Macquarie Park 132/33kV STS

EMF Assessment

Ausgrid

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1 Project Overview

1.1 Background

It is understood that Ausgrid has received a number of major Connection Applications in the Macquarie Park area and that these loads will require significant subtransmission capacity to be provided. Accordingly, Ausgrid proposes to construct a 132/33kV subtransmission substation (STS) on Ausgrid property, adjacent to the existing Macquarie Park 132/11kV Zone Substation (ZS) at 17-21 Waterloo Road, Macquarie Park. The existing ZS, which is at the northern end of the property, will be retained and the STS will be established at the southern (Waterloo Road) end. The project will also involve the installation of 6 outgoing 33kV feeders, and 6 spare conduits to Waterloo Road, together with a further 12 spare conduits along a shared driveway (on Ausgrid property) away from Waterloo Road, along with some 132kV feeder rearrangements at the site.

In connection with these works, Aurecon has been engaged to conduct an independent assessment of the predicted EMF at the boundaries of the Ausgrid site. It is understood that the results of this assessment will be used by Ausgrid to inform their overall environmental assessment of the project.

1.2 Scope

The scope of Aurecon's assessment is to encompass the following:

- Provide a brief description of the EMF health issue.
- Perform calculations to predict the magnetic field levels at 1m above ground level (as per the relevant standard) at the site boundaries, both shortly after commissioning and under ultimate loading conditions.
- Undertake an assessment of the compliance of the proposed works with the relevant national and international EMF guidelines (ICNIRP 2010).
- Undertake an assessment of compliance of the proposed design against precautionary and prudent avoidance principles as defined in the relevant literature.
- Prepare a report documenting the above.

1.3 Site Description

The site of the proposed STS is shown (highlighted in blue) in Figure 1-1. The existing ZS can also be seen, edged with a dotted blue line.

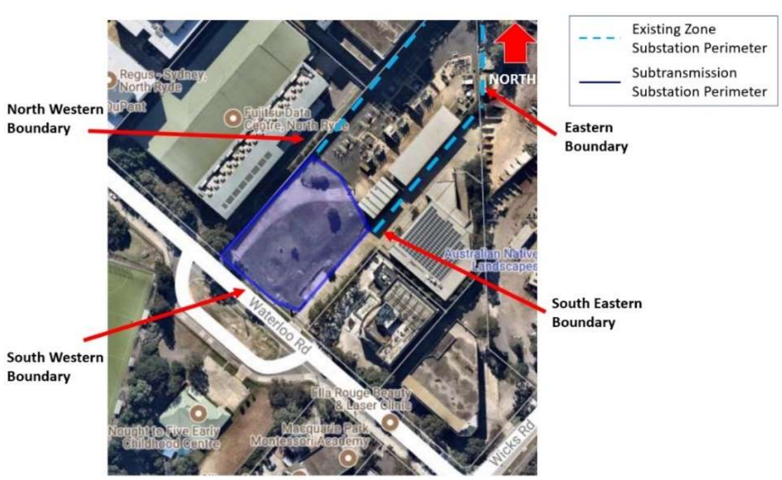

Figure 1-1: Site of Macquarie Park STS

1.4 Approach

In undertaking the assignment, Aurecon has adopted the following approach:

- Perused relevant background information supplied by Ausgrid, including single line diagrams, details of the substation layout, detailed cable routes including their trench section details and cable specifications, loading forecasts and other relevant technical details.
- Measured the existing magnetic fields along the site boundaries.
- Performed calculations to predict the contribution of the proposed works to the magnetic fields at the boundaries of the site, 1m above ground (in accordance with the relevant standard), both after commissioning and under ultimate loading conditions.
- Reviewed compliance of the proposed design against relevant EMF guidelines
- Reviewed the proposed design, including any proposed or potential magnetic field mitigation options, against relevant precautionary and prudent avoidance principles.

2 Overview of Electric and Magnetic Fields

2.1 General description

Whenever electrical equipment is in service, it produces an electric field and a magnetic field. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric wires.

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

Further detail on electric and magnetic fields can be found in Appendix A.

2.2 Electric and magnetic field / health issue

The possibility of adverse health effects due to the EMFs associated with electrical equipment has been the subject of extensive research throughout the world for more than 40 years. To date, while adverse health effects have not been established, the possibility that they may exist cannot be ruled out. In the context of the present assignment, it should be noted that underground cables produce no external electric field and, accordingly, only the magnetic field component of EMF associated with underground cables requires assessment. Further discussion of the EMF/health issue can be found in Appendix B.

2.3 Health guidelines

Since late 2015, the relevant Australian regulator, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), has adopted the international guideline published by the International Commission on Non-Ionising Radiation Protection (ICNIRP) in 2010. Details of the current guideline "Reference Levels" for electric and magnetic field exposure can be found in Appendix C.

