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Flow Modeling of a Flood Event in a Small Mountain Catchment Varkaankuru:

Tool Creation for Outdoor Infrastructure Planning

Tatu Nylund

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About Us

Environmental Surveying & Water Management

We are a surveying and environmental services department based in Rovaniemi, specializing in:

- **Environmental services related to hydropower, windpower and water management**
- **Hydrological and hydraulic surveying & modeling**
- **Snow water equivalent monitoring**
- **Dam safety and geotechnical consulting**
- **Field surveys, data analysis, and modeling tools to support water infrastructure planning**

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General Background and Modeling solution example: Varkaankuru, Ylläs

There is currently no definitive information on how climate change would affect peak flows or design flood specifically in the Varkaankuru area.

Due to lack of observations in the catchment, the aim was to estimate the current design flood event with hydrological nomograms and regional parameters and iterate modeling results to reproduce similar flow conditions.

A rain-on-grid model is used to create the flood event by distributing rainfall evenly to the area. At the downstream end of the watershed, the event is calibrated to match the desired event magnitude. A 20-minute rainfall event was used.

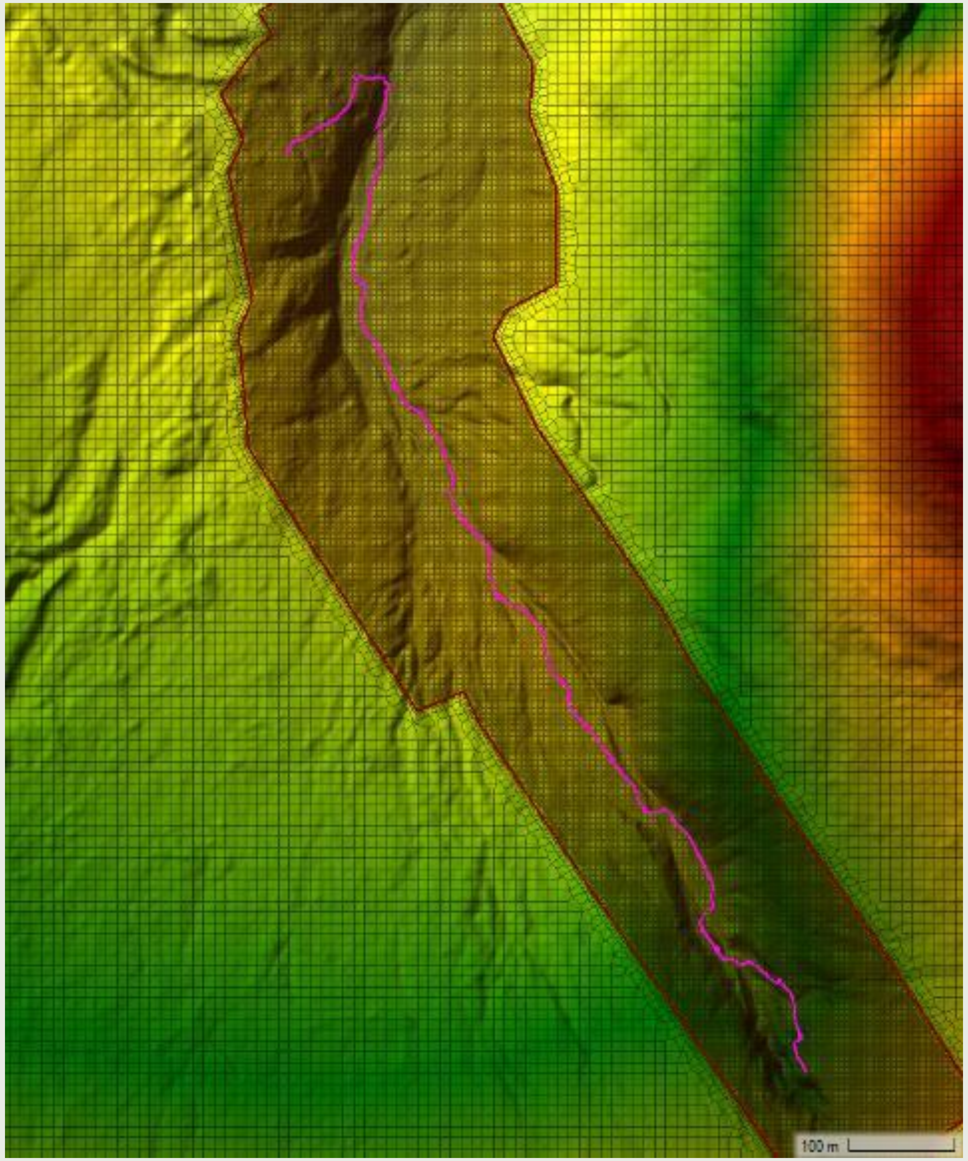
Even though the method does not simulate the complexity of snowmelt flood, it distributes water evenly and creates the desired flood event at a downstream point.

The event magnitude was scaled to 4 different scenarios, ranging from a low flow to an extreme event.

Catchment area size 6,2 km2

Modeling Method: HEC-RAS 2D Rain-on-Grid (RoG)

HEC-RAS 2D Rain-on-Grid modeling simulates surface runoff by applying rainfall directly to a gridded terrain surface. In this approach, rainfall is distributed across the computational mesh, allowing the model to dynamically route overland flow based on topography and surface characteristics. The model provides a spatially distributed estimate of runoff and flood extent.



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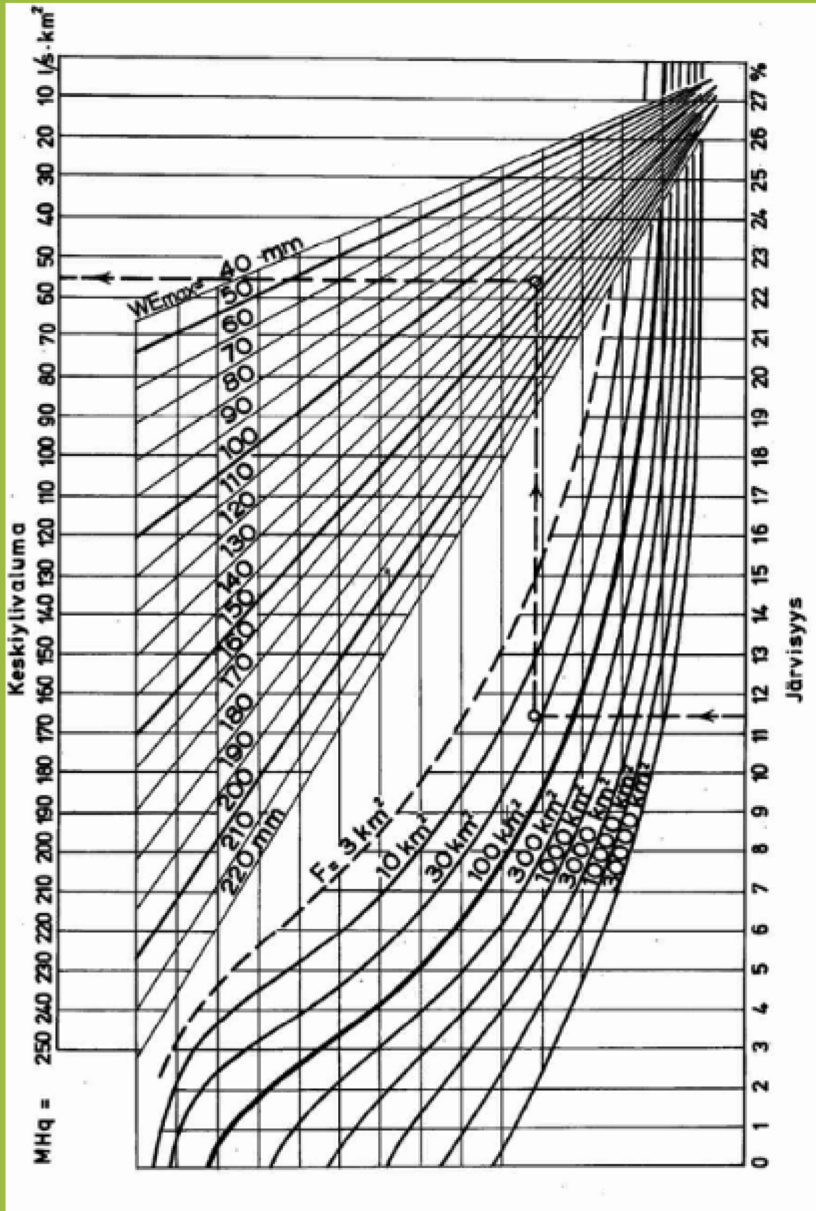


Kuva 1. Kaiteran nomogrammi (1949)

If discharge observations are not available, various nomograms can be used to estimate peak runoff at a downstream point of the catchment. These nomograms are widely used in hydraulic structure design.

