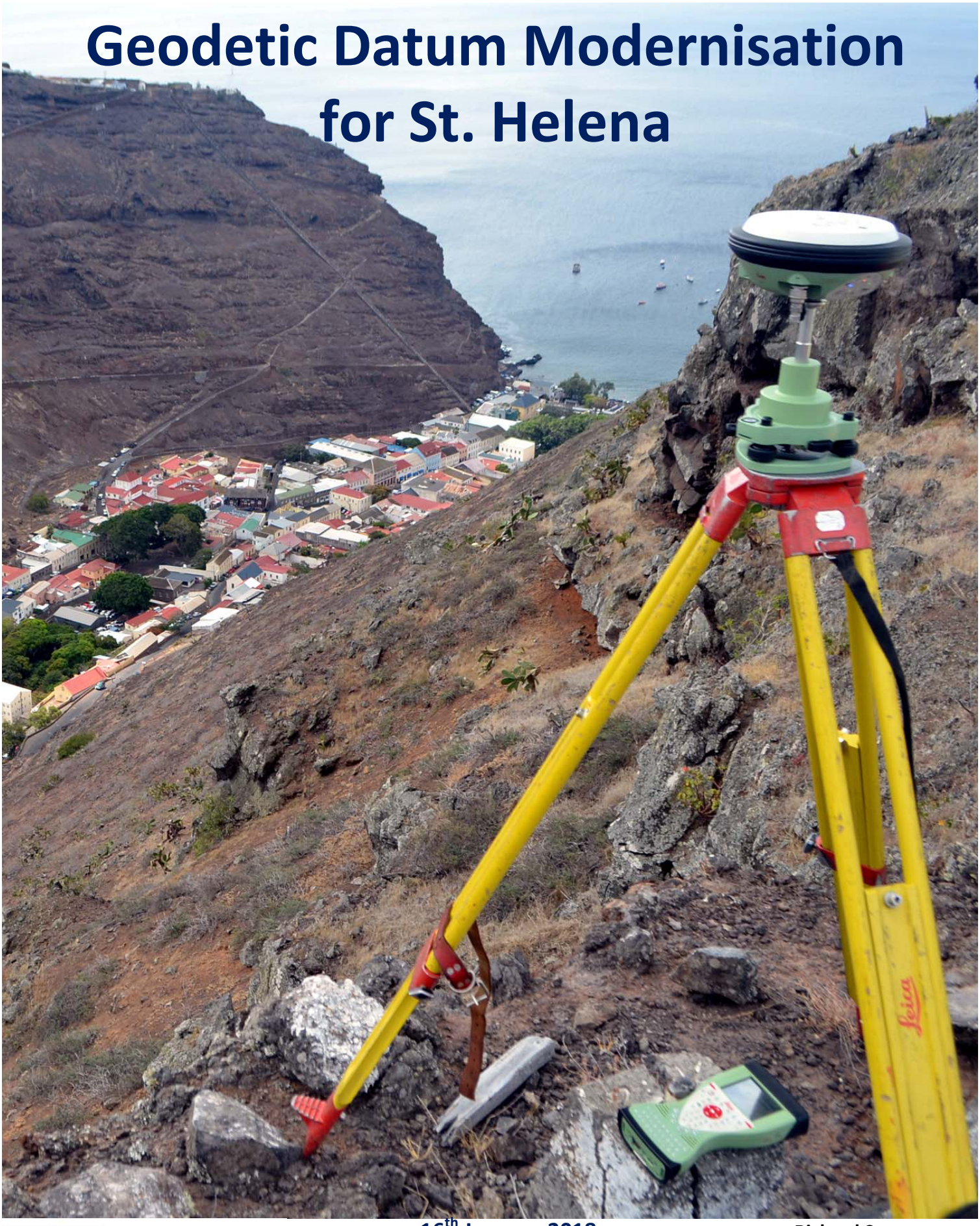
Geodetic Datum Modernisation for St. Helena



St Helena Government

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Geodetic Datum modernisation for St Helena

Background and motivation

The existing geodetic datum used on St Helena is the Astro DOS 71/4 datum (also referred to as the St Helena 1971 datum in the EPSG Registry) established by the UK Directorate of Overseas Surveys in 1972 and forms the basis for the current series of topographic maps published in 1990. Astro DOS 71/4 also defines the St Helena Local Grid 1971 (SHLG71) that is widely used on the island for planning, cadastral surveying and civil engineering (although the new airport and wharf civil works uses a slightly different grid called the Tritan Grid). Geodetic analysis of the datum indicates that it is misaligned from modern geocentric reference frames such as ITRF2014, ITRF2008 and WGS84 by 535 metres in Longitude and 500 metres in Latitude (732 metres in total). ITRF2014, ITRF2008 and WGS84 are now aligned at the centimetre level and can be considered the same for most practical purposes. This large difference is a result of the inherent inaccuracy of the 1971 astronomical determination of the DOS 71/4 origin as precise satellite positioning systems had not yet been developed at that time.

A new topographic map for St Helena is currently in preparation and it has been considered prudent to adopt a geocentric ITRF based geodetic datum compatible with GNSS positioning equipment and satellite imagery as a basis for the new map. It has also been considered prudent to continue using the St Helena Local Grid (SHLG) to ensure consistency of survey data for existing land and engineering surveys. This will require computation of a new set of transformation and projection parameters from a modernised ITRF based geodetic datum.

Between October 2014 and December 2015 the GIS section of ENRD have conducted static GPS surveys over the geodetic network of St Helena (including many existing Astro DOS 71/4 stations and survey control established for Basil Read) in order to enable accurate transformation parameters to be estimated for transformation of Astro DOS 71/4 coordinates to a new datum. These parameters will enable spatial data in the old Astro DOS datum and derived UTM and SHLG projections to be transformed precisely to the new geocentric datum.

Fig. 1 ENRD Survey team with Leica GPS above Jamestown

Datum definitions, projection and transformation parameters were submitted to the global geodetic registry EPSG in September 2016 after extensive validation by GIS staff at ENRD. EPSG definitions were formalised in December 2016 in version 9 of the registry and the parameters are being currently implemented in GIS updates (e.g. Esri and QGIS) during 2017 and 2018. The geodetic survey also verified the MSL elevations of the three main peaks of St. Helena, confirming that Diana's Peak is 820 metres, Cuckholds Point is 815 metres and Actaeon is 814 metres.

Development of the St Helena Geodetic Datum 2015 (SHGD2015)

St Helena has hosted an IGS CORS station since 2009 (STHL at the Longwood Meteorological Station). This station is an important station in the global space geodetic tracking network that defines the International Terrestrial Reference Frame (ITRF). The coordinates and site velocity of STHL estimated by the Jet Propulsion Laboratory (JPL) of

NASA were used to estimate the ellipsoidal coordinates and height of the CORS antenna mount at epoch 2015.0 (1st January 2015). This was used to define the origin of the new horizontal datum for St Helena, the St Helena Geodetic Datum 2015 (SHGD2015). Seven days of 24 hr observations at STHL either side of epoch 2015.0 were processed using Geoscience Australia's AusPOS service to validate the JPL solution and an agreement of 2 mm was estimated. A difference of 2 mm can be expected from long-term time series analysis if seasonal signals (coloured noise) are modelled. SHGD2015 is fully consistent with ITRF2008 at epoch 2015.0 and WGS84 at epoch 2015.0, however it should be noted that St Helena is moving NE at 29 mm/yr due to movement of the Nubian (African) tectonic plate on which St Helena sits.

