by Andrew Richman and Patrick Hogarth

Before the British Deluge

Using Mobile Lidar Data to Manage Risk in Flood-Prone

More than five million people in England and Wales live and work on properties that are at risk of flooding from rivers or the sea. The Environment Agency for England and Wales is responsible for managing this flood risk. One of its principal aims is to reduce the probability of flooding by managing land, river systems, and flood and coastal defenses.

A critical key to risk reduction is to gather relevant data on waterways: tidal periods, flood patterns, precipitation records, high/low water levels, and ground absorption and runoff patterns. Amassing data and refining its accuracy allows for the development of computer models with improved capacity for predicting outcomes.

The Environment Agency Geomatics Group is a leader in capturing high-quality lidar survey and remote sensing data. Over the past 12 years, the Geomatics Group has been responsible for the Environment Agency's project of collecting a national picture with airborne lidar data, then storing, classifying, and analyzing the resultant survey data. From this data, the Geomatics Group delivers integrated spatial data solutions and products that support a wide range of applications, including environmental planning, flood monitoring, and asset management. In addition to lidar, the Geomatics Group also gathers a range of other data types, including those derived from digital aerial photography, hyperspectral imaging, and bathymetric soundings.

Deploying the Mobile Mapper

In some flood risk management projects, the Geomatics Group used the Lynx Mobile Mapper, Optech's mobile terrestrial lidar system, to collect data. Mounted on a Land Rover Discovery, the Lynx system captures 3D georeferenced spatial data (X, Y, Z points) of features within the floodplain and urban areas, such as bridges, buildings, barriers, lighting, and vegetation.

The Lynx Mobile Mapper is typically configured with two lidar sensors mounted on the roof rack of a survey vehicle (**Figure 1**). Each of these sensors has a 360° field-of-view, which minimizes shadowing from other road vehicles. The sensors are capable of emitting up to 200,000 laser pulses per second (200 kHz), a repetition rate that produces a very dense concentration of laser points on the survey area and results in high-resolution 3D georeferenced spatial data.

The Lynx integrates a GPS system to accurately track the survey vehicle's path as it travels through the survey area. An on-board Inertial Navigation System (INS) further refines the GPS position information, taking into account the position and attitude (heading, pitch, and roll) of the sensors as the vehicle maneuvers through the survey area. The combination of GPS and INS positioning systems yields a measurement accuracy of ±5 cm and a spatial resolution of up to 1 cm at survey speeds of up to 100 km/h. Because spatial data is captured at normal driving speed, the scanning range of up to 200 m makes it possible to survey very large areas in very little time, thereby offering a highly cost-effective solution.

Along with the two lidar sensors, two high-resolution digital cameras are also mounted on the roof rack. The cameras are boresighted with respect to the angular orientation of the lidar sensors so that photographic images can readily be aligned with the 3D point clouds. In this way, 3D spatial data can be "draped" with the camera's RGB values to produce a visually striking and spatially accurate 3D model of the area of interest.

Figure 1

Quickly capturing accurate 3D spatial data is especially helpful in flood risk management and flood-related applications because it provides information on the performance of existing asset management, assists with archaeological surveys prior to scheme construction, and helps to develop surface water/drainage flood modeling research. For example, in one survey, the Geomatics Group was tasked with mapping the remains of a medieval causeway to provide a digital "preservation by record" with the local archaeology trust. The area of land surrounding the medieval causeway was used as the source of clay material for part of the earthworks in a flood defense scheme in Conwy, Wales. The provision of clay from this site resulted in a cost savings of £250k (≈ $377,000) for the overall scheme. The Lynx was able to traverse the site and capture a digital record of all features, prior to construction, and within a single day of surveying (**Figure 2**).

