Application of Hydrodynamic Model for the Case Study of the Kolbudy II Reservoir Embankment Hypothetical Failure

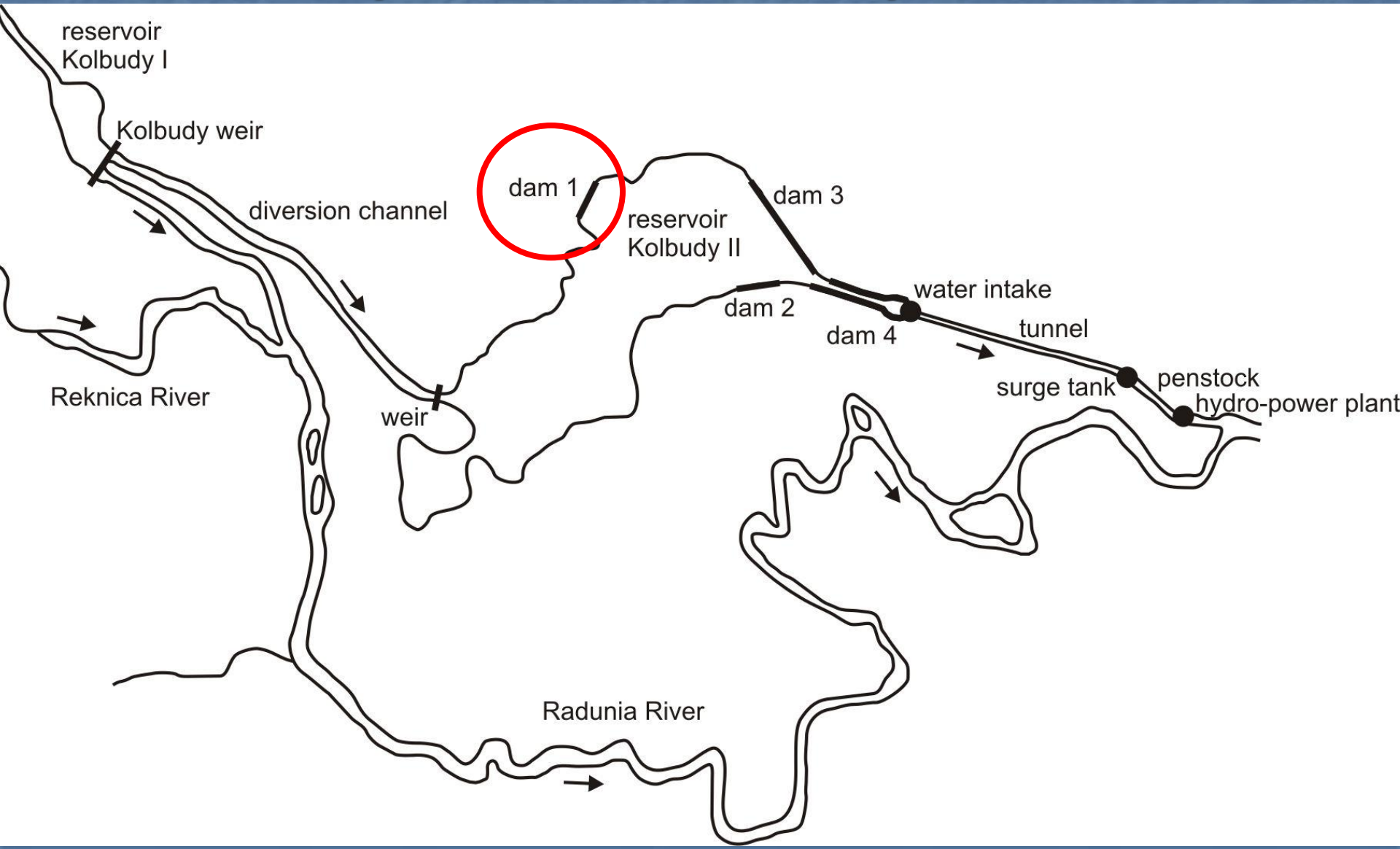
Michał Szydłowski

Gdańsk University of Technology
Faculty of Civil and Environmental Engineering
Department of Hydro-engineering

