2D-Modelling of Dam Breaches: Case Studies Zurich

Basement User Meeting, 26.01.2023

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- Introduction
- Method
- Results and Discussion of Case Studies
- Outlook

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Introduction

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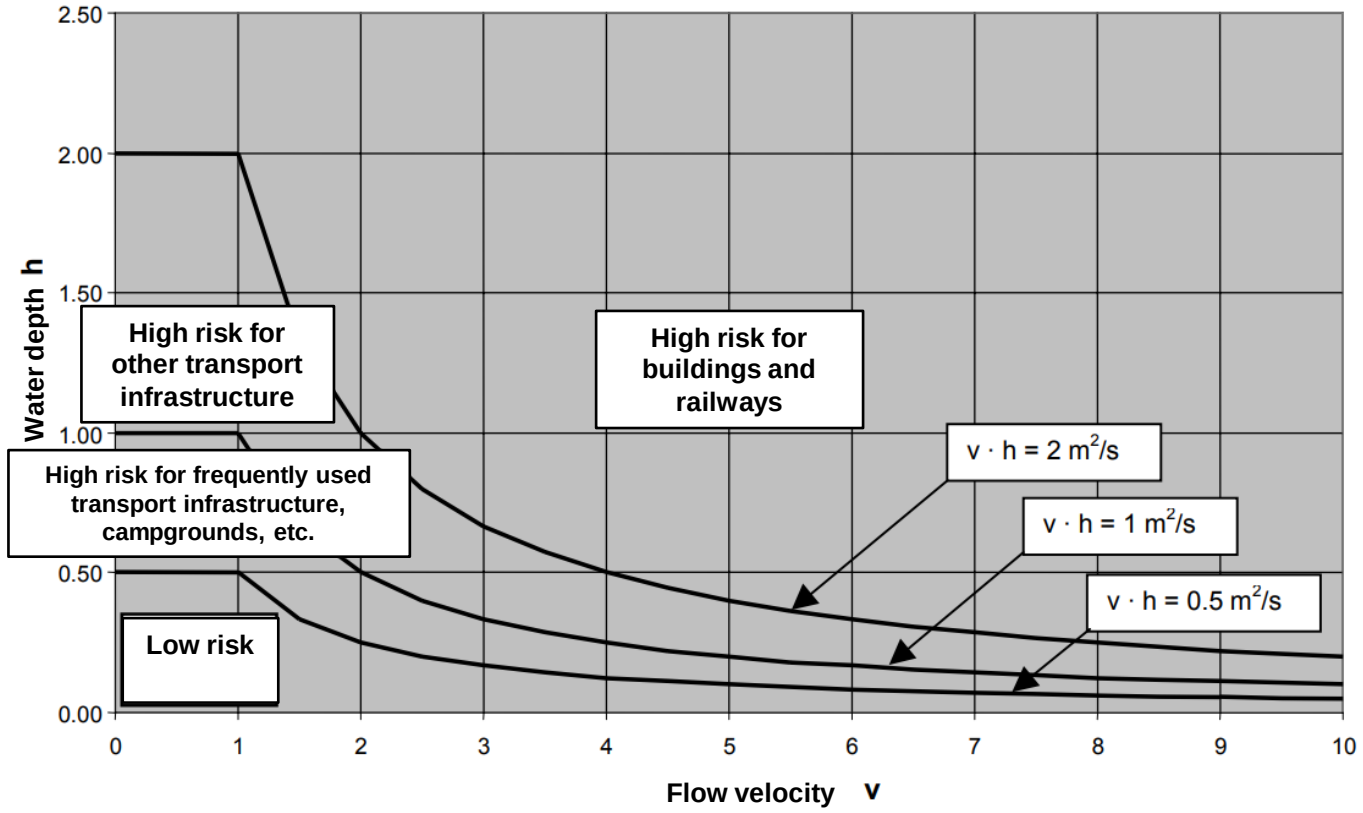
Introduction: Legal Basis

- Water Retaining Facilities Act WRFA and Water Retaining Facilities Ordinance WRFO regulate the safety of water retaining structures from construction phase through to operating phase
- Criteria:
  - Size (dam height > 10 m **or** dam height > 5 m and volume > 50’000 m^3)
  - High risk potential (danger to human lives and/or extensive property)
- If subjected to WRFA and WRFO:
  - Increased demands on dam stability and flood safety
  - Increased demands on maintenance and monitoring

Introduction: High Risk Potential

- Obligation to check the high risk potential for all small dams in Switzerland



BFE, 2014

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Introduction: Water Retaining Structures in Zürich

> 300

Small in size

→ assess high risk potential

35

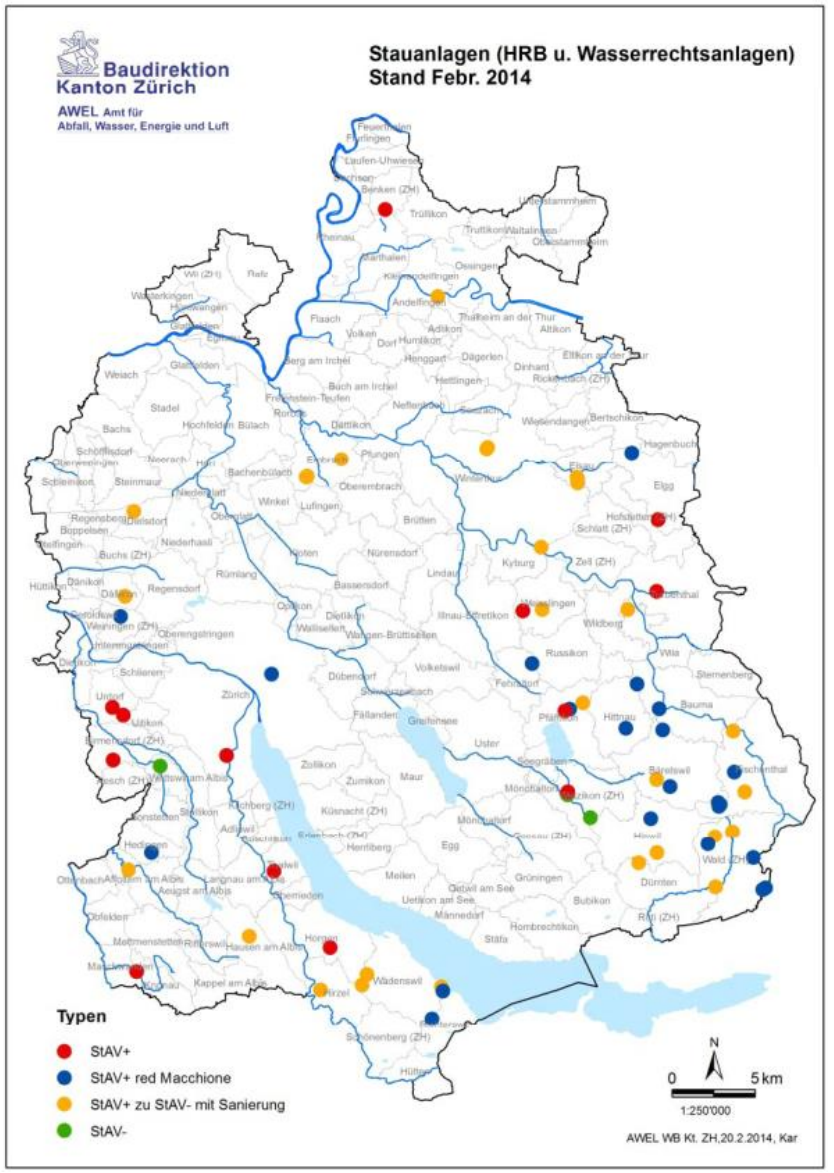
High Risk Potential

30

Measures are necessary

Rest

No High Risk Potential



AWEL, 2014

Introduction: Previous Studies

- Pöyry:
  - Use of empirical formula for breach discharge, dependent on breach geometry (standard breach, instant failure, volume is not considered)
  - Empirical estimation of flood wave propagation and intensity based on CTGREF (1D) or BEFFA (2D)
- Case Studies
  - Assessment of flood wave propagation and intensity with 2D-modeling

BFE, 2014

Rechteck:

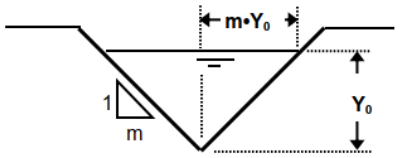
$Q_b = 0.93 \cdot L \cdot Y_0^{3/2}$

$F = L \cdot Y$

Dreieck:

