Chapter 1.
Landscape Visualisation: A LiDAR Topographic Model

SURVEY AREA

One of the key project elements involved in the '*Where Rivers Meet*' project design was the creation of a LiDAR (**Li**ght **D**istance **A**nd **R**anging) based DEM/DTM (Digital Elevation Model/Digital Terrain Model) of the complete survey area. DEM's/DTM's can be established by other means, for example Orthphotography, Ordnance Survey Panorama data or Aster Satellite imagery. However, the benefits of a LiDAR survey, large point density, the intensity readings (see below), the capture of the landscape as current as possible, and the flexibility of output makes for a highly appropriate method. The coverage of LiDAR in the case of *Where Rivers Meet* approximated to 72km^2 of South Staffordshire, from just north of Tamworth in the south to just below Burton upon Trent in the North.

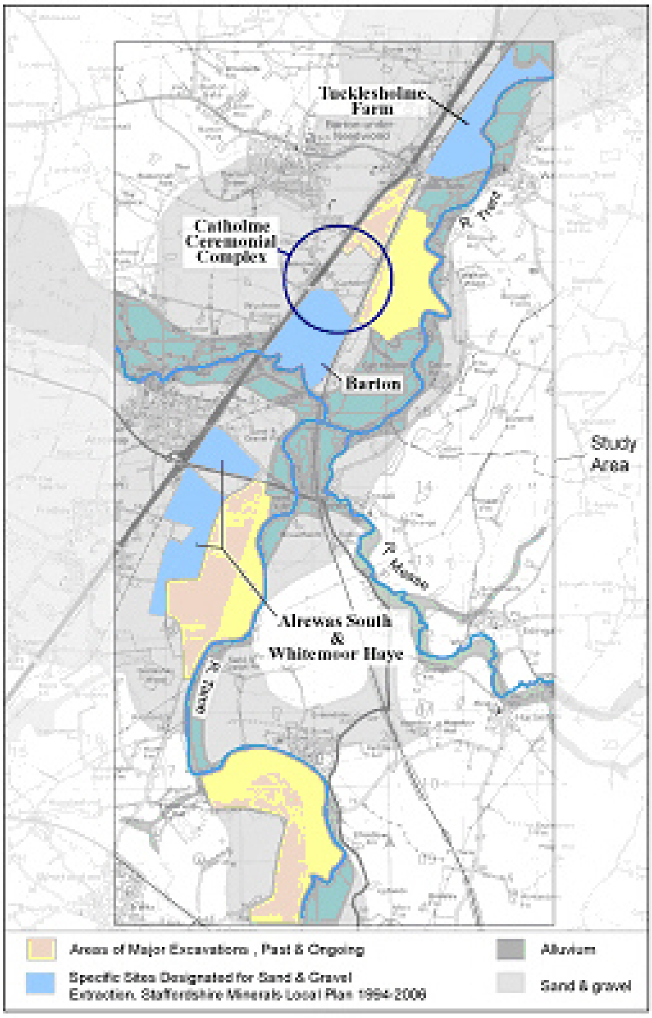

Figure 1: Where Rivers Meet LiDAR survey area

DATA COLLECTION

The LiDAR survey was commissioned in February 2002 to be flown by Infoterra Ltd using their Optech ALTM 2033 (Airborne Laser Terrain Mappers) system, as operated by NERC and the Environment Agency. The survey was scheduled to take place as soon as an open weather window became available. Undertaking the survey at this time of year takes full advantage of the lack of vegetation cover from crop growth and foliage. Care has to be taken not to fly directly after heavy rain as large areas of standing water may adversely effect the resulting data. The system is mounted in a light aircraft or helicopter with the laser at 90 degrees to the base of the plane. The aircraft will then follow a predetermined flight plan of transects over the survey area with the pilot attempting to keep the aircraft at a set altitude and consistent angle relative to the landscape surface. The laser beam then scans the ground surface in 20-degree swaths. LiDAR lasers are not eye safe and will shut off if an object passes under the beam close to the plane. Therefore air traffic clearance and laser cut off buffer zones around large towers/obstacle are important issues.

