

5. THE ESTABLISHMENT OF PERMANENT AND OTHER SURVEY CONTROL POINTS

This chapter provides specific guidelines on the establishment of different types of survey control. It prescribes survey procedures, beacon building techniques and the physical distribution of the different types of control beacons. It standardizes the quality and the format of the data and also makes provision for the verification procedures of existing Permanent Survey Control.

5.1. General requirements for Permanent Survey Control and Photo Control Points

5.1.1 General

- a) Survey system
 - i) A back bone of Permanent Survey Control shall be established for all surveys along the survey strip or in an area as defined and shall be on the WGS84 Co-ordinate System. (As per the Hartebeeshoek Radio Astronomy Telescope as the origin of the system).
 - ii) The Permanent Survey Control shall be based on any existing control system and/or the National Trigonometric Network as specified. Residuals with reference to the adopted control must be submitted with the final survey records.
- b) Spacing of the Permanent Survey Control
 - i) Permanent Survey Control for road surveys must be established in safe positions and not more than 300m apart along the alignment of the road and not more than 1m from the Road Reserve in order to allow the survey instrument to set up with ease. This spacing may be varied with prior approval of the Client.
 - ii) Permanent Survey Control shall be established in a 300m grid for all others surveys undertaken and where alignments are not involved. This Control shall be established at safe and suitable locations for use during construction activities.
 - iii) A minimum of three (3) Permanent Survey Control beacons must always be established, irrespective of the size of the survey area.
- c) Marking of Permanent Survey Control beacons
 - i) For road surveys each Permanent Survey Control beacon must be clearly marked by painting the closest Road Reserve fence standard or post white. An arrow of approximately 400mm x 200mm shall be painted, using white road marking paint, on the hard Road Surface and pointing in the direction of the beacon. Where no

fences exist, the beacon must be marked with a cairn of white washed stones 0.5m in diameter and 0.5m in height or to such other specific requirements as dictated to by the Client.

- ii) For all other surveys, each Permanent Survey Control beacon must be marked by means of a cairn of white washed stones 0.5m in diameter and 0.5m in height or by a 1.8m iron standard, driven ± 0.8 m into the ground. The iron standard must be painted with white enamel paint and be placed in such a position so as to protect the beacon. The Surveyor must mark the beacon's position so as to prevent any damage or injury to a person or thing. The marking of beacons in open fields with iron standards is not recommended. These requirements may vary with prior approval from the Client.

d) Numbering of beacons – refer to **Annexure 10**

- i) Unless otherwise specified, all Permanent Survey Control for road surveys shall be numbered in sequence and in the direction of increasing route and/or road section numbers. The number must be stamped onto a strip of aluminium 0.7mm to 1.5mm in thickness and firmly set in the concrete surrounding the beacon.
- ii) The numbering of beacons for all other surveys shall conform to the Clients' specific requirements and may reflect the year in which it was constructed. After the number a '/' must separate the number and the year, e.g. AB24/10.
- iii) Unless otherwise specified, the following information must be stamped with text that does not exceed 7mm;
 - Station number/year, e.g. NRB 2/10 or PRD 99/10 for beacons built in 2010.
 - Route & section number, e.g. N17/1 for Route N17 Section 1.

The number must be readable when facing in the direction of the next survey station.

e) Establishment of terminal Permanent Survey Control where no existing height control is available

If no level Datum Point is available within 5 kilometers of the survey, the Client may approve the use of the Trignet Base Stations in order to determine orthometric elevations for such control.

The control points at the start and end of the survey project and those intermediate control points determined by a maximum spacing of 20km must, where GPS is used, be observed in static GPS mode for a minimum period of 2 hours and at 5 second recording intervals. Such control must be processed in reference to a minimum of 2 of the nearest Trignet Base Stations in order to derive orthometric elevations between sequential control observed in static GPS mode. In addition an overlap of static GPS data of at least 5 minutes plus 1 minute per kilometer of the distance between such sequential control, must be observed.