Peak flows are typically result of snowmelt.

Nomograms are empirical formulas presented graphically. One of the most commonly used in Finland is **Kaitera's nomogram** (left), which allows the estimation of the mean spring peak runoff (MHq) based on the lake percentage of the catchment, the catchment area, and the average annual maximum snow water equivalent.

Alternative approach is **Nissinen's nomogram** (right). Nissinen developed a nomogram based on Kaitera's work, specifically for the catchment areas of ditches and small streams. This nomogram allows for the estimation of the peak runoff for catchments with no lakes.

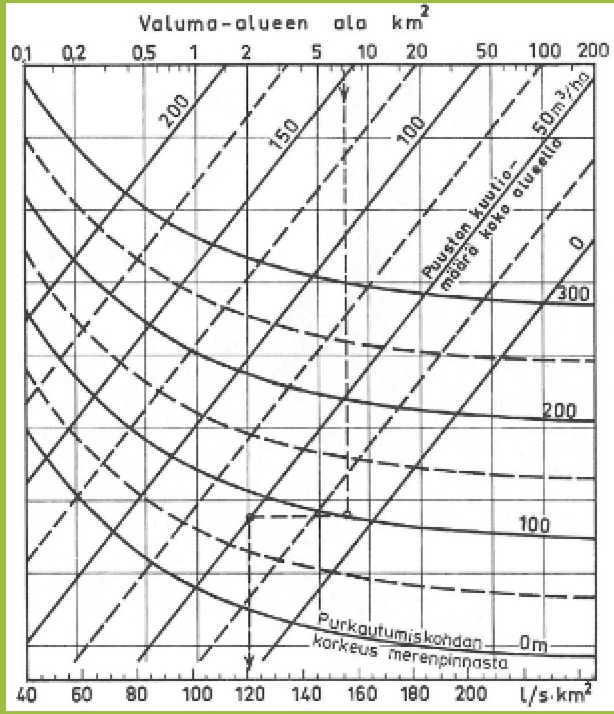
Kaitera: HQ 1/20 ~ 2,25 m3/s

Nissinen: HQ 1/20 ~ 1,65 m3/s

Peak runoff was also estimated with comparison to reference catchments, which were provided by the Lapland ELY Centre. The corresponding HQ 1/20 estimate, based on size adjusted comparison was calculated:

HQ 1/20 ~ 1,45 – 1,70 m3/s

Estimating the peak discharge statistically



Land classification for flow roughness factor

The CORINE 2018 land cover dataset was used as the basis for assigning Manning's roughness coefficients for modeling.

Different land cover classes were interpreted in terms of surface roughness, allowing appropriate values to be assigned spatially across the model.

This approach provides method for representing surface resistance in overland and channel flow calculations without actual calibration surveys.

Data covers all of Europe and should be freely available across the Nordics.

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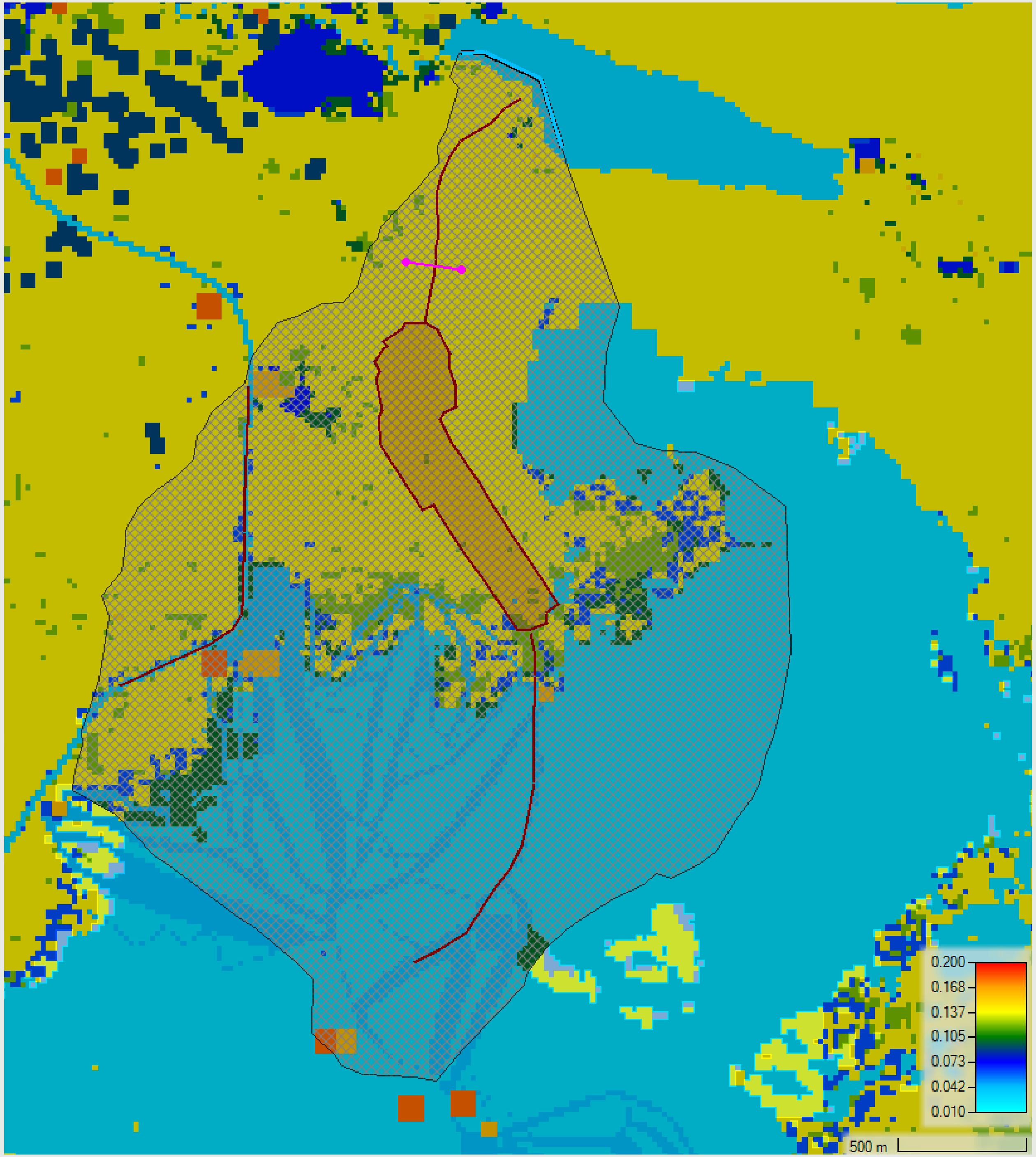


