Survey control requirements

Technical Guide

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About this release

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1 Introduction

This guide provides assistance with understanding of the standard conventions relating to geodetic control surveys for Transport for NSW projects.

This document should be read in conjunction with the following documents:

- QA Specification G71 - Construction Surveys
- QA Specification NG71 – Guide to QA Specification G71 Construction Surveys
- QA Specification G73 - Detail Survey
- Surveying Manual - 3.2 CADD Manual and Industry Resource Pack

2 Background

The NSW Survey Control Information Management System (SCIMS) contains a network and asset database of established permanent survey control marks that make up the State Control Survey. The network is considered to be a key element in the State's infrastructure.

Survey marks (both state survey control and cadastral marks) are protected under the Surveying and Spatial Information Act 2002 (NSW) Section 24. The following penalties and orders apply for unauthorised removal of survey marks:

- Maximum penalty of 25 units, currently $2,750 per mark; and
- Up to $10,000 per mark in compensation to the Surveyor General of NSW towards the cost of reinstatement of each survey mark; and
- Up to $10,000 per mark in compensation to any other person towards any loss or damage suffered by that person as a consequence of the offence.

It is inevitable that permanent survey marks will be destroyed from time to time as a result of TfNSW infrastructure projects. If works are likely to impact a state control survey mark, an application under the Surveying and Spatial Information Regulation 2017 Clause 90 must be lodged with the Surveyor General for approval to destroy the mark. For TfNSW projects application to the Surveyor General must be made by TfNSW Surveying section.

The Preservation of Survey Infrastructure (POSI) Collaborative Working Agreement between Roads and Maritime (now TfNSW) and Land and Property Information (now Spatial Services) provides TfNSW Surveying discipline with the authority to provide advice on the preservation of state survey control and cadastral mark infrastructure to internal staff and its contractors on behalf of SS-DFSI. This advice, and subsequent review of control survey data, ensures compliance with regulatory requirements.

Surveyor General's Directions No. 11 – Preservation of Survey Infrastructure (SGD11) and Surveyor General's Directions No. 12 – Control Surveys and SCIMS (SGD12) are industry documents providing guidelines on the survey requirements for the coordination and replacement of established control marks. SGD11 and SGD12 refer to the Inter-Governmental Committee on Surveying and Mapping (ICSM) Standards and Practices for Control Surveys (SP1) version 1.7 as the NSW standard of survey required to replace such marks. By satisfying the requirements of SP1 version 1.7, TfNSW can ensure critical components of SGD11 and SGD12 are fulfilled.

SP1 version 1.7 Part B describes in detail the best practice guidelines for surveys and reductions. SP1 also states "The recommended survey and reduction practices should be viewed as a guide only" (page v). The guidelines are based on technology and equipment several generations old. Thus it is now possible to achieve, and in most cases exceed, the levels of accuracy required for control marks of varying Class by modifying the field survey requirements whilst utilising modern instrumentation.

The POSI Collaborative Working Group (CWG) has discussed specific requirements documented in SP1 version 1.7 for various Classes of survey. The CWG has developed a range of modifications that still fulfil the accuracy requirements specified in the document. This technical guide documents these best practice amendments enabling a consistent set of standards to be applied across TfNSW infrastructure projects and its contractors and endorsed by Spatial Services.

As outlined in TfNSW specifications G73 Detail Survey and G71 Construction Surveys, TfNSW project managers and Contractors must discuss the requirements with TfNSW Surveying personnel who will consult with Spatial Services as required.

This technical guide does not specify the Class or extent of survey required to preserve the local datum defined by permanent control mark infrastructure when marks are destroyed. Refer to this guide once the Class requirements have been determined.

3 Recommended techniques

A summary of the requirements for various Classes of horizontal and vertical control survey are stated in SP1 version 1.7 Part B. Generally, changes are shown in highlighted blue text in the following tables.

The Classes of survey relevant to TfNSW infrastructure surveying specifications are provided in the following sections.

3.1 Electronic Distance Measurement (EDM)

3.1.1 EDM instrument and distance observation requirements

With reference to SP1 Version 1.7 Part B clause 2.2 and recommended changes.