Areas

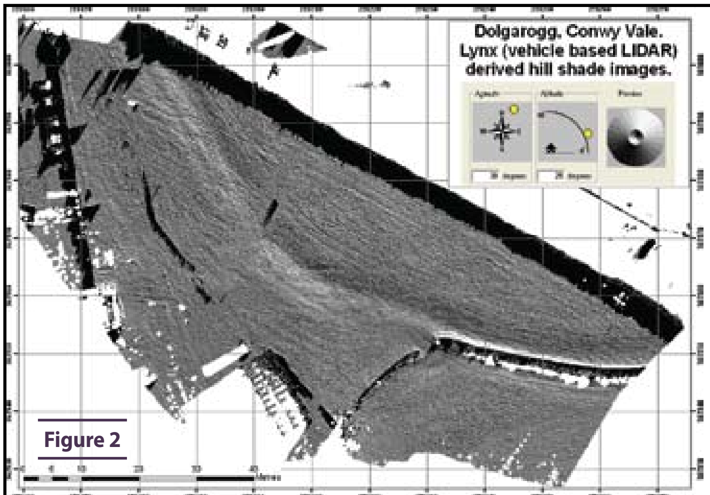


Figure 2

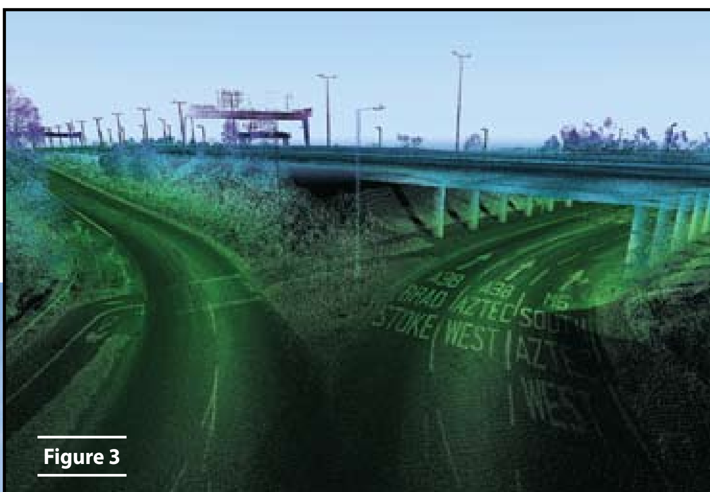


Figure 3

Figure 1
Lynx Mobile Mapper mounted on survey vehicle

Figure 2
Lidar-derived hill shade image

Figure 3
A Lynx-derived 3D point cloud colored by elevation and intensity

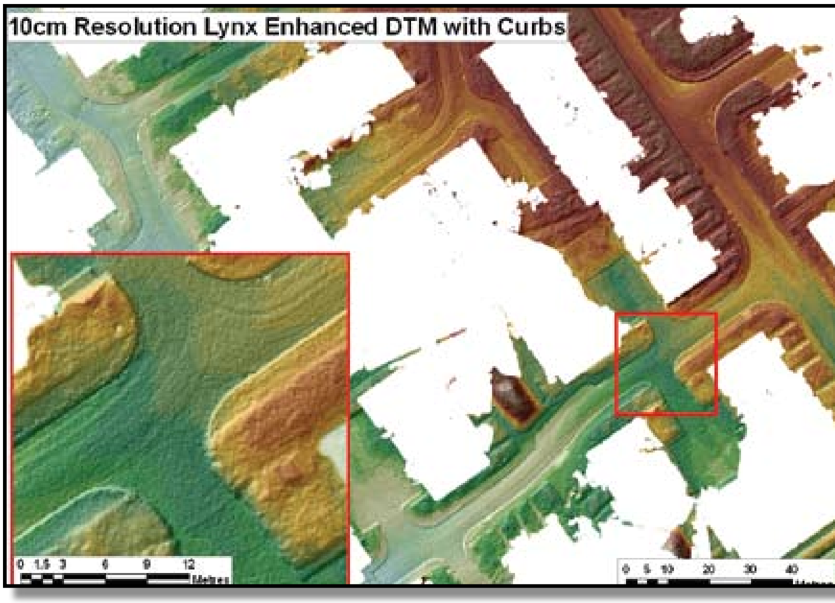
Revealing an Invisible Risk

The Geomatics Group Lynx survey team has now captured data for urban locations for research into surface water modeling. One of the first surveys was for a section of urban high street for Torbay council, Devon, England. The data was provided to Torbay council under joint funding from UK Water Industry Research and Flood Risk Management Research Council with Imperial College University, London. From the Lynx Mobile Mapper data it was possible to extract precise X, Y, Z height vectors and points of features, such as manhole covers, and link these to the underground sewage network. This vector output was then used in part of the flood modeling tools to assess overland flows during a high rainfall event.

Other towns where data has been collected include Shipston-upon-Stour, Staffordshire, Morpeth, Blyth, and Clitheroe, England. Teams within the Environment Agency are interested in developing better visualizations to show residents what their environment would look like "before and after" building flood-defense schemes. Being able to provide such highly detailed, street-level data is very useful for information-gathering sessions aimed at increasing public awareness and engagement. Providing such data can also be instrumental in advancing (or averting) policy decisions that affect municipal construction and infrastructure management.

From the gathered data, the Geomatics Group has generated spatially-referenced 3D images of survey routes and the local surroundings (**Figure 3**), providing data suitable not only for 3D visualizations but also for precise measurement extraction of engineering quality within AutoCAD. This is one of the great advantages of using the Lynx Mobile Mapper: because the data is directly digital, it can be imported to AutoCAD and other commercial software programs without intermediate conversion steps.

One of these applications has been in developing 3D visualizations to show people the return-period flood levels on their street, and hence, what level of flood risk they can anticipate. Ultimately, the aim is to encourage people to be more proactive in making their properties more flood resilient. Such visualizations are useful at events and exhibitions to stimulate interest and



Left
Digital terrain model derived from Lynx lidar data, 10 cm resolution