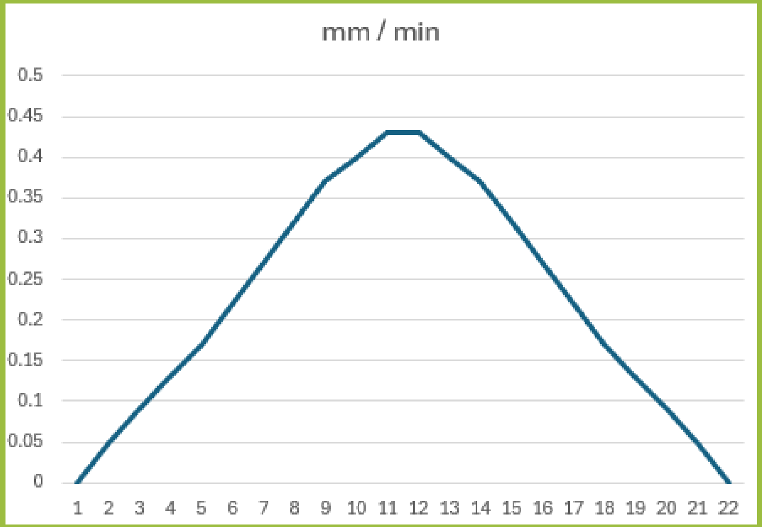
Rain event used with ROG-modelling

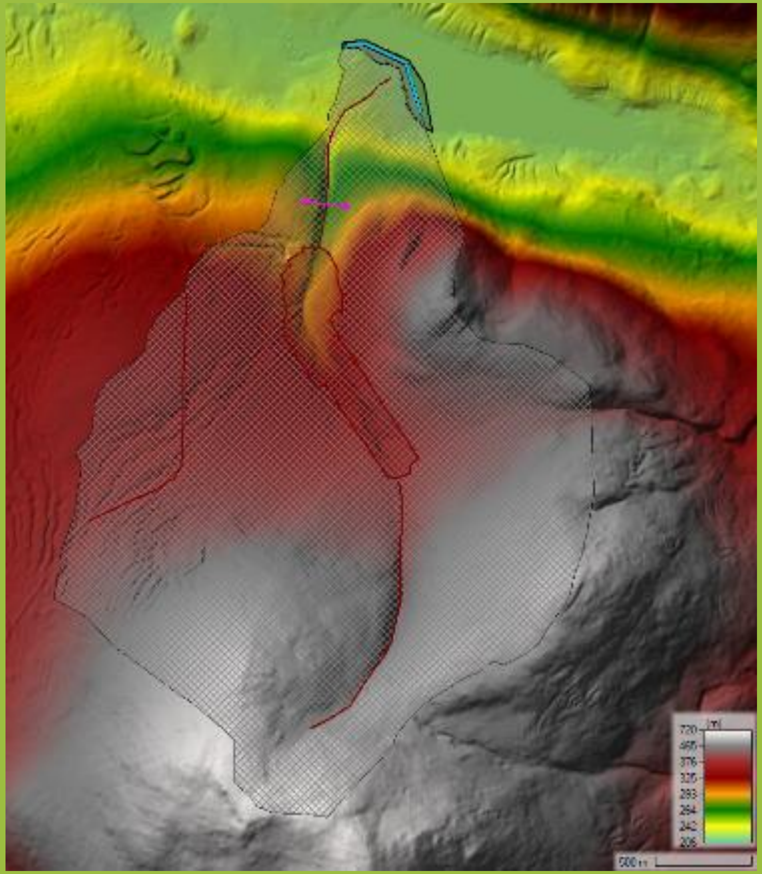
The design hyetograph was applied in the HEC-RAS Rain on Grid model by defining a specified precipitation time series.

The 20-minute rainfall event, structured as a symmetric parabolic hyetograph was input as the precipitation boundary condition of the model. The rainfall was applied uniformly across the computational grid (the catchment).

Soil infiltration was not estimated, but instead included in the total discharge iteration so that the resulting peak discharge matched the estimated peak runoff in the downstream end of the catchment.

The resulting flow distribution is likely to be more uneven in reality due to variability in soil infiltration properties and snow accumulation.





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Flow Scenarios

Discharge Scenarios and Selection Basis

Four rain events / discharge scenarios were modeled by iteration process:

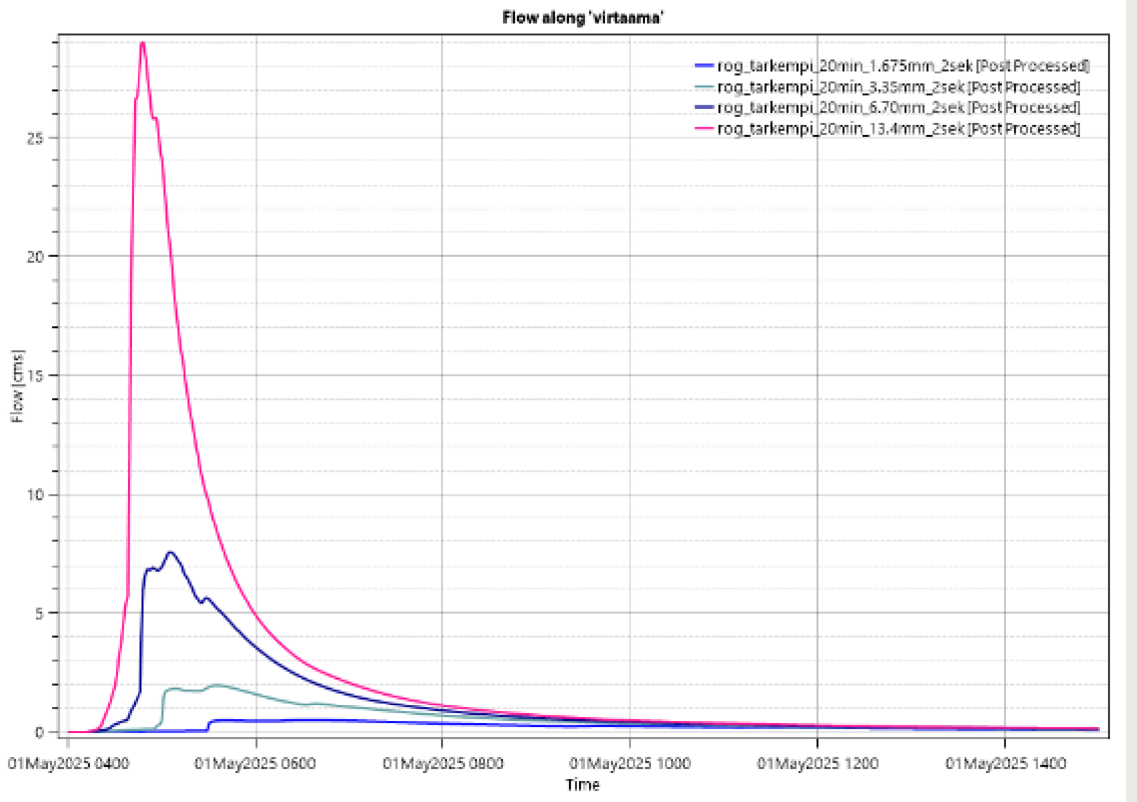
Peak flows at the downstream point “virtaama”

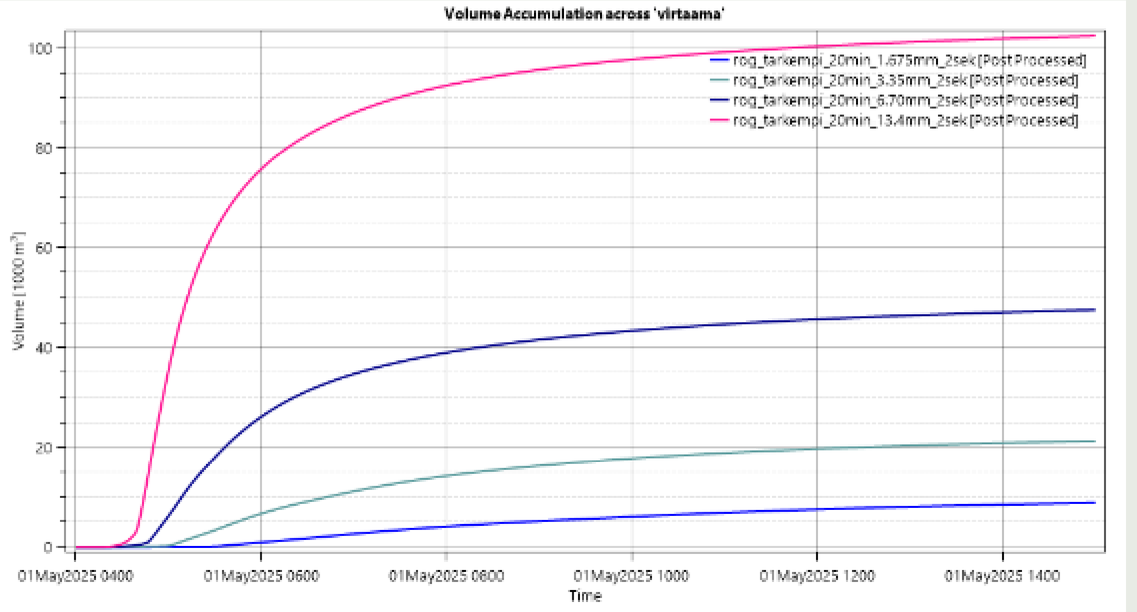
0.5, 2.0, 7.5, and 29.0 m³/s

The scenarios represent a range of flow conditions from a low flow to an extreme flood event

Purpose of the scenario range is to identify potentially vulnerable locations for outdoor infrastructure

The green curve (max 2.0 m³/s) matches the magnitude of the estimated 20-year flood event





