



Budapest University of Technology and Economics
Department of Hydraulic and Water Resources Engineering

BSc, Technical practice (BMEEODHAI42)

Report

16 January - 24 February 2017

By
Gabriella Lükő
(BO4ZA1)

The first week of the practice started with meetings and administrative work at the Civil and Environmental Engineering Department of the Norwegian University of Science and Technology (NTNU). I had to take an online laboratory safety course. I was able to work in the lab only after I took it. My task in the laboratory was to do the grain size analysis for the collected bedload samples. The samples are from Norwegian rivers called Gaula and Lundesokna, and the measurements were carried out in the framework of the project called Hyrdocourse. There were both bottom probe and freeze plate samples as well. First I had to measure the weight of the samples, then put them to the oven at 110 °C to dry, this meant I had to keep drying the samples until their weight would not change anymore after more drying (Figure 1, left). The next step was using a sieving machine (Figure 1, right), for 10 minutes each sample. After sieving I measured the weight of different sized pile of gravels.



Figure 1. Used oven (left) and sieving machine (right) in the NTNU laboratory.

After the lab work, on the second week of my practice I finished the calculation of the grain size distributions, edited diagrams and made a 15-page-long report of the measurements and results, where I used up old Masters' Theses about the topic and collected information about the measurement method itself. Samplers were taken at the same spot but with two different sampling methods. These samples grain size distribution are supposed to be related as the created diagram shows below as well (Figure 2)

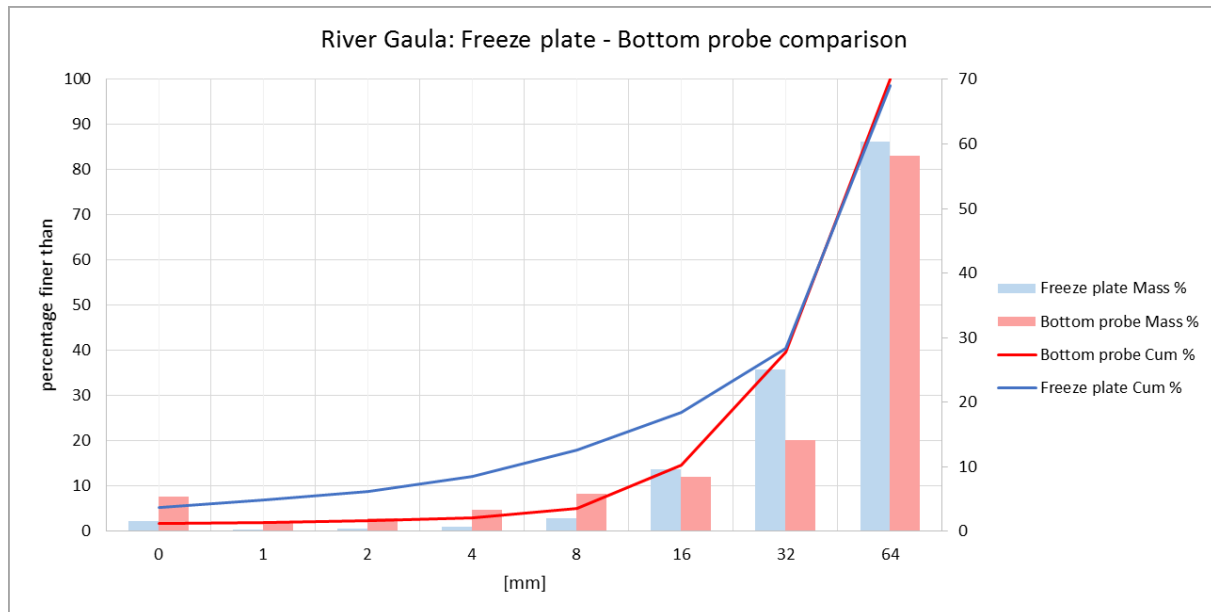


Figure 2. Grain size distribution comparison for Freeze plate and Bottom probe samples