With the SHGD2015 coordinate origin estimated, static GPS observations over a wide network of stations over St Helena (including 19 original Astro DOS stations) were observed by the GIS section and post-processed using Sokkia Spectrum Office with validation by Leica Geo Office. The precision of the network is 6 mm Horizontal at 95% CI and 10 mm ellipsoidal height at 95%CI.

Least squares estimation of the transformation parameters between the Astro DOS 71 coordinates and SHGD2015 coordinates show that the internal precision of the 1971 network has a 2D RMS of 12 cm which is very satisfactory for the period and the intended purpose of the 1971 survey to support production of 1:10,000 and 1:25,000 topographic mapping. The mean elevation difference between the 1971 Mean Sea Level elevations and elevations using the EGM2008 geoid model is 0.2 m but with an uncertainty of 0.23 m at 1σ. The high uncertainty is most likely due to the use of trigonometric heighting techniques used to transfer MSL over the 1971 geodetic network and also any uncertainty (typically 0.2 m) of the EGM2008 geoid model used. The use of extensive geometric levelling is impractical on St Helena due to its rugged topography. GPS observations were made at the Jamestown wharf network of Tide Gauge benchmarks in order to estimate the relationship between the ellipsoid height, EGM2008 geoid and local/chart MSL vertical datums. The relationship was validated by tidal measurements made at a TBM on the Lower Landing steps. Analysis of the observed difference between the EGM2008 geoid surface and MSL (0.24 m) agrees with the Mean Dynamic Topography (MDT) model developed by the Danish Technical University (DTU) (0.23 m estimate at Jamestown).

Fig 2. DOS 71/4 Station at Ladder Hill

Coincidentally, Tritan Surveys, a South African survey firm have also conducted extensive GPS surveys in St Helena independently of the SHG especially in the Ruperts Wharf, haul road and airport areas to support engineering surveys for development of the new airport. Tritan surveys have also used the IGS STHL CORS station and although not specified in their report appears to have adopted an epoch of approximately 2011.773 for estimation of transformation and projection parameters to the existing St Helena Local Grid. Tritan and Basil Read surveyors have constructed a number of high quality geodetic monuments and pillars near the work areas and these monuments will be included in the SHGD2015 network.

Projection parameters were also estimated for the St Helena Local Grid directly from SHGD2015, however there is a small difference between these and the earlier St Helena Local Grid SHLG71 (12 cm RMS when compared with tabulated 1971 data). For consistency a decision was made to retain SHLG71 and St Helena Tritan for local use in order to avoid having three closely related local grids which would cause confusion and uncertainty.

Geodetic control listings for primary geodetic control observed by static GPS between 2014 and 2015 (Figure 3) for the principal datums used are shown in Appendices 3 to 4.

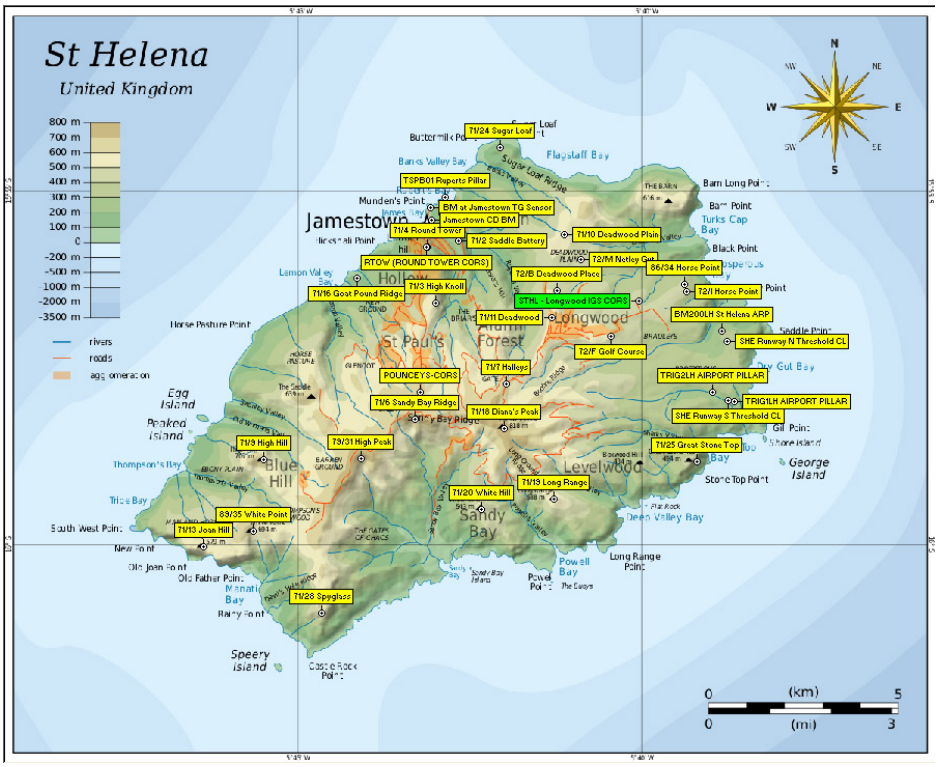


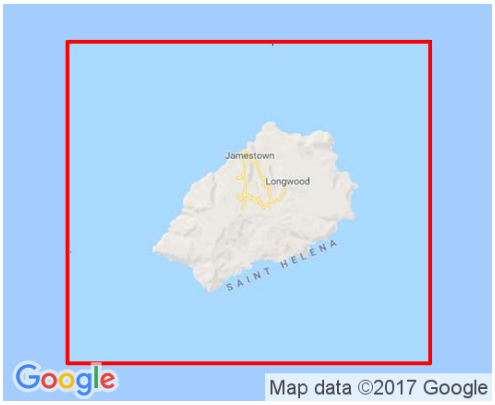
Fig. 3 Primary geodetic control locations

The EPSG bounds for St. Helena island datums and projections are shown beloe (Fig. 4):

St Helena datum boundary (EPSG 3183)

North Limit Latitude -15.85°

West Limit Longitude -5.85°



East Limit Longitude -5.58°

South Limit Latitude -16.08°

Fig. 4 Extents of SHGD and SHMG

Guide to usage and implementation of SHGD2015, height datums and transformations

For most practical purposes, SHGD2015, WGS84, St. Helena Tritan and ITRF are the same at an accuracy of 0.3 metre between 2005 and 2022. Outside this period, the accuracy degrades by 0.03 m per year (so 0.5 m by 2030).
If 0.5 m positional accuracy is sufficient then default WGS 84 settings can be used in positioning equipment such as personal GNSS navigation devices (such as handheld GPS, Car satnavs, and smartphones).

