Exercise 3F1. Flood hazard assessment using 2D flood propagation model outputs

Expected time:	3 hours
Data:	data from Subdirectory: /Exercise 3 Hazard assessment/Flood hazard
Objectives:	This exercise aims at showing how to extract flood parameters through the simulation of diferent return periods flood events. Flood depth, velocity, and rising time will be extracted for each simulated return period event using SOBEK 1D-2D flood propagation model.

Background information: River morphology and landforms

River geomorphology consists in complex landforms, produced by rivers erosion/sedimentation, that vary from the source to the mouth. The overall river environment can be divided into three main sections (Fig. 1).

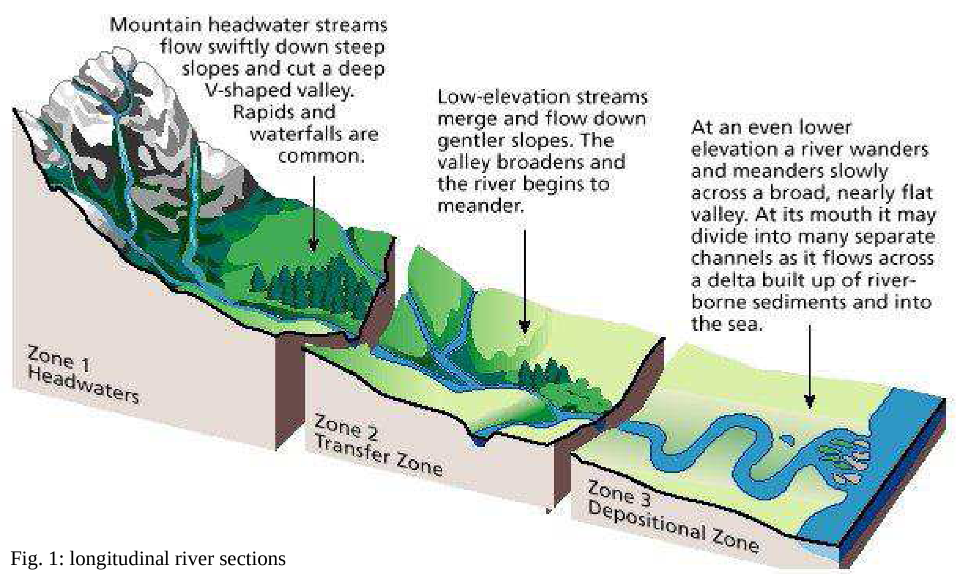

Fig. 1: longitudinal river sections

Starting from the source, the Headwaters represent the younger stage of the river: here the stream flows in upstream areas with high internal relief; the regime is torrential: very high flow velocity due to the high slope gradient, low discharges or even waterless in dry seasons and high discharges picks in rainy seasons. Due to the high flow velocity, the dominating pattern is the straight channel following the valley bottom. The river erosion is dominating on the deposition and it is stronger during high discharges periods; the river creates with its activity steep V-shaped valleys and when the slope changes abruptly at the exit of the mountain chains, the river widen into streams and form the so called alluvial fans, concave deposition bodies formed by coarse sediments (gravels and coarse sand).

The Depositional Zone next to the mouth represents the terminal stage of the river path: the river widely meanders in downstream lowland flat areas; the discharges are higher and more constant in the course of the year. The floodable areas next to the water course are close to the elevation of the river or even lower if backswamps systems have been created; the flood prone region is identified as floodplain. Part of the floodplain can be protected by artificial or natural levees. The deposition is dominant, and it increases during flood events. When the river overflow the bankfull conditions the water spreads onto large areas in the floodplain, where it deposits the sediment load, which is mainly suspended silt and clay. The bed load (sand – fine sand) is deposited right next to the river and it forms the natural levees along the main course. The compaction of the clay material in the floodplain produces a relative subsidence on those areas that can become lower than the river channel. The flow characteristics are: low flow velocity, high suspended load, and high deposition rates especially during flood events. The position and the width of the meander slowly changes during the periods of normal discharge, where erosion and deposition take place simultaneously.

Transfer Zone represents the transition section from upstream to downstream areas. The channel pattern can be straight (characteristic of the upstream area) meandering (present in the downstream areas), or braided. This pattern consists of a series of secondary channels meeting and re-dividing each others. Braided channels have steeper gradients than meandering rivers but more gentle than straight channels; the channels remain stable during the normal flow while they change shape and direction during flood events.

