Survey of Currock Hill

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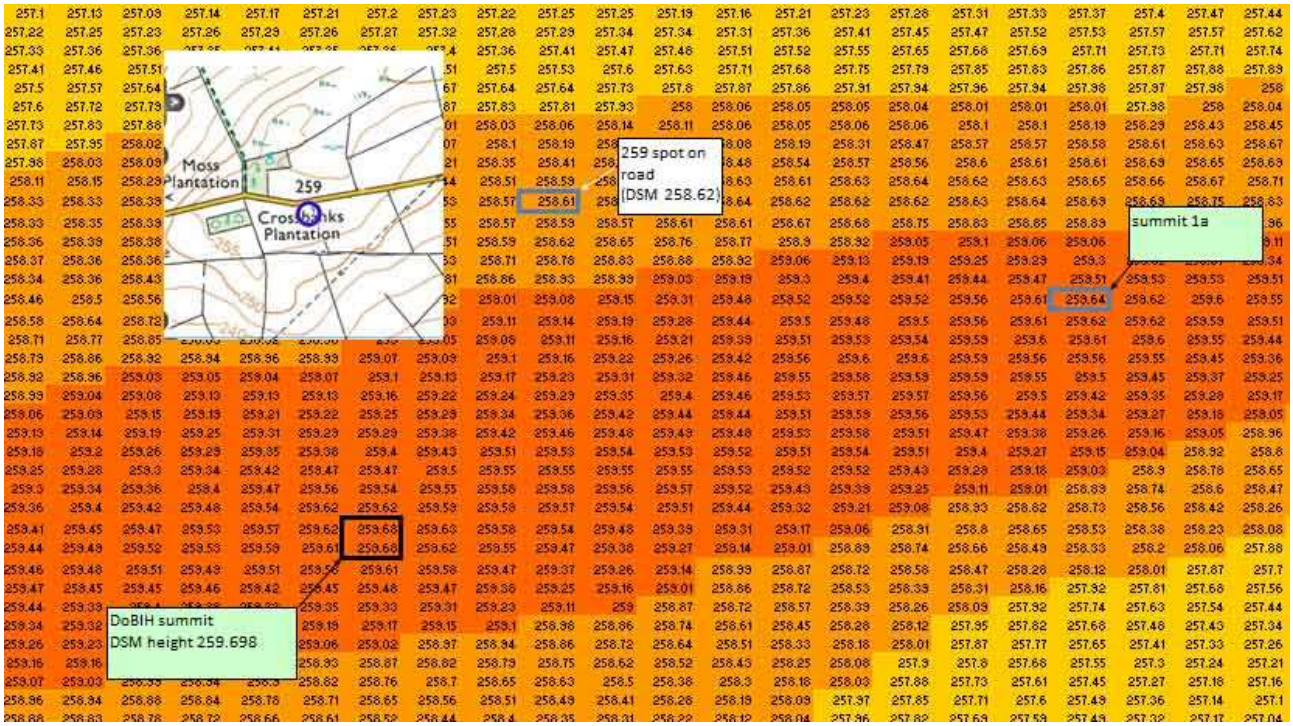
1) Introduction

Currock Hill (Hill Number 19212, Section 35A, OS 1:50000 Map 88, OS 1:25000 Map 307, Grid Ref. NZ096593) is listed as a Hump, a hill with greater than 100m of drop, in the Database of British and Irish Hills (DoBIH). The adjacent hill, Currock Hill East Top (Hill Number 5306, Section 35A, OS 1:50000 Map 88, OS 1:25000 Map 307, Grid Ref. NZ106953) is listed as the Gateshead Unitary Authority County Top and the Administrative County Top for Tyne and Wear.

