New South Wales Government

Surveyor General's Directions

No. 9

GNSS for Cadastral Surveys

(Global Navigation Satellite System for Cadastral Surveys)

DOCUMENT CONTROL SHEET

Contact for Enquires and Proposed Changes

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Page

Table of Contents

1. Introduction

This Surveyor General's Direction outlines the recommended procedures for use of Global Navigation Satellite System (GNSS) methods to undertake cadastral surveys in accordance with the Surveying and Spatial Information Regulation 2012 (SSIR 2012) under the Surveying and Spatial Information Act 2002 (SSIA 2002).

The use of GNSS for control surveys is dealt with by Surveyor General's Direction Number 12, "Control Surveys and SCIMS", and the Intergovernmental Committee on Surveying and Mapping (ICSM) through the publication: "Standards and Practices for Control Surveys" (SP1). The SP1 publication can be accessed on the ICSM Internet site at
https://www.icsm.gov.au/sites/default/files/2017-05/sp1v1-7.pdf

As GNSS is an evolving technology, this Direction will be subject to review.

It is the responsibility of the surveyor to ensure that their GNSS equipment and the methods they employ in measurement will achieve the accuracy required.

The most appropriate way to ensure accuracy of GNSS methods is by connection to the State Survey Control network including:

- GNSS Continuously Operating Reference Stations (CORS), such as "CORSnet-NSW",
- Established permanent survey marks,
- Survey marks with accurate AHD values (SSIR 2012).

The Surveyor may choose some other independent means such as:

- Confirm GNSS measurements against calibrated EDM distances.
- Use survey marks that have a Regulation 13 certificate (under the National Measurement Regulation 1999)

This will also ensure the survey's reliability, scale and orientation. The correct use of GNSS allows these connections to be made effectively and efficiently.

The legal traceability of GNSS measurements is an extremely complex and as yet unresolved issue at a State, Federal and International level. This should NOT deter surveyors from using this technology for legal purposes. Surveyors are strongly encouraged to connect to accurate marks in the NSW State Survey Control network for each survey.

> Current analysis and research indicates that GNSS **must not** be used to derive or measure a distance under **100 metres** as part of a cadastral survey to meet the requirements of the SSIR 2012. The exception is for a survey not requiring strict accuracy under SSIR 2102 (Clause 9)

These directions are specific to the use of GNSS as a means of measurement for cadastral surveys. All existing regulations, specifications, procedures and practices still apply.

2. GNSS General Requirements for Cadastral Surveys

The results from using GNSS methods are dependent upon factors such as:

a) The GNSS method used,
b) Session length,
c) Redundancy,
d) Proximity to existing control,
e) Atmospheric conditions,
f) Obstruction of the antenna, and
g) Homogeneity with existing control.

GNSS observations produce either three-dimensional absolute position measurements or relative three-dimensional vector measurements between positions. These measurements must be converted to two-dimensional (Grid bearing and horizontal ground distance) measurements for inclusion on the survey plan. Grid distances may be shown for long measurements, particularly for those greater than 5km in length. Where Grid Distances are shown, they must be annotated as such.

A GNSS measurement will be deemed as a direct measurement if it is determined from a single GNSS vector which was observed simultaneously at each end of the line. A GNSS measurement will be deemed as a derived measurement, if it is determined indirectly by non-simultaneous GNSS observations at each end of the line.

Any bearings and distances shown on the plan must satisfy all angular, length and misclose requirements stated in the SSIR 2012. All lengths quoted on a Deposited Plan must attain a minimum accuracy of 10 mm + 50 parts per million (ppm) at a confidence interval of 95% (as per Clause 25(2) SSIR 2012).

2.1 Accepted GNSS Methods

The accepted GNSS methods for cadastral surveys include:

2.1.1. STATIC – This involves post processing single baseline solutions usually using commercial GNSS software producing static or fast/rapid static results.

2.1.2. CORS STATIC- This involves post processing single baseline solutions with data from the users' receiver together with data obtained from a recognised CORS. A recognised CORS adheres to Tier four or better according to the DCS Spatial Services Guidelines for CORS. Refer to https://www.spatial.nsw.gov.au/__data/assets/pdf_file/0005/129398/CORSnet-NSW_Web_Portal_User_Guide_V23.pdf

2.1.3. AUSPOS - Post processing of multi baseline solutions using AUSPOS, Geoscience Australia's Online GPS Processing Service

2.1.4. RTK - Real Time Kinematic single base solutions using a local independent base station usually located at the site of the survey,

2.1.5. CORS RTK - Real Time Kinematic or Network Real Time Kinematic (NRTK) solutions, using the Virtual Reference Station (VRS) or the Master-Auxiliary Concept (MAC) for CORSnet-NSW

2.1.6. PPP - Precise Point Positioning (post processed).

All survey plans that use GNSS in the survey must state one or more of the above methods.

3. GNSS Annual Verification

Verification and validation are NOT calibration. Unlike EDM equipment, GNSS receivers cannot be calibrated for scale because the definition of scale is inherent in the satellite and orbit data.

Annual Verification must occur for each GNSS method that is used to determine survey accurate observations for inclusion on a survey plan.

Annual Verification is not required for GNSS methods used for “surveys not requiring strict accuracy” under Clause 9 SSIR 2012. However, it is good practice to check the field coordinates against an established survey mark to ensure the datum and projection parameters are set correctly.

Verification is a rigorous, three-dimensional verification procedure. It must be conducted annually for any GNSS equipment or method used. Field and reduction methods used for the verification must conform to those typically used by the surveyor and with the manufacturer’s guidelines.

3.1 Minimum requirements for verifying GNSS Equipment

The following is the minimum requirements for verifying GNSS equipment:

3.1.1. The verifying network must include a minimum of four permanent survey marks with Geocentric Datum of Australia 1994 coordinates (GDA94) recorded in SCIMS of Order 2 or better and vertical Order 2 or better, preferably with the same SCIMS Source ID (i.e. the coordinates were determined within a single adjustment).

3.1.2. A braced quadrilateral formed between at least four (4) established permanent survey marks of Class B Order 2 or better shall be observed or derived. The six baselines are to be observed/derived and processed as independent vector measurements.

3.1.3. Users should follow the recommendations set out in the manufacturer's handbook and manuals. All ancillary equipment must be checked and be in good adjustment and repair.

3.1.4. Field observation log sheets should be completed for each session. The receiver type, serial number and firmware used must be recorded on these log sheets. A GNSS log sheet can be obtained from https://www.spatial.nsw.gov.au/__data/assets/pdf_file/0019/221734/Generic_GNSS_Log_Sheet.pdf

3.1.5. Meteorological readings are not required, but rapidly changing weather conditions can affect all GNSS results especially over longer distances.

3.1.6. A minimally constrained least squares adjustment of the observed baseline network must be carried out holding one permanent survey mark fixed at the “official” SCIMS value, to verify that the survey meets the required standards. All adjustments of GNSS data should be 3 dimensional in terms of the GDA94.

3.1.7. As there are many software updates and upgrades during the life span of GNSS equipment, the use of “old GNSS test data” is essential to ensure accurate processing results are achieved after each software upgrade. Usually software upgrades happen more frequently than equipment upgrades and the orderly archival and retrieval of GNSS data sets will be beneficial

3.1.8. Surveyors may seek approval for a local verifying network by sending a submission and data in a form as specified in SG Direction 12 to the Chief Surveyor, DCS Spatial Services.

Trigonometrical Stations and Permanent Marks should be used in preference to State Survey Marks due to their superior stability. The latest coordinates (GDA94/AHD71) must be obtained from SCIMS. By holding the values of one of these marks fixed, the three-dimensional GDA94/AHD71 coordinates for the other non-fixed marks are derived using the GNSS method.

Surveyors should bear in mind that co-ordinates in SCIMS are derived from adjusted networks, and reflect adjusted bearings and distances, not direct observations. If significant difference is found when using the State Survey Control Network, please contact your local Survey Control office to clarify the accuracy of the local network.

Preference should be given to using a State GNSS Test Network where possible. Note that the State GNSS Test Networks have their own value coordinate that may have a higher accuracy than the value recorded in SCIMS.

Surveyors should reject the verification if the difference between their measurement and the derived vector from the published coordinates is greater than 15mm + 10ppm

The results of the annual verification must be forwarded to the Surveyor General if requested.

3.2 State GNSS Test Networks

To enable the rigorous testing of new GNSS technology the Surveyor General has currently established two precise GNSS test networks. Both are based upon existing EDM calibration testlines. They are located in Sydney (Bass Hill area) and Newcastle (Newcastle University area), see Figures 1 & 2. These networks may be used for annual verification. Precise three-dimensional local GDA94 and AHD71 coordinates are available for all marks in the test networks. These precise coordinates should be used in annual verifications as they may differ slightly to those in SCIMS.