Table 1. EDM equipment and observation techniques

CLASS	A	B	C	D & E
Number of days of observations	1	1	1	1
Number of sets of full measurements [2]	4	1	1	1
Move prisms between sets [4]	Yes	Optional	Optional	--
Range of fine readings [1]	<2(5+d)mm	<2(5+d)mm	7ppm	D: 15ppm E: 30ppm
Difference between two sets [1]	<2.5(5+d)mm	<2.5(5+d)mm	--	--
Difference between mean of each day's measurements [1]	--	--	--	--
Observations between 2 hours before local noon and 2 hours before local sunset [5]	Yes	Optional	Optional	Optional
Atmospheric dial setting (where possible)	Zero	Optional	Optional	Optional
Allow minimum warm up time [3]	Yes	Optional	Optional	Optional

CLASS	A	B	C	D & E
Thermometer type	Mercury in glass or digital [7]	Mercury in glass or digital [7]	Mercury in glass or digital [7]	Mercury in glass or digital [7]
Graduation Interval	< 1°C	< 1oC	< 1°C	1°C
Estimate temperature to:	0.1°C	0.1°C	0.1°C	1°C
Estimate pressure to:	0.3 hPa	0.3 hPa	0.3 hPa	3 hPa
Wet bulb readings or relative humidity readings	*Yes*	Optional	Optional	--
Mets. at both ends of measured lines before and after measurements	Yes [8]	Yes [8]	At time of obs	--
Reciprocal vertical angles [6]	Yes simultaneous	Yes	Optional	Optional
National standard traceability of EDM	Yes	Yes	Yes	Yes
Mark Type	Refer to Table 13 (page 19)			

NOTES:

1. *Where d is the length, measured in km.*
2. *A full measurement with a direct readout instrument shall consist of a number of readings (eg, 6 to 10) over several minutes, after which the instrument should be re-pointed and electronically realigned, for a number of further group readings. This comprises a set. A full measurement with an indirect readout instrument shall consist of a series of fine readings on the relevant different frequencies. A set is defined as two full measurements, taken one after the other. A distance should be measured in two sets for CLASS B, and four sets spread over two different days for CLASS 2A.*
3. *The minimum warm-up time to be determined during frequency determination.*
4. *Not required if the coarse distance is known.*
5. *Observations may be performed outside of the specified times (except at Sunset or Sunrise) as long as a statistically proven correction factor is applied.*
6. *Simultaneous reciprocal or reciprocal vertical angles are not required if the heights of both ends of the line are known accurately. A one way vertical angle is sufficient to determine K, the coefficient of refraction accurately. Reciprocal vertical angles are not required if differential levelling of the affected marks to minimum Class LD standard is undertaken.*
7. *Mercury in glass thermometers can no longer be purchased. Digital thermometers calibrated against a known standard may be used.*
8. *Required when observing lines in excess of 300m, or where meteorological conditions are unlikely to be consistent over the length of the lines.*

3.1.2 EDM distance reduction requirements

With reference to SP1 Version 1.7 Part B clause 2.2 and recommended changes

Table 2. EDM distance reduction requirements

CLASS	A	B	C	D & E
Additive constant correction	Yes	Yes	Yes	Yes
Reflector additive constant correction	Yes	Yes	Yes	Yes
Cyclic error correction	Yes	Yes	Yes	Optional
Frequency correction	Yes	Baseline	Baseline	Baseline
Barometer correction	Yes	Yes	Yes	Optional
Thermometer correction	Yes	Yes	Yes	Optional
1st velocity correction (atmospheric correction)	Yes	Atmos. dial	Atmos. dial	Atmos. dial
Arc to chord correction (beam curvature correction)	Yes	Over 5km	Over 5km	Optional
2nd velocity correction (dip correction)	Yes	Over 5km	Over 5km	Optional
Chord to chord correction (combined slope & mean sea level)	Yes	Combined scale factor	Combined scale factor	Yes
2nd chord to arc correction (geoidal chord to arc correction.)	Yes	Yes [1]	Optional	Optional
Geoid to ellipsoid correction	Yes	Yes [1]	Optional	Optional
Mark Type	Refer to Table 13 (page 19)			

NOTE:

1. Surveyor must ensure this process is undertaken by the software used to process observations.

3.2 Horizontal angle measurement

With reference to SP1 Version 1.7 Part B clause 2.3 and recommended changes.