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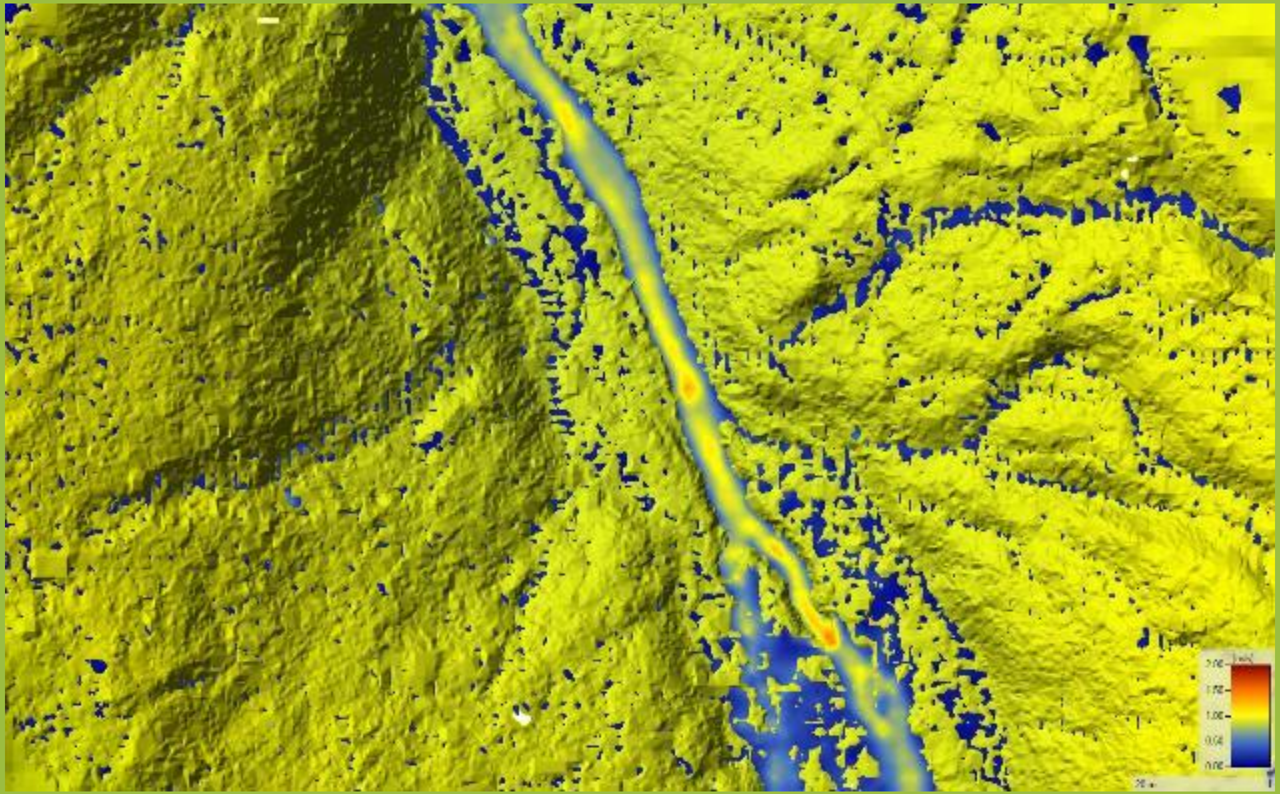
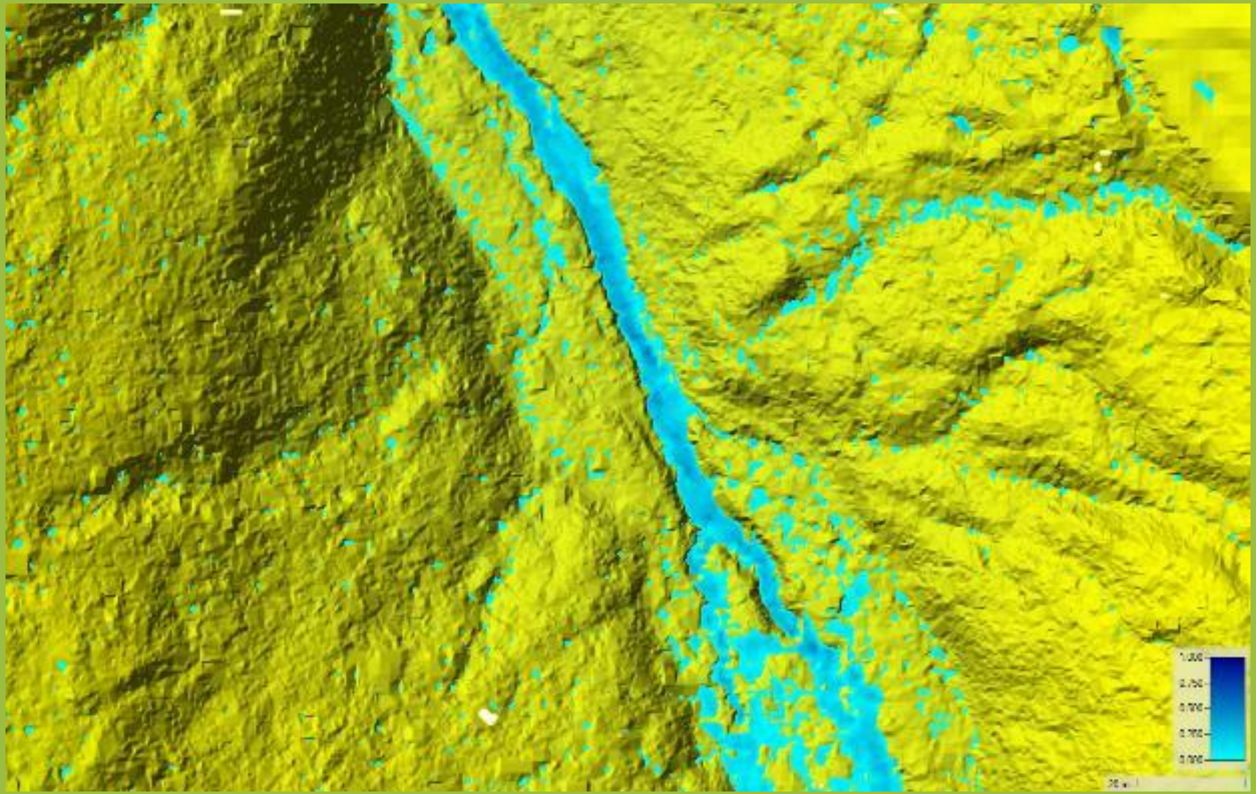
Modeling results

The HEC-RAS Rain-on-Grid model was used to simulate rainfall-runoff and flood dynamics.

The results include flow paths, flood extents, water depths (right), and flow velocities (left). Outputs can be exported in GIS format.

Hydrographs, time series at desired time-steps from any location.



