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| EDM Calibration Handbook  Edition 16 |
|  |
| December 2017 |

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| EDM Calibration Handbook  Edition 16 |

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| Office of Surveyor-General Victoria |

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| Report produced by:  Office of Surveyor-General Victoria  Land Use Victoria  Department of Environment, Land, Water and Planning  2 Lonsdale Street  Melbourne, Victoria 3000  Phone (03) 9194 0770  Website: [www.propertyandlandtitles.vic.gov.au/surveying](http://www.propertyandlandtitles.vic.gov.au/surveying)>Survey equipment calibration – EDM |

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# Preface

In relation to land surveying, the professional surveyor is not only intent on measuring accurately but also on ensuring measurement integrity. EDM calibration baselines are essential for verifying the accuracy of electronic distance measurement equipment against the national standard for length.

The Surveyor-General of Victoria sets standards for property surveys under the Surveying (Cadastral Surveys) Regulations 2005, including requirements for the calibration and standardisation of survey equipment. To assist licensed surveyors in meeting these standards, the Surveyor-General is responsible for issuing practical implementation advice and providing certified calibration facilities.

The [Surveyor-General of Victoria Practice Directives](https://www.propertyandlandtitles.vic.gov.au/surveying/surveying), September 2014 ([www.propertyandlandtitles.vic.gov.au/surveying](http://www.propertyandlandtitles.vic.gov.au/surveying)) the requirements regarding calibration of Electro-optical Distance Meter (EDM) instruments. It states that EDM instruments must be calibrated over a certified baseline at intervals not exceeding 12 months, or more frequently if conditions warrant it. It also states that a licensed surveyors report must detail calibration information about the EDM used in the survey including: make and model, serial number, EDM calibration site and date of calibration.

This EDM Calibration Handbook provides the specification and practice direction for achieving EDM calibration at each of the six baselines across the state. The Surveyor-General is a verifying authority for length (up to 1160 metres) and is responsible for the annual re-certification of the baselines as subsidiary standards of length.

The Surveyor-General, through Geodetic Survey, provides the continued certification of the baselines and the periodic updates of the handbook, and acknowledgement is also made of the assistance of Land Use Victoria staff throughout the state.

The Surveyor-General acknowledges the co-operation and support provided by Brayley & Hayes Pty. Ltd., Nacha Moore Land Surveyors Pty. Ltd., SMEC Urban Pty. Ltd. (Gippsland) and St. Quentin Consulting Pty. Ltd. for their assistance with the Hamilton, Mitcham, Cowwarr and Geelong baselines, respectively.

Craig L Sandy

Surveyor-General of Victoria

December 2017

# Introduction

This handbook deals with the calibration and standardisation of Electro-optical Distance Meters (EDM) in the state of Victoria.

There are six baselines in Victoria that are maintained as subsidiary standards of length and as such are suitable for the calibration and standardisation of EDM. All baselines are designed to accommodate a number of different EDM unit lengths. In particular, Mitcham and Hamilton are of Sprent/Zwart (Hobart) design; Bendigo and Geelong are a modified Schwendener design; and Braeside and Cowwarr are custom designed to support the mass of EDM unit lengths available in the modern market.

The calibration of EDM is concerned with the determination of instrument errors; whereas, standardisation refers to the comparison of the instrument to a standard of length traceable to the national standard. Instruments must be calibrated within a prescribed level of precision in order to be standardised. Chapter 3 discusses the legal background of standardisation.

The theory of EDM calibration is summarised in Chapter 4 along with an explanation of the instrument errors that are determined.

The observing procedures outlined in Chapter 5 are based on the instructions on the ‘Verification of Electro-optical Short-Range Distance Meters on Subsidiary Standards of Length in the Form of EDM Calibration Baselines’ proposed by Dr. J.M. Rueger (1984).

EDM users who wish to perform calibrations need to book the use of baselines in advance. Chapter 6 lists the baselines and offices that can be contacted to make bookings and obtain further information.

The Surveyor-General of Victoria has adopted the EDM instrument calibration software known as Baseline, version 6.0.0.5. This software has been developed by the Western Australia Land Information Authority (Landgate) for the calibration of EDM instruments against standard baselines.

# Legal traceability of length measurements

## Background

In accordance with Regulation 73 of the National Measurement Regulations 1999, the Surveyor-General of Victoria is appointed as a Verifying Authority with respect to length. This enables certification of subsidiary standards of length to a certain precision pursuant to Regulation 13 of the National Measurement Regulations 1999.

Although not common, the validity of length measurement may be challenged in a court of law. The validity will be strengthened if traceability to the national standard can be proved.

In 1983 the National Standards Commission (NSC), now incorporated into the National Measurement Institute (NMI), formed a working party on the Calibration of Electromagnetic Distance Measuring (EDM) Equipment. Following both the recommendations of this working party and research by the NSC, it was established that monumented baselines could be certified as subsidiary standards of length under Regulation 13 of the National Measurement Regulations 1999 to provide legal traceability for EDM measurements.

The standard of length was transferred to baselines through use of standard tapes or EDM as prescribed by the National Standards Commission. The Kern Mekometer and the Comrad Geomensor were the only EDM prescribed by the NSC. These instruments needed to be compared with the national frequency standard and certified as reference standards prior to their use for baseline certification.

The Kern Mekometer ME3000 owned by Melbourne Water/WBCM Surveys Pty Ltd has been used to certify the Victorian baselines in the past. When this instrument ceased operating in 1994, the Kern Mekometer ME5000 owned by Hydro Tasmania was used for this purpose. In 2006, the Leica TCA2003 total station owned by the Department of Transport Energy and Infrastructure South Australia and certified by NMI was used to re-verify the five EDM baselines. In 2008, Surveyor-General Victoria purchased a Leica TCA2003 total station which is used to certify the six baselines. This class of instrument is expected to be used in the near-medium future.

