

# Surveys of Cynriau Nod and Foel Cedig

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## 1) Introduction

Cynriau Nod (Hill Number 2105, Section 30E, OS 1:50000 Map 125, OS 1:25000 Maps 239 and 255, Grid Ref. SH988279) is listed in the Database of British and Irish Hills (DoBIH) as a Marilyn, Sim, Hewitt and Nuttall. Both of the above current Ordnance Survey Maps have a spot height of 667m marked for the summit position but on older editions of these maps the spot height was marked as 666m. This hill was surveyed by John Barnard and Myrddyn Phillips on 13 June 2014 in order to identify the summit position which was found to be on unfeatured ground approximately 13m north of the cairn.

About 800m WNW of Cynriau Nod is another summit called Foel Cedig that is currently marked on OS Maps with a spot height of 666m. For some time there has been debate as to whether this summit is higher than Cynriau Nod and if it were then it would replace Cynriau Nod as the Marilyn, Sim, Hewitt and Nuttall. In August 2018, Myrddyn Phillips surveyed these two hills with his Trimble GeoXH 6000 and measured the heights of Foel Cedig and Cynriau Nod to be 667.4m and 666.2m respectively, thereby confirming that Foel Cedig is indeed the higher hill. These results have been accepted by the authors of the relevant lists.

The purpose of this survey was to repeat these measurements using our Leica Viva GS15 by collecting 2-hour GNSS datasets on each hill. These would then be submitted to Ordnance Survey so that the relevant changes could be made to OS Maps for everyone's benefit.

## 2) Equipment used and Conditions for Survey

Where necessary, 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.

The absolute heights of the summits 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.

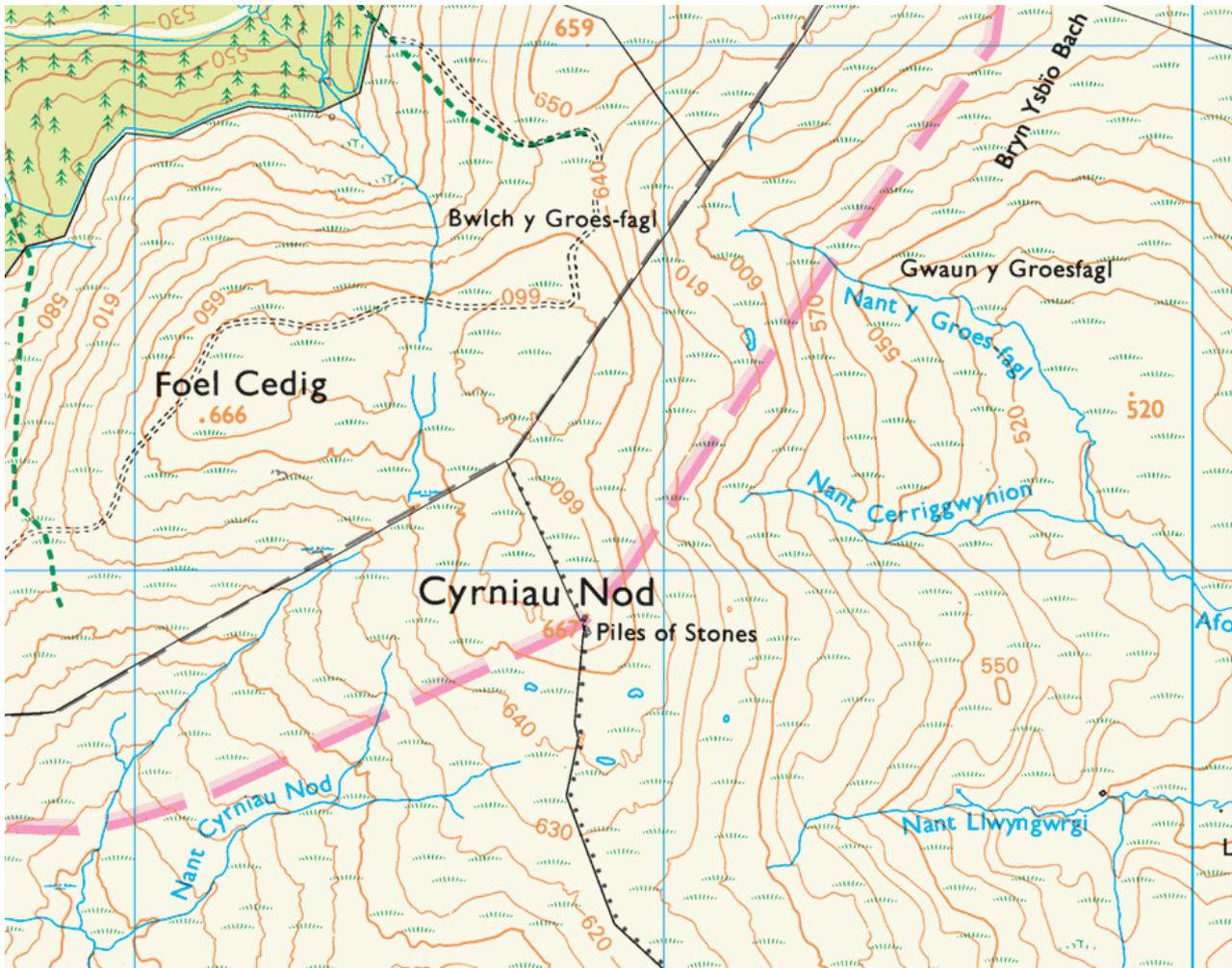
Note that most small hand-held GNSS receivers used for general navigation in the UK can receive signals from up to 12 GPS and 8 GLONASS satellites and each at a single frequency. Therefore, these instruments have a poorer positional accuracy of  $\pm 8$  metres and a height accuracy of no better than  $\pm 10\text{-}15$  metres – accuracy reported as three times standard deviation. Some older and "bottom of the range" handheld receivers can only receive signals from GPS satellites. However, their accuracy is very similar but GLONASS greatly improves the speed at which modern receivers can achieve a satellite "fix", particularly in areas where the view of the sky may be limited. Satmap Active instruments are more accurate than the current Garmin models.