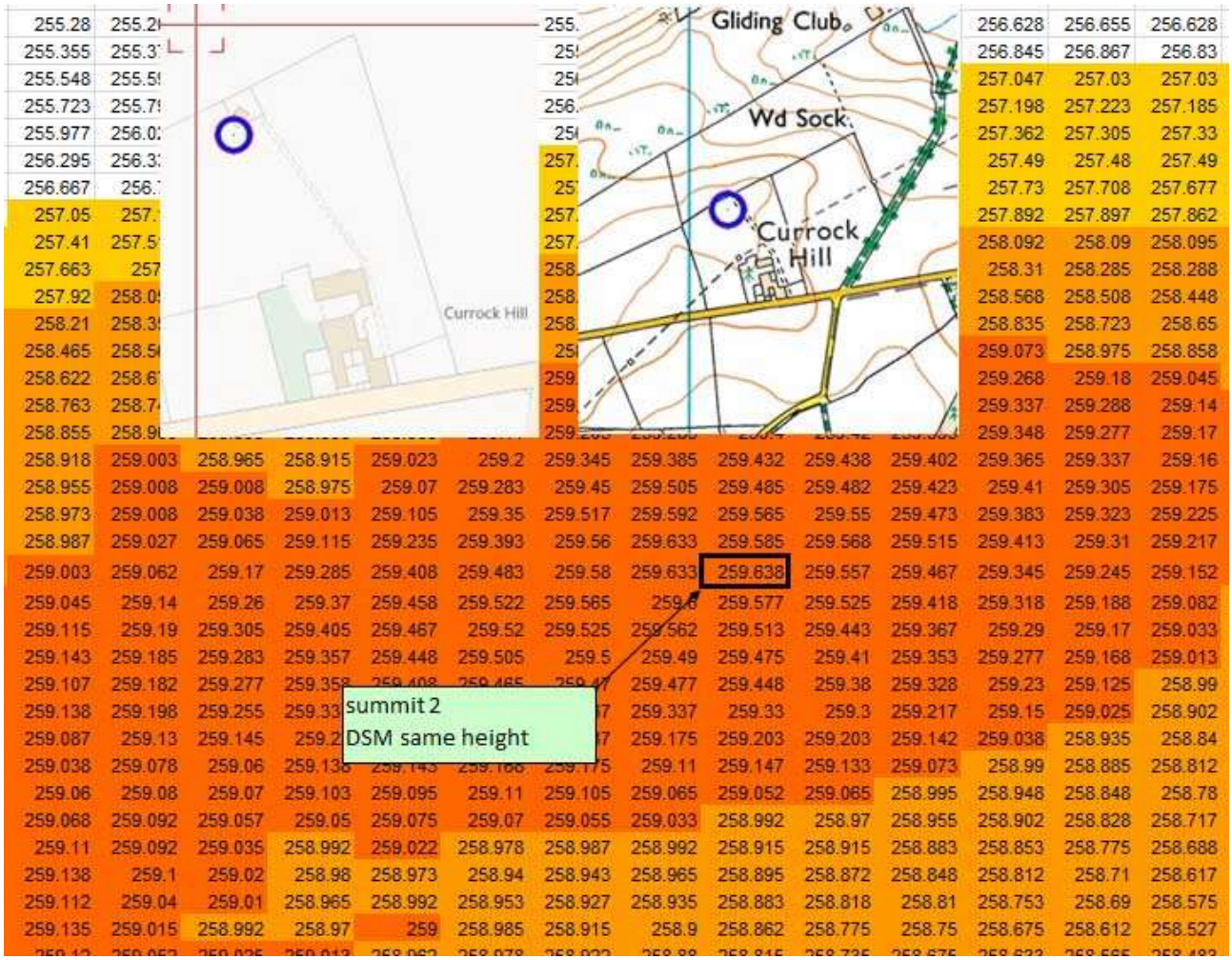
Jim Bloomer visited this area in mid-2016 and from his observations thought the summit of Currock Hill had at that time not been identified correctly. He concluded that the East Top, which is the County Top, was lower than a point to the West by a stone communications tower near Currock Hill Farm.

Further information was subsequently provided from an analysis of the Environmental Agency's LIDAR (Light Detection and Ranging) data by Chris Crocker.



The LIDAR data identified two possible summit locations for Currock Hill, 535m apart and differing in height by only 0.044m. The spreadsheet extract above shows the summit (called Summit 1 in this report) in fields east of Crossbanks Plantation (1:25k map inset). Here there are two high points labelled in the diagram which are about 30m apart (labelled Pt 1 and Pt 2 in this report). The DTM (Digital Terrain Model) heights are 259.68m and 259.64m respectively. 535m ENE of this area is a second potential summit location (called Summit 2 in this report) also with a DTM height of 259.64m (see diagram below). The East Top (Summit 3) gave a DTM height of 258.55m and a summit further east (Summit 4) gave a DTM height of 257.77m. Summit 4 was also

of interest as a possible Tump However LIDAR gave a drop of 28.2m. The data in the DoBIH for Currock Hill were changed accordingly.



