Upper Deschutes Watershed Council

Technical Memo

Mapping continuous spatial heterogeneity in stream velocity using image velocimetry from Unoccupied Aerial Systems (UAS)

Whychus Creek, Oregon, July 2022

Prepared by

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May 2023

Acknowledgements

This memo and the work summarized therein were funded by a grant from the Portland General Electric Habitat Support Program.

Many thanks to Brandon Overstreet, PhD, for his contributions to Whychus Creek LSPIV analysis as a technical advisor and practitioner.

Introduction

Velocity is a critical habitat variable but mapping velocity in highly heterogenous river reaches such as in Stage Zero restoration sites is impossible or at best extremely time consuming using conventional measurement and modeling techniques. A developing remote sensing approach known as Large-Scale Particle Image Velocimetry (LSPIV) enables non-contact measurement of streamflow velocity from both UAS and handheld videos. This technology has the capability to increase the spatial and temporal measurement of velocity when using video collected from UAS and is well suited for the complex post-restoration channels discussed above. PIV uses image processing methods to detect features as they move through a video frame. In the context of rivers and streams these features can be waves, bubbles, or particles on the water surface.

Testing of image velocimetry methods to quantify surface velocity in Whychus Creek began in 2020 with the collection of UAS videos at dispersed sites in a variety of channel conditions including restored and unrestored reaches of Deschutes Land Trust preserves. Initial workflows for PIV testing on Whychus Creek incorporated several GIS and image processing software packages to create scaled video-derived velocity across the video frame. While the 2020 methodology supported measurement of velocity magnitude and flow complexity, it lacked an efficient method for assigning spatial dimensions to PIV-derived surface velocity outputs in geographic coordinates. And, while the initial workflow could capture general velocity patterns at a single site, mapping these patterns at the reach scale was time consuming.

Summary of 2020 video processing

Initial workflows for PIV analysis on Whychus Creek incorporated several GIS and image processing software packages to create maps of velocity at each site. PIV analysis of 2020 video was conducted using two open source software platforms called RIVer (Rectification of Image Velocity Results; Patalano et al 2017) and PIVLab (Thielicke et al 2014). Video stabilization preprocessing of videos was required to account for aircraft motion prior to any PIV assessment. Video stabilization was done using USGS Video-Stabilizer software (https://github.com/frank-engel-usgs/Video-Stabilizer).

The initial, 2020 methodology lacked an efficient method for assigning spatial dimensions to PIV-derived surface velocity outputs. Scaled PIV outputs provided velocity information in meters/second, but no geographic positions were provided. PIV outputs were subsequently manually scaled from image coordinates to real-world distances using markers placed in the video frame at the time of video collection. In some cases markers were not visible in the video and co-collected orthoimagery was used to scale the outputs. This methodology required additional GIS analysis to identify and match tie points visible in both the video and orthoimagery. Mismatched resolution of the orthoimagery, collected at lower resolution, and video, collected at higher resolution, made tie point identification difficult and therefore time-intensive.

Initial results from PIV analysis of 2020 videos showed that velocity could be mapped from UAS videos in both simple and complex channel arrangements where there was sufficient texture created by waves on the water surface. Velocimetry was not feasible in test plots with little water surface texture such as in pools or slow-flowing channel margins due to the lack of detectible features in the videos. Additionally, although the 2020 workflow was able to capture general velocity patterns at a single site, mapping these patterns at the reach scale would have been extremely time consuming.

Key 2020 lessons and recommendations

2020 imagery and video acquisition on Whychus Creek represented a preliminary attempt to capture imagery and video to support analysis of Stage 0 metrics, including velocity. Key insights gained through analysis of 2020 video informed the following lessons and recommendations:

