

3. SURVEY REGULATIONS AND STANDARDS OF ACCURACY

This chapter specifies all accuracies for different types of large scale surveys. It also makes provision for general comments regarding a specific type of survey activity. Detail specifications on the different activities will be dealt with under the relevant chapters.

3.1. Survey control beacon accuracies

3.1.1 Fixing of Permanent Survey Control Beacons for monitoring surveys

a) General

It is not imperative for survey control for monitoring surveys to be connected to a Survey System and Datum and may be undertaken on a local system. The National Co-ordinate System can be used if so instructed.

The reasons for the preferred use of a local system are as follows:

- i) The output data sets reflect displacements and not co-ordinates;
- ii) The system can be orientated to suit a particular reference line (for instance if monitoring points are on a straight line and the expected displacements are perpendicular to that line then the y- axis can be placed on that line. The “dx” perpendicular displacements between 2 measurements will then be the same as the difference of the X co-ordinate values between the 2 measurements. The same applies to the “dy” displacements); and
- iii) The control co-ordinates must reflect dimensions which are ‘true’ at the site level i.e. the local context.

b) Vertical accuracy

The vertical accuracy to be achieved is as follows:

- i) For precise levelling: Not to exceed 3mm per square root of a kilometer for double run levelling; and
- ii) For Total Station observations: Total Station observations will not achieve required accuracy specifications as a result of refraction. Accordingly, observations must be undertaken such that the mean vertical angle between 2 observed arcs of circle left and right do not differ by more than 2.5 arc seconds.

c) Horizontal accuracy

Horizontal accuracy is dependent on the accuracy of distance measurements, horizontal observations, the control network configuration and redundancy of observations and as follows:

- i) The use of an instrument with a specification of +/- 2mm +2 ppm for distance measurements. An accuracy of less than 3mm over 500m can be achieved provided accurate pressure and temperature observations are taken and utilised in the reduction of the distances;
- ii) The use of an instrument with a 1 second angular measurement capability where a mean error of less than 2 seconds can then be achieved. At a distance of 100m the accuracy is 1mm and becomes progressively larger by 1mm for every increased distance of 100m; and
- iii) Accordingly the horizontal accuracy must be less than 2.5mm with a confidence level of 95%.

3.1.2 Fixing of Permanent Survey Control for topographical surveys

a) Horizontal accuracy

i) Triangulation Method

Triangulated survey stations shall be surveyed in accordance with the Land Survey Act 1997, (Act 8 of 1997) and the Survey Regulations promulgated in terms of Section 10 of this Act i.e. to class "A" Accuracy.

Where A is equal to $0.04 + S/30\ 000$ and S is the distance in meters between the known and unknown survey station. The comparison is made between any observed ray or measured distance from the final co-ordinate of the survey station fixed and a known survey station.

ii) Traverse and Polar Method

Traversed survey stations shall be surveyed in accordance with the Land Survey Act 1997, (Act 8 of 1997) and the Survey Regulations promulgated in terms of Section 10 of this Act i.e. to class A Accuracy.

Where $A = 0.04 + S/30\ 000$ and the comparison is made to the linear misclosure of the traverse, where S is the total length of the traverse in metres.

iii) Global Positioning (GPS) Survey Method

Global Positioning (GPS) survey stations shall be surveyed in accordance with the Land Survey Act 1997, (Act 8 of 1997) and the Survey Regulations promulgated in terms of Section 10 of this Act i.e. to class A Accuracy.

Where $A = 0.04 + S/30000$ and the comparison is made between the vector derived from the final co-ordinate and the measured vector after the datum transformation has been applied. S is the distance in meters between the known and the unknown survey station.

Note: Use of the latest geoidal model by NGI is regionalised for all GPS measurements. These heights shall not be used as final heights for Permanent Survey Control.

- iv) The final co-ordinates shall be recorded to two (2) decimals of a meter.