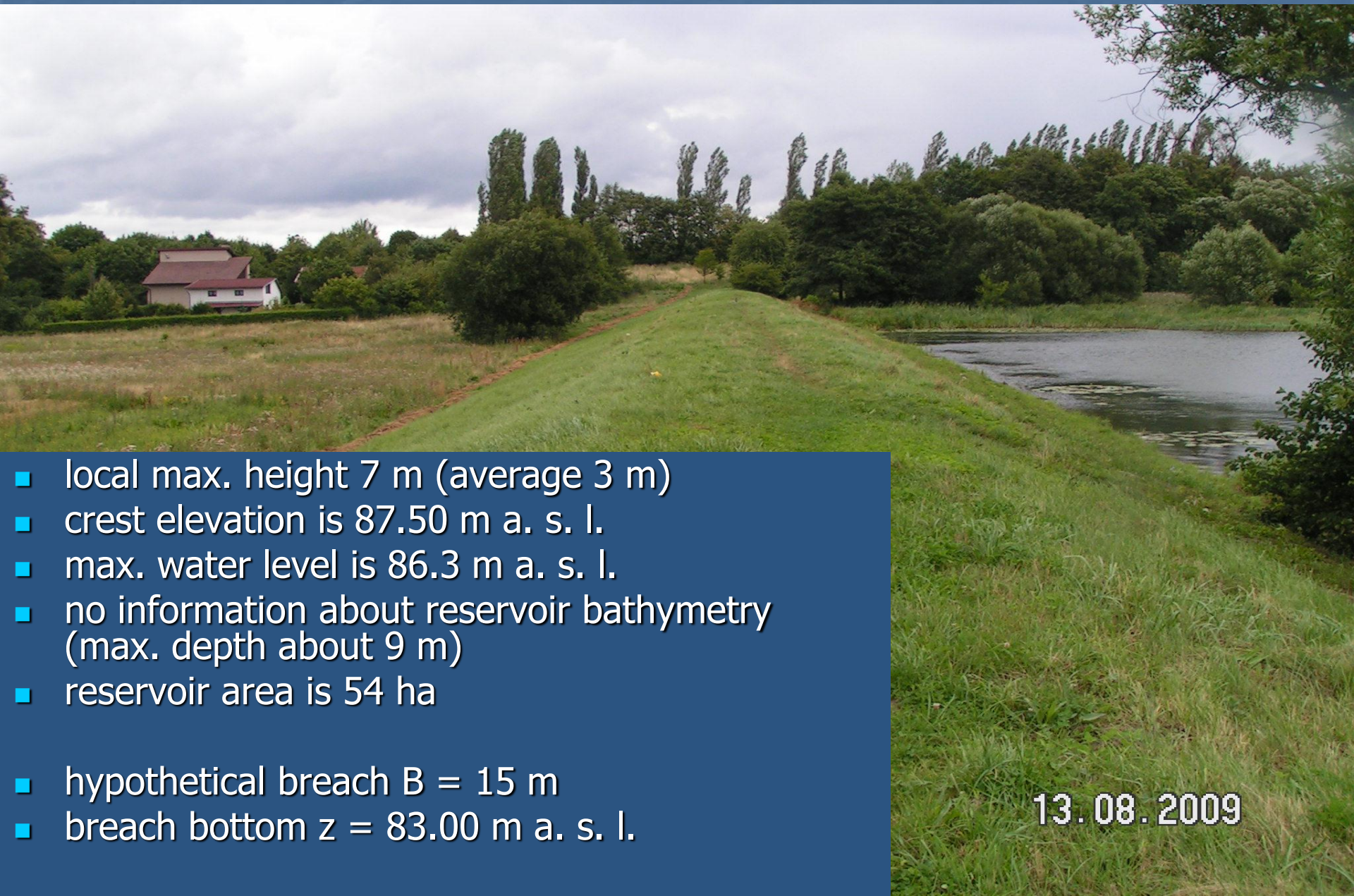
Aim of the work

- The polish law requires the analysis of the catastrophic flood events following the hypothetical failures of the dams and the reservoirs embankments.
- The flood zones must be determined for the dams with total water head greater than 2 m or water capacity greater than 0.2 million cubic meters.
- The paper presents an example of numerical simulation of flood wave propagation resulting from the Kolbudy II reservoir embankment break.

Bielkowo hydro-power plant hydrotechnical system



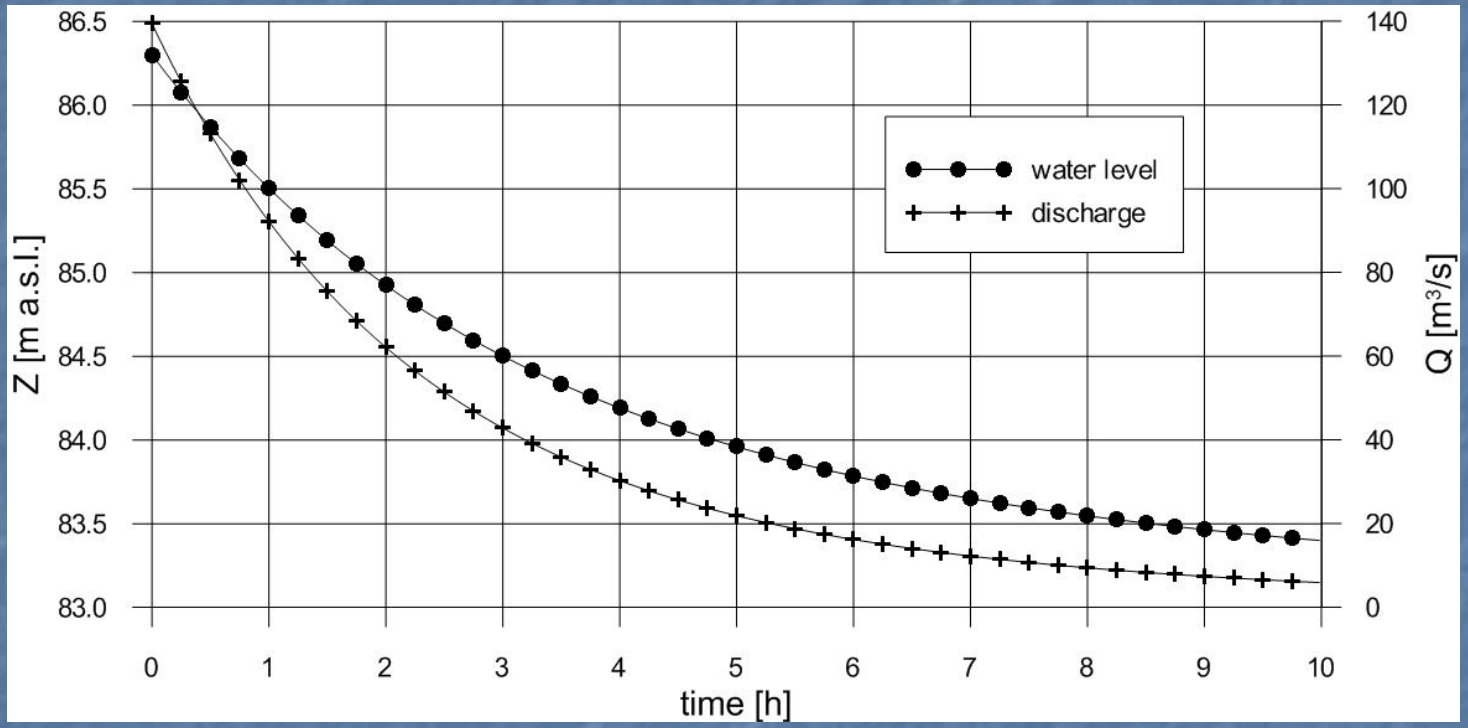
The dam 1



- local max. height 7 m (average 3 m)
- crest elevation is 87.50 m a. s. l.
- max. water level is 86.3 m a. s. l.
- no information about reservoir bathymetry (max. depth about 9 m)
- reservoir area is 54 ha

- hypothetical breach B = 15 m
- breach bottom z = 83.00 m a. s. l.

The hydrograph of the water outflow through the breach



- It was estimated using known reservoir stage–area relation and applying the broad crest flow equation for calculation of discharge inside the breach.

