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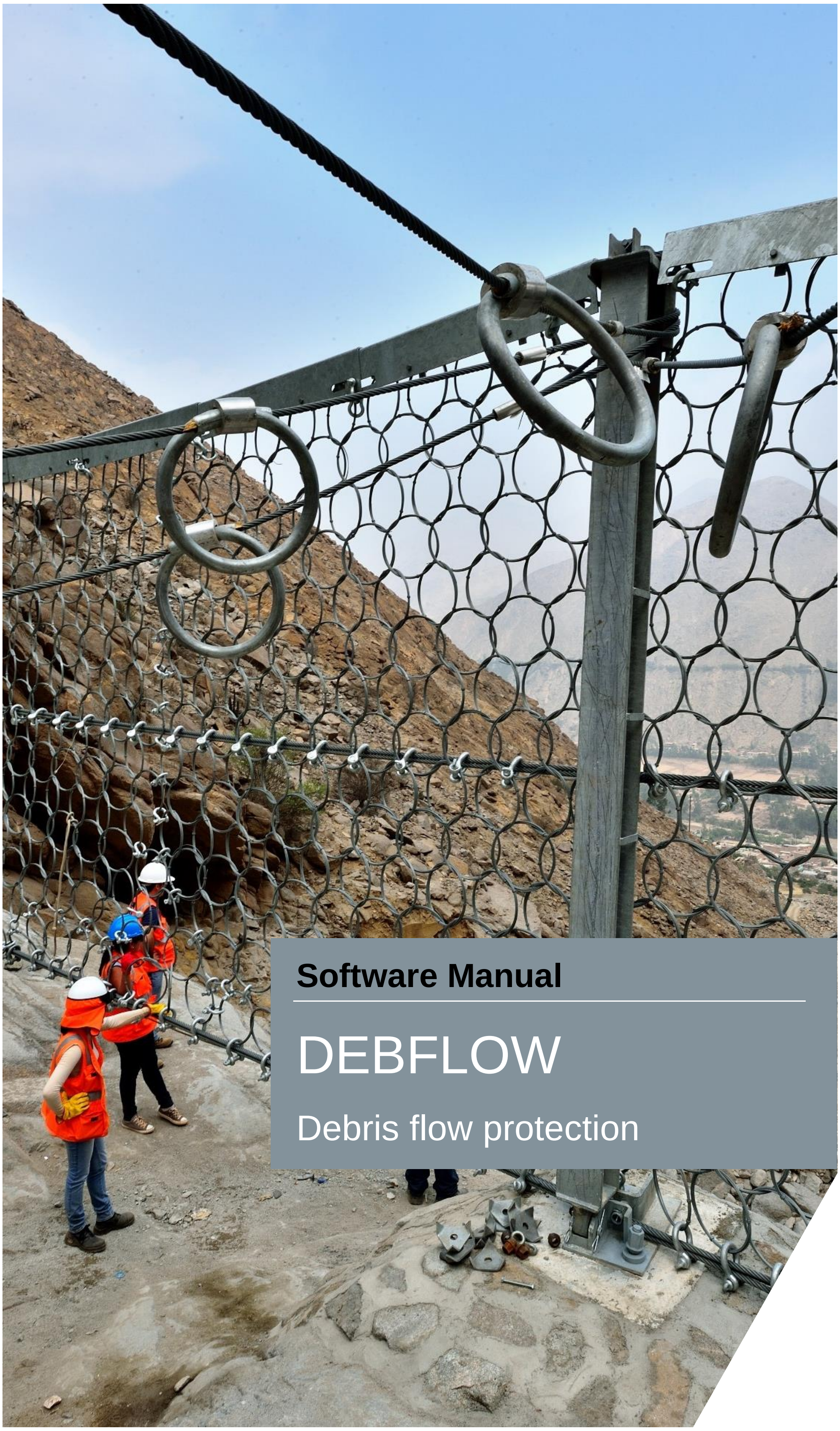
Dimensioning tool for flexible ring net barriers against debris flows



Software Manual

DEBFLOW

Debris flow protection

Date: 25.03.2021

Subject to change without notice.

PREFACE

Thank you for using DEBFLOW, the dimensioning tool for flexible ring net barriers against debris flows established by the Geobrugg AG, Geohazard Solutions. Every effort is made to give you the best possible support for the dimensioning of our flexible debris flow protection systems.

DEBFLOW offers you the possibility of considering a dynamic impact of a debris flow wave into the ring net and the corresponding static load case of a filled and overtopped barrier. Additionally, a first rough estimation of the retention volume can be carried out. The calculations are based on International Units in English and several other languages.

This manual provides you with the most important references and function descriptions to enable you to use the program correctly. Please read the operating instructions carefully prior using the program for the first time. Keep this reference book close at hand at all times.

Numerous parameters need to be entered for the dimensioning operations. It is the responsibility of the user of this program to select and enter these parameters correctly.

Nadine Feiger
Geobrugg AG

March 2021

PRODUCT LIABILITY

Rockfall, landslides, debris flows or avalanches are sporadic and unpredictable. Causes can be e.g. human (construction, etc.) or environmental (weather, earthquakes, etc.). Due to the multiplicity of factors affecting such events it is not and cannot be an exact science that guarantees the safety of individuals and property.

However, by the application of sound engineering principles to a predictable range of parameters and by the implementation of correctly designed protection measures in identified risk areas the risks of injury and loss of property can be reduced substantially.

Inspection and maintenance of such systems are an absolute requirement to ensure the desired protection level. The system safety can also be impaired by events such as natural disasters, inadequate dimensioning parameters or failure to use the prescribed standard components, systems and original parts; and/or corrosion (caused by pollution of the environment or other man-made factors as well as other external influences).

DISCLAIMER

1. The programs are only approved for preliminary designs and preliminary projects. Both the input parameters and output values must always be checked and confirmed by a specialist. All values are average values; they have to be checked and confirmed on project base before any application of a Geobrugg system.

Geobrugg cannot be held liable for damages of all kind - namely direct or indirect damages, cost of defects and damages due to defects, losses or costs - which occur by using wrong assumptions or input parameters.

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1. INTRODUCTION

The software DEBFLOW serves to dimension flexible debris flow protection systems consisting of the high-tensile steel wire ring net ROCCO®**,** support ropes with a determined number of brake rings, flexible spiral rope anchors and a specially designed abrasion protection device.

The software DEBFLOW is based on FARO [9] simulations of each standard barrier system for the given debris flow input parameters. The design concept is described in [11].
The DEBFLOW concept analyzes the stability of the chosen barrier system and calculates the appearing dynamic and hydrostatic forces during the filling process and the overtopping.

The dimensioning of the anchors in the slopes must be carried out carefully and respect the prevailing geological circumstances. Anchor forces up to 350 kN have to be transmittable into the slopes.

Figure 1: Application of ring net barriers as an additional building to a concrete check dam in the Illgraben in Canton Valais in Switzerland (left) and a successfully filled ring net barrier in Italy (right).

2. The Geobrugg VX/UX debris flow protection systems

The VX debris flow protection system has been developed by Geobrugg AG and consists of the following elements: The support ropes with its brake rings to absorb the energy while the debris flow impact, the ROCCO® ring net which is clamed between the support ropes, border ropes at each site of the slope and finally the additional abrasion protection (see figure 2).

