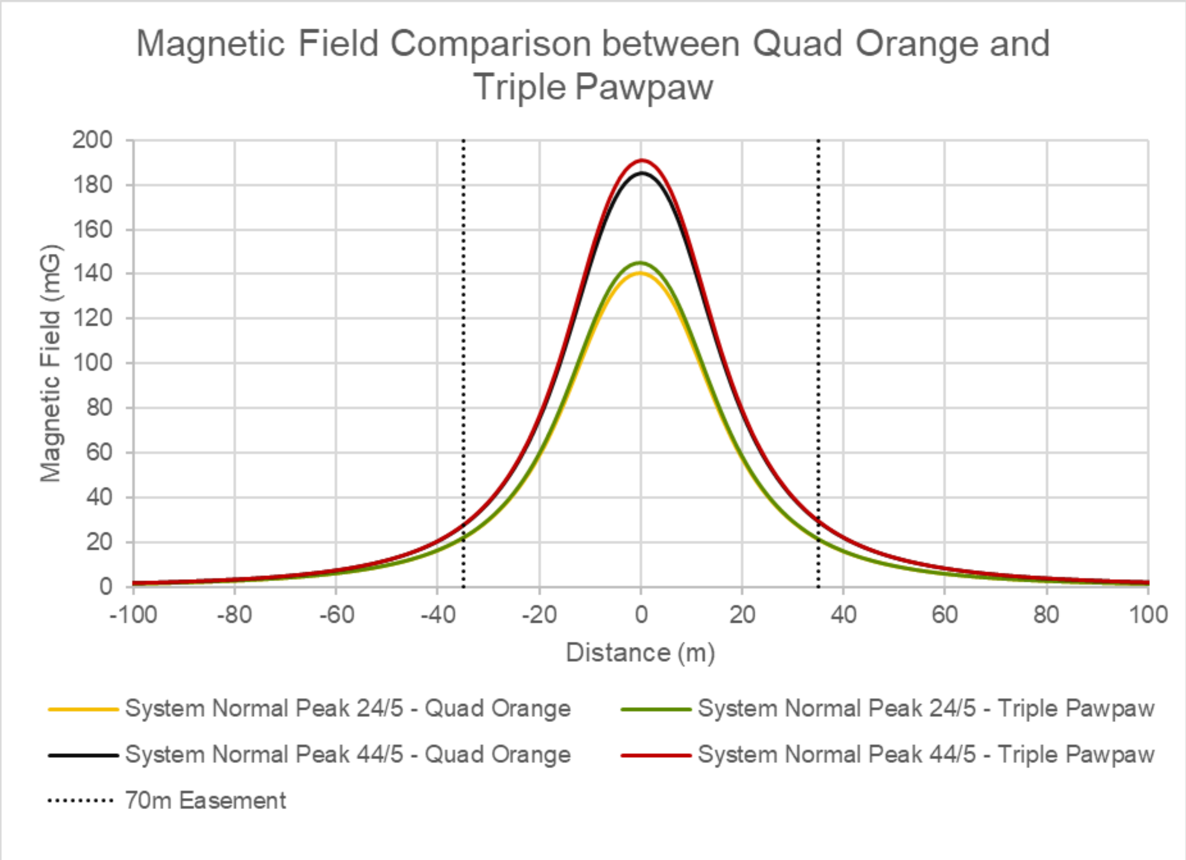

Figure E-1: Magnetic field comparison between triple paw paw and quad orange conductors

It can be seen from Figure E-1 that the magnetic fields from the triple paw paw conductors are a few percent higher than those from the quad orange conductors in all locations. However, beyond a few metres from the centre of the line, the differences are insignificant.

[24] *These examples are based on the Wondalga-Bannaby line, but the general pattern is representative.*

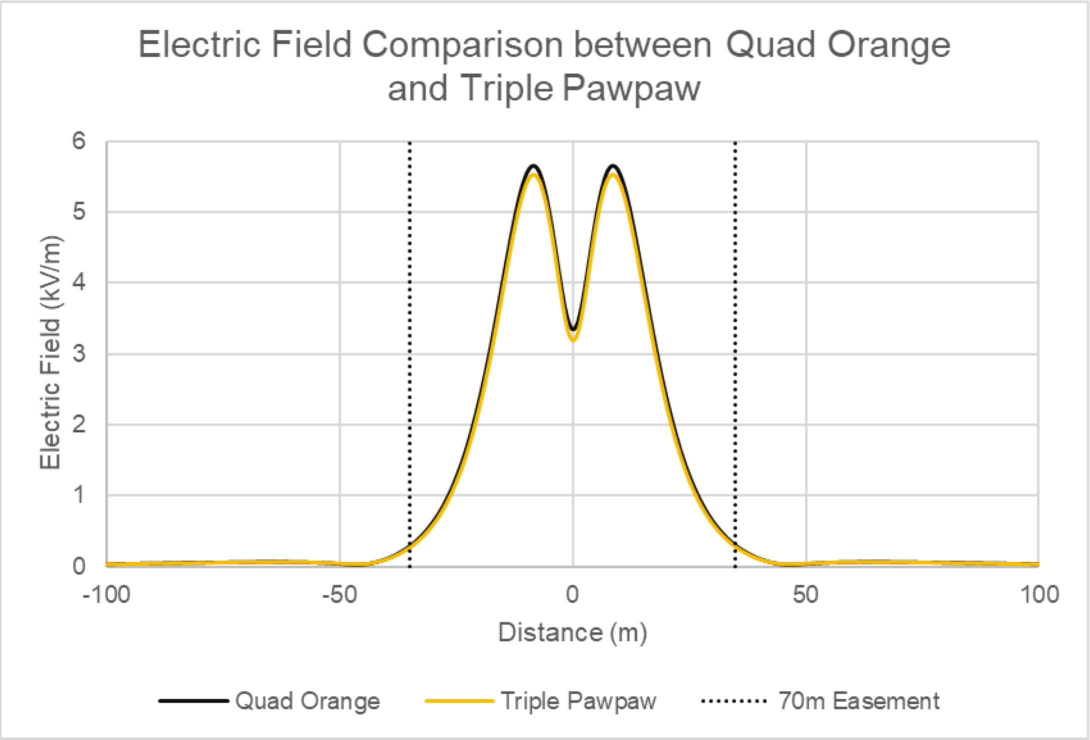

Figure E-2: Electric field comparison between triple paw paw and quad orange conductors

It can be seen from Figure E-2 that the electric fields from the quad orange conductors are a few percent higher than those from the triple paw paw conductors in all locations. However, beyond a few metres from the line, the differences are insignificant.