Mathematical model of water flow

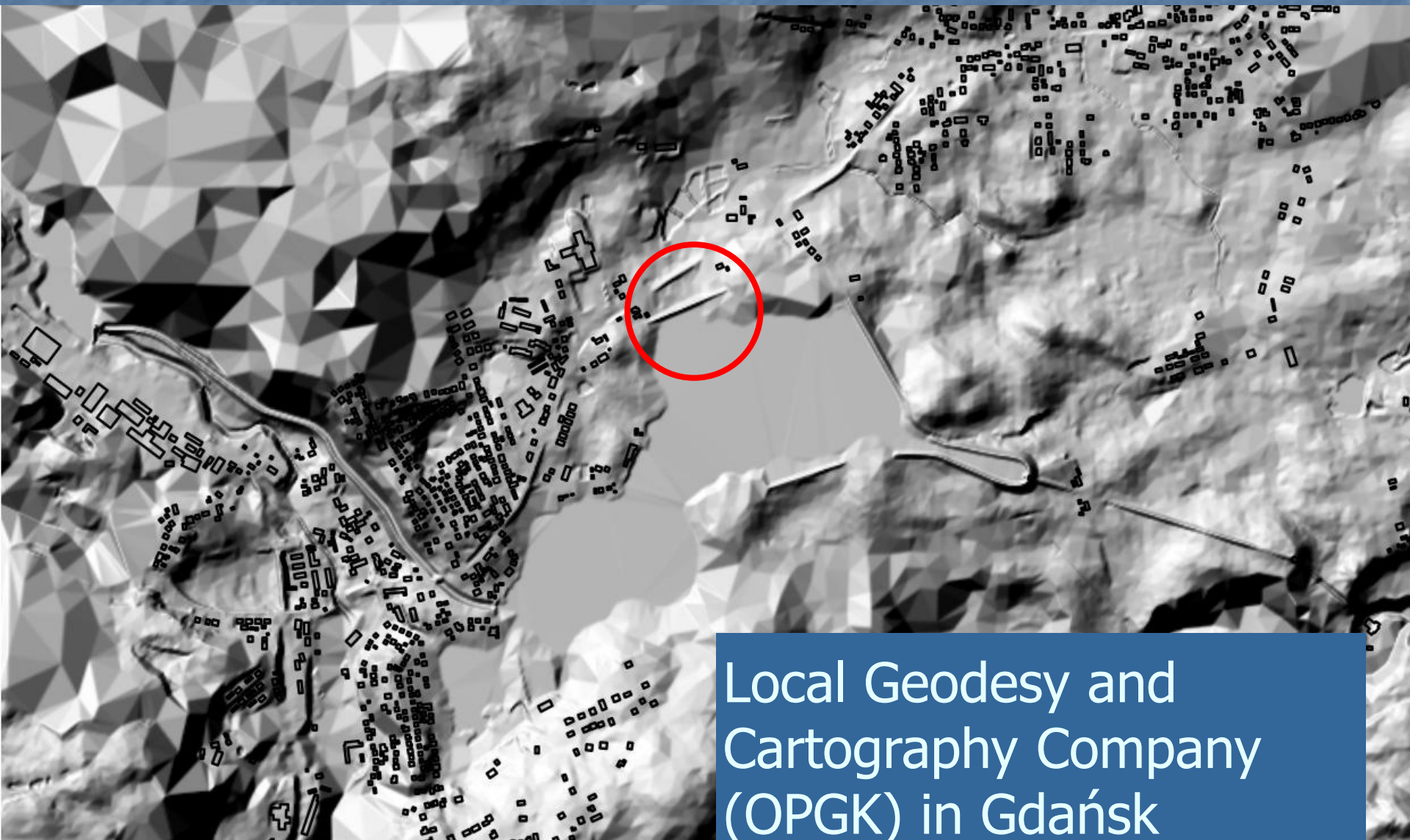
2D Shallow Water Equations

$$\frac{\partial \mathbf{U}}{\partial t} + \frac{\partial \mathbf{E}}{\partial x} + \frac{\partial \mathbf{G}}{\partial y} + \mathbf{S} = 0$$

$$\mathbf{U} = \begin{pmatrix} h \\ uh \\ vh \end{pmatrix}, \quad \mathbf{E} = \begin{pmatrix} uh \\ u^2 h + 0.5 g h^2 \\ uvh \end{pmatrix}, \quad \mathbf{G} = \begin{pmatrix} vh \\ uvh \\ v^2 h + 0.5 g h^2 \end{pmatrix}, \quad \mathbf{S} = \begin{pmatrix} 0 \\ -g h\left(S_{ox} - S_{fx}\right) \\ -g h\left(S_{oy} - S_{fy}\right) \end{pmatrix}$$

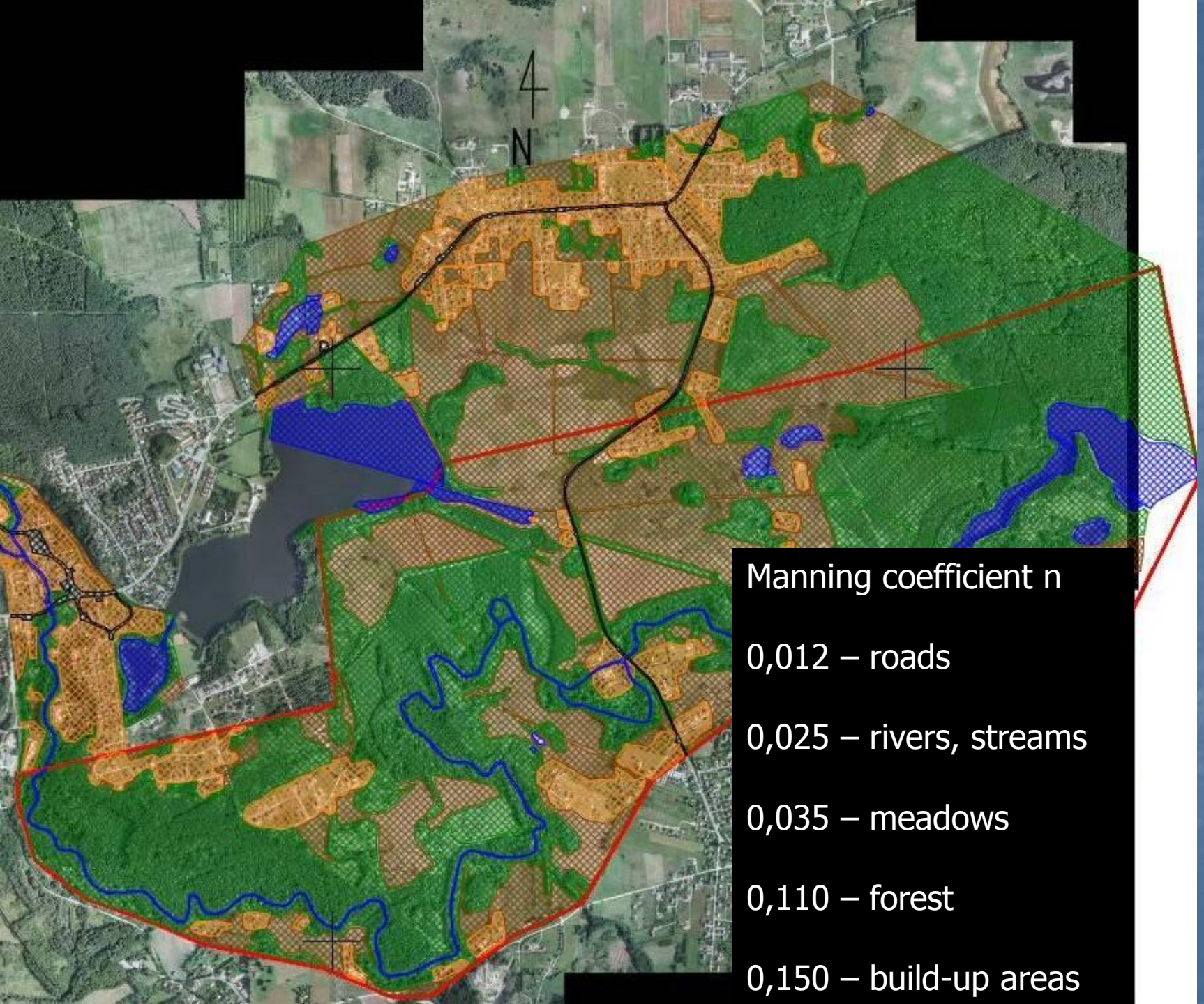
- FVM, Roe scheme
- initial condition, boundary conditions

