Practical Uses of LiDAR

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1 Introduction

1.1 Background

To quantify the impact of the 2016 Kaikōura Earthquake on topography and water resources, the Flaxbourne Settlers Group (FSG) captured high resolution LiDAR information. This has been used to derive a 1m Digital Terrain Model (DTM) of the Waima/Ure, Mizra and Flaxbourne catchments.

High resolution LiDAR and DTMs can be used to assist land use decisions on both a large and small scale. For example, slope and aspect can be delineated to highlight possible irrigable areas, and flow paths can be defined to inform options for both drainage and seasonal water storage.

When used in conjunction with information on soils and land cover, the LiDAR and DTMs can also be used to better understand a wide range of other issues; including nutrient loss and erosion rates. These can be assessed at both a farm or catchment scale. As a result, the LiDAR and DTMs are valuable tools for informing and assisting with farm management decisions. These tools can also be used to provide catchment-wide plans or inform local stakeholders of where they can target specific land management interventions to, for example, reduce erosion and nutrient loss.

1.2 Purpose

The purpose of this report is to describe and illustrate a range of tasks that can be undertaken using the high-resolution LiDAR with reference to a number of characteristic landscapes.

2 Methodology

Available LiDAR data was used to derive a Digital Elevation Model (DEM). The LiDAR was obtained after the Kaikōura Earthquake (2016-2018) and covers the full extent of the Flaxbourne, Waima/Ure and Mirza catchment areas.

For the purpose of this report, three areas were selected to demonstrate the uses of this LiDAR. These three areas are within the Flaxbourne catchment and have been chosen because they reflect different potential land management issues.

- Survey area 1: This area has been known to have some drainage problems. Identification of depression zones and potential drainage channel locations could help with management of this area.
- Survey area 2: This area has been recently filled by the land owner. Calculating the volume of soil required to fill a gully would assist land owners to determine possible costs. The change in potential for irrigation could then be assessed.
- Survey area 3: Understanding the potential volume of an area within a gully at a range of relative heights would help determine the potential for on farm water storage.

A range of outputs have been generated from the LiDAR for these three areas. These include maps of: the DEM, hillshade, aspect, slope, overland flow paths, depression zones and small dam storage volumes. Further information of other potential uses of LiDAR for agriculture are provided but not specifically modelled for these areas because of time and costs constraints.

3 Outputs

3.1 A digital elevation model (DEM)

A digital elevation model is a 3D representation of a terrain surface and is a fundamental basis for mapping relief. It is the basis of many applications which require some knowledge of the underlying terrain to make informed land management decisions.

Figure 3-1 (left) shows the DEM for survey areas 1 & 2, with areas of higher elevation in the eastern part of the lower block. From the DEM the hillshade can be generated (Figure 3-1, right) which highlights topographical features of the landscape.