An EDM is considered to measure distances traceable to the national standard of length if:

(a) it is calibrated on a certified baseline,

(b) it is calibrated in accordance with the procedures laid down herein,

(c) the current inter-pillar distances (as determined from re-verification measurements) are used to compute the calibration and

(d) the instrument correction has been computed to a prescribed level of precision.

Recommendations of specific interest from the NSC working party referred to in 2.4 and 2.7 above are:

**No.2** To be certified as a subsidiary standard a baseline must be capable of being calibrated with an uncertainty of ± (1.5 + 20 10-3 L) mm at the 95% level of confidence, where L is the interval length in metres.

**No.8** It is recommended that, in general, the minimum standard for the uncertainty of calibration of an EDM, assuming calibration against a monumented base, should be (5 + 30 10-3 L) mm at the 95% level of confidence, where L is the interval length in metres.

Six Victorian baselines are certified annually in accordance with Recommendation No.2. The calibration procedures outlined in this handbook and the analysis techniques contained in Baseline are capable of meeting the requirement of Recommendation No.8.

## Surveyor-General of Victoria Practice Directives – September 2014

The Surveyor-General sets standards for surveying title boundaries through the Surveying Act 2004, Surveying (Cadastral Surveys) Regulations 2005, and standards of measurement under the Survey Co-ordination Regulations 2014.

These standards include calibration and standardisation of survey equipment, record keeping and reporting, specifications for units of measurement and levels of precision achievable.

The Surveyor-General issues practice directives to aid licensed surveyors in the interpretation of regulations and inform them of changes to the requirements of either the Surveyors Registration Board of Victoria and/or the Surveyor-General.

The Surveyor-General of Victoria Practice Directives, September 2014, address the Surveyor-General’s requirements regarding calibration of Electro-optical Distance Meter (EDM) instruments.

**The Surveyor-General has determined that an adequate survey equipment comparison process requires the calibration of EDM surveying instruments over a baseline certified by the Surveyor-General at intervals not exceeding 12 months.**

Where adverse conditions of use warrant it, more frequent EDM calibration may be required, including after every repair to all or part of such equipment.

Where an EDM surveying instrument is used in a cadastral survey, the Surveyor-General requires the following information to be included in the surveyor's report:

* Make and model of instrument
* Serial number
* EDM calibration site
* Date of calibration

The Surveyor-General has determined that survey plans signed after 31 January 2002 must comply with these requirements in relation to EDM survey instrument calibration.

The latest version of the Practice Directives can be downloaded from the Surveyor-General’s website at www.delwp.vic.gov.au > Property and land titles > Surveying > Surveyor-General Victoria > Surveyor-General of Victoria Practice Directives.

## Surveying (Cadastral Surveys) Regulations 2005

Regulations 6(1)(a)&(b) require a licensed surveyor to use survey equipment which has been compared to a standard of measurement and ensure that the process and basis of comparison are adequate to obtain the accuracy required under the Surveying (Cadastral Surveys) Regulations 2005.

Regulation 6(2) requires licensed surveyors to retain records of comparisons and make them available for inspection upon request by the Surveyor-General.

Regulation 15(2)(b) stipulates that a licensed surveyor’s report must provide details on the date of calibration of measuring equipment used in the cadastral survey.

## Survey Co-ordination Regulations 2014

Regulation 13 of the Survey Co-ordination Regulations 2014 requires surveyors to use and maintain survey equipment that has been compared to a standard of measurement. The units of measurement are specified in Regulation 12(a)(i) and levels of precision to be achieved are set out in Regulation 12(b)

It is considered that the requirements of the Surveying (Cadastral Surveys) Regulations 2005 and the Survey Co-ordination Regulations 2014 are satisfied for EDM if points (a) to (d) in section 2.7 are performed.

# The theory of EDM calibration

EDM calibration is performed in order to determine the instrument errors. The instrument errors can be used to monitor the performance of the EDM over time and if significant, should be applied to measurements taken subsequent to the calibration.

If the calibration is performed over a certified baseline to a prescribed level of precision, the EDM is considered to be standardised.

## Instrument errors

### Additive constant (correction for zero index error)

All distances measured by a particular EDM/reflector combination are subject to a constant error. It is caused by three factors:

(a) electrical delays, geometric detours, and eccentricities in the EDM,

(b) differences between the electronic centre and the mechanical centre of the EDM,

(c) differences between the optical and mechanical centres of the reflector.

The additive constant or zero/index correction is added to measured distances to correct for these differences.

Note: that this error may vary with changes of reflector, after jolts, with different instrument mountings and after service.

### Scale error

The scale error describes errors that are linearly proportional to the length of line measured. These can arise from:

(a) variations in the modulation frequency of the EDM,

(b) non-homogeneous emission/reception patterns from the emitting and receiving diodes (phase inhomogeneities),

(c) unmodelled variations in atmospheric conditions which affect the velocity of propagation

(d) errors in the collection and use of atmospheric data. This includes the use of uncalibrated thermometers/barometers, not taking atmospheric measurements in the shade and the incorrect entry of the atmospheric correction into the EDM.

### Cyclic error (short periodic error)

Cyclic error is a function of the internal phase measurement of an EDM. Error in the internal phase measurement is caused by unwanted feed through the transmitted signal onto the received signal.

Cyclic error is usually sinusoidal in nature with a wavelength equal to the unit length of the EDM. The unit length is the scale on which the EDM measures the distance, and is derived from the fine measuring frequency. Unit length is equal to one half of the modulation wavelength of an EDM (Rueger 1980).

As cyclic error repeats itself for every unit length contained within a measured distance, its sign and magnitude varies depending on the length measured. The magnitude of the error could be in the order of 5mm to 10mm; however, in modern EDM it is usually less than 2mm (negligible). Cyclic error can increase in magnitude as the components of an EDM age.

