



Guidelines and Specifications for GPS Surveys of ISN Markers

Version 2.3

August 2006

SINGAPORE LAND AUTHORITY
SURVEY SERVICES
8 SHENTON WAY #26-01
TEMASEK TOWER
SINGAPORE 068811

This document is available on the Singapore Land Authority website.
URL: <http://www.sla.gov.sg/>.

Revision History

Revision	Revision Date	Amendments Made
Version 1.0	24 December 2002	-
Version 2.0	September 2004	Delete "Zero Baseline Test" in Item 4(a)
Version 2.1	December 2004	Insert "Zero Baseline Test in Item 4(a); Substitute "GPS Network Test" in Item 4(a) with "GPS Gross Error Test" Insert samples of GPS Gross Error Test submissions in Appendix B and Appendix C
Version 2.2	June 2006	Amend item (1) by deleting "Part III of the Land Surveyors Act ..." and inserting "the Boundaries and Survey Maps (Conduct of Cadastral Surveys) Rules 2005." Amend item 4(a) para (6) by substituting 26.925m with 26.824m. Amend item (9) - delete "in CD to SLA" and replace with "by E-submission (CORENET) to SLA." Amend item (9a) – Delete "Network" in para (1), insert "Zero Base Line Test" at para (2), amend para (5), insert para (6) and (11). Amend item 9(b) – replace "800x600 pixels" in para (1) with "1024x768 pixels," insert para (2), amend para (5), delete Table 3 and 4 and insert samples at Figure 1, 2 and 3. Amend Appendix A and Appendix A (Sample) by deleting "26.925m" and inserting "26.824m." Amend Appendix C and Appendix C (sample) by inserting "Receiver Serial No."
Version 2.3	August 2006	Replace all "SIMRSN" with "SiReNT." Amend item (10) on SiReNT Reference Station Data Support.

Guidelines and Specifications for GPS Surveys of ISN Markers

1. Introduction

This document aims to provide guidelines for static GPS survey (hereinafter known as GPS Survey or the Survey) using the Singapore Satellite Positioning Reference Network (SiReNT) to establish secondary control marks (or ISN markers/point) for cadastral survey. It also describes the submission requirement for the survey as well as the reference station data availability.

The Surveyor must conduct all the survey works in accordance with the Boundaries And Survey Maps (Conduct Of Cadastral Surveys) Rules 2005. The survey works conducted by the Surveyor must also conform to the procedures and standards of accuracy as described in the CS Directive on Cadastral Survey Practices.

These guidelines include the following headings:

1. Introduction
2. Accuracy Standard
3. Equipment
4. Equipment Testing
5. Site Planning and Reconnaissance
6. Planting of ISN Markers
7. Field Procedures
8. GPS Data Processing
9. Report Submission and Data Format
10. SiReNT Reference Station Data Support
11. GPS Survey in the Absence of SiReNT

These guidelines will be subjected to review as the GPS technology is continually evolving with the advancements in technologies and techniques. Please note that these guidelines do not represent the legal traceability of measurement. It is the responsibility of the surveyor to ensure that all equipment used in a measurement will achieve a result in terms of the accuracy required. These guidelines do not guarantee that particular survey accuracy will be attainable. It is the responsibility of the surveyor to ensure that the standards are achieved.

The Surveyor must ensure that these guidelines are strictly adhered to when carrying out the GPS Survey of ISN markers, unless otherwise instructed by the Chief Surveyor, Survey Services, SLA.

2. Accuracy Standard

The following standard is the minimally acceptable level of differential relative positional accuracy required for ISN marker survey.

- 95% confidence level less than or equal to 0.020 m for Northing and Easting components and 0.060 m for height component.

3. Equipment

GPS receiver and antenna used in the survey should be of geodetic or survey grade equipment. Listed below are the minimum specifications of receiver and antenna used for the survey:

- Dual frequency
- Carrier phase tracking
- Minimum 16 channels for L1 and L2

4. Equipment Testing

Equipment testing is required in order to ensure that they are in operational condition.

