NATIONAL NETWORK OF REGIONAL COASTAL MONITORING PROGRAMMES

SPECIFICATION FOR LIDAR SURVEYS

Record of Changes

Version	Date	Status	Modifications
1.0	11 August 2015	Final	-
1.1	27 November 2020	Draft	Update to NEC4 terminology

1. PURPOSES AND OBJECTIVES OF LIDAR SURVEYS

Lidar surveys are undertaken to obtain topographic data, over areas of extensive saltmarsh, sand dunes, wide sand flats or cliffs, or beaches which are otherwise inaccessible.

2. PROJECT SPECIFICATIONS

2.1 General		
2.1.1	Performance monitoring arrangements	An annual review will be undertaken by the Client to examine the performance of the Contractor during the contract period. If the Contractor is shown to be failing in his obligations to comply with the terms of the Contract, Specification or Scope, the Client may exercise his rights under clause 90 of the Conditions of Contract to terminate the contract.
2.1.2	Quality control of data	The Contractor is responsible for undertaking quality control of the lidar data to ensure that the data meets the standards and requirements of the Specification and the Scope. The Client will undertake QC checks on the processed data within 4 weeks of delivery of each polygon. If data rejected by the Client requires re-processing, the re-processed data will be supplied within 3 weeks of notification of failure. Survey polygons, or partial sections of a polygon, which are rejected due to the survey extent not being complete (or any other failure to meet the Specification which cannot be corrected by re-processing) must be re-flown within 6 weeks of notification or, if there is no appropriate tide/weather window within 6 weeks of notification, during the next suitable window. In such cases, in order to maintain data integrity, the rejected area must be re-flown from the seaward to the landward limit in its entirety. All costs of remedial work will be borne by the Contractor.
2.1.3	Health and Safety	The Contractor shall comply with all relevant legislation and bylaws when carrying out the Survey. Aircraft, equipment and survey personnel provided by the Contractor for work in connection with the contract shall be the Contractor's responsibility at all times. The said aircraft, equipment and survey personnel and any loss, injury or damage suffered or caused by them shall be at the Contractor's risk throughout. All risks of data acquisition, including aircraft hire and demurrage will be borne by the Contractor. The Client is unaware of any special hazards other than those normally associated with aerial surveying. The Contractor shall carry out a full Risk Assessment before each survey and shall prepare a Safe System of Working/Survey Management Plan based on the Assessment. All survey personnel provided by the Contractor shall adhere to laid down safety procedures at all times. A copy of the Survey Management Plan shall be forwarded to the Client's Representative by email, at least 48 hours before the commencement of survey operations.

2.1 General		
2.1.4	Site Conditions/ Restrictions, Access and Public Relations	It is the Contractor's responsibility to obtain flight permission from Air Traffic Control authorities, and in other areas where security clearance is required. The Contractor shall be responsible for obtaining all permissions needed for use of equipment associated with the work and for adhering to government legislation regarding permits to survey and for entry on to land to make measurements. In respect of authorities to be consulted, the Contractor's particular attention is drawn to the procedures to be adopted when obtaining permits for surveys undertaken on or where access is required over areas designated as SSSI, railway property, or involving MOD property. The Contractor shall make himself aware of the limitations on access both in terms of the method of working and timing, which the relevant authorities might impose. Where access is required to set up over a Regional Monitoring Programme control point, contact details for permissions will be provided by the Client.
2.1.5	Flights near nuclear power stations	The Client has an agreement with Office for Civil Nuclear Security regarding over-flights of nuclear power stations – contact details will be supplied to Contractor on award of Contract. All data which covers the nuclear power plant, its grounds and outflow pipes *must be removed* from the initial raw data at the earliest stage in processing, including from any back-ups held by the Contractor. Nuclear power station sites where this data removal is required will be indicated in the Scope.
2.1.6	Progress reports	8 weeks prior to the commencement of the flying season, an outline programme of planned flights shall be provided to the Client. On commencement of flying, the Contractor shall supply, by email, a fortnightly report outlining progress of data collection and processing. A spreadsheet template will be supplied to the Contractor for this purpose.
2.1.7	Delivery schedule	Final deliverables shall be sent to the Client within 6 weeks of completion of all flying for a survey polygon.
2.1.8	Ownership and copyright	All data and accompanying documents and records, both working and fair, acquired or created in the contract shall become the property and copyright of the Client. Copyright and intellectual property rights will belong to the Client. All data collected under this contract will be made freely available and free to all, via the internet.

