BEFORE A COMMISSIONER APPOINTED BY THE SELWYN DISTRICT COUNCIL

IN THE MATTER OF	the Resource Management Act 1991
AND	
IN THE MATTER OF	applications by KeaX Limited for resource consent to establish a solar array at 150 Buckleys Road, Brookside.

STATEMENT OF EVIDENCE OF MARTIN GLEDHILL

ON BEHALF OF THE APPLICANT

(Electromagnetic Fields)

Dated: 16 February 2024

KeaX Limited
Applicant
Campbell McMath
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1 INTRODUCTION

1.1 My full name is Martin David Gledhill.

1.2 I have an MA degree in Natural Sciences (Physics) and an MSc in Medical Physics. I am a member of the Australasian Radiation Protection Society and of the Bioelectromagnetics Society.

1.3 I am a Director of Monitoring and Advisory Services NZ Ltd (MAASNZ), which through its EMF Services division provides professional measurement and advisory services related to possible health effects of electromagnetic fields. These services are provided to central and local government (including the Ministries of Health and the Environment), the public and industry.

1.4 Before forming MAASNZ I was head of the non-ionising radiation section at the National Radiation Laboratory of the New Zealand Ministry of Health, where my role was similar to what it is now. It included presenting expert evidence at local authority and Environment Court hearings.

1.5 I was engaged by KeaX Limited in December 2022 to provide advice on electromagnetic fields that could result from a proposed solar array on Buckleys Road, Brookside. In particular my work has involved the preparation of this evidence based on my experience and the results of measurements of low frequency electric and magnetic fields (EMFs) around the Kea Energy Wairau Valley solar farm.

1.6 In preparing this evidence, I have reviewed the following:

(a) The resource consent applications for the Proposal (including the AEE);

(b) The evidence of Campbell McMath (applicant);

(c) The joint submission of Donna Irons and Simon Robinson, the joint submission of Ewan Chapman, Anneka Dalley and Michael Dalley (Haurere Farms) and the submission of Clark Casey.

(d) The Section 42A report for Selwyn District Council; and

(e) Proposed consent conditions.

1.7 Whilst this is a Council hearing, I acknowledge that I have read and agree to comply with the Environment Court's Code of Conduct for Expert Witnesses, contained in the Environment Court Practice Note 2023. My qualifications as an expert are set out above. Other than where I state that I am relying on the advice of another person, I confirm that the issues addressed in this statement of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

2 EXECUTIVE SUMMARY

2.1 My evidence covers the electric and magnetic fields (EMFs) that will be created by the proposed Buckleys Road solar farm. Estimates of the strengths of those fields are based on measurements of a Kea Energy solar farm in the Wairau Valley.

2.2 The measurements show that at distances more than a metre from the inverter skid, electric and magnetic field levels around the site were very low in comparison to the limits recommended by ICNIRP in 1998 and 2010, and would satisfy the relevant rules in Partially Operative Selwyn District Plan. The solar panels themselves, and the combiner boxes mounted beneath each string of panels, only produce very weak fields. Beyond the security fence the solar farm would make an indiscernible difference to electric and magnetic field exposures.

2.3 On this basis, electric and magnetic fields from the solar farm would have no effect on the health of people around it.

2.4 It is also highly unlikely that the EMFs would affect bees or birds in the neighbourhood.

3 SCOPE OF EVIDENCE

3.1 My evidence addresses:

(a) The proposed activities;

(b) The receiving environment;

(c) Measurements made at another Kea Energy site, and how they can be used to estimate electric and magnetic fields at the proposed Buckleys Road installation;

(d) Potential health effects of the proposal;

(e) The submissions of Donna Irons and Simon Robinson, Ewan Chapman, Anneka Dalley and Michael Dalley (Haurere Farms), and Clark Casey that raise issues about potential effects on health, and effects on wildlife, including birds and pollination by bees;

(f) The s42A Report in relation to the application and matters raised by submitters; and

(g) The proposed conditions of consent.

4 RELEVANT ACTIVITIES

4.1 I understand that KeaX Limited proposes to construct and operate a 111 ha solar array on the Buckleys Road site (Site) which will have a generating capacity of 50 MW AC/75 MW DC on completion. The solar array will comprise:

a. a total of 140,000 tracking solar panels, arranged in tables with 52 panels per table.

b. 1 Single Skid Inverter – 10.2m long, 2.1m wide, and 2.25m high, covering an area of approximately 21.42m².

c. 6 Twin Skid Inverters – 9.2m long, 5.4m wide, and 2.35m high, covering an area of approximately 25m².

d. A future battery site.

5 THE RECEIVING ENVIRONMENT

5.1 The area surrounding the Site is used for dairy farming and other agricultural activities, with some semi-rural lifestyle blocks. A substation (designated: Brookside Substation) owned by Orion New Zealand Limited (Orion) is located at the junction of Buckleys Road and Branch Drain Road, adjacent to the north-western corner of the Site.

5.2 There are several houses near the site, the closest of which appears to be about 15 metres from the site boundary and 25 m from the nearest panels.

6 BACKGROUND EMF MONITORING UNDERTAKEN

6.1 The Site is made up of 13 modules, each consisting of an array of solar panels connected to an inverter. While the total size of the Buckley's Road site is much greater than the Kea Energy Wairau Valley site, the individual Buckley's Road modules are similar to the Kea Energy installation at the Wairau Valley site. For that reason, measurements of EMFs at the Wairau Valley site can be used to estimate EMFs that can be expected from the modules at the Buckley's Road site, and from the entire installation.

6.2 The report on my EMF measurements at the Wairau Valley site ("the Report") is attached as Appendix 1 to this evidence. Key conclusions from my measurements (see section 3.1 of the Report) are as follows:

(a) The highest fields are found close to the inverter skid[1].

(b) Electric and magnetic fields at distances greater than 1 metre from the inverter skid were very low in comparison to limits recommended by the International Commission on Non-Ionising Radiation Protection (ICNIRP) in 1998 and 2010.

(c) The solar panels and the combiner boxes mounted beneath each string of panels only produce very weak fields.

(d) All field levels decrease rapidly with increasing distance from their source (the inverter skid or combiner box) and they would be indiscernible outside the security fence surrounding the site.

6.3 Section 3.3 of the Report considers the effect of modules with larger capacity, such as those proposed for Buckleys Road. It concludes that such modules would still make an indiscernible difference to EMFs outside the security fence.

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[1] Note that this is erroneously referred to as the "combiner skid" in section 3.1 of the Report.

6.4 Rules EI-REQ6 and EI-REQ7 of the Partially Operative District Plan set limits for EMFs in all zones (noting that this Site is in a rural zone) at frequencies from 3 kHz to 300 GHz, and at 1 Hz to 100 kHz respectively. These rules essentially adopt the ICNIRP 1998 limits at frequencies between 3 kHz to 300 GHz and ICNIRP 2010 limits at frequencies between 1 Hz and 100 kHz. At the frequencies where these two sets of limits overlap (3 kHz-100 kHz) I have assumed that the more restrictive set of limits applies.

6.5 Based on the findings from the EMFs from the Wairau Valley site, the KeaX installation at Buckley's Road will therefore comply with the rules in the Partially Operative District Plan.

6.6 On this basis, EMFs from the Buckleys Road solar farm will not adversely affect the health of nearby residents.

7 PROPOSED EMF MITIGATION AND MONITORING

7.1 As the Buckleys Road solar farm is expected to make an indiscernible difference to EMF levels outside the site, in my opinion there is no need to mitigate any effects and monitoring is not necessary.

