Transgrid

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Environmental Impact Statement

EnergyConnect (NSW – Eastern Section)

Technical paper 13 – Electric and magnetic field study

Sensitivity: General

Beca

Project EnergyConnect
Technical Paper 13 – Electric and Magnetic Field Study – EIS2

Prepared for Transgrid

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6 December 2021

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Glossary of Terms

µT	Microtesla
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
EF	Electric field
EFS	Electric field strength
ELF	Extremely low frequency
EMF	Electric and magnetic fields
MFD	Magnetic flux density
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
kV/m	Kilovolts per metre
pu	per unit
WHO	World Health Organisation
V/m	Volts per metre

Executive Summary

As part of Project EnergyConnect, which consists of a new interconnector between the electricity grids of South Australia and New South Wales, Transgrid are planning a new double circuit 330 kilovolt (kV) transmission line between the Buronga Substation and the proposed Dinawan Substation and a double circuit 500 kV transmission line between the Dinawan Substation and Wagga Wagga Substation.

This report is an assessment of the electric and magnetic field (EMF) performance of the concept transmission line designs based on an operating voltage of 330 kV between the Buronga substation and the proposed Dinawan Substation and 500 kV between the Dinawan substation and Wagga Wagga substation. The purpose of the assessment is to check the EMF levels beneath the proposed 330 kV and 500 kV double circuit lines against the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) recommended ICNIRP public exposure guidelines.

The magnetic field levels directly under the proposed lines are well below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) general public exposure reference limit of 2,000 milligauss (mG) in all cases, including during the contingency case of one circuit in service with increased load and the other circuit out of service.

Based on the minimum ground clearance for the proposed lines, the electric field levels directly under the proposed line are within 9.1 kilovolts per metre (kV/m), in all cases. The 9.1 kV/m value can be shown to meet the ICNIRP general public basic restriction of 0.02 V/m for the central nervous system tissues of the head, as determined by Transgrid commissioned modelling. The minimum clearance is typically at the middle of the span between towers where the conductor is at its lowest, and the majority of the line is well above this clearance. The minimum ground clearance (maximum sag) also only applies when the line is running at its maximum rating which occurs for the contingency case in hot weather conditions only.

The EMF levels associated with the contingency loads will only occur for short periods on rare occasions. Time weighted average figures are provided to give more typical levels during normal operation both under the line and at the edge of the easement.

1 Introduction

Transgrid, with ElectraNet, are planning a new interconnector between the electricity grids of South Australia and New South Wales. Project EnergyConnect will deliver the proposed new interconnector. Transgrid's Project EnergyConnect scope includes the following new transmission lines:

- Buronga Substation to the new Dinawan Substation, approximately 60 km south of Darlington Point – approximately 380 km in length, double circuit, 330 kV line.
- New Dinawan Substation to Wagga Wagga Substation, approximately 160 km in length, double circuit, 500kV line.

The proposed routes for the two transmission lines are shown in Figure 1-1.

Figure 1-1: Proposed line routes for Project EnergyConnect between Buronga and Wagga Wagga

Beca has been commissioned by Transgrid to undertake an assessment of the electric and magnetic field (EMF) performance of the concept transmission line designs. The purpose of the assessment is to check the EMF levels beneath the line against the International Commission for Non-Ionizing Radiation Protection (ICNIRP) public exposure guidelines. The use of the ICNIRP public exposure guidelines is recommended by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

Typical structure outlines used for the study are shown in Figure 2. Structure concept design drawings are provided in Appendix F.

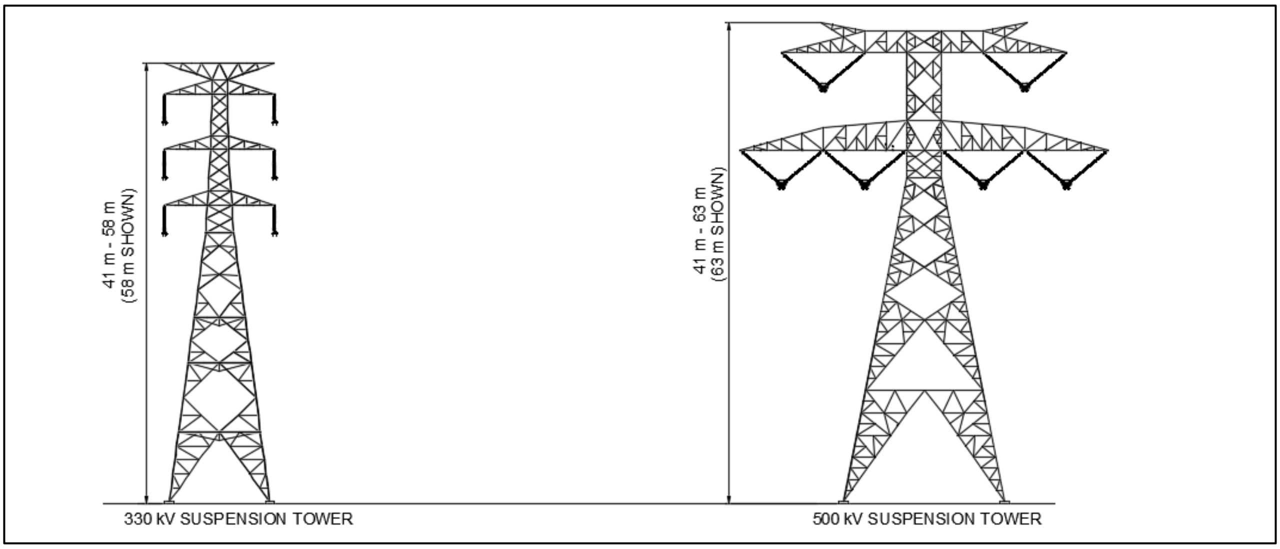

Figure 1-2: Typical 330 kV and 500 kV structure outlines used for the assessment

2 Overview of Electric and Magnetic Fields

This section provides an overview of EMF setting out the exposure limits adopted for Project EnergyConnect based on applicable national and international guidelines.

2.1 What are electric and magnetic fields?

Electric and magnetic fields exist wherever electricity is generated, transmitted or distributed in power lines or cables, or used in electrical appliances. Electrical systems used for the transmission of electricity in Australia operate at a frequency of 50 Hertz (Hz) and give rise to extremely low frequency (ELF) EMF in their vicinity.

Electricity has two principal components, an electrical component and a magnetic component. Electric fields are determined by voltage, and the electric field at any given location around a transmission line will be largely constant. The electric field is proportional to the voltage, which remains within a plus/minus 10% level as long as the equipment is energised. The higher the operating voltage of the line, the higher the electric field around the conductor itself. This is partially offset at ground level as the higher voltage lines are run at a greater height above ground.

Magnetic fields on the other hand, will change in strength over time in line with the magnitude of the current (Amps). Whenever an electric charge moves, a magnetic field is created that is proportional to the current. Therefore, the higher the current, the higher the magnetic field. Variations in the current follow fairly typical patterns, with morning and evening peaks, and larger loads reflecting seasonal variations.

Magnetic fields are normally quantified in terms of the magnetic flux density which is measured in tesla (T). Measurements are most frequently given in microtesla (μT), which is 1 millionth of a tesla. Another unit commonly used to measure the magnetic field is the gauss (G) or milligauss (mG), where 10 mG is the equivalent of 1 μT. Electric fields are measured in units of volts per metre (V/m) and are normally given as kilovolts per metre (kV/m) where 1 kV/m = 1000 V/m.

Electric and magnetic fields reduce rapidly with distance from their source. For transmission lines, electric and magnetic fields are up to approximately four times lower for every doubling of distance from a line. Electric fields are shielded by most objects, including trees, buildings and human skin. Unlike electric fields, magnetic fields cannot easily be shielded and pass through most materials.

The current carried by a transmission line directly influences the magnetic field. It also indirectly influences the electric field levels experienced below the line. The current has a heating effect on the conductors so that increasing current increases the conductor sag. Weather conditions such as air temperature, solar radiation, and wind speed also affect line sag. As line sag increases, the electric and magnetic fields experienced below the lines at ground level also increase. This is because the distance between the line (the source of the fields) and the ground decreases.

The table below provides typical field strengths from the measurement of fields from a range of sources. While field strengths will usually be within the ranges of values shown, values outside the range are possible.

Table 2-1: Typical range of magnetic fields and electric fields*

	Source	Typical range of magnetic fields (mG)[1]	Typical range of electric fields (kV/m)[2]
Around the home / office	Background in the home or office	0.5 – 1.5	0.003 – 0.02
	Electric stove	2 – 30	0.07 – 0.10
	Refrigerator	2 – 5	
	Electric kettle	2 – 10	
	Toaster	2 – 10	
	Television	0.2 – 2	
	Electric blanket	5 – 30	0.058 – 0.6
	Hair dryer	10 – 70	0.3 – 0.8
	Pedestal fan	0.2 – 2	
In public streets / neighbourhood	Street powerlines (directly underneath)	2 – 30	0.01 – 0.06
	Street powerlines (10 m away)	0.5 – 10	
	High voltage transmission line (directly underneath)	10 – 1000[3]	0.003 – 9[4]

* Note: Levels of magnetic fields may vary from the range of measurements shown.

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[5].

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[1] Sourced from ARPANSA: https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/measuring-magnetic-fields

[2] Sourced from Transpower New Zealand Ltd, EMF Fact Sheet 3: https://www.transpower.co.nz/resources/factsheet-3-electric-and-magnetic-field-strengths

[3] Sourced from ENA (Energy Network Association), Electric and Magnetic Fields, The Facts, January 2012, https://www.nationalgrid.com/sites/default/files/documents/13791-Electric%20and%20Magnetic%20Fields%20-%20The%20facts.pdf

[4] This range covers the lower value of the range for 110kV line through to a 500kV line and hence the large difference in the range.

[5] New Zealand Ministry of Health, *Electric and Magnetic Fields and Your Health, Information on electric and magnetic fields associated with transmission lines, distribution lines and electrical equipment (2013 Edition),* Page 14.

2.2 Health and electric and magnetic fields

Potential effects of electric and magnetic fields

It is well known and understood that ELF electric and magnetic fields induce internal electric fields and currents in the body. If the external fields are strong enough, these induced electric fields can interfere with the body's nervous system causing nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system[6]. The effects on the human body include hair movement, the magneto-phosphene effect and micro-shocks[7]. These effects, described below, occur at field strengths well above field strengths found below a transmission line (i.e. well above the limits set out in Section 2.3):

- Hair movement - Hair can be caused to move by strong electric fields.
- The magneto-phosphene effect - This effect results from currents induced in humans by either electric or magnetic fields. These weak currents can cause a flickering in the peripheral vision. Although the magneto-phosphene effect is mildly distracting it is a temporary effect on vision which has no lasting health effect after field levels reduce.
- Micro-shocks – Micro-shocks may occur in particular circumstances when the body comes into contact with objects such as fence lines that may have a voltage induced in them.

The exposure guidelines set out in Section 2.3 are in place to protect against these biological effects.

Health research

A large number of studies have been conducted over many years to investigate the possibility of adverse health consequences from extremely low frequency (ELF) electric and magnetic fields (EMF). 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. In general, the results have been reassuring but, in the case of childhood leukaemia, a number of studies have reported a statistical association between childhood leukaemia and prolonged exposure to higher than normal magnetic fields.

In 2002, the International Agency for Research on Cancer (IARC), (part of the World Health Organisation (WHO)) published a monograph classifying ELF magnetic fields as "possibly carcinogenic to humans" – Group 2B[8]. 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. The Monograph identifies that *"this classification was based on 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 3 to 4 mG*". Evidence for all other cancers in children and adults, as well as other types of exposures (i.e. static fields and ELF electric fields) was considered "not classifiable" either due to insufficient or inconsistent scientific information[9].

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[6] Sourced from World Health Organisation: https://www.who.int/peh-emf/publications/facts/fs322/en/

[7] Energy Networks Australia, EMF Management Handbook, January 2016, pp 12

[8] The agents classified by the IARC Monographs are available at https://monographs.iarc.fr/list-of-classifications

[9] Sourced from World Health Organisation: https://www.who.int/peh-emf/publications/facts/fs322/en/

In June 2007 the WHO reported on the possible health effects of exposure to ELF magnetic fields. The *Extremely Low Frequency Fields Environmental Health Criteria (EHC) Monograph No.238* examined scientific evidence suggesting that everyday, chronic low-intensity (above 3 to 4 mG) power-frequency magnetic field exposure poses a health risk based on epidemiological studies demonstrating a consistent pattern of increased risk for childhood leukaemia. The principal conclusions on health risks were as follows[10]:

- There are established acute effects of exposure to strong ELF electromagnetic fields, and compliance with existing international guidelines provides adequate protection.
- Epidemiological studies suggest an increased risk of childhood leukaemia for long-term (i.e., periods of years) average exposures greater than 3 to 4 mG. Some aspects of the methodology of these studies introduce uncertainties in the hazard assessment. Laboratory evidence and mechanistic studies do not support a causal relationship, but the evidence is sufficiently strong to remain a concern.
- If the relationship is causal, ELF fields could be responsible for 0.2–4.9% of leukaemia cases worldwide. Hence the global impact on public health, if any, is limited and uncertain.
- Scientific data suggesting a link with other diseases (other childhood and adult cancers, depression, suicide, reproductive problems, developmental and immunological disorders, and neurological disease) is much weaker, but in some cases (e.g. cardiovascular disease, breast cancer) is sufficient to rule out a causal relationship.

Based on this review of health effects, the WHO advises that:

> *"Despite the feeling of some people that more research needs to be done, scientific knowledge in this area is now more extensive than for most chemicals. Based on a recent in-depth review of the scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields."*[11]

Overall, the picture is largely unchanged since publication of the WHO review in 2007. The possibility that long-term exposures to magnetic fields somehow increases the risk of developing childhood leukaemia remains an open question. The results from epidemiological data (which show an association between ELF magnetic field exposure and an increased risk of childhood leukaemia) are not supported by experimental and mechanistic data[12]. The research on possible links with neurodegenerative diseases has also provided no consistent results[13].

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) states in regard to establishing exposure guidelines based on the WHO Monograph:

> *"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. In particular, if the relationship is not causal, then no benefit to health will accrue from reducing exposure."*[14]

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[10] WHO, Extremely Low Frequency Fields Environmental Health Criteria (EHC) Monograph No.238.

[11] Accessed from https://www.who.int/peh-emf/about/WhatisEMF/en/index1.html on 21 July 2020.

[12] WHO, Electromagnetic fields and public health fact sheet, accessed from https://www.who.int/peh-emf/publications/facts/fs322/en/ on 21 July 2020.

[13] Interagency Committee on the Health Effects of Non-ionising Fields, Report to Ministers 2015.

[14] ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz - 100 kHz), 2010.

2.3 Exposure limit guidelines for electric and magnetic fields

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is the Federal Government agency charged with the responsibility for protecting the health and safety of people, and the environment, from EMF. The ARPANSA recommends the use of the exposure guidelines provided by ICNIRP. These exposure guidelines are set out below.

International Commission for Non-Ionizing Radiation Protection Guidelines

The ICNIRP *Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz - 100 kHz)* set fundamental limits on electrical fields induced in the body by EMF. The limits which are expressed in terms of induced electric fields in the body are termed 'basic restrictions'.

Induced electric fields in the body are difficult to measure or calculate, so the guidelines also provide reference levels. Reference levels are in terms of the more easily measured ambient electric and magnetic fields that give rise to the induced internal electric fields. Provided field strengths are below the reference levels, resulting induced electric fields will be within the basic restriction. If exposures exceed the reference level, this does not necessarily mean that the basic restriction is also exceeded, however, a more comprehensive analysis is required in order to verify compliance with the basic restrictions.

The ICNIRP reference levels for exposure of the public are 200µT and 5kV/m for magnetic and electric fields respectively. These limits apply to both children and adults. ICNIRP re-issued their guidelines in 2010, revising the public exposure limit for magnetic field from 100 to 200 µT (micro tesla). The essential biological basis for the guidelines has remained unchanged for more than 20 years. The ICNIRP basic restriction and reference levels are provided in Table 2-2.

Table 2-2: EMF guidelines for the general public (ICNIRP)

		Level
Basic restriction		
Central nervous system tissues of the head		0.02V/m
All tissues of head and body		0.4V/m
Reference level	Electric field	5kV/m
	Magnetic field	200µT

ICNIRP's limiting thresholds for general public exposure are widely accepted as providing complete protection against all known adverse health effects of electric and magnetic fields. ARPANSA's current advice is *"The ICNIRP Extremely Low Frequency (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".*

Transgrid's approach to the management of electric fields

It is Transgrid policy to comply with the ICNIRP Guidelines at all times and to meet the general public reference levels 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 the basic restrictions.

Transgrid's *Transmission Line Design Manual – Major New Build* specifies that electric fields produced by a new transmission line shall be limited to the meet the basic restrictions stated within the ICNIRP guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz) 2010. Compliance shall be against the peak maximum voltage at lowest ground clearance for the transmission line (i.e. the worst case).

330 kV and 500 kV lines typically do not fully comply with the 5 kV/m reference level and additional consideration of internal electric fields as provided by the guidelines is required.

Transgrid has previously commissioned Exponent, Inc to undertake dosimetric analyses[15] of the internal electric fields to evaluate compliance with the ICNIRP general public basic restrictions for electric field. This was completed using an anatomically accurate human body model beneath 330 kV and 500 kV transmission lines at midspan, where the conductors are closest to a person and electric-field levels are highest. The analysis used the internal electric fields of 0.02 V/m for the central nervous system tissues of the head, being the most restrictive limit (with 0.04 V/m applying for all tissues of the head and body). The analysis determined that to meet the ICNIRP general public basic restriction of 0.02 V/m, the maximum external electric field shall not exceed 9.1 kV/m at 1 m height above the ground. Based on this, Transgrid has specified that electric-field levels for the Project EnergyConnect 330 kV and 500 kV transmission lines shall not exceed 9.1 kV/m in all cases. It should be noted that these high levels are only reached in certain specific locations under uncommon operating scenarios.

2.4 Exposure limits

The exposure limits used as the basis of this report are based on the Transgrid commissioned modelling and the selection of a limit as listed in Table 2-3.

Table 2-3: EMF exposure limits for the general public

Field	Level
Electric field	9.1 kV/m
Magnetic field	2,000 mG

2.5 Implantable medical devices

The commonest active medical devices are pacemakers and defibrillators. There is a great deal of variation between different medical implants, including the function of the device, the model and the way it is fitted and programmed. Members of the general public are generally briefed by their physician regarding the management of their medical implant and its susceptibility to interference.

Standards for the designers and manufacture of medical devices require that the devices need to be designed with an immunity up to the general public reference levels as set by ICNIRP[16]. This means that older devices are considered to be immune up to 100μT (1,000mG), being the ICNIRP 1998 level. A very small proportion of cardiac pacemakers has been found to be sensitive to 50Hz electric and magnetic fields close to the ICNIRP limits for public exposure. Where this is the case, it is most likely that they will revert to a fixed pacing mode, which poses no immediate threat to the wearer[17].

[15] Dosimetric analyses involves the measurement, calculation and assessment of the amount and distribution of electric field absorbed by an object, usually the human body.

[16] For example CENELEC 50527-1 and European Directive 90/385/EEC.

[17] Ministry of Health, Electric and Magnetic Fields and Your Health, 2013 edition.

For persons wearing a hearing aid or cochlear implant, 50Hz magnetic field noise can occur when near transmission lines (heard as a buzzing sound), however, this will not damage the devices or the ear[18].

2.6 Effects on food production and animals

Electric and magnetic fields have the potential to affect farmed mammal species similarly to humans. Therefore, where EMF levels are within the ICNIRP Guidelines, there is unlikely to be any perceptible effect on animals. There is limited published material addressing this matter. One that is widely referenced is the Gibbs Report[19] which concluded that: *'The magnetic fields created by power lines do not affect the health or reproductive capacity of farm animals'*.

For vegetation it noted that *'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'* and that *'No reason exists for concern as to the effect of the fields on animals or plants* . However, the report did note that beehives near power lines can be adversely affected. This can be addressed by earthed shielding above the beehives if necessary. Regarding the growth of trees under the line being reduced by the effect of corona, this only applies to certain specific tree types and is unlikely to be a concern in Australia. Tree growth under the lines needs to be limited for clearance reasons anyway.

There is a body of research examining the effects of EMF on the reproductive biology and physiology of birds in the wild and under aviary conditions. Most studies indicate that EMF exposure of birds generally changes, but not always consistently in effect or in direction, their behaviour, reproductive success, growth and development, physiology and endocrinology, and oxidative stress under EMF conditions[20].

2.7 Managing electric and magnetic fields

Transgrid designs new infrastructure to meet ICNIRP public exposure guidelines. This is done by modelling transmission lines and other infrastructure to enable the accurate prediction of electric and magnetic field strengths. Predictions of field levels as they relate to typical (and worst case) operation give an indication of likely field levels to members of the public and to consenting authorities. The results of this modelling are provided in Section 3.

Scientific uncertainty around the association between EMF and childhood leukaemia has led to significant debate. From a risk management perspective, prudent avoidance and precautionary approaches have been advocated. In Australia, prudent avoidance was defined by the former Chief Justice of the High Court of Australia, Sir Harry Gibbs, as *“doing whatever can be done at modest cost and without undue inconvenience to avoid the possible risk to health”*[21].

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[18] British Cochlear Implant Group: https://www.bcig.org.uk/safety/

[19] 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.

[20] Kim J. Fernie & S. James Reynolds (2005) *The Effects of Electromagnetic Fields from Power Lines on Avian Reproductive Biology and Physiology: A Review*, Journal of Toxicology and Environmental Health, Part B, 8:2, 127-140, DOI: 10.1080/10937400590909022

[21] Gibbs, Sir Harry (1991)

In a June 2007 report on possible EMF health effects the WHO make the following statements: '*In recommending precautionary approaches, an overriding principle is that any actions taken should not compromise the essential health, social and economic benefits of electric power*.' and '*Provided that these benefits are not compromised, implementing precautionary procedures to reduce exposures is reasonable and warranted*.'[22] The WHO stated that these precautionary approaches do not support setting exposure limits below those determined by the analysis of the health effects research. In addition, in relation to the selection of measures, the WHO states that *"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."*[23]

The techniques that are available to reduce EMF exposures associated with transmission lines relate to the characteristics of electric and magnetic fields and can be summarised as:

- the reduction of field levels with distance from their source; and
- mutual cancellation of the fields from different phases.

It has been advised by Transgrid that the transmission line corridor selection process implemented for Project EnergyConnect included the consideration and selection of a corridor which maximises distances to dwellings and inhabited areas wherever possible. The route corridor selection and refinement process applied for Project EnergyConnect is documented separately by Transgrid in the Environmental Impact Statement, EnergyConnect (NSW – Eastern Section) (November 2021).

The transmission line minimum heights above ground have been designed to keep EMF levels within ICNIRP public exposure guidelines directly under the line. There are other drivers, both cost and aesthetic, to keep the line as low as possible.

Low reactance phase arrangements are utilised in the design to allow mutual cancellation of the fields from different phases.

2.8 Cumulative effects

In places, the new transmission lines will be close to other transmission lines and smaller distribution lines. There is a cumulative effect arising from multiple transmission lines. Multiple power lines can lead to enhancement or reduction of magnetic fields depending on their configuration. Given that the EMF levels fall away rapidly with distance, this effect is only notable when the lines are in very close proximity. For known assets, this cumulative effect can be calculated.

The smaller distribution lines will have much lower EMF levels, will be out of phase with the larger transmission lines and the cumulative effect will be minimal. The largest magnetic field from each source will govern.

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[22] WHO, *Extremely Low Frequency Fields Environmental Health Criteria (EHC) Monograph No.238*.

[23] WHO, *Extremely Low Frequency Fields Environmental Health Criteria (EHC) Monograph No.238*, pp 13.

3 Electric and magnetic field simulation results

3.1 Calculations

SES-EnviroPlus, a commercial software package, was used to calculate the EMF at 1 m above the normal standing position of the public. The concept 330 kV and 500 kV light suspension towers phase and circuit spacings were used for the new lines. The concept 330 kV and 500 kV strain towers phase and circuit spacings were used for the landing spans. There is negligible difference between the two tower types for each voltage. The geometries and general outline drawings of the towers used for the assessment are provided in Appendix F.

Actual design dimensions may vary from the concept dimensions used. Differences are likely to be small but reconfirmation of the calculated values may be required if designs vary significantly.

