ELF EMF Measurement

FOR:

NSW GOVERNMENT HEALTH INFRASTRUCTURE
c/o Wood & Grieve Engineers
6/207 Pacific Hwy
St Leonards, NSW 2065

PROJECT:

BYRON SHIRE CENTRAL HOSPITAL DEVELOPMENT
Evingsdale Road
Byron Bay, NSW 2481

REPORT: **F1019**
DATE: June 2014

ELF EMF Measurement

Report: **F1019**
Issue: June 2014

Test Location: Lot 54
Evingsdale Road
Byron Bay, NSW 2481

Client Details: NSW Government Health Infrastructure

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Specification: National Health & Medical Research Council (NH&MRC)
Interim guidelines on limits of exposure to 50/60 Hz electric and magnetic fields (1989), Radiation Health Series No.30.

AS/NZS™ 61000.6.1:2006 Electromagnetic Compatibility (EMC) Generic standards – Immunity for residential, commercial and light-industrial environments

AS/NZS™ 61000.4.8:2012 Electromagnetic compatibility (EMC) - Testing and measurement techniques - Power frequency magnetic field immunity test

AS/NZS™ 3003:2011
Electrical installations – Patient areas

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REVISION HISTORY

Revision	Issue date	Changes
Draft	10/06/2014	n/a
0	16/06/2014	**p. 4**, second opening paragraph: word "*eastern*" corrected with "*western*"
		Section 2: conversion table expanded
		Section 4.3.1.2: references to specific MRI unit manufacturer removed sentence about application of HV transformer distances to cables removed
		Section 8.4: explanatory sentence "*where the cables' distance to the ground was the shortest*" removed
		Section 8.5: words "*where the cables' distance to the ground was the shortest*"
		Section 9.1: measured minimum and maximum magnetic field levels inserted
		Section 9.2: first paragraph: *"up to 68% (winter load)"* was replaced with *"to up to 68% (winter load) of the substation's total capacity"* second paragraph: last sentence revised and moved to Section 9.3
		Section 9.3: "first paragraph revised"
		Spelling, grammatical and syntax errors corrected

ELF EMF MEASUREMENT
for

NSW GOVERNMENT HEALTH INFRANSTRUCTURE c/o WOOD & GRIEVE ENGINEERS

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SUMMARY

As part of the development of Byron Shire Central Hospital, new buildings will be constructed on Lot 54 at Evingsdale Road, Byron Bay, NSW.

Lot 54 is adjacent to the electrical Zone Substation owned by Essential Energy. High Voltage (HV) cabling is distributed overhead along the northern boundary of the lot, while the western, and in parts southern boundaries have the HV and Low Voltage (LV) services laid underground. See Fig. 1 in Appendix A.

Concerns were raised about the possible impact of the electrical services on people, and medical equipment/instrumentation sensitive to electromagnetic interference.

Faraday Pty Ltd was engaged to:

- conduct power frequency electromagnetic field (EMF) measurements within Lot 54 to establish the levels of the electromagnetic interference (EMI) from the Zone Substation and associated overhead and underground cabling
- extrapolate the levels of EMI at present, and considering future maximum demand
- assess the measured and calculated EMI levels against limits set in the relevant standards and guidelines
- recommend solutions in cases of non-compliance, including EMF mitigation and/or establishing of exclusion zones, if necessary.

The following documents were taken into consideration in establishing the required levels of exposure for the new facility:

- National Health & Medical Research Council (NH&MRC)
  Interim guidelines on limits of exposure to 50/60 Hz electric and magnetic fields
- UK National Radiological Protection Board - Advisory Group on Non-Ionising Radiation (AGNIR)
  Power Frequency Electromagnetic Fields and the Risk of Cancer
- Australian and New Zealand Standard AS/NZS™ 61000.6.1:2006
  Electromagnetic Compatibility (EMC) Generic standards – Immunity for residential, commercial and light-industrial environments
- Australian and New Zealand Standard AS/NZS™ 61000.4.8:2012
  Electromagnetic compatibility (EMC) - Testing and measurement techniques - Power frequency magnetic field immunity test
- Australian/New Zealand Standard AS/NZS™ 3003:2011
  Electrical installations – Patient areas
- various MRI units installation manuals

The 50Hz magnetic field measurements were taken along Lot 54's boundaries and reported as the combined field value of the three axes.

