New South Wales Government

Surveyor General's Directions

No. 3

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Control for Cadastral Surveys

DOCUMENT CONTROL SHEET

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Surveyor General of NSW
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Part 1: Control For Cadastral Surveys

1 Introduction

In order to extend the State Survey Control Network, Spatial Services – Department of Finance, Services & Innovation has a program to compute coordinate values for Permanent Survey Marks placed as part of a cadastral survey. The coordinates will be computed using a least squares horizontal adjustment program called HAVOC.

This direction outlines the standard of accuracy expected for coordinates, and the recommended field practices required to obtain that accuracy. Using these practices, coordinates calculated through this program will be of sufficient accuracy for adoption of MGA orientation as required by Clause 12 of the Surveying and Spatial Information Regulation 2012.

Coordinates computed from cadastral survey information will be placed into the Survey Control Information Management System (SCIMS) with a Horizontal Class of C.

The coordinates will only be computed if sufficient information is shown on the survey plan (Deposited Plan) to enable the confident calculation of coordinates.

From 31 March 2000, Permanent Marks listed in SCIMS with Horizontal Class of 3A, 2A, A, B or C can be used for adoption and verification of MGA orientation.

2 Accuracy Classifications

In July 1990, the Intergovernmental Committee on Surveying and Mapping (ICSM) introduced ICSM Special Publication No.1 on Standards and Practices for Control Surveys (SP1 Version 1.7, http://www.icsm.gov.au/publications/sp1/sp1v1-7.pdf). These standards and specifications recommend accuracies and procedures for observations over distances greater than one kilometre. In NSW these accuracy classifications are being adopted for lines shorter than one kilometre, but recommendations for observational procedures for survey control derived through cadastral surveys are found in this Direction.

SP1 introduced the concept of **Class** and **Order** to classify the accuracy of all types of surveys, but particularly control surveys.

The **Class** of a survey is a function of the relative precision of a set of coordinates within a control survey network, assigned on the basis of the field survey methods, reduction techniques and the results of a minimally constrained adjustment.

The **Order** is a function of conformity of the new set of coordinates to existing established coordinates from the State Control Survey. The order assigned is also limited by the class assigned to a survey.

Coordinates computed from cadastral survey networks performed as part of a cadastral survey should meet SP1 Class C standards of accuracy. The Class C standard will be met if the one standard deviation semi-major axis (r) of the relative error ellipse between two points derived from a minimally constrained adjustment satisfies the following formula adopted by ICSM for control surveys:

$$r = c\,(d + 0.2)$$

where r is the semi-major axis in mm.
d is the distance in kilometres
c is 30 for Class C surveys
0.2 allows for centring errors especially on short lines

The corresponding rejection values for residuals based on a 95% confidence level (i.e. 2.5r) for various distances are:

Distance	**r**	**Rejection value**
100 m	9 mm	22 mm
200 m	12 mm	30 mm
500 m	21 mm	52 mm

State Control Surveys undertaken by direction of the Surveyor General are generally carried out at SP1 Class B level where c = 15 in the above formula. The State Geodetic Survey uses values of c less than or equal to 7.5.

3 Observation Requirements

Modern technology has made it possible to efficiently measure a breakdown survey network to a very high accuracy.

It is prudent to make enough new measurements so that the survey network can be adjusted with minimum constraints and a check made on the internal consistency of the new observations, while at the same time providing a quality and consistency check on the existing coordinates.

The adjustment program HAVOC is capable of handling numerous redundancies. Extra observations between marks and to distant trigonometrical stations, over and above the traditional closed traverse, can all be handled, and help in providing internal consistency checks, and checks on the State Survey Control Network.

In order to protect against gross errors, the following field practice is recommended:

1. All horizontal angles, directions or bearings should be determined by two rounds of face left and face right observations.

If the difference between the two rounds is greater than:
30 seconds for distances up to 200 m;
20 seconds for distances between 200 m and 400 m;
15 seconds for distances greater than 400 m;
then another round should be observed to determine which round to reject.

2. All distances should be measured both ways. If the difference between the two distances is greater than 10 mm + 15 ppm (i.e. 10 mm + 1.5 mm / 100 m), the distance should be measured again to determine which distance to reject.

3. Atmospheric conditions should be observed regularly, and the resulting atmospheric correction entered into the electronic distance measuring instrument.