If personal GNSS systems are being used in conjunction with the 1990 series 1:25,000 and 1:10,000 topographic maps or derived plans which use Astro DOS 71, then personal GNSS navigation devices should have the datum configuration changed to Astro DOS 71 (or similar naming) so that the displayed coordinates can be plotted on these older paper maps. The coordinate difference between Astro DOS 71 (UTM coordinates) and WGS 84 is about 730 metres so some care needs to be taken. The accuracy of the transformation currently built into these devices (the NIMA parameters) is about 3 metres. If WGS 84 is the only option for the device then 535 metres should be subtracted from WGS 84 UTM Zone 30 S Eastings to obtain Astro DOS 71 UTM Zone 30 S Eastings, and 500 metres should be added to WGS 84 UTM Zone 30 S Northings to obtain Astro DOS 71 UTM Zone 30 S Northings.

For more precise surveying applications, much more care needs to be taken. Cadastral and detailed feature surveys use the St. Helena Local Grid 1971 (SHLG71) which is a tailored plane grid for St. Helena Island usage only where scale factors are averaged to unity over much of the island (UTM scale factors are not close to unity which means that UTM grid distances don't match horizontal ground distances). SHLG71 is shown with a brown graticule on the 1990 1:10,000 topographic maps. For conventional total station or terrestrial surveys, the existing practice of using tabulated SHLG71 coordinates for control stations can continue. If precision GPS is used (using base and rover stations on the island) then the seven parameter datum transformation from SHGD2015 to Astro DOS 71 and the SHLG71 projection parameters should be entered into any GPS controllers and tested or validated with known data prior to surveys taking place. This will ensure that the accuracy of the GPS survey will be 0.05 m or better. For heighting the SHGEOID15 geoid model should be used within the GPS controllers or for post-processing. This will ensure that orthometric heights close to MSL can be estimated. If global RTK or PPP GNSS/GPS techniques are used (without using a local base station) then the dynamic ITRF coordinates first need to be converted to epoch 2015.0 (epoch of SHGD2015) and transformed to Astro DOS 71 and then projected using the SHLG71 projection parameters. To convert dynamic ITRF UTM coordinates to SHGD2015/SHMG the following expressions can be used:

$$\text{Easting}_{SHMG} = \text{Easting}_{ITRF\_UTM30} + 0.0228(2015\text{-}t)$$
$$\text{Northing}_{SHMG} = \text{Northing}_{ITRF\_UTM30} + 0.0186(2015\text{-}t)$$

where t is the decimal year of observation. t can be computed from the day of year (DOY) by dividing the DOY by 365 and adding this to the year (e.g. 19th September 2018 is DOY 262 of 2018, so t = 2018 + (262/365) = 2018.718)

Engineering surveys related to the new airport, access road and Ruperts wharf have adopted a direct approximation of SHLG71 called SHLG Tritan. For conventional total station or terrestrial surveys tabulated SHLG Tritan coordinates should be used. If precision GPS is used (using base and rover stations) SHLG Tritan projection parameters should be entered into any GPS controllers and tested or validated with known data prior to surveys taking place. This will ensure that the accuracy of the GPS survey will be 0.02 m or better. For heighting no geoid model should be configured as the Tritan height datum just uses a constant -17.073 m offset over the whole island to convert ellipsoid heights to orthometric heights. If global RTK or PPP GNSS/GPS techniques are used (without using a local base station) then the dynamic ITRF coordinates first need to be converted to epoch 2011.773 (epoch of WGS 84 Tritan) and then projected using the SHLG Tritan projection parameters. To convert dynamic ITRF UTM coordinates to WGS84 Tritan UTM the following expressions can be used:

$Easting_{Tritan\_UTM} = Easting_{ITRF\_UTM30} + 0.0228(2011.773-t)$

$Northing_{Tritan\_UTM} = Northing_{ITRF\_UTM30} + 0.0186(2011.773-t)$

where *t* is the decimal year of observation (as described above).

For GIS users, transformation of spatial datasets and imagery will become straightforward once the EPSG transformations are included in GIS updates during 2017. Care needs to be taken that the correct geodetic datum and map projection is assigned to the spatial data so that the data can be transformed correctly within the GIS. Any transformation should be checked using the data in Appendix 3.

Validation of GPS and GIS Configuration and transformations

Grid coordinates for 9 imagery ground control points (Fig. 5) in the different map projections have been provided in the table below. Any configuration should be validated with these coordinates before use.

Fig. 5 Imagery ground control points for validation

	SHGD2015 / SHMG		WGS84 Tritan UTM Zone 30 S		Astro DOS UTM Zone 30 S		SHLG71 (from 7 par AstroDOS)		SHLG Tritan	
	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing	Easting	Northing
GCP001	209486.979	8228810.242	209486.909	8228810.183	208951.739	8229310.180	299719.356	1996482.690	299719.311	1996482.935
GCP002	212268.613	8231602.574	212268.543	8231602.515	211733.397	8232102.632	302535.471	1999236.800	302535.420	1999236.925
GCP003	212318.160	8236433.810	212318.090	8236433.751	211782.864	8236933.994	302647.861	2004064.077	302647.908	2004064.093
GCP004	215011.179	8235509.606	215011.109	8235509.547	214475.968	8236009.811	305327.044	2003105.486	305327.012	2003105.468
GCP005	208448.307	8237142.799	208448.237	8237142.740	207912.898	8237642.936	298789.927	2004822.858	298790.075	2004822.936
GCP006	209525.711	8234683.698	209525.641	8234683.639	208990.372	8235183.789	299834.597	2002351.494	299834.670	2002351.606
GCP007	207022.826	8233761.286	207022.756	8233761.227	206487.438	8234261.311	297321.497	2001462.311	297321.608	2001462.495
GCP008	206590.860	8230129.502	206590.790	8230129.443	206055.522	8230629.425	296842.526	1997838.790	296842.572	1997839.064
GCP009	208913.989	8237538.472	208913.919	8237538.413	208378.586	8238038.627	299260.418	2005212.200	299260.564	2005212.260

Table. Ground Control Points (GCP) in the different grid systems used on St. Helena