On my third week of the practice I had a meeting with my supervisor and we decided to start preparing for the next task, which is creating the Digital terrain model (DTM) of a 1 km long river section in Albania. The method we use is called Structure from Motion (SfM), which creates a 3D model from only using an image sequence. The most convenient way to collect the images of the object is using an Unmanned Aerial Vehicle (UAV) or also called a drone. I already had some experience on this topic, I wrote my paper for the Student Associations' Conference (TDK) last year about testing UAV-based measurements. So I started doing test flights with the drone near NTNU, where I could check if the battery capacity in winter weather and the application is working on my phone. The applied UAV is a DJI Phantom 3 Professional (Figure 3)



Figure 3. DJI Phantom 3 Professional

The batteries were doing well even in these freezing Norwegian weather conditions. Also recorded some videos from the UAV so I can test the 3D modeling softwares as well. I cut and painted large reference points (Figure 4) in the laboratory for the SfM method, which is important if we want to georeference our model. We measure the real coordinates of the reference points with GPS.

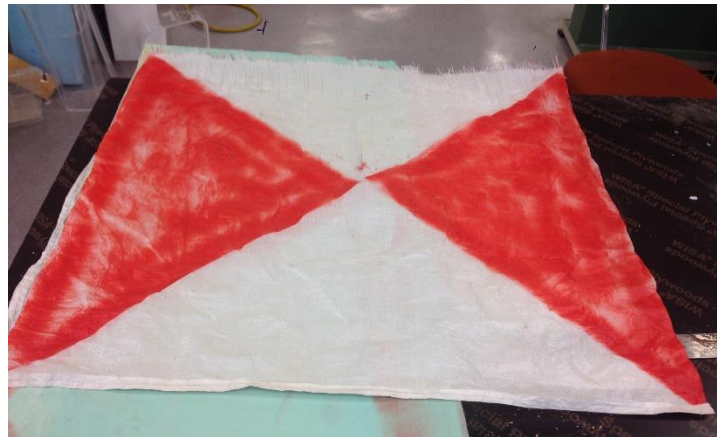


Figure 4. Handmade reference point (80x80 cm)

Otherwise originally the method just puts the model into a random scale coordinate system, but if we add the real coordinates of a few reference points then whole pointcloud can be transformed into the real coordinate system, so we have a fully georeferenced model. The aim of making this SFM model is having a detailed digital terrain model so the sediment transport and the morphology can be detected throughout a hydrodynamic model. There is too much sediment in this river in Albania called Devoll. There are very fine sand and large stones at the same place. This is why it is very interesting to analyze the grain size distribution of this river. There is a Matlab-based software called BaseGrain developed in ETH Zürich, which calculates the grain size distribution from only analyzing images. Since this software was new to me I tried to gain some experience analyzing underwater pictures from some previous measurements. As I mentioned I have tested the SFM software this time too. All of them are freely available academic software. When I got the drone videos, first I need to convert the MOV videos to AVI files, which I am doing with GoPro Studio now. Then I have to create an image sequence from the video with defining how many images I want in a second (frames per second, fps). Then to process the drone images I use is a software called VisualSFM where I add the images and do the 3D reconstruction itself, so I get a point cloud. Then another software called Meshlab is used to clean up any inappropriate vertices in the model and also the georeferencing is happening. I also made a detailed plan for our 3 day long measurement in Albania as I could plan and get to know the field from satellite photos. I wrote a necessary equipment list, also it was important to check if all of them is working properly. This is was done by the end of the fourth week of the practice.

The fifth week of the practice I spent in Albania where we did the field measurements at the Devoll River at low water, so the geometry of the river bed is mostly visible. The first day we only did drone flight and video tests on the field. There were insane wind conditions and it seemed dangerous first, but the drone stood firm. We checked in the evening on the computers if the reference points are visible on small test models and everything looked alright for the next day for the actual measurements. So on the second day we placed the reference points first on 600 meter long downstream section from the bridge in the middle (Figure 5).

