

# Surveys of Corwharn and Ladylea Hill

18/19 March 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, mountains 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 Elsie's 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 two hills, Corwharn and Ladylea Hill, are both below 2000 feet and therefore no longer qualify for the list of Grahams. However, this 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. These hills are given in the latest SMC Hillwalkers' Guide "The Grahams & The Donalds" but with a note against each that the surveys show that these hills are below 2000 feet in height. However, the SMC require that, the heights of hills have to be verified by Ordnance Survey to be accepted for their Guide Books and in these cases this verification has not been obtained.

The aim of these surveys is to resolve this situation and obtain accurate heights for the summits of Corwharn and Ladylea Hill 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 them 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 positions were identified using a Leica NA730 Professional Automatic level (X30 telescopic system)/tripod system and a "1m" E-staff extendable to 5m.

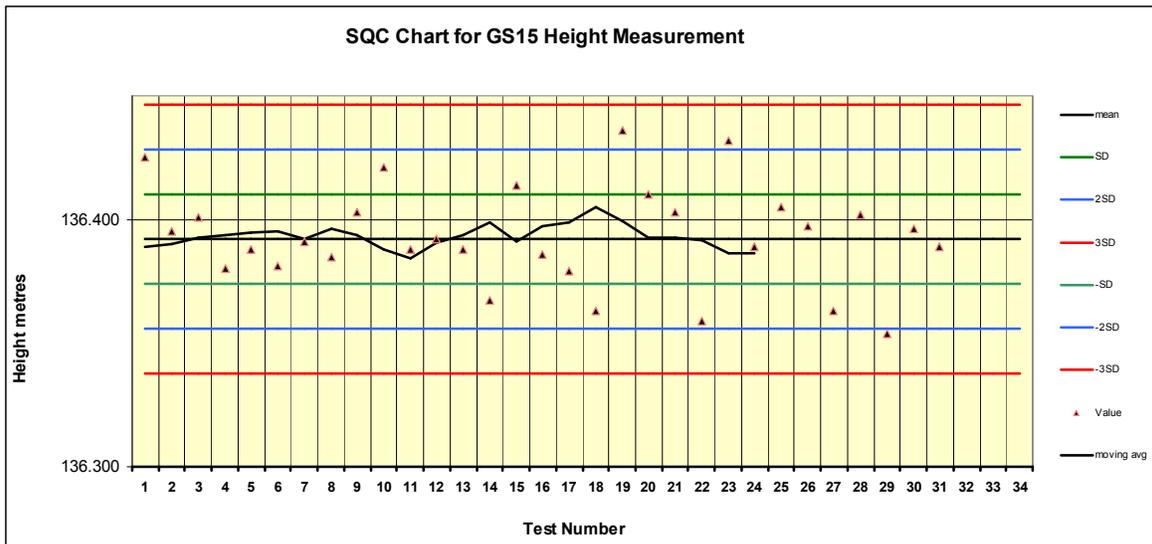
Absolute heights were measured using a Leica Geosystems Viva GS15 Professional receiver. This instrument is dual-frequency and multi-channel, which means it is capable of locking on to a maximum of 12 GPS and 8 GLONASS satellites as availability dictates, and receives two signals (at different frequencies) 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 ( $\pm 0.01\text{m}$ ) and heights ( $\pm 0.05\text{m}$ ), 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  $\pm 5\text{metres}$  and a height accuracy of no better than  $\pm 10\text{ metres}$ . 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 last and penultimate measurements were carried out within two days after and before the mountain surveys described in this report. The results shown on the graph are all within a range of  $\pm$  three SD (Standard Deviation), in this case one SD is  $\pm 0.018\text{m}$  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 12 November 2015 and 29 March 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	12-11-2015	73.22
JB/GVJ GeoOffice 8.3	29-03-2016	73.23

Conditions for the survey of Corwharn, which took place between 11.30hr and 14.45hr GMT on 18 March, were poor. The temperature was about 5 degrees Celsius on the summit with no wind. At the start of the survey, visibility was significantly reduced due to low cloud and mist. This limited the amount of surveying that could be carried out with level and staff since it was not possible to take staff readings beyond 20-30m distance. Towards the end of the survey, the mist cleared and any remaining survey work with level and staff was carried out.