8 SUBMISSIONS

8.1 Six submissions have been received in relation to the application.

8.2 The joint submission from Donna Irons and Simon Robinson raises concerns about "Negative effect of the solar waves on the insect life and consequent effects on natural wildlife, birds and pollination process." I am not sure what is meant by "solar waves" but presume that this is a reference to the EMFs produced by the installation.

8.3 There is limited research on the effects of EMFs such as those created around the solar farm on insect life and other fauna. The European Union EKLIPSE project on "The impacts of artificial Electromagnetic Radiation[2] on wildlife" assessed research quality in this area and, particularly with respect to studies on invertebrates such as insects, considered that it was very mixed and it was difficult, if not impossible,

[2] Goudeseune Lise, Balian Estelle, Ventocilla Jorge. (2018). The impacts of artificial Electromagnetic Radiation on wildlife (flora and fauna). Report of the web conference. A report of the EKLIPSE project.

to draw any firm conclusions. This has been borne out by more recent publications, such as those by Popov[3] and Thill[4].

8.4 Where effects have been noted, for example on bees, these largely concern exposures of the magnitude found close to high voltage transmission lines. The measurements at the Wairau Valley solar farm showed that electric fields within the entire site are thousands of times below those levels. Apart from very close to the inverter skid transformer, magnetic fields were hundreds of times lower. Because the region within which elevated magnetic fields exist is largely restricted to a small volume around the inverter skid this would be unlikely to have any more than a minimal effect, if any, on insect life. It is perhaps worth noting that magnetic fields of a similar magnitude probably exist already very close to the transformers at the substation at the junction of Buckleys and Branch Drain Roads (and similar-sized or larger substations), and also within a few tens of centimetres of the power lines that run along roads near the proposed site. (There would, however, be no cumulative effect because the magnetic fields from these sources also decrease to very low levels over distances of a few metres.)

8.5 The submission of Ewan Chapman, Anneka Dalley and Michael Dalley (Haurere Farms) also raises questions about possible effects on local invertebrate and vertebrate health and populations, especially bees and birds. They also consider that EMF will increase with larger transmission lines installed to take power away from the substation, which will have major health impacts on existing households living close to Branch Drain, Buckleys, Stewarts and Brookside-Dunsandel Roads. They believe that over 200 people in the local community will be impacted by EMF.

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[3] Pophof, B., Henschenmacher, B., Kattnig, D. R., Kuhne, J., Vian, A., & Ziegelberger, G. (2023). Biological Effects of Electric, Magnetic, and Electromagnetic Fields from 0 to 100 MHz on Fauna and Flora: Workshop Report. *Health physics*, *124*(1), 39–52. https://doi.org/10.1097/HP.0000000000001624

[4] Thill, A., Cammaerts, M. C., & Balmori, A. (2023). Biological effects of electromagnetic fields on insects: a systematic review and meta-analysis. *Reviews on environmental health*, 10.1515/reveh-2023-0072. Advance online publication. https://doi.org/10.1515/reveh-2023-0072

8.6 I have discussed possible effects of EMF from the installation in paragraphs 8.3 and 8.4. Research on birds has looked at two possible effects of electromagnetic fields on bird navigation. One concerns a possible interaction at frequencies around 1 MHz, which is a far greater frequency than would be produced by the solar farm and is not discussed further. The other concerns lower frequency fields. Because the region within which elevated magnetic fields exist is largely restricted to a small volume around each inverter skid this does not appears unlikely to have more than a minimal, if any, effect. Here too it is worth noting that magnetic fields of a similar magnitude to those near the inverter skids probably exist already near the transformers at the substation at the junction of Buckleys and Branch Drain Roads (and similar-sized or larger substations).

8.7 The proposal does not include upgrading or replacing existing lines to increase their capacity, so any consideration of this is hypothetical. The application notes that if the substation needs to be upgraded this will be the subject of a separate application by Orion, and the same would apply to any upgrade or replacement of the existing power lines. Should there be any changes to the existing lines (or the substation), Orion would still have to comply with rule EI-REQ7 of the Partially Operative District Plan, which restricts exposures to EMFs to levels set in health-based limits.

8.8 The submission of Clark Casey expresses concern about health impacts on himself and his family but does not give further details on the possible causes of those effects. As discussed in section 7 of my evidence, based on the measurements of EMFs made at Wairau Valley I conclude that the Buckleys Road solar farm will make an indiscernible difference to EMFs outside the Site, so the question of potential health effects from EMFs does not arise.

9 SECTION 42A OFFICER'S REPORT

9.1 I have read the section 42a report for Selwyn District Council (SDC) in relation to KeaX Limited's land use consent application and agree with the summary of electromagnetic radiation matters.

10 CONSENT CONDITIONS

10.1 I have reviewed the proposed consent conditions and agree that an EMF condition is not necessary.

11 CONCLUSION

11.1 My key conclusions are as follows:

(a) The Buckleys Road solar farm will make an indiscernible difference to EMF levels in the surrounding area.

(b) EMFs from the solar farm will have no effects on the health of nearby residents.

(c) The solar farm is highly unlikely to make any difference to the ability of bees to pollinate nearby crops or birds to navigate in the area.

Martin Gledhill

16 February 2024

Electric and magnetic fields around the Kea Energy Wairau Valley solar farm

EMF Services
Professional EMF measurement and advisory services

Report 2023/01

This report was prepared for:

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Report prepared by: Martin Gledhill
Finalised: 23 January 2023

About EMF Services and the author of this report

EMF Services is a division of Monitoring and Advisory Services NZ Ltd (MAASNZ), and provides professional measurement and advisory services related to possible health effects of electromagnetic fields (EMFs), such as the extremely low frequency (ELF) electric and magnetic fields found around any wiring, appliances or infrastructure carrying mains electricity, and the radiofrequency (RF) fields produced by radio transmitters and some industrial equipment.

Martin Gledhill has an MA degree in Natural Sciences (Physics) and an MSc in Medical Physics. He is a member of the Australasian Radiation Protection Society and of the Bioelectromagnetics Society. Before forming MAASNZ he was head of the non-ionising radiation section at the National Radiation Laboratory of the New Zealand Ministry of Health. In this position he provided advice to central and local government, the public and industry on the health effects of EMFs, and carried out measurement and assessment services in this area. This work included providing policy advice to the Ministries of Health and the Environment, preparation of public information material, presenting expert evidence at local authority and Environment Court hearings, and assessing exposures to EMFs by both measurements and calculations.

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Electric and magnetic fields around the Kea Energy Wairau Valley solar farm

1 Introduction

This report presents the results of measurements of low frequency electric and magnetic fields (EMFs) around the Kea Energy Wairau Valley solar farm. The solar farm consists of a large array of solar panels that generate direct current (DC) electricity. The DC electricity is fed into a central 2.2 MVA inverter and a high voltage transformer that converts it to alternating current (AC) electricity at 11 kV. The AC supplies the local electricity distribution network.

