EA-NCEDS BOX 2.

National Centre for Environmental Data and Surveillance

ENVIRONMENT AGENCY

ENHANCEMENT OF LIDAR DIGITAL ELEVATION MODELS USING HIGH RESOLUTION CASI IMAGES

EXECUTIVE SUMMARY

The use of the LIDAR system to accurately measure height and produce digital elevation models (DEM) has been demonstrated (R&D Project E1-009, R&D Technical Report E43). There is great potential for enhancing the information derived from this system using high resolution multispectral imagery, for example from the Compact Airborne Spectrographic Imager (CASI).

Two examples have been investigated. CASI data is first draped over the LIDAR derived DEM for Spurn Head, to allow enhanced visualisation of both the CASI and elevation data. LIDAR and CASI data of a further study area, the River Arun, are then combined and used in the analysis of flood damage. This involves the use of digital classification of the CASI data to distinguish land cover types, which in turn are attributed land values in terms of housing equivalents. These two examples clearly illustrate the advantage of combining these two datasets.

1 INTRODUCTION

The National Centre for Environmental Data and Surveillance (NCEDS) has developed the use of the LIDAR system to accurately measure height and produce digital elevation models (DEM). Previous to this, NCEDS had developed a wealth of experience in the collection and analysis of Compact Airborne Spectrographic Imager (CASI) data. This optical image data had been used, for example, in the identification of oceanographic features in the marine environment, the investigation of open cast mines and studies of vegetation health. This report presents the findings of a project undertaken to investigate the benefits of combining high resolution CASI imagery with a LIDAR generated (DEM). The objective of the project is to demonstrate the technique and benefits of combining the two data sets, and to investigate the possibility of using this technique for estimating the effects of flooding.

The report first describes a simple case of combining the two data sets, allowing the visualisation of the LIDAR data of the Humber Estuary. The combined data set is then used in the investigation of flooding effects for an example in West Sussex.

2 USING CASI TO VISUALISE LIDAR DATA

The simplest use for the combined data is the generation of true colour 3D views. By overlaying the true colour image over the DEM using 3D rendering software it is possible to create a 'true to life' representation of the surface of the study area. The tools available in the software used in this project, PCI Imageworks, allow the user to roam freely through the study area and view items of interest from any position.

The study area used to demonstrate this technique is Spurn Head at the mouth of the Humber Estuary on the east coast of England. A CASI image with 2m spatial resolution was used as the true colour data and the height data came from the DEM generated by LIDAR for the study area. This DEM had 25cm height increments and a spatial resolution of 1m. The CASI image was geocorrected and orientated to the Ordnance Survey National Grid then warped to fit the LIDAR surface therefore allowing it to be overlayed directly on to the LIDAR DEM.

The two data sets were then entered into a piece of 3D rendering software and a true colour version of the surface was created. The surface was investigated using the tools available. A sample set of views are shown in Plate 1.

3 FLOOD DAMAGE ASSESSMENT USING LIDAR AND CASI

The combination of high resolution DEMs, generated from LIDAR, and optical imager multispectral data, generated from CASI, makes it possible to estimate the area and use of land inundated by a flood of a certain severity. These values can then be used along with housing equivalents (standard flood defence system used for assessing flood damage) to assign a value to different levels of flooding.

3.1 Study Area

The study area is the lower reaches of the river Arun near Littlehampton, West Sussex, on the south coast of England. It is 24km^2 in area and predominantly covers the river flood plain where arable and pasture agriculture are the main land uses.

3.2 Data and Imagery

One of the many advantages of LIDAR is that it can produce a DEM of exceptional accuracy. This is particularly important in predicting floods in areas where water level fluctuations are in the magnitude of centimetres. A DEM had been generated from the LIDAR data with a height increment of 25cm and a spatial resolution of 1m. Plate 2 shows the DEM of the study area generated using LIDAR. Black areas depict the lowest height values. The height values increase through red, orange, yellow, green and blue with purple representing the highest areas.

The CASI imagery used was a mosaic of data from four flight lines. This produced one image covering the study area. While mosaicing, the CASI images were geocorrected to the Ordnance Survey National Grid thus allowing it to fit directly to the LIDAR generated DEM. The CASI data has fifteen spectral bands ranging through the visible and infra red parts of the electromagnetic spectrum. Plate 3 shows a true colour composite of the study area created using the mosaiced CASI image.

3.3 Method

All the bands from the CASI data were input into an unsupervised statistical classification to separate different land cover types (Tou and Gonzalez, 1974). The results of the classification produced 29 statistically different classes. These classes were amalgamated using the true colour composite (Plate 3) and ground truth of the study site to identify the different land covers. Five broad classes were constructed; forest, water, arable, rough grassland and pasture. The urban areas included a large number of different classes and were impossible to group successfully using spectral techniques. They were digitised on screen using the true colour composite image and were placed into the final classification image as an extra class (making a total of six classes). Plate 4 shows the final results of the classification.