Detailed instructions for both GNSS Test Networks, and any future GNSS test networks, may be obtained from:
https://www.spatial.nsw.gov.au/surveying/publications/current_documents

Also see the Surveyor-General of the Australian Capital Territory - Guideline No 9. “GNSS Equipment Verification” for details of the GNSS Verification network within the Australian Capital Territory. https://www.planning.act.gov.au/__data/assets/pdf_file/0011/892703/Guideline_No_9_-_GNSS_Verification.pdf

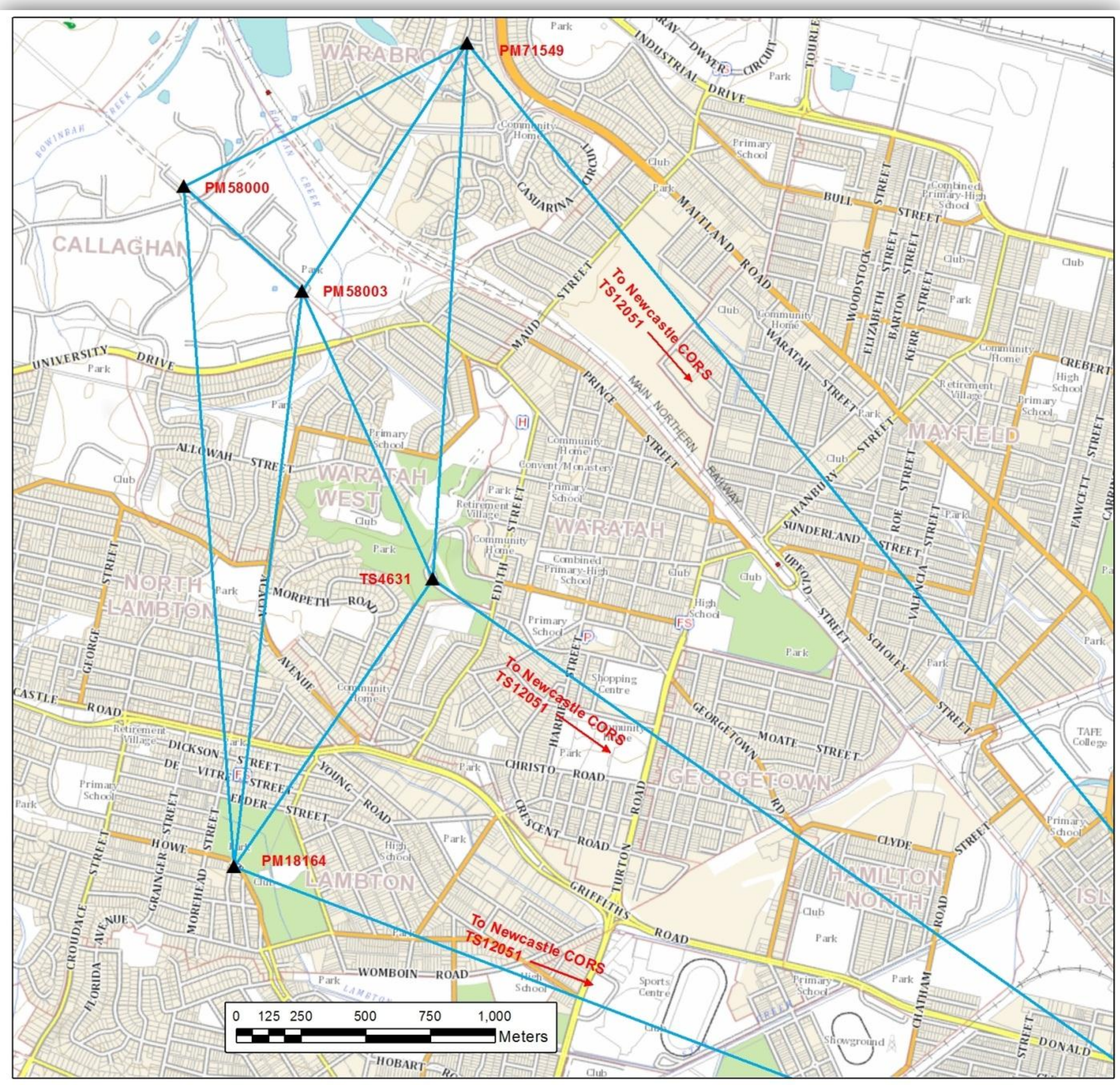


Figure 1: Newcastle GNSS Test Network

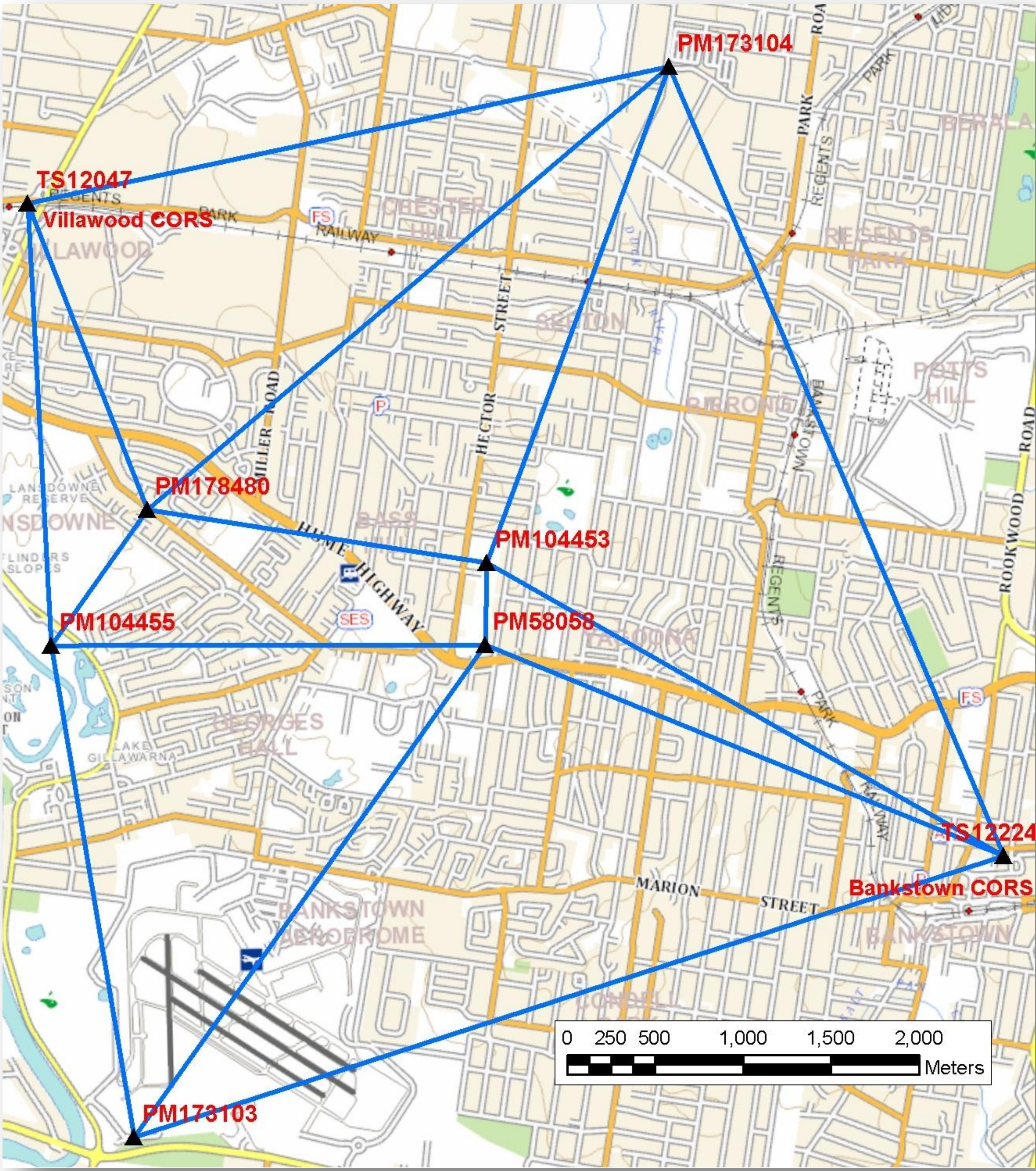


Figure 2: Bass Hill GNSS Test Network

4. Survey Validation

All GNSS are operated by international parties. Most GNSS augmentation systems (e.g. CORSnet-NSW, GPSnet, etc.) are operated by Government or commercial third parties. These are NOT under the surveyor's direct control. As such, any GNSS equipment and methods used must be confirmed:

4.1.1. In each and every survey that they are employed - (Survey Validation), and

4.1.2. Annually against higher order established marks in the State Survey Control Network (Class B, Order 2) or special GNSS Test Networks - (GNSS Annual Verification - see Section 3).

Survey validation is a basic, three-dimensional, "relative" check against an external source. It must be conducted for all GNSS methods used in a survey i.e. each day for RTK/NRTK and for Static at each location. External sources of measurement validation may include:

- 4.2.1. The MGA bearing and ground distance between a pair of established permanent survey marks, or
- 4.2.2. An independent distance validation measurement by EDM.
- 4.2.3. A minimum of two AUSPOS positions can be used to validate RTK/NRTK if:
  - 4.2.3.1. observation periods are longer than two hours,
  - 4.2.3.2. distance between the positions is greater than 500 metres and
  - 4.2.3.3. rapid orbits are used for the position processing
- 4.2.4. Static can validate RTK/NRTK when carried out to class C standards

The check validation line should be commensurate with the size and nature of the survey.

Validation is achieved if the comparison of bearings and distances between the GNSS result and the external source achieve Class C (30(d+0.2)).

5. Best Practice Guidelines

The GNSS methods used must be recognised by surveyors as good practice and for RTK methods in particular, should always support good cadastral survey practice such as:

- working from the whole to the part
- establishing a control framework that is fit for purpose
- "running the boundary" where appropriate
- Avoiding unchecked radiations.

If the survey accuracy required is at the limits of the GNSS method, then the surveyor must select a different method that will ensure the accuracy required.

Predominantly, only GNSS receivers capable of using carrier phase observations are to be used. The general exception being handheld "code only" receivers that may be used to determine the approximate location of permanent survey marks.

In order to minimise processing errors and biases, calculation of baselines must start from a mark which has MGA coordinates and an ellipsoidal height. The accuracy of these values must be better than 10 metres both horizontally and vertically. These coordinates help ensure that baselines have the correct scale and ambiguity resolution. For example: a 10 metre error in the starting coordinate will result in a 1 ppm baseline error.

Connection to the State Survey Control network is the most appropriate way to ensure that an accurate starting coordinate is used. GDA94 coordinates are equivalent to WGS84 (to about 1 metre). Ellipsoid height is obtained from AHD with the appropriate Geoid-Ellipsoid separation value applied. Geoid-Ellipsoid separation values, commonly referred to as "N" values, should be sourced from AUSGeoid09. The AUSGeoid09 can be accessed at: www.ga.gov.au/geodesy/ausgeoid/nvalcomp.jsp.