A line voltage equal to the system highest voltage of 10% above normal and the rated line loading outlined in Table 3-1 was applied for the calculations. The current in each phase was calculated using Equation 1.

$$\mathrm{I} = \frac{\mathrm{S} \times 10^3}{\sqrt{3}.\mathrm{V}_{LL}} \; [A]$$

Where: S = Apparent circuit power [MVA]

V_{LL} = Rated line voltage [kV]

Table 3-1: Transmission line ratings

Transmission Line	Maximum contingency loading – per circuit		Time weighted average loading – per circuit	
	MVA	A	MVA	A
Concept 500 kV	3800	4388	1600	1848
Concept 330 kV	1080	1890	400	700
Concept 220 kV(1)	1100	2887	400	1050
Circuit 62 (330 kV)	1385	2423	700	1225
Circuit 63 (330 kV)	1385	2423	800	1400
Circuit 99A (132 kV)	168	735	120	525
Circuit 99L (132 kV)	168	735	120	525
Circuit 996 (132 kV)	168	735	120	525
Circuit X5 (220 kV)	596	1564	400	1050
Circuit X3 (220 kV)	596	1564	400	1050

[1] The proposed 220 kV line that forms part of the NSW – Western Section of EnergyConnect

Calculations are done for the worst case voltage and current on the lines. The contingency case is with only one line in service with a higher current. The time weighted average gives a typical daily average load and both circuits in service.

The EMF levels associated with the contingency loads will only occur for short periods on rare occasions. The time weighted average figures are provided to give more typical levels during normal operation.

For the contingency case the calculations were done for the minimum ground clearance of the circuit. For the time weighted average case the ground clearance was increased based on the change in conductor sag between the contingency and time weighted average cases. The change in conductor sag was calculated for an average span and the time weighted average case conductor sag considered the mean maximum ambient temperature across summer months (between 1991-2020).

3.2 Concept Transmission Lines

The calculated worst case EMF levels at mid span and edge of the easement are summarised in Table 3-2 and Table 3-3 respectively. These are based on the concept light suspension towers phase and circuit spacings. The EMF plots are included in Appendix B. The calculated EMF for other tower types resulted in almost the same values as the concept light suspension tower types.

The EMF levels fall rapidly with distance from the line. This is shown in the figures given for the edge of the easement and in the profiles in Appendix B.

Table 3-2: Maximum calculated EMF directly under line mid span

Transmission Line	Maximum contingency circuit loading		Time weighted average circuit loading	
	EFS (kV/m)	MFD (mG)	EFS (kV/m)	MFD (mG)
Concept 330 kV	6.32	272	4.65	99
Concept 500 kV	7.96	627	5.59	176

Table 3-3: Worst case maximum calculated EMF at edge of 80 m easement

Transmission Line	Maximum contingency circuit loading		Time weighted average circuit loading	
	EFS (kV/m)	MFD (mG)	EFS (kV/m)	MFD (mG)
Concept 330 kV	0.19	35	0.07	6.50
Concept 500 kV	1.41	146	1.33	43.31

3.3 Substation Landing Spans

Table 3-4 and Table 3-5 summarise the calculated worst-case EMF directly under the line and at edge of easement respectively for a landing span into a substation. The concept strain towers were used for the calculation. Refer to Appendix C for EMF plots.

Table 3-4: Maximum calculated EMF directly under line for landing spans

Transmission Line	Maximum contingency circuit loading		Time weighted average circuit loading	
	EFS (kV/m)	MFD (mG)	EFS (kV/m)	MFD (mG)
330 kV concept strain	6.29	272	4.40	116
500 kV concept strain	7.93	623	7.74	252

Table 3-5: Worst case maximum calculated EMF at edge of easement for landing spans

Transmission Line	Maximum contingency circuit loading		Time weighted average circuit loading	
	EFS (kV/m)	MFD (mG)	EFS (kV/m)	MFD (mG)
330 kV concept strain	0.15	66	0.44	21
500 kV concept strain	1.55	152	1.41	51

3.4 Parallel Transmission Lines

The proposed EnergyConnect transmission lines run parallel to existing Transgrid 330 kV, 220 kV and 132 V transmission lines in places along the proposed alignments. The phasing of the adjacent circuit is assumed to be the worst for cumulative EMF. The calculated worst case EMF directly under the line and at edge of easement are summarised in Table 3-6 and Table 3-7 respectively in these circumstances. The EMF plots are included in Appendix D.

This study does not include the assessment of the existing 330 kV transmission line 51. The EnergyConnect transmission line may run adjacent to the line 51 for the approach to Wagga Wagga substation, however this is subject to change.

Table 3-6: Maximum calculated EMF directly under line mid span – parallel lines

Transmission Line	Maximum contingency circuit loading		Time weighted average circuit loading	
	EFS (kV/m)	MFD (mG)	EFS (kV/m)	MFD (mG)
New 330 kV parallel with Circuit X5	6.33	357	4.66	219
New 330 kV parallel with Circuit X3	6.33	357	4.66	219
New 330 kV parallel with Circuit X3 & New 220kV(1)	6.33	440	4.66	217
New 500 kV parallel with Circuits 62 & 63	7.96	618	6.43	331
New 500 kV parallel with Circuit 63	7.93	647	6.44	345
New 500 kV parallel with Circuit 99A	7.96	626	5.59	177

Table 3-7: Maximum calculated EMF at edge of easement – parallel lines

Transmission Line	Maximum contingency circuit loading		Time weighted average circuit loading	
	EFS (kV/m)	MFD (mG)	EFS (kV/m)	MFD (mG)
New 330 kV parallel with Circuit X5	0.43	39	0.52	37
New 330 kV parallel with Circuit X3	0.43	39	0.52	37
New 330 kV parallel with Circuit X3 & New 220kV(1)	0.44	36	0.52	37
New 500 kV parallel lines with Circuits 62 & 63	2.08	221	1.45	82
New 500 kV parallel with Circuit 63	1.07	144	1.33	79
New 500 kV parallel with Circuit 99A	1.41	146	1.33	43

[1] The proposed 220 kV line that forms part of the NSW – Western Section of EnergyConnect

3.5 Crossing Transmission Lines

The proposed EnergyConnect transmission lines cross existing Transgrid 330 kV, 220 kV and 132 kV transmission lines in places along the proposed alignments. The HIFREQ module of CDEGS, was used to calculate the EMF under these crossings at 1 m above the normal standing position of the public. The calculated EMF is summarised in Table 3-8.

The electric field strength at the crossing with the existing 330 kV circuit 62 marginally exceeds the 9.1 kV/m limit if circuit 62 is only 9 m above ground at this point (based on Transgrid minimum design ground clearance). This high value only applies in a very small, localised area where the outer phases of circuit 62 cross beneath the proposed double circuit line. Where the minimum ground clearance is above 9.1 m, the maximum EFS is below the 9.1 kV/m limit as detailed in Table 3-8. This crossing will need to be designed accordingly.

Similarly, the electric field strength at the crossing with the existing 220 kV circuit X5 marginally exceeds the 9.1 kV/m limit if circuit X5 is only 8.3 m above ground at this point (based on Transgrid minimum design ground clearance). This high value only applies in a very small, localised area where circuit X5 cross beneath the proposed double circuit line. Where the minimum ground clearance is above 8.6 m, the maximum EFS is below the 9.1 kV/m limit as detailed in Table 3-8. This crossing will need to be designed accordingly.

Table 3-8: Worst-case calculated EMF at crossing

Transmission Line	Maximum contingency circuit loading		Time weighted average circuit loading	
	EFS (kV/m)	MFD (mG)	EFS (kV/m)	MFD (mG)
New 330 kV Crossing Circuit X5	9.04	358	8.85	255
New 330 kV Crossing Circuit 99L	6.32	244	4.83	182
New 500 kV Crossing Circuit 996	7.37	506	5.52	301
New 500 kV Crossing Circuit 62	8.98	657	7.78	344
New 500 kV Crossing Circuit 99A	6.80	450	5.47	222

Table 3-9: Worst-case calculated EMF not within any transmission line easements (easement boundary) – crossing lines

Transmission Line	Maximum contingency circuit loading		Time weighted average circuit loading	
	EFS (kV/m)	MFD (mG)	EFS (kV/m)	MFD (mG)
New 330 kV Crossing Circuit X5	1.15	50	0.93	28
New 330 kV Crossing Circuit 99L	0.62	50	0.66	27
New 500 kV Crossing Circuit 996	1.77	157	1.42	51
New 500 kV Crossing Circuit 62	3.33	251	2.81	106
New 500 kV Crossing Circuit 99A	2.63	180	1.93	70

4 Summary of Results

The magnetic field levels directly under the proposed lines are well below the ICNIRP general public exposure reference level of 2,000 mG in all cases. During the contingency case of one circuit in service with increased load and the other circuit out of service, the magnetic field is 22% of the reference level for the 330 kV line and 33% of the reference level for the 500 kV line. Under time weighted average conditions, the magnetic field is 13% of the reference level for the 330 kV line and 18% of the reference level for the 500 kV line.

Based on the minimum ground clearance for the proposed lines, the electric field levels directly under the proposed lines are within 9.1 kV/m for the new 330 kV and 500 kV lines, in all cases. The 9.1 kV/m value can be shown to meet the ICNIRP general public basic restriction of 0.02 V/m for the central nervous system tissues of the head, as determined by Transgrid through separate modelling (as detailed in section 2.3). The minimum clearance is typically at the middle of the span between towers where the conductor is at its lowest, and the majority of the line is well above this clearance. The minimum ground clearance (maximum sag) also only applies when the line is running at its maximum rating which occurs for the contingency case in hot weather conditions only. For the 330 kV line, the electric field is 70% of the 9.1 kV/m level in all cases except where the proposed line crosses the existing X5 220 kV line. In this location, greater than standard clearances are required to keep electric field within 9.1 kV/m level. For the 500 kV line, the electric field is 88% of the 9.1 kV/m level in all cases except where the proposed line crosses the existing 62 330 kV line. In this location, greater than standard clearances are also required to keep electric field within 9.1 kV/m level.

The EMF levels associated with the contingency loads will only occur directly under the line for short periods on rare occasions. Time weighted average figures are provided to give more typical levels during normal operation. Figures are provided for both directly under the line and at the edge of the easement.

5 References

[1] International Commission on Non-Ionizing Radiation Protection, “Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (100 KHZ TO 300 GHZ)). Health Physics 99(6):818-836; 2010.

[2] Institute of Electrical and Electronics Engineers, “Standard C95.1-2019 - IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz”, 2019.

[3] New Zealand Ministry of Health, “Interagency Committee on the Health Effects of Non-ionising Fields: Report to Ministers 2015”, April 2015.

[4] World Health Organisation, “Extremely Low Frequency Fields Environmental Health Criteria Monograph No.238”, June 2007.

[5] World Health Organisation, “Electromagnetic fields and public health fact sheet”, https://www.who.int/peh-emf/publications/facts/fs322/en/

Appendix A – Transmission Line Input Data

Oper. kV	Circuit No.	Substations From	Substations To	Rated kV	Owner Name	Section No.	Split Phase	Length (km)	Structures From	Structures To	Structures Type	Structures Side	Structures Name	Phase Conductors No.	Phase Conductors Type	Overhead Earthwires First	Overhead Earthwires Second	Phase Rot'n	Comm. Date	Design Temp.	Mutual Coup. Section	Mutual Coup. Split	Mutual Coup. Circuit
	62	Jindera	Wagga 330		TG	Total		99.600															
				330	TG	1		4.439	271	27	SCST	L	SC	2 x	Mango	SC/GZ 7/.144	OPGW B 24/3.	WBR	May-80	85			
				330	TG	2		3.653	27	16	SCST	L	SC	2 x	Mango	SC/GZ 7/.144	OPGW A 8/3.3	WBR	May-80	85			
				330	TG	3		91.510	16	1	SCST	L	SL	2 x	Mango	SC/GZ 7/.144	OPGW A 8/3.3	WBR	May-80	85			
	63	Darlngt Pt	Wagga 330		TG	Total		151.700															
				330	TG	1		3.669	414a	404	SCST	L	QSA	2 x	Mango	Opal	Opal	WBR	Mar-88	85			
				330	TG	2		139.900	404	26	SCST	L	QSA	2 x	Mango	SC/GZ 7/3.75	SC/GZ 7/3.75	WBR	Mar-88	85			
				330	TG	3		3.653	26	16	SCST	L	SC	2 x	Mango	SC/GZ 7/3.75	SC/GZ 7/3.75	WBR	Mar-88	85			
				330	TG	4		4.439	16	1	SCST	L	SC	2 x	Mango	Opal	Opal	WBR	Mar-88	85			
	64	Lowertumut	Uppertumut		TG	Total		40.600															
				330	TG	1		0.087	Ltss	105	SCST	L	SA		Jarrah	SC/GZ 7/.144	OPGW B 24/3.	WBR	May-57	65			
				330	TG	2		34.830	105	17	SCST	L	SA	2 x	Bison 0.35"	SC/GZ 7/.144	OPGW A 8/3.3	WBR	May-57	65			
				330	TG	3		2.755	17	7	SCST	L	SAH		Jarrah	SC/GZ 7/.144	OPGW A 8/3.3	WBR	May-57	71			
				330	TG	4		1.534	7	6	SCST	L	SAH		Jarrah	SC/GZ19/.128	OPGW A 8/3.3	WBR	May-57	71			
				330	TG	5		1.398	6	Utss	SCST	L	SAH		Jarrah	SC/GZ 7/.144	OPGW B 24/3.	WBR	May-57	85			
220	0X1	Buronga Ss	Red Clf Ts		TG	Total		23.900															
				220	TG	1		22.500	T.60	Bord	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	RBW	Mar-79	85			
				220	TG	2		1.404	Bord	T.1	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	RBW	Mar-79	85			
	X2	Broken Hil	Buronga Ss		TG	Total		259.500															
				220	TG	1		41.150	T711	T608	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	BWR	Mar-79	85			
				220	TG	2		87.920	T608	T388	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	WRB	Mar-79	85			
				220	TG	3		63.490	T388	T229	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	RBW	Mar-79	85			
				220	TG	4		66.910	T229	T.61	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	BWR	Mar-79	85			
	X5/1	Balranald	Darlngt Pt		TG	Total		249.800															
				220	TG	1		123.300	Balr	319	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	RBW	Jun-88	85			
				220	TG	2		63.170	319	162	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	WRB	Jun-88	85			
				220	TG	3		10.120	162	140	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	BWR	Jun-88	85			
				220	TG	4		18.330	140		SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	BWR	Jun-88	85			
				220	TG	5		21.740			SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	BWR	Jun-88	85			
				220	TG	6		10.220			SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	BWR	Jun-88	85			
				220	TG	7		0.884		7	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	BWR	Jun-88	85			
				220	TG	8		2.076	7	1	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	BWR	Jun-88	85			
	X5/3	Balranald	Buronga Ss		TG	Total		148.000															
				220	TG	1		3.340	Balr	637	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	RBW	Jun-88	85			
				220	TG	2		63.280	637	796	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	WRB	Jun-88	85			
				220	TG	3		81.380	796	998	SCST	L	NSA	2 x	Lemon		SC/GZ 7/3.25	BWR	Jun-88	85			
	996/2	Morven Tee	Wagga 330		TG	Total		64.970															
				132	TG	1		60.500	T193	T37	SCWP	L	VP-AA		Panther 0.2"	SC/GZ 7/.128	SC/GZ 7/.128	RWB	May-81	85			
				132	TG	2		4.470	T37	W330	DCST	R	DSL		Panther 0.2"	Wolf 0.15"	Wolf 0.15"		May-81	85	1		994

Oper.	Circuit	Substations		Rated	Owner	Section	Split	Length	Structures					Phase Conductors		Overhead Earthwires		Phase	Comm.	Design	Mutual Coup.		
kV	No.	From	To	kV	Name	No.	Phase	(km)	From	To	Type	Side	Name	No.	Type	First	Second	Rot'n	Date	Temp.	Section	Split	Circuit
	99A	Finley 132	Uranquinty	132	**TG**	1		167.300	Fnly	T9-8	SCWP	L	VP-AA		Panther 0.2"	SC/GZ 7/.128	SC/GZ 7/.128		May-71	85			
	99L	Coleambaly	Deniliq132		**TG**	Total		152.700															
				132	**TG**	1		21.740	1050	1130	SCCP	L	LQH		Lemon	SC/GZ 7/3.25	SC/GZ 7/3.25	RWB	May-89	85			
				132	**TG**	2		18.330	1130	1196	SCCP	L	LQH		Lemon	SC/GZ 7/3.25	SC/GZ 7/3.25	WBR	May-89	85			
				132	**TG**	3		19.440	1196	1261	SCCP	L	LQH		Lemon	SC/GZ 7/3.25	SC/GZ 7/3.25	WBR	May-89	85			
				132	**TG**	4		44.950	1261	1501	SCCP	L	LQH		Lemon	SC/GZ 7/3.25	SC/GZ 7/3.25	BRW	May-89	85			
				132	**TG**	5		47.200	1501	1754	SCCP	L	LRK		Lemon		SC/GZ 7/3.25	RBW	May-89	85			
				132	**TG**	6		1.000	1754	1760	SCCP	L	LRK		Lemon		Cherry	RBW	May-89	85			

Appendix B – Concept Lines EFS and MFD Calculations

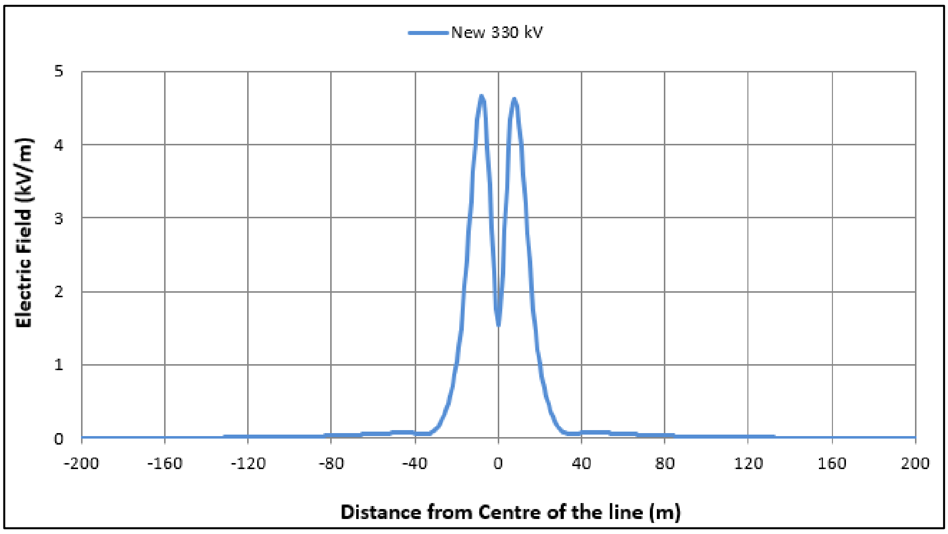


Figure B-1: Concept 330 kV line electric field strength – time weighted average case

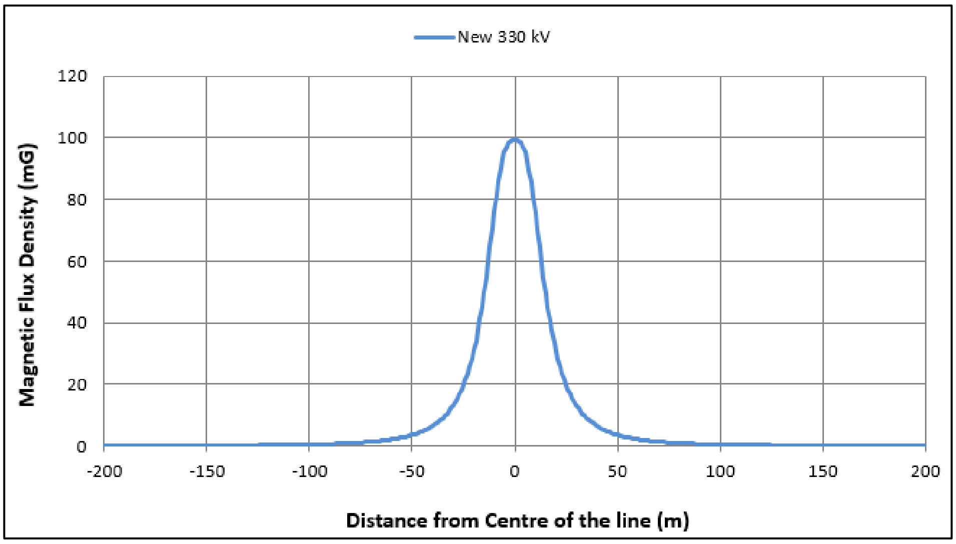


Figure B-2: Concept 330 kV line magnetic flux density – time weighted average case

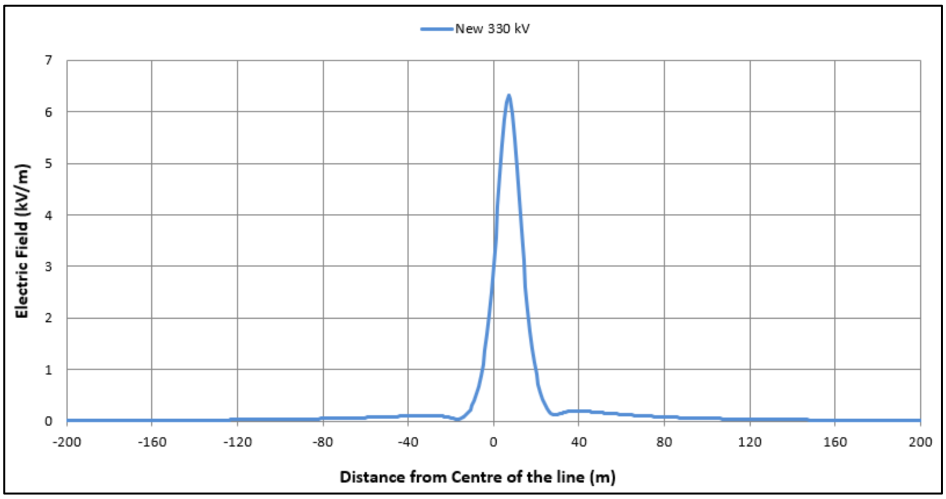


Figure B-3: Concept 330 kV line electric field strength – maximum contingency case

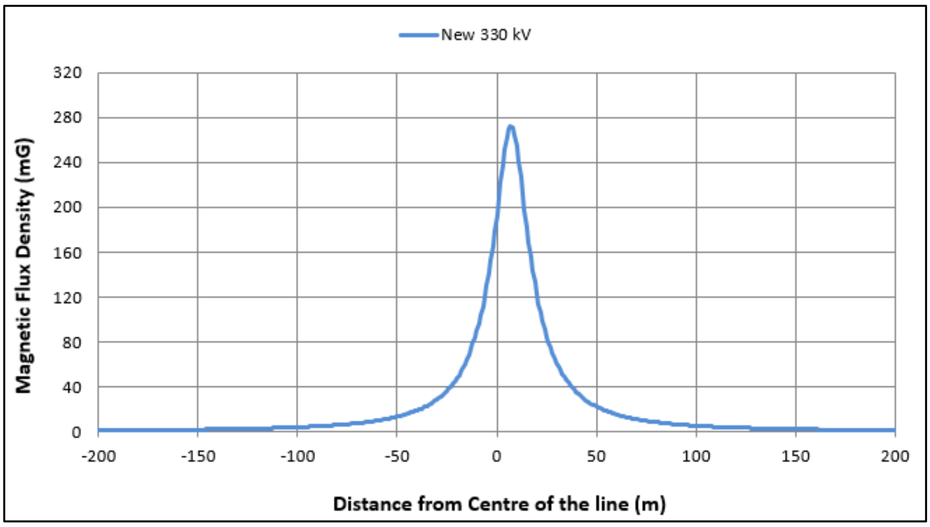


Figure B-4: Concept 330 kV line magnetic flux density – maximum contingency case

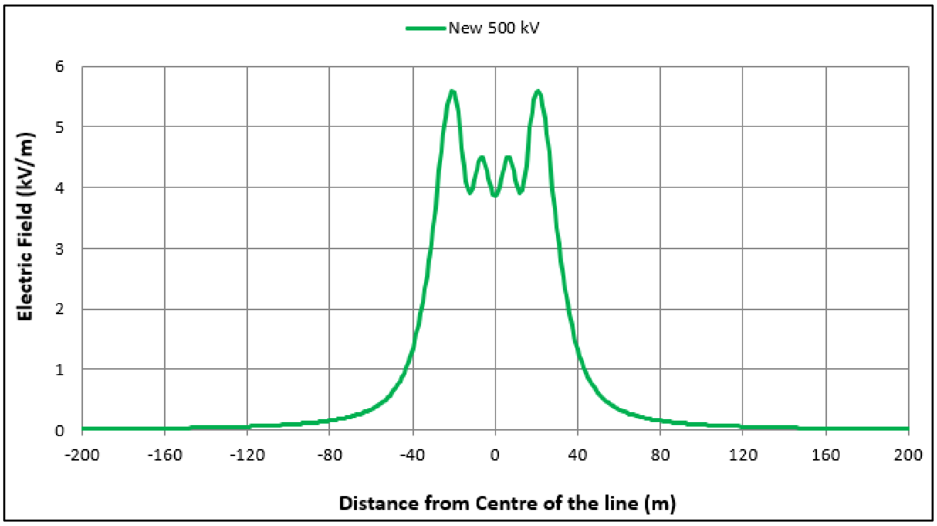


Figure B-5: Concept 500 kV line electric field strength – time weighted average case

