# METRO NORTH

# ORAL HEARING

Mater Hospital

Assessment of Magnetic Field Strengths

23 February 2009

**Metro North**

# ASSESSMENT OF MAGNETIC FIELD STRENGTHS FROM PROPOSED METRO NORTH SYSTEM AT MATER PRIVATE HOSPITAL

Issue 1

## DOCUMENT HISTORY LOG

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# 1.0 ASSESSMENT OF MAGNETIC FIELD STRENGTHS FROM PROPOSED METRO NORTH SYSTEM AT MATER PRIVATE HOSPITAL

## 1.1 Introduction

At the request of the Railway Procurement Agency CEI has carried out an assessment of the potential for electromagnetic interference from the proposed Metro North railway on equipment located in the Mater Hospitals.

## 1.2 Background

The Mater Private Hospital (MPH) had raised concerns regarding the impact of magnetic field emissions from the proposed Metro North system and the potential effects on hospital equipment using electron beams including Linear Accelerators and CT Scanners. There was anecdotal evidence that these devices had experienced operational problems at the Beth Israel Hospital in New York because of the proximity to the New York Subway.

## 1.3 Proposed Metro System

Light Metro Vehicles (LMV) using the proposed system will draw current from the overhead conductor system (OCS) and return that current to the supply substation via the rails and bonding cables routed alongside the track. DC magnetic fields result which decrease at distances from the track. As the current in the OCS is flowing in a different direction to the current in the tracks a significant amount of natural cancellation results. Magnetic fields pass undiminished through common construction materials and earth works. Steelwork may reduce the fields by a small amount. Conversely electric and radiofrequency fields do not pass easily through the earth works and these can be ignored.

The magnetic field from each conductor is defined by:

$$H = I / (2 * \pi * r)$$

where:

H: magnetic field intensity [measured in amps per metre];

I: traction current (Amps A):

r: distance between source point and receptor.

At any determined point in space, magnetic fields of various sources may interfere with each other. The resulting magnetic field may be amplified or compensated as a result of these interferences.

The field intensity (strength) depends upon the magnitude of the current and the distance between that conductor (source) and the destination point (receptor). A planar view of the conductors is shown in Figure 1.1.

The current flows in the overhead conductor and returns via the rails split equally between the two. Therefore, the magnetic fields partially cancel.

The magnetic flux density is related to the magnetic field strength by the relationship:

$$B = \mu_0 * \mu_r * H$$

where:

B: magnetic flux density (measured in Tesla [T]);

$\mu_0$: absolute permeability (physical constant);

$\mu_r$: relative permeability (coefficient of materials).

In air B (μT) = 1.26 x H (A/m)

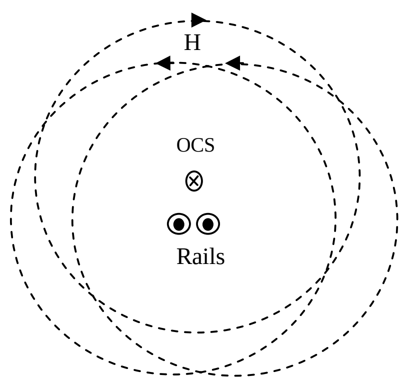


**Figure 1.1: Cancellation effect of current in OCS and rails**

The earth's magnetic field is static at approximately 50 µT. However, large metal objects such as a passing truck, a coasting rail vehicle or a high speed lift can perturb the static magnetic field to yield a time variant field.

