Survey of Stob na Boine Druim-fhinn

06 May 2016

The Team:
Surveyors – John Barnard and Graham Jackson of G&J Surveys.

1) Introduction

G&J Surveys has agreed a project with the Scottish Mountaineering Trust (SMT) to measure accurate heights for several Scottish mountains. The aim of the project is the resolution of anomalies that currently exist in several lists of the hills that are of interest to both the Scottish Mountaineering Club (SMC) and the wider hillwalking community. One such list is the Grahams, hills in Scotland of height between 2000 feet and 2500 feet but with 150 metres or more of drop. This list was published by Fiona Graham in the November 1992 issue of The Great Outdoors, the same year as the publication of The Relative Hills of Britain by Alan Dawson. Fiona Graham's list was not identical to the subset of Marilyns termed the Elsies in The Relative Hills of Britain, but the two authors met and decided to unify the lists. The unified list was to be called The Grahams, but the data used would be taken from Alan Dawson's book. Upon Fiona Graham's death Alan became the sole list author.

Alan Dawson has remeasured a number of hills within the original Graham's list using a Leica RX1250 GPS receiver. One of his conclusions is that Stob na Boine Druim-fhinn has only 149.5m of drop and therefore does not qualify as a Graham. However, this survey has been carried out in a way that the Ordnance Survey is currently not prepared to accept. The OS is the national authority responsible for the maintenance of Britain's geographical features and both the SMT and SMC feel it is in the interest of the hillwalking community that the heights of hills are officially verified by Ordnance Survey for inclusion on their mapping for the benefit of all.

The aim of this survey is to resolve this situation and obtain accurate heights for the summit and bealach for Stob na Boine Druim-fhinn using a survey grade Leica Viva GS 15 Professional GNSS (Global Navigation Satellite System) receiver and submit the data sets collected to Ordnance Survey for verification. This will then lead to the heights being included on Ordnance Survey mapping and enable the SMC and others to provide the officially recognised heights in their future publications.

2) Equipment used and Conditions for Survey

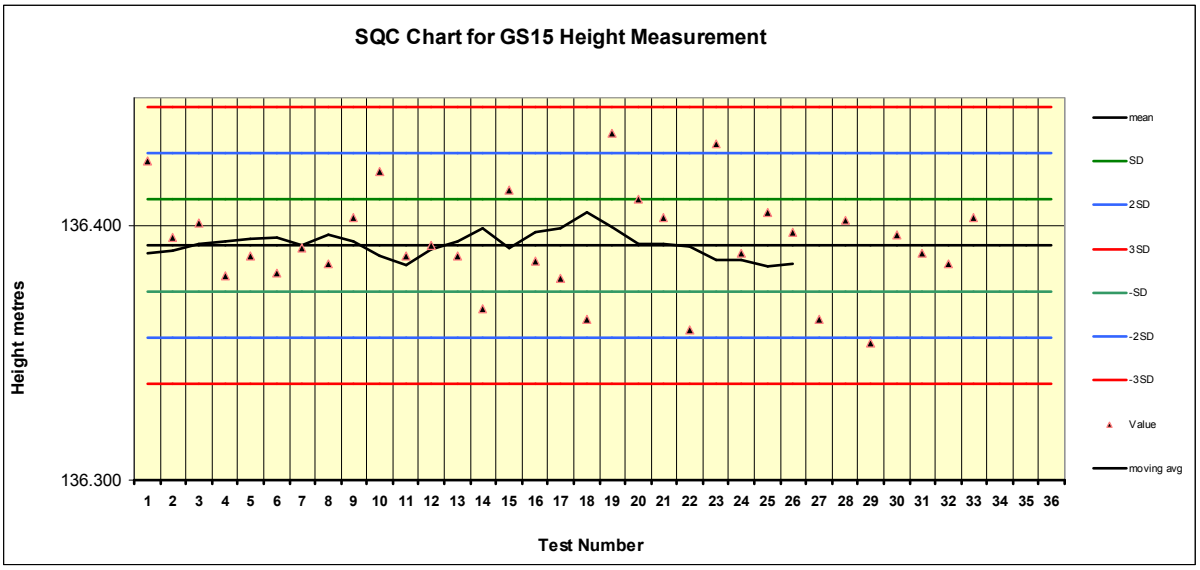
The summit and bealach positions were identified using a Leica NA730 Professional Automatic level (X30 telescopic system)/tripod system and a "1m" **E**-staff extendable to 5m as required by Ordnance Survey.

