Survey of Heaton Park

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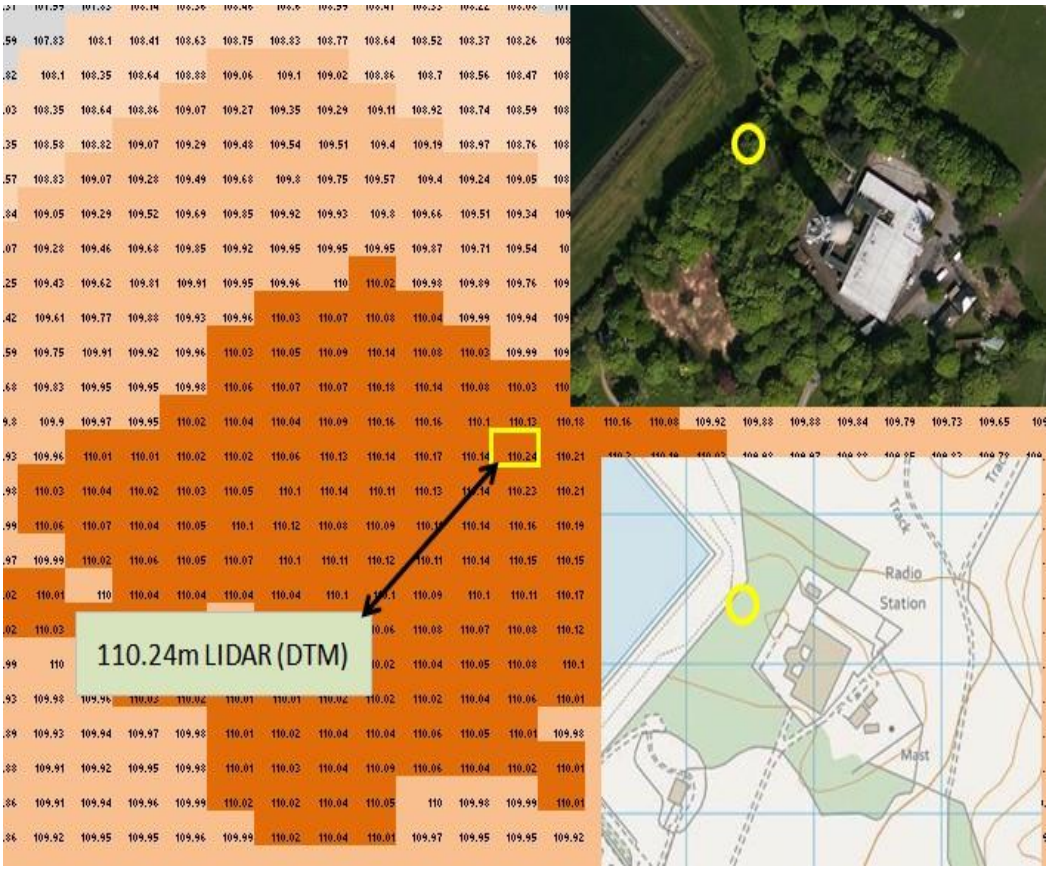
1) Introduction

Heaton Park (Hill Number 5516, Section 36, OS 1:50000 Map 109, OS 1:25000 Map 277, Grid Ref. SD834045) is listed as the Manchester Metropolitan District top in the Database of British and Irish Hills (DoBIH). A folly called The Temple adorns the official summit and by it is a notice board proclaiming its status as the highest point within the boundary of Manchester. The views on a good day are extensive with Jodrell Bank easily visible across the city and 34km to the South. The folly itself is an imposing circular structure built of stone and standing about 12m high. It is surrounded by a circular balustrade and the ground within the balustrade is paved. The spot height on the 1:25000 map is by the entrance way in the balustrade that gives access to the paved area around The Temple. Recently, it has been reported by George Gradwell and his brothers David and Ed that this might not be the highest point, as the 1:25000 map shows a tiny 110m contour about 400m to the West between a BT communications tower and Heaton Park Reservoir. This area is wooded, but accessible to the public.

Further research by George Gradwell using the Environment Agency's LIDAR (**Li**ght **D**etection **a**nd **R**anging) data has added weight to this claim. LIDAR data at the BT tower summit showed that there was an area of ground over 110m high, the highest point being ground close to Heaton Park Reservoir perimeter fence. The DTM (Digital Terrain Model) gives a height of 110.24m at SD 83139 04840 (OSGB).



The diagram above shows this along with an aerial photograph and 1:10000 map of the same area. LIDAR data for the Temple summit is shown below, again with the 1:10000 map and aerial photograph of the same area.