GNSS methods that involve distant CORS sites or similar may produce results that are not homogeneous with the local horizontal and vertical networks. This may result from:

5.0.1. The CORS site using a completely different datum (e.g. ITRF or WGS84), or
5.0.2. The CORS site using a different regional or local realisation of GDA94/AHD71 (e.g. a Reg 13 recognised value standard for position), or
5.0.3. The accuracy of the CORS site survey, or
5.0.4. Distortions in the national horizontal geodetic and vertical levelling networks, or
5.0.5. Local distortions in the State Survey Control Network.

When selecting a GNSS method the surveyor should fully understand the nature, extent and impact of that method and how it affects the local coordinates determined.

5.1 Datum

A single AUSPOS solution or a single measurement to a CORS or an established survey mark brings GDA (i.e. the horizontal datum) to the land surveyed. But, this does not mean the land surveyed is oriented on MGA

A second independent AUSPOS solution or a second measurement to a CORS or a measurement to another established survey mark will enable MGA orientation to be determined.

5.2 Orientation of Surveys (Datum Line) using GNSS

The position of survey marks defining the Datum Line of any survey must be determined specifically for each survey to ensure the survey marks' veracity and stability. It is strongly encouraged that GNSS Surveys adopt an MGA orientation where the datum line is based upon permanent survey marks or reference marks.

If GNSS methods are used, then Clause 12(7) (b) of the SSIR 2012 states "..the survey plan must state from what the orientation has been derived...", therefore, the plan must state one of the accepted methods shown in section 2.1.

The Datum Line should be local to the plan, that is, within a few kilometres of the land survey.

Specifically,

5.2.1. For rural surveys, AUSPOS, CORS Static or CORS RTK observations are acceptable methods to determine an MGA orientation if there are no established permanent survey marks within 1000 metres from land surveyed and survey validation requirements in section 4 are satisfied, and

5.2.2. The Datum Line must be over 500m in length and be comprised of permanent survey marks or reference marks as defined by SSIR2012.

While surveyors are strongly encouraged to use GNSS to determine MGA orientation for their survey, this Direction does not exclude the use of GNSS that adopts a previous plan's datum as the orientation.

5.3 Accuracy Requirements

Cadastral survey length accuracy (10mm + 50ppm) closely equates to the Class C category. Table 1 below shows the relationship between the class of surveys with relation to point error and relative errors over a line. This means that if the GNSS equipment/method being used has a stated point accuracy of no better than 0.020m (without regard for setup errors and site considerations) to attain class C the minimum length measured should be 400m. Using GNSS equipment under 400m for cadastral purposes would require proof of point error accuracy through validation.

RTK and NRTK must **not** be used to measure directly or derived measurements for short lines (under 100m) as it does not meet the requirements of SSIR 2012 Clause 25(2). This requirement includes measurements to reference marks at corners.

Table 1: Class derived from station density and point error ellipse size (at 95%). The relative error ellipse size used in the determination of Class is stated in parentheses.

Point and (Relative) Error Ellipse / **Station Density (km)**	0.010 m (0.014 m)	0.020 m (0.028m)	0.030 m (0.042m)	0.040 m (0.056m)	0.050 m (0.070 m)	0.060 m (0.084m)	0.070 m (0.096 m)
0.1	C	D	E	E	–	–	–
0.2	C	D	E	E	E	–	–
0.4	B	C	D	D	E	E	E
0.6	B	C	C	D	D	E	E
0.8	A	B	C	C	D	D	D
1	A	B	B	C	C	D	D
2	A	A	B	B	C	C	C
5	2A	2A	A	A	A	B	B
10	3A	2A	2A	2A	A	A	A

5.4 Observational Guidelines

Regardless of the method used these guidelines provide a framework for the survey.

5.4.1. Work from the whole to the part. Observe a primary network to establish the datum, then in-fill other control as necessary. Where possible, connections to accurate height control should include additional marks to verify the datum.

5.4.2. The overall network geometry must be "fit-for-purpose". This implies redundancy, closed figures and no unchecked radiations.

5.4.3. Tripod setups should be used for all temporary base stations, high accuracy and/or static (including fast or rapid) methods. Bipods are superior to range poles and must be used by the rover for static surveys using kinematic methods and RTK surveys requiring best accuracy. All bulls-eye bubbles should be high accuracy and all surveying equipment including tribrachs, bipods and range poles should be maintained in correct adjustment.

5.4.4. Always provide independent checks for antenna heights by taking a second measurement using imperial units (inches) and ensure the two measurements agree.

5.4.5. GNSS surveying is a three-dimensional (3D) measurement method. GNSS observations are measured to the Antenna Phase Centre (APC). Exact offset measurements from the ground mark to the APC are always required. The "antenna height" is best measured vertically from the ground mark to the base of the antenna, commonly referred to as the Antenna Reference Point (ARP). The correction from the ARP to the APC is applied by either:

5.4.5.1. An offset value usually specified in millimetres which is sufficient for most standard applications, or

5.4.5.2. Applying an absolute (IGS) antenna model that specifies the offset and also accounts for the elevation and azimuth of each satellite and variations in the APC for higher accuracy. This is particularly important for heighting applications and when mixing antennas from different manufacturers (e.g. CORS).

5.4.6. The dilution of precision (DOP) is a measure of the diluting effect of satellite geometry on GNSS outputs such as position, height and time. The PDOP (Position) or GDOP (Geometric) value are most commonly used by surveyors to assess quality of position. A GDOP/PDOP value less than eight (8) is acceptable. However, it is different for many methods so the recommendations as set out in the manufacturer's handbooks should be followed. Planned GDOP/PDOP values may differ to those actually encountered in the field due to satellite availability and local obstructions. The combined effect of local obstructions at both ends of any baseline must be considered in all relative GNSS methods.

5.4.7. The minimum number of satellites observed at any one time must be four. Many GNSS methods generally require at least five satellites. All methods benefit from additional satellites.

5.4.8. Observation/epoch rates should follow the recommendations as set out in the manufacturer’s handbooks.

5.4.9. The elevation mask used in typical processing should usually be set at 15º and not be less than 10º above the horizon.

5.4.10. There is no need to use meteorological readings; use software default values.

5.4.11. Rapidly changing weather conditions can affect all GNSS results especially over longer distances.

5.4.12. Interference of GNSS signals can affect the quality of results or ability of the receiver to achieve an ambiguity fixed solution. Typical situations where this can occur is near radio towers or transmitters or high voltage power lines.

5.4.13. The observation period (i.e. session length) should be sufficient to enable ambiguity resolution (i.e. a FIX solution). To achieve this, follow the recommendations as set out in the manufacturer’s handbooks.

5.4.14. Single frequency receivers should not to be used to measure accurate baselines over 10 km.

5.4.15. Multipath is the reception of reflected signals and is primarily caused by large regularly shaped flat metallic surfaces such as buildings, vehicles and large water surfaces. Multipath errors are not constant. They change rapidly over time and are therefore particularly hard to detect. However, the errors tend to reduce over a reasonably short period of time, e.g. two to thirty minutes. Session lengths should be increased to minimise the effects of multipath and/or reoccupation should occur at a different time of day, resulting in different satellite geometry to avoid multipath effects. Short occupation periods used in real time methods are highly susceptible to multipath and can cause significant errors. Observing longer periods of GNSS data will not eliminate multipath, but it should reduce its effect if it exists.

5.4.16. Incorrect ambiguity resolution during initialisation and re-initialisation may occur in multipath environments, especially when using real time methods, and can cause errors of decimeters.

5.5 RTK Specific Guidelines

RTK GNSS observations may contain small biases that cannot be accounted for by even the most rigorous surveying practice. The result is increased uncertainty in the computed baselines in the order of a one centimetre (10mm). This is at the accuracy threshold of the SSIR 2012 and such methods must be avoided on short distances (less than 100 metres). The surveyor should be prudent and select a non-GNSS measurement method for distances under 100m. If it is necessary to use a kinematic method on short distances, then the surveyor must ensure that the accuracy of the measurement is assured by including a closed figure containing EDM/angle measurements, or the measurement is used only for lower accuracy applications.

5.5.1. Only correctly adjusted tribrachs or bipods are to be used. Range pole should only be used for natural features and/or lower accuracy detail work.

5.5.2. RTK base stations must have clear sky above 15º elevation for 360º horizontal view (tripod best).

5.5.3. RTK communication by radio or internet must be continuous while observing.

5.5.4. Initialisation at an established control mark or re-initialisation at a proportion of surveyed points must be undertaken. This is achieved by:

5.5.4.1. Moving the rover 10 metres away from the surveyed mark, i.e. out of the local multipath environment, and

5.5.4.2. Re-initialising the rover receiver (i.e. by a user command, or turning the receiver off and on again or turning the antenna upside down so that lock is lost to all satellites), and

5.5.4.3. Reoccupying the mark and comparing the position difference, or,

5.5.4.4. Other methods deemed suitable by the surveyor.

5.5.5. If **local** GDA94 coordinates and accurate AHD are required, adopt the coordinates of, and validate on, at least three established permanent survey marks with accurate AHD height, preferably surrounding the survey.

5.5.6. The best RTK check is to move the base station to a different established mark, or select a different CORS station then reoccupy all surveyed points. A single occupation using two or more base stations or CORS stations simultaneously does not constitute reliable redundancy.

5.5.7. In RTK and NRTK surveys undertaken by DCS Spatial Services, the following guide is used:

5.5.7.1. Observe for 2 minutes at a one second data collection rate (epoch) to obtain an averaged position. Averaging reduces the effect of individual outliers. Averaging for 2 minutes delivers a huge improvement in positioning quality whereas averaging for longer than two minutes is generally not expected to provide substantial further improvements,

5.5.7.2. Reoccupy each point at least once after waiting at least 30 minutes. Waiting any longer is not likely to provide any further benefits, These subsequent observations must use a different base station (RTK) or CORS station (CORSnet-NSW). If using NRTK a second occupation is adequate after 30 minutes.