Measurement results are expressed as a percentage of the exposure limits recommended for the public by the International Commission on Non-Ionising Radiation Protection (ICNIRP). ICNIRP is an independent scientific body recognised by the World Health Organisation for its independence and expertise in this area. They have published limits in 1998, and updated these in 2010. While the underlying basis of the 1998 and 2010 limits is the same, the 2010 update takes account of more recent research that allowed some refinement of the recommendations. In New Zealand, several local authorities require electrical utilities to comply with the 1998 limits, while others refer to the 2010 limits. The Ministry of Health recommends compliance with the 2010 limits. Regulations under the Resource Management Act (RMA) covering maintenance and upgrades of the national electricity grid operated by Transpower refer to the 1998 limits, but a National Policy Statement under the RMA now references the 2010 limits. In practice, compliance with either set of limits protects against health effects, and in this report, the measurement results are compared against both sets. Further information about the ICNIRP recommendations is provided in Appendix 2.

Some background information on low frequency EMFs is provided in Appendix 1.

2 Measurement results

The main sources of EMFs at the solar farm are the combiner boxes that combine the outputs from a string of 22 solar panels to send a direct current to the inverter, and the inverter and transformers on the inverter skid. EMF measurements were made with a Narda EHP-50F electric and magnetic field analyser, with the readout through a tablet PC running the Narda EHP50-TS software.

Because the AC output of the solar power system is at a frequency of 50 Hz measurements were made in the meter's 2 kHz frequency range which would capture fields at this frequency, and any 50 Hz harmonics present. The inverter and other components could well create EMFs at other frequencies, so additional measurements were made in the meter's 10 kHz and 400 kHz frequency ranges to capture these. At each measurement position spectra were recorded in these three frequency ranges for later analysis.

Further details of the measurement equipment and data analysis are presented in Appendix 3.

2.1 Combiner boxes

Combiner boxes are mounted on the frame beneath the solar panels. Measurements were made near one of the combiner boxes as shown in the sketch plan in figure 1. A photo of the measurement probe and combiner box, taken from behind the panels, is in figure 2.

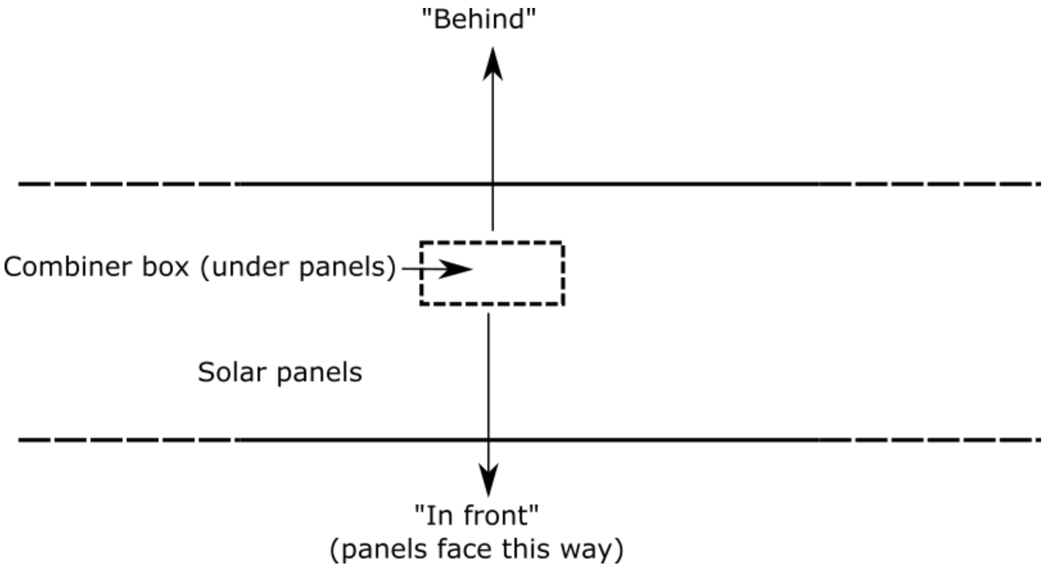

Fig 1. Sketch plan of the measurement positions near the combiner box.

Fig 2. Measurement probe behind the combiner box

There was another row of panels about 10 m behind the combiner box, but no other rows of panels in front of it. Measurements were made 0.3, 1 and 5 metres behind the box, and 5 and 10 metres in front of it.

Measurement results are plotted in figure 3 (electric and magnetic fields as a percentage of the ICNIRP 1998 public limits) and figure 4 (electric and magnetic fields as a percentage of the ICNIRP 2010 public limits).

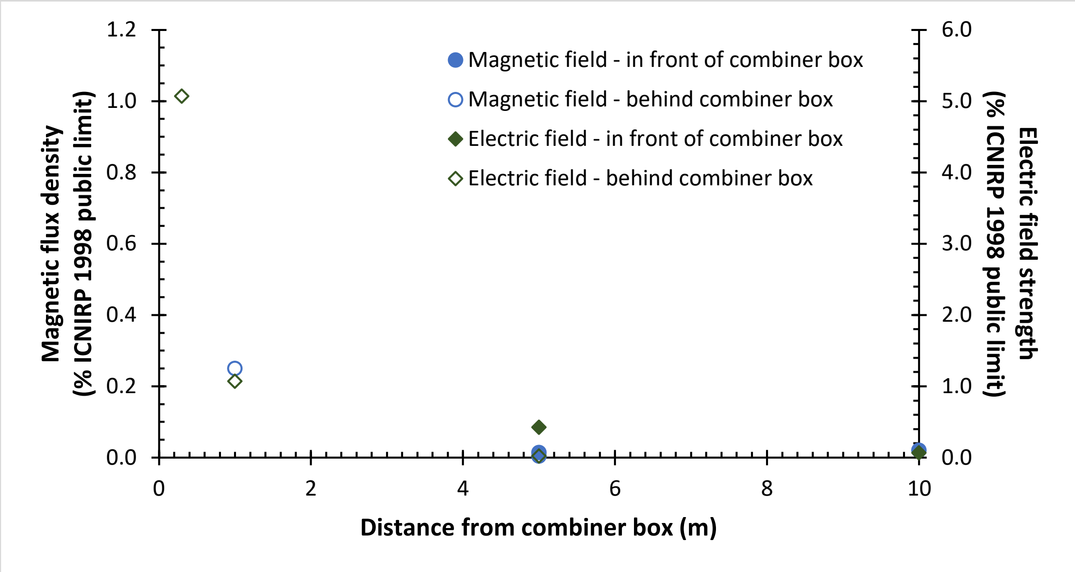

Fig 3. Electric and magnetic fields near the combiner box as a percentage of the ICNIRP 1998 public limits. Filled and open blue circles show magnetic fields in front of and behind the combiner box, respectively, and values are read off the left hand vertical scale. Filled and open green diamonds show electric fields in front of and behind the combiner box, respectively, and values are read off the right hand vertical scale.