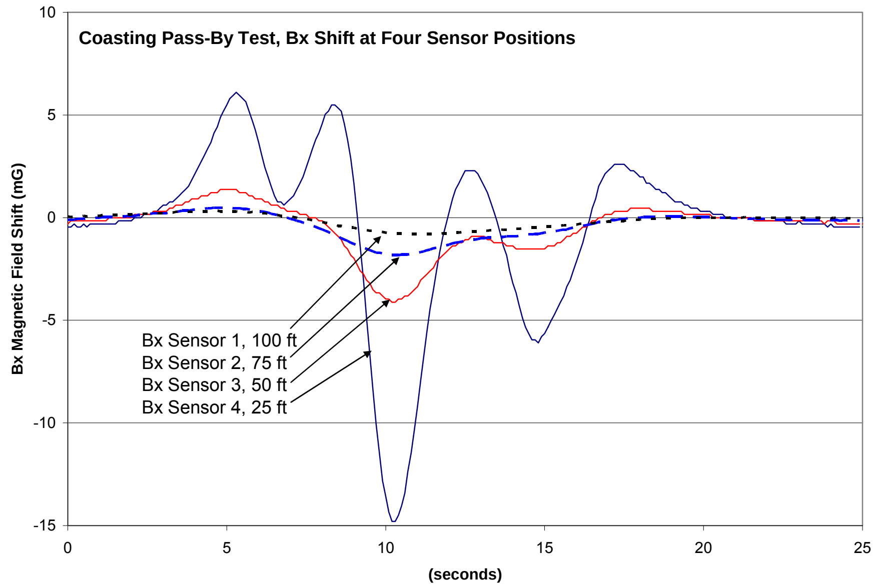


**Figure 1.2: Recorded magnetic field shifts of the Bx magnetic field component for a three-car train coasted pass the sensor array with the pantograph down.**

Source: Denver RTD, ERM Inc

Note 1: Bx only shown as being the maximum component

Note 2: 10 mG = 1µT

CEI has previously carried out DC magnetic field measurements at the Luas Red line at Tallaght hospital as shown below.

