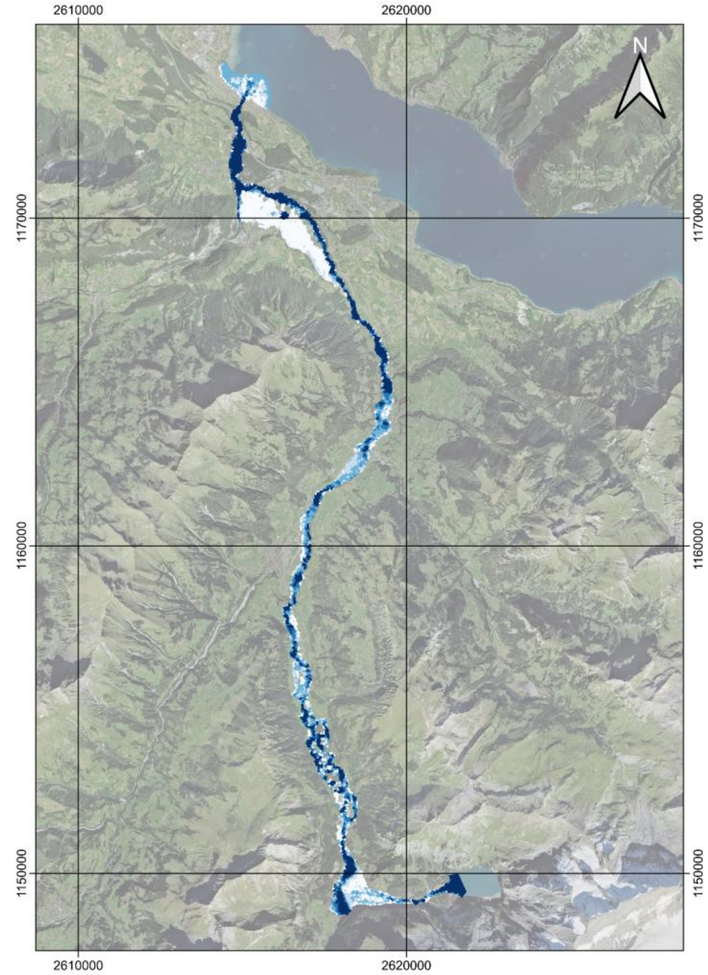
Hydraulic Model of the Glacial Lake Outburst Flood at Lake Oeschinen, Switzerland



Seminar in Geodata analysis and modelling
Spring term 2021

Presented to:
Prof. Dr. Andreas Paul Zischg and Dr. Pascal Horton

Submitted by:
Michèle Grindat, 16-131-286
Sibylle Wilhelm, 16-124-703

1. Introduction

“Spitze Stei” is a rockfall-prone area close to Kandersteg in the Bernese Oberland. The area consists of labil hard rock as well as unconsolidated rock. Those move between a few decimeters up to several meters per year. Lake Oeschinen is located in close distance to the “Spitze Stei”, and parts of the rockfall material can be deposited in front and in the lake.
Consequently, a natural dam could form in front of the lake, which which would then lead to an accumulation of water in the lake. Due to erosion this dam may collapse, with the result that a flood wave would flow from Lake Oschinen downwards to Lake Thun. This flood wave can impact huge parts of the Kander valley. An analysis of the resulting flood wave was already made by Markus Zimmermann, resulting in two different flood scenarios. This analysis only used an empirical approach, i.e. estimating the peak discharge based on the dam height and the outbreak volume, calculating the gauge in the cross section (with the Strickler method) and validation of the results in the field.
The aim of this seminar work is therefore to provide a hydraulic model that can be taken into account when discussing potential outburst flood scenarios and its consequences. The hydraulic model will deliver a layer with maximum flow depth as well as the buildings that are located in the inundated area.

2. Methods and Materials

The hydraulic model was built in BASEMENT, by using the design parameters that resulted from the empirical calculations. To provide a rough estimation about how many houses will be affected by the flood scenarios, the building layer of the Kander valley will be overlayed with the resulting flood layer. Furthermore, the results will be visualized in QGIS. The detailed approach will be explained in the following chapter.

2.1. Preprocessing

In the preprocessing the scenarios for the model are defined and the input data is processed in a way that the modeling software can use it.

