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AECOM

Technical Paper 12 - Electro Magnetic Field Assessment Report

20-Sep-2023
Central West Orana Renewable Energy Zone Transmission

Client: Energy Corporation

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Glossary of Terms

AC	Alternating Current
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
AS	Australian Standards
CNS	Central Nervous System
CSSI	Critical State Significant Infrastructure
DPE	Department of Planning and Environment
EIS	Environmental Impact Statement
ELF	Extremely Low Frequency
EMF	Electro Magnetic Field
ENA	Energy Networks Association
EnergyCo	Energy Corporation of NSW
EP&A Act	Environmental Planning and Assessment Act
EPBC Act	Environment Protection and Biodiversity Conservation Act
IARC	International Agency for Research on Cancer
ICNIRP	International Commission for Non-Ionizing Radiation Protection
LGAs	Local Government Areas
NEM	National Electricity Market
RFI	Radio Frequency Interference
REZs	Renewable Energy Zone
SEARs	Secretary's Environmental Assessment Requirements
WHO	World Health Organisation

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Summary

This technical paper assesses the potential impacts from an electromagnetic field (EMF) from the Central West Orana Renewable Energy Zone Transmission project (the project). It has been prepared to support and inform the Environmental Impact Statement (EIS) for the project.

The impacts have been assessed in accordance with the Secretary's Environmental Assessment Requirements (SEARs) issued by the NSW Department of Planning and Environment (DPE) and against relevant legislation and guidelines as they apply to EMF.

Project overview

The NSW Government is leading the development of Renewable Energy Zones (REZ) across NSW to deliver renewable energy generation and storage, supported by high voltage transmission infrastructure. Energy Corporation of NSW (EnergyCo) is proposing the construction and operation of new high voltage electricity transmission infrastructure and new energy hubs and switching stations required to connect new energy generation and storage projects within the Central-West Orana REZ to the existing electricity network (the project). The project is located within the Warrumbungle, Mid-Western Regional, Dubbo Regional and Upper Hunter local government areas (LGAs) and extends north to south from Cassilis to Wollar and east to west from Cassilis to Goolma.

The project would enable at least three gigawatts of new network capacity to be unlocked by the mid-2010s and enable renewable energy generators within the Central-West Orana REZ who are successful in their bids to access the new transmission infrastructure to export electricity to the rest of the network. Importantly, the development of renewable energy generation projects in the Central-West Orana REZ is the sole responsibility of private generators and subject to separate planning and environmental approvals.

Legislative and policy context

The assessment of potential EMF risks from the project was carried out in accordance with the International Commission for Non-Ionizing Radiation Protection (ICNIRP) Guideline for Limiting Exposure to time-varying electric, magnetic and electromagnetic fields (ICNIRP, 2010).

The ICNIRP (2010) set limits on electrical and magnetic fields induced in the body by EMF. The ICNIRP sets 'Basic Restrictions', which are the limitations of exposure that may lead to established health effects.

However, given the difficulties in assessing internal electric field strength, the ICNIRP also sets 'Reference Levels' for external electric field that are conservatively estimated based on Basic Restrictions. The compliance for electromagnetic levels for public safety is assessed against the "Reference Levels, which are summarised below.

EMF Component	Public Reference Level
Electric Field V/m	5,000
Magnetic Field mG (Am^{-1+})	2,000 (159)

Methodology

The assessment of potential EMF risks from the project included the following key steps:

- Determining the Reference Levels from ICNIRP (2010).
- Identifying sensitive receivers (dwellings) using publicly available data.
- Determining the geometry, physical and electrical characteristics and capacity of the transmission lines.
- Reviewing areas with significant or complex interaction between transmission lines, especially where transmission lines run in parallel or intersect each other.
- Reviewing the location and layout of substations, energy hubs and switching stations.
- Modelling the Reference Levels for 500kV and 330kV transmission lines the following configurations and determining EMF levels at the ground level at the edge of easement.
- Two (2) Double Circuit 500kV lines operating at 500kV in parallel.
- Two (2) Double Circuit 500kV lines operating at 330kV in parallel.
- Two (2) Double Circuit 500kV lines operating at 500kV and one (1) 330kV double circuit line in parallel.
- Two (2) Double Circuit 500kV lines operating at 330kV and one (1) 330kV double circuit line in parallel.
- Two (2) Double Circuit 330kV lines in parallel.
- One (1) Double Circuit 330kV line. (All 330kV transmission line modelled as double circuit for conservative approach to assessment.
- 500/330kV Energy Hubs.
- 330kV Energy Hubs.
- 330kV Switching Station.
- Transgrid 330kV Line 79 overcrossings with two (2) 500kV Double circuit lines operating at 500kV.

  At these locations, the cumulative effects of interfacing EMF sources are considered.

Existing Environment

Largely rural location with existing transmission lines, townships and national park within proximity to the project area.

Potential impacts

The EMF assessment found the electromagnetic field levels at the boundary of the project (edge of transmission line easement and boundary of energy hubs) is compliant with the Reference Levels contained within the ICNIRP, and that there was no dwelling within the vicinity of the transmission line easement that would be exposed to EMF levels exceeding the Reference Level.

Based on this assessment, it was concluded that no mitigation or modifications are required for the project.

A Radio Frequency Interference (RFI) Assessment was not undertaken as the presence of RFI does not impact the location of transmission lines, generator connectors, energy hubs, substations and switching stations.

1.0 Introduction

1.1 Background

New South Wales (NSW) is currently undergoing an energy sector transformation that will change how we generate and use energy. The NSW Government is leading the development of Renewable Energy Zones (REZs) across NSW to deliver renewable energy generation and storage projects, supported by transmission infrastructure. A REZ connects renewable energy generation and energy storage systems to transmission infrastructure via energy hubs, requiring the coordination of power generation, power storage and transmission infrastructure. By doing so, REZs capitalise on economies of scale to deliver clean, affordable and reliable electricity for homes, businesses and industry in NSW.

The Central-West Orana REZ was formally declared on 5 November 2021 under the *Electricity Infrastructure Investment Act 2020*. As NSW's first REZ, the Central-West Orana REZ will play a pivotal role in underpinning NSW's transition to a clean, affordable and reliable energy sector. The Central-West Orana REZ declaration (November 2021) provides for an initial intended network capacity of three gigawatts. The NSW Government is proposing to amend the declaration to increase the intended network capacity to six gigawatts, which would allow for more renewable energy from solar, wind and storage projects to be distributed through the NSW transmission network.

The proposed amendment is consistent with the NSW Network Infrastructure Strategy (EnergyCo, 2023) which identifies options to increase network capacity to 4.5 gigawatts initially under Stage 1 (which would be based on the infrastructure proposed in this assessment) and up to six gigawatts by 2038 under Stage 2 (which would require additional infrastructure beyond the scope of this assessment, and subject to separate approval). The proposed amendment also supports recent modelling by the Consumer Trustee in the draft 2023 Infrastructure Investment Objectives Report (AEMO, 2023) showing more network capacity will be needed to meet NSW's future energy needs as coal-fired power stations progressively retire.

Energy Corporation of NSW (EnergyCo), a NSW Government statutory authority, has been appointed as the Infrastructure Planner under the *Electricity Infrastructure Investment Act 2020*, and is responsible for the development and delivery of the Central-West Orana REZ. EnergyCo is responsible for coordinating REZ transmission, generation, firming and storage projects to deliver efficient, timely and coordinated investment.

EnergyCo is seeking approval for the construction and operation of new electricity transmission infrastructure and new energy hubs and switching stations that are required to connect energy generation and storage projects within the Central-West Orana REZ to the NSW transmission network (the project).

1.2 Purpose of this paper

This technical paper assesses the potential impacts to human health due to EMF from the construction and operation of the project and has been prepared to support and inform the Environmental Impact Statement (EIS).

This technical paper has been prepared to address the relevant Secretary's environmental assessment requirements[1] (SEARs) for the project issued by the Secretary of the NSW Department of Planning and Environment (DPE) for the project on 7 October 2022, and the supplementary SEARs on 2 March 2023. The SEARs relevant to the assessment of EMF are presented in Table 1

Table 1: Secretary Environmental Assessment Requirements (SEARs) relevant to this paper

Reference	Assessment requirement	Location where it is addressed
Hazards and Risks - health	an assessment of potential hazards and risks associated with electric and magnetic fields (EMF) having regard to the latest advice of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)	Section 4.0 of this document

[1] https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSI-48323210%2120221007T061127.689%20GMT]

1.3 Project overview

The project comprises the construction and operation of new electricity transmission infrastructure, energy hubs and switching stations within the Central-West Orana REZ. The project would enable 4.5 gigawatts of new network capacity to be unlocked by the mid-2020s (noting the NSW Government's proposal to amend the Central-West Orana REZ declaration to allow for a transfer capacity of six gigawatts) and enable renewable energy generators within the Central-West Orana REZ who are successful in their bids to access the new transmission infrastructure to export electricity onto the National Electricity Market (NEM). A detailed description of the project, including a description of key project components, the construction methodology and how it would be operated is provided in Chapter 3 of the EIS.

1.3.1 Features

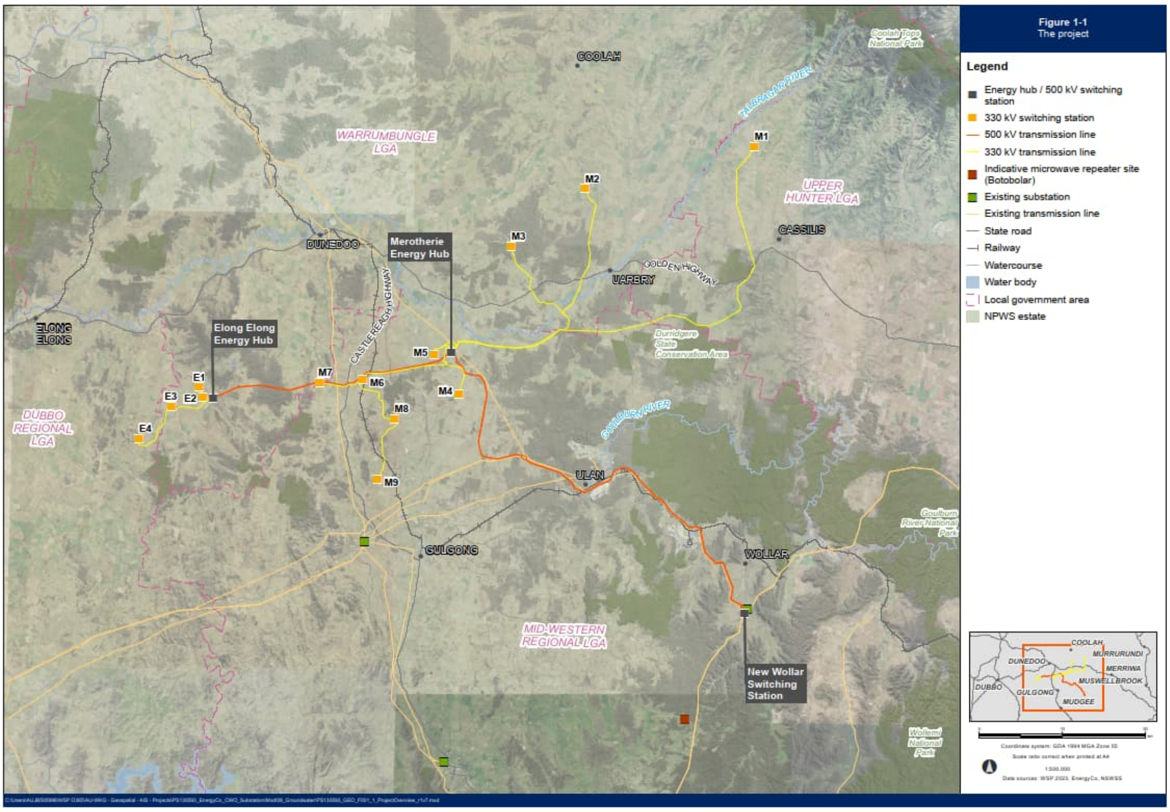
The project would comprise the following key features:

- A new 500 kV switching station (the New Wollar Switching Station), located at Wollar to connect the project to the existing 500 kV transmission network
- Around 90 kilometres of twin double circuit 500 kV transmission lines and associated infrastructure to connect two energy hubs to the existing NSW transmission network via the New Wollar Switching Station
- Energy hubs at Merotherie and Elong Elong (including potential battery storage at the Merotherie Energy Hub) to connect renewable energy generation projects within the Central-West Orana REZ to the 500 kV infrastructure
- Around 150 kilometres of single circuit, double circuit and twin double circuit 330 kV transmission lines, supported on towers, to connect renewable energy generation projects within the Central-West Orana REZ to the two energy hubs
- Thirteen switching stations along the 330 kV network infrastructure at Cassilis, Coolah, Leadville, Merotherie, Tallawang, Dunedoo, Cobbora and Goolma, to transfer the energy generated from the renewable energy generation projects within the Central-West Orana REZ onto the project's 330 kV network infrastructure
- Underground fibre optic communication cables along the 330 kV and 500kV transmission lines between the energy hubs and switching stations
- A maintenance facility within the Merotherie Energy Hub to support the operational requirements of the project
- Microwave repeater sites at locations along the alignment, as well as outside of the alignment at Botobolar, to provide a communications link between the project and the existing electricity transmission and distribution network. The Botobolar site would be subject to assessment at the submissions report stage.
- Establishment of new, and upgrade of existing access tracks for transmission lines, energy hubs, switching stations and other ancillary works areas within the construction area (such as temporary waterway crossings, laydown and staging areas, earthwork material sites with crushing, grinding and screening plants, concrete batching plants, brake/winch sites, site offices and workforce accommodation camps)
- Property adjustment works to facilitate access to the transmission lines and switching stations. These works include the relocation of existing infrastructure on properties that are impacted by the project
- Utility adjustments required for the construction of the transmission network infrastructure, along with other adjustments to existing communications, water and wastewater utilities. This includes adjustments to Transgrid's 500kV transmission lines 5A3 (Bayswater to Mount Piper) and 5A5 (Wollar to Mount Piper) to provide a connection to the existing NSW transmission network, including new transmission line towers along the Transgrid network along the frontage of the New Wollar Switching Station, and other locations where there is an interface with Transgrid's network.