Conditions for the survey of Ladylea Hill, which took place between 11.30hr and 14.30hr GMT on 19 March were also poor. The temperature was lower, between 1 and 3 degrees Celsius with a constant wind of about 15mph which contributed significantly to wind chill. However, there were times when visibility improved significantly so that all necessary work with level and staff could be carried out prior to data collection.

### 3) **Character of the Hills**

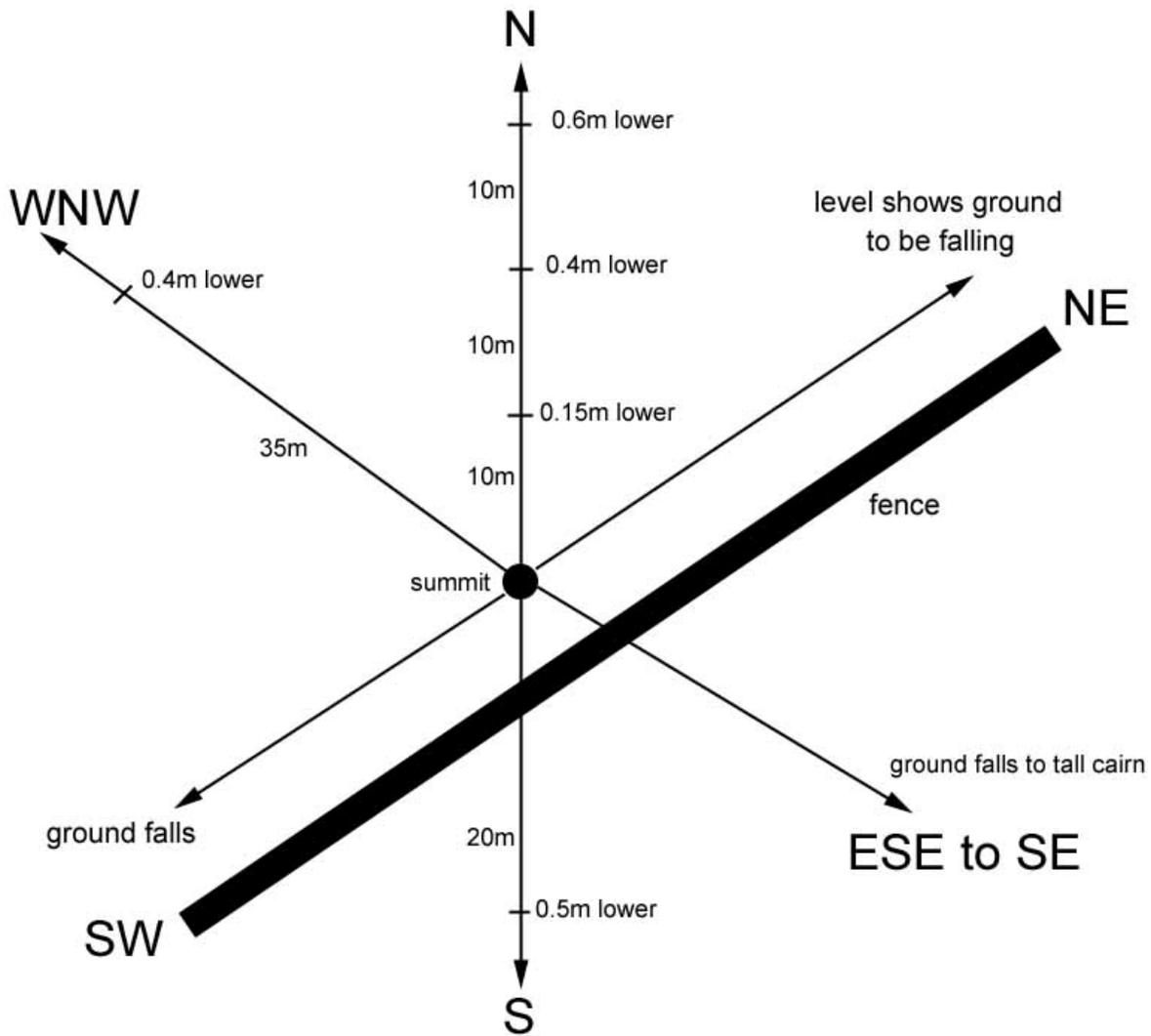
Corwharn (Hill Number 503, Hill Section 7A, OS 1:50000 Map 44, OS 1:25000 Maps OL53S 388S, Grid Ref NO288651) lies at the western side of Glen Prosen and is about 3km south of the end of the minor road which terminates at Glenprosen Lodge. The easiest approach to Corwharn is from Glen Prosen via the track that starts next to Cormuir. Parking is rather limited here, but there is a small space a few hundred metres down Glen Prosen on the north side of the road. The track leads easily beneath Hill of Strone up to a bealach between Corwharn and its neighbour Eskielawn. From here a fence is then easily followed up the NW ridge of the hill, finally taking a second fence SW for 300m to reach the summit. The summit area is covered with thick tussock grass and is quite flat. There is a tall cairn incorrectly identified as the summit position in the SMC Guide Book since it is a few metres lower than the true summit. The summit is an area of unfeatured ground on the NW side of the fence and about 3m from it. The views from Corwharn are extensive and this hill gives a feeling of remoteness. It was good to see significant numbers of lapwing and curlew whose calls removed the silence of these generally quiet and remote hills. Corwharn's near neighbour, Eskielawn is 4m lower as given on the OS 1:50k map. While unlikely to be higher we wished also to verify this during the survey.