Background information: Flood definitions and classifications

- A flood is a natural event for rivers and streams. Excess of water from snowmelt, rainfall, or storm surge accumulates and overflows onto the banks and adjacent floodplains. Floodplains are lowlands, adjacent to rivers, lakes (and oceans) that are subject to recurring floods (FEMA, 2001).
- A flood is a high stream flow that overtops natural or artificial banks of a stream.
- A flood is a body of water that inundates land that is infrequently submerged and, in doing so, causes or threatens to cause damage and loss of life.
- Flood is a natural and recurring event for a river or stream.

The term flood includes different events; the primary differences among flood types are established considering the triggering factors and the morphological characteristics of the affected areas, which drive the duration and the intensity of the flood events.

Riverine Floods are the result of intense and/or persistent rain for several days or even weeks over large areas. The riverine floods occur in level land with a very low internal relief (transition–deposition zone), where the river shows a braided or, more frequently, meandering pattern; such flood prone areas are identified as floodplains. The flood depth varies according to the morphology of the area. The flood extent can be as wide as the floodplain during extremely severe events. The flow velocity is generally low and it rapidly decreases moving away from the main channel. The water rising rate is slow and the flood duration last from days to weeks, especially if backswamps are present in the floodplain, or if the water overflowed the levees systems. Weather predictions and boundary conditions (upstream-downstream catchments conditions and tributaries contributions) are important in riverine flood early warning.

Flash Floods are mostly local events and scattered in time and space. They are the result of intense rainfall over small upstream areas within a short period of time (usually less than 6 hours) causing water to rise and fall quite rapidly. They affect mainly areas with moderate to high slope gradient. Flash floods are extremely dangerous for their sudden nature; the flow velocity is high and the water level rises very rapidly. The sediment load is abundant and it can include from fine sediments to gravels and blocks, due to the high transport capacity of the water body, increasing the destructive power of the flash flood. The flood duration is short and the early warning systems are based on precipitations predictions.

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Post processing of flood modeling

Figure xxx : Opening screen of SOBEK.

Hydraulic simulation software, for instance SOBEK, can be used to analyze the flow of water in greater detail. Especially 2D flood models can be used to characterize flood events over complex topography, such as in an urban environment. In this exercise we will work with the data that is generated by hydraulic simulation software, for instance SOBEK.

The output data of the model consists of a series of water depth and flow velocity maps at different time steps. In this case the maps are generated at one hour intervals. The model also creates a set of maps that summarize the simulation; these include a **maximum water depth** map (representing the highest water depth value that was reached at some point during the simulation), a **maximum flow velocity map** (representing the highest flow velocity value that was reached at some point during the simulation), two maps that indicate **the time at which the maximum water depth and the maximum flow velocity** were reached and a map that shows the time at which a pixel **started being inundated**.

This exercise consists of two parts: Part 1 is a classical flood hazard assessment. Here we will combine the maximum water depth maps of flood scenarios with different return periods into a map giving the annual probability of inundation. Part 2 focusses on one single event and is a demonstration how the flood simulation results can be used to calculate derivative maps that characterize the flood event in a more meaningful way.

PART 1: Flood hazard map

Data:

File name	Meaning
Max_h_5y	Maximum water depth, flood return period = 5 years
Max_h_10y	Maximum water depth, flood return period = 10 years
Max_h_20y	Maximum water depth, flood return period = 20 years
Max_h_50y	Maximum water depth, flood return period = 50 years
Max_h_100y	Maximum water depth, flood return period = 100 years
Max_h_200y	Maximum water depth, flood return period = 200 years
Building_map_segments	Vector map with the building blocks.
DEM10	Georeference (10m)
Building_map_segments	Domain and representation of the vector map

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- Open the maps **max_h_5y** and **max_h_200y** and check the content of the file. Both maps contain the water depth in meters.

Question 1:
Which map shows the greatest flood extent and water depths; Why?

- Close both maps.

Hazard is defined as the probability that an event of a certain magnitude occurs in a given area within a specified period of time. If we want to calculate the annual probability, that is the chance that a flood of a certain magnitude occurs in the coming year, we have to divide 1 by the return period.

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- Fill in the following table:

Map	Return Period	Annual Probability
Max_h_5y	5 Year	
Max_h_10y	10 years	
Max_h_20y	20 years	
Max_h_50y	50 years	
Max_h_100y	100 years	
Max_h_100y	200 years	

- Create the map with the annual probability for the flood with the 5 year return period by typing the following statement in the command-line:

```
Prob_5y:=iff(max_h_5y>0, xxx, 0)
```

Where xxx is the annual probability you calculated in the table.