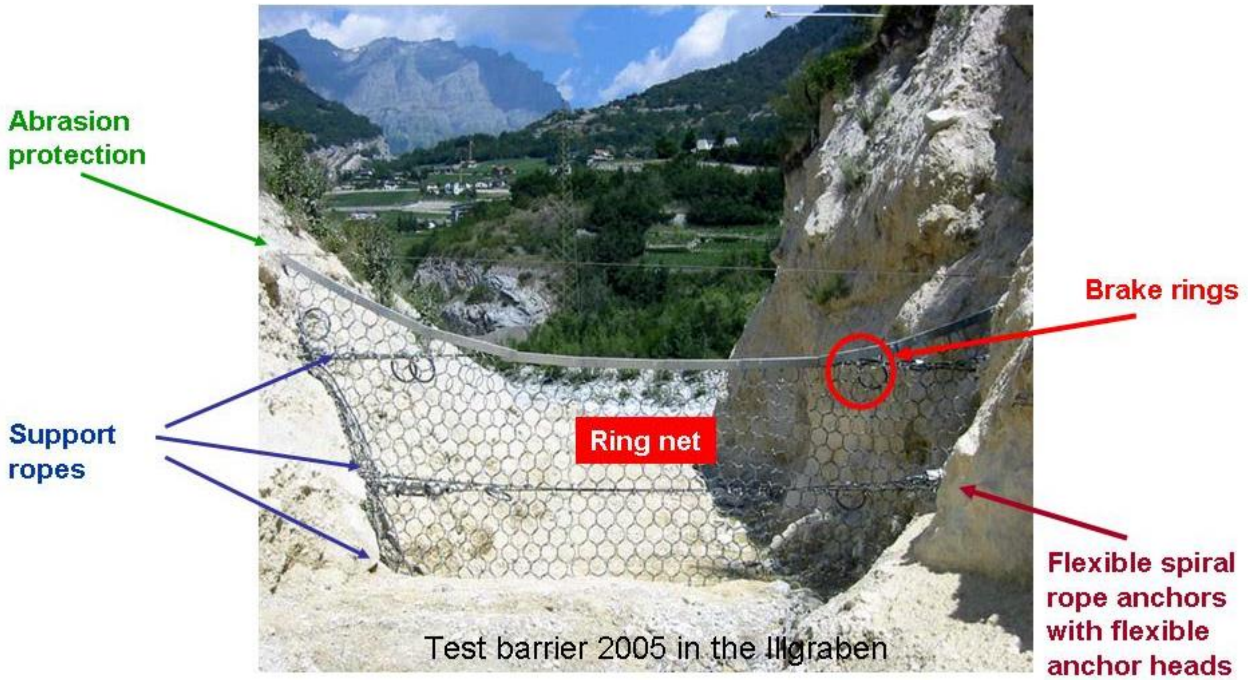


Figure 2: Components of a flexible VX barrier installed in the Illgraben in 2005.

The UX protection system has nearly the same construction design. The important difference is that the UX system is used for larger torrent widths and so posts are necessary keeping the barrier height when the barrier gets filled [10].

The ring net of ROCCO® mesh has openings of 300 mm in size and depending on the standard system a different number of windings. The support ropes used for this application consist of high-tensile steel wire ropes. These support ropes are fixed in the slope with spiral rope anchors or self-drilling anchors with special flexible heads, which ensure that forces not working directly in the pulling direction can also be transmitted. To protect the upper ropes from abrasion, an angle profile was developed and is fixed with shackles to the upper ropes. So, also overtopping of filled barriers is possible without any damages on the structural system.
To increase the limited retention volume of one barrier, so called “multilevel barriers”, barriers installed in line are possible. With multilevel barriers arbitrary retention volumes can be achieved. One example for multilevel barriers is the installation of 13 barriers at the Hasliberg Region in the Bernese Alpes in Switzerland (see figure 3). The total retention volume of several barriers in line can be roughly calculated with the DEBFLOW software tool. But the most accurate method to estimate the retention volume is by laser scanning of the river bed and creating a 3D model.
If there are muddy debris flows expected with small corn sizes, a secondary mesh can be added additionally to the ROCCO® 300 mm mesh size. This secondary mesh is not decisive for the dimensioning concept and is so not considered in the DEBFLOW software tool.

Figure 3: Multilevel barriers in the Hasliberg region in the Bernese Alpes.

3. TESTING OF THE COMPONENTS IN 1:1 FIELD TESTS AND CALIBRATION OF FINITE ELEMENT MODEL

All the barrier components were tested in 1:1 field tests against debris flows. The measured results in the field tests led to a calibrated finite element model with the Software FARO created at the WSL [9]. All the standard barriers were calculated with this simulation tool. More information about the field tests with debris flow barriers and the development of the finite element model is described in [11].

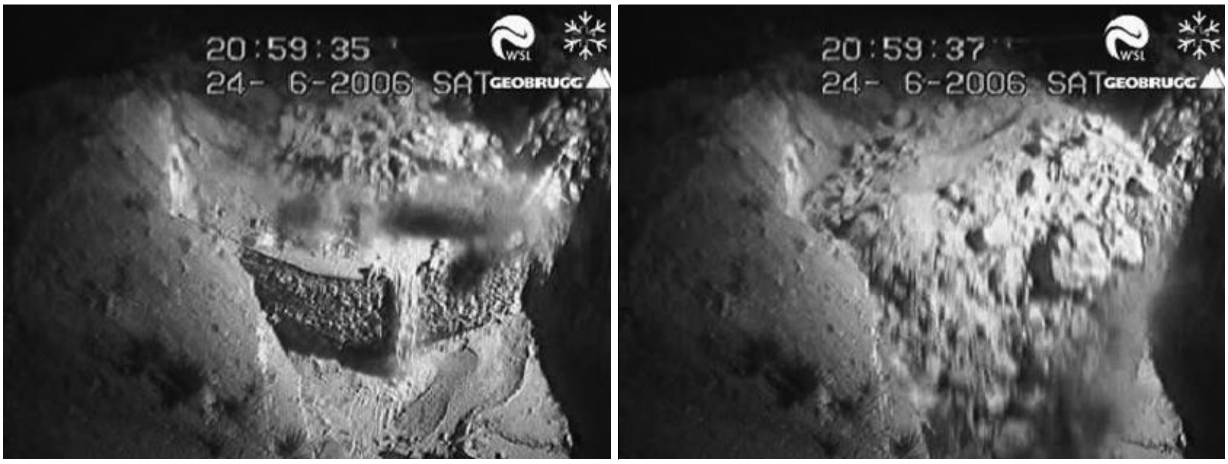


Figure 4: Test barrier in the Illgraben with a granular debris flow front arriving (left) and overtopping of the debris flow barrier (right).

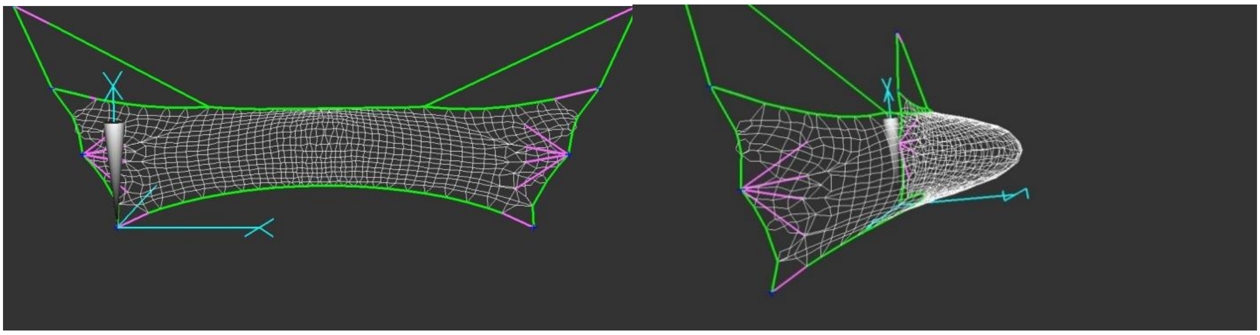
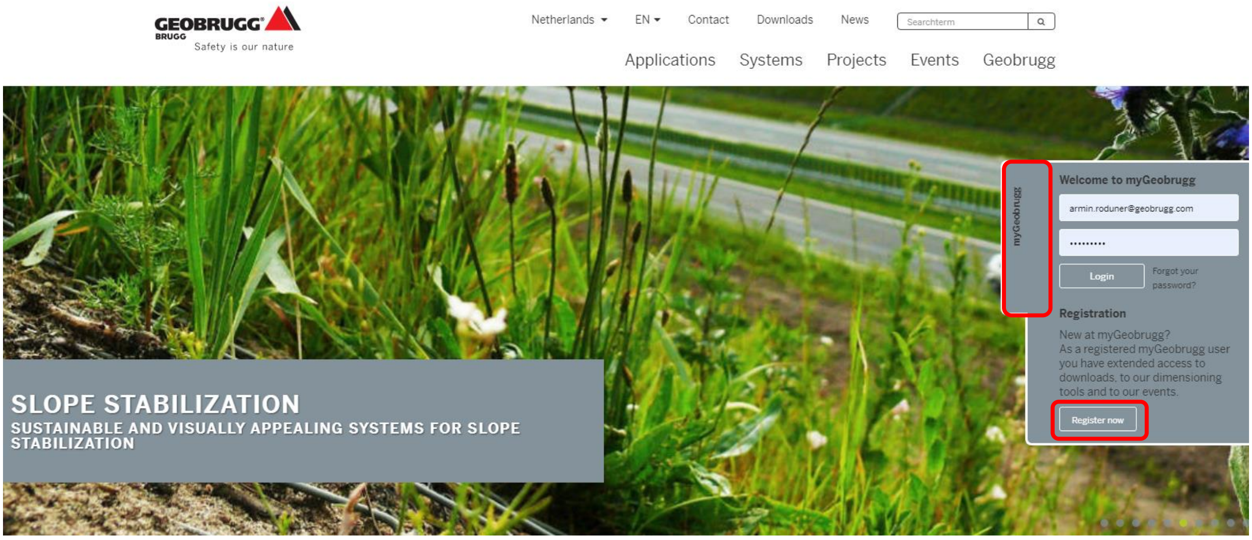


Figure 5: Finite element model in FARO of the test barrier in the Illgraben.