Appendix 1 - Table of datum and projection parameters

Geodetic Datum	St. Helena Geodetic Datum 2015	**St. Helena Tritan**	**Astro DOS 71**
Alternative Datum Name	SHGD2015	WGS 84 Tritan St. Helena	St. Helena 1971
EPSG Code (Geodetic Datum)	1174	1173	6710
Datum Reference Frame	ITRF2008	WGS 84	Astronomical Obs.
Reference Frame Epoch	2015.0	2011.773	1971.000
Reference Epoch Epoch date	1st January 2015	9th October 2011	1st January 1971
Datum Origin (Monument)	**STHL** IGS CORS Longwood	**STHL** IGS CORS Longwood	DOS 71/4 Ladder Hill
Origin Latitude (D M S)	S 15° 56' 33.1198"	S 15° 56' 33.1217"	S 15° 55' 30.0000"
Origin Longitude (D M S)	W 5°40' 02.4412"	W 5°40' 02.4436"	W 5°43' 25.0000"
Origin Ellipsoid Height	453.183 m	453.288 m	Not specified
Origin Orthometric Height	436.312 m	436.215 m	267.858 m
Origin Positional Uncertainty	3 mm	100 mm	730 m
Geodetic CRS (Geographical 2D)	SHGD2015 (EPSG: 7886)	St. Helena Tritan (EPSG: 7881)	Astro DOS 71 (EPSG: 4710)
Geodetic CRS (Geographical 3D)	SHGD2015 (EPSG: 7885)	St. Helena Tritan (EPSG: 7880)	n/a
Geodetic CRS (Geocentric)	SHGD2015 (EPSG: 7884)	St. Helena Tritan (EPSG: 7879)	n/a
Reference Ellipsoid	GRS 1980	WGS 84	International 1924
EPSG Code (ellipsoid)	7019	7030	7022
Semi-Major Axis (m)	6378137	6378137	6378388
Inverse flattening	298.257222101	298.257223563	297
Vertical Datum (Orthometric)	St. Helena Vertical Datum 2015	St. Helena Tritan Vertical Datum 2011	Jamestown 1971
Alias name	SHVD2015	MSL Tritan	MSL 1971
EPSG Code (Vertical Datum)	1177	1176	1175
Vertical Datum Reference Surface	MSL from tidal obs.	Ellipsoid Ht - 17.073 m	Approximate MSL
Vertical Datum Origin	Jamestown CD BM	**STHL** IGS CORS Longwood	DOS 71/4 Ladder Hill
Vertical Datum Origin Elevation	5.519 m	436.215 m	267.858 m
EPSG Code (Height transformation)	7891	7890	none
Geoid Model	SHGEOID15	None	Not specified
EPSG Code (Geoid Model)		None	Not specified
Projected CRS (1)	**SHMG2015**	**St. Helena Tritan / UTM Zone 30S**	**Astro DOS 71 UTM**
Full Name	St. Helena Map Grid 2015	**St. Helena Tritan / UTM Zone 30S**	Astro DOS 71 / UTM zone 30S
EPSG Code (Projection)	7887	7883	7878
Projection Type	TM	TM	TM
Projection Units	Metres	Metres	Metres
Projection Zone	UTM Zone 30S (South)	UTM Zone 30S (South)	UTM Zone 30S (South)
Zone Width	6°	6°	6°
True Origin Latitude	S 0° (0°)	S 0° (0°)	S 0° (0°)
True Origin Longitude (CM)	W 3° (-3°)	W 3° (-3°)	W 3° (-3°)
False Easting at True Origin	500000.000 m	500000.000	500000.000
False Northing at True Origin	10000000.000 m	10000000.000	10000000.000
Scale Factor at origin	0.9996	0.9996	0.9996
Northing at Proj. Origin (0°)	10000000.000	10000000.000	10000000.000
Projected CRS (2)	**SHLG2015**	**SHLG(Tritan)**	**SHLG71**
Full Name	St. Helena Local Grid 2015	St. Helena Local Grid(Tritan)	St. Helena Local Grid 1971
EPSG Code (Projection)	(not adopted)	7881	7877
Projection Type	TM	TM	TM
Projection Units	metres	metres	metres
Projection Zone	1	1	1
Zone Width	1°	1°	1°
True Origin Latitude	S 15°58' (-15.966666667°)	S 15°58' (-15.966666667°)	S 15°58' (-15.966666667°)
True Origin Longitude (CM)	W 5°43' (-5.716666667°)	W 5°43' (-5.716666667°)	W 5°43' (-5.716666667°)
False Easting at True Origin	299483.637	299483.737	300000.000
False Northing at True Origin	2000527.733	2000527.879	2000000.000
Scale Factor at origin	1.0000	1.0000	1.0000
Northing at Proj. Origin (0°)	3766482.348	3766482.494	3765975.725

Appendix 2 - Table of datum transformation parameters

Transformation Parameters (higher accuracy 7 parameter transformations)

Transformation	SHGD2015 to Astro DOS 71 (CF method)	SHGD2015 to Astro DOS 71 (PV method)	Astro DOS 71 to SHGD2015 (CF method)	Astro DOS 71 to SHGD2015 (PV method)
EPSG Code	7896 (CF)	7896	7895 (CF)	7895
Tx (m)	112.771	112.771	-112.854	-112.854
Ty (m)	-12.282	-12.282	12.270	12.270
Tz (m)	18.935	18.935	-18.913	-18.913
Rx (sec)	2.1692	-2.1692	-2.1692	2.1692
Ry (sec)	16.8896	-16.8896	-16.8896	16.8896
Rz (sec)	17.1961	-17.1961	-17.1961	17.1961
Sc (ppm)	19.54517	19.54517	-19.54517	-19.54517
Precision (m)	0.05	0.05	0.05	0.05

Transformation Parameters (medium accuracy 3 parameter transformations)

Transformation	SHGD2015 to Astro DOS 71	SHGD2015 to St. Helena Tritan	SHGD2015 to WGS 84
EPSG Code	7893 reversed	7897 reversed	Null transform
Tx (m)	323.65	0.077	0
Ty (m)	-551.39	-0.079	0
Tz (m)	491.22	-0.086	0
Precision (m)	0.1	0.05	0.2 (2008 to 2022)

Transformation	Astro DOS 71 to SHGD2015	Astro DOS 71 to St. Helena Tritan	Astro DOS 71 to WGS 84	Astro DOS 71 to WGS 84 (NIMA)
EPSG Code	7893	7893 and 7897	7894	15798
Tx (m)	-323.65	-323.57	-323.65	-320
Ty (m)	551.39	551.31	551.39	550
Tz (m)	-491.22	-491.31	-491.22	-494
Precision (m)	0.1	0.1	0.2 (2008 to 2022)	3

Transformation	St. Helena Tritan to SHGD2015	St. Helena Tritan to Astro DOS 71	St. Helena Tritan to WGS 84
EPSG Code	7897	7897 and 7893	Null transform
Tx (m)	-0.077	323.57	0
Ty (m)	0.079	-551.31	0
Tz (m)	0.086	491.31	0
Precision (m)	0.05	0.1	0.2 (2005 to 2019)

Transformation	WGS 84 to SHGD2015	WGS 84 to Astro DOS 71	WGS 84 to St. Helena Tritan
EPSG Code	Null transform	7894 reversed	Null transform
Tx (m)	0	323.65	0
Ty (m)	0	-551.39	0
Tz (m)	0	491.22	0
Precision (m)	0.2 (2008 to 2022)	0.2 (2008 to 2022)	0.2 (2005 to 2019)