The extent of different flood levels were then modelled using the elevation data. Initially five floods at one metre increments ranging from 1m to 5m were modelled by selecting the areas that lie below the level of flood being modelled i.e. a 3m flood would be modelled by selecting the areas less than 3m. This gave a range of five images of increasing area as the level of flood increases (Plate 5). The large difference in area between the 1m flood and the 2m flood shown in Plate 5 suggested that the flood levels of interest were those that lay between 1 and 2m. Therefore a series of floods were modelled at twenty five centimetre increments between 1 and 2m (Plate 6).

The classification image was then overlaid with the flood extent images. A report containing the area of each class under the flooded area was generated for each flood level.

The standard matrix of Housing Equivalents versus land class area used by the Environment Agency Flood Defence function were used (Table 1). For most of the classes contained in the classification a standard value was provided, however no single value for an urban area was given. Therefore an estimate value for the urban area had to be calculated from the values given for residential areas and five different types of industry. This value was derived by calculating the average number of houses per hectare of urban area (by counting the number of houses in randomly placed 1ha blocks). This value was related to the values for industrial buildings provided and a suitable value (15H.E./ha) was settled upon. With these values it was possible to calculate total housing equivalents for each class.

Table 1 Housing equivalents for each land class.

Class	Housing equivalent / Ha.
Arable	0.532
Pasture	0.026
Rough grassland	0.0106
Forest	0.0002
Urban	15

It is also possible to create views and move through the flooded area by modelling a flood into the DEM and CASI data. This is carried out by converting the values in the DEM that are covered by the flood extent image to the level of the flood and then converting the same area in the CASI data to equal blue. These two datasets can then be viewed using 3D rendering software where it is possible to roam through the area and view from any direction.

3.4 Results and Discussion

The areas inundated by the different levels of flooding are shown in Figure 1 and the corresponding total housing equivalent are shown in Figure 2. The curve of the graph in Figure 1 shows that there is a rapid increase in the area inundated by flood water between the 1m and 2m flood levels. However the curve showing the corresponding housing equivalents (Figure 2) shows a curve of the opposite shape. This suggests that although there are large increases in area of land being inundated up to the 2m flood level, the majority of the area is covered by land classes which have lower housing equivalent values than areas higher up the floodplain.

Figure 1 Area inundated at different flood levels.

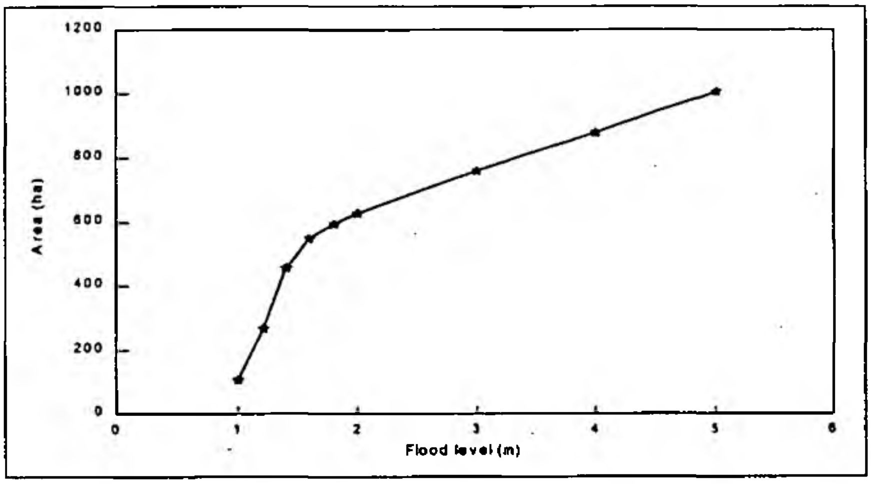
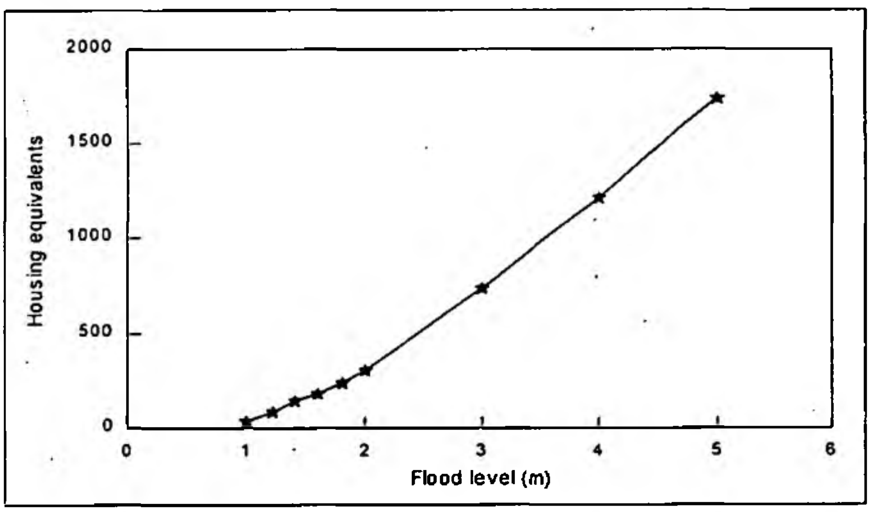
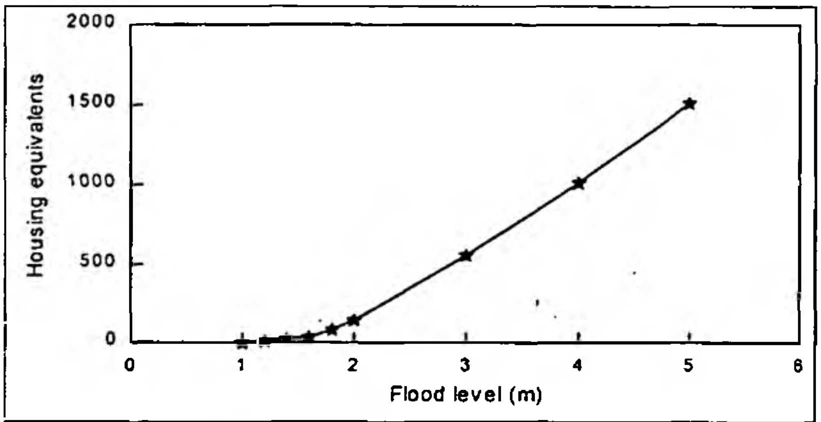