Question 2:
What is the meaning of this ILWIS statement?

- Repeat this for the other 5 maps and create the maps Prob_10y, Prob_20y, Prob_50y, Prob_100y and Prob_200y.

We now have 6 maps with the annual probability. To combine the maps into an integrated hazard maps we have to follow a stepwise approach.

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- Type the following statement in the command line:

```
Hazard_a:=max(prob_5y,prob_10y,prob_20y)
```

followed by <enter>; Have a look at the intermediate map.

- Then type:

Hazard_b:=max(prob_50y,prob_100y,prob_200y)

- Combine both maps, by typing in the command line:

Hazard:=max(hazard_a,hazard_b)

- Have a look at the result
- Close all maps.

To combine this map with other data-layers, for instance topographical data, it is useful to transform the raster format hazard map into vector format.

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Question 3a:
What is the current domain of the hazard map?

Question 3b:
Why is it not possible to transform maps with such a domain to vector format?

In order to make the conversion to vector format we have to classify the hazard map. In ILWIS this is called "slicing". The first step is to create a domain to define the class boundaries; then we "slice" the hazard map.

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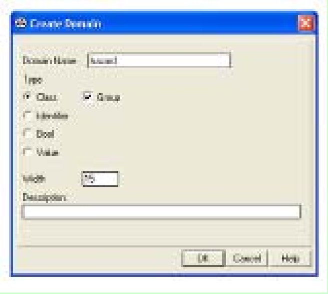

Domain Name: hazard
Type
● Class ☑ Group
○ Identifier
○ Bool
○ Value
Width: 15
Description:

- Go to the "*file*" pull-down menu on the ILWIS main page and select "*create*" and then "*domain*".
- Give the new domain the name "hazard"
- Make sure the tick-box "*group*" checked
- Click <*OK*>

  The *create domain group hazard* window is opened
- Use the <insert> key of your key-board open the "add domain item" window.
- Type for Upper Bound: `0.004` and for Name: "`less than 1/200`". Click <OK>.
- Add the following class boundaries:

Upper Bound: 0.004
Name: less than 1/200
Code:
Description:

Upper Boundary	Name	Color
0.004	Less than 1/200	⬜
0.009	1/200	🟩
0.019	1/100	🟨
0.049	1/50	🟧
0.099	1/20	🟨
0.19	1/10	🟧
1	1/5	🟥

- After the class boundary is added, close the “domain group” window.
- In the ILWIS catalogue window open the class representation “`hazard`” and chance the color scheme as indicated in the table.
- Right-click on the map “`hazard`” and select *image processing* and then *slicing*.
- Give the new map the name: `hazard_cla`
- Select for Domain: “`hazard`”
- Click <*OK*>.
- Open the new map and add the segment map “`building_map_segments`”
- Save the view as “`hazard`”.
- Right-click on the map `hazard_cla` and select “*Vectorize*” and then “*raster to polygon*”
- Accept the defaults and name the output map `hazard_cla`.
- Click <show> to have a look at the result.

PART 2: Indicator maps

Data:

Name	Type	Meaning
RiskCity_DSM	raster	Digital Elevation Model
import	Script	Imports SOBEK asci-files in ILWIS, replaces no_value data with zero-values and adds a standard georeference to all maps.
slicing		Classifies the maximum maps
classify		Classifies the hourly maps to create map lists
rising		Calculates the speed of rising of the water level in m/h
impulse		Calculate the maximum impulse in m^2/s
duration		Estimates the flood duration
sediment		Estimates the relative sedimentation / scouring potential of the flood
Building_map_segment	vector	Contains the building blocks of RiskCity
Building_map_segment	Domain / representation	
Duration		Group domain to classify the duration map
Maxc		Group domain to classify the maximum flow velocity map and the hourly flow velocities maps
Maxh		Idem for waterdepth
Maxi		Idem for impulse
Maxr		Idem for rising of the water level
Sediment		Idem for sediment estimates
ttf		Idem for the flood propagation (time to flooding)
DEM10	georeference	Standard georeference for all raster maps
	Asci maps	SOBEK output (summary maps)
DM1MAXD0.ASC		Map contains the maximum water depth during the scenario
DM1MAXC0.ASC		Map contains the maximum flow velocity during the scenario
DM1TMAXC.ASC		Map contains the time at which the maximum flow velocity was reached.
DM1TMAXD.ASC		Map contains the time at which the maximum water depth was reached
DM1TWT00.ASC		Map contains the time at which a pixel is flooded for the first time.
DM1C0000.asc **DM1C0001.asc** **DM1C0002.asc** **DM1C………….** **…….** **DM1C0048.asc** **DM1D0000.asc** **DM1D0001.asc** **DM1D0002.asc** **DM1D………….** **…….** **DM1D0048.asc**	Asci maps	SOBEK output at hourly intervals DM1C is velocity maps DM1D is water depth