$Q_0 = 0.72 \cdot m \cdot Y_0^{5/2}$

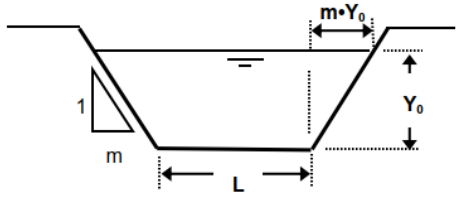
$F = m \cdot Y^2$



Trapez:

$Q_b = 0.72 \cdot m \cdot Y_0^{5/2} + 0.93 \cdot L \cdot Y_0^{3/2}$

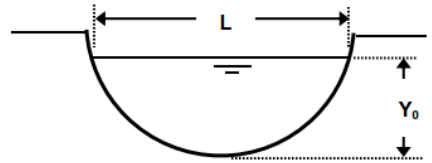
$F = L \cdot Y + m \cdot Y^2$



Parabel:

$Q_b = 0.54 \cdot L \cdot Y_0^{3/2}$

$F = 2/3 \cdot L \cdot Y$



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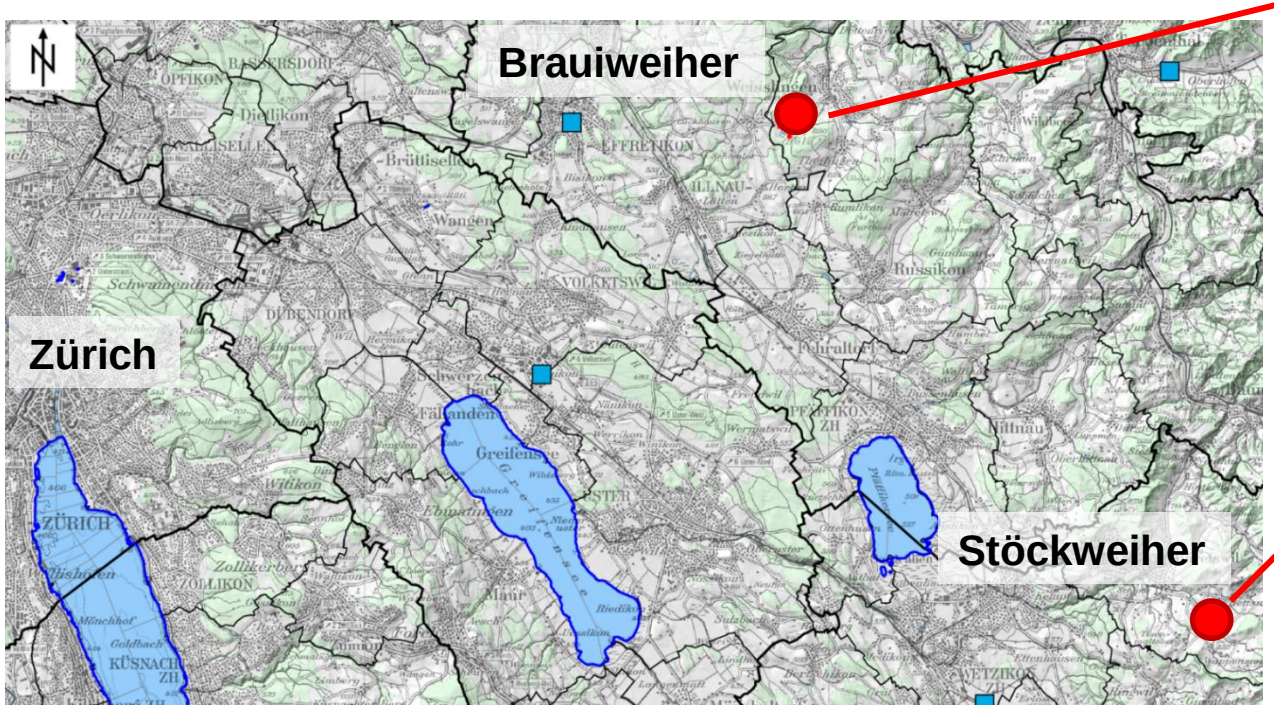
Introduction: Case Studies

- Commissioned by the canton of Zurich,
  Amt für Landschaft und Natur (ALN)

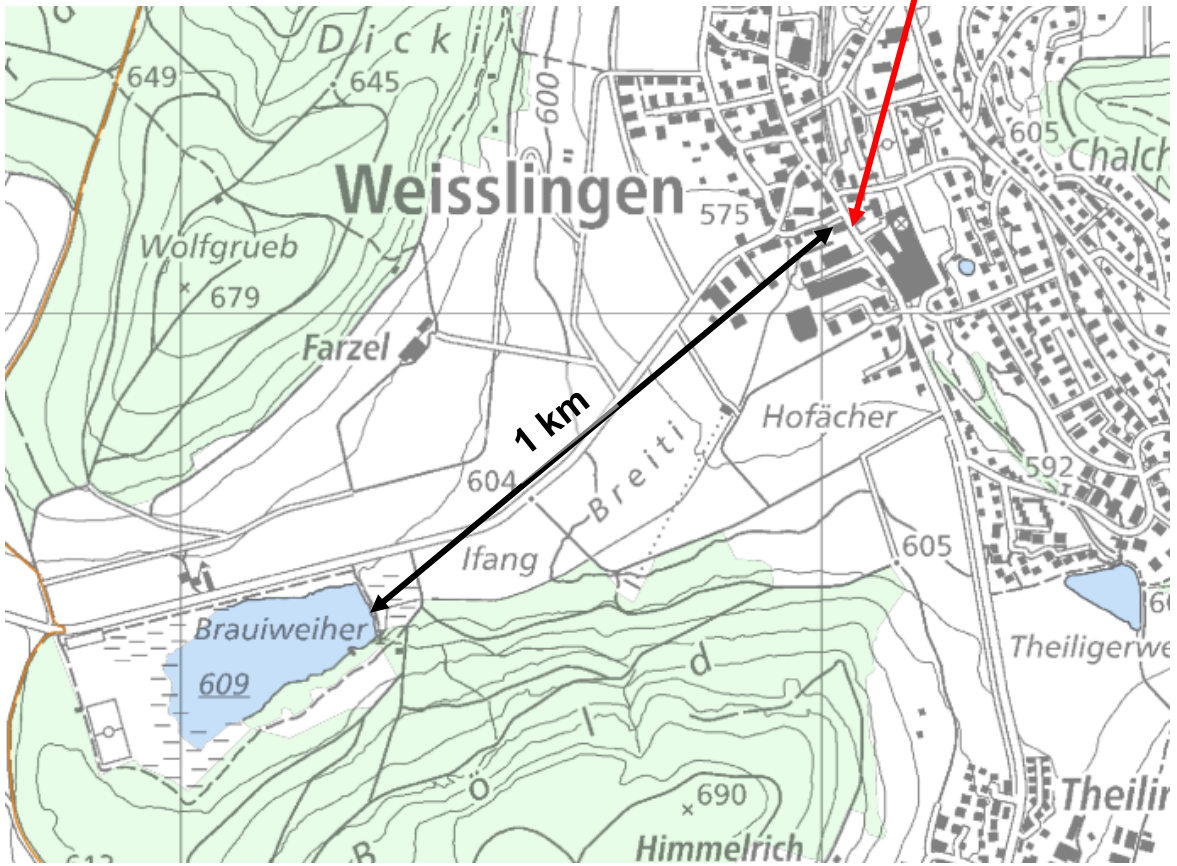


Maps.zh.ch, 2022

Introduction: Brauiweiher

Reservoir Capacity V	110’000 m^3
Dam Height H	3.1 m
Historical Use	ice production for a brewery, reservoir
Current Use	nature reserve

Intensity 2.7 m^2/s (Pöyry)