2.1.1 Definition of Project Scenarios

The key parameters for the two flood scenarios were provided by Markus Zimmermann and consist of description of the hydrological conditions of the flood (see table 1).

Table 1: Key Parameters of the two flood scenarios

	Small flood wave	**Big flood wave**
Outbreak volume	13 Mio. m^3	44 Mio. m3
Peak Discharge	1‘300 m^3	4‘500 $m^{3/}s$
Speed	4 – 8 m^3/s	4 – 8 m^3/s
Flowtime of Peak Discharge (Lake Oeschinen to Lake Thun)	1 h 45 min	1 h 45 min
Raising Limb	1 – 2 h	1 – 2 h
Total Duration	5 – 10 h	5 – 20 h

The model perimeter stretches from Lake Oeschinen to Kandersteg, through the Kander Valley all the way down to Lake Thun (see fig. 1).

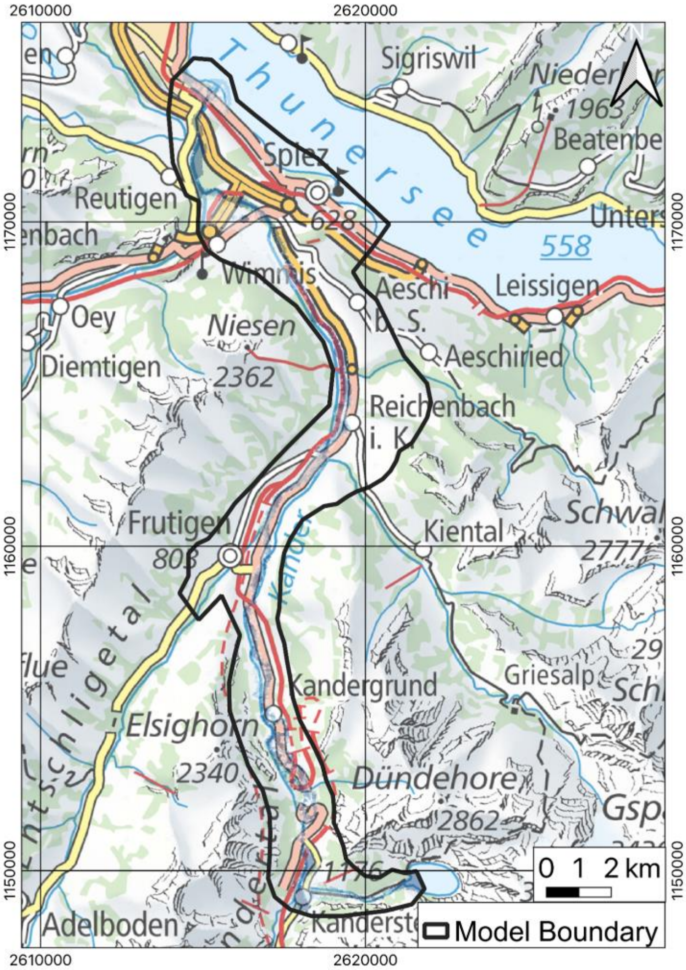


Figure 1: Model boundary for the flood calculation in BASEMENT

2.1.2 Grid generation

The hydraulic model needs topographical input data to calculate the flow path of the water. As BASEMENT cannot process raw topographical input data, a grid, consisting of points, edges and the area in between, has to be created. Therefore, the QGIS plugin “BASEmesh" was used.

In the first step, the quality mesh was generated. This breaks down the area for which the flood will be calculated into triangles of unequal sizes. To generate this mesh, a model boundary is needed. The model boundary for this seminar work is a shapefile containing a polygon of the model perimeter (see fig. 1). For the generation, a minimum triangle angle of 28 degrees was set, with a maximum triangle size of 2’500 m^2. The outputs of the quality meshing are two separate shapefiles, one containing the nodes and one containing the elements of the mesh.

The quality mesh lacks any elevation data. For it to be used in simulations, elevation data has to be interpolated on the nodes of the quality mesh. The elevation data used for this work is a digital elevation model (DEM) in a raster format, with a cell size of 2 m x 2 m. The output is a node shapefile. The locations of the newly created and interpolated nodes are the same as the ones of the quality mesh but contain interpolated elevation data attributes. The interpolated mesh was then exported as a computational grid in a “.2dm” format.