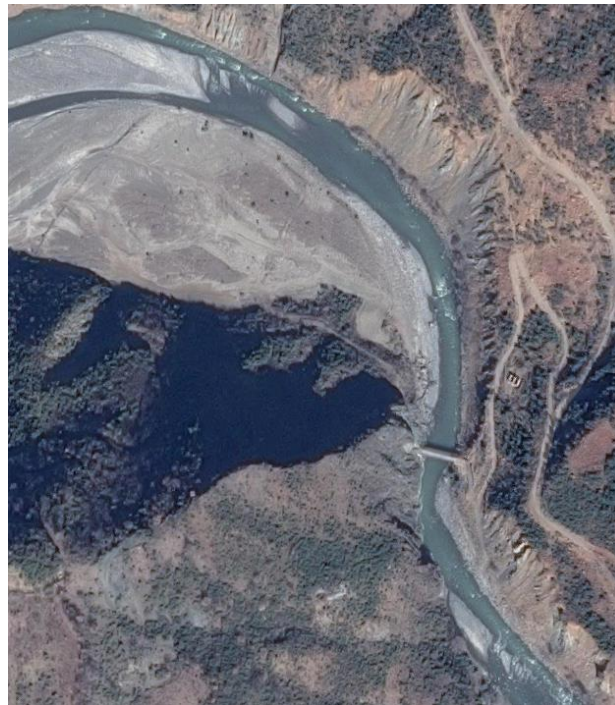


Figure 5. Measurement field, with upstream (north) and downstream (south) part from the bridge

Then we did the drone flight above the river to capture the river bed from two different altitude. Then we had to charge the batteries of the drone. While they were charging the GPS measurements happened for each reference points (Figure 5.)

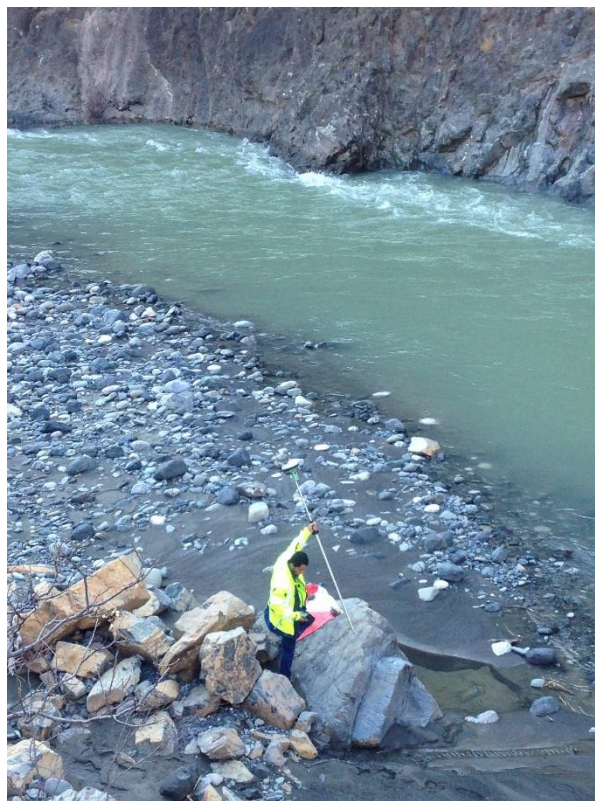


Figure 5. GPS measurement of the reference points.

After all the reference points were laid down, we did the first UAV flight for the 600 meter long downstream part with one video about 50 m altitude. Two people were necessary for this task, one person controls the remote, the other one the smart phone with the DJI Go app, watching the camera view and helping the other person since the UAV and its motion is not very visible after few hundred meters. After this flight, we went uphill back to the car to charge the UAV battery. Meanwhile we carried out another flight from the hill about 100 m, so larger area can be recorded. Then later we moved the reference points to the upstream part from the bridge, they were GPS measured too, then we carried out another UAV flight for that 300 meter long section successfully.

The next day we carried out flights for the Large Scale Particle image velocimetry, which means we needed to record the water surface of a cross-section. Some reference points have to be at the banks and tracers are needed to flow on the surface as well. In this case natural tracers were not enough, so pieces of wood, bread and paperballs were dropped into the water from the bridge upstream. Another task was that day, to take UAV videos of the bed material with a scale on the image as well for the Basegrain software which will analyse the grain size distribution. Meanwhile the UAV measurements, ADCP flow survey has been done every day to measure the discharge of the river.