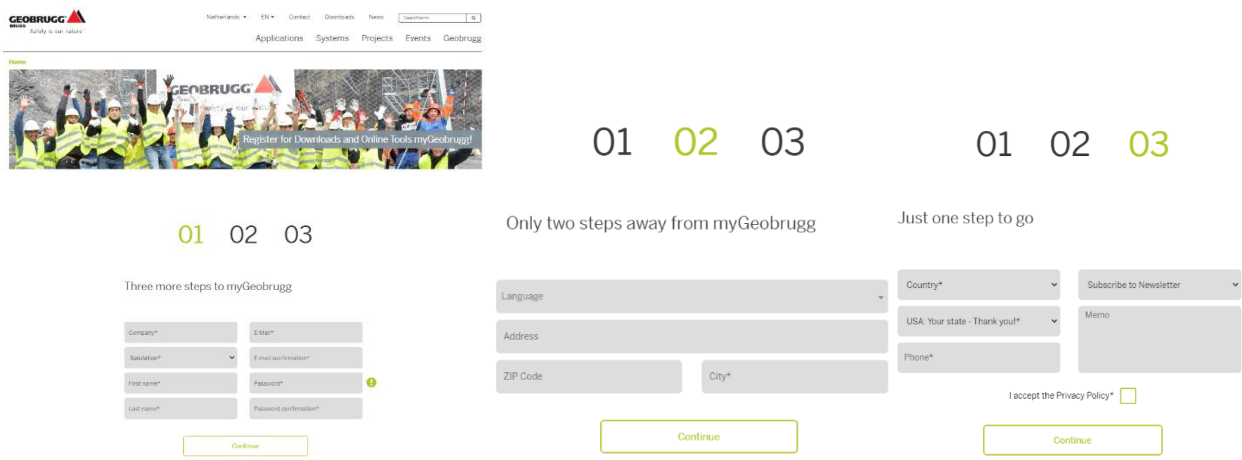
4. ACCESS TO THE ONLINE-TOOL

Our homepage www.geobrugg.com offers the access to the online software.

After clicking on the top right corner to “myGeobrugg” the below shown window appears, which offers the possibilities of the first-time personal registration, the Login and the function of the delivery of the forgotten password per e-mail.



If the program is used the first time one must click on “register here" and the registration form with the 3 steps should be filled out once. Afterwards one will get the personal username and password automatically sent per e-mail.



With the so gotten personal login it can be logged in to “myGeobrugg”.

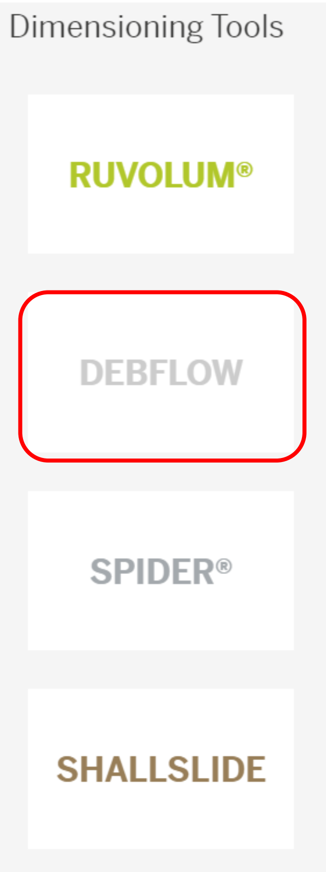
One can choose between the following dimensioning software packages:

RUVOLUM® Online Tool
The dimensioning tool for the TECCO® and SPIDER® slope stabilization system, in German, English, Spanish, Polish, Portuguese, Romanic, Russian, Chinese, Turkish, French and Italian.

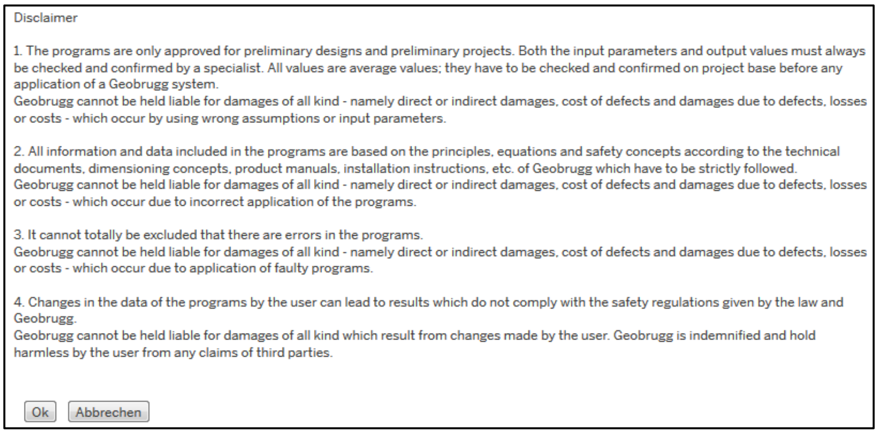
DEBFLOW
The dimensioning tool for flexible ring net barriers against debris flows, in German, English, Spanish, French, Russian and Chinese.

SPIDER®
The dimensioning tool for the SPIDER® rock protection system in German and English.

SHALLSLIDE
The dimensioning tool for flexible barriers against shallow landslides in German and English.



When starting the online tool, there is first a disclaimer to be accepted:


Disclaimer

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Ok Abbrechen

There is no installation of the software on the user’s computer neither necessary nor possible. The software has to be used online only.
Every calculation can be stored as a json or pdf file with all information included.

5. THE SOFTWARE

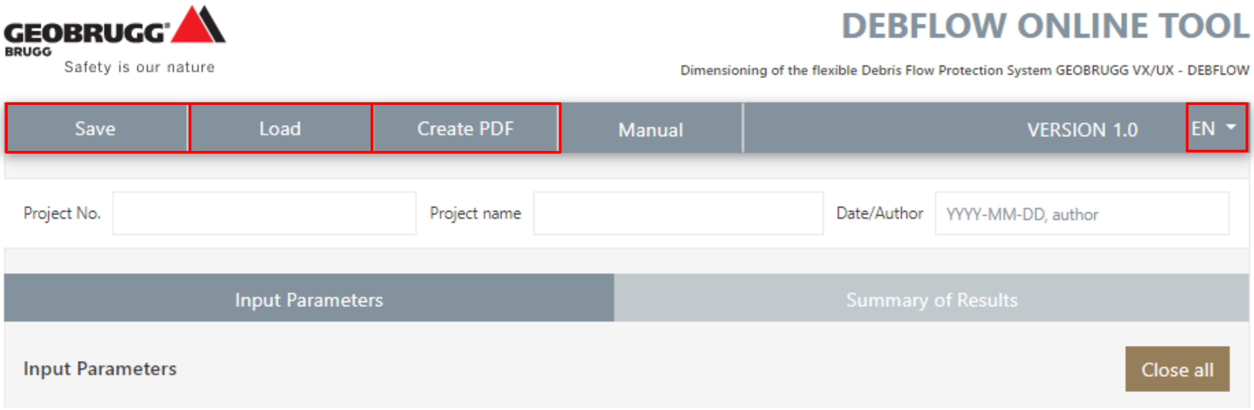
The software is structured in two pages format with “Input parameters” and “Summary of results”. After accessing the program, the below window will appear:

All the white colored boxes in the software indicates that they can be and has to be filled in manually according to the project specific conditions while the values without boxes indicate automatically calculated figures.

The software is structured as follows:

The upper part of the window

In this section four tabs are selectable:



Save: It allows the performed calculation to be saved locally on the computer.