1.3.2 Location

The project is in central-west NSW within the Warrumbungle, Mid-Western Regional, Dubbo Regional and Upper Hunter Local Government Areas (LGAs). It extends north to south from Coolah to Wollar and east to west from Cassilis to Goolma. The location of the project is shown in Figure 1

Figure 1 Current CWO REZ Route



1.3.3 Timing

Construction of the project would commence in the second half of 2024, subject to NSW Government and Commonwealth planning approvals, and is estimated to take about four years. The project is expected to be commissioned/energised (i.e. become operational) in late 2027).

1.3.4 Construction

Key construction activities for the project would occur in the following stages:

- enabling works
- construction works associated with the transmission lines
- construction works associated with energy hubs and switching stations
- pre-commissioning and commissioning of the project
- demobilisation and rehabilitation of areas disturbed by construction activities.

Excavation and land forming works within the construction area would be required for transmission line tower construction, site preparation works at the energy hubs and switching station sites to provide level surfaces, to create trenches for drainage, earthing, communications infrastructure and electrical conduits, and to construct and upgrade access tracks.

Construction vehicle movements would comprise heavy and light vehicles transporting equipment and plant, construction materials, spoil and waste from construction facilities and workforce accommodation camp sites. There would also be additional vehicle movements associated with construction workers travelling to and from construction areas and accommodation camp sites. These movements would occur daily for the duration of construction.

To support the construction of the project a number of construction compounds would be required including staging and laydown facilities, concrete batching plants, workforce accommodation camps and construction support facilities. The main construction compounds would be established as enabling works and demobilised at the completion of construction. The size of the construction workforce would vary depending on the stage of construction and associated activities. During the peak construction period, an estimated workforce of up to around 1,800 people would be required.

1.3.5 Operation

During operation, the project would transfer high voltage electricity from the Central West-Orana REZ to the NEM. Permanent project infrastructure 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). Regular inspection and maintenance activities are expected to include:

- regular inspection (ground and aerial) and maintenance of electrical equipment and easements
- fault and emergency response (unplanned maintenance)
- general building, asset protection zone and landscaping maintenance
- fire detection system inspection and maintenance
- stormwater maintenance
- remote asset condition monitoring
- network infrastructure performance monitoring.

Operation of the project would require the establishment of transmission line easements. These easements would be around 60 metres for each 330kV transmission line and 70 metres for each 500kV transmission lines. Where network infrastructure is collocated, easement widths would increase accordingly (for example, a twin double circuit 500kV transmission line would have an easement about 140 metres wide). Vegetation clearing would be required to some extent for the full width of the transmission line easement, depending on the vegetation types present.

1.4 Overview of electric and magnetic fields

1.4.1 Electromagnetic Fields Explained

Electric and magnetic fields, or electromagnetic fields exist wherever Alternating Current (AC) electric current flows, e.g. in transmission power lines, residential wiring and electrical appliances. Electricity is widely used in modern life, which means electric and magnetic fields are all around us and exist wherever electricity is used.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), an Australian Government agency, is responsible for the regulation of EMF. ARPANSA also undertakes research, provides services and promotes national uniformity and the implementation of international best practice across all states and territories.

The ARPANSA provides the following definition of Extremely low frequency (ELF) electric and magnetic fields (EMF):

> "*Extremely low frequency (ELF) electric and magnetic fields (EMF) occupy the lower part of the electromagnetic spectrum in the frequency range 0-3000 Hz. ELF EMF result from electrically charged particles. Artificial sources are the dominant sources of ELF EMF and are usually associated with the generation, distribution and use of electricity at the frequency of 50 Hz in Australia or 60 Hz in some other countries. The electric field is produced by the voltage whereas the magnetic field is produced by the current.*"

The strength of the force associated with an electric field is related to the voltage: the higher the force/voltage, the stronger the electric field. The electric field strength is measured in volts per metre (V/m). Electric fields are strongest closest to the source but reduce quickly with distance. In addition, most materials act as a barrier to shield electric fields.

Magnetic fields are produced by the flow of an electric current: the higher the current (measured in amps), the greater the magnetic field. The strength of magnetic fields is commonly measured and referred to in either milli-Gauss (mG) or micro-Tesla (µT). Magnetic fields are highest closest to the source but also reduce quickly with distance. The magnetic field strength produced by electrical infrastructure or equipment also varies over time. It must be noted that magnetic fields computed as part of this assessment are based on the maximum electrical load, providing conservatism to the magnetic field levels computed.

In October 2005, the World Health Organisation (WHO) convened a Task Group of scientific experts to assess the potential human health risks associated with exposure to electric and magnetic fields in the frequency range 0 to 100 kHz (WHO, 2007 [2]). The Task Group concluded that there are no substantive health issues related to electric fields at levels generally encountered by members of the public as most materials act as a barrier to electric fields. However, the Task Group identified potential for adverse health effects associated with short-term and long-term exposure to magnetic fields (as discussed in Section 1.4.3

1.4.2 Electric Field and Impact on Human Health

The known acute/short-term effects during exposure to high electric fields are the stimulation of excitable tissue such as nerve and muscle.

Dosimetry describes the relationship between external electric fields and the induced electric field within the body. The human body will perturb an extremely low frequency (ELF) electric field, such that the internal electric field within the body is typically 5-6 orders of magnitude smaller than the external electric field. Transmission line power frequency is 50Hz which is within the ELF classification of 0-3000Hz.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2010) guideline[3] is adopted in Australia for defining the Basic Restrictions to electric fields, which are the mandatory limits where biophysical interactions begin to occur and may lead to adverse health effects.

For a transmission line power frequency of 50Hz, the Basic Restriction limits refer to the internal electric field in the Central Nervous System (CNS) tissue of the head. Basic Restriction limits are defined for two categories due to the different levels of exposure. These limits are 100mV/m for occupational staff and 20mV/m for the public respectively. The electric fields which are emitted by the EMF sources (i.e. transmission lines, energy hubs) are external electric fields Therefore the limits for external electric fields applied in this assessment, have been derived from the Basic Restriction limits. The limits for external 50Hz electric fields are 50kV/m for occupational staff and 10kV/m for the public respectively.

The ICNIRP (2010) guideline[3] then defines Reference Levels, which are set below the Basic Restriction limits with additional margin.

The ICNIRP (2010) 50Hz electric field Reference Level are defined as:

- 10kV/m for occupational staff
- 5kV/m for the general public. The smaller reduction for the general public, compared to occupational staff does not equate to a less conservative approach, because the Basic Restriction limits for the general public were set with additional margin below the occupational limits where known synaptic effects may occur
- The Reference Levels are described as ICNIRP (2010) as "practical or "surrogate" parameters that may be used for determining compliance with the Basic Restrictions" and "assume an exposure by a uniform (homogenous) field with respect to the spatial extension of the human body". ICNIRP 2010 states that the *"reference levels for electric and magnetic field exposure in this document may be exceeded if it can be demonstrated that the basic restrictions are not exceeded"* Where the Reference Levels are exceeded, further interrogation to demonstrate that the Basic Restrictions are not exceeded must be conducted.
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1.4.3 Magnetic Field and Impact on Human Health

Several animal and human studies have been undertaken to assess the potential health effects of exposure to magnetic fields, including studies published by WHO (2007) and the ICNIRP, (2010). A summary of the short-term and long-term health effects identified within this assessment and relevant guidelines are discussed below.

ICNIRP (2010) notes that "*the main interaction of magnetic fields is the Faraday induction of electric fields and associated currents in the tissues*". Potential human health effects are therefore associated with internal electric fields induced by external magnetic fields.

It is important to note that ARPANSA states:

- *"The scientific evidence does not establish that exposure to ELF EMF found around the home, the office or near powerlines and other electrical sources is a hazard to human health"; and*
- *"There is no established evidence that the exposure to magnetic fields from powerlines, substations, transformers or other electrical sources, regardless of the proximity, causes any health effects"*

1.4.3.1 Short Term Impacts

At high levels of acute/short-term exposure, ICNIRP (2010) and WHO (2007) reported that there are established health effects including:

- Direct stimulation of nerve and muscle tissue,
- Induction of retinal phosphenes, and
- Changes in nerve cell excitability in the central nervous system (CNS).

There was also indirect scientific evidence that brain functions such as visual processing and motor co-ordination can be transiently affected by induced magnetic fields.

[3] ICNIRP 'Guidelines for limiting exposure to time-varying electric and magnetic fields (1Hz –100kHz), 2010

ICNIRP (2010) states that *"the most robustly established effect of electric fields [4] below the threshold for direct nerve or muscle excitation is the induction of magnetic phosphenes, the perception of faint flickering light in the periphery of the visual field, in the retinas of volunteers exposed to low frequency magnetic fields. The minimum threshold flux density for the induction of retinal phosphenes is around 5 mT (50,000 mG) at 20 Hz, rising at higher and lower frequencies.*

Health guidelines (discussed further in Section 2.1) are based on these noted short team health effects.

1.4.3.2 Long Term Impacts

In 2002, International Agency for Research on Cancer (IARC) published a monograph[5] classifying extremely low-frequency magnetic field as Group 2B "possibly carcinogenic to humans". This classification is 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.

As stated by the WHO (2007), *"this classification was based on a pooled analyses of epidemiological studies demonstrating a consistent pattern of a two-fold increase in childhood leukaemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 µT*". However, WHO (2007) noted that the epidemiological evidence is weakened by:

- Potential selection bias,
- There are no accepted biophysical mechanisms that would indicate that low-level exposure leads to cancer development, and
- Animal studies, for the most part, have been negative.

Other potential health effects associated with long-term exposure to magnetic fields have been studied including other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease. WHO (2007) identified that the scientific evidence supporting these other health effects is much weaker (or not at all) than for childhood leukaemia.

WHO (2007) noted that:

> "*there are uncertainties about the existence of chronic effects, because of the limited evidence for a link between exposure to ELF magnetic fields and childhood leukaemia. Therefore, the use of precautionary approaches is warranted. However, it is not recommended that 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*."

In consideration of the uncertainty regarding long-term effects, WHO (2007) recommended that:

- *"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"; and*
- *"Government and industry should monitor science and promote research programmes to further reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure".*

In relation to other potential health effects, ICNIRP (2010) concluded:

- The available data do not indicate that low frequency magnetic fields affect the neuroendocrine system in a way that would have an adverse impact on human health.
- The evidence for the association between low frequency exposure and Alzheimer's disease and amyotrophic lateral sclerosis is inconclusive.
- The evidence does not suggest an association between low frequency exposure and

[4] i.e. internal electric fields induced by magnetic fields
[5] International Agency for Research on Cancer. Static and extremely low frequency electric and magnetic fields. Lyon, France: IARC; IARC Monographs on the Evaluation of Carcinogenic Risk to Humans Volume 80; 2002

cardiovascular diseases.

- The evidence for an association between low frequency exposure and developmental and reproductive effects is very weak.

1.4.4 Impact on Livestock and Plants

An independent and wide-ranging review of the EMF effects on animals and plants was undertaken in the Gibbs Inquiry[6].