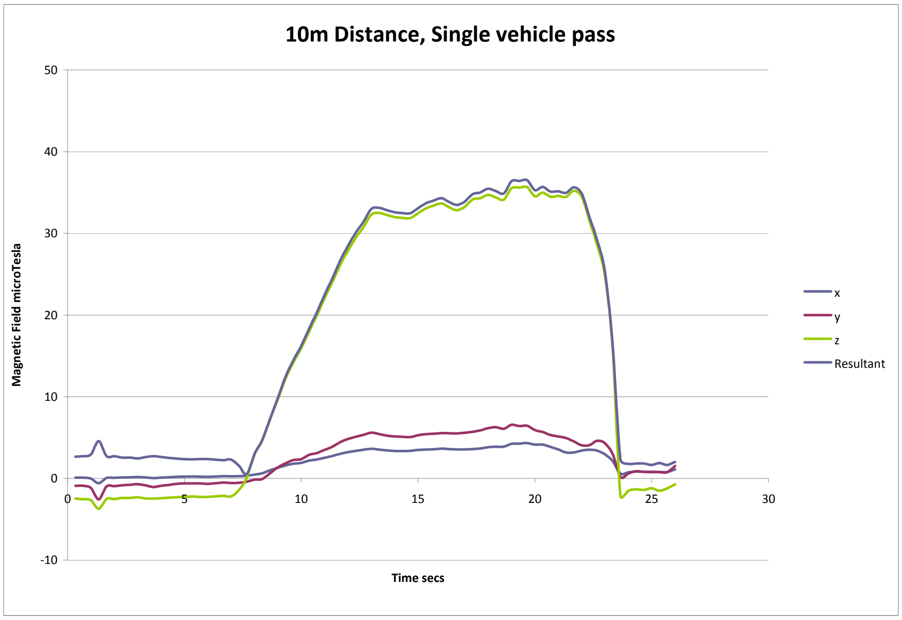


**Figure 1.3: Measurement of Magnetic Field at 10m from Red Line, Tallaght**

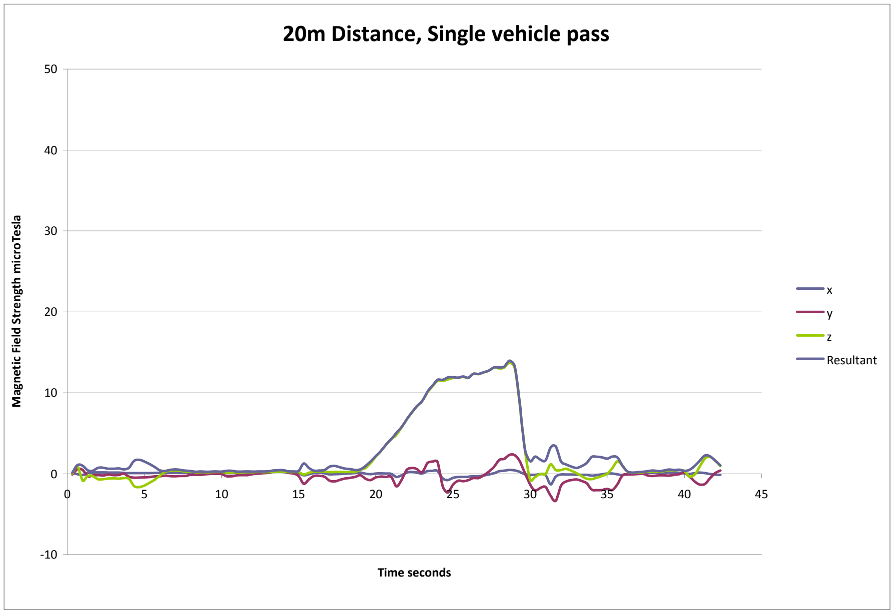


**Figure 1.4: Measurement of Magnetic Field at 20m from Red Line, Tallaght**

The results taken at Tallaght were for a 6m height OCS which produces higher magnetic fields than the 3.9m system used on underground sections because of the lesser cancellation yielded.

### 1.4 50 Hz Power frequency and Radiofrequency Fields

The Metro North will utilise a 20 kV ring to feed power to the traction substations and local services. In addition, there will be a two way radio system in operation.

The 20 kV ring is routed via a multicore cable with the conductors arranged in a triform configuration. As a result, the three phases are very closely coupled and the natural cancellation of the magnetic fields is very high. Considering the distances of the MPH from the circuit any magnetic fields emitting from this source will be negligible at ground level. It should also be noted that magnetic fields are solely a function of current. The current in 20 kV circuits is low compared to low voltage cables. As a result, the local magnetic fields in the hospital will be predominated by the building wiring.

The radiofrequency fields generated in the tunnels, as noted earlier, will be totally absorbed by the earthworks. In any event, the radiofrequency emissions will be similar to those caused by the plethora on street licensed transmitters such as ambulances, Garda Síochana, taxis, security handhelds, mobile phones etc.

### 1.5 Electromagnetic Immunity

The equipment that tends to be susceptible to DC field variations normally uses electron beam technology. The most common device is cathode ray tube (CRT) computer monitors and TVs. There are a variety of scientific and medical instruments that use similar technology including Scanning Electron Microscopes, NMRs, CT Scanners and Linear Accelerators (Linac).

European and international electromagnetic compatibility regulation rarely specify immunity levels for DC magnetic fields. In part this is because of the small number of environments where static magnetic fields occur other than the earth’s magnetic field to which all equipment is exposed. In addition, when a limit is specified, there is a tendency to specify DC field immunity level of 50 μT which is the earth’s magnetic field. Whilst equipment may tolerate the static field caused by the earth, little is known about susceptibility to the time varying DC field caused by DC traction systems.

There are no EMI immunity values from IEEE, EEC, EN or other governing standard organizations for time varying DC fields

**MAGNETIC FRINGE FIELDS**

MAGNETIC FIELDS MAY AFFECT THE FUNCTION OF DEVICES IN THE VICINITY OF THE MAGNET. THESE DEVICES MUST BE OUTSIDE CERTAIN MAGNETIC FIELDS. THE DISTANCES LISTED ARE FROM THE MAGNET ISOCENTER AND DO NOT CONSIDER ANY MAGNETIC ROOM SHIELDING.

| X/Y AND Z AXIS | DEVICES |
|---|---|
| 6'-2" / 8'-3" 3.0mT | SMALL MOTORS, WATCHES, CAMERAS, CREDIT CARDS, MAGNETIC DATA CARRIERS (SHORT-TERM EXPOSURE) |
| 7'-7" / 11'-6" 1.0mT | COMPUTERS, MAGNETIC DISK DRIVES, OSCILLOSCOPES, PROCESSORS |
| 8'-3" / 13'-2" 0.5mT | CARDIAC PACEMAKERS, X-RAY TUBES, INSULIN PUMPS, B/W MONITORS, MAGNETIC DATA CARRIERS (LONG-TERM STORAGE) |
| 10'-3" / 16'-9" 0.2mT | SIEMENS CT SCANNERS |
| 10'-10" / 17'-9" 0.15mT | COLOR MONITORS, SIEMENS LINEAR ACCELERATORS |
| 14'-2" / 23'-6" 0.05mT | X-RAY IMAGE INTENSIFIERS, GAMMA CAMERAS, PET/CYCLOTRON, ELECTRON MICROSCOPES, LINEAR ACCELERATORS |

THE OWNER/USER IS TO VERIFY THE LOCATION OF THE 0.5mT FIELD AND ENSURE THAT IT IS MAINTAINED AS A RESTRICTED AREA.