- 2020 analysis showed that videos collected at ~66 feet (20 m) above ground level (AGL) provided more than enough detail to extract velocity information; similarly 30 second videos at 30 frames per second provided more than enough data for PIV analysis.
- PIV requires visible tracers on the water surface. In lab settings this is done by seeding the water surface with floating objects such as woodchips or plastic pellets. Seeding is not feasible in natural systems. In the absence of seeding, natural features on the water surface, like bubbles or the downstream translation of small waves on the water surface, can provide trackable features to measure stream velocity. The 2020 analysis showed that stream velocity could be measured using PIV in areas with water surface texture such as riffles and runs, but slower moving areas of the channel such as pools and channel margins did not have adequate tracers.
- The 2020 analysis highlighted the key importance of camera orientation to highlighting water surface texture. Improper camera orientation can lead to saturation of the video with sun glint such that no data can be derived from the video.
- The 2020 analysis used ground scaling. As an alternative to ground scaling, aircraft position and altitude could allow georeferencing of velocity outputs, which would facilitate surface velocity mapping.
- Some of the 2020 videos were collected in high wind conditions which impacted water surface texture and also led to false velocity results due to movement of riparian vegetation. Future acquisitions should target low wind conditions for best results as well as for improved video stability.

2022 planning and data collection

The USGS worked with UDWC and Wolf Water Resources (W2r) to 1) develop a UAS data collection methodology to collect spatially continuous video and 2) develop a PIV study based on lessons learned from 2020 data collection and analysis, for a recently modified reach of Whychus Creek which included multiple flowpaths and thousands of pieces of wood.

Video and high-resolution RGB (red-green-blue; true color) orthoimagery were collected on July 20, 2022. The data collection methodology included collecting overlapping videos using a hovering DJI Phantom 4 Pro UAS operated by W2r. Aircraft orientation and height were determined in the field to optimize stream coverage while capturing the surface texture of the stream needed for effective image velocimetry. Video was collected at 250 feet AGL, higher than in 2020; the increased flying height provided a wider field of view, capturing more of the channel, especially important where the stream is valley-wide. Each consecutive video overlapped the previous video, which provided complete channel coverage for PIV analysis. Ground control targets were placed throughout the video analysis area, and high resolution RGB orthoimagery was collected on the same day as video and at a similar spatial resolution to the videos to allow identification of ground control points in both the video and orthoimagery. This allowed geospatial referencing of the video (Figure 1).