Electric and magnetic fields have the potential to impact livestock similarly to humans. However, the relevant findings from the Gibbs Inquiry are as follows:

> *"The electric fields and the magnetic fields created by transmission lines do not affect the health or reproductive capacity of livestock."*

The only known impact to plants is where leaf damage may occur if the electric field is high enough to cause corona, causing the leaves to dry out reducing growth. This concern is typically limited to tall trees with pointed leaves. Whereas any crops at ground level would not grow high enough to reach the electric field levels where corona may occur.

The Gibbs Inquiry concluded:

> *"From a practical point of view, the electric fields created by transmission lines have no adverse effect on crops, pasture grasses or native flora, other than trees, growing under or near to the lines."*

[6] Gibbs, Sir Harry (1991). Inquiry into community needs and high voltage transmission line development. Report to the NSW Minister for Minerals and Energy. Sydney, NSW: Department of Minerals and Energy, February 1991

2.0 Legislative and policy context

Environmental planning approval for the project is required in accordance with the *Environmental Planning and Assessment Act 1979* (EP&A Act). The project is also a controlled action and therefore requires Commonwealth assessment and approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Sections 5.12 and 5.13 of the EP&A Act provide for the declaration of State significant infrastructure (SSI) and Critical State significant infrastructure (CSSI). On 23 November 2010, the Minister for Planning made the Environmental Planning and Assessment Amendment (Central-West Orana Renewable Energy Zone Transmission Order) 2010. The Order declares the whole Central-West Orana REZ Transmission project to be CSSI.

Electric and magnetic fields, or electromagnetic fields exist wherever Alternating Current (AC) electric current flows, e.g. in transmission power lines, residential wiring and electrical appliances. Electricity is widely used in modern life, which means electric and magnetic fields are all around us and exist wherever electricity is used.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), an Australian Government agency, is responsible for the regulation of EMF. The ARPANSA provides the following definition of Extremely low frequency (ELF) electric and magnetic fields (EMF):

"Extremely low frequency (ELF) electric and magnetic fields (EMF) occupy the lower part of the electromagnetic spectrum in the frequency range 0-3000 Hz. ELF EMF result from electrically charged particles. Artificial sources are the dominant sources of ELF EMF and are usually associated with the generation, distribution, and use of electricity at the frequency of 50 Hz in Australia or 60 Hz in some other countries. The electric field is produced by the voltage whereas the magnetic field is produced by the current."

The strength of the force associated with an electric field is related to the voltage: the higher the force/voltage, the stronger the electric field. The electric field strength is measured in volts per metre (V/m). Electric fields are strongest closest to the source but reduce quickly with distance. In addition, most materials act as a barrier to shield electric fields.

Magnetic fields are produced by the flow of an electric current: the higher the current (measured in amps), the greater the magnetic field. The strength of magnetic fields is commonly measured and referred to in either milli-Gauss (mG) or micro-Tesla (µT). Magnetic fields are highest closest to the source but also reduce quickly with distance. The magnetic field strength resulting from an electrical installation varies continually with time and is affected by several factors including the total electrical load, and the layout and arrangements of the conductors.

EMF standards and guidelines are overseen by ARPANSA. The ARPANSA regulates entities that use or produce radiation with the aim of protecting people and the environment from harm. ARPANSA also undertakes research, provides services and promotes national uniformity and the implementation of international best practice across all states and territories.

ARPANSA states:

> "*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."*

In 2010, EMF standards and guidelines were updated by the International Commission for Non-Ionizing Radiation Protection (ICNIRP) and were adopted by ARPANSA.

Reference Levels are defined by ICNIRP (2010) as "*the electric and magnetic fields and contact currents to which a person may be exposed without an adverse health effect and with acceptable safety factors*".

2.1 Policy, standards and guidelines

EMF standards and guidelines are overseen by ARPANSA. The ARPANSA regulates entities that use or produce radiation with the aim of protecting people and the environment from harm.

ARPANSA states:

> "*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."*

In 2010, EMF standards and guidelines were updated by the International Commission for Non-Ionizing Radiation Protection (ICNIRP) and were adopted by ARPANSA.

The ICNIRP (2010) set the limits on electrical and magnetic fields induced in the body by EMF. Within ICNIRP (2010), limitations of exposure that may lead to established health effects are termed 'Basic Restrictions'. The physical quantity used to specify the 'Basic Restrictions' on EMF exposure is the internal electric field strength, as it is the internal electric field that effects nerve and other cells.

However, given the difficulties in assessing internal electric field strength, 'Reference Li' (Reference Levels) for external electric field were derived from relevant Basic Restrictions using measured and/or computational techniques.

Reference Levels are defined by ICNIRP (2010) as "*the electric and magnetic fields and contact currents to which a person may be exposed without an adverse health effect and with acceptable safety factors*".

The ICNIRP (2010) electric and magnetic field Reference Levels for the general public are provided in Table 2. These are the levels used for the assessment discussed in Section 3.0 and 4.0 of this report.

Table 2 ICNIRP EMF and RFI Reference Body Exposure Limits (General Public)

EMF Component	Public Reference Level
Electric Field V/m	5,000
Magnetic Field mG (Am^{-1+})	2,000 (159)

The Reference Levels described in ICNIRP (2010) as "*practical or "surrogate" parameters that may be used for determining compliance with the Basic Restrictions*" and "*assume an exposure by a uniform (homogenous) field with respect to the spatial extension of the human body*". However, if the Reference Levels are exceeded it does not necessarily mean that a health effect will occur if it can be demonstrated that the Basic Restrictions are not exceeded. Rather, it identifies the need to undertake a detail assessment to confirm compliance with the ICNIRP Guidelines.

As stated in ICNIRP (2010), compliance with the present guidelines may not necessarily preclude interference with, or effects on, medical devices such as metallic prostheses, cardiac pacemakers and implanted defibrillators and cochlear impacts. Interference with pacemakers may occur at levels below the recommended Reference Levels.

However, WHO (2007) notes:

> "*electric power brings obvious health, social and economic benefits, and precautionary approaches should not compromise these benefits. Furthermore, given both the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia, and the limited impact on public health if there is a link, the benefits of exposure reduction on health are unclear. Thus the costs of precautionary measures should be very low.*

It should be noted that the ICNIRP (2010) *"consider the scientific evidence related to possible health effects from long-term, low-level exposure to ELF fields insufficient to justify lowering these quantitative* *exposure limits"* (WHO, 2007).

2.2 Prudent Avoidance

The practice of Prudent Avoidance has been adopted by the Energy Networks Association (ENA) and most Australian power utilities. In accordance with the latest advice from ENA EMF Management Handbook[7], it states:

> "*Prudent Avoidance does not mean that 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."*

The application of Prudent Avoidance for this project has been addressed In Section 3.0 – Methodology and Section 4.0 – Impact Assessment

[7] ENA 'EMF Management Handbook', 2016

3.0 Methodology

3.1 Assessment Methodology

This section described the methodology used in this assessment of electromagnetic field hazard associated with the CWOREZ transmission infrastructure. The findings of this assessment are documented in this report.

- Determining the Reference Levels from ICNIRP (2010) which are used as the assessment criteria, as reported in Table 2
- Identifying sensitive receivers (dwellings) with respect to the proposed infrastructure, using publicly available data
- Determining the geometry, physical and electrical characteristics and capacity of the transmission infrastructure; namely the transmission lines and energy hubs
- Modelling and computation of the resultant EMF levels for the various proposed/identified transmission infrastructure configurations including:
    - Substations, energy hubs and switching stations
    - Parallel transmission lines run in parallel or transmission line crossings
    - EMF levels are assessed at 1m above ground level and assessed for compliance at the easement boundaries (ranging from 30m up to 100m from easement center)
- The computed EMF levels will be assessed against Reference Levels.
- As EMF levels decrease with increased distance from the EMF source; the EMF levels at the transmission line easement boundary and the energy hub site boundary; are good indicators that the proposed easement alignment is sufficient in addressing EMF risk to the public.

3.1.1 Constraints

The project was developed and refined to avoid or minimise impacts on environmental, social and land use features including agricultural and mining land, high-value-biodiversity areas, and dwelling clusters. Where the transmission line passes in vicinity to dwellings; clearance in excess of the required distances determined from the assessment was provided, in line with the principle of prudent avoidance"

3.2 Modelling Parameters

3.2.1 Transmission Lines and Towers

The location of the transmission lines and the tower design would impact the level of EMF emitted by the project. The interface between existing transmission lines and the project has also been considered. Interface locations and considerations are discussed further in section 3.4 and 4.1.7

Electric fields from transmission lines are relatively stable because the overall voltage passing through them does not change. Magnetic fields are dependent on the current flowing through transmission lines, as discussed in Section 1.4.1. The current flow is dependent on changing customer demands i.e. the electrical load. As a result, magnetic fields also fluctuate in response to changing loads. Typically, EMF is higher where transmission lines run in parallel or intersect each other. The parallel or intersecting transmission lines act as additional sources of EMF where the respective individual EM fields can (or worst case) combine into larger ones. The geometry of the interface such as intersection angle and separation distance are key factors in how the individual fields combine.

Tower height, spacing and clearance height can also impact the levels of EMF. The location of towers corresponds to the required ground clearance at certain locations along the transmission line and can be influenced by factors such as temperature, terrain and identified environmental constraints. Specific design requirements were adopted for the project including crossing major roads, railways, waterways and major transmission lines in accordance with AS/NZS7000 and advice from EnergyCo.

A summary of the transmission line and tower design requirements for the project are shown in Table 3.

Table 3 Reference Design Requirements

Design Requirements	500kV Transmission Line	330kV Transmission Line
Easement Width	70 m	60 m
Tower Height	50.4 m to 71.8 m	45 m to 58 m
Tower Spacing	400 m to 600 m	400 m to 600 m
Tower Ground Clearance	11.5 m	9 m

3.2.2 Substations, Energy Hubs and Switching Stations

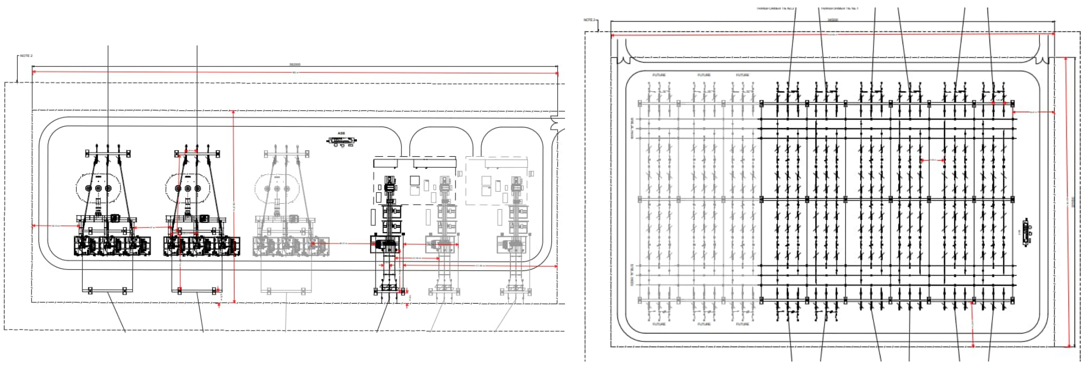
The project includes Merotherie and Elong Elong energy hubs, new switching station at Wollar and 13 switching stations along the 330kV transmission line that includes 500/330kV transformers and a combination of 500kV and 330kV switchgear. Typically, EMF is higher at substations, energy hubs and switching stations due to the presence of multiple EMF sources in a localised area such as outdoor switchgear, cables and transmission lines. However, other than the connecting transmission lines, EMF sources at energy hubs are typically located furthest away from the site boundary. This provides separation distance between the EMF source at these locations, which reduces likelihood of exposure to EM fields beyond the respective site boundaries.

The substations, energy hubs and switching stations have been modelled based on the respective Reference Design site layout as shown in Figure 2. The equipment within these sites, i.e. the EMF sources are modelled as voltage and current sources, located at a distance above ground as per typical equipment heights. Distances between the site boundary and the EMF transmitters are important to confirm that sufficient clearance have been provided in the design.

Consequently, the EMF levels at the site boundary are used to assess compliance against the Reference Levels .

The expected EMF levels at the energy hub and switching station boundaries confirm compliance with standards and guidelines and presented in Section 4.1.6 of this report.

Figure 2 Energy Hub Layout Configurations sampling from Reference Design



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3.3 Modelling Assumptions

As mentioned in Section 3.2.1, the geometry of the transmission line varies at different points and is influenced by factors such as temperature, terrain and identified environmental constraints.