4 Network Connections

All permanent marks should be included in a closed survey network, which includes a traverse that commences from two established permanent marks and closes on two other established permanent marks. No mark should be left “hanging” at the end of a radiation. A connection to the cadastre should not have to be used to close a survey network.

Ideally, the network should be such that it is interpolated between existing coordinated marks. The more existing coordinated marks that are included in the survey network, particularly those surrounding the survey, the better the adjustment can be fitted to the existing control.

Extrapolation will be accepted provided the survey network has sufficient redundancies or angles/bearings to trigonometrical stations to give an internal check on the survey network and provide orientation control. Extrapolation without a close or redundancies will not give reliable results and will not be computed.

Angles/bearings should be observed to any trigonometrical station visible from any point. If a trigonometrical station is within measuring range, measurements should be made to it from two marks, if practicable.

Four diagrams are included at the end of this direction showing typical survey networks in differing situations.

5 Connections to the Cadastre

Clause 42(3) of the Surveying and Spatial Information Regulation 2012 requires that all connections are proved by closed survey and shown on the survey plan. Every Permanent Mark must have a connection shown to a cadastral corner or road intersection point. The connections are proved by closed survey when the dimensions between Permanent Marks are also shown on the plan.

The exception to showing a connection to the cadastre is where a distant mark has been observed to confirm the MGA orientation of the survey, and a connection to the cadastre in the vicinity of that mark has no influence on the cadastral definition.

6 Survey Plan

All dimensions between Permanent Marks should be shown as reduced means of the observations.

Bearings should be shown to one second or half the least count of the instrument used. Distances should be shown to a millimetre.

7 Pre-Calculation

Coordinates can be computed prior to plan lodgement if a diagram of the survey network is forwarded to Survey Information & Systems, Spatial Services. The network will be computed and the results entered into SCIMS.

If a network is computed by a surveyor using an acceptable least squares adjustment program, the input file and output file can be forwarded to the Office of the Surveyor General, Spatial Services by email. The results will be ratified and entered into SCIMS.

In both the above cases, a SCIMS printout will be returned to the surveyor submitting the survey control information.

For larger subdivisions, where suitable survey control is not available, Survey Services, Sydney, Bathurst or the Regions, should be consulted at an early stage. This will allow sufficient time to arrange a control survey that will provide sufficient surround control for the subdivision.

Contact details:

Office of the Surveyor General
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Department of Finance, Services & Innovation
Queens Square Building
1 Prince Albert Rd
SYDNEY NSW 2000

or

GPO Box 15
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Department of Finance, Services & Innovation
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Diagram 1 - Fringe Development Area