Processing of the GPS observations must be carried out using recognised and acceptable post-processing software which utilises an up to date geoidal model e.g. South African Geoid 2010. The ellipsoidal elevations of the Trignet Base Stations are to be adopted for the purpose of processing the base line vectors. Utilising the geoidal model, orthometric elevations may then be derived. The differences between the adopted and processed elevations must be supplied together with the survey report

Raw survey data, in Receiver Independent Exchange (RINEX) format, calculations and final data must be submitted to the Client for approval prior to finalising the Permanent Survey Control heights.

f) Construction of the Permanent Survey Control beacons

i) Conical Beacons

Unless otherwise specified, every Permanent Survey Control beacon must be constructed using a 16mm diameter steel peg which must be driven into the ground in such a way that the top of the peg is not damaged or burred. The steel peg must be 450mm long, where 30mm of the steel peg must protrude above ground level. A hole, 275mm deep and 300mm in diameter, must be dug around the peg and filled with concrete which is comprised of a mixture of one part fresh cement, three parts clean sharp sand and five parts crushed stone (minimum crushing strength of concrete is to be 15 MPa) and placed so as to leave approximately 5mm of the steel peg protruding above the concrete. Refer to **Annexure 10**.

A mould 250mm in diameter and which does not exceed 100mm in height, must be used to shape and finish off the top of the concrete beacon. The final height of the concrete shall not be more than 25mm above ground level. Refer to **Annexure 10**.

ii) Pillar beacons (Refer to paragraph 5.2.4 "Construction" for additional requirements on Pillar beacons for monitoring surveys)

Pillar Beacons shall only be placed on request from and in consultation with the Client.

Unless otherwise specified, every Pillar Beacon shall be constructed as follows:

- The base of the beacon must be a solid block of concrete 500mm square and 500mm high and which is comprised of a mixture of one part cement, three parts of sharp sand and four parts of crushed stone. The size of the base may be increased depending on the soil conditions. The Surveyor must advise the Client on any ground conditions where he is of the view that the prescribed dimensions will not result in a stable beacon;
- 8mm reinforced steel bars, 1600mm in length, with wire binders separating the bars in a 150mm square, 200mm apart from top to bottom, must be cast into the concrete block. The reinforced steel must be cast 450mm into the base and must protrude 1150mm above the base;

- A 250mm diameter PVC or pitch fibre casing must be located over the steel bars reinforcing and up to a depth of 150mm into the concrete base and must protrude 1300mm above the concrete base. The casing must be filled with the same concrete mixture as specified for the base;
- The Surveyor must ensure that the casing is 100% vertical and that it is screeded to smooth level surface;
- A 200mm long sleeve, sufficiently large enough to hold a 20mm Ø galvanised pipe, must be cast into the top of the beacon. A removable target, painted red, white and black as indicated in **Annexure 11**, must be placed into the sleeve;
- A brass or stainless steel stud which complies with the specification for “studs in pavements and structures” must be affixed to the base and which will serve as the level (height) for the Pillar Beacon; and
- For detail specifications refer to **Annexure 11**.

iii) Studs in pavements and on structures

Where it is not possible to construct normal beacons, then studs placed into pavements, on structures and rocks must be used. Such studs must comply with the following specifications:

- A hole with a minimum diameter of 10mm must be drilled into the paving/structure/rock. A brass or stainless steel stud with an approximate diameter of 10mm, together with a washer of minimum 20mm Ø must then be inserted into such hole using a suitable epoxy approved by the Client; and
- A circle, 200mm Ø, must be painted around the stud using white road marking paint.

The beacon number must be punched on the washer.

g) Vertical fixing of Permanent Survey Control beacons

i) Levelling

- Unless otherwise specified, accuracies to be achieved are set out in paragraph 3.1.1(b) “Vertical accuracy” above. The elevations of Permanent Survey Control and survey ‘working’ control must be determined from spirit levelling.
- Level instrument adjustment checks must be performed daily and prior to the commencement of the survey work and must be recorded in the survey records.

- All Permanent Survey Control elevations and temporary working control must be determined ensuring a double run spirit levelling technique in opposite directions.
- Observation distances shall not exceed 40m.
- The final level, recorded to 3 decimals of a metre, must be with reference to the top of the steel peg marking the Permanent Survey Control. Where a steel peg protrudes more than 40mm above the ground then the height difference to the top of the peg above normal ground level must be recorded to two decimals of a metre in addition to its final level.
- Where the control network for the levelling is such that two or more lines of levels run parallel to each other, they shall be connected by cross levelling at intervals not exceeding 1 kilometer. The adjustment of the spirit levelling network must be done in successive circuits commencing from a terminal Bench mark (Datum Point) along the left hand level line, crossing over at a 1 kilometer distance point to the right hand level line and then back to another terminal Bench mark. For successive circuits the survey beacons established at the cross over positions from the left hand to the right hand lines shall be used as terminal Bench Marks.
- All spirit levelling of Permanent Survey Control must, in addition to the reverse levelling, be independently checked by GPS levels or via trigonometrically observed heights and where these are determined during the survey of such Permanent Survey Control.
- The 'check' results shall be recorded as follows and in Excel format:

FINAL LEVELLED HEIGHT	CHECKED LEVEL HEIGHT	DIFFERENCE

Note: Simultaneous levelling using a common staff is not permitted.

ii) Trigonometrical height traversing

Subject to the written approval of the Client, the use of simultaneous reciprocal trigonometric levelling for the determination of elevations in steep terrain and where normal spirit levelling is not possible or practical, may be permitted. If this method of height determination is used, then distances between consecutive survey stations must be within 500m and the vertical angle must be determined from at least two arcs of observations. Signal and instrument heights must be measured and recorded before and after the completion of the observations.

iii) GPS heighting

GPS survey methods shall not be used to determine the elevations of Permanent Survey Control except in the establishment of terminal survey stations as specified in paragraph 5.1.1(e) "Establishment of terminal Permanent Survey Control where no existing height control is available".

iv) Elevations: reduction and calculation

- The reduction of spirit levelling observations must be done either by the "rise and fall" or "collimation" methods. All adjustments shall be shown and form part of the final data records.
- For simultaneous reciprocal trigonometrical levelling no corrections must be applied for curvature and refraction.
- A comparison of the height differences between successive control beacons determined by the levels and check levels must be submitted in Excel format.
- Reduced levels shall be recorded in full and as follows:
 - Spirit levelling to 3 decimals of a metre.
 - Trigonometrical height traversing to 2 decimals of a metre (3 decimals for simultaneous reciprocal observations).
 - Trigonometrical levelling to 1 decimal of a metre.

h) Horizontal fixing of Permanent Survey Control

i) General

GPS and Total Station observations are acceptable for the horizontal fixing of Permanent Survey Control and temporary survey control. Single GPS vectors and single Total Station polars are not acceptable. The necessary checks must be carried out in both cases.

Total Station observations undertaken at any control point must consist of at least one arc.

ii) Traversing by Total Station Method

- Unless otherwise specified, the maximum number of traverse legs between traverse terminal points shall be 20 (twenty). Outside orientation observations must be observed wherever possible.
- When traversing between two fixed points, observations must be taken at both fixed points in order for the traverse to be correctly adjusted.

- For accuracy limits and allowable errors see paragraph 3.1.2(a) “Horizontal accuracy”

iii) Global Positioning System Method (GPS)

- In a Global Positioning (GPS) survey the position of a Permanent Survey Control beacon shall be determined from at least two different known points. Sufficient GPS vectors must be measured to determine the local relationship between the GPS datum i.e. World Geodetic System of 1984 (WGS 84) and the National Coordinate System by connecting to at least three trigonometrical stations or other Permanent Survey Control beacons notwithstanding the fact that the Surveyor may have been instructed to base his survey on existing control on site. The Surveyor will generally be instructed to verify existing control.
- For control establishment within a network adjustment, the survey project must be contained within the perimeter as defined by trigonometrical stations or the Permanent Survey Control beacons, thereby ensuring no extrapolation of the survey. All GPS observation adjustments for the determination of the final co-ordinates of the Primary Survey Control beacons must be achieved by post processing. RINEX files of all measurements shall be submitted.
- Surveys undertaken on local coordinate systems must be within the perimeter as defined by the Permanent Survey Control.
- Traversing between fixed stations using observed GPS vectors is permissible. Traverse closures must adhere to paragraph 3.1.2(a) “Horizontal Accuracy”. Traverse calculations must be submitted.
- If real-time GPS vectors are used for GPS traversing, traverse legs must be measured in both directions.
- Local co-ordinate system parameters must be submitted with the survey data.

iv) Calculations and Co-ordinate List

- A co-ordinate list as per **Annexure 12** must be compiled which must reflect all final co-ordinates and heights of the new Permanent Survey Control and any working control. The co-ordinate list must also contain all points used to base the survey on. The elevation and description of the Datum Point of the survey must be highlighted on this list. The co-ordinate list must be in alphanumeric order.
- The final co-ordinate list must be checked and certified by a Registered Surveyor.