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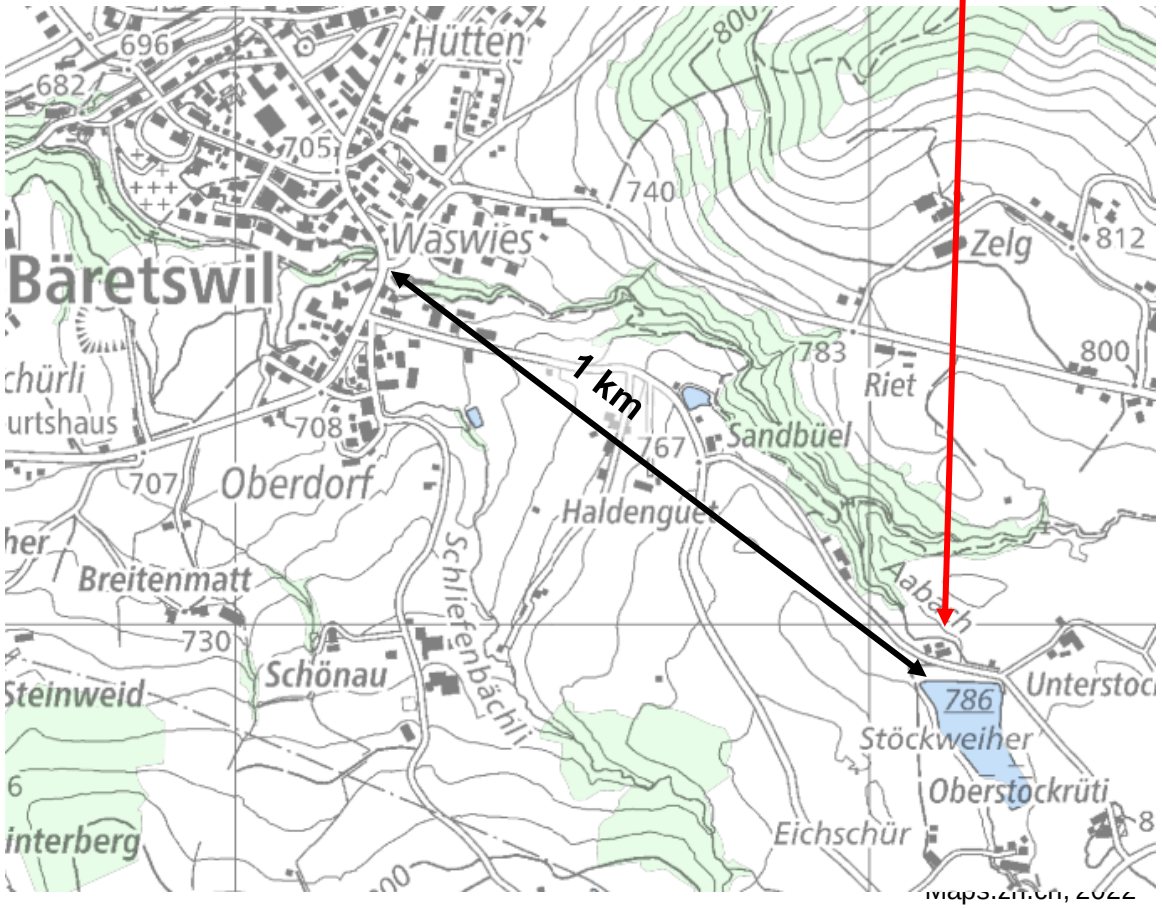
Introduction: Stöckweiher

Reservoir Capacity V	50’000m^3
Dam Height H	5.5 m
Historical Use	hydropower
Current Use	nature reserve

Intensity 8 m^2/s (Pöyry)



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Method

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Automated Mesh Generation (1)

- Goal: Efficient export of breaklines and points for mesh generation from cadastral survey

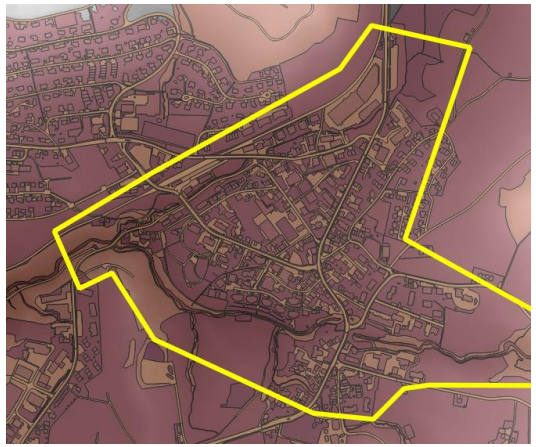
Automated Mesh Generation (2)

Input

Perimeter:
- Polygon (.shp)

Land coverage:
- Polygons (.shp)

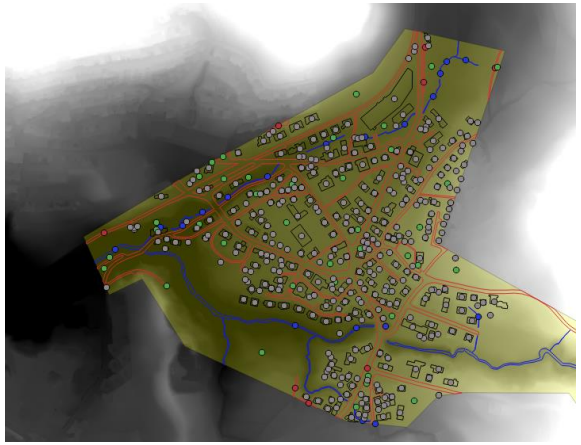
Elevation (DEM):
- Raster (.tif)



Putput

FME

Automated generation of relevant break lines and region points

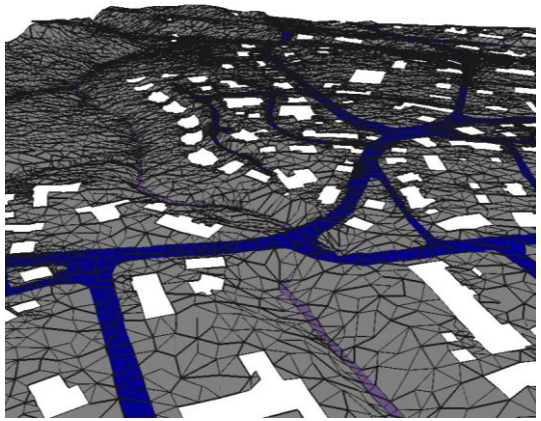


QGIS, BASEmesh

- If necessary: Adjustment of break lines and region points
- Generation of XL-Mesh with BASEmesh

Output

Automatically generated mesh (.2dm)



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Automated Mesh Generation (3)

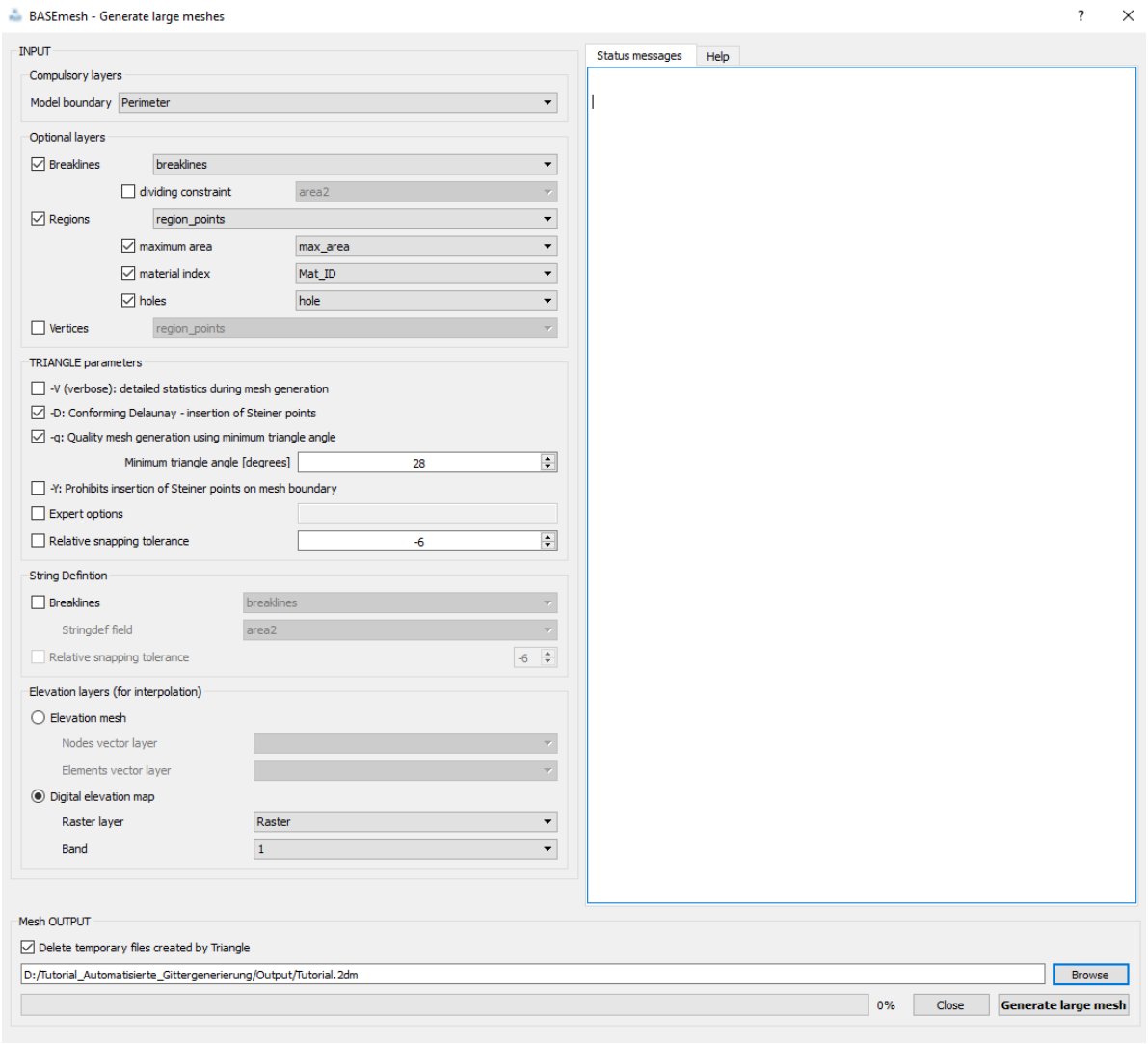
FME-Tool:

- 1. Open FME Workbench
- 2. Attach Input data (Perimeter und Land Coverage)
- 3. Define folder for Output data (Break Lines and Region Points)
- 4. Run FME

Automated Mesh Generation (4)

QGIS:

- 1. Adjust Input Data (Breaklines, Region Points) if necessary
  - Breaklines and Region Points contain the attribute «Type», where the object category is recorded
- 2. Generating mesh using XL-Mesh (BASEmesh)



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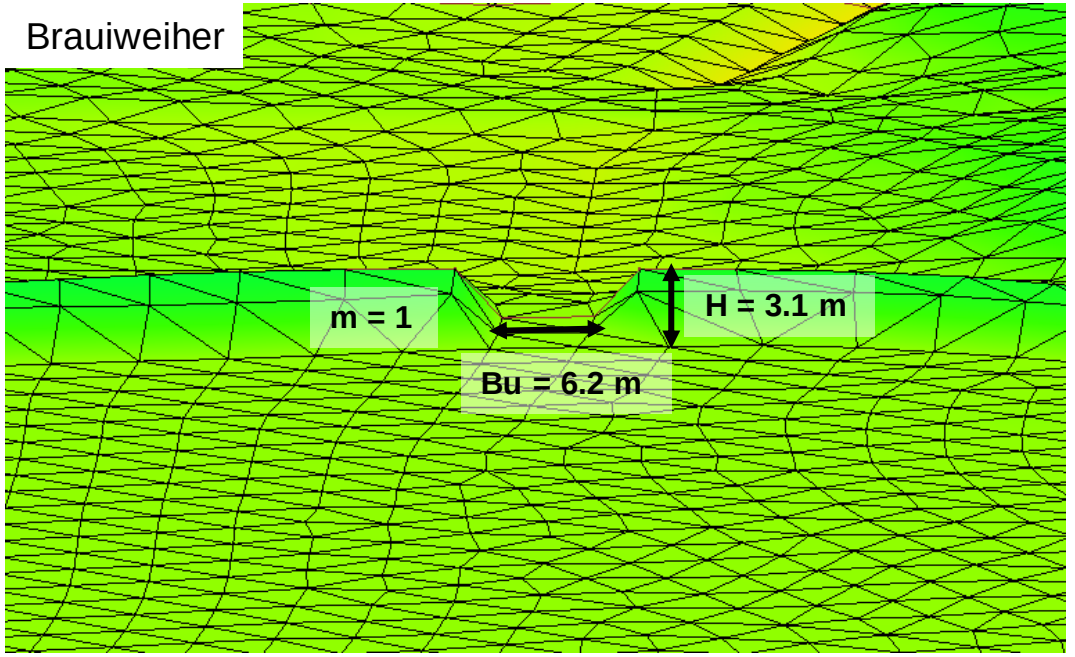
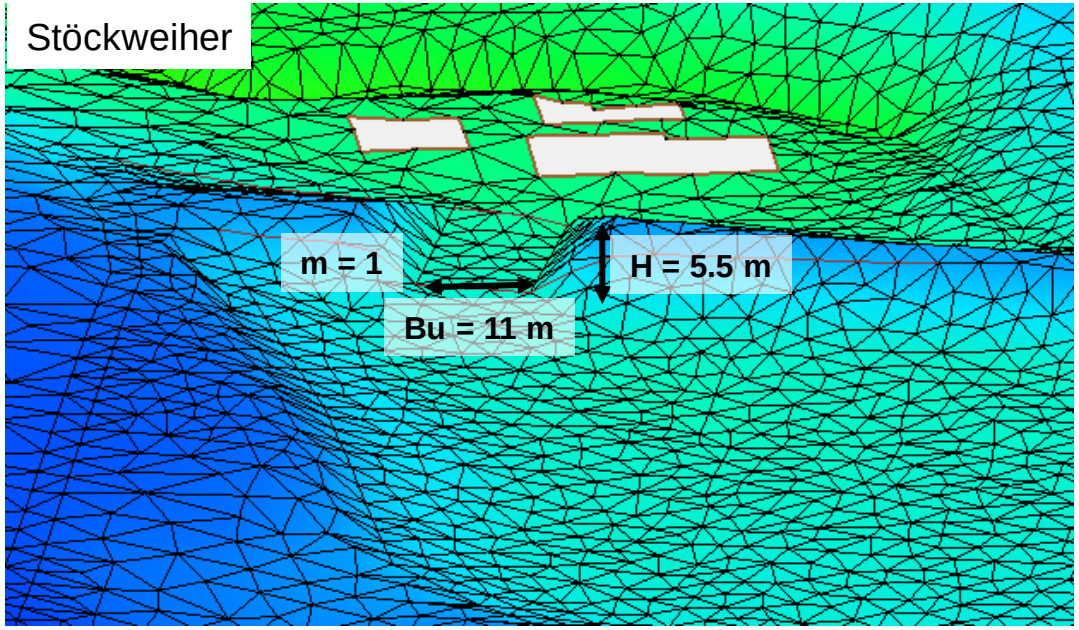
Geometric breach

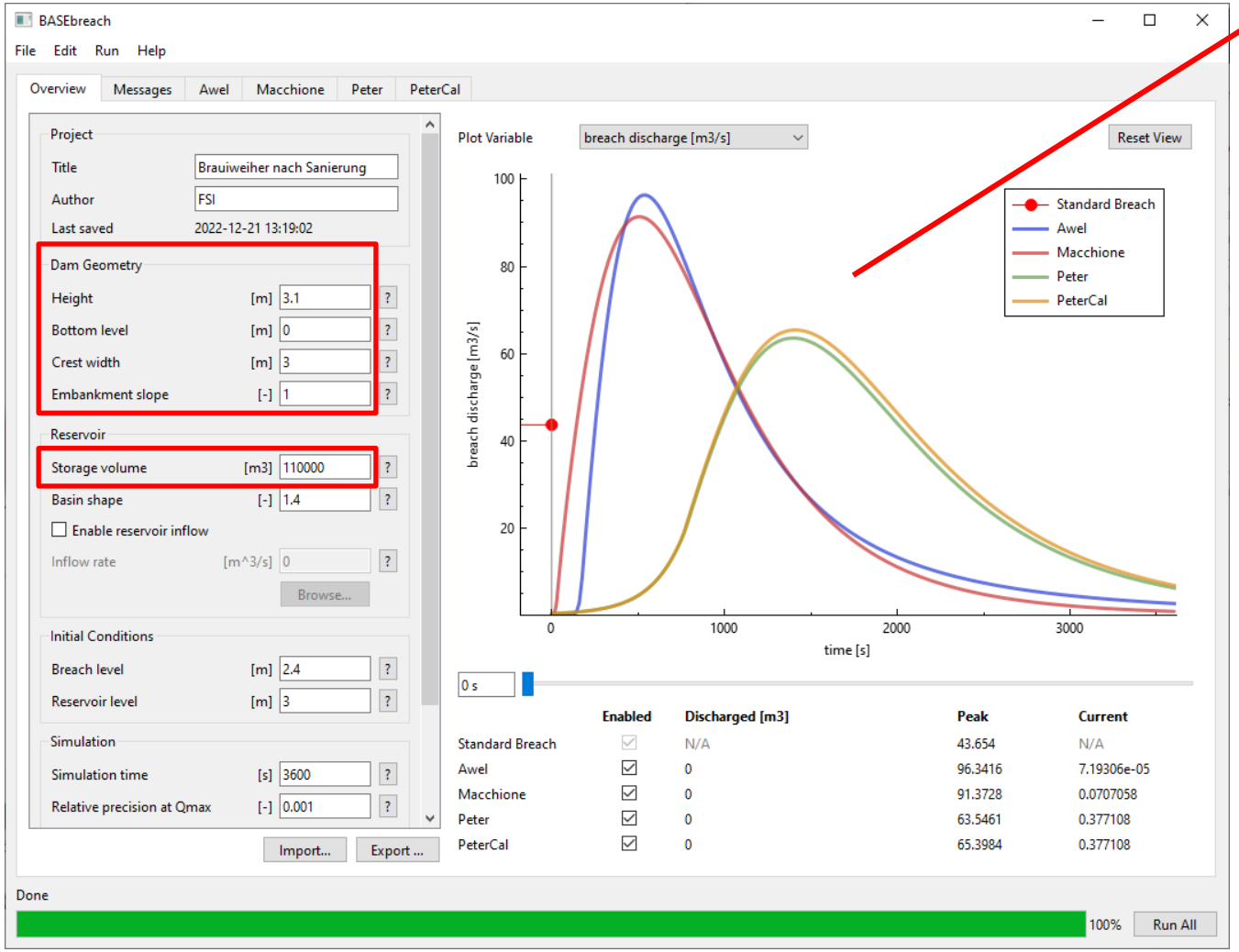
- Implementation of standard breach as geometric adjustment in mesh
- Initial state = reservoir is filled up to full supply level
- No reservoir inflow