Conditions for the surveys, which took place between 09.30hr and 17.00hr BST, were fair. The temperature was about 12 degrees Celsius. Although cloudy, the cloud base was over 900m so visibility was good. The wind speed as measured with an anemometer was between 20 and 30mph with gusts up to about 40mph.

This created some significant wind chill while awaiting the two hours of data collection! Fortunately, the weather was dry while the actual surveys were being carried out.

### 3) Character of Hills

An extract of the Ordnance Survey 1:25000 scale map (Crown Copyright Ordnance Survey) showing Foel Cedig and Cynriau Nod is presented below.



Cynriau Nod and Foel Cedig are situated in the western Berwyns south of the Penllyn Forest. The western Berwyns have a reputation for the luxuriant growth of heather and tussock grass, and progress can be very arduous if direct lines are taken to go from hill to hill. The whole area is also quite flat and rather featureless earning it the epithet of “Boring Berwyns”. However, there are very few places south of the Scottish border where you can stand in the middle of the area and see no sign of human habitation. At the time of this survey, apart from a few hardy sheep, the most common sights of animal life were the numerous groups of meadow pipits and numbers of woolly brown caterpillars, later to become Fox Moths if they survive the winter, basking on top of the vegetation.

Access to these western Berwyns is easy as an excellent forestry track runs east from the top of the pass on the minor road that leads from Bala to Lake Vyrnwy. This starts at an altitude of 500m, where there is space to park one or two cars, and after an ascent to over 600m within the first kilometre, the track undulates, twists and turns as it passes by three 2000-foot summits (Nuttalls) over a distance of about 4km. Two other 2000-foot summits, Cefn Gwyntog and Cynriau Nod can be reached on the south side of the forestry track via often faint walkers’ paths that have now made progress a lot easier, although they can be very boggy in places. The path to Cynriau Nod, that follows the line of a fence for much of its way, is now marked by a small cairn on the main forestry track.

#### 4) Survey of the Summit of Foel Cedig

The first task was to locate the position of the summit. This was easily done as it is clear that the highest point is the top of a flat raised rocky area that was covered with heather and grass. However, there was a contender a few metres away from this point. Having set up the Leica NA730 at a convenient position, staff measurements confirmed the contender to be a few centimetres lower once the thick vegetation had been removed.

To obtain an absolute measurement of height the Leica Viva GS15 receiver was mounted on the short tripod assembly directly over the summit position (see photograph in Appendix 1). GNSS data were collected at the point for 2 hours with an epoch time of 15 seconds. A photograph is also shown in Appendix 1 of the tape reading, 0.388m, for the short tripod set up.

The data for the Leica Viva GS15 were processed in Leica GeoOffice 8.3 using the ten nearest base stations: (Machynlleth – MACY 36km, St Asaph – ASAP 46km, Shrewsbury – SHRE 56km, Shobdon – SHOD 79km, Crewe - CREW 81km, Daresbury – DARE 81km, Aberdaron – ADAR 83km, Stone – STON 90km, Holyhead – HOLY 92km and Brecon - BREC 99km). 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 Hopfield Tropospheric model was chosen for the calculations because, in this case, it gave the most precise calculations. The vertical offset from measuring point to the summit was 0.388m plus 0.255m for the tribrach/hook system and this was used in the calculations.

The results are given in the table below: -

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	298170.216	0.001	328327.193	0.002	667.479	0.007

#### 5) Survey of the Summit of Cynriau Nod

The summit position of Cynriau Nod had been identified in a previous survey carried out with a Leica NA730 level and staff in June 2014. However, the survey to locate the summit position was repeated using the same apparatus and its position confirmed as previously found, being unfeathered ground about 13m north of the cairn.