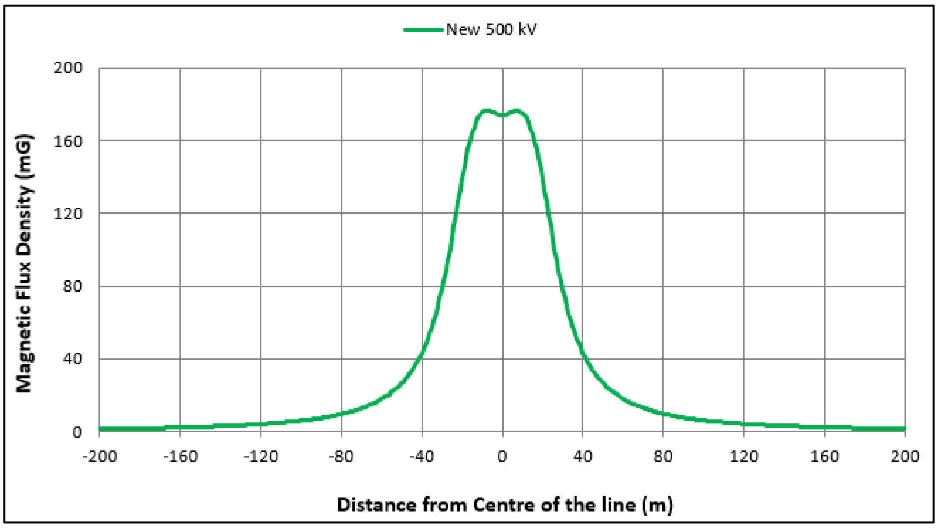


Figure B-6: Concept 500 kV line magnetic flux density – time weighted average case

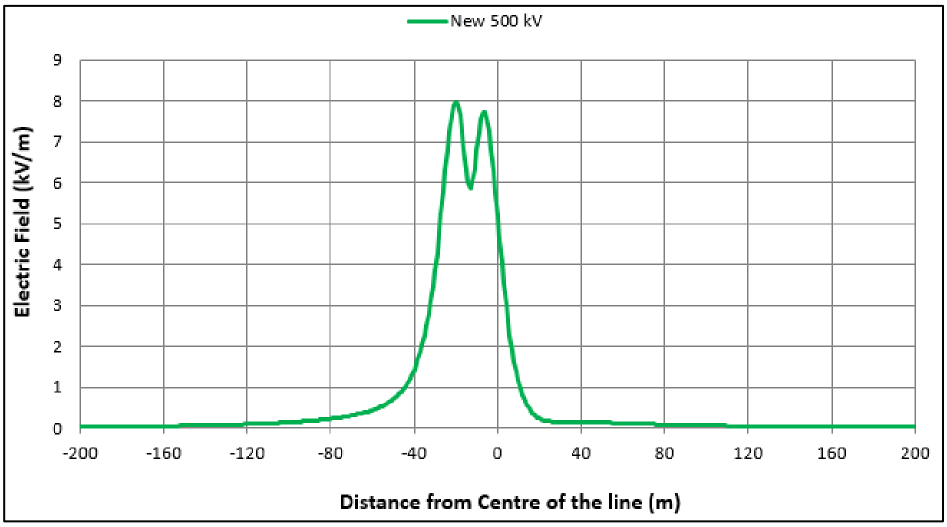


Figure B-7: Concept 500 kV line electric field strength – maximum contingency case

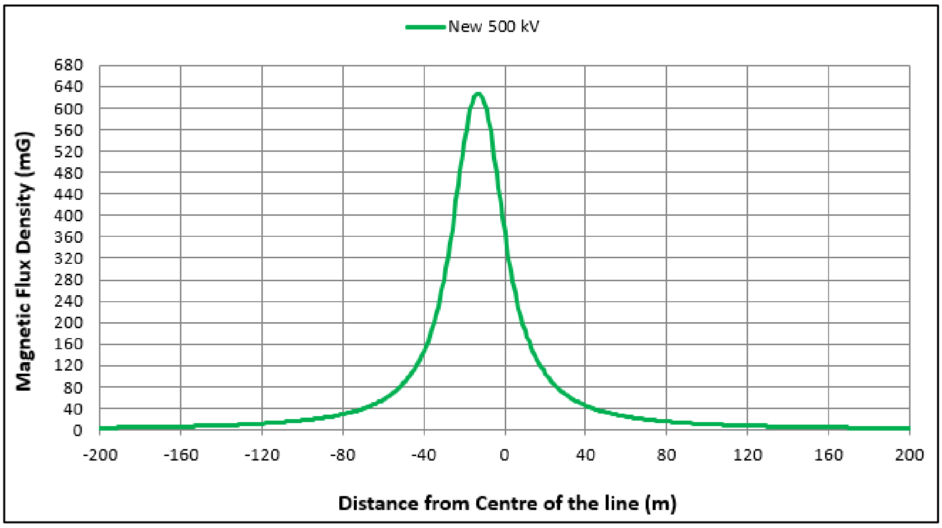


Figure B-8: Concept 500 kV line magnetic flux density – maximum contingency case

Appendix C – Substation Landing Spans EFS and MFD Calculations

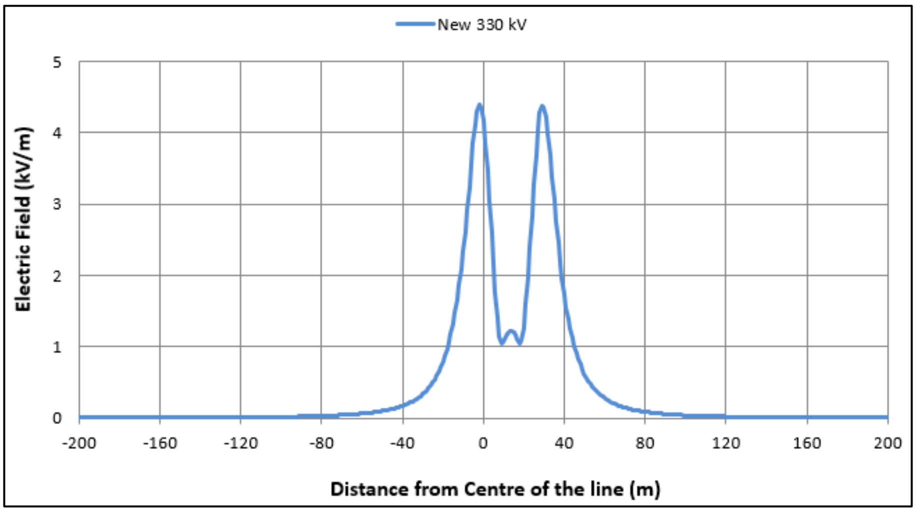


Figure C-1: Substation Landing Span - Concept 330 kV line electric field strength – time weighted average case

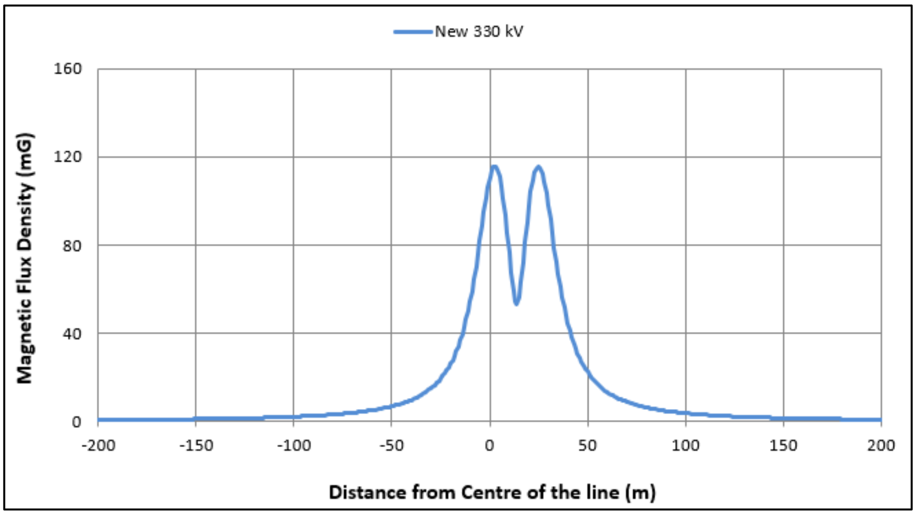


Figure C-2: Substation Landing Span - Concept 330 kV line magnetic flux density – time weighted average case

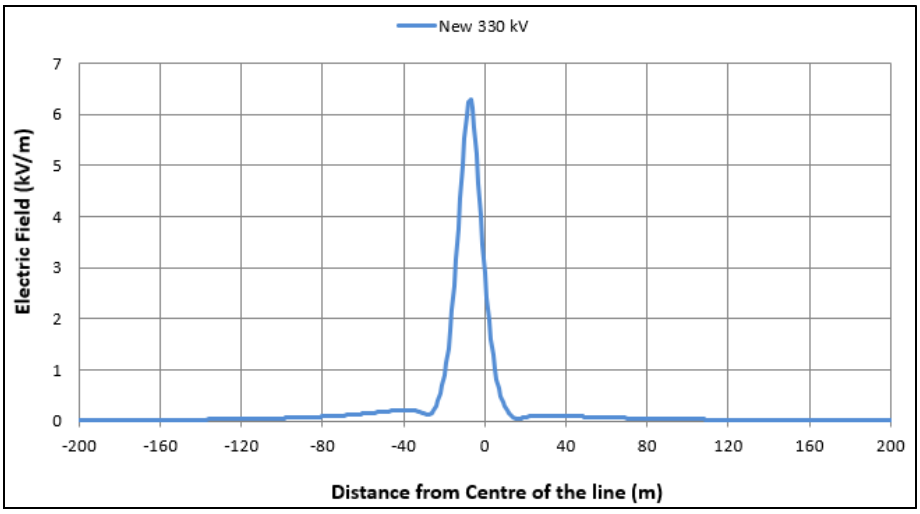


Figure C-3: Substation Landing Span - Concept 330 kV line electric field strength – maximum contingency case

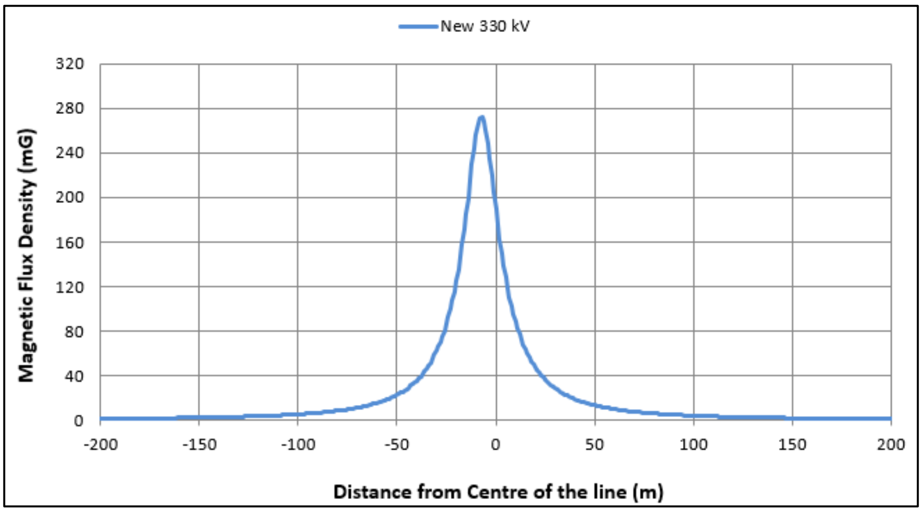


Figure C-4: Substation Landing Span - Concept 330 kV line magnetic flux density – maximum contingency case

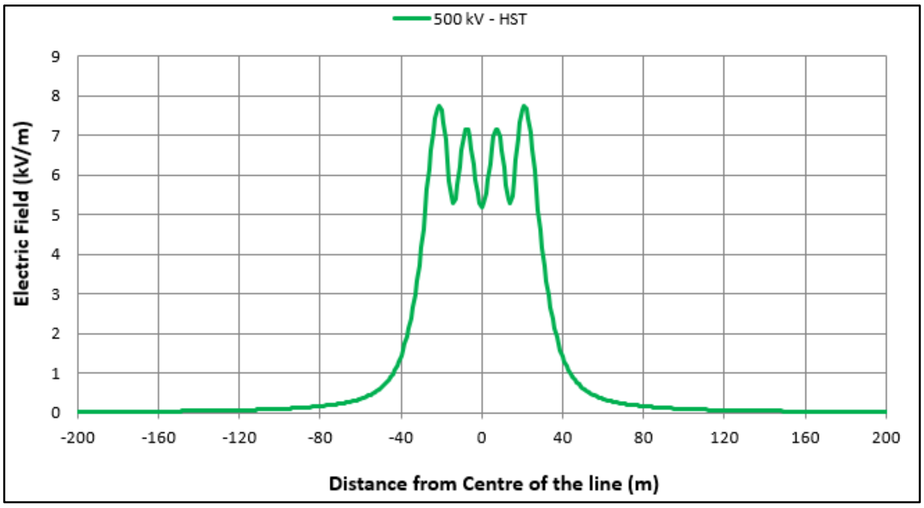


Figure C-5: Substation Landing Span - Concept 500 kV line electric field strength – time weighted average case

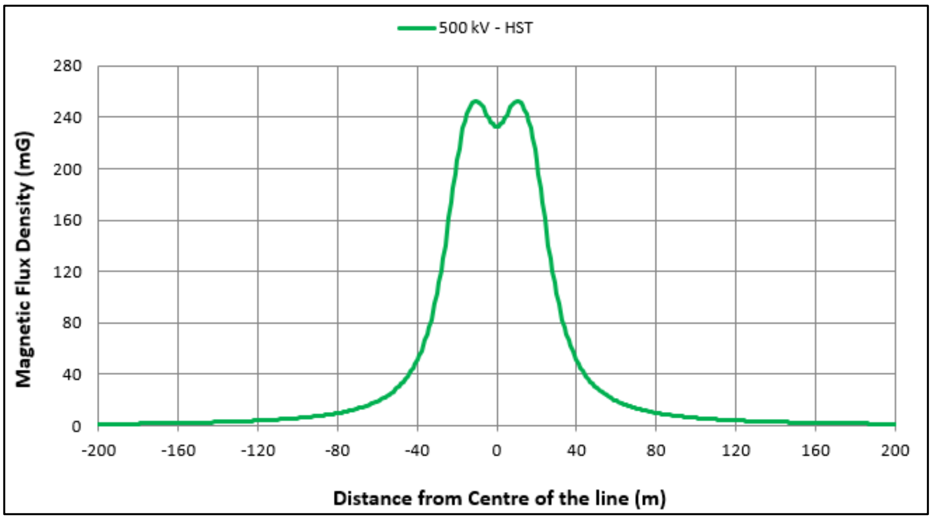


Figure C-6: Substation Landing Span - Concept 500 kV line magnetic flux density – time weighted average case

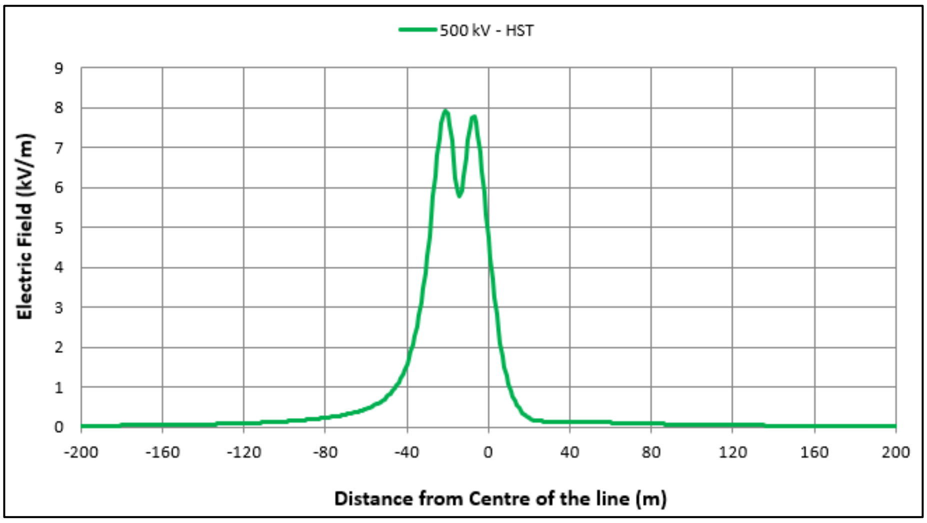


Figure C-7: Substation Landing Span - Concept 500 kV line electric field strength – maximum contingency case

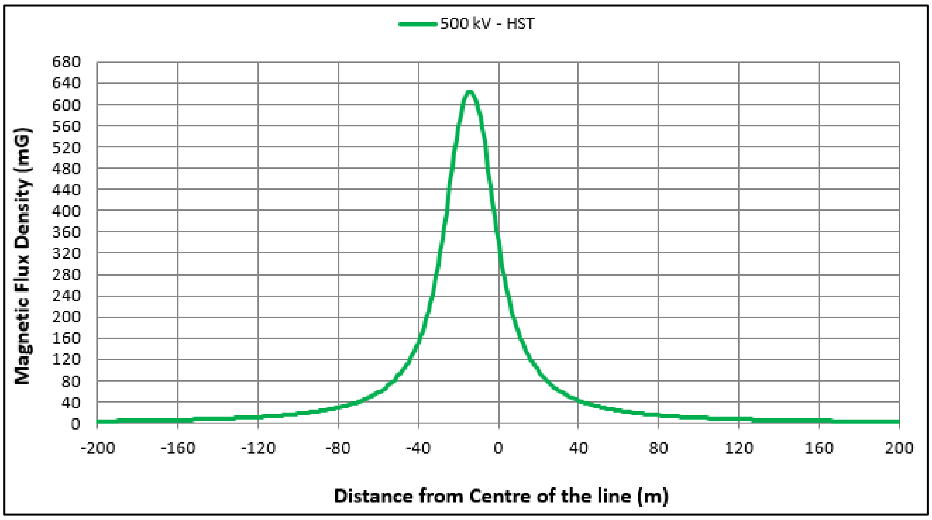
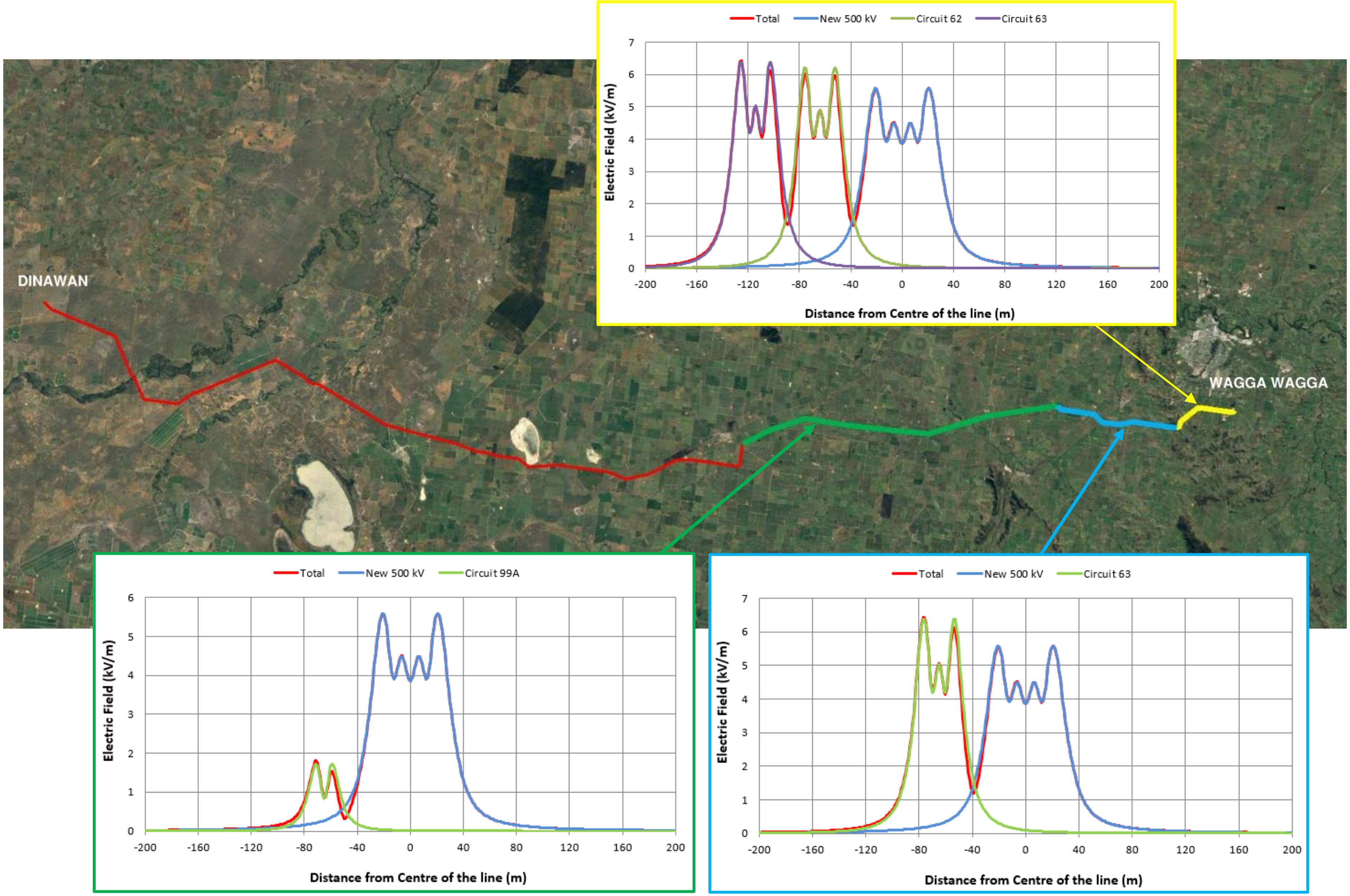


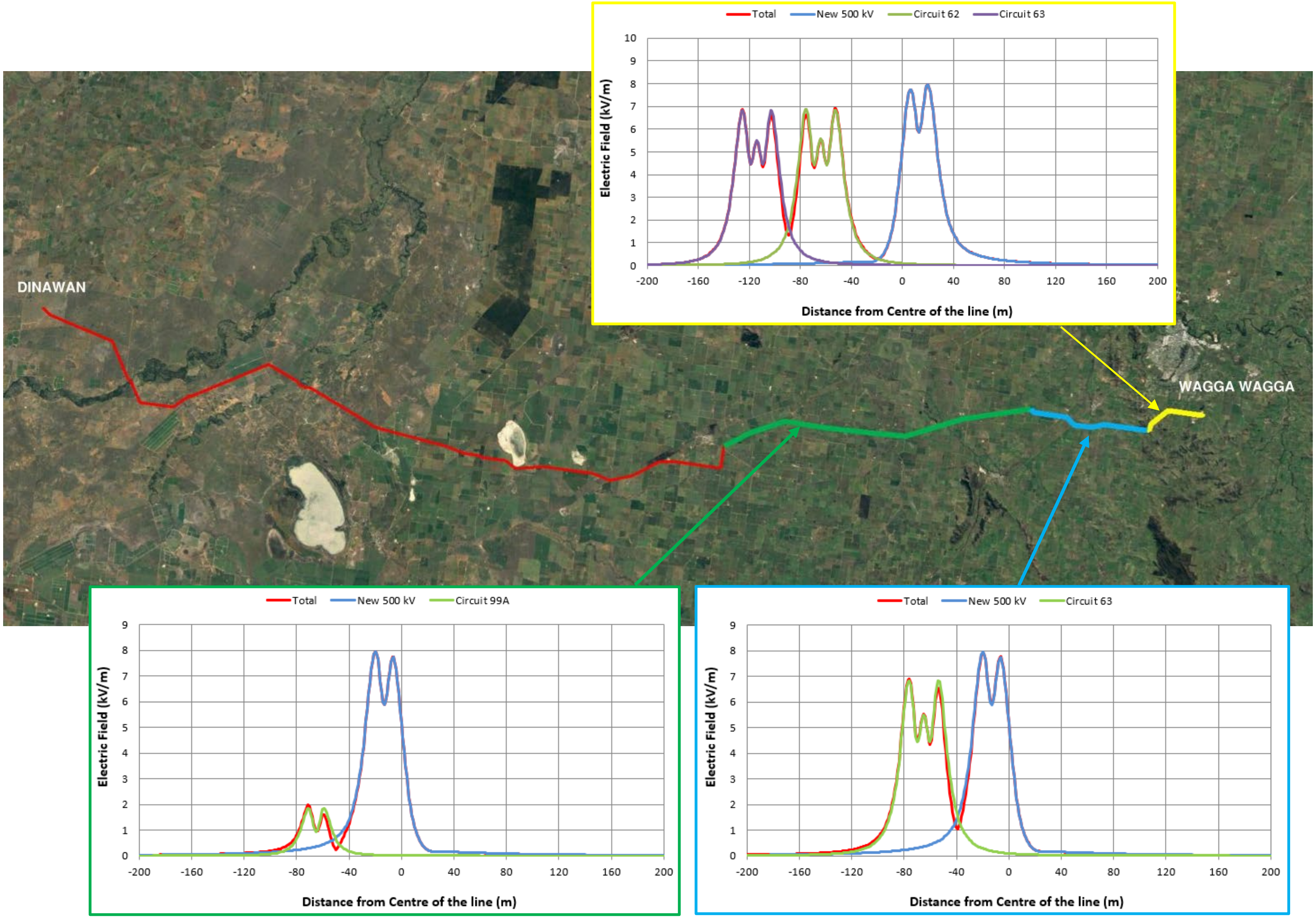
Figure C-8: Substation Landing Span - Concept 500 kV line magnetic flux density – maximum contingency case