For this assessment, requirements have been calculated for different transmission line and tower configurations with the following assumptions:

1. Using the lowest transmission line and double circuit (DCST) tower arrangements for 500kV and 330kV. This will ensure exposure limits are modelled lowest to the ground and present a conservative or 'worst case scenario'.
2. Conductor heights are based on conductor attachments with the minimum allowable ground clearance for the lowest conductor (or a 30% sag factor) whichever is lower. This will ensure exposure limits are modelled lowest to the ground and present a conservative or 'worst case scenario'.
3. Transmission line capacities have been based on the capacity of the connected energy hubs (allowing for a single redundancy) and switching stations.

A summary of the transmission line geometry, physical characteristics and conductor types from the project is shown in **Table 5** and **Figure 3.**

Figure 3 Transmission Line Geometry

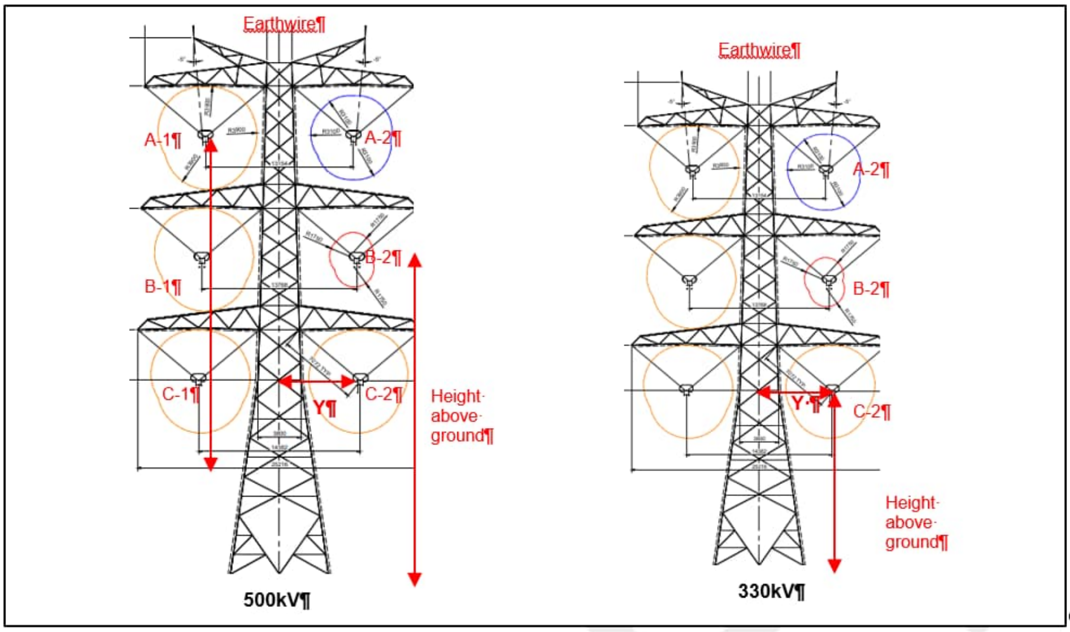


Table 4 Transmission Line Geometry

Line Type	500kV DCST		330kV DCST	
Conductor ID	Y axis coordinate from center (m)	Height Above Ground Level (m) Min clearance	Y axis coordinate from center(m)	Height Above Ground Level (m) Min clearance
Phase A-1	-8.838	11.165	-7.61	9[8]
Phase B-1		18.725		18
Phase C-1		26.285		23.4
Earthwire 1		50.15		45
Phase C-2	8.838	11.165	7.61	9
Phase B-2		18.725		18
Phase A-2		26.285		23.4
Earthwire 2		50.15		45

The transmission line capacity or load current is a significant contributor to the magnitude of electric and magnetic fields generated. The transmission line capacities for the 500kV transmission line per circuit (including 500kV lines initially operating at 330kV) have been determined from 100% of the capacity of the largest 500/330kV connected energy hubs. The largest connected energy hub has a combined four (4) x 1500MVA transformers in operation to transmit, initially a combined maximum capacity of 4.5GW and planned increase to 6GW.

EMF Modelling was also carried out based on maximum output from the combination of four (4) transformers available to deliver a combined capacity of 6GW on the associated transmission line loads.

The transmission line capacities for the 330kV transmission line per circuit have been based on a conservative rounding up to 1,000MVA from the imposed 330kV transmission line capacity limit of 700MVA.

All 330kV transmission lines are modelled as double circuit lines as a conservative approach to this assessment.

Transmission line capacities applied in this assessment are summarised in **Table 5**

[8] Based on minimum ground clearance for 330kV allowed for lowest phase conductor for most conservative assessment.

Table 5 Transmission Line Capacity (A)

Transmission Line	Maximum Capacity (A)	Maximum Capacity per line (MVA)	REZ Capacity Basis
500kV Double circuit	3,462 x 2	6,000	4 x 1,500MVA
500kV Double Operating at 330kV	5,249 x 2	6,000	4 x 1,500MVA
330kV Double Circuit	1,750 x 2	2,000	Conservative based on NSW transmission network constraint of 700MVA per 330kV single circuit or 1400MVA for double circuit

3.4 Modelling Scenarios

Based on the transmission line geometry, characteristics and capacity outlined in Sectio3.2, EMF exposure levels were modelled for the Stage 1 Reference Design.

The modelling in the following sections is applicable to significant sections of the transmission line route i.e., typical locations, to assess the easement widths allowed for in the Reference Design. This assessment includes the following Stage 1 Reference Design arrangements.

- Two (2) Double Circuit 500kV lines operating at 500kV in parallel
- Two (2) Double Circuit 500kV lines operating at 330kV in parallel
- Two (2) Double Circuit 500kV lines operating at 500kV and one (1) 330kV double circuit line in parallel.
- Two (2) Double Circuit 500kV lines operating at 330kV and one (1) 330kV double circuit line in parallel.
- Two (2) Double Circuit 330kV lines in parallel.
- One (1) Double Circuit 330kV line. All 330kV transmission line modelled as double circuit for conservative approach to assessment
- 500/330kV Energy Hubs.
- 330kV Energy Hubs.
- 330kV Switching Station.
- Transgrid 330kV Line 79 overcrossings with two (2) 500kV Double circuit lines operating at 500kV.

  At these locations, the cumulative effects of interfacing EMF sources are considered.

4.0 Impact assessment

4.1.1 500kV Transmission Line Operating at 500kV

Figure 4 shows the predicted electric field for one double circuit 500kV transmission line during maximum steady state load conditions. As shown, the electric fields dissipate quickly with distance and fall below the Reference Level of 5000V/m at less than 20 metres from the centre of the transmission line. This is within the transmission line easement width of 70 metres for 500kV transmission lines.

Figure 4 One double circuit 500kV Transmission Line Operating at 500kV Electric Field

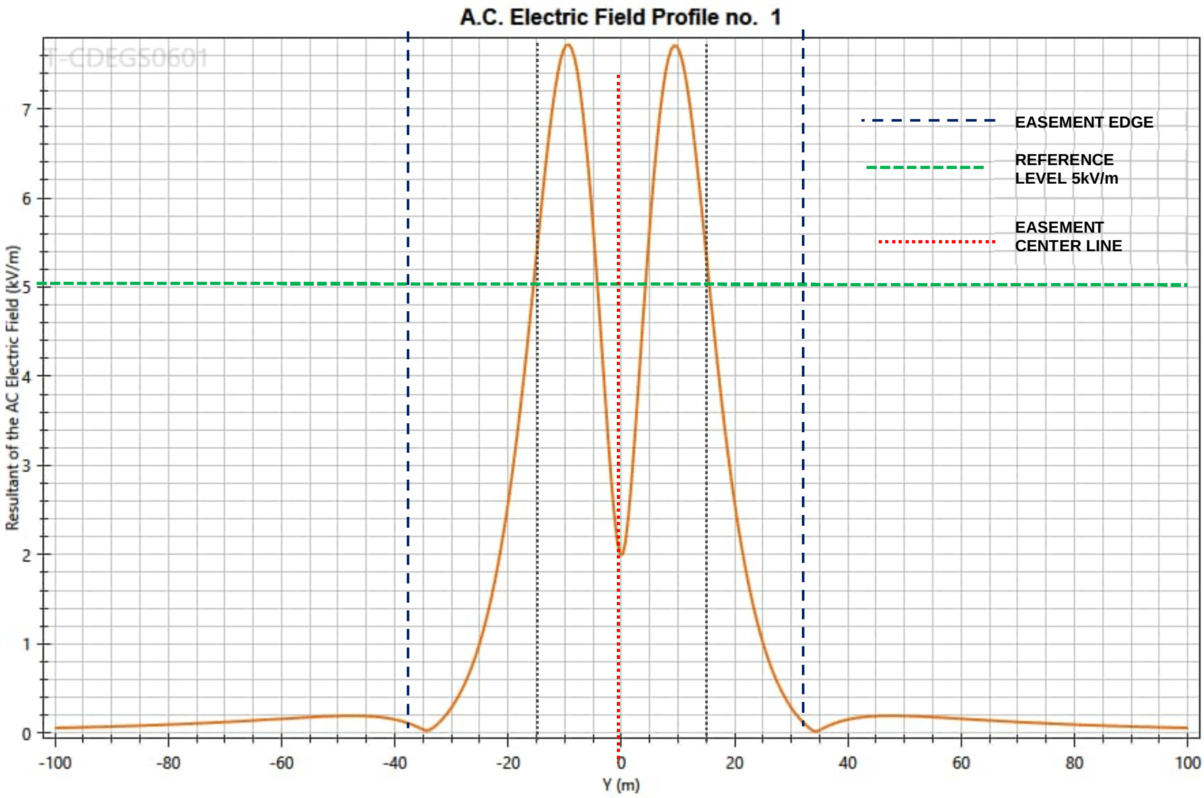
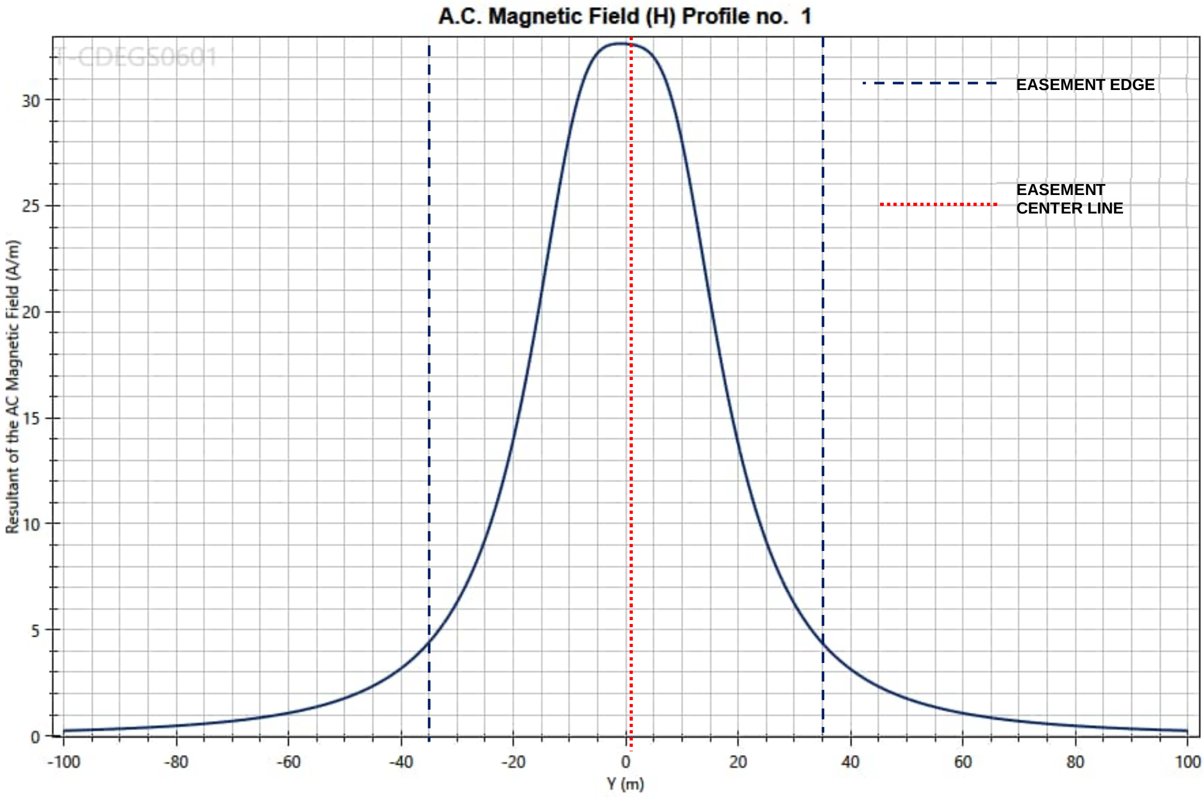


Figure 5 shows the predicted magnetic field for one double circuit 500kV transmission line. As shown, the magnetic fields dissipate consistently with distance and remains significantly below the Reference Level of 159A/m (2000mG). The project hasis not reached this arrangement at any location along the easement.