These "Reference Levels" have been used as the principal assessment criteria for this assignment and are reproduced in Table 2-1. It should be noted that these criteria are independent of duration of exposure.

Table 2-1: ICNIRP Guideline Reference Levels (General Public)

Parameter	Reference Level
Electric Field	5,000 Volts per metre (V/m)
Magnetic Field	2,000 milligauss (mG)

2.4 Prudent avoidance

Given the inconclusive nature of the science regarding EMF and human health, it is widely considered that a prudent approach is the most appropriate response under the circumstances. Under this approach, subject to modest cost and reasonable practicality, the owners of electric power infrastructure should design their facilities to reduce the intensity of the fields they generate in frequented areas. Further general discussion on this subject can be found in Appendix D and the implications for this project are discussed in Section 5.2.

3 Input information and aspects of field predictions

3.1 Input information

The input data required for the calculations on which this assessment is based has been supplied by Ausgrid and is summarised below.

- Design drawings for the proposed STS and associated feeders.
- Details of typical daily load currents in the existing and proposed 11, 33 and 132kV feeders, shortly after commissioning and in the long term.
- Relevant electrical data regarding the various underground cables and the proposed 132kV overhead connection.
- Detailed cross sections showing the dimensions and phasing of each different section of 11, 33 and 132kV cable or overhead line within and/or leaving the STS site.
- Details of the existing and proposed incoming and outgoing 132kV, 33kV and 11kV feeder locations in the immediately vicinity of the substation.

3.2 Assumptions for modelling

In undertaking this EMF assessment, the modellers have made the following assumptions in consultation with Ausgrid:

- The existing Zone Substation is already fully loaded and this is not expected to increase in the future.
- Where the phasing arrangement is not available, it is reasonable to assume a conservative phasing arrangement for modelling purposes.
- The initial loading on the first tranche of outgoing 33kV feeders has been estimated in consultation with the designers (Stowe), based on the customer loads immediately before commissioning of the STS.
- The STS provides for future outgoing 33kV feeders, exiting either via Waterloo Road or via the shared laneway on the south-eastern side. As these routes influence different boundaries, the modelling for the "ultimate load" case for the Waterloo Road boundary assumes that the future feeders exit via Waterloo Road and the modelling for the "ultimate load" case for the south-eastern boundary assumes that the future feeders exit via the shared laneway.

3.3 Magnetic field dependence on load

Being related to the equipment voltage, electric fields, where they exist, are relatively stable over time, whereas the magnetic fields from electrical equipment depend on the loadings at the time. As this assignment involves multiple feeders, both existing and proposed, in proximity to one another, their interaction will influence the resulting fields. Accordingly, in characterising the magnetic fields at the boundaries of the STS, it is necessary to make practical assumptions regarding the loadings on the various items of equipment at the time.

This approach has been followed in our modelling calculations, with the loadings in the existing and proposed feeders being assumed to be the time-weighted average[1] values, as advised by Ausgrid. These loadings are summarised below.

Table 3-1: Line loadings used for modelling

Feeder	2020 Load (Amps)	Ultimate Load (Amps)
132kV Cable 92AX	117	117
132kV Cable 92AY	117	117
132kV Overhead 92B	109	604
33kV Customer 1	87	394
33kV Customer 2	65	131
33kV Customer 2	65	262
33kV Customer 1	87	394
33kV Customer 2	65	131
33kV Customer 2	65	262
33kV Future	0	420
33kV Future	0	420

4 Field characterisation

4.1 Site measurements

The existing magnetic fields around the site boundaries were measured between 1130 and 1300 on 18th November, 2018.

The magnetic field measurements were undertaken using an Emdex 2 magnetic field meter, in conjunction with an Enertech linear data acquisition system "LINDA", at a height of 0.9 metres above ground, as dictated by the (US) equipment used. Prior to undertaking the measurements, the instrument used was checked using a purpose-built National Electricity "Emdex 2 Functional Test Unit" and found to be within the specified levels of accuracy.

At the time of the measurements, the load on the ZS was approximately equal to the time weighted average values advised by Ausgrid.

4.1.1 Eastern boundary

A total of 80 measurements were made. All were quite low, ranging from 0.3mG at the northern end to 2 towards the southern end.

[1] *Time weighted average values are selected as this parameter has frequently been used in epidemiological health studies associated with magnetic fields.*

4.1.2 South-eastern boundary

A total of 140 measurements were made. Due to traffic and obstructions in the Australia Post area of the shared driveway, the measurements were made along the inner (NW) edge of the driveway and would have overstated the influence of the substation. The majority were 1mG or less, except for the section immediately adjacent to the 11kV cable basement, where fields between 3 and 7mG were recorded. These could be expected to fall to 1 or 2mG at the actual property boundary.