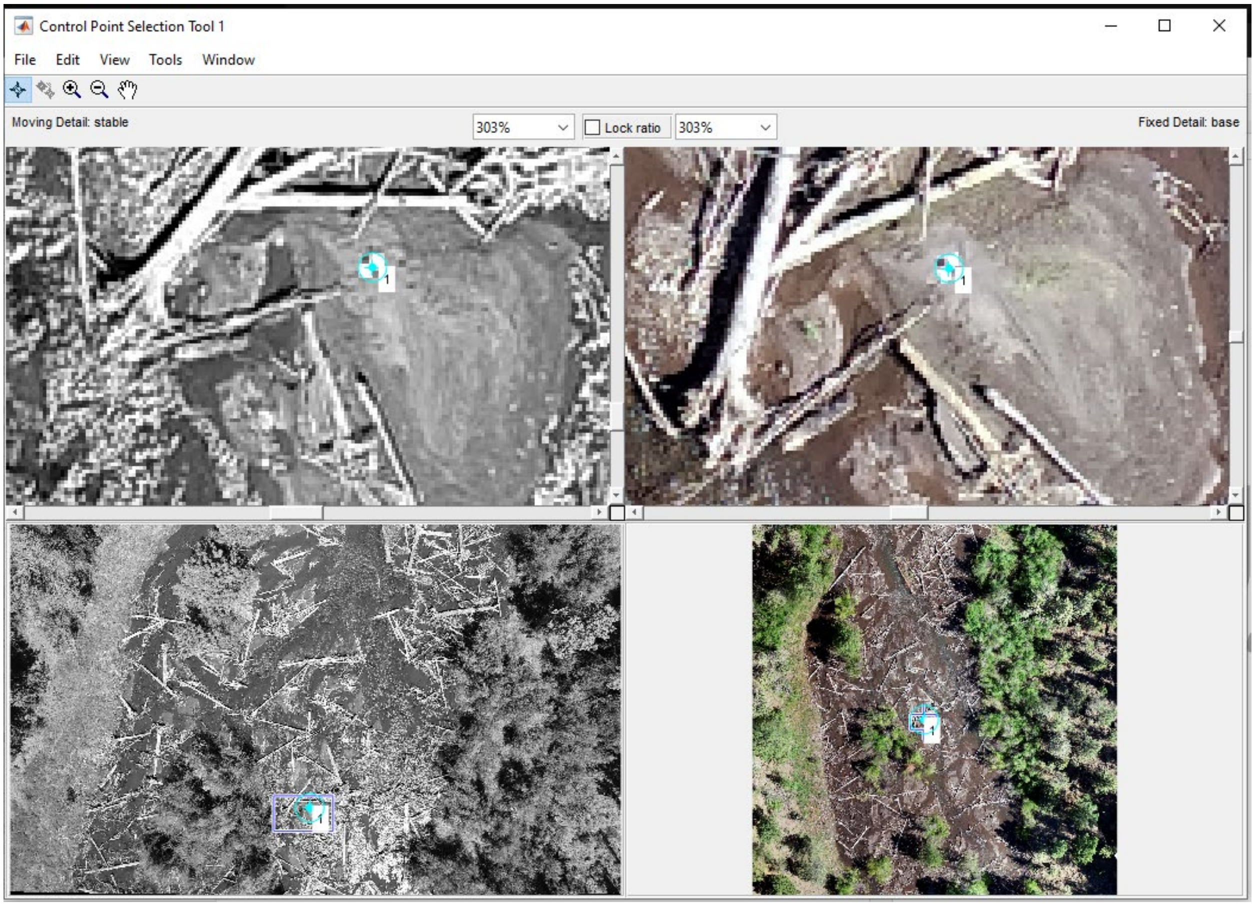

Figure 1. Screen shot of the TRiVIA video georeferencing module. Ground control targets visible in both the video frame (left panels) and the spatially referenced RGB orthophoto (right panels) are used to transform the video to spatial coordinates.

In-situ stream velocity measurements were collected using a SonTek Flowtracker2 acoustic Doppler velocimeter along four transects within the velocity mapping area of interest (Figure 2). Transects were established by placing 1 foot x 1 foot ground control targets at the endpoints of the transect lines. A survey tape was stretched between the targets, and velocity measurements were referenced as distance from the river right transect end point. Five to ten velocity stations were measured along each transect at non-uniform spacing dictated by the wood and sediment bars along the transect. Velocity was measured at 0.6 total depth and each measurement was averaged over 40 seconds. Targets were placed for five transects but only four were measured due to time constraints.