Appendix 3 - Geodetic Control listings

SHGD2015 ellipsoidal coordinates									
Station Name	Latitude			Longitude			Latitude	Longitude	Ellipsoid
	deg	min	sec	deg	min	sec	dec. degrees	dec. degrees	height (m)
STHL - Longwood IGS CORS	-15	56	33.1198	-5	40	2.4412	-15.942533270	-5.667344792	453.183
71/10 Deadwood Plain	-15	55	37.1896	-5	41	8.0485	-15.926997111	-5.685569017	553.169
71/11 Deadwood	-15	56	47.2811	-5	41	18.6223	-15.946466965	-5.688506189	548.467
71/13 Joan Hill	-16	0	2.0218	-5	46	22.6171	-16.000561617	-5.772949193	595.745
71/16 Goat Pound Ridge	-15	56	14.0921	-5	44	9.2265	-15.937247805	-5.735896256	243.892
71/18 Diana's Peak	-15	58	21.3497	-5	42	0.9407	-15.972597127	-5.700261312	836.633
71/19 Long Range	-15	59	20.8843	-5	41	17.2988	-15.989134530	-5.688138546	604.564
71/2 Saddle Battery	-15	55	42.4929	-5	42	40.5079	-15.928470252	-5.711252194	284.284
71/20 White Hill	-15	59	30.1013	-5	42	19.7901	-15.991694800	-5.705497237	559.776
71/24 Sugar Loaf	-15	54	23.4525	-5	42	3.7680	-15.906514578	-5.701046676	288.454
71/25 Great Stone Top	-15	58	49.3430	-5	39	12.2476	-15.980373058	-5.653402104	510.451
71/28 Spyglass	-16	0	58.1061	-5	44	39.3893	-16.016140584	-5.744274792	589.480
71/2 SAT	-15	55	41.5466	-5	42	41.4015	-15.928207384	-5.711500427	282.721
71/3 High Knoll	-15	56	34.9582	-5	42	59.6890	-15.943043945	-5.716580265	600.589
71/4 Round Tower	-15	55	47.1673	-5	43	7.6368	-15.929768688	-5.718787989	284.367
71/6 Sandy Bay Ridge	-15	58	13.7190	-5	43	18.2252	-15.970477495	-5.721729217	764.033
71/7 Halleys	-15	57	44.1361	-5	41	57.8215	-15.962260019	-5.699394870	696.812
71/9 High Hill	-15	58	48.4500	-5	45	30.5498	-15.980125000	-5.758486057	723.234
72/B Deadwood Place	-15	56	24.3779	-5	41	14.3070	-15.940104980	-5.687307508	510.038
72/F Golf Course	-15	57	3.1427	-5	40	27.3388	-15.950872983	-5.674260769	519.516
72/I Horse Point	-15	56	25.3015	-5	39	20.4996	-15.940361525	-5.655694324	419.928
72/M Netley Gut	-15	55	57.3836	-5	40	52.8578	-15.932606550	-5.681349381	490.563
79/31 High Peak	-15	58	46.9767	-5	44	4.8725	-15.979715749	-5.734686815	814.720
86/34 Horse Point	-15	56	18.9163	-5	39	22.5230	-15.938587853	-5.656256377	423.891
89/35 White Point	-15	59	48.6602	-5	45	39.6274	-15.996850062	-5.761007606	710.808
BM at TG Sensor	-15	55	13.8077	-5	43	4.2810	-15.920502150	-5.717855836	17.700
BM200LH St Helena ARP	-15	56	58.0022	-5	38	50.8872	-15.949445051	-5.647468677	321.843
C139 Shy Road	-15	55	49.1553	-5	42	55.6146	-15.930320928	-5.715448496	137.058
C195 The Arch	-15	55	27.5305	-5	43	7.1746	-15.924314023	-5.718659616	22.657
C197 Ruperts	-15	55	10.4964	-5	42	45.5564	-15.919582340	-5.712654543	25.352
Jamestown CD BM	-15	55	24.3370	-5	43	3.4997	-15.923426945	-5.717638799	22.351
NE Threshold Corner	-15	57	7.2701	-5	38	45.2149	-15.952019463	-5.645893035	322.866
POUNCEYS-CORS	-15	57	50.5634	-5	43	13.4765	-15.964045376	-5.720410132	697.478
RTOW (CORS)	-15	55	47.3528	-5	43	7.7198	-15.929820218	-5.718811056	286.362
SHE Runway N Threshold CL	-15	57	7.3454	-5	38	45.9669	-15.952040393	-5.646101912	323.162
SHE Runway S Threshold CL	-15	57	57.7577	-5	38	44.7879	-15.966043795	-5.645774410	318.288
TRIG1LH AIRPORT PILLAR	-15	57	58.2929	-5	38	39.4662	-15.966192483	-5.644296153	306.223
TRIG2LH AIRPORT PILLAR	-15	57	50.6696	-5	38	58.0715	-15.964074876	-5.649464312	320.352
TSPB01 Ruperts Pillar	-15	55	5.8914	-5	42	51.5471	-15.918303174	-5.714318640	22.336

SHMG2015 Grid Coordinates and MSL (SHGEOID15)				Local Uncertainty 1σ		
Station Name	Easting	Northing	MSL (SHGEOID15) Elevation	East	North	Up
	(metres)	(metres)	(metres)	(m)	(m)	(m)
STHL - Longwood IGS CORS	214446.980	8235594.603	436.312	0.000	0.000	0.000
71/10 Deadwood Plain	212472.613	8237289.664	536.306	0.001	0.001	0.003
71/11 Deadwood	212185.745	8235129.949	531.558	0.001	0.001	0.002
71/13 Joan Hill	203219.710	8229021.785	579.094	0.004	0.003	0.008
71/16 Goat Pound Ridge	207095.801	8236084.638	227.103	0.002	0.002	0.006
71/18 Diana's Peak	210964.040	8232220.561	819.711	0.002	0.001	0.004
71/19 Long Range	212286.145	8230406.382	587.715	0.002	0.002	0.004
71/2 Saddle Battery	209723.245	8237090.972	267.406	0.009	0.010	0.008
71/20 White Hill	210430.743	8230098.788	542.881	0.002	0.002	0.006
71/24 Sugar Loaf	210785.127	8239536.060	271.675	0.002	0.002	0.005
71/25 Great Stone Top	215993.923	8231424.216	493.735	0.002	0.002	0.004
71/28 Spyglass	206313.461	8227337.625	572.726	0.003	0.003	0.008
71/2 SAT	209696.273	8237119.731	265.845	0.010	0.010	0.015
71/3 High Knoll	209173.458	8235469.945	583.696	0.002	0.001	0.005
71/4 Round Tower	208917.791	8236936.702	267.522	0.002	0.002	0.004
71/6 Sandy Bay Ridge	208661.574	8232425.287	747.132	0.002	0.002	0.006
71/7 Halleys	211041.998	8233366.280	679.868	0.002	0.002	0.005
71/9 High Hill	204738.645	8231305.233	706.489	0.003	0.002	0.007
72/B Deadwood Place	212305.067	8235835.991	493.145	0.002	0.001	0.004
72/F Golf Course	213717.979	8234661.763	502.620	0.001	0.000	0.002
72/I Horse Point	215691.925	8235850.984	403.141	0.001	0.001	0.002
72/M Netley Gut	212932.649	8236674.416	473.693	0.001	0.001	0.003
79/31 High Peak	207287.120	8231384.213	797.867	0.003	0.003	0.008
86/34 Horse Point	215629.215	8236046.590	407.103	0.001	0.001	0.002
89/35 White Point	204493.166	8229449.782	694.073	0.004	0.003	0.008
BM at TG Sensor	209004.290	8237963.996	0.877	0.013	0.012	0.002
BM200LH St Helena ARP	216585.842	8234856.510	305.101	0.003	0.003	0.008
C139 Shy Road	209276.353	8236880.218	120.196	0.002	0.002	0.005
C195 The Arch	208923.670	8237540.823	5.827	0.004	0.002	0.007
C197 Ruperts	209560.216	8238073.086	8.505	0.010	0.013	0.017
Jamestown CD BM	209031.760	8237640.465	5.519	0.022	0.021	0.002
NE Threshold Corner	216758.238	8234573.628	306.131	0.011	0.010	0.005
POUNCEYS-CORS	208793.553	8233139.303	680.565	0.006	0.004	0.003
RTOW (CORS)	208915.394	8236930.964	269.517	0.002	0.001	0.004
SHE Runway N Threshold CL	216735.894	8234571.027	306.426	0.003	0.002	0.007
SHE Runway S Threshold CL	216790.673	8233021.088	301.574	0.003	0.002	0.006
TRIG1LH AIRPORT PILLAR	216949.214	8233006.638	289.520	0.002	0.002	0.005
TRIG2LH AIRPORT PILLAR	216392.683	8233234.050	303.603	0.002	0.002	0.004
TSPB01 Ruperts Pillar	209380.088	8238212.398	5.501	0.004	0.003	0.009