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Bringing ideas to life

HumeLink

Technical Report 15.2 Substation Electric and Magnetic Fields (EMF) Assessment

Transgrid

June 2023

Contents

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Tables

1 Introduction

1.1 Overview

The Australian energy landscape is transitioning to a greater mix of low-emission renewable energy sources, such as wind and solar. To support this transition, meet our future energy demands and connect Australian communities and businesses to these lower cost energy sources, the national electricity grid needs to evolve.

Transgrid proposes to increase the energy network capacity in southern New South Wales (NSW) through the development of around 360 kilometres of new 500 kilovolt (kV) high-voltage transmission lines and associated infrastructure between Wagga Wagga, Bannaby and Maragle. This project is collectively referred to as HumeLink. The project would be located across five Local Government Areas (LGAs) including Wagga Wagga City, Snowy Valleys, Cootamundra-Gundagai Regional, Upper Lachlan Shire and Yass Valley. The location of the project is shown on Figure 1-1.

HumeLink would involve construction of a new substation east of Wagga Wagga as well as connection to existing substations at Wagga Wagga and Bannaby and a future substation at Maragle in the Snowy Mountains (referred to as the future Maragle 500 kV substation). The future Maragle 500 kV substation is subject to a separate major project assessment and approval (reference SSI-9717, EPBC 2018/836).

The project would deliver a cheaper, more reliable and more sustainable grid by increasing the amount of renewable energy that can be delivered across the national electricity grid, helping to transition Australia to a low carbon future. It would achieve this by supporting the transfer of energy from existing renewable generation as well as facilitate development of new renewable generation in the Wagga Wagga and Tumut Renewable Energy Zones (REZs). The project would provide the required support for the network in southern NSW, allowing for the increase in transfer capacity between new renewable generation sources and the state's demand centres of Sydney, Newcastle and Wollongong. The project would also improve the efficiency and reliability of the current energy transfer in this part of the network.

Furthermore, HumeLink would form a key part of the transmission line infrastructure that supports the transfer of energy within the National Electricity Market (NEM) by connecting with other major interconnectors. The NEM incorporates around 40,000 kilometres of transmission lines across Queensland (QLD), NSW, Australian Capital Territory (ACT), Victoria (VIC), South Australia (SA) and Tasmania (TAS).

Construction of the project is targeted to commence in 2024, subject to the required planning and regulatory approvals. Once construction has commenced, the project is estimated to take approximately 2.5 years to build and would become operational by the end of 2026.