- Whenever control has been measured or observed on more than one occasion, then the comparison between the various measurements and the finally adopted values shall be clearly recorded and must be submitted with the survey data.

Note: Final co-ordinates of all surveyed beacons must be displayed to two decimal places. Final heights must be displayed as specified in Paragraph 5.1(g)(iv) “Vertical fixing of Permanent Survey Control Beacons”.

5.2 Specific requirements for the establishment of monitoring survey control beacons

5.2.1 General

Survey Datum height and position:

Refer to paragraph 3.1.1 “Fixing of Permanent survey control for monitoring surveys”.

5.2.2 Co-ordinates and decimal for fixes

The co-ordinate list must include the co-ordinates of all the control and monitoring points. The Y, X and Z values must be displayed to 4 decimals and rounded off to the nearest 0.1mm.

5.2.3 Distribution/Geometry

The distribution and geometry of the Control is dependent on several factors and must be considered on a case by case basis and where the Client’s approval must be obtained.

5.2.4 Construction

- a) The construction of a Pillar Beacon must be comprised of a mild steel or PVC pipe with a minimum diameter of 200mm filled with concrete and steel reinforcement. The column length shall be 1300mm and fixed to a concrete base of 1m² and 500mm in height. Refer to **Annexure 11** for other general requirements related to the construction of Pillar Beacons. The foundations may vary and must be adapted to suit the specific ground conditions or as specified by the Client.
- b) Level Bench Marks must consist of either a brass or stainless steel stud affixed to the base of the Pillar Beacon or drilled and affixed into solid rock. The type of studs used may vary in accordance to the specific requirements. Also refer to paragraph 5.1.1(f) “Construction of Permanent Survey Control beacons” for specific requirements on studs in pavement and structures.

5.2.5 Fixing in the vertical and horizontal plane

Refer to paragraphs 3.1.1(b) "Vertical accuracy" and 3.1.1(c) "Horizontal accuracy".

5.3 Specific requirements for the establishment of Bridge site survey ground control

In addition to the general requirements for the establishment of Permanent Survey Control, the following shall also be applicable:

5.3.1 Establishment of the Permanent Survey Control

- a) A minimum of four Permanent Survey Control beacons of a conical or pillar nature as instructed by the Client must be positioned in selected positions within every Bridge site survey area. This is to ensure proper control of the setting out work and the construction work. It must be specifically noted that these co-ordinates are with reference to the Geodetic ordinate system.
- b) The Permanent Survey Control beacons must be intervisible and shall be established on the WGS84 Co-ordinate System. (As per the Hartebeeshoek Radio Astronomy Telescope as origin of this system). Further, these beacons must be connected to the network of Permanent Survey Control beacon network alongside the road and directly adjacent to the proposed Bridge site.
- c) In the absence of existing Permanent Survey Control elevations shall be based on National Geodetic Benchmarks. In the event that there are no such Datum Points within 5km of the Bridge site, then specific instructions must be obtained from the Client.
- d) The construction of these Permanent Survey Control beacons shall be undertaken in accordance with paragraph 5.1.1(f) "Construction of the Permanent Survey Control beacons".
- e) The Construction Surveyor must adjust the published co-ordinates so as to reflect a scale factor of 1 (one) for setting out purposes if necessary.

5.3.2 Spacing of the Permanent Survey Control

- a) Care should be taken to ensure that the Permanent Survey Control beacons are placed away from the Road Shoulder and from drains and as far as possible outside areas of agricultural activity. These Permanent Survey Control beacons must not be placed closer than 30m from the centre line of the proposed road and preferably no further than 50m from the proposed location of the Bridge/structure.
- b) These beacons must remain in place and functional after completion of the construction work and serve as control for subsequent deflection surveys which may be required as part of the Bridge maintenance program. Due care must be exercised at all times when

selecting their positions so as to ensure their stability and safety from possible disturbance during, and after construction.

- c) The Surveyor must liaise with and agree with the Client on the proposed positions and type of beacon prior to construction of such beacons.