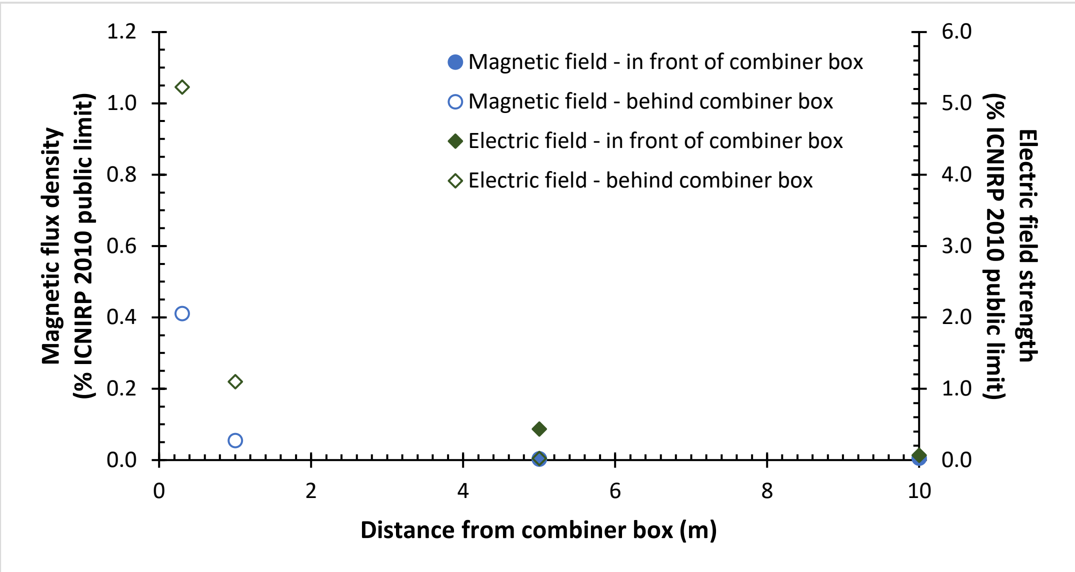

Fig 4. Electric and magnetic fields near the combiner box as a percentage of the ICNIRP 2010 public limits. Filled and open blue circles show magnetic fields in front of and behind the combiner box, respectively, and values are read off the left hand vertical scale. Filled and open green diamonds show electric fields in front of and behind the combiner box, respectively, and values are read off the right hand vertical scale.

The key features of these results are that the electric and magnetic field values are low with respect to both the ICNIRP 1998 and 2010 public limits, and decrease rapidly with increasing distance from the combiner box. At a distance of 10 m in front of the box the readings were effectively just instrument noise.

Close to the combiner box there were weak electric and magnetic fields at frequencies up to about 300 Hz, and also at frequencies around 2.8, 5.6 and 8.4 kHz. Apart from very weak signals at 50 and 100 Hz, these were no longer present at a distance of 10 metres.

2.2 Inverter skid

A quick survey along the sides of the inverter skid showed that the strongest fields were found near the auxiliary transformer (shown in figure 5).

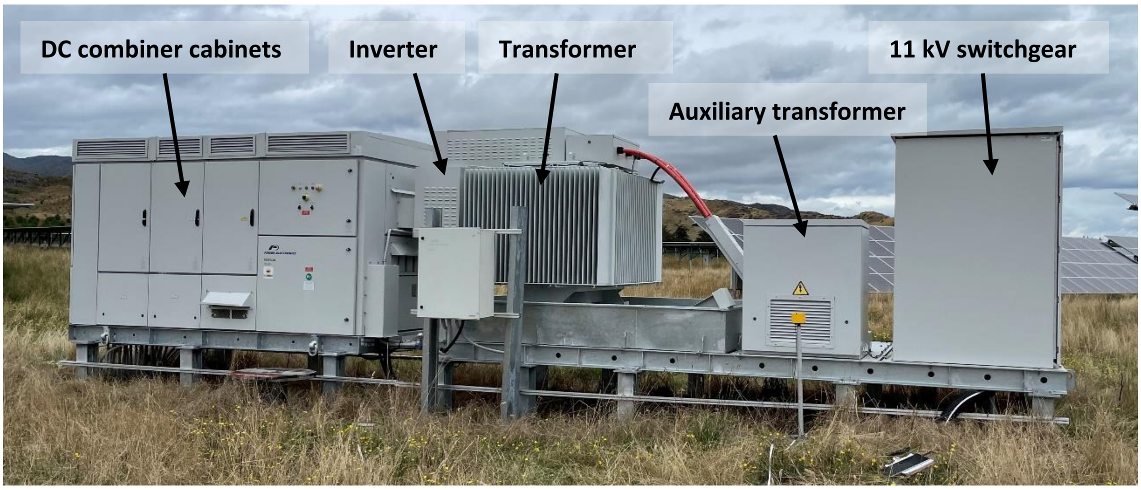

Fig 5. Inverter skid viewed from the east.

Measurements were made to the east of the skid, starting by the auxiliary transformer, as shown in figure 6.

Fig 6. Line along which measurements made near the inverter skid.

Measurement results are plotted in figure 7 (electric and magnetic fields as a percentage of the ICNIRP 1998 public limits) and figure 8 (electric and magnetic fields as a percentage of the ICNIRP 2010 public limits).

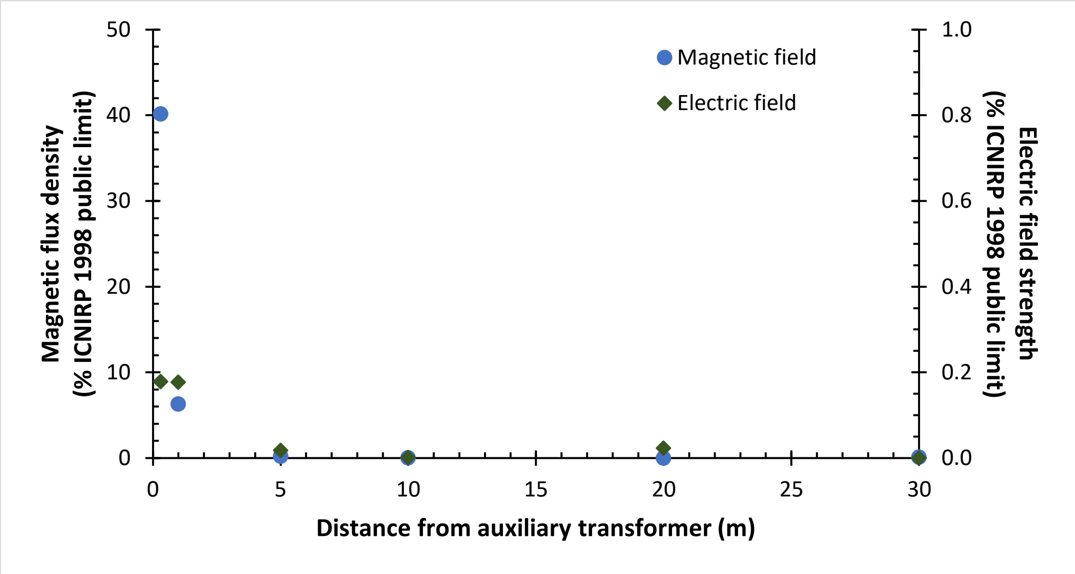

Fig 7. Electric and magnetic fields east of the auxiliary transformer as a percentage of the ICNIRP 1998 public limits. Filled blue circles show magnetic fields and values are read off the left hand vertical scale. Filled green diamonds show electric fields and values are read off the right hand vertical scale.