Appendix D – Parallel Lines EFS and MFD Calculations

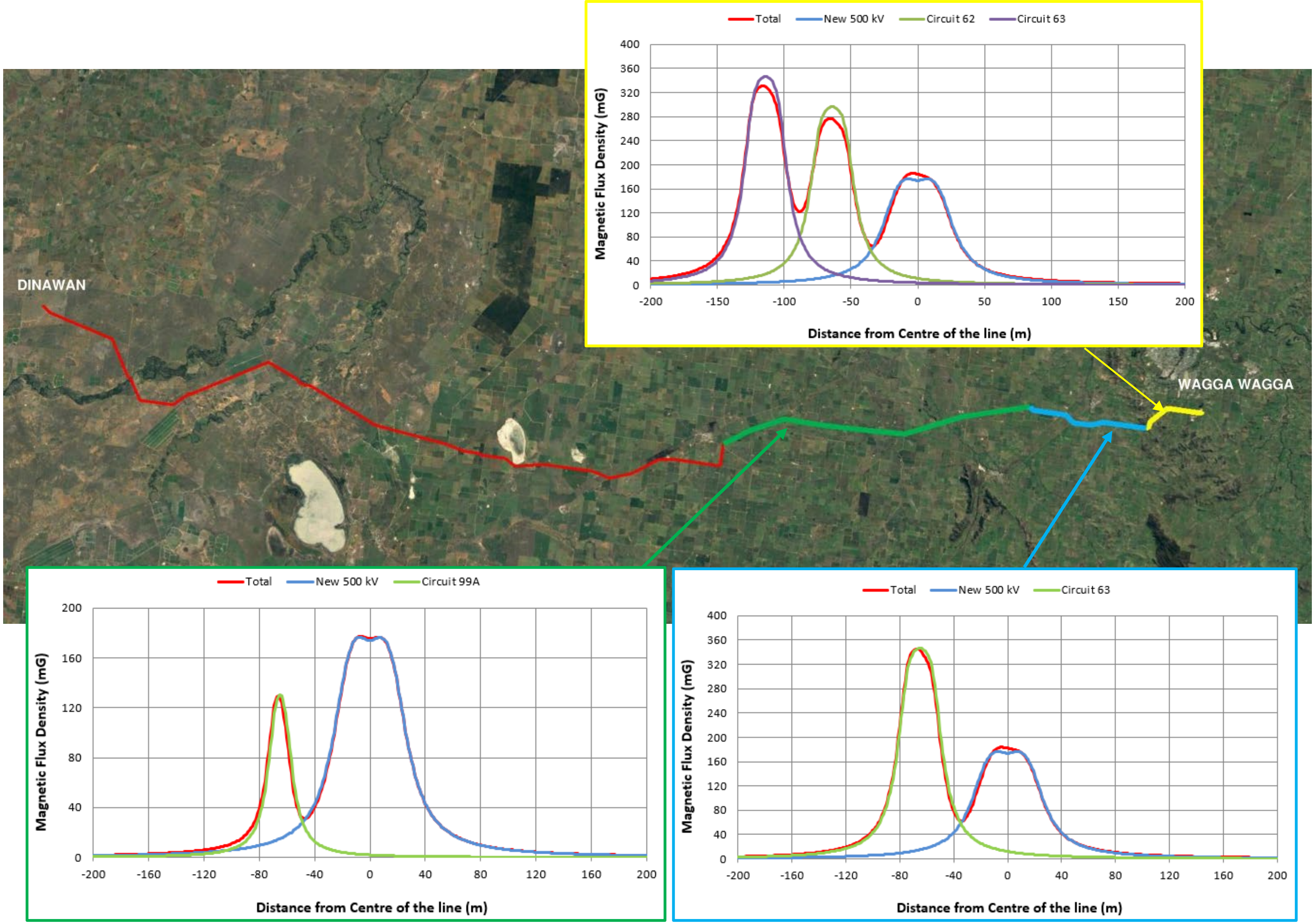
Wagga – Dinawan (Concept 500 kV) - Electric Field Strength - Time weighted average case



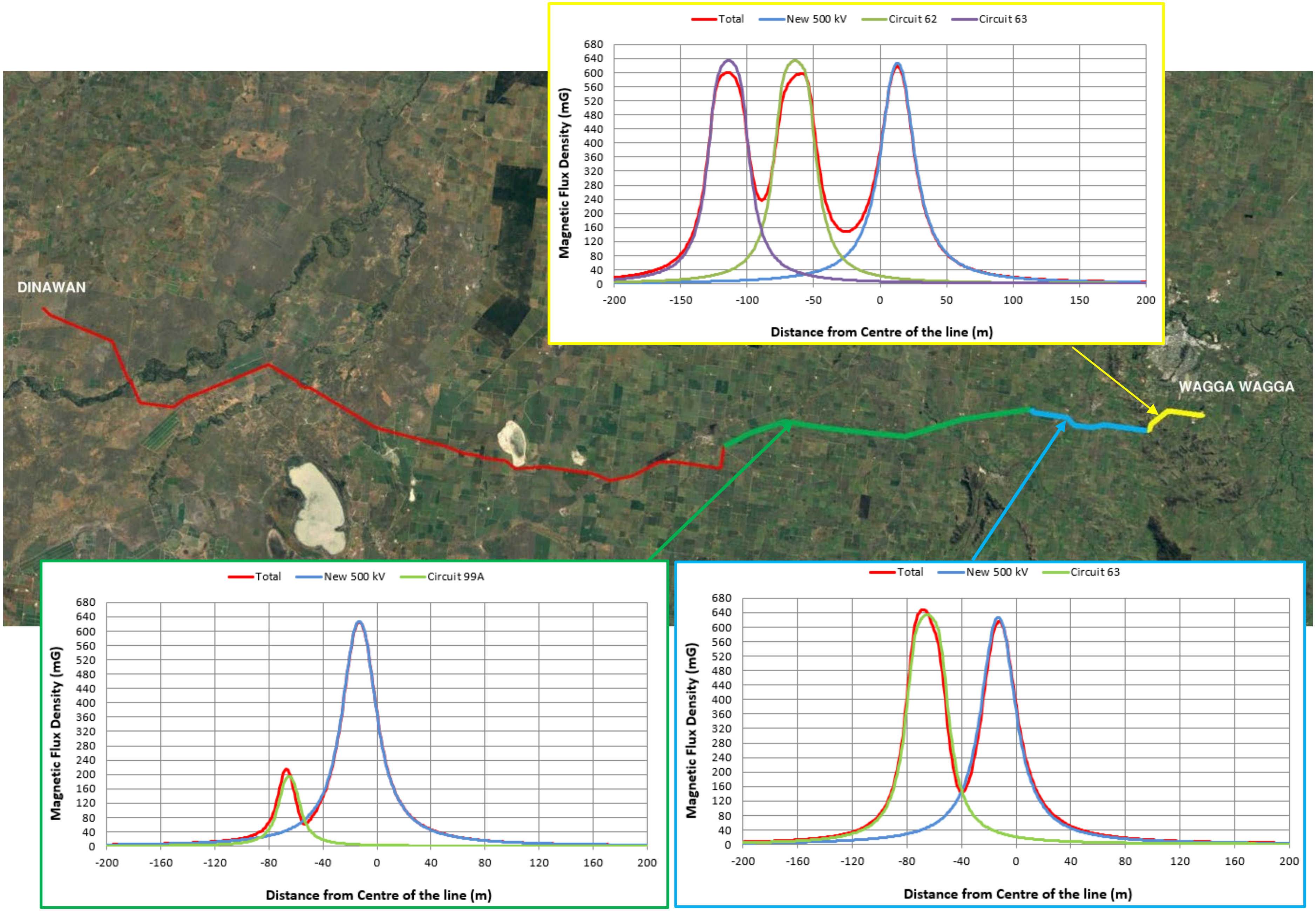
<u>Wagga – Dinawan (Concept 500 kV)</u> - Electric Field Strength – Maximum contingency case



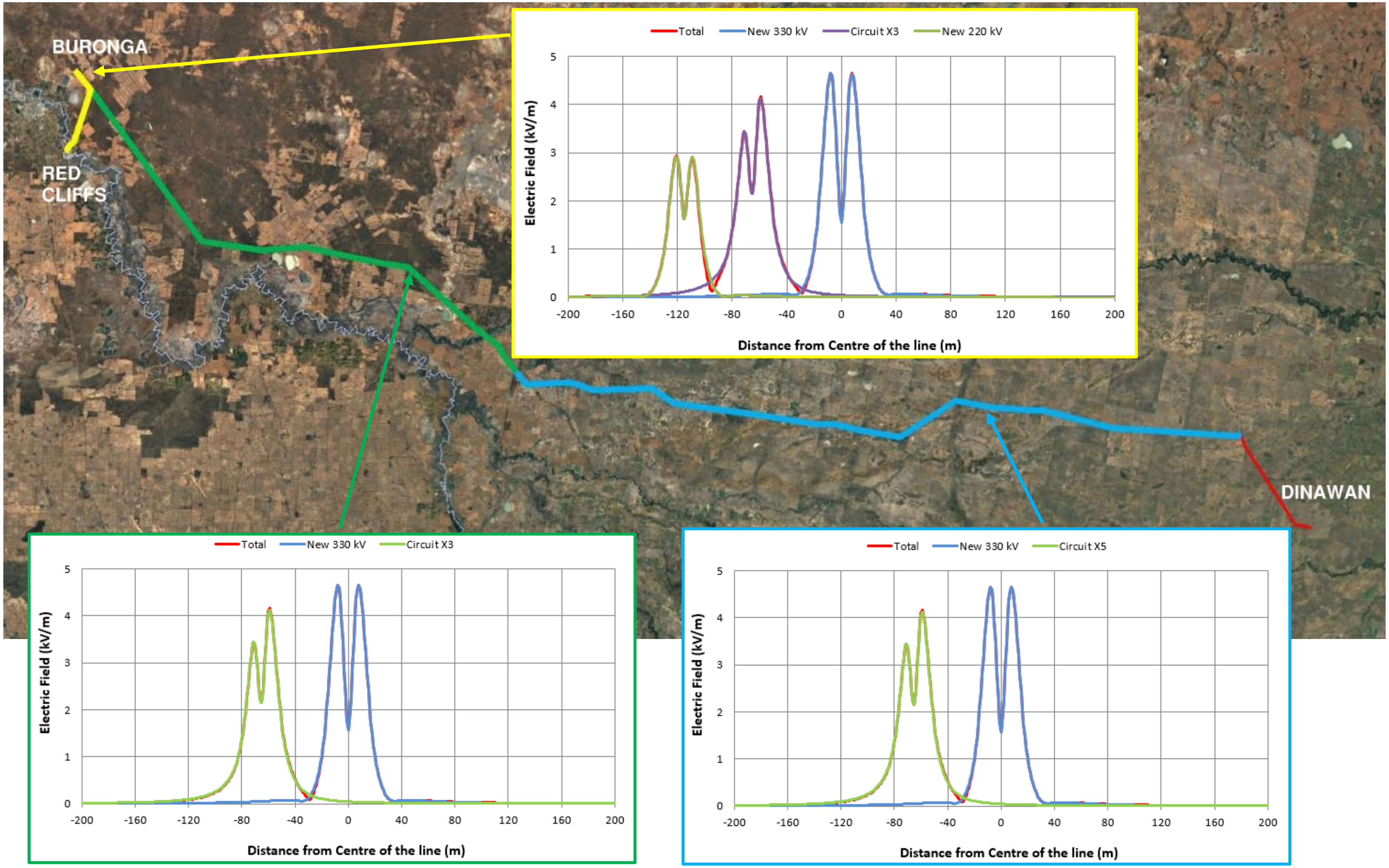
Wagga – Dinawan (Concept 500 kV) - **Magnetic Flux Density - Time weighted average case**



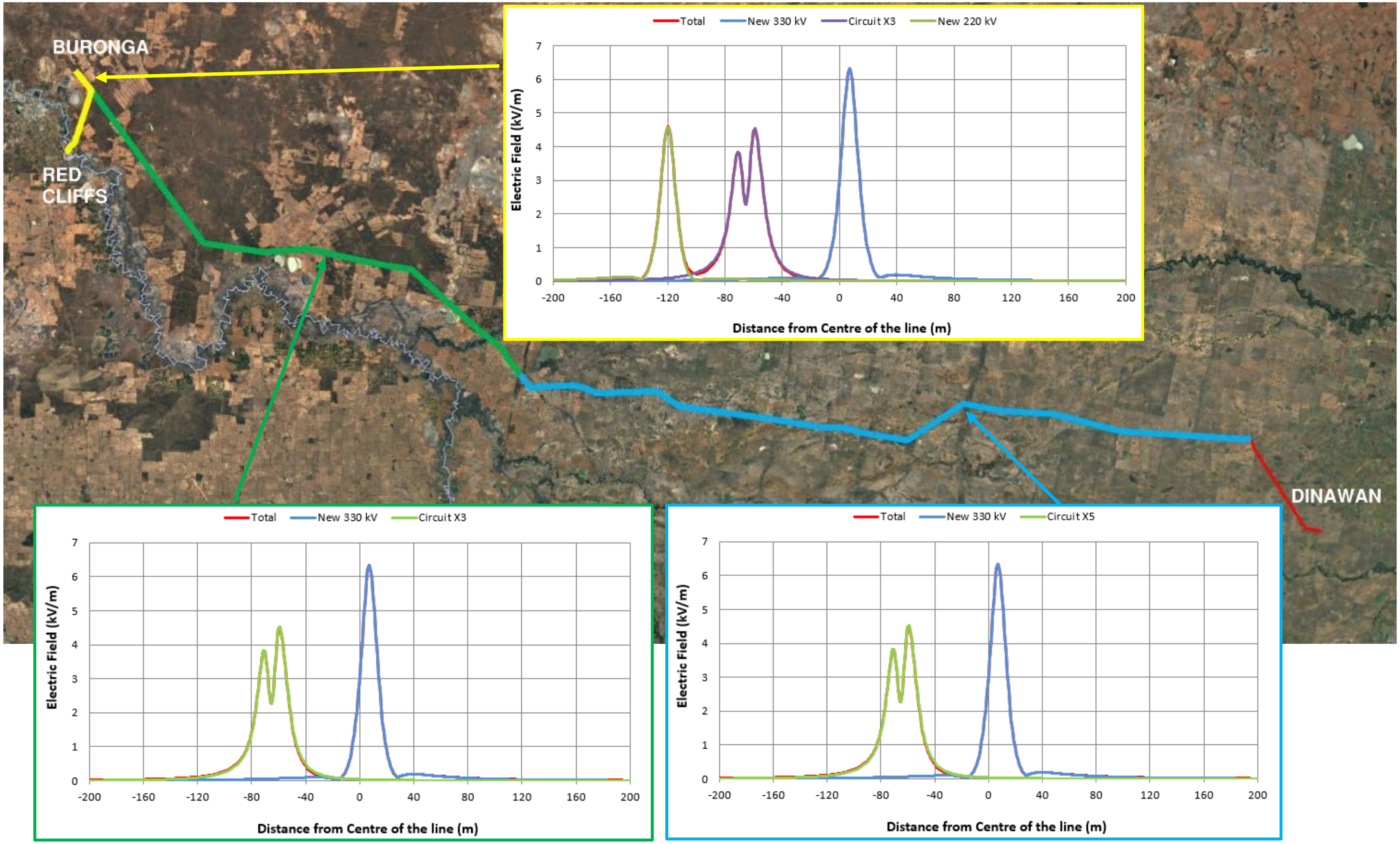
Wagga – Dinawan (Concept 500 kV) - Magnetic Flux Density – Maximum contingency case



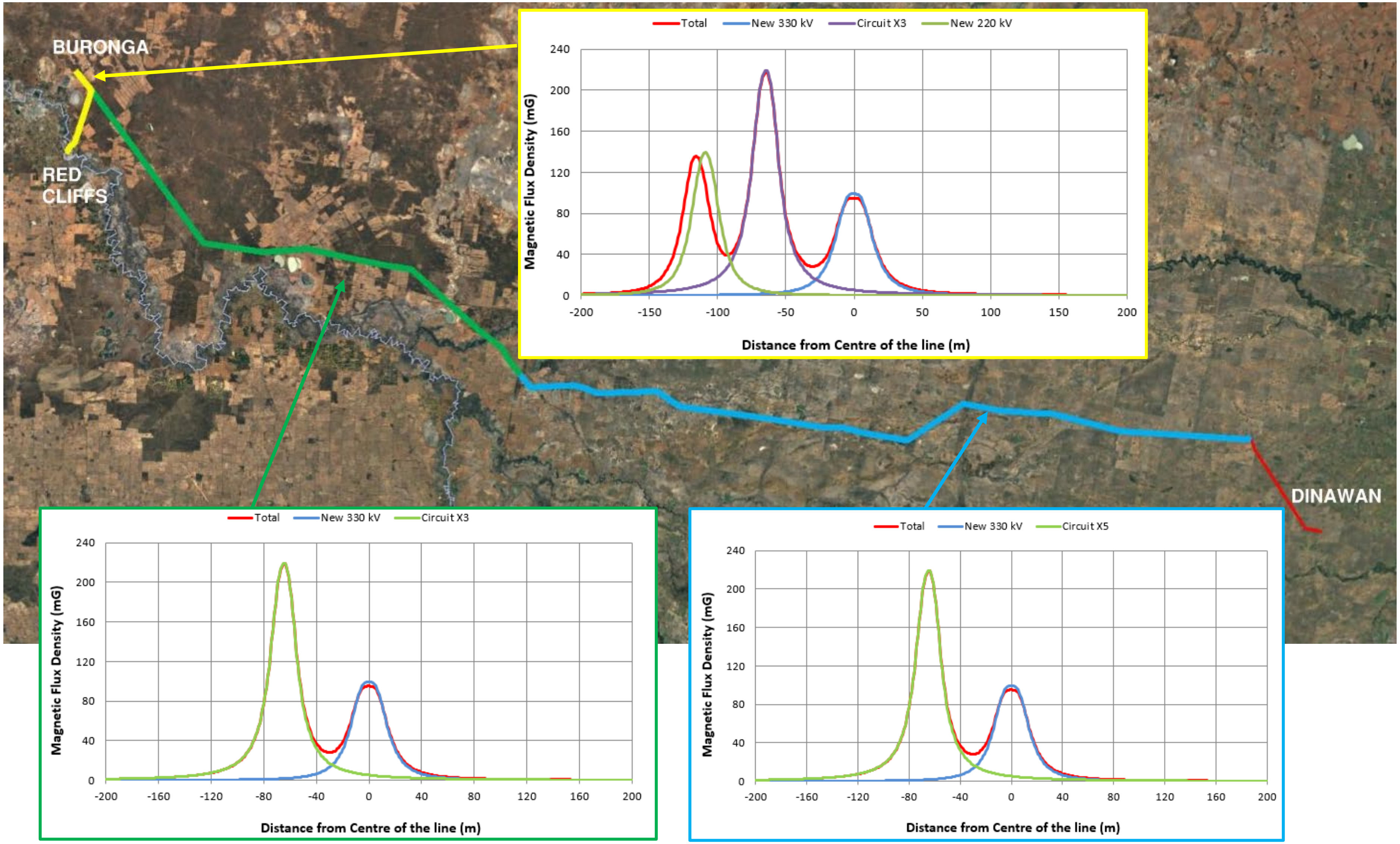
Dinawan - Buronga (Concept 330 kV) - **Electric Field Strength - Time weighted average case**



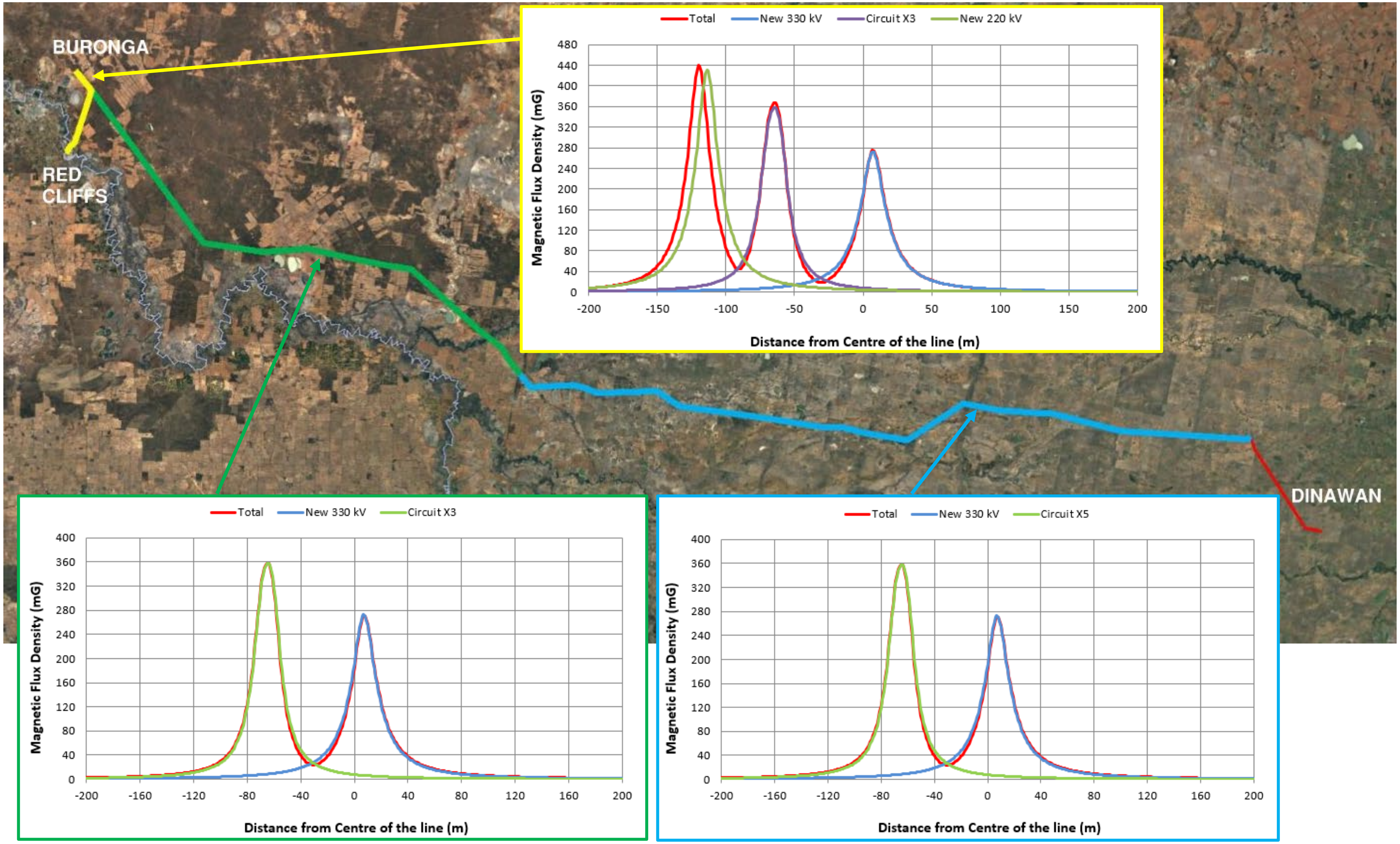
Dinawan - Buronga (Concept 330 kV) - Electric Field Strength – Maximum contingency case



Dinawan - Buronga (Concept 330 kV) - Magnetic Flux Density - Time weighted average case