The output data of the model consists of a series of maps, which represent flood depth and flow velocity at different time steps. They are in ASCII format.

The aim of this exercise is to derive several indicator maps that may be used to characterize the complexity of flood events. We need to carry out the following steps:

- Import the files in ILWIS;
- Change the georeference;
- Classify the map in a limited number of classes;
- Create the indicator maps.

Importing the SOBEK output files in ILWIS

The first step in the analysis is the import of the datafiles in ILWIS. We will do one file manually, and after that use a script to import the rest.

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- Open the asci file **Dm1d030.asc** in a texteditor (notepad) and check the content of the file (it contains water depth in meters). Close it again
- From the file menu select *Import / Maps*.
- Select the option *ArcInfo.ASC or .NAS (Non-compressed ASCII raster)*
- Import the asci-file **DM1d0030.asc** and give it the ILWIS file name **d30**
- Open the map **d30** (play with the stretch to get a better result on the screen) and check the result.

It would be possible to import all maps like this; however, it would take a lot of time. Therefore we have made a script called **Import** that will do the import in one time. The script is given below, with a description of the activities in italics.

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- Run the script file Import by typing the following statement in the command line: `run import`. **This will take some time**.
- Have a look at some of the resulting maps.

You can see that the maps have a larger pixel size than the other maps in the dataset (10 meters instead of 1 meter) and that they cover a different area. This was done to reduce the calculation time in the SOBEK model.

Script	Description
rem import waterdepth files	
import arcinfonas(dm1d0000.asc, h000x) import arcinfonas(dm1d0001.asc, h001x) …… …… import arcinfonas(dm1d0047.asc, h047x) import arcinfonas(dm1d0048.asc, h048x)	*Import files the hourly waterdepth ASCI maps using the ArcInfo NAS import option for ASCII files. An ILWIS file with the name h000x is created.*
rem import flow velocity files	
import arcinfonas(dm1c0000.asc, c000x) import arcinfonas(dm1c0001.asc, c001x) …… …… import arcinfonas(dm1c0047.asc, c047x) import arcinfonas(dm1c0048.asc, c048x)	*Idem for the hourly flow velocity maps*
rem georeferencing	
setgrf c*.mpr dem10.grf setgrf h*.mpr dem10.grf	*All imported files get the same georeference dem_10m.grf*
del -force h*.grf del -force c*.grf	*The other georeference files are deleted*
rem ongedfinieerd wordt 0 h000:=ifundef(h000x,0,h000x) h001:=ifundef(h001x,0,h001x) …. ….. h047:=ifundef(h047x,0,h047x) h048:=ifundef(h048x,0,h048x)	*The undefined values in all the map are replaced by zero- values*
c000:=ifundef(c000x,0,c000x) c001:=ifundef(c001x,0,c001x) ….. ….. c047:=ifundef(c047x,0,c047x) c048:=ifundef(c048x,0,c048x)	*Idem for the velocity files.*
del -force h???x.mpr del -force c???x.mpr	*All intermediate maps are deleted*
import arcinfonas(dm1maxd0.asc, max_hx) import arcinfonas(dm1maxc0.asc, max_cx) import arcinfonas(dm1twt00.asc, ttfx) import arcinfonas(dm1tmaxc.asc, tmax_cx) import arcinfonas(dm1tmaxd.asc, tmax_hx)	*The summary maps are imported*
setgrf max_hx.mpr dem10.grf setgrf max_cx.mpr dem10.grf setgrf ttf.mpr dem10.grf setgrf tmax_cx.mpr dem10.grf setgrf tmax_hx.mpr dem10.grf	*The summary maps get the georeference*
max_h:=ifundef(max_hx,0,max_hx) max_c:=ifundef(max_cx,0,max_cx) tmax_h:=ifundef(tmax_hx,0,tmax_hx) tmax_c:=ifundef(tmax_cx,0,tmax_cx) ttf:=ifundef(ttfx,999,ttfx)	*Undefined values are replaced by zero-values*
del -force max_hx.mpr del -force max_cx.mpr del -force tmax_hx.mpr del -force tmax_cx.mpr del -force ttfx.mpr	*All intermediate maps are deleted*
del -force max_hx.grf del -force max_cx.grf del -force tmax_hx.grf del -force tmax_cx.grf del -force ttfx.grf	*All georeferences are deleted*