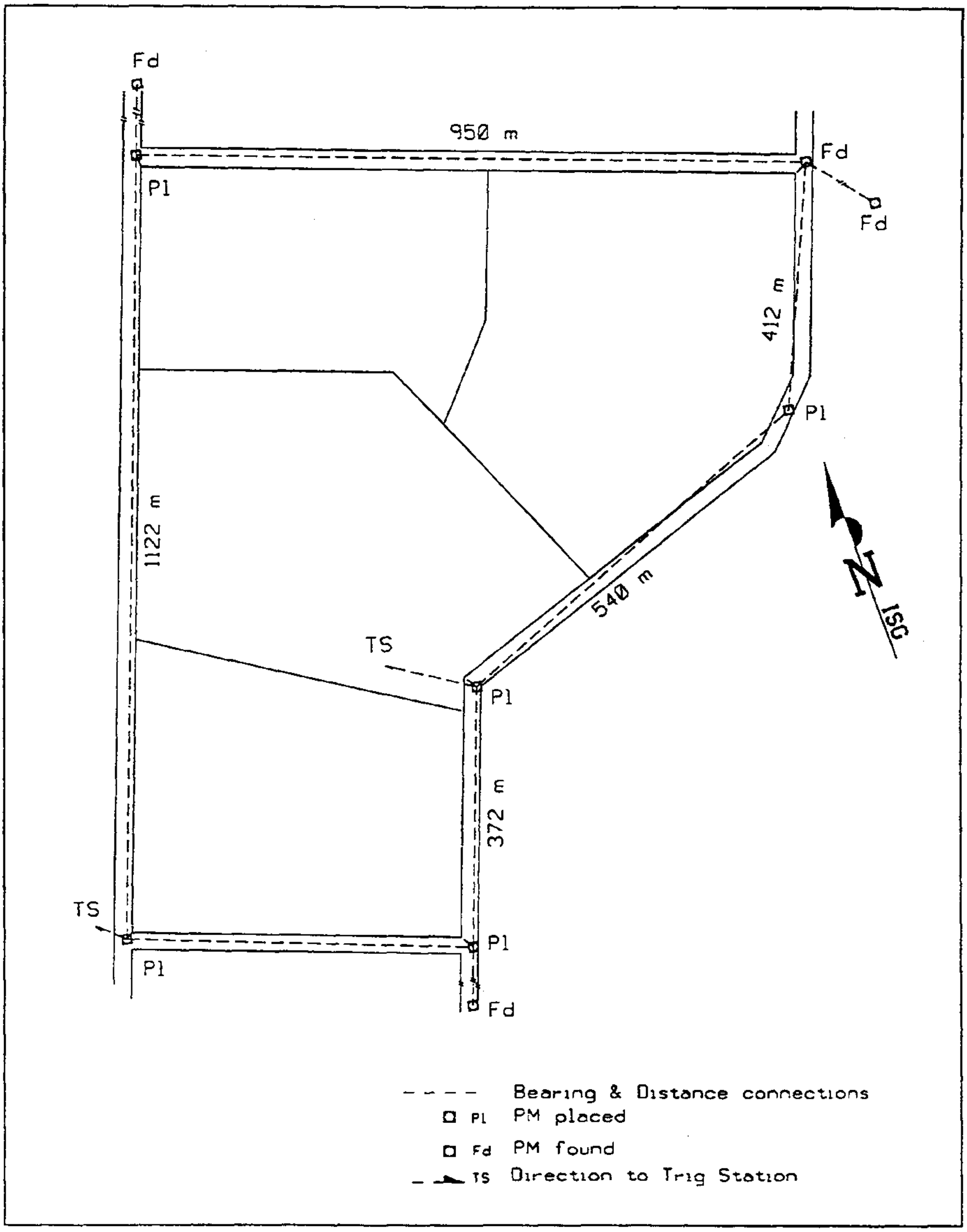


Diagram 2 - New Residential Subdivision

