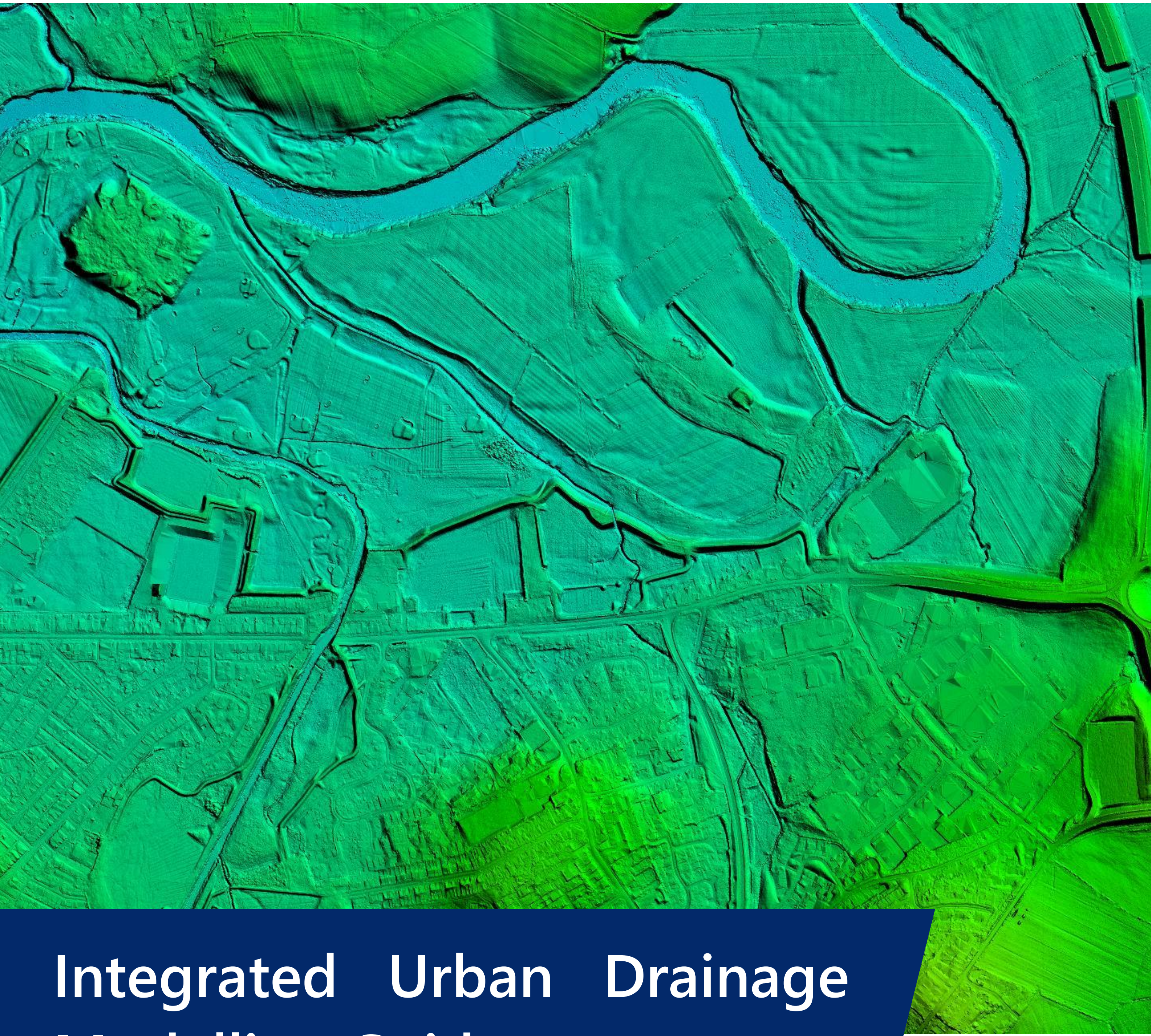


Integrated Urban Drainage Modelling Guide

Appendix C

Lidar Data

CIWEM Chartered Institution of Water and Environmental Management

C1. What is LiDAR?

