High resolution remote sensing of water surface patterns

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1. Introduction – Surface Flow Types

Surface flow types (SFTs) are patterns present on the water surface which result from the interaction between underlying river channel morphology, water depth and velocity[1]. They reflect the local flow hydraulics and have been shown to be both biologically and hydraulically distinct[2,3].

Some examples of different SFTs are shown in Figure 1.

Figure 1. Example SFTs

In the UK, the Environment Agency's 'River Habitat Survey' (RHS) conducts assessments of in-stream habitat quality to meet European requirements concerning river health (The Water Framework Directive). This survey includes estimating the spatial coverage of SFTs by eye from the river banks. Such an approach is affected by issues of user subjectivity and inaccuracies in the spatial extent of mapped SFT units[4].

2. Aims of this Research

This PhD research is focussed on the use of remote sensing for assessing fluvial habitats. Specifically, it aims to investigate whether recent developments in unmanned aerial systems (UAS – Figure 2) may offer an alternative approach for SFT mapping. UAS are capable of rapid and repeatable collection of very high resolution imagery from low altitudes, under bespoke flight conditions[5,6,7]. It is hoped that the output imagery will provide a more objective and spatially accurate method of mapping SFTs and provide a platform for exploring the dynamic nature of SFTs in relation to fluvial habitats.

Figure 2. The Draganflyer X6 – an unmanned aerial system

A number of systematic experiments are being carried out to investigate how our ability to accurately and objectively map SFTs is affected by collecting imagery under the following conditions:

1. Different flying altitudes (therefore different spatial resolutions)
2. Different viewing angles (i.e. vertical & oblique)
3. Different flow levels (& turbidity levels)

This poster presents some initial findings of this on-going PhD research.

3. Site Location

The research site is a section of the River Arrow, located in Warwickshire, UK (Figures 3 & 4).

Figure 3. The River Arrow

This site was chosen for its SFT diversity over short reaches, its accessibility and suitability for flying.

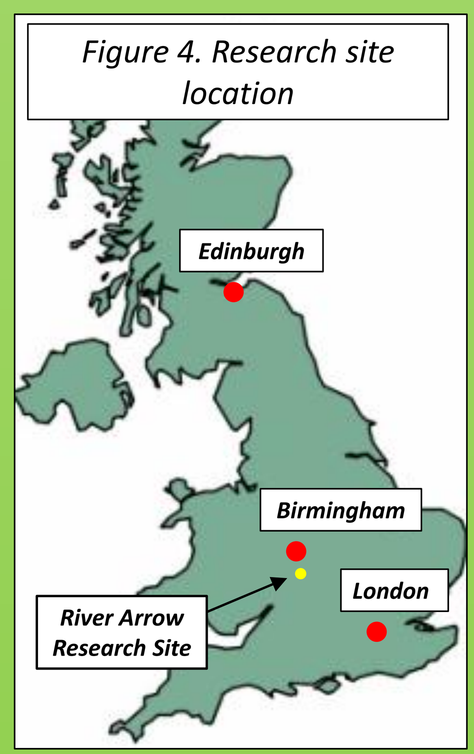

Figure 4. Research site location

4. Data Collection

High resolution imagery is being collected using a consumer-grade 10.1 megapixel digital camera attached to a small, lightweight, rotary-winged UAS known as the Draganflyer X6 (Figure 2).

To date, imagery has been collected at 3 different flying altitudes, at 2 different viewing angles and at 2 different flow levels, as detailed in Table 1. Camera calibration experiments were carried out prior to data collection to establish the relationship between flying altitude, image resolution and image footprint size.

Flying altitude	80m	35m	10m
Image resolution	3cm	1.3cm	0.4cm
Spatial extent	300m x 120m	500m x 40m	50m x 25m
Viewing angle	Vertical	Vertical	Oblique
Flow level	Low	High	Low

Table 1. UAS image data collected to date

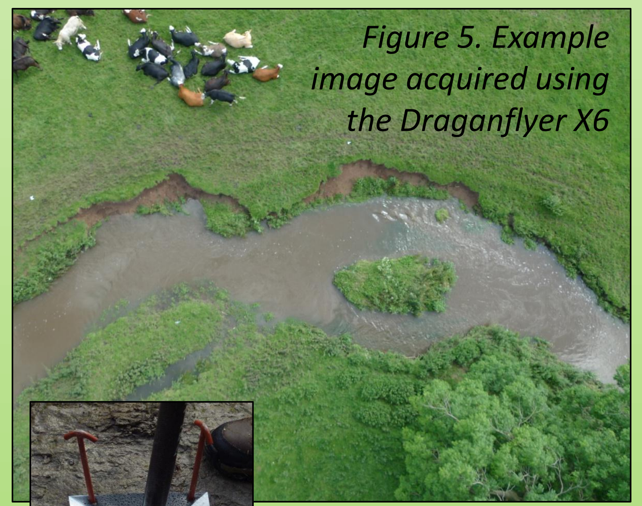

Figure 5. Example image acquired using the Draganflyer X6

Figure 6. An artificial ground control point (GCP)

Images are collected with a high level of overlap (>80%) to allow subsequent image matching. An example image is shown in Figure 5 (35m altitude flight). SFT mapping by eye is conducted concurrently with each data collection session.

