Airborne lidar data provides location and elevation information that defines the surface of the earth and the heights of above-ground features. With a suite of lidar sensors and advanced processing and production techniques, Fugro remains a leader in the lidar industry.

Lidar is an active laser system that measures the time of return from the emitted signal to the target. Airborne lidar systems can be categorised into bathymetric or topographic systems. Bathymetric systems are used to measure water depth using multiple green lasers. Airborne lidar data defines topography and the elevation of above-ground features, such as buildings, roads and tree canopy. Mounted on a helicopter or fixed-wing aircraft, topographic lidar systems use the near-infrared portion of the electro-magnetic spectrum to collect data night or day, in shadow, and beneath clouds.

Fugro’s suite of lidar sensors produce from 1 to 40 points per square metre (ppsm). The systems can record multiple returns from one laser pulse, providing measurements above and below tree canopy from a single pulse. The systems also record an intensity value from each pulse - this is used to produce a raster image for feature detection. Our lidar technology includes Riegl, Leica and in-house developed sensors that acquire data in many formats, including full waveform. We also specialise in bathymetric lidar, providing a full solution of land-to-sea elevation information.
LIDAR PRODUCTS
Lidar range and intensity data help generate bare-earth surface models, feature extraction and land-use characterisation. Fugro’s proprietary production routines include automated processing of data to bare ground, automatic extraction of water boundaries, generation of synthetic 3D breaklines and creation of land-cover classifications for calculating roughness of hydrologic features. We use these processes deliver detailed and reliable lidar and related mapping products.

- **Digital elevation models** – lidar provides a fast and cost-effective method for producing digital elevation models (DEMs), including reflective-surface DEMs from first returns for elevation of above-ground features, and bare-earth DEMs for accurate measurement of the earth’s surface.

- **Point cloud** – once all the elevation points are computed from the individual returns, the resulting dataset consists of a ‘cloud’ of points that represents elevations of ground and above-ground features. Lidar point clouds can be imported directly into numerous computer-aided design (CAD) programmes for volume computations, visualisation, fly-throughs, 3D modelling, line of sight, feature extraction, orthorectification and other applications.

- **Classifications** – Fugro meets all of the United States Geological Survey’s (USGS) base QL lidar classifications: processed, unclassified, bare earth, low noise, water, ignored ground, bridge decks, and high noise. Additional classifications are available to meet any client-specific requirements, including buildings, culverts, roads and low, medium and high vegetation.

- **Intensity images** – georeferenced lidar intensity images look similar to low-resolution photographs. They can be used to extract planimetric features and serve as ancillary input for lidar data processing. Intensity images can also be used to check the horizontal accuracy of the lidar data and other criteria.

- **Contours** – lidar-derived contours can be generated at 1’ to 5’ intervals, meeting National Map Accuracy Standards in accordance with the Federal Emergency Management Agency (FEMA) lidar mapping specifications and the American Society for Photogrammetry and Remote Sensing (ASPRS) standards.

- **Hydro-flattening** – is a cartographic or aesthetic enhancement to a DEM. A hydro-flattened DEM is created by extracting breaklines along water features within the lidar dataset to present a constant elevation for water bodies. Streams and rivers are flattened bank-to-bank and forced in a downhill flow to accurately represent flow.

- **Hydro-enforcement** – used for hydraulic and hydrologic modeling. In a hydro-enforced model, terrain is cut away at false obstructions (bridges and culverts) to model drainage connectivity, simulating how water would flow through the bridges and culverts. In the absence of hydro-enforcement, water would essentially be dammed by the topography, giving a false sense of pooling in areas where bridges or culverts exist.