To obtain an absolute measurement of height the Leica Viva GS15 receiver was mounted on the short tripod assembly directly over the summit position (see photograph in Appendix 1). GNSS data were collected at the point for 2 hours with an epoch time of 15 seconds. A photograph is also shown in Appendix 1 of the tape reading, 0.551m, for the short tripod set up.

Processing the GNSS Data was carried out as described for Foel Cedig except the appropriate vertical offset of  $0.255\text{m} + 0.551\text{m} = 0.806\text{m}$  was used.

The results are given in the table below: -

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	298847.970	0.001	327918.846	0.002	666.234	0.009

## 6) Summary of Operating Conditions

Parameter	GS15 on Foel Cedig	GS15 on Cyrniau Nod
Data Collection summit (min)	122	121
Number of Base Stations used in Processing for all points	10	10
Epoch Time (sec)	15	15
Geoid Model	OSGM15	OSGM15
Cut off Angle (degs)	15	15

## 7) Coordinate Recovery Analysis

In order to verify the precision and consistency of a GNSS dataset, Ordnance Survey (OS) 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 are first processed with reference to only the nearest Base Station, in this case Machynlleth (MACY). The data are 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, only “Separation  $D_{ij}$  metres”, the distance in 3-d space between the measured and actual OS values for each Base Station, is presented in the table below. The results for the summit measurements for Foel Cedig and Cyrniau Nod calculated using the Hopfield Tropospheric model are: -

Base Station	Code	Distance to Survey Point km.	Foel Cedig Separation $D_{ij}$ metres	Cyrniau Nod Separation $D_{ij}$ metres
Machynlleth	MACY	36	Reference	Reference
St Asaph	ASAP	46	0.0315	0.0164
Shrewsbury	SHRE	56	0.0316	0.0182
Shobdon	SHOD	79	0.0546	0.0196
Crewe	CREW	81	0.0124	0.0437
Daresbury	DARE	81	0.0426	0.0279
Aberdaron	ADAR	83	0.0253	0.0103
Stone	STON	90	0.0179	0.0611
Holyhead	HOLY	92	0.0360	0.0245
Brecon	BREC	99	0.0453	0.0092

The results show consistent datasets, as all measured OS Base Stations are within 0.06m distance and height of the OS actual values for Base Station distances up to about 100km. and are below the 0.1m requirement of OS.

## 8) Discussion of Results

For the Leica Viva GS15, two independent repeatability studies have shown that a 120-minute data collection time with good satellite reception gives heights with a measurement uncertainty of  $\pm 0.05\text{m}$  (3 standard deviations).

Although the rocky area on the summit of Foel Cedig was covered with vegetation, we were able to scrape this away from the highest point. Therefore, being well defined, we would estimate the height uncertainty in its location to be  $\pm 0.02\text{m}$ . However, being on grassy and soft unfeatured ground, the height uncertainty for the location of the summit of Cynriau Nod is larger and we would estimate that to be  $\pm 0.07\text{m}$ . Therefore, the overall uncertainty in the height measurement of the summit of Cynriau Nod and Foel Cedig is  $\pm 0.1\text{m}$  and  $\pm 0.05\text{m}$  respectively.

The Coordinate Recovery results where Base Stations were measured to heights better than 0.06m of the Ordnance Survey data are consistent with the above estimations of accuracy.

## 9) Verification by Ordnance Survey

The GNSS data for the heights of Foel Cedig and Cynriau Nod together with the Coordinate Recovery Data were sent to Mark Greaves at Ordnance Survey. The heights have been verified by Ordnance Survey and spot heights of 667m and 666m for Foel Cedig and Cynriau Nod will appear on Ordnance Survey maps.

## 10) Summary and Conclusions

The **summit of Foel Cedig** is at grid reference \*SH 98170 28327 and is the top of a raised rocky area covered with heather and grass. Its height is  **$667.48 \pm 0.05\text{m}$** .

The **summit of Cynriau Nod** is at grid reference \*SH 98847 27918 and has no feature but is approximately 13m north of the cairn. Its height is  **$666.2 \pm 0.1\text{m}$** .

As **Foel Cedig** is the higher of these two hills its status changes and **becomes the Marilyn, Sim, Hewitt and Nuttall** as agreed with the respective Hill list authors.

\*Grid References in OSTN15

## 11) Acknowledgements

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

John Barnard and Graham Jackson, 20 October 2018

## Appendix 1

The Leica GS15 collecting GNSS Data on the Summit of Foel Cedig



Tape Reading for the Summit measurement on Foel Cedig



**The Leica GS15 collecting GNSS Data on the Summit of Cyrniau Nod**



**Tape Reading for the Summit measurement on Cyrniau Nod**