WGS84 Tritan ellipsoidal coordinates									
Station Name	Latitude			Longitude			Latitude	Longitude	Ellipsoid
	deg	min	sec	deg	min	sec	dec. degrees	dec. degrees	height (m)
STHL - Longwood IGS CORS	-15	56	33.1217	-5	40	2.4436	-15.942533804	-5.667345452	453.288
71/10 Deadwood Plain	-15	55	37.1915	-5	41	8.0508	-15.926997636	-5.685569678	553.274
71/11 Deadwood	-15	56	47.2830	-5	41	18.6247	-15.946467490	-5.688506850	548.572
71/13 Joan Hill	-16	0	2.0237	-5	46	22.6195	-16.000562142	-5.772949854	595.850
71/16 Goat Pound Ridge	-15	56	14.0940	-5	44	9.2289	-15.937248330	-5.735896917	243.997
71/18 Diana's Peak	-15	58	21.3515	-5	42	0.9431	-15.972597652	-5.700261972	836.738
71/19 Long Range	-15	59	20.8862	-5	41	17.3011	-15.989135054	-5.688139206	604.669
71/2 Saddle Battery	-15	55	42.4948	-5	42	40.5103	-15.928470777	-5.711252854	284.389
71/20 White Hill	-15	59	30.1032	-5	42	19.7924	-15.991695324	-5.705497898	559.881
71/24 Sugar Loaf	-15	54	23.4544	-5	42	3.7704	-15.906515103	-5.701047336	288.559
71/25 Great Stone Top	-15	58	49.3449	-5	39	12.2500	-15.980373583	-5.653402765	510.556
71/28 Spyglass	-16	0	58.1080	-5	44	39.3916	-16.016141108	-5.744275453	589.585
71/2 SAT	-15	55	41.5485	-5	42	41.4039	-15.928207909	-5.711501087	282.826
71/3 High Knoll	-15	56	34.9601	-5	42	59.6913	-15.943044469	-5.716580925	600.694
71/4 Round Tower	-15	55	47.1692	-5	43	7.6391	-15.929769212	-5.718788649	284.472
71/6 Sandy Bay Ridge	-15	58	13.7209	-5	43	18.2276	-15.970478019	-5.721729878	764.138
71/7 Halleys	-15	57	44.1380	-5	41	57.8239	-15.962260544	-5.699395530	696.917
71/9 High Hill	-15	58	48.4519	-5	45	30.5522	-15.980125524	-5.758486717	723.339
72/B Deadwood Place	-15	56	24.3798	-5	41	14.3094	-15.940105504	-5.687308168	510.143
72/F Golf Course	-15	57	3.1446	-5	40	27.3411	-15.950873507	-5.674261430	519.621
72/I Horse Point	-15	56	25.3034	-5	39	20.5019	-15.940362050	-5.655694985	420.033
72/M Netley Gut	-15	55	57.3855	-5	40	52.8601	-15.932607075	-5.681350041	490.668
79/31 High Peak	-15	58	46.9786	-5	44	4.8749	-15.979716273	-5.734687475	814.825
86/34 Horse Point	-15	56	18.9182	-5	39	22.5253	-15.938588377	-5.656257038	423.996
89/35 White Point	-15	59	48.6621	-5	45	39.6298	-15.996850586	-5.761008267	710.913
BM at TG Sensor	-15	55	13.8096	-5	43	4.2834	-15.920502674	-5.717856497	17.805
BM200LH St Helena ARP	-15	56	58.0041	-5	38	50.8896	-15.949445576	-5.647469337	321.948
C139 Shy Road	-15	55	49.1572	-5	42	55.6170	-15.930321453	-5.715449156	137.163
C195 The Arch	-15	55	27.5324	-5	43	7.1771	-15.924314547	-5.718660314	22.762
C197 Ruperts	-15	55	10.4983	-5	42	45.5587	-15.919582864	-5.712655203	25.457
Jamestown CD BM	-15	55	24.3389	-5	43	3.5021	-15.923427469	-5.717639459	22.456
NE Threshold Corner	-15	57	7.2720	-5	38	45.2173	-15.952019988	-5.645893696	322.971
POUNCEYS-CORS	-15	57	50.5652	-5	43	13.4789	-15.964045900	-5.720410793	697.583
RTOW (CORS)	-15	55	47.3547	-5	43	7.7222	-15.929820743	-5.718811716	286.467
SHE Runway N Threshold CL	-15	57	7.3473	-5	38	45.9693	-15.952040918	-5.646102573	323.267
SHE Runway S Threshold CL	-15	57	57.7596	-5	38	44.7903	-15.966044319	-5.645775070	318.393
TRIG1LH AIRPORT PILLAR	-15	57	58.2948	-5	38	39.4685	-15.966193008	-5.644296813	306.328
TRIG2LH AIRPORT PILLAR	-15	57	50.6714	-5	38	58.0739	-15.964075401	-5.649464972	320.457
TSPB01 Ruperts Pillar	-15	55	5.8933	-5	42	51.5495	-15.918303699	-5.714319300	22.441