The main purpose of this survey was to locate the highest point of Currock Hill and obtain an accurate height.

2) Equipment used and Conditions for Survey

Optical work and Line Surveys 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 dual-frequency and multi-channel, which means it can lock 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 which has been determined as ±8 metres and a height accuracy which has been determined as ±13 metres. There is also a positive bias for height determination on some instruments of a few 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 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 the Ordnance Survey which were post-processed using Leica Geo Office 8.3 software.

Conditions were satisfactory for the survey which took place between 09.30 and 15.00hrs GMT. The weather was cold, 4 degrees Celsius, and dull with high cloud. The wind was light, 4-8mph, and therefore did not interfere with the survey.

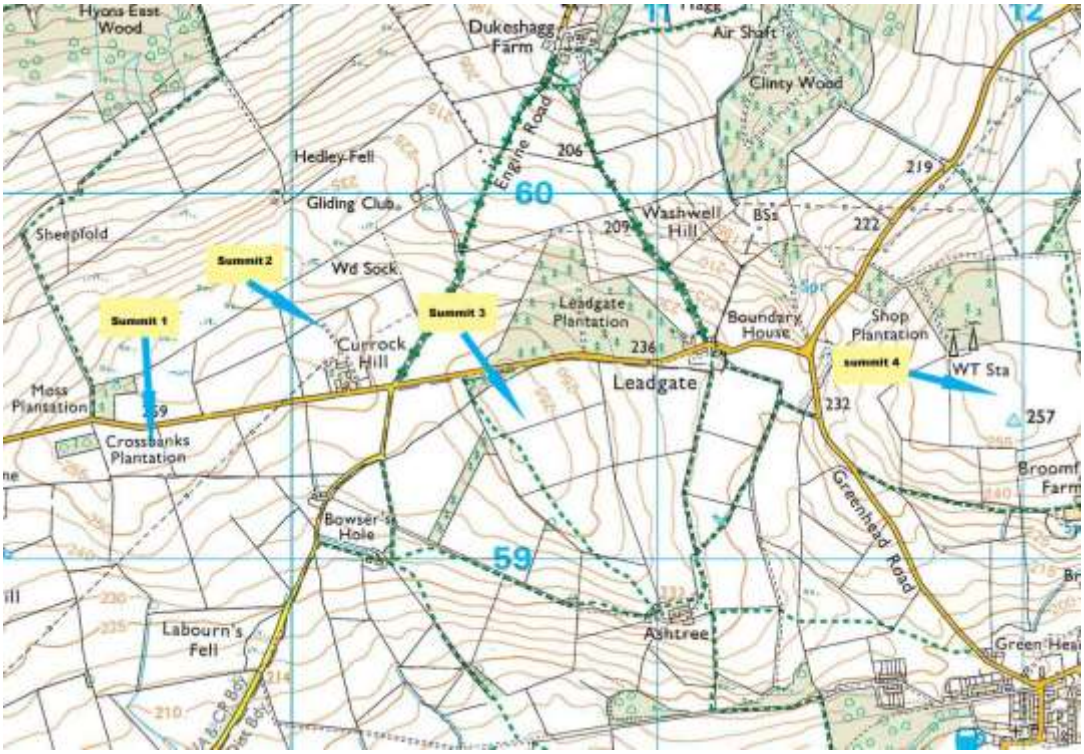
3) Character of Hills

Currock Fell and its associated summits are situated in approximately the centre of the triangle of roads the A68, A69 and A692 and the hill is about 10km North of Consett and a similar distance West South West of Newcastle on Tyne. This is rolling agricultural country interspersed with hedges, fences and areas of trees. There are footpaths, but most of the land is private so not all the tops are accessible. The important area for this survey was the minor road (see extract from Ordnance Survey 1:25000 map below) running West to East from Moss Plantation to Leadgate. There are several high points in the fields along either side of the road and few have any specific feature to identify them. The hedges on either side of the road interfere with visibility and it is quite difficult to get direct line-of-sight from one top to another.