Ladylea Hill (Hill Number 1497, Hill Section 21A, OS 1:50000 Map 37, OS 1:25000 Maps OL62W 420W, Grid Ref NJ343168) lies in Glen Buchat on the Candacraig Estate to the North of Strathdon. It is encircled by a minor road that starts at Bellabeg about 5km SSE of the hill. Access to the hill is not easy since most of its lower slopes are surrounded by forestry. The most straightforward approach is probably from the South near Torrancroy where the slopes are clear of conifer trees. However, a shorter approach, as used for this survey, is from the North West. Many of the forest tracks are not marked on older maps, but the latest 1:25000 maps clearly show the forest tracks starting from Corriemore. Beyond the forest there is an "unclimbable" deer fence surrounding

this part of the hill, so it is important to find the gate through it as recommended in the SMC Guide. The summit area of the hill is rounded and covered with short heather rather than tussock grass which makes going very easy. There is a cairn and a low mound either of which visually could mark the summit of the hill. As for Corwharn, Ladylea Hill is an excellent view point but the conifer plantations here reduce the abundance of bird life.

**4) Survey of Corwharn**

The first task for the survey was to identify the highest point using the Leica NA730 automatic level and staff. As stated earlier in this report, the mist and cloud on the summit of this hill restricted visibility through the optical level and at first it was not possible to make staff measurements beyond about 25m. However, we were able to systematically survey the area around the currently accepted position for the summit and we were able to identify the highest point in this area. A diagram for the summit area is shown below.



Although the forecast predicted that the weather would improve and the mist would lift, we could not afford the time to wait for this to happen. Therefore the tripod was set-up over the highest point we had identified 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 0.524m (see photograph in Appendix) plus 0.255m for the tribrach/hook system. GNSS data were collected for 2hr with an epoch time of 15 seconds.

