

Survey of Kingswood Bank

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The Team:

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1) Introduction

Kingswood Bank (Hill 16766, Section 36, OS 1:50000 Maps 118, OS 1:25000 Map 258, current Grid Ref SJ855405) is listed as a TuMP with a drop of 42m. (A TuMP is any hill in England, Scotland, Wales, Isle of Man and Ireland with a minimum drop of 30m). The OS 1:50000 map shows five 180m contour rings along the ridge (see Appendix 1 Figure 1) with a 188m spot height on the next to northerly one (hill 4 in Figure 1), whilst the OS 1:25000 map (Appendix 1 Figure 2) puts a 185m contour ring on the next summit South (hill 2) but gives no spot heights. The 1:10000 map gives a 184m spot height on the most northerly summit (Hill 4) and also shows the 185m contour ring on Hill 2.

Rob Woodall recently visited Kingswood Bank and concluded the 188m spot height on Hill 3 was an error and the summit was either Hill 4 or Hill 2, with Hill 4 being the preferred option. Ten-figure grid references were recorded for Hills 1 – 4. With conflicting information on the different scale maps and the on-site visit challenging the 188m spot height, a resolution was considered desirable.

The purpose of this survey was to locate and measure accurately the heights of the five summits and determine the true summit position and height of Kingswood Bank.

2) Equipment used and Conditions for Survey

Ground surveys to determine the positions of the summits and line surveys to determine height differences between some of the tops 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. The 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 which were post-processed using Leica Geo Office 8.3 software.

Conditions for the survey, which took place between 11.00hr and 16.00hr GMT, were fair. The weather was overcast, the wind light, and the temperature was about 5 degrees Celsius.

3) The Survey

3.1) Character of Hill

Kingswood Bank is situated just to the South of Newcastle-under-Lyme and is part of the Trentham estate. Trentham Gardens lies on the East side of the hill and the M6 motorway lies immediately to the West. There are two lay-bys on the A519 which give ample parking at SJ853399, where a public footpath passes over the motorway and up to the summit ridge of the hill. From there it continues East towards the entrance to the gardens. The land on the ridge to the South of the path is oak woodland and is designated a Site of Special Scientific Interest (SSSI). A high fence separates this land from the rest of the ridge, but a gate gives ready access and a wide track continues to beyond Hill 0. To the North of the path used for access, the ridge comprises mainly grass and small trees on the summit with heathland to the West and East. A wide gravel track runs along the ridge and this section is popular with locals.

3.2) Summary of Survey Method

We first made a reconnoitre of the whole ridge to enable a plan for the survey to be formulated. The summit area of Hill 1 was inside the SSSI and comprised open oak woodland. There was a small clearing not too far away and this would offer a location for setting up the Leica Viva GS15. Hill 0 was about another 250m along the track to the South, but with both summits being close to the track this offered a convenient route for a line survey which would be much quicker than collecting GNSS data on Hill 0. Hill 2 had a wide open area on its summit, although the highest point itself was close to trees. The Leica Viva GS15 could be set up in this open area and the level and staff used to determine the height difference between the two points. Hill 3 turned out to be just a very minor rise in the ridge and a line survey to it from Hill 2 would be quite quick. Finally, we arrived at Hill 4 and established we could set up the Leica Viva GS15 a few feet away from the summit, once again to avoid interference from two trees in close proximity to it. The level and staff would be used to determine the height difference between our set-up position and the summit. This plan would enable us to complete the whole survey in a single day.

3.3) Hill 4

The Leica NA730 automatic level was setup on a tripod at a convenient position about 10m away from the summit area. Staff readings were then taken systematically and the summit position was located. The height difference between the summit position and the set-up position for the Leica Viva GS15 was then measured. 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 (the vertical offset – see Figure 3 in the Appendix 1) was then measured with the integral tape. The vertical offset from measuring point to the ground was 0.626m (see photograph) plus 0.255m for the tribrach/hook system. GNSS data were collected for 35min with an epoch time of 15 seconds.

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

Garmin Montana 600	SJ 85560 40507	Height = 183m	Acc = averaged
Garmin Etrex 20	SJ 85561 40511	Height = 186m	Acc = averaged
Magellan Explorist 100	SJ 85561 40511	Height = 186m	Acc = 9m
Garmin Oregon 450	SJ 85561 40512	Height = 192m	Acc = 4m

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 ten nearest base stations and the Hopfield model for tropospheric correction.

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	385552.024	0.001	340506.774	0.001	183.982	0.005

Height recorded by Leica Viva GS15 (allowing for vertical offset of 0.881m) = 183.982m

Staff reading for summit position = 0.828m

Staff reading for set-up position = 1.130m

Height difference = 0.302m

Height of Hill 4 = 183.982 + 0.302 = 184.28m

3.4) Hill 3

The Leica NA730 level was set up on a tripod at a convenient position near to the summit of Hill 2 and staff readings were taken with the staff set up on the summit position. Once this set of readings had been taken (Backsights BS) the staff was then moved to a downhill position, but the level not moved apart from a rotation through 180 degrees to take another set of readings (Foresights FS). The line survey route then continued towards Hill 3. This process of alternately moving the staff and level was repeated until the final reading was taken with the staff on the summit position of Hill 3. Readings were taken from the horizontal and also the lower and upper stadia lines of the level to provide a check on any staff misreadings and to improve accuracy. If in any set of three readings the average was greater than 1mm different from the horizontal reading, then that set was remeasured. The line survey readings are given in Appendix 2 where it is seen that Hill 3 is 5.24m lower than Hill 2. The summit was found to be unmarked ground by bushes about 5m NE of the track.