Double occupations are required to eliminate blunders. Re-occupation should be made after 30 minutes has elapsed.

5.5.7.3. Beware that coordinate quality indicators provided by GNSS rover equipment are often overly optimistic, even under favourable satellite visibility and multipath conditions.

If clear sky is not possible, or multipath is likely, observation times should be extended.

Overall, it is up to the surveyor's professional experience and discretion to select the most appropriate survey method.

5.6 AUSPOS Specific Guidelines

AUSPOS is Geoscience Australia's free online GPS processing service, available for static point observations of extended duration. AUSPOS delivers coordinates that are independent of the local survey control network. AUSPOS positions are similar to GDA94(2010) coordinates derived by CORSnet-NSW without a site transformation. AUSPOS coordinates are derived by applying transformation parameters from the current global reference frame (ITRF20xx) to GDA94.

Heights are derived from ellipsoidal height values with the geoid-ellipsoid separation applied and are therefore not strictly AHD71 (the current AUSGeoid09 geoid model provides AHD71 heights from GNSS observations with an estimated accuracy of 50 mm across NSW)

AUSPOS accuracy is dependent on observation length, the antenna model and the satellite orbit data adopted for processing. The following guidelines are to be used;

5.6.1. Observation period must be at least 4 hours for acceptance into SCIMS at Class C,
5.6.2. GNSS observations use the rapid orbit data or better in the AUSPOS Processing,
5.6.3. The permanent survey marks (PM) and/or reference marks (RM) are to be more than 500 metres apart,
5.6.4. The AUSPOS reports of position measurement observed on PM's and/or RM's shall be attached to the DP at plan lodgement to enable DCS Spatial Services to update SCIMS ,
5.6.5. The orientation and length of a datum line is confirmed by Static or RTK. The length of a datum line can be confirmed by EDM measurements.

DCS Spatial Services uses coordinates from precisely determined AUSPOS sites for quality assurance of the existing survey control network. The position measurement may be included in future re-adjustments of the datum. DCS Spatial Services encourages surveyors to submit the RINEX data and log sheets together with theAUSPOS Report at https://www.spatial.nsw.gov.au/surveying/online_forms using the AUSPOS Submission form.

The major issue with AUSPOS surveys is their proximity to existing control. In some areas of the State, the difference between absolute GDA94 (2010) and locally GDA 94 (1997) derived GDA and AHD is significant (<0.3m horizontal, <0.5 height). If local GDA 94 (1997) coordinates are required, the surveyor must adopt the coordinates of, and validate on, at least three established permanent survey marks, preferably surrounding the survey.

With regard to network design, a single AUSPOS solution is a radiation (or an unchecked measurement) and is treated accordingly. Good survey practice is to ensure all measurements are checked.

Surveyors wishing to contribute AUSPOS data to the State Survey Control Network should consult Surveyor General's Direction No. 12: Control Surveys and SCIMS, available at:
https://www.spatial.nsw.gov.au/__data/assets/pdf_file/0004/231862/SG_Direction_12_.pdf

Horizontal accuracy up to and including Class A may be assigned depending upon observation session length and number of sessions at the survey mark. For example all Reg13 certification for CORSnet-NSW sites require at least 7 days of 24 hour sessions. AHD accuracy will not exceed class C.

5.7 Continuously Operating Reference Station (CORS)

CORSnet-NSW (https://www.spatial.nsw.gov.au/surveying/corsnet-nsw) is a network of GNSS continuously operating reference stations (CORS) providing fundamental positioning infrastructure for New South Wales that is accurate, reliable and easy to use. The CORSnet-NSW network continuously observes and corrects satellite navigation signals in order to provide international standard, high-accuracy positioning across NSW. Real-time data is streamed to users via a wireless internet connection. The following guidelines apply to all GNSS measurements using CORSnet-NSW and other recognised CORS;

Various observation methods are used in conjunction with CORS networks:

5.7.1. CORS STATIC: Post processing method, where static observations are made in the field and baseline vectors from the CORS sites are computed using processing software.

5.7.2. CORS RTK:

5.7.2.1. A single-base RTK, where the rover computes the position from a baseline vector from a single CORS site using correction data transmitted via a communication link in real time.

5.7.2.2. A Network RTK (NRTK) solution, where the rover computes a position in real time after receiving corrections transmitted via a communication link from multiple CORS sites surrounding the user.

There are benefits from using AUSPOS or CORS networks in cadastral surveying. However, fundamental surveying principles and accuracy requirements still apply.

Although CORSnet-NSW reference stations are assigned local GDA94(1997) and AHD71 values (available through SCIMS), the coordinates derived directly from CORSnet-NSW using RTK/NRTK refer to GDA94(2010) and are absolute in terms of adjacent existing marks. Therefore, as with AUSPOS, the proximity of the survey to existing local control must be taken into consideration. If local GDA94(1997) coordinates are required, the surveyor must adopt the coordinates of, and validate on, at least three established permanent survey marks, preferably surrounding the survey.

In instances where local coordinates are not required (e.g. distance and bearing) absolute coordinates are sufficient and a site calibration is not necessary.

With regard to network design, a single CORS observation is a radiation and is treated accordingly.

For CORS RTK results under optimal conditions, horizontal and vertical accuracy will not exceed Class C. Therefore CORS RTK cannot be used for Stratum surveys under the SSIR2012 where accurate heights are required.

6. Information Shown on Deposited Plans

The use of GNSS leads to a variety of outcomes not achievable by traditional cadastral survey methods. Therefore, it is desirable that the next user of a Deposited Plan is made aware that GNSS observations were used to derive some of the measurements.

All survey plans in which some bearings and distances were derived from GNSS methods must state one or more of the accepted GNSS methods that were used (see section 2.1). This will be acceptable to comply with Clause 67 of the SSIR 2012. For example, *all distances greater than xxxx metres shown on this plan have been derived by xxxx GNSS methods*

The results of the Survey Validation, i.e. the comparison of a GNSS observation and the independent check measurement, must be clearly shown on the survey plan.

Table 2: Survey Validation of Datum Line (Clause 61(3))

From	To	Grid Bearing	Grid Distance	Ground Distance	Method
PM 124152	PM124167	357º 49’ 22”	8 757.706	8 754.111	CORS RTK
PM 124152	PM124167	357º 49’ 22”	8 757.713	8 754.123	CORS Static

Where coordinates derived from GNSS observations are being shown on a survey plan, they shall be provided as MGA coordinates (i.e. E, N) with the appropriate Zone (see Table 3).

Table 3: MGA Coordinates of Permanent Survey Marks Found and/or Placed.

Surveying and Spatial Information Regulation 2012 – Clause 35 & 61.							
Mark	Easting	Northing	H Class	H Order	CSF	Method	Status
TS 12080	539 226.623	6 864 078.944	B	3	0.999 606	SCIMS	FOUND
PM 124152	520 142.235	6 862 227.083	B	2	0.999 590	SCIMS	FOUND
PM 61150	519 533.96	6 870 391.00	D	4	0.999 583	STATIC	FOUND
PM 81941	520 133.703	6 870 371.754	C	-	0.999 58	AUSPOS	PLACED
PM 124167	519 809.666	6 870 974.875	C	-	0.999 577	CORS RTK	PLACED
PM 124168	520 576.865	6 869 886.611	C	-	0.999 581	RTK	PLACED
Zone 56	Source = SCIMS; 01/04/2008						

All heights shown on survey plans must be referred to the Australian Height Datum 1971 (AHD71). Where heights are derived from GNSS methods AUSGEOID09 interpolated N values must be applied to GNSS ellipsoidal heights to determine AHD71 values.

Bench marks derived under SSIR 2012 Clause 13(3) for limitations in height must "...attain an accuracy equal to or better than Class B...". This is not attainable using CORS RTK. Therefore conventional terrestrial methods such as spirit levelling or trig levelling must be used to obtain the accuracy required.

6.1 Corrections – Grid to Ground Distance

As previously noted, GNSS produce either three-dimensional absolute (i.e. position) or relative (i.e. vector) results. These should be converted to two-dimensional (Grid bearing and horizontal ground distance) observations for inclusion on the survey plan.

A combined scale factor (using the sea level factor and either point or line scale factor) will be required to convert observed distances, or calculated MGA distances, to horizontal ground distances as required for cadastral surveys. The combined scale factor is made up of two components:

- Sea level correction – converts the ellipsoidal distance to a ground level distance (height factor) and,
- Scale correction – converts an ellipsoidal distance to a MGA projection distance (proximity to Central Meridian)

The application of the combined scale factor can lead to corrections of up to 500 ppm, therefore, it must be calculated and applied accurately for each point observed.

All distances shown on Deposited Plans in New South Wales must be horizontal ground distances. GNSS methods enable efficient measurement of long lines. For surveys greater than 5 km in length a combined scale factor for each permanent survey marks' coordinate must be shown on the survey plan. See Table 3 above. For surveys less than 5 km in length, it is acceptable to show a single combined scale factor for the entire survey.

It is no longer required to show long connections to distant CORS sites to derive the origin of the survey datum. The survey plan must state from what the orientation has been derived and also the survey validation of the datum line.

Extreme care and meticulous data archiving/quality assurance procedures are required to avoid grid and ground distance confusion at all stages of the survey.

7. Practical Considerations

Ideally, survey marks should be inter-visible, particularly Boundary to Reference Marks.

Where a survey combines both GNSS and Total Station methods, it is recommended that three (3) GNSS control stations are placed in order to adopt and validate the bearing for traversing. This will allow the field validation of both GNSS and Total Station measurements. Distances between GNSS control stations of greater than 300m are recommended in order to meet the angular accuracy requirements of the SSIR2012.