## Baseline design

EDM can be calibrated by measuring a combination of distances on a baseline. An important feature of baseline design is to enable the determination of all instrument errors to an appropriate level of precision. Three types of baselines are in use in Australia. The difference between their designs lies in the associated methodology used to determine cyclic error, and the observation procedures applicable to each one.

In general, calibration measurements over short distances assist in the determination of the additive constant while longer distances help determine scale error. One objective of the design is to ensure that the additive constant and scale error are determined independently of any cyclic error contributions. However, it is not possible to solve for a scale error unless the inter-pillar distances for the baseline are known. Only prescribed EDM are used to determine these distances and hence control scale.

The certified baselines in Victoria consist of Sprent/Zwart (Hobart) baseline design, Schwendener design and custom designs intended to accommodate the mass of EDM unit lengths in use. The Bendigo baseline has been modified to include an additional pillar at a chainage of 5m. This enables the Sprent/Zwart method of calibration to be employed at this baseline.

The original Sprent/Zwart design has been altered in Victoria by slightly changing the pillar locations so that the additive constant is determined with greater precision. Nevertheless, calibrations using this design are marginally less precise than other baseline designs. The great advantage of the Sprent/Zwart method is its ease of use, and this unquestionably offsets the slightly lower precision.

The additive constant and scale error are able to be determined independent of cyclic error on Sprent/Zwart baselines because their design has the effect of cancelling out cyclic error. If pairs of measurements are taken from pillars separated by half the unit length of the EDM, the cyclic error affecting each pair will be equal in magnitude and opposite in sign. An analysis, which treats the measurements as pairs, can eliminate the effect of cyclic error.

All but two of the certified baselines in Victoria have instrument pillars at chainages of 0m, 5m and 10m, enabling the Sprent/Zwart method of calibration to be used for EDM with unit lengths of 10m and 20m. The Bendigo and Geelong baselines are the exception with instrument pillars at chainages of 0m and 5m, making it suitable for EDM with a unit length of 10m.

A list of common EDM and their associated unit length are provided on the Surveyor-General’s EDM calibration website . The lists show that in addition to 10m and 20m, there are EDM with unit lengths of 2m, 3m, 5m, 30m and 33m. Due to the difficulties with computing cyclic error, a slightly different calibration procedure is recommended for EDM with unit lengths other than 10m or 20m, details of which are given in Chapter 4.

The procedures recommended in this handbook are designed to specifically meet the requirements of legal surveys, and Rueger (1985) shows that the Sprent/Zwart method of taking measurements from 2 pillars separated by half the unit length is easily capable of satisfying Recommendation No. 8 of the National Standards Commission (see 2.8).

Calibrations of a higher precision can be achieved by occupying all pillars and measuring all combinations of distances on a baseline.

## Pillars

The baselines available for calibration and standardisation in Victoria have specially constructed pillars for the stations. The reasons for this are that:

(a) forced centring is essential to eliminate setting-up errors

(b) the speed and ease of the calibration procedure is enhanced

(c) a precision EDM is able to be used to its full capacity

(d) constant instrument heights are obtained.

Calibration techniques assume that there is no pillar movement between the time when the baseline is certified and when the user calibrates the EDM. Unfortunately, pillars do demonstrate seasonal movement; although, in most cases the movement is too small to have any significant effect.

Baseline stability is closely monitored to ensure that calibrations can be performed to the required precision. If it is suspected that pillar movement has occurred, it should be reported to the Geodetic Survey section within the Office of Surveyor-General Victoria for immediate action and resolution.

# Recommended observing procedure

The Surveyor-General as the verifying authority has the responsibility for having certain pillared baselines measured by an EDM prescribed by the NMI. This means, the Surveyor-General is able to issue Regulation 13 certificates for these baselines, certifying them as subsidiary standards of length.

Each baseline is controlled by an office, which can be contacted to make bookings for its use and to obtain information on access to the umbrella, pillar-cap key and standard thermometer and barometer required for the calibration. Note that all baseline pillars are fitted with 5/8" BSW threads for mounting purposes.

Baseline locations, access details and pillar layouts, together with addresses and telephone numbers of the controlling offices, can be found later in this chapter.

## General procedures

The following procedures have been based on the proposals of Rueger (1984) and are to be followed when calibrating EDM on Victorian baselines.

### Booking sheets

Calibration data may only be recorded on official booking sheets provided by Land Victoria. All details must be recorded and booking sheets must be signed and dated. Measurements shall be recorded in units of metres (distance), degrees Celsius (temperature) and millibars (pressure). Controlling offices may have small quantities of booking sheets available, however it is preferred that baseline users have their own copies for use. Sample booking sheets are included in the Appendices. In addition, the booking sheet may be downloaded from the Survey Equipment Calibration website at www.delwp.vic.gov.au > Property and land titles > Surveying > Survey equipment calibration – EDM > EDM Calibration Booking Sheet

### Set up and shade

Initially, set up the EDM on pillar 1. The instrument must be shaded by an umbrella at all times during the calibration. At no time should it be put in its box, or left in the sun. It must be switched on and allowed to run, in the shade, for at least 15 minutes before measurements commence.

### Atmospheric correction

The atmospheric correction for the EDM must be set to zero (ppm) for all the calibration measurements. This function is usually performed by one of the following methods:

(a) an atmospheric correction knob/dial

(b) direct input using the EDM keypad

(c) entry of the temperature and pressure for which the EDM is standardised. In this case the temperature and pressure corresponding to zero ppm should be entered, not the ambient conditions of the calibration.

Note: for instruments with a unit length of zero and pulsed instruments, the meteorological observations must be entered into the instrument at the time of the calibration.