Figure 5 One double circuit 500kV Transmission Line Operating at 500kV Magnetic Field



4.1.2 500kV Transmission Line Operating at 330kV

Figure 6 shows the predicted electric field for one double circuit 500kV transmission line operating at 330kV during maximum steady state load conditions. As shown, the electric fields dissipate quickly with distance and falls below the Reference Level of 5000V/m at less than 10 metres from the centre of the transmission line.

Figure 6 One double circuit 500kV Transmission Line Operating at 330kV Electric Field

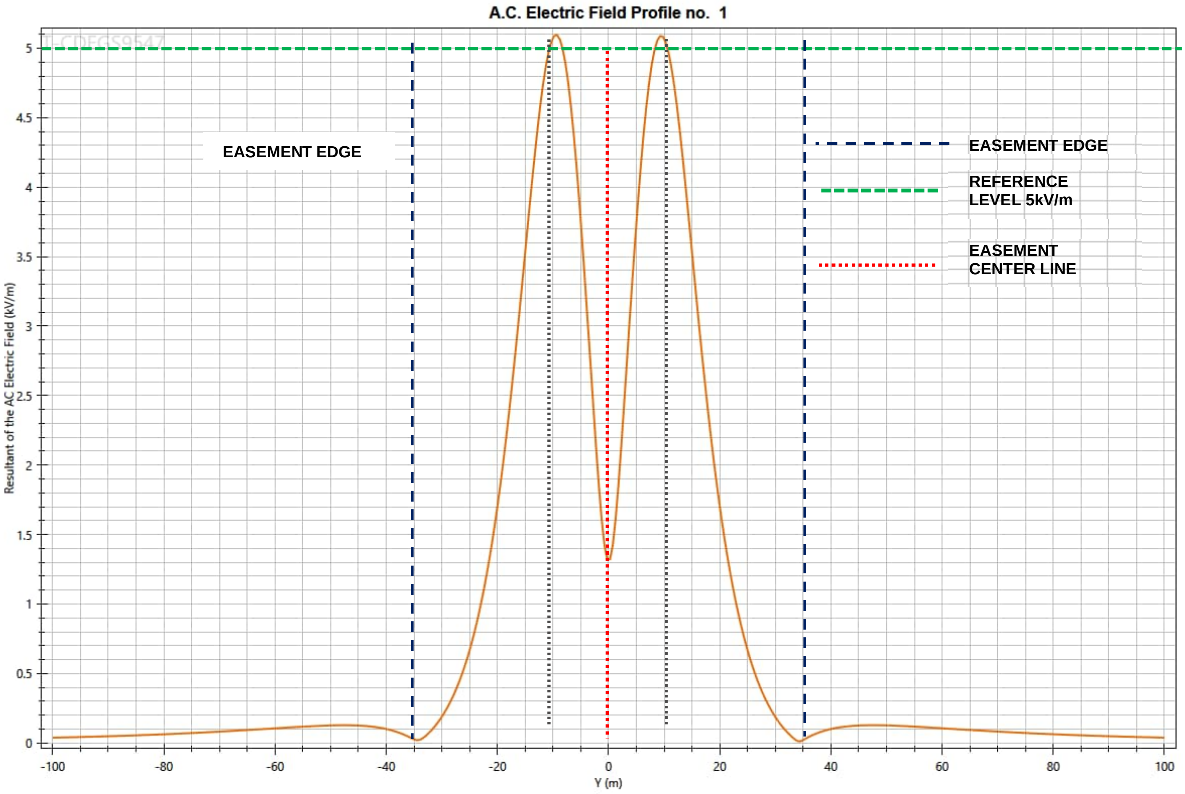
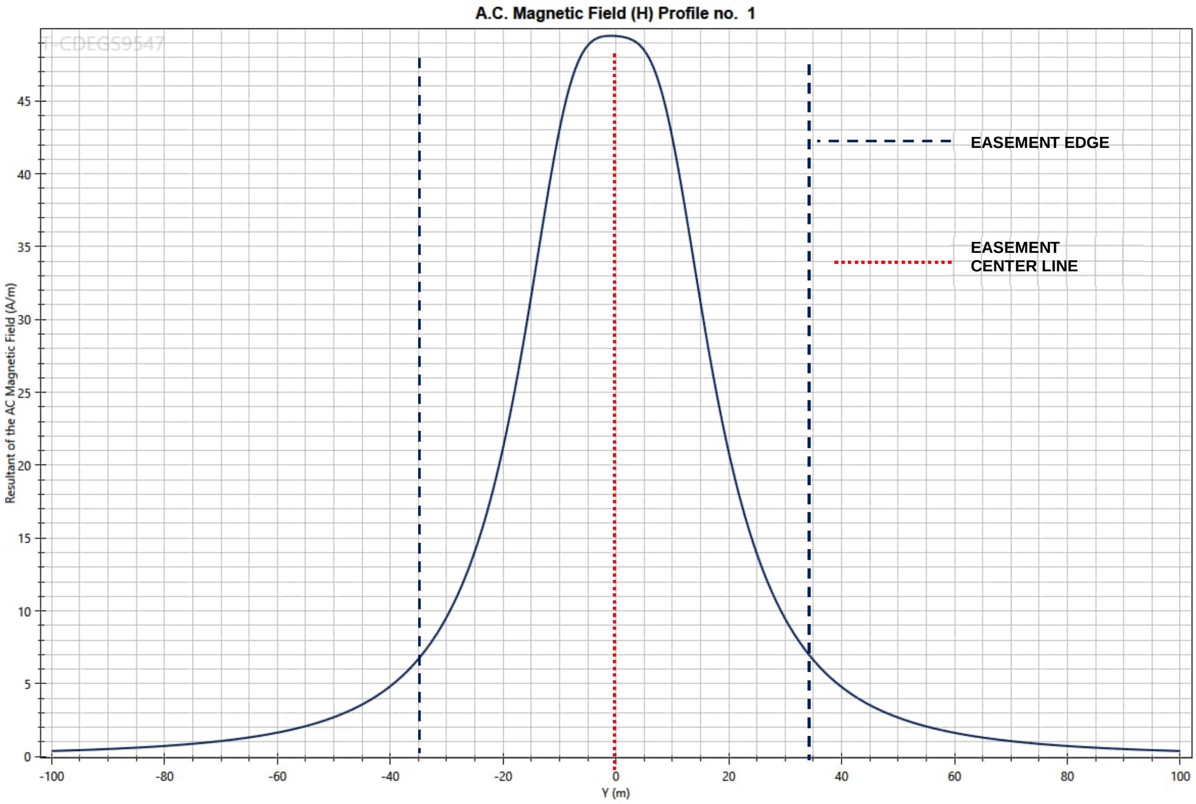


Figure 7 shows the predicted magnetic field for one double circuit 500kV transmission line operating at 330kV. As shown, the magnetic fields dissipate consistently with distance and remains significantly below the reference level of 159A/m (2000mG). The project has not reached this arrangement at any location along the easement.

Figure 7 One double circuit 500kV Transmission Line Operating at 330kV Magnetic Field



4.1.3 500kV Transmission Lines Operating in Parallel

Figure 8 shows the predicted electric field for two double circuit 500kV transmission lines in parallel during maximum steady state load conditions. As shown, the electric fields dissipate quickly with distance and falls below the Reference Level of 5000V/m at 20 metres from the centre of the respective transmission lines. This is within the transmission line easement width of 140 metres for the two 500kV transmission lines.

Figure 8 two double circuits 500kV Transmission Lines in Operating in Parallel Electric Field

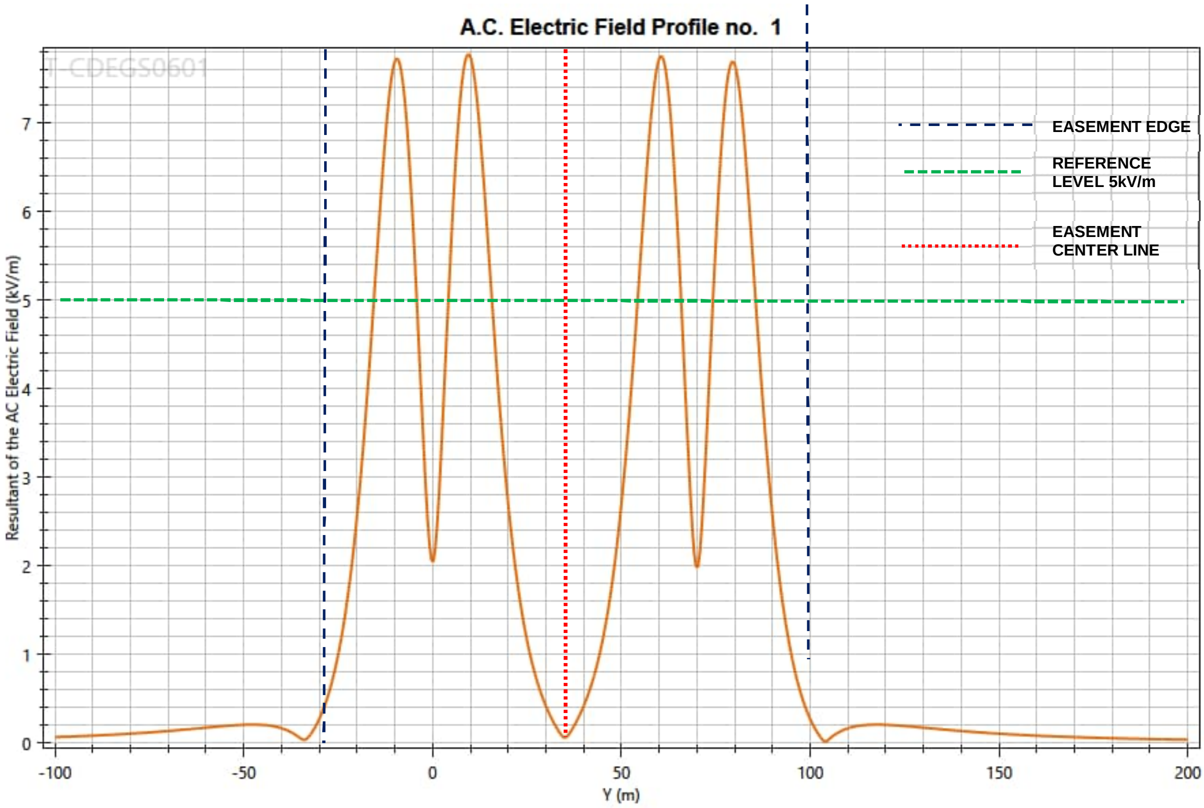
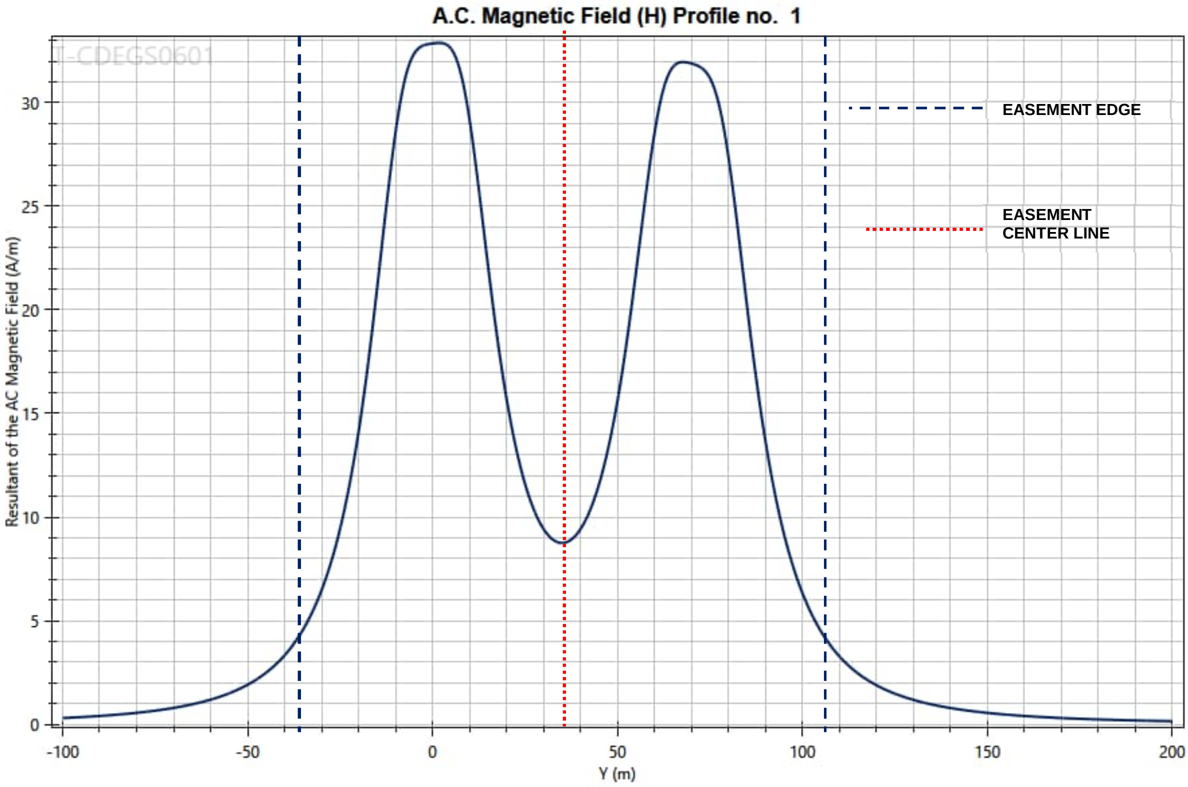


Figure 9 shows the predicted magnetic field for two double circuit 500kV transmission lines in parallel during maximum steady state load conditions. As shown, the magnetic fields dissipate consistently with distance and remains significantly below the Reference Level of 159A/m (2000mG). The project has not reached this arrangement at any location along the easement.