8. Field Notes & Data Archiving

Field notes and log sheets are an invaluable record of what was actually surveyed and must be kept for each GNSS occupation. They should contain the following information:

Project name,
Observers' name,
Date and session start/stop times,
Mark type and name/number,
Receiver filenames,
Equipment details (receiver/antenna) including models, serial numbers and antenna types,
Antenna height measurement and confirmation (check cm & inches),
Antenna height measurement method used (e.g. vertical or slant distance, ARP or APC),
GDOP/PDOP and number of observed satellites, and
a simple sketch.

A copy of DCS Spatial Services' GNSS Log Sheet is available from:
https://www.spatial.nsw.gov.au/__data/assets/pdf_file/0019/221734/Generic_GNSS_Log_Sheet.pdf.

A session-by-session observation diagram allows for easy analysis of network design and, in particular, determining redundancy.

Field notes and log sheets, raw observational data and adjustment results must be suitably archived.

All practically available observations must be retained when GNSS observations are used in the preparation of a survey plan. Exceptions include many "real time" GNSS methods, where it is not possible to retain correction/augmentation signals. Similarly, when "online" processing is used (e.g. AUSPOS), the surveyor must retain a copy of their own GNSS data and a copy of the AUSPOS report. The AUSPOS report/s must be forwarded to both SCIMS@customerservice.nsw.gov.au and be attached to the deposited plan at lodgement if the AUSPOS coordinates are used for MGA orientation of the survey.

9. Tips for GNSS Users

9.1. Do not measure, or derive measurements, shorter than 100m with GNSS.

9.2. Know your Kit

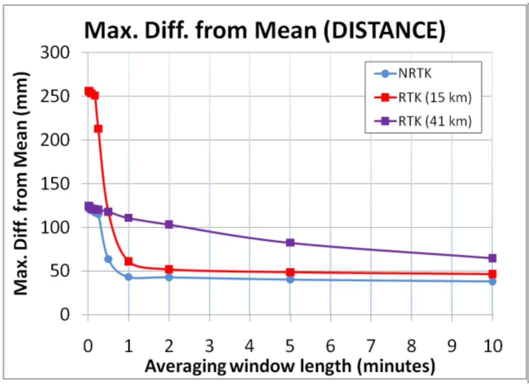
Surveyors are encouraged to know how to operate their equipment. A thorough understanding of the instrument settings is required and how those settings affect the results.

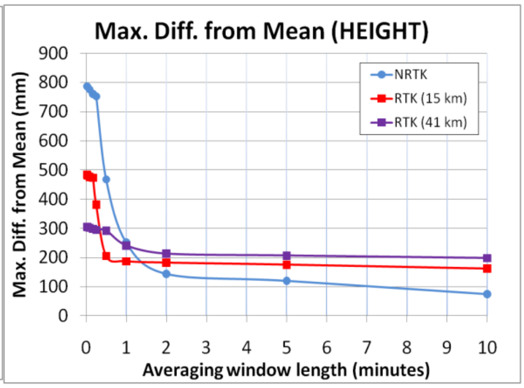
9.3. Traceability

Surveyors must adopt GNSS best practices to ensure reliable results. GNSS observations are currently NOT traceable to a recognised value standard.

9.4. Averaging (Windowing)

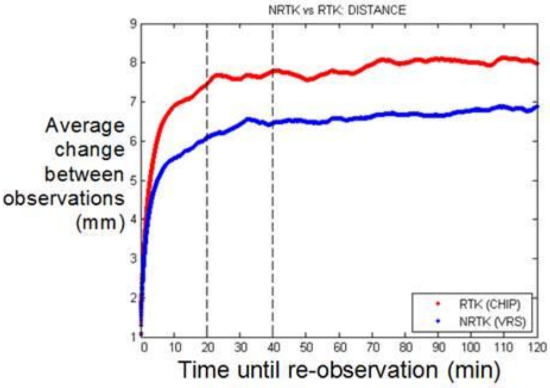
RTK surveys should observe for 2 minutes to remove large outliers.





9.5. Double Occupations

Double occupations are required to eliminate blunders. The height of the antenna should be varied. Research has shown that re-occupation should be made after 30 minutes has elapsed (see graph below). This allows the satellite constellation to change enough to provide a unique check.



9.6. Site Transformation

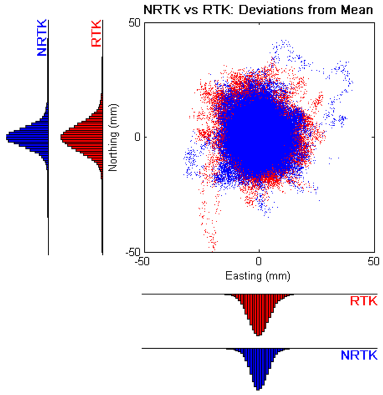
Adopt the coordinates of, and validate on, at least 3 established survey marks that have accurate AHD values. Four or more marks will give a better result. The marks should surround the survey project to avoid extrapolation.

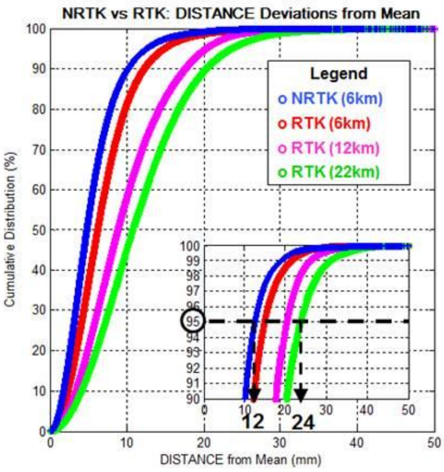
9.7. Antenna Models & Heights

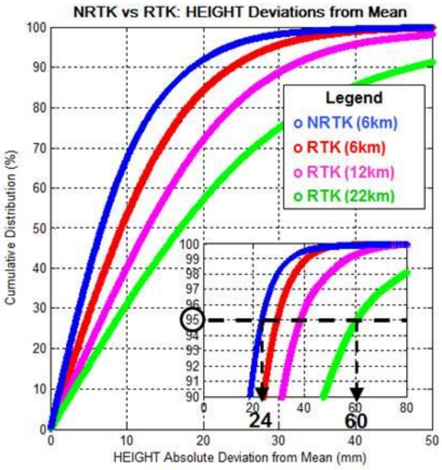
Only use ABSOLUTE antenna models. Use IGS models and consult your GNSS dealer for assistance. Measure the antenna height using cm and inches to check precision.

9.8. Network RTK

Network RTK has the same look and feel as single base RTK, only better, faster and more reliable.





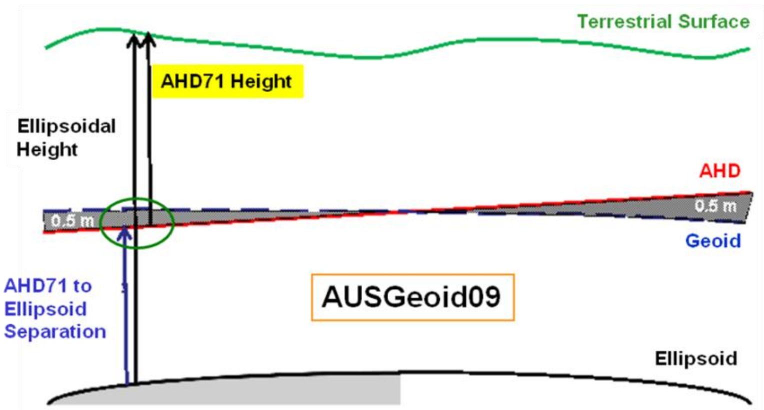


9.9. Cadastral Surveys

The Surveying & Spatial Information Regulation 2012 specifies outcomes from surveys, not methods.

9.10. AUSGeoid09

Use AUSGeoid09, rather than AUSGeoid98. AUSGeiod09 gives superior results for CORS and AUSPOS users.



AUSGeoid09 provides improved access to AHD71 due to the introduction of the geometric “sliver” component

9.11. Nearest Base

Use the nearest CORS Base Station for single base users.

9.12. Poor Mobile Coverage

Mobile communications will be dependent upon signal strength. If signals are weak it may be possible to rebroadcast the signal, however special permission may be required in the future.

10. Education

The Surveyor General highly recommends that, as a minimum standard, surveyors using GNSS should attend a University of NSW GNSS Short course (or similar) before attempting cadastral surveys with this technology.

All GNSS users should regularly consult with the manufacturer or supplier of new GNSS equipment or software to ensure they are using it correctly.

11. Conclusion

Many GNSS methods may be used in cadastral surveys but it is up to the surveyor's professional judgment to determine the most appropriate GNSS method having regard to the accuracy required by the survey and comply with the SSIR2012.

Appendix A.

CONTACTS:

Manager
Survey Infrastructure and Geodesy
DCS Spatial Services
PO Box 143
Bathurst NSW 2795
Ph: 02 6332 8200

Submission of proposed GNSS Verification Networks:

Surveyor General
DCS Spatial Services
McKell Building
2-24 Rawson Place
Sydney NSW 2000

surveyor-general@customerservice.nsw.gov.au

Attention: Chief Surveyor

Appendix B.