### Operations

The measurements must be taken with the attenuator or aperture setting as prescribed by the instrument manufacturer's instructions.

### Power

If sufficient power is available, the EDM should be left switched on for the whole calibration (instruments with oven-controlled oscillators must remain switched on). All instruments must remain switched on while the minimum number of measurements (four, refer to 4.3.11) are taken.

### Height of instrument

The height of the mounted EDM above the base of the tribrach (pillar plate) must be accurately measured and recorded on the booking sheet. This should be done with the footscrews in mid-setting.

### Reflector mountings

The same reflector, reflector mounting and tribrach should be used for all measurements. The height of the reflector must be measured and recorded in the same manner as for the EDM. The reflector must have a unique identification (serial number), which must be entered on the booking sheet.

### Levelling of equipment

All equipment should be levelled with care and any spot bubbles used for this purpose must be checked before the calibration.

### Conditions

All calibration measurements must be taken either fully in daytime or fully at night. A mixture of conditions is not acceptable. EDM that are typically used in daytime should be calibrated in daytime.

### Meteorological observations

The Surveyor-General of Victoria maintains a ‘transfer standard’ temperature and pressure gauge. The transfer standard is calibrated against the national standards for temperature and pressure on a biennial basis. During the annual baseline recertification surveys, each of the baseline standard thermometer and barometer devices is compared against the transfer standard. These comparisons are undertaken to monitor and record the offset of the baseline standard thermometer and barometer.

In order to ensure that values derived from thermometers and barometers used in instrument calibration are comparable to the national standards for temperature and pressure, the recorded offset for the baseline standard to transfer standard must be applied as a correction. These corrections are listed on the Survey Equipment Calibration website at www.delwp.vic.gov.au > Property and land titles > Surveying > Survey equipment calibration – EDM, and must be included on the instrument calibration booking sheet.

Field thermometers and barometers must be compared with the baseline’s standard thermometer and barometer both prior to and at the conclusion of the calibration measurements. There is provision on the booking sheets to record these comparisons. The baseline standard thermometer and barometer shall remain in the controlling office at all times, and under no circumstances should they be used on the baseline.

Temperature and pressure must be measured in the shade at the instrument pillar. Temperature and pressure can be measured at the height of the instrument. These measurements are to be taken and recorded on the booking sheet (in the space provided) every time the prism has moved.

### Calibration measurements

On each line, four separate distance measurements should be taken as a minimum, with re-pointing after each measurement. Pointing can be optically or electronically performed as prescribed by the manufacturers.

## Measurement sequence (excluding Bendigo and Geelong baselines)

The recommended measurement sequence is dependent on the unit length of the EDM being calibrated. A list of EDM and their associated unit lengths are provided on the Surveyor-General’s EDM calibration web site at www.delwp.vic.gov.au > Property and land titles > Surveying > Survey equipment calibration – EDM.

### EDM with a 10m unit length

1. Set up the EDM on pillar 1 and measure to pillars 4,5,6,7 and 8 in turn. If the baseline has additional pillars located beyond pillar 8, they should be measured to also.

2. Move the EDM to pillar 2 and repeat the measurements taken above in the reverse order.

This sequence requires the reflector to be moved up and down the baseline only once.

1 → 4, 5, 6, 7, 8

2 → 8, 7, 6, 5, 4

### EDM with unit lengths other than 10m

The Victorian baselines were designed and constructed at a time when the majority of EDM in use had either 10m or 20m unit lengths. The baselines, in conjunction with the measurement sequences described above, enable the satisfactory determination of errors for these EDM.

The modern trend in EDM, however, is smaller unit lengths, with 2m, 3m and 5m instruments becoming more common. There are also EDM in use with unit lengths of 30m and 33m. As the baselines were not designed to efficiently cater for the calibration of these EDM, a different measuring sequence is required.

It is recommended for instruments with unit lengths other than 10m that additional measurements to the normal sequence outlined above be taken. For example, measurements from pillars 1, 2 and 4 to the other pillars can be observed. The instrument correction determined from these measurements would still satisfy the requirement of the NMI.

1 → 4, 5, 6, 7, 8

2 → 8, 7, 6, 5, 4

4 → 5, 6, 7, 8

If a more precise determination of the instrument corrections is required, then all combinations of measurements on a baseline can be observed. For an 8 pillar baseline the sequence would be:

1 → 4, 5, 6, 7, 8

2 → 8, 7, 6, 5, 4

4 → 5, 6, 7, 8

5 → 8, 7, 6

6 → 7, 8

7 → 8

Generally, the precision of the computed instrument correction is increased as more measurements are taken on a baseline.

## Measurement sequence - Bendigo and Geelong baselines only

Refer to the list of EDM and their associated unit lengths on the Surveyor-General’s EDM calibration web site at www.delwp.vic.gov.au > Property and land titles > Surveying > Survey equipment calibration – EDM.

### EDM with a 10m unit length

1. Set up the EDM on pillar 1 and measure to pillars 3, 4, 5, 6, 7 and 8 in turn. For the Bendigo baseline, completely ignore the old pillar at 20m chainage; pillar 3 is located approximately 60m from pillar 1.

2. Move the instrument to pillar 2 at chainage 5m and repeat the measurements taken above in the reverse order.

1 → 3, 4, 5, 6, 7, 8

2 → 8, 7, 6, 5, 4, 3

### EDM with unit lengths other than 10m

It is recommended for these instruments that measurements in addition to those outlined above be taken. As a minimum, measurements from pillar 3 to pillars 4, 5, 6, 7 and 8 should also be observed.

1 → 3, 4, 5, 6, 7, 8

2 → 8, 7, 6, 5, 4, 3

3 → 4, 5, 6, 7, 8

If the EDM is required to be calibrated to the highest precision possible on this baseline, then all combinations of measurements should be observed. This involves occupying pillars 1 to 7 (inclusive) with the instrument.