- b) Vertical standard of accuracy for Permanent Survey Control
 - i) Circuit Levelling

The closing error (in metres) of a levelled circuit shall not exceed: $0,003 \sqrt{\text{setups}}$, in height difference between the forward and reverse levelling of successive Permanent Survey stations e.g. for 1km (10 setups) levelling and 10 setups check levelling = 20 setups. For 1km = $0,003 \sqrt{20 \text{ setups}} = 0,013\text{m}$ (13mm).

 - ii) Closing on terminal points

The mean closing error of a levelled circuit between terminal points shall not exceed: $0.013 \sqrt{K}$ metre, where K is the single length of the circuit in kilometres between the terminal points. For example, for 16km the closing error shall not exceed 0.052m (52mm).

 - iii) Forward and check spirit levelling shall not be done simultaneously.

 - iv) The level and check level height differences between successive points shall not exceed 5mm per 300m.

 - v) The final elevations of spirit levelled beacons shall be recorded to three (3) decimals of a metre.

- c) Fixing of working stations for topographical surveys

The accuracy for all working stations shall adhere to the accuracy determined for Permanent Survey Control.

- d) Fixing of Photo Ground Control for photogrammetric surveys

Horizontal and vertical Photo Control Points shall be sufficiently accurate so as to meet the requirements as set out in paragraph 3.2.4 "Photogrammetric and Orthophoto detail contour and DTM surveys".

3.2 Topographical surveys

3.2.1 Ground detail, contour and DTM surveys

Feature	Resultant Horizontal Accuracy	Vertical Fixing Accuracy
Kerbing and edge of asphalt	50 mm	10 mm
Road Surface (Seal/Asphalt/Concrete)	50 mm	10 mm
Storm water pipes	50 mm	15 mm
Lined Drains	50 mm	15 mm
Gravel Road Surface	100 mm	30 mm
General Topographic Detail of the Road Prism	100 mm	10 mm
Spot shots not on the Road Prism (DTMs)	100 mm	50 mm
All other detail	100mm	50mm

These tolerances apply to the actual spots surveyed.

All features surveyed and which do not form part of the DTM shall be excluded from the DTM.

The accuracy of these types of surveys shall comply with the following:

- a) 80% of the 'check points surveyed' must yield a dz or dy & dx value which does not exceed 3 x (three times) the stipulated vertical accuracies and the resultant horizontal linear accuracies must not exceed 1.5 x (one and a half times) the stipulated horizontal accuracies; and
- b) Where dz and dy & dx respectively is the difference in the Y, X & Z co-ordinates between the DTM and detail and the 'check points surveyed'.

3.2.2 Ground railway line surveys

Feature	Resultant Horizontal Accuracy	Vertical Fixing Accuracy
Kerbing and edge of asphalt	50 mm	10 mm
Rail levels	20 mm	5 mm
Road Surface (Seal/Asphalt/Concrete)	50 mm	10 mm
Storm water pipes	50 mm	15 mm
Lined Drains	50 mm	15 mm
Gravel Road Surface	100 mm	30 mm
General Topographic Detail of the road and rail prisms	100 mm	10 mm
Spotshots not on the road and rail prisms	150 mm	50 mm
All other detail	100mm	50mm

These tolerances apply to the actual spots surveyed.

All features surveyed not forming part of the triangulation shall be excluded from the DEM.

The accuracy of these types of surveys shall comply with the following:

- a) 80% of the 'check points surveyed' must yield a dz or dy & dx value which does not exceed 3 x (three times) the stipulated vertical accuracies and the resultant horizontal accuracies must not exceed 1.5 x (one and a half times) the stipulated horizontal linear accuracies ; and
- b) Where dz and dy & dx respectively is the difference in the Y, X & Z co-ordinates between the DTM and detail and the 'check points surveyed'.

3.2.3 Borrowpit ground surveys

Feature	Resultant Horizontal Accuracy	Vertical Fixing Accuracy
General Topographic Detail and DTM observations	100 mm	50 mm

These tolerances apply to the actual spots surveyed.