2.2 Data capture		
2.2.1	Extent of survey	The extent of the survey for each Work Package is given in the Scope and in the accompanying GIS polygons. The Work Package is divided into several polygons for the purpose of data collection. The GIS polygons will show the indicative area to be covered. The landward and lateral extents of the area to be captured are defined in the polygons.

<table>
<tr><th colspan="3">2.2 Data capture</th></tr>
<tr><td></td><td></td><td>The polygons provide an indicative boundary for the seaward limit. As this zone is dynamic and the purpose of the surveys is to identify changes to the extent and geometry of the intertidal zone, the actual boundary of the dynamic seaward limit will be determined during the survey and controlled by tidal elevation. The seaward extent of the survey area is defined as plan (XY) position of the elevation above which the data shall not contain seawater i.e. the tide at time of data capture must be to seaward of seaward boundary. The minimum elevation to be achieved is Mean Low Water Springs (MLWS).</td></tr>
<tr><td>2.2.2</td><td>Coastal surveys</td><td>Flights shall be planned to minimise potential shadow effects from dune fields, coastal cliffs and other steep slopes. This will usually involve a minimum of two flight lines, one to seaward and one to landward of the feature. Where only one flight line is used for a coastal survey, the centre of the flight line shall be seaward of Mean High Water (MHW). It is the Contractor's responsibility to demonstrate that flight lines are appropriate to achieve the required coverage and to minimise shadowing and distortion at the edges of the swath.

If the survey extent includes inter-tidal areas, the entire inter-tidal area (of a given stretch of coastline within a polygon) shall be flown in a single tidal window i.e. the lower and upper beach sections must be flown in the same tide; however, the area above Highest Astronomical Tide (HAT) may be flown within ± 3 days of the inter-tidal section.

If the survey extent includes inter-tidal areas, the processed data must be broadly free of seawater at the seaward extent. This requirement can generally be met only if the flight occurs at or close to the time of Low Water over the larger spring tides. It is the responsibility of the Contractor to meet this requirement. Small patches of standing water in e.g. runnels or beach creeks are acceptable, as is estuarine water, but on open coast it is expected that there will be no sea present in the data landward of the required seaward boundary.</td></tr>
<tr><td>2.2.3</td><td>Point cloud data</td><td>Point cloud lidar shall be collected for the areas indicated in the Scope. Grids will be prepared from the processed, cleaned point cloud data, at a resolution defined in the Scope. Depending on the required processed grid resolution, the point cloud data shall be collected at a minimum density of:

<table>
<tr><th>Required processed grid resolution (m)</th><th>Minimum density of points/m^2</th></tr>
<tr><td>1 x 1</td><td>1</td></tr>
<tr><td>0.5 x 0.5</td><td>4</td></tr>
</table>
</td></tr>
<tr><td>2.2.4</td><td>Accuracy</td><td>Minimum accuracy of elevations in processed data shall be +/- 0.10m RMSE. Minimum position standard deviation shall be < 0.05m. Full details shall be</td></tr>
</table>

2.2 Data capture		
		included with the Method Statement to demonstrate the combination of equipment and method of operation to achieve the minimum accuracies required.
2.2.5	Flight lines	Flight lines will be planned at a spacing to ensure sufficient swath overlap to meet the required accuracy at the required resolution. Tie lines shall be flown at right angles to the main flight lines. Tie lines shall be flown at approximately 10 km intervals, or with a minimum of 2 tie lines per polygon, whichever is the closer spacing.