SHLG (Tritan) Grid Coordinates and Reduced Levels			
Station Name	Easting (metres)	Northing (metres)	RL (metres)
STHL - Longwood IGS CORS	304764.310	2003197.753	436.215
71/10 Deadwood Plain	302813.390	2004917.331	536.201
71/11 Deadwood	302498.607	2002762.880	531.499
71/13 Joan Hill	293459.517	1996776.239	578.777
71/16 Goat Pound Ridge	297424.798	2003783.163	226.924
71/18 Diana's Peak	301239.843	1999871.496	819.665
71/19 Long Range	302537.321	1998041.351	587.596
71/2 Saddle Battery	300063.407	2004754.557	267.316
71/20 White Hill	300679.229	1997758.213	542.808
71/24 Sugar Loaf	301156.318	2007184.070	271.486
71/25 Great Stone Top	306255.812	1999010.063	493.483
71/28 Spyglass	296528.885	1995052.909	572.512
71/2 SAT	300036.829	2004783.646	265.753
71/3 High Knoll	299492.917	2003141.869	583.621
71/4 Round Tower	299256.533	2004610.881	267.399
71/6 Sandy Bay Ridge	298941.720	2000106.113	747.065
71/7 Halleys	301332.689	2001015.376	679.844
71/9 High Hill	295007.111	1999038.092	706.266
72/B Deadwood Place	302627.040	2003466.868	493.070
72/F Golf Course	304023.663	2002275.060	502.548
72/I Horse Point	306011.737	2003437.746	402.960
72/M Netley Gut	303265.095	2004296.530	473.595
79/31 High Peak	297554.696	1999083.746	797.752
86/34 Horse Point	305951.617	2003634.035	406.923
89/35 White Point	294737.586	1997187.265	693.840
BM at TG Sensor	299356.334	2005636.298	0.732
BM200LH St Helena ARP	306892.092	2002432.305	304.875
C139 Shy Road	299614.098	2004549.772	120.090
C195 The Arch	299270.268	2005214.483	5.689
C197 Ruperts	299913.273	2005738.078	8.384
Jamestown CD BM	299379.575	2005312.646	5.383
NE Threshold Corner	307060.685	2002147.368	305.898
POUNCEYS-CORS	299082.915	2000817.884	680.510
RTOW (CORS)	299254.063	2004605.179	269.394
SHE Runway N Threshold CL	307038.322	2002145.060	306.194
SHE Runway S Threshold CL	307072.857	2000595.455	301.320
TRIG1LH AIRPORT PILLAR	307231.103	2000578.947	289.255
TRIG2LH AIRPORT PILLAR	306677.914	2000813.463	303.384
TSPB01 Ruperts Pillar	299735.088	2005879.631	5.368

Astro DOS 71/4 and SHLG71 coordinates using 7 parameter transformation										
Station Name	Latitude			Longitude			UTM Zone 30 Grid coordinates		SHLG71 Grid coordinates	
	deg	min	sec	deg	min	sec	Easting	Northing	Easting	Northing
STHL - Longwood IGS CORS	-15	56	15.9533	-5	40	19.8123	213911.753	8236094.801	304764.328	2003197.763
71/10 Deadwood Plain	-15	55	20.0225	-5	41	25.4167	211937.306	8237789.872	302813.329	2004917.338
71/11 Deadwood	-15	56	30.1146	-5	41	35.9902	211650.467	8235630.097	302498.584	2002762.832
71/13 Joan Hill	-15	59	44.8563	-5	46	39.9728	202684.303	8229521.622	293459.417	1996775.871
71/16 Goat Pound Ridge	-15	55	56.9249	-5	44	26.5872	206560.375	8236584.724	297424.641	2003783.034
71/18 Diana's Peak	-15	58	4.1839	-5	42	18.3071	210428.780	8232720.612	301239.851	1999871.358
71/19 Long Range	-15	59	3.7191	-5	41	34.6672	211750.950	8230906.409	302537.397	1998041.200
71/2 Saddle Battery	-15	55	25.3257	-5	42	57.8722	209187.870	8237591.129	300063.288	2004754.504
71/20 White Hill	-15	59	12.9360	-5	42	37.1558	209895.505	8230598.775	300679.269	1997758.017
71/24 Sugar Loaf	-15	54	6.2846	-5	42	21.1337	210249.738	8240036.298	301156.173	2007184.093
71/25 Great Stone Top	-15	58	32.1779	-5	39	29.6211	215458.807	8231924.332	306255.949	1999010.010
71/28 Spyglass	-16	0	40.9413	-5	44	56.7494	205778.163	8227837.471	296528.889	1995052.567
71/2 SAT	-15	55	24.3793	-5	42	58.7658	209160.897	8237619.888	300036.709	2004783.593
71/3 High Knoll	-15	56	17.7913	-5	43	17.0526	208638.096	8235970.050	299492.819	2003141.768
71/4 Round Tower	-15	55	30.0000	-5	43	25.0000	208382.398	8237436.841	299256.399	2004610.808
71/6 Sandy Bay Ridge	-15	57	56.5529	-5	43	35.5883	208126.251	8232925.305	298941.673	2000105.933
71/7 Halleys	-15	57	26.9700	-5	42	15.1880	210506.721	8233866.362	301332.676	2001015.265
71/9 High Hill	-15	58	31.2840	-5	45	47.9075	204203.239	8231805.155	295006.999	1999037.807
72/B Deadwood Place	-15	56	7.2112	-5	41	31.6751	211769.780	8236336.159	302627.005	2003466.838
72/F Golf Course	-15	56	45.9765	-5	40	44.7089	213182.749	8235161.924	304023.684	2002275.033
72/I Horse Point	-15	56	8.1351	-5	39	37.8724	215156.726	8236351.210	306011.777	2003437.786
72/M Netley Gut	-15	55	40.2167	-5	41	10.2267	212397.364	8237174.616	303265.057	2004296.533
79/31 High Peak	-15	58	29.8108	-5	44	22.2338	206751.779	8231884.180	297554.640	1999083.514
86/34 Horse Point	-15	56	1.7498	-5	39	39.8957	215094.011	8236546.820	305951.652	2003634.078
89/35 White Point	-15	59	31.4947	-5	45	56.9848	203957.785	8229949.651	294737.506	1997186.932
BM at TG Sensor	-15	54	56.6402	-5	43	21.6443	208468.882	8238464.164	299356.182	2005636.250
BM200LH St Helena ARP	-15	56	40.8361	-5	39	8.2614	216050.683	8235356.725	306892.172	2002432.341
C139 Shy Road	-15	55	31.9881	-5	43	12.9783	208740.970	8237380.362	299613.973	2004549.705
C195 The Arch	-15	55	10.3630	-5	43	24.5380	208388.267	8238040.978	299270.122	2005214.424
C197 Ruperts	-15	54	53.3289	-5	43	2.9204	209024.820	8238573.266	299913.131	2005738.044
Jamestown CD BM	-15	55	7.1695	-5	43	20.8630	208496.358	8238140.625	299379.430	2005312.591
NE Threshold Corner	-15	56	50.1041	-5	39	2.5893	216223.088	8235073.839	307060.776	2002147.402
POUNCEYS-CORS	-15	57	33.3971	-5	43	30.8398	208258.221	8233639.342	299082.857	2000817.723
RTOW (CORS)	-15	55	30.1855	-5	43	25.0830	208380.001	8237431.104	299253.930	2004605.106
SHE Runway N Threshold CL	-15	56	50.1794	-5	39	3.3413	216200.743	8235071.237	307038.412	2002145.093
SHE Runway S Threshold CL	-15	57	40.5921	-5	39	2.1625	216255.550	8233521.259	307072.980	2000595.454
TRIG1LH AIRPORT PILLAR	-15	57	41.1274	-5	38	56.8410	216414.095	8233506.811	307231.229	2000578.949
TRIG2LH AIRPORT PILLAR	-15	57	33.5039	-5	39	15.4455	215857.546	8233734.220	306678.023	2000813.459
TSPB01 Ruperts Pillar	-15	54	48.7238	-5	43	8.9109	208844.685	8238712.578	299734.939	2005879.596

Glossary and Abbreviations

BM - Bench Mark

A stable geodetic monument used primarily as a reference for elevations and heights, but can also be used for horizontal control.