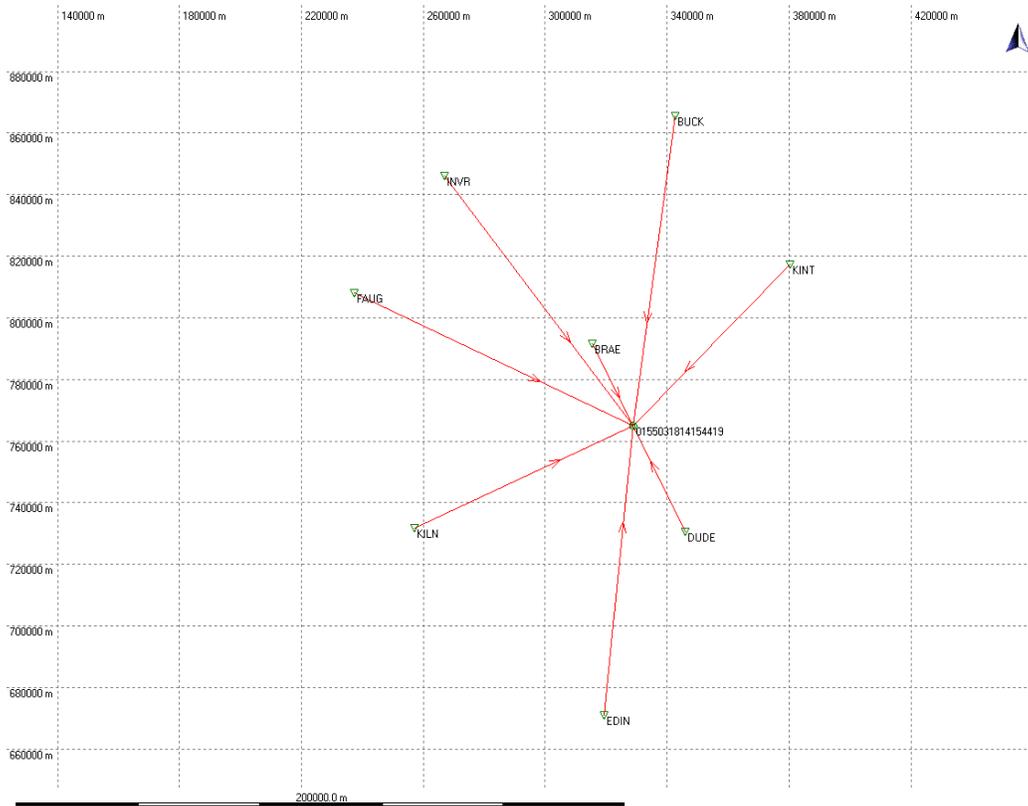
Towards the end of the period when we were collecting the GNSS data, the mist cleared and visibility improved. Therefore after we had collected 2hrs of GNSS data, we setup the level on the tripod in order to make absolutely sure that we had not overlooked any higher ground. Our observations confirmed this and that we had collected data directly on the summit of Corwharn (see photograph in the Appendix).

Regrettably, mist had still not cleared from Corwharn’s northerly neighbour Eskielawn at the conclusion of our work and we descended back to the beach. At this point however, the sky cleared completely giving way to late afternoon sunshine. Consequently, we climbed Eskielawn, set up the level on the summit by the cairn and then observed the summit area of Corwharn. Corwharn is clearly higher. Using the height of the fence posts (1.25m) we estimated that the height difference between the two hills was approximately 1.75m - 2m. This hill has been measured by Alan Dawson who found its height to be 607.2m.

#### **4.1) Results for Corwharn**

The data for the Leica Viva GS15 were processed using Leica GeoOffice 8.3 using the eight nearest base stations: (Braemar– BRAE 29km, Dundee – DUDE 39km, Kintore - KINT 74km, Killin – KILN 78km, Edinburgh– EDIN 95km, Fort Augustus- FAUG 100km, Inverness – INVR 101km and Buckie – BUCK 102km). 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.