Absolute heights were measured using a Leica Geosystems Viva GS15 Professional receiver. This instrument is dual-frequency and multi-channel, which means it is capable of locking on to a maximum of 12 GPS and 8 GLONASS satellites as availability dictates, and receives two signals (at different frequencies) from each of these satellites. The latter feature reduces inaccuracies that result from atmospheric degradation of the satellite signals. As a stand-alone instrument it is capable of giving position and height to an accuracy of about two metres and five metres respectively. Despite the on-board features of the Viva GS15 receiver, there are still sources that create residual errors. To obtain accurate positions (+/- 0.01m) and heights (+/-0.05m), corrections were made to the GNSS (Global Navigation Satellite System) data via imported RINEX data from

Ordnance Survey and this dataset was post-processed using Leica Geo Office 8.3 software. Confirmation of heights was carried out by Mark Greaves, Geodetic Analyst of Ordnance Survey.

Note that small hand-held GPS receivers used for general navigation can only receive up to 12 GPS satellites and each at a single frequency and therefore these instruments have a poorer positional accuracy of +/-5metres and a height accuracy of no better than +/-10 metres. Some recently produced hand held GPS Garmin receivers can also receive signals from GLONASS satellites which greatly improve the speed at which these units can achieve a satellite "fix".

The Leica NA730 level is routinely checked to make sure that the line of sight is correct when the instrument is set up horizontally; there is a standard surveying method to do this described in the users' manual for these instruments. We also regularly check the functioning of the Leica Viva GS15 GNSS receiver against Statistical Quality Control (SQC) charts generated for a marked position. The chart associated with height measurement is shown below. The mean height above ODN (Ordnance Datum Newlyn) for a fixed point (measured on 20 different occasions for 30mins of data collection at each time) was calculated to be 136.392m. Further height measurements have been made on separate occasions over a period of 18 months using the same process parameters. The penultimate and last measurements were carried out before and after the surveys described in this report. The results shown on the graph are all within a range of +/- three SD (Standard Deviation), in this case one SD is +/-0.018m and the moving average is within 1SD. This demonstrates that our Leica Viva GS15 GNSS receiver is giving consistently precise results within the expected errors for the measurements (all points are within a range of 0.07m of one another).



In addition, we check the instrument periodically by taking measurements on an Ordnance Survey Fundamental Bench Mark, processing the data and comparing it with the OS derived values. Height should agree within about 0.02-0.03m.

Checks were carried out on 24 April 2016 and 17 May 2016 at the Daresbury Fundamental Bench Mark and the results in the table below show excellent agreement between the Ordnance Survey measurement and our own.

Processing	Date	Height(m)
OS measurement		73.24
JB/GVJ GeoOffice 8.3	24-04-2016	73.23
JB/GVJ GeoOffice 8.3	17-05-2016	73.22

Conditions for the survey of Stob na Boine Druim-fhinn which took place between 10.00hrs and 16.30hrs GMT on 06 May 2016 were excellent. The temperature was about 15 degrees Celsius. No wind was recorded on the bealach but later in the afternoon the wind speed at the summit was about 15mph. Visibility all day was excellent and there were no problems carrying out any of the optical observations.

