UAS-based river bathymetry acquisition: applications in environmental studies in Central Asia

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Many aquatic ecosystems in Central Asia experience severe anthropogenic pressures, leading to the decline of biodiversity due to water scarcity and poor water quality. The main causes of hydromorphological river degradation are water abstraction for irrigation and flow retention by multipurpose barrages used for annual runoff regulation and energy generation. Transboundary water issues in many cases remain unresolved, with upstream regions exploiting their geographical advantage over downstream water users. Particularly, lowland areas are affected; many rivers there carry little or no water. With the global shift towards renewable energy sources and Central Asia's extensive hydropower potential, the construction of new hydropower plants is expected to increase. Given the known pressures that hydropower plants impose upon aquatic ecosystems and the existing high levels of degradation, careful planning is necessary to ensure that negative effects are minimised as much as possible.

The EU-funded Hydro4U project aims to introduce advanced European hydropower technologies in combination with state-of-the-art methods to assess and mitigate negative environmental impacts. Detailed river bathymetry data are the foundation for ecological and hydromorphological studies. Within the Hydro4U project, such studies were carried out in three application cases. Here we present the latest advances in remote sensing of river bathymetry with Unmanned Aerial Systems (UAS) as a prerequisite for subsequent environmental studies.

Multi-camera photogrammetric surveying for engineering applications has developed considerably over the last 10-15 years. The standard procedure for creating a three-dimensional (3D) surface model using UAS photos relies on the so-called Structure from Motion (SfM) technique. As a result, SfM enables precise terrain acquisition with dense point clouds or fine meshes. However, the SfM-method cannot be used directly for underwater areas. These areas emerge flatter than in reality due to the water's light refraction effect. Underwater areas can theoretically be corrected if the water level at each point of the river is known. In most cases, however, especially for inaccessible river sections, streams with high gradients and coarse substrates, extensive measurements of the water level are not possible or are too labour-intensive. We present application examples for the use of an innovative method that combines multi-camera photogrammetry with iterative, two-dimensional (2D) hydraulic modelling. Using this method, we can obtain precise bathymetry as well as a calibrated hydraulic model of the studied river section. The method enables the efficient processing of long and heterogeneous river sections that cannot be surveyed using conventional geodesic methods based on cross-sections (e.g. with total station or echosounder). Central Asian rivers with clear, relatively shallow waters during extended low flow periods and sparse riparian vegetation are well-suited for the application of this method, as its most important prerequisite is the visibility of the river bottom.

The method was successfully applied to provide the base data (water depths and flow velocities at different flow rates) for deriving ecologically acceptable environmental flows through habitat modelling at the Central Asian sites Shakhimardan (Uzbekistan) and Badam (Kazakhstan). Our approach also offers new possibilities for geomorphological studies by enabling remote surveys of reservoir/river sedimentation or

floodplain bathymetry evolution. To summarize, the presented method, in combination with applied ecological studies, helps to maintain or even improve the condition of Central Asian rivers under a changing climate and increasing flow regulation and water abstraction.