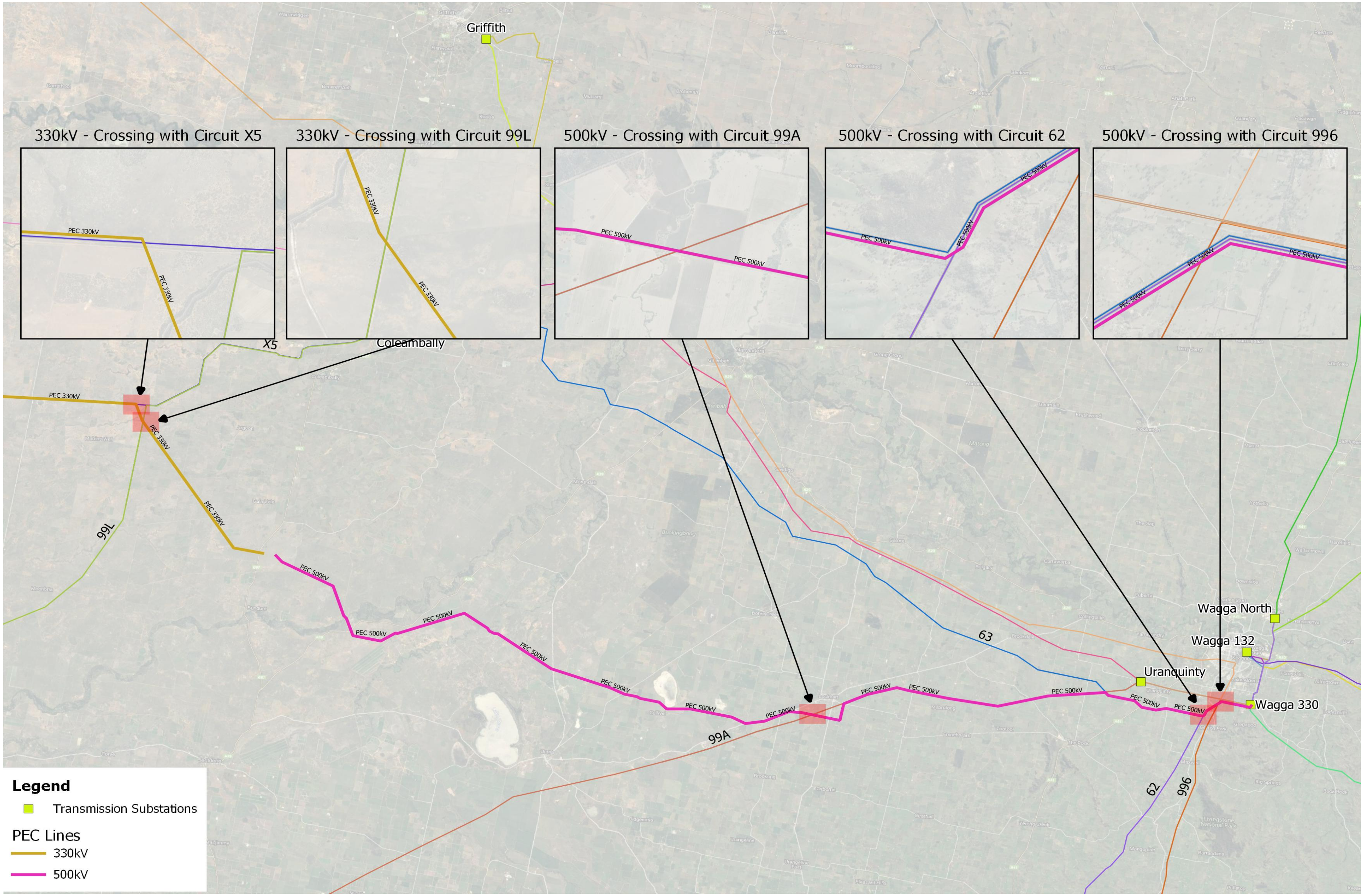


Dinawan - Buronga (Concept 330 kV) - Magnetic Flux Density – Maximum contingency case



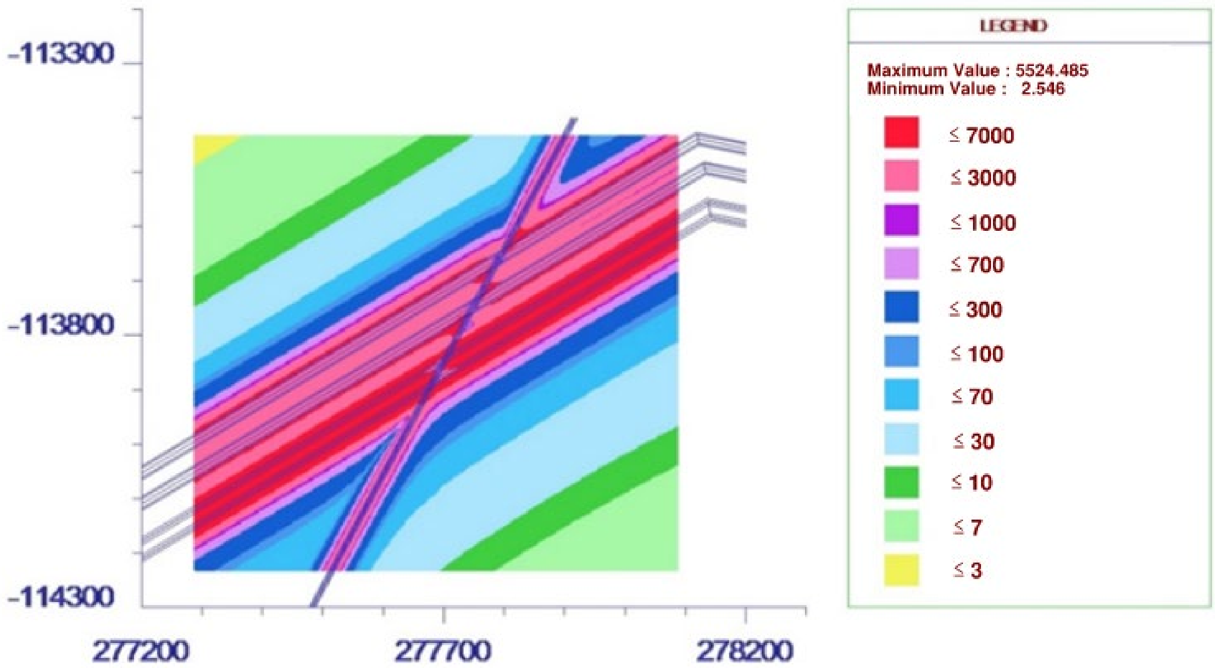
Appendix E – Crossing Line EFS and MFD Calculations

Crossings Layout

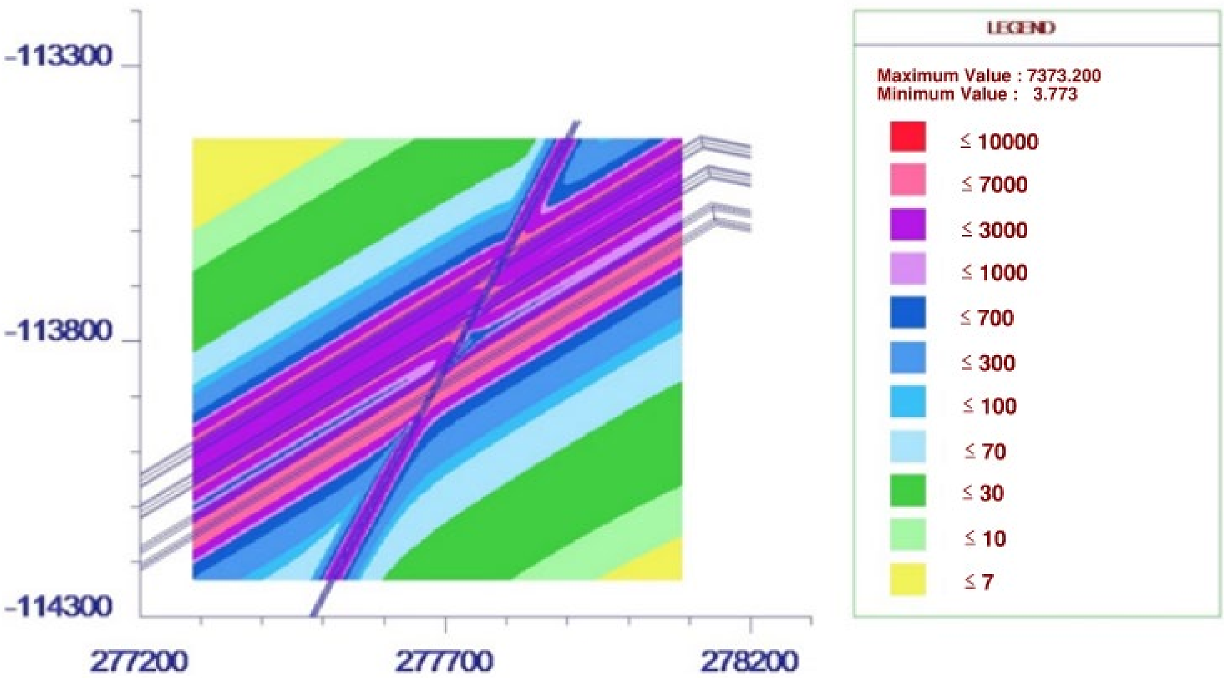


500kV – Crossing with Circuit 996

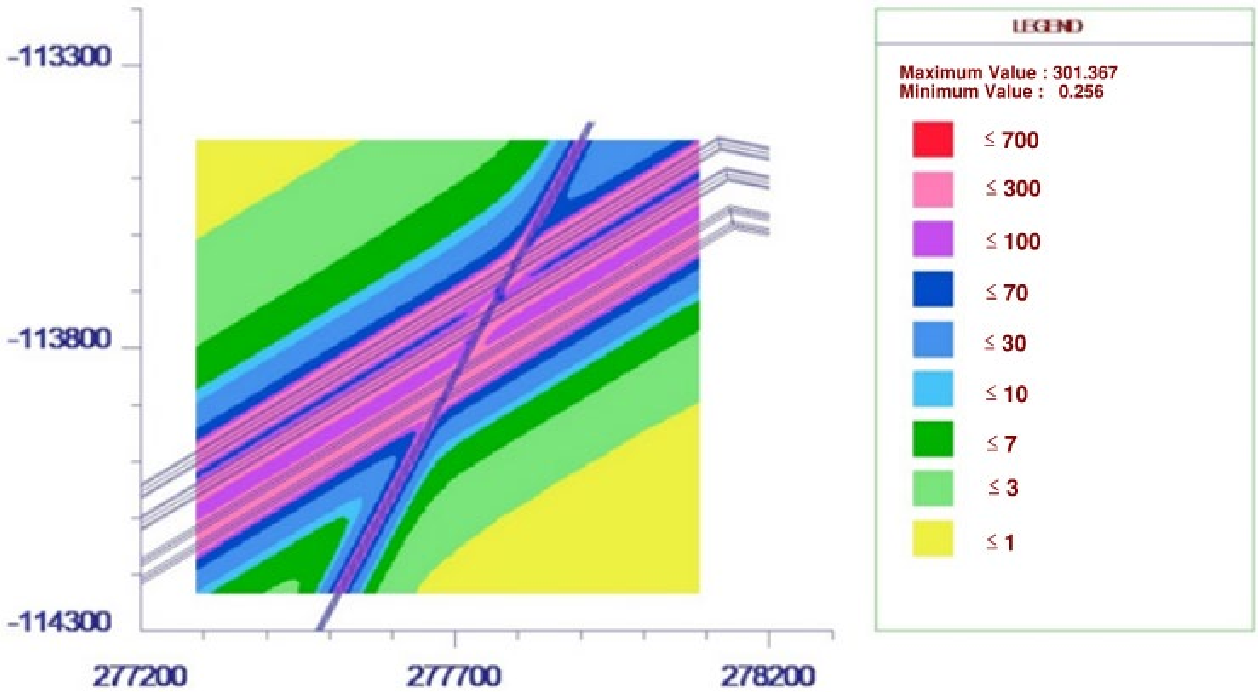
EFS – Time Weighted Average (V/m)



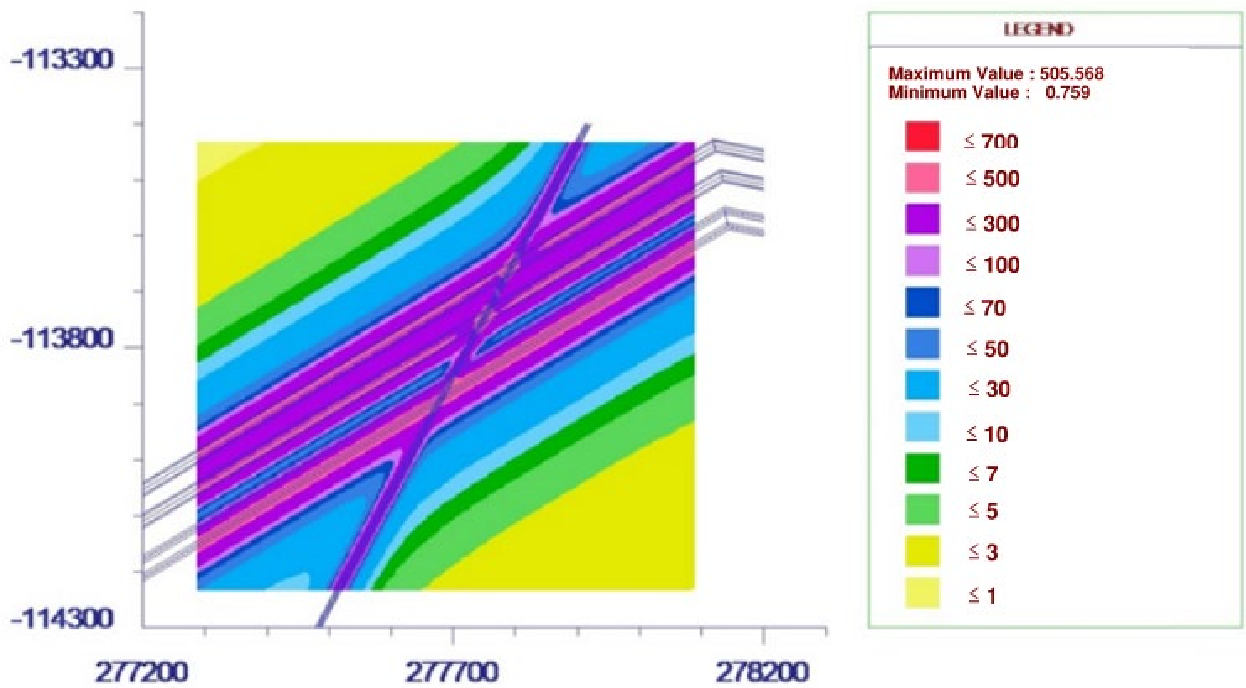
EFS – Max Contingency (V/m)



MFD – Time Weighted Average (mG)

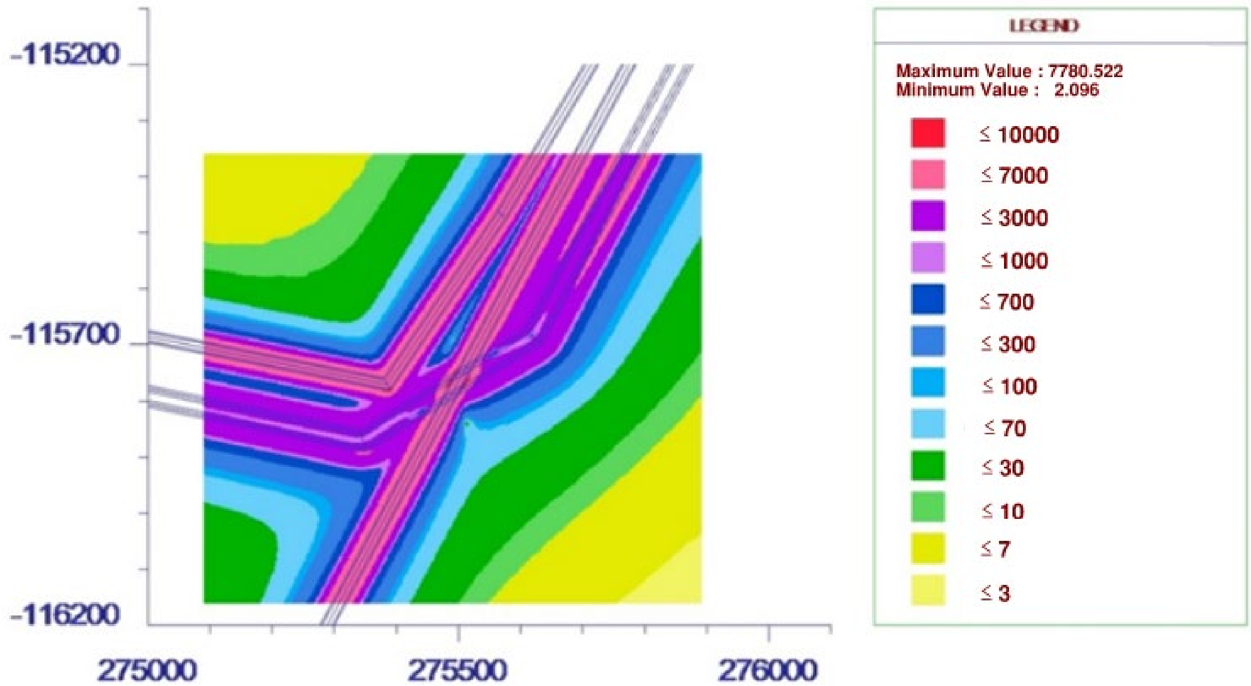


MFD – Max Contingency (mG)

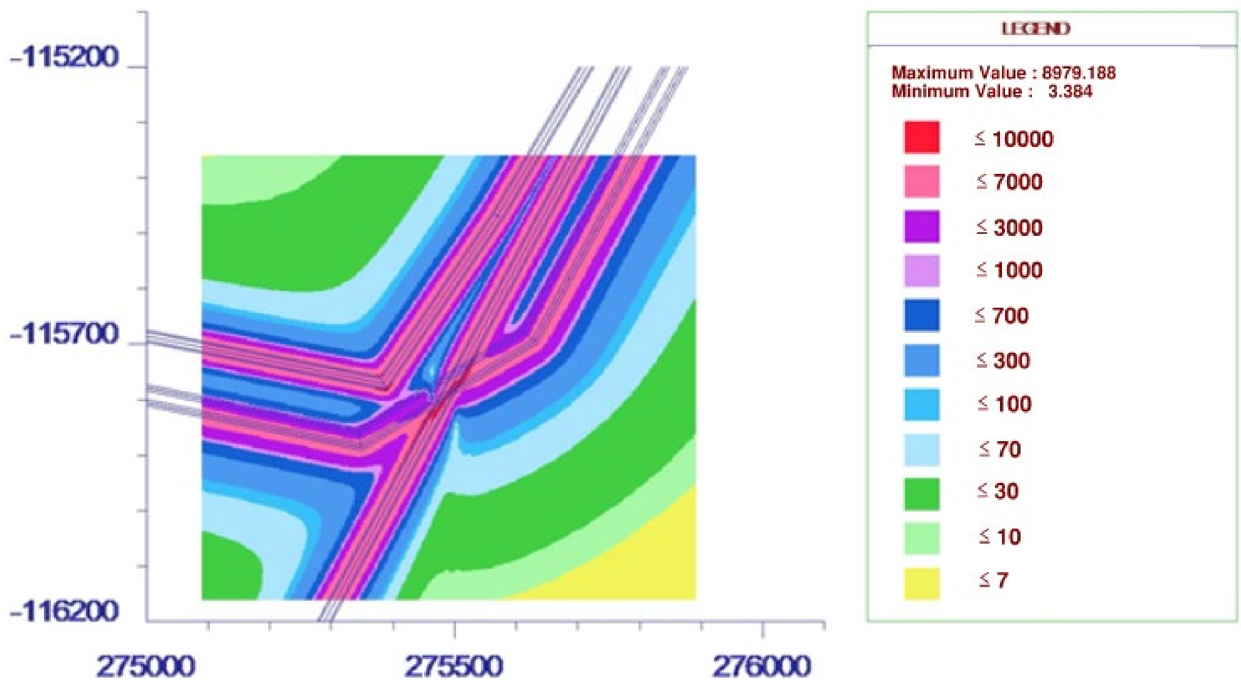


500kV – Crossing with Circuit 62

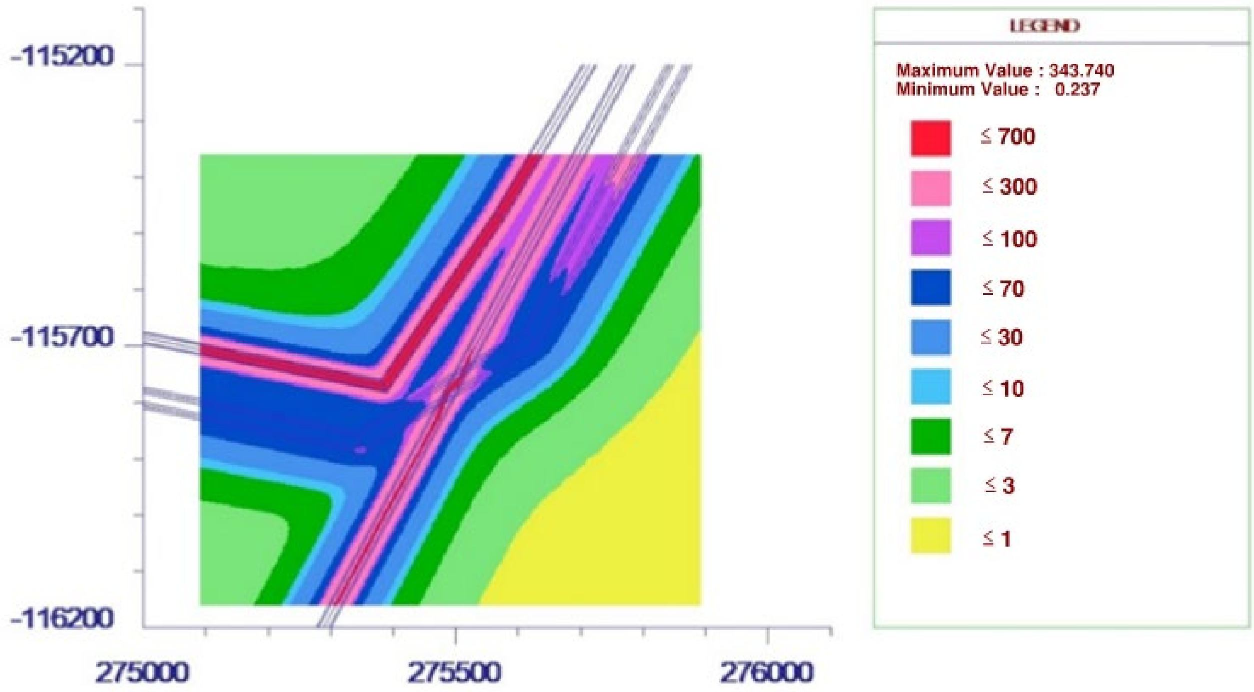
EFS – Time Weighted Average (V/m)



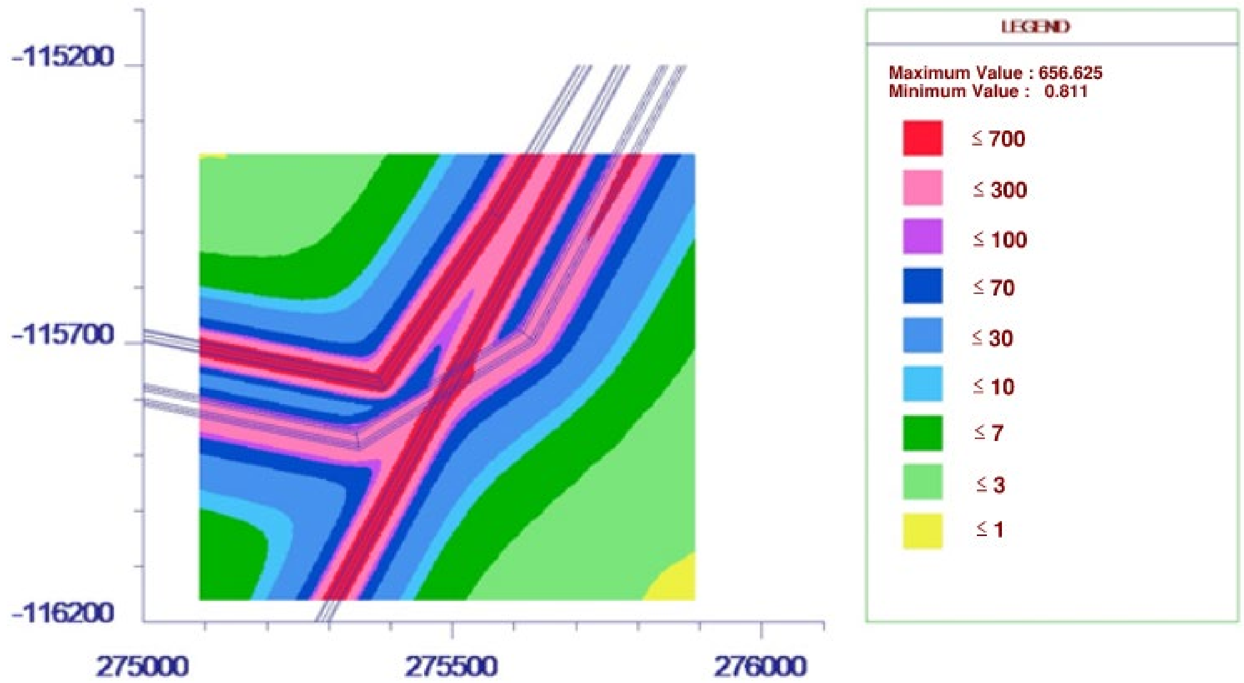
EFS – Max Contingency (V/m)