5.3.3 Fixing of the Permanent Survey Control

- a) Horizontal fixing of Permanent Survey Control shall be undertaken in terms of paragraph 5.1.1(h) "Horizontal fixing of Permanent Survey Control".
- b) Vertical fixing of Permanent Survey Control shall be undertaken in accordance with paragraph 5.1.1(g) "Vertical fixing of Permanent Survey Control beacons" and to the level of accuracy as per paragraph 3.1.2(b) "Vertical standard of accuracy for Permanent Survey Control".

5.4 Specific requirements for the establishment of Permanent Survey Control for Borrowpit surveys

5.4.1 General

In addition to the general requirements for the establishment of Permanent Survey Control, the following shall also be applicable:

- a) A minimum of three (3) inter-visible Permanent Survey Control beacons are required. At least one of the beacons must be located directly adjacent to the Borrowpit boundary to be used for future quantity measurements during the construction phase;
- b) Horizontal fixing of this Permanent Survey Control must be undertaken in terms of Paragraph 5.1.1(h) "Horizontal fixing of Permanent Survey Control". The accuracy levels shall be in accordance with Paragraph 3.1.2(a) "Horizontal accuracy"; and
- c) Where the Borrowpit is less than 2km from such Datum Point, the Datum Level must be established by levelling from a known Datum Point.

In the event that the Borrowpit is greater than 2km from a Datum Point then the Datum Level may be established by GPS heighting. This must be achieved by the measurement of two independent GPS vectors to one Borrowpit control point. A geoidal adjustment shall be applied to this final datum height using the latest geoidal model. Refer to paragraph 5.1.1(e) "Establishment of terminal Permanent Survey Control where no existing height control is available" Levelling in terms of Paragraph 5.1.1(g) "Vertical fixing of Permanent Survey Control beacons" to the remaining Borrowpit control points must be undertaken from this Datum Point.

5.5 Photo Ground Control (Applicable to Conventional and Lidar surveys as indicated)

5.5.1 Identification, premarking and fixing of Photo Ground Control for photogrammetric mapping and the production of Orthophotos

a) General requirements for the establishment of Photo Ground Control (PC) points

A Photo Ground Control point (PC) is a premarked point or a point of natural detail which is easily and positively identifiable on an aerial photograph. Further, such points must be chosen so as to ensure that, when viewed stereoscopically, the position and height achieves a high degree of confidence.

- i) These points may also be the Permanent Survey Control points which are augmented by Photo Ground Control points which are selected in appropriate areas so as to meet the requirements for Photo Control Points with reference to the aerial triangulation.
- ii) All Permanent Survey Control points established on a survey project must also be used as Photo Ground Control and must be marked by means of a white cross (Premark). Where unusual conditions (e.g. on white sand) are encountered then a black cross may be used. These control points must be visible on the photograph. The points shall be physically observed during stereo plotter operations (orientation and/or aerial triangulation) and must be driven according to the survey co-ordinates and shall be observed without positive identification of the exact position;
- iii) The distribution of Photo Ground Control points for photogrammetric mapping (non-Lidar surveys) and the production of Orthophotos must adhere to the following requirements:
 - Each fully controlled model must have one control point in each corner of the model which is located well outside of the area to be mapped and is not less than 15mm from the edge of the photograph and one control point in the centre of the stereoscopic model.
 - Where aerial triangulation in a block is used then the maximum distance between Photo Ground Control points at the top, the bottom and the centre of the photo shall be determined by the formula $0.27 S$ where S is the contact scale of the photography. This then represents approximately 3 x the distance between the photo centres of 60% Overlapping photography.
 - Where Aerial triangulation is used for a single strip, the photo control distribution at the top, the bottom and the centre of the photo shall be such that at a photo contact scale of 1:6000 the control points must be $\pm 170\text{mm}$ apart, reckoned in the direction of the flight line and as measured on the photograph compared to $\pm 1000\text{m}$ as measured on the ground. This distance then represents every second model's base which must apply to

any scale photography. No extrapolation shall be permitted. In adverse and extreme terrain conditions these requirements may, in consultation with the Client, be relaxed. These points may be premarked where aerial triangulation is used.