4.1.3 Waterloo Road boundary

A total of 100 measurements were made. A localised peak of 65mG was observed where the 132kV cables enter the site. The fields along the remainder of the boundary were 5mG or less.

4.1.4 North-western boundary

A total of 180 measurements were made. Readings ranged from 0.3mG at the NE end to 18mG at the Waterloo Road end The dominant sources of the measured fields were the Zone substation, particularly the busbars (up to 13mG), and the incoming 132kV cables. The influence of the outgoing 11kV cables towards the Waterloo Road end was minor. An unidentified source (14mG) was observed approximately 75 metres from the Waterloo Road boundary. As no source was evident within the Ausgrid property, it is likely that the source was associated with the adjacent Fujitsu facility.

4.2 Modelling

Based on the available design and loading information, the magnetic field contribution of the proposed STS and relevant existing feeders has been modelled using in-house software, which applies well established engineering formulae and has been extensively validated against other software packages and field testing. The modelling has covered the four STS site boundaries, with two cases having been modelled, namely, shortly after commissioning of the STS and a long term (“ultimate”) condition.

The electric field contribution of the proposed section of overhead 132kV line entering the STS has also been modelled.

In all cases, the fields have been calculated at a height of 1m above ground, in accordance with international practice (Ref B-1).

4.3 Magnetic field results

The results obtained from the magnetic field modelling are shown in the following sections, in the form of profiles along the respective boundaries.

4.3.1 Eastern Boundary

The calculated magnetic field along the Eastern boundary is shown in Figure 4-1. The lower curve is shortly after commissioning and the upper curve is the long-term case, with the STS fully loaded and includes future 33kV feeders which may ultimately leave the STS via a different route. The influence of the possible future 33kV feeders can be seen towards the right hand end of Figure 4-1. Should these feeders leave the substation via the Waterloo Road alternative, the long term magnetic field will remain as shown by the lower curve.

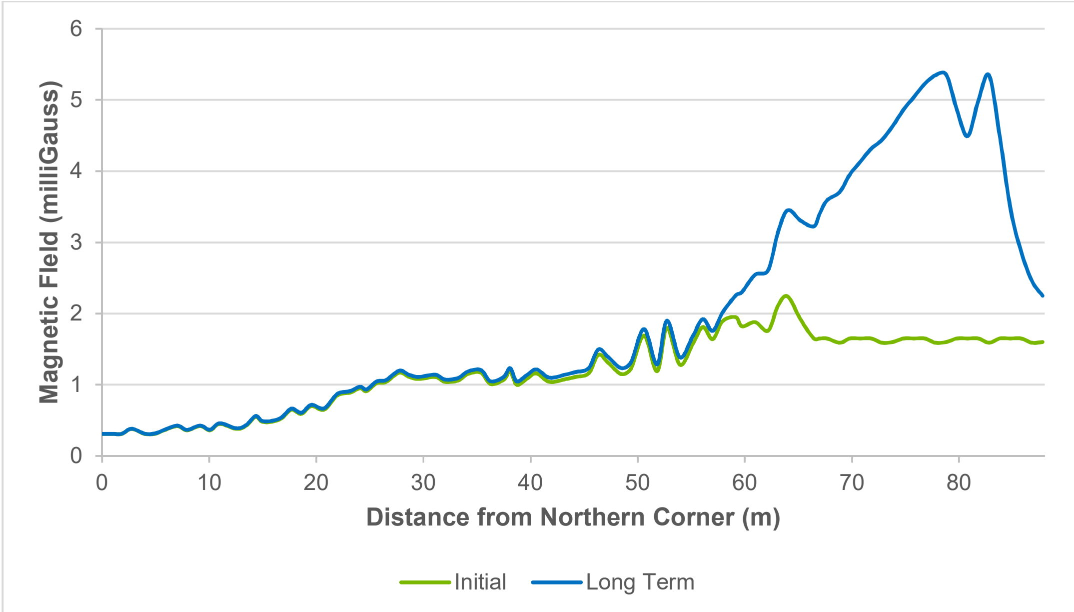

Figure 4-1: Calculated Magnetic Field Profile along Eastern Boundary

It can be seen from Figure 4-1 that in the short term, the magnetic field along the Eastern boundary of the site is less than 2mG. In the longer term, in the event that the future feeders exit the site via the shared driveway, the field above those cables will be up to 5.4mG. Otherwise, the long term magnetic fields will be similar to the short-term fields.