3) Character of the Hill

Stob na Boine Druim-fhinn (Hill Number 1428, Hill Section 19C, OS 1:50000 Map 56, OS 1:25000 Maps OL37N 363N, Grid Ref NN168025) lies about 3km West of Lochgoilhead and is part of the five Grahams and two Corbetts that surround that village at the northern end of the Cowal peninsular. It can easily be climbed on its own from Lochgoilhead or be combined in a round to take in Beinn Tharsuinn and Beinn Lochainn. Parking is available on a dirt layby on the banks of Loch Goil. Having followed the road up past the Drimsynie Estate Office, the track goes through a gate and ascends the firebreak, the trees to the right have now been felled. Once out onto open hillside the rocky SE Ridge leads to the hill's summit. Alternatively a feint track contours around the Eastern side of the hill and leads to the critical bealach about 500m South of the summit. From there the ascent to the summit can easily be made over grass and rocky outcrops.

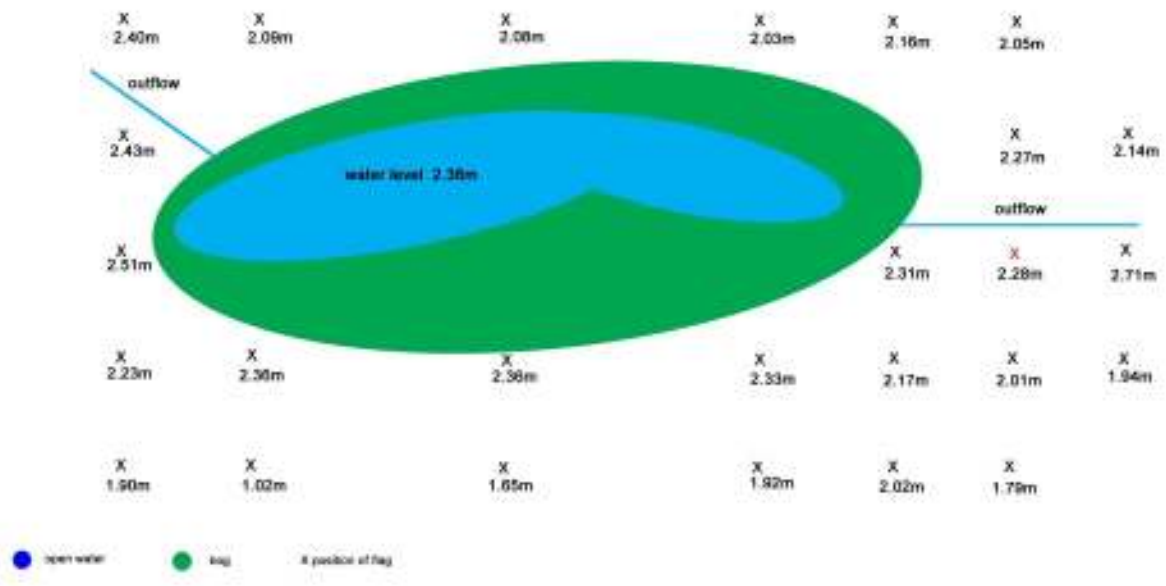
An extract from the OS 1:25000 map is shown below.

The summit area of the hill comprises three knolls, one of which is crowned with a trig point (map height 658m). The critical bealach, 500m South of the summit is marked with a small lochan. At the time of visit to this hill this lochan was perhaps better described as "a peaty bog" and was not as extensive as suggested on the map.

4) Survey of the Bealach of Stob na Boine Druim-fhinn

The first task for the survey was to try to identify the position of the bealach using the Leica NA730 automatic level and staff which was set up at a convenient position on higher ground to the North side of the bealach. A matrix of flags was laid out at 5m intervals in the "hill to hill" and "valley to valley" directions. However, because the area around the "lochan" was very flat, the two rows there in the hill to hill direction were placed 10m apart (interpolation could be carried out later if deemed necessary from the staff measurements). A schematic diagram of the bealach, with lines of flag positions orientated SSE to top of page in the "hill to hill" direction with staff measurements is shown below. Note that the higher the staff reading for any flag, then the lower the ground. The red cross represents the position measured by Alan Dawson within the limitation of our hand-held GPS receivers which have a positional accuracy of only +/-5m.