All readings were taken at the present (as on 4/06/2014, between 10:am and 3pm) load conditions for the existing electrical system.

Field levels varied between less than 10nT (0.01μT) and 830nT (0.83 μT) with the load fluctuations at the time of the measurements not exceeding ±5%.

The harmonic content of the measured magnetic field did not exceed 2.5% and registered the highest value of 4nT with the fundamental of 160nT.

A significant reduction of the magnetic field was observed when the measurements were taken inside Lot 54's boundaries, away from the electrical services. The minimum decrease of 34% (from 0.35μT to 0.23μT) occurred 5m into the property, gradually reaching 72% (from 0.23μT to 0.065μT) at 20m.

From the measurements, none of the magnetic field limits prescribed in the reference standards and guidelines were exceeded within the boundaries of Lot 54.

The 132kV load data obtained from Essential Energy indicate that the electrical system was loaded to 46.2% at the time of measurement.

The company forecasts the increase in power consumption to up to 68% (winter load) of the substation's total capacity by 2019.

There are presently no plans to increase the designed capacity of the substation, but the recorded magnetic field may still double after 2019. However, for the next five years, the magnetic field should not increase to levels exceeding its current values by 50%.

Considering the information obtained to date, none of the magnetic field limits, as stated in the referenced standards and guidelines, should be exceeded in the event of the Zone Substation being loaded to its maximum capacity. This is with the exception of faults or severely unbalanced phase loads.

The expected increases in the magnetic field level may impact only on the most sensitive hospital equipment as defined in section 4.3.2 of this report. This is because the externally generated field will combine with the field generated by in-building electrical services.

Irrespective of the above, magnetic shielding may be required to some of the in-building electrical services to protect the highly sensitive hospital equipment. The future shielding requirement, if any, can be determined based on the magnetic field calculations considering the field sources external and internal to the building.

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As part of the development of Byron Shire Central Hospital, new buildings will be constructed on Lot 54 at Evingsdale Road, Byron Bay, NSW.

Lot 54 is adjacent to the electrical, 30MVA (N-1) Zone Substation owned by Essential Energy. High Voltage (HV) cabling is distributed overhead and underground along northern boundary of the lot, while the western, and in parts southern boundaries have the HV and Low Voltage (LV) services laid underground only. See Fig. 1 in Appendix A.

Concerns were raised about the possible impact of the electrical services on people, and medical equipment/instrumentation sensitive to electromagnetic interference.

1. SCOPE

Faraday Pty Ltd was engaged to:

- conduct power frequency electromagnetic field (EMF) measurements within Lot 54 to establish the levels of the electromagnetic interference (EMI) from the Zone Substation and associated overhead and underground cabling
- extrapolate the levels of EMI at present, and considering future maximum demand
- assess the measured and calculated EMI levels against limits set in the relevant standards and guidelines – see specification on page 2 of this report
- recommend solutions in cases of non-compliance, including EMF mitigation and/or establishing of exclusion zones, if necessary.

2. UNITS

For the purpose of this report, the magnetic flux densities have been expressed in Tesla, abbreviated as T.

Note that the older unit, used prior to year 1988 (when full transition from the Imperial to the International System of Units, SI, occurred in Australia), was Gauss - abbreviated as Gs or G:

1 T = 10 kGs	1 kGs = 0.1 T	1 T = 10^6 µT
1 mT = 10 Gs	1 Gs = 0.1 mT	1 µT = 10^3 nT
1 µT = 10 mGs	1 mGs = 0.1 µT	1 nT = 10^{-3} µT
1 nT = 10 µGs	1 µGs = 0.1 nT	

3. REGULATIONS

3. 1 Human exposure to power frequency magnetic field

3.1.1 Currently there is no standard in Australia regulating human exposure to power frequencies electromagnetic field.

In December 2006 Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) released the draft *Radiation Protection Standard: Exposure Limits for Electric and Magnetic Fields 0Hz – 3kHz*. The standard, however, has not been ratified to date.

3.1.2 Human exposure to power frequency magnetic fields is currently regulated by the National Health and Medical Research Council (NHMRC) *Interim guidelines on limits of exposure to 50/60 Hz electric and magnetic fields (1989), Radiation Health Series No.30*.