Digital Terrain Model (DTM)



Local Geodesy and Cartography Company (OPGK) in Gdańsk

Land cover



Manning coefficient n

0,012 – roads

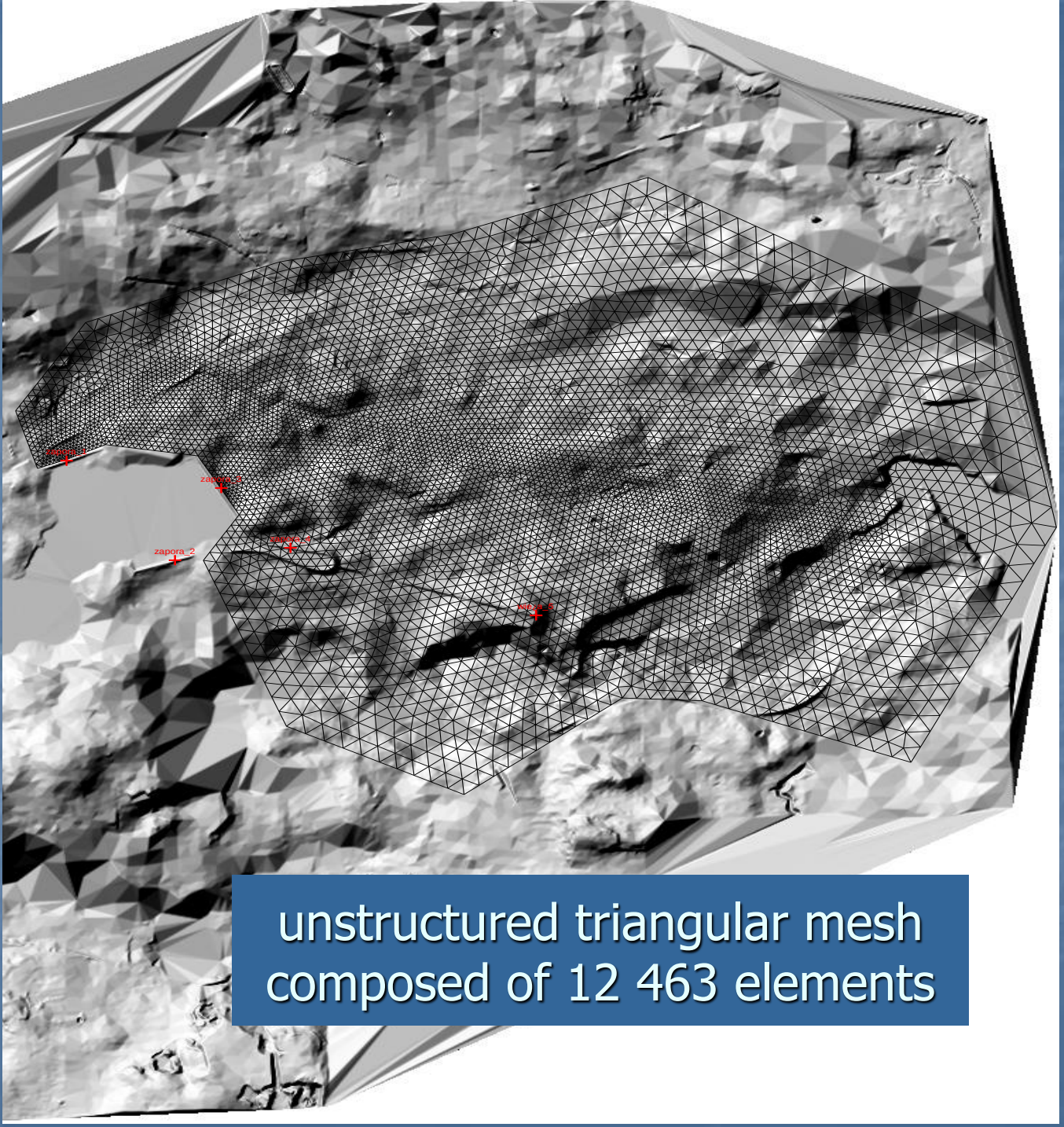
0,025 – rivers, streams