2.3 Positioning, survey control and calibration		
2.3.1	Positioning	Data points are to be positioned by using dual frequency carrier phase GNSS combined with the Ordnance Survey Active Networks *i.e.* Post Processed Kinematic GNSS. The Contractor shall demonstrate that the method chosen for positioning results in the overall horizontal uncertainty requirements being met.
2.3.2	Satellite availability	A minimum of 7 satellites and GDOP < 3 is required for position fixing for data capture
2.3.3	Survey control	Adequate survey control shall be used to provide data to the required resolution and accuracy. Existing control networks of E1 and E2 stations may be used for ground control stations, as shown in the Scope. The Contractor will install any additional points required for ground control. Control surveys will be conducted according to the Environment Agency's National Specifications v.3.2, Section II. Any extension of existing geodetic control and the establishment of new stations shall be fully documented.
2.3.4	Ground-truthing	Ground-truthing shall be undertaken on areas of hard surface and/or features that are unlikely to change between surveys, with known elevations. These features should typically cover 100m^2 of level surface, such as concrete or tarmac, and shall be used to establish the height accuracy of the survey (as RMSE of the compared points). The ground-truthing areas should be identified within the survey polygon, where possible, or at the closest suitable location. Alternatively, Contractors may set up temporary platforms within the survey polygon, on or above the ground surface for this purpose. The ground-truthing survey will be conducted using RTK/PPS GPS in accordance with the Environment Agency National Survey Specifications v.3.2, Section III. The vertical accuracy of each ground survey point shall be ± 0.03m. Ground survey data shall have been surveyed within 3 years of the lidar flight.

2.3 Positioning, survey control and calibration		
		The results from the ground-truthing survey shall be compared to those obtained from the lidar survey. The comparison may be either: • the lidar gridded surface (at the required resolution) compared to individual survey points on the ground *or* • the gridded surface of the ground survey (at the required resolution) compared to individual points of the lidar point cloud Ground-truthing shall be carried out approximately every 10-15km; a polygon less than 15km in extent will require ground-truthing near either end of the survey area.

2.4 Data processing		
2.4.1	Survey geodesy and time zone	The processed survey geodesy shall be OSGB36 (British National Grid)/Ordnance Datum. If initial data are collected using WGS84, data shall be transformed to OSGB36 using OSTN02/OSGM02. All times shall be UTM.
2.4.2	Nuclear power stations	If survey areas include nuclear power stations, as defined in the Scope, data are to be removed in accordance with Clause 2.1.5.
2.4.3	Data amalgamation and cleaning	Data from one or more flight lines within a polygon shall be combined prior to processing. Data from overlapping lines and independent tie lines shall be cross-checked. Spurious data points *e.g.* flying birds, fog *etc.* shall be removed during processing.
2.4.4	Removal of seawater	Along the open coast, seawater shall be removed from the final processed data. One of the following methods of removal of seawater shall be employed: • By contour level • By polygon boundary as supplied by the Client • By automatic classification which can discriminate land and sea This process applies only to seawater on the open coast or along large estuaries, and is not required for beach runnels, creeks or small rivers, swimming pools or ponded water *etc*. The resulting processed, cleaned data, free of water at its seaward extent, but including buildings, vegetation and open ground, in the required geodesy and at the required resolution, is referred to henceforth as "unfiltered" data.

2.5 Additional data processing		
2.5.1	Additional data processing tasks	This section details a range of further processing stages which may or may not be required. The applicable tasks will be indicated in the Scope.
2.5.2	Filtering of vegetation, buildings and other objects	Vegetation and/or buildings and all other objects above ground level shall be filtered from the unfiltered data to produce "bare earth" terrain data. Coastal structures such as piers and beach huts or ephemeral features such as boats and caravans may be required to be filtered, as detailed in the Scope. Data which has undergone filtering of vegetation, buildings structures and any other required items is referred to henceforth as "filtered" data.
2.5.3	Extraction of profiles	Profiles shall be extracted from the filtered gridded data, as detailed in the Scope. The Client will provide a list of profiles (profile name, start co-ordinates and bearing) to be extracted. Profiles shall be extracted only from within the extents of the survey polygon. The chainage is to be calculated as distance in metres from the Start of Line co-ordinates. The sample distance of measured data points along the profile shall be no greater than the lidar cell size, unless the profile runs through "No data" areas. "No data" areas shall be excluded from the profile.