As most of the high points that needed investigation were adjacent to the minor road access was easily obtained through various field gates. The summit near to the tower on the North side of Currock Hill Farm was accessed from the track leading to the Gliding Club after permission had been obtained from Currock Hill Farm to enter on to their land.

4) The Survey – General Strategy

An extract of the Ordnance Survey 1:25000 scale map is shown below. Four important summits have been labelled 1 to 4. Summit 4 has a trig pillar and transmitting towers on its summit area. Although this is a dominating summit in the area, it is not a contender for the highest point. The trig pillar has a map height of 257m and LIDAR gives the highest point at NZ 11932 59378 as 257.8m. This summit was not surveyed but observation through the Leica NA730 automatic level set up on Summit 2 showed it to be clearly lower (see final photograph in the Appendix).



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Summit 3, hill number 5306 and Currock Hill East Top in the DoBIH, is given at NZ10650 58362 with a height from LIDAR of 258.6m and is higher than Summit 4. In 'A walking guide to the County Tops of Wales, the North of England and the Isle of Man' by Howard Mann it is called Leadgate. This is a very flat and grassy area. Measurements by Jim Bloomer with an Abney level showed this summit to be lower than Summit 2 by the telecoms tower. Observations through the Leica NA730 level set up on Summit 2 also showed it to be lower and confirmed the LIDAR data. A photograph of Summit 3 is shown in the Appendix.

This survey then concentrated on the two areas around Summits 1 and 2. LIDAR data gives heights of 259.682m and 259.638m respectively; the 0.044m height difference is insufficiently definitive to identify the summit position. GNSS data from the Leica GS15 were collected at both these summits, but not from the highest point of summit 2. The GS15 needed to be set up in a position where the antenna had an unobstructed view of the sky and a tall building in proximity to the highest point on Summit 2 obstructed much of the North-East area of sky. Setting up at a convenient position away from the building allowed us to find the highest point with level and staff, while GNSS data were being collected, thus saving time. Staff readings for the GNSS set-up position and the highest point of Summit 2 then allowed a correction to be applied to the GNSS data.

For the absolute height measurements in each case the Leica GS15 was mounted on a 2.000m pole and held in a Leica Quickset tripod. For the Summits 1 and 2, 2hrs 20 mins and 1 hour datasets of GNSS data were collected respectively, each with an epoch time of 15 seconds. The data for the Leica Viva GS15 were processed in Leica GeoOffice 8.3 using the ten nearest base stations under 100km distance. These were: - Newcastle - NCAS 17km, Wearhead – WEAR 31km, Morpeth – MORP 34km, Catterick – CATT 62km, Carlisle - CARL 69km, Shap – SHAP 71km, Loftus - LOFT 76km, Kelso - KELO 83km, Eskdalemuir - ESKD 96km and Yearsley –YEAL 98km). 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 computed Tropospheric model was chosen for the calculations to suit the data collection times and the wide difference in height between the base stations and the summit of the hill. A 2.000m offset was entered into Leica GeoOffice to allow for the height of the pole upon which the GS15 was mounted.

4.1) Survey of Summit 2

Summit 2 is crowned by a stone building and a communications mast which are both surrounded by a fence (see photograph in Appendix). Natural ground within the fence was lower than the area just outside of it on the South West side. The Leica NA730 automatic level was set up on a tripod about 8m distant from the South West corner of the fence and staff readings were taken systematically in the area. The highest point was found to be on grass 3.5m South West of the fence corner. Since this point was too close to the stone building and communications tower for the GS15 to have an unobstructed view of the sky (see above), it was set up at a point 14m distant and in a direction of 230 degrees from the summit position which had been marked with a flag. The processed result at this location is given below.

	Easting	**error(1SD)**	**Northing**	**error(1SD)**	**Height(m)**	**error(1SD)**
GS15 Setup	410057.920	0.002	559618.350	0.001	259.229	0.005

In order to calculate the height of Summit 2 the following correction was applied.

