

# Survey of Coed Mawr and Rhos Fawr

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The Team:

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## 1) Introduction

Coed Mawr and Rhos Fawr (Hills 5204 & 5623, Section 31A, OS 1:50000 Map 136, OS 1:25000 Map 214E and 214W, Grid Refs SO013873 & SN999883) are situated in Mid Wales 11km SW of Newtown and 5km NE of Llanidloes. They are listed as a twin HuMP since each has a map height of 308m but with a drop of only 91m between them. (A HuMP is any hill in England, Scotland, Wales, Isle of Man and Ireland with a minimum drop of 100m). Since map heights, as determined by photogrammetry, have a measurement uncertainty of +/- 3m it is likely that, if measured accurately, one hill would prove to be higher than the other. A first attempt was made by one of the authors (7<sup>th</sup> February 2014) using the Trimble Geo XH 6000. The measured height difference of 0.06m determined by Myrddyn Phillips was smaller than the associated measurement uncertainty and consequently this has led to the survey described in this report. If a successful measurement is made, then the higher hill will become the HuMP and the lower will become a subHuMP.

The purpose of this survey was to measure the height of each summit accurately and thus clarify its status.

## 2) Equipment used and Conditions for Survey

Ground surveys to determine the positions of the summits 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 11.00hr and 17.30hr BST, were fair. The weather was overcast for most of the survey, but the cloud-base was always above the summits of the hills. The temperature was 12 degrees Celsius with a light wind of 5-10mph.

### 3) The Survey

#### 3.1) Character of the Hills

Coed Mawr and Rhos Fawr are inconspicuous hills when approached from Newtown as they are hidden by the bulk of the Pegwn Mawr group of hills until the junction of the A489 and A470, near the village of Caersws, is passed. Then they come into view quite suddenly forming an attractive back-drop to the Severn valley on its Western side. Both hills comprise sheep pasture on their summits, although Coed Mawr is surrounded by conifer forest at its base. A minor road passes between the two hills and within just a few metres of the bwlch (SO000874). This road provides ready access, but is very narrow and has few parking places along it. We were fortunate in finding a cottage, where we were kindly granted permission to park. The Severn Way also passes between the hills and traverses the upper slopes of Coed Mawr at its northern end. This gives convenient access from the bwlch and although a longer route, it is easier to follow than the rather obscure footpath through the farm of Cefn, which is situated about 800m SE of the bwlch. Rhos Fawr is also easily climbed via a track that starts from the minor road just above the bwlch and passes within about 100m of the summit. A gate gives ready access to the sheep pasture in which the summit of cropped grass lies. Sheep are ever present on both hills and once accustomed to the presence of strangers prove an inquisitive and attentive audience for aspiring surveyors.

#### 3.2) Summary of Survey Method

The summit of both hills required minimal measurement with level and staff. With short grass and uninterrupted views all round, both summits were readily identified. They were no specific features marking either summit.

The absolute heights of both summits were measured with the Leica Viva GS15 receiver and the Trimble GeoXH 6000 receiver with data from both GPS and GLONASS satellites being collected. The Leica GS15 was set up with tripod support to hold it firmly over the point to be measured and was mounted on a 2m pole at both summits. For all locations the GeoXH 6000 was put directly on to the feature to be measured. Data were collected by the Leica GS15 for two hour with an epoch time of 15 seconds on both summits. Data were collected by the GeoXH 6000 for 10min on both summits and an epoch time of 1sec was used at each position.

In addition, each summit was viewed through the level from its twin and photographs taken for further analysis. The distance between the stadia lines (the short lines either side of the central line seen in the eyepiece) is  $1/100^{\text{th}}$  of the distance between the level and the object viewed in the eyepiece. It is therefore possible to determine the height difference between the set-up position of the level and the object in view. For this work the level was set up so that the eyepiece was level with the summit of the hill upon which it was standing. The results (see appendix) are only approximate (measurement uncertainty is about  $\pm 0.3\text{m}$ ) but provide a visual record to supplement the GNSS data.

#### 3.3) Coed Mawr

The summit was surveyed with level and staff as described in Section 3.2 and we are confident this was achieved to within  $\pm 0.01\text{m}$  of height. There is a line of mature hawthorn trees that are situated near the summit ridge just on its East side. Consequently, the Leica

GS15 was set up about 20m away and slightly downhill to eliminate the possibility of multipath reflections from the trees into the receiver, as this would compromise the data-set. For the same reason the GeoXH 6000 was also placed at this point for data collection once the Leica GS15 and tripod had been removed following data collection. The level and staff were used to determine the height difference between the summit and the set-up position and a small metal survey nail was used to provide firm placement for the staff and for the pole supporting the Leica GS15.

Staff reading at summit = 0.645m

Staff reading on summit on bolt = 0.635m

Staff reading at GPS set-up position on bolt = 1.319m

GS15 set-up position is  $1.319 - 0.645 = 0.674\text{m}$  lower than the summit and note that the head of the nail is 1cm in height.