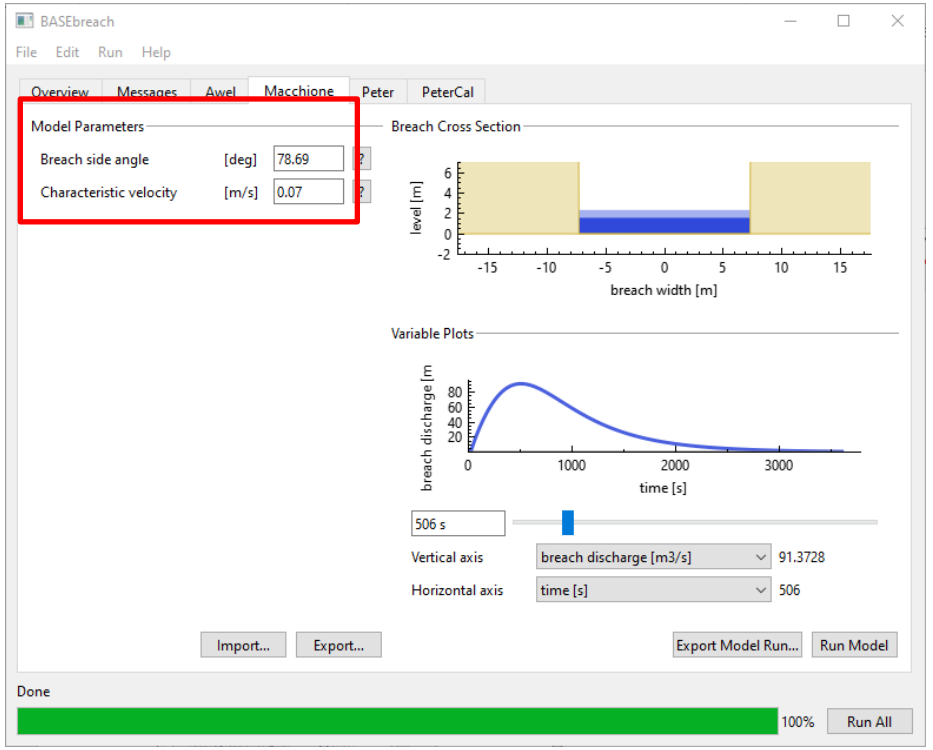




BASEbreach

Breach Hydrograph = External Source





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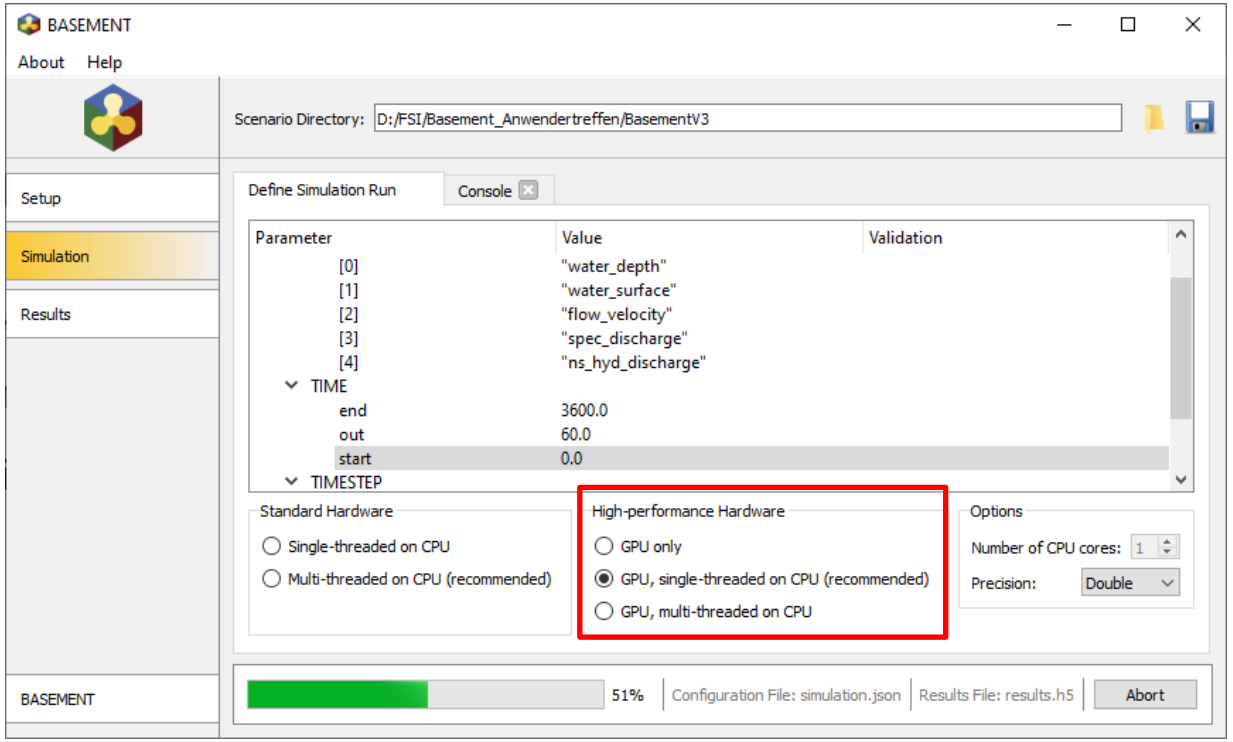
Use of BASEMENT Version 3.2

- Computation on GPU
  - GPU: RTS = 60
  - CPU: RTS = 3
  - Computation on GPU is 20 times faster
- Implementation of culverts using h-Q-relation
- Modelling of log jams by adjusting h-Q-relation



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Results and Discussion of Case Studies