MFD – Time Weighted Average (mG)

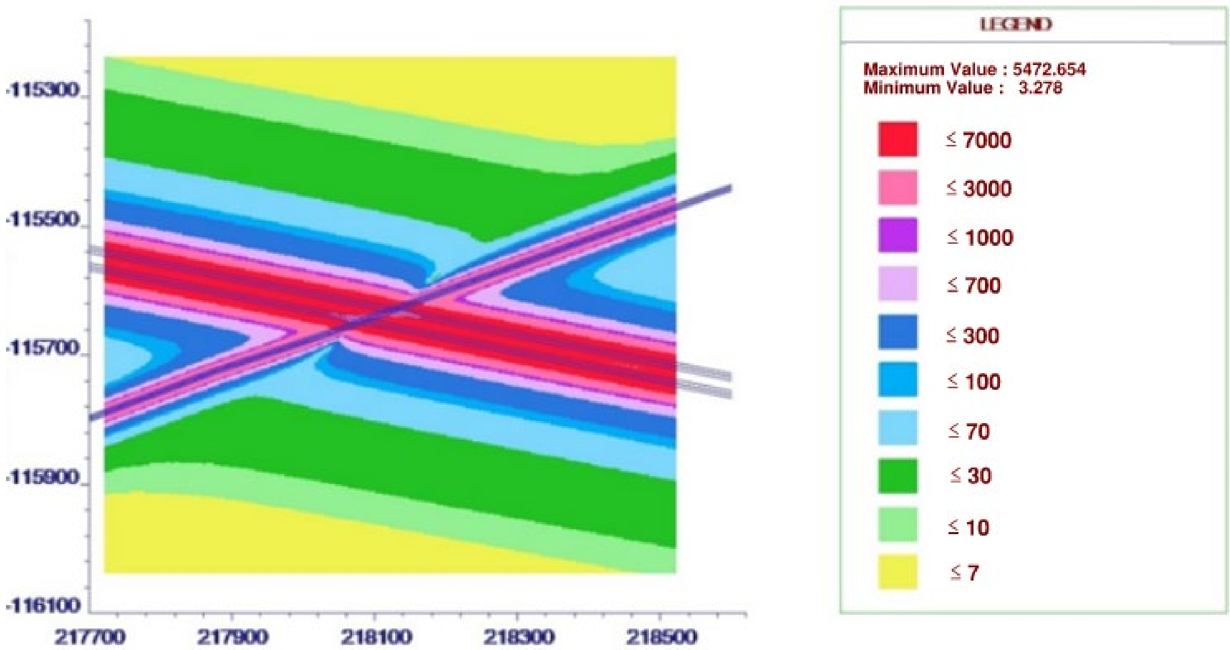


MFD – Max Contingency (mG)

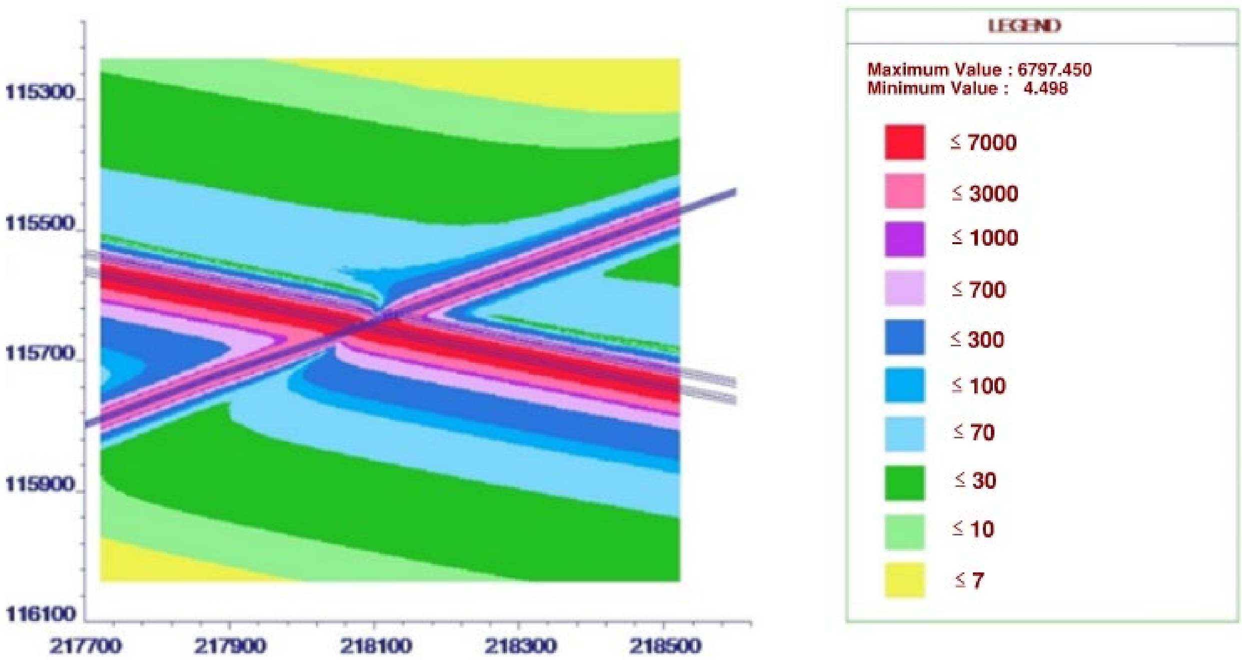


500kV – Crossing with Circuit 99A

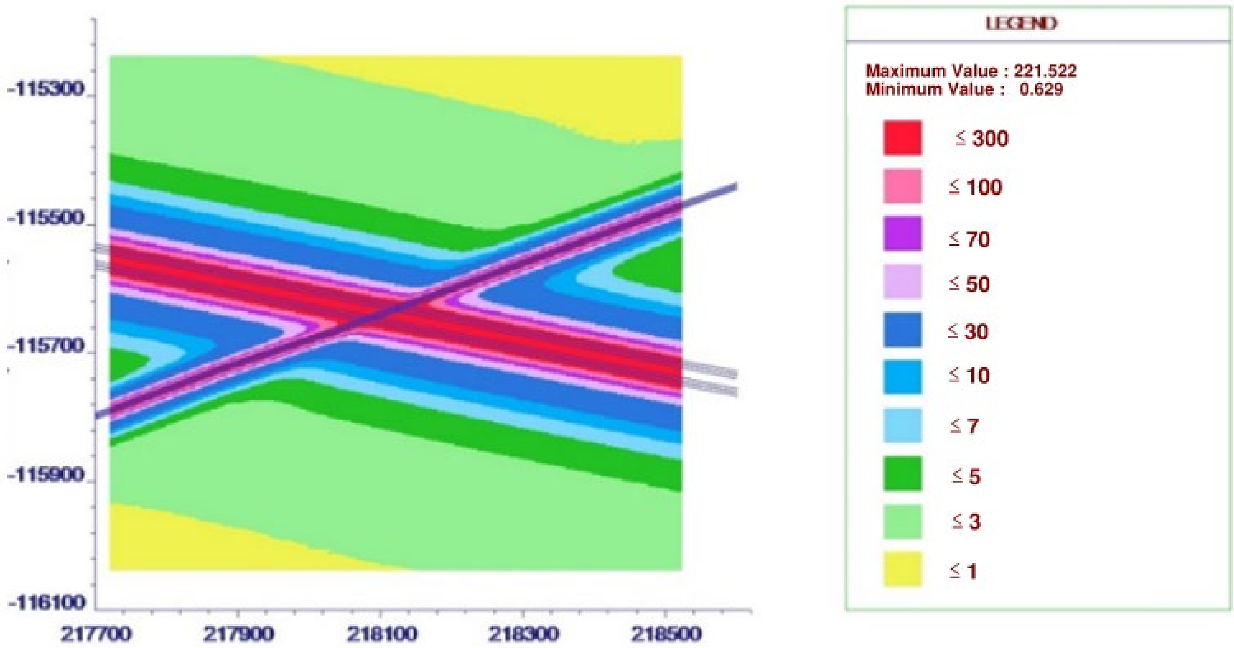
EFS – Time Weighted Average (V/m)



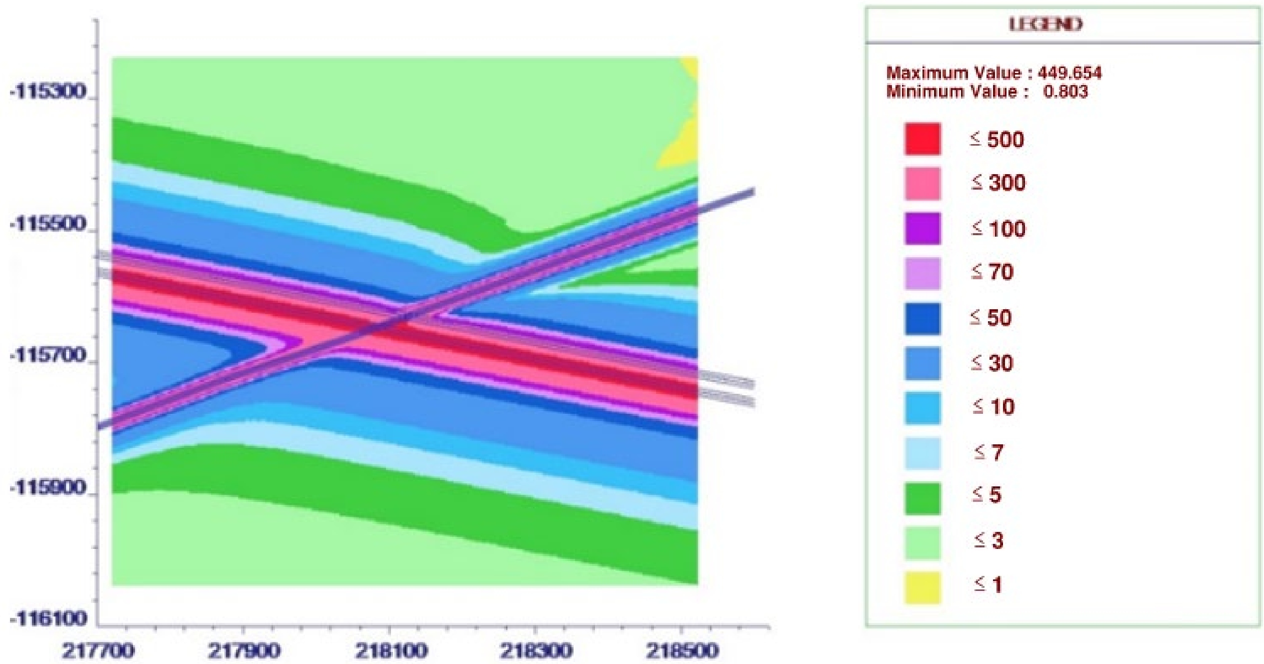
EFS – Max Contingency (V/m)



MFD – Time Weighted Average (mG)

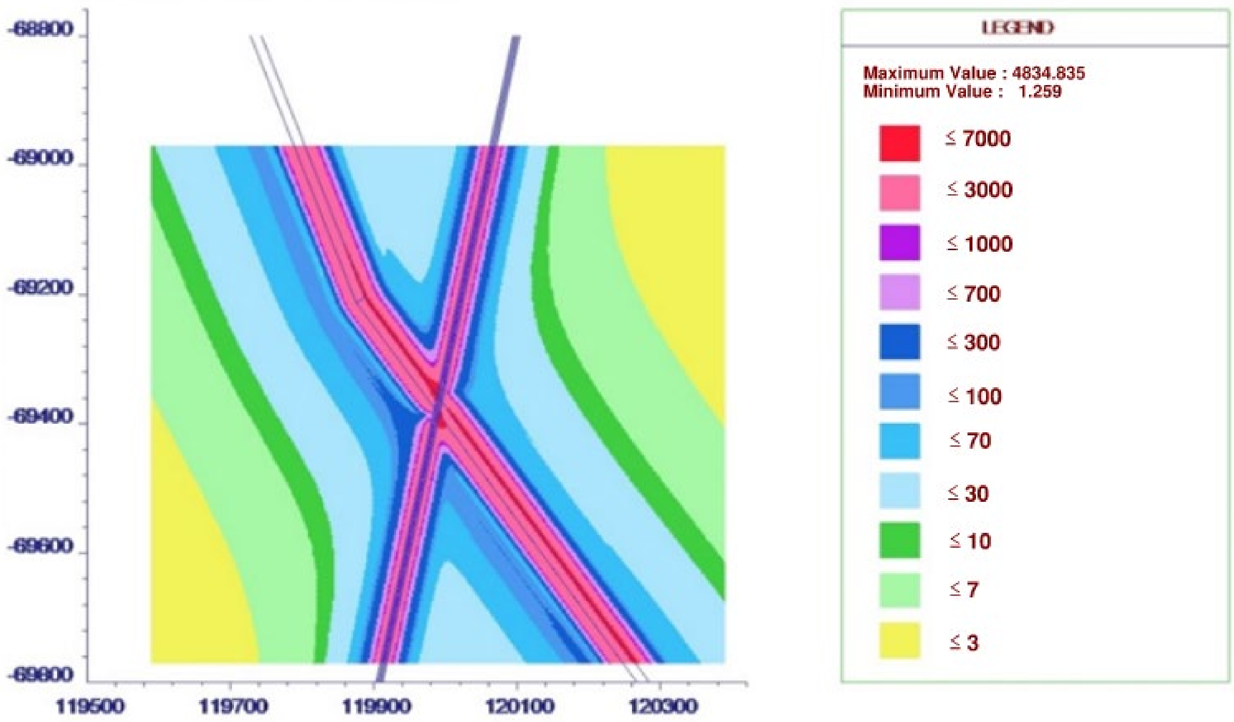


MFD – Max Contingency (mG)

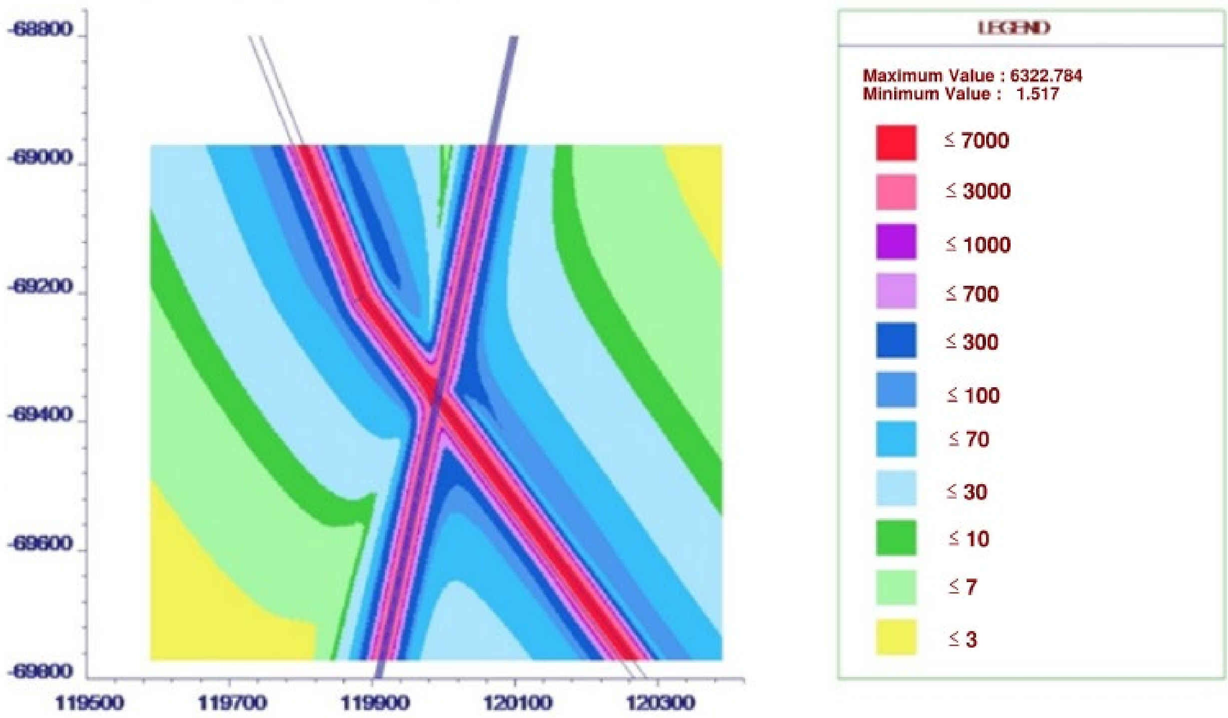


330 kV – Crossing with Circuit 99L

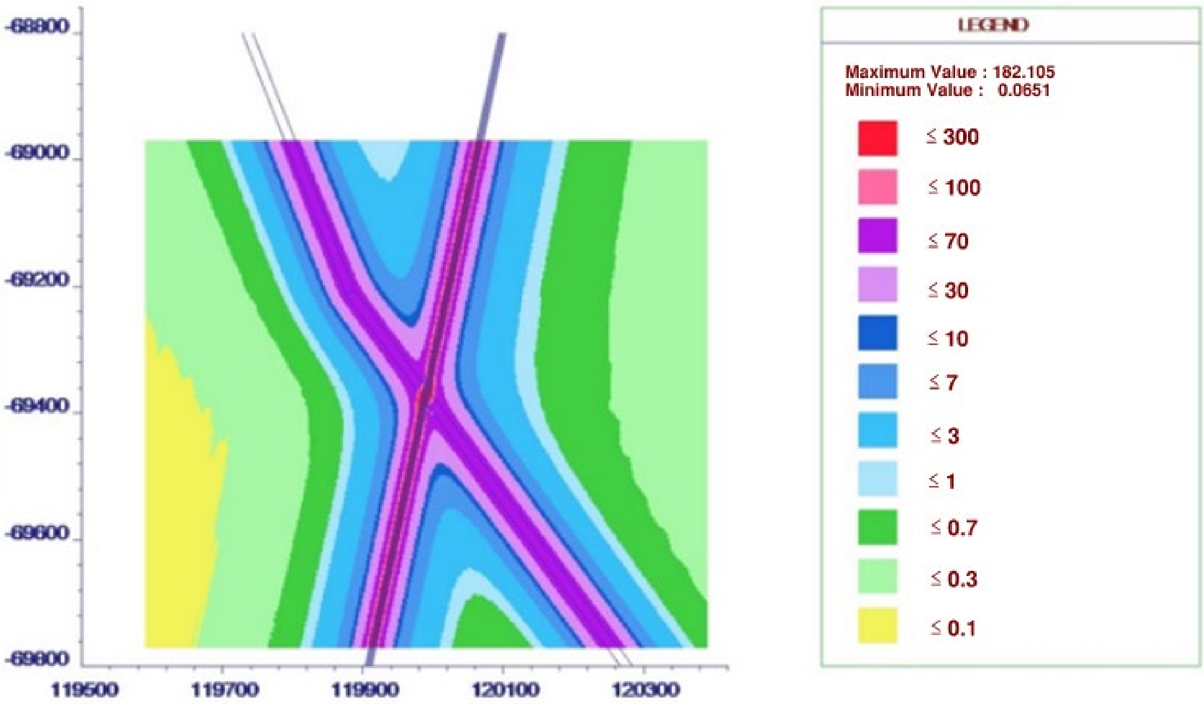
EFS – Time Weighted Average (V/m)



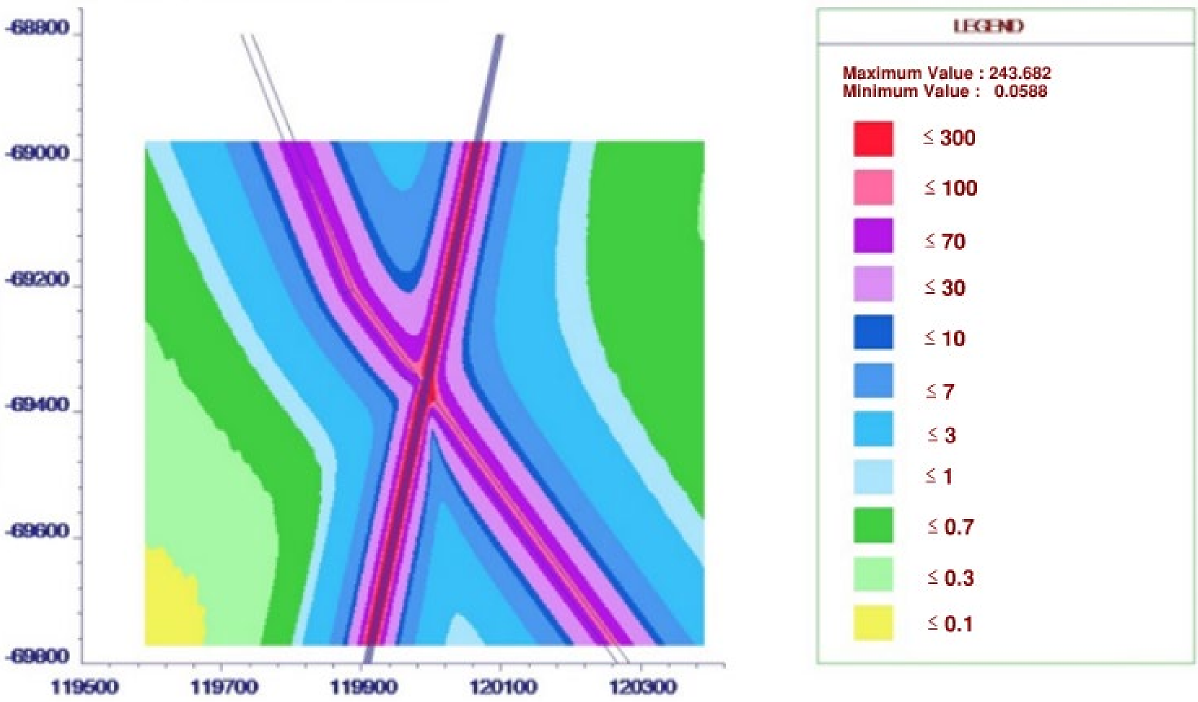
EFS – Max Contingency (V/m)



MFD – Time Weighted Average (mG)

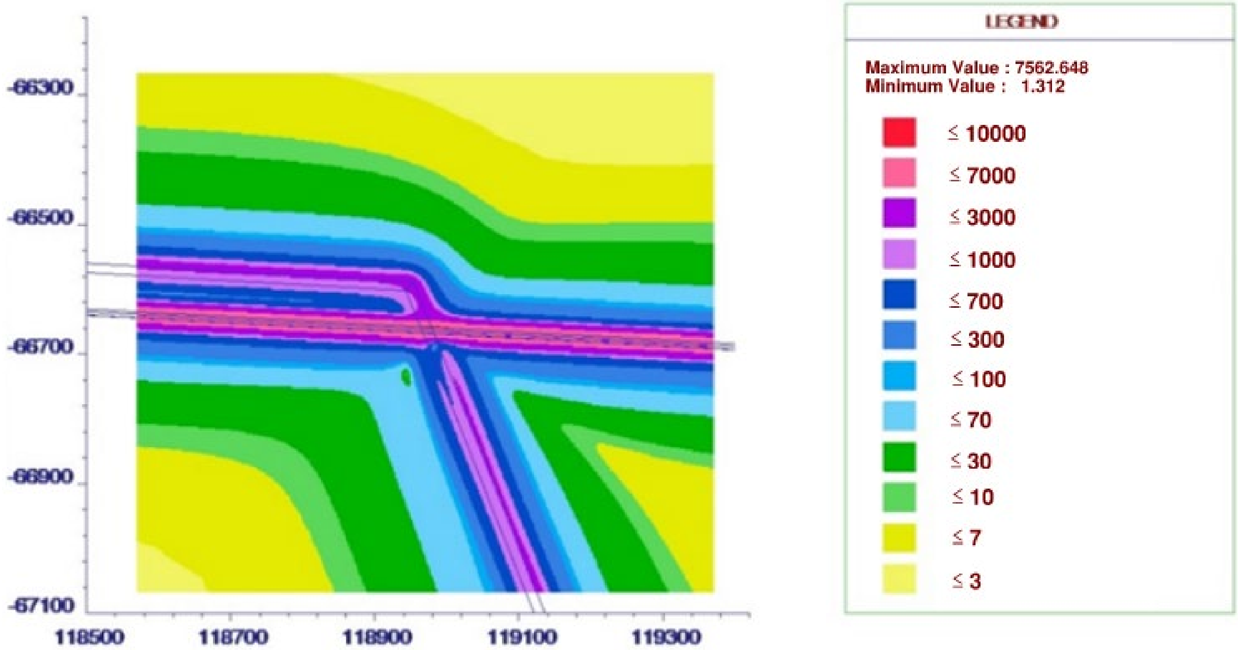


MFD – Max Contingency (mG)