Table 3. EDM horizontal angle requirements

CLASS	A **	B	C	D	E
1. Required time of day					
Two hours either side of sunrise/set	Yes				
Any time, except 1200-1500hrs (LMT)					
Any time, subject to checks		Yes	Yes	N/A	N/A
2. Instrument least count category					
Highest	0.2”				
High	1”	1”	1”	1”	
Medium				6”	6”
3. Horizontal zero settings	No longer applicable				
Examples of horizontal circle settings for six Zero – No longer applicable					
4. Sets					
A. Minimum number of sets	6 *	1	1	1	1
B. Number of rounds per set	6	6	6	4	2
* Sets should be observed in equal proportion over two days ** Instrument and tripod should be shaded					
5. Field Checks					
A. Residuals from mean of any direction within each set:					
(i) should seldom exceed	3”	3”	3”	5”	10”
(ii) should never exceed	4”	5”	6”	10”	20”
B. Ranges from mean of any direction within each set:					
(i) should seldom exceed	6”	6”	6”	10”	15”
(ii) should never exceed	8”	10”	12”	20”	30”
For applicable sets, an additional round should be observed when a range is exceeded, however if two rounds exceed the range the sets should be re-observed, under improved conditions:					
C. Ranges between sets:					
(i) should seldom exceed	2”	N/A	N/A	N/A	N/A
(ii) should never exceed	4”	N/A	N/A	N/A	N/A
6. Observation Corrections					
Instrument systematic errors	Yes	Yes	Yes	Yes	Yes
Signal phase errors	Yes	Yes	Yes	Yes	Yes
Dislevelment of the trunnion axis	Yes	Yes	Yes	--	--
Horizontal refraction [1]					
Deflection of the vertical	Yes	--	--	--	--
Skew normals	Yes	--	--	--	--
Mark type	Refer to Table 13 (page 19)				

NOTE:

1. *Minimise using appropriate procedures for prevailing conditions.*

3.3 Differential levelling

With reference to SP1 Version 1.7 Part B clause 2.4.1 – Spirit, Auto or Digital Levelling

3.3.1 Differential levelling equipment characteristics

Table 4. Differential levelling equipment

CLASS	LA	LB	LC	LD & LE
Level-minimum requirements	0.4mm/km automatic non digital level with parallel plate micrometer or 0.4mm/km digital level.	As for LA.	1.0-1.5 mm/km or better automatic or digital level.	1.5mm/km or upward (ie. less sensitive) auto-collimating or digital or spirit level
Staff construction minimum requirements (Analog or bar coded) [1]	Rigid Invar	Rigid Invar	Folding staff of wood or fibreglass	Telescopic staff of wood, fibreglass or aluminium
Staff graduation interval (Analog staves)	5mm or 10mm	As for LA	10mm	10mm
Tripod construction	Rigid	Rigid	Rigid or telescopic [2]	Rigid or telescopic [2]
Bubble attached (fixed) to staff [3]	Yes	Yes	Optional	Optional
Solid, portable change points	Yes	Yes	Yes	Optional
Umbrella for level	Yes	No	No	No
Mark Type	Refer to Table 14 (page 19)			

NOTE:

1. ***Analog*** *refers to staves that have accepted metric or foot face patterns that have been developed over time for optical levels. Bar coded refers to staff face patterns developed specifically for digital levels.*
2. *Legs on telescopic tripod must be fully extended and kept fully extended during levelling survey (ie, no adjusting the tripod legs).*
3. *Bubble must be attached to staff whilst height reading is being observed.*