2.2 Flood simulation

In a next step, the computational grid and the layers created in preprocessing must be inserted into the BASEMENT command file. The final flood wave can be modelled in BASEMENT and then visualized in QGIS.

Various parameters characterizing the flood or i.e. the flood wave must be introduced in BASEMENT. For example, information on physical properties such as the gravity, viscosity and type of fluid is provided. For the viscosity the default value of $1e^{-6}$ was chosen as well as for the density of the fluid, hence 1000 kg/m^3. It is possible to enter more detailed parameters in various subcategories in BASEMENT. For example, in the subcategory geometry the start and end in the terrain of the flood wave can be specified (see Stringdef Inflow and Outflow in command file). This is indicated in BASEMENT by the raster cells within the boundary layer. For this seminar paper, most parameters were entered in the subcategory hydraulics. Since the model is a hydraulic flooding model, possible bedload was not included and only characteristics on the water were given in BASEMENT. For example, one compulsory parameter of BASEMENT is the friction. First, the type of friction has to be defined; here the Strickler coefficient *kstr* [$m^{(1/3)}$/s] was chosen. For this flood model the default friction (30) was entered, and no wall friction was set (see table 2). This is because the underground of the terrain, where the flood wave flows through, is assumed uniform and hence all elements have the same friction coefficient.

Table 2: Input parameters BASEMENT command file

Physical Properties		Viscosity	0.000001
Hydraulics	Boundary	Rho Fluid	1000
	Friction	Hydrograph	Inflow_stationary.txt
		Friction Type	Strickler
		Default_friction	30
		Wall_friction	off

However, the probably most important parameter in the subcategory hydraulics is the hydrograph of the flood wave, which was written and inserted into BASEMENT in a text file called “inflow_stationary.txt” (see table 2). For this seminar paper, a large flood scenario and a smaller flood scenario were created. As can be seen in table 3, the hydrograph of the small flood wave reaches its peak flow after two hours with 1250 m^3/s and lasts a total of 5.7 hours. The hydrograph of the large flood wave also reaches its peak flow of 4450 m^3/s after 2 hours and lasts a total of 5.5 hours. Our model assumes that there is a baseflow of 50 m^3/s. Therefore, these 50 m^3/s were subtracted from the peak flow given by Markus Zimmermann in the hydrograph. The duration of the hydrograph was calculated with a Python script, which was provided by Andreas Zischg. The total duration of the entire flooding can be defined in the subcategory timestep in BASEMENT. The total duration was set to 11 hours for the small flood wave and 20 hours for the large flood wave, based on the information given by Markus Zimmermann. With these duration values, the flood wave can flow from Lake Oeschinen to its outlet into Lake Thun. Finally, the output has also to be defined, i.e. which values should finally be in the output. In this case, the flow depth and the flow velocity are of great interest. The format of the output is a shapefile, which then can be used in QGIS to visualize the flood.

Table 3: Hydrograph of the small and the big flood scenario

	[s]	**[m^3/s]**
Small flood	0	50
	7200	1250
	20800	50
Big flood	0	50
	7200	4450
	19775	50

2.3 Flood layer analysis

To further investigate the consequences of the two flood scenarios, a python script with several features was created.

The input data were the two flood layers produced during the BASEMENT simulation as well as a shapefile containing the buildings located in the study area, with information about their object type. The number of affected buildings per flood scenario and flow depth was calculated, as well as the corresponding building type affected by the flood. The script is available on GitHub, and is accompanied by a “readme” file, where a detailed explanation of the code can be found (see annex for the link).

3. Results

3.1 Inundated Area

The maps in figure 2 show the resulting flooded areas for both the small flood scenario (left) and the big flood scenario (right). The flood travels along Oeschibach and reaches the Kander. Most of the buildings in Kandersteg are affected in both flood scenarios (see fig. 3). On its way to Lake Thun, the flood has to transit the Kander Valley and Frutig Valley, where mostly buildings close by the river are affected. As the terrain gets flatter before the Simme flows into the Kander, a huge inundation area is produced in Wimmis. The flood then passes into Lake Thun in Gwatt (Thun). It is noticeable that the inundated area is very similar during most of the flow path for both scenarios. However, the big difference is the maximum flow depth. The flood produced by higher peak discharge and total volume leads to flow depth over 3 m in many areas of the flow path.