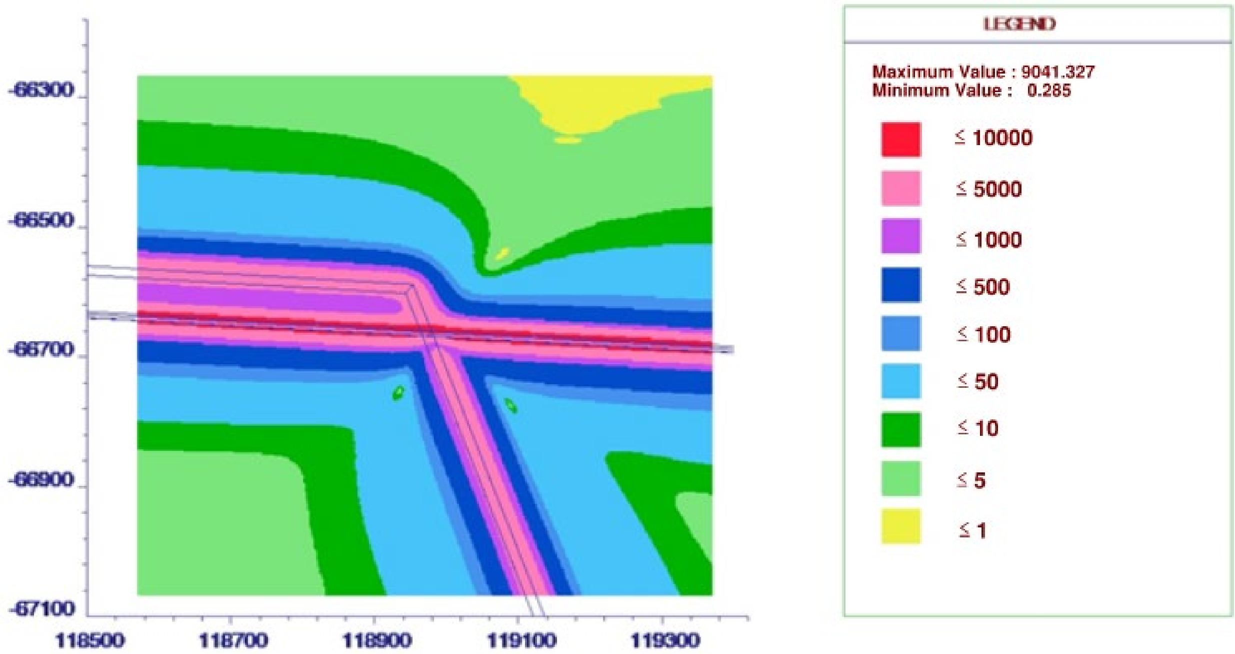


330 kV – Crossing with Circuit X5

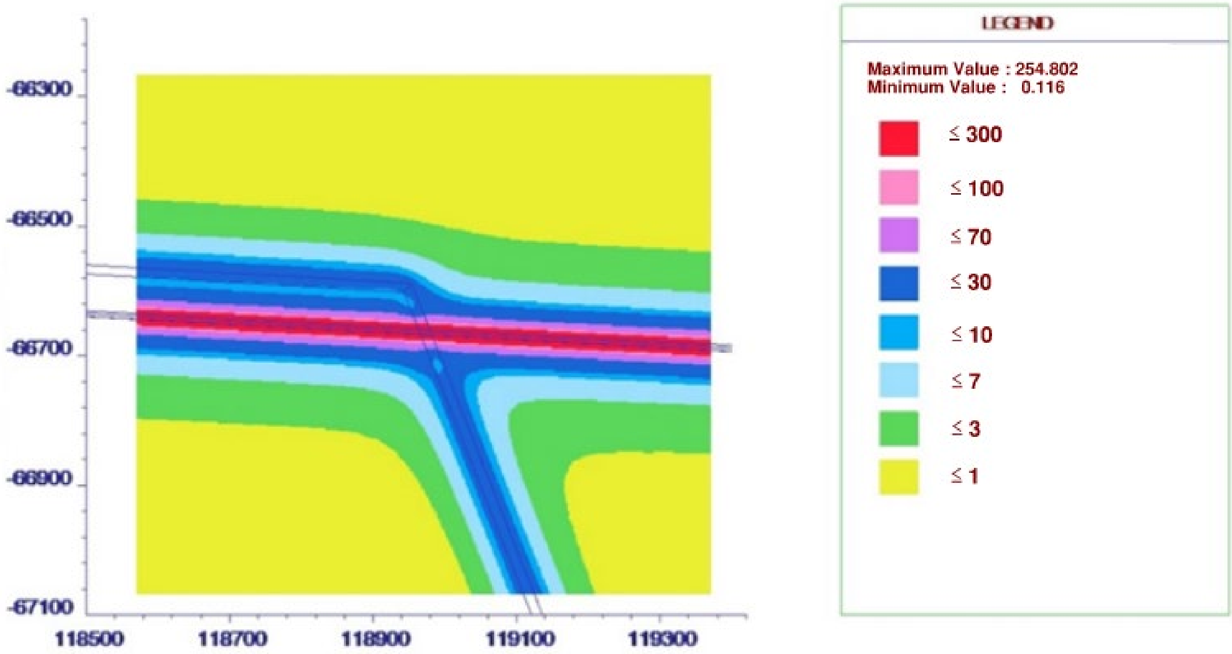
EFS – Time Weighted Average (V/m)



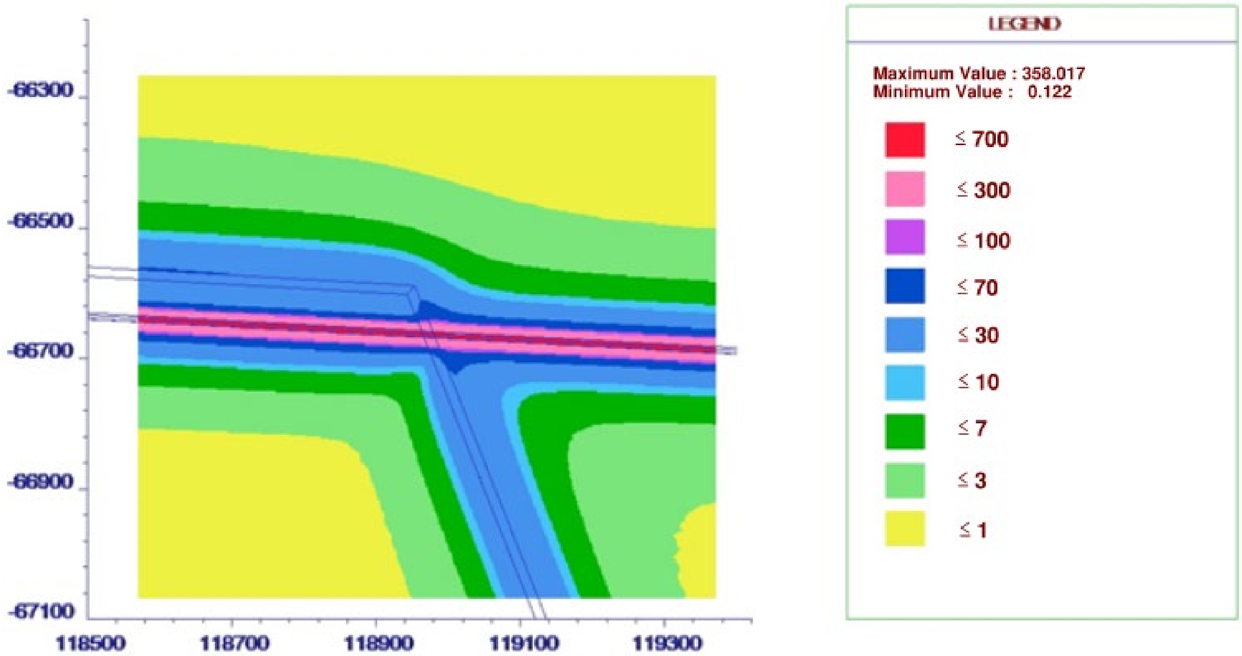
EFS – Max Contingency (V/m)



MFD – Time Weighted Average (mG)



MFD – Max Contingency (mG)



Appendix F – Tower Geometries

New 330 kV parallel with Circuit X5 or X3 (time weighted average case)

COORDINATES OF PHASE CONDUCTORS (EXCLUDING CIRCUIT OFFSET)

BUNDLE NUMBER	COORDINATES-OF-BUNDLE ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
1	-7.150	10.200	1
2	-7.150	17.400	2
3	-7.150	24.600	3
4	7.150	24.600	1
5	7.150	17.400	2
6	7.150	10.200	3
7	-69.300	14.200	1
8	-69.800	8.800	2
9	-60.200	8.800	3

New 330 kV (bundles 1–6)

Circuit X5 or X3 (bundles 7–9)

COORDINATES OF NEUTRAL WIRES (EXCLUDING CIRCUIT OFFSET)

NEUTRAL WIRE NUMBER	<COORDINATES-OF-WIRE> ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
10	-7.150	28.600	0
11	7.150	28.600	0
12	-65.700	22.300	0

New 330 kV (wires 10–11)

Circuit X5 or X3 (wire 12)

<u>New 330 kV parallel with Circuit X5 or X3 (Maximum contingency case)</u>

COORDINATES OF PHASE CONDUCTORS (EXCLUDING CIRCUIT OFFSET)

BUNDLE NUMBER	COORDINATES-OF-BUNDLE ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
1	-7.150	9.000	1
2	-7.150	16.200	2
3	-7.150	23.400	3
4	7.150	23.400	1
5	7.150	16.200	2
6	7.150	9.000	3
7	-69.300	13.700	1
8	-69.800	8.300	2
9	-60.200	8.300	3

New 330 kV (bundles 1–6)

Circuit X5 or X3 (bundles 7–9)

COORDINATES OF NEUTRAL WIRES (EXCLUDING CIRCUIT OFFSET)

NEUTRAL WIRE NUMBER	<COORDINATES-OF-WIRE> ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
10	-7.150	27.400	0
11	7.150	27.400	0
12	-65.700	22.100	0

New 330 kV (wires 10–11)

Circuit X5 or X3 (wire 12)

New 330 kV parallel with Circuit X3 & New 220 kV (time weighted average case)

COORDINATES OF PHASE CONDUCTORS (EXCLUDING CIRCUIT OFFSET)

BUNDLE NUMBER	COORDINATES-OF-BUNDLE ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
1	-7.150	10.200	1
2	-7.150	17.400	2
3	-7.150	24.600	3
4	7.150	24.600	1
5	7.150	17.400	2
6	7.150	10.200	3
7	-69.300	14.200	1
8	-69.800	8.800	2
9	-60.200	8.800	3
10	-119.700	9.600	1
11	-119.700	15.300	2
12	-119.700	21.000	3
13	-110.300	21.000	1
14	-110.300	15.300	2
15	-110.300	9.600	3

New 330 kV (bundles 1–6)

Circuit X3 (bundles 7–9)

New 220 kV (bundles 10–15)

COORDINATES OF NEUTRAL WIRES (EXCLUDING CIRCUIT OFFSET)

NEUTRAL WIRE NUMBER	<COORDINATES-OF-WIRE> ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
16	-7.150	28.600	0
17	7.150	28.600	0
18	-65.700	22.300	0
19	-119.700	23.500	0
20	-110.300	23.500	0

New 330 kV (wires 16–17)

Circuit X3 (wire 18)

New 220 kV (wires 19–20)

New 330 kV parallel with Circuit X3 & New 220 kV (Maximum contingency case)

COORDINATES OF PHASE CONDUCTORS (EXCLUDING CIRCUIT OFFSET)

BUNDLE NUMBER	COORDINATES-OF-BUNDLE ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER	
1	-7.150	9.000	1	New 330 kV
2	-7.150	16.200	2	
3	-7.150	23.400	3	
4	7.150	23.400	1	
5	7.150	16.200	2	
6	7.150	9.000	3	
7	-69.300	13.700	1	Circuit X3
8	-69.800	8.300	2	
9	-60.200	8.300	3	
10	-119.700	8.300	1	New 220 kV
11	-119.700	14.000	2	
12	-119.700	19.700	3	
13	-110.300	19.700	1	
14	-110.300	14.000	2	
15	-110.300	8.300	3	

COORDINATES OF NEUTRAL WIRES (EXCLUDING CIRCUIT OFFSET)

NEUTRAL WIRE NUMBER	<COORDINATES-OF-WIRE> ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER	
16	-7.150	27.400	0	New 330 kV
17	7.150	27.400	0	
18	-65.700	22.100	0	Circuit X3
19	-119.700	22.200	0	New 220 kV
20	-110.300	22.200	0	

New 500 kV parallel with Circuits 62 & 63 (time weighted average case)

COORDINATES OF PHASE CONDUCTORS (EXCLUDING CIRCUIT OFFSET)

BUNDLE NUMBER	COORDINATES-OF-BUNDLE ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
1	-7.665	14.200	1
2	-18.495	14.200	2
3	-13.083	26.800	3
4	13.083	26.800	1
5	18.495	14.200	2
6	7.665	14.200	3
7	-53.300	9.600	1
8	-64.000	9.600	2
9	-74.700	9.600	3
10	-103.500	9.400	1
11	-114.000	9.400	2
12	-124.500	9.400	3

New 500 kV

Circuit 62

Circuit 63

COORDINATES OF NEUTRAL WIRES (EXCLUDING CIRCUIT OFFSET)

NEUTRAL WIRE NUMBER	<COORDINATES-OF-WIRE> ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
13	-13.415	35.306	0
14	13.415	35.306	0
15	-56.400	16.800	0
16	-71.600	16.800	0
17	-106.700	16.600	0
18	-121.300	16.600	0

New 500 kV

Circuit 62

Circuit 63

New 500 kV parallel with Circuits 62 & 63 (Maximum contingency case)

COORDINATES OF PHASE CONDUCTORS (EXCLUDING CIRCUIT OFFSET)

BUNDLE NUMBER	COORDINATES-OF-BUNDLE ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
1	-7.665	11.800	1
2	-18.495	11.800	2
3	-13.083	24.400	3
4	13.083	24.400	1
5	18.495	11.800	2
6	7.665	11.800	3
7	-53.300	9.000	1
8	-64.000	9.000	2
9	-74.700	9.000	3
10	-103.500	9.000	1
11	-114.000	9.000	2
12	-124.500	9.000	3

New 500 kV

Circuit 62

Circuit 63

COORDINATES OF NEUTRAL WIRES (EXCLUDING CIRCUIT OFFSET)

NEUTRAL WIRE NUMBER	<COORDINATES-OF-WIRE> ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
13	-13.415	32.906	0
14	13.415	32.906	0
15	-56.400	16.200	0
16	-71.600	16.200	0
17	-106.700	16.200	0
18	-121.300	16.200	0

New 500 kV

Circuit 62

Circuit 63

New 500 kV parallel with Circuit 99A (time weighted average case)

COORDINATES OF PHASE CONDUCTORS (EXCLUDING CIRCUIT OFFSET)

BUNDLE NUMBER	COORDINATES-OF-BUNDLE ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
1	-7.665	14.200	1
2	-18.495	14.200	2
3	-13.083	26.800	3
4	13.083	26.800	1
5	18.495	14.200	2
6	7.665	14.200	3
7	-60.400	7.900	1
8	-65.000	7.900	2
9	-69.600	7.900	3

New 500 kV

Circuit 99A

COORDINATES OF NEUTRAL WIRES (EXCLUDING CIRCUIT OFFSET)

NEUTRAL WIRE NUMBER	<COORDINATES-OF-WIRE> ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
10	-13.415	35.306	0
11	13.415	35.306	0
12	-62.700	10.000	0
13	-67.300	10.000	0

New 500 kV

Circuit 99A

New 500 kV parallel with Circuit 99A (Maximum contingency case)

COORDINATES OF PHASE CONDUCTORS (EXCLUDING CIRCUIT OFFSET)

BUNDLE NUMBER	COORDINATES-OF-BUNDLE ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
1	-7.665	11.800	1
2	-18.495	11.800	2
3	-13.083	24.400	3
4	13.083	24.400	1
5	18.495	11.800	2
6	7.665	11.800	3
7	-60.400	7.600	1
8	-65.000	7.600	2
9	-69.600	7.600	3

New 500 kV (bundles 1–6)

Circuit 99A (bundles 7–9)

COORDINATES OF NEUTRAL WIRES (EXCLUDING CIRCUIT OFFSET)

NEUTRAL WIRE NUMBER	<COORDINATES-OF-WIRE> ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
10	-13.415	32.906	0
11	13.415	32.906	0
12	-62.700	9.700	0
13	-67.300	9.700	0

New 500 kV (wires 10–11)

Circuit 99A (wires 12–13)

New 500 kV parallel with Circuit 63 (time weighted average case)

COORDINATES OF PHASE CONDUCTORS (EXCLUDING CIRCUIT OFFSET)

BUNDLE NUMBER	COORDINATES-OF-BUNDLE ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
1	-7.665	14.200	1
2	-18.495	14.200	2
3	-13.083	26.800	3
4	13.083	26.800	1
5	18.495	14.200	2
6	7.665	14.200	3
7	-54.500	9.400	1
8	-65.000	9.400	2
9	-75.500	9.400	3

New 500 kV

Circuit 63

COORDINATES OF NEUTRAL WIRES (EXCLUDING CIRCUIT OFFSET)

NEUTRAL WIRE NUMBER	<COORDINATES-OF-WIRE> ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
10	-13.415	35.306	0
11	13.415	35.306	0
12	-57.700	16.600	0
13	-72.300	16.600	0

New 500 kV

Circuit 63

New 500 kV parallel with Circuit 63 (Maximum contingency case)

COORDINATES OF PHASE CONDUCTORS (EXCLUDING CIRCUIT OFFSET)

New 500 kV

Circuit 63

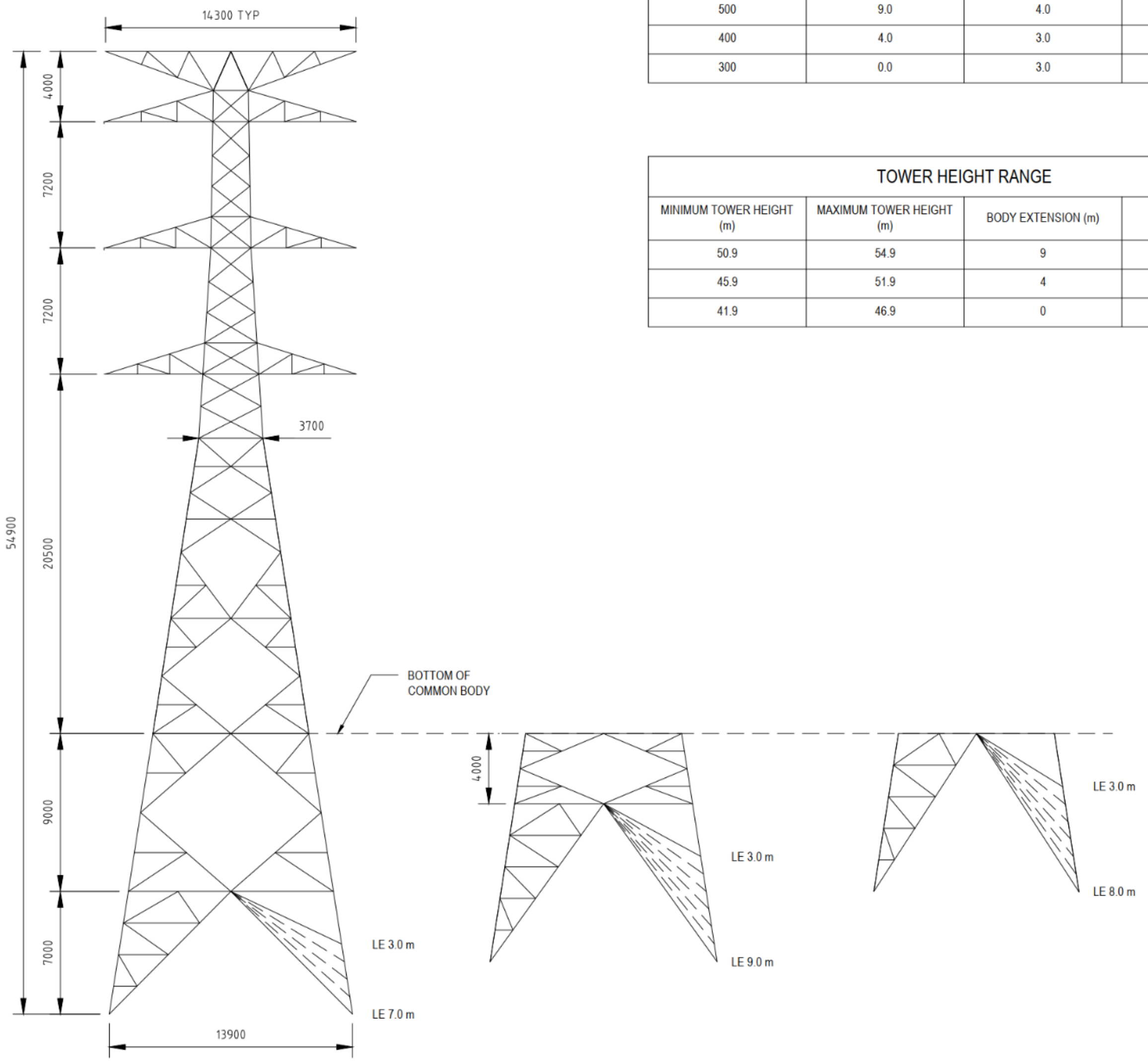
BUNDLE NUMBER	COORDINATES-OF-BUNDLE ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
1	-7.665	11.800	1
2	-18.495	11.800	2
3	-13.083	24.400	3
4	13.083	24.400	1
5	18.495	11.800	2
6	7.665	11.800	3
7	-54.500	9.000	1
8	-65.000	9.000	2
9	-75.500	9.000	3

COORDINATES OF NEUTRAL WIRES (EXCLUDING CIRCUIT OFFSET)

New 500 kV

Circuit 63

NEUTRAL WIRE NUMBER	<COORDINATES-OF-WIRE> ABSCISSA meter(s)	HEIGHT meter(s)	PHASE NUMBER
10	-13.415	32.906	0
11	13.415	32.906	0
12	-57.700	16.200	0
13	-72.300	16.200	0



TRANSVERSE ELEVATION
(MAXIMUM HEIGHT TOWER)
9m BODY EXTENSION
LEG EXTENSIONS 3 m TO 7 m

4m BODY EXTENSION
LEG EXTENSIONS 3 m TO 9 m

0m BODY EXTENSION
LEG EXTENSIONS 3 m TO 8 m

INDICATIVE TOWER HEIGHT AND WEIGHT vs SPAN LENGTH

SPAN LENGTH (m)	BODY EXTENSION (m)	LEG EXTENSION (m)	TOWER HEIGHT[2] (m)	TOWER WEIGHT (kg)
500	9.0	4.0	51.9	17300
400	4.0	3.0	45.9	15500
300	0.0	3.0	41.9	13100

TOWER HEIGHT RANGE

MINIMUM TOWER HEIGHT (m)	MAXIMUM TOWER HEIGHT (m)	BODY EXTENSION (m)	LEG EXTENSION (m)
50.9	54.9	9	3 TO 7
45.9	51.9	4	3 TO 9
41.9	46.9	0	3 TO 8

NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS STATED OTHERWISE.
2. TOWER HEIGHTS ARE PROVIDED FOR GUIDANCE ONLY AND ARE BASED ON THE FOLLOWING:
   - TWIN 54/7/3.00 mm ACSR CONDUCTOR WITH MAXIMUM OPERATING TEMPERATURE OF 85°C.
   - FLAT TERRAIN, WITH HEIGHTS GOVERNED BY MID SPAN GROUND CLEARANCE UNDER MAXIMUM OPERATING TEMPERATURE CONDITION.
   - A MAXIMUM EVERYDAY TENSION OF 22.5% UTS. NOTE TENSIONS WILL VARY DEPENDENT UPON THE RULING SPAN OF THE SECTION.
3. STRUCTURE WEIGHTS SHOWN INCLUDE THE FOLLOWING;
   - 2 m LONG STUB LEGS.
   - 10% ALLOWANCE FOR GUSSETS AND PLATES.
4. STRUCTURE WEIGHTS SHOWN EXCLUDE ANY ALLOWANCE FOR BOLTS, LADDERS, AND GALVANISING.

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DRAFT

No.	Revision	By	Chk	Appd	Date
B	ISSUED FOR INFORMATION	EG	MB	MJ	09.19
A	ISSUED FOR INFORMATION	EG	MB	MJ	07.19

Drawing Originator: Beca

Original Scale (A3): 1:300

Design	EG	07.19
Drawn	MD	07.19
Dsg Verifier	MB	07.19
Dwg Check	MB	07.19

* Refer to Revision 1 for Original Signature

Approved For Construction*

Date

Client: TransGrid

Project: ENERGYCONNECT

Title: BORDER TO DARLINGTON POINT LIGHT SUSPENSION STRUCTURE OUTLINE

Discipline: TRANSMISSION

Drawing No. 2589087-UT-411/1 Rev. B

Document No. 2589087-UT-411_1.DWG

DO NOT SCALE

IF IN DOUBT ASK.