0,035 – meadows

0,110 – forest

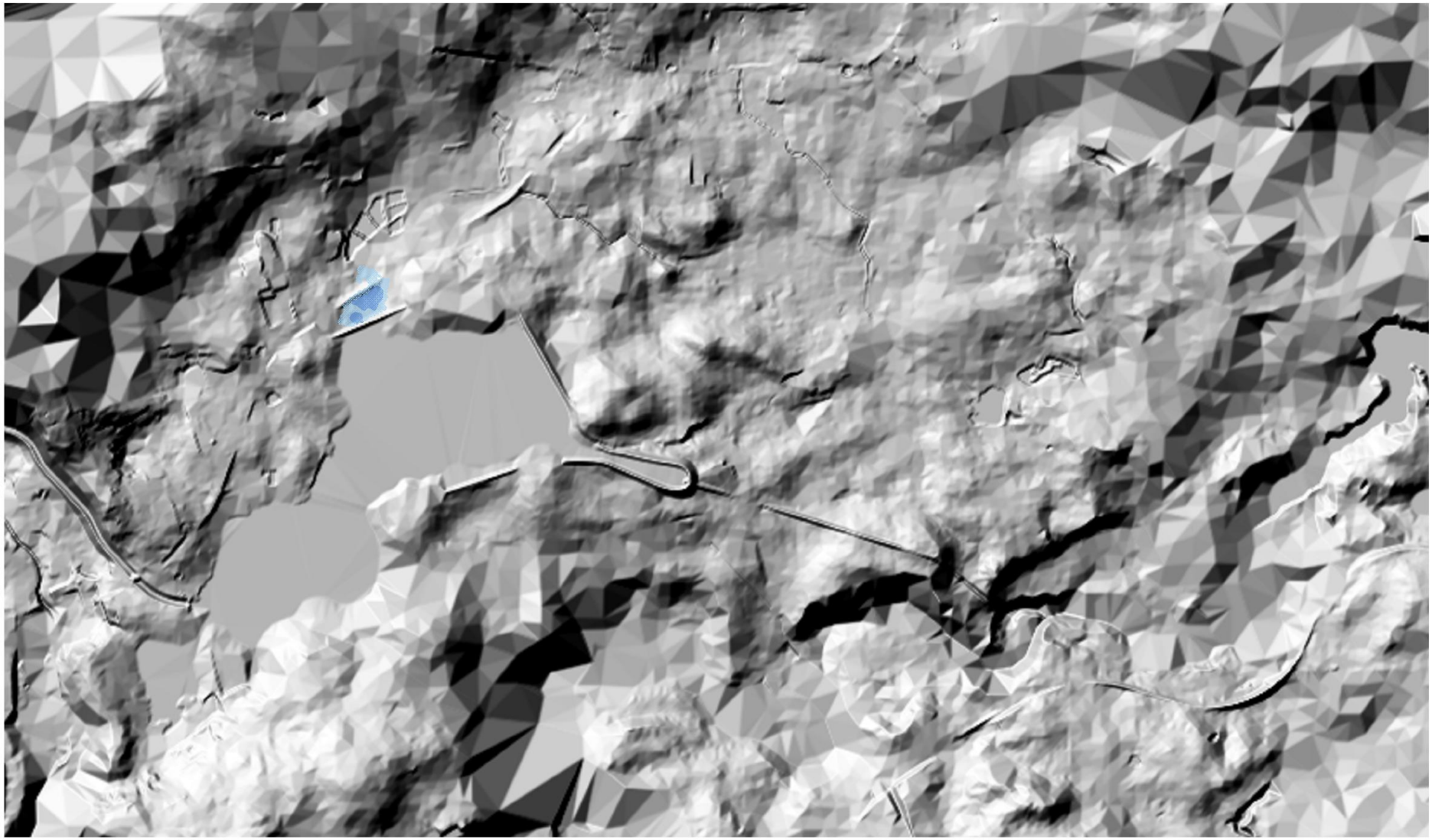
0,150 – build-up areas

Numerical mesh

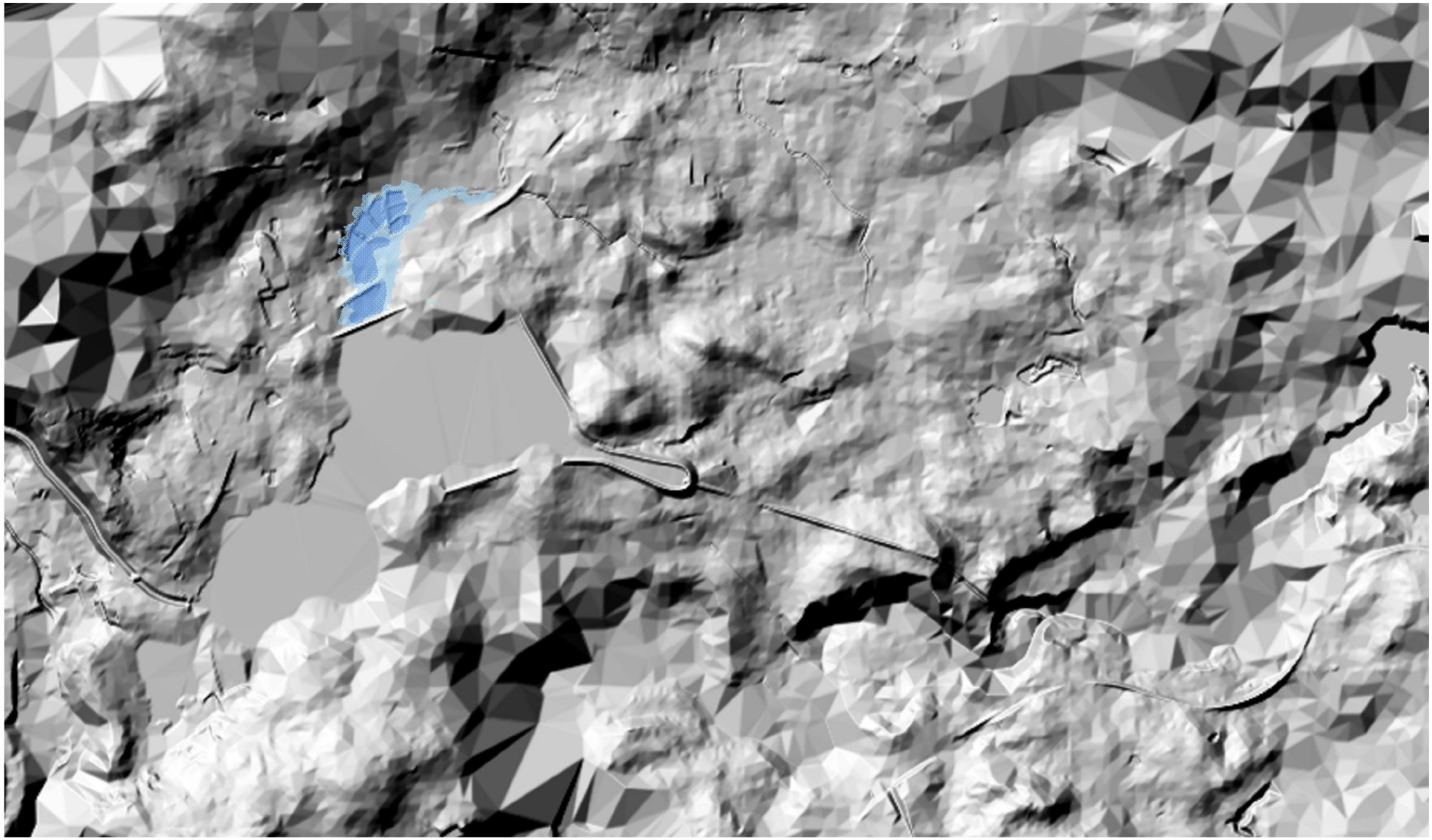


unstructured triangular mesh