The sixth week of my practice I spent with postprocessing the data we collected in Albania:

- UAV videos of the topography (Structure from Motion)
- RTK-GPS measurements (reference points)
- UAV videos for Large Scale Particle Image Velocimetry
- UAV images for bed composition analysis (BaseGrain)
- Flow survey with ADCP

First I am showing the postprocessing of the topography videos, Figure 6 shows the flow chart of the methods and its processing time. The videos need to be converted to AVI files, then they need to be cut up to an image sequence. The images can be loaded in VisualSFM which created the 3D point cloud. Then the georeferencing is done in Meshlab. The total postprocessing time for a 300 meter long river reach was less than 3 hours which shows the method's cost-effectiveness.

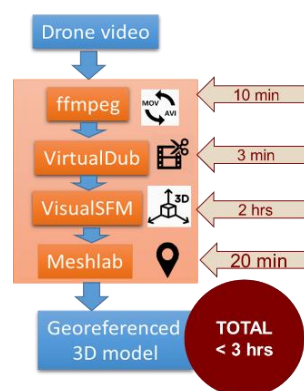


Figure 6. Postprocessing of the UAV videos

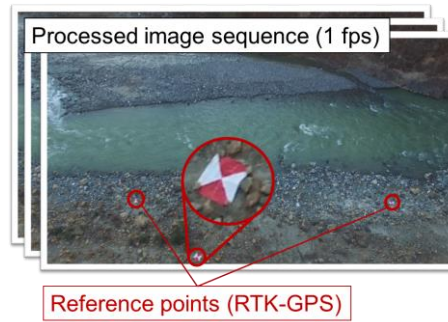


Figure 7. The raw image

Figure 8 shows the raw results of the point cloud of the 300 meter long river reach with more than 1,300,000 vertices. It is very detailed and the reference points can be seen properly when we zoom in. We do not have data where there is water, since those points are moving all the time, they are never the same on image pairs, which would be essential for the analysis.



Figure 8. 3D point cloud in VisualSFM of a 300 meter long river reach

On Figure 9 the 3D surface can be seen where the reference points (red crosses) are visualized properly. Even the bed material is detailed, the individual gravels can be seen along with the reference points.



Figure 9. Detailed 3D surface of the river reach

From Meshlab software where the georeferencing happened the mesh can be exported in a PLY file which contains the real XYZ coordinates of the point cloud (Figure 10). Altogether we got over 5,000,000 points.

X	Y	Z
440309.417	4514415.635	302.662
440309.395	4514415.994	302.687
440309.287	4514416.062	302.686
440310.133	4514414.495	302.665
440310.078	4514414.581	302.667
440310.008	4514414.646	302.664
440309.707	4514415.407	302.665
440309.709	4514415.425	302.646
440309.577	4514415.597	302.59
440309.457	4514415.734	302.558
440309.481	4514415.81	302.597
440309.439	4514415.84	302.653
440309.338	4514416.027	302.61
440309.348	4514416.006	302.6

Figure 10. Real XYZ coordinates of the model

Now I am showing the results of the postprocessing the LSPIV videos, which I have done with the Fudaa-LSPIV software. The raw image can be seen on Figure 11 with the small tracers on the surface. The imageprocessing for the whole video took less than an hour.



Figure 11. Raw image for LSPIV analysis with tracers on the surface

After the usual sensitivity analysis the following free surface velocity distribution was resulted (Figure 12). The discharge is calculated from the $Q = A \cdot v$ continuity equation, where v , the mean velocity equals 0.9 times the surface velocity of the cross section since we assume the vertical logarithmic velocity profile. The LSPIV estimated discharge and the ADCP data has only 1% difference ($Q \sim 15 \text{ m}^3/\text{s}$)