Schematic Diagram of Col Showing Grid of Flags and Staff Readings



Photographs of the area of the bealach taken from approximately each of the four main compass points are shown in Appendix 1. All measurements in the boggy area yielded a staff reading of 2.36m the same as that of the water's surface showing how flat the bealach area was. An important feature of the bealach is that there are two outflows from the "lochan" shown to the left and right in the diagram. Therefore, the bealach position lies at one or both of the outflow positions. Staff readings taken around the edge of the "lochan" were very consistent and showed this whole area to be quite flat as readings only varied by about 0.05m. Given the extremely boggy nature of the ground it was not possible to collect GNSS data at either outflow position. Instead the Leica Viva

GS15 receiver was set up at a convenient position where the staff reading was 2.36m, but the ground was sufficiently solid to support the weight of the tripod and receiver and the operators!! Given the ground conditions, the best that could be achieved in determining the grid references of the outflows was to estimate these from the ten-figure grid references measured with our Garmin hand-held receivers for the four corner flags of the matrix. These yield values of NN 1697 0208 for that on the left of the diagram and NN 1695 0209 for that on the right of the diagram, but note that these are estimates and not actual readings.

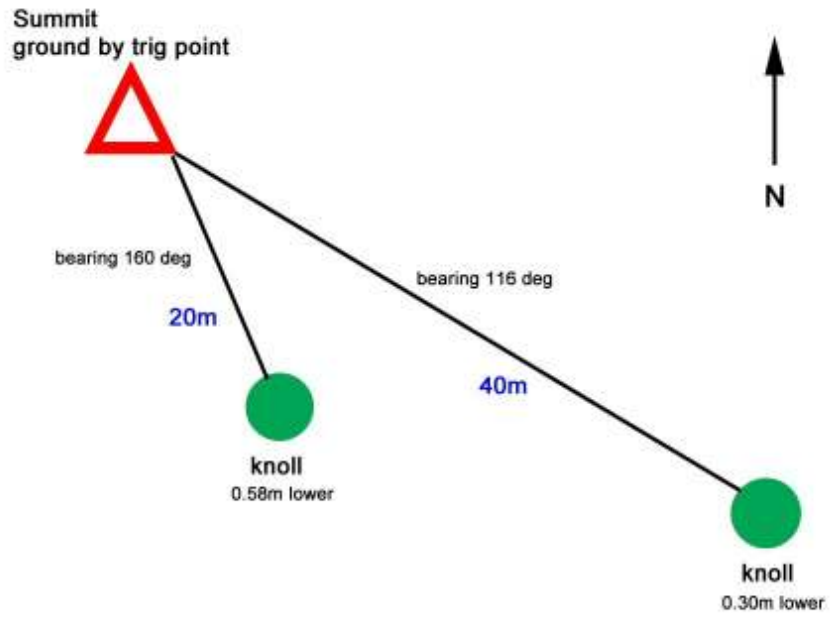
The height difference between the bealach position determined by Alan Dawson's survey and that determined in this report is 0.08m with the former position being the higher.

The Leica Viva GS15 was set up over the above chosen position using the short tripod configuration (see photo in Appendix 1). The height of the receiver above the ground was then measured with the integral tape. The vertical offset from measuring point to the ground was 0.604m (see photograph in Appendix 1) plus 0.255m for the tribrach/hook system. GNSS data were collected for 2hr with an epoch time of 15 seconds.

5) Survey of the Summit of Stob na Boine Druim-fhinn

Upon arrival at the summit a visual inspection of the terrain showed there to be three knolls, one of which bore a trig point, all vying for summit position. While the knoll nearer the trig point appeared to be lower, the further one appeared to be about the same height to the unaided eye. A schematic diagram of the summit area is shown below (North to top). Also a photograph of this area with the Leica GS15 set up over the summit position is shown in Appendix 2.

Schematic diagram of summit area



The Leica NA730 level was set up on a tripod at a convenient position and staff measurements were taken at possible summit candidates. The highest point was found to be ground adjacent to the trig point. The rocky knoll about 20m SSE of the trig point was measured to be 0.58m lower. The other main candidate about 40m ESE was measured to be 0.30m lower. Staff readings were also taken from the summit point and the Flush Bracket on the trig point.