**Figure 1.5: Copy of Siemens Recommendations for the Immunity of Devices – data supplied with 3T MRI.**
Note: 0.05mT = 50 μT

## 1.6 Survey at Beth Israel Hospital, New York

Mr Michael Hiles of Field Management Services Corp, acting on behalf of CEI, visited Beth Israel Hospital in New York on Friday 19th December 2008 and carried out a magnetic field survey of a Linac room and recently installed shielded room.

Tests inside and outside the shielded room were carried out using two Meda/Walker datalogging meters running in parallel. This enabled specific magnetic field events to be compared and the shielding effectiveness of the room assessed. Measurements of the three orthogonal axes were carried out and separately recorded. The root sum square of these has been calculated to give the resultant magnetic field (magnetic flux density).

The measurements in the room were carried out at the epicenter of the Linac. Starting times were around 11.39am EST.

Mr Hiles also had a discussion with a Medical Physicist, Dr Eli Furhang, at Beth Israel who was familiar with the interference issues. The shield had been installed because the prior medical equipment had experienced substantial deflection of the beam, due to DC field shifts, and a new room was shielded before installing the new machines. There was subsequent telephone communications with Dr Furhang during the first week of February 2009 and the satisfactory operation of the CT scanner confirmed.

The DC shifts were dominated by the passing trains, which stopped and started one floor down and to the edge of the walls. The distance was approximately 12m. The New York Transit Metropolitan Transportation Authority (MTA) vehicles uses 625V DC which is similar to the proposed Metro North system. The MTA uses a third rail configuration whereas the Metro North will use an overhead line. Prior data provided by the MTA indicates that, statistically, each substation could be operating at 100% of rated power during any one hour period; at 200% of rated power during any 15 minute period; at 300% of rated power during any 5 minute period and at 500% of rated power during any 1 minute period.

The following table calculates the load on the individual stations according to these statistical possibilities.

**Table 1.1 Stated Loading at MTA Substation**

| | | | | |
|---|---|---|---|---|
| Load | 100% | 200% | 300% | 500% |
| Amps | 4,800 | 9,600 | 14,400 | 24,000 |

The hospital was not using the Linear Accelerator at the time of the survey, but a CT Scanner had been tested in the shielded room and it was understood to have worked satisfactorily. It was also believed that the CT scanner was more sensitive than the Linac.