STATIC CHECKLIST

ISSUE	GUIDELINE	Yes/No or n/a
Equipment	Is the GNSS receiver capable of Class C or better (10mm + 50ppm)	
	Single frequency receiver must only measure lines under 10km	
	Single frequency for surveys not requiring strict accuracy	
	Dual frequency recommended	
Verification	Receiver, method and software verified annually against GNSS test network, an approved local network or minimum 4 established permanent marks of Class B order 2 or better	
Validation	At each survey location by connection to a minimum of 2 established permanent marks	
	Or by comparison with a measured EDM baseline	
Orientation	MGA orientation from two independent connections to established permanent marks, or	
	From plan on record showing comparison distance between at least two existing survey monuments	
Best Practice	Working from the whole to the part with a closed figure	
	Establish a control network that is fit-for-purpose	
	Always “run the boundary” where appropriate	
	Use correctly adjusted tripods or bipods only	
	Move all receivers each session or “Leapfrog” when traversing	
	If resetting tripods the antenna height should be more than 0.1m different	
	Check antenna heights independently (mm & inches)	
	Use correct absolute antenna models	
	PDOP should be <8	
	At least 4 satellites should be available (more is always better)	
	Weather conditions should be stable	
	Ensure ambiguities are resolved	
	Elevation mask minimum 10º (>15º recommended)	
	Baseline observations times should be 10 minutes + 2 minutes per km	
	Multipath or obstructions increase observation times	
Plan	Lines derived from GNSS should be clearly indicated on plan	
	Distances shown should be ground distances	
	SCIMS coordinate box should indicate an estimate of class for permanent survey marks	

RTK CHECKLIST

ISSUE	GUIDELINE	Yes/No or n/a
Equipment	Is the GNSS receiver capable of Class C or better (10mm + 50ppm)	
	Single frequency receiver must only measure lines under 10km	
	Single frequency for surveys not requiring strict accuracy	
	Dual frequency recommended	
Verification	Receiver, method and software verified annually against GNSS test network, an approved local network or minimum 4 established permanent marks of Class B order 2 or better	
Validation	Every day and at each survey location by connection to a minimum of 2 established permanent marks	
	Or by comparison with a measured EDM baseline	
	Or against two AUSPOS stations (if >500m apart,>4hrs data, rapid orbits)	
	Or against a static GNSS measured line done to Class C standard or better	
Orientation	MGA orientation from two independent connections to established permanent marks (these can be two CORS stations processed as static lines)	
	From plan on record showing comparison distance between at least two existing survey monuments	
Best Practice	Never to be used to derive a distance under 100m or to a reference mark	
	Working from the whole to the part within a closed figure	
	Always “run the boundary” where appropriate	
	minimum 2 minutes observation	
	Multipath, obstructions or height required always increase observation times	
	Minimum of two independent observations (i.e. using two base stations)	
	Independent observations at least 30 minutes apart	
	Use correctly adjusted tripods or bipods only	
	Check antenna heights independently (mm & inches)	
	Use the correct absolute antenna models	
	PDOP should be <5	
	At least 4 satellites should be available (more is always better)	
	Weather conditions should be stable	
	Ensure ambiguities are resolved	
	Elevation mask minimum 15º	
	Base stations must be clear sky above 15º elevation for 360º (tripod best).	
	Radio signal from base station must be continuous during observation	
	Range poles only to be used for defining natural boundaries	
Plan	Lines derived from GNSS should be clearly indicated on plan	
	Distances shown should be ground distances	
	SCIMS coordinate box should indicate an estimate of class for permanent survey marks	

CORS RTK CHECKLIST

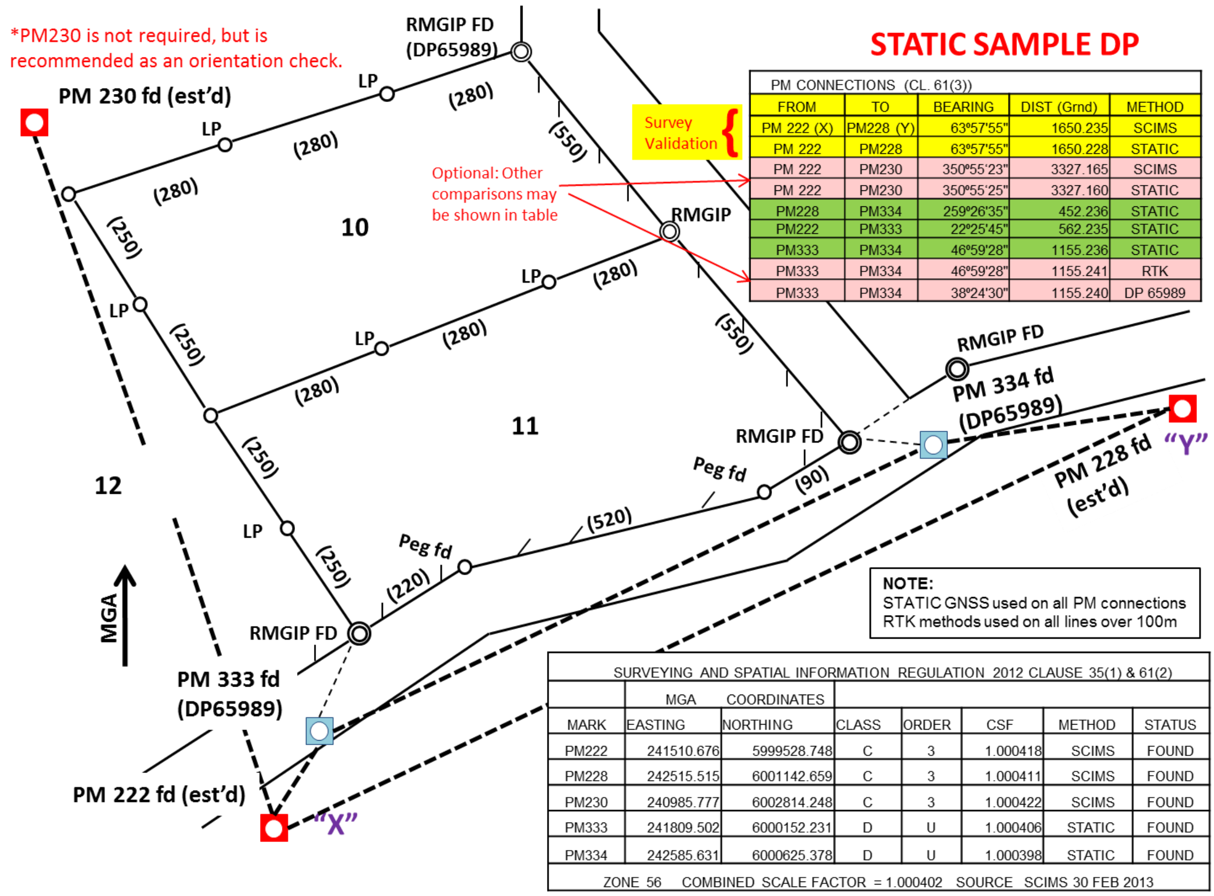
ISSUE	GUIDELINE	Yes/No or n/a
Equipment	Is the GNSS receiver capable of Class C or better (10mm + 50ppm)	
	Single frequency receiver must only measure lines under 10km	
	Single frequency for surveys not requiring strict accuracy	
	Dual frequency recommended	
Verification	Receiver, method and software verified annually against GNSS test network, an approved local network or minimum 4 established permanent marks of Class B order 2 or better	
Validation	every day and at each survey location by connection to a minimum of 2 established permanent marks	
	or by comparison with a measured EDM baseline	
	Or against two AUSPOS stations (if >500m apart,>2hrs data, rapid orbits)	
	Or against a static GNSS measured line done to Class C standard or better	
Orientation	MGA orientation from two independent connections to established permanent marks	
	Or, for rural surveys only, from a minimum two CORS RTK coordinated survey marks if they are 1000m from established permanent survey marks, >500m apart	
Best Practice	Never to be used to derive a line or distance to a reference mark under 100m	
	Working from the whole to the part within a closed figure	
	Always “run the boundary” where appropriate	
	minimum 2 minutes observation	
	Multipath, obstructions or height required always increase observation times	
	Minimum of two independent observations (i.e. using two CORS stations)	
	Independent observations at least 30 minutes apart	
	Use correctly adjusted tripods or bipods only	
	Check antenna height independently (mm & inches)	
	Use the correct absolute antenna models	
	PDOP should be <5	
	At least 4 satellites should be available (more is always better)	
	Weather conditions should be stable	
	Ensure ambiguities are resolved	
	Elevation mask minimum 15º	
	Always use AUSGeoid09 parameters	
	CORS correction signal must be continuous during observation	
	Range poles only to be used for defining natural boundaries	
Plan	Lines derived from GNSS should be clearly indicated on plan	
	Distances shown should be ground distances	
	SCIMS coordinate box should indicate an estimate of class for permanent survey marks	

AUSPOS CHECKLIST

ISSUE	GUIDELINE	Yes/No or n/a
Equipment	The GNSS receiver must be capable of Class C or better (10mm + 50ppm)	
	Single frequency receiver must measure lines under 10km only	
	Single frequency for surveys not requiring strict accuracy	
	Dual frequency recommended	
Verification	Receiver, method and software verified annually against GNSS test network, an approved local network or minimum 4 established permanent marks of Class B order 2 or better	
Validation	at each survey location by connection to a minimum of 2 established permanent marks	
	or by comparison with a measured EDM baseline	
	Or against a static GNSS measured line done to Class C standard or better	
Orientation	MGA orientation from two independent connections to established permanent marks	
	Or, in rural areas, MGA can be derived from two stations if a minimum 2 hour of observations, the stations are at least 500m apart and over 1000m from established permanent survey marks and rapid orbits are used for the processing. AUSPOS reports to SG and accompany DP at lodgement	
	Or, from plan on record showing comparison distance between at least two existing survey monuments	
Best Practice	Never to be used to derive a line under 500m	
	Working from the whole to the part within a closed figure	
	minimum 4 hours observation for Class C in SCIMS	
	Multipath, obstructions or height required always increase observation times	
	Use correctly adjusted tripods or bipods only	
	Check antenna height independently (mm & inches)	
	Use the correct absolute antenna models	
	PDOP should be <5	
	At least 4 satellites should be available (more is always better)	
	Weather conditions should be stable	
	Elevation mask minimum 15º	
	Always use AUSGeoid09 parameters	
	Must be set directly on durable survey marks (i.e. PM or RM)	
Plan	Lines derived from GNSS should be clearly indicated on plan	
	Distances shown should be ground distances	
	SCIMS coordinate box should indicate an estimate of class for permanent survey marks	

Appendix C.