(a) GPS receiver and antenna

- Zero baseline test

The GPS receiver used must be subjected to zero baseline test at yearly interval or after service and maintenance. This test is to be carried out by a GPS equipment vendor or the authorised dealers. The northing, easting and the height components of the zero-baseline should all be less than 1 mm.

- GPS Gross Error Test

A gross error test is to be adopted for GPS receivers and antennae at yearly interval or after service and maintenance. The test is to be carried out at Pillar 7 of Lower Peirce Reservoir. Registered Surveyors are not required to submit the report and results of the test to SLA. However, the results must be submitted to SLA upon request. Registered Surveyors need to certify that the test was carried out appropriately and submit the certification to SLA together during each ISN job submission. The GPS test certification is attached in Annex A.

Field procedures stated in para 7(a), 7(b) and 7(c) must be adhered.

The coordinates of the Pillar 7 are to be computed using to the following criteria and procedures:

- Minimum one-hour session of observation; with reference to at least 2 SiReNT reference stations.
- The baseline acceptance criteria in Table 2 must be adhered.
- The adjusted northing and easting of Pillar 7 must be within 20mm on each direction of the fix coordinate N.38834.121 E.27135.303.
- The adjusted ellipsoidal height of Pillar 7 must be within 60mm of 26.824m.

Surveyors are required to suitably archive RINEX data of the observation recorded at Pillar 7; the SiReNT reference station data used in the test; baseline processing report as well as the adjustment results of the baselines. Surveyors are required to contact SLA for the arrangement to use the Pillar 7. He may use the “GPS Station Observation Log” to record each observation.

(b) Tribrachs

- Tribrachs (all plumbing/centering equipment) should be periodically checked.

5. Site Planning and Reconnaissance

Site Planning and Reconnaissance is required for the establishment of ISN markers. GPS survey requires good visibility of the sky in order to receive signals from as many satellites as possible during survey.

Site Planning and reconnaissance is carried out to ensure that:

- The location of the intended ISN marker is well located in terms of ground stability, accessibility, clear sky views, protection from vandalism and disturbance.
- The GPS surveys are conducted during periods when the maximum number of satellites is in view, and the value of PDOP is at its minimum.

6. Installation of ISN Markers

The ISN markers should be planted on / at

- Concrete surface such that the stability and reasonable permanency for the marker is assured.
- A site which is safe from potential vandalism and disturbance.

- A site with good sky view for maximum satellite visibility.
- A site with minimum multipath effects.
- A site where no existing ISN markers in vicinity of 300 metres radius to avoid marker proliferation and to improve existing network.

7. Field Procedures

Surveyors should adhere to the following guidelines in the course of conducting the field observation of the GPS surveys:

- (a) GPS Satellites Availability
 - Number of satellites observed – minimum 5 satellites all the time.
 - PDOP (Position Dilution of Precision) – less than or equal to 6 all the time.
- (b) Weather
 - Observations during heavy rain are not recommended.
- (c) GPS Observation Setting
 - Elevation mask – minimum 15 degrees
 - Observation rate – minimum 15 seconds
- (d) GPS Observation Session
 - Two independent observation sessions are needed to determine the coordinates of each ISN control point. For each session, the GPS receiver (and tripod) has to be physically reset.
 - Refer to Table 1 for the duration of observation session for different baseline lengths.
 - Duration of observation is subjected to site condition.

Table 1: Observation time for different baseline length

Baseline Length (km)	Recommended Minimum Observation Time (minutes)
0 – 5	30
5 – 10	40
10 – 15	50
15 – 20	60
20 – 30 (Not recommended)	120

- (e) GPS Antenna Set Up
- GPS antenna is not required to be oriented to true north.
 - Antenna height must be measured (to nearest mm) and must be precisely documented in the GPS Station Observation Log (Appendix C).
 - Antenna height must be measured once before and after each survey and/or each physical reset of the GPS antenna.
- (f) GPS Station Observation Log
- The field officer must fill up a proper observation log to be submitted to SLA.