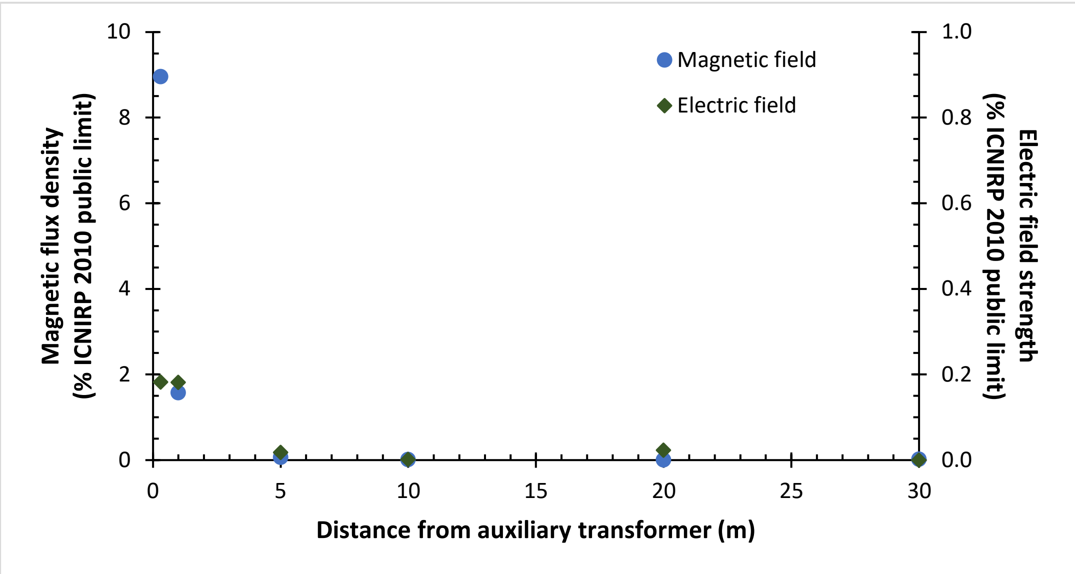

Fig 8. Electric and magnetic fields east of the auxiliary transformer as a percentage of the ICNIRP 2010 public limits. Filled blue circles show magnetic fields and values are read off the left hand vertical scale. Filled green diamonds show electric fields and values are read off the right hand vertical scale.

The key features of these results are that while the magnetic fields are relatively high close to the auxiliary transformer (primarily due to 50 Hz electric currents in the transformer) they decrease rapidly with distance. Electric fields are low everywhere. At a distance of 30 m, examination of the spectra shows that the readings are effectively just due to instrument noise.

2.3 Other locations

Measurements were made in two other locations:

- 50 and 80 m to the west of the inverter skid
- Close to the DC combiner cabinets on the inverter skid

2.3.1 50 and 80 m west of the inverter skid

Measurements were made at the locations indicated on the aerial photo in figure 9.

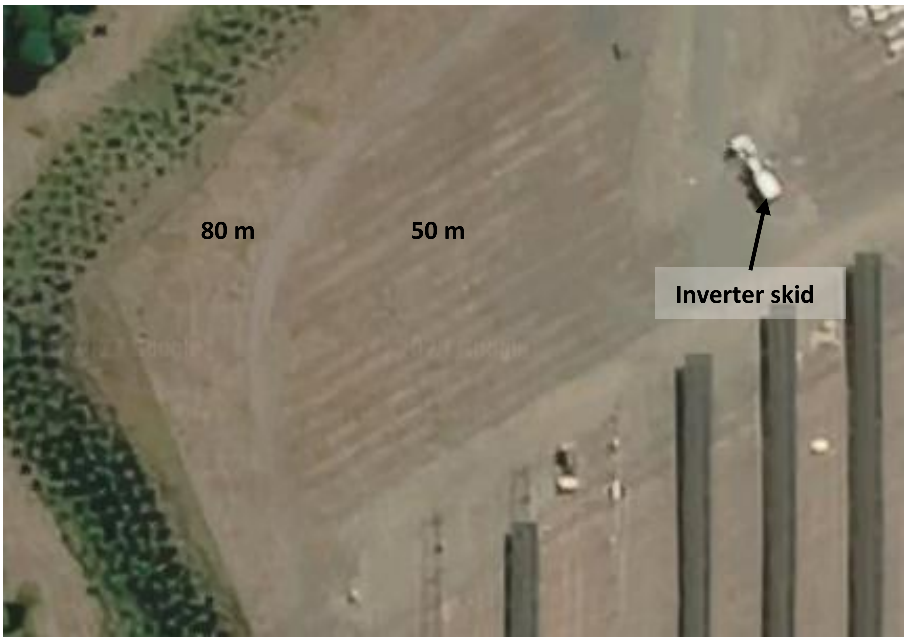

Fig 9. Measurement locations west of the inverter skid. Since this aerial photo was taken, additional rows of solar panels have been added west of the inverter skid.

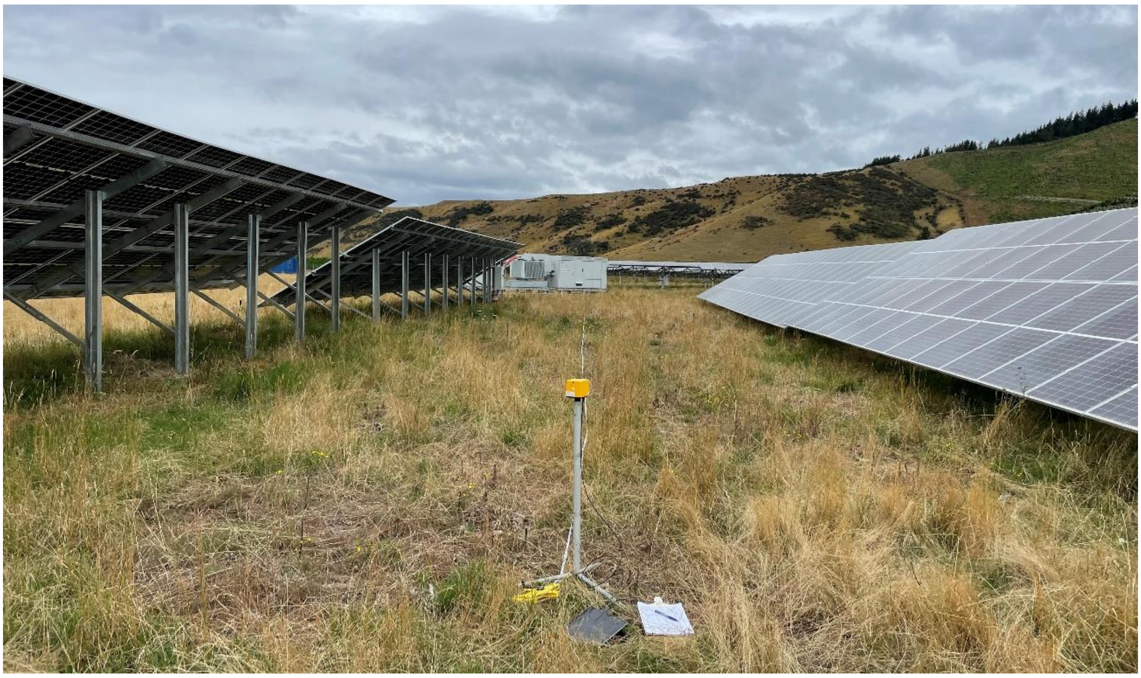

Fig 10. Measurement location 50 m west of the inverter skid.

Results are summarised in Table 1.

Measurement distance	Field level as percentage of ICNIRP limits			
	ICNIRP 1998		ICNIRP 2010	
	E	B	E	B
50 m	0.31	0.000	0.32	0.000
80 m	0.031	0.008	0.031	0.001

Table 1. Electric and magnetic field levels 50 and 80 m west of the inverter skid. Figures give the levels as a percentage of the ICNIRP 1998 and ICNIRP 2010 public limits.