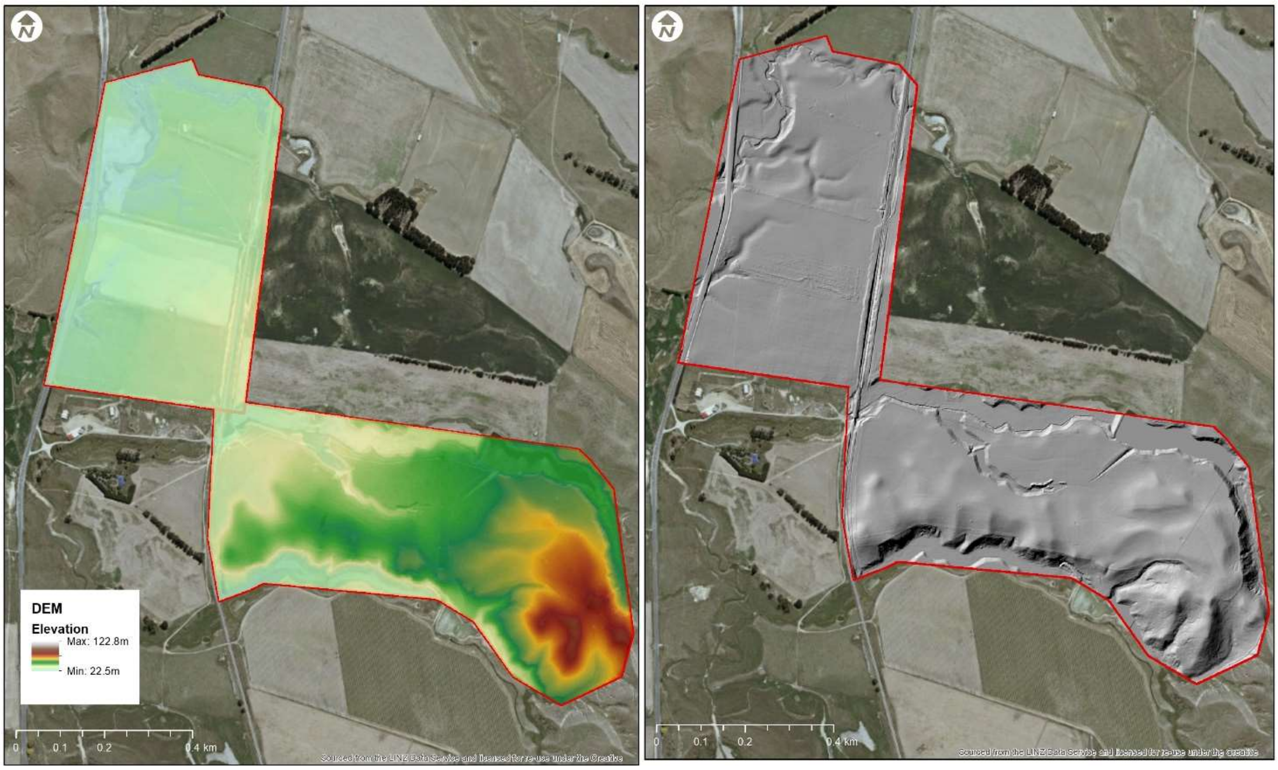

Figure 3-1: Digital Elevation Model (DEM, left) and hillshade (right) maps of Survey Areas 1 & 2.

3.2 Slope analysis

The DEM can be used to produce slope maps, which can then be used to inform the best use of the land and irrigation potential. Figure 3-2 (left) classifies slope according to the Land Use Capability Survey Handbook (1974). In Figure 3-2 (right), slope has been converted into bands which represent the ease with which large irrigation infrastructure could be used on different parts of the farm blocks.

Figure 3-2: Slope map for Survey Areas 1 & 2 (left) and a classification based on ease with which large irrigation infrastructure could used.

3.3 Aspect analysis

The DEM can also be used to produce an aspect map (Figure 3-3). The direction in which a slope faces affects the amount of sun it receives, and also whether it is protected from the prevailing wind. This can have an impact of soil temperatures, productivity and evapotranspiration rates.