8. GPS Data Processing

GPS data processing involves baselines processing and adjustment. The details are as follow:

- (a) Baseline Processing
- Carrier phase observation processing is required for the survey.
 - Broadcast ephemeris can be used for baseline processing, but precise ephemeris is recommended for long baseline (more than 10 km). The precise orbit data can be obtained from the International GPS Service for Geodynamics (IGS) web site.
 - Each ISN point has to be connected to at least two SiReNT reference stations.
 - Each of the connection should be observed in two sessions as described in 7(d).
 - It is recommended to accept short baselines.
 - Baselines may be accepted based on the criteria listed in Table 2.

Table 2: Baseline acceptance criteria

Baseline Length (km)	Baseline Fix Type	RMS (m)	Ratio
< = 5	L1 fix	< 0.015	> 3
> 5	Ionosphere free fix	< 0.020	> 3

(b) Adjustment

- Only accepted baseline will be used in the network adjustment.
- No outliers in observations.
- Northing and Easting error less than 0.020m and ellipsoidal height error less than 0.040m
- The adjustment must pass the statistical test (e.g. Chi-square, F-test)

9. Report Submission and Data Format

The Surveyor is required to submit the GPS survey report by E- transmission (CORENET) to SLA.

(a) Submission of the GPS survey must include:

- GPS Test Certification – see Appendix A
- Zero Base Line Test Certification
- GPS Station Obstruction Diagram – see Appendix B.
- GPS Station Observation Log – see Appendix C.
- Original unretouched colour digital photograph of the ISN marker in JPEG format.
- Edited colour digital photograph of the ISN marker in JPEG format, with arrow pointing to the marker, two indicator arrows, measurements to two permanent structures, and identification number of the ISN marker, as per specifications in (b) below.
- Location sketch of the ISN marker in JPEG format.
- GPS Processing Report including processing parameters (e.g. information of GPS data used in the processing), Adjustment and Statistical Testing Report.
- Results of consistency check or data verifications. (e.g. agreement between repeated baselines).
- Observation Data (RINEX or compact RINEX format) for the ISN point surveyed, clearly labelled.
- XML file (*.hcp) containing final SVY21 coordinates and other information of the ISN point. A HTML tool is provided by SLA to generate the XML file to be submitted. The HTML tool can be downloaded from SLA webs site ([http: www.sla.gov.sg](http://www.sla.gov.sg)): Circulars -> Land Survey -> Chief Surveyor Directive, Services, Guidelines and Specifications -> HTML Tool for ISN Markers Submission.

The HTML tool and the XML files are described below in Figure 1 and Figure 2.

- Other report and information deemed necessary by SLA.

(b) Digital photograph of the ISN marker must be in JPEG format

- Picture size – 1024 x 768 pixels (Landscape only). See Figure 3 for sample.
- File size – not more than 1MB
- Red arrow with black trim, points vertically down at marker location.
- Black box at the bottom left corner indicating the ISN marker number in white font. (Font : Arial; Bold : Yes; Size : 18)
- The ISN marker must be referenced to 2 permanent structures, e.g. lampposts (with identification number), fire hydrants (with identification number) , electric boxes (with identification number) In the absence of such structures, the ISN marker is to be referenced to corner of buildings, walls, fences, gates, manholes and other suitable points. The reference distances (to 2 decimal places of a metre, font size:12) must be shown. Indicator arrows specifications: dashed, with arrow heads at both ends, 1.5 point thickness.

Figure 1: HTML Tool for XML file creation

Surveyor needs to key in all values into the form shown above and click on "Create HCP" button to generate the XML file (*.hcp) which can be viewed using NotePad or other text viewers. For help, please click "Help" button at the bottom of the form.