3. 2 Electronic and electrical equipment exposure to magnetic fields

3.2.1 The following standards regulate exposure to power frequencies magnetic field for general and medical electronic and electrical equipment:

- Australian and New Zealand standard *AS/NZS™ 61000.6.1:2006 Electromagnetic Compatibility (EMC) Generic standards – Immunity for residential, commercial and light-industrial environments*
- Australian and New Zealand standard *AS/NZS™ 61000.4.8:2012 Electromagnetic compatibility (EMC) - Testing and measurement techniques - Power frequency magnetic field immunity test*
- Australian and New Zealand standard *AS/NZS™* 3003:2011 *Electrical installations – Patient areas.*

3.2.2 The most sensitive to electromagnetic interference medical equipment has the immunity levels individually specified by the manufacturer. This includes Magnetic Resonance Imaging (MRI), Electroencephalography (EEG), Electromyography EMG), and Electronystagmography (ENG), devices.

4. EXPOSURE LIMITS

4. 1 Human exposure limits

4.1.1 The NHMRC guidelines recommend the following limits of exposure to the power frequency magnetic field:

- *members of the general public should not be exposed on a continuous basis to unperturbed magnetic flux densities exceeding 0.1mT. This restriction applies to areas in which members of the general public might reasonably be expected to spend a substantial part of the day*

- *for the general public, exposures to magnetic flux densities between 0.1mT and 1mT should be limited to a few hours per day. When necessary, exposures to magnetic flux densities in excess of 1mT should be limited to a few minutes per day*

- *continuous occupational exposure during the working day should be limited to magnetic flux densities not greater than 0.5mT*

- *short-term occupational whole body exposure for up to two hours per workday should not exceed a magnetic flux density of 5mT. When restricted to the limbs, exposures up to 25mT can be permitted.*

4.1.1.1 Concerns about the NH&MRC values were already summarised in the NSW Government commissioned comprehensive report by Sir Harry Gibbs: *Inquiry into Community Needs and High Voltage Transmission Line Development (1991)*.

The report outlines that the recommended exposure levels are well above the levels at which the fields may create a risk, as suggested in the guidelines. However, it should be recognised that the guidelines were established on the basis of instantaneous or short term exposure to the EMF. The limits, therefore, do not apply to the avoidance of a risk resulting from chronic exposures to power frequency electromagnetic fields.

4.1.1.2 The scientific report published in 2000 by the British Journal of Cancer, *A pooled analysis of magnetic fields and childhood leukaemia, 83(5), 692–698 (2000)*, suggests a statistical correlation between the time weighted long term average exposure level of 0.4μT and increased occurrences of childhood leukaemia.

4.1.1.3 The UK National Radiological Protection Board Advisory Group on Non-Ionising Radiation (AGNIR) accepted the BJC's report findings: *Power Frequency Electromagnetic Fields and the Risk of Cancer (2001).*

4.1.1.4 Due to increasing concerns about the effect of magnetic fields on people, a growing number of scientific and health organizations around the world tend to agree that the limit for continuous exposure to power frequency magnetic field should be set below 0.4μT time weighted average.

4.1.1.5 Considering the limit given above, a 24 hour continuous exposure to 0.4μT magnetic field is equivalent to 1.2μT exposure over an 8 hour (typical workday) period:

$$0.4\mu T \cdot 24 \text{ hours} \equiv 1.2\mu T \cdot 8 \text{ hours}$$

As it is impossible to guarantee no exposure to magnetic field after the 8 work hours, the calculated 1.2μT level needed to be reduced to 1μT. This allows for the additional continuous average exposure of 0.1μT during the rest of the day:

$$0.4\mu T \cdot 24 \text{ hours} \equiv 1\mu T \cdot 8 \text{ hours} + 0.1\mu T \cdot 16 \text{ hours}$$

4.1.2 The 1μT human exposure level as stated above is to be considered as an alternative to the 100μT non-occupational limit prescribed by NH&MRC.

4. 2 Electronic and electrical equipment exposure limits by Standards

4.2.1 *AS/NZS™ 61000.6.1:2006* sets the generic limit for immunity to power frequency magnetic fields as:

- 3A/m (equivalent to approximately 3.75μT) for all equipment
- 1A/m (equivalent to approximately 1.25μT) for magnetic deflection screen based equipment (ie Cathode-Ray Tube (CRT) Visual Display Units (VDUs).