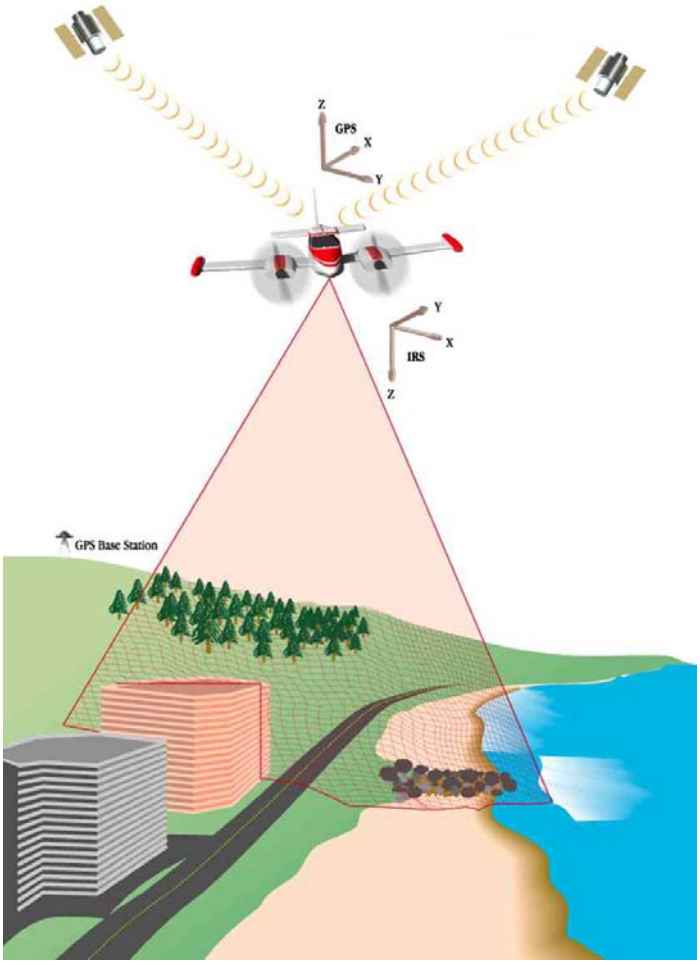

Figure 2: LiDAR survey positioning information (Optech ALTM www.optech.on.ca/prodaltm.htm)

Unlike the majority of other airborne survey techniques LiDAR is not effect by lighting levels, with the ability to operate at night or to be calibrated for extremely bright environments. Reflectivity does not generally cause a problem for LiDAR units, with the exception of water, however, different reflective elements do effect the returning signal strength, a property that can be utilised by imaging the resulting return intensity (see below).

LiDAR surveys produce highly accurate topographical information, but still based around basic survey principles. LiDAR surveys generate x, y, z point information but collect millions of these during the flight, the ALTM 2033, using a time of flight format, generating 33,000 points per second. The density of the point spacing can be varied by flight speed, by the number of passes made over the target area, and by narrowing the band swath the laser collects. For the '*Where Rivers Meet'* (WRM) survey an effective minimum spacing of 1 point per metre (ppm) was specified. A further reading, known as intensity, was also collected (see below). The LiDAR system records not only the data coming back from the laser but also the GPS (Global Positioning System) and INS (Inertial Navigation System, the role, pitch, and yaw, or 'attitude' of the plane). By combining the two onboard measurements the LiDAR system can produce a relatively accurate positional fix. However to reach to desired positional accuracy of the point data, stated as +/-15cm for the ALTM 2033, this navigational information has to be related to a positional fix on the ground. As the LiDAR survey takes place a GPS base station on the ground collects observations from a fixed point for the duration of the flight. The observations gathered from this base station are then merged with the GPS/INS from the LiDAR sensor in the initial stage of post-processing to provide the very accurate positional fix (Figure 1).

Initial Data Processing

There are two levels of point data collected by the LiDAR survey along with the intensity measurement mentioned above. Data from first pulse and last pulse are elements of the same survey referring to different stages in the measuring process. First pulse refers to the fastest return signal to the LiDAR sensor and can be thought of as the 'first return' of the laser. As the laser beam can penetrate vegetation cover and some man made materials a last pulse is also received; this refers to the final return of the pulse. These differences in return time produce varying end products. Point clouds generated from first pulse data will normally have a far greater emphasis on vegetation cover and fine objects (e.g. power lines from electricity pylons).