Figure 2: XML File (.hcp) generated

```
<?xml version="1.0" ?>
<ControlPoint>
<CP_NUMBER>14652</CP_NUMBER>
<NORTHING>30576.862</NORTHING>
<EASTING>6606.902</EASTING>
<LONGITUDE>103 38 27.934</LONGITUDE>
<LATITUDE>1 17 34.056</LATITUDE>
<EHEIGHT>12.654</EHEIGHT>
<SURVEYOR>Peter Tan</SURVEYOR>
<ASSTSURVEYOR>John Lee</ASSTSURVEYOR>
<DATE_OF_SURVEY>13/04/2005</DATE_OF_SURVEY>
<LOCATION>Geylang East Avenue 2</LOCATION>
<DESC_CP>Cross Screw</DESC_CP>
<REMARKS></REMARKS>
</ControlPoint>
```

Figure 3: Colour digital photograph of ISN Marker in JPEG format

10. SiReNT Reference Station Data Support

There are currently 5 permanent GPS reference stations in SiReNT. The SiReNT reference station coverage is shown in Figure 4.

(a) Data Availability

- The reference station data are available in RINEX 2.1 format or compact RINEX (HATANAKA) format.
- Data rate – 1-, 5- , 10- and 15-second
- Data from the SiReNT reference stations can be obtained through Post Processing On-Demand service of SiReNT. Upon signing up, users would be issued UserID and Password to download RINEX files from SiReNT website at <http://www.sirent.sla.gov.sg>. Users can specify the date, time and data rate of RINEX files to be purchased.
- RINEX data of 1-year-old from date of request is available for download from SiReNT website.

(b) Operational Status of SiReNT

- The operational status of the reference stations will be available on the SiReNT website at <http://www.sirent.sla.gov.sg>.

(c) Quality and Data Gaps

- Effort will be made to ensure smooth operation of the reference stations. SLA is not liable for any claims whatsoever arising from data errors or missing data.

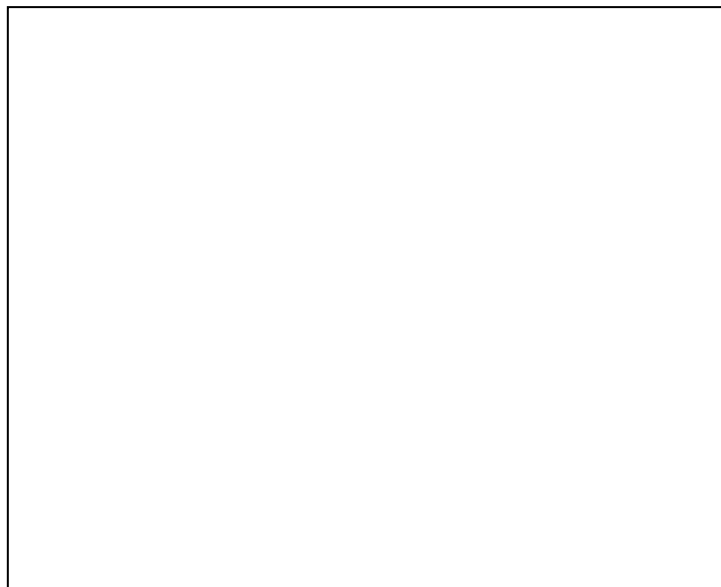


Figure 4: SiReNT reference station coverage

11. GPS Survey in the Absence of SiReNT

In the event that SiReNT is unavailable for whatever reasons, the following procedures must be adhered to when survey the ISN markers.

- (d) The ISN marker survey will be carried out with reference to primary control marks.
- (e) At least 2 reference stations should be set up over any 2 primary control marks.
- (f) The 2 local reference stations should preferably not to be set up more than 10 km apart.
- (g) Each independent baseline should preferably not to be more than 6.5 km.
- (h) Receivers and antennae of different models and manufacturers may be used in the same survey provided that the measurement types can be combined during processing. However, the use of the same type of receivers and antennae on same survey is recommended in order to minimise antenna phase centre biases.
- (i) The rest of the guidelines for field procedures, GPS receiver and antenna, and GPS data processing apply as above.