Staff Reading at summit position = 0.669m

Staff Reading at GS15 setup position = 1.122m

Therefore, height correction to GS15 measurement is 1.122 - 0.669 = 0.453m

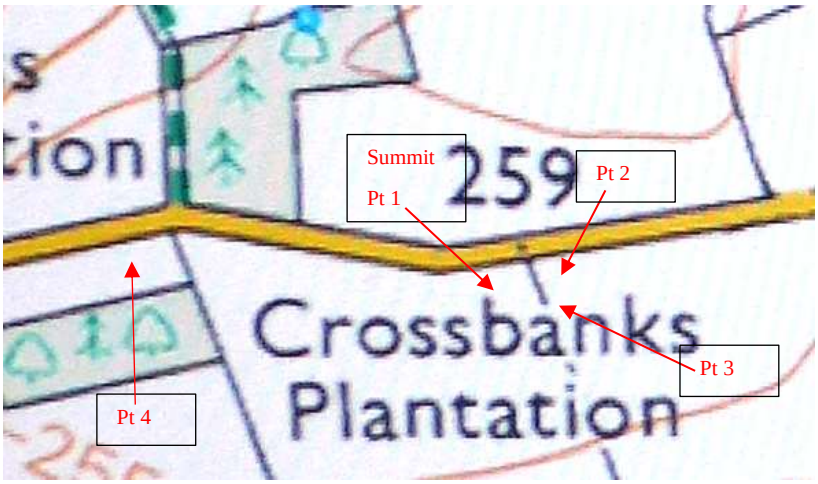
Height of Summit 2 = 259.229 + 0.453 = 259.682m

The following Garmin Grid References were collected at the summit position:-

Garmin Oregon 450	NZ 10068 59628	Accuracy: averaged	Height = 265m
Garmin Montana 600	NZ 10068 59627	Accuracy: averaged	Height = 261m
Garmin Etrex 20	NZ 10070 59630	Accuracy: averaged	Height = 262m

4.2) Survey of Summit 1

The highest area South of the minor road is situated, as shown in the map extract below, near to the 259m marked spot height. This area is hidden from the road by a tall hedge. Further to the West, where the road bends slightly to the North there is a gate which allows access into the "Crossbanks Plantation". Between Pts 1 and 2 there is a 4m wide gap in the thorn hedge adjacent to the road which allowed easy access between the fields.



The Leica NA730 automatic level was set up on a tripod near the gap in the thorn hedge between the two fields so that staff readings could be taken from both areas. The hedgerow itself is sited on a bank for all its length which is about 0.75m high. This bank is clearly a man-made boundary between the fields and was either constructed prior to the planting the hedge or at the time of planting. It was not considered an eligible candidate for the highest point of Summit 1. The highest point in this area was found to be the position labelled Pt 1 in the diagram above. The next highest point is marked Pt 2 in the diagram.

Staff reading at Pt 1 = 0.832m

Staff reading at Pt 2 = 0.875m

Pt 1 is higher than Pt 2 by 0.043m.

The Leica NA730 was repositioned near Pt 1 so that the area to the West could be observed and staff readings taken. The ploughed field to the South of the minor road contains the highest point in this area and staff readings were taken here to identify it, labelled Pt 4. The results were:-

Staff reading at Pt 1 = 0.12m

Lowest staff reading at Pt 4 = 0.66m

Pt 1 is higher than Pt 4 by 0.54m

As Pt 4 is 0.5m lower than Pt 1 no further surveying was needed in this area.

Once the highest point had been identified in the above process, the Leica GS15 was set up over this point and GNSS data were collected. The processed result is given below.

	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
Summit 1 Pt1	409625.291	0.002	559332.288	0.001	259.701	0.004

The two GNSS data sets show that Summit 1 is higher than Summit 2 by 259.701 – 259.682 = 0.019m.

The following Garmin grid references were collected at the summit position (Pt 1): -

Garmin Oregon 450	NZ 09624 59333	Accuracy: averaged	Height = 265m
Garmin Montana 600	NZ 09626 59333	Accuracy: averaged	Height = 263m
Garmin Etrex 20	NZ 09624 59332	Accuracy: averaged	Height = 259m

A Garmin grid reference for Pt 2 was also taken: -

Garmin Oregon 450	NZ 09650 59356	Accuracy: averaged	Height = 266m

Since we knew from the LIDAR data that the height difference between Summit 1 and Summit 2 was small we wished to complement the GNSS measurements with optical measurements made with the NA730 level. However, it was not possible to observe Summit 2 from Summit 1 because of the high hedge and therefore an alternative position had to be located that allowed Summit 2 to be visible. A convenient point was found and is labelled Pt 3 in the diagram above. Although Pt 1 was not visible from Pt 3, Pt 2 was visible and the height difference between Pt 1 and Pt 2 had already been measured. With the level set up at a convenient position staff readings were then taken from Pts 2 and 3 which enabled a height difference between Points 1 and 3 to be calculated.