4.3.2 South-Eastern Boundary

The calculated magnetic field along the south-eastern boundary is shown in Figure 4-2. The lower curve is shortly after commissioning and the upper curve is the long-term case with the STS fully loaded and includes future 33kV feeders which may ultimately leave the STS via a different route.

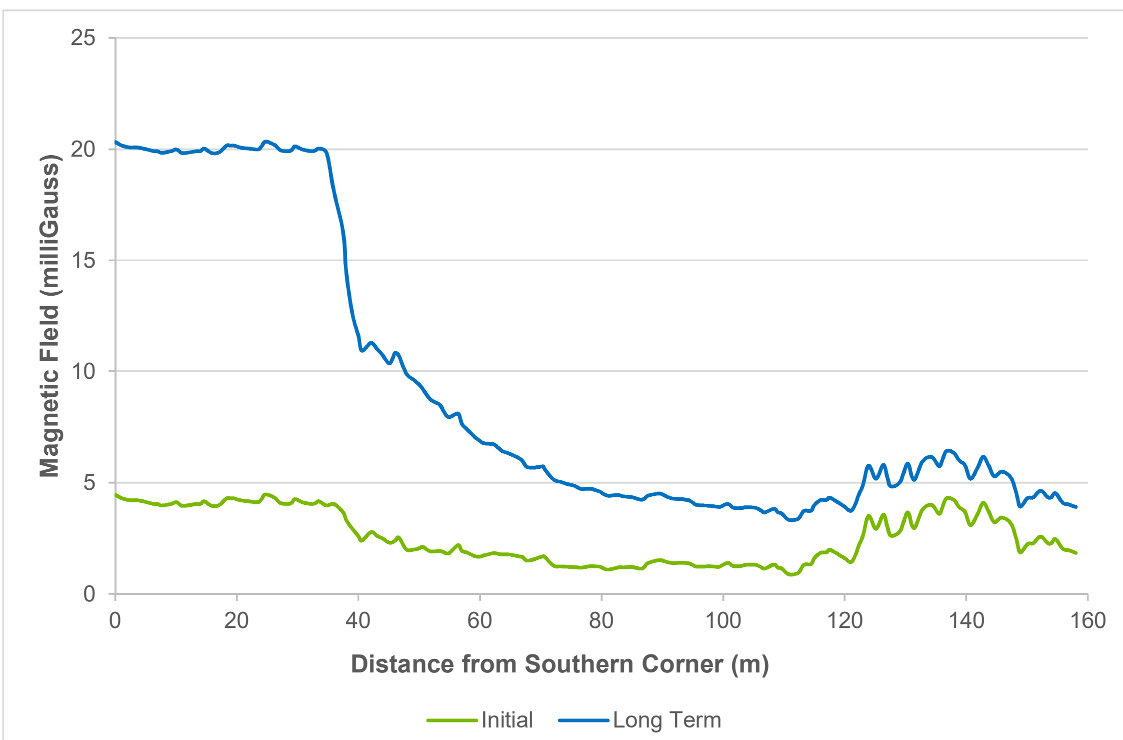

Figure 4-2: Calculated Magnetic Field Profile along South-Eastern Boundary

It can be seen from Figure 4-2 that the magnetic field along the south-eastern boundary of the STS, shortly after commissioning, is less than 5mG.

In the long term, the field at the Waterloo Road end will increase to 20mG, due to the increased current in the incoming 132kV overhead line. The influence of the possible future 33kV feeders can be seen for the northern section of the boundary but is only of the order of 2mG. In the event of these feeders exiting via Waterloo Road, the long term field in the northern part of this boundary will remain as shown by the lower curve.

4.3.3 South-Western (Waterloo Road) Boundary

The calculated magnetic field along the south-western (Waterloo Road) boundary, is shown in Figure 4-3. The lower curve is shortly after commissioning and the upper curve is the long-term case with the STS fully loaded and includes future 33kV feeders which may ultimately leave the STS via a different route. The influence of the various groups of feeders entering and exiting the site is readily visible, with the existing 132kV cables being the most significant source[2].