3.3.2 Differential levelling equipment testing

Table 5. Differential levelling equipment testing

CLASS	LA	LB	LC	LD & LE
System test prior to commencement (eg ISO, DIN or Princeton)	Yes	Optional	Optional	Optional
Maximum standard error in the slope of the line of sight as determined by the system test	Spirit level: 1.5”/2mm run. Automatic or digital: 0.4” setting accuracy	Spirit level: 4”/2mm run. Automatic or digital: 0.8” setting	Spirit level: 10”/2mm run. Automatic or digital: 1.0”setting accuracy	--
Vertical collimation check (eg. Two-Peg Test) Frequency Maximum collimation error	Daily 2” or 0.8 mm over 80m	Daily 4” or 1.5 mm over 80m	Daily 10” or 4 mm over 80m	As required 10” or 4 mm over 80m
Level cross-hair verticality check	Yes	Yes	Yes	Optional
Staff calibration frequency	--		--	Optional
	Minimum 2 years [1]		Optional	
Staff bubble verticality to be within	10’	10’	10’	10’
Thermometers accurate to	1°C	1°C	1°C	Optional
Mark Type	Refer to Table 14 (page 19)			

NOTE:

1. *Staff calibration recommended at two (2) year intervals. This may extend to a maximum of five (5) year intervals if the staff is well maintained. A staff subject to a heavy impact must be immediately calibrated.*

   The National Measurement Institute (NMI), a division within the Department of Industry, Innovation and Science, is Australia’s peak measurement body. NMI has developed a procedure and offers a service for calibration of invar staffs.
   Refer to: https://www.measurement.gov.au/

   Note: The Western Australian Land Information Authority is a statutory authority operating under the business name of Landgate. Landgate have published a procedure for the validation of levelling staffs.
   Refer to: https://www0.landgate.wa.gov.au/business-and-government/specialist-services/geodetic/related-documents/GSU-05-Barcoded-Staff-Calibration-Procedure-V1.0.pdf

   Landgate offers a barcode staff validation and data processing service. Alternatively, users may develop their own similar validation system.

3.3.3 Differential levelling observation procedures

Table 6. Differential levelling observation procedures

CLASS	LA	LB	LC	LD & LE
Instrument levelled by "unsystematic" method [1]	Yes	Yes	Yes	Optional
"Leap-Frog" system of progression used [2]	Yes	Yes	Yes	Optional
Staff readings recorded to nearest:	0.1mm For digital levels – as for L2A (0.01mm) but with an indicated sd. of 0.001m or less	0.1mm For digital levels – as for LA	1mm For digital levels – as for LA	LD 1mm LE 10mm
Temperature recorded (when used)	At start and finish of each levelling run and at pronounced changes of temperature		--	
Maximum length sight	40m	60m	80m	100m
Minimum ground clearance of line of sight	0.5m	0.5m	0.3m	0.2m
Back-sight and fore-sight lengths to be equal within	1%	2%	2%	5%
Observing times (LMT)	Before 10 am & after 2 pm		Any time provided atmospheric conditions allow positive resolution of staff graduation	
Two-way levelling	Yes	Yes	Yes	Yes
Even number of instrument set-ups between bench marks	Yes	Yes	Yes	Optional
Minimum number of holding marks used for temporary suspension of levelling	Not to be suspended	2	2	1
Minimum number of holding marks used for temporary suspension of levelling > 5 days	Not to be suspended	overlapping marks re-levelled within: 2√d 12√d		1
Maximum allowable misclosure (mm) of forward and reverse levelling runs	4√d	8√d	12√d	LD = 18√d LE = 36√d
Minimum number of bench marks used to prove datum	3	3	3	2
Datum bench marks to be double levelled	Yes	Yes	Yes	Yes
Maximum misclose (mm) on datum bench marks	4√d	8√d	12√d	LD = 18√d LE = 36√d
	where *d* is the distance in kilometres between benchmarks			
Orthometric correction to be applied	Yes [3]	Yes [3]	Yes	N/A
Mark Type	Refer to Table 14 (page 19)			

NOTE:

1. ***Unsystematic** method of levelling instrument: When centring automatic levels with circular bubbles, the "unsystematic" method of levelling the instrument should be used whereby the telescope is pointed in forward and reverse directions at alternate set-ups, ie. always towards the same staff-man who will be "leap-frogging" each instrument set-up.*