Staff reading at Pt 2 = 0.714m

Staff reading at Pt 3 = 0.923m

Therefore, Pt 2 is higher than Pt 3 by 0.923 – 0.714 = 0.209m

As Pt 1 is higher than Pt 2 by 0.043m (see Section 4.2) then

Pt 1 is higher than Pt 3 by 0.209 + 0.043 = 0.252m

4.3) Optical Measurement of Summits 1 and 2

Although requiring a frequent number of trips between these two summits (Thanks to Jim for providing the transport and the patience to do it!), we managed to get staff readings from each summit to the other, albeit by an indirect method from Pt 3. In the dull conditions, reading the staff through the level at a distance of 500m was not easy and we could only take readings to the nearest centimetre over this distance as given in the calculations below.

Summit 1 to Summit 2: -

The Leica NA730 level was set up on its tripod at approximately the position of Pt 3 so that a clear view of both Pt 2 and Summit 2 could be seen and staff readings at these points were taken.

Staff reading to Summit 2 = 0.72m

Staff Reading to Pt 2 = 0.715m

Hence staff reading to Summit 1 = 0.715 – 0.043 = 0.67m

Therefore, Summit 1 is higher by 0.05m

Summit 2 to Summit 1: -

For this determination the Leica NA730 level was set up on its tripod directly over Summit 2. The height of the centre of the lens from the ground at this point was measured with the staff. A staff reading to Pt 3 on Summit 1 was also taken.

Staff reading to Pt 3 = 1.00m

Since the correction from Pt 3 to Summit 1 (see Section 4.2) is 0.252m,

Corrected staff reading to Summit 1 = 1.00 – 0.25 = 0.75m

Staff measurement to Summit 2 = 0.80m

Therefore Summit 1 is higher by 0.05m.

The close agreement between the two measurements is fortuitous because the correction for earth curvature is significant when sighting over long distances. The effect is to lower the observed height of the sighted object, increasing the staff reading. Each measurement included one sighting over 500m for which the correction is 0.017m. As Summit 1 was measured as higher than Summit 2, the corrected height difference becomes 0.03m in the first measurement and 0.07m in the second. The correction for earth curvature cancels when the two measurements are averaged, as does the systematic component of the collimation error.

4.4) Currock Hill East Top

An approximate height for this summit (Summit 3) was obtained by sighting from Summit 2 and estimating the distance between the highest ground and the stadia lines. A photograph taken through the level is given in the Appendix. The level line is the horizontal line in the centre of the field of view and the two smaller horizontal lines above and below it are the stadia lines. The distance between the stadia lines is $1/100^{th}$ of the distance between the level and the object in view.

The horizontal distance, as measured from the map, is 700m. The distance between the stadia lines is therefore 7m. The distance from the sighted ground to the level line is 0.29 of the distance between the stadia lines, i.e. 0.29 x 7 = 2.01m. The height of the level above the ground on Summit 2 was 0.8m and earth curvature over 700m is 0.04m. Therefore the ground in the photograph is 2.01 - 0.8 - 0.04 = 1.17m lower than Summit 2. Since Summit 2 was measured as 259.7m, the height of Currock Hill East Top is about 258.5m. The LIDAR height is 258.55m.

5) Discussion of Errors

5.1) GNSS measurement

The conditions used for the GS15 GNSS measurements are summarised below: -

Variable	Summit 2	Summit 1
Data collection summit (min)	61	141
Number of Base Stations used in Processing for all points	10	10
Epoch Time (sec)	15	15
Tropospheric Model	Computed	Computed
Geoid Model	OSGM36(15)	OSGM36(15)
Cut off Angle (deg)	15	15

For 1 and 2 hour GNSS datasets, previous work has shown the measurement uncertainty in height to be less than ±0.06m and ±0.05m respectively (3 standard deviations). The associated uncertainty in height in determining the correct position for either of the two summits is estimated as ±0.02m. Assuming independence of errors, the uncertainty in the height difference between summits 1 and 2 is $\sqrt{\{(0.06)^2+(0.05)^2+(0.02)^2+(0.02)^2\}} = \pm 0.08$m.