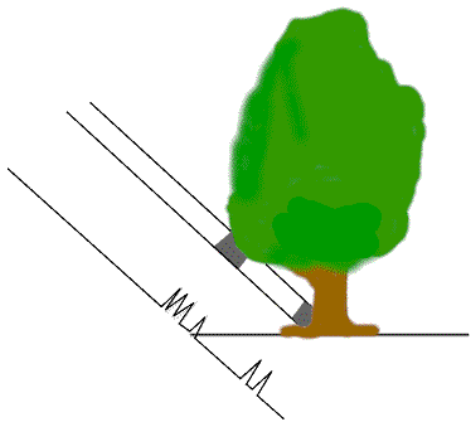

Figure 3: First pulse/last pulse return. Surfaces under vegitation can often be picked up by a last pulse measuement (www.optech.on.ca/aboutlaser.htm)

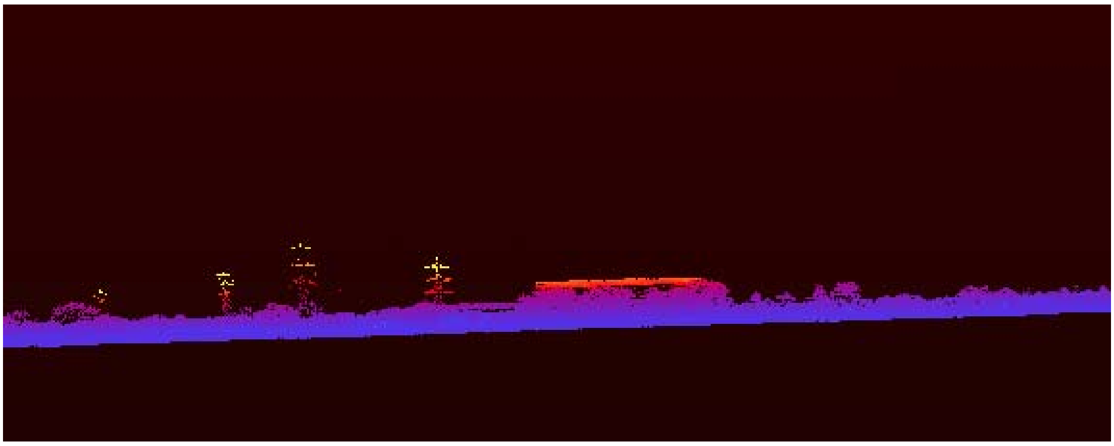

Figure 4: Profile view of raw first pulse points file. vegitation & pylons are clearly visable

Point clouds generated from the last pulse return will often have passed through some of the vegetation and will more accurately represent surface or ground features. Therefore first pulse data is best used in the creation of a Digital Elevation Models (DEM) where the highest point of every surface is required and so will include vegetation, buildings, vehicles and groups of people. Last Pulse point clouds will pick up thicker vegetation but will also have more points relating to the actual landscape surface. As such last pulse point clouds are closer to a Digital Terrain Model (DTM) but while still requiring further processing. This initial separation of points into first and last pulse clouds can be performed as a first output straight after the ground and airborne navigation integration and correction. The output of this will be an ascii (see glossary) text file with x, y, z and intensity (int) columns for first and last pulse. Although the first pulse data can be taken and used for a DEM the last pulse data requires a further stage of separation to filter out more points.

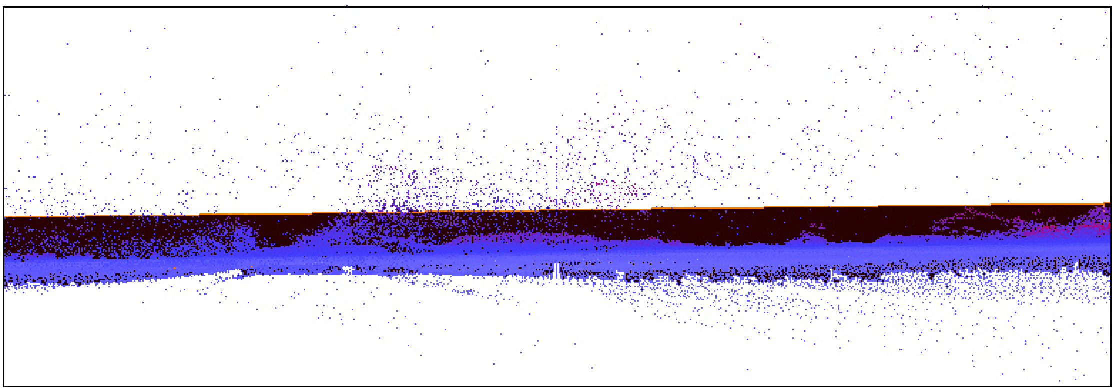

Figure 5: Raw point cloud showing out-liers (above surface normal) and erroneous points (below surface normal)