composed of 12 463 elements

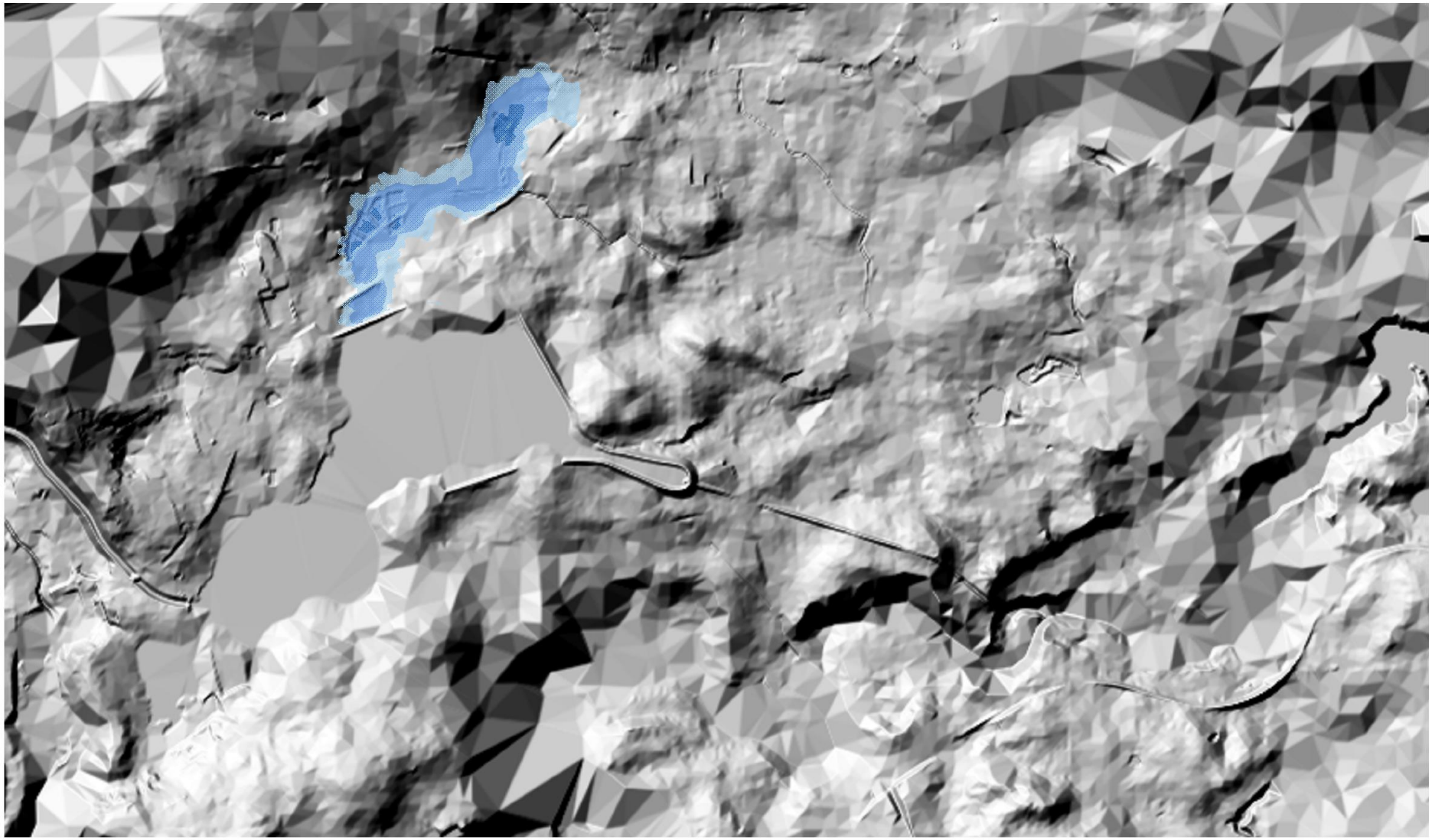
Numerical simulation – depth after t = 1 min



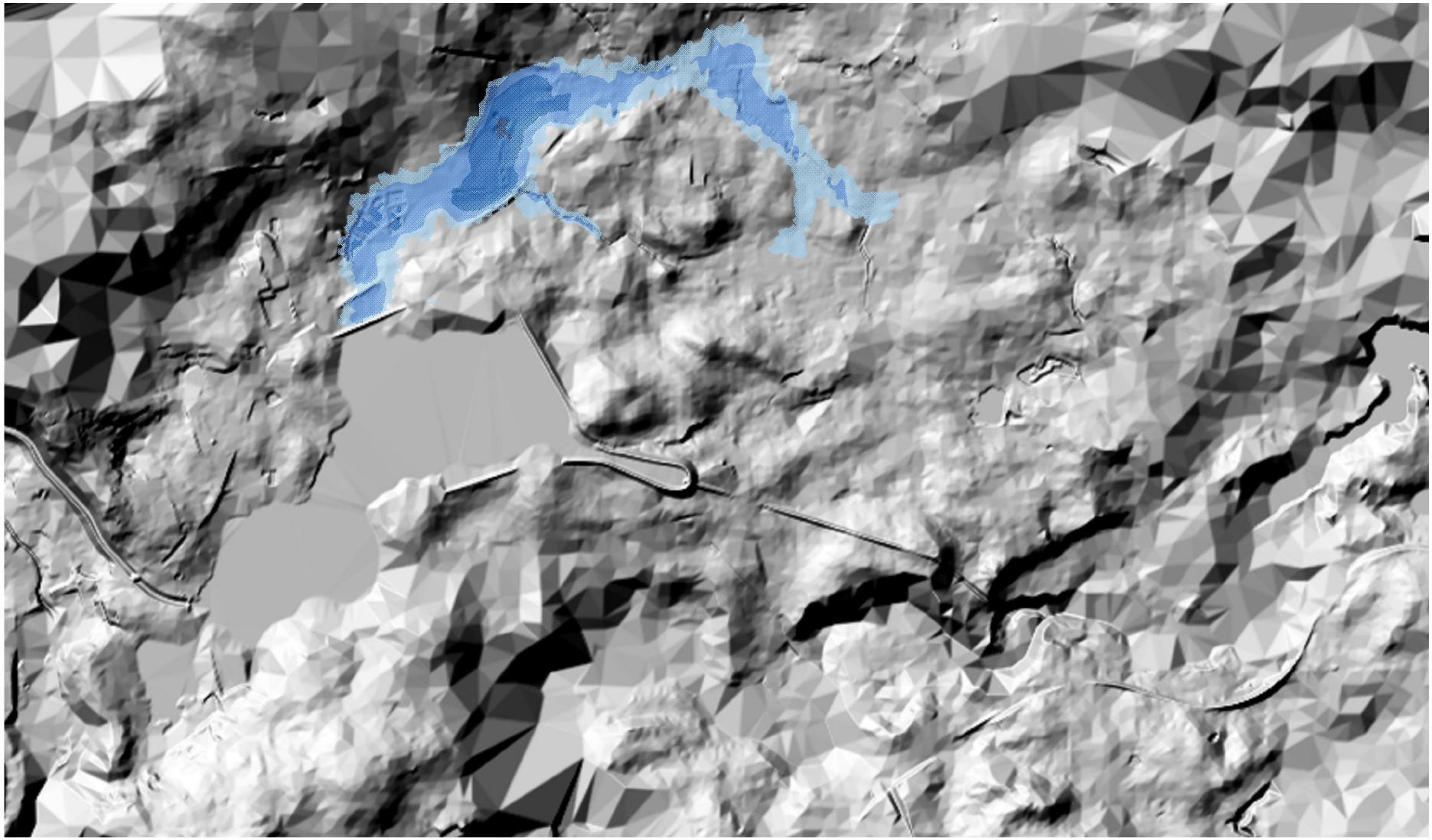
Numerical simulation – depth after t = 5 min