GPS Test Certification

Version 2.2

Test Date :	/ / 20		
Observed By :	_____		
Agency/Company :	_____		
Pillar 7	Known Value	Survey Value	Difference
Northing	N. 38834.121		
Easting	E. 27135.303		
Ellipsoidal Height (measured from baseplate)	26.824m		

Receiver Type/Model :	_____		
Receiver Serial No. :	_____		
Receiver Firmware Version :	_____		
Antenna Type/Model :	_____		
	with ground plane <input type="checkbox"/>	without ground plane <input type="checkbox"/>	
	choke ring <input type="checkbox"/>	with radome <input type="checkbox"/>	
Antenna Serial No. :	_____		

Certification:

I certify that the GPS gross error test was carried out by me or under my supervision at the Pillar 7, Lower Peirce Reservoir and the result of the test is acceptable within the limit set out in the "Guidelines and Specifications for GPS Surveys of ISN Markers". I will also adhere to the following procedures.

- Surveyors are required to suitably archive RINEX data of the observation recorded at the Pillar 7; the SiReNT reference station data used in the test; baseline processing report as well as the adjustment results of the baselines.
- The report and results of the test must be submitted to SLA upon request.

_____	_____
Signature	Date
Registered Surveyor : _____	

GPS Test Certification

Version 2.2

Test Date :	<u>9 / 12 / 2004</u>		
Observed By :	<u>Jimmy Tan Chwee Hock</u>		
Agency/Company :	<u>Singapore Land Authority</u>		
Pillar 7	Known Value	Survey Value	Difference
Northing	N. 38834.121	N. 38834.129	+0.008
Easting	E. 27135.303	E. 27135.300	-0.003
Ellipsoidal Height (measured from baseplate)	26.824m	26.824m	0.000

Receiver Type/Model :	<u>Trimble 5700</u>		
Receiver Serial No. :	<u>0220188888</u>		
Receiver Firmware Version :	<u>1.24</u>		
Antenna Type/Model :	<u>Zephyr</u>		
	with ground plane choke ring	<input type="checkbox"/>	without ground plane with radome
		<input type="checkbox"/>	<input checked="" type="checkbox"/>
Antenna Serial No. :	<u>11909888</u>		

Certification:

I certify that the GPS gross error test was carried out by me or under my supervision at the Pillar 7, Lower Peirce Reservoir and the result of the test is acceptable within the limit set out in the "Guidelines and Specifications for GPS Surveys of ISN Markers". I will also adhere to the following procedures.

- Surveyors are required to suitably archive RINEX data of the observation recorded at the Pillar 7; the SiReNT reference station data used in the test; baseline processing report as well as the adjustment results of the baselines.
- The report and results of the test must be submitted to SLA upon request.