Figure 2 Damage caused by different levels of flooding.



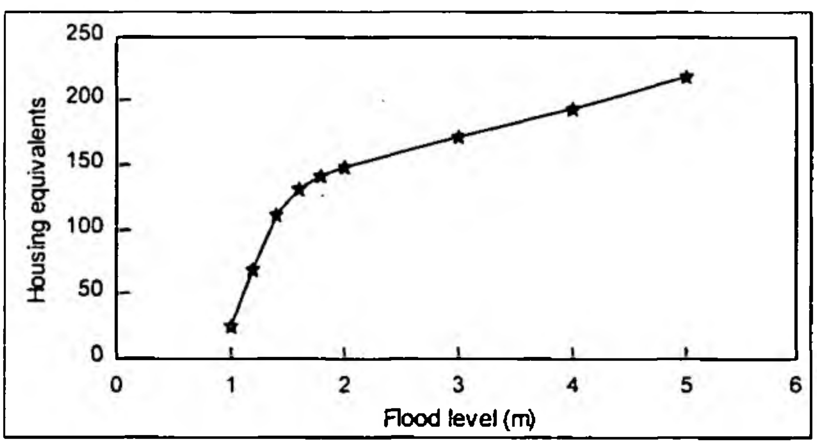
The reasons behind this can be explained by looking at the individual classes and how they are affected by the different flood levels. The urban land class is only affected slightly by flooding up to the 1.5m flood level after which rapid inundation occurs. However the housing equivalent value for the urban land use class is so high that even these very small areas being flooded are causing high levels of damage (figure 3). Therefore it is logical that the graph showing the urban areas housing equivalents for the floods (figure 3) is very similar to the graph showing the total housing equivalents for the floods (figure 2).

Figure 3 Damage caused to urban areas by different levels of flood.



The arable class shows an opposite trend to that shown by the urban areas. There is a rapid inundation up to the 1.75m flood level above which the area affected by the flood at each flood level does not increase as readily. The housing equivalent value for this land class is low, relating to the amount of damage caused by flooding, however the vast extent of the area covered means that the total housing equivalent value becomes quite substantial (Figure 4).

Figure 4 Damage to arable land caused by different flood levels.



An example of how the classes are affected by flooding and the damage caused by the flood is shown by table 2. This is the effect of a 2m flood showing the area of each class inundated, the housing equivalent attributed to that class and the total housing equivalent for each class. The similar values for the arable and urban classes total housing equivalents, show that not only urban areas have high values of damage. The large areas of arable land which lie in easily flooded areas mean that flood damage can become quite substantial i.e. the floodplain is working correctly, but putting arable land on it is a risk.

Table 2 Results of a 2m flood.

Class	Area (ha)	Housing equivalent/Ha	Total housing equivalents
Arable	280.11	0.532	149.02
Pasture	229.17	0.026	5.96
Rough grassland	53.18	0.0106	0.56
Forest	40.49	0.0002	0.08
Urban	10.19	15	152.85
Total	613.14		308.40

The use of 3D rendering software to roam and view areas within the data set means that it is possible to explore and gain a greater understanding of the effects of the flood. It is possible to see if specific areas of interest have been affected and gives the user the ability to generate images with more realism and thus are easier to understand (Plate 7).