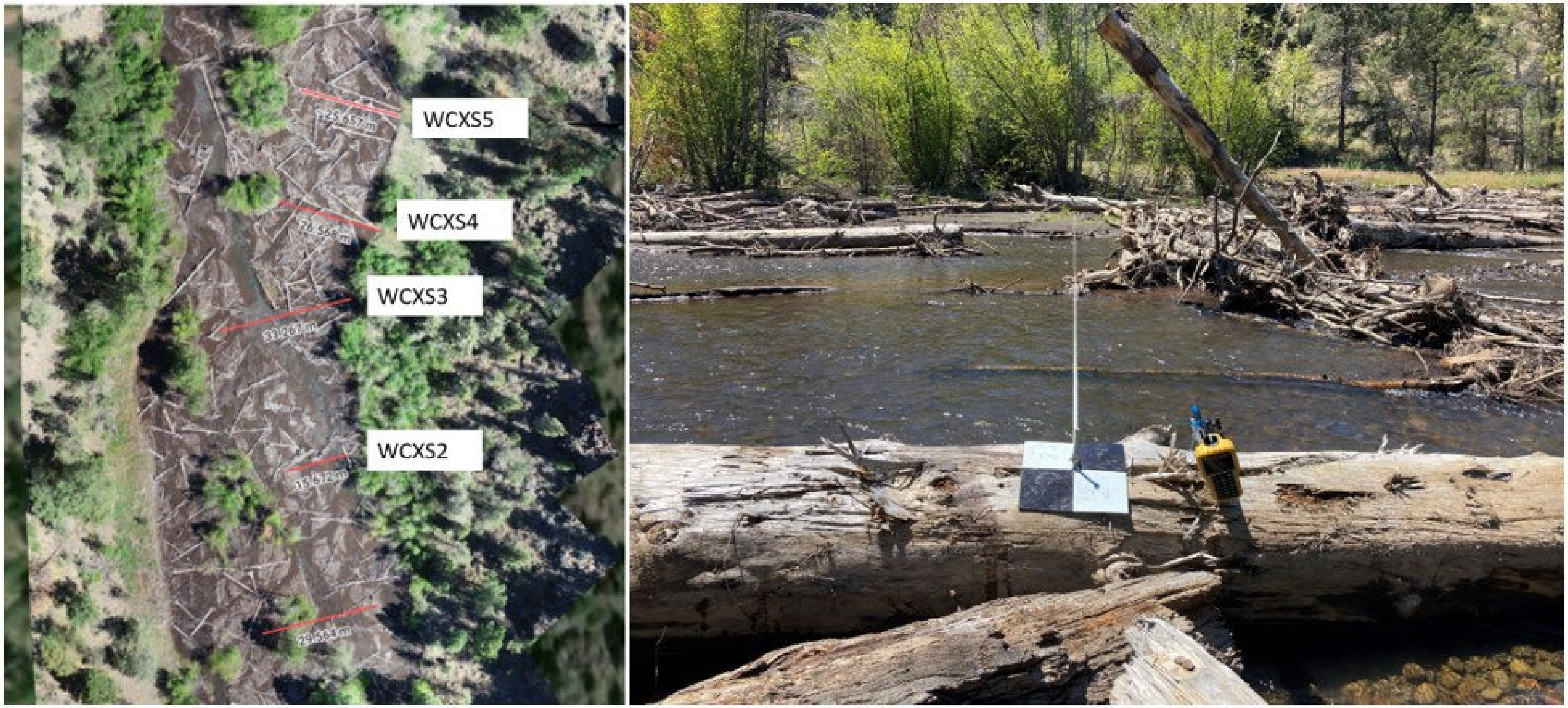

Figure 2. Four velocity transects within the velocity mapping area of interest in Phase 2a of restoration, implemented in 2021, at Deschutes Land Trust's Whychus Canyon Preserve.

2022 data processing

2022 data processing used an end-to-end processing software developed by the USGS for river mapping (Legleiter, 2023). A significant advance in the new software is a georeferencing module that provides a workflow for transforming video frames from arbitrary image coordinates to geographic coordinates. The module facilitates matching features between drone-derived RGB orthophoto and the video frames. With this advance, the PIV outputs include geographic positions. The USGS conducted preliminary PIV analysis of data collected on Whychus Creek in July, 2022 using the new USGS software (Figure 3).