2. ***Leap-frog System**: "Leap-frog" levelling involves the one staff remaining at a particular change point for both sightings. To avoid staff index error the same staff is used for the first back-sight and the last fore-sight of each levelling run.*

3. *Orthometric corrections to differential levelling observations require the horizontal coordinates of all change points (preferred), or all benchmarks (minimum requirement if change point coordinates are not observed) to be observed. This information must accompany the levelling data submitted to TfNSW.*

   Coordinates may be recorded as latitude/longitude or eastings/northings clearly stating the datum, and accurate to within a few metres. Coordinates observed by hand-held GNSS units are acceptable.

   Distances between levelled mark should be recorded, particularly if the levelling run deviates from a straight line between benchmarks.

3.4 EDM height traversing

With reference to SP1 Version 1.7 Part B clause 2.4.2 and recommended changes.

Differential levelling is the conventional method of levelling for the propagation of orthometric heights. An alternative of the common technique of spirit levelling is EDM Height Traversing (leap frog) where the difference in height between marks or change points is determined using observations of zenith angles and slope distances. This method observes to two reflectors of fixed height in the usual backsight / foresight mode used in levelling with the instrument set-up in the middle.

The alternative mode of (non-simultaneous) reciprocal EDM Height Traversing is not discussed in detail since it requires special techniques to connect to bench marks and to minimise the effects of unequal instrument and reflector heights, particularly when attempting Class L2A and LA results. Refer to 'Non-simultaneous reciprocal EDM height traversing observation procedure' notes below.

3.4.1 EDM height traversing 'leap frog' equipment characteristics

Table 7. EDM height 'leap frog' traversing equipment

CLASS	LA	LB	LC	LD & LE
Electronic Tacheometer (Total Station) requirements	2 mm + 2 ppm distance and 1" zenith angle	2 mm + 2 ppm distance and 2" zenith angle	2 mm + 2 ppm distance and 3" zenith angle	2 mm + 2 ppm distance and 5" zenith angle
Accuracy of level sensor or compensator	0.5"	1"	1.5"	2.5"
Diametrical Circle Reading on Vertical Circle (or equivalent)	N/A	N/A	N/A	N/A
Entry of Temperature and Pressure for on-line First Velocity Correction	Yes	Yes	Yes	Yes
Refraction and Earth Curvature Correction enabled	Yes	Yes	Yes	Yes
Target / Reflector construction: Minimum requirements [1]	2 Fixed Height Reflector Rods w permanently mounted, balanced and tilting prism	1 - 2 Fixed Height Reflector Rods w permanently mounted, balanced and	1 - 2 Standard Reflector Rods with balanced and tilting Prism	1 - 2 Standard Reflector Rods with balanced and tilting Prism

CLASS	LA	LB	LC	LD & LE
		tilting prism		
Reflector Rod Support	Bipod / Two Leg Struts	Bipod / Two Leg Struts	Bipod / Two Leg Struts	Bipod / Two Leg Struts
Bubble attached to Reflector Rod	Yes	Yes	Yes	Optional
Solid, portable change points [2]	Yes	Yes	Yes	Yes
Umbrella for instrument	Yes	No	No	No
Mark Type	Refer to Table 14 (page 19)			

NOTE:

1. *For Classes L2A, LA and LB the target/reflector must be securely attached to the fixed height reflector rod. If the target/reflector assembly is not permanently attached but screwed and locked into place on each day, the height of reflector must agree to 0.01 mm between multiple attachments. The reflector should be tiltable about a horizontal axis that intersects the symmetry axis well inside the prism ("balanced" prism, NO "zero error" prisms). The height of the triangular target patterns on the left and right of the prism must have the same height as the prism (to 0.01 mm) since pointing on close range (to 60 m) is to the apex of the prism and on longer range to the target.*

2. *All temporary (change plates) and permanently marked change points must feature a small central hole so that the reflector rod does not slide off.*