Examination of the spectra showed that there were just very low peaks at frequencies around 100 Hz and 2.8 kHz, probably from nearby combiner boxes, but much of the spectrum was simply instrument background noise.

2.3.2 Close to DC combiner cabinets on the inverter skid

A measurement was made close to the DC combiner cabinets on the west side of the inverter skid. Results are shown in Table 2.

Field level as percentage of ICNIRP limits			
ICNIRP 1998		ICNIRP 2010	
E	B	E	B
0.33	13	0.34	3.0

Table 2. Electric and magnetic field levels on the west side of the inverter skid, near the DC combiner cabinets. Figures give the levels as a percentage of the ICNIRP 1998 and ICNIRP 2010 public limits.

The main contributions to the magnetic fields were at frequencies around 2.8 kHz.

3 Discussion

3.1 Overview of results

The measurements show that at distances more than a metre from the combiner skid, electric and magnetic field levels around the site were very low in comparison to the limits recommended by ICNIRP in 1998 and 2010. The solar panels themselves, and the combiner boxes mounted beneath each string of panels, only produce very weak fields. Beyond the security fence the solar farm would make an indiscernible difference to electric and magnetic field exposures.

On this basis, electric and magnetic fields from the solar farm would have no effect on the health of people around it.

3.2 Static electric and magnetic fields

This survey measured alternating EMFs produced by alternating current components of the solar farm equipment. Static electric and magnetic fields arising from DC currents in the system (eg the DC current generated by the solar panels) were not measured.

DC electric fields would be very low, for two main reasons:

- The metal frames and housings would effectively shield any static electric fields;
- The arrangement of the wiring carrying DC currents, with the positive and negative cables running side by side, results in any DC electric fields to be self-cancelling.

Running the positive and negative cables side by side would also result in self-cancelling of static magnetic fields produced by the DC currents. Any resulting field would be much weaker than the earth's static field, and decrease very rapidly with distance.

3.3 Variation of field strengths with generated power

At the time the measurements were made, the system was generating 600 kVA. The maximum generating capacity is 2.2 MVA (ie about 3.7 times higher than at the time the measurements were made). Future Kea Energy solar farms may use inverter skids with higher capacity, either a single skid with 4.4 MVA capacity or a dual skid housing two 4.4 MVA inverters and an 8.8 MVA transformer. The effects of the greater generation at the Wairau Valley site, and greater capacity at future sites, are considered below.

3.3.1 Combiner boxes

Fields near the combiner boxes only depend on the number of panels being handled by the box and the power generated by those panels, but not the power generated by the whole system. If the Wairau Valley system were to be generating the full 2.2 MVA of which it is capable, then the magnetic fields near the combiner boxes would be approximately 3.7 times higher than measured in this survey, due to the increased current flow. While the electric fields may also change a little (as the operating voltage of the panels varies somewhat, depending on the power being generated) it would be by no more than about a factor of 1.5.

Should a combiner box handle more panels, say 26 instead of the 22 at Wairau Valley, then the magnetic field could increase proportionately. In other words, for a combiner box handling 26 panels generating to their full capacity the magnetic fields could be up to 4.3 times higher than measured in this survey.

The EMFs near the combiner box would still be well below the ICNIRP 1998 and 2010 public limits, and make a negligible difference to fields a few tens of metres from the box.

3.3.2 Inverter skid

The strongest fields were measured near the auxiliary transformer. The purpose of this transformer is to supply power to electrical equipment used at the site (for example, computers and other electronics that control the site). In principle this would not vary as more power is generated. Magnetic fields produced by the main transformer would, however, increase.

A conservative approach would be to assume that the magnetic fields measured by the auxiliary transformer are all attributable to the main transformer, and that they scale in proportion to the power being generated. (The electric fields would be little different, because the system voltage stays the same and the metal housings of the inverter, transformer and other components shield the electric fields). With this worst-case assumption, magnetic fields close to the auxiliary transformer would still comply with the ICNIRP 2010 public limit, and with the ICNIRP 1998 limit for occupational exposures, when the current system is at maximum capacity (noting that normally the public would not be able to get so close to the inverter skid).

For a larger capacity system (eg 4.4 MVA), simply scaling the magnetic field levels measured by a factor of (skid capacity in MVA)/0.6 would almost certainly overestimate the magnetic field. This is because while the currents would increase, the size of the components largely responsible for generating the fields (mostly the transformers) would also increase, which would effectively increase the distance of a measurement point from the centre of the transformer. According to Kea Energy, the auxiliary transformer in these larger systems would be mounted inside the inverter, which increases the distance from that transformer to the edge of the skid. The layout of other components may also differ. Experience measuring large transformers in hydro generating stations and in local power distribution networks suggests that in practice fields close to the transformers would be expected to comply with the ICNIRP 1998/2010 public limits, and certainly comply with the occupational limits.

Even with the larger inverter skids, there would be indiscernible changes to fields outside a security fence around such an installation.

3.4 Fields from the cable feeding into the local distribution network

The power from the solar farm is fed into the local distribution network via a buried 11 kV cable. At future sites a 33 kV cable may be used instead.

There will be no electric fields detectable from this cable, for two main reasons:

- The ground shields all electric fields.
- The close spacing of the conductors in this cable results in self-cancellation of any fields over a very short distance.

Magnetic fields are not shielded by the ground. However, the close spacing of the conductors in the cable again results in self-cancellation of any fields over a very short distance. Measurements above higher capacity buried cables in other places show that directly above the cable the magnetic field is less than 0.2% of the ICNIRP 1998 public limit/0.1% of the 2010 ICNIRP public limit, and decreases rapidly with increasing distance to the side of the cable.

Appendix 1 Nature of low frequency EMFs

Magnetic fields

A field is a concept used to explain how one body can influence or exert a force on another body that is some distance from it. A magnet, for example, attracts an iron nail even though the two objects may be separated by several centimetres. To explain this, we say that the magnet is surrounded by a magnetic field. The magnetic field has the property that it attracts anything made of iron.

A field is often represented by “lines of force”, whose number or density indicate the strength of the field. Around a magnet, the strength and shape of the magnetic field can be visualised by sprinkling iron filings over a piece of paper and holding the paper over the magnet. The filings align themselves in a pattern indicating the shape and direction of the field.

A wire carrying electric current generates a magnetic field around the wire. This field is exactly the same in its nature and properties to the magnetic field around a bar magnet, except that the “lines of force” form circular loops around the wire. The strength of the field decreases with increasing distance from the wire.

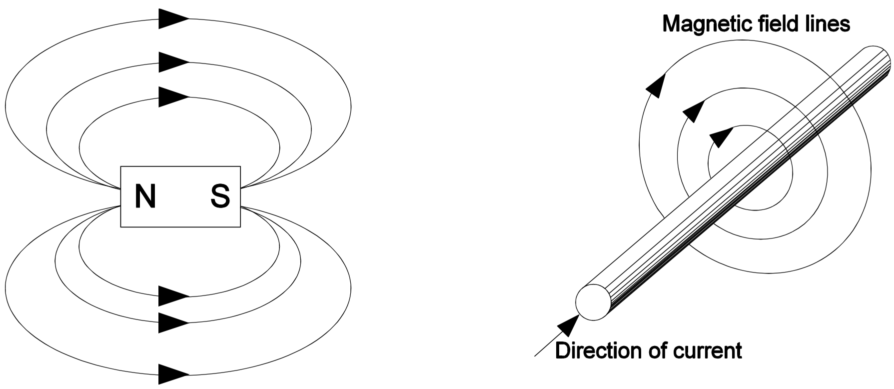

Figure 11. Magnetic field lines around a bar magnet (left) and a current-carrying wire (right)

If the wire carries an alternating current (ie, one which undergoes regular changes in its direction), then the magnetic field around the wire also undergoes regular changes in direction at the same frequency. Current in cables or equipment carrying mains electricity oscillates at a frequency of 50 Hz (ie, 50 times per second) and hence gives rise to a magnetic field that also oscillates at 50 Hz.