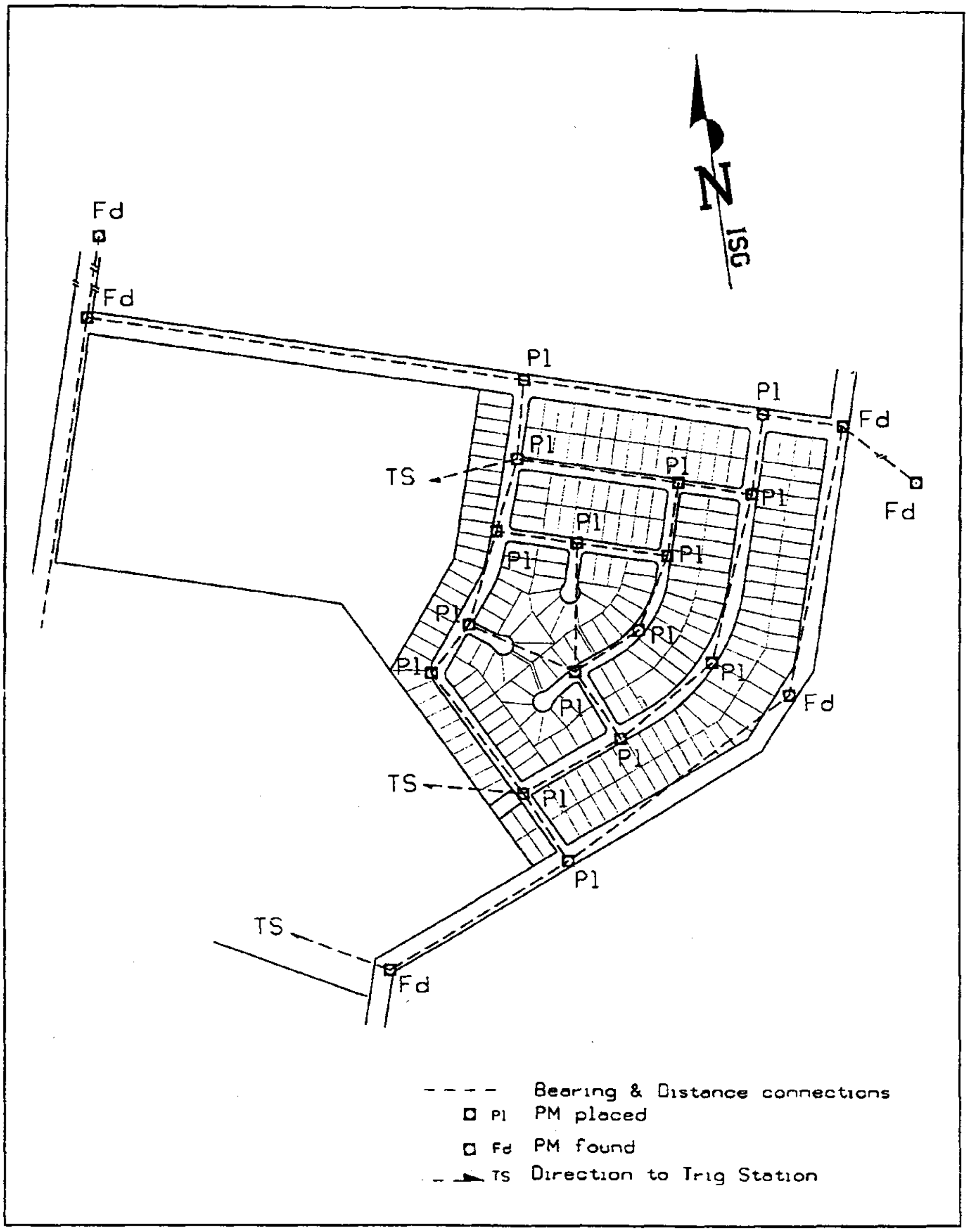


Diagram 3 - Subdivision of Urban Lot