3.5 Limitations

This technique relies upon the accuracy of the land classification being used to evaluate the damage caused by the flood. The classification image has to be as reliable as possible or the values produced for extent of damage will be incorrect. Good ground control and simultaneous CASI / LIDAR acquisition would lead to more reliable statistical methods being applicable such as supervised classification.

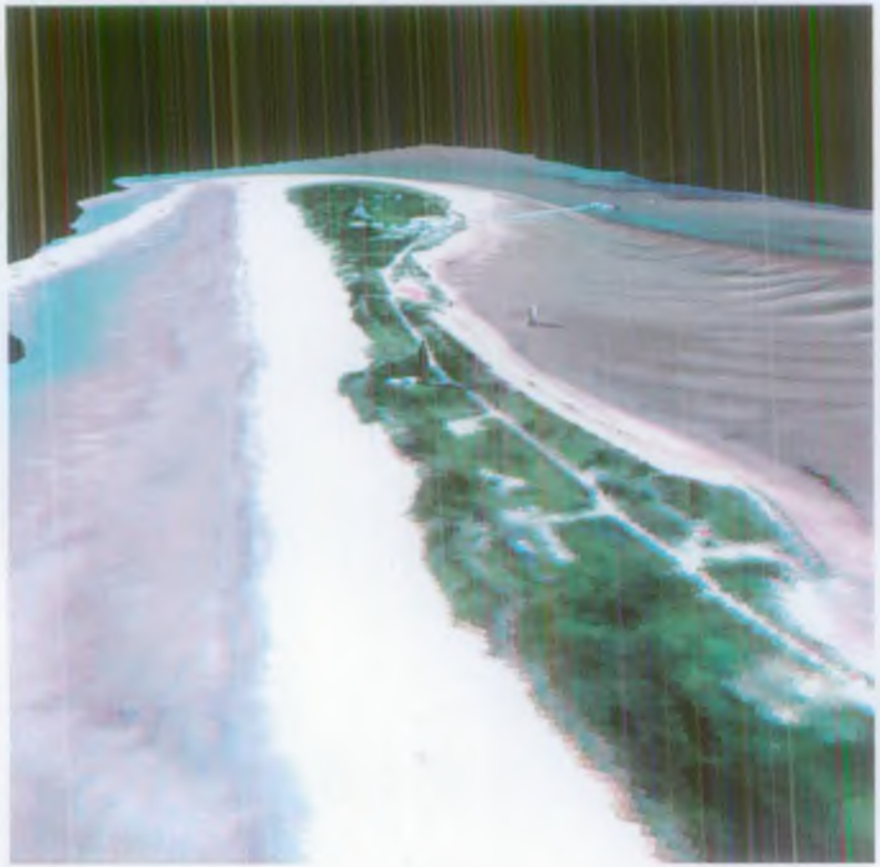
The other limitation of the method is that there is no flow/channel modelling included. The flood coverage model is created by finding all the areas on the DEM lower than the value of flood height specified therefore areas of flood can be created behind areas of high ground where flood water could not reach. This will introduce errors into the values of damage being returned, as well as many other differences caused by 'flood filling' to a height rather than using hydrodynamic modelling.