50 Hz magnetic fields are found around any cables or appliances carrying mains electricity. Some electronics uses higher frequency currents, and produces higher frequency fields. If the current passes through a coil, as in a transformer or electric motor, the field lines are concentrated and a much stronger field is produced. However, the strength of the field falls off very quickly with distance, in inverse proportion to the square or cube of the distance (in other words, fields measured twice as far away are four to nine times lower). Magnetic fields are not shielded by most materials: special alloys or grades of steel are needed to provide effective shielding.

Magnetic fields are measured in units of microtesla (μT), the unit of magnetic flux density in the SI (International System) of units. In some literature on the subject, an older unit, the milligauss, is sometimes used. There is a factor of ten difference between these two units: 1 microtesla = 10 milligauss, 0.1 microtesla = 1 milligauss etc.

Typical 50 Hz magnetic field levels found in various locations are summarised in the table below.

Location	Typical magnetic fields (μT)
Beneath high voltage power lines (66 kV - 220 kV)	0.3 - 5
30 metres from high voltage line	0.1 - 1.2
Beneath low voltage street lines	0.15 - 2
Along central city streets (no overhead lines)	0.05 - 0.8
Background in houses, offices	0.05 - 0.15
Close to appliances	0.05 - 7
1 metre from appliances	0.005 - 1
Near electric range	0.5 - 2.2

Electric fields

The voltage on a conductor or electrical equipment creates an electric field. Electric fields are created by electric charges. Most people are familiar with the static electric charges created by walking across certain types of carpet when the humidity is very low, or by rubbing synthetic clothing.

Like the electric current, the voltage on a conductor or electrical appliance carrying mains current is not constant but alternates 50 times (cycles) every second. Therefore the electric field also alternates, and the equipment is surrounded by an alternating electric field.

As with magnetic fields, electric fields can be represented by "lines of force". Electric field lines are easily distorted by many materials, even those that are normally thought of as poor conductors. Because of this, electric fields are easily shielded. Trees or shrubs near a transmission line, for example, considerably reduce the electric field strength at ground level. The electric fields are also shielded by buildings and the strength inside a building near a transmission line is much lower than that outside the building.

Electric field measurement results are reported in units of volts per metre or kilovolts per metre (kV/m), the unit of electric field strength in the SI (International System) of units.

Typical 50 Hz electric fields encountered in different situations are tabulated below.

Location	Typical electric fields (kV/m)
Beneath high voltage power lines (66 kV - 220 kV)	0.3 - 4
30 metres from high voltage line	0.03 – 0.3
Beneath low voltage street lines	0.01 – 0.08
Background in houses, offices	0.003 - 0.02
30 cm from appliances	0.006 – 0.9
1 metre from appliances	0.001 – 0.01

Appendix 2 ICNIRP recommended exposure limits

The New Zealand Ministry of Health recommends the use of exposure Guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). ICNIRP is a scientific body, recognised by the World Health Organisation (WHO) for its independence and expertise in this area. Their Guidelines are based on a careful examination of the research data on the health effects of exposure to electric and magnetic fields, and include margins for safety. ICNIRP periodically reviews its Guidelines to take account of new research data, and the most recent revision covering the frequencies of interest in this survey was published in December 2010[1] and updated previous Guidelines published in 1998[2]. The 2010 revision is largely based on a comprehensive review of the relevant research data published by the WHO[3]. The underlying basis for the Guidelines has remained unchanged for more than twenty years. The ICNIRP guidelines have been adopted by a number of overseas health bodies.

Both sets of ICNIRP guidelines set fundamental limits, referred to as *basic restrictions*, on quantities directly based on electric and magnetic field interactions with the body. In the 1998 Guidelines the basic restrictions are on the current density induced in the body by external electric and magnetic fields: in the 2010 version the basic restriction is on the electric fields induced in the body[4] by external fields. As induced current density and electric fields are difficult to measure, the guidelines also prescribe *reference levels* in terms of the more easily measured external magnetic flux density and electric field strength. Compliance with the reference levels ensures compliance with the basic restrictions, and in most applications the reference levels can effectively be regarded as ICNIRP's "exposure limits" (although this term is not used by ICNIRP). If exposures exceed the reference levels, 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.

A *National Policy Statement on Electricity Transmission* published in 2008 under the Resource Management Act requires that planning provisions dealing with ELF fields be based on the 1998 version of the ICNIRP Guidelines and subsequent revisions (ie the 2010 version), as well as recommendations in the WHO review. A National Environmental Standard issued in 2009, which applies to changes to existing transmission lines and cables, also references the 1998 ICNIRP guidelines.

Several local authorities require compliance with the ICNIRP 1998 or 2010 limits in district plan rules dealing with electrical utilities that generate 50 Hz EMFs. Some also have rules requiring compliance with the New Zealand radiofrequency field exposure Standard NZS 2772.1:1999 *Radiofrequency Fields Part 1: Maximum exposure levels – 3 kHz*

1 International Commission on Non-Ionizing Radiation Protection. Guidelines for limiting exposure to time-varying electric and magnetic fields (up to 300 GHz). Health Physics, 99 (6), 818 – 836. Available at: www.icnirp.org.

2 International Commission on Non-Ionizing Radiation Protection. Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz). Health Physics, 74 (4), 494 - 522. Available at: www.icnirp.org.

3 WHO. Environmental health criteria 238. Extremely low frequency fields. WHO, Geneva, 2007. Available for download at: www.who.int/peh-emf/publications/elf_ehc/en/index.html

4 Current density and electric field are effectively two different ways to measure the same effect as they are related by the conductivity of the body: current density = electric field strength x conductivity.

to 300 GHz. As NZS 2772.1 is based on the ICNIRP 1998 Guidelines, this effectively mandates compliance with the ICNIRP 1998 Guidelines at frequencies greater than 3 kHz.

The ICNIRP 1998 and 2010 reference levels vary with frequency as shown in figure 12.