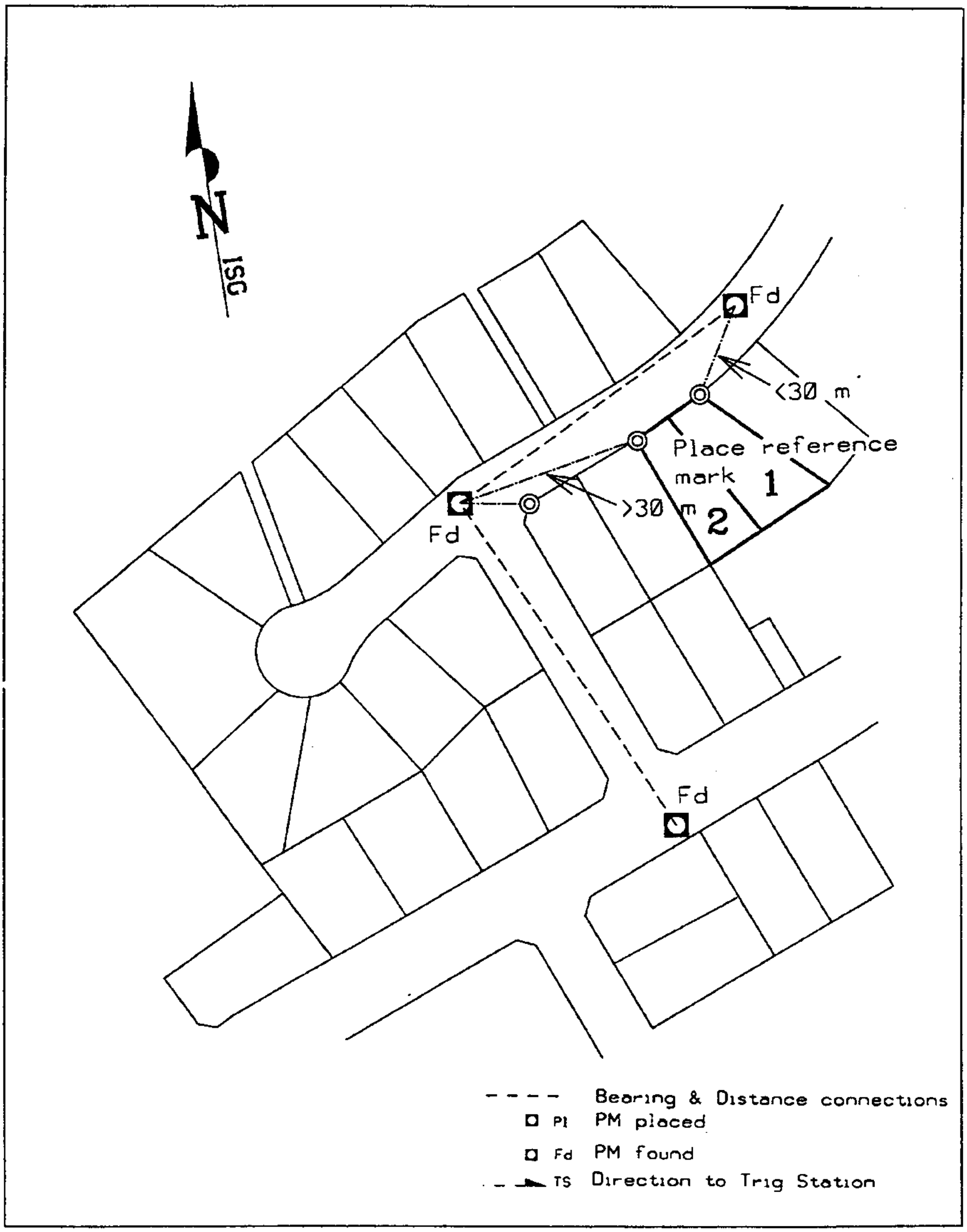
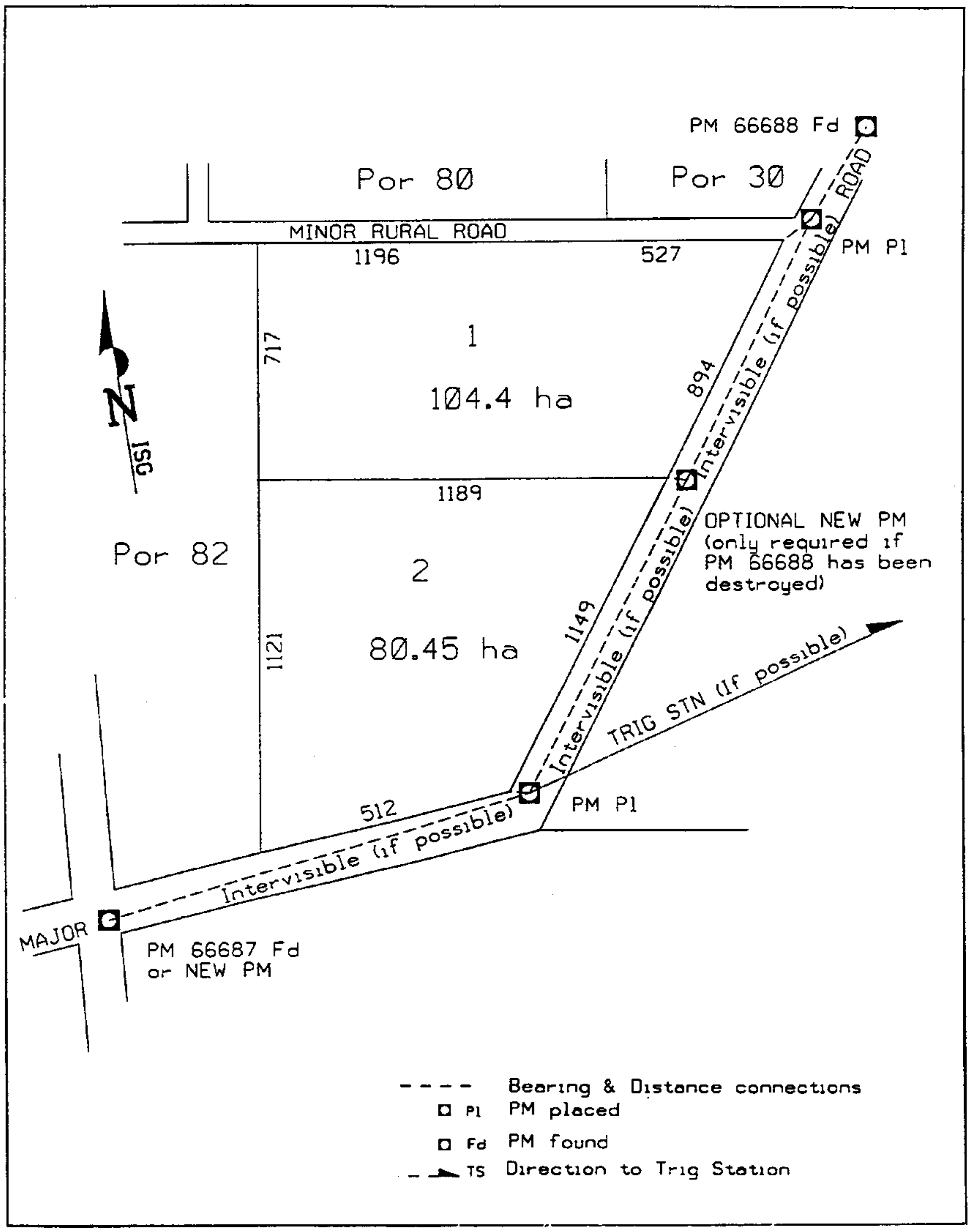