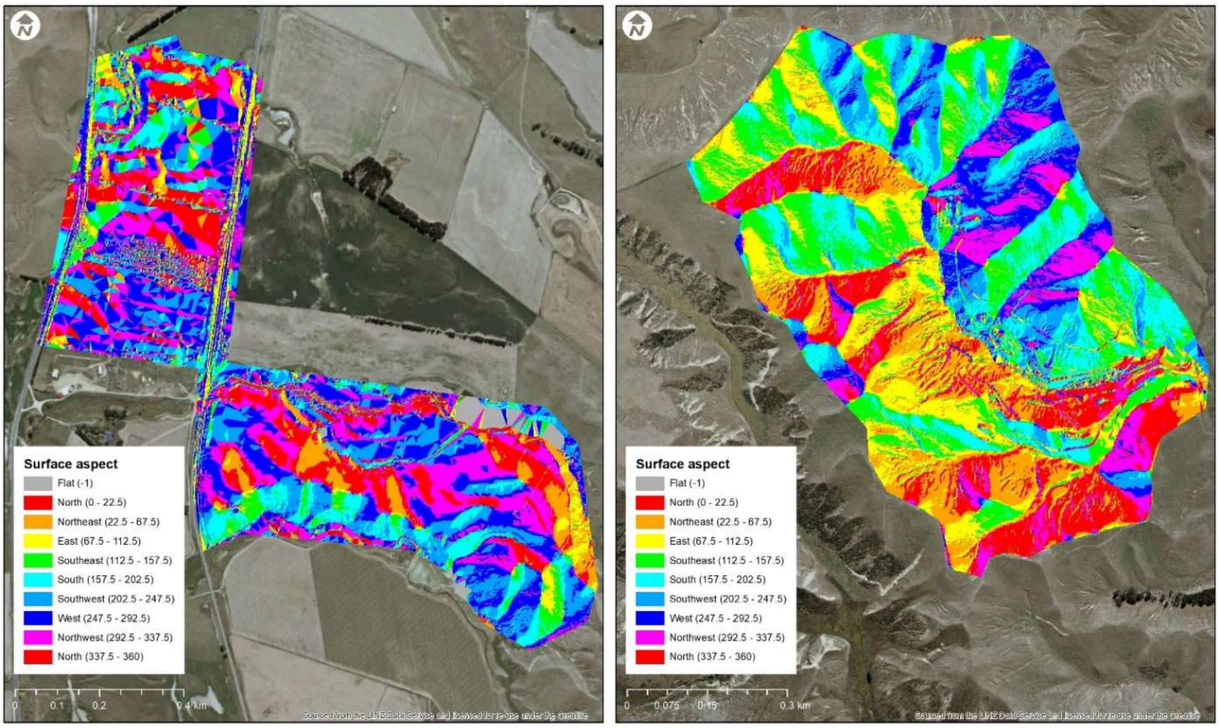

Figure 3-3: Aspect maps for Survey Areas 1 & 2 (left) and Survey Area 3 (right).

3.4 Overland flow path and depression zone delineation

Identifying and understanding the areas where overland flow occurs can provide information relating to the flood risk and aid in decision-making options for locating farm infrastructure. Mapping overland flow paths provides a tool that can be used to design drainage and culvert systems to improve drainage in the area of interest.

Overland flow paths are a function of the topography. A flow direction is assigned to each cell within the DEM, from the higher elevation cell to the lower. This flow direction is used to indicate were flow is accumulating within the catchment. Once the number of cells that are flowing into each other is greater than a given threshold, a flow path is delineated. Figure 3-4 shows overland flow paths, where the flow accumulation threshold was set at 2000 cells in the DEM, or 2000m^2 in this case.

Flood prone areas are also depicted in Figure 3-4. These are areas where the topography would allow water to pond. These areas highlight where drainage networks could be used to make land more productive, or where potential on-stream and off-stream water storage ponds could be located.