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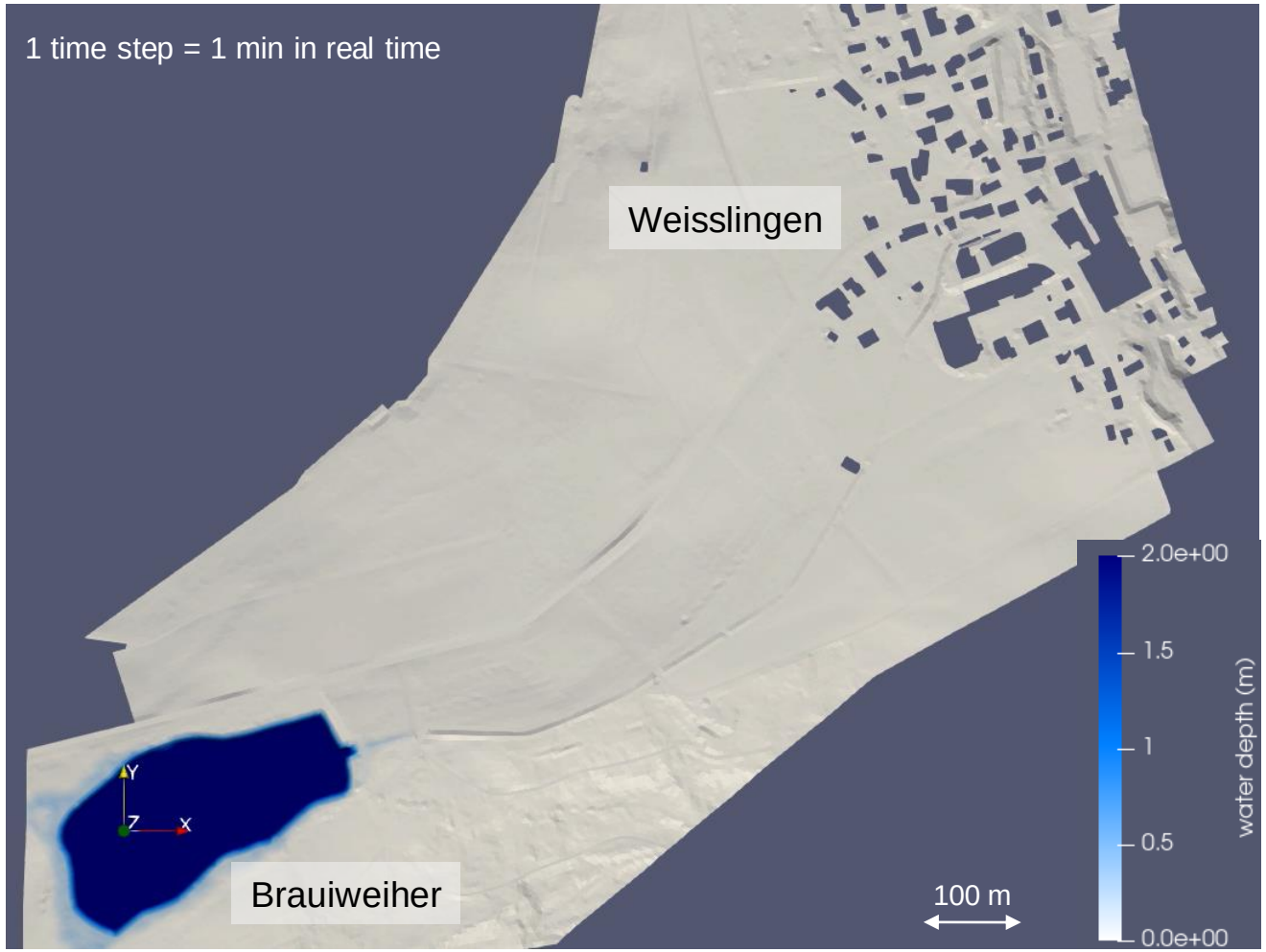
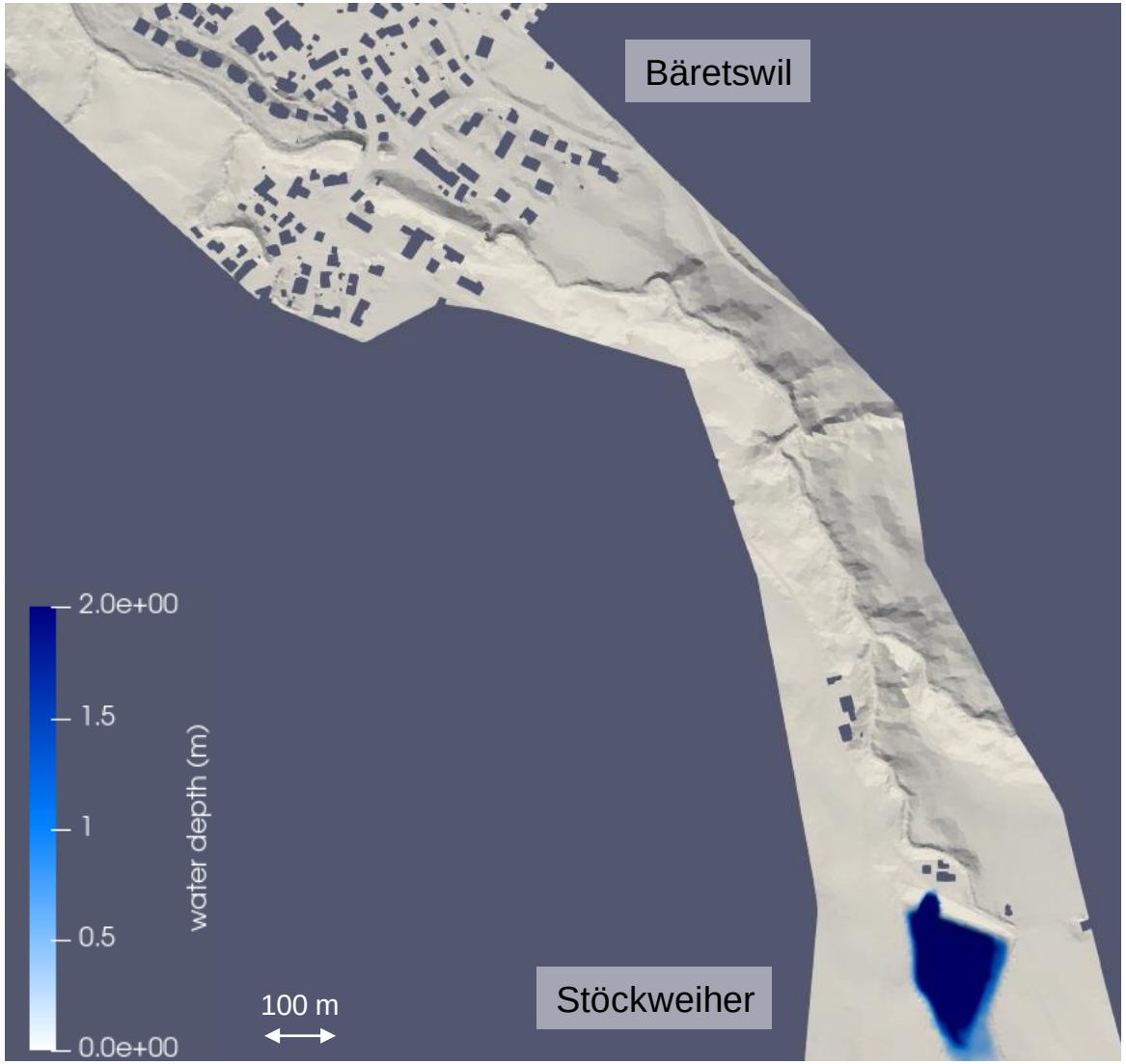
Animation