- GPS survey methods shall not be used to determine the elevation of Photo Control Points unless evidence can be submitted that a sufficient number of known height points, spread over the entire survey project, have been included in the observations to model the exact geoid of the area, for interpolation to the geoid on the new points.
- Aerial Triangulation may be used in order to reduce the number of Photo Ground Control Points.

iv) Selection of Photo Ground Control points on existing photography

- A photo control point shall be selected on a photograph using a stereoscope so as to obtain what is known as an “operator’s view”.
- The emphasis here must be on the quality of the selected point determined by its clear definition and it being on level ground as opposed to the ease with which it can be fixed.
- In extreme terrain conditions such additional points should be identified and fixed.

v) Marking of identified ground control: Photo Control Points (PC’s)

- The point must be marked on the photograph on which it appears nearest to the photo centre, by an ink circle \pm 5mm diameter and on the front of the photo and must be numbered as specified.
- Where the point is not premarked then its position must be ‘pricked’ on the photograph using a very fine needle (a ‘pricker’). The number must be printed above the circle on the front of the photograph and then also above the sketch on the back of the photograph.

vi) Field sketch

- Non premarked points must have sketches prepared where these are prepared in the field using a suitable pen in accordance with the following:
 - The photograph must be turned over in the direction of the strip;
 - The sketch must then be drawn on the reverse side of the photograph in relation to the area of the point;
 - The sketch must be drawn as viewed with a stereoscope and not as seen on the ground;

- The sketch must be annotated by a description of the point so as to assist with its identification in the stereoplotter;
- Where the selection of a point, which is located on a raised position in relation to the ground level cannot be avoided, the Surveyor shall state clearly as to whether the height refers to the raised position or to ground level and where the height difference must also be recorded; and
- Sketches for Lidar Photo Ground Control points may be made on a separate sheet of paper. These sketches must be submitted with the final data.

vii) Premarking

- General requirements
 - Each Permanent Survey Control station on a survey project must be premarked;
 - Photo Ground Control points must be premarked such that they from a contrast to the surrounding background and must be positioned where the probability of them being destroyed or covered by dust is minimized;
 - Care must be taken to ensure that the Photo Ground Control point will not be covered by 'shadow' during the time that the photographic flights are undertaken; and
 - The Surveyor must satisfy himself that the Photo Ground Control point will not be obscured by any feature of a tall nature (i.e. not less than 45° from the horizontal).
- Specific requirements for Photo Ground Control survey Premarks
 - In order for the premark to be clearly seen on the photograph its overall length must be at least 0.5mm measured at the scale of the negative (e.g. for 1:6000 photography the overall length of the premark will be 3.0m – The length of each leg of the premark will thus be 1.5m). Also refer to **Annexure 9.1**.
 - Where a 'black' cross is utilised then the width must be at least 0.35m in order to offset the effect of 'halation' (flare) and must not display any shiny or reflective material therein.
 - Premarks must not be placed on steep slopes as this then makes it very difficult for the stereoplotter operator to accurately height the point in the photo model. Also refer to **Annexure 9.1**.

- Specific requirements for lidar survey Photo Ground Control Premarks

In order for the Premark to be clearly seen on the photograph and to be able to adhere to all the specific observational requirements for lidar surveys, the Premark must adhere to the following requirements:

- The Premark must be in the form of a circle, 600mm in diameter. Also refer to **Annexure 9.2**;
- The Premark must be on a flat surface and where the surveyed peg is placed in the centre;
- The ground surface must be smooth and preferably constructed with a concrete surround to the peg;
- Stones or gravel shall not be used to build a Premark;
- A Premark must be painted with durable white paint; and
- Permanent Survey Control can be premarked as per **Annexure 9.1** as if for 1:6000 scale photography.

viii) Levels of Accuracy

Horizontal and vertical Photo Control Points shall be sufficiently accurate so as to produce data that meets the requirements as set out in paragraph 3.2.4 “Photogrammetric and Orthophoto detail contour and DTM surveys”.

ix) Flight Plan and Photo Control Positions

The Surveyor must submit a copy of the Flight Plan in hard and digital format and on which the Photo Ground Control Points used are clearly shown i.e. reflecting its number and position.

5.6 Verification of existing Permanent Survey Control

The purpose of this survey is to verify the accuracy and quality status of existing Permanent Survey Control prior to be used for any other survey or to base another survey on.

5.6.1 General

- a) Obtain a co-ordinate list of the existing Permanent Survey Control to be verified from the Client.
- b) Locate the beacons in the field and compile a status report on the quality and functionality of the beacon and submit same to the Client (refer to **Annexure 14** for the format of a status report.)

- c) Such a verification survey must be carried out on all beacons located within the limits of a new survey or as otherwise instructed by the Client.