Figure 9 Two double circuit 500kV Transmission Lines in Operating in Parallel Magnetic Field



4.1.4 330kV Transmission Line Operating at 330kV

Figure 10 shows the predicted electric field for one 330kV transmission line operating at 330kV during maximum steady state load conditions. As shown, the electric fields dissipate quickly with distance and remains well below the Reference Level of 5000V/m. The project has not reached this arrangement at any location along the easement.

Figure 10 One 330kV Transmission Line Operating at 330kV

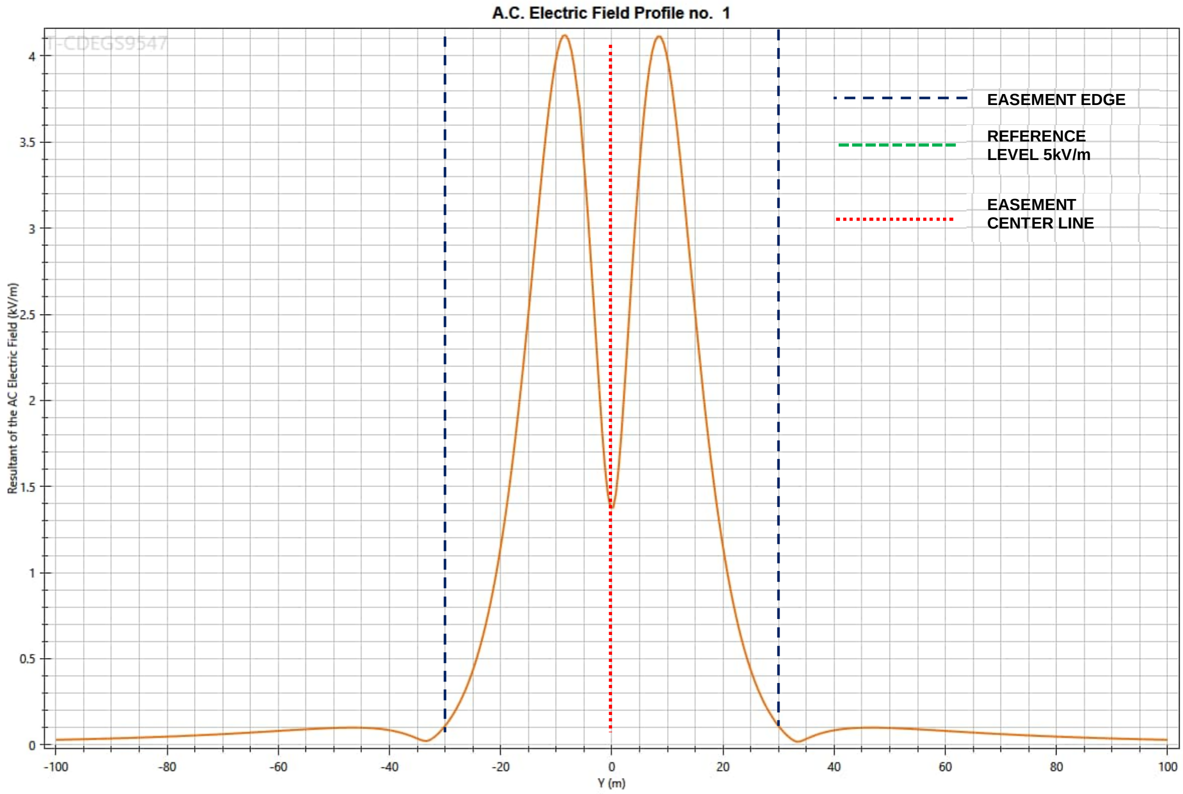
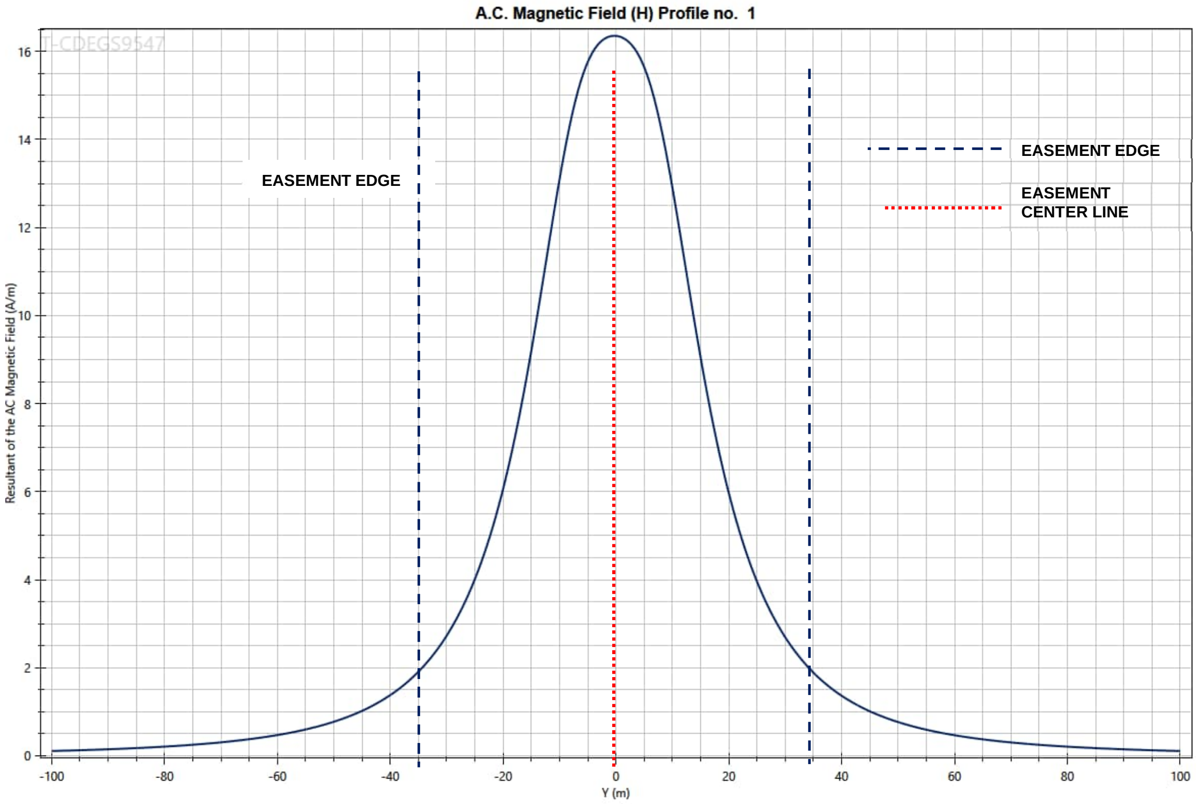


Figure 11 shows the predicted magnetic field for one 330kV transmission line operating at 330kV. As shown, the magnetic fields dissipate consistently with distance and remains significantly below the Reference Level of 159A/m (2000mG). The project has not reached this arrangement at any location along the easement.

Figure 11 One 330kV Transmission Line Operating at 330kV



4.1.5 500kV Transmission Lines Operating with a 330kV Transmission Line

This scenario is applicable in locations where there are two 500kV lines and one 330kV line are running adjacent. This includes the area where the 500kV lines run adjacent to the existing Transgrid 330kV line and when 330kV generator lines run adjacent to the 500kV lines.

Figure 12 shows the predicted electric field for two 500kV transmission lines operating in parallel with one 330kV transmission line during maximum steady state load conditions. As shown, the electric fields dissipate quickly with distance and fall below the reference levels of 5000V/m. This is within the transmission line easement width of 200 metres for the two 500kV transmission lines and 330kV transmission line.

Figure 12 Two 500kV Transmission Lines with a 330kV Transmission Line Electric Field

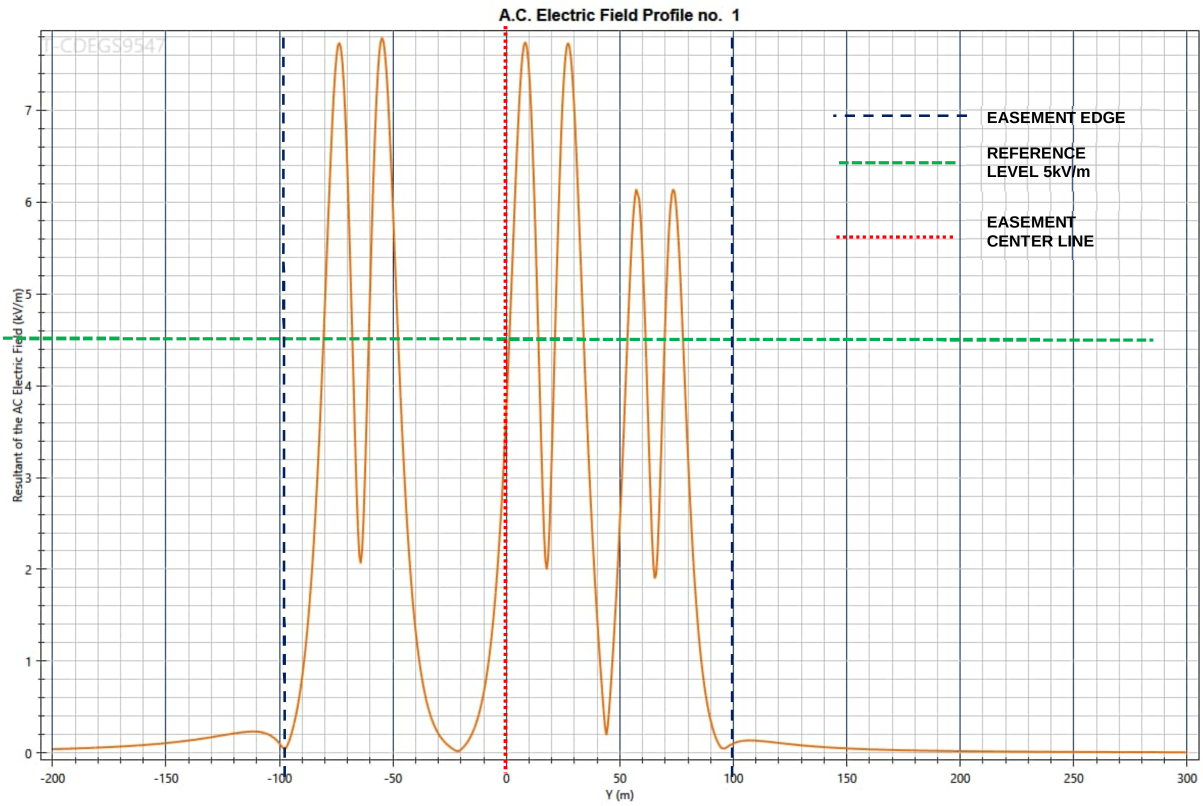
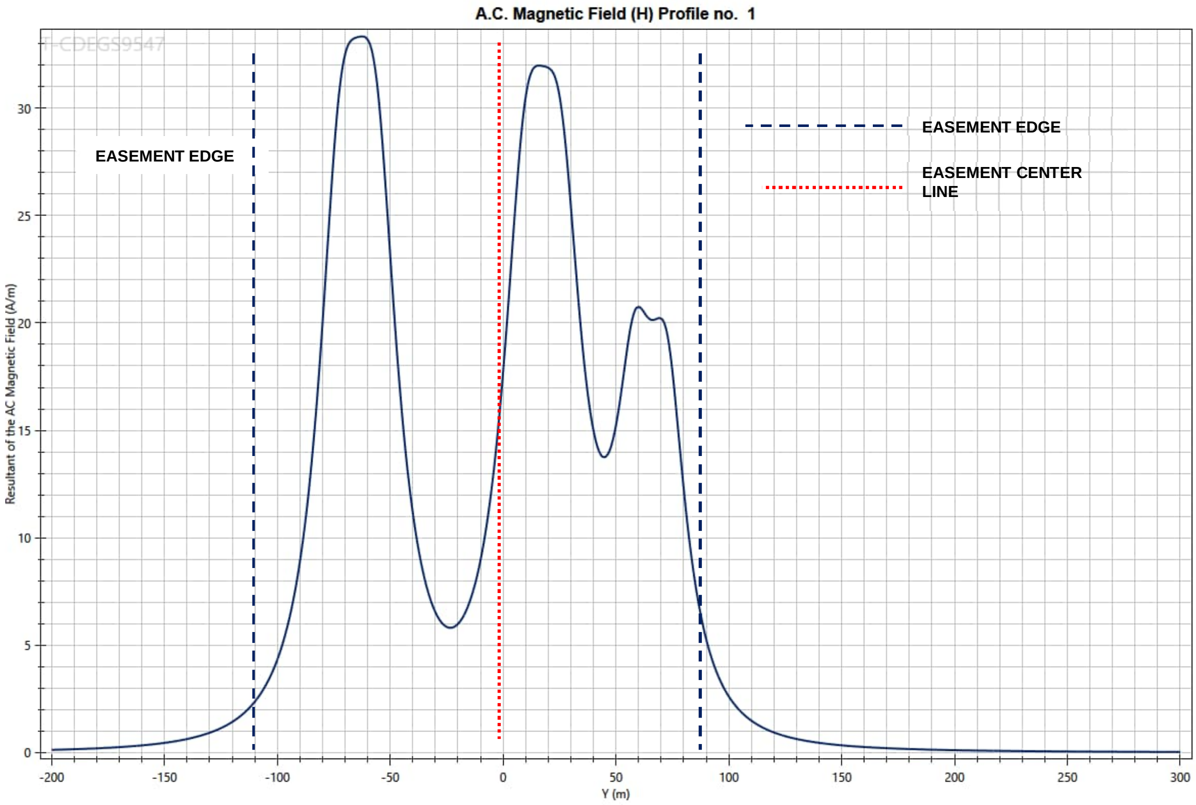