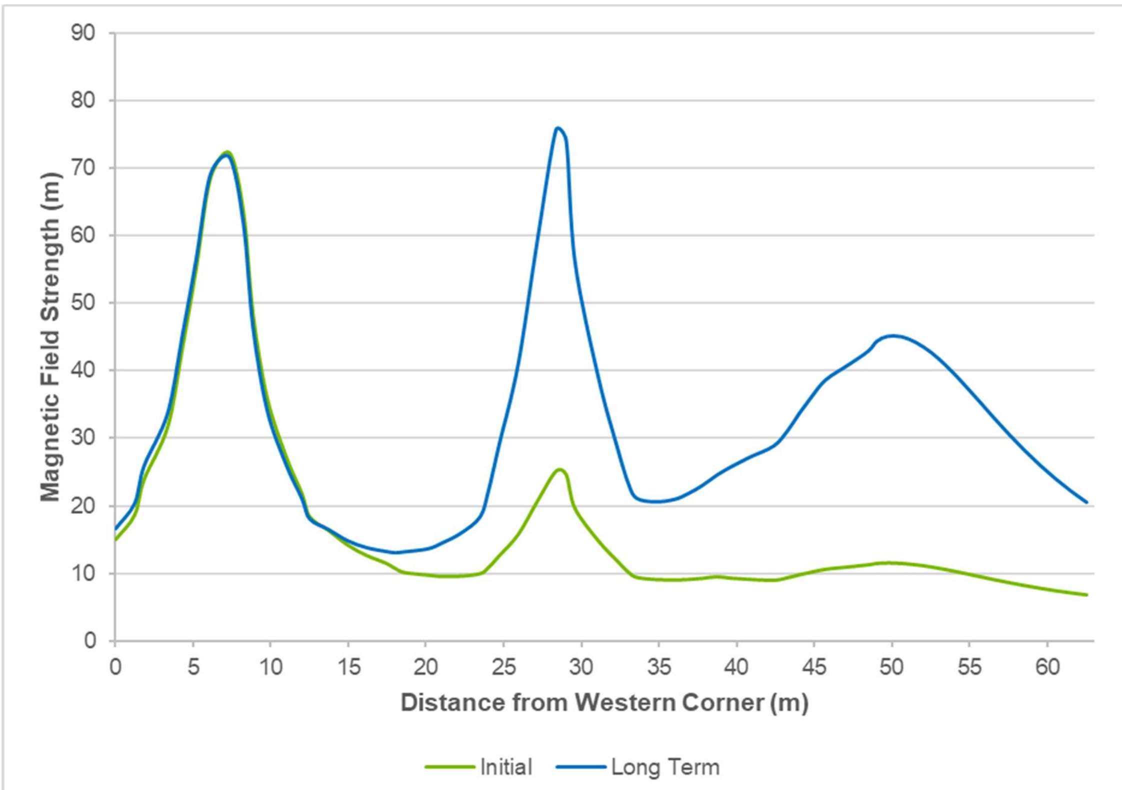

Figure 4-3: Calculated Magnetic Field Profile along South-Western (Waterloo Road) Boundary

It can be seen from Figure 4-3 that, in the short term, the magnetic field along the south-western (Waterloo Road) boundary, is generally about 10mG, rising to 72mG above the incoming 132kV cables (existing) and 25mG above the outgoing 33kV cables. In the long term, the field will tend to be dominated by the peaks associated with the incoming 132kV cables (unchanged), the outgoing 33kV cables (up to 76mG) and the 132kV overhead line (up to 45mG).

The influence of the outgoing 11kV cables and the possible future 33kV cables is relatively minor and not readily discernible in Figure 4-3.

[2] *The fields above the existing 132kV cables are based on site measurements at a time when the loading approximated the time weighted average loading. Due to uncertainty as to the actual cable installation details, the measured values were considered to give a fairer representation of the actual situation.*

4.3.4 North-Western Boundary

The predicted magnetic fields along the north-western boundary are shown in Figure 4-4. As this boundary is substantially remote from the proposed STS infrastructure, field levels are not expected to change appreciably from the present values.