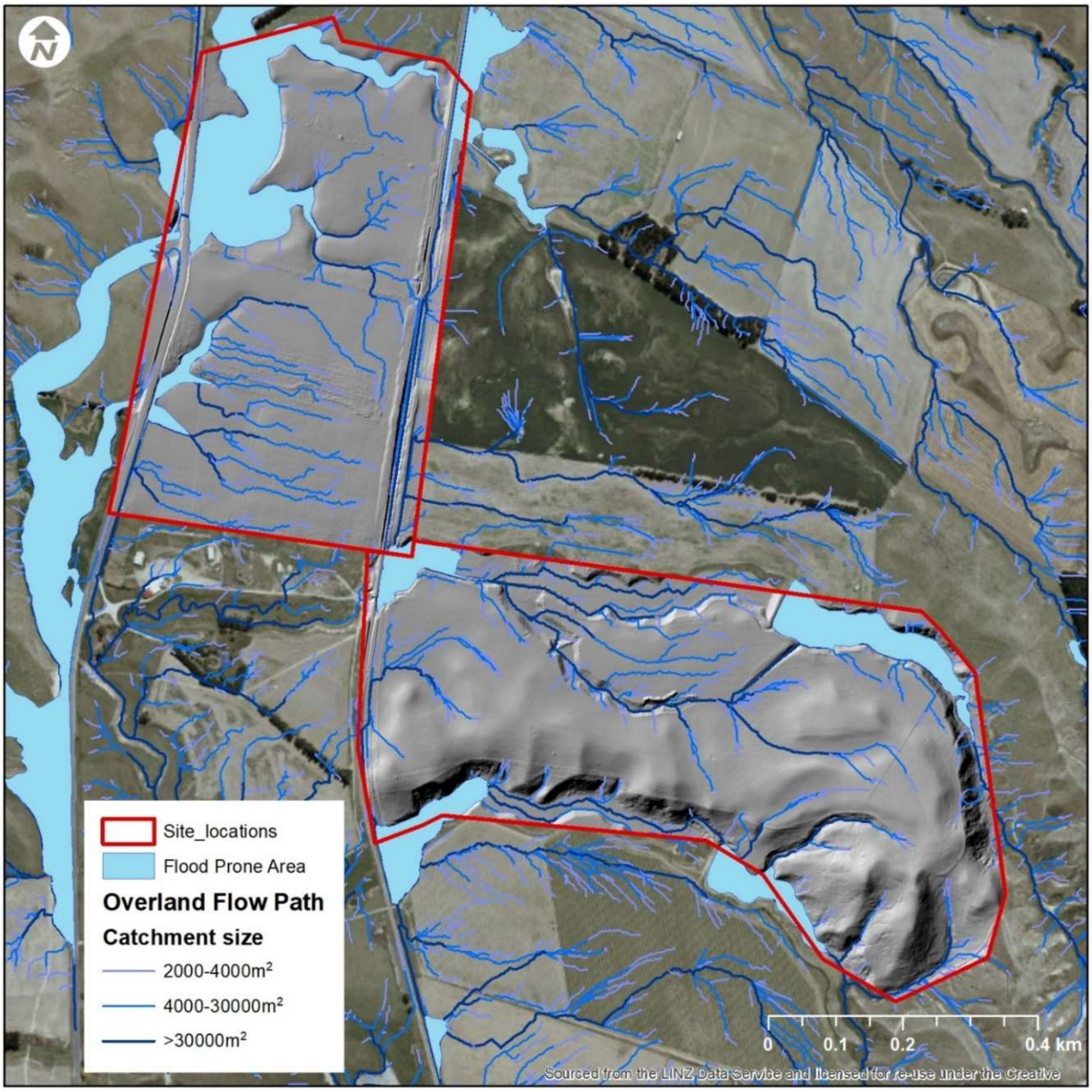

Figure 3-4: Overland flow paths in Survey Areas 1 & 2.

3.5 Small dam volume analysis

A newly constructed earth dam is located within the Flaxbourne catchment. Since the LiDAR was flown before the earth dam was fully constructed, the valley floor where the dam is situated is present in the DEM. As such, a volume analysis can be estimated for the finished dam.

When the LiDAR was flown in 2016-2017, the dam was in the first stages of construction. Although there is no dam structure in the LiDAR, some of the earth works are present. The approximate location of the dam wall was provided, together with the fully constructed height of the dam (i.e. 18m).

A line was drawn across the valley were the dam is located and the elevation of these cells were raised by 18m. The area behind the dam was filled in 2m increments (Figure 3-5) and the storage volume up to each increment is provided in Table 3.1.