Staff reading at summit = 0.575m

Staff reading at Flush Bracket = 0.403m

Thus, the use of the level not only enabled us to determine the summit position, it also enabled us to determine accurately the height differences between the different features there.

Next the tripod was set-up over the summit position and the Leica Viva GS15 was then fixed to it with a clamp and tribrach (the "short tripod" configuration). The height of the receiver above the ground was then measured with the integral tape. The vertical offset from measuring point to the ground was 0.556m (see photograph in Appendix 2) plus 0.255m for the tribrach/hook system. GNSS data were collected for 2hr with an epoch time of 15 seconds.

5.1) Results for Stob na Boine Druim-fhinn

The data for the Leica Viva GS15 were processed using Leica GeoOffice 8.3 using the seven nearest base stations: (Lochgilphead – LOCG 35km, Oban – OBAN 42km, Killin – KILN 51km, Glasgow - GLAS 55km, Campbletown – CAML 93km, Drumlabin – DRUM 98km and Arisaig – ARIS 98km). We used Broadcast Ephemeris data received by the GPS during the survey rather than Precise Ephemeris data, since we have found this makes little difference to the height results. The computed Tropospheric model was chosen for the calculations to suit the data collection times and the wide difference in height between the base stations and the summit of the mountain.

As far as is possible, the base stations are evenly distributed around the survey points and heights measured from each base station were within +/-0.05m of the mean results for both summit and bealach.

The results for Stob na Boine Druim-fhinn are tabulated below:

Hill	Feature	Easting	Northing	Height(m)
Summit	None	216878.834	702536.313	658.365
Bealach	None	216964.188	702099.005	508.778

The data for the trig point on Stob na Boine Druim-fhinn recorded by hand-held Garmin GNSS receivers were:-

Garmin Oregon 450	NN 16884 02530	Accuracy: averaged	Height = 667m
Garmin Montana 600	NN 16885 02531	Accuracy: averaged	Height = 663m
Garmin Etrex 20	NN 16885 02529	Accuracy: averaged	Height = 662m

The data for the second highest point 40m ESE from the trig point recorded by hand-held Garmin GNSS receivers were:-

Garmin Oregon 450	NN 16915 02510	Accuracy: averaged	Height = 666m

Garmin Montana 600	NN 16916 02509	Accuracy: averaged	Height = 661m
Garmin Etrex 20	NN 16915 02510	Accuracy: averaged	Height = 662m

The data for the third highest point 20m SE of the trig point recorded by hand-held Garmin GNSS receivers were:-

Garmin Oregon 450	NN 16890 02509	Accuracy: averaged	Height = 666m
Garmin Montana 600	NN 16888 02508	Accuracy: averaged	Height = 660m
Garmin Etrex 20	NN 16890 02510	Accuracy; averaged	Height = 659m

The heights of summit and bealach for Stob na Boine Druim-fhinn are 658.37m and 508.78m respectively.

6) Summary of Operating Conditions

Variable	GS15 on Bealach	GS15 on Summit
Data collection summit (min)	124	121
Number of Base Stations used in Processing for all points	7	7
Epoch Time (sec)	15	15
Tropospheric Model	Computed	Computed
Cut off Angle (degs)	15	15

7) Discussion of Results

Since the position of the summit was clearly defined, we would estimate a height uncertainty associated with its correct location of +/-0.02m. The height uncertainty associated with a 2hr dataset has been measured by us and is +/-0.05m for data processed in propriety software. The measurement uncertainty for the height of the summit is therefore $(0.02^2 + 0.05^2)^{0.5} = 0.05$m.

The biggest measurement uncertainty lies with the determination of the bealach height. On the day a large number of staff readings all gave the same value to better than 0.05m in and around the bog as well as the water's surface. The measurement uncertainty for the height of the bealach is therefore $(0.05^2 + 0.05^2)^{0.5} = 0.07$m. The height of the bealach determined by Alan Dawson is 508.86m which is 8cm higher than the GNSS value in this report (508.78m); this difference is in exact agreement with the staff measurement (8cm) described earlier.

