

# Survey of Snowdon

5<sup>th</sup> June & 2<sup>nd</sup> September 2014

The Team:

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## 1) Introduction

Yr Wyddfa, or Snowdon as it is popularly known (Hill Number 1963, Grid reference SH609543, OS 1:50000 map 115 and OS 1:25000 map 17W) is the highest mountain in the UK south of the Scottish border and it is one of the very few mountains to have a railway running to its summit. Not surprisingly therefore the combination of easy access and stunning views makes Yr Wyddfa a very popular mountain and it is estimated that over 400,000 people visit the summit each year. Yr Wyddfa's iconic status led Stephen Edwards (CREAD cyf) and Aled Llŷr (SLAM Media) to develop the idea of making a series for television based on the theme of how Yr Wyddfa shaped the lives of people who work in its shadow. The idea was taken up by ITV Wales and a six-part series entitled 'The Mountain' was commissioned. Stephen had discussed projects with G&J Surveys on previous occasions, so once planning of the series began he contacted us and explored the possibility of accurately measuring the height of Yr Wyddfa. We agreed and suggested inviting Ordnance Survey into the project to add a further dimension. Ordnance Survey would be present during the measurement and process our datasets to generate the official result. The survey comprised two visits. The first was a reconnoitre of the summit area to determine how the survey would be carried out and whether equipment could be operated with so many visitors in the vicinity. The second visit was the measurement itself.

Following our work SLAM Media and Cread also produced a half-hour documentary devoted to the survey. Entitled 'Snowdon Climbing New Heights' it was shown on ITV Wales on 14 October 2014.

## 2) Equipment used and Conditions for Survey

Ground surveys of the summit area were carried out 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 a dual-frequency, multi-channel instrument, which means it is capable of locking on to a maximum of 12 GPS and 8 GLONASS satellites as availability dictates, and receive 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. 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". Despite the on-board features of the Leica Viva GS15 receiver, there are still sources that create residual errors. To obtain accurate

positions and heights, corrections were made to the GNSS (Global Navigation Satellite System) data via imported RINEX data from Ordnance Survey. These were post-processed using Leica Geo Office 8.3 software.

Conditions for the surveys, which took place between 08.30hr and 16.00hr GMT on 5<sup>th</sup> June and between, 17.00hr and 07.20hr GMT on 2<sup>nd</sup>/3<sup>rd</sup> September were good. On 5<sup>th</sup> June the day started cold with cloud over the summit, but by 13.00hr there was unbroken sunshine. On 2<sup>nd</sup>/3<sup>rd</sup> September the weather was again fine with clear skies for most of the evening and night. A breeze (20mph) at the start of the survey abated in late evening.

### **3) The History of the Summit Architecture**

The first known depiction of the summit is a drawing made in about 1850. It shows what appears to be a natural flat-topped rock tor upon which is a very sizeable cairn. If the scale of the human figures is accurate then this would have been at least 4m high. An estimate from this period of the height of the mountain gives a value of 3570ft (1088m). Drawings from this time also show buildings in the vicinity of the tor and these may explain the flat areas that are present today. Indeed the area SW of the tor still has a sizeable retaining wall that demonstrates the degree to which engineering work in the past has shaped the summit area.

The first photograph we have seen dates from the late 19<sup>th</sup> century. This again shows the rock tor but with a smaller, although still sizeable, cairn. New height measurements gave a value of 3560ft (1085m) and this has remained the official height of Snowdon to the present day.

Post 1960 photographs are shown in Figure 1 & 2. The summit now supports a trig point on a plinth that surmounts what appears to be the flattened remnant of the original cairn. Beneath this are the rocks of the tor, the natural summit of the mountain. The original surveyors' records show that great care was taken to obtain several readings around the plinth to determine the average height difference between the plinth and the flush bracket of the trig point. The subsequent height measurement was again 3560ft (1085m).

Figure 3 is a photograph of the summit taken by us during the survey. We know that when the cafeteria was built in 2009 the summit was also remodelled and this is evident by comparing the three photographs. Individual rocks of the tor may be identified in both the recent and post 1960 photographs and these are shown by the numbered arrows (1, 2 & 3). The rock labelled number 1 is just to the right of the highest natural rock of the tor that is visible although, of course, it is possible that higher rock is hidden by the cairn and plinth. It is also clear from the two photographs that the diameter (now about 2m in radius) and height of the plinth has been increased and the stones around the base of the plinth, identified in the reconnaissance, were almost certainly added at this time.