The height of Hill 3 is $186.242 - 5.237 = 181.01\text{m}$ (see next section for height of hill 2)

The ten-figure Grid References recorded for the summit of Hill 3 were:-

Garmin Montana 600	SJ 85645 40401	Height = 176m	Acc = averaged
Garmin Etrex 20	SJ 85645 40401	Height = 179m	Acc = averaged
Magellan Explorist 100	SJ 85645 40400	Height = 188m	Acc = 8m
Garmin Oregon 450	SJ 85645 40401	Height = 187m	Acc = 4m

3.5) Hill 2

Once the line survey was complete the Leica NA730 level was re-sited at a convenient position near the summit of Hill 2 and the height difference measured between the summit, an obvious high point on the edge of an old quarry, and the position where the Leica Viva GS15 was to be sited. As described earlier this position was in an area clear of trees and about 15m away from the summit itself. 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 (the vertical offset – see Figure 4 in the Appendix 1)

was then measured with the integral tape. The vertical offset from measuring point to the ground was 0.700m (see Figure 4) plus 0.255m for the tribrach/hook system.

The ten-figure Grid References recorded for the summit of Hill 3 were:-

Garmin Montana 600	SJ 85662 40321	Height = 182m	Acc = averaged
Garmin Etrex 20	SJ 85661 40321	Height = 187m	Acc = averaged
Magellan Explorist 100	SJ 85661 40321	Height = 191m	Acc = 9m
Garmin Oregon 450	SJ 85660 40322	Height = 191m	Acc = 4m

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 ten nearest base stations and the Hopfield model for tropospheric correction are given in the table below.

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	385672.395	0.002	340311.271	0.001	185.276	0.005

Height recorded by Leica GS15 (allowing for vertical offset of 0.955m) = 185.276m

Staff reading for summit position = 0.390m

Staff reading for set-up position = 1.356m

Height difference = 0.966m

Height of Hill 2 = 185.276 + 0.966 = 186.24m

3.6) Hill 1

Next the survey proceeded to Hill 1 situated just inside the SSSI. Using the Leica NA 730 automatic level and staff we quickly confirmed the summit to be by a tree stump as described by Rob Woodall. Next the height difference was also measured between the summit and the previously identified set-up position for the Leica Viva GS15 which was in the clearing. Then the tripod was set-up over this position and the Leica Viva GS15 was fixed to it with a clamp and tribrach (the “short tripod” configuration). The height of the receiver above the ground (the vertical offset) was then measured with the integral tape. The vertical offset from measuring point to the ground was 0.636m (see Figure 3 in Appendix 1) plus 0.255m for the tribrach/hook system.

The ten-figure Grid References recorded for the summit of Hill 3 were:-

Garmin Montana 600	SJ 85814 40163	Height = 182m	Acc = averaged
Garmin Etrex 20	SJ 85815 40161	Height = 187m	Acc = averaged
Magellan Explorist 100	SJ 85814 40162	Height = 191m	Acc = 6m
Garmin Oregon 450	SJ 85815 40162	Height = 198m	Acc = 6m

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 ten nearest base stations and the Hopfield model for tropospheric correction are given in the table below.

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	385791.011	0.002	340163.662	0.001	181.451	0.007

Height recorded by Leica Viva GS15 (allowing for vertical offset of 0.891m) = 181.451m

Staff reading for summit position = 0.436m

Staff reading for set-up position = 1.955m

Height difference = 1.519m

Height of Hill 1 = 181.451 + 1.519 = 182.97m

3.1) Hill 0

The summit height of Hill 0 was determined by line survey, the method being identical to that described for Hill 3 (see Appendix 2). Upper and lower stadia readings were not taken for this survey. The line survey readings are given in Table 2 where it is seen that Hill 0 is 2.16m lower than Hill1. The summit of Hill 0 was found to be ground near the South end of a line of mature beech trees about 15m NE of the track.

Therefore the height of Hill 0 is $182.97 - 2.16 = 180.81\text{m}$

The ten-figure Grid References recorded for the summit of Hill 3 were:-

Garmin Montana 600	SJ 85974 39851	Height = 175m	Acc = averaged
Garmin Etrex 20	SJ 85973 39852	Height = 188m	Acc = averaged
Magellan Explorist 100	SJ 85971 39854	Height = 186m	Acc = 7m
Garmin Oregon 450	SJ 85973 39847	Height = 187m	Acc = 6m

4) Summary of Operating and Process Conditions

GS15	
Data collection summits (min)	35
Number of Base Stations used in Processing for all points	10
Epoch Time (sec)	15
Tropospheric Model	Hopfield
Cut off Angle (degs)	15

5) Discussion of Results

The uncertainties in the height measurement taken by the GS15 for the summits are +/-0.02m associated with its location (hills 4, 3, 2) and +/-0.05m for Hills 1 and 0. For the GNSS

35min data sets the measurement uncertainty is $\pm 0.07\text{m}$. This gives an overall uncertainty in the summit heights of $\pm 0.08\text{m}$.