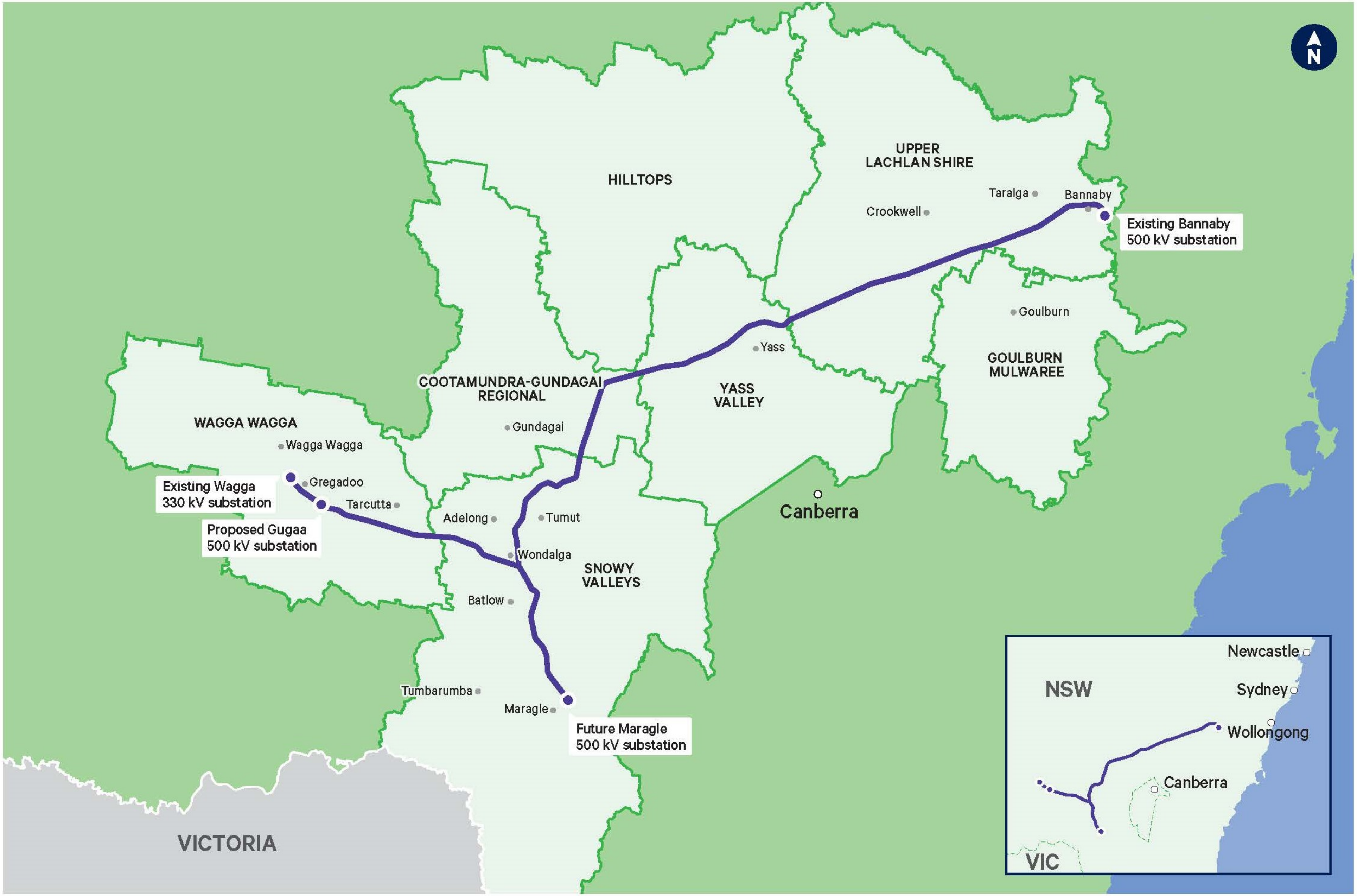
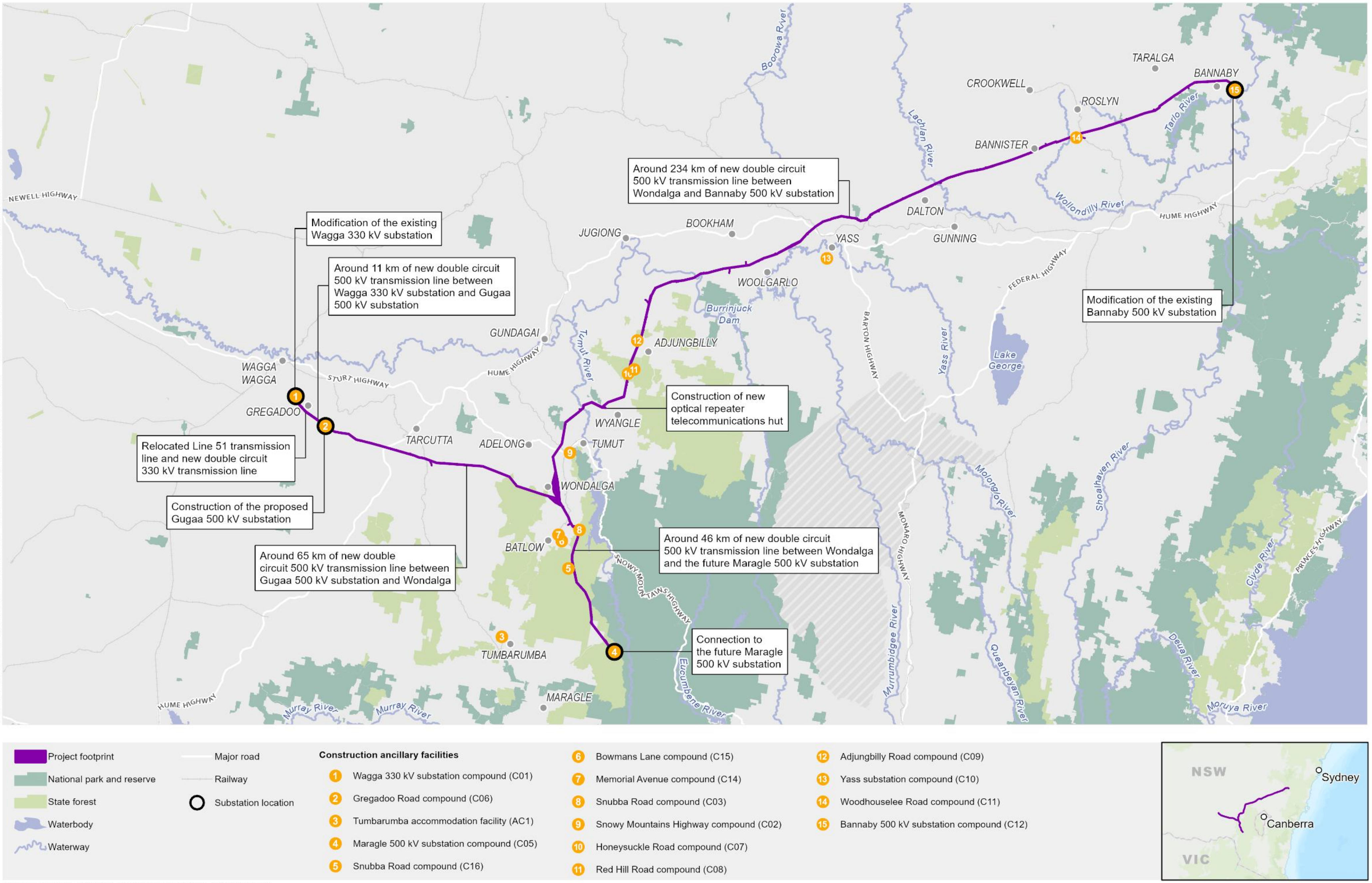


Figure 1-1 | Location of the project

1.2 Key components

The project includes the following key components (refer to Figure 1-2):

- construction and operation of around 360 kilometres of new double circuit 500 kV transmission lines and associated infrastructure between Wagga Wagga, Bannaby and Maragle
- construction of a new 500/330 kV substation at Gregadoo (Gugaa 500 kV substation) approximately 11 kilometres south-east of the existing Wagga 330/132 kV substation (Wagga 330 kV substation)
- demolition and rebuild of a section of Line 51 (around two kilometres in length) as a double circuit 330 kV transmission line connecting into the Wagga 330 kV substation
- modification of the existing Wagga 330 kV substation and Bannaby 500/330 kV substation (Bannaby 500 kV substation) to accommodate the new transmission line connections
- connection of transmission lines to the future Maragle 500/330 kV substation (Maragle 500 kV substation, approved under the Snowy 2.0 Transmission Connection Project (SSI-9717))
- provision of one optical repeater telecommunications hut and associated connections to existing local electrical infrastructure
- establishment of new and/or upgraded temporary and permanent access tracks
- ancillary works required for construction of the project such as construction compounds, worker accommodation facilities, utility connections and/or relocations, brake and winch sites, and helipad/helicopter support facilities.



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Source: *Aurecon, Transgrid, Spatial Services (DCS), ESRI Basemap*

1:925,000

0 20 40km

Projection: GDA 1994 MGA Zone 55

HumeLink **Electric and Magnetic**

FIGURE 1-2: Key components of the project

1.3 Purpose and scope of this report

Aurecon has been engaged to assess the EMF expected at substations with consideration of relevant health guidelines.

The scope of Aurecon's assessment relates to the Gugaa, Wagga, Bannaby and Maragle substations and is to encompass the following:

- Provision of a brief description of EMF in relation to human health
- Identification of relevant national and international EMF guidelines to be used for EMF assessment in substations.

The report does not provide any modelling or calculations to calculate the EMF levels associated with the substations as the substations would be designed to operate within the EMF Guideline Levels listed in Table 3-1.

1.4 Structure of this report

The structure and content of this report is as follows:

- Chapter 1 – Introduction: outlines the overview, key components and the purpose and scope of this report
- Chapter 2 – Project description summary: provides an outline and summary of the key components of the project
- Chapter 3 – Overview of electric and magnetic fields: provides a description of EMF and outlines the key guidelines relating to EMF
- Chapter 4 – Substation electric and magnetic field impacts: provides a description of the impacts related to substation EMF emissions.