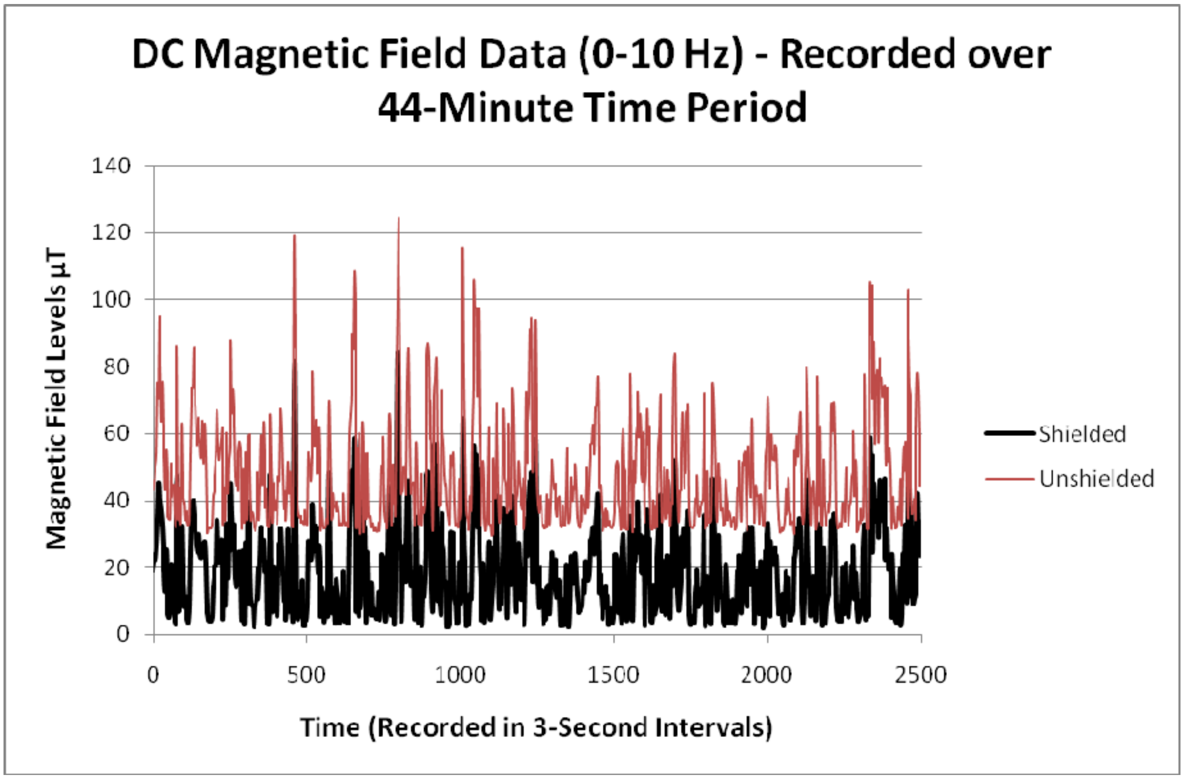


**Figure 1.6: Comparison of concurrent measurements of magnetic field values inside and outside the shielded room.**

As can be seen from Figure 1.6 the shielding effectiveness of the shielded room was approximately 2:1 giving a field reduction of 50%.

Based on successful operation of the equipment in this environment we can assess that the immunity level of the CT scanner and Linac is in the region 60 µT to 80 µT.

### 1.7 Modelling of Field Strengths at Mater Private Hospital

The Metro North route is proposed to pass 1m laterally and 17m below the bottom floor of the Mater Private Hospital. Coincidentally, the most sensitive equipment in the hospital, Linear Accelerators and CT scanners, are located at this location.

Modelling of the magnetic strengths has been carried out using data supplied by the RPA. The data is summarized below.

**Table 1.2 LMV Data**

| | Per LMV | Per train (two LMVs) |
|---|---|---|
| Peak current | 1800A | 3600A |
| Continuous RMS current | 1200A | 2400A |
| Maximum braking current | 1800A | 3600A |

**Table 1.3 Track and OCS Parameters**

| | |
|---|---|
| Vehicle width | 2.4 metres |
| Track gauge | 1435mm |
| Overhead Catenary height | 3.9 metres |

To cater for the variation and combination of EMI from different LMVs, the calculations for the foreseeable worst case levels are based upon the following operational scenarios:

- both LMVs starting and accelerating (peak current) on both tracks at the same time (This is a worst case scenario at the same longitudinal location on both tracks along the alignment).
- traction power supply system is fed from only one substation (e.g. in case of maintenance), the traction current of both tracks will be in the same direction.

During normal operation the traction power supply is fed from two substations (one at each end of each section), which means that the current is split between two adjacent substations and magnetic fields strengths will be halved.

Figures 1.7 and 1.8 below show the predicted field strengths at the Mater Private Hospital campus. These have been calculated on a pessimistic basis using worst case assumptions. The computer model has been verified by measurements on the Luas Red Line at Tallaght.

The magnetic field strength in the Linac rooms is predicted to be in the region of 11 μT on a worst case basis.

### 1.8 Conclusions

The Linear Accelerators and CT scanner at Mater Private Hospital are located approximately 20m from the rails of the proposed Metro North southbound rail line.

Conservative calculations, calculated on a worst case combination of substation outage and simultaneous acceleration of two vehicles show that the magnetic flux density at this location, will be in the region of 11 μT.

Measurements carried out at Beth Israel Hospital in New York showed that satisfactory operation of a CT scanner has been achieved in magnetic flux densities of between 60 and 80 μT. CT scanners are considered to be more sensitive than Linacs. The specification for the Linac at Mater Private Hospital has been declared to be 50 μT.