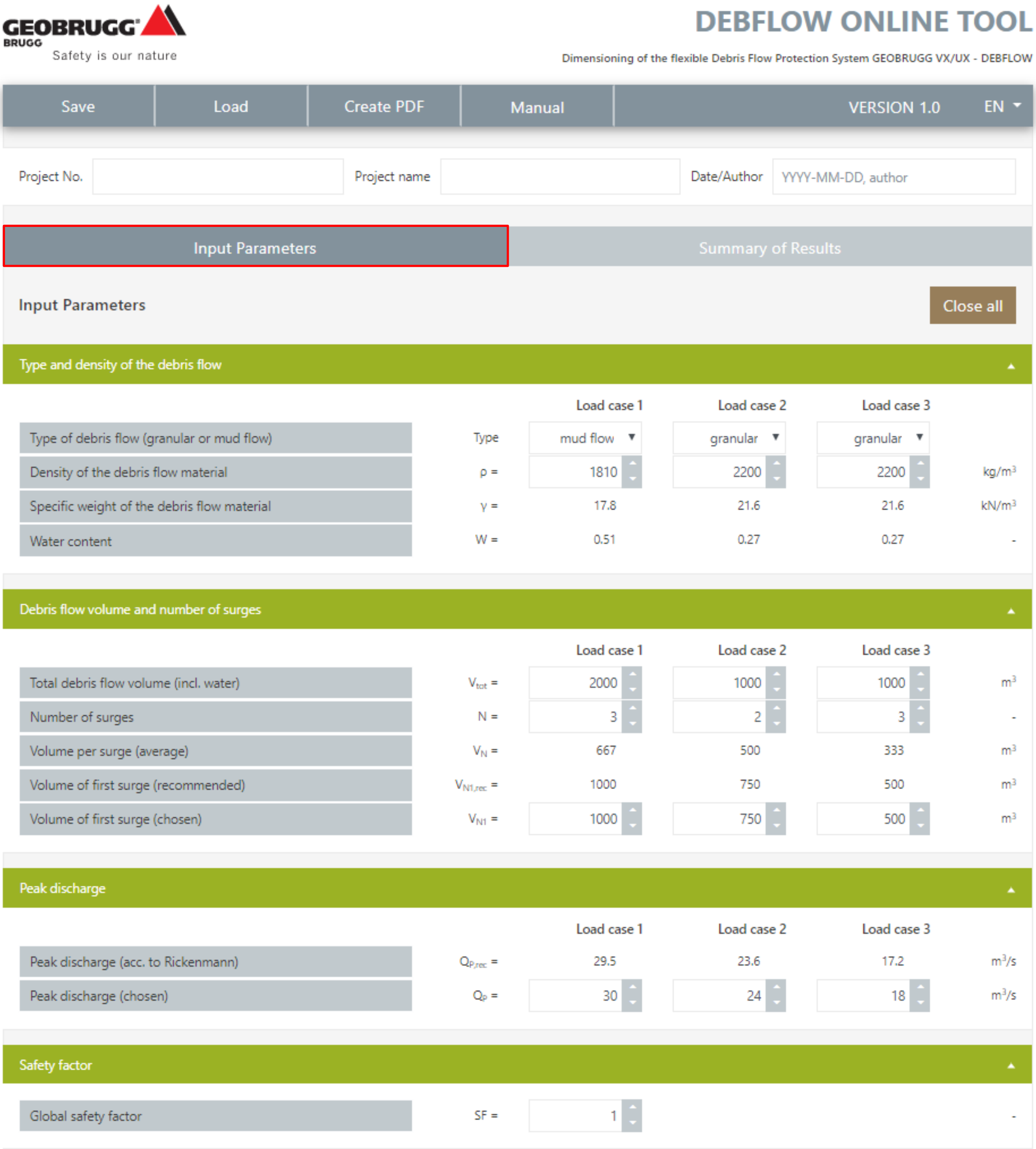
Load: It allows to load a previous saved calculation.

Create PDF: It allows to generate a PDF and print it out.

Language: Choose between English, German, Spanish, Russian and Chinese

Information about the project and the date can be typed in which will appear then on the print out in the head area.

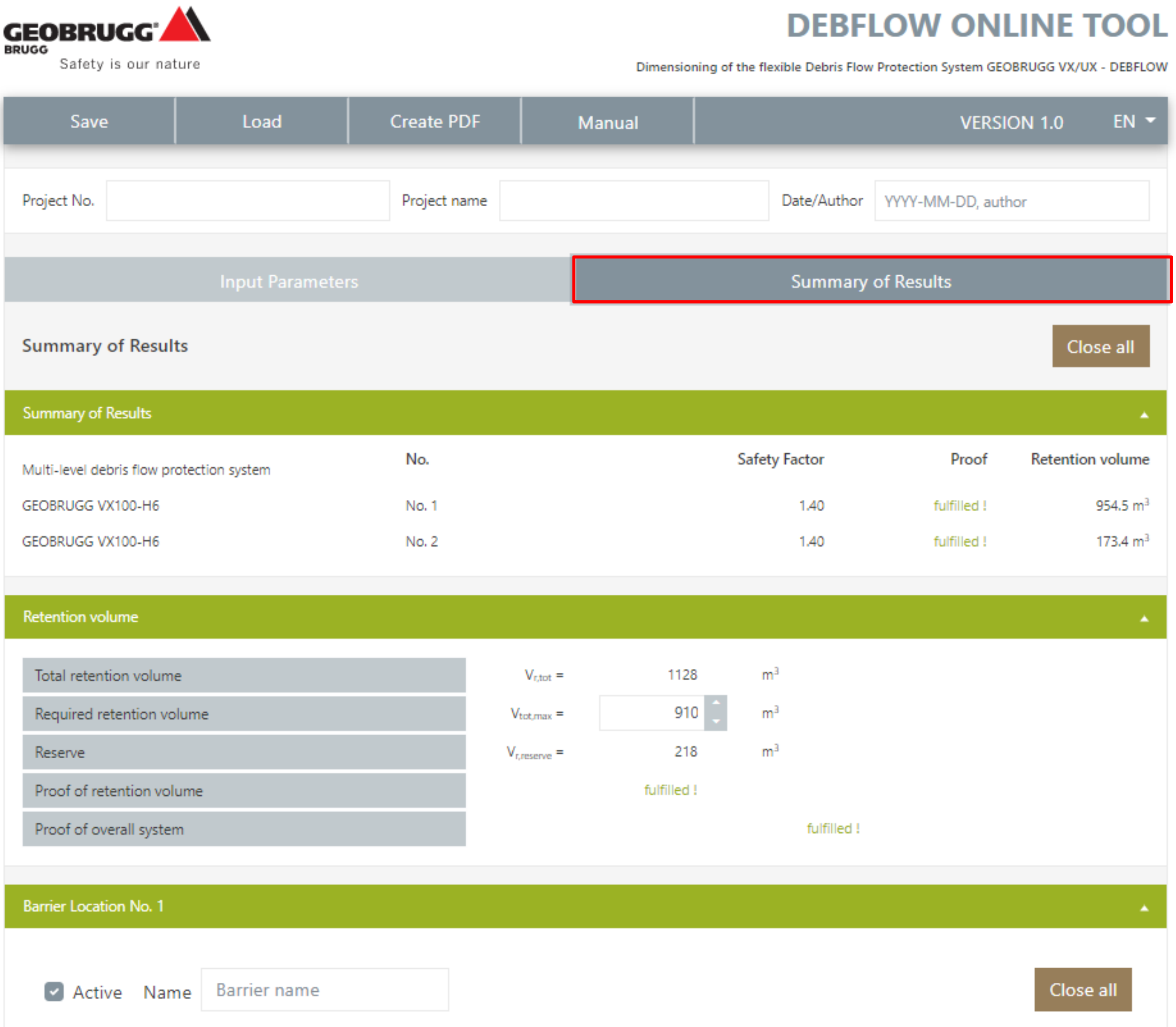
“Input parameters” window:



The main input parameters to be considered in the calculation are directly visual in the starting window and can be adapted there. They can be overwritten in the field or adjusted by clicking with the mouse. When the window is active, the “Input parameters” button has a steel color while when is not active is grey colored.

"Summary of results" window:

This window facilitates choosing the right type of the debris flow barrier with the corresponding dimensions and verifies if the proofs are satisfied or not. The window becomes active by clicking the grey colored "Summary of results" button which turns into a steel colored afterwards.