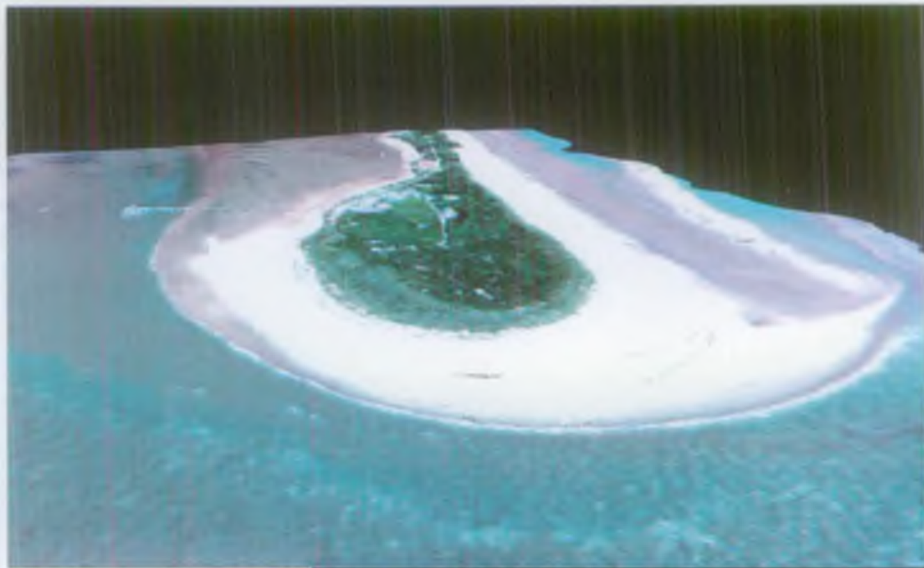
3.6 Conclusions

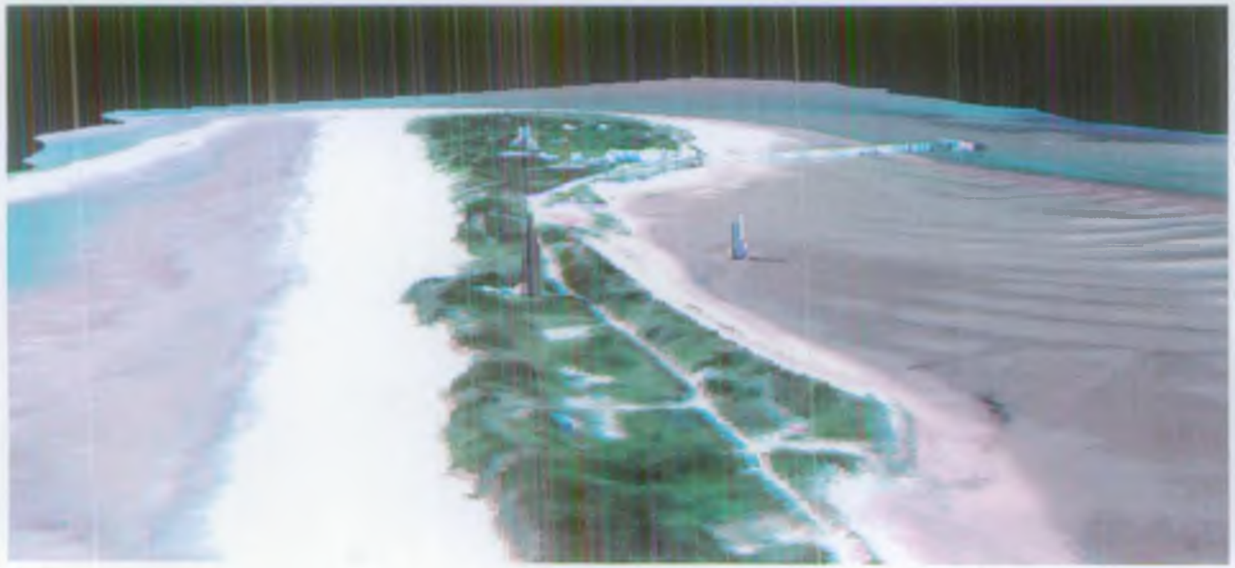
This technique, if used with the limitations stated in mind has proved itself to be a successful method for estimating the effects of floods of differing severities. The method can give an estimation of the extent of water coverage of a flood and the type of land cover the flood is affecting. The method also proves the usefulness of LIDAR generated DEMs for applications where accurate surface models are required.

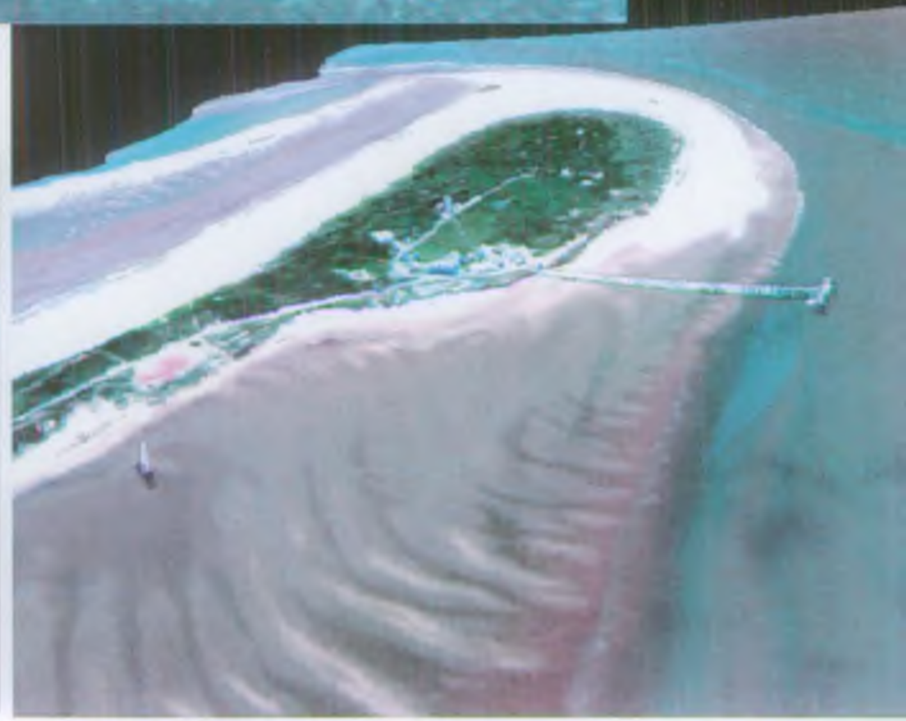
Plate 1

High resolution CASI images of Spurn Head draped over a LIDAR digital elevation model