Under very dry conditions the ground at the bealach would sink as water was lost, thereby reducing the height of the bealach and increasing the drop. Nevertheless, in our view the measured value of the col height given in this report is unlikely to decrease by more than 0.3m as a result of desiccation, although this can only be a rough estimate. The drop for Stob na Boine Druim-fhinn was measured to be 658.37 – 508.78 = 149.6 +/- 0.07m. Should desiccation at the bealach under drought conditions lead to our estimated shrinkage of the ground, this would only yield a drop value of 149.9m, still below the criterion height of 150m required for Graham status to be achieved. As stated in the Introduction to this report, Alan Dawson had already surveyed Stob na Boine Druim-fhinn using his Leica RX 1250 GPS receiver and measured the drop to be 149.5m.

The Ordnance Survey Database gives the height of the Flush Bracket on the trig point to be 658.368m. However, in the OS Database the same values for coordinates are quoted for both the old trig pillar and the new pillar. Using level and staff we measured the height of the Flush Bracket to be 0.575 – 0.403 = 0.172m HIGHER than the hill's summit. Therefore our measurement for the height of the Flush Bracket is 658.365 + 0.172 = 658.536m. The difference between the two measurements is 0.17m and is larger than the few centimetres that are normally obtained. We note that the OS quoted flush bracket height coincides with our summit height.

8) Coordinate Recovery Analysis

In order to verify the accuracy and consistency of a GNSS dataset, Ordnance Survey recommends a procedure called Coordinate Recovery Analysis. Instead of processing the data with reference to all the nearest OS Base Stations under approximately 100km distance, as used in this report, the data is first processed with reference to only the nearest Base Station. The data is then reprocessed with the survey point taken as a Reference Point and all the remaining Base stations taken as survey points. These measured values for the OS Base Stations can then be compared directly with the actual OS values for Position and Height. (This has been carried out via an Excel Spreadsheet supplied to us by OS).

Although the spreadsheet calculates a number of different parameters, two important ones are presented in the tables below. "Height Difference **U** metres**"** is the vertical height difference between the height of the Base Station as measured in this survey compared with the actual OS value. "Separation $\mathbf{D_{ij}}$ metres" is the distance in 3-d space between the measured and actual OS values for each Base Station.

The results for the two surveys are presented below.

Stob na Boine Druim-fhinn bealach:-

Base Station	Code	Distance to Survey Point km.	Height Difference **U** metres	Separation $\mathbf{D_{ij}}$ metres
Lochgilphead	LOCG	35		
Oban	OBAN	42	0.014	0.020
Killin	KILN	51	-0.002	0.014
Glasgow	GLAS	55	-0.014	0.019
Campbletown	CAML	93	0.033	0.041
Drumalbin	DRUM	98	0.003	0.026
Arisaig	ARIS	98	-0.024	0.027
Girvan	GIRA	104	-0.045	0.054
Edinburgh	EDIN	108	0.040	0.043
Fort Augustus	FAUG	108	-0.022	0.024

Stob na Boine Druim-fhinn summit:-

Base Station	Code	Distance to Survey Point km.	Height Difference **U** metres	Separation $\mathbf{D_{ij}}$ metres
Lochgilphead	LOCG	35		
Oban	OBAN	42	-0.002	0.015
Killin	KILN	51	0.001	0.017
Glasgow	GLAS	55	0.014	0.024
Campbletown	CAML	93	0.056	0.056
Drumalbin	DRUM	98	-0.014	0.030
Arisaig	ARIS	98	-0.012	0.017
Girvan	GIRA	104	-0.182	0.239
Edinburgh	EDIN	108	0.022	0.034
Fort Augustus	FAUG	108	-0.026	0.026

Apart from the Coordinate recovery for Girvan (GIRA) for the dataset measured from the summit of Stob na Boine Druim-fhinn (0.239m), all the rest of the datasets have recovered to 0.06m or better in terms of distance and height of the OS actual values. In order to try to resolve whether the anomaly for GIRA was within the network, the Coordinate recovery analysis was repeated using Lochgilphead as the survey point and Oban as the nearest Base station. If the recovery for GIRA is still unacceptably high then the "fault" would lie within the OS network.