The distances and directions of the base stations from Corwharn are shown in the scaled diagram below. As far as is possible, the base stations are evenly distributed around the survey point and heights measured from each base station were within +/-0.04m of the mean result for the summit of Corwharn.



The results for Corwharn are tabulated below:

Processing	Feature	Easting	Northing	Height(m)
Leica GeoOffice 8.3	No feature	328863.525	765102.832	609.053

The data for the summit of Corwharn recorded by hand-held Garmin GNSS receivers was:-

Garmin Oregon 450	NO 28866 65094	Accuracy: averaged	Height = 612m
Garmin Montana 600	NO 28865 65091	Accuracy: averaged	Height = 605m
Garmin Etrex 20	NO 28865 65094	Accuracy: averaged	Height = 614m

The data for the summit of Eskielawn recorded by hand-held Garmin GNSS receivers was:-

Garmin Oregon 450	NO 27352 66455	Accuracy: averaged	Height = 612m
Garmin Montana 600	NO 27354 66456	Accuracy: averaged	Height = 608m
Garmin Etrex 20	NO 27354 66457	Accuracy: averaged	Height = 606m

### 5) Survey of Ladylea Hill

The summit area of Ladylea Hill is quite flat with a cairn which maybe on the hill's summit, although as mentioned previously there is also a shallow mound 25m NNE which vies as the

summit feature. The Leica NA730 level was setup on a tripod a few metres NW of the cairn and staff readings were taken at 5m intervals in a North to South direction crossing the base of the cairn. The measurements showed that the cairn was at the highest point and the ground fell away to the North and the South of it. Staff readings were now repeated in a similar routine in the West to East direction through the base of the cairn and again the cairn was found to be at the highest point. To locate the summit of the hill, staff readings were then taken around the base of the cairn and the highest point was found to be on its East side. The base of what may be an old cairn (the low mound) about 25m ENE of the summit is 0.5m lower.