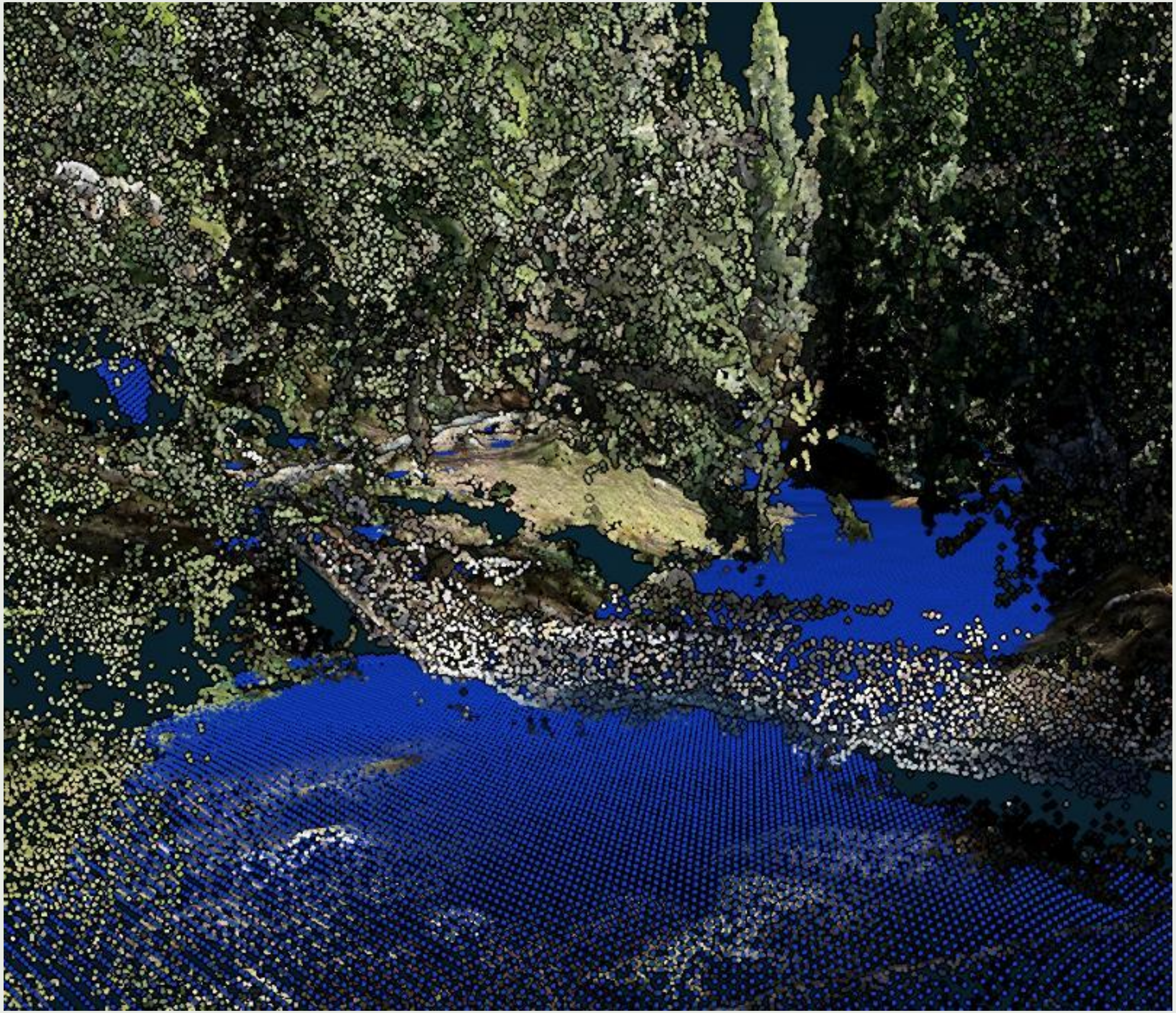


Results Visualization with the Lidar point cloud

The results of the flow modeling were imported into the Lidar data processing software as a point layer

This allowed for the creation of useful visualizations combining the modeled water levels with the measured, existing recreational structures.

The results is an estimation of a situation where uniform rain on grid creates a peak runoff in the watershed.



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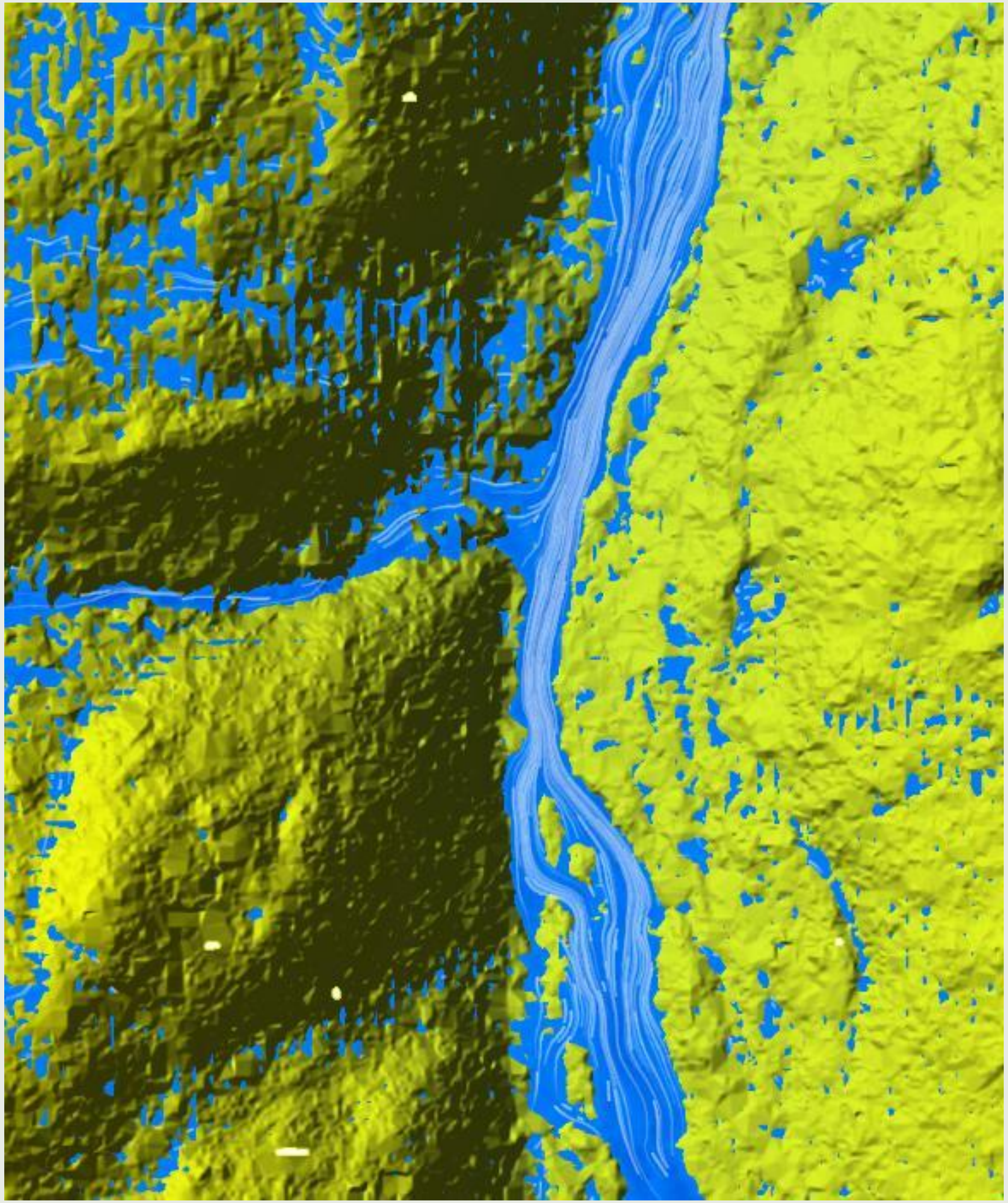
Step-by-step

Workflow (mandatory data *)

- * A digital elevation model (public resource or preferably high-resolution Lidar)
- * Catchment data (area, lake-%, etc.)
- Land cover data, soil infiltration data
- Calibration data (a known flood event and measured water level, etc.)
- Long term hydrological data or nomographic tools for design flood estimation

An assessment can be made without all specific data or calibration surveys, but the result will less accurate. However, even less accurate results can be used relatively to plan a more consistent and lower vulnerability route.

-> Modeling combines the given data and flow is calculated in 2D computational grid



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For the Structure Designer

Model provides various useful datasets to support planning:

- Simulated water levels
- Flow velocities
- Flow paths
- Inundation boundaries
- Hydrographs

Benefits for the Designer

- Estimated discharge hydrographs for dimensioning of hydraulic structures
- Map layouts for designing the route to avoid potentially flooding areas

All results can be supplied as GIS data (geotiff, shapefile)