LiDAR is an acronym for a measurement technique known as Light Detection And Ranging, and was developed by taking advantage of the invention of lasers in the 1960s. Originally deployed on a fixed wing aircraft, LiDAR is an active sensor, operating by emitting a laser pulse and measuring the time taken for the pulse to be reflected off the feature of interest, and detected back at the instrument. LiDAR is an active sensor, as it fires a beam of light, as opposed to a passive sensor, e.g. a camera which detects light reflecting from the ground.

By accurately measuring the intervening time, distances or ranges to the object being measured can be deduced. Modern systems make use of Global Navigation Satellite Systems (GNSS) technologies to convert the ranges into a 3D position of each laser pulse forming a LiDAR point cloud accurately depicting the terrain below the sensor.

Since their first usage they have become the predominant method of obtaining accurate 3D data from aerial survey and offer advantages over photogrammetric methods such as the ability to capture data at night and under trees.

The most important metrics when discussing LiDAR data are data accuracy and the LiDAR point density or resolution. The laser point density expressed as the number of points per m^2 is a measure of the spatial resolution of the LiDAR data. The higher the point density the higher the spatial resolution and therefore more detail will be visible in the data.

The point density is influenced by the characteristics of the instrument itself. In simple terms the more powerful laser systems operate at higher flying heights. The field of view (FOV) of the instrument controls the ground coverage, together with the flying height, as shown in Figure 1. As the flying height increases the footprint on the ground increases with the same FOV. Areal coverage is achieved by capturing adjacent strips.