### **4) The Reconnoitre**

We arrived at the summit station at 09.00hr BST on the service train which delivers staff and supplies to the café. The summit was deserted, but when the first scheduled train arrived an hour later many people thronged around the tor and its trig point. It was immediately clear that a survey during the daytime, while the train service was operating, would be impossible. Even setting up the GNSS receiver on the flatter areas to the South-West or North of the tor would risk damage to the equipment or at best a compromised dataset. Our second task was an investigation of the construction of the tor and cairn to confirm our conclusions from the study of old and recent photographs as described in Section 2. An investigation of the gaps between stonework and in the upper sections of the summit showed all of these to be about 0.6m in length, terminating at the position of the exposed upper section of the plinth. Thus, the stonework in this upper section of the construction is cosmetic and there to hide the substantial foundations of the plinth itself.

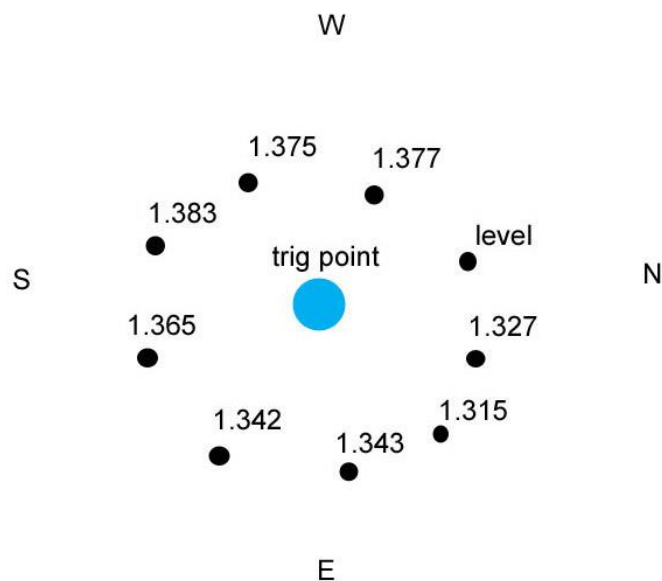
The level and staff were used to locate the highest visible natural rock of the tor which is on its West side facing the café. Staff measurements were also taken of the flush bracket and the base of the trig point.

## 5) The Survey

Following the reconnoitre, permission was given for us to use the cafeteria as a base and conduct the survey overnight when it was hoped the summit would be deserted. The 16.30hr train had been reserved and this took the team plus sleeping and surveying gear to the summit station. Once it had departed with the last visitors of the day, the summit was soon free of people and we were able to begin work. Once again the level and staff were used to confirm our previous findings to determine height differences between the flush bracket on the trig point, the plinth and the highest visible natural rock. This time more attention was paid to the plinth with numerous readings being taken around it to determine its unevenness (the individual stones are not perfectly flat) and if it was perfectly level. Ordnance Survey had advised us to take our measurement on the plinth; the official height used is that of a bolt fixed into the highest natural rock, but this is buried beneath the plinth and we were advised it was no longer accessible. Finally, the Leica Viva GS15 receiver was set up on the highest point of the plinth and data collected for 3hr from 18.50hr to 21.50hr GMT. A second dataset was also collected from 04.20hr to 07.20hr GMT. Thus a total of 6hr of data were collected and over a 12hr period. The Bernese software used by Ordnance Survey to process data is capable of combining both datasets and processing them as one.

### 5.1) The Summit Measurements

The Leica NA730 automatic level was setup on a tripod at a convenient position on the plinth and readings taken around it approximately mid-way between the centre and the circumference. Individual readings (in metres) are shown in the diagram below along with the approximate orientation (the direction to the cafeteria is at the top).



The unevenness of individual stones was of the order of 1-2cm and from the staff readings it may be seen that there was a slight slope on the plinth of about 6cm with the highest point being to the NE and the lowest to the SW. Note that this procedure was also carried out by Ordnance Survey staff during the height determination of Yr Wyddfa in the early 1960s.

The first plan was to set up the Leica Viva GS15 receiver on top of the trig point using a fixing plate provided by Ordnance Survey. Regrettably, it soon became apparent that the trig point had been rebuilt during the construction work on the cafeteria in 2009. The three hooks on the top of the trig point were no longer present and it was also noticed that the flush bracket was sited 0.6m above the base of the plinth at that point (flush brackets are usually sited 0.3 to 0.4m above ground level). The absence of the hooks prevented the fixing of the GS15 receiver to the trig point.