# Location of baselines

**Baseline/Location Controlling Office Telephone**

**BENDIGO** Land Use Victoria – Survey section (03) 5430 4637

McDowells Road, adjacent to 1 Taylor St

Bendigo Aerodrome Epsom 3551

**BRAESIDE (Melway 88 D10)** Land Use Victoria (03) 9194 0770

Braeside Park Level 11, 2 Lonsdale Street

Lower Dandenong Road Melbourne 3000

Braeside 3195

Note. The ancillary equipment for the Braeside baseline is stored in a cabinet adjacent to the Braeside Park rangers office. The cabinet key is available from the office staff.

**GEELONG (Melway 452 H10)** St Quentin Consulting Pty. Ltd. (03) 5229 2011

Bellarine rail trail 51 Little Fyans Street

Boundary Road South Geelong 3220

Newcomb

**HAMILTON** Brayley & Hayes Pty. Ltd. (03) 5571 9171

Balkins Road 85 Kennedy Street

2km West of Fairburn Road Hamilton 3300

Hamilton 3300

**COWWARR** SMEC Urban Pty. Ltd. (Gippsland) (03) 5173 0100

Foxs Road West 18 Breed Street

Cowwarr Traralgon 3844

**MITCHAM (Melway 48 F12)** Nacha Moore Land Surveyors Pty. Ltd. (03) 9194 0770

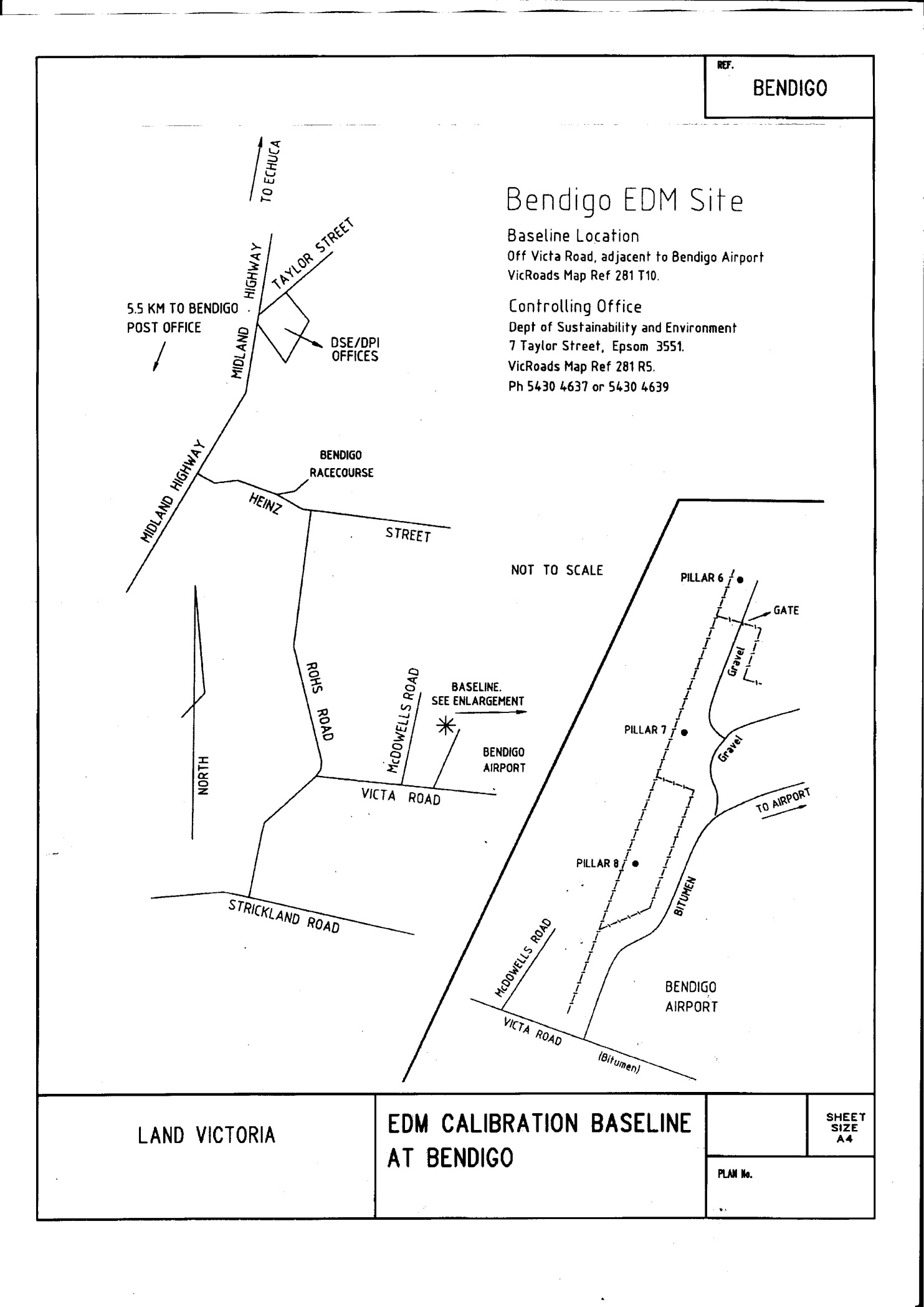
Menin Road 226 Mitcham Road (03) 9872 5512