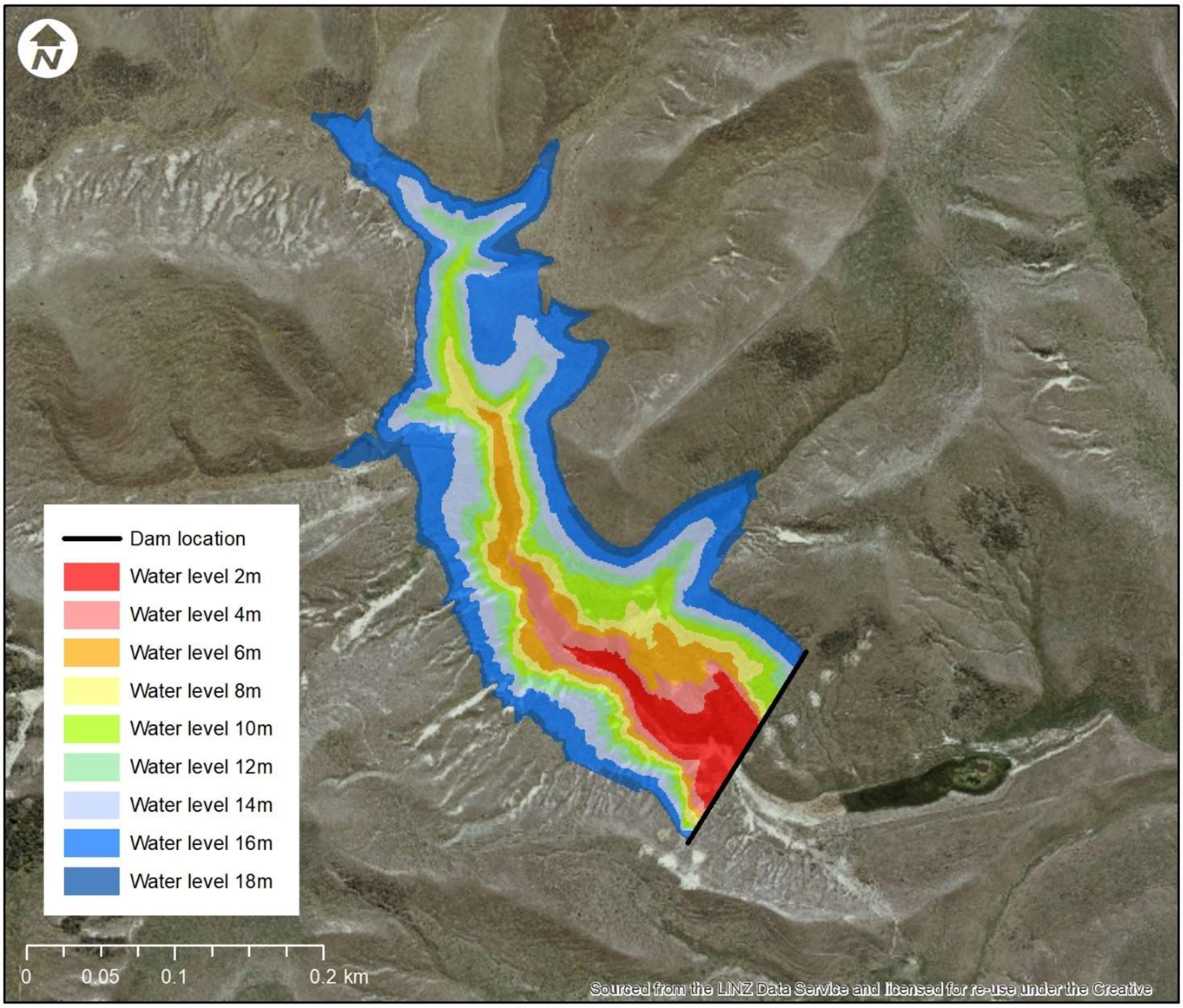

Figure 3-5: Small dam volume analysis in Survey Area 3.

Table 3.1: Estimated dam volume as water level increases behind the 18m dam.

Water level (m)	2m	4m	6m	8m	10m	12m	14m	16m	18m
Volume (m³)	4329	15261	34857	64328	103916	156062	222551	356905	417136

There is a large quantity of available storage upstream of the dam. At maximum capacity, and assuming no freeboard, the dam can hold 417,136m^3 of water.

It should be noted that no modifications have been made to the landscape i.e. DEM, behind the dam. The volume of storage is estimated assuming the topography remains unchanged. There is also no account for possible losses from leakage or evaporation.