The following input parameters (the debris flow parameters) can be defined:

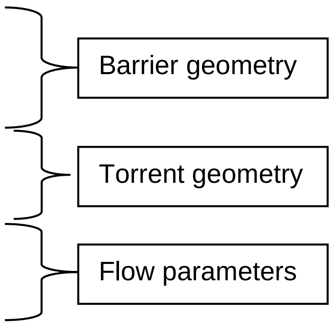
- Choice of three different load cases possible
- Type and density of the expected debris flow
- Total volume
- Expected number of waves
- Expected peak discharge or empirically calculated peak discharge
- Global safety factor

Summary of results concerning the retention volume

- Checking of retention volume compared to required retention volume

Barrier specific input parameter for each selected barrier

- Height of selected barrier
- Span width of the upper support ropes
- Span width of the lower support ropes
- Distance to previous barrier (in case of multilevel barriers)
- River bed inclination
- Inclination angle of the deposition (to calculate the retention volume)
- Calculated or expected front velocity
- Calculation of the flow height
- Recommended maximum basal opening height



Choice of the standard barrier system

- Proof of geometric barrier design data compared to geometry of standard systems

Proofs of maximum dynamic loading (stopping process)

- Proof of dynamic loading compared to resistance of barrier
- Resistance depends on the chosen standard system and the global safety factor
- Dynamic loading depends on the debris flow input parameters and the flow parameters

Proofs of static loading (overtopping)

- Calculation of the static loading depending on the chosen system
- Checking the resistance of the barrier against the hydrostatic debris pressure

Proof of the chosen standard system

- Checking of dynamic load case
- Checking of static load case
- Checking of all given load cases (Loadcase 1, 2 and 3)
- Checking of geometrical parameter

Activation of the next projected barrier in case of a multilevel barrier system

Calculation of the overall retention volume of all selected barriers

5.1 Input Parameters

5.1.1 Debris flow parameters

Debris flows behave different all over the world and may not even act in the same manner in one torrent. Therefore, a range of input parameters can be specified for the software tool DEBFLOW which seem to be common. These ranges of input parameters are shown in the following Table 1.

Parameters	Short sign [ ]		Default value	Minimum value	Maximum value
Density granular flow	$\rho_{granular}$	[kg/m³]	2200	1900	2300
Density muddy flow	$P_{mudflow}$	[kg/m³]	1800	1600	2000
Debris flow volume	V_{total}	[m³]	1000	100	10000
Number of surges	N	[-]	3	1	10
Volume of first surge	$V_{N,1}$	[m³]	3000	10	10000
Peak discharge	Q_P	[m³/s]	50	1	100

Table 1: Debris flow input parameters

More about how to choose the input parameter of debris flow can be found in several articles like [12] or [11]. These input parameters can be varied for three different kinds of load cases.

5.1.2 Load cases

In the program three different kind of load cases can be chosen (see figure 6). This option is necessary, if different load cases appear and have to be considered.

Example:
Two load cases have to be considered

- Mudflow, release volume ≈ 2000 m³ in three surges, density ρ ≈ 1800 kg/m³ with high velocity v = 9 m/s
- Granular flow, release volume ≈1000 m³ in two surges, density ρ ≈ 2200 kg/m³ with slower velocity v = 3 m/s
- Optional load case 3

For every load case, the discharge will be calculated empirically based on Rickenmann [7]. But if you have better information about peak discharge data you can choose your own decisive value in the program directly after the proposed value. If you don't have any experiences in evaluate the peak discharge please set $Q_{p}=Q_{p,rec}$.

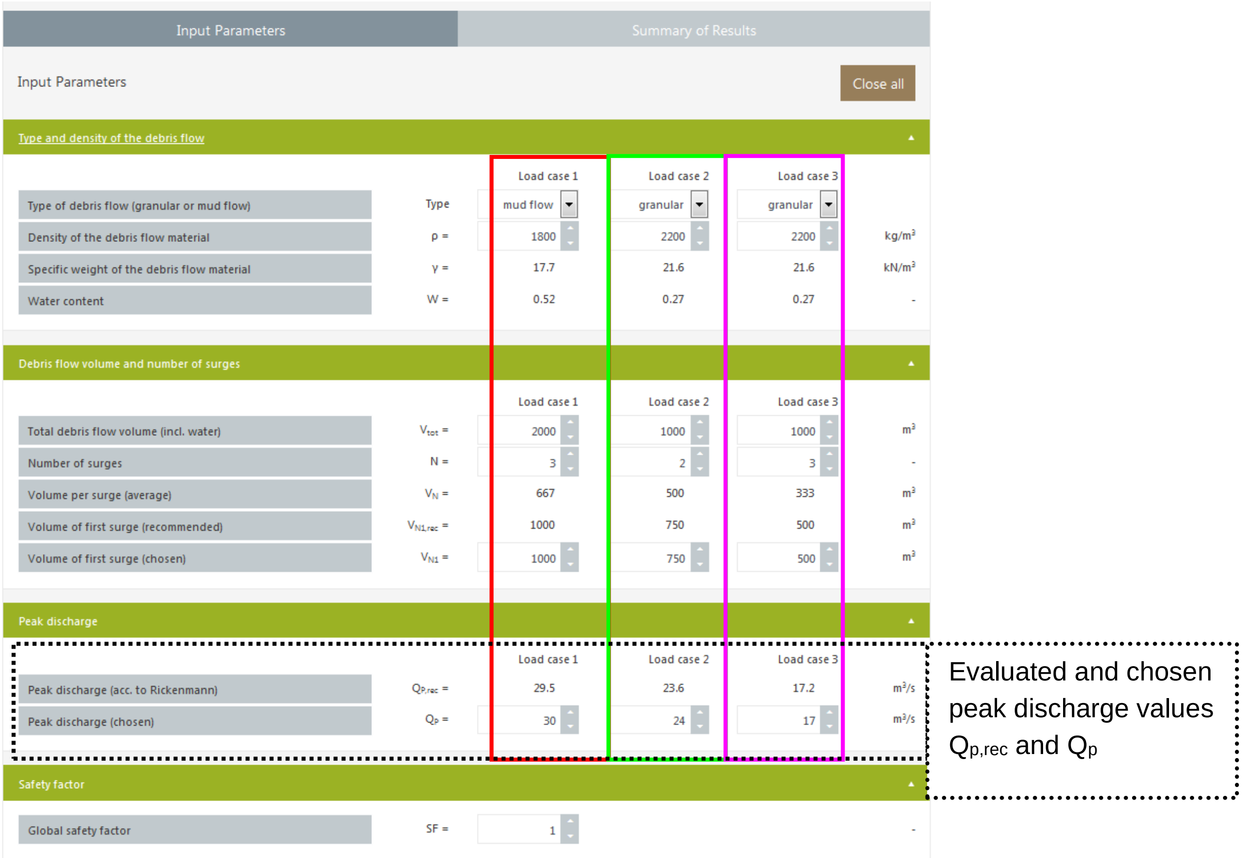


Figure 6: Choice of load cases for different kind of expected debris flow events.

Also the velocity can be chosen for every load case separately. The decisive load case is determined by the DEBFLOW software afterwards. More about the barrier design input parameters is written in Chapter 5.1.4 and the later necessary decisive barrier design is shown in Chapter 5.1.5.

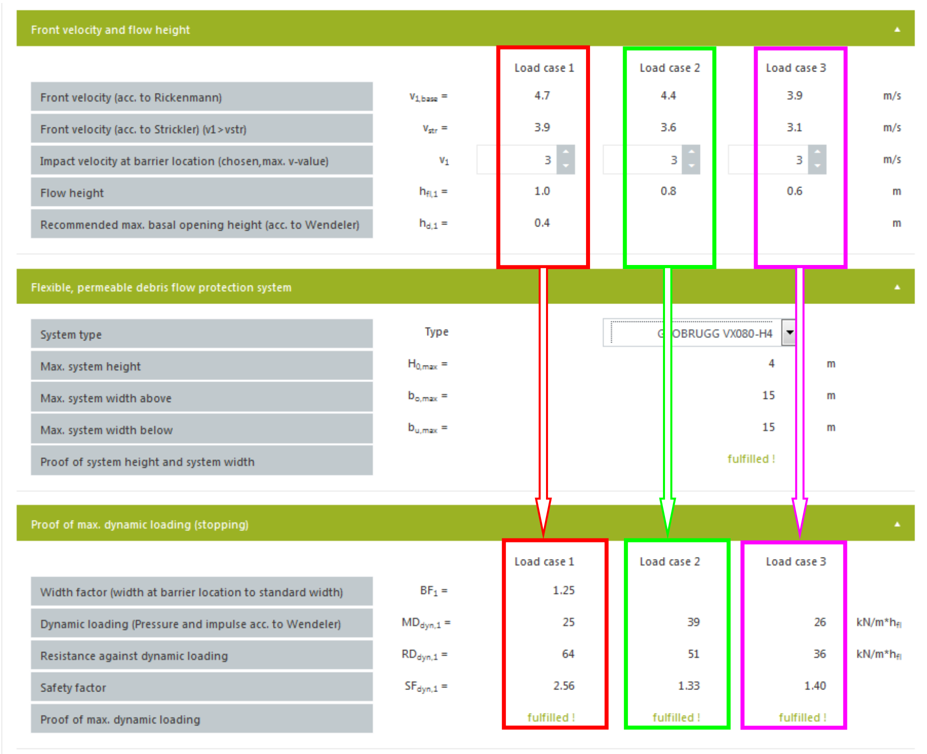


Figure 7: Velocity input for different load cases.