2D model developed by Davood Farshi on behalf of B&H



2D model developed by Sebastian Ritsch on behalf of B&H



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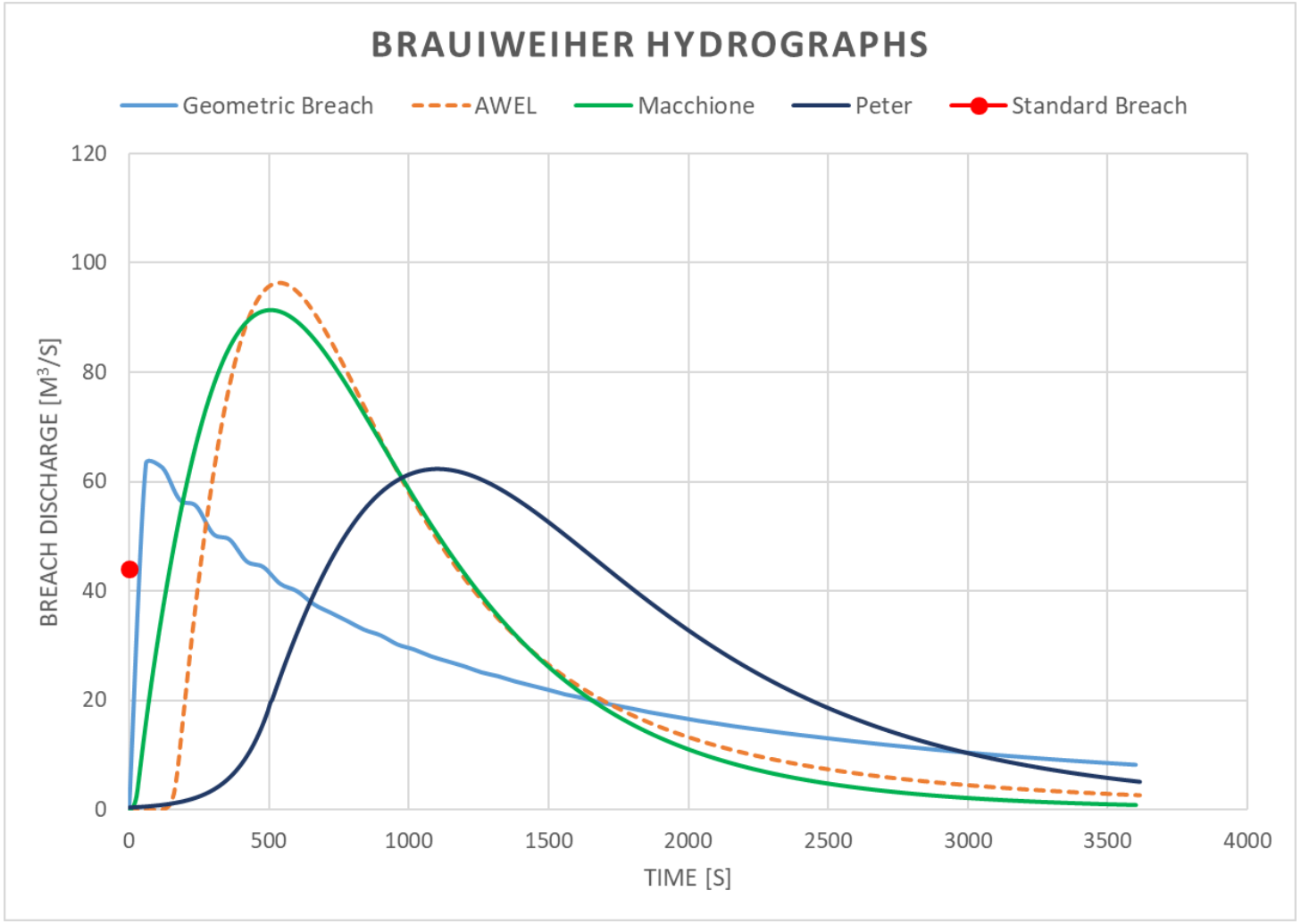
Comparison of Hydrographs - Brauiweiher



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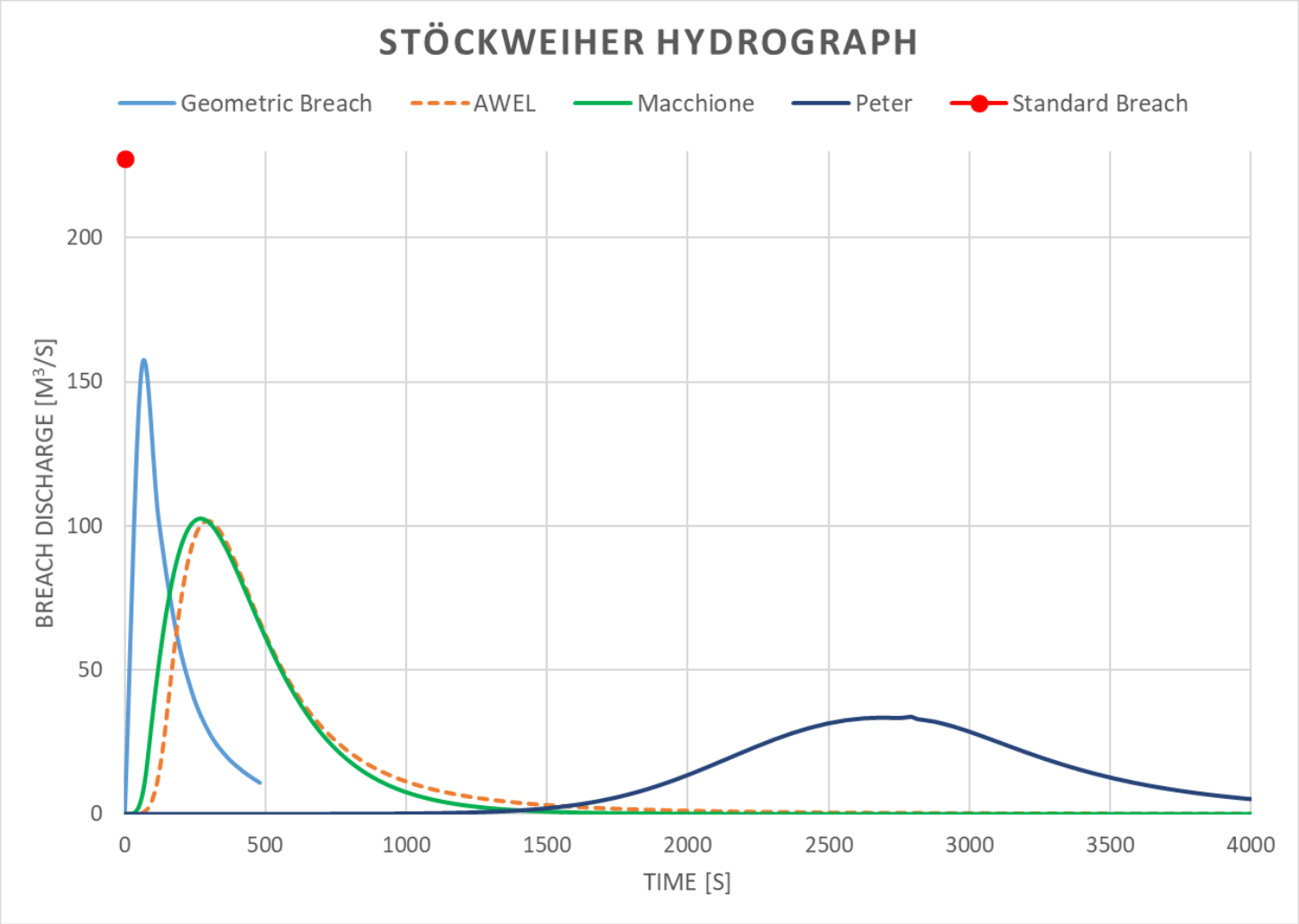
Comparison of Hydrographs - Stöckweiher



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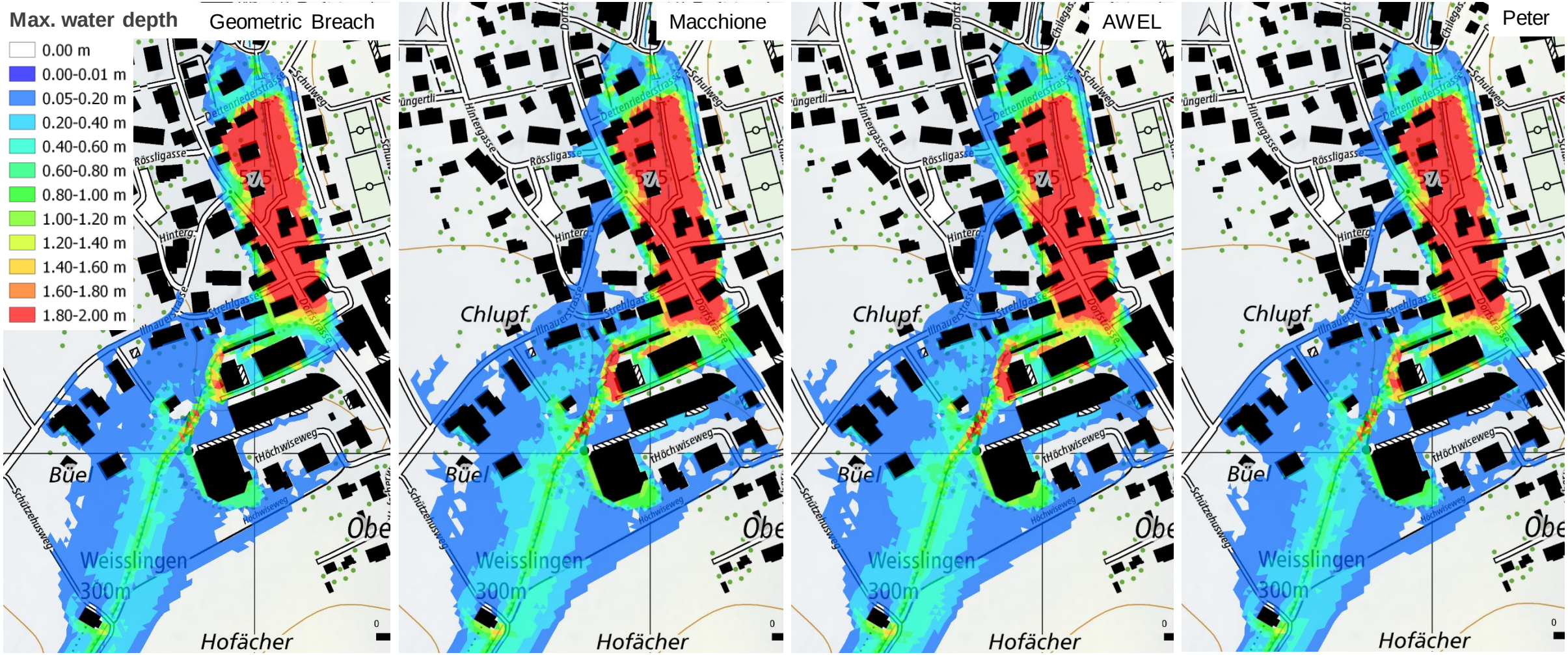
Comparison of Hydrographs