EXAMPLE PLANS

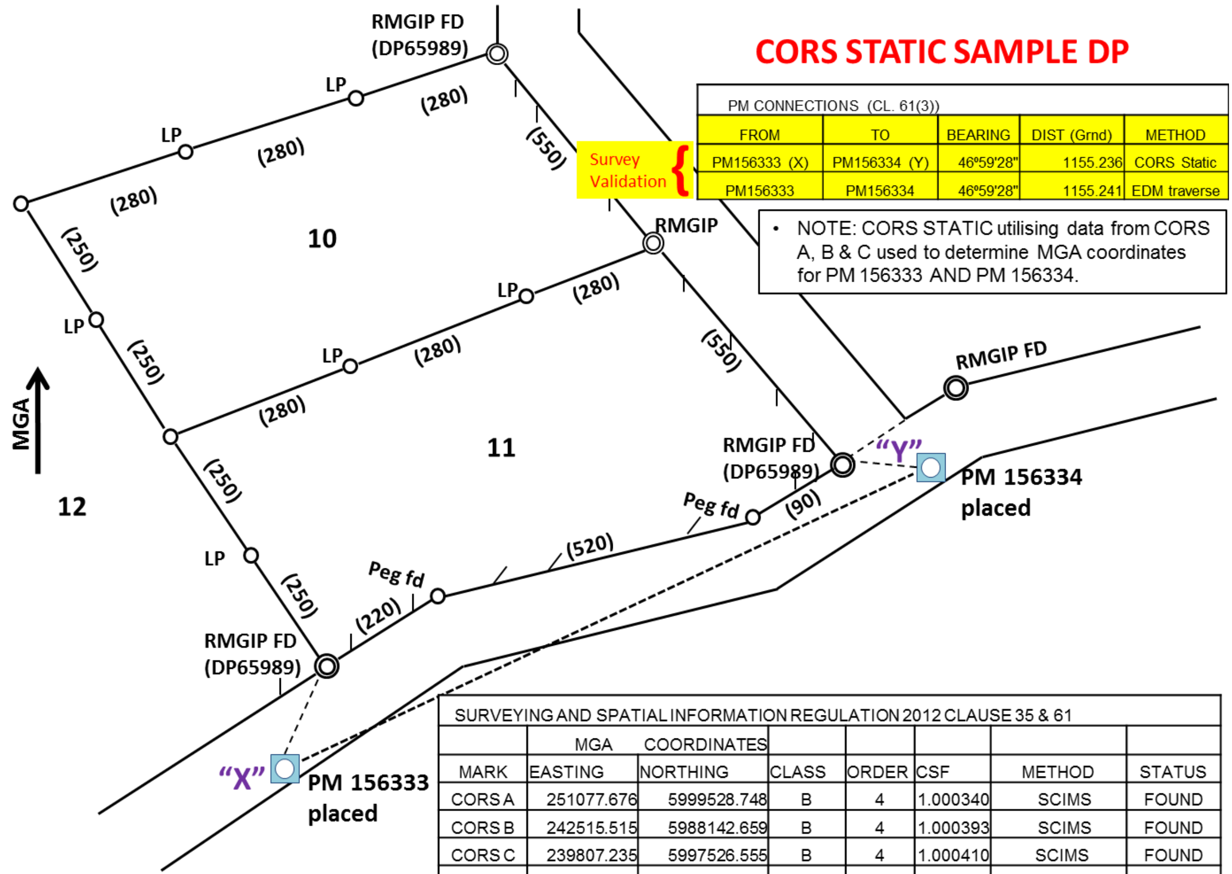


PM CONNECTIONS (CL. 61(3))				
FROM	TO	BEARING	DIST (Grnd)	METHOD
PM 222 (X)	PM228 (Y)	63º57'55"	1650.235	SCIMS
PM 222	PM228	63º57'55"	1650.228	STATIC
PM 222	PM230	350º55'23"	3327.165	SCIMS
PM 222	PM230	350º55'25"	3327.160	STATIC
PM228	PM334	259º26'35"	452.236	STATIC
PM222	PM333	22º25'45"	562.235	STATIC
PM333	PM334	46º59'28"	1155.236	STATIC
PM333	PM334	46º59'28"	1155.241	RTK
PM333	PM334	38º24'30"	1155.240	DP 65989

SURVEYING AND SPATIAL INFORMATION REGULATION 2012 CLAUSE 35(1) & 61(2)							
	MGA COORDINATES						
MARK	EASTING	NORTHING	CLASS	ORDER	CSF	METHOD	STATUS
PM222	241510.676	5999528.748	C	3	1.000418	SCIMS	FOUND
PM228	242515.515	6001142.659	C	3	1.000411	SCIMS	FOUND
PM230	240985.777	6002814.248	C	3	1.000422	SCIMS	FOUND
PM333	241809.502	6000152.231	D	U	1.000406	STATIC	FOUND
PM334	242585.631	6000625.378	D	U	1.000398	STATIC	FOUND
ZONE 56 COMBINED SCALE FACTOR = 1.000402 SOURCE SCIMS 30 FEB 2013							

*PM230 is not required but is recommended as a check on orientation.

CORS STATIC SAMPLE DP



PM CONNECTIONS (CL. 61(3))				
FROM	TO	BEARING	DIST (Grnd)	METHOD
PM156333 (X)	PM156334 (Y)	46º59'28"	1155.236	CORS Static
PM156333	PM156334	46º59'28"	1155.241	EDM traverse

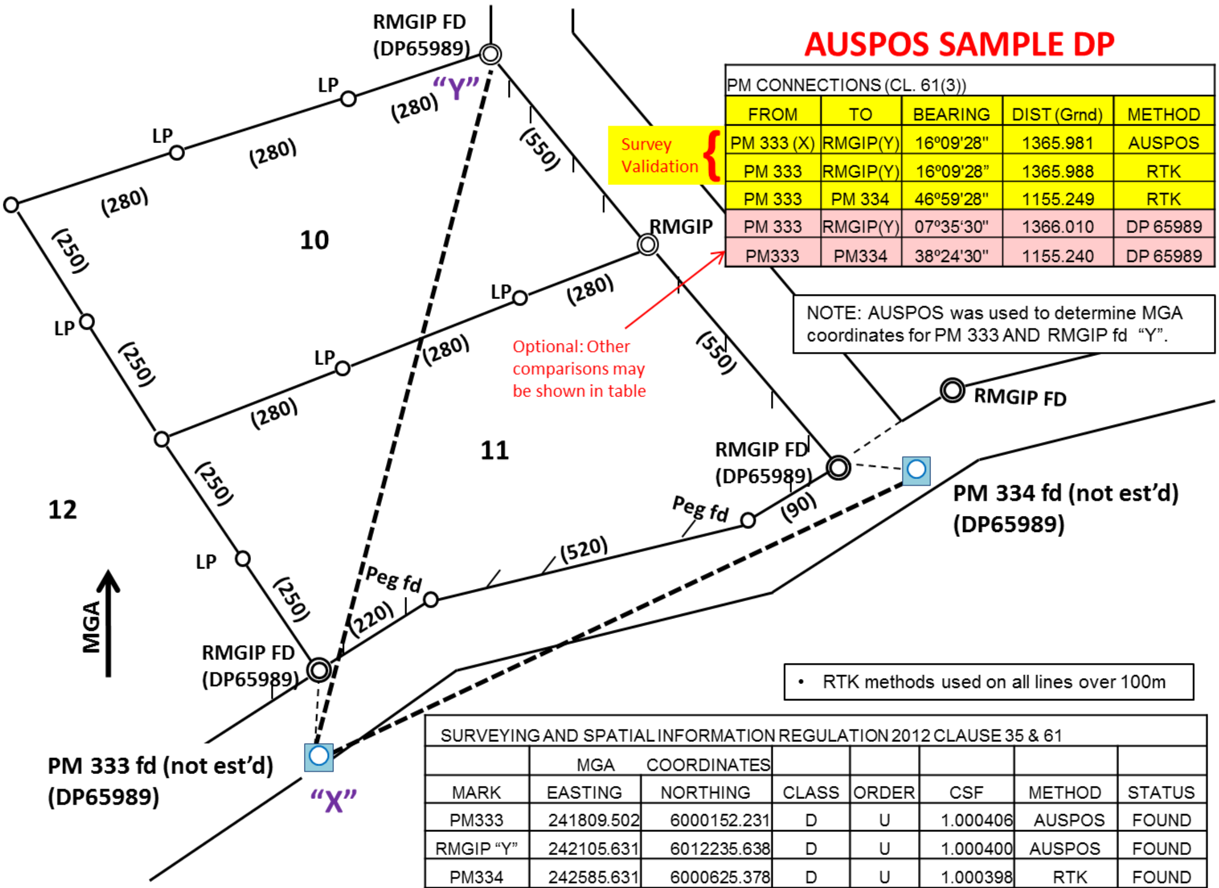
- NOTE: CORS STATIC utilising data from CORS A, B & C used to determine MGA coordinates for PM 156333 AND PM 156334.