5.1.3 *Global safety factor*

The global safety factor SF can be chosen between 1.0 up to 1.5 depending on the risk potential in case of damages [11].

5.1.4 *Input parameters for the barrier design*

5.1.4.1 Geometry of barrier location

Most of these parameters influence the later chosen standard barrier system. The range of application is shown in Table 2.

Parameters	Short sign [ ]		Default value	Minimum value	Maximum value
System height	H_0	[m]	4	2	6
Width of torrent at the bottom	b_u	[m]	10	4	12
Width of torrent at the top	b_o	[m]	15	6	25
Distance to previous barrier upstream	L_o	[m]	500	5	500
river bed inclination	I_S	[%]	18	5	80
Deposition inclination of filled barrier	I_S'	[%]	12	0	80

Table 2: Geometric parameters for the projected installation place.

If the minimum value $L_0 = 5.0$ m is selected, the impact velocity of the flow is reduced to $v_{red}=0.4 \cdot \max(v_{base};v_{str})$ (see figure 10) according to the performed laboratory tests [13]. Because of the overflowing process the impact velocity to next barrier is reduced.

5.1.4.2 Calculation of retention capacity

With values of table 2 and the fixed barrier inclination ξ (barrier always 5 ° inclined in forward) the approximately retention capacity of each barrier is calculated. If the length of the retained material $L_1, L_2, \ldots > L_{0,1}, L_{0.2}\ldots$, the retention capacity is influenced by the next barrier upstream and DEBFLOW software is considering this in the retention capacity. The maximum length of the retained material is then $L_1, L_2, \ldots = L_{0,1}, L_{0.2}\ldots$.

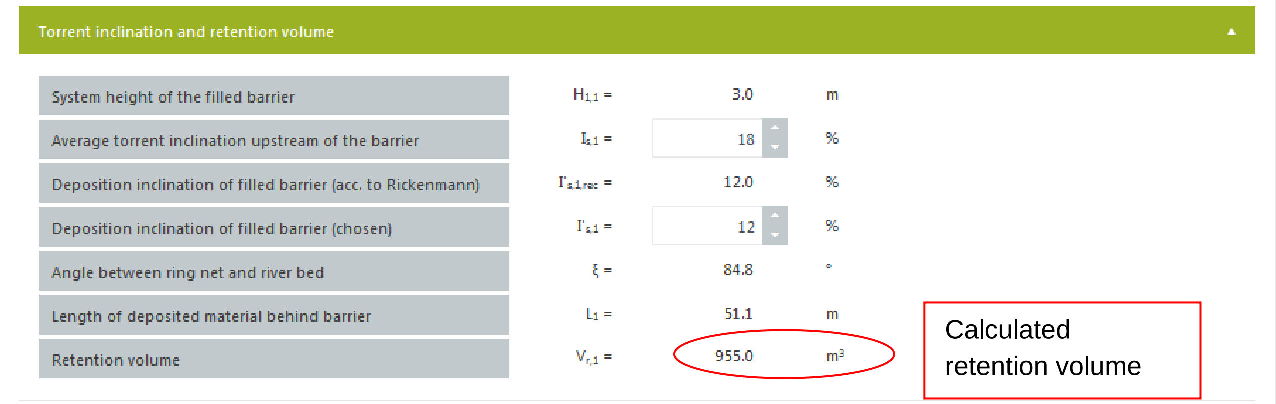


Figure 8: Calculation of retention capacity of entered barrier.

5.1.4.3 Impact flow parameters

The flow parameters are important to calculate the impact force of the debris flow surge impacting the barrier. Caused by resistance of flexible barriers and very high impact forces there are the following limitations for the design of impact velocity:

Parameters	Short sign [ ]	Default value	Minimum value	Maximum value
Chosen front velocity	v [m/s]	3	1	10

Table 3: Flow specific input parameters for every barrier location

Debris flow front velocities can be determined out of curve deposit, river bed inclination and deposit behavior in general. But therefore, an explicit reconstruction of a past event is necessary. If you don't have any information about front velocities, please take the empirical calculated values the DEBFLOW program advices you! The first velocity value is based on empirical values published by Rickenmann [7] and the second check of flow velocity is done with v_{str} based on Japanese Guidelines for debris flow [8] (based on a Strickler flow regime).

Based on the condition of continuity, the flow height of the debris flow h_{fl} is determined out of the flow velocity and the channel width at the bottom. A maximal possible value for the basal opening h_d is proposed by DEBFLOW calculated out of the determined flow height h_{fl}.

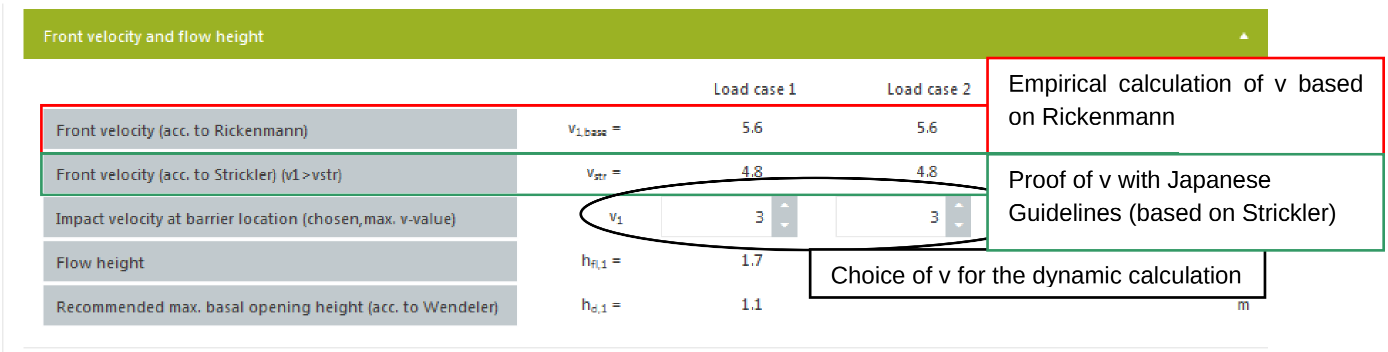


Figure 9: Calculation of flow velocity and entry value.