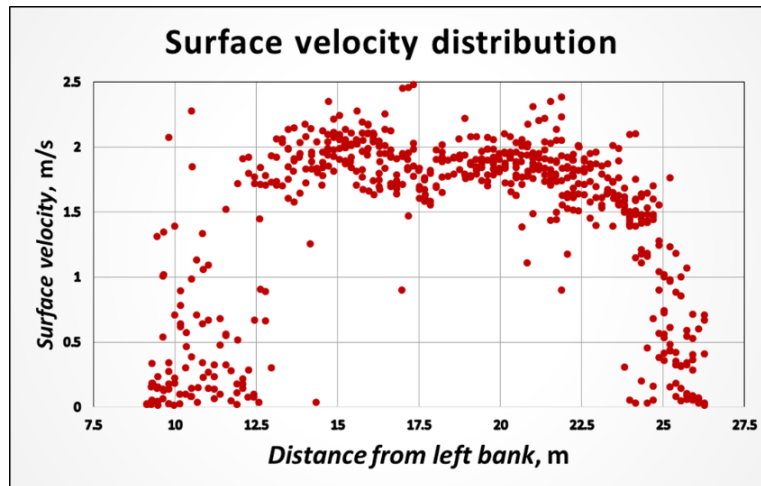


Figure 12. Surface velocity distribution from LSPIV analysis

Now I am showing the results of the image based bed material analysis, which I have done with Basegrain software. On Figure 13 the postprocessed image can be seen, straight lines show a-axis and b-axis of the fitted ellipses.

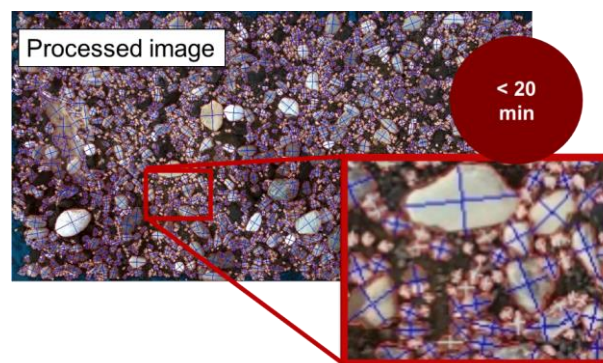


Figure 13. Processed image with Basegrain, with a and b axis of the fitted ellipses

Taking the processed image and its calculated geometry of the gravels, the grain size distribution was visualized on Figure 14 where the fraction weighter mean diameter and the mass percentile at 90% sieve throughput can be seen too. These data are important for numerical models estimating Manning's roughness (k).

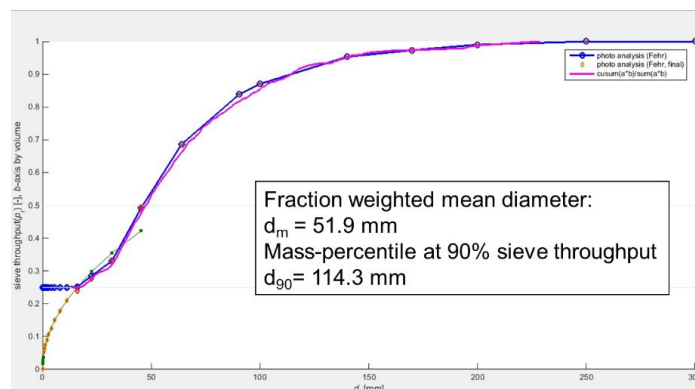


Figure 14. Grain size distribution (Basegrain)

The goal of this study was to create

- Digital Elevation model (DEM);
- Grain size distribution;
- Surface velocity;

from UAV so we can build a numerical model. The DEM of the 1 km long river section can be seen on Figure 15. The data is from the SFM analysis and the interpolation of 1D cross section data for the underwater parts.