The LIDAR data is colour coded with the medium grey showing the lowest ground, the light grey the next higher, then the yellow, brown and finally the blue which is the highest area on the map. The dark brown is the folly with the blue being the apex of the roof. The yellow area is the paving that surrounds the folly and the circle of yellow is the balustrade. These features may be discerned in the two photographs. The highest 'natural' ground was identified at SD 83502 04551 and is 107.72m. The Environment Agency states that the height error for this technique is +/-15cm and positional error +/-5cm.

The purpose of the survey was to determine which of these two positions was the higher.

2) Equipment used and Conditions for Survey

A Leica NA730 Professional Automatic level (X30 telescopic system)/tripod system and a "1m" **E**-staff extendable to 5m were used to determine the positions of both summits.

Absolute heights were measured using a Leica Viva GS15 receiver. This receiver 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 receiving 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 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 GeoOffice 8.3. Repeated measurements with the Leica Viva GS15 instrument made on the same point yield a height precision of +/-0.06m.

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 +/-8 metres and a height accuracy of no better than +/-15 metres. Some recently produced hand held GPS Garmin receivers can also receive signals from GLONASS satellites which greatly improve the speed at which these instruments can achieve a satellite "fix".

Conditions for the survey, which took place between 10.45hr and 14.45hr GMT, were fair. The weather was cool, 3 degrees Celsius, but mist throughout the survey limited visibility to 50m or less. The wind was light and less than 5mph.

3) The Survey

3.1) Character of Hill

Heaton Park lies on the northern boundary of the City of Manchester and covers an area of about 3km^2. It is easily accessed from the M60 motorway just to the North and there are five large car parks around its periphery. It is a popular venue for families and boasts woodland, open parkland and a golf course. The Temple lies near the centre of the park while the high point by the BT tower lies on the north-western edge and by Heaton Park Reservoir. Metalled pathways run from The Temple to within 100m of the high point by the BT tower. The last 100m is in trees but of easy access. The trees are deciduous and being winter time, cover was open. Also at the time of the survey there was little ground cover. In summer this is not the case, as we understand there is then an extensive understory of dense vegetation.

3.2) Summary of Survey Method

Upon arrival we made our way first to the area by the BT tower and reconnoitred the summit area in the trees. Regrettably, the tree cover, although largely deciduous, was sufficiently dense to preclude our setting up the GNSS receiver at the highest point. Instead we identified a convenient route through the trees and to a position on the grass parkland well away from the woodland. This position was about 150m away from the area of the summit. Our original plan was next to reconnoitre The Temple summit before commencing on survey work. However, having explored the summit by the BT tower, the decision was made to concentrate on this the more complicated part of the days surveying.

3.3) The BT Summit

Upon returning to the summit area in the trees, the Leica NA730 automatic level was set up at a convenient position and staff readings were taken in three areas which vied for being the highest point. One of these was by the fence surrounding the BT tower, another was near the fence by the reservoir and the third area was about 50m SW of this second position and also near the reservoir fence. This last position was quickly rejected, as preliminary measurements showed it to be over 1m lower. For the remaining two areas staff readings were taken in each area to determine the local high points which were marked with flags. Finally, staff readings were taken of the highest position at each location.

Staff reading by BT tower fence = 0.77m

Staff reading near reservoir fence = 0.43m

The ground near the reservoir fence is 0.34m higher than the ground by the BT tower fence.

Next a line survey was carried out in order to determine the height difference between the summit and the set-up position for the Leica Viva GS15 GNSS receiver, as identified by the earlier

reconnoitre. The staff was held vertically on the summit position and the Leica NA730 automatic level set up on a tripod at a convenient position. Once a set of readings had been taken (Backsight Reading), the staff was then moved to a position further down the hill towards the set-up position, but the level was not moved apart from a rotation through "180 degrees" to take another set of readings (Foresight Readings). Each set comprised a reading of the central level line and the upper and lower stadia lines. The average of these three reading was then calculated and, provided this average was within 1mm of the central line reading, then the set was accepted and the line survey continued. The process of alternately moving the staff and level was repeated until the final reading was taken with the staff positioned at the identified set-up position for the Leica GS15. This process was then repeated in the reverse direction back to the summit. The difference between the two sets of measurements (the closing error) gives the precision of the determination. The line survey determined the height difference between set-up position and summit to be 5.177m. The details of the line survey are given in Appendix 2.