Diagram 4 - Rural Subdivision



Part 2: Class B Trigonometrical Levelling

1 Introduction

This Specification defines how to combine trigonometrical levelling as part of the horizontal control traverse outlined in Part 1 of this Direction.

Adoption of this Specification will achieve:

- Class B accuracy standards for trigonometrical levelling; that is, a standard deviation for each height observation of 15(d + 0.2), where d is the distance to any station in kilometres (see ICSM SP1 on Standards and Practices for Control Surveys, Version 1.7, http://www.icsm.gov.au/publications/sp1/sp1v1-7.pdf).

- Economic benefits in combining trigonometrical levelling with horizontal traversing.

2 Technical Requirements

2.1 Datum

All heights are to be based on the Australian Height Datum (AHD) 1971, originating from, and closing onto, at least two existing Permanent Marks which have AHD heights with vertical class of L2A, LA, LB, LC, LD, 2A, A, or B, as approved by the Surveyor General.

It is desirable that trigonometrical levelling runs be connected to all existing Permanent Marks, with accurate AHD heights, located in the vicinity of the survey. This not only strengthens the connections to AHD, but also provides an essential check of the results.

Where any Permanent Mark is destroyed, damaged, or cannot be located, the circumstances must be reported to the Surveyor General.

2.2 Precision

The observations necessary to achieve Class B accuracy are to be checked for their internal consistency by repetition of the individual observations (zenith angles, slope distances, heights of instruments/reflectors).

Atmospheric refraction is one of the most severe accuracy limitations of trigonometrical levelling. However, the effect of atmospheric refraction can be reduced significantly using reciprocal zenith angle observations. **Reciprocal zenith angle observations cannot be considered to be independent observations for height difference.**

They must be considered in pairs with the mean value being adopted for the height difference calculation between marks.

3 Equipment

3.1 General

In order to achieve Class B accuracy, it is essential that all survey equipment is in good adjustment prior to field operation. Measurements must be carried out using constrained (forced) centring, and heavy duty tripods are recommended.

3.2 Theodolite

A single second reading theodolite with an automatic vertical circle compensator is required. To reduce the possibility of random errors, it is recommended that a theodolite with an integrated Electronic Distance Measuring (EDM) unit be used as a minimum; that is, a total station or semi-total station.

The use of a single second total station offers advantages through its automatic reading of circles and provision for electronic data recording.

3.3 EDM Unit

An EDM unit which is capable of measuring to a single prism at distances up to 400 m with a precision of 5 mm or better is required.

3.4 Reflectors (Targets)

It is preferable that the reflector assembly that is used in the constrained centring be compatible with the total station.

For computations it is an advantage if the reflector height is identical to the total station trunnion axis height.

Tilting reflector assemblies, where the reflector is offset from the tilting axis, must not be used.

3.5 Measurement of Height of Instrument/Reflector

In order to transfer trigonometrically levelled heights from the trunnion axis of the total station to each surveyed ground mark, the instrument and reflector heights must be measured accurately.

Appropriate measuring devices are:

- Pocket tape with both millimetre and inch graduations.
- A graduated centring rod with an accurate zero mark.

3.6 Levelling Staff (if used for permanent mark connections)

Use a good quality metric staff. Only one staff is required, thus minimising the effect of staff calibration errors. The zero mark should be checked before use.

4 Field Procedures

4.1 General

The best observation periods for zenith angle observations, in order to reduce the effect of atmospheric refraction, is between 1 hour after sunrise to 1 hour before sunset. If observations need to be made outside this recommended period, then the time between reciprocal observations must be reduced to a minimum.

