

Survey of Foel

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The Team:

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1) Introduction

Foel (Hill 7513, Section 30A, OS 1:50000 Maps 115/123, OS 1:25000 Map 254, Grid Ref SH450506) is listed as a sub HuMP with a drop of 99m. (A HuMP is any hill in England, Scotland, Wales, Isle of Man and Ireland with a minimum drop of 100m). The OS 1:25000 map shows a spot height of 223m at the summit, whilst the OS 1:50000 map shows a spot height of 221m at the summit which in metric terms matches the old 725ft imperial height given this hill, and using interpolation of contours the height of the bowlch is estimated to be 124m. Consequently there is a significant chance that the drop could be greater than 100m thereby promoting this hill to the main HuMP list.

Myrddyn Phillips has recently carried out two surveys of this hill using a Trimble GeoXH 6000 GNSS mapper. The results of the two surveys indicated drops of 100.9m and 101.6m indicating that this hill should be promoted. However the discrepancy between the two datasets remains unexplained, but a likely factor creating a greater uncertainty in the measurements was the presence of trees at the bowlch which may have interfered with satellite reception.

The purpose of this survey was to locate and measure accurately the heights of the bowlch and summit of Foel to clarify its status.

2) Equipment used and Conditions for Survey

Ground surveys to determine the positions of the bowlch and summit 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 and a Trimble GeoXH 6000 receiver. Both instruments are dual-frequency, multi-channel instruments, which means they are 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 stand-alone instruments they are 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 Viva GS15 and GeoXH 6000 receivers, 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 the Ordnance Survey which were post-processed using Leica Geo Office 8.3 software for the GS15 data and Trimble GPS Pathfinder Office processing software for the GeoXH 6000 data.

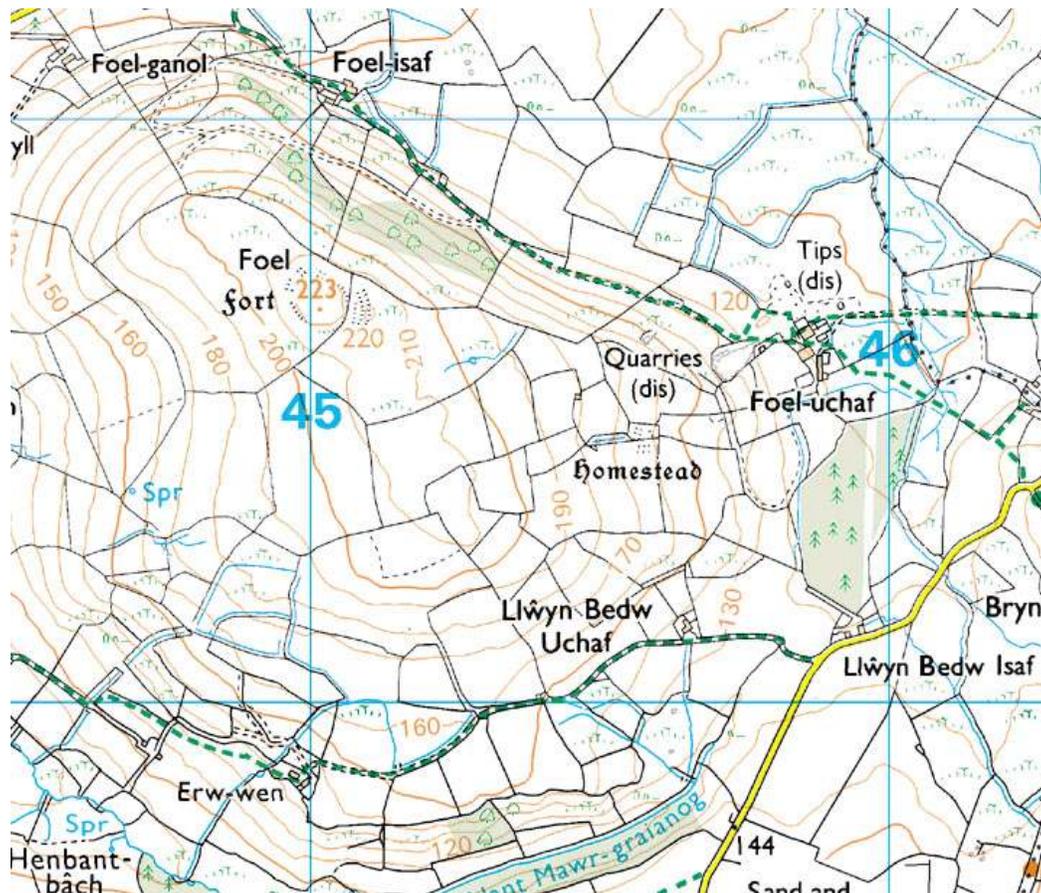
Conditions for the survey, which took place between 10.00hr and 15.00hr GMT, were fair. The weather was a little cloudy but with good sunny periods. The temperature was about 3 degrees Celsius, although it felt much colder even though there was only a light wind.