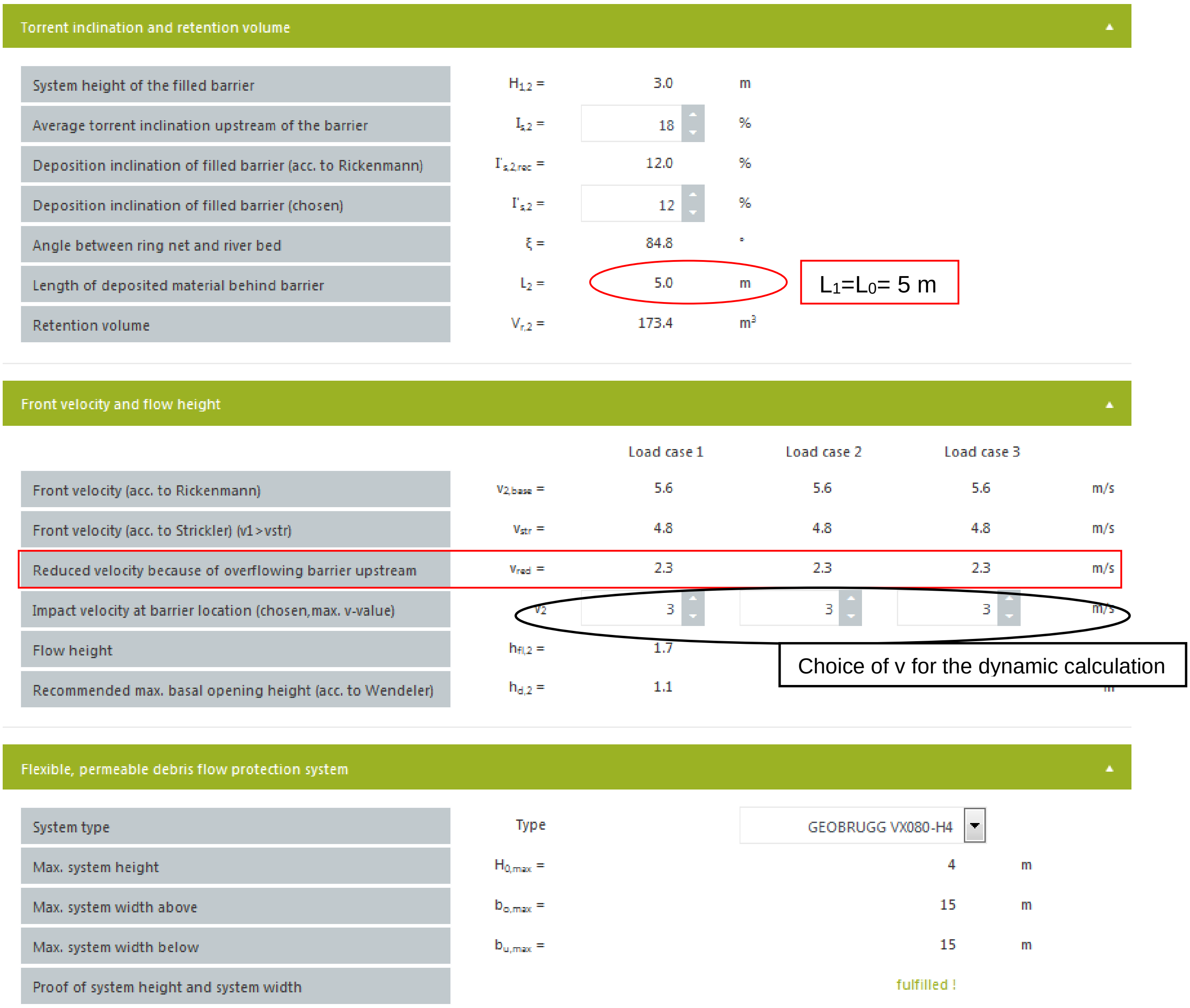


Figure 10: Calculation of reduced flow velocity v_{red} for very close together planned barriers with L_0=L_1=5 m.

5.1.5 *Choice of the decisive standard barrier system*

An overview of the standard systems and their design and geometrical limitations are shown in Table 4.

Standard barrier system	max Height H_{max} [m]	max width top $b_{o.,max}$ [m]	max width bottom $b_{u,max}$ [m]
Type VX060L-H4	4	10	5
Type VX080-H4	4	15	8
Type VX140-H4	4	15	8
Type VX100-H6	6	15	10
Type VX160-H6	6	15	10
Type UX060L-H4	4	20	10
Type UX100-H4	4	25	10
Type UX160-H4	4	25	10
Type UX120-H6	6	24	12
Type UX180-H6	6	24	12

Table 4: Standard systems based on FARO simulations.

The first number is the intensity of the debris flow surge acting on the width of the barrier and the second number describes the height of the barrier. The VX systems are without posts for smaller sections and the UX with two posts in the middle for wider flow sections. You can only choose the standard system which fits to your geometric input values. If the standard barrier you have chosen is too weak for the debris flow loading, the DEBFLOW software tells you that the proof of the barrier is not fulfilled. In this case you have to choose a stronger standard barrier.

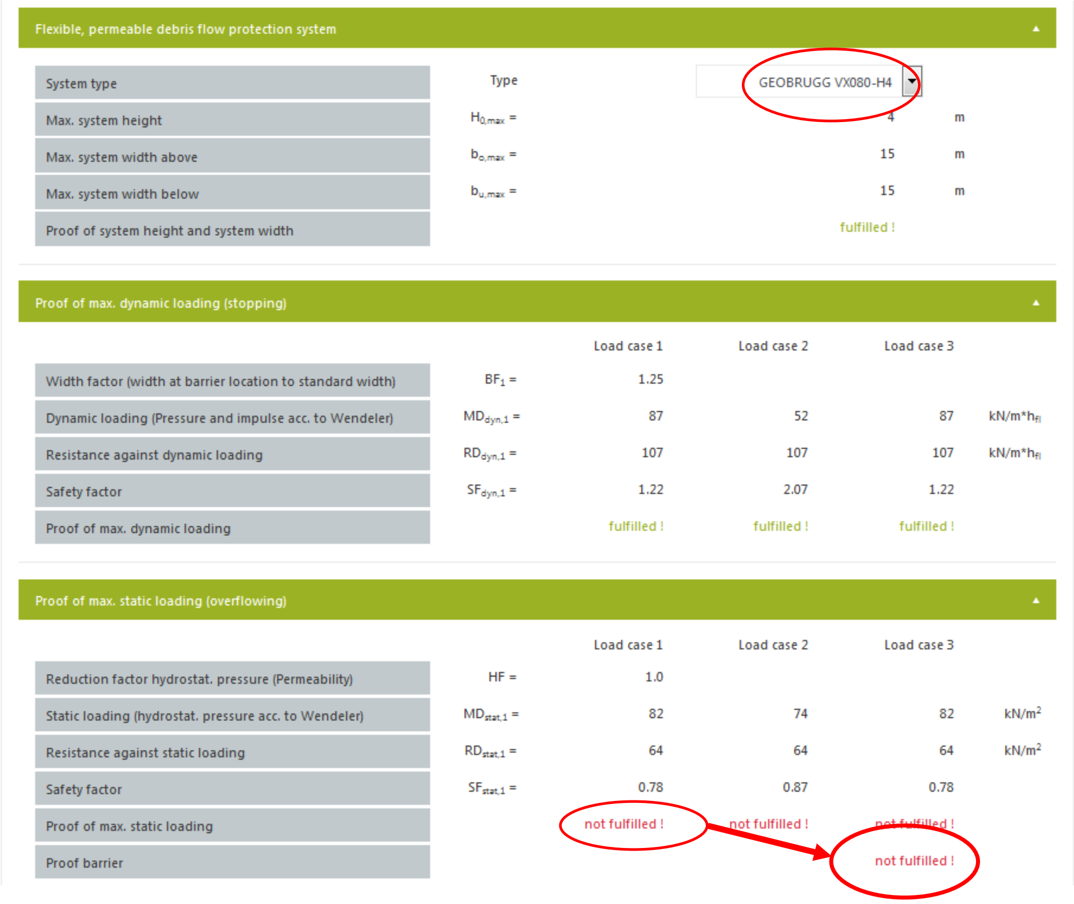


Figure 11: Example for a too weak barrier for the static loading case

5.1.6 *Calculation of multilevel barriers*

If you want to calculate several barriers in line, you have first to activate the second barrier after the successful input of the first one (see figure 12).