4.2.2 AS/NZS 61000.4.8:2012 sets the 3A/m (equivalent to approximately 3.75μT) for all medical electrical equipment.

4.2.3 AS/NZS™ 3003:2011 sets the maximum allowed power frequencies magnetic field level in patient areas, where low-voltage medical equipment will contact patients at:

- 3μT – broadband total
- 1.6μT – individual harmonics.

4.2.3.1 Patient areas, are defined as:

- cardiac catheterisation laboratories
- intensive care units
- coronary care units
- resuscitation units
- accident and emergency departments
- outpatient departments for diagnostic, i.e. ECG
- stress testing units.

4. 3 Specific medical equipment exposure limits to electromagnetic interference

4.3.1 MRI equipment manufacturers typically specify minimum required distances to the magnet for various types of electromagnetic disturbance sources e.g. ferromagnetic objects in motion (not in the scope of this report), power transformers. Some manufacturers also identify permissible magnetic field levels depending on the source's distance to the magnet.

4.3.1.1 MRI units are typically susceptible to 50Hz magnetic fields of approximately 2μT level.

4.3.1.2 The table below gives typical distances to 1.5T MRI units at which HV power transformers are allowed to be present not to cause interference:

Transformer	Minimum distance to iso-center of a magnet [m]	
	perpendicular to patient table	along patient table
< 100kVA	5.5	6.5
100 – 250kVA	6	7
250 – 650kVA	6.5	8
650 – 1600kVA	7	9.5

4.3.1.3 As the exposure limits vary between the MRI systems' manufactures and also differ depending on the type of magnet, the above given values are not to be applied universally.

4.3.2 An electromagnetic environment for EEG, EMG, ENG equipment; equipment used for electrophysiological and vestibular assessments is substantially more restrictive. The manufacturers often do not specify immunity levels as they depend on the equipment setup, patient's physical condition, and nature of the conducted medical examinations.

Some of the devices are sensitive to magnetic fields even below 0.1μT.

5 TEST EQUIPMENT

MAGNETIC FIELD MEASURING SYSTEM			
DEVICE	**MAKE/MODEL**	**SERIAL NO.**	**Cal. Due**
LF Spectrum Analyser	Aaronia AG / Spectran NF-5035	42538	21/01/2016

6 TEST METHODOLOGY

6.1 The 50Hz magnetic field measurements were taken along Lot 54's boundaries at regular intervals 1m above the ground.

6.2 The measurements were taken with the test equipment set to measure the combined field value of the three axes.

6.3 Spot measurements were taken where required to check the field reduction rate with distance.

6.4 Harmonics' level was monitored to establish its content in relation to the fundamental frequency.

7 LIMITATIONS

5.1 Measurements were taken at the present (as on 4/06/2014, between 10:am and 3pm) load conditions for the existing electrical system.

The load conditions are as per Table 1.

5.2 Following changes in power consumption, it may be necessary to investigate the possibility of increased magnetic field emissions.

Table 1. Phase load in Amperes [A], averaged over 5 minute periods.

Date / Time	132kV	11kV
4/06/2014 10:00	112	394
4/06/2014 10:05	106	394
4/06/2014 10:10	106	394
4/06/2014 10:15	106	394
4/06/2014 10:20	106	394
4/06/2014 10:25	106	394
4/06/2014 10:30	106	394
4/06/2014 10:35	108	407
4/06/2014 10:40	108	408
4/06/2014 10:45	108	408
4/06/2014 10:50	108	408
4/06/2014 10:55	108	407
4/06/2014 11:00	114	404
4/06/2014 11:05	115	406
4/06/2014 11:10	109	397
4/06/2014 11:15	107	397
4/06/2014 11:20	101	380
4/06/2014 11:25	101	379
4/06/2014 11:30	101	375
4/06/2014 11:35	101	375
4/06/2014 11:40	101	375
4/06/2014 11:45	101	375
4/06/2014 11:50	93	375
4/06/2014 11:55	93	381
4/06/2014 12:00	93	374
4/06/2014 12:05	95	379
4/06/2014 12:10	95	376
4/06/2014 12:15	95	378
4/06/2014 12:20	99	386
4/06/2014 12:25	100	375
4/06/2014 12:30	100	375
4/06/2014 12:35	94	373
4/06/2014 12:40	94	378
4/06/2014 12:45	97	372
4/06/2014 12:50	99	371
4/06/2014 12:55	102	371
4/06/2014 13:00	104	378