Next the Leica Viva GS15 receiver was mounted on a 2.000 metre pole supported by a Leica "Quickset" tripod (see photograph in Appendix 1). GNSS data were collected at the point for 1 hour 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. The results are given in the table below:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	383175.803	0.001	404708.360	0.001	105.075	0.007

The height of the GS15 set-up position = 105.075m (this result takes into account the 2m pole)

Height difference between the GS15 setup position and summit = 5.179m

Height of BT Summit = 105.075 + 5.179 = 110.254m

The ten figure grid references recorded by hand-held Garmin GNSS receivers for the summit were:-

Garmin Oregon 450	SD 83136 04846	Accuracy: averaged	Height = 125m
Garmin Montana 600	SD 83139 04845	Accuracy: averaged	Height = 118m
Garmin Etrex 20	SD 83138 04844	Accuracy: averaged	Height = 121m
Garmin Fenix 3	SD 83143 04847		
Garmin GPSmap 60cx	SD 83143 04847		

The ten figure grid references recorded by hand-held Garmin GNSS receivers for the GS15 set-up position were:-

Garmin Montana 600	SD 83178 04715	Accuracy: averaged	Height = 108m
Garmin Etrex 20	SD 83177 04712	Accuracy: averaged	Height = 108m
Garmin Fenix 3	SD 83177 04720		
Garmin GPSmap 60cx	SD 83177 04720		

3.4) The Temple

A folly called The Temple sits on the summit of the official Manchester Metropolitan District top and is surrounded by a wide (circa 7m) paved area that slopes slightly down towards an encircling stone balustrade (see photograph in Appendix 1). It is highly likely that the whole of the summit area has, in the past, been extensively landscaped. Outside of the balustrade the hill comprises short mown grass in common with much of the rest of the park. This was taken to be the natural ground, but with the above caveat.

Next the tripod was set up at a convenient position within the balustrade in order to give the best view of the encircling ground and minimise that obscured by The Temple. Staff readings were then taken of the ground immediately outside of the balustrade following its course around the folly. Note that the ground fell away from the balustrade in all directions. The highest point was found to be about 2m from the path leading to the folly (see photograph in Appendix 1). The 1:25000 map gives a 108m spot height just on the far side of the path. All the measurements taken by the balustrade following its course around The Temple were within 5cm of one another.

Next the Leica Viva GS15 receiver was mounted on a 2.000 metre pole supported by a Leica "Quickset" tripod (see photograph in Appendix 1). GNSS data were collected at this point for 1 hour 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. The results are given in the table below:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	383502.416	0.001	404552.910	0.001	107.667	0.011

The height of ground by The Temple = 107.667m (this result takes into account the 2m pole)

The ten figure grid references recorded by hand-held Garmin GNSS receivers for the Temple summit were:-

Garmin Oregon 450	SD 83504 04558	Accuracy: averaged	Height = 113m
Garmin Montana 600	SD 83505 04558	Accuracy: averaged	Height = 111m
Garmin Etrex 20	SD 83506 04559	Accuracy: averaged	Height = 111m
Garmin Fenix 3	SD 83502 04559		
Garmin GPSmap 60cx	SD 83505 04557		

4) Summary of Operating Conditions

The latest geoid model was employed and just over one hour's data were collected at each point. The cut-off angle of 15 degrees prevents data from satellites close to the horizon being employed in the processing; at these low angles errors due to atmospheric effects compromise the accuracy of the data.

Parameter	**GS15**
Data Collection BT summit (min)	74
Data collection Temple (min)	64
Number of Base Stations used in Processing for all points	10
Epoch Time (sec)	15
Tropospheric Model	Computed
Geoid Model	OSGM15
Cut off Angle (degs)	15

5) Coordinate Recovery Analysis

In order to verify the precision and consistency of a GNSS dataset, Ordnance Survey recommends a procedure called Coordinate Recovery Analysis. Instead of processing the data with reference to all the nearest OS Base Stations under approximately100km distance, as used in this report, the data is first processed with reference to only the nearest Base Station (in this case Manchester). The data is 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, two important ones are presented in the tables below. "Height Difference **U** metres**"** is the vertical height difference between the height of the Base Station as measured in this survey compared with the actual OS value. "Separation $\mathbf{D_{ij}}$ metres" is the distance in 3-d space between the measured and actual OS values for each Base Station. The results for the survey of the BT summit are presented below.

Base Station	Code	Distance to Survey Point km.	Height Difference **U** metres	Separation $\mathbf{D_{ij}}$ metres
Manchester	MANR	3	Reference	Reference
Daresbury	DARE	33	-0.0385	0.0386
Buxton	BUXT	41	-0.0457	0.0458
Leek	LEEK	49	-0.0397	0.0398
Leeds	LEED	49	-0.0130	0.0157
Blackpool	BLAP	58	-0.0567	0.0568
Hoober	HOOB	59	-0.0194	0.0208
Giggleswick	GIGG	60	-0.0359	0.0368
St Asaph	ASAP	87	-0.0602	0.0604
Shrewsbury	SHRE	96	-0.0403	0.0408

The results for the BT Summit show a consistent dataset as all measured OS Base stations are within 0.06m distance and height of the OS actual values even for Base Stations up to 100km distance.