Figure 13 shows the predicted magnetic field for two 500kV transmission lines operating in parallel with one 330kV transmission line. As shown, the magnetic fields remain well below the reference level of 159A/m (2000mG). The project has not reached this arrangement at any location along the easement.

Figure 13 Two 500kV Transmission Lines with a 330kV Transmission Line Magnetic Field



4.1.6 Energy Hubs and Switching Stations

EMF assessments were conducted for the following energy hub and switching stations

1. 500kV energy hub (switchyard)
2. 500/330kV energy hubs
3. 330kV switching station

The EMF model is based on the energy hub arrangement adopted for the project

The worst-case scenario that was modelled occurs at Merotherie due to the proximity of the above energy hub infrastructure in one location.

The EMF assessment results find the following:

- The electric field levels remain well below the Reference levels within the energy hub boundary.
- The magnetic field levels remain well below the Reference levels within the energy hub boundary.

There are no EMF issues identified associated with the energy hubs.

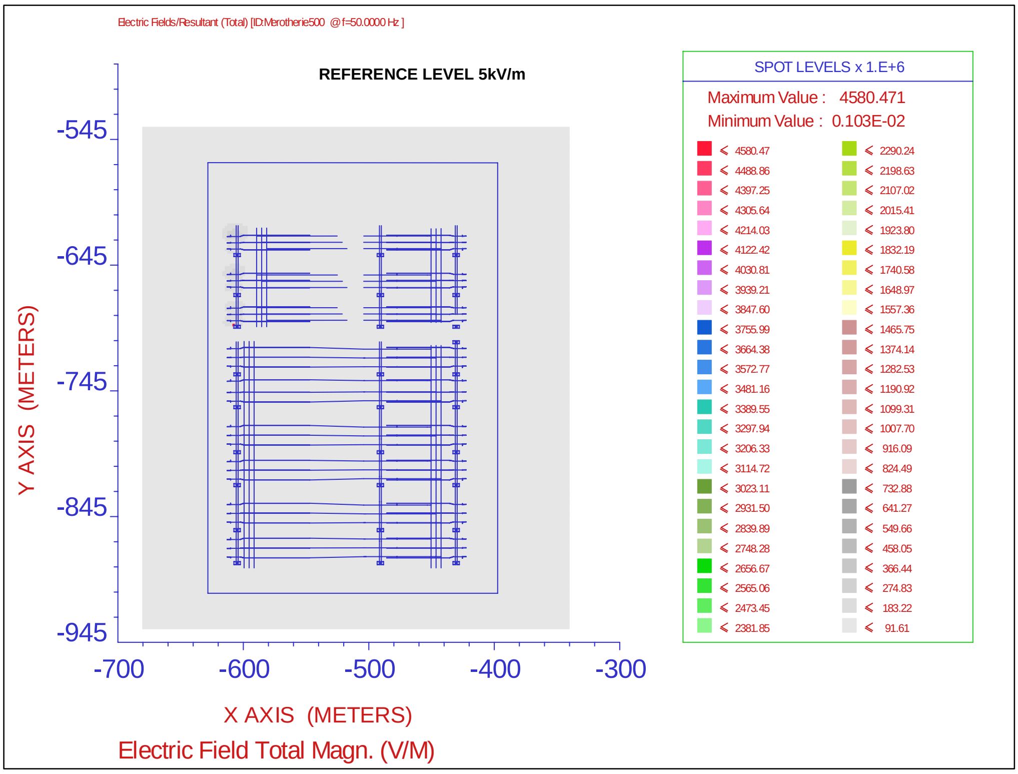


Figure 14 Merotherie 500kV Energy Hub Electric Field

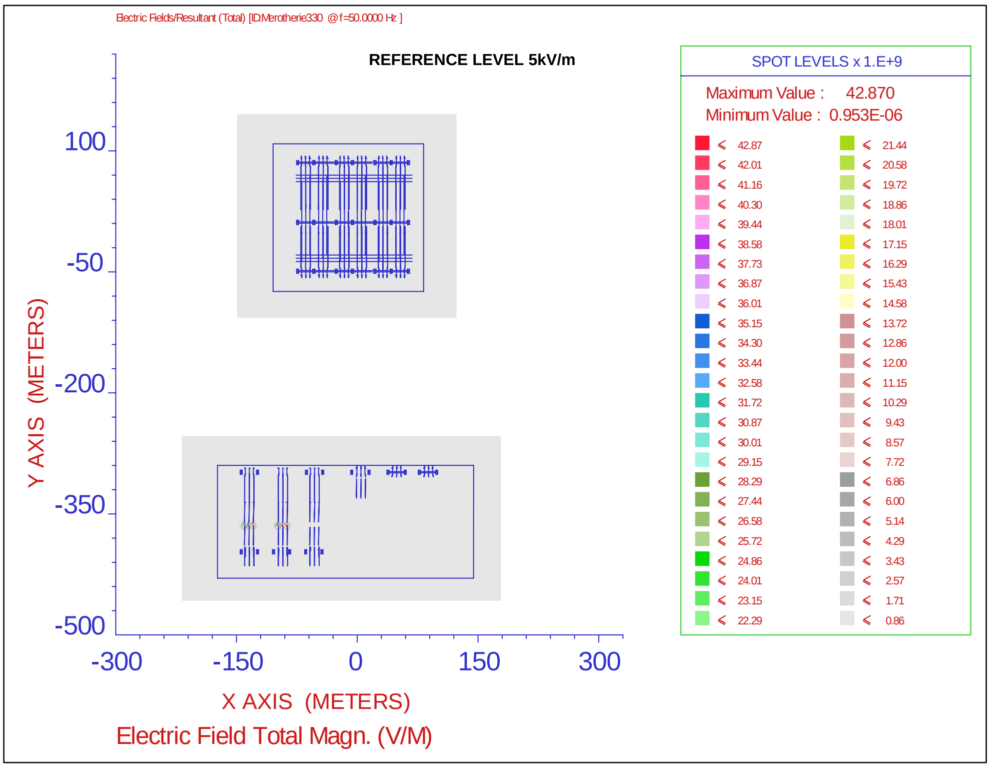


Figure 15 Merotherie 500/330kV & 330kV 1&2 Energy Hub Electric Field

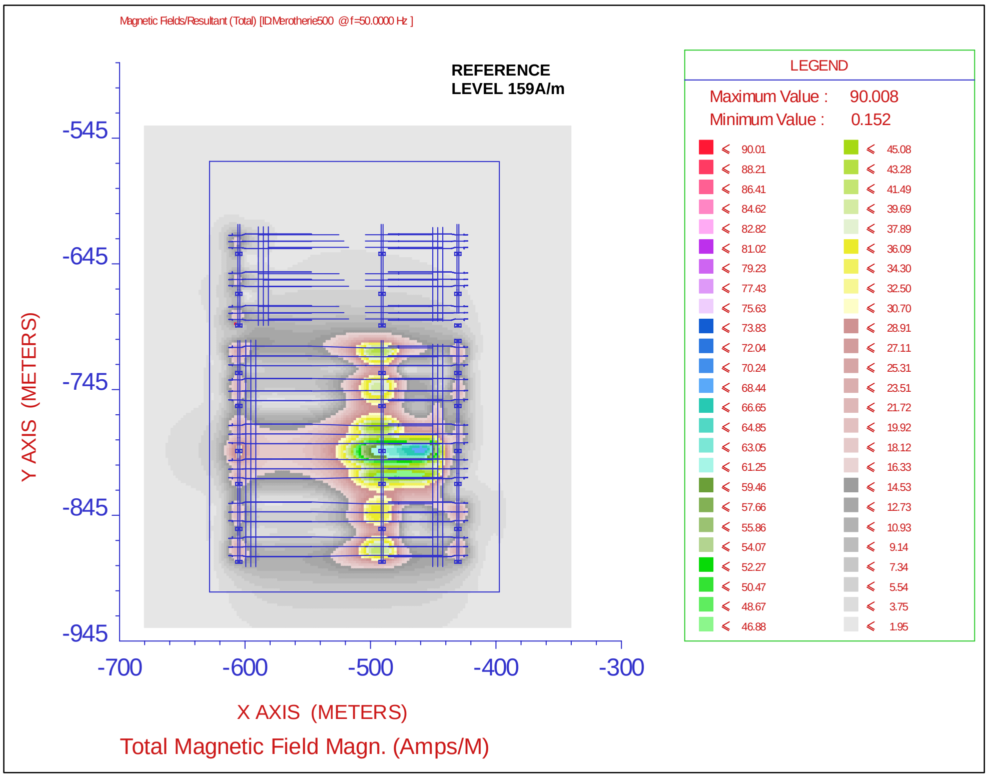


Figure 16 Merotherie 500kV Energy Hub Magnetic Field

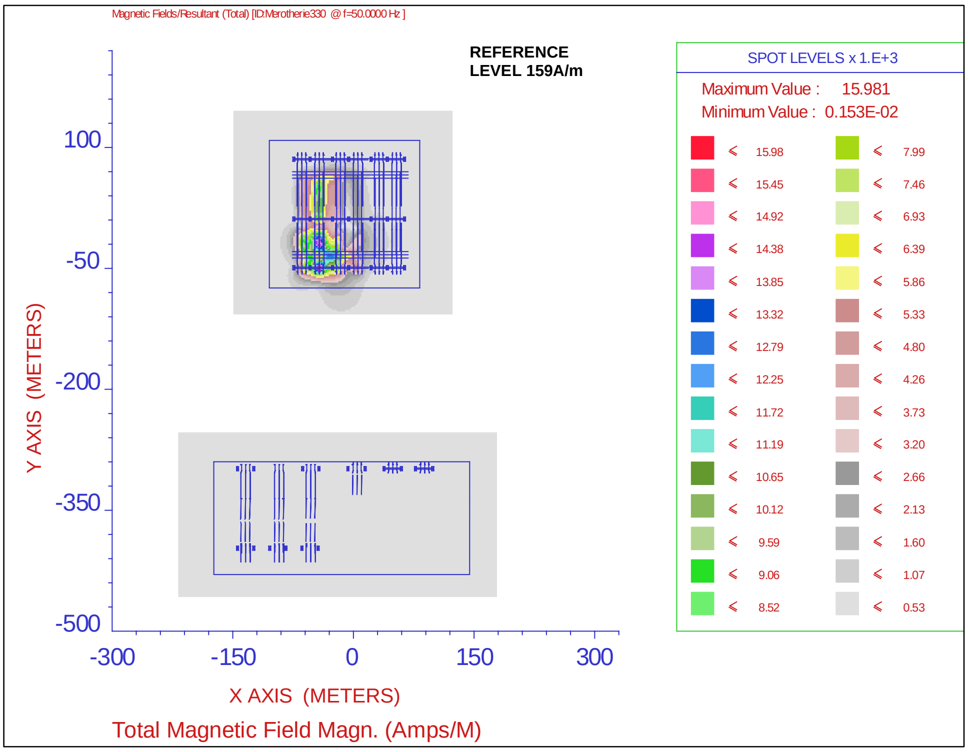


Figure 17 Merotherie 500/330kV & 330kV 1&2 Energy Hub Magnetic Field

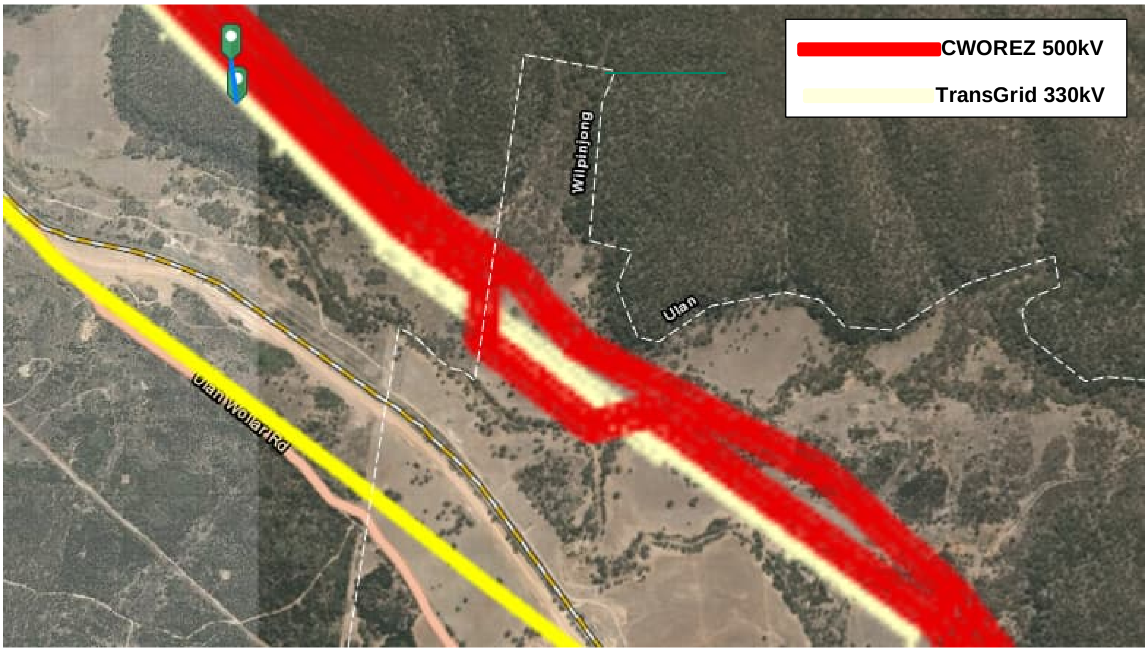
4.1.7 Interface/Crossing with TransGrid Transmission Line