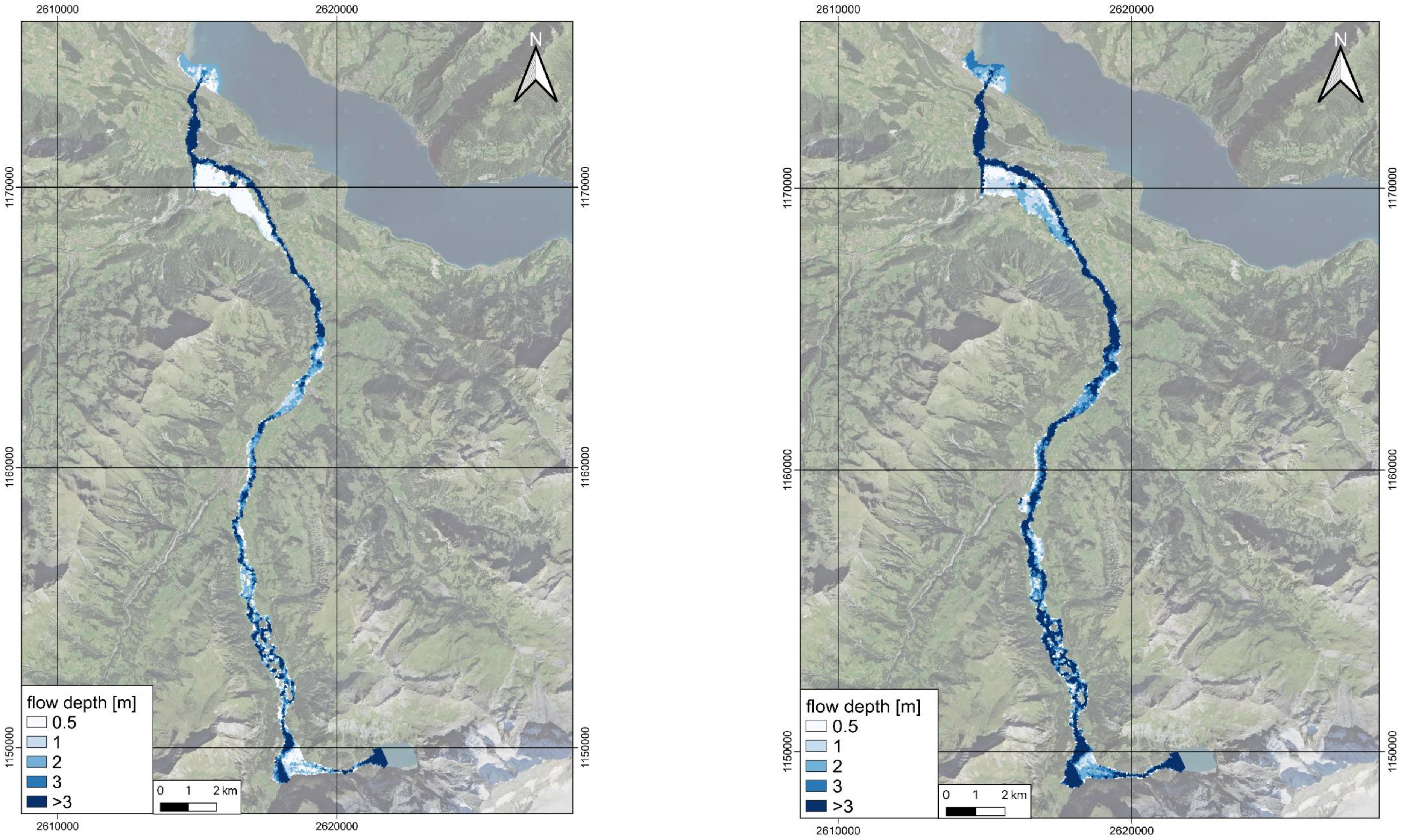


Figure 2: Left: Flooded area between Lake Oeschinen and Lake Thun for the small flood scenario. Right: Flooded area between Lake Oeschinen and Lake Thun for the big flood scenario