5.2) Optical measurement

The main sources of error are the uncertainty in sighting the staff and the collimation error of the level. The former is determined by the accuracy one can read a staff at a distance of 500m with a X30 telescope on the optical level, which is not easy to gauge. Since the individual centimetre segments of each E of the staff were identifiable, our best estimate is ±0.01m.

Any systematic error in the collimation of the level will cancel when forward and backward measurements are averaged, leaving a random error which is reduced by averaging. The random error of the NA730 has been determined in an experiment (prompted by this survey and undertaken one month later) reported in www.hills-database.co.uk/error_in_level_and_staff_measurements.pdf. The standard deviation of a measurement using single wire levelling is 1.05mm per 100m distance. The standard error of the mean of forward and backward determinations over 500m is therefore $5*1.05/\sqrt{2} = 3.7$mm, which when multiplied by 3 gives a maximum error of ±0.011m for this component of the total error.

The errors in measuring the height differences over the short legs are of the order of 1mm or less, which can be ignored as their contribution to the total error is negligible. They also discount the possibility of Pt 2 being a candidate for Summit 1. Compounding the two errors above and factoring in the ±0.02m uncertainty associated with each summit position gives a total error of ±0.031m for the height difference between summit 1 and 2.

The difference between the forward and backward determinations of the height difference is 0.038m after correcting each determination for earth curvature. The systematic component of the collimation error of the level was estimated as 1mm per 100m distance in the experiment referenced above, which contributes 10mm to the figure above. The maximum expected error in the difference between the forward and backward measurements is 0.036m which is slightly less than the 0.038m observed. It is possible that the sighting error has been underestimated. Alternatively, small variations in the staff placements on Pt 2 and Pt 3 between the various sightings might account for a centimetre.

5.3) LIDAR

The summit heights and positions inferred from the LIDAR DTM data at 1m spacing are given below together with the GNSS determinations.

Summit	Height LIDAR	Position LIDAR	Height GNSS	Position GNSS
Summit 1 Pt 1	259.682	NZ 09624 59332	259.701	NZ 09625 59332
Summit 1 Pt 2	259.643	NZ 09648 59356	259.658	NZ 09651 59358*
Summit 2	259.638	NZ 10070 59626	259.682	NZ 10069 59630*

*Grid references taken from Garmin receivers and converted to OSTN15

The slight differences in location for the second and third summits agree are well within the error in the Garmin instrument. The published accuracy figures for the LIDAR heights are 0.15m root mean square error for absolute height (reducing to 0.05m in the most recent surveys) and 0.05m for relative height. The agreement with the GNSS summit heights is well within these figures even though they do not include the error due to the 1m grid missing the summit (hence summit heights

tend to be underestimated) nor the modelling error in estimating the ground height beneath the vegetation[1].

The maximum expected error in the height difference between Summit 1 and Summit 2 is ±0.15m assuming the quoted LIDAR figure applies to the difference between two neighbouring heights. As explained above, this will be an underestimate due to the spatial resolution of the grid and vegetation. A study of the accuracy of LIDAR data in progress by C Crocker suggests a maximum error in the region of ±0.3m may be appropriate in this terrain.

5.4) Summary

The height difference between Summit 1 and Summit 2 measured by the three techniques is tabulated below.

Technique	Height difference	Maximum error
GNSS	0.019	0.08
Optical	0.05	0.03
LIDAR	0.044	0.3

The optical measurement is sufficient on its own to establish that Summit 1 is higher. In theory, the best estimate of the height difference is obtained by taking a weighted average of the three measurements. This gives a pooled estimate of 0.046 ± 0.028m.

The discussion of the optical measurements at the end of section 5.3 raises the possibility that the total error in this determination is greater than ±0.03m. However, it is unlikely to be sufficient to cast any doubt on the inference that Summit 1 is higher.

6) Conclusions

The **summit** of **Currock Hill (Summit 1 Pt 1)** is at **NZ 09624 59330*** and is the highest point of grass 25m South of the road, 15m from a thorn hedge. **Its height is 259.70±0.05m**.