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- Open the map **max_h**. (apply a stretch of 0 – 10 in the display communication window)
- Display the segment map **Buildings_map_segments** on top of it, so you can study the map together with the topographical information.
- Do the same with the maps:
  - **max_c** (apply a stretch of 0 – 2)
  - **ttf** (strectch 0 – 15),
  - **t_maxh** (stretch 10 – 15)
  - **t_maxc** (stretch (5 – 25)

Question:

What are the units of these 5 maps?

Calculating flood parameter maps

A lot of important information for hazard and risk assessment is contained within the time series of maps with water depth and flow velocity. To analyze this data an aggregation procedure has been developed to create seven parameter maps that describe the different aspects of the flood event. These parameter maps are (see Figure xxx):

- Maximum water depth
- Maximum flow velocity
- Flood propagation characteristics (also Time to Flooding)
- Maximum impulse
- Maximum rising of the water level
- Duration
- Sedimentation

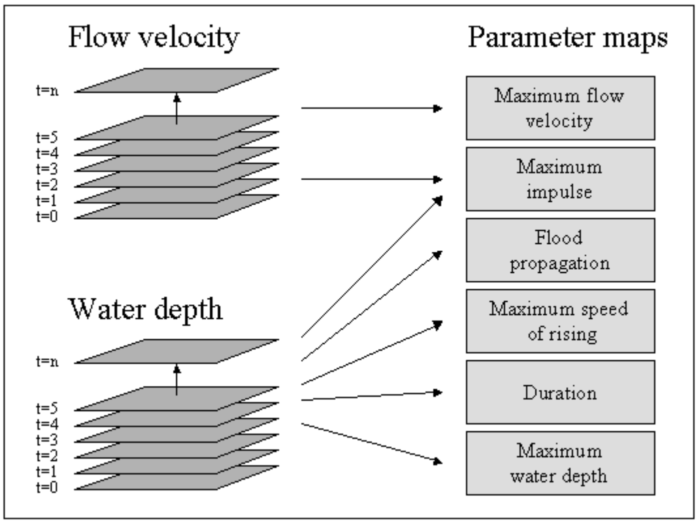

Figure. Transformation of the model output maps into flood hazard parameter maps.

The first three maps are already calculated by SOBEK; These maps are **max_h**, **max_c** and **ttf**.

1 Maximum water depth (unit: m);

This map shows the maximum depth that occurred during the inundation. The rationale behind this parameter map is that areas with deep water are more dangerous to people and potentially more damaging to objects like houses and cars. It identifies areas where the second floor of houses, or even the third or fourth floor, is not a safe refuge. The maximum water depth map also serves as a possible means for model calibration. Maximum water depth is one of the few flood parameters that can easily be retrieved after a flood event because of wetting marks in and on structures.

2 Maximum flow velocity (unit: m/s);

This map shows the maximum flow velocity that occurred during the inundation. The rationale behind this parameter is that velocity is a component of the floodwater that can sweep people off their feet and make cars float away. This map shows where preferential flow paths may develop that could be dangerous for children, adults and cars.

3 Flood propagation characteristics (unit: h);

This map shows how the flood propagates through the area. After each time interval the flooded area is identified and compared with the situation at the previous time interval. It records the time at which a cell is inundated for the first time. The rationale behind this parameter map is that it shows how much time it takes for the first floodwater to reach a certain location and thus how much warning time people have to prepare themselves. Areas that are flooded quickly are potentially more dangerous than areas further away.

The ILWIS script “**slicing**” classifies these three maps.