involvement, something the Environment Agency already does through the use of 2D maps and 3D fly-throughs.

The Geomatics Group has done further work on producing a 10-cm raster-enhanced digital terrain model (DTM) product (**Figure 4**). This data set was made possible by processing the Lynx data to separate surface objects from ground objects while retaining the height of curbs, roads, paths, and pavements. The break-lines of these features (e.g., road center-line heights and back-of-pavement heights) can then be extracted as 3D vectors, again for use in surface-water modeling.

Future Challenges

Whenever the survey team works in urban areas they must consider factors that affect the efficiency of the survey and, ultimately, the quality of lidar data acquired. GPS and GNSS coverage are essential to ensuring quality data. Confirming through a GPS almanac and then planning the survey for a time of optimal GPS signal reception is fundamental. Various techniques for driving the survey vehicle, such as "leap-frogging"—maneuvering the vehicle to an open space, clear of obstruction, to regain a blocked GPS signal—can be critical in urban surveys. Accessing streets at the right time of day (when the fewest number of cars are parked) increases the likelihood of getting the best data set. Fortunately, the Lynx Mobile Mapper is an active laser sensing system, which means that it works independent of ambient lighting and can therefore survey at night when there is generally less traffic. Another challenge to surveyors can arise when trying to acquire suitable ground truth data for calibrating and quality control of the final data set.

The Lynx Mobile Mapper provides very good detail of the features that can be seen within line-of-sight and for collecting features such as road, pavement, and curb surfaces. High-resolution airborne lidar data (1 m and 50 cm) provides a very good plan view of an area, so one challenge for the Environment Agency now is to develop the best ways to integrate both airborne and vehicle-based lidar data sets for use in urban flood modeling.

For those areas where very high-resolution terrestrial data is required for improved flood modeling, one potential that is being researched involves combining high-resolution airborne lidar data with "hot spots" of Lynx data. The Environment Agency Geomatics Group has flown complete 1-m-resolution lidar coverage of urban areas and then used Lynx ground-based lidar data to provide higher resolution details of specific streets within the urban center for more complex street-level flood modeling. The Agency will also continue to develop its applications and uses of Lynx data.

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