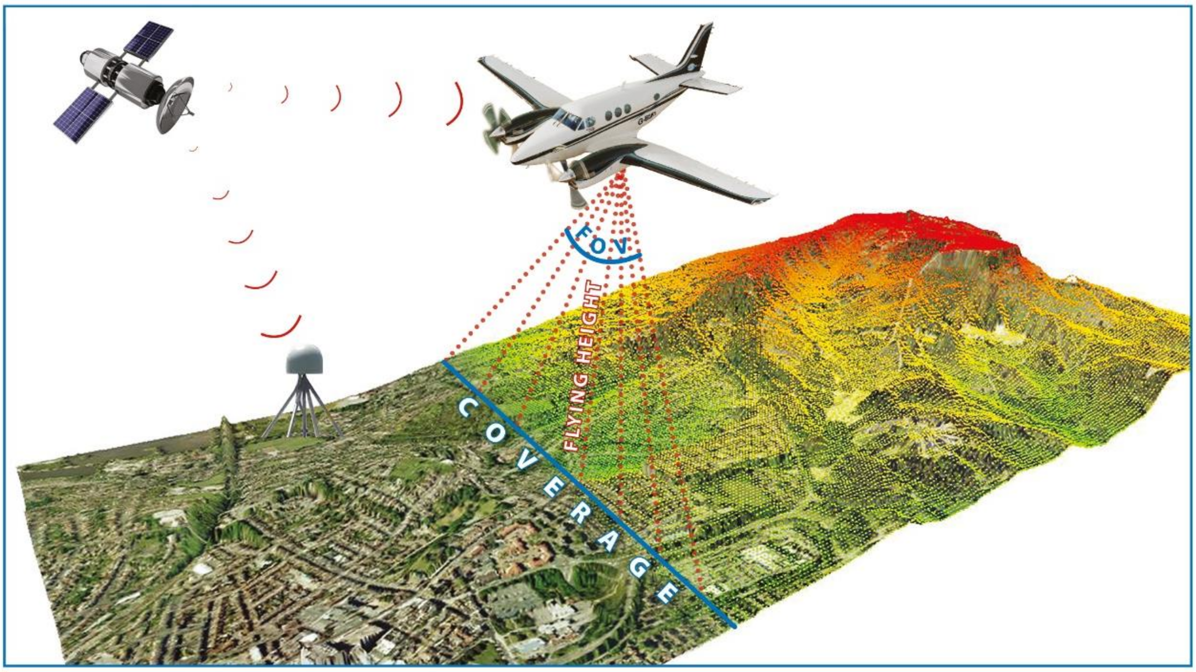


Figure 1: The relationship between flying height FOV and coverage

The point density is controlled by the laser Pulse Rate Frequency (PRF) or the number of times the laser fires every second and the laser scan rate. The higher the PRF and scan rate the higher the point density for a given FOV and aircraft speed. If the aircraft speed is slowed down this will also increase the point density.

Therefore, there is a balance to be struck between obtaining high point densities at lower altitudes and slower aircraft speeds and the cost of the survey.

LiDAR data accuracy is dependent on the flying height and on the specification of GNSS / IMU navigation equipment used with the LiDAR instrument. Laser ranging and timing errors are also a factor. Accuracy values are commonly quoted in RMSE figures.

C2. LiDAR Data Capture

The starting point for any LiDAR survey should always be a geo-referenced digital file supplied by the client showing their area of interest (AOI), e.g a KMZ or SHP file. In many cases this is accompanied by a specification document providing details of the targeted point density, accuracy requirements, any project constraints and the deliverable products to be created.

The LiDAR data capture contractor will then be able to accurately plan the necessary flights taking into consideration, mobilisation flights the local topography, and any controlled airspace restrictions, and a price provided accordingly.

C2.1 Project Constraints

During the project commissioning process, it is important to identify and address any constraints that are likely to restrict the LiDAR data capture at the earliest opportunity.

These can include the following:

- Prevailing Weather: LiDAR data cannot be captured in fog, damp or wet conditions as any standing water or excess moisture will absorb the laser energy pulse and therefore no returns will be recorded. Similarly, in excessively windy conditions it may be unsafe to fly.
- Military or Civil Security Clearances: These may be required to fly over, photograph, and process data of sensitive locations or to be able to operate in particular countries.
- Air Traffic Control Requirements: Some element of air traffic control is required to operate fixed wing, helicopters and UAV’s in congested airspace. This may require applying for permissions in advance, which are time sensitive. Your flying contractor will have the responsibility to obtain these permissions. Permissions are more difficult to obtain around major airports or over military training areas.
- Time of Year: The normal flying season is from April to October in the northern hemisphere to maximise the available opportunities in the best weather and when the vegetation is in full bloom. However, some clients, particularly in the US, may specify winter “leaf-off” flying conditions. The timing of this period is variable and should be subject to agreement between the client and the contractor.

- Tidal Constraints: This is a common requirement for coastal projects where it is beneficial for the maximum amount of land to be exposed during the data capture period. An agreement is required regarding the definition of the tidal window. This will of course limit the amount of time available to carry out the survey.
- Health and Safety / Environmental Requirements: Some clients may require risk assessments to be prepared for example low level flights in sensitive local areas, during unsociable hours.
- Special Limitations: There may be special limitations relating to observance of religious days or for security reasons when flying may also be restricted.

C3. Data Quality

The decision to fly or not to fly on a particular day is crucial in determining the final LiDAR data quality.

The following guidance notes are intended to act as a set of acceptable quality limits (AQL's) to provide guidance on maintaining LiDAR data quality.

- LiDAR data can be captured independent of solar altitude.
- Flights can take place during the winter and at night.
- Point density and point cloud accuracy specifications must be met.
- Full coverage must be achieved.
- There should be a good match between flight runs, with sufficient overlap.
- The LiDAR shall only be flown in good conditions, in the absence of rain, cloud, atmospheric haze, snow, and flooding.

C3.1 Ground Control Requirements

Independent ground control points are required to validate aerial LiDAR surveys. To be effective these ground control points need to be captured with a higher accuracy technique.