***** Grid references given in Summary and Conclusions are for users of Garmin GNSS receivers

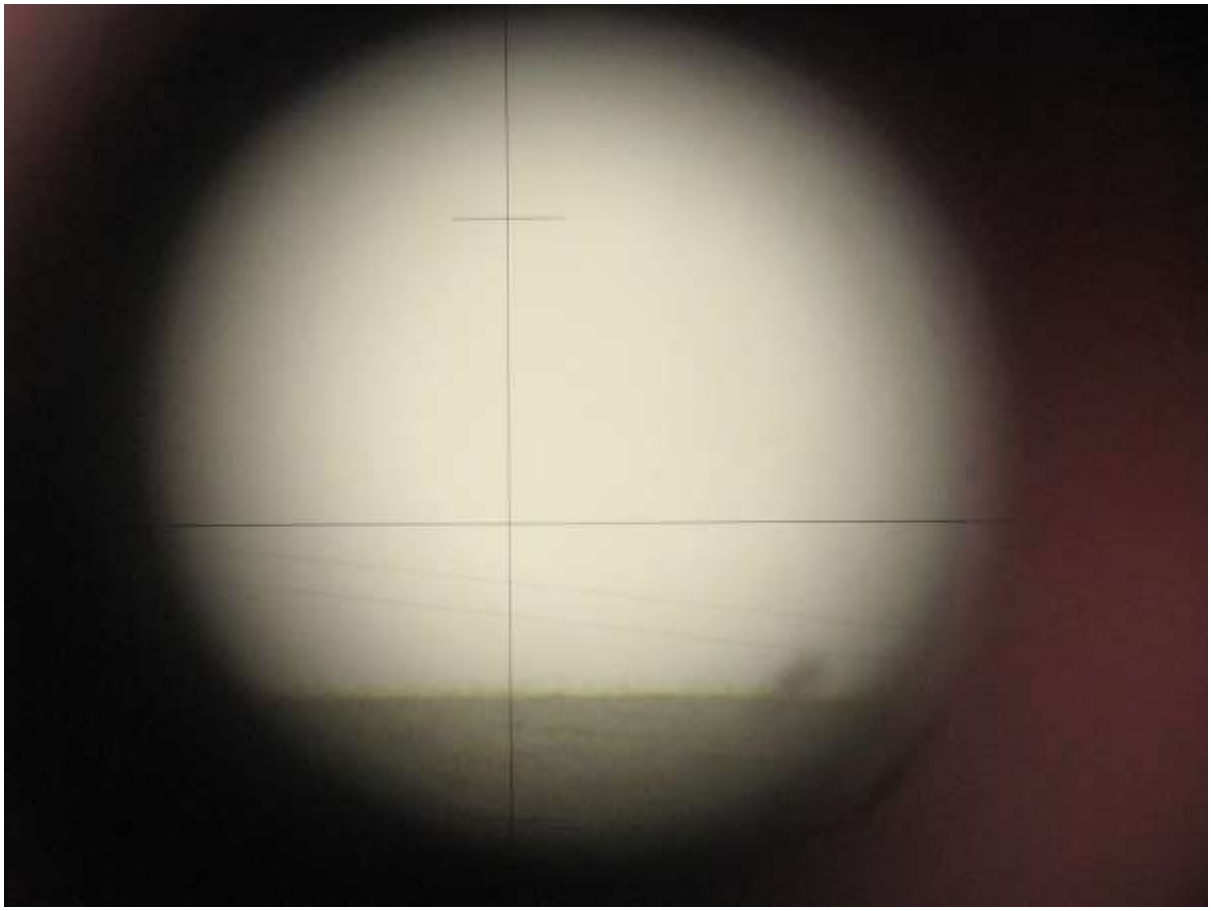
John Barnard, Jim Bloomer, Chris Crocker and Graham Jackson, 2 March 2017.

[1] The DTM is a "bare earth" model, whereas the DSM dataset gives the heights reflected by the laser. For the three summits in the table the DSM heights are 259.698, 259.650 and 259.643, respectively.

Appendix

Leica Viva GS 15 set up position on Summit 2

Leica Viva GS15 set up on Summit 2. Highest point is near front right corner of fence.



Currock Hill East Top as seen from Currock Hill Summit 2 by the communications tower

Summit 4 as seen from Currock Hill Summit 2 by the communications building. Trees and bushes prevented an estimate of its height.