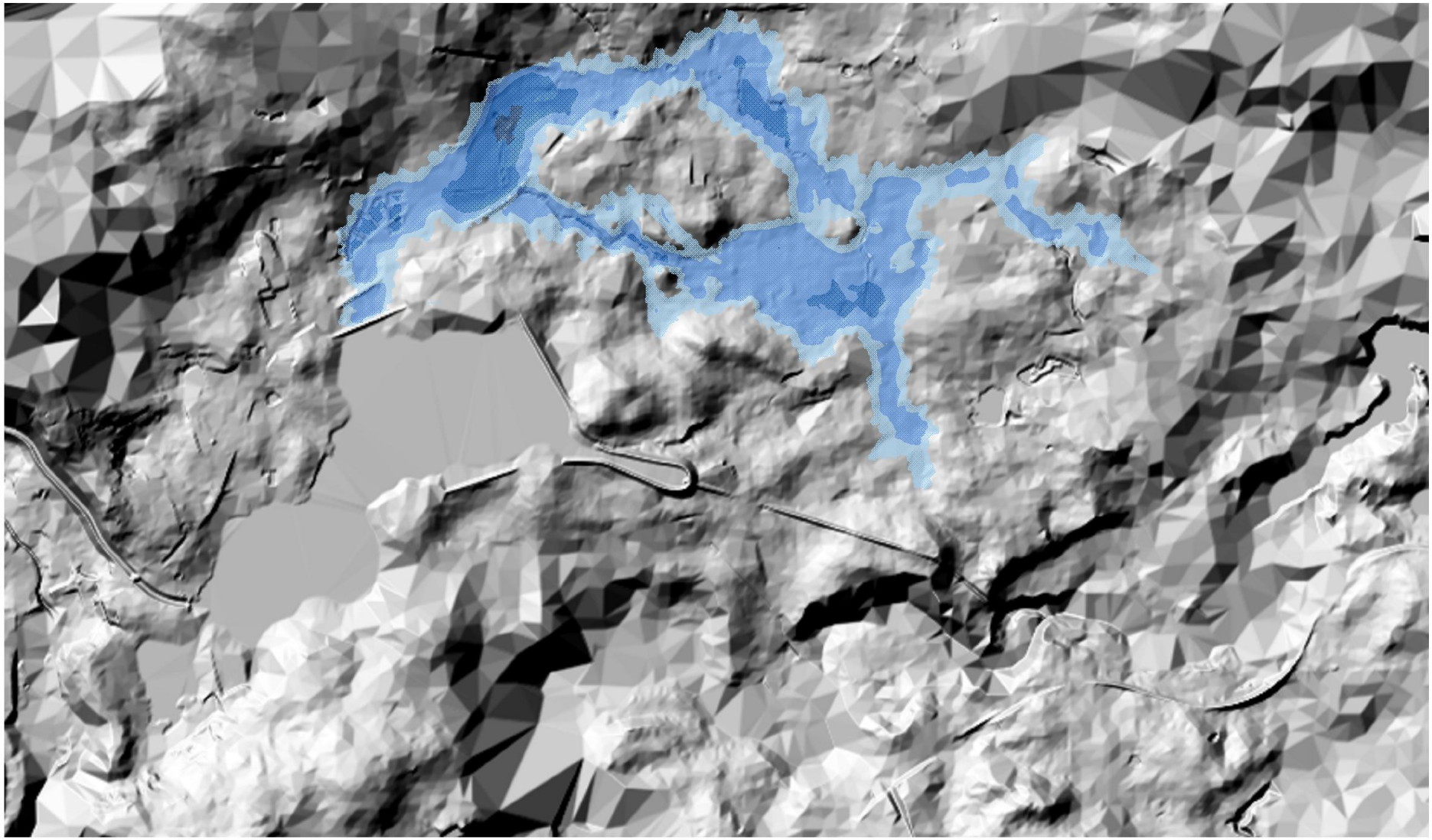
Numerical simulation – depth after t = 15 min