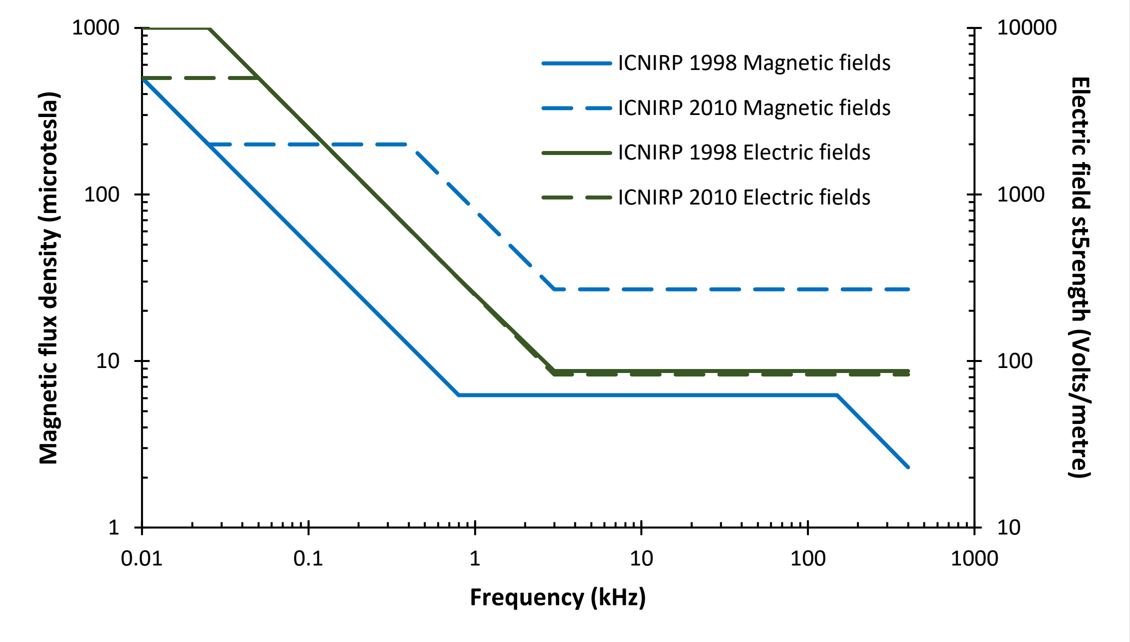

Fig 12. ICNIRP 1998 electric and magnetic field reference levels (limits).

At a frequency of 50 Hz (the frequency of mains electricity) the magnetic field reference levels for continuous exposures of the public in the 1998 and 2010 Guidelines are 100 μT and 200 μT respectively. For occupational exposures, the reference levels are 500 and 1000 μT. The reasons for adopting different limits for occupational and public exposures are:

- Occupational exposures are normally restricted to a limited period of the day;
- People exposed occupationally should normally be aware of the exposure and any precautions that may need to be taken;
- People exposed occupationally would normally be in good health, whereas the public may be of any age and in any state of health.

The Ministry of Health recommends that the occupational limits should only be applied to people like electricians or others who are aware of their exposures and trained in any precautions that might be necessary. In homes, offices and most other work sites, the public limits should apply.

The main reason for the differences between the 1998 and 2010 reference levels is improved understanding of the dosimetry (ie the relationship between external field strengths and electric fields and currents induced in the body).

The ICNIRP Guidelines are based on the prevention of interference with the body's nervous system by electric and magnetic fields. These were the most sensitive health effects of LF fields which could be established with any certainty by WHO. A lot of research has been carried out to try and determine whether there may be other effects at exposure levels much lower than the ICNIRP limits. Although the major focus of the research has been possible effects of exposure EMFs on cancer, other outcomes such as effects on pregnancy, neurodegenerative diseases (Alzheimer's disease, amyotrophic lateral sclerosis (ALS) etc) and cardiovascular disease have also been investigated. This data has been reviewed by the WHO, and also by other groups[5,6,7,8,9]..

Overall, these groups find that there is a weak but relatively consistent association between prolonged exposure to relatively strong magnetic fields (fields greater than around 0.4 μT when averaged over long periods) and childhood leukemia. There is no known mechanism that could explain this association, and so there is doubt whether EMF magnetic fields actually cause the observed increase in childhood leukemia. Evidence of links between exposures and adult cancers are, at most, very weak, and generally inconsistent. There is no good laboratory evidence suggesting any effect of LF fields on the development of cancer. Research data on other outcomes does not provide persuasive evidence that there are any effects, and for some conditions (eg cardiovascular disease and unusual sensitivity to LF fields) it is sufficient to rule out any relationship.

The WHO review concluded that the evidence of an association between LF magnetic fields and childhood leukemia is too weak to suggest a cause and effect relationship and does not justify changing current exposure guidelines. On the other hand, implementing very low cost precautionary measures to reduce exposure is reasonable and warranted provided that the health, social and economic benefits of electric power are not compromised. The WHO has published an information sheet[10].

5 Swedish Radiation Safety Authority (SSM). Scientific Council on Electromagnetic Fields. Fourteenth report, 2020. Report no. 2020:04. Available at: www.stralsakerhetsmyndigheten.se.

6 SCENIHR (Scientific Committee on Emerging and Newly Identified Health Risks). Potential health effects of exposure to electromagnetic fields (EMF). 27 January 2015. Available at: http://ec.europa.eu/health/scientific_committees/consultations/public_consultations/scenihr_consultation_19_en.htm

7 French Agency for Food, Environmental and Occupational Health & Safety (ANSES). Opinion on the Health effects associated with exposure to low-frequency electromagnetic fields. April 2019. Available at: https://www.anses.fr/en/system/files/AP2013SA0038EN.pdf

8 Schuz et al. 2016. Extremely low frequency magnetic fields and risk of childhood leukemia: a risk assessment by the ARIMMORA consortium. Bioelectromagnetics, 37(3) 183-189.

9 Health Council of the Netherlands. Power Lines and Health Part I: Childhood cancer. No. 2018/08. Available at: https://www.healthcouncil.nl/documents/advisory-reports/2018/04/18/power-lines-and-health-part-i-childhood-cancer

10 Available at http://www.who.int/mediacentre/factsheets/fs322/en/index.html

Appendix 3 Electric and magnetic field measuring equipment

The instrument used to measure the electric and magnetic fields was a Narda EHP-50F electric and magnetic field analyser, with the readout through a Windows tablet PC running the Narda EHP50-TS software version 1.78 connected via a fibre optic cable. All readings are true RMS (root-mean-square) values (a kind of average used for alternating quantities). Full specifications are given in the table below.

Manufacturer	Narda Safety Test Solutions GmbH, Pfullingen, Germany
Probe	EHP-50F electric and magnetic field analyser, s/n 000WX60517, firmware v 5.67
Measurement ranges (selectable)	Magnetic fields: 0.003 – 100 μT, 0.03 – 10,000 μT Electric fields: 0.005 – 1,000 V/m, 0.5 – 100,000 V/m
Frequency ranges (selectable)	5 – 100 Hz, 5 – 200 Hz, 6 – 500 Hz, 12 – 1,000 Hz, 0.024 – 2 kHz, 0.12 – 10 kHz, 1.2 – 100 kHz, 4.8 – 400 kHz
Calibration	By the manufacturer, November 2022
Recommended calibration interval	2 years
Measurement uncertainty at 5 Hz – 100 kHz (including calibration uncertainty)	Magnetic fields (0.05 – 10 μT): 5.9% Electric fields (1 V/m – 1000 V/m): 10.3%
Last performance check	January 2023

All measurements were made on the 100 μT and 1000 V/m scales, in the 24 Hz – 2 kHz, 0.024 – 10 kHz and 4.8 – 400 kHz ranges. The probe was supported on a non-conducting stand 1 m above ground level. The measurements were made on 11 January 2023 between about 13:00 and 14:30.

In the data analysis, peaks in the spectra greater than found in a background spectrum were evaluated as a percentage of applicable limits at the frequency of the peak, and the values of each peak summed over the entire frequency range. This gives a conservative evaluation compared with the "weighted peak" approach described in ICNIRP 2020.