The results for the Temple summit are shown in the following table:

Base Station	Code	Distance to Survey Point km.	Height Difference **U** metres	Separation $\mathbf{D_{ij}}$ metres
Manchester	MANR	3	Reference	Reference
Daresbury	DARE	33	-0.0709	0.0717
Buxton	BUXT	41	-0.0725	0.0727
Leek	LEEK	49	-0.0684	0.0688
Leeds	LEED	49	-0.0139	0.0155
Blackpool	BLAP	58	-0.0396	0.0407
Hoober	HOOB	59	-0.0313	0.0331
Giggleswick	GIGG	60	-0.0170	0.0171
St Asaph	ASAP	87	-0.0909	0.0919
Shrewsbury	SHRE	96	-0.0777	0.0783

Once again all the results are within the accepted limit of 0.1m, although St Asaph is only just so.

Note there is also a small bias in that all the height differences for U in both datasets are negative; the cause may lie with the fact that the Manchester Base Station is in very close proximity to the survey position.

Values for U and D_{ij} for 2hr datasets are usually 0.05m or less, which shows the advantage of longer collection times.

6) Discussion of Results

For the Leica Viva GS15, a one hour data collection time gives results with a measurement uncertainty of +/-0.06m. This measurement uncertainty applies to both summit measurements. The summit positions were found to within +/-0.05m of height as determined by the staff measurements. Therefore, the overall measurement uncertainty for both summit determinations from the Leica Viva GS15 is +/-0.08m [square root (0.06^2 +0.05^2)]. The line survey gave a closing error of 0.001m over an order of magnitude less than the error associated with the GNSS results.

The height of the BT summit was measured to be 110.26m at SD 83139 04843 (average of hand-held receivers converted to OSTN15) and that of the Temple summit 107.67m at SD 83502 04552 a difference of 2.6m to the nearest 0.1m. This value is well outside the estimated experimental measurement uncertainty of +/-0.08m.

The LIDAR results for the two summits are:

BT Tower summit: 110.24m at SD 83139 04840

Temple summit: 107.72m at SD 83502 04551

The agreement in height for the two methods is excellent and well within the +/-15cm given by the Environment Agency. The 3m difference in position between LIDAR and the average of the hand-held receivers (the GS15 had to be set up outside the tree covered summit about 150m away) for the BT summit is also well within the measurement uncertainty of the hand-held receivers.

7) Summary and Conclusions

The **summit** of **the Manchester Metropolitan District top** is at grid reference * SD 83140 04846 and is ground near the BT tower and close to the Heaton Park reservoir fence. Its height is **110.3m+/-0.08m**.

The currently accepted County Top by the **Temple** is at * SD 83503 04556 and is ground by the entrance to the folly. Its height is **107.7+/-0.08m.**

- NB: Grid references for Garmin receivers are quoted in the summary.

John Barnard, George Gradwell & Graham Jackson, 30 Dec 2017

Appendix 1

The BT summit marked with the white flag

Leica Viva GS15 set up away from trees: BT summit hidden by fog in top left of picture

Leica Viva GS15 set-up at Temple summit

Leica Viva GS15 set-up at Temple summit

Appendix 2

Heaton Park BT Summit

Instrument:- Leica NA730 **Date:- 18 December 2017**

	Horizontal Line		Lower Stadia Line		Upper Stadia Line							
Point Number	Backsight R	Foresight F	Backsight R	Foresight F	Backsight R	Foresight F		Mean BS	Mean FS	Height Diff	BS Distance	FS Distance
	(m)	(m)	(m)	(m)	(m)	(m)		(m)	(m)	(m)	(m)	(m)
Top to GS15 Data Collection Point (GVJ Staff, GG Data and JB Level)												
1	0.428	1.265	0.342	1.110	0.514	1.420		**0.428**	**1.265**		17.200	31.000
2	0.712	4.735	0.666	4.628	0.758	4.840		**0.712**	**4.734**		9.200	21.200
3	0.165	0.276	0.132	0.155	0.199	0.397		**0.165**	**0.276**		6.700	24.200
4	0.799	1.006	0.692	0.886	0.907	1.129		**0.799**	**1.007**		21.500	24.300
							Sum =	**2.105**	**7.282**	**-5.178**	**54.600**	**100.700**
GS15 Data Collection Point to Top (GVJ Staff and JB level)												
1	1.006	0.798	0.886	0.690	1.129	0.905		**1.007**	**0.798**		24.300	21.500
2	0.305	0.195	0.184	0.161	0.428	0.230		**0.306**	**0.195**		24.400	6.900
3	4.716	0.694	4.611	0.648	4.823	0.740		**4.717**	**0.694**		21.200	9.200
4	1.280	0.443	1.126	0.346	1.432	0.538		**1.279**	**0.442**		30.600	19.200
							Sum =	**7.309**	**2.129**	**5.179**	**100.500**	**56.800**