2.6 Data management		
2.6.1	General	All lidar data (positions and elevations) shall be in metres to 2 decimal places. Processed XYZ data and grids shall be provided in 1km by 1km Ordnance Survey tiles. There shall be no overlapping adjacent tiles. Processed XYZ data, grids and point cloud data shall also be provided per survey polygon. Any data collected from the planned flight lines outside the extent of the survey polygons shall also be delivered. Where a survey was conducted over 2 or 3 contiguous days, the survey date to be used for the 1km filenames shall be the last date of the survey. However, where tiles of data within a survey area were collected more than a week apart, files should be named separately. Filenames shall not contain spaces.
2.6.2	File format – gridded data (*.asc)	Ascii raster format: ncols number of columns in the dataset nrows number of rows in the dataset xllcenter or xllcorner x-coordinate of the centre or lower-left corner of the lower-left cell

2.6 Data management		
		yllcenter or yllcorner — y-coordinate of the centre of lower-left corner of the lower-left cell cellsize — cell size for the dataset nodata_value — value in the file assigned to cells whose value is unknown. This keyword and value is optional. The nodata_value defaults to -9999 The first row of data is at the top of the dataset, moving from left to right. Cell values should be delimited by spaces. No carriage returns are necessary at the end of each row in the dataset. The number of columns in the header is used to determine when a new row begins. The number of cell values must be equal to the number of rows times the number of columns. Example: ncols 250 nrows 250 xllcorner 602000 yllcorner 117000 cellsize 2 NODATA_value -9999 -9999 -9999 -9999 -9999 -9999 -9999….. -9999 -9999 -9999 -9999 -9999 -9999….. -9999 -9999 -9999 -9999 -9999 -9999…..
2.6.3	File format – XYZ data (*.txt)	Tab-delimited text files, with 3 columns of data and 1 header row. Example: Easting Nothing Elevation_OD 103567.245 90568.103 13.568 103568.245 90568.103 13.065
2.6.4	File format – point cloud data (*.las)	Data shall be delivered in accordance with the ASPRS LAS specification: http://www.asprs.org/society/committees/standards/LAS_1_3_r11.pdf *.las files shall contain X, Y, Z, Intensity, Return Number, Number of Returns, Classification
2.6.5	File format – profile data (*.txt)	Profile files shall be tab-delimited text files with 7 columns of data and 1 header row. Example: Easting Northing Elevation_OD Chainage FC Profile Reg_ID 484955.63 92411.06 0.76 171.00 ZZ CHI166 5a00001 484955.01 92410.27 -0.790 172.00 ZZ CHI166 5a00001 484954.40 92409.48 -0.790 163.00 ZZ CHI167 5a00002 Profile is the local name of the profile, Reg_ID is the Regional linename. FC refers to the Feature Code (for sediment type), which is ‘ZZ’ for all lidar surveys, since sediment type is not derived.