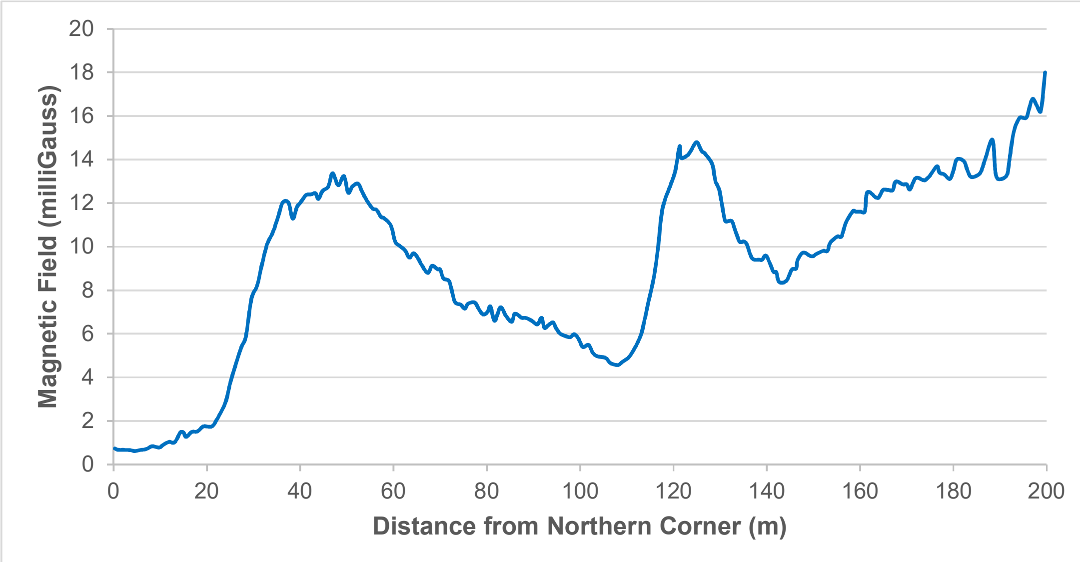

Figure 4-4: Magnetic Field Profile along North-Western Boundary

It can be seen from Figure 4-4 that the magnetic field along the north-western boundary ranges from 0.3mG at the NE end to 18mG at the Waterloo Road end. The influence of the Zone substation, particularly the busbars (up to 13mG), can be seen towards the northern end. The other major contributing source is the incoming 132kV cables. The influence of the outgoing 11kV cables towards the Waterloo Road end is minor. The source of the 14mG peak approximately 120 metres from the northern corner is thought to be external, possibly associated with the adjacent Fujitsu facility.

4.4 Magnetic fields experienced in everyday life

In considering the fact that the magnetic fields along the boundaries of the proposed ZSS are unlikely to be experienced by people, other than intermittently and with the highest fields being quite localised, it is important to recognise that life in the modern world involves moving from one source of magnetic fields to another. To put this into perspective, the Energy Networks Association has published a series of typical magnetic field levels associated with particular appliances and infrastructure at normal user distance. These are set out in Table 4-1.

Table 4-1: ELF Magnetic Field Levels Associated with Appliances and Infrastructure (source: Energy Networks Association)

	Typical Measurement (mG)	Range of Measurements (mG)
Electric Stove	6	2 – 30
Refrigerator	2	2 – 5
Electric Kettle	3	2 – 10
Toaster	3	2 – 10
Television	1	0.2 – 2
Personal Computer	5	2 – 20
Electric Blanket	20	5 – 30

	Typical Measurement (mG)	Range of Measurements (mG)
Hair Dryer	25	10 – 70
Pedestal Fan	1	0.2 – 2
Substation - Substation Fence	5	1 – 8
Distribution Line - Under Line - 10m Away	10	2 – 30 0.5 – 10
Transmission Line - Under Line - Edge of Easement	20 10	10 – 200 2 – 50

From the above range of fields, it can be seen that the predicted magnetic field contributions along the boundaries of the proposed STS are within the range of fields commonly encountered in everyday life. The fields above the (existing) 132kV cables and proposed 33kV cables are within the range normally associated with such cables or their overhead equivalents.

4.5 Electric field results

The only asset likely to produce electric field at the substation boundary is the incoming 132kV overhead feeder 92B and, accordingly, the electric field beneath it has been modelled. The results are shown in Figure 4-5 in the form of a profile indicating the electric fields along a line at right angles to the proposed overhead line.

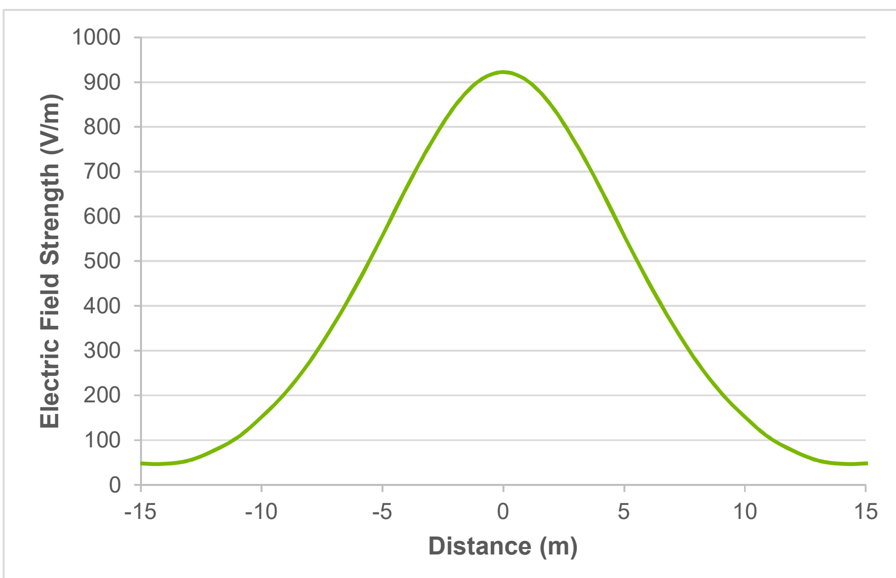

Figure 4-5: Calculated Electric Field Profile beneath incoming 132kV Feeder 92B

It can be seen from Figure 4-5 that the electric field beneath the proposed incoming 132kV overhead line is predicted to be 900 Volts/metre directly under it, decreasing to a negligible level at a distance of 10 metres.