INDICATIVE TOWER HEIGHT AND WEIGHT vs SPAN LENGTH

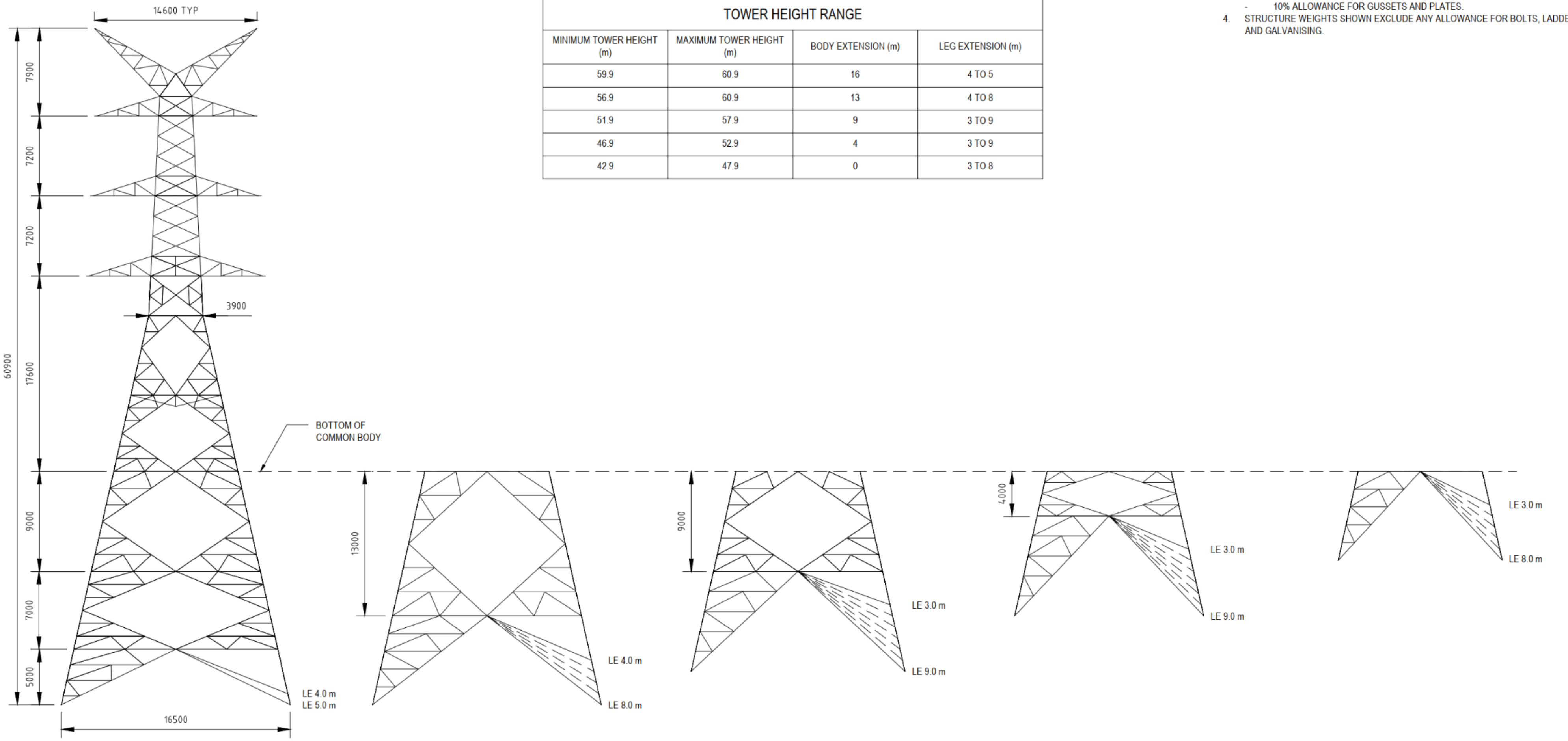
SPAN LENGTH (m)	BODY EXTENSION (m)	LEG EXTENSION (m)	TOWER HEIGHT[2] (m)	TOWER WEIGHT (kg)
600	16.0	4.0	59.9	37300
500	9.0	4.0	52.9	28100
400	4.0	3.0	46.9	24200
300	0.0	3.0	42.9	19800

TOWER HEIGHT RANGE

MINIMUM TOWER HEIGHT (m)	MAXIMUM TOWER HEIGHT (m)	BODY EXTENSION (m)	LEG EXTENSION (m)
59.9	60.9	16	4 TO 5
56.9	60.9	13	4 TO 8
51.9	57.9	9	3 TO 9
46.9	52.9	4	3 TO 9
42.9	47.9	0	3 TO 8

NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS STATED OTHERWISE.
2. TOWER HEIGHTS ARE PROVIDED FOR GUIDANCE ONLY AND ARE BASED ON THE FOLLOWING:
   - TWIN 54/7/3.00 mm ACSR CONDUCTOR WITH MAXIMUM OPERATING TEMPERATURE OF 85°C
   - FLAT TERRAIN, WITH HEIGHTS GOVERNED BY MID SPAN GROUND CLEARANCE UNDER MAXIMUM OPERATING TEMPERATURE CONDITION
   - A MAXIMUM EVERYDAY TENSION OF 22.5% UTS. NOTE TENSIONS WILL VARY DEPENDENT UPON THE RULING SPAN OF THE SECTION.
3. STRUCTURE WEIGHTS SHOWN INCLUDE THE FOLLOWING;
   - 2 m LONG STUB LEGS.
   - 10% ALLOWANCE FOR GUSSETS AND PLATES.
4. STRUCTURE WEIGHTS SHOWN EXCLUDE ANY ALLOWANCE FOR BOLTS, LADDERS, AND GALVANISING.



TRANSVERSE ELEVATION (MAXIMUM HEIGHT TOWER) 16 m BODY EXTENSION LEG EXTENSIONS 4 m TO 5 m

13 m BODY EXTENSION LEG EXTENSIONS 4 m TO 8 m

9 m BODY EXTENSION LEG EXTENSIONS 3 m TO 9 m

4m BODY EXTENSION LEG EXTENSIONS 3 m TO 9 m

0m BODY EXTENSION LEG EXTENSIONS 3 m TO 8 m

DRAFT

No.	Revision	By	Chk	Appd	Date
B	ISSUED FOR INFORMATION	EG	MB	MJ	09.19
A	ISSUED FOR INFORMATION	EG	MB	MJ	07.19

Drawing Originator: Beca

Original Scale (A3): 1:300

Design	EG	07.19
Drawn	MD	07.19
Dsg Verifier	MB	07.19
Dwg Check	MB	07.19

Approved For Construction*

Date

* Refer to Revision 1 for Original Signature

Client: TransGrid

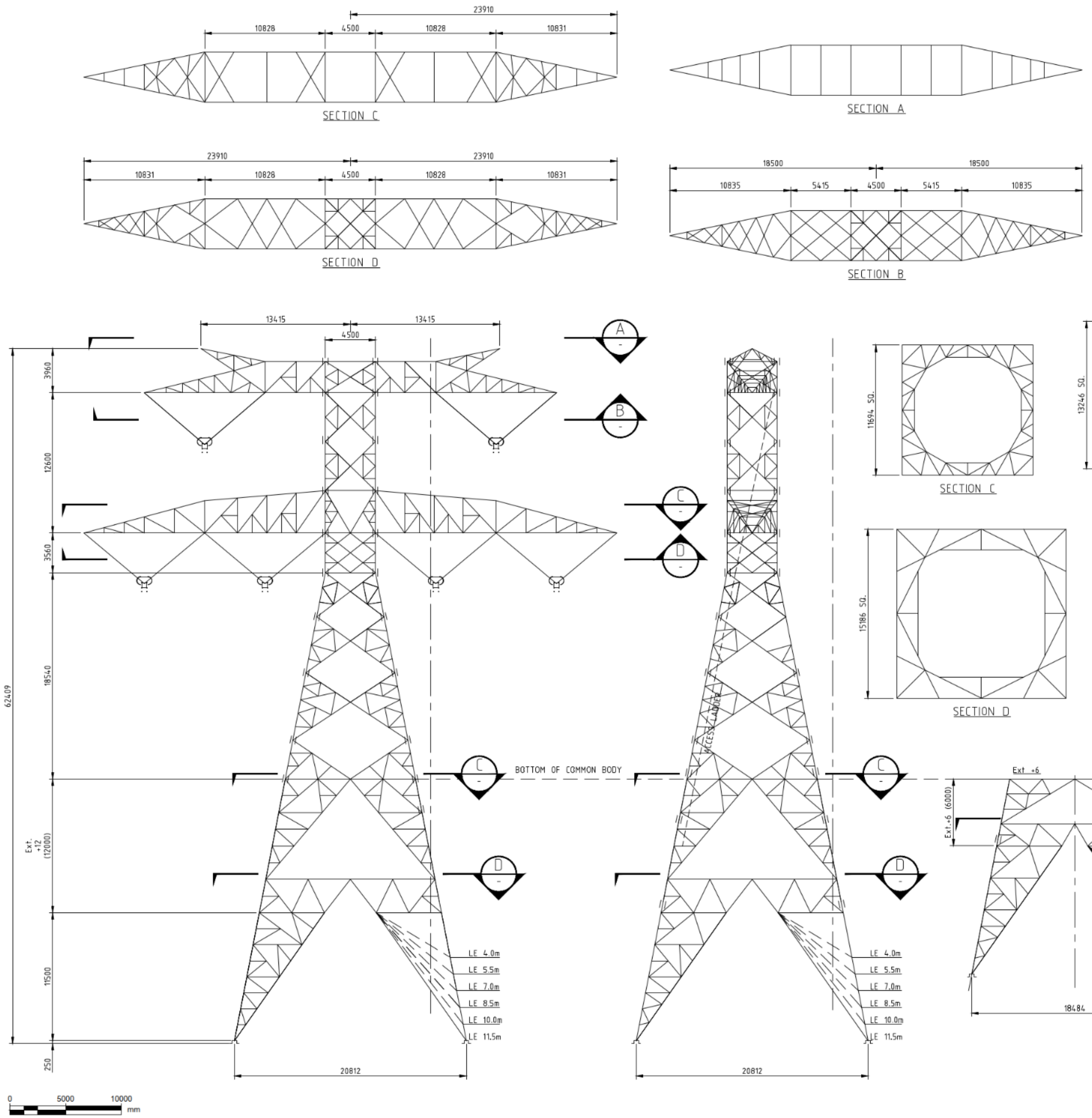
Project: ENERGYCONNECT

Title: BORDER TO DARLINGTON POINT MEDIUM ANGLE STRAIN STRUCTURE OUTLINE

Discipline: TRANSMISSION

Drawing No. 2589087-UT-414/1

Rev. B



TOWER HEIGHT RANGE				
MINIMUM TOWER HEIGHT (m)	MAXIMUM TOWER HEIGHT (m)	BODY EXTENSION (m)	LEG EXTENSION (m)	TOWER WEIGHT (kg)
54.36	61.86	Ext+12	4, 5.5, 7, 8.5, 10, 11.5	36414, 37349, 38289, 39199, 40124, 41059
48.36	55.86	Ext+6	4, 5.5, 7, 8.5, 10, 11.5	32610, 33545, 34519, 35469, 36414, 37349
42.36	49.86	Ext+0	4, 5.5, 7, 8.5, 10, 11.5	28900, 29835, 30775, 31685, 32610, 33545

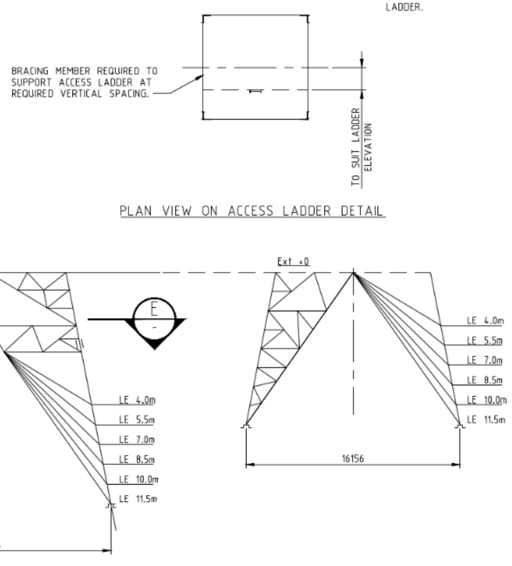
LINE DETAILS	
CONDUCTOR	QUAD ORANGE (54/7/3.25 mm) ACSR/GZ
EARTHWIRE	7/4.25 SC/AC
OPGW	OPGW TYPE A
SHIELDING ANGLE - EARTHWIRE/OPGW	-5 DEGREES TO HIGHEST CONDUCTOR
SUSPENSION INSULATOR ARRANGEMENT	TL-158096
WIND SPAN (m)	420
WEIGHT SPAN (m) - MAX	630
WEIGHT SPAN (m) - MIN	90% OF WIND SPAN
LINE ANGLE (°)	0° - 0.5°

REFERENCES

60628126-TL-3081 500kV LIGHT SUSPENSION TOWER ELECTRICAL CLEARANCE DIAGRAM
60628126-TL-3082 500kV LIGHT SUSPENSION TOWER LOADING CHART

NOTES

1. ALL DIMENSIONS IN MILLIMETRES UNLESS STATED OTHERWISE.
2. TOWER HEIGHTS ARE PROVIDED FOR GUIDANCE ONLY AND ARE BASED ON THE FOLLOWING:
   - QUAD ORANGE (54/7/3.25 mm) ACSR/GZ CONDUCTOR WITH MAXIMUM OPERATING TEMPERATURE OF 120°C.
   - FLAT TERRAIN, WITH HEIGHTS GOVERNED BY MID SPAN GROUND CLEARANCE UNDER MAXIMUM OPERATING TEMPERATURE CONDITION
   - A MAXIMUM EVERYDAY TENSION OF 22.5% UTS. NOTE TENSIONS WILL VARY DEPENDENT UPON THE RULING SPAN OF THE SECTION.
3. STRUCTURE WEIGHTS SHOWN INCLUDE THE FOLLOWING;
   - 2.6m LONG STUB LEGS.
   - 10% ALLOWANCE FOR GUSSETS AND PLATES.
   - TOWER BOLTS.
   - GALVANISING.
4. STRUCTURE WEIGHTS SHOWN EXCLUDE CLIMBING LADDER.
5. CLIMBING UP THE TOWER BODY TO BE FACILITATED VIA AN INTERNALLY MOUNTED STEP LADDER AND NOT ON TOWER CORNERS AS A DEVIATION FROM NORMAL PRACTICE DUE TO INTERNAL CLEARANCE REQUIREMENTS AND THE HEIGHT OF THE TOWERS. PROVISION TO BE MADE FOR FALL ARREST SYSTEM ON THE LADDER.



FOR TENDER

AMENDMENT:

PROJECT No.60628126

AMDT	AMENDMENT DETAILS	DRN	DESIGN	CHK'D	APP'D	DATE
1	ISSUED FOR TENDER	KB	LB	KZ	JL	28.08.20

secureenergy

AECOM AUSTRALIA PTY LTD
ABN 20 093 846 925

TransGrid

REFERENCE DRAWINGS

DRAWN
REVIEWED
VERIFIED
APPROVED
APPROVAL STATUS: TENDER
SCALE 1:200

ENERGY CONNECT
DINAWAN TO GUGGA
500kV LIGHT SUSPENSION TOWER
SUSPENSION TOWER
TOWER OUTLINE

A1 60628126-TL-3080 01
PREFIX NUMBER SHEET AMDT

566x801mm
PLOT ISSUE DATE
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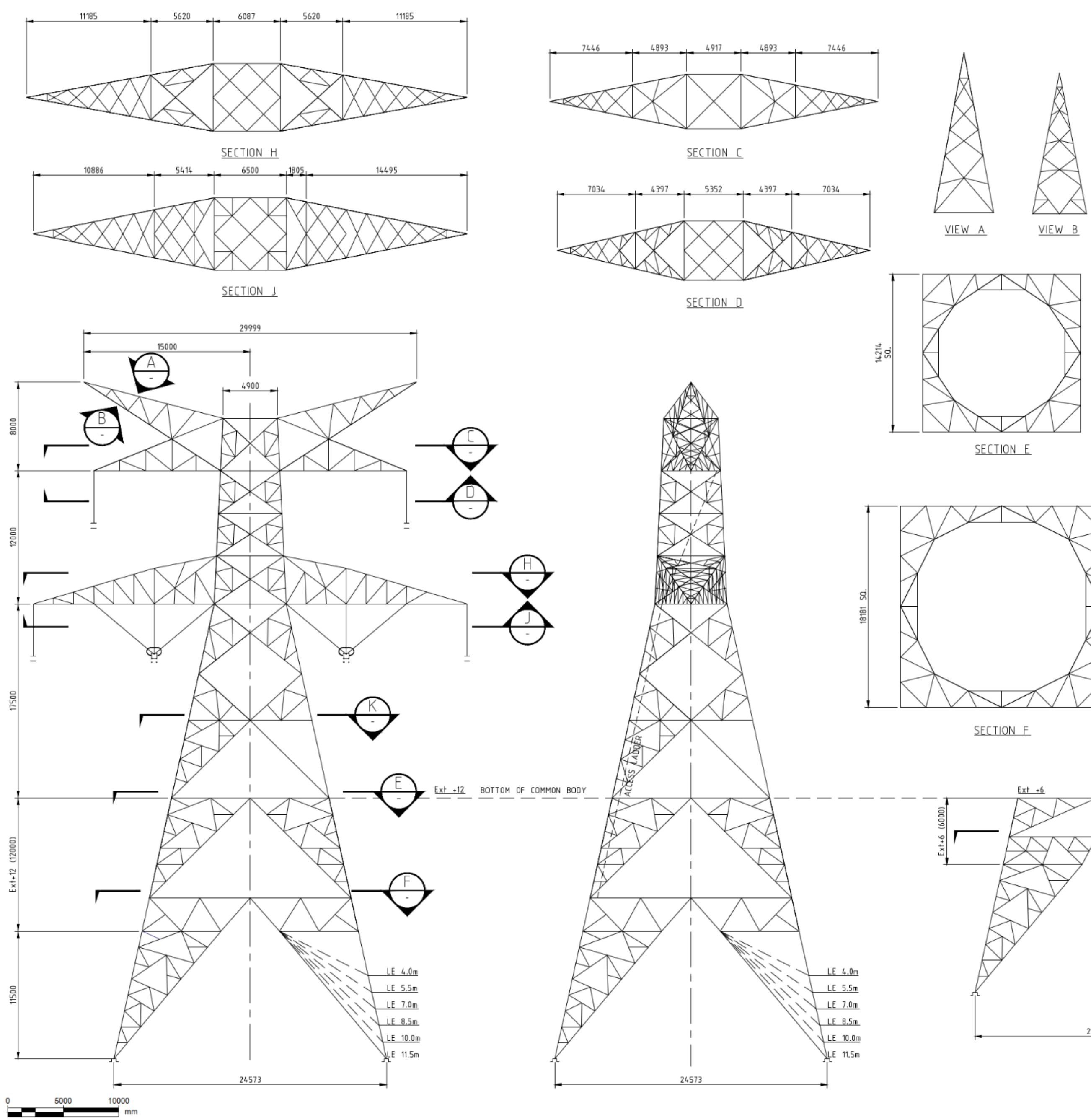
SUPERSEDES
SUPERSEDED BY
INDEX CLASS'N



TOWER HEIGHT RANGE				
MINIMUM TOWER HEIGHT (m)	MAXIMUM TOWER HEIGHT (m)	BODY EXTENSION (m)	LEG EXTENSION (m)	TOWER WEIGHT (kg)
53.55	61.05	Ext+12	4, 5.5, 7, 8.5, 10, 11.5	81834, 83514, 90045, 91605, 93215, 94895
47.55	55.05	Ext+6	4, 5.5, 7, 8.5, 10, 11.5	69188, 70868, 78664, 80224, 81834, 83514
41.55	49.05	Ext+0	4, 5.5, 7, 8.5, 10, 11.5	63148, 64558, 66018, 67578, 69188, 70868

LINE DETAILS	
CONDUCTOR	QUAD ORANGE (54/7/3.25 mm) ACSR/GZ
EARTHWIRE	7/4.25 SC/AC
OPGW	OPGW TYPE A
SHIELDING ANGLE - EARTHWIRE/OPGW	-5 DEGREES TO HIGHEST CONDUCTOR
STRAIN INSULATOR ARRANGEMENT	TL-158095
WIND SPAN (m)	420
WEIGHT SPAN (m) - MAX	630
WEIGHT SPAN (m) - MIN	90% OF WIND SPAN
LINE ANGLE (°)	0° - 65° OR FULL TERMINATION

REFERENCES

60628126-TL-3090 500kV HEAVY STRAIN TOWER ELECTRICAL CLEARANCE DIAGRAM
60628126-TL-3091 500kV HEAVY STRAIN TOWER LOADING CHART

NOTES

1. ALL DIMENSIONS IN MILLIMETRES UNLESS STATED OTHERWISE.
2. TOWER HEIGHTS ARE PROVIDED FOR GUIDANCE ONLY AND ARE BASED ON THE FOLLOWING:
   - QUAD ORANGE (54/7/3.25 mm) ACSR/GZ CONDUCTOR WITH MAXIMUM OPERATING TEMPERATURE OF 120°C.
   - FLAT TERRAIN, WITH HEIGHTS GOVERNED BY MID SPAN GROUND CLEARANCE UNDER MAXIMUM OPERATING TEMPERATURE CONDITION
   - A MAXIMUM EVERYDAY TENSION OF 22.5% UTS. NOTE TENSIONS WILL VARY DEPENDENT UPON THE RULING SPAN OF THE SECTION.
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   - GALVANISING.
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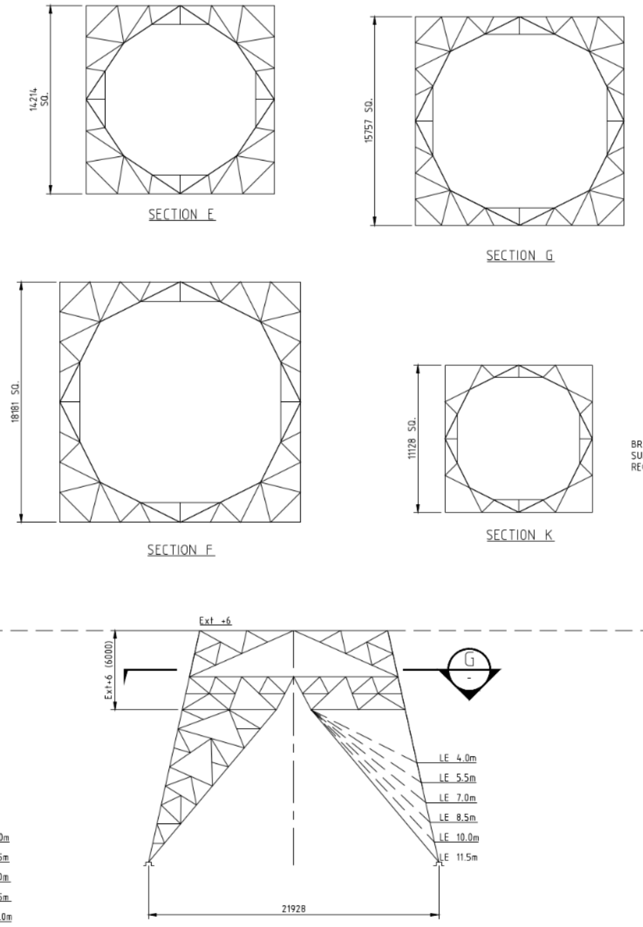

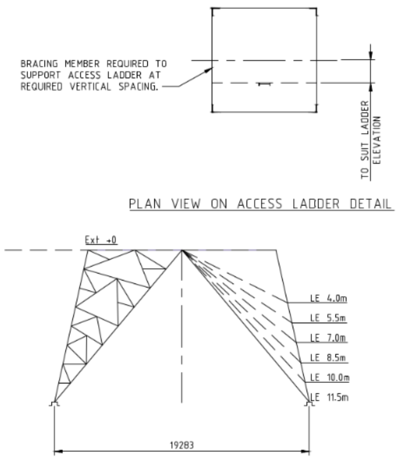

FOR TENDER

AMENDMENT:						
PROJECT No.60628126						
1	ISSUED FOR TENDER	KB	LB	KZ	JL	28.08.20
AMDT	AMENDMENT DETAILS	DRN	DESIGN	CHK'D	APP'D	DATE

PLOT ISSUE DATE

AECOM AUSTRALIA PTY LTD ABN 20 093 846 925

REFERENCE DRAWINGS

COPIED FROM | SUPERSEDES | SUPERSEDED BY

DRAWN	
REVIEWED	
VERIFIED	
APPROVED	
APPROVAL STATUS	TENDER
SCALE	1:200

ENERGY CONNECT
DINAWAN TO GUGGA
500kV HEAVY ANGLE STRAIN TOWER
HEAVY STRAIN TOWER
GENERAL ARRAGEMENT

A1	60628126-TL-3089	01
	PREFIX NUMBER SHEET	AMDT

INDEX CLASS'N

566x801mm