This section assesses the worst-case interface between the TransGrid 330kV transmission line and the proposed 500kV transmission line. These crossings occur in proximity to Goulburn River National Park. The 500kV transmission line heights are higher than the average Reference Design height to maintain clearance from the TransGrid 330kV transmission line. The increased clearance also aims to reduce the magnitude of any the combined EM fields propagated from each transmission line.

The EMF assessment results find the following:

- The electric field levels remain well below the Reference Levels within the respective transmission line easements.
- The magnetic field levels remain well below the Reference Levels within the respective transmission line easements.

Figure 18 TransGrid crossing with proposed 500kV near Goulburn River National Park



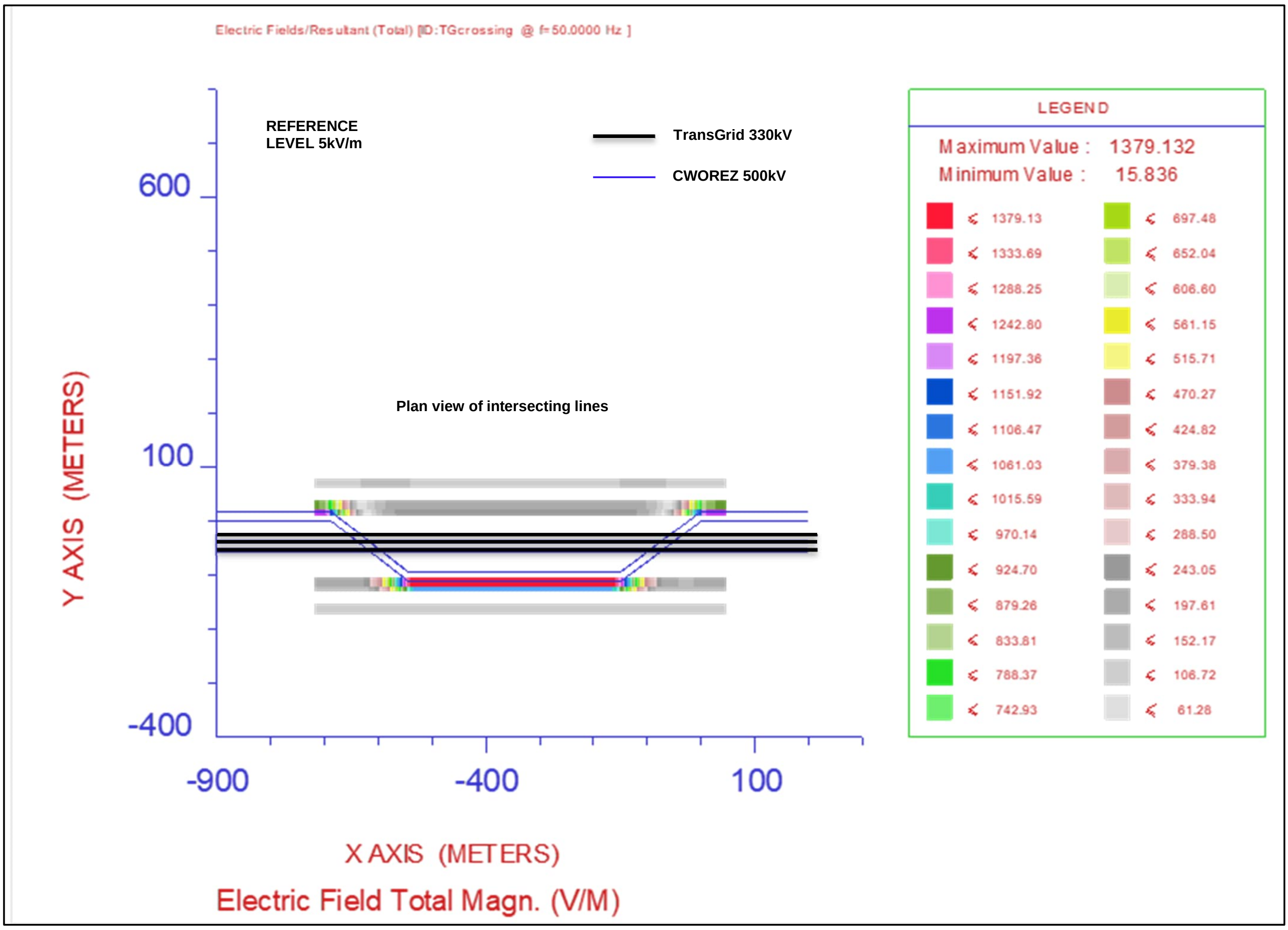


Figure 19 Electric Field Contours at Transmission Line Crossing (Up to Edge of Easement)

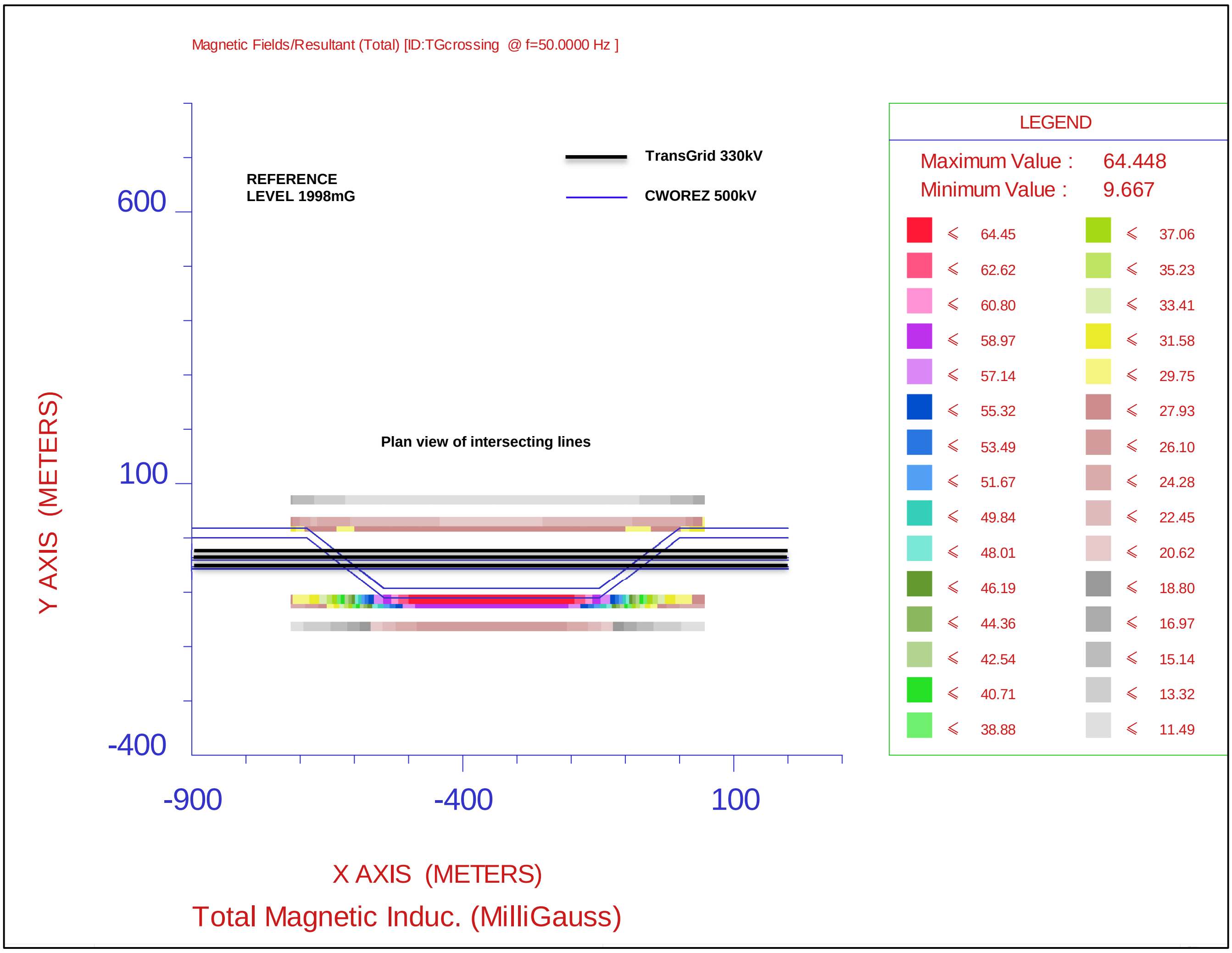


Figure 20 Magnetic Field Contours at Transmission Line Crossing (Up to Edge of Easement)

5.0 Management and Mitigation measures

The EMF Assessment has concluded that the electromagnetic field levels at the boundary of the transmission line easement is compliant with the current standards and guidelines administered by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

Based on this assessment, the EMF Assessment also concluded that no mitigation or modifications are required to the project so long as dwellings are located outside of the transmission line easement.

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