4.2 Selection of Traverse Stations

The location of traverse stations is dictated by the following:

4.2.1 Horizontal Traverse Stations

When trigonometrical levelling is combined with horizontal traversing, the traverse stations are dictated by the horizontal traverse requirements.

4.2.2 Sight Length

The sight length between traverse stations should not be less than 40 m and not longer than 300 m. If a sight length between traverse stations is greater than 300 m, then an intermediate change point **must** be installed.

4.2.3 Inclination of Sight Line

In general, sight line inclinations should not exceed ±6°. However, an occasional inclination of up to 10° can be accommodated.

4.2.4 Ground Clearance

Within 50 m of the total station standpoint, the minimum ground clearance of a sight line is 0.8 m. Beyond 50 m the sightline should never go closer than 0.5 m to the ground.

4.3 Reciprocal Zenith Angle Observations

The time between reciprocal zenith angle observations should be kept to a minimum. However, the reciprocal observations **do not** have to be carried out simultaneously.

The time difference between reciprocal observations should not exceed 30 minutes.

Three arcs (FL&FR) of zenith angles are to be observed. The standard deviation of the mean must be less than ±3 seconds of arc.

4.4 Height of Instrument/Reflector Measurements

This particular measurement is crucial to the accuracy of trigonometrical levelling. The height needs to be independently measured twice, with both measurements requiring agreement within 2 mm.

An error in this measurement only affects the height of the individual station. The error is not propagated throughout the trigonometrical levelling run.

4.5 Use of Level Staff

A good quality metric levelling staff may be used in place of a pocket tape or centring rod for the height connection to permanent marks, with accurate AHD levels, not included in the horizontal traverse and within 40 m of the instrument standpoint. The one staff should be used for all vertical connections.

When using a level staff and total station, the following procedure is recommended for height transfer measurements:

1. With the staff set vertically above the Permanent Mark, it is observed with the total station on face left (FL) set at exactly 90°.

2. A second reading is taken on face right (FR) with the total station set exactly at 270°.

3. Both readings are to be to the nearest millimetre.

4. The FL & FR readings are meaned.

5. Steps 1-4 should be repeated and the two means compared. The measurement procedure needs to be repeated, if the difference between the means exceeds 2 mm. The average of the means is used for the height transfer.

4.6 EDM Observations

Each EDM observation is the mean of a minimum of two separately pointed observations. If the two observations disagree by more than 3 mm, then the measurement needs to be repeated.

4.7 Meteorological Observations

No other meteorological observations are required other than those observed for the EDM distance corrections.

5 Recommended Field Sequence

5.1 Trigonometrical Levelling with Horizontal Traversing

At each traverse station, the measurements are carried out according to the following sequence when using a semi-total or total station:

1. Replace the reflector with the total station.
2. Observe the zenith angles to the back station.
3. Measure the height of the reflector.
4. Measure the height of total station.
5. Observe the horizontal directions.
6. Observe the backward and forward EDM distances.
7. Measure the height of total station (check).
8. Observe the zenith angles to the forward station.
9. Replace the total station with the reflector.
10. Measure the height of the reflector (check).

When using a total station with a data recorder, horizontal directions, zenith angles and EDM distances can be observed simultaneously.

Holding Point

If the traverse observations cannot be concluded on a particular day, the last observed traverse station is called a **holding point**.

Finishing on a holding point means that the zenith angle and the EDM distance are observed to the back station (see steps (1) to (4) above).

When the survey re-commences, a reflector is set at the back station, the reflector height measured, and the measurement procedure started with step (4) above. This is to ensure that the time difference between zenith angle observations is less than 30 minutes.

Change Points

If a traverse leg exceeds 300 m in length, a suitable intermediate change point needs to be established between the two traverse stations in order to avoid the detrimental effect of refraction. The sequence of measurement is that shown above.

5.2 Stand-Alone Trig Levelling

For stand-alone trigonometrical levelling, there is no need to establish the change point on the ground, or to observe horizontal angles.

The sequence of measurement in this instance is:
1. Zenith angles to the back station.
2. EDM distances to the back and forward station.
3. Zenith angles to the forward station.

6 Conclusion

Where AHD heights are determined, the following should be sent to Survey Services, Sydney, within two weeks (see address below):

(a) For permanent marks placed, a locality sketch plan with AHD height clearly shown;

(b) For existing permanent marks, the AHD height value.

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Spatial Services – Department of Finance, Services & Innovation
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End of Direction