SURVEYING AND SPATIAL INFORMATION REGULATION 2012 CLAUSE 35 & 61

	MGA	COORDINATES					
MARK	EASTING	NORTHING	CLASS	ORDER	CSF	METHOD	STATUS
CORS A	251077.676	5999528.748	B	4	1.000340	SCIMS	FOUND
CORS B	242515.515	5988142.659	B	4	1.000393	SCIMS	FOUND
CORS C	239807.235	5997526.555	B	4	1.000410	SCIMS	FOUND
PM156333	241809.502	6000152.231	D	U	1.000406	CORS STATIC	PLACED
PM156334	242585.631	6000625.378	D	U	1.000398	CORS STATIC	PLACED

ZONE 56 COMBINED SCALE FACTOR = 1.000402 SOURCE SCIMS 30 FEB 2013

AUSPOS SAMPLE DP



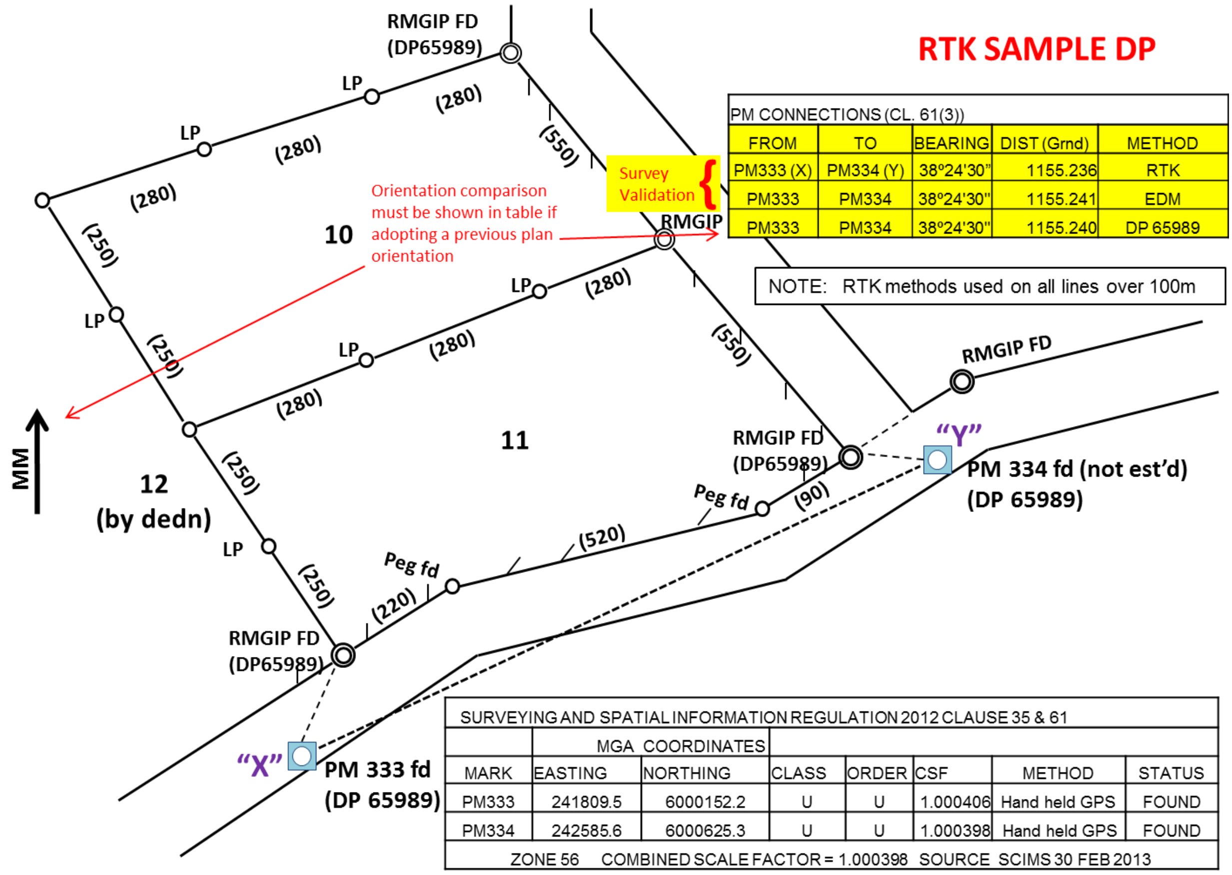
PM CONNECTIONS (CL. 61(3))

FROM	TO	BEARING	DIST (Grnd)	METHOD
PM 333 (X)	RMGIP(Y)	16º09'28"	1365.981	AUSPOS
PM 333	RMGIP(Y)	16º09'28"	1365.988	RTK
PM 333	PM 334	46º59'28"	1155.249	RTK
PM 333	RMGIP(Y)	07º35'30"	1366.010	DP 65989
PM333	PM334	38º24'30"	1155.240	DP 65989

SURVEYING AND SPATIAL INFORMATION REGULATION 2012 CLAUSE 35 & 61

	MGA	COORDINATES					
MARK	EASTING	NORTHING	CLASS	ORDER	CSF	METHOD	STATUS
PM333	241809.502	6000152.231	D	U	1.000406	AUSPOS	FOUND
RMGIP "Y"	242105.631	6012235.638	D	U	1.000400	AUSPOS	FOUND
PM334	242585.631	6000625.378	D	U	1.000398	RTK	FOUND

ZONE 56 COMBINED SCALE FACTOR = 1.000402 SOURCE SCIMS 30 FEB 2013



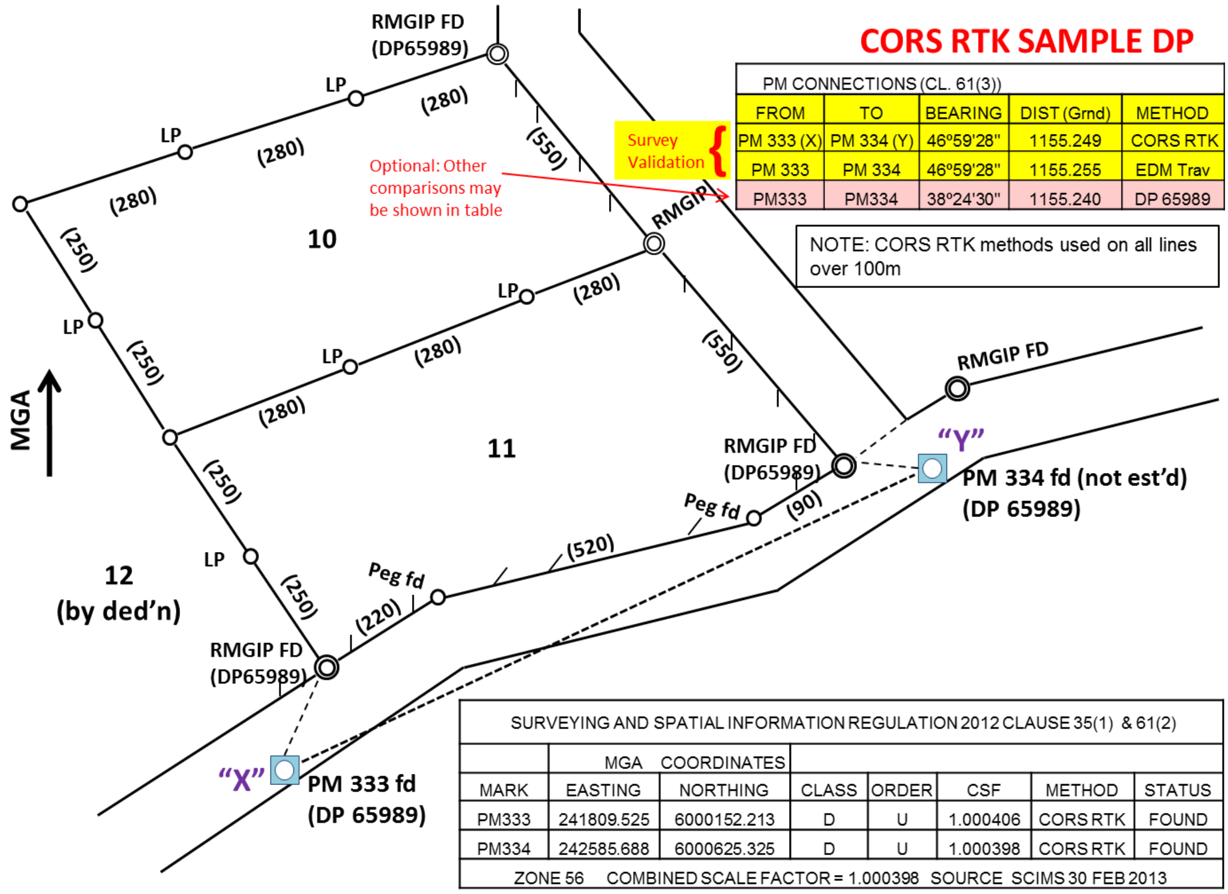
PM CONNECTIONS (CL. 61(3))

FROM	TO	BEARING	DIST (Grnd)	METHOD
PM333 (X)	PM334 (Y)	38°24'30"	1155.236	RTK
PM333	PM334	38°24'30"	1155.241	EDM
PM333	PM334	38°24'30"	1155.240	DP 65989

SURVEYING AND SPATIAL INFORMATION REGULATION 2012 CLAUSE 35 & 61

	MGA COORDINATES						
MARK	EASTING	NORTHING	CLASS	ORDER	CSF	METHOD	STATUS
PM333	241809.5	6000152.2	U	U	1.000406	Hand held GPS	FOUND
PM334	242585.6	6000625.3	U	U	1.000398	Hand held GPS	FOUND

ZONE 56 COMBINED SCALE FACTOR = 1.000398 SOURCE SCIMS 30 FEB 2013



PM CONNECTIONS (CL. 61(3))				
FROM	TO	BEARING	DIST (Grnd)	METHOD
PM 333 (X)	PM 334 (Y)	46°59'28"	1155.249	CORS RTK
PM 333	PM 334	46°59'28"	1155.255	EDM Trav
PM333	PM334	38°24'30"	1155.240	DP 65989

NOTE: CORS RTK methods used on all lines over 100m

SURVEYING AND SPATIAL INFORMATION REGULATION 2012 CLAUSE 35(1) & 61(2)							
	MGA COORDINATES						
MARK	EASTING	NORTHING	CLASS	ORDER	CSF	METHOD	STATUS
PM333	241809.525	6000152.213	D	U	1.000406	CORS RTK	FOUND
PM334	242585.688	6000625.325	D	U	1.000398	CORS RTK	FOUND
ZONE 56 COMBINED SCALE FACTOR = 1.000398 SOURCE SCIMS 30 FEB 2013							

- END of Direction -