3.2. Affected buildings

In the small flood scenario, a total number of 3530 buildings will be affected by the flood. In the big flood scenario, 4488 buildings will be affected, meaning that the big flood leads to about a third more affected buildings than the small flood. Figure 3 summarizes the number of affected buildings per flow depth. It is noticeable that a large portion of buildings in the small flood scenario are either affected by a flow depth of < 0.5 m or > 3 m. Whereas the three categories in between all account for about the same amount of buildings. In the big flood scenario, the portion of buildings affected by flow depths of 3 m or higher is much bigger than in the small flood scenario. Furthermore, flow depths of > 0.5 appear only half as much as in the small flood scenario.

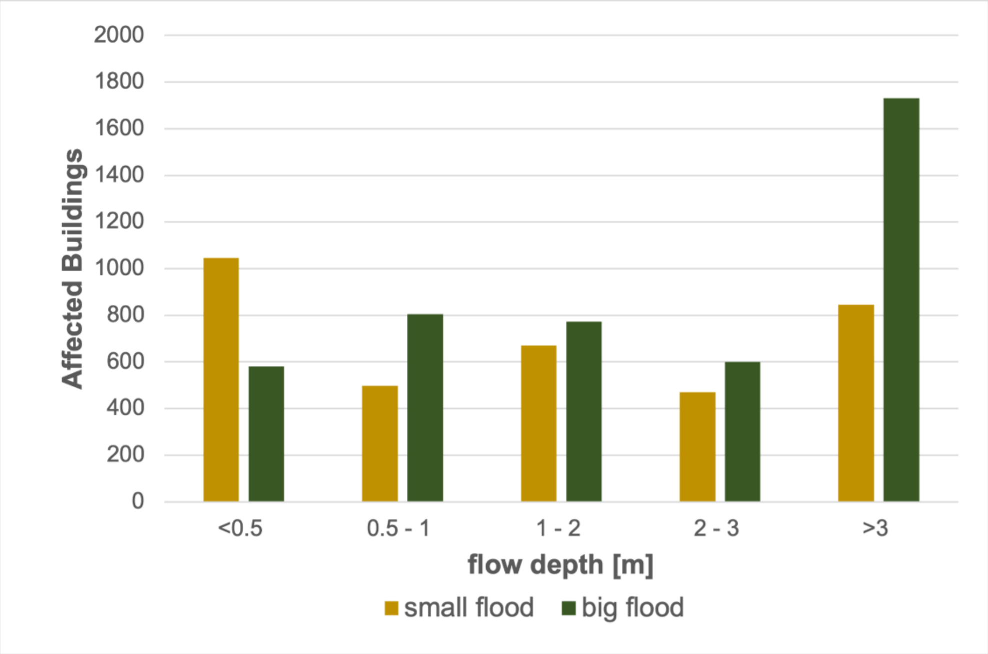


Figure 3: Number of affected buildings per flow depth and flood scenario

Furthermore, the distribution of flow affected buildings was analyzed (see table 4). It is noticeable that the differences between the big and small flood scenarios are small. This is mainly due to the fact that the object type “overground building” accounts for most of the buildings.

Table 4: Number of affected buildings per building type

Object type	**Small flood**	**Big Flood**
overground building	3021	3823
high funnel	1	1
storage tank	70	93
open building	401	524
green house	1	1
under construction	13	13
sacral tower	1	1
sacral building	5	5
flying roof	13	23
wall	3	3
bridge	1	1
total	**3530**	**4488**

The number of affected buildings and different flow depths in Kandersteg are compared in figure 4. It appears that the number of affected buildings is somewhat higher in the big flood scenario. Those buildings are mainly located in the North-East of the village, along the main road and the river Kander. Another difference can be spotted in the flow depth. Most of the buildings in the big flood scenario are affected by a flow depth of 2 meters or higher. Furthermore, buildings affected by flow depth of 3 m or higher are more abundant in the big flood scenario, mainly in the area close to the river Kander.