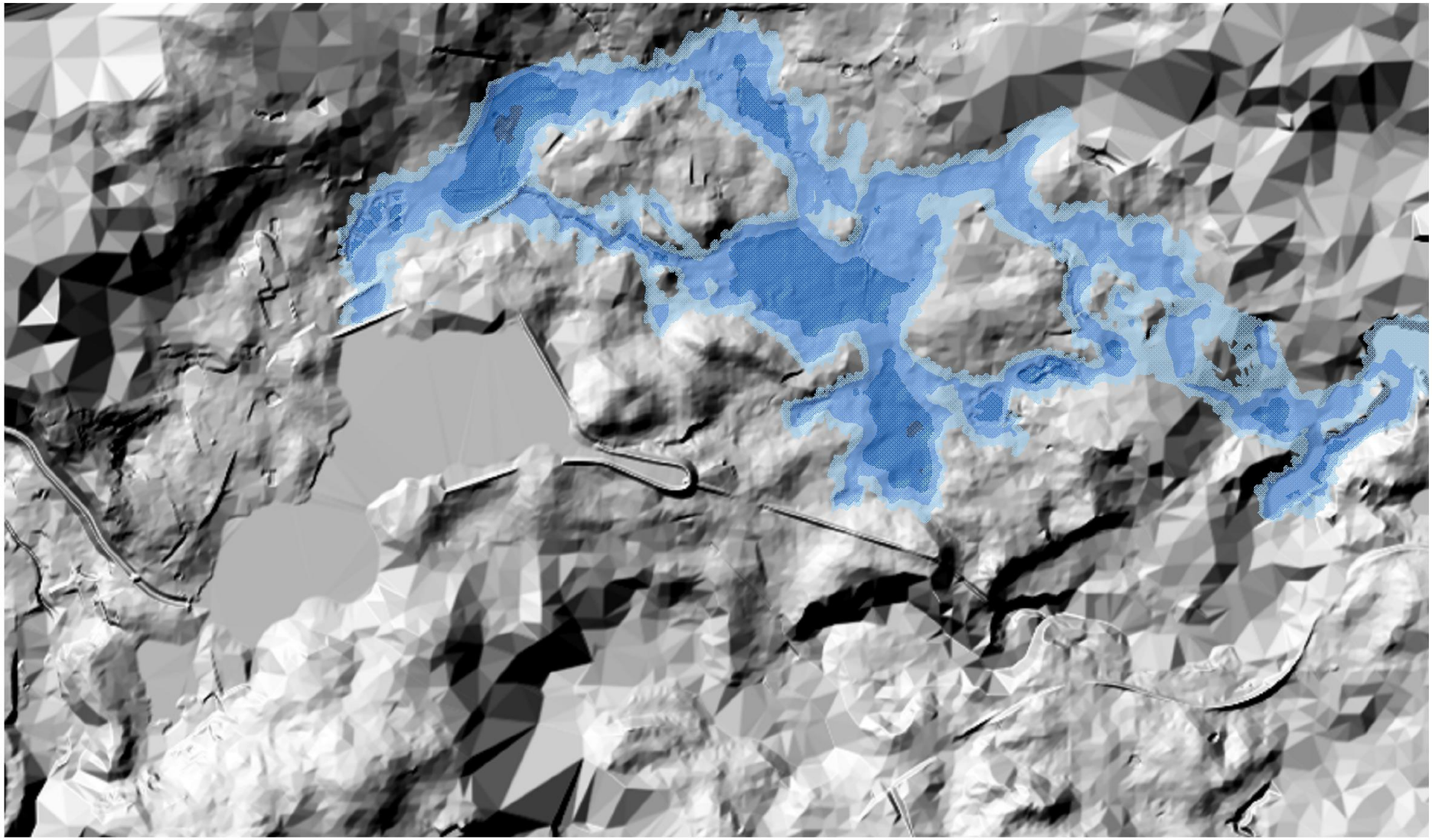
Numerical simulation – depth after t = 30 min



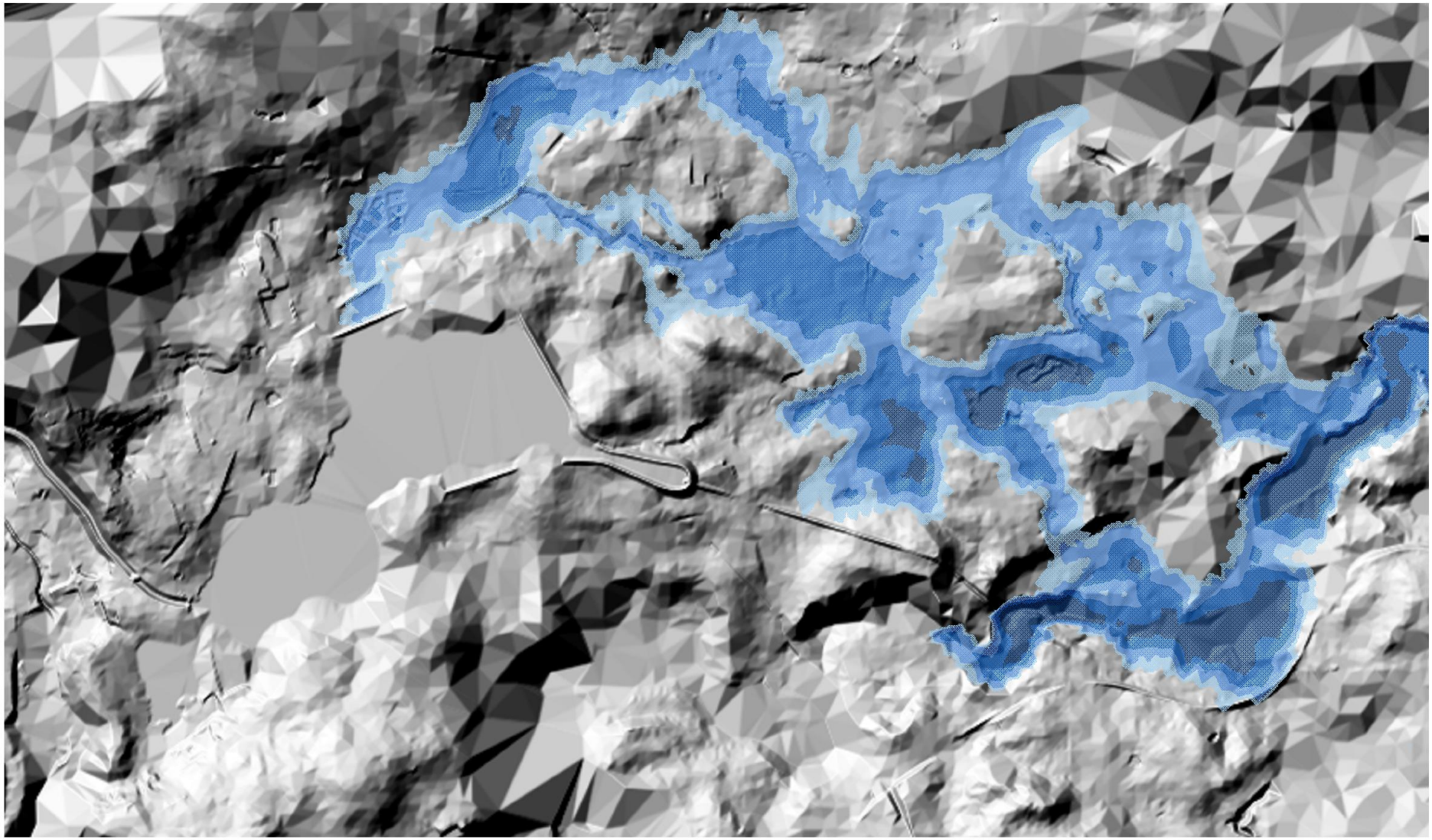
Numerical simulation – depth after t = 45 min



Numerical simulation – depth after t = 60 min



Numerical simulation – depth after t = 90 min



Conclusions

- The simulations were used by the ENERGA Elektrownie Straszyn Ltd. to create the flood risk maps of depth, velocity and time of catastrophic flooding.

  The maps are used by the Gdańsk Board of Water Management to manage the flood risk in the Radunia catchment.

- The Bielkowo hydro–power plant is the one of the eight power plants located on the Radunia River.

  Considering the cascade form of the Radunia hydro–power system the mathematical modeling of flood routing along whole Radunia River valley is necessary to manage the flood risk in this region.