3) The Survey

3.1) Character of Hill

Although Foel is only 223m high it is an excellent viewpoint with Yr Eifl on the Lley Peninsular to the West and the hills of the Nantlle ridge and Snowdonia to the East. According to the map, see extract from the OS 1:25000 scale map below, the summit is an ancient fort. The summit is on private land set aside for grazing and is owned by the farm Foel-uchaf to the East of the summit. The track leading to the farm of Llwyn Bedw Uchaf (SH 456 501) and beyond is a Right of Way which also provides access to the critical bwllch as well as the summit. Permission was sought and willingly given to access both the summit and the bwllch for this survey.

It is possible to park one car at the entrance to the track leading to Llwyn Bedw Uchaf. The bwllch appears visually to lie on this track within a light canopy of trees. The track then leads uphill and past the farm. Access to the hill then is made through the private fields up to the grassy summit where there is a small cairn.



3.2) Summary of Survey Method

The survey commenced at the summit and visually the highest point appeared to be in the vicinity of the cairn. This was confirmed with level and staff measurements. GNSS data were then collected with both the Leica GS15 and Trimble GeoXH 6000 placed over the summit position.

Next the survey moved to the bwlch. Visually the bwlch appeared to be on the farm track about 80m West from where the track leading to Llwyn Bedw Uchaf commences at the minor road. Level and staff measurements confirmed the ground either side of the track was lower and descending the further one went away from the track and that the current bwlch lay on the track. However, if the track were discounted because it was clearly man made, then the original bwlch would have lain under the track. GNSS data were collected with both the Leica GS15 and Trimble GeoXH 6000 in the field to the West of the track at a convenient position where satellite signals would not be impeded by the tree cover. Staff measurements were taken to obtain the height correction from the GNSS setup position and the bwlch.

3.3) The Summit

The Leica NA730 automatic level was setup on a tripod at a convenient position about 20m away from the summit cairn. Staff readings were then taken systematically in the area around the cairn and the summit position was confirmed to be adjacent to the cairn. This position had also been identified in the earlier surveys carried out by Myrddyn Phillips. The ground around the cairn is quite bumpy and these localised “high points” resulted from either buried stones, presumably from the ancient fort, or tussocks of grass and therefore were discounted. We estimated that we had located the summit position to a height uncertainty within +/-0.05m.

The Leica GS15 was then setup on a 2.000m pole and supported by a Quickset tripod over the summit position. GNSS data were collected for 1 hour with an epoch time of 15 seconds. Subsequently the Trimble GeoXH 6000 was placed on the ground over the summit and data were collected for 11 minutes using the internal antenna set with an epoch time of 1 second. (See photographs in Appendix).

When the GS15 data was subsequently post processed, it was found that the data file had been corrupted. Leica Technical Service were contacted and we were told that the problem had been caused by a renumbering of one of the GLONASS satellites which caused a mismatch between the satellite almanac stored on the machine and the observed data, rendering the file useless. A firmware upgrade has now been supplied by Leica Geosystems to prevent a repeat of this problem. Consequently the summit of the hill was revisited on 20 February and another 1 hour dataset was collected. This time the GS15 was set up on the short tripod assembly with a measured vertical offset of 0.390m (see photograph in Appendix). Epoch time was again 15 seconds.

The ten-figure Grid References measured for the summit were:-

Garmin Montana 600	SH 45024 50680	Height = 226m
Garmin Etrex 20	SH 45024 50677	Height = 223m

The position and height data for the summit that were recorded by the Leica Viva GS15 was post-processed with Leica GeoOffice 8.3 using imported OS RINEX data for the six nearest base stations and the Hopfield model for tropospheric correction. These results and for the Trimble GeoXH 6000 processed in Trimble GPS Pathfinder Office using the five nearest base stations are given in the table below:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	245021.823	0.001	350673.723	0.003	221.336	0.012
GeoXH 6000	245021.773	<0.05	350673.728	<0.05	221.268	<0.05

The height of the Foel is 221.34m

3.4) The Bwlch

The Leica NA730 level was setup on a tripod on the West edge of the track near to where we had visually estimated the bwlch to be. Four sets of three staff readings were taken across the track each set about 5m apart. The measurements showed the track in this area to be quite flat as staff readings only varied by less than +/-0.04m. Staff readings were also taken either side of the track to estimate the depth of the foundations for the track. Finally a staff reading was taken at the point in the field on the West side of the track that was chosen for the GNSS setup position.

Staff reading at bwlch on track = 0.900m

Staff reading at West side of track = 1.6m

Staff reading at East side of track = 1.3m

Staff reading at GNSS setup position = 0.448m

The above readings taken on and either side of the track suggest the foundations to the track have been built up by a height of approximately 0.4 metre.