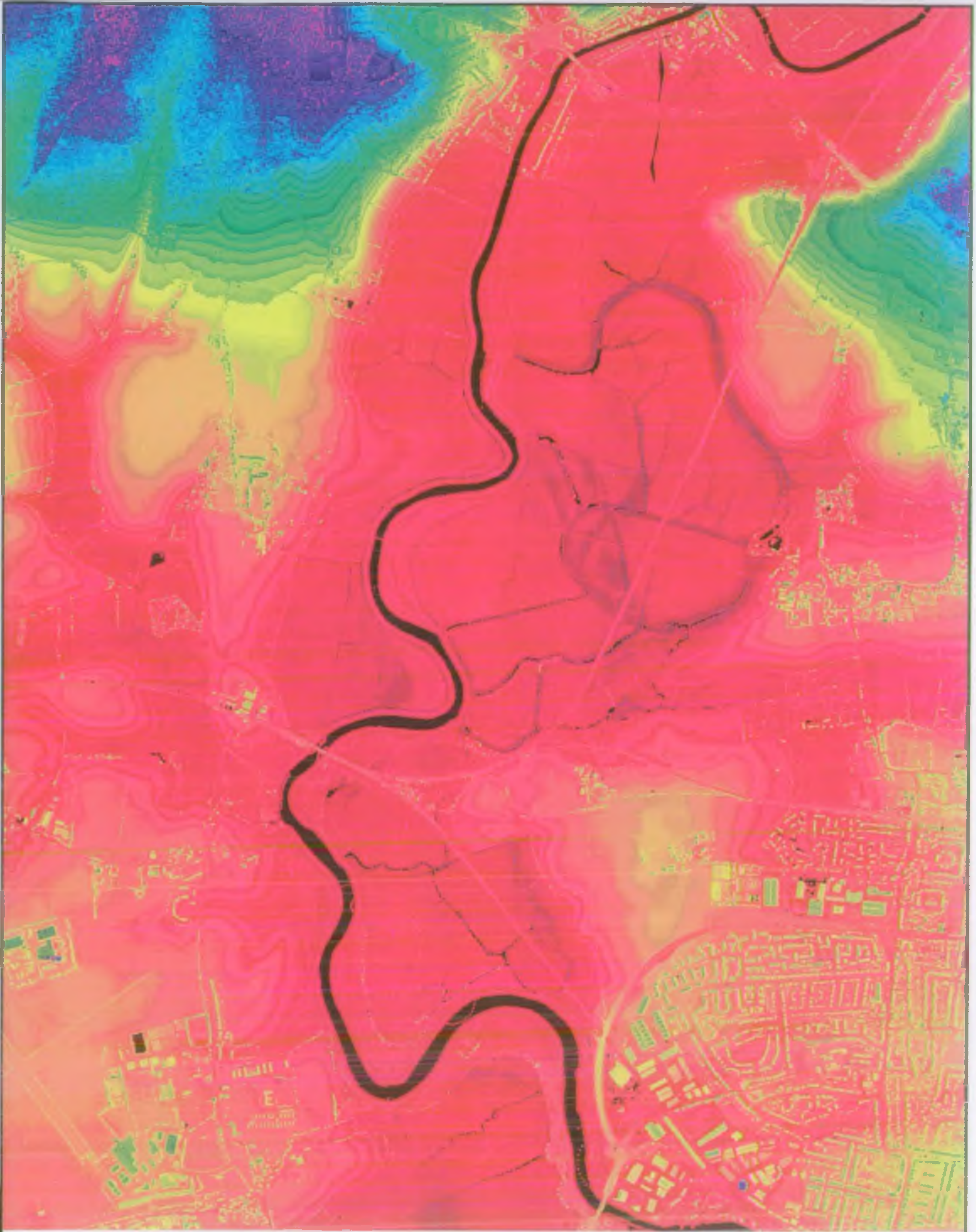


Plate 2

Digital elevation model (DEM) of the River Arun catchment created from LIDAR data flown on the 22/7/97

Plate 3

CASI true colour composite of the River Arun catchment
Created from CASI imagery flown on 22/7/97.