CD - Chart Datum

Used in hydrographic surveying. A datum plane at or below the lowest astronomical tide used as a basis for hydrographic charting.

CF - Coordinate Frame

A convention used for seven parameter geodetic transformations where the rotation parameters are positive counter-clockwise (mathematical convention). Care is required when manually entering rotation parameters if the system uses a PV (Position vector) convention which have the same magnitudes but opposite sign.

CI - Confidence Interval

A range of values so defined that there is a specified probability (e.g. 95%) that the value of a parameter lies within it.

CM - Central Meridian

The longitude origin of a Transverse Mercator (TM) grid system.

CORS - Continuously Operating Reference Station

A GPS or GNSS station running continuously and usually forms part of global or regional GPS networks as well as a local reference station for GPS surveys.

DOS - The Directorate of Overseas Surveys (UK)

The survey and mapping agency of the UK government responsible for overseas territories. Founded in 1946 and merged with the Ordnance Survey in 1984 as the Overseas Surveys Directorate, renamed Ordnance Survey International in 1991 before being wound up in 2001.

DOY - Day of Year

The calendar date converted to a sequential day of the year with 1st January being day 1 and the 31st December being day 365 (or Day 366 if a leap year).

DTU - Technical University of Denmark (Danish: *Danmarks Tekniske Universitet*)

EGM - Earth Gravitational Model

A geopotential model of the Earth (approximating sea level) managed by the US National Imagery and Mapping Agency (NIMA) and US National Geospatial-Intelligence Agency (NGA)

ENRD - The Environment and Natural Resources Directorate (St Helena Government)

The St. Helena government department responsible for surveying and mapping on St. Helena island.

EPSG - The European Petroleum Survey Group

Formed in 1986 and absorbed into the International Association of Oil and Gas Producers (IOGP) in 2005. The EPSG geodetic registry is the primary global reference for ellipsoids, geodetic datums, geographic and projected coordinate systems, height datums, transformation parameters and units of measurement.

GIS - Geographic Information System

A system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data

GNSS - Global Navigation Satellite System

A collective term for a number of different satellite systems used for positioning and navigation such as GPS, Glonass, Galileo, QZSS, Compass.

GPS - Global Positioning System

The satellite navigation system operated by the US Department of Defence.

GRS80 - Global Reference System 1980

The international reference ellipsoid adopted by ITRF that approximates the Earth surface

IGS - International GNSS Service

A voluntary federation of over 200 self-funding agencies, universities, and research institutions in more than 100 countries; working together to provide the highest precision GPS satellite orbits.

ITRF - International Terrestrial Reference Frame

The principal global geodetic reference frame which is a realisation of the International Terrestrial Reference System (ITRS). The ITRF is defined by a global network of geodetic stations with tabulated coordinates and velocities. The latest realisation is ITRF2014.

JPL - Jet Propulsion Laboratory

Part of NASA hosted by the California Institute of Technology (CALTECH) in Pasadena, California. JPL operate a large number of CORS on the IGS network including STHL at Longwood.

MDT - Mean Dynamic Topography

Mean dynamic topography is the long term meaned difference between the mean sea level and the geoid mainly caused by temperature variations in the ocean column and currents.

MSL - Mean Sea Level

The long term average of the sea level surface at any given location.

NASA - National Aeronautics and Space Administration (US)

NASA is an independent agency of the executive branch of the United States federal government responsible for the civilian space program, as well as aeronautics and aerospace research.

NIMA - National Imagery and Mapping Agency (US)

The US government department responsible for mapping and imagery. Renamed the National Geospatial-Intelligence Agency (NGA) in 2004.

PPP - Precise Point Positioning

A GNSS technique for estimating precise positions using orbit and clock corrections. PPP does not use corrections from local reference stations and the positioning datum is usually ITRF.

PV - Position Vector

A convention used for seven parameter geodetic transformations where the rotation parameters are positive clockwise (geodesy convention). Care is required when manually entering rotation parameters if the system uses a CF (Coordinate Frame) convention which have the same magnitudes but opposite sign.

RMS - Root Mean Square

The arithmetic mean of the squares of a set of numbers. A similar measure to standard deviation.

RTK - Real Time Kinematic

A GNSS positioning technique where GNSS carrier phase measurements are differenced and broadcast in real-time via radio or mobile data link between a base station and a rover station.

Rx, Ry, Rz - Rotations

Rotations about the three Cartesian axes x, y and z

Sc - Scale

Scale difference between one reference frame and another

SHGD - St. Helena Geodetic Datum

A new geodetic datum for St. Helena released in 2016 to supersede Astro DOS. SHGD is based on ITRF2008 at epoch 2015.0 (1st January 2015).

SHGEOID - St. Helena Geoid

A new geoid model for St. Helena released in 2016 to assist with reduction of GNSS derived elevations (ellipsoid heights) to approximate MSL over St. Helena. The model is a grid of differences between the ITRF2008 ellipsoid and Mean Sea Level over St. Helena.

SHLG - St. Helena Local Grid

A plane map grid to support cadastral and engineering surveys on St. Helena with scale factors close to 1.

SHMG - St. Helena Map Grid

A Transverse Mercator map grid of SHGD over St. Helena. SHMG is very closely aligned to the UTM Zone 30 S projection of ITRF.

SHVD - St. Helena Vertical Datum

A new vertical datum for St. Helena referenced to the STHL IGS Station at Longwood.

TBM - Temporary Bench Mark

A non-permanent survey mark used as a temporary reference for levelling (e.g. for construction surveys).

TM - Transverse Mercator

A form of map projection where the ellipsoid is projected onto a oblate cylinder that intersects the ellipsoid along one or two lines of longitude.

Tx, Ty, Tz, Translations

Translations of the three Cartesian axes x, y and z

UTM - Universal Transverse Meractor

A global map projection system where the Earth's surface (excluding polar regions) is divided into sixty 6 degree longitude wide zones. Each zone is defined by a TM projection with a central meridian (CM) and scale factor (SF) of 0.9996 along the central meridian. The Easting along the CM is always 500,000 metres. The Northing at the equator is 10,000,000 metres for the Southern hemisphere part of the zone and 0 metres Nouthern hemisphere part of the zone.

WGS - World Geodetic System

A global geodetic system developed by the US Department of Defence and used as the reference system for GPS. The current version is WGS 84. WGS 84 is now very closely aligned with ITRF at the centimetre level, however coordinates on the Earth surface change by several centimetres a year due to plate tectonics.