The ten-figure Grid References recorded for the bwlch were:-

Garmin Montana 600 SH 45826 50108 Height = 126m

Garmin Etrex 20 SH 45825 50110 Height = 123m

The GNSS setup position was chosen so that satellite reception at this point would not be impeded by the trees and be visible from where the automatic level had been set up to determine the bwlch position. The Leica GS15 was set up on a 2.000m pole and supported by a Quickset tripod. Data were collected for 1 hour with an epoch time of 15 seconds.

Data were also collected at this point with the Trimble GeoXH 6000. Three different measurement sets were taken. For the third dataset, the XH 6000 was placed on the ground and data were collected for 11 minutes using the internal antenna. For the second and third data sets the XH 6000 was connected to an external antenna which was mounted on a 2.000m pole (see appendix for photos). Two different options on the drop down menu for the vertical offset are available on the receiver. These are “bottom of antenna mount” and “top of notch”. Currently we are not sure which is the correct setting for the external antenna configuration and therefore 11minute and 10minute datasets were collected respectively for both options. In all cases an epoch time of 1 second was used.

The position and height data for the summit that were recorded by the Leica Viva GS15 and post-processed with Leica GeoOffice 8.3 using imported OS RINEX data for the six nearest base stations and the Hopfield model for tropospheric correction are given in the table below. Results for the Trimble GeoXH 6000 processed in Trimble GPS Pathfinder Office using the five nearest base stations are likewise given in this table:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	245772.289	0.002	350104.174	0.003	120.594	0.014
GeoXH 6000 int antenna	245772.323	<0.05	350104.333	<0.05	120.618	<0.05
GeoXH 6000 ext antenna	245772.289	<0.05	350104.251	<0.05	120.604	<0.05
Bottom of mount						
GeoXH 6000 ext antenna	245772.328	<0.05	350104.288	<0.05	120.562	<0.05
Top of notch						

The height of the bwlch is therefore $120.590 + 0.448 - 0.900 = 120.14\text{m}$

4) **Summary of Operating and Process Conditions**

	GS15	GeoXH 6000
Data Collection bwlch (min)	60	10-11
Data collection summit (min)	60	11
Number of Base Stations used in Processing for all points	6	5
Epoch Time (sec)	15	1
Tropospheric Model	Hopfield	Unknown
Cut off Angle (degs)	15	5

5) **Discussion of Results**

The drop for Foel is $221.34 - 120.14 = 101.20\text{m}$ and therefore Foel is reclassified as a HuMP. Note that the track passes over the bwlch. The document that describes our surveying protocols, Summits and Cols, advises that, in this situation, the bwlch height is measured on the track. The natural ground immediately on the East side is 0.4m lower and if this were considered instead then the drop would be greater. Thus, there is no doubt that the drop significantly exceeds the 100m criterion.

The uncertainties in the height measurement taken by the GS15 for the summit are $\pm 0.05\text{m}$ associated with its location and $\pm 0.05\text{m}$ for the GNSS 1 hour data set. This gives an overall uncertainty in the summit height of $\pm 0.07\text{m}$. The Trimble GeoXH 6000 measurement is in good agreement, being 0.07m lower.

For the bwlch the uncertainties in the height measurements are estimated to be $\pm 0.05\text{m}$ for the location of the bwlch and $\pm 0.05\text{m}$ for the data set which gives an overall uncertainty of $\pm 0.07\text{m}$.

The agreement between the data collected for the **bwlch** at the GNSS set up position between the two receivers is excellent with a range of results within 0.04m. The two datasets collected for the Trimble GeoXH 6000 with the different offset options did not clarify completely which option should be used but “bottom of the antenna mount” seems a more likely description of the setup and the dataset collected with this option gave a result closer to the Trimble on the ground and the GS15 measured heights.

The previous two surveys carried out with the Trimble GeoXH 6000 to measure the drop for Foel gave results of 100.9m and 101.6m which differ by 0.3 and 0.4m respectively from the result obtained in this survey. No explanation for this wider difference can be given from this survey but other work is being carried out with the Trimble receiver to optimise its operational settings and assess its accuracy.

6) Summary and Conclusions

The **summit** of **Foel** is at grid reference * SH 45024 50679 and is unfeatured ground next to the small cairn. Its height is **221.34+/-0.07m**.

The **bwlch** for Foel is at grid reference *SH 45826 50109. Its height is **120.14+/-0.07m**.

The **re-ascent** from the **bwlch to the summit** is **101.2m** and therefore **Foel is reclassified from sub-HuMP to HuMP**.

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

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Appendix

View of GS15 set-up at summit on 2m pole (16 Feb2014)



Summit GS15 Vertical offset at 0.390m (20 Feb 2014)



Trimble GeoXH 6000 on Summit



Locating the Bwlch with Leica NA730 level and staff



Leica GS15 setup position with bwch in the background



Trimble GeoXH 6000 setup with external antenna supported on a 2.00m pole