5.6.2 Survey observations

This survey may be undertaken by making use of GPS observations in order to verify the inter-relational co-ordinate accuracy and their relation to the Trigonometric beacons in the area. A single vector onto each point will be permissible.

The heights must be verified by 'one way spirit-levelling' in order to be able to compare the height differences and final heights in relation to the given heights and the check levelled heights.

If discrepancies are discovered in position and/or height then a second vector measured from an independent point must be observed for the co-ordinate verification and a second level run must be undertaken with reference to the control points in doubt.

The Surveyor must also record the GPS determined heights. The latest geoidal model must be used to derive orthometric elevations. These corrected heights must then also be compared with the heights as provided by the Client.

5.6.3 Reporting

- a) A comparison/verification and status report must be timeously submitted to the Client for further instructions. The Surveyor must make recommendations to the Client as to the necessary remedial actions that must be taken.
- b) Thereafter the Client will issue instruction as to the final acceptance of the co-ordinates for the new survey work.
- c) All reports must be submitted with the final data submission on completion of the survey; and
- d) Refer to **Annexure 14** for the format of a comparison and verification reports.

5.6.4 Further actions to be taken

In the event that control beacons require either the Y, X and Z values to be re-determined and/or where the existing Y, X and Z values may be adopted then such action and instruction must be confirmed in writing by the Client.

5.7 Ground control for Lidar surveys

5.7.1 The dependency on ground control is far less for photogrammetric surveys and accordingly the requirements are significantly less and as follows:

- a) In a typical corridor (e.g. road, pipe route, etc.) a minimum of one ground control point per kilometer must be established;
- b) In a typical area of interest (e.g. Greenfields) one ground control point per square kilometer will be sufficient; and
- c) There must be a minimum of five ground control points established per project and where such points are well spaced, e.g. survey area corners, the start and end of a corridor, etc.

5.7.2 Ground control may be established by pre- or post-marking as specified in paragraph 5.5.1(a) "General requirements for the establishment of Photo Ground Control (PC) points".

5.7.3 Different types of ground control required for Lidar surveys:

- a) Horizontal ground control which is in reference only to Y and X co-ordinates and vertical ground control which is in reference only to height (Z) control.

5.7.4 The identification and placement of vertical ground control point must comply with the following requirements:

- a) Where a theoretical circle of radius 300mm in diameter around the identified ground control point where such point (peg) is at even level with the surrounding ground, then the relative height difference between any two lidar points within the circle shall not exceed 10mm;
- b) The surface area must be free of any vegetation and must be situated on a hard surface such as concrete or a road surface;
- c) The surface area within the above named theoretical circle must be of a homogeneous colour and must display good reflective capabilities; and
- d) In fact such a point could be chosen in the centre of a road marking line or the like.

5.7.5 It be noted that, where the height of such a point, which is determined by laser methods, exceeds the height of the control point by more than 30mm, then such point may not be adopted as ground control.

5.7.6 The identification and placement of horizontal ground control must comply with the following requirements:

- a) The exact position, where a point is to be established in Y and X, must be clearly identifiable;

- b) The position must be in contrast to its surroundings so as to ensure that the variations in the reflection can be identified by the laser;
- c) An ideal point would be the corner of a painted line (white) on a (black) road surface or the like; and
- d) Where the co-ordinate of the ground control point, measured using the laser method, differs by more than half of a pixel in size from that of the surveyed value, then such point may not be used on a ground control point.

5.7.7 It be noted that ground control points, which comply with both of the above named criteria, may then be utilized as individual ground control points provided that the co-ordinates (Y, X and Z) have been determined in accordance with the required specifications.

5.7.8 The establishment of permanent survey control as per paragraph 5.1 “General requirements for Permanent Survey Control and Photo Control Points” and all related paragraphs shall also be applicable to all lidar type surveys.

5.7.9 The existing or newly established permanent survey control shall be used as follows:

- a) As the basic network from which all photo ground control is fixed from;
- b) For the determination of the local geoid for the project and its subsequent use in all measurement taken on the project; and
- c) As a test point so as to determine the lidar survey accuracy after all surveys have been completed.

5.7.10 Where the permanent survey control is located such that it does not adequately serve as a suitable “test point”, as described above, then an additional point must be established in the immediate vicinity of the relevant permanent survey control point such that such additional point fully satisfies the criteria of a suitable test point,