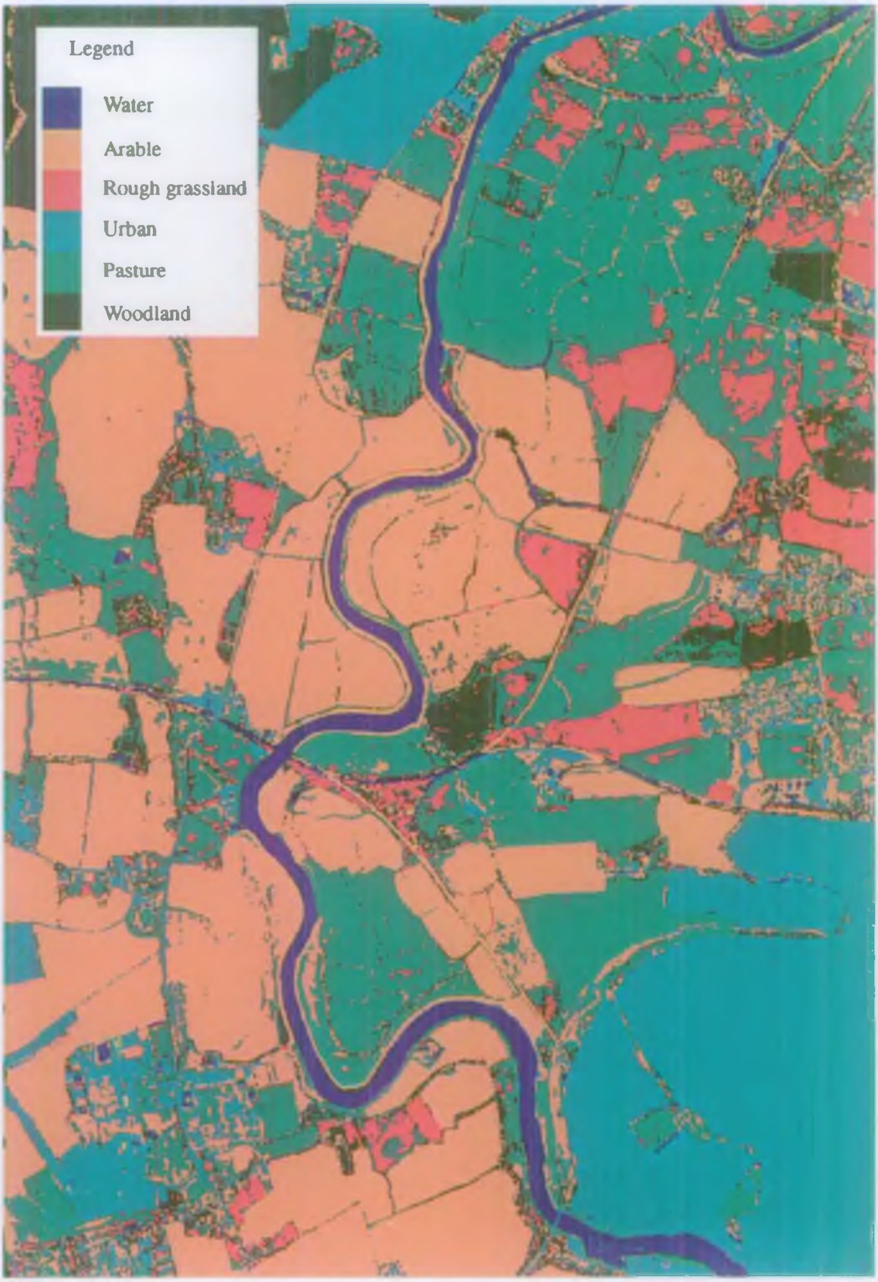


Plate 4

Unsupervised classification of the River Arun catchment

Created from CASI imagery flown on 22/7/97.

Plate 5

CASI true colour composite overlaid with areas affected by different levels of flood