A number of artificial ground control points (GCP) were made (Figure 6) and are distributed across the study site prior to image acquisition. These were then surveyed in using a Trimble R8 differential GPS (sub-cm accuracy) (dGPS), and used for subsequent geo-rectification of the imagery.

5. Image Processing

Images are mosaicked together using a 3D 'Structure from Motion' software package called PhotoScan Pro. This software works by matching points from multiple, overlapping images & estimating camera positions to reconstruct a 3D point cloud of the scene geometry. When combined with the GCP positions, this process allows the creation of an orthophoto and a digital elevation model (DEM) of the research site (Figures 7 & 8).

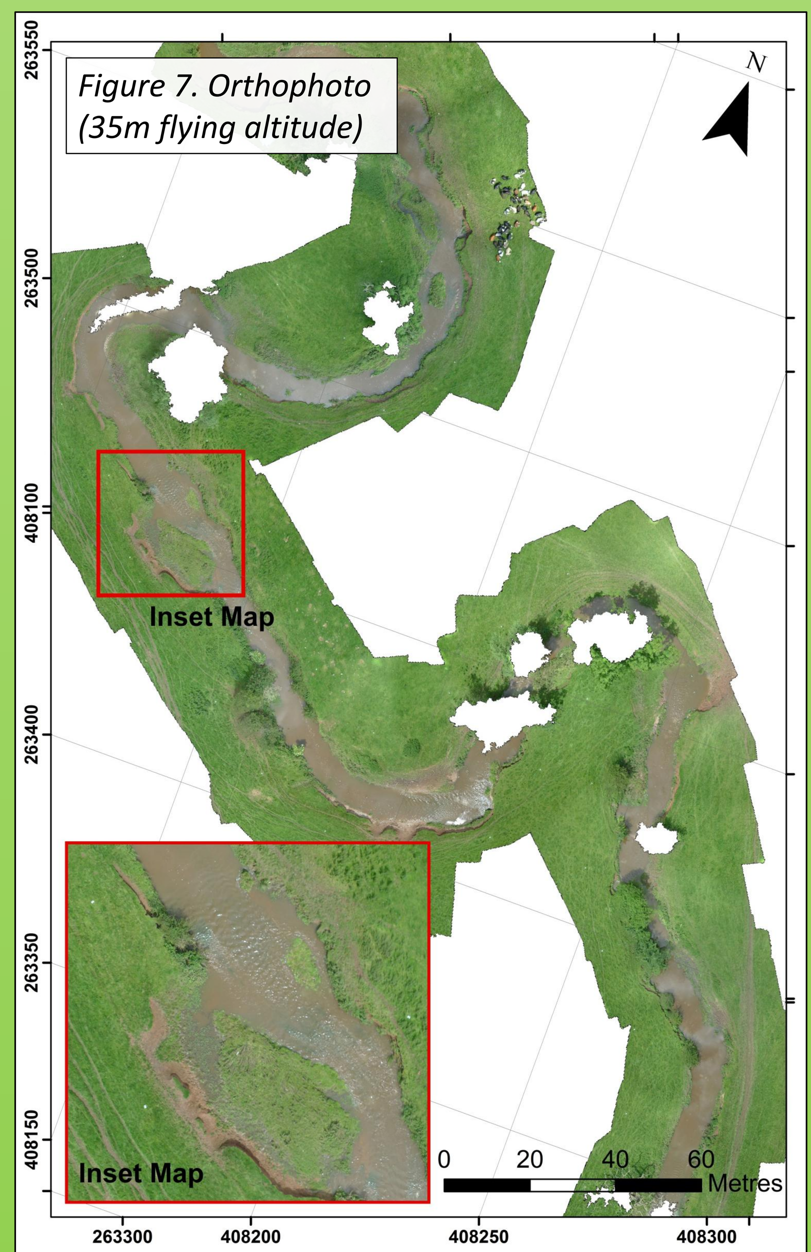

Figure 7. Orthophoto (35m flying altitude)