2 Project description summary

The project description in this chapter is based on a concept design and indicative construction methodology for the project. The design and construction methodology would continue to be refined and confirmed during detailed design and construction planning by the construction contractors. Further details on the project are provided in Chapters 3 and 4 of the EIS.

2.1 Summary of key components of the project

Key components of the project are summarised in Table 2-1.

Table 2-1 | Summary of key components of the project

Component	Description
Transmission lines and supporting infrastructure	
Transmission lines and structures	The project includes the construction of new 500 kV transmission line sections between: ▪ Wagga 330 kV substation and Gugaa 500 kV substation (approximately 11 km) ▪ Gugaa 500 kV substation and Wondalga (approximately 65 km) ▪ Wondalga and Maragle 500 kV substation (approximately 46 km) ▪ Wondalga and Bannaby 500 kV substation (approximately 234 km). The transmission line section between the Wagga 330 kV substation and proposed Gugaa 500 kV substation would operate at 330 kV under HumeLink. The project also includes the rebuild of approximately 2 km of Line 51 as a new 330 kV transmission line between the Wagga 330 kV substation and around Ivydale Road, Gregadoo. This would be adjacent to the new transmission line between the existing Wagga 330 kV and proposed Gugaa 500 kV substations. The 500 kV transmission lines would be supported on a series of free-standing steel lattice structures that would range between around 50 m up to a maximum of 76 m in height and generally spaced between 300 to 600 m apart. The typical transmission line structure height would be around 60 m. Earth wire and communications cables would be co-located on the transmission line structures. The 330 kV structures for the rebuild of Line 51 would range between 24 m and 50 m in height and have a typical height of 40 m. Indicative configurations of transmission line structures that may be used as part of the project are shown in Figure 2-1. The type and arrangement of the structures would be refined during detailed design. The footings of each structure would require an area of up to 300 to 450 m^2, depending on ground conditions and the proposed structure type. Additional disturbance at each structure site may be required to facilitate structure assembly and stringing.
Transmission line easements	The easements for the 500 kV transmission lines are typically 70 m wide. However, a number of locations may require wider easements of up to 110 m wide at transposition locations[1] and up to 130 m wide where the new transmission line would parallel the relocated section of Line 51. The easement provides a right of access to construct, maintain and operate the transmission line and other operational assets. The easement also generally identifies the zone of initial vegetation clearance and ongoing vegetation management to ensure safe electrical clearances during the operation of the lines. Vegetation management beyond the easement may also occur where nearby trees have the potential to fall and breach safety clearances.

[1] Transposition is the periodic swapping of positions of the conductors of a transmission line in order to improve transmission reliability.

Component	Description
Telecommunications huts	Telecommunications huts, which contain optical repeaters, would be required to boost the signal in the optical fibre ground wire (OPGW). One telecommunications hut would be required for the project. The telecommunications hut would be located adjacent to existing transmission line structures. Cables would be installed between the transmission line structure and the local power supply. The telecommunications hut would be surrounded by a security fence. A new easement would be established for the telecommunications hut power connection. The project also involves a telecommunications connection of OPGW between two proposed transmission line structures and the future Rye Park Wind Farm substation (SSD-6693). This removes the need for an additional telecommunications hut in this area of the project.
Substation activities	
Construction of the proposed Gugaa 500 kV substation	A new 500/330 kV substation would be constructed at Gregadoo, about 11 km south-east of the Wagga 330 kV substation. The substation would include seven new 500/330 kV transformers and three 500 kV reactors. The proposed Gugaa 500 kV substation is expected to occupy an area of approximately 22 hectares.
Modification of the existing Bannaby 500 kV substation	The existing Bannaby 500 kV substation on Hanworth Road, Bannaby would be expanded to accommodate connections for new 500 kV transmission line circuits. The modification would include changes to the busbars, line bays, bench and associated earthworks, steelwork, drainage, external fence, internal/external substation roads, secondary containment dams, sediment containment dams, cabling, and secondary systems. All of the work would be restricted to the existing substation property.
Modification of the existing Wagga 330 kV substation	The existing Wagga 330 kV substation on Ashfords Road, Gregadoo would be reconfigured to accommodate new bays for two new 500 kV transmission line circuits within the existing substation property. This would include modifications to the busbars, line bays, existing line connections, bench and associated earthworks, relocation of existing high voltage equipment, drainage, external fence, internal substation roads, steelwork, cabling, and secondary systems.
Connection to the future Maragle 500 kV substation	The project would connect to the future Maragle 500 kV substation approved under the Snowy 2.0 Transmission Connection Project (SS1-9717). Construction of the Maragle substation is proposed to be undertaken between 2023 and 2026. Further detail on the Snowy 2.0 Transmission Connection project is available at the Department of Planning and Environment's Major Projects website: www.planningportal.nsw.gov.au/major-projects/project/10591.
Ancillary facilities	
Access tracks	Access to the transmission line structures and the substations would be required during construction and operation. Wherever possible, existing roads, tracks and other existing disturbed areas would be used to minimise vegetation clearing or disturbance. Upgrades to existing access tracks may be required. In areas where there are no existing roads or tracks, suitable access would be constructed. This may include waterway crossings.
Construction compounds	Construction compounds would be required during construction to support staging and equipment laydown, concrete batching, temporary storage of materials, plant and equipment and worker parking required to construct the various elements of the project. Fourteen potential construction compound locations have been identified. The proposed use of the construction compounds and their proposed boundaries/layout would be refined as the project design develops in consultation with relevant stakeholders and the construction contractors.