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

Montana 600	SO 01351 87381	Height = 312m
Etrex 20	SO 01353 87384	Height = 311m
Garmin Oregon 450	SO 01352 87386	Height = 314m

The position and height data for Coed Mawr that were recorded by the Leica Viva GS15 and post-processed with Leica GeoOffice 8.3 using imported OS RINEX data for the eight nearest base stations and the computed model for tropospheric correction are given in the table below. An offset of 2m (pole height) – 0.674m (set-up position) was entered into the software to allow for the set-up configuration. Consequently, the result generated by the software is the corrected height. Results for the Trimble GeoXH 6000 were processed in Trimble GPS Pathfinder Office using the five nearest base stations and are likewise given in this table with the above offset applied:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	301336.970	0.002	287363.791	0.002	307.063	0.007
GeoXH 6000	01336	<0.05	87363	<0.05	307.057	<0.05
GeoXH 6000 (1 <sup>st</sup> visit)	01350	<0.05	87380	<0.05	307.098	<0.05

The height of the Coed Mawr is 307.06m

### 3.4) Summit of Rhos Fawr

The exact position of the summit was established using the level and staff as described in Section 3.2 and again we are confident this was achieved to better than +/-0.01m in height. The Leica GS15 was set up on the summit position on a 2m pole. The Trimble GeoXH 6000 was placed directly on the summit and data recorded once the Leica GS15 had been removed.

The ten-figure Grid References for the summit are:-

Montana 600	SN 99908 88388	Height = 312m.
Etrex 20	SN 99905 88389	Height = 311m
Garmin Oregon 450	SN 99907 88386	Height = 314m

The position and height data for Rhos Fawr that were recorded by the Leica Viva GS15 and post-processed with Leica GeoOffice 8.3 using imported OS RINEX data for the eight nearest base stations and the computed model for tropospheric correction are given in the table below. An offset of 2m was entered into the software to allow for the set-up configuration. Consequently, the result generated by the software is the corrected height. Results for the Trimble GeoXH 6000 were processed in Trimble GPS Pathfinder Office using the five nearest base stations:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	299903.370	0.002	288383.766	0.002	307.175	0.007
GeoXH 6000	99903	<0.05	88383	<0.05	307.213	<0.05
GeoXH 6000 (1 <sup>st</sup> visit)	99902	<0.05	88383	<0.05	307.160	<0.05

The height of Rhos Fawr is 307.18m

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

	GS15	GeoXH 6000
Data Collection Coed Mawr (min)	120	10
Data collection Rhos Fawr (min)	120	10
Number of Base Stations used in Processing for all points	8	5
Epoch Time (sec)	15	1
Tropospheric Model	Computed	Unknown
Cut off Angle (degs)	15	0

#### 5) Discussion of Results

The largest measurement uncertainty was associated with the instrumental measurements (+/-0.05m for the Leica Viva GS15) for each summit. Therefore the overall uncertainty in the measurement for the hill is no more than +/-0.07m as determined by this instrument. We have no data yet to assess the measurement uncertainty of the GeoXH 6000.

The result for the Leica GS15 makes Rhos Fawr 0.11m higher than Coed Mawr with a confidence of >99%.

The result for the GeoXH 6000 makes Rhos Fawr 0.16m higher than Coed Mawr with unknown confidence.

The result for the 7<sup>th</sup> Feb determination by the GeoXH 6000 made Rhos Fawr 0.06m higher than Coed Mawr with unknown confidence.

The average of the visual determinations makes Rhos Fawr 0.07m higher than Coed Mawr with a confidence of just over 50%.

Clearly the height difference between the two summits is very small, but all four determinations make Rhos Fawr the higher of the two summits by about 0.1m.

## **6) Summary and Conclusions**

The **summit** of **Rhos Fawr** is at grid reference \* SN 99907 88388 and is no specific feature. Its height is **307.18m +/-0.05m**.

The **summit** of **Coed Mawr** is at grid reference \* SO 01352 87384 and is no specific feature. Its height is **307.06m +/-0.05m**.

**Rhos Fawr is higher than Coed Mawr by 0.11+/-0.07m and becomes the HuMP while Coed Mawr becomes a subHuMP.**

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

John Barnard, Graham Jackson and Myrddyn Phillips 9 May 2014.

## Appendix 1

**View of GS15 set-up on Coed Mawr on 2m pole with summit in background marked with yellow flags**



**View of GS15 set-up at summit of Rhos Fawr on 2m pole**



### Surveying for summit position on Rhos Fawr



### Lamb eating surveying gear



### Surveyor retrieving surveying gear



## Appendix 2

### Visual determination of height difference between Coed Mawr and Rhos Fawr

#### Rhos Fawr from Coed Mawr



The level was set up a few metres from the summit position of Coed Mawr and aligned so that the horizontal line was level with the summit. The level was then focussed on the summit of Rhos Fawr to give the view seen in the above photograph. The horizontal line is shown cutting just above the summit of Rhos Fawr.

The stadia lines enable height difference between the two hills to be calculated provided the distance between the level and the object is known, which in this case is 1.76km. The lower stadia line is the short horizontal line at the bottom of the picture. The distance between the lower stadia line and the central horizontal line is  $1/50^{\text{th}}$  of the distance between the level and the object in view, that is  $1/50^{\text{th}}$  of 1.76km.

From this measurement the apparent height difference between the summit of Rhos Fawr and the horizontal line is found to be 0.08m, that is Rhos Fawr appear to be 0.08m lower than Coed Mawr. (The measurement was made with the image enlarged on the computer screen). However, earth curvature must also be taken into account which over 1.76km is 0.24m making the summit of Rhos Fawr  $0.24 - 0.08 = 0.16\text{m}$  higher than Coed Mawr.

### Coed Mawr from Rhos Fawr



The same procedure was applied on the summit of Rhos Fawr to produce this photograph of the summit of Coed Mawr. This time the measurements from the photographs show the apparent height difference between the two summits to be 0.22m. Once again applying a value of 0.24m for earth curvature gives a result of Coed Mawr being higher than Rhos Fawr by 0.02m.

Taking the average result Rhos Fawr is higher than Coed Mawr by  $(0.16-0.02)/2 = 0.07\text{m}$ .