9.12.2004

Signature

Date

Registered Surveyor : Chan Fook Onn

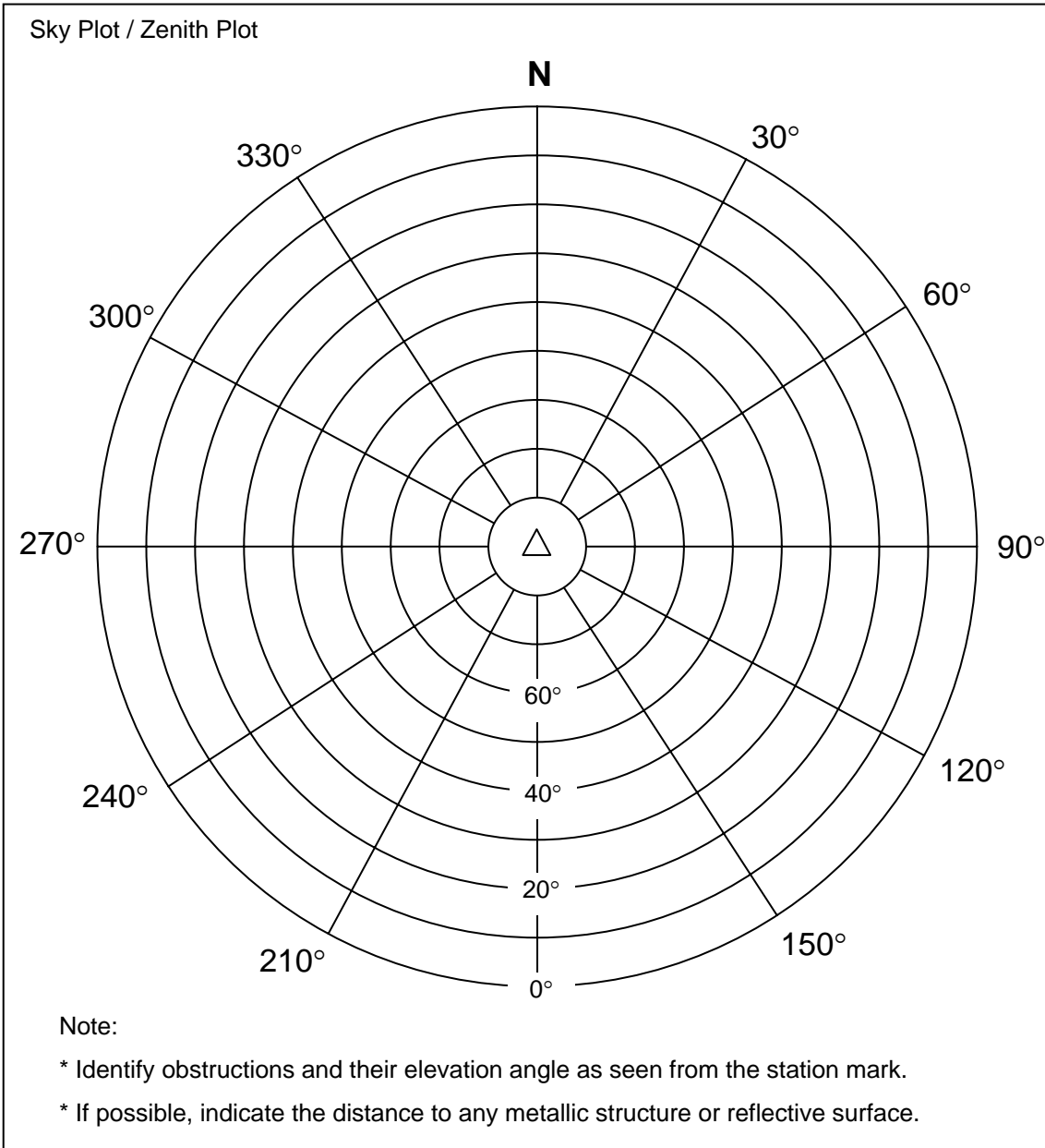
GPS Station Obstruction Diagram

Version 2.2

Date : _____ Sketched By : _____

Station Name/No. : _____ JPEG File : _____

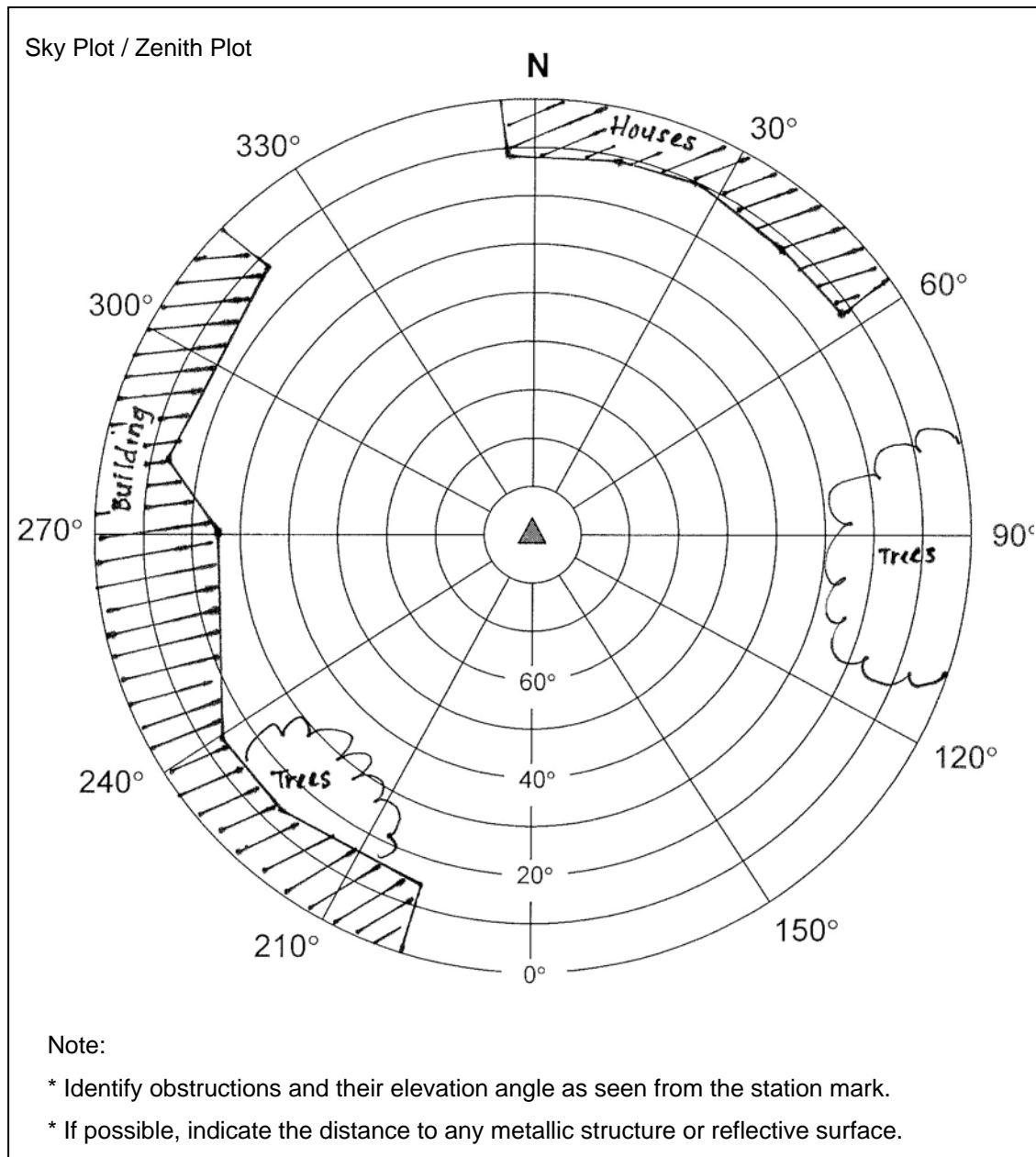
Station Location : _____



GPS Station Obstruction Diagram

Version 2.2

Date :	<u>9/12/2004</u>	Sketched By :	<u>Jimmy Tan Chwee Hock</u>
Station Name/No. :	<u>14980</u>	JPEG File :	<u>Yes</u>
Station Location :	<u>Harvey Crescent</u>		