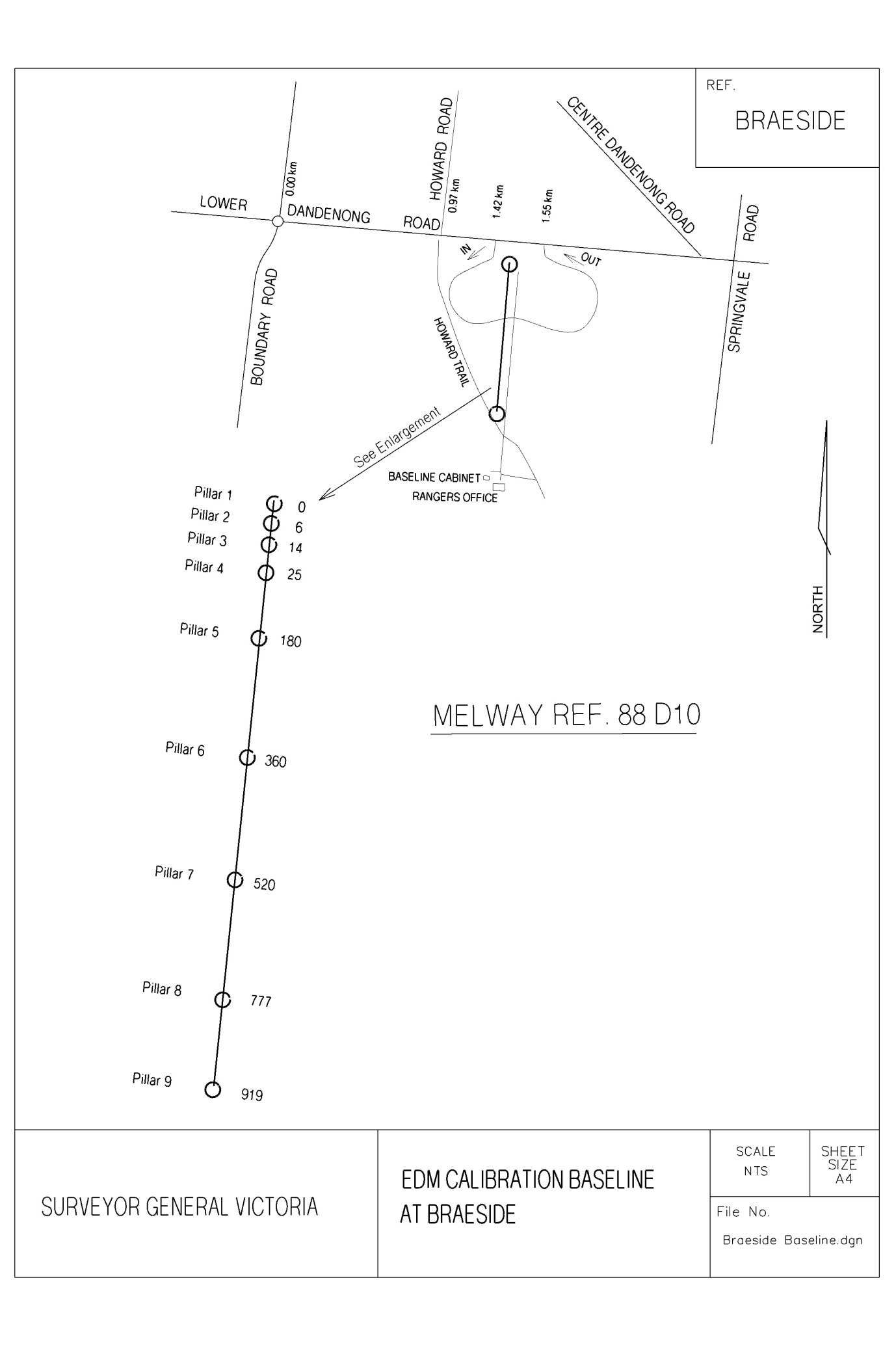
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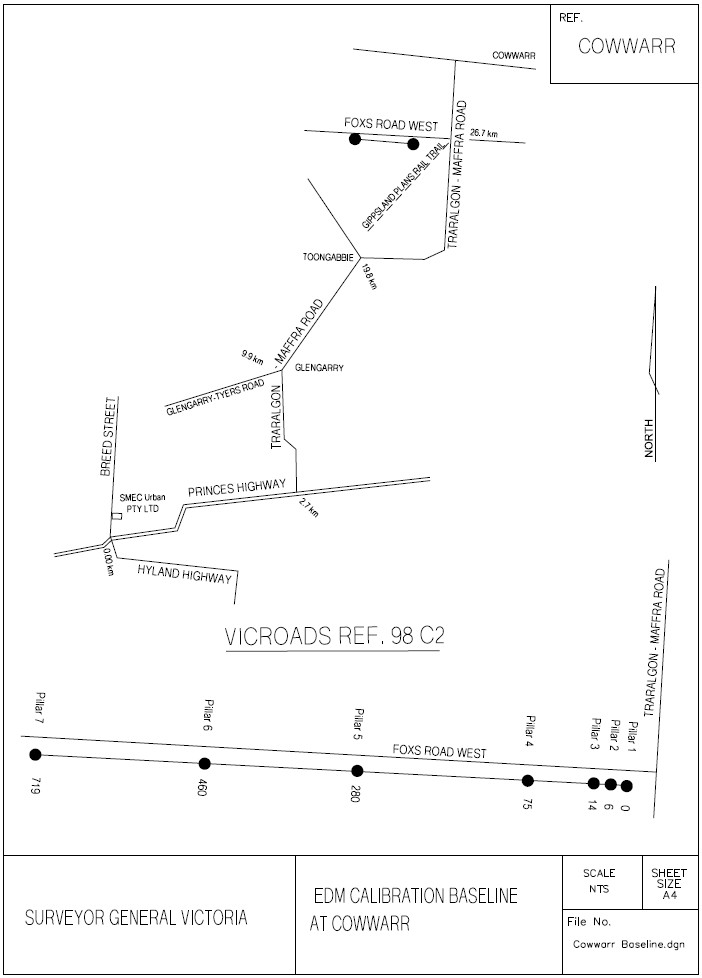
1. Bookings to use the baselines are to be made in advance using the online facility within SMES. Go to:

www.delwp.vic.gov.au > Property and land titles > Surveying > SMES > EDM Calibration Booking System