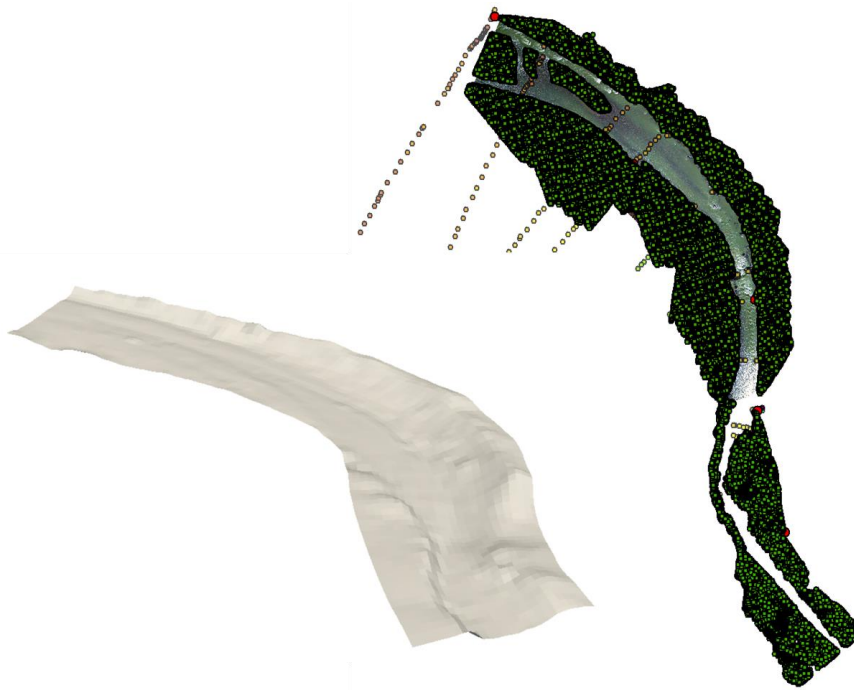


Figure 16. Digital elevation model from SFM and 1D data

The model used is the fully three dimensional computational fluid dynamics model for open channel flows, SSIIM. SSIIM is developed at the Norwegian University of Science and Technology and is free ware. <http://folk.ntnu.no/nilsol/ssiim/>. The model solves the Reynolds averaged Navier stokes equation with a k-e turbulence closure and the SIMPLE algorithm for the pressure calculation. Figure 16 shows the real water surface (left) and the calculated velocity distribution (right) of the river reach. Boundary conditions were discharge and water stage values from LSPIV and ADCP measurements and the water level from the SFM measurements. Manning's k roughness was used for calibration.