3.4.2 EDM height traversing equipment testing

Table 8. EDM height traversing equipment

CLASS	LA	LB	LC	LD & LE
System test prior to commencement	Yes	Optional	Optional	Optional
Calibration of index errors of vertical circle and level sensor	Daily	Daily	Daily	As required
Staff bubble verticality to be within	10'	10'	10'	10'
Barometers accurate to	2 hPa	2 hPa	2 hPa	2 hPa
Thermometers accuracy	1°C	1°C	1°C	Optional
Mark Type	Refer to Table 14 (page 19)			

3.4.3 EDM height traversing observation procedures

Leap Frog EDM height traversing: This involves the one target remaining at a particular point for both sightings. To avoid the possibility of the target being placed on a different point the target is not moved between the back-sight and foresight. Two target/reflectors are employed (on reflector rods with struts). As in spirit levelling, it is imperative that the EDM (total station) is set up in the middle between the two reflectors. Recorded are the height differences (between the instrument's trunnion axis and the reflector) that are computed by the electronic tacheometers. In consequence, the ambient temperature and pressure must be input into the instrument since the slope distances must be corrected for temperature and pressure (first velocity correction) on-line. See Rüeger & Brunner (1982) and The Canadian Surveyor, 36(1): 69-87.

Non-Simultaneous Reciprocal EDM height traversing: Normal EDM traversing equipment is employed with one EDM, two reflector/target assemblies and two to three tripods. To connect to bench marks, the instrument has to be set up within 20 m. The height difference between instrument and bench mark is obtained by zenith angle measurements to some marks on a levelling staff on the bench mark (or to a prism on reflector rod with struts on the bench mark). Between tripods, the zenith angles and the slope distances are measured forward and backwards. Since this provides two height differences per leg, reciprocal EDM Height Traversing is only done one-way. Depending on the accuracy requirements, the lengths of the legs can be significantly longer than in Leap Frog EDM Height Traversing. See Rüeger & Brunner (1982).

Table 9. EDM height traversing observation procedures

CLASS	LA	LB	LC	LD & LE
EDM Height Traversing Method	Leap-Frog	Leap-Frog or Reciprocal	Leap-Frog or Reciprocal	Leap-Frog or Reciprocal
Number of sets to target	2	1	1	1
Pointings in first set: (In second set, if applicable, first FS, then BS)	BS(FL) BS(FR) BS(FR) BS(FL) FS(FL) FS(FR) FS(FR) FS(FL)	BS(FL) BS(FR) BS(FR) BS(FL) FS(FL) FS(FR) FS(FR) FS(FL)	BS(FL) BS(FR) BS(FR) BS(FL) FS(FL) FS(FR) FS(FR) FS(FL)	BS(FL) BS(FR) BS(FR) BS(FL) FS(FL) FS(FR) FS(FR) FS(FL)
Max Spread per set	1.5 mm	1.5 mm	1.5 mm	3.0 mm
Height difference recorded to nearest	0.1 mm per pointing	0.1 mm per pointing	1 mm per pointing	D: 1 mm E: 5 mm per pointing
Temperature and Pressure measured and entered into the instrument	At start, middle and finish of each ‘levelling‘ run and at pronounced changes of temperature			At start of ‘levelling’ run
Maximum length sight in Leap Frog EDM height traversing	75 m	90 m	120 m	150 m
Slope distance recorded (for balancing FS and BS distances) to:	0.1 m	0.1 m	1.0 m	1.0 m
Minimum ground clearance of line of sight	1.0 m	1.0 m	0.3 m	0.2 m
Back-sight and fore-sight lengths to be equal within	2 m (set out)	5 m (set out)	10 m (set out)	20 m (set out)
Observing times	Sight lengths might have to be reduced to achieve “Max Spread per Set” in poor observing conditions (e. g. heat shimmer)			
Two-way levelling in Leap-Frog EDM height traversing	Yes	Yes (But NOT in reciprocal EDM Height Traversing)		