Component	Description
Worker accommodation facility	Existing accommodation facilities within towns adjacent to the project would provide temporary accommodation for the majority of the construction workers. However, a potential shortage in accommodation has been identified close to the project footprint. A potential option to provide additional temporary worker accommodation during the construction period is the establishment of a temporary worker accommodation facility at the corner of Courabyra Road and Alfred Street, Tumbarumba to accommodate about 200 construction workers. The worker accommodation facility would consist of demountable cabins and would be connected to existing utilities. All required amenities for the accommodation facility would be provided including services and worker parking for light and heavy vehicles. However, the ultimate delivery of the project may include multiple temporary worker accommodation facilities in various forms, which would be outlined in the Worker Accommodation Strategy for the project. The strategy will be developed in consultation with councils, and other relevant stakeholders. Any new or changed worker accommodation facility would be subject to additional environmental assessment, as required.
Helipad/helicopter facilities	To facilitate construction of the project, helicopters may be used to deliver materials/equipment and transfer personnel to construction areas particularly within high alpine regions. To enable helicopters to operate safely and allow easy access to the site, a helicopter landing pad would be required. The helipad is expected to occupy an area of around 30 m by 30 m and would be remediated after construction. These areas would typically be located on existing disturbed land not subject to inundation and a reasonable distance from waterways, sensitive receivers and drainage lines. Eight locations have been identified and assessed as potential helipad locations. The exact locations to be used would be confirmed during detailed design by the construction contractors. In addition to this, the existing facilities at the Wagga Wagga Airport and Tumut Airport may be used.
Utility connections, adjustments and protection	The project would require utility connections, adjustments and protection. Such works include interfaces with other transmission lines and connections to existing services for temporary facilities. Potential impacts to existing services and utilities would be confirmed during detailed design and any proposed relocation and/or protection works would be determined in consultation with the relevant asset owners.

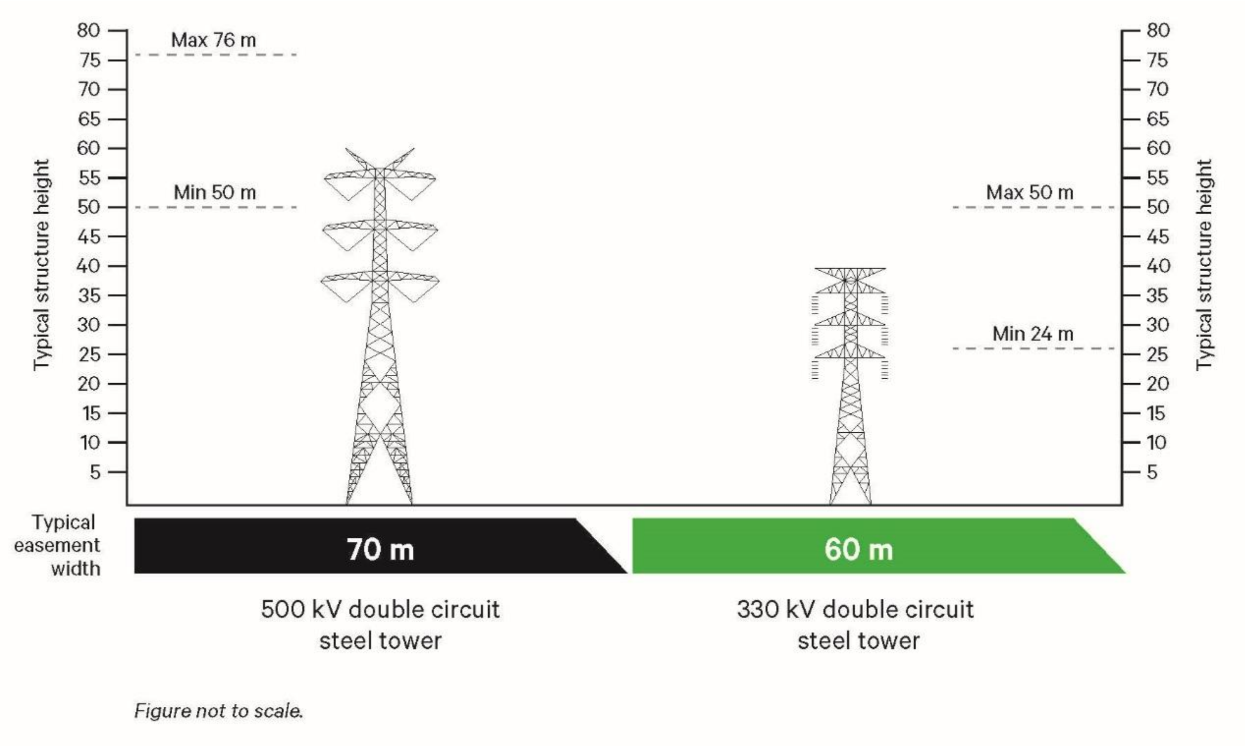

Figure 2-1 | Indicative transmission line structures

2.2 Construction of the project

2.2.1 Construction activities

- Key construction activities would generally include (but are not limited to):
  - site establishment work, such as:
  - clearing of vegetation and topsoil
  - establishment of construction compounds and helipad/helicopter facilities
  - utility relocations and/or adjustments
  - construction of new access tracks and waterway crossings and/or upgrade of existing access tracks to transmission line structures
  - road improvement work
  - establishment of environmental management measures and security fencing
  - construction of temporary worker accommodation.
- construction of the transmission lines, including:
  - earthworks and establishment of construction benches and brake and winch sites for each transmission line structure
  - construction of footings and foundation work for the new transmission line structures including boring and/or excavation, steel fabrication works and concrete pours
  - erection of the new transmission line structures
  - stringing of conductors, overhead earth wires and OPGW
  - installation of associated transmission line structure fittings inclusive of all earthing below ground level.

- relocation of a section of Line 51, including:
  - demolition of the existing section of Line 51
  - erection of new transmission line structures for the rebuild of Line 51 in a new location
  - stringing of conductors, overhead earth wires and OPGW
  - installation of associated transmission line structure fittings inclusive of all earthing below ground level.
- construction of the proposed Gugaa 500 kV substation, including:
  - bulk earthworks to form the substation bench, access roads, drainage and oil containment structures
  - installation of concrete foundations, bund walls, fire walls, noise walls and kerbs including excavation
  - installation of reinforced concrete and piled foundations for the electrical equipment and associated steel support structures
  - installation of electrical conduits, electrical trenches, site stormwater drainage, oil containment work and associated concrete pits, pipes and tanks including excavation
  - installation of new ancillary and equipment control buildings
  - erection of galvanised steel structures to support electrical equipment
  - installation of electrical equipment on foundations and/or steel support structures
  - installation of conductors, cabling, wiring, electrical panels and electrical equipment
  - erection of the substation site boundary security fencing, including site access gates
  - connection of the proposed transmission lines to the substation.
- modification of the existing Wagga 330 kV substation to enable the proposed connection and operation of the new transmission lines, including:
  - demolition and removal of redundant electrical equipment, fencing and cabling
  - bulk earthworks to form the extended substation bench and modified drainage structures
  - installation of concrete foundations and kerbs including excavation
  - installation of reinforced concrete and piled foundations for the electrical equipment and associated steel support structures
  - erection of galvanised steel structures to support electrical equipment
  - installation of electrical equipment on foundations and/or steel support structures
  - installation of electrical conduits, electrical trenches, and modified site stormwater drainage including excavation
  - installation of conductors, cabling, wiring, electrical panels and electrical equipment
  - installation of fencing, lighting and other security features
  - testing and commissioning
  - connection of the proposed transmission lines to the substation.
- modification of the existing Bannaby 500 kV substation to enable the proposed connection and operation of the new transmission lines, including:
  - bulk earthworks to form the extended substation bench, new access road, modified stormwater drainage, modified oil containment and modified sediment control structures
  - installation of concrete foundations, retaining walls, bund walls, fire walls and kerbs including excavation
  - installation of reinforced concrete and piled foundations for the electrical equipment and associated steel support structures