Volume analysis such as this can be used on a range of applications including quantification of the amount of fill required to flatten/stabilise an area, or the amount of fill that would need to be removed to form a dam.

4 Other Potential Uses

4.1 Land use development assessment

LiDAR can also be used to develop a detailed map of a farm or catchment, to show the farm boundary, locate infrastructure (e.g. fences, buildings, roads etc), monitor GPS-tracked equipment, and map irrigation paths. With subsequent LiDAR information, changes to the landscape or farm can be identified and quantified over time.

In conjunction with other information, LiDAR outputs can be used to assess development opportunities on the farm. For example, areas of high, medium and low crop production could be ascertained from information on the aspect and slope of an area (obtained from the LiDAR) as well as soils and land cover information (available from other public databases).

The outputs can be used to modify farm management practices to improve productivity and identify where management could be changed to address resource limitations (e.g. measures to reduce soil erosion).

4.2 The use of land management decision-support tools

Land management decision-support tools enable better spatial planning of land management interventions. An accurate representation of the land surface is often a fundamental input to these tools. The resolution of the input data (i.e. the DEM) is fundamental to the level at which questions about land management opportunities can be reliably answered. Some models have the ability to operate at very fine spatial scales, providing more detailed information about the land and opportunities to improve management.

The Land Utilisation Capability Indicator (LUCI) is an example of a land management decision-support tool that operates at a fine spatial scale. LUCI is an ecosystem service model designed to analyse the impact of land management decisions on the provision of ecosystem services (the benefits we get from nature, e.g. flood mitigation, water purification, habitat). LUCI uses readily available national/regional data that can be enhanced with local knowledge. It can model a range of services including agricultural production, carbon, water quality, water quantity, erosion, sediment delivery and coastal/floodplain inundation. LUCI accounts for landscape organisation and spatially targets intervention opportunities.

To run, LUCI requires a DEM, landcover and soils information. It operates at the scale of the DEM and therefore a finer resolution DEM allows sub-field level management decisions to be assessed. It is also capable of comparing multiple ecosystem services at once, identifying where trade-offs or co-benefits in ecosystem services exist.

4.3 Estimate soil loss

The Revised Universal Soil Loss Equation (RUSLE) is widely used to calculate mean annual soil loss from agricultural landscapes. It is made up of 6 components including a rainfall and runoff factor, soil erodibility factor, slope length and steepness factors, cover and support practice factors. Originally developed at the farm-plot scale, the RUSLE can be run at very fine scales across a landscape to estimate the risk from soil erosion. Accurate slope and steepness estimations are important to determine soil loss and these are obtained from a DEM. The finer the resolution of the DEM, the more detailed the information obtained. The LiDAR for the Flaxbourne area would be suitable for use in the RUSLE.

4.4 Small scale drainage models

There are a range of hydrologic and hydraulic models that rely on a fine resolution DEM. TUFLOW™ is an example of one such model which relies on a fine resolution DEM to accurately simulate the hydrodynamic, sediment transport and water quality processes in rivers and floodplains. TUFLOW™ was used to generate the flood models for the Flaxbourne, Mirza and Waima/Ure catchments as part of the wider Flaxbourne Water Resource Study. Other models include the DHI suite and HEC-HMS and HEC-RAS etc.

An example of some of the output from TUFLOW™ has been provided in the Flood Hazard Report for the Flaxbourne, Waima/Ure and Mirza catchments. TUFLOW can also be used to model smaller scale drainage for a farm or field. Scenarios can be run to demonstrate the effect of smaller scale changes to the farm or field (e.g. adding drainage and culverts etc) on flow over the area of interest.

5 Summary

There are many potential uses of LiDAR which can assist land use decisions at both large and small scales. LiDAR information can create detailed maps of farms and on-farm equipment, and can assist with planning and production. High resolution DEMs (generated from LiDAR) are often fundamental inputs to a range of tools which can provide more detailed analysis and assessment of the land and opportunities to improve land management.

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