4.6 Commentary on calculated fields

As **magnetic fields** are dependent on the load current in the source, which can vary from time to time, the actual values can differ from those calculated. At times of infrequent high load or emergency conditions, the contributions of the infrastructure modelled in this assessment could be 2-3 times higher than those reported. However, such occasions would be rare and of short duration.

In practice, the **electric fields** are likely to be considerably lower than the calculated values, due to the effects of the shielding provided by trees along the south-eastern boundary.

5 Compliance with EMF guidelines and prudent avoidance principles

5.1 Compliance with health guidelines

5.1.1 Magnetic fields

The combined contribution of the Substations to the magnetic field environment at the site boundaries is a small fraction of the ICNIRP Guideline Reference Level of 2000mG. The contribution to the existing magnetic field environment along the various boundaries is summarised in Table 5-1.

Table 5-1: Contribution to the existing magnetic field environment along the boundaries

	Eastern Boundary	South-Eastern Boundary	Waterloo Road Boundary	North-Western Bndry (existing)
Typical range (short term)	0.5-2mG	2-5mG	10mG	1-18mG
Typical range (long term)	0.5-2mG	Less than 10mG	N/A	1-18mG
Highest value (short term)	2mG	5mG	72mG (existing)	18mG
Highest value (long term)	10mG	20mG	76mG	18mG

Both in the short and long terms, the highest predicted magnetic field contribution of the proposed STS is less than 4% of the Guideline Reference Level and of the same order as at present.

5.1.2 Electric fields

The only source of electric fields will be the overhead 132kV line entering the site from Waterloo Road. The field directly under the line is predicted to be 900Volts per metre, which is less than 20% of the ICNIRP Guideline Reference Level. This will diminish to a negligible level within 10 metres. The field at the south-eastern boundary will be negligible.

5.2 Assessment against prudent avoidance principles

As noted in Section 2.4, given the inconclusive nature of the science, it is considered that a prudent/precautionary approach continues to be the most appropriate response in the circumstances. Under this approach, the operators of electricity infrastructure should design their facilities to reduce the intensity of the magnetic fields they generate, and locate them to minimise the fields that people, especially children, encounter over prolonged periods, provided this can be readily achieved without undue inconvenience and at reasonable expense, and be consistent with good engineering and risk minimisation practice.

In this context, it is noted that:

- The main substation equipment is located well within the site boundaries, thereby minimising its external influence.
- The use of compact gas-insulated switchgear for the 132kV side of the substation is a low-field option.
- The vertical configuration which has been selected for the incoming 132kV line is a low-field option.

The most significant source of magnetic fields associated with the proposed STS will be the outgoing 33kV feeders at the Waterloo Road boundary, particularly in the long term. The peak field is still less than 4% of the ICNIRP Guideline Reference Level and comparable to the existing field from the incoming 132kV cables.

As noted in Appendix D, an objective of Prudent Avoidance is to minimise the fields that people, especially children, encounter over prolonged periods. As the Waterloo Road boundary involves only transitory exposure for passing pedestrians, there is no prolonged exposure and no further measures to reduce magnetic fields along that boundary are warranted.

6 Conclusions

Based on Aurecon's modelling of the electric and magnetic fields likely to be associated with the proposed Subtransmission Substation, the following conclusions may be drawn.

6.1 Magnetic fields

Both in the short and long terms, the highest predicted magnetic field contribution of the proposed STS is less than 4% of the Guideline Reference Level and of the same order as at present.

6.2 Electric fields

The only source of electric fields will be the overhead 132kV line entering the site from Waterloo Road. The field directly under the line is predicted to be 900Volts per metre, which is less than 20% of the ICNIRP Guideline Reference Level. This will diminish to a negligible level within 10 metres. The field at the south-eastern boundary will be negligible.

6.3 Prudent avoidance

In the context of Prudent Avoidance, it is noted that:

- The main substation equipment is located well within the site boundaries, thereby minimising its external influence.
- The use of compact gas-insulated switchgear for the 132kV side of the substation is a low-field option.
- The vertical configuration which has been selected for the incoming 132kV line is a low-field option.

Further measures to reduce magnetic fields along the site boundaries are not warranted.