- erection of galvanised steel structures to support electrical equipment
- installation of electrical equipment on foundations and/or steel support structures
- installation of electrical conduits, electrical trenches, site stormwater drainage, oil containment works and associated concrete pits, pipes and tanks including excavation
- installation of conductors, cabling, wiring, electrical panels and electrical equipment
- installation of fencing, lighting and other security features
- demolish redundant fencing including footings and kerbs
- testing and commissioning
- connection of the proposed transmission lines to the substation.

- connection of the proposed transmission lines to the future Maragle 500 kV substation, including:
  - stringing conductors between transmission line structures and the future Maragle 500 kV substation gantry (including overhead earth wire (OHEW) and OPGW)
  - installing droppers from the future substation gantry to the switchgear.
- construction of the telecommunications hut, including:
  - bulk earthworks to form the pad for the hut
  - excavation and preparation for concrete foundations
  - installation of reinforced concrete and piled foundations
  - excavation and installation of electrical equipment conduits, trenches and general site drainage work
  - installation of the building, site wiring and electrical equipment
  - installation of security fencing and site access gates.
- installation of buried cabling from the 500 kV transmission line structures to Rye Park Wind Farm substation
- testing and commissioning of new electrical infrastructure
- demobilisation and rehabilitation of areas disturbed by construction activities.

A number of activities are expected to commence in accordance with the project conditions of approval before the key construction activities outlined above. These activities are considered pre-construction minor work and would comprise low impact activities that would begin after planning approval but prior to approval of the Construction Environmental Management Plan.

2.2.2 Construction program

Construction of the project is targeted to commence in 2024 and is estimated to take about 2.5 years to complete. The project is expected to be fully operational by the end of 2026 (refer to Figure 2-2).

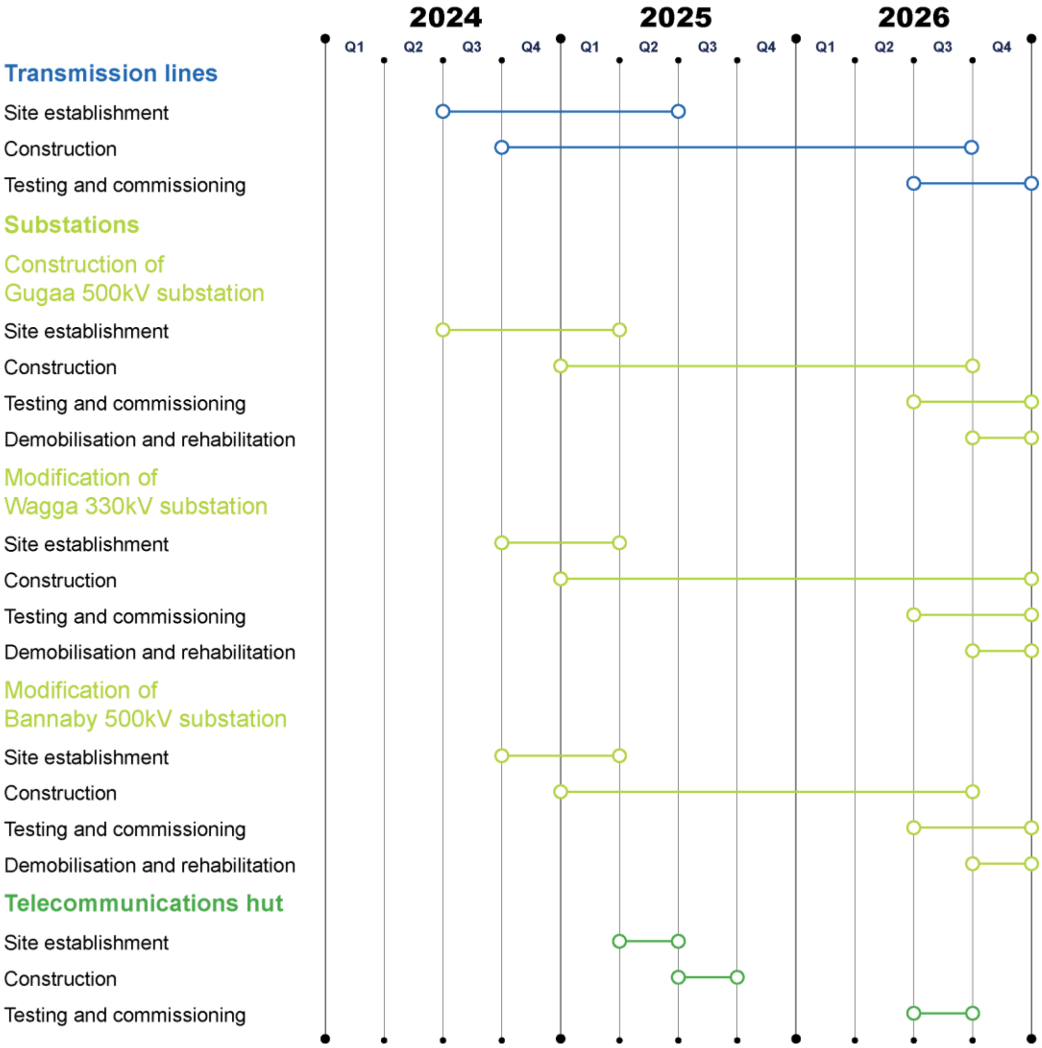

Figure 2-2 | HumeLink indicative construction program

Indicative duration of construction activities

Construction at each transmission line structure would be intermittent and construction activities would not occur for the full duration at any one location. Durations of any particular construction activity, and inactive/respite periods, may vary for a number of reasons including (but not limited to):

- multiple work fronts
- resource and engineering constraints
- work sequencing and location.

Figure 2-3 presents an indicative duration of construction activities associated with an individual transmission line structure.