CLASS	LA	LB	LC	LD & LE
Even number of instrument set-ups between bench marks	Yes in Leap Frog EDM Height Traversing with two reflector rods (Not applicable for Reciprocal EDM Height-Traversing)			Optional
Minimum number of holding marks used for temporary suspension of levelling	Not to be suspended	2	2	1
Minimum number of holding marks used for temporary suspension of levelling > 5 days	Not to be suspended	3 overlapping marks re-levelled within 2√d	3 overlapping marks re-levelled within 2√d	1
Maximum misclosure (mm) of forward and reverse levelling runs	4√d	8√d	12√d	LD = 18√d LE = 36√d
Minimum number of bench marks used to prove datum	3	3	3	2
Maximum misclose (mm) on datum BM's (d = distance in km between BM's)	4√d	8√d	12√d	LD = 18√d LE = 36√d
Mark Type	Refer to Table 14 (page 19)			

3.4.4 EDM height traversing reduction procedure

Table 10. EDM height traversing reduction procedure

CLASS	LA	LB	LC	LD & LE
Orthometric correction to be applied	Yes [1]	Yes [1]	N/A	N/A
Mark Type	Refer to Table 14 (page 19)			

NOTE:

1. *Orthometric corrections to differential levelling observations require the horizontal coordinates of all change points (preferred), or all benchmarks (minimum requirement if change point coordinates are not observed) to be observed. This information must accompany the levelling data submitted to TfNSW. Coordinates may be recorded as latitude/longitude or eastings/northings clearly stating the datum, and accurate to within a few metres. Coordinates observed by hand-held GNSS units are acceptable. Distances between levelled marks should be recorded, particularly if the levelling run deviates from a straight line between benchmarks.*

3.5 Trigonometric Heighting

With reference to SP1 Version 1.7 Part B clause 2.5 and recommended changes.

Trigonometric heighting is achieved using several individual items of survey equipment. Unless directly specified to achieve a desired **CLASS** of trigonometrical heighting, use procedures and standards for the particular observation type (eg vertical angle, distance) as set out elsewhere in Part B and this guide.

Table 11. Trigonometric Heighting observation requirements

CLASS	A	B	C
Trigonometric Heighting Observation Requirements			
Simultaneous reciprocal	Yes	Optional	Optional
Non-simultaneous Reciprocal		Yes	Optional
One way Observations			Yes
Observing times (LMT) d>16km d<16km	 1400-1600 1000-1600	 1400-1600 1000-1600	 1400-1600 1000-1600
Number of sets	2	1	1
Number of pointings (per set)	6	6	6
Maximum range per set	6”	6”	8”
Meteorological Observations	Yes	Yes	Yes
Mark Type	Refer to Table 14 (page 19)		

3.6 Global Navigation Satellite Systems (GNSS)

With reference to SP1 Version 1.7 Part B clause 2.6 Global Positioning Systems (GPS) and recommended changes.

Observation technique is only one factor in determining the Class of a control survey. Class is function of the planned and achieved precision of a survey network and is dependent upon the network design, the survey practices adopted, the equipment and instruments used, and the reduction techniques employed, all of which are proven by the result of a minimally constrained least squares network adjustment.

These guidelines generally refer only to **relative** GPS/GNSS positioning, which requires two or more GPS/GNSS receivers, observing carrier phase observations. The exception to this is the section on observations for global/regional processing (clause 2.6.14) where only one survey quality GPS/GNSS receiver is required, but the data collected is later processed with data from global and regional GPS/GNSS sites, using on-line processing services.

It is the responsibility of the user to assess which GPS/GNSS technique or combination with traditional techniques should be used to achieve the task being undertaken, having regard to the manufacturer's specifications for the equipment and survey specification requirements.