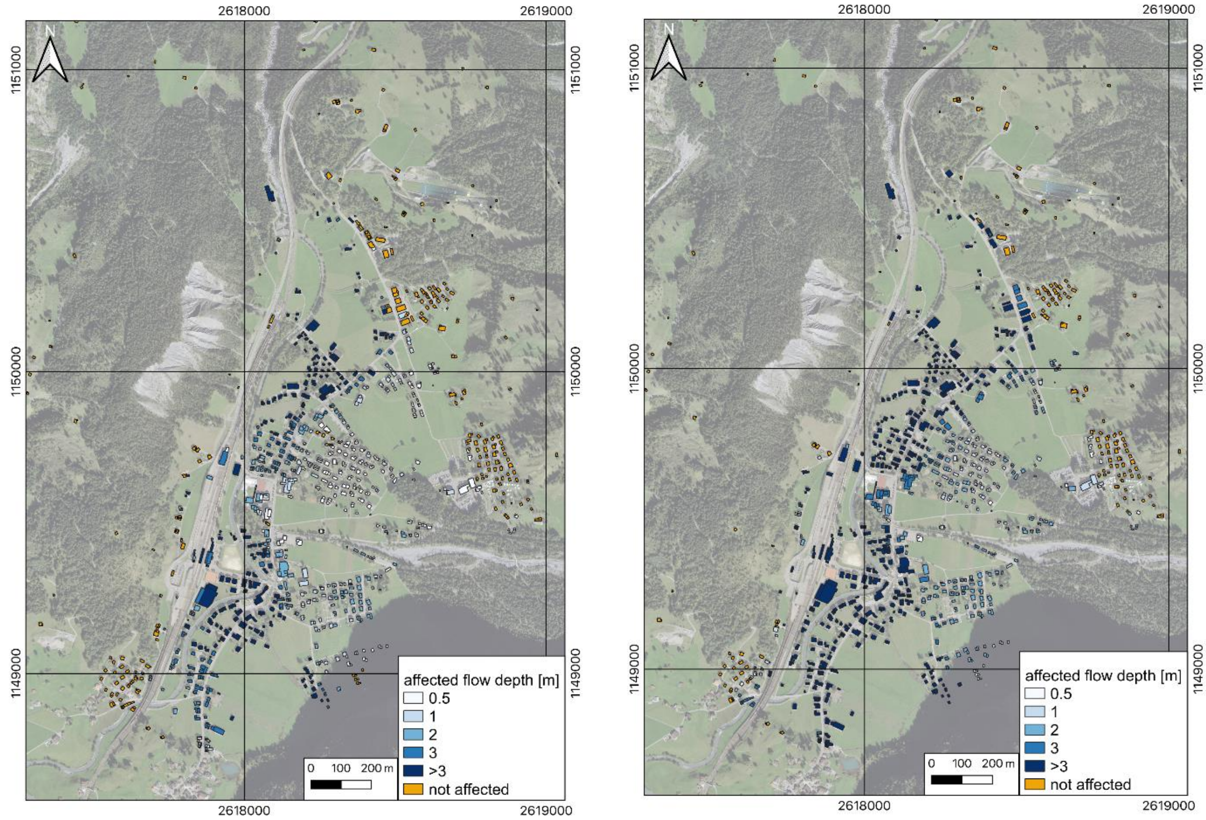


Figure 4: Affected buildings with their corresponding flow depth in Kandersteg for the small flood scenario (left) and big flood scenario (right).

5. Conclusion

The flood was calculated with the assumption that only water would flow out of the lake. In real life, the water would also take sediments out of the lake and would lead to erosion of sediments in the river bed. This would lead to a different flood dynamics than it was presented here. Furthermore, possible backwater processes in the rivers, e.g. the river Kander are not considered. Nevertheless, the model provides a notion of the dimension of a flood wave that would occur if Lake Oeschinen would burst out as a consequence of a rockfall from “Spitze Stei”. It demonstrates that large parts of the area along the river between Lake Oeschinen and Lake Thun would be flooded, and high flow depths are reached in many cases. This has to be taken into account when developing possible flood protection measures to prevent an outburst at Lake Oeschinen.

Annex

The input data, the BASEMENT file and the Python script can be found at:

https://github.com/unibe-geodata-modelling/2021-lake-outburst-modelling