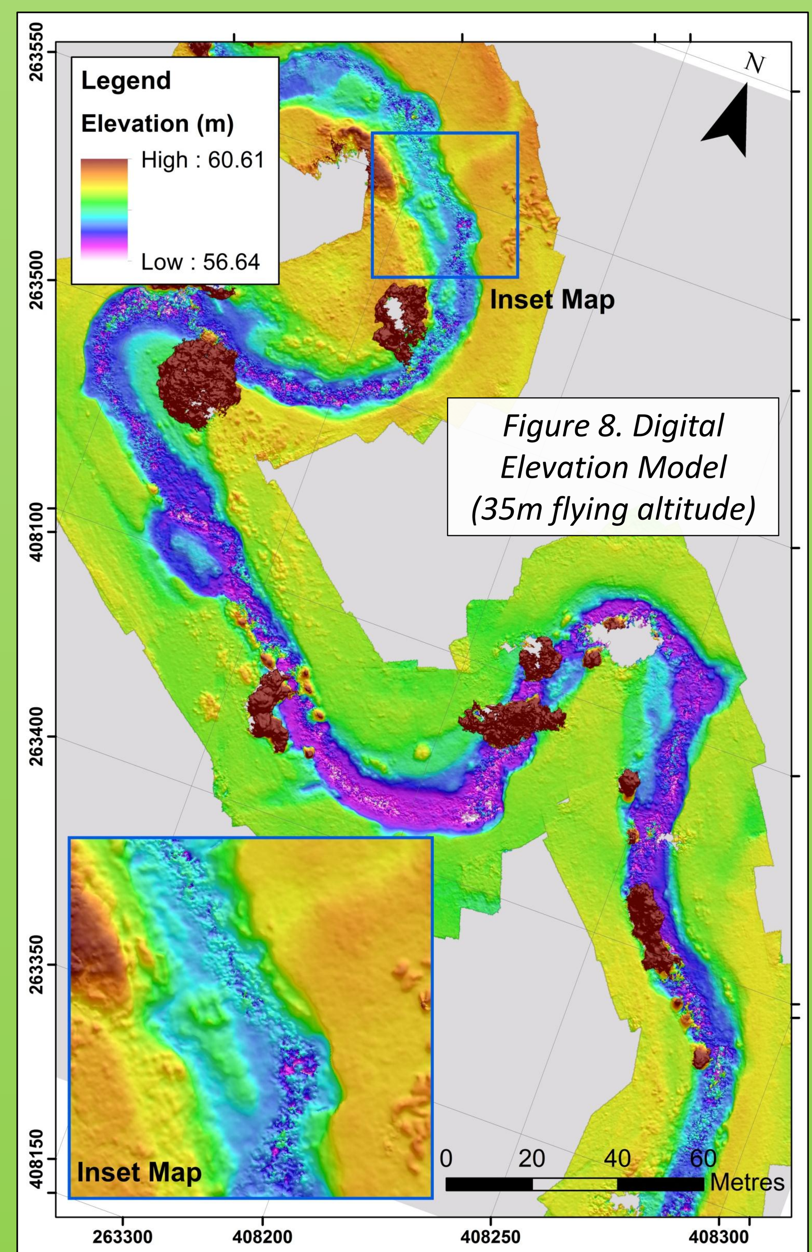

Figure 8. Digital Elevation Model (35m flying altitude)

6. Initial Analysis & Findings

Initial analyses have focussed on the visual comparison of field-mapped SFTs with the UAS orthophotos (Figure 9). Initial qualitative findings are as follows:

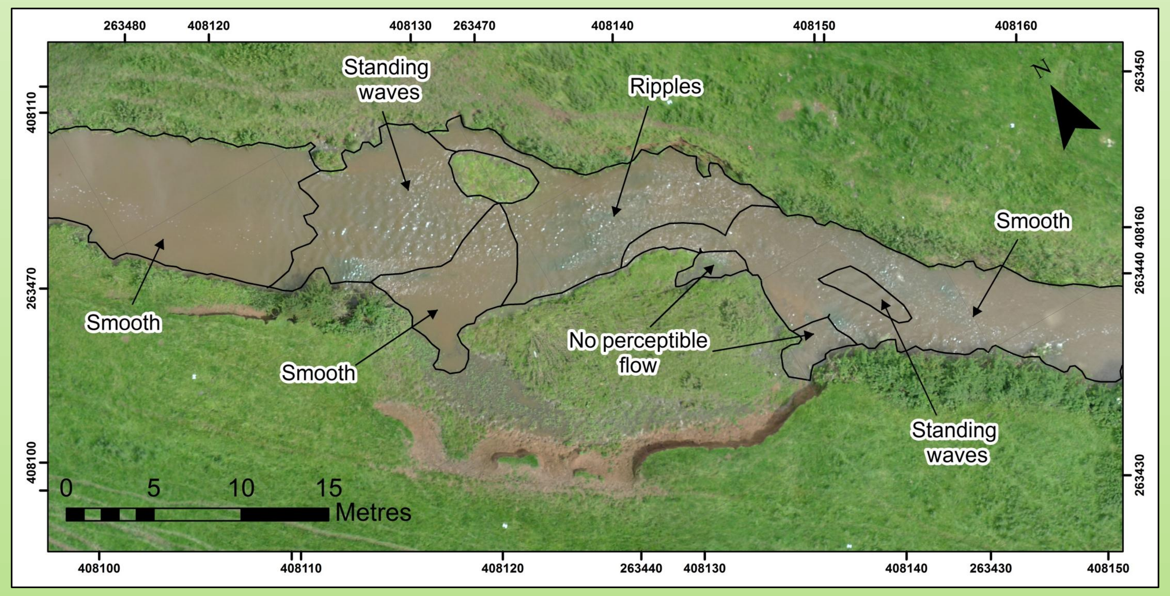

Figure 9. Field-mapped SFTs shown over orthophoto (collected at 35m altitude)

- Difficult to distinguish between SFTs 'smooth' &'no perceptible flow' using imagery, but easier in the field
- Difficult to distinguish between SFTs 'standing waves' & 'ripples' using high altitude imagery (80m) at low flow levels, but easier using lower altitude imagery (35m) at high flow level - possibility due to turbidity variations
- Sunny conditions aid differentiation of smooth & rough water surfaces on all image datasets
- Spatial coverage of SFTs varies between field mapping & image mapping - by as much as 3m (full quantitative comparison yet to be completed)

Efforts are also on-going to assess DEM accuracy & to determine if the DEM can assist SFT mapping. This involves investigating if the DEM represents the channel bed or water surface (or neither) in submerged areas. A topographic survey of the channel bed & banks is being undertaken for this purpose. Initial findings using the 35m altitude data are shown in Figure 10, which indicates:

- Flat banks typically show <0.05m error
- Steep banks show up to 0.3m elevation error, probably due to XY positioning issues
- Submerged areas typically show 0.1-0.4m overestimation of channel bed elevation - on average greater where SFT is 'smooth' than where SFT is 'standing waves' (on-going research is assessing this further)

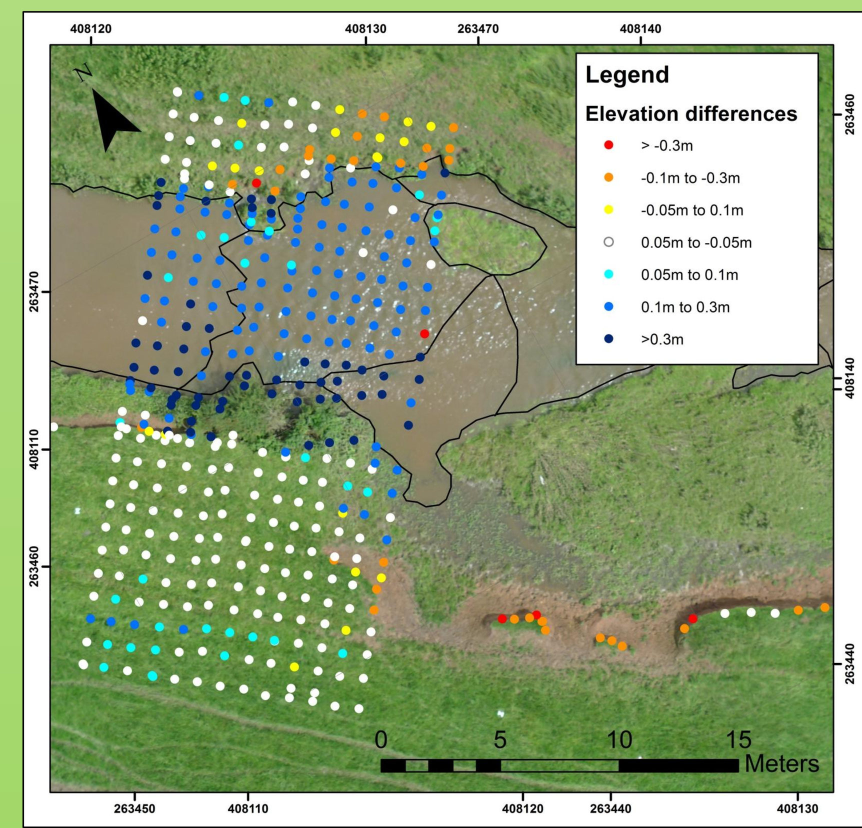

Figure 10. Point colours represent differences between elevations values on DEM & from Total Station

7. Next Steps

Research is currently on-going to investigate the following:

- Further image acquisition under the other permutations of the three key conditions (altitude, view angle, flow level)
- Collection of water depth and flow velocity data with each additional flight
- Quantitative comparison of SFT field mapping with that mapped from imagery
- Further assessment of DEM accuracies against larger dGPS dataset & against each other
- Investigation of object-based image analyses for delineating SFTs
- Consideration of what defines SFTs & the usefulness of SFTs as habitat availability indicators

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