Table 12. GNSS procedures

CLASS	3A	2A	A	B	C	D
Technique						
Classic Static	✓	✓	✓	✓	✓	✓
Quick Static			✓	✓	✓	✓
Stop and Go			✓ [1]	✓	✓	✓
Real Time kinematic (RTK)			✓ [1 2]	✓	✓	✓
Guide to minimum station spacing (km) [3]	5	1.5	0.5	0.1	N/A	N/A
Typical station spacing in km [4]	100-500	10-100	0.5-10	0.1-5	>0.05	N/A
Independent occupations per station [5] At least 3x (% of total stations) [6] At least 2x (% of total stations) [6]	 50% 100%	 40% 100%	 20% 100%	 10% 100%		
Minimum independent baselines at each stn	3	3	2	2	2	2
Mark Type	Refer to Table 13 (page 19)					

NOTE:

1. *The Stop and Go method can achieve Class A with careful attention to the network design.*
2. *As the minimally constrained adjustment is usually not applicable in RTK, Class for this method is determined differently (see section 'Analysis using misclosure comparisons'. Class A and Order 1 can be achieved with careful attention to the network design.*
3. *Minimum station spacing is illustrated using a 5 mm noise level after adjustment. Below these minimum distances, special efforts are required to reduce the error budget. For a noise level of 10 mm these values are to be approximately doubled.*
4. *These values relate to the using of conventional equipment and proprietary software.*
5. *Independent occupations per station may be back to back, but the antenna should be re-set for each occupation. The minimum observation period should be observed with each occupation as per the manufacturers' recommendations.*
6. *For example for a CLASS A network aim for:*
   i. *20% of stations are to be occupied at least three times;*
   ii. *100% of stations are to be occupied at least twice.*

4 Type of mark to be placed

Spatial Services have provided the following requirements for placement of permanent survey marks in NSW.

Permanent survey marks placed and surveyed for inclusion on public record in the SCIMS database must fulfil the requirements of Surveyor General's Directions No. 1 – *Approved Permanent Survey Marks*.
A further requirement is that the Type of mark placed must be suitable for the desired Class of survey.

4.1 Horizontal angle, EDM and GNSS measurement Class

Table 13. Permanent survey mark type requirements for Class of horizontal survey

Type of mark defined by SGD No. 1	Class of Survey			
	A	B	C	D & E
Type 1 (SSM – Large) [1]	Yes, but not recommended	Yes, but not recommended	Yes	Yes
Type 2 (SSM – Small) [1]	No	Yes, but not recommended	Yes	Yes
Type 4 (Urban)	Yes	Yes	Yes	Yes
Type 6 (Non-urban)	Yes, but not recommended	Yes	Yes	Yes
Type 8 (DWR "C-Type" mark)	No	Yes, but not recommended	Yes	Yes
Type 9 (Trig Station)	Yes	Yes	Yes	Yes
Type 15 (Pin and Disc)	No	No	Yes	Yes
Type 16 (SSM) [2]	Yes, but not recommended [3]	Yes, but not recommended [3]	Yes	Yes

4.2 Differential levelling

Table 14. Permanent survey mark type requirements for Class of vertical survey

Type of mark defined by SGD No. 1	Class of Survey			
	LA	LB	LC	LD & LE
Type 1 (SSM – Large) [1]	Yes	Yes	Yes	Yes
Type 2 (SSM – Small) [1]	No	No	Yes	Yes
Type 4 (Urban)	Yes	Yes	Yes	Yes

Type of mark defined by SGD No. 1	Class of Survey			
	LA	LB	LC	LD & LE
Type 6 (Non-urban)	No	No	Yes	Yes
Type 8 (DWR "C-Type" mark)	Yes	Yes	Yes	Yes
Type 9 (Trig Station)	Yes	Yes	Yes	Yes
Type 15 (Pin and Disc)	No	No	No	Yes
Type 16 (SSM) [2]	Yes [3]	Yes [3]	Yes	Yes

NOTE:

1. *Type 1 and Type 2 marks to be retired in 2019.*
2. *Type 16 marks (released 2019) replace Type 2 marks.*
3. *Must be set in concrete block with at least 0.07 cubic metres and shaped as per diagram in Surveyor General's Directions No. 1 – Approved Permanent Marks (SGD1).*

5 Geocentric Datum of Australia (GDA) 2020

While Australia's new Geocentric Datum 2020 (GDA2020) will change the Map Grid of Australia (MGA) coordinates of a point by 1.5 to 1.8 metres from the existing Geocentric Datum of Australia 1994 (GDA94) values, there will be no changes to the determination of 'Class' for state control marks in SCIMS.

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