Although some vegetation will be missing from the last pulse information it will still contain hard vegetation (tree trunks, thick canopy), buildings, and vehicles. To create a useful DTM these points need to be filtered out to achieve last pulse ground file, just the points relating to the ground surface. This can be performed in a number of software packages, REALM (www.optech.on.ca/altmsys.htm), TerraScan (www.terrasolid.fi), Amira (www.tgs.com), using varying techniques. Most have mathematical algorithms that trace a path from point to point in the data looking for changes in the height value. By scanning surrounding points and referring to a configurable tolerance they can detect points that are unlikely to be the natural ground surface. These points can then be separated off and a more realistic ground surface generated. This process is not always completely accurate and some manual editing is often necessary. Very large one to two story warehouses, aircraft hangers (especially old domed military hangers) and open shaft mines can all occasionally be interpreted incorrectly and require reassigning. Packages such as TerraScan allow multiple levels of grouping and targeting algorithms to allow much finer segregation. This allows for producing files containing ground points and intermittent larger vegetation but not buildings and scrub. However these will often require more user intervention.

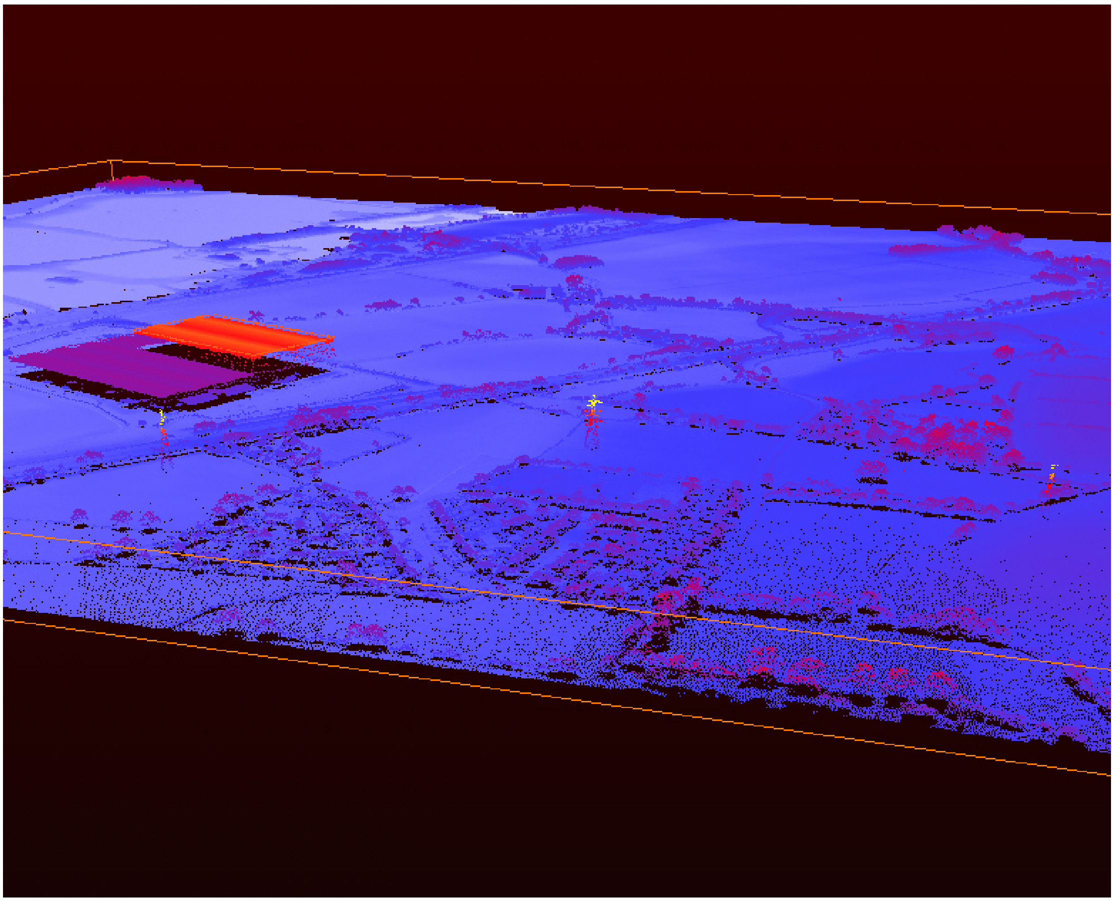

Figure 6: Overview of WRM focus area generated from raw first pulse points