There are two types of points – ground control areas (GCAs) a grid of 121 points, acting as a higher accuracy patch of DTM, to validate the height of the captured data, and ground control points (GCPs), captured on points of detail to validate the plan X,Y position.

Land survey techniques such as GNSS, or the use of a total station are appropriate methods for this type of validation work. In general terms the ground control points should have an accuracy of three times as accurate as the LiDAR survey being controlled.

Ground control areas do not necessarily need to be completely flat. They should be established on hard smooth surfaces, such as a car park within the survey area away from aerial obstructions such as tall buildings or trees. If there is space, a 5m x 5m grid should be established with a point roughly every 0.5m, giving a total of 121 points.

Ground control points are captured on points of detail, on hard surfaces, within the project area away from overhead obstructions which can be located in the LiDAR data. Suitable points are along the tops of kerb lines, low wall corners, changes in pavement types. 20 points in each location are enough for this purpose.

The number of ground control point locations are dependent on the size and shape of the area being surveyed.

C3.2 Assessment of Data Quality

LiDAR data quality can be assessed by reviewing the following:

- Coverage
- Point Density
- Fit to ground control
- LiDAR instrument
- Capture conditions

The coverage can be checked by simply reviewing the captured data against the specified area of interest, taking into consideration areas of water where no LiDAR points will be captured.

The point density should meet the specified value, and be evenly distributed across the area of interest, with the exception of areas of water.

The absolute accuracy of the point cloud can be verified by reviewing the fit to the independent ground control points as specified in Section 3.1. The independent ground control points can be automatically assessed against the LiDAR point cloud in both plan and height and a numerical report created.

The data quality in any LiDAR project is largely dependent on the data capture. Consequently, the contractor will focus on ensuring that the LiDAR instrument is in good working order and that the data is captured in good quality conditions.

It is recommended that the contractor delivers a survey report with the final data deliverables detailing the five points above. This will go a long way to ensure that the specified data quality has been met.

C4. Data Deliverables

In the past ten years LiDAR data has established itself as a high-point density, high accuracy source of three-dimensional data. LiDAR also offers advantages in the speed of data capture of large areas and the ability to penetrate vegetation. LiDAR has found applications in the management of water drainage networks, flood risk management, coastal erosion, forestry, engineering design, engineering asset management, 3D topographic mapping and 3D city modelling.

The two most common LiDAR products are DTM / DSM and Classified Point Clouds. A DTM or a Digital Terrain Model is where a ground class is extracted from points located on the ground under trees and bridges. A DSM or a Digital Surface Model includes the ground points plus all surface features such as buildings and the tops of tree canopies, as shown in Figure 2.