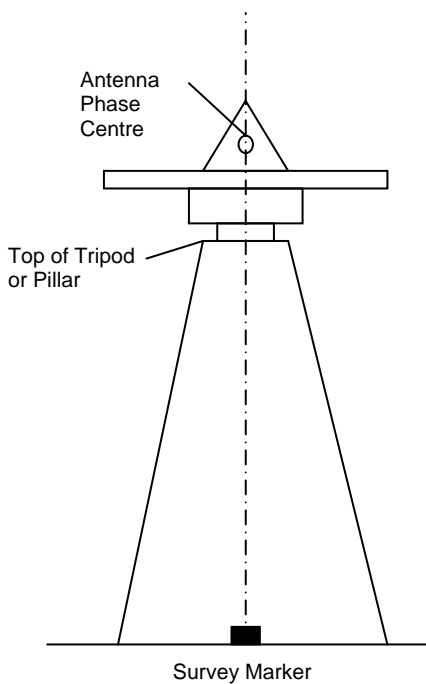
GPS Station Observation Log

Version 2.2

Date : _____ / _____ / 20____ Surveyed By : _____
 Station ID/No. : _____ Monument Type : _____
 Station Location : _____
 Weather Condition : _____ Agency : _____
 RINEX File : _____ JPEG File: _____ Yes No

Receiver Type/Model : _____
 Receiver Serial No : _____
 Receiver Firmware Version : _____
 Antenna Type/Model : _____
 with ground plane without ground plane
 choke ring with radome
 Data Rate : 1 sec 5 sec 10 sec 15 sec

Show on sketch measurements taken to derive the antenna height. If slant measurements are taken, make measurement on two opposite sides of the antenna. Make measurements before and after observing session.



Session 1 _____
 Start Time: 11.01 am
 End Time: 12.02 pm
 Instrument Height:
 Before 1.606 m
 After 1.606 m
 Mean 1.606 m
 Measure To: Top of notch

 Session 2 _____
 Start Time: 12.08 pm
 End Time: 1.09 pm
 Instrument Height:
 Before 1.638 m
 After 1.638 m
 Mean 1.638 m
 Measure To: Top of notch

GPS Station Observation Log

Version 2.2

Date :	<u>9 / 12/ 2004</u>	Surveyed By :	<u>Jimmy Tan Chwee Hock</u>
Station ID/No. :	<u>14351</u>	Monument Type :	<u>Cross screw</u>
Station Location :	<u>Harvey Crescent (LP 9 & LP 24)</u>		
Weather Condition :	<u>Clear</u>	Agency :	<u>Singapore Land Authority</u>
RINEX File :	<u>71182640/71182641</u>	JPEG File:	<u>Yes <input checked="" type="checkbox"/> No <input type="checkbox"/></u>

Receiver Type/Model :	<u>Trimble5700</u>		
Receiver Model No.	<u>022017118</u>		
Receiver Firmware Version :	<u>1.22</u>		
Antenna Type/Model :	<u>Zephyr</u>		
	with ground plane <input type="checkbox"/>	without ground plane <input checked="" type="checkbox"/>	
	choke ring <input type="checkbox"/>	with radome <input type="checkbox"/>	
Data Rate :	1 sec <input type="checkbox"/>	5 sec <input type="checkbox"/>	10 sec <input type="checkbox"/> 15 sec <input checked="" type="checkbox"/>

Show on sketch measurements taken to derive the antenna height. If slant measurements are taken, make measurement on two opposite sides of the antenna. Make measurements before and after observing session.

Session 1

Start Time: 11.01 am
End Time: 12.02 pm

Instrument Height:

Before	<u>1.606</u>	<u>m</u>
After	<u>1.606</u>	<u>m</u>
Mean	<u>1.606</u>	<u>m</u>

Measure To: Top of notch

Session 2

Start Time: 12.08 pm
End Time: 1.09 pm

Instrument Height:

Before	<u>1.638</u>	<u>m</u>
After	<u>1.638</u>	<u>m</u>
Mean	<u>1.638</u>	<u>m</u>

Measure To: Top of notch

Version 2.2

GPS Station Location Sketch



Version 2.2

GPS Station Location Sketch

A large, empty rectangular box with a thin black border, intended for a hand-drawn sketch of a GPS station location. The text 'GPS Station Location Sketch' is positioned at the top left corner of the box.