Appendices

Appendix A

General description of electric and magnetic fields

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

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

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

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

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

Alternating electric and magnetic fields are produced by any electric wiring or equipment carrying alternating current (AC). This current does not flow steadily in one direction but oscillates backwards and forwards at a frequency[3] of 50Hz and hence the fields produced by AC systems oscillate at the same frequency. This frequency falls into a range referred to as **extremely low frequency** (ELF), so the electric and magnetic fields are referred to as ELF fields.

Electromagnetic Radiation

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

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

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

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

visible light[4], ultraviolet radiation, X-rays and gamma rays. Whereas EMR causes energy to be radiated outwards from its source e.g. light from the sun or radio-frequency signals from a television transmitter, EMFs cause energy to be transferred along electric wires.

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

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

References

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

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

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

Appendix B
Overview of EMF health issue

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

Extremely Low Frequency (ELF) Fields

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

While EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields. Nevertheless, high electric field strengths, such as those associated with high voltage equipment in major substations can approach a level at which "nuisance shocks" can occur and this phenomenon needs to be managed. Magnetic fields are not readily shielded, are more ubiquitous and remain the subject of some debate. Accordingly, much of the remainder of this section is directed towards magnetic fields.

The most recent scientific reviews by authoritative bodies are reassuring for most potential health issues. However, statistical associations[5] between prolonged exposure to elevated magnetic fields and childhood leukaemia have persisted. This led the International Agency for Research on Cancer (IARC) (Ref. B-2) in 2002 to classify magnetic fields as a "possible carcinogen" [6].

The fact that, despite over 30 years of laboratory research, no mechanism for an effect has been established, lends weight to the possibility that the observed statistical associations reflect some factor other than a causal relationship. This point is made in the 2001 report of the UK National Radiological Protection Board's (NRPB) Advisory Group, chaired by eminent epidemiologist, the late Sir Richard Doll (Ref. B-3)

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

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4 It should be noted that a statistical association does not necessarily reflect a cause and effect relationship.

[5] IARC publishes authoritative independent assessment by international experts of the carcinogenic risks posed to humans by a variety of agents, mixtures and exposures. These agents, mixtures and exposures are categorised into 5 groups, namely:

- *Group 1 – the agent is carcinogenic to humans – 118 agents are included in the group, including asbestos, tobacco and ultraviolet radiation*
- *Group 2A – the agent is probably carcinogenic – 79 agents have been included in this group, including diesel engine exhaust, creosotes and PCBs*
- *Group 2B – the agent is possibly carcinogenic to humans – 290 agents have been included in this group, including coffee, gasoline, lead, nickel, petrol engine exhaust and extremely low frequency magnetic fields*
- *Group 3 – the agent is not classifiable as to carcinogenicity – 501 agents have been included in this group, including caffeine, coal dust, extremely low frequency electric fields and static electric and magnetic fields*
- *B-2. National Radiological Protection Board, (UK), ELF Electromagnetic Fields and the Risk of Cancer, Report of an Advisory Group on Non-Ionising Radiation, Chairman, Sir Richard Doll, NRPB Vol. 12 No. 1, 2001.*
- *Group 4 – the agent is probably not carcinogenic to humans – only 1 agent (caprolactam) has been included in this group.*

References

B-1. The Institute of Electrical and Electronics Engineers, Inc, IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields From AC Power Lines, Submission to the NSW Government, 1995.

B-2. World Health Organisation, International Agency for Research on Cancer, Lyon, France: IARC Monographs on the evaluation of carcinogenic risks to humans. Non-Ionising Radiation Part 1: Static and Extremely Low Frequency (ELF) Electric and Magnetic Fields. (2001)

B-3. National Radiological Protection Board, (UK), ELF Electromagnetic Fields and the Risk of Cancer, Report of an Advisory Group on Non-Ionising Radiation, Chairman, Sir Richard Doll, NRPB Vol. 12 No. 1, 2001.

Appendix C
Health guidelines

Health Guidelines for Extremely Low Frequency Electric and Magnetic Fields

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

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

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

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

In line with the regulator's advice, AJJV has applied the current international ICNIRP guideline reference levels to this assessment.

The reference levels for both electric and magnetic fields contained in the current ICNIRP guidelines are summarised in the table below

Health Guideline Reference Levels

Parameter	ICNIRP 2010 Reference Levels
Electric Fields – General Public	5kV/m
Electric Fields – Occupational	10kV/m
Magnetic Fields – General Public	2,000mG
Magnetic Fields – Occupational	10,000mG

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

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

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

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

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

References

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

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

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

Appendix D
Prudent avoidance

Extremely Low Frequency Magnetic Fields

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

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

- Adverse health effects have not been established
- The possibility cannot be ruled out
- If there is a risk, it is more likely to be associated with the magnetic field than the electric field

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

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

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

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

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

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

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

It also states:

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

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

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

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

It also states:

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

References

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

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

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

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

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

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