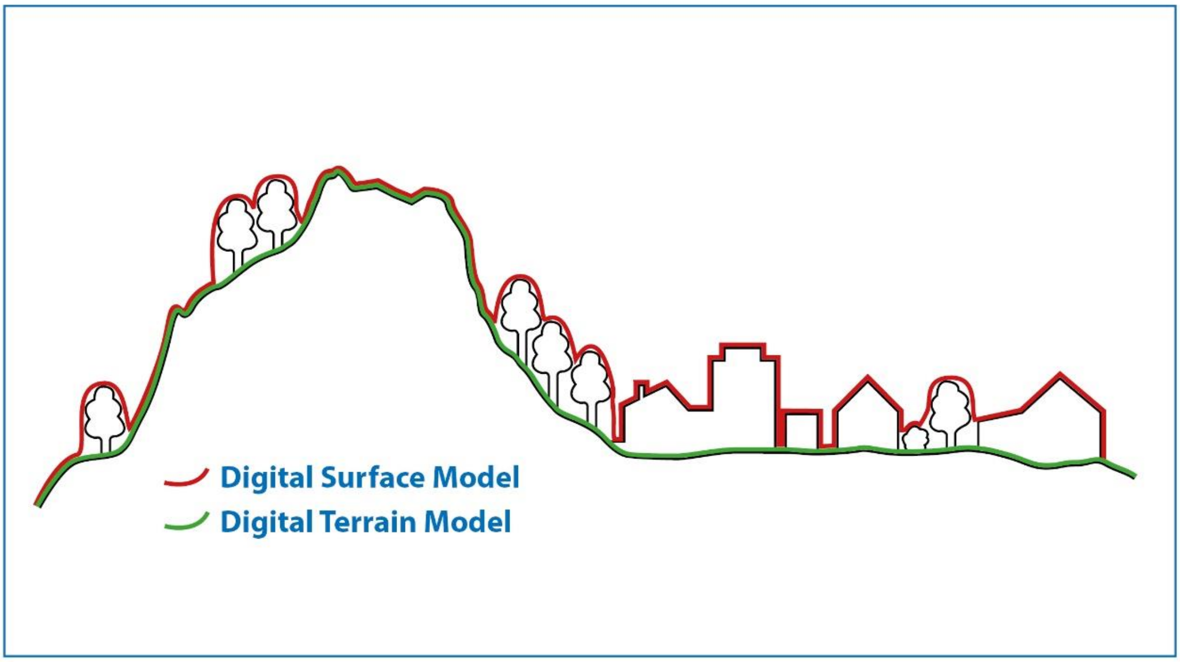
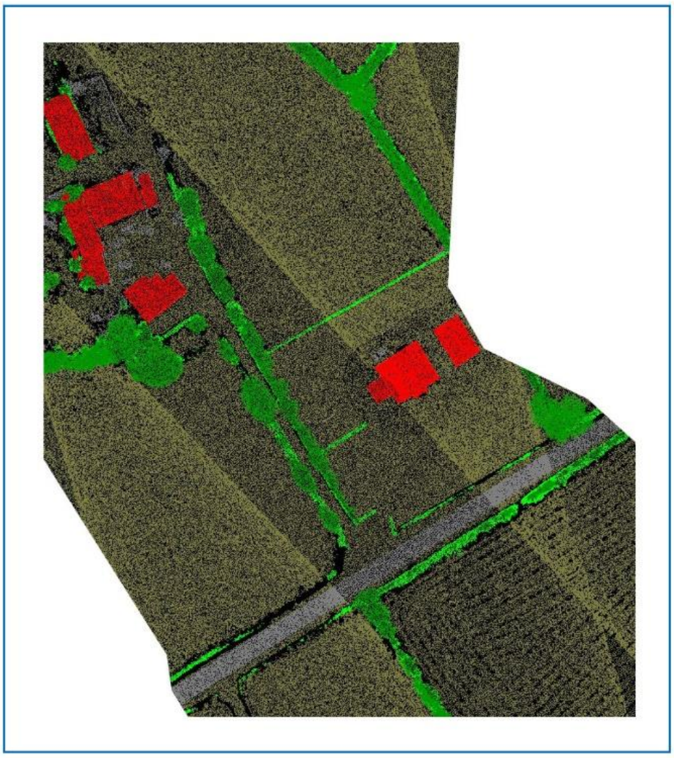


Figure 2: DTM and DSM data

Hydraulic modelling, Flood Risk Assessments, flood management and coastal erosion are more likely to use DTM data whereas Forestry and 3D city modelling applications will make more use of DSM data. Clients frequently commission both DTM and DSM data, allowing flexibility for their particular applications. Frequently both surfaces are used together to create a difference map.

DTM and DSM data can also be created using photogrammetric techniques. These types of data are derived from the captured stereo imagery. In contrast LiDAR data is composed of directly measured points and is frequently able to provide ground points underneath areas of vegetation.



Classified point clouds provide additional detail by further classifying the data into separate classes to suit particular applications of the data. In this scenario the points above the ground can be classified further by classifying the buildings, hard surfaces, high and low vegetation, an example is shown in Figure 3.

Figure 3: Classified point cloud