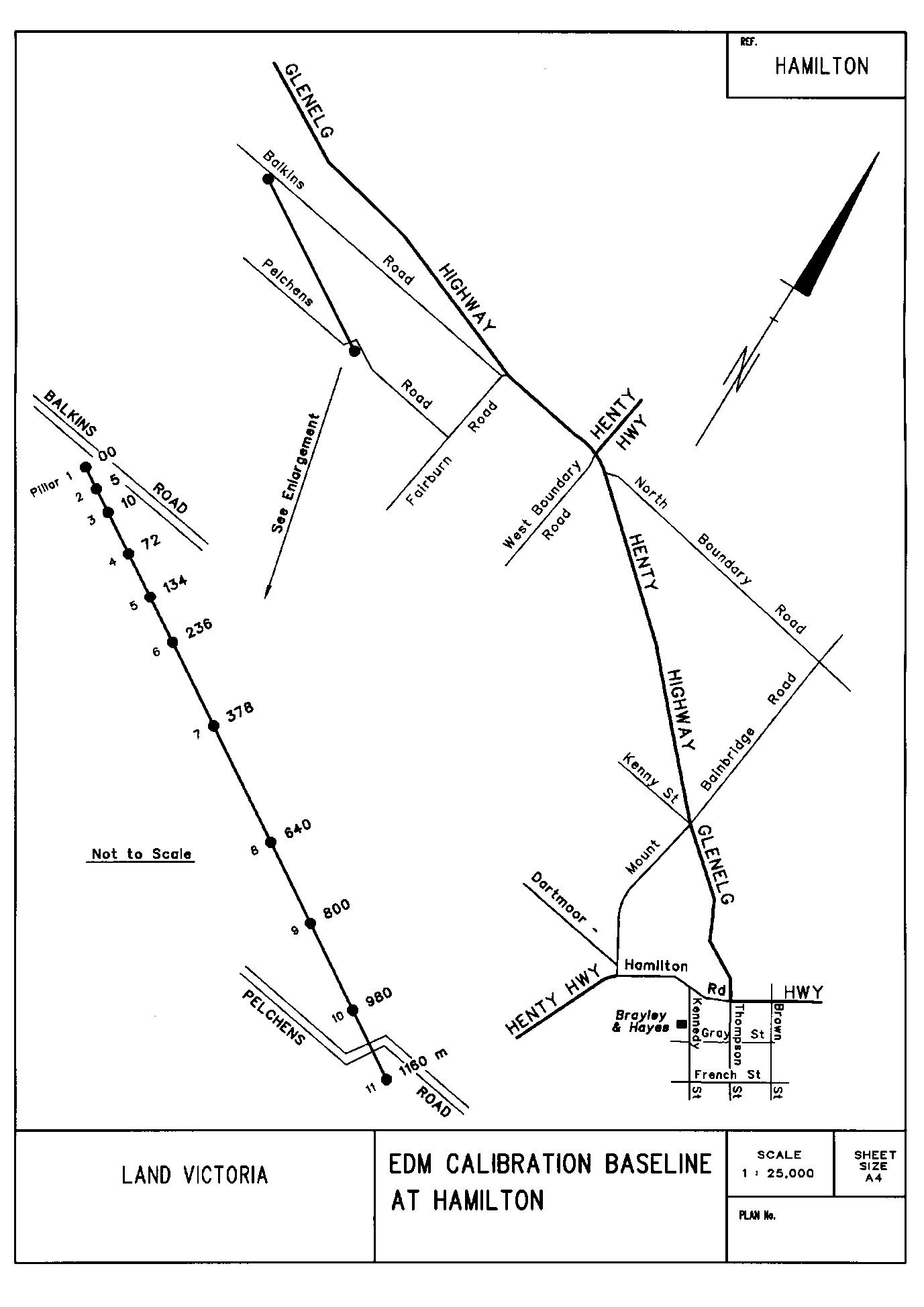
1. Controlling offices are open between 8.30am and 4.30pm, Monday to Friday.
2. Baselines are available for use on weekdays only.
3. Users are required to have their own copies of official booking sheets.
4. No rubbish is to be left behind.
5. All gates must be left in their original position.
6. Pillar caps are to be re-fitted upon completion.
7. When using non-standard prisms, sighting difficulties may be experienced between pillars. The same prism must be used for the observations to achieve a valid calibration.