- **Land use / land cover** – data may be used to generate preliminary land-cover classification depicting open, scrub or shrub, urban, and forested classifications. This can be useful for hydrologic and hydraulic modelling in support of floodplain mapping.
APPLICATIONS
Lidar data serves a wide range of applications:

- **Base mapping** – lidar DEMs are accurate for image orthorectification as well as for contour generation.
- **Floodplain mapping** – lidar data supports erosion forecasting, flood hazard analyses and hydrologic and hydraulic modelling.
- **Natural resources management** – lidar data is used to calculate tree-stand heights, biomass, and timber density. It is also useful in establishing volume calculations for mineral extraction.
- **Transportation and utility corridor mapping** – lidar data can supplement traditional ground and aerial surveys in the planning and design of new transportation and utility corridors, as well as ongoing maintenance of utility corridors.
- **Urban modeling** – 3D models from bare-earth and reflective-surface lidar data can be used to analyse and visualise things like urban planning, line-of-sight studies and view-shed analysis.
- **Change detection** – point clouds from multiple years of elevation data can be compared, to reveal areas of change and to track urban change, as well as for disaster mapping, forest restoration and shoreline mapping.

PROJECT PLANNING
Proper point spacing and vertical accuracy are critical considerations for any lidar mapping project. Factors that determine optimum point spacing include desired vertical accuracy, terrain, land cover, and the ultimate data application. More is not always better; the higher the point density, the greater the volume of data and the higher the processing cost. For many applications, a lower point density is sufficient and can save potential data storage and handling difficulties. To that end, Fugro plans projects with optimum flying height, point spacing, field of view and overlap between flight lines to meet project-specific requirements.
Base Lidar Specifications

<table>
<thead>
<tr>
<th>USGS National Geospatial Program lidar base specification V1.2</th>
<th>Vertical accuracy (RMSEz)*</th>
<th>NVA at 95% confidence level</th>
<th>Compilation</th>
<th>Product</th>
<th>ASPRS 1990 Class 1 contour interval</th>
<th>ASPRS 1990 Class 2 contour interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>QL0</td>
<td>8</td>
<td>≤5.0 cm</td>
<td>≤9.8 cm</td>
<td>Water bodies such as lakes and ponds ≥8000 sqm or 2 acres, streams and rivers ≥30 m or 100'</td>
<td>Hydro-flattened DEM (0.5 m, 1’), raw lidar point cloud, classified point cloud, hydro breaklines, Federal Geographic Data Committee (FGDC) compliant metadata</td>
<td>15 cm</td>
</tr>
<tr>
<td>QL1</td>
<td>8</td>
<td>≤10.0 cm</td>
<td>≤19.6 cm</td>
<td>Water bodies such as lakes and ponds ≥8000 sqm or 2 acres, streams and rivers ≥30 m or 100'</td>
<td>Hydro-flattened DEM (0.5 m, 1’), raw lidar point cloud, classified point cloud, hydro breaklines, FGDC compliant metadata</td>
<td>30 cm</td>
</tr>
<tr>
<td>QL2</td>
<td>2</td>
<td>≤10.0 cm</td>
<td>≤19.6 cm</td>
<td>Water bodies such as lakes and ponds ≥8000 sqm or 2 acres, streams and rivers ≥30 m or 100'</td>
<td>Hydro-flattened DEM (1 m, 2’), raw lidar point cloud, classified point cloud, hydro breaklines, FGDC compliant metadata</td>
<td>30 cm</td>
</tr>
<tr>
<td>QL3</td>
<td>0.5</td>
<td>≤20.0 cm</td>
<td>≤39.2 cm</td>
<td>Water bodies such as lakes and ponds ≥8000 sqm or 2 acres, streams and rivers ≥30 m or 100'</td>
<td>Hydro-flattened DEM (2 m, 5’), raw lidar point cloud, classified point cloud, hydro breaklines, FGDC compliant metadata</td>
<td>60 cm</td>
</tr>
</tbody>
</table>

Additional products available:
- Digital surface model (DSM)
- Hydro enforced DEM
- Hillshade

USGS base classifications:
- 1: Processed, unclassified
- 2: Bare earth
- 7: Low noise
- 9: Water
- 10: Ignored ground
- 17: Bridge decks
- 18: High noise

Additional classes:
- Buildings
- Culverts
- Roads
- Low vegetation
- Medium vegetation
- High vegetation

* RMSEz - Root mean square error in z
Vertical accuracy is calculated using non-vegetated surfaces at a 95 % confidence level = 1.96 RMSEz

(Left) Buildings represented as an additional classification in a QL2 DEM. (Right) A comparison DEM to illustrate hydro-enforcement - the surface obstruction, a bridge in this case, is removed in the far right image to create a seamless flow through a culvert.

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