Based on the above it is considered that the operation of Metro North will have no adverse effect on the operation of Linac or CT equipment in the Mater Hospitals.

The contribution to the ambient magnetic field caused by the perturbation of the earth's magnetic by a passing train is estimated to be in the region of 0.3 μT and can be ignored.

It is recommended that this report is circulated to the relevant equipment vendors to ensure that this assessment is valid.

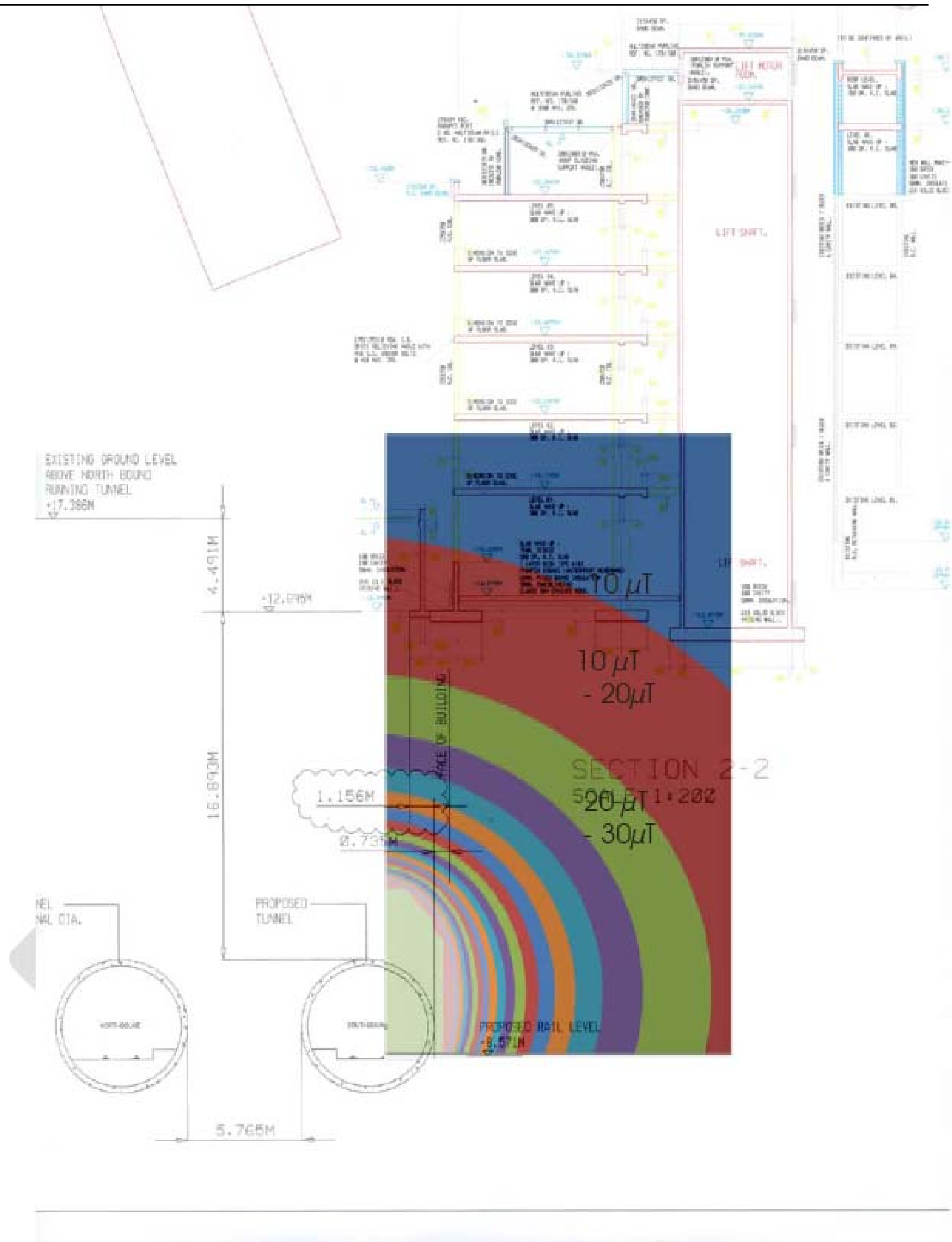


**Figure 1.7: Section View of Predicted Magnetic Flux Densities at Mater Private Hospital**

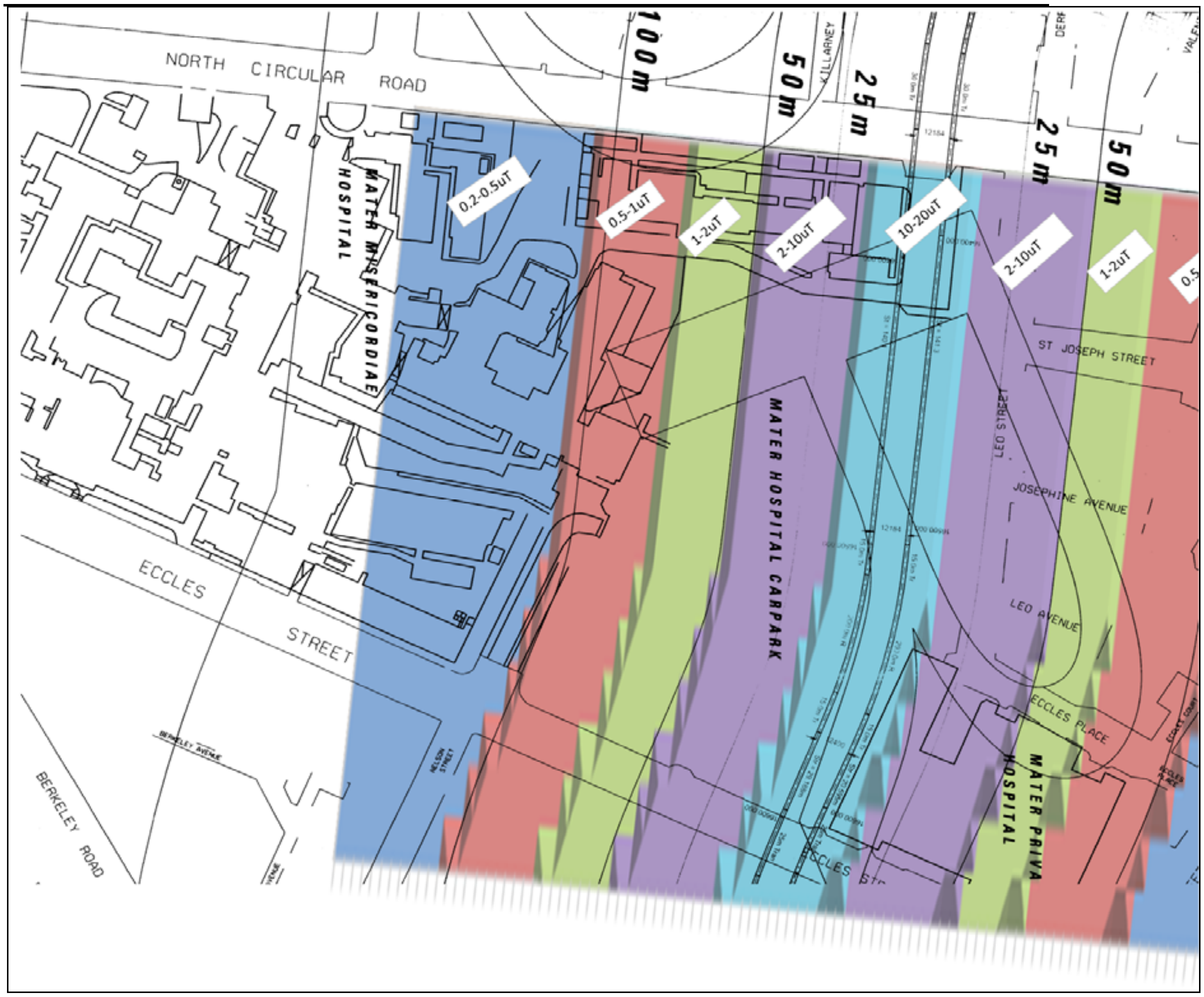


**Figure 1.8: Plan View of Predicted Magnetic Flux Densities at Mater Private Hospital**

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