Finally, staff readings were taken on the chosen setup position for the Leica Viva GS15 (the highest point on the plinth which is approximately NE of the trig point), the flush bracket and the highest visible natural rock which was found to be on the West side of the tor facing the cafeteria close to position 1 shown in the photographs in the Appendix.

Staff reading on set-up position (the summit) = 1.307m

Staff reading on flush bracket = 0.767m

Staff reading on top of trig point = 0.252m

Staff reading on highest natural rock = 2.810m

Set-up position is  $2.810 - 1.307 = 1.503\text{m}$  higher than highest natural rock

Next the tripod was placed over the set-up position and the Leica Viva GS15 mounted on a 2m pole. GNSS data were collected for 3 hours from 18.50hr to 21.50hr GMT with an epoch time of 15 seconds. A second dataset of 3 hours was also collected from 04.20hr to 07.20hr GMT.

Historical ten-figure Grid References measured for the summit are:-

Garmin Etrex	SH 60987 54381	Height = 1089m (IB 17/02/06)
Garmin GPSmap 60C	SH 60990 54379	Height = 1091m (DF 25/10/10)
Garmin eTrex Legend	SH 60987 54381	Height = 1088m (DB 22/02/09)

The position and height data for the summit that were recorded by the Leica Viva GS15 were post-processed with Leica GeoOffice 8.3 using imported OS RINEX data for the six nearest base stations and the Computed model for tropospheric correction. The results are given in the table below for which the vertical offset (2m) has been subtracted:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	260986.742	0.003	354375.458	0.002	1085.663	0.004
GS15	260986.741	0.002	354375.456	0.002	1085.670	0.007

The height of Yr Wyddfa is 1085.67m.

The combined dataset was also processed by Ordnance Survey using Bernese software and precise ephemeris data to give the definitive result that will appear on OS maps. The result is given in the table below:

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	260986.750		354375.461		1085.67	

The height of 1085.67m for Yr Wyddfa agrees very well with the result from Leica GeoOffice 8.3.

The summit height for the highest visible natural rock is  $1085.67 - 1.50 = 1084.17\text{m}$ .

## 6) Summary of Operating and Process Conditions

	GS15
Data collection summit (min)	2 sets of 180min
Number of Base Stations used in Processing for all points	6
Epoch Time (sec)	15
Tropospheric Model	Computed
Cut off Angle (degs)	15

## 7) Discussion of Results

The uncertainties in the height measurement taken by the Leica Viva GS15 for the summit are  $\pm 0.01\text{m}$  associated with its location and  $\pm 0.05\text{m}$  with height for the GNSS 6 hour data set. This gives an overall uncertainty in the summit height of  $\pm 0.05\text{m}$ .

The Ordnance Survey result has a measurement uncertainty of  $\pm 0.02\text{m}$ .

## 8) Summary and Conclusions

The accessible **summit** of **Yr Wyddfa** is at grid reference \* SH 60990 54379 and is the highest point on the plinth approximately 1m NE of the trig point. Its height is  $1085.67 \pm 0.02\text{m}$ .

The highest natural ground is a rock close to Position 1 in the underlying tor. Its height is  $1084.17 \pm 0.02\text{m}$ . The highest rock lies beneath the plinth and this contains the OS bolt that conforms with a map height of Snowdon. We have recently learnt that this is indeed accessible via the weather station that is contained within the trig point; a small locked door in the side of the trig point gives access. We hope to pursue this at a future date.

\* NB average hand-held Garmin/Magellan GPS grids are quoted in the summary.

John Barnard, Graham Jackson, Myrddyn Phillips 15 September 2015.

## Appendix 1

These three views of the summit show the changes that took place during the refurbishment of 2009. In the first rocks in the tor labelled 1, 2 and 3 may be seen in the third photograph taken during this survey. The second photograph is a closer view of the trig point and cairn pre 2009. It may be seen through a comparison of these photographs that the width and height of the cairn was increased as part of the 2009 refurbishment and the trig point was also dismantled and reconstructed. The highest visible natural rock lies to the left of the rock labelled number 1.



**The Summit Tor Prior to 2009**



**Closer View of Summit Tor Prior to 2009**

Copyright: Stephen Elwyn Roddick



**Summit Tor 2014: Photograph Taken as Part of Survey**



**The Leica Viva GS 15 collecting data in late evening**



**Night Time Vigil**



**Dawn from Snowdon's Summit**





# **SNOWDON**

Climbing New Heights

**ITV WALES**

14 OCT, 2014 at 19.30pm