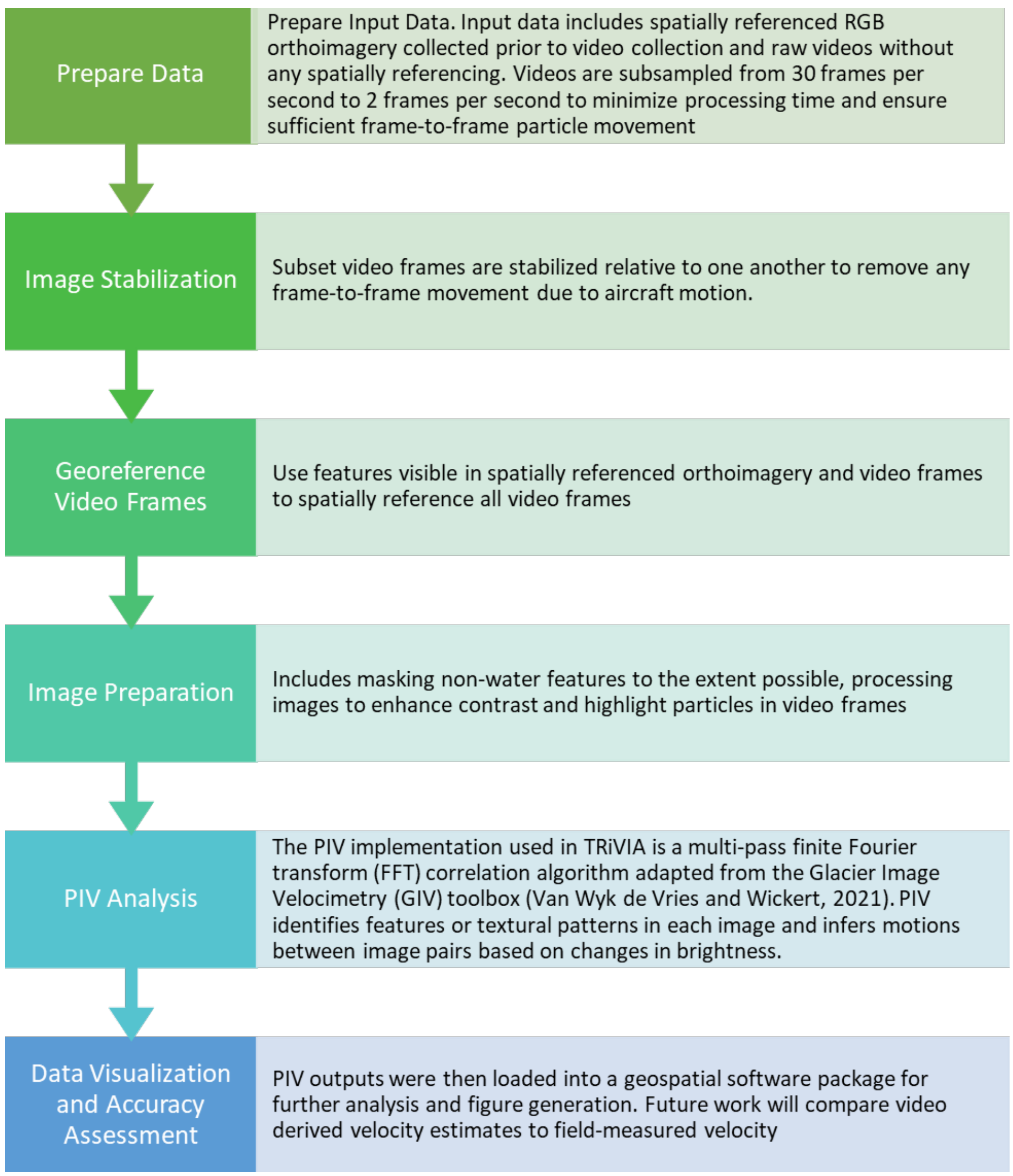

Figure 3. LSPIV processing workflow using TriVIA software

2022 results and future work

Preliminary results from PIV analysis in the Whychus Canyon Phase 2a reach one year post-restoration show high heterogeneity in velocities, with a high proportion of velocity vectors characterized by velocities less than 0.3 m/s (1 ft/s), the upper threshold of optimal velocity for rearing salmon and trout (Figure 4, Appendix A). The PIV method resolved velocity in areas where surface flow patterns had higher texture such as the left channel in Figure 4 and was able to resolve complex flow patterns around in-channel wood. The PIV method was not able to resolve continuous velocity in areas of the channel with slower velocity regions or very smooth inundated areas such as the right channel in Figure 4.

Figure 4. PIV-derived flow velocity vectors (m/s) and number of vectors per 0.05 m/s bin along 70 m valley length of the Whychus Canyon Phase 2a restoration reach showed high heterogeneity in velocities and a high proportion of velocity vectors with velocities less than 0.3 m/s, the upper limit of optimal velocity for rearing salmon and trout.

2022 data collection and analysis advanced our understanding of data and imagery requirements and developed a LSPIV workflow to support remotely sensed flow velocity measurement in complex channels. In January 2023 UDWC submitted a grant proposal to OWEB to fund imagery acquisition, data collection, and analysis on Whychus Creek restoration reaches in summer 2024; in April 2023 the OWEB board approved funding for the proposed project. This project will include further LSPIV analysis of 2020 and 2022 video and inform 2024 video acquisition and field validation data collection. Specific tasks will include:

- Applying the workflow developed from 2022-2023 to process the 2022 velocity dataset including orthorectified overlapping videos and transect-based velocity measurements;
- Processing the 2020 velocimetry datasets;
- Assessing the accuracy of LSPIV analysis of 2022 videos using transect-based velocity measurements
- Designing 2024 video acquisition and LSPIV analysis in response to what is learned from 2022 LSPIV analysis and accuracy assessment (video acquisition to be performed by W2R)
- Collecting field validation data during July 2024 UAS flights

Remaining work to be funded through future grants will include:

- Analysis of 2024 videos using LSPIV;
- Comparison of 2024 and 2022 videos, velocities, and flow directions to 2020 videos, velocities, and flow directions for all reaches; and
- Summarization of data sets, data and findings, including publication of PIV outputs and field data in the USGS ScienceBase database.