8 MEASUREMENT RESULTS

8.1 The measurement results taken along each of the boundaries of Lot 54 are given it table 2.

Table 2. Magnetic field, in nT, measured along boundaries of Lot 54

Boundary A (at each post)	Boundary B (each ~5m)	Boundary C	Boundary D (each ~10m)
345 (corner)	830 (corner)	<10 (corner)	340 (corner)
195 (2.6m from corner)	695	<10 (~5m from prev.)	265
140 (each 4.2m)	190	<10 ↓	350
100 ↓	80	10 ↓	350
70 ↓	50	10 ↓	355
55 ↓	35	10 ↓	320
45 ↓	25	15 ↓	305
25 ↓	20	15 ↓	275
20 ↓	15	15 ↓	245
30 ↓	15	20 ↓	225
55 ↓	10	20 ↓	230
75 ↓	10	25 ↓	250
105 ↓	<10	25 (C2 - gate)	270
155 ↓	<10	30 (4.1m from prev.)	305
165 ↓	<10	30 ↓	320
150 ↓	<10	30 ↓	335
140 ↓	<10	35 ↓	350
135 ↓	<10	35 ↓	345
140 ↓	<10	35 ↓	350
130 ↓	<10	40 ↓	350 (corner)
135 ↓	<10	40 ↓	
135 ↓	<10	40 ↓	
135 ↓	<10	45 ↓	
135 ↓	<10	55 ↓	
130 ↓	<10	70 ↓	
135 ↓	<10	80 ↓	
130 ↓	<10	100 ↓	
125 ↓	<10	135 ↓	
130 ↓	<10	175 ↓	
135 ↓	<10	230 ↓	
120 (2.5m from prev.)	<10	335 ↓	
130 (each 4.2m)	<10		
135 ↓	<10		
135 ↓	<10		
140 ↓	<10		
130 ↓	<10		
135 ↓	<10		
160 ↓	<10		
155 ↓	<10		
140 ↓			
180 ↓			
290 (5m from prev.)			
530 (2.5m from prev.)			
830 (4.1m from prev.)			

8.2 The harmonic content of the measured magnetic field did not exceed 2.5% and registered the highest value of 4nT with the fundamental of 160nT.

They were the 5th and 3rd harmonics, in the order of effect, having the biggest impact on the measured field.

8.3 Measurements taken inside Lot 54's boundaries, at various distances from the electrical cabling resulted in the following minimum reductions in the magnetic field levels as compared with the levels obtained at the boundaries:

- at 5m distance: 34% reduction (from 350nT to 230nT)
- at 10m distance: 48% reduction (from 230nT to 120nT)
- at 15m distance: 63% reduction (from 230nT to 85nT)
- at 20m distance: 72% reduction (from 230nT to 65nT)

8.4 The magnetic field measured directly under the overhead HV cabling reached the maximum of 570nT.

8.5 The substation load fluctuations at the time of the measurements did not exceed ±5%.

9 ANALYSIS, CONCLUSIONS, RECOMMENDATIONS

9.1 From the measurements, none of the magnetic field limits prescribed in the reference standards and guidelines were currently exceeded within the boundaries of Lot 54. The field levels varied between less than 10nT (0.01μT) and 830nT (0.83 μT). However, the recorded values will increase, following the increased load on electrical system as well as expansion of services by Essential Energy.

9.2 The 132kV load data obtained from Essential Energy indicate that the electrical system was loaded to 46.2% at the time of measurement.

Essential Energy forecasts the increase in power consumption to up to 68% (winter load) of the substation's total capacity by 2019.

9.3 There are presently no plans to increase the designed capacity of the substation, but the recorded magnetic field may still double after 2019. However, for the next five years, the magnetic field should not increase to levels exceeding its current values by 50%.