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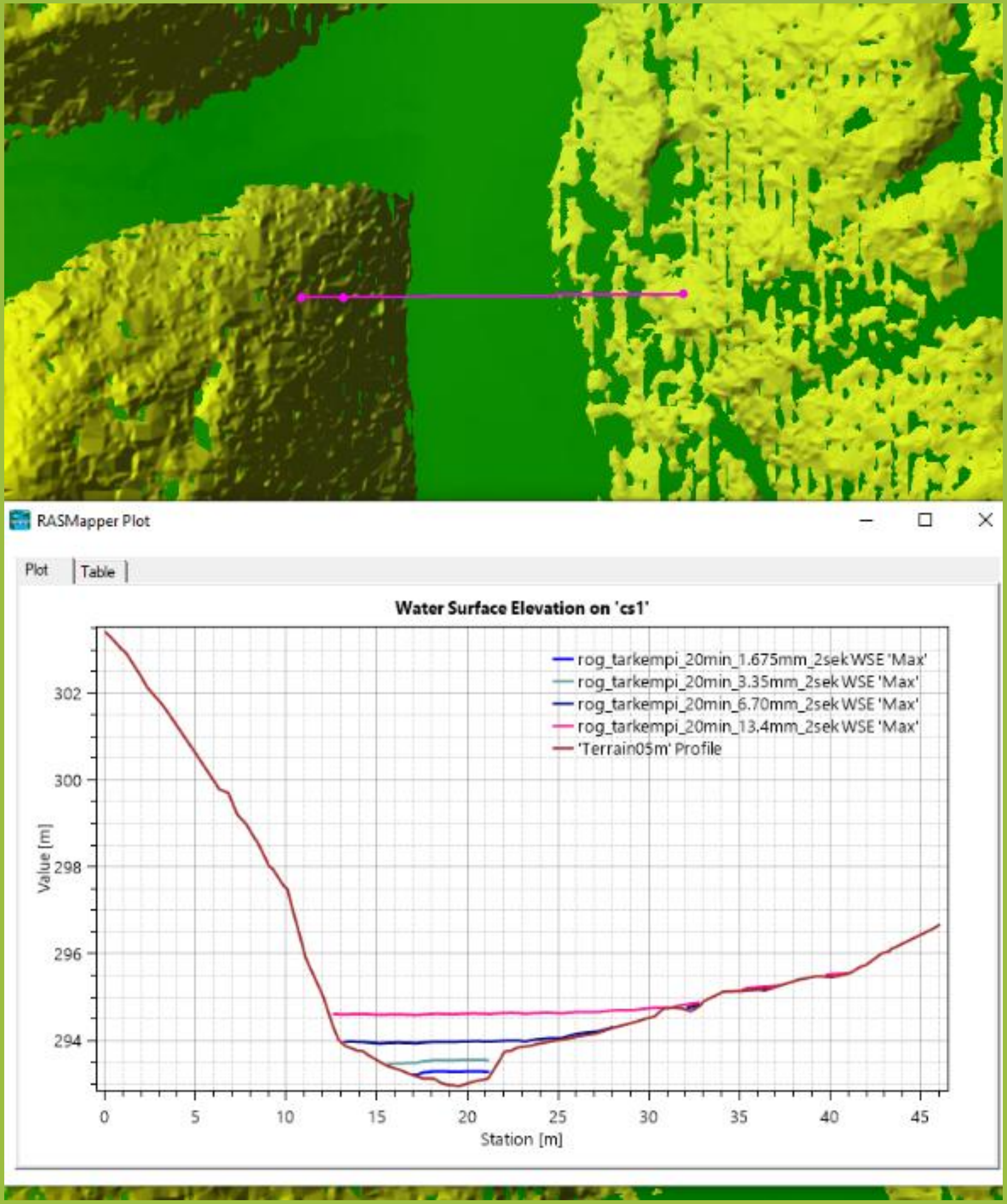

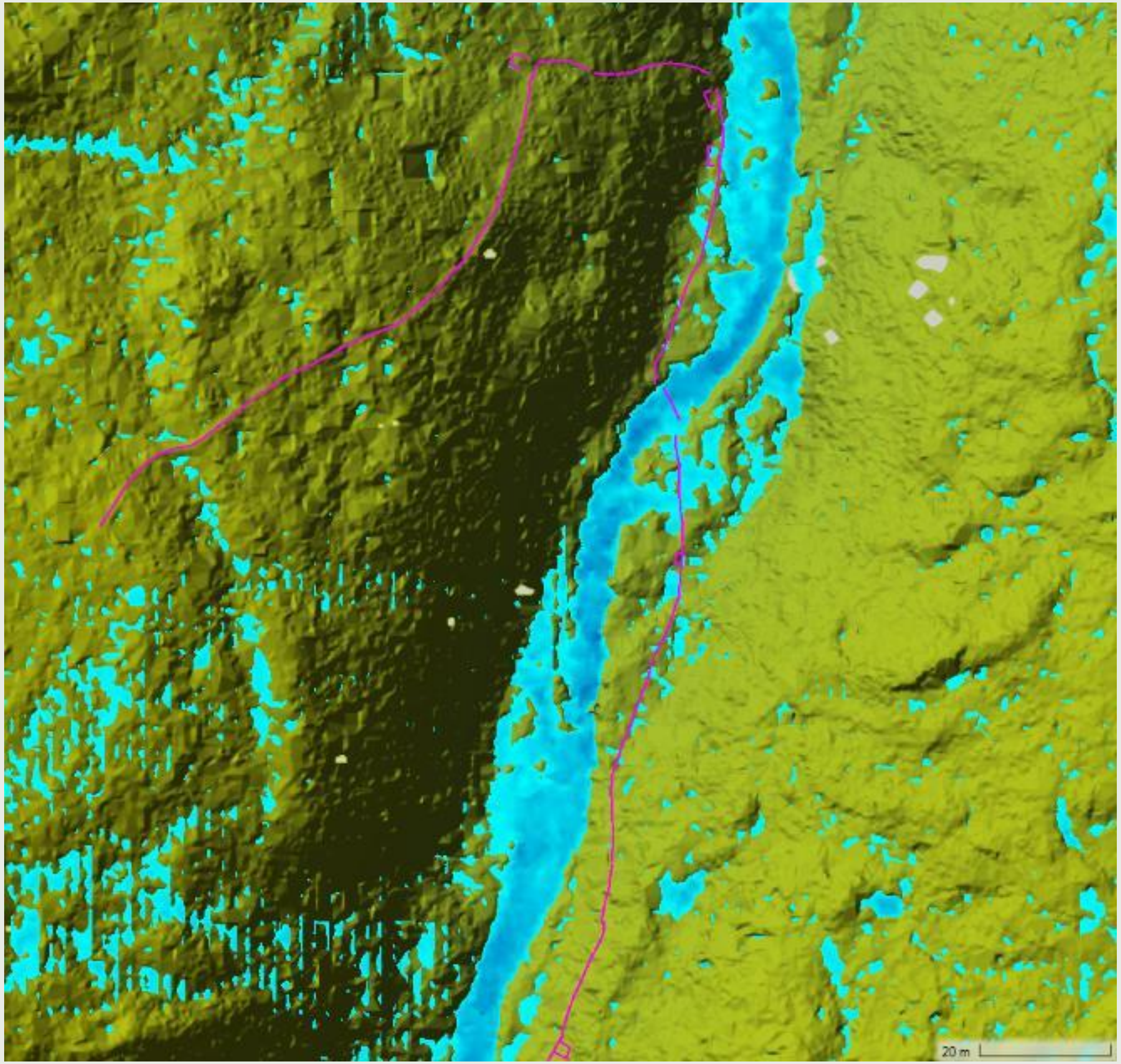
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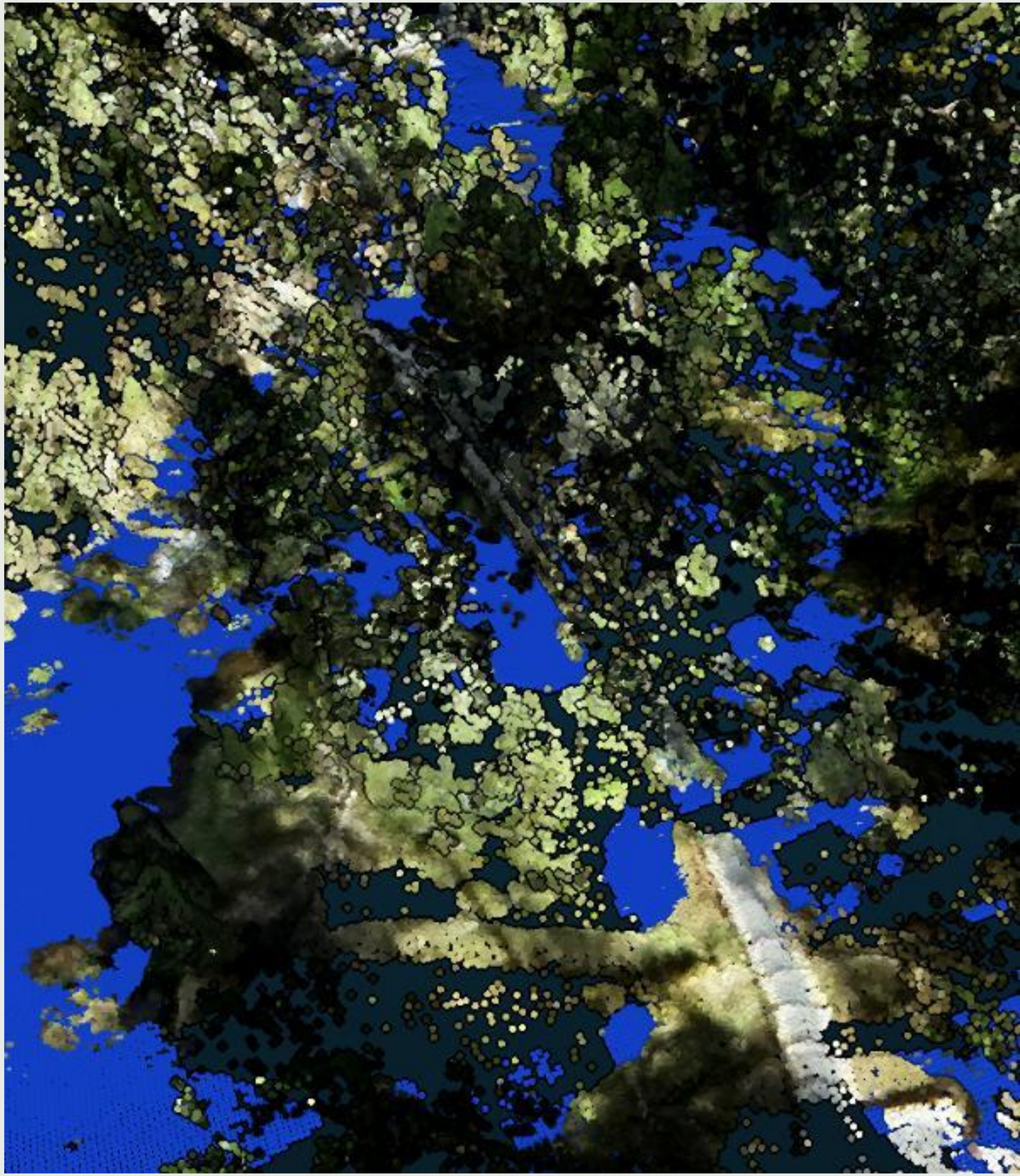