Stob na Boine Druim-fhinn summit network check:-

Base Station	Code	Distance to Survey Point km.	Height Difference **U** metres	Separation $\mathbf{D_{ij}}$ metres
Lochgilphead	LOCG	35		
Oban	OBAN	42		
Killin	KILN	51	-0.003	0.030
Glasgow	GLAS	55	0.009	0.033
Campbletown	CAML	93	0.048	0.051
Drumalbin	DRUM	98	-0.007	0.038
Arisaig	ARIS	98	-0.004	0.017
Girvan	GIRA	104	-0.010	0.037
Edinburgh	EDIN	108	0.028	0.049
Fort Augustus	FAUG	108	0.025	0.072

The results for GIRA in fact show an acceptable recovery of 0.037m for distance and height and therefore the anomaly does not appear to lie within the OS Network. For some unexplained reason, Leica GeoOffice V8.3 will not effectively model the atmospheric conditions between the survey point on the summit of Stob na Boine Druim-fhinn and the GIRA Base station.

Two points should be noted:

Firstly, raw data are processed with base stations up to 100km from the survey point. Beyond this distance the models used to determine atmospheric corrections begin to break down because the atmosphere (in terms of pressure, temperature and composition) is less likely to be uniform over distances greater than this. (Of course 100km is somewhat arbitrary but has become generally accepted through surveying working practice). However, Coordinate Recovery uses distances greater than 100km to help probe the robustness of a GNSS dataset. The base stations GIRA, EDIN and FAUG were NOT used in the calculation of the heights of the summit and bealach.

Secondly, even a 2hr GNSS dataset can produce anomalies, although only one base station, GIRA, was involved in this case. Nevertheless, it emphasises the importance of long collection times for maximising accuracy and consistency for position and height determinations.

9) Ordnance Survey Verification

The results for this survey were submitted for validation to Mark Greaves at Ordnance Survey. The height for Stob na Boine Druim-fhinn was accepted and there is no change to the map height. Mark has also accepted the result for the bealach and has asked Ordnance Survey Cartography that a spot height of 509m be placed for the bealach on the 1:50000 and 1:25000 scale maps.

10) Summary of Heighting Results

Stob na Boine Druim-fhinn was measured to be **658.4+/-0.05m** and the summit is unfeatured ground next to the trig point at NN 16885 02581*.

The bealach was measured to be **508.8 +/-0.1m.**

The drop was measured to be **149.6 +/-0.1m** and therefore **Stob na Boine Druim-fhinn does not have the required 150m of drop for it to qualify as a Graham.**

The results have been accepted by Ordnance Survey and forwarded to OS Cartography for relevant map changes.

*grid references for use with Garmin hand-held receivers

11) Acknowledgements

Many people contributed to the success of this survey.

We would especially like to thank the Scottish Mountaineering Trust for generously supporting the work and Rab Anderson and Andy Nisbet of the Scottish Mountaineering Club for their guidance and encouragement.

We also wish to thank Mark Greaves of the Ordnance Survey, who accepted the data and forwarded the results to OS Cartography for map changes. We also thank Mark for his support and advice that has helped us carry out our mountain heighting work over the past seven years.

John Barnard and Graham Jackson, 20 June 2016

Appendix 1 – Stob na Boine Druin-fhinn Bealach

Bealach looking East showing outflow on West side

Bealach looking North

Bealach looking West

Leica GS15 collecting data at a convenient position on bealach area, photo looking South

Measuring the Offset, 0.604m, for the GS15 on the bealach

Appendix 2 – Stob na Boine Druim-fhinn Summit

Leica GS15 Collecting data on the Summit

Measuring the offset, 0.556m, for the Leica Viva GS15 on the summit