2.6 Data management		
2.6.6	Filenames - 1km tiles	Filenames for XYZ and gridded data are based on OS 1km tiles: OSOSOS_YYYYMMDDlidarxx.* where: OSOSOS is the Ordnance Survey 1km tile name (6 digits) YYYY is the year of the survey (4 digits) MM is the month of the survey (2 digits) DD is the day of the survey (2 digits) *xx* is a suffix to denote data type: • Suffix 'u' represents unfiltered data • Suffix 'f' represents filtered data Examples: TQ1234_20111027lidaru.txt SY6789_20121202lidarf.asc
2.6.7	Filenames - mosaics	Filenames for data delivered in polygons (*.asc, *.las) are based on the Work Package polygon number, survey date and data type: WPNN_PP_YYYYMMDD*.* where: WP is the Work Package name (variable number of characters/digits) PP is the polygon number (2 digits) Examples: LSW01_01_20111027lidarf.las LSW02_04_20111027lidaru.las
2.6.8	Filenames - point cloud flight lines	As for 2.6.8 with addition of Line number (L*) or Tie Line number (T*) as appropriate: Examples: LSE01_01_20111027_L1lidaru.las LSE05_04_20121202_T3lidaru.las
2.6.9	Filenames - profiles	Extracted profiles shall be supplied per survey polygon (*.txt), using the file suffix 'p'. Example: LSE04_01_20111027lidarp.txt
2.6.10	Filenames - Report of Survey	The Report of Survey (*.pdf) is named according to the survey area and the last flying date. Example: Report_lidar_LSW01_20111027.pdf
2.6.11	Filenames - metadata	The metadata file (*.xlsx) is named according to the survey polygon, the Contractor and the last flying date for the survey polygon. Example: Meta_lidar_Blom_20111027.xlsx
2.6.12	Transfer medium	The Contractor will maintain an FTP site which will be used for delivery of interim data. Final data shall be delivered on a hard drive.

2.7 Deliverables		
2.7.1	Preliminary data	Preliminary data (*i.e.* unprocessed, but in geographic co-ordinates, lidar data in *las format) shall be submitted within 15 days of completion of flying of each survey polygon.

2.7 Deliverables		
2.7.2	Report of Survey	The Report of Survey shall contain, as a minimum: • System type (platform and instruments) • System parameters, including scan angle and frequency, pulse frequency, no. of channels • Swath width, divergence and footprint • Laser Calibration certificate • IMU instrumentation and calibration certificate • Calibration flight date • Survey Control, including base stations used, observation periods, and VDOP (as graphs), standard deviation of horizontal and vertical positions, details of cycle slips • Flight plans and log including lines flown (and tie lines), direction of flight, flying speed and height, scan width and times of data collection • ESRI shape file of the smoothed best estimate of trajectory (SBET, point spacing <100m for fixed wing aircraft, <50m for rotary wing) including, as attributes, time, original position and attitude data as recorded by the GNSS/IMU • Image showing extent of area surveyed, including flight lines and tie lines • Environmental conditions, including cloud cover and height • Tie line comparison • Data processing methodology, including any filtering • Ground-truthing data, including both ground survey and lidar data points used for ground- truthing (as *.shp). Scatter plot of ground survey points vs. lidar points, regression
2.7.3	Metadata	A metadata form shall be supplied with the delivered data. Only one metadata form is required per survey polygon, providing the information is appropriate for all submitted data. A template metadata *.xlsx will be supplied by the Client.
2.7.4	Data files	• Unfiltered lidar data <u>Per 1km OS tile</u> ○ Grids (*.asc) ○ XYZ (*.txt) <u>Per survey polygon</u> ○ Grids (*.asc) ○ XYZ (*.txt) ○ Point cloud (*.las) • Filtered lidar data <u>Per 1km OS tile</u> ○ Grids (*.asc) ○ XYZ (*.txt) <u>Per survey polygon</u> ○ Grids (*.asc) ○ XYZ (*.txt)

2.7 Deliverables		
		○ Profiles (*.txt)
	Miscellaneous data	• Supplementary ground control (if applicable) • Ground-truthing data (*shp)

3. METHOD STATEMENT

As part of the Method Statement, the Contractor will provide full details to show that the technical requirements of the Specification and Scope can be met. The Method Statement shall, as a minimum, make reference to:

- The method to be used to obtain the position of the lidar platform
- Instrumentation to be used, including achieved accuracies
- Instrument certification (including eye-safe operation of laser)
- Methodology for flight planning, including how to meet seaward boundaries and avoid shadowing
- Proposed survey control
- Proposed procedure for ground-truthing
- Data processing software and methods
- Proposed method for removal of open coast sea water
- Proposed method to filter (permanent) buildings, vegetation and coastal structures
- Quality control procedures
- Outline programme for achieving survey within given time frame