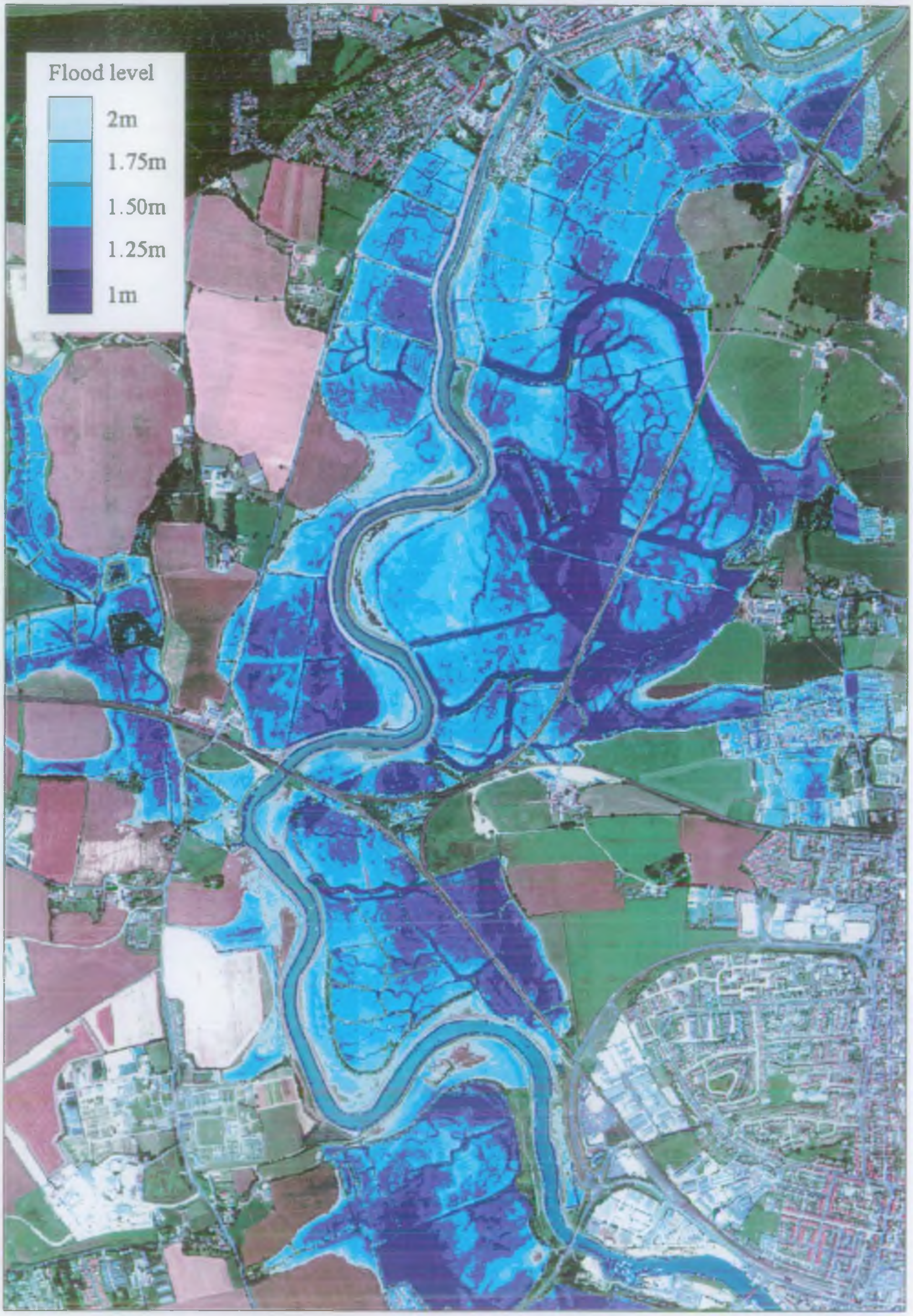


Plate 6
CASI true colour composite overlaid with areas affected by 20cm increases in flood level between 1m and 2m

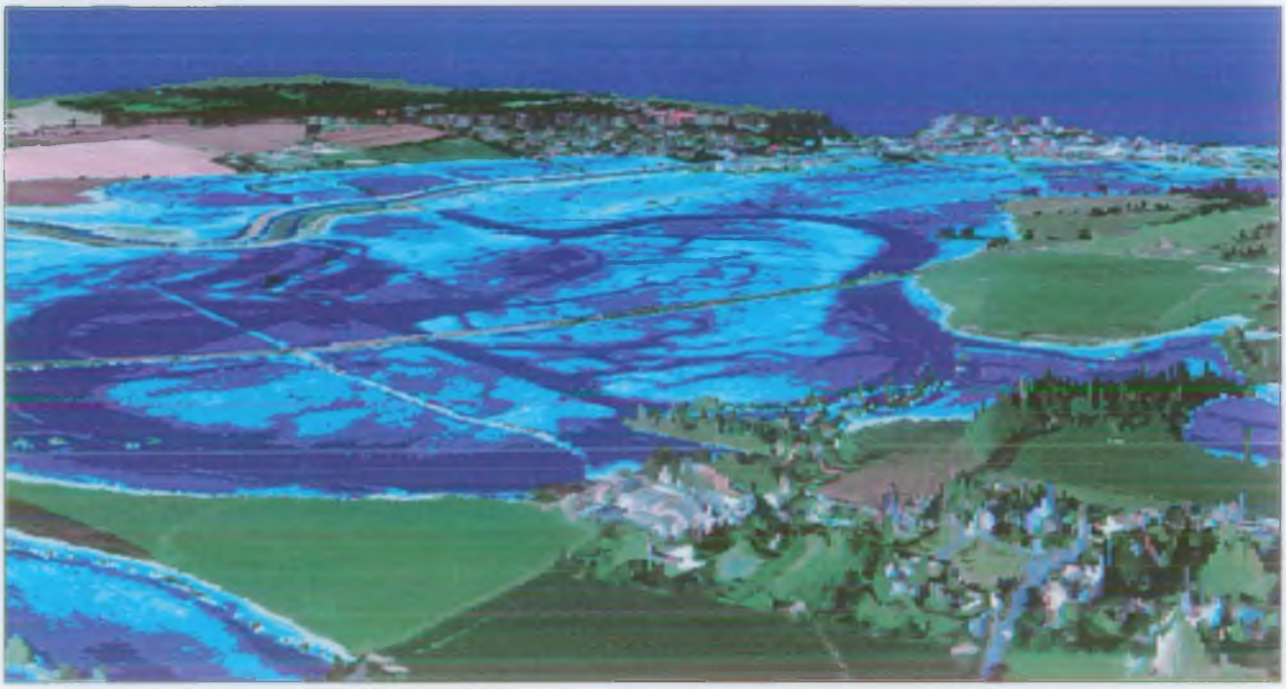


Plate 7

Views of the River Arun catchment with a flood at 25cm intervals