None of the magnetic field limits, as stated in the referenced standards and guidelines, should be exceeded in the event of the Zone Substation being loaded to its maximum capacity. This is with the exception of faults or severely unbalanced phase loads.

9.4 The expected increases in the magnetic field level may impact only on the most sensitive hospital equipment as defined in section 4.3.2 of this report. This is because the externally generated field will combine with the field generated by in-building electrical services.

Irrespective of the above, magnetic shielding may be required to some of the in-building electrical services to protect the highly sensitive hospital equipment. The future shielding requirement, if any, can be determined based on the magnetic field calculations considering the field sources external and internal to the building.

APPENDIX A

Drawings

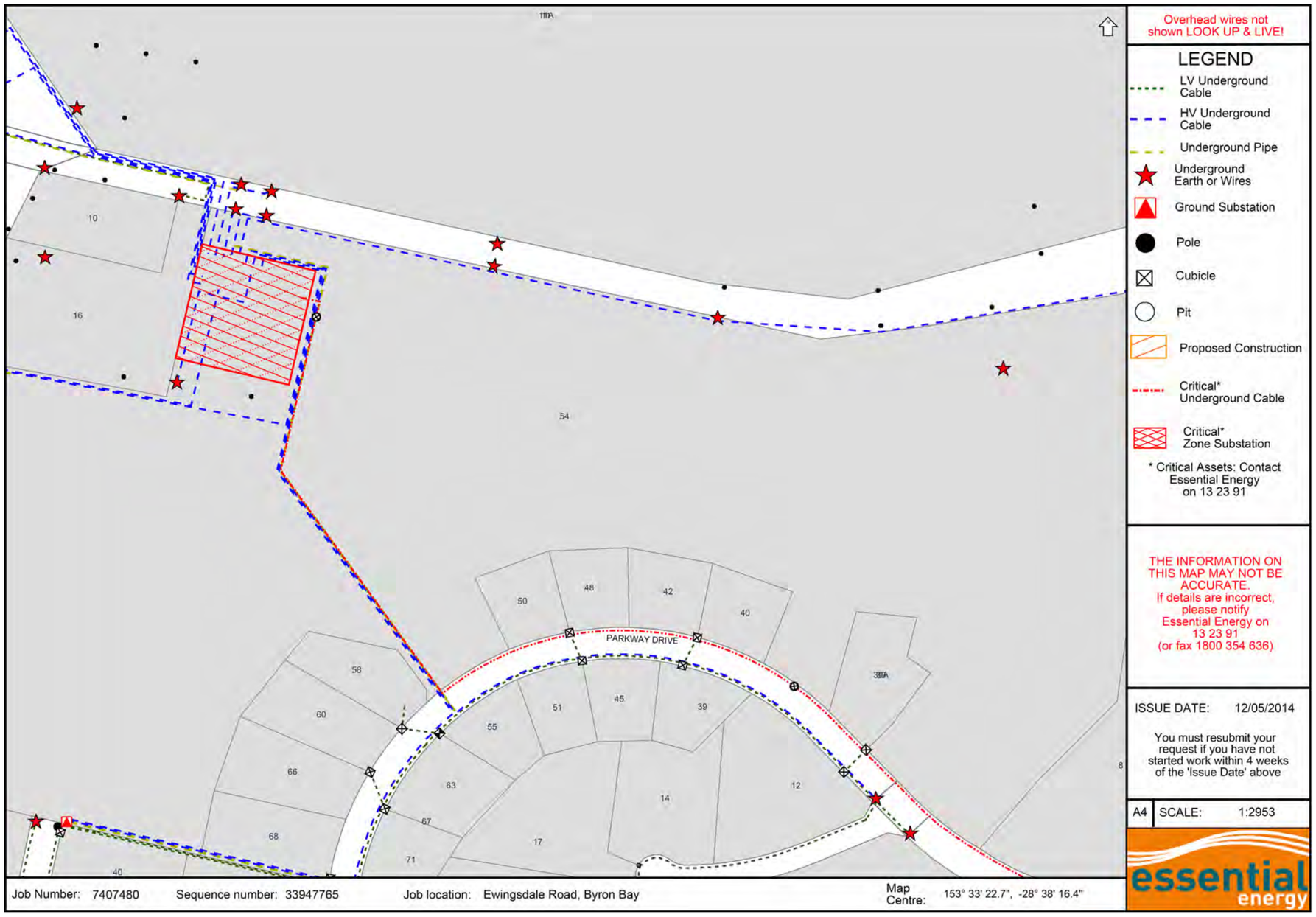

Fig. 1. Location of electrical Evingsdale Road Zone Substation and relevant cable network