The heights for the five summits are:

Hill 4 = 184.28m

Hill 3 = 181.01m

Hill 2 = 186.24m

Hill 1 = 182.97m

Hill 0 = 180.81m

6) **Summary and Conclusions**

The **summit of Kingswood Bank** is Hill 2 at grid reference * SJ 85661 40321 and is unfeatured ground on the edge of an old quarry. Its height is **186.24 \pm 0.08m**.

As observed by Rob Woodall the 188m spot height assigned to hill 3 on the 1:50000 map is anomalous. The measurement error of $\pm 3\text{m}$ (3 standard deviations) associated with photogrammetry is significantly exceeded in this case. It is probable that this spot height was intended for Hill 2.

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

John Barnard and Graham Jackson 20 February 2015.

Appendix 1



Figure 1: 1:50k map of Kingswood Bank showing 188m spot height on Hill 3

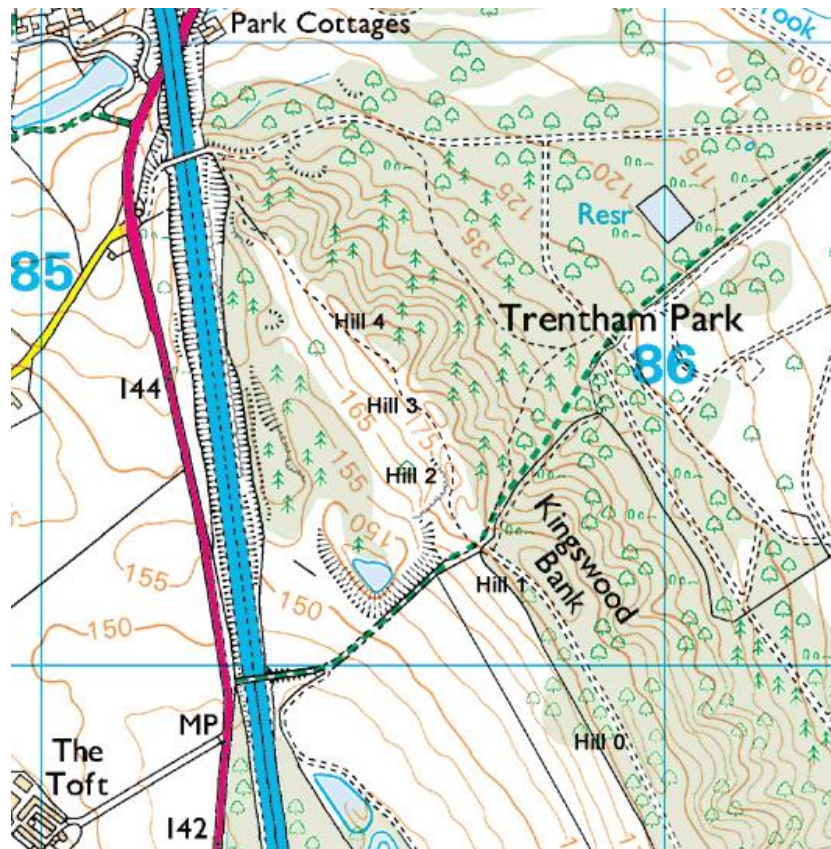


Figure 2: 1:25k map of Kingswood Bank showing 185m contour on Hill 2



Figure 3: GS15 vertical offset at 0.626m on Hill 4



Figure 4: GS15 vertical offset at 0.700m on Hill 2



Figure 5: GS15 vertical offset at 0.636m on Hill 1

Appendix 2

Title:- Survey of Kingswood Bank

Instrument:- Leica NA370 Automatic level

Date:- 12/02/2015

Point Number	Horizontal Line		Lower Stadia Line		Upper Stadia Line		Mean BS metres	Mean FS metres	Height Difference metres
	Backsight BS metres	Foresight FS metres	Backsight BS metres	Foresight FS metres	Backsight BS metres	Foresight FS metres			
Hill 2 to Hill 3 (GJ Level, JB Staff, JJ Data recording)									
1	0.468	4.615	0.443	4.498	0.493	4.733	0.468	4.615	
2	0.139	1.640	0.107	1.400	0.172	1.878	0.139	1.639	
3	0.829	0.418	0.781	0.375	0.878	0.462	0.829	0.418	
						SUM =	1.437	6.673	-5.236
Hill 1 to Hill 0 (GJ Level, JB Staff, JJ Data recording)									
1	0.445	3.743					0.445	3.743	
2	0.185	0.374					0.185	0.374	
3	1.999	0.670					1.999	0.670	
						SUM =	2.629	4.787	-2.158