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- Run the script “**slicing**”
- Open the three created classified maps
  - maxh_cla
  - maxc_cla
  - ttf_cla

4 Maximum impulse (unit: m^2/s);

This map shows the maximum impulse that occurred during the inundation. The impulse is calculated at each time step by multiplying water depth and flow velocity. For each pixel this value represents the amount of movement of the water mass (per pixel the mass only depends on the water depth, since the surface area of the pixel and volume weight of water are constant). The rationale behind this parameter is that flow velocity alone does not suffice to estimate the amount of potential damage or danger to humans and cars to be swept away. Shallow water with a high flow velocity does not have a lot of kinetic energy or momentum and neither has deep, but practically still-standing water. Deep, fast flowing water however is potentially dangerous for people and vehicles and is potentially damaging to objects like houses and crops. Especially in urban environments this parameter shows that streets become preferential flow paths for water.

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- Run the script “**impulse**”
- Open the classified map **maxi_cla**

5 Maximum rising of the water level (unit: m/h);

This map shows the maximum speed at which the water level rose at some point during the inundation. It is calculated by taking the difference between two successive water depth maps, divided by the time interval between the two maps. The result is an increase in water depth per hour. The rationale behind this parameter map is that a quick rising of the water level is potentially dangerous for people who may not have sufficient time to seek higher ground or elevated structures.

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- Run the script “**rising**”
- Open the classified map **maxr_cla**

The parameters **water depth**, **flow velocity**, **impulse and rising of the water level** fluctuate with time. In ILWIS it is possible to display these mapseries as an animation. But before that is possible the maps in the mapseries must be classified first, else they cannot be included in a map list. The script “classify” does exactly this.

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- Run the script “**classify**”
- Create a map list (*file* menu, *create*, *map list*)
- Name it “velocity”
- Move all the *c---_cla* maps to the right-hand side window (use the <Ctrl> key to make multiple selections)
- When all the c---_cla files are moved, click <OK>
- In the ILWIS catalogue window go to the *view* menu and select “*customize catalogue*”. Check the tick-box “*hide objects that are member of an object collection*”. Click <OK>
- Open the map-list “**velocity**”
- Click on the “open as slide show” icon 🎞 in the top map-list window, accept the default settings and click <OK>.
- Click <OK>
- The animation with the flow velocity will start.
- Create map lists for **depth**, **impulse** and **rising** and add the maps *h---_cla*, *i---_cla* and *r---_cla* respectively.
- Display each map series as an animation.

6 Duration (unit: h).

This map estimates the time the floodwater remains at a certain location. It is based on several assumptions regarding the drainage of the floodwater from the flooded area. For instance in the studies presented in this book it is assumed that there is free drainage at the lowest point of the inundated area through a “canal” of a certain width (1 or more pixels wide). It also requires a sufficiently long simulation run that includes the descending limb of the flood wave. The rate of water level change is calculated as dh/dt, where dh is the difference between the maximum water depth and the water depth at the end of the simulation and dt is the difference between the time at the end of the simulation and the time the maximum water depth is reached. The duration is estimated by extrapolating this rate of change until the moment of a water depth of zero is reached - see Figure xxx9.

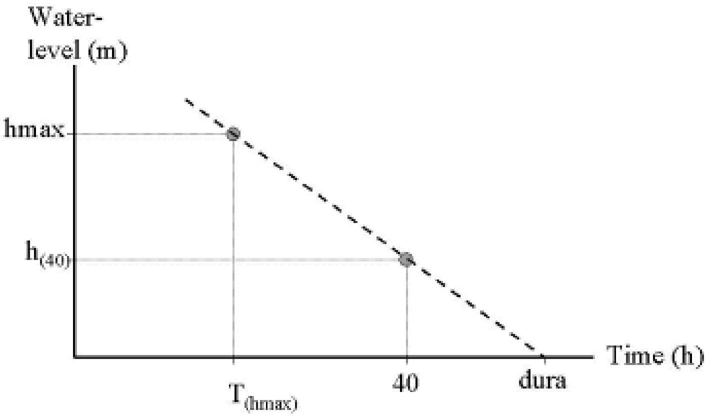

Figure. Estimation of the parameter “duration”.

The rationale behind this parameter is that it gives a first, rough impression of how long the floodwater will stay in the area. This is the minimum time period that people have to be relocated, that businesses and industries are closed and that transportation in and through the area might be impossible or hindered. It is a strong parameter to assess the economic and social impact of the flood on the people living and working in the area. It is also an important parameter to estimate agricultural damage because many crops, like fruit bearing trees and vineyards can withstand inundation of their stems for a short time (usually some days), but if the period becomes too long the roots will starve from oxygen depletion and the trees will die.