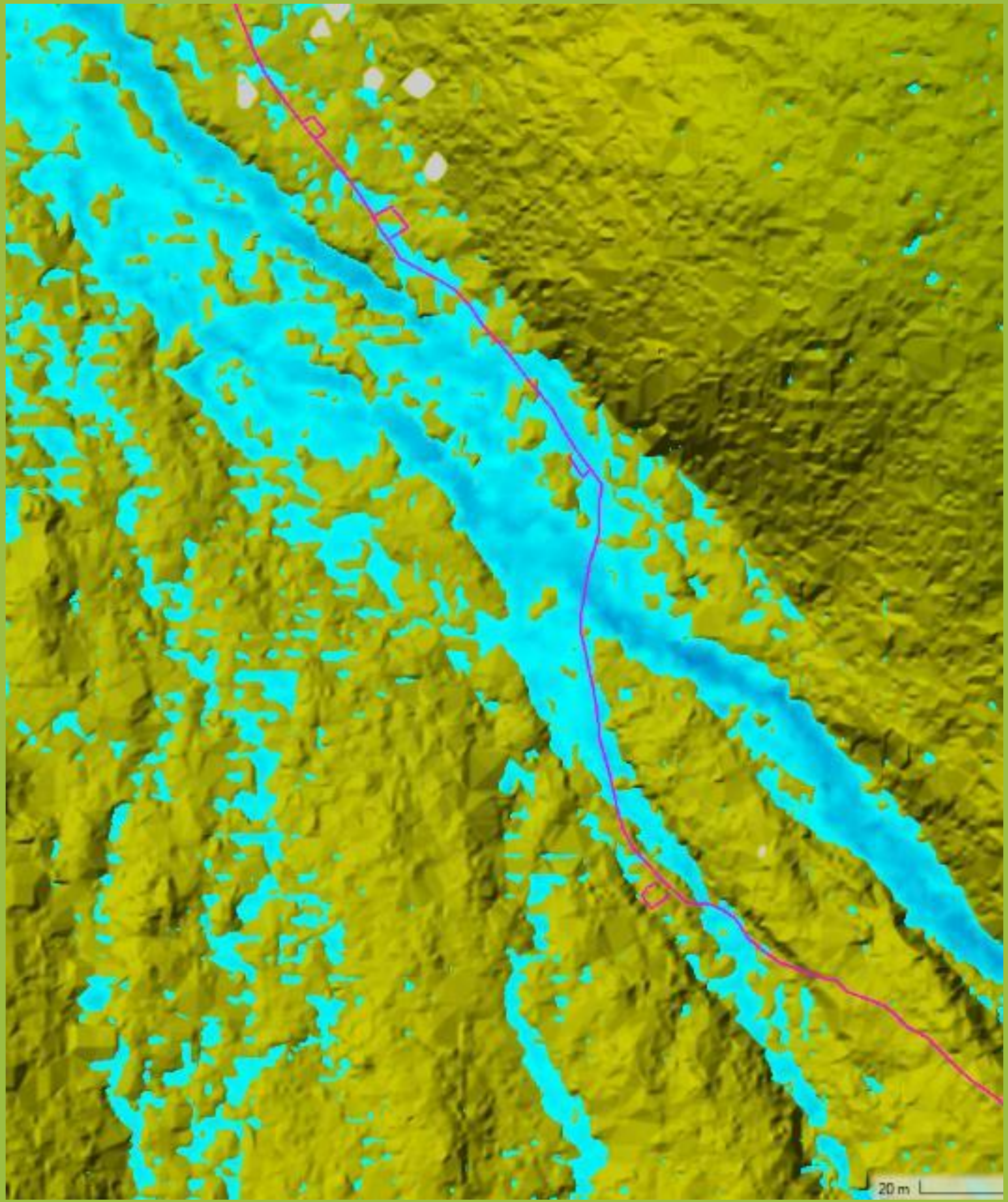

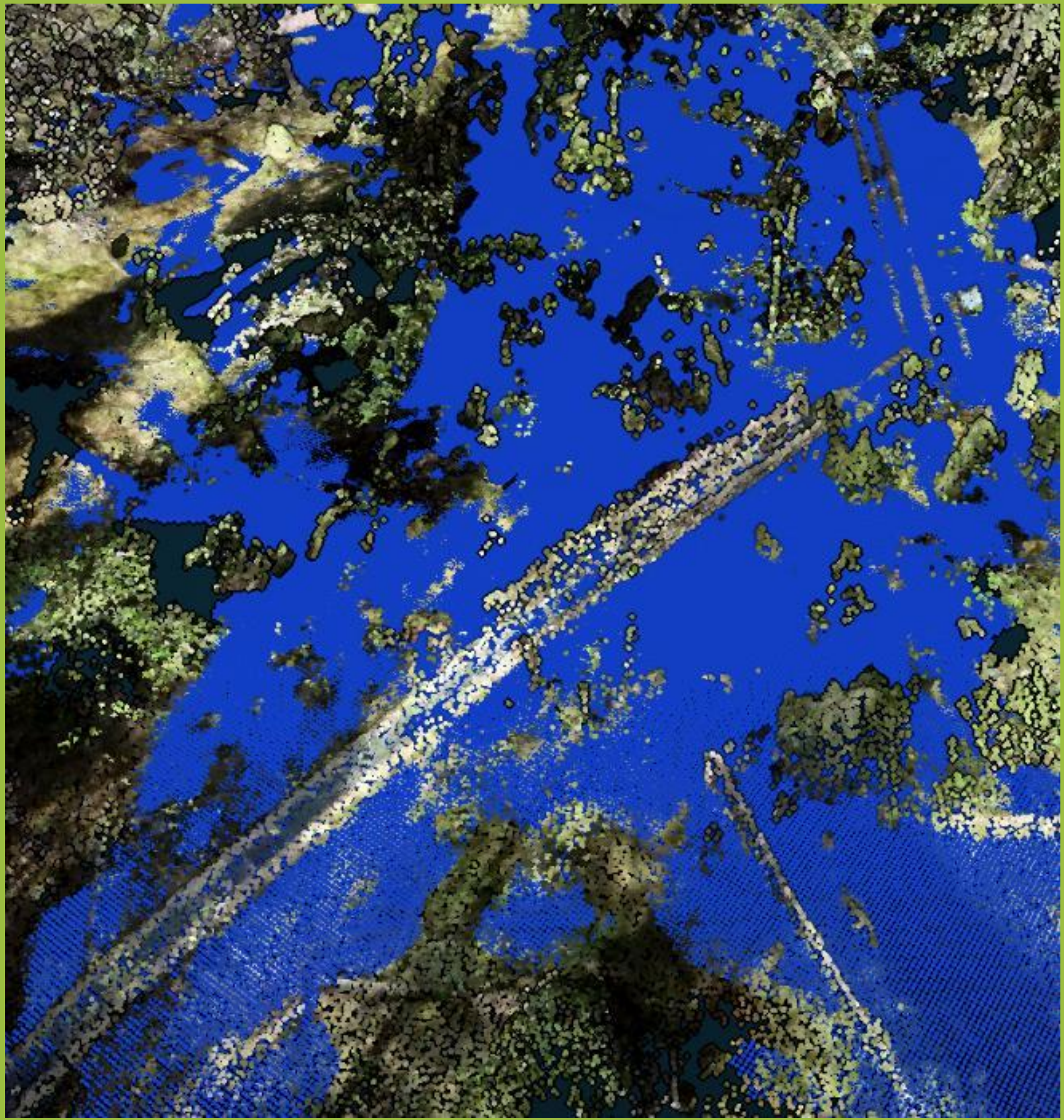

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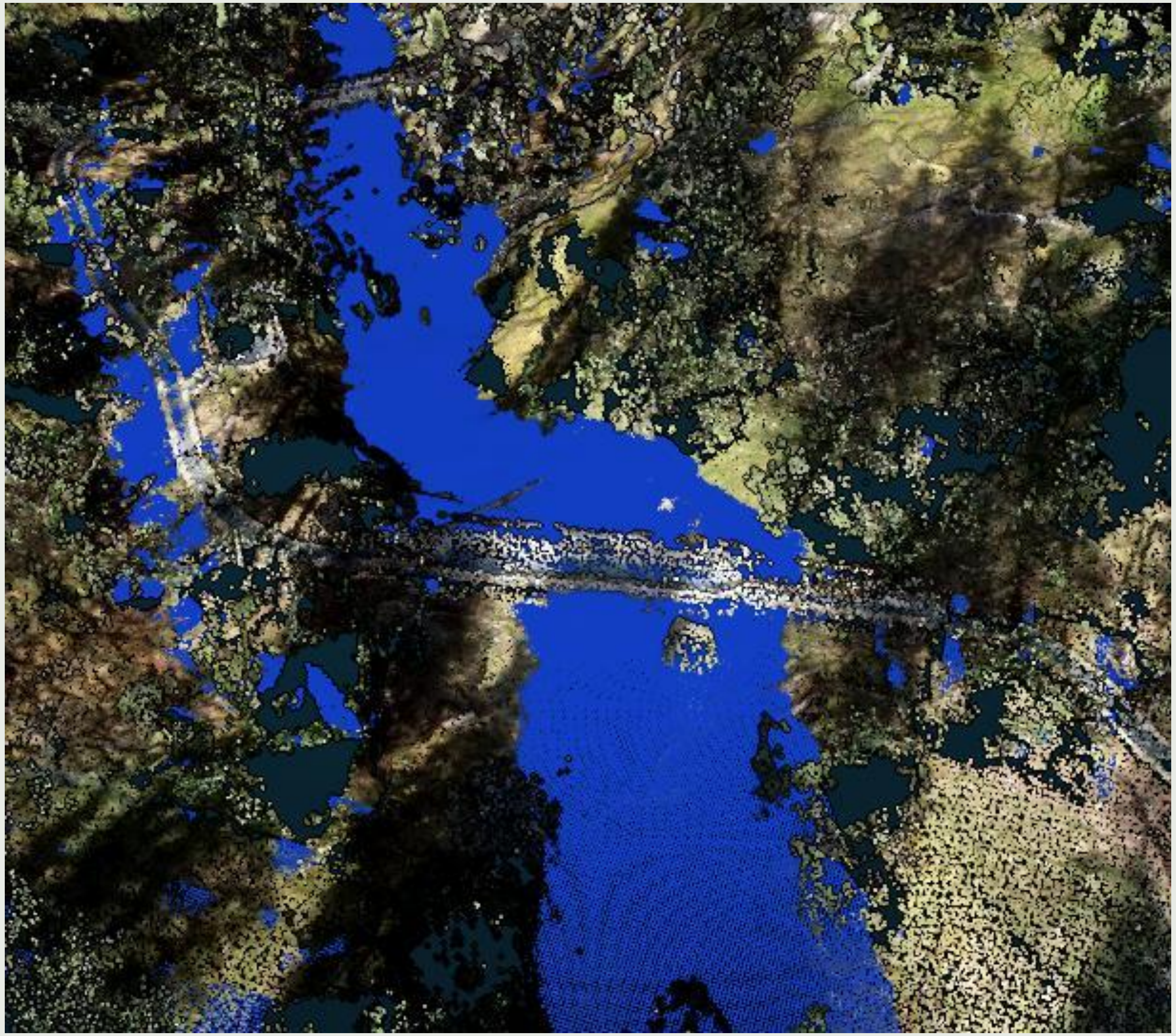

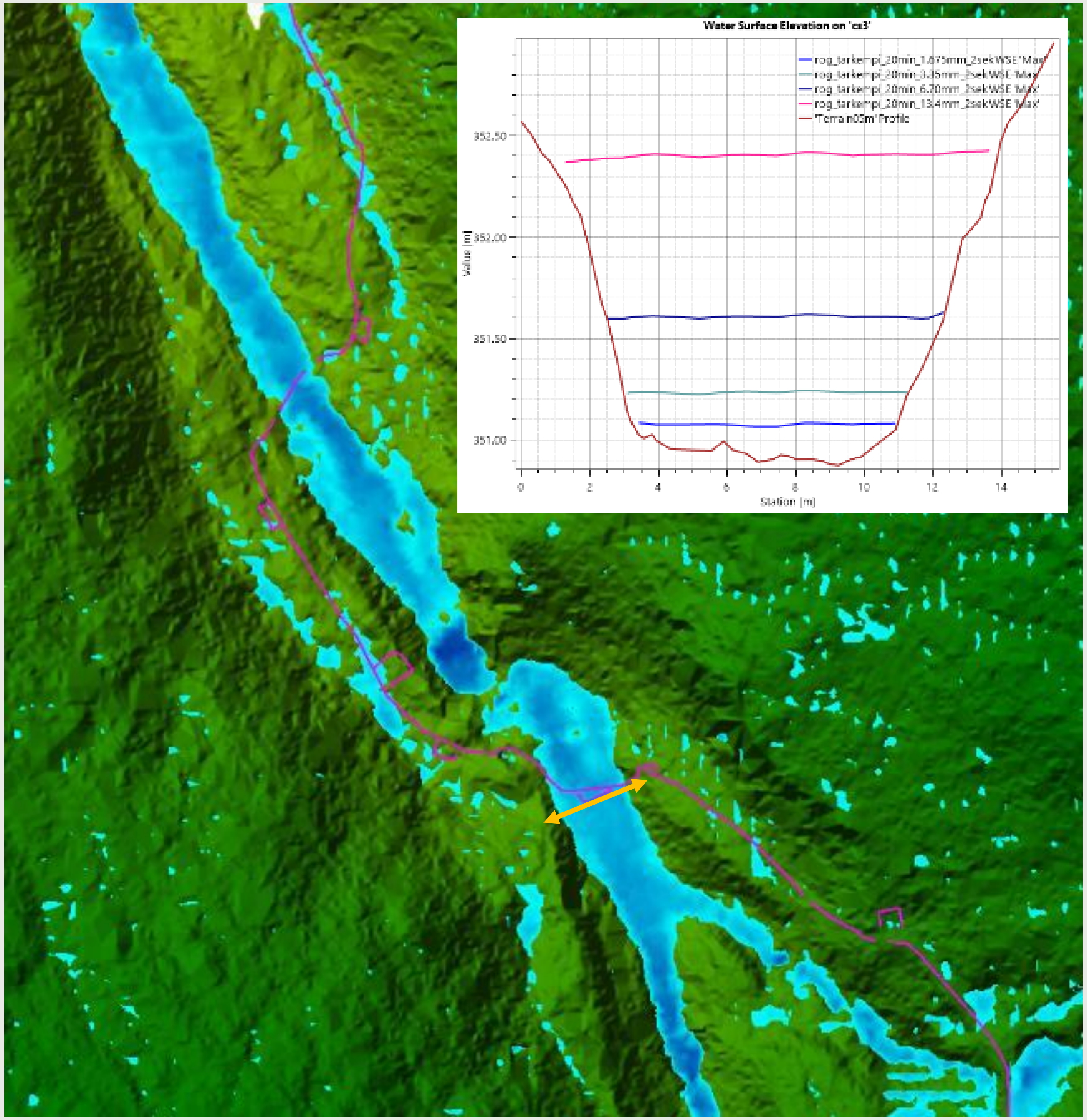

Water Surface Elevation on 'cs3'
rog_tarkempi_20min_6.70mm_2sek WSE 'Max'
rog_tarkempi_20min_13.4mm_2sek WSE 'Max'
'Terra n03m' Profile
352,50
352,00
351,50
351,00
Value [m]
0
2
4
6
8
10
12
14
Station [m]

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Thank you
Tack
Takk
Giitu
Kiitos

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