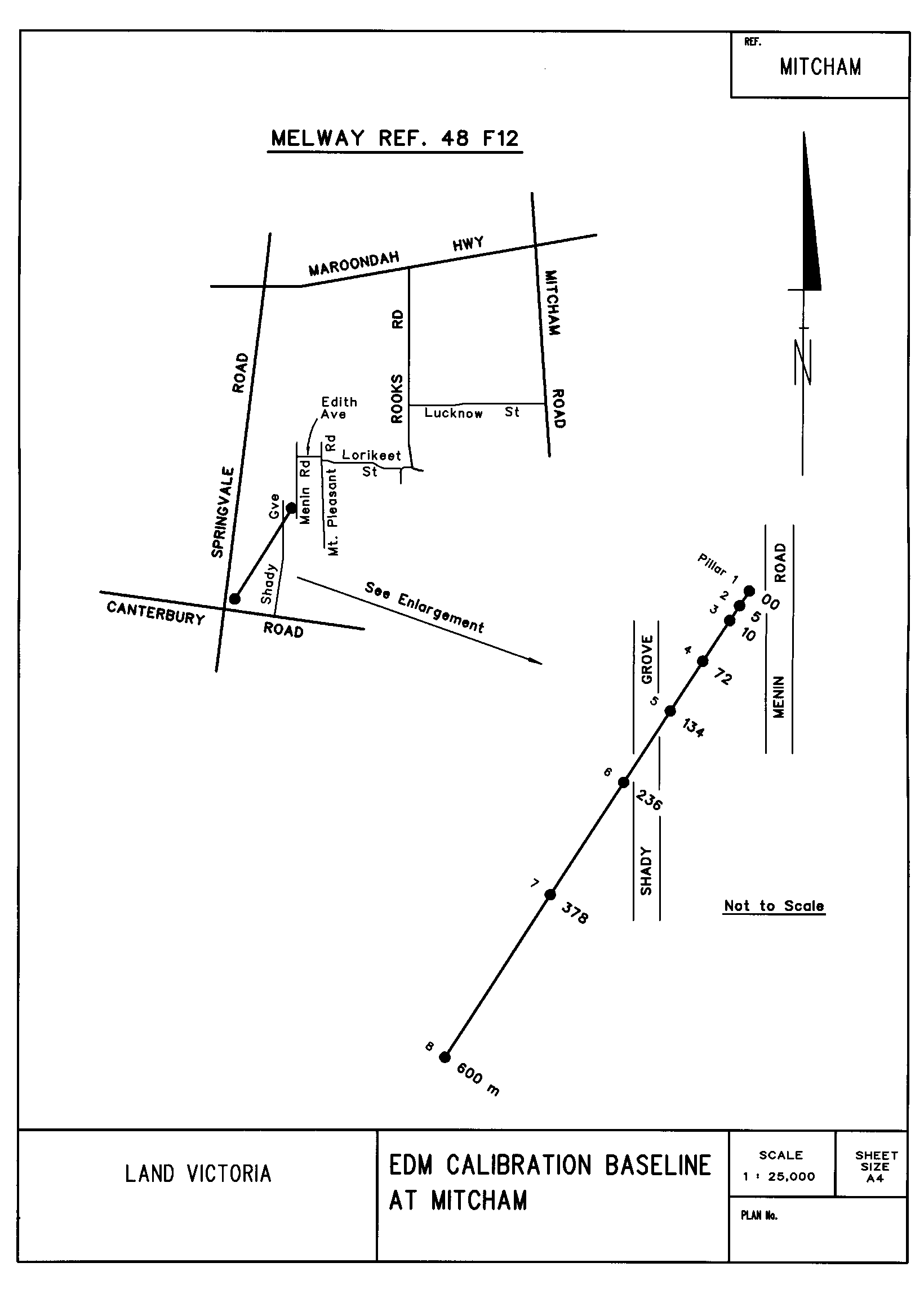
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# EDM instrument parameters

EDM instrument parameters, such as unit length, frequency, carrier wavelength and manufacturer estimates of EDM standard deviation constant and parts per million are supplied for the majority of instruments within the Baseline software.

Detailed listings of instrument parameters are supplied in the instrument parameter sheets on the Survey Equipment Calibration website at www.delwp.vic.gov.au > Property and land titles > Surveying > Survey equipment calibration – EDM.

## Pulsed instruments and instruments with a unit length of zero

For instruments with a unit length of zero and pulsed instruments, the meteorological observations must be entered into the instrument at the time of the calibration.

The unit length, frequency and carrier wave length are used in the calculation of the meteorological corrections and cyclic errors within the Baseline software. Surveyors can enter the instrument into the register, and leave all the details blank and the software will still process the data correctly.

# Reduction and interpretation

The Surveyor-General of Victoria has adopted the EDM calibration computer program known as Baseline, version 6.0.0.5 (July 2012), developed by the Western Australia Land Information Authority (Landgate) for the calibration of EDM instruments against standard baselines. The calibration of EDM instruments is carried out to determine the instrument corrections to be applied to measurements and to ensure its reliability. Online help provides the user with the instructions necessary to run this software application. Software download is also freely available from the Survey Equipment Calibration website, available from www.delwp.vic.gov.au > Property and land titles > Surveying > Survey equipment calibration – EDM > Distribution file

The software stores the measurements and calibration results of each determination to serve as an archive.

The Braeside, Bendigo, Geelong, Hamilton, Cowwarr and Mitcham baseline inter-pillar distances resulting from the annual re-verification surveys (performed in November) have been included in the database. All inter-pillar distances are updated on an annual basis. A selection of EDM instruments and reflector makes and models are also included. For EDM makes and models which are not included in the list, Baseline will accept the entry of new instruments although it requires the input of the unit length and the modulation frequency of the instrument by the operator.

The instrument details, measured distances and observed meteorological details (un-tick the ‘Mets Dial Set’ box to enter the meteorological data) are entered interactively by the operator. After the observed data is reduced to obtain horizontal distances and their associated variances, a least square adjustment is performed. The adjustment is made as suggested by Dr J.M Rueger (Rueger 1984) for modelling systematic errors in EDM measurements.

The program produces several reports for analysing an EDM instrument calibration and for analysing a calibration of a baseline. A certificate which summarises the results of an EDM instrument calibration is also produced.

As a Verifying Authority, the Surveyor-General can issue Regulation 13 certificates for EDM, certifying them as reference standards of measurement. Normally this is reserved for precise EDM that are intended to be used to transfer the standard of length. For a Regulation 13 certificate to be issued, the entire calibration procedure can only be performed by Geodetic Survey within the Office of Surveyor-General Victoria, and a fee is applicable for this service.

The minimum standards for the uncertainty of calibration are described in terms of Recommendation No. 8 of the working party of the National Standards Commission (now NMI) on the calibration of EDM Equipment of 1 February 1983. All uncertainties are specified at the 95% confidence level.

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# Appendices – sample booking sheets