All features surveyed and which do not form part of the DTM shall be excluded from the DTM.

The accuracy of these types of surveys shall comply with the following:

- a) 80% of the 'check points surveyed' must yield a dz or dy & dx value which does not exceed 3 x (three times) the stipulated vertical accuracies and the resultant horizontal linear accuracies must not exceed 1.5 x (one and a half times) the stipulated horizontal accuracies; and
- b) Where dz and dy & dx respectively is the difference in the Y, X & Z co-ordinates between the DTM and detail and the 'check points surveyed'.

3.2.4 Photogrammetric and Orthophoto detail contour and DTM surveys

Feature	Resultant Horizontal Accuracy	Vertical Fixing Accuracy
Kerbing and edge of asphalt	150 mm	100 mm
Storm water pipes	200 mm	100 mm
Lined Drains	200 mm	100 mm
Gravel Roads	200 mm	100 mm
Greenfields	300 mm	150 mm
General Topographic detail	300 mm	150 mm

These tolerances apply to the actual spots surveyed.

All features surveyed and which do not form part of the DTM shall be excluded from the DTM.

The accuracy of these types of surveys shall comply with the following:

- a) 80% of the 'check points surveyed' must yield a dz or dy & dx value which does not exceed 2 x (twice) the stipulated vertical accuracies and the resultant horizontal linear accuracies must not exceed 1.5 x (one and a half times) the stipulated horizontal accuracies; and
- b) Where dz and dy & dx respectively is the difference in the Y, X & Z co-ordinates between the DTM and detail and the 'check points surveyed'.
- c) The accuracy of the contours shall comply with the following:
 - i) 80% of the check points surveyed must yield a dz value which does not exceed 0.2 x (zero point two times) the contour interval and where the contour interval is normally 0.5m, 1.0m, 2.0m etc. and where dz is the difference between the "check point surveyed" elevation and those elevations interpolated from the contours of each "check point surveyed".

3.3 Staking

3.3.1 Staking of road centre line

- a) Accuracy of Key points

Key Points shall be staked and fixed in Y, X and Z to the same accuracy as specified above for the fixing of Permanent Survey Control. See Paragraph 3.1.2(a) "Horizontal accuracy" and 3.1.2(b) "Vertical standard of accuracy for Permanent Survey Control". The staked positions may not differ by more than 20mm from their theoretical position.

- b) Intermediate points accuracy

Unless otherwise specified, the position of staked points at 20m intervals shall not differ from their required theoretical position by more than 20mm.

The distance between any two consecutive staked points when compared to the theoretical distance shall comply with a 1:1000 accuracy limit and where over a 500m distance the comparison shall comply with a 1:5000 accuracy limit.

Intermediate points need not be spirit levelled. Their heights may be determined using GPS or Tachometric survey methods. Use of the latest South African geoidal model is compulsory when undertaking GPS measurements. The height accuracies shall conform

to the requirements stipulated above for the survey of ground detail, contours and DTM survey.

c) Accuracy for Curves

In the case of curves, the closing error (cord) shall not exceed 1:5000. Any error less than 1:5000 may be adjusted once only and on a pro-rata basis over the entire length of the curve. Where the error exceeds 1:5000 then the curve must be re-staked so that the resultant error is less than 1:5000 and that error is then adjusted on a pro-rata basis over the entire curve length.

The height accuracy must accord with those specified for key and intermediate points staked.

3.3.2 Accuracy of Cross sections

a) Vertical accuracy

Vertical accuracy for measurements on surfaced road shall be 10mm.

Distances measured to any point on the cross section from a 'control point' shall not exceed 150m. This limit is so as to mitigate the refraction effect on the measurement taken.

The Horizontal and vertical accuracy of measurements taken off the Road Surface shall comply with the above accuracies stipulated for ground detail, contour and DTM surveys.