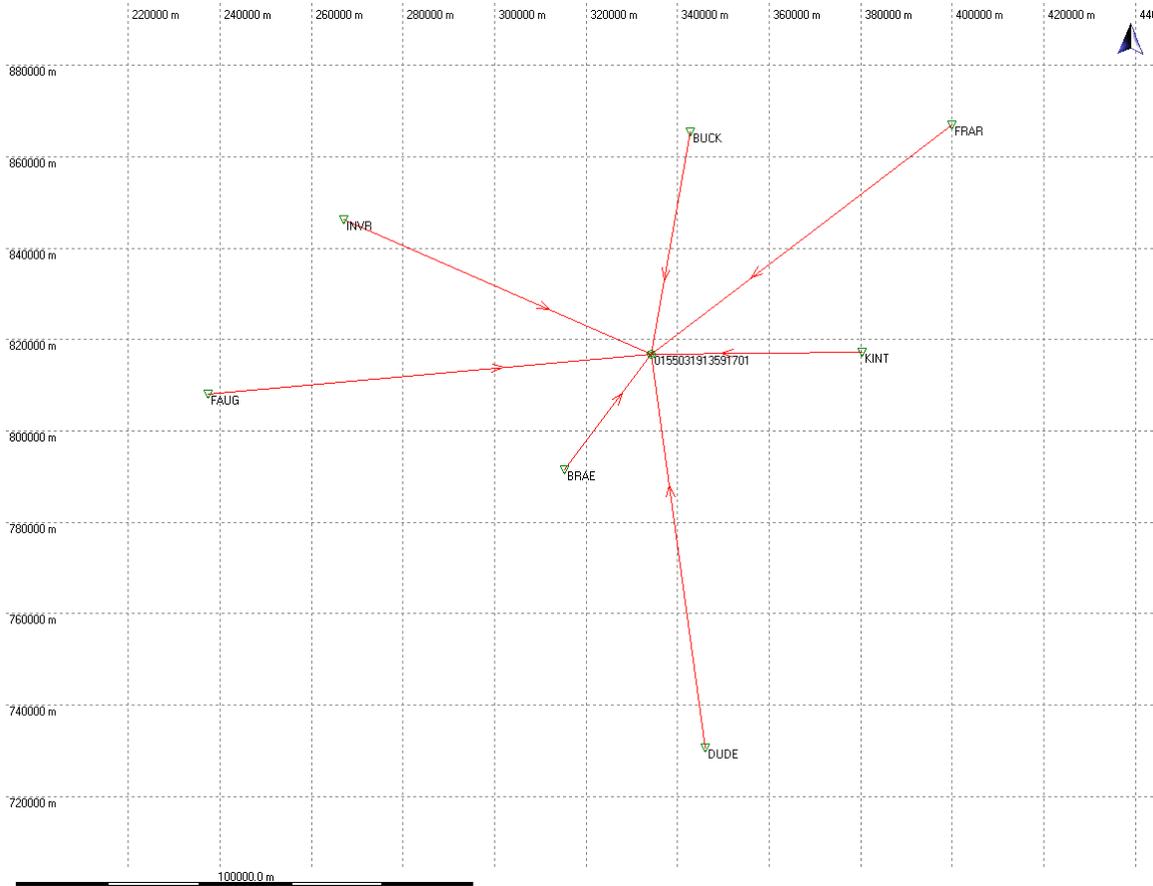
In addition the summit cairn was investigated to determine if higher ground could exist beneath it. The cairn is about 0.8m high and from the photograph in the Appendix it may be seen that the top half of it is made up of large stone blocks which cannot hide natural ground. The remainder comprises smaller stones. The circumference of the cairn was investigated and no evidence was found of rising ground at the base or as far into the structure as we could probe. Our conclusion was that if higher ground were concealed by the cairn, this could not be more than 0.1m higher than the summit position where the Leica Viva GS15 was to be set up.

Next the tripod was set-up over this 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 0.682m (see photograph in Appendix) plus 0.255m for the tribrach/hook system. GNSS data were collected for 2hr with an epoch time of 15 seconds. A photograph of the GS15 over the summit position is also shown in the Appendix.

### **5.1) Results for Ladylea Hill**

The data for the Leica Viva GS15 were processed using Leica GeoOffice 8.3 using the seven nearest base stations: (Braemar– BRAE 31km, Kintore – KINT 46km, Buckie - BUCK 50km, Inverness – INVR 73km, Fraserburgh– FRAR 83km, Dundee- DUDE 86km and Fort Augustus – FAUG 97km). 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.

The distances and directions of the base stations from Ladylea Hill are shown in the scaled diagram below. As far as is possible, the base stations are evenly distributed around the survey point and heights measured from each base station were within +/-0.04m of the mean result for summit of Ladylea Hill.



The results for Ladylea Hill are tabulated below:

Processing	Feature	Easting	Northing	Height(m)
Leica GeoOffice 8.3	Next to cairn	334302.499	816801.756	609.080

The data for the summit of Ladylea Hill recorded by hand-held Garmin GNSS receivers was:-

Garmin Oregon 450	NJ 34304 16792	Accuracy: averaged	Height = 615m
Garmin Montana 600	NJ 34304 16794	Accuracy: averaged	Height = 610m
Garmin Etrex 20	NJ 34305 16794	Accuracy: averaged	Height = 611m

The ten-figure grid reference for the shallow mound was:

Garmin Oregon 450	NJ 34314 16818	Accuracy: averaged	Height = 616m
Garmin Montana 600	NJ 34312 16819	Accuracy: averaged	Height = 608m
Garmin Etrex 20	NJ 34315 16821	Accuracy: averaged	Height = 612m