References

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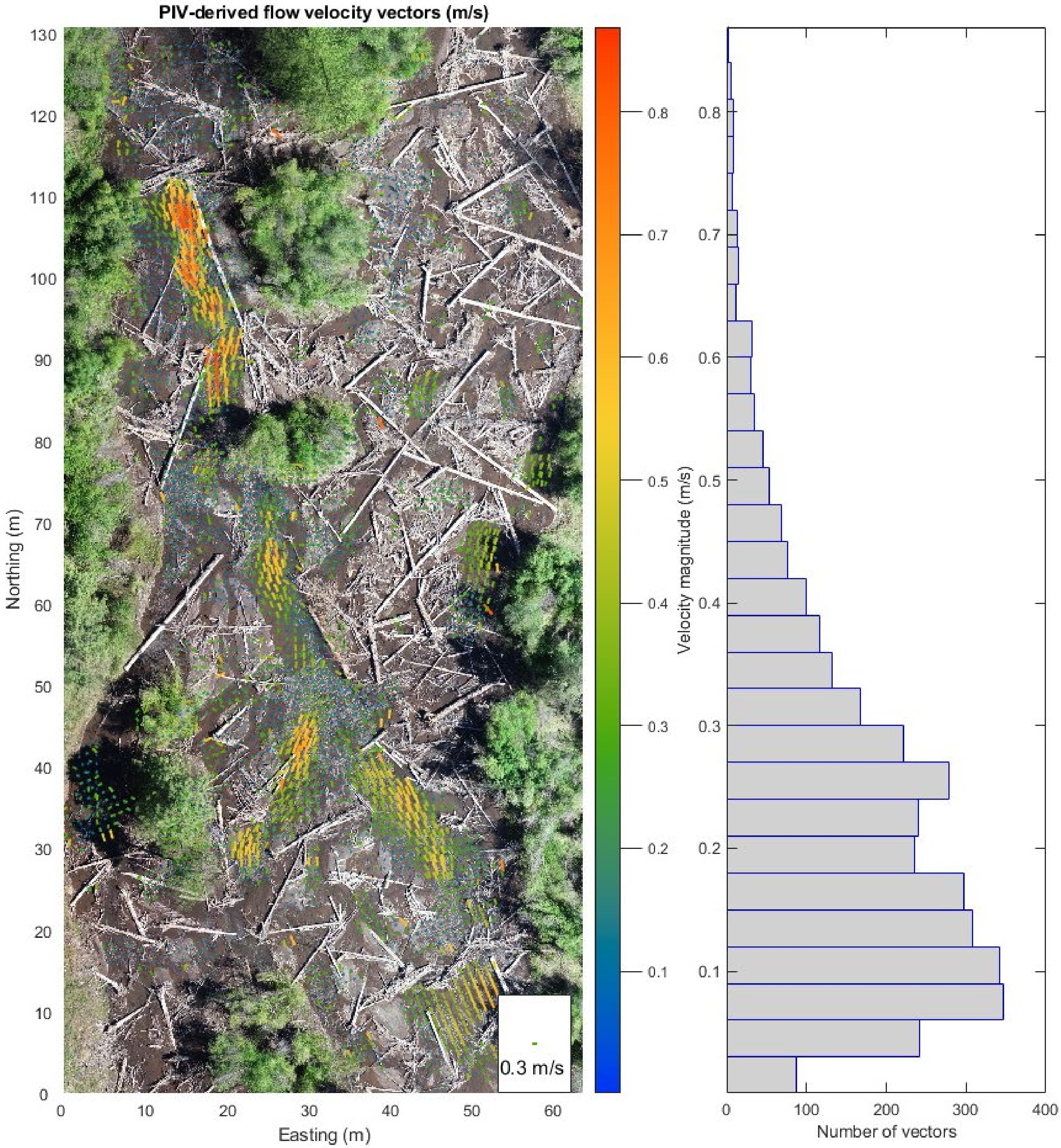
Appendix A. Velocity outputs from four overlapping videos representing the 2022 survey reach



Lower left: 626205 m E, 4914225 m N