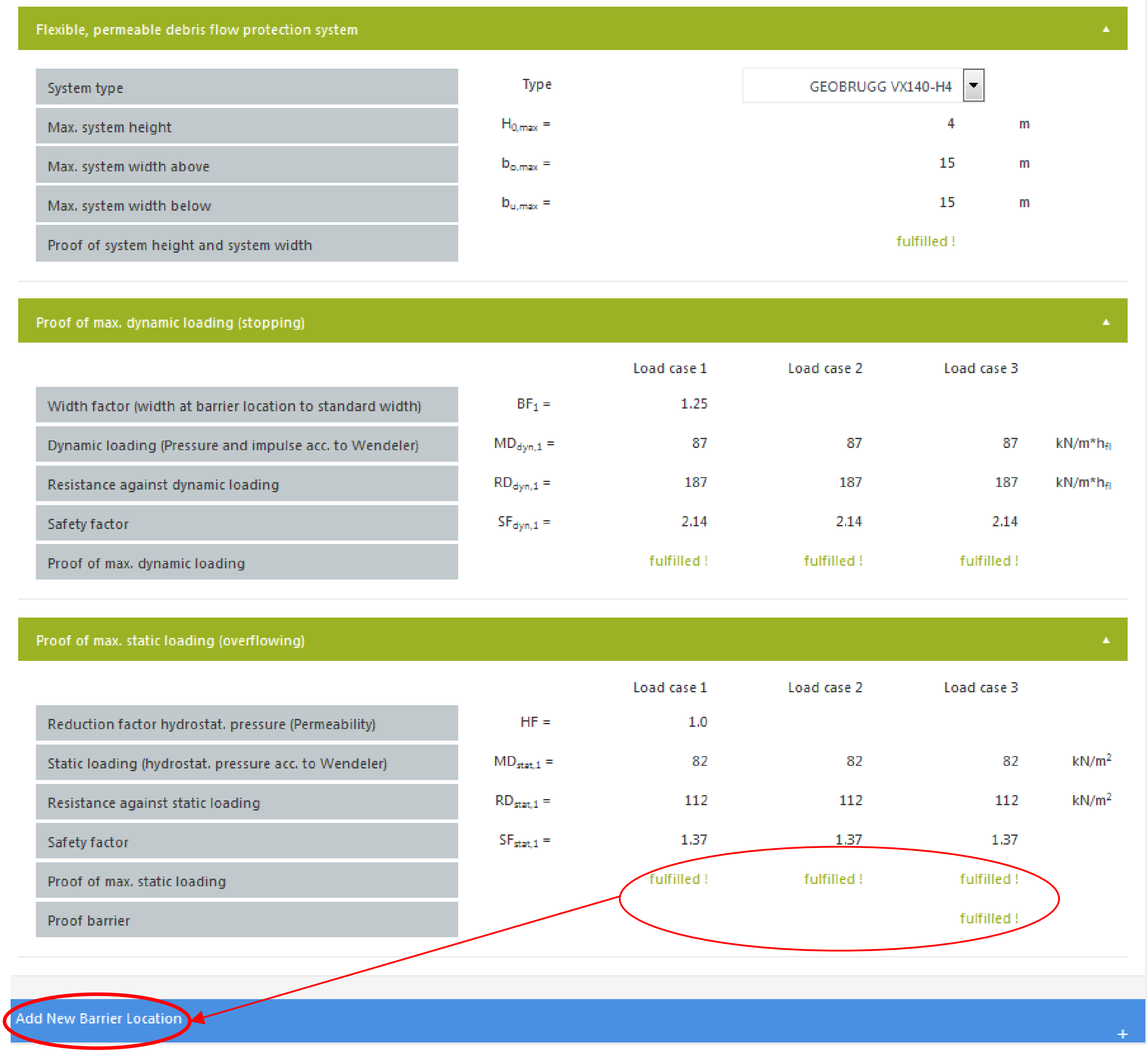


Figure 12: Activation of barrier 2 after the successful calculation of the barrier at location 1.

After design of the second barrier you have to continue with the next barrier until you will achieve your desired retention volume. The overview of the retention volume of each barrier compared to the required retention volume is shown in DEBFLOW. An example for two barriers is shown in Figure 13. Every safety factor of each barrier is checked with the chosen global safety factor. If each safety factor of each barrier is equal or bigger than the chosen global safety factor the complete multilevel barrier is fulfilled. If also the required retention capacity is fulfilled all the calculations are fulfilled (see figure 13).

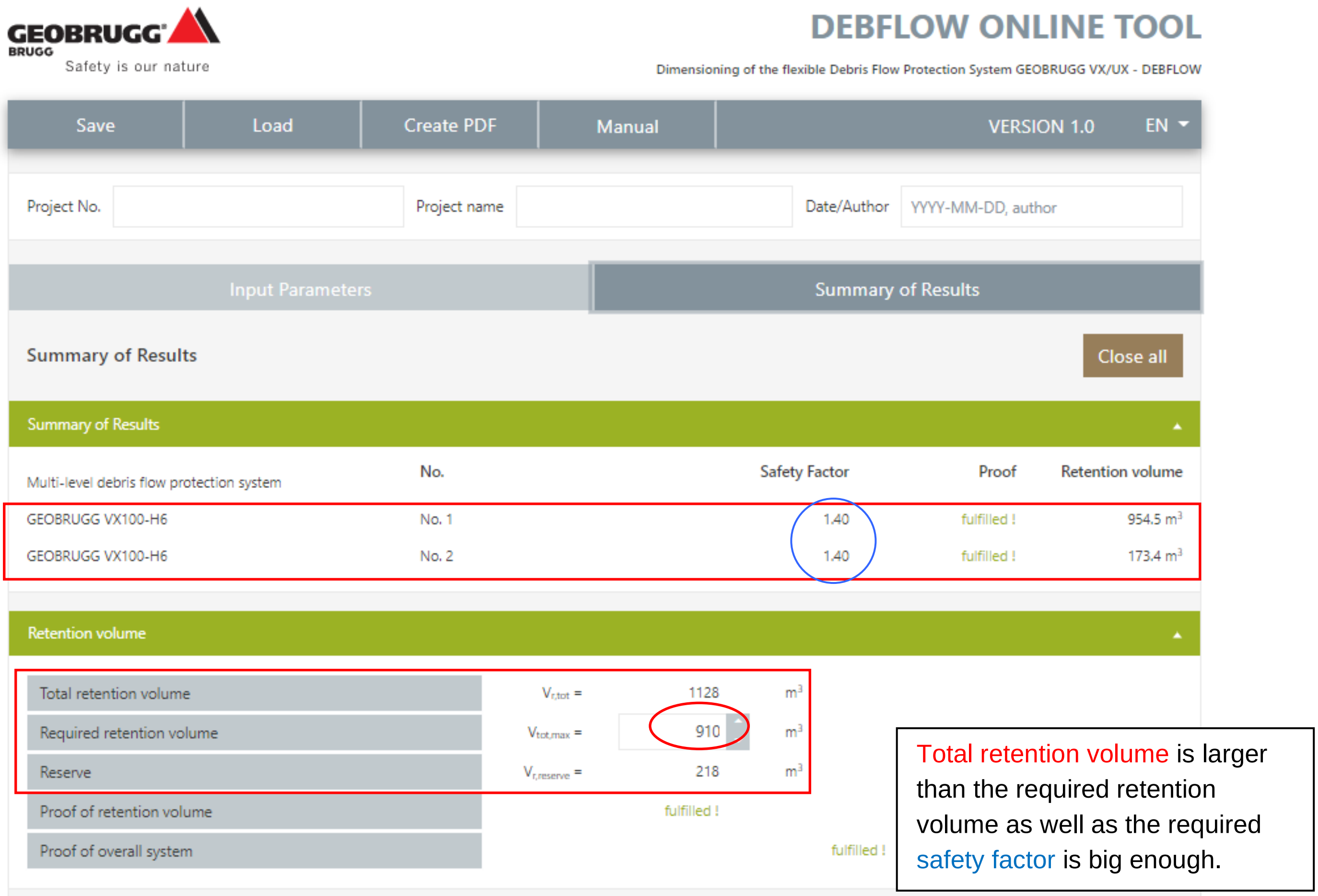


Figure 13: Summary of the results for all activated barriers (safety factor and retention volume)

6. CONCLUSIONS

- DEBFLOW covers STANDARD TYPE debris flow barriers with flexible ring nets for muddy and granular debris flow within certain limits
- Proof of barrier resistance is given for stopping of the front, filling of the barrier and overflowing
- Proof of standard channel retention geometries is given

The program should be used as a quick and reliable calculation in the earliest planning stage. If some parameters of the barrier do not correspond to standard barrier parameters, a solution may still be possible! Please contact your Geobrugg agent for a design proposal.

REFERENCES

[1] De Natale, J.S. et al. (1996). Response of the Geobrugg cable net system to debris flow loading, report by California Polytechnic State University.

[2] Duffy, J.D., Peila, A. (1999). Case studies on debris and mudslide barrier systems in California.

[3] Mitzuyama et al. (1992). Prediction of debris flow peak discharge, Interpraevent, Bern, Bd. 4, 99-108.

[4] Muraishi, H., Sano, S. (1997). Full scale rockfall test of ring net barrier and components.

[5] Philips, C. J. and Davies, T. R. H. (1991). Determing rheological parameters of debris flow material. Geomorphology, 4:101-110.

[6] PWRI (1988). Technical Standard for measures against debris flows (draft), Ministry of Construction, Japan.

[7] Rickenmann, D. (1999). Empirical relationships for debris flows, Natural Hazards, 19(1), 47-77.

[8] Rickenmann, D. (2001). Estimation of debris flow impact on flexible wire rope barriers, Birmensdorf, interner Bericht, unpublished.

[9] Volkwein, A. (2004). Numerische Simulation von flexiblen Steinschlagschutzsystemen.

[10] Wendeler, C., B. W. McArdell, D. Rickenmann, A. Volkwein, A. Roth, and M. Denk (2006). Testing and numerical modeling of flexible debris flow barriers. In Zhang, M. and H. Wang: Proc. Of the sixth International Conference on Physical Modeling in Geotechnics, pp. 1573-1578. Balkema.

[11] Wendeler, C. (2009). Loading approach for flexible debris flow barriers, in preparation.

[12] Iverson, R. M. (1997). The physics of debris flow. Rev. Geophysics, 35(3): 245-296.

[13] Speerli, J., R. Hersperger (2009). Murgangmodellierung Geobrugg, Bericht des IBU Hochschule für Technik Rapperswil.