**6) Summary of Operating Conditions**

<b>Variable</b>	<b>GS15 on Corwharn</b>	<b>GS15 on Ladylea Hill</b>
Data collection summit (min)	123	123
Number of Base Stations used in Processing for all points	8	7
Epoch Time (sec)	15	15
Tropospheric Model	Computed	Computed
Cut off Angle (degs)	15	15

**7) Discussion of Results**

The summit positions of both tops were on unfeatured ground and consequently the height uncertainty associated with locating these positions was estimated to be no more than +/-0.02m. The height uncertainty associated with the GNSS measurement from a 2hr dataset has been measured by us and is +/-0.05m for data processed in propriety software. The measurement uncertainty for the heights of each summit is therefore:  $(0.05^2 + 0.02^2)^{0.5} = 0.05\text{m}$ .

Both Corwharn and Ladylea Hill were measured to be 609.1m which is below 2000 feet (609.6m). The only additional uncertainty in the measurement of the height of Ladylea Hill was that the cairn could conceal an embedded rock up to 0.1m higher beneath it. If this were the case the summit would still be 0.4m lower than 609.6m (2000ft). Moreover, it is worth recording that there were no other permanent rock features anywhere on the summit of Ladylea Hill. Therefore we are confident that both of these hills are less than 2000 feet.

As stated in the Introduction to this report, Alan Dawson had already surveyed these hills using his Leica RX 1250 GPS receiver. Although Alan did not use a level and staff to identify the highest points, the summit coordinates that he obtained are very close to those measured in these surveys (0.55m for Ladylea Hill and 0.08m for Corwharn). Also our measurements of 609.1m for the heights are in exact agreement with his results.

**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  $D_{ij}$  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.

**Corwharn:-**

Base Station	Code	Distance to Survey Point km.	Height Difference U metres	Separation D <sub>ij</sub> metres
Braemar	BRAE	29		
Dundee	DUDE	39	0.043	0.049
Kintore	KINT	74	0.013	0.017
Killin	KILN	78	-0.008	0.019
Edinburgh	EDIN	95	0.027	0.032
Fort Augustus	FAUG	100	-0.005	0.015
Inverness	INVR	100	0.012	0.014
Buckie	BUCK	102	-0.021	0.025

**Ladylea Hill:-**

Base Station	Code	Distance to Survey Point km.	Height Difference U metres	Separation D <sub>ij</sub> metres
Braemar	BRAE	31		
Kintore	KINT	46	0.000	0.009
Buckie	BUCK	50	-0.041	0.043
Inverness	INVR	73	-0.014	0.016
Fraserburgh	FRAR	83	0.071	0.076
Dundee	DUDE	86	0.030	0.035
Fort Augustus	FAUG	97	-0.015	0.017

The results for both Corwharn and Ladylea Hill show consistent datasets as all measured OS Base stations are within 0.08m distance and height of the OS actual values.

**9) Summary of Heighting Results**

**Corwharn** was measured to be **609.1 +/- 0.05m**, the summit is unfeatured ground at NO 28865 65093\*.

**Ladylea Hill** was measured to be **609.1 +/- 0.05m**, the summit also being an embedded rock at NJ 34304 16793\*.

**Both Corwharn and Ladylea Hill are below 2000 feet (609.6m) in height and therefore do not qualify for Alan Dawson's list of Grahams.**

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

### **10) Acknowledgements**

Many people contributed to the success of these two surveys.

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.

\*grid references for use with Garmin hand-held receivers

John Barnard and Graham Jackson, 10 April 2016

## Appendix



**Leica Viva GS 15 over the summit of Corwharn**



**Measuring the offset for the Leica Viva GS15 on the summit of Corwharn**



**View NE of undulating terrain shown by the level to be lower than the identified summit position of Corwharn**



**Leica Viva GS15 collecting data on the summit of Ladylea Hill**



**Measuring the offset for the Leica Viva GS15 on the summit of Ladylea Hill**



**Summit of Ladylea Hill with the shallow mound in the foreground**