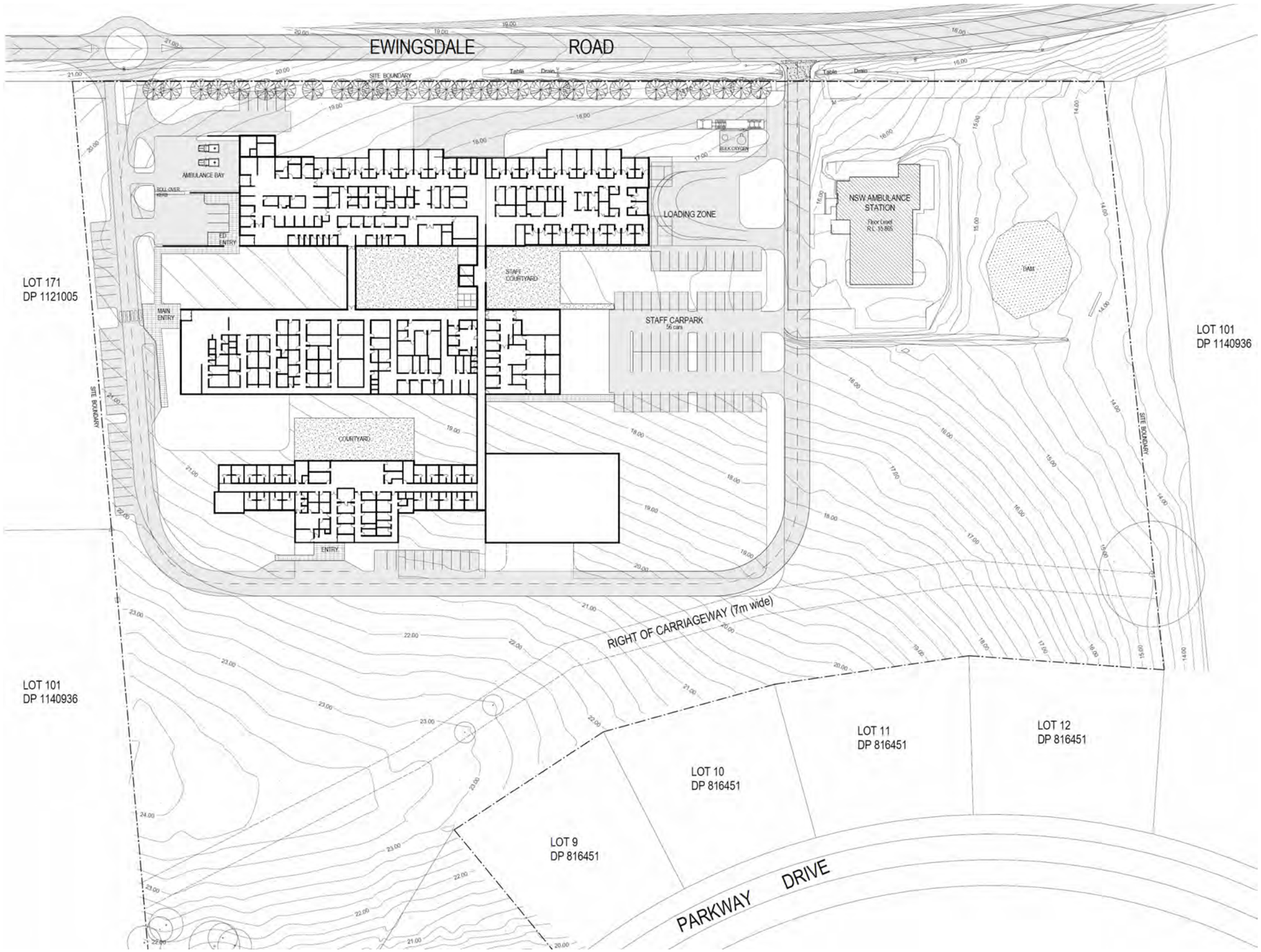

Fig. 2 Proposed Byron Shire Central Hospital Development

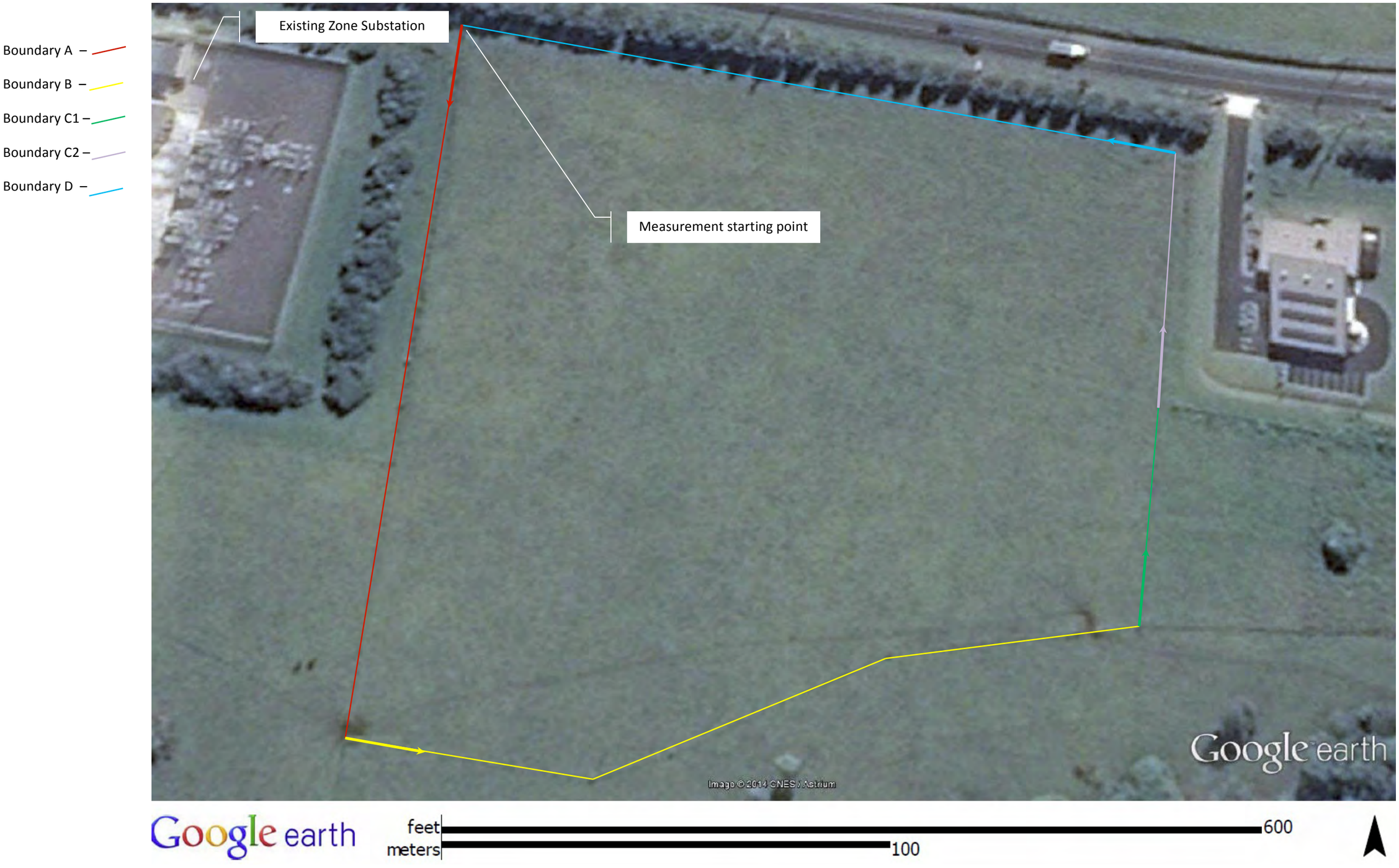

Fig. 3. Test points location

APPENDIX A

Photographs

Phot. 1. View of boundary A (red marked)

Phot. 1. View of boundary B (yellow marked)

Phot. 1. View of boundary C1 (green marked)

Phot. 1. View of boundary C2 (purple marked)