3.3.3 Kilometer Markers and Staked Positions

a) General

Kilometer Marker staked positions must be positioned at a standard offset from the edge of the road. The Kilometer Marker Board must then be placed next to the Road Reserve fence and perpendicular to the road, opposite the Kilometer Marker staked position.

b) Accuracy of Staked Position

The staked position shall be within 100mm of its theoretical position.

c) Height accuracy

Not applicable.

3.3.4 Road Reserve Beacons

a) Position and accuracy

The position of the staked Road Reserve shall correlate with its theoretical position and where the resultant horizontal displacement does not exceed 50mm.

b) Height accuracy

Not applicable.

3.3.5 'Setting out' for construction works

a) Profiles

- Height accuracy 5mm
- Position and accuracy 20mm

b) Batter boards

- Height accuracy 5mm
- Position and accuracy 100mm

c) Structural Foundation

- Height accuracy 10mm
- Position and accuracy 20mm

3.4 Structural Surveys

- Height accuracy 5mm
- Position and accuracy 5mm

3.5 Accuracy of Monitoring survey

3.5.1 Total Station observations

a) Height accuracy

Total Station observations used to determine heights are affected materially due to the refraction of light and accordingly angular differences between arcs shall not exceed 2.5 arc seconds.

b) Position and accuracy

The positional accuracy of the target is dependent on several factors such as discussed in paragraph 3.1.1 "Fixing of Permanent Survey Control Beacons for monitoring surveys". The positional accuracy achieved should be less than 3.0mm with a confidence factor of 95% for such measurements to be useable.

Total Station observations shall be undertaken with a Total Station which guarantees a minimum of 1 arc second in the horizontal and vertical standard deviation which is based on Deutsches Institut für Normung (DIN) 18723 standards. DIN standards are also known as the German Institute for Standards.

Distances: +/- (2 mm +2 ppm) or better

c) Accuracy of precise levelling

Precise levelling accuracy shall not exceed 3mm per km for a 'double run' levelling and consecutive monitoring points which are less than 40m apart shall not exceed 0.2mm.

Precise levelling shall be done with a high order precise level instrument and 'invar' staves. The level instrument's specification shall enable a standard deviation per kilometer 'double run' levelling of less than 1mm to be achieved.

3.6 Construction supervision surveys

Standards of Accuracy: The standards of accuracy for such surveys shall comply with the relevant Standard Specifications for Road and Bridge Works and the relevant Project Specifications.

3.7 Lidar Scanning

Accuracy of detail with reference to the imagery:

- Height: 100mm
- Position: 100mm

Accuracy of DTM and determined with reference to the laser data:

- Height: 100mm
- Position: 100mm

3.8 Survey instrument accuracies

The Surveyor shall ensure that all instruments and equipment used in a survey are in good order and within proper adjustment. Calibration Certificates issued by the relevant supplier shall not be older than twelve months and shall be submitted on instruction from the Client. The

Client may demand updated Calibration Certificates should there be any suspicion by the Client as to the accuracy of the instrument.

Accordingly all instruments used on survey projects must be suitable in order to achieve the required accuracies as specified.

3.9 Drafting and Orthophoto image accuracies

The position of all well-defined detail must be plotted in relation to a co-ordinate grid so as to achieve a positional accuracy which does not exceed 0.5mm on the hard copy plan.

The co-ordinates and heights of any feature or spot shot in a digital CAD drawing or Orthophoto shall correlate absolutely with co-ordinates and heights as surveyed when 'snapping' onto such a point in the CAD or Orthophoto.

The accuracy for position and height shall be relative to those prescribed accuracies as stated in the paragraph headed "Photogrammetric and Orthophoto detail contour and DTM surveys". Paragraph 3.2. "Topographical Surveys"

3.10 Accuracy of Cadastral data on topographical plans

Errors in the calculation and plotting of Cadastral boundaries shall not exceed 1mm in reference to the co-ordinate grid.

The co-ordinates when 'snapped' onto for Cadastral beacons in a digital CAD drawing shall correlate exactly with the co-ordinates originally imported into the drawing.