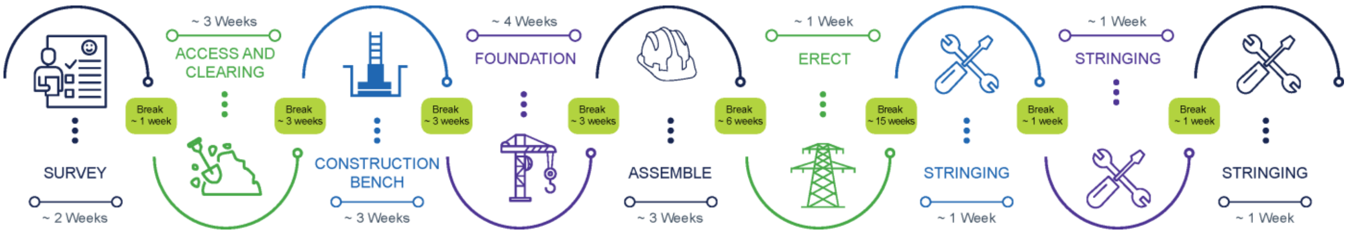

Figure 2-3 | Indicative duration and sequence of construction activities for transmission line structures

Construction of the proposed Gugaa 500 kV substation could take up to 2.5 years.

2.2.3 Construction hours

It is expected that construction activities would largely be undertaken during standard construction hours. However, there would be times when working outside of standard construction hours would be required (as defined by the *Interim Construction Noise Guideline* (DECC, 2009)), subject to approval. As the details of construction methodology and project needs are developed, these hours will be refined for certain activities.

Where extended hours are proposed for activities in proximity to sensitive receivers, additional measures would be implemented and the work would be managed through an out-of-hours work protocol.

A series of work outside the standard construction hours is anticipated to include (but is not limited to) the following:

- transmission line construction at crossings of a main road or railway as these locations are expected to have restricted construction hours requiring some night work for activities such as conductor stringing over the crossing(s)
- work where a road occupancy licence (or similar) is required, depending on licence conditions
- transmission line cutover and commissioning
- the delivery of equipment or materials outside standard hours requested by police or other authorities for safety reasons (such as the delivery of transformer units)
- limited substation assembly work (eg oil filling of the transformers)
- connection of the new assets to existing assets under outage conditions (eg modification and/or connection work at Bannaby 500 kV substation, Wagga 330 kV substation and Maragle 500 kV substation), which is likely to require longer working hours
- emergency work to avoid the loss of lives and/or property and/or to prevent environmental harm
- work timed to correlate with system planning outages
- situations where agreement is reached with affected sensitive receivers
- activities that do not generate noise in excess of the applicable noise management level at any sensitive receiver.

2.2.4 Construction plant and equipment

An indicative list of construction plant and equipment likely to be required during construction is provided below.

- air compressors
- backhoe
- bobcat
- bulldozers
- concrete agitator
- concrete pump
- cranes (various sizes up to 400 tonnes)
- crawler crane with grab attachments
- drill and blast units and associated support plant/equipment
- drones
- dumper trucks
- elevated working platforms
- excavators (various sizes)
- flatbed Hiab trucks
- fuel trucks
- generators
- graders
- helicopter and associated support plant/equipment
- mulchers
- piling rig
- pneumatic jackhammers
- rigid tippers
- rollers (10-15 and 12-15 tonnes)
- semi-trailers
- tilt tray trucks
- trenchers
- transport trucks
- watercarts
- winches.

2.2.5 Construction traffic

Construction vehicle movements would comprise vehicles transporting equipment, waste, materials and spoil, as well as workers' vehicles. A larger number of heavy vehicles would be required during the main civil construction work associated with the substations. Non-standard or oversized loads would also be required for the substation work (eg for transformer transport) and transportation of transmission line structure materials and conductors.

Hume Highway, Sturt Highway, Snowy Mountains Highway, Batlow Road and Gocup Road are the main national and state roads proposed to provide access to the project footprint. These roads would be supported by regional and local roads throughout the Local Government Areas (LGAs) of Wagga Wagga City, Snowy Valleys, Yass Valley, Cootamundra-Gundagai Regional and Upper Lachlan Shire that connect to the project footprint.

2.2.6 Construction workers

The construction worker numbers would vary depending on the stage of construction and associated activities. During peak construction activities, the project could employ up to 1,200 full time equivalent construction workers across multiple work fronts. It is expected that the maximum number of construction workers at any one location would not exceed 200.

2.2.7 Testing and commissioning

Prior to energisation of the infrastructure, a series of pre-commissioning activities would be conducted. This would include testing the new transmission lines and substation earthing, primary and secondary equipment.

2.2.8 Demobilisation and rehabilitation

Demobilisation and site rehabilitation would be undertaken progressively throughout the project footprint and would include the following typical activities:

- demobilisation of construction compounds and worker accommodation facility
- removal of materials, waste and redundant structures not required during operation of the project
- removal of temporary fencing and environmental controls.

2.3 Operation and maintenance of the project

The design life of the project is 50 years, which can be extended to more than 70 years for some assets.

The substations and transmission lines would be inspected by field staff and contractors on a regular basis, with other operational activities occurring in the event of an emergency (as required). The project would require about five workers (in addition to Transgrid's existing workers) during operation for ongoing maintenance activities. Likely maintenance activities would include:

- regular inspection (ground and aerial) and maintenance of electrical equipment
- general building, asset protection zone and access road/track
- vegetation clearing/trimming within the easement
- fire detection system inspection and maintenance
- stormwater drainage systems maintenance.

It is expected that these activities would only require light vehicles and/or small to medium plant (depending on the work required).

3 Overview of electric and magnetic fields

3.1 General description

Whenever electrical equipment is in service, it produces an electric field and a magnetic field. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric conductors. Being related to voltage, the electric fields associated with high voltage equipment remain relatively constant over time, except where the operating voltage changes. Conversely, being related to current, the magnetic field strength resulting from an electrical installation varies continually with time as the load on the equipment varies.

The electric and magnetic fields associated with electrical equipment, whilst interrelated, are not dependent on each other and as such can exist independently.

3.2 Electric and magnetic fields and health

It is known that electric and magnetic fields at magnitudes much higher than those encountered in everyday life can interact with the central nervous system. In addition, the possibility of adverse health effects due to the much lower EMFs associated with electrical equipment has been the subject of extensive research throughout the world for more than 40 years.