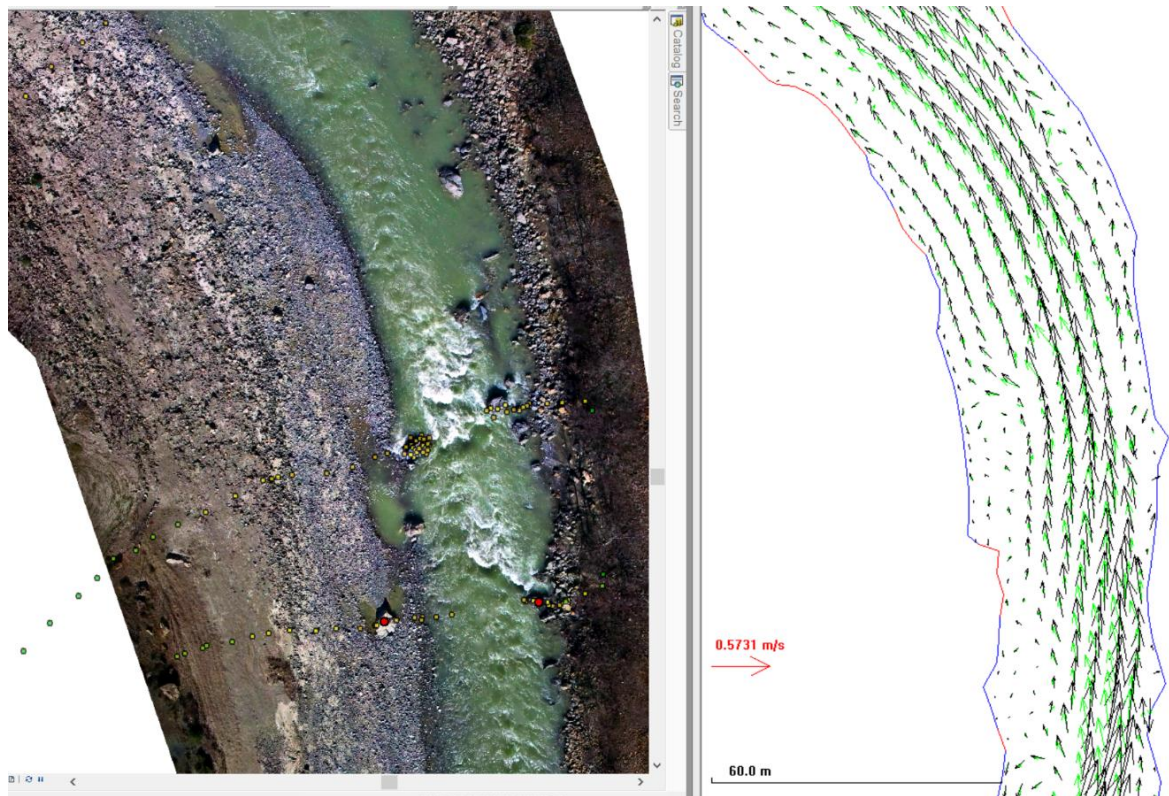


Figure 16. Real water surface (left) and calculated velocity distribution

Figure 17 shows the calculated horizontal velocity distribution in 3D.

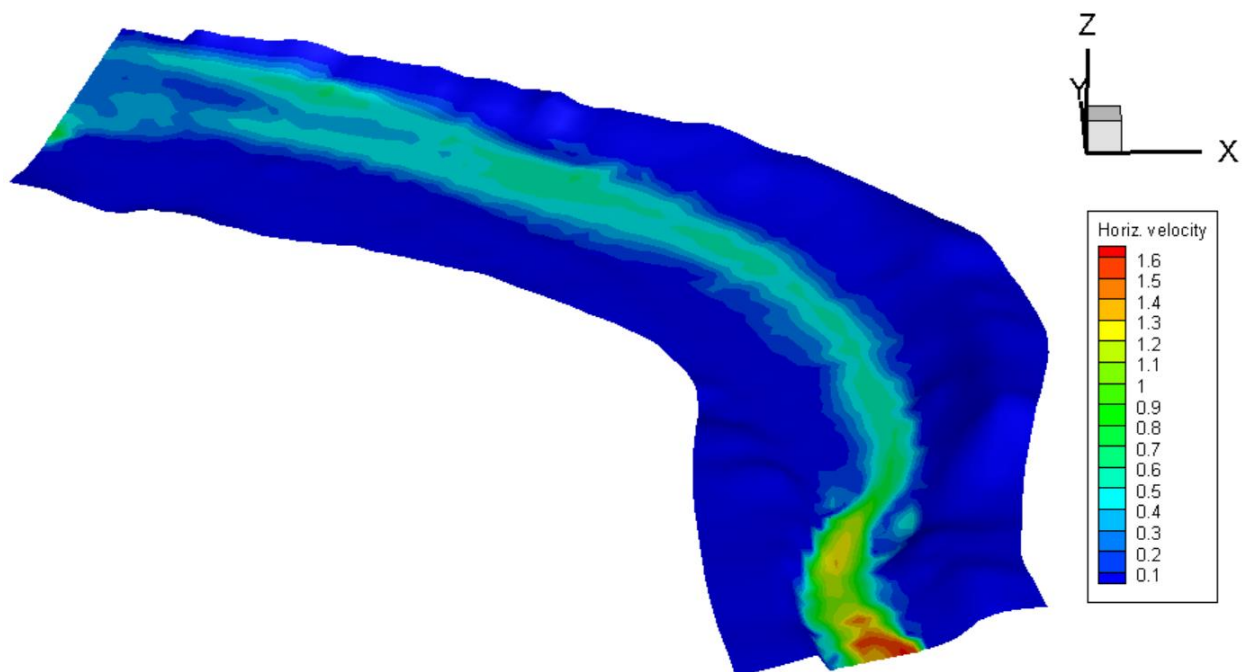


Figure 17. Horizontal velocity distribution of the 1 km long river section