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- Run the script “**duration**”
- Open the classified map **duration_cla**

Question:

What is the estimated duration of this flood event? What is the time unit?

7 Estimation of scouring and sedimentation

The estimation of the sedimentation and scouring is based on the Rouse number that gives the ratio of downward (falling) velocity of a particle to the shear velocity (turbulence acting to keep particles suspended). The method applied here was suggested by Kleinhans (2002).

$$Z = \frac{W_s}{\kappa u^*} \;-1 \qquad 7.1$$

Where:
= Rouse number [-]
= Kármàn constant (=0.4) [-]
u* = Shear velocity [m/s]
Ws = Downwards velocity for a particle of certain grain size [m/s].

This criterion is calculated at the hourly time steps, for sediment particles with a diameter of 210 m. When Z > 0, sedimentation is possible because the downward velocities are larger than the upward directed velocities. The particles present in the water will experience a net downward movement and may sediment on the surface. When Z < 0, then the upward directed velocities are higher than the downward velocities which means there is potential for uplifting of particles (scouring) and available particles will remain in suspension. The downward velocity Ws of a particle with a diameter between 100 and 1000 m (fine sand) is given by:

$$W_s = 10\,\frac{\nu}{d}\left(\sqrt{1+\frac{(0.01(s_p - s_w)/s_w\, g\, d^3}{\nu^2}} \;-1\right) \qquad 7.2$$

Where:
= viscosity of water = 1.2 * 10-6 [m2/s]
sp = density of quartz = 1.65 * 103 [kg/m3]
sw = density of water = 1 * 103 [kg/m3]
d = grain size diameter = (in this study) 210 * 10-6 [m]
g = gravity acceleration = 9.81 [m/s2]

Since all parameters in formula 7.2 are constant, Ws is approximately 0,01 m/s for a particle with a diameter 0f 210 m. The shear velocity is given by:

$$u^* = \frac{\kappa\;\; U}{\ln\left(\frac{0.37\,h}{3.97\;10^6\,n^6}\right)} \qquad 7.3$$

Where:
U = flow velocity [m/s]
h = water depth [m]
n = Manning’s roughness coefficient

The flow velocity and water depth are computed by the model, whereas the spatial distribution of Manning’s coefficient is one of the known boundary conditions. All parameters are known at hourly time-steps. The final sedimentation / scouring gives the accumulated hourly values of the

dimensionless parameter Z to identify areas where sedimentation or scouring are dominant. In this procedure, positive and negative values can cancel each other out: the higher the value, the more potential for sedimentation; the lower the value the more potential for scouring. Zero means no net sedimentation or scouring. To estimate the availability of sediment, three additional assumptions were made:
the sediment-load of water flowing into the area decreases inversely with time (high at the start, then decreasing with time);
the sediment is distributed uniformly in the floodwater and is never zero - the sediment fluxes are proportional to the water fluxes;
sedimentation and scouring occurs only in the first 150 hours of the flood (the time period for which this parameter map was calculated).

This approach does not yield estimates for sedimentation and scouring in terms of deposition or scouring depth, but provides an indication where and to what degree sedimentation and scouring can be expected.

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- Run the script “**sediment**”
- Open the classified map **sediment_cla**

Question:
The maps show areas of potential scouring and deposition. What does that mean?

Deliverables: 7 maps:

maxh_cla
maxc_cla
maxi_cla
maxr_cla
duration_cla
ttf_cla
sediment_cla

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- Open each the first of the seven above mentioned maps.
- Add to it the vector map **buildings_map_segment**
- Under the "*file*" menu in the map-window select "*create layout*"
- Give a name to the map-view (e.g. `maxh` for the first).
- For scale use 1:5000 and click <OK>.
- Click on the map to make it active
- In the lay-out window under the "*insert*" menu, select *legend*.
- Select the appropriate map legend. Click <OK>
- Make sure that the tick-box transparent is not checked.
- Click <OK>
- If you want you may add additional map attributes such as scale, north arrow, etc. to the map.
- Under the *file* menu in the lay-out window you select "*export to bitmap*"
- Give an appropriate name and reduce the resolution to 40 or 50 dpi (make sure the result is still readable.
- Repeat this for all seven maps.
- Paste all seven maps in a MS-Word or MS-Powerpoint file.
- Create also a layout of the `hazard_cla` map you created in part 1 and add it to the document.
- This document must be submitted.