To date, adverse health effects due to fields of the levels normally associated with electrical infrastructure, have not been established. However, due to a body of epidemiological evidence, the possibility that such effects may exist has not been ruled out.

3.3 Health guidelines

Since late 2015, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)[2] , has adopted the *Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz))* published by the International Commission on Non-Ionising Radiation Protection (ICNIRP) in 2010. In adopting the ICNIRP Guidelines ARPANSA noted:

> *"The ICNIRP ELF guidelines are consistent with ARPANSA's understanding of the scientific basis for the protection of the general public (including the foetus) and workers from exposure to ELF EMF." (Ref. C-2)*

The ICNIRP Guideline sets 'Basic Restrictions', which are derived from the levels at which interactions with the central nervous system (CNS) are established, with a safety factor applied. The Basic Restrictions are expressed in terms of Electric Field levels within the human body but, as these levels can only be assessed by sophisticated computer modelling of the body, ICNIRP also sets 'Reference Levels', expressed in terms of kV/m and microtesla[3] for electric and Magnetic Fields respectively. These levels are conservatively set such that, provided they are met, the Basic Restrictions will also be met without the need for more comprehensive analysis.

The ICNIRP 'Basic Restrictions' and 'Reference Levels' for the general public are reproduced in Table 3-1. As noted above, these criteria apply to both adults and children and are independent of duration of exposure.

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[2] *ARPANSA is the Australian government agency that is charged with the responsibility, inter alia, for protecting the health and safety of people and the environment from EMF.*
[3] *Magnetic fields are often expressed in units of milligauss, where 1 milligauss is equal to 0.1 microtesla. The units used for this report are milligauss.*

Table 3-1 | ICNIRP Guideline Levels

Parameter	Basic Restriction (Volts per metre)	Reference Level
Electric Field – General Public	CNS Tissue of the head: 0.02 All tissue of head & body: 0.4	5,000 Volts per metre (V/m)
Magnetic Field – General Public		2,000 milligauss (mG)
Electric Field – Occupational	CNS Tissue of the head: 0.1 All tissue of head & body: 0.8	10,000 Volts per metre (V/m)
Magnetic Field – Occupational		10,000 milligauss (mG)

The general public guidelines have been considered to apply outside the substation yard and the occupational levels have been considered to apply for within the substation accessible areas.

4 Substation electric and magnetic field impacts

HumeLink would connect four substations to reinforce the transmission network in southern NSW. This section provides a brief description of the substation sites and proposed substation works, modifications and upgrades, line connections being carried out as part of the project.

4.1 Proposed Gugaa 500 kV substation

A new 500/330kV substation is proposed to be built as part of HumeLink at Gregadoo NSW about 11 kilometres south-east of the existing Wagga 330 kV substation.

The configuration of the proposed substation (the proposed Gugaa 500 kV substation) would include two line bays at the western end to enable line connections to the Wagga 330 kV substation and two line bays at the eastern end to provide line connection to the Bannaby 500 kV substation and the future Maragle 500kV substation.

The infrastructure and equipment of the new substation would typically include:

- seven new single-phase 500/330 kV transformers (six to be put into service and one spare)
- three new three-phase 500 kV reactors
- a range of supporting 500 kV and 330 kV circuit breakers, current transformers, voltage transformers, disconnectors, earth switches and other high voltage equipment
- 125V DC and 400V AC electrical distribution systems.

The proposed Gugaa 500 kV substation would be enclosed by security fences and access to the substation would be controlled to authorised persons only. The substation would be designed to ensure that EMF in accessible areas of the substation would comply with the ICNIRP Occupational Guideline Level.

The substation design would also ensure that the EMF levels outside the substation fence line where the general public can access are below the ICNIRP General Public Guideline Reference Levels. Given the above, and that the nearest sensitive receiver is located about 540 metres north of the substation, it is not expected that the proposed substation would result in any potential human health risks.

4.2 Future Maragle 500 kV substation

The future Maragle 500/330kV substation is proposed to be constructed as part of the Snowy 2.0 Transmission connection project. As part of HumeLink, the transmission lines would be connected to provide connections to the proposed Gugaa 500 kV substation and Bannaby 500 kV substation.

The connection of lines to the substation is not expected to change the overall EMF impacts associated with the proposed operation of the substation. However, the connection of transmission line to the line bays would be designed to ensure that the landing span EMF levels are below the ICNIRP Guideline Level listed in Table 3-1.

No sensitive receivers have been identified in proximity to the substation.

4.3 Bannaby 500 kV substation

The existing Bannaby 500kV substation located on Hanworth Road, would be expanded as part of HumeLink to accommodate connections for new 500 kV transmission lines. The new 500 kV transmission lines would provide connections to the future Maragle 500 kV substation and proposed Gugaa 500 kV substation.

As part of the proposed modification to the existing substation, the existing Bannaby substation yard would be expanded on northern and western sides. Proposed modifications include installation of two 500 kV reactors, extension of 500 kV busbars, addition of high-voltage switchyard equipment and installation of secondary systems in the existing control building.

The new modifications proposed in the substation would be designed to ensure that EMF within those areas of the substation accessible to authorised persons are well below the ICNIRP Occupational Guideline Levels. The additional upgrade to the Bannaby substation is not expected to change the overall EMF impacts associated with the existing operation of the substation.

The design of the modifications would also ensure that the EMF levels outside the substation are below the ICNIRP Guideline Reference Levels for General Public. Given the above, and that the nearest sensitive receiver is located about 680 metres south-east of the substation, it is not expected that the proposed substation augmentation would result in any potential health risk.

4.4 Wagga 330 kV substation

The existing Wagga 330 kV substation would be reconfigured as part of the HumeLink project to accommodate new bays for two new transmission lines which provide connections to the proposed Gugaa 500 kV substation.

The modifications are mainly proposed for the southern part of the substation. The modifications include modifications to the busbars, line bays, and existing line connections.

An existing vacant bay at the substation would be equipped with the new 330 kV double circuit infrastructure associated with Line 51.

Prior to the execution of the HumeLink project, the existing Wagga 330 kV substation would be extended towards the west as part of the Energy Connect project.

The modifications proposed to the existing Wagga 330kV substation as part of HumeLink are not expected to change the overall EMF impacts associated with the existing operation of this substation.

The closest sensitive receiver is a residential dwelling located about 270 metres south-east of the substation. The substation has been designed to operate within the ICNIRP Public Reference Levels listed in Table 3-1 and the proposed modification would also be designed to ensure compliance with these levels.

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