- small volumes & large dam heights → smaller discharge than standard breach
- large volumes & small dam heights → larger discharge than standard breach
- In accordance with findings from VAW / L. Vonwiller

Comparison of Results Brauiweiher



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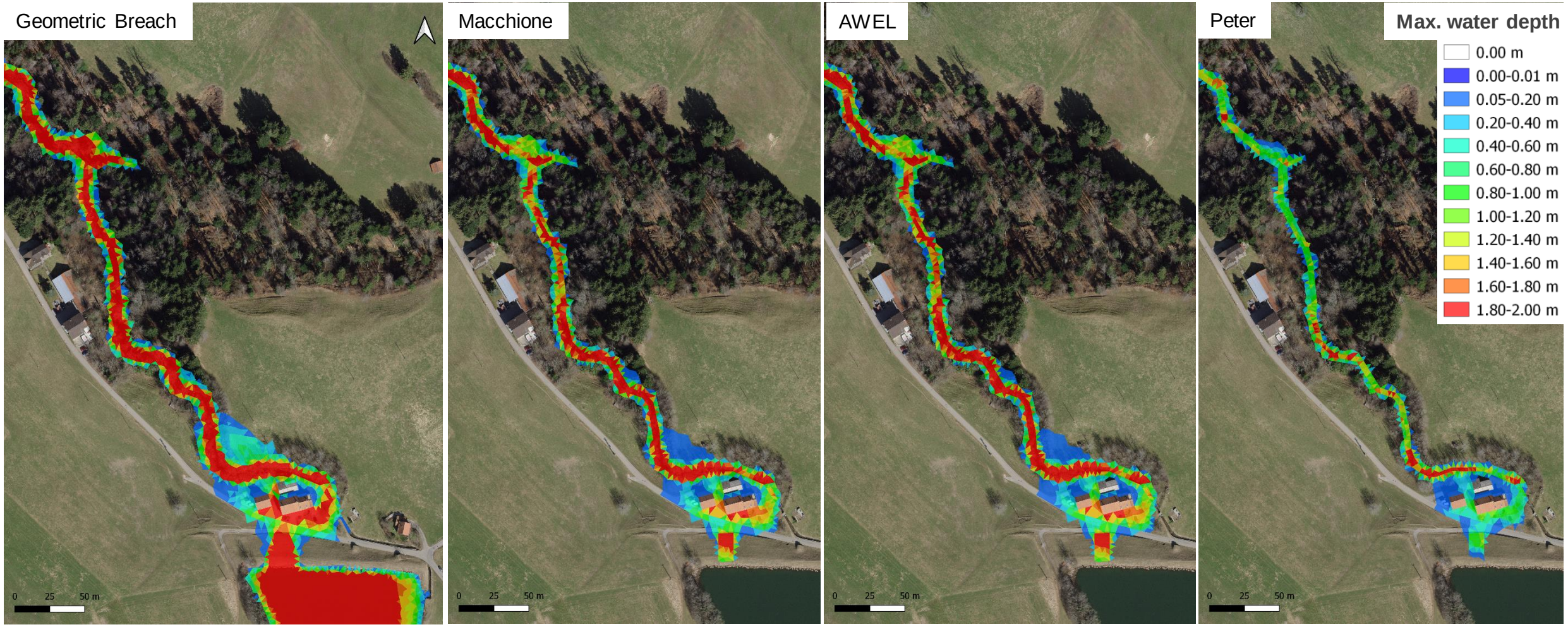
Comparison of Results Stöckweiher



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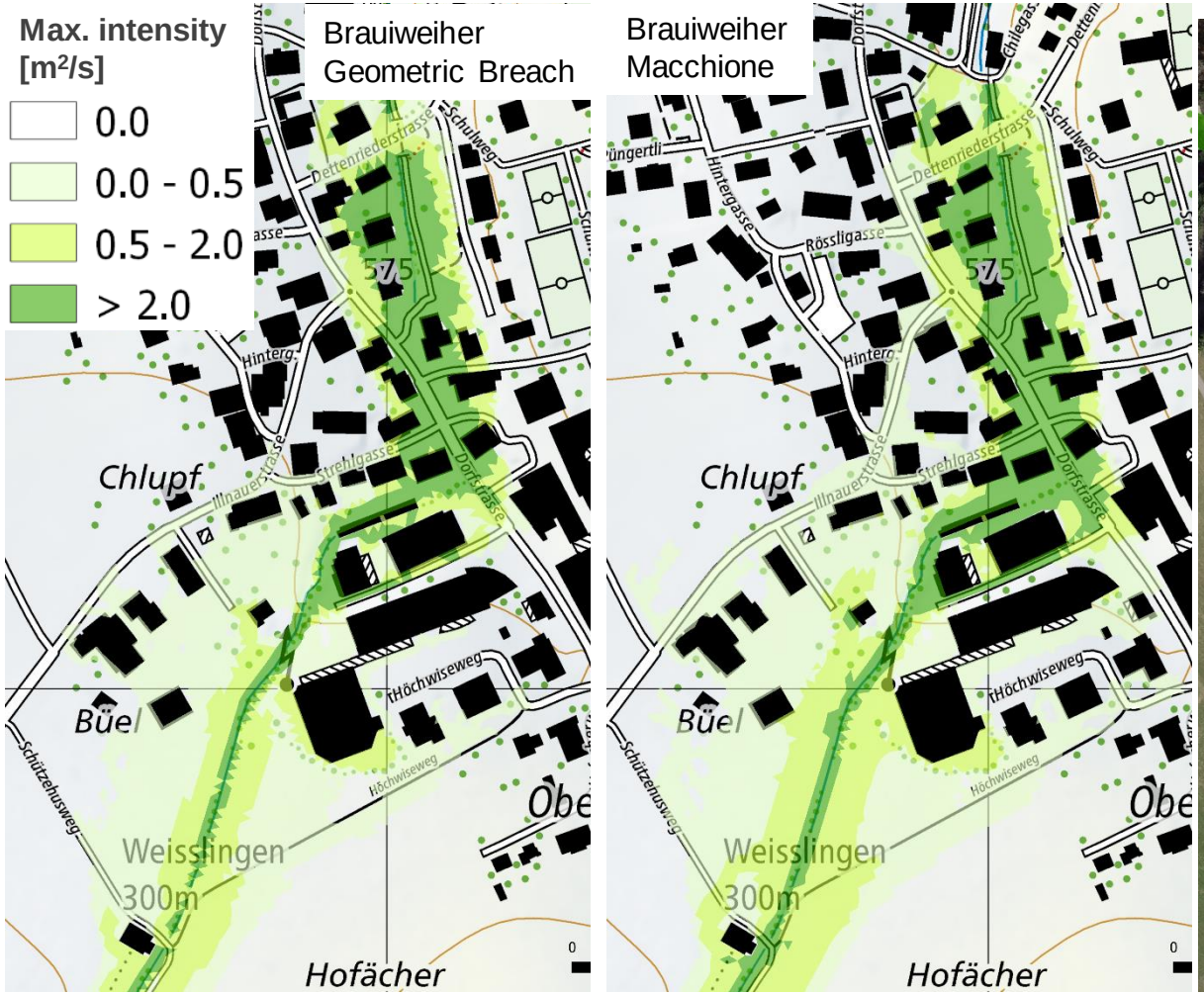
Comparison of Results: Maximum Intensity



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Measures taken

- Brauiweiher:
  - Construction of new spillway as an 8 m wide free overflow section
  - No risk of log jams
  - In case of dam breach, the relevant dam height is the height of the spillway
  - Reduced breach discharge
  - New 2D model shows reduced intensity < 2.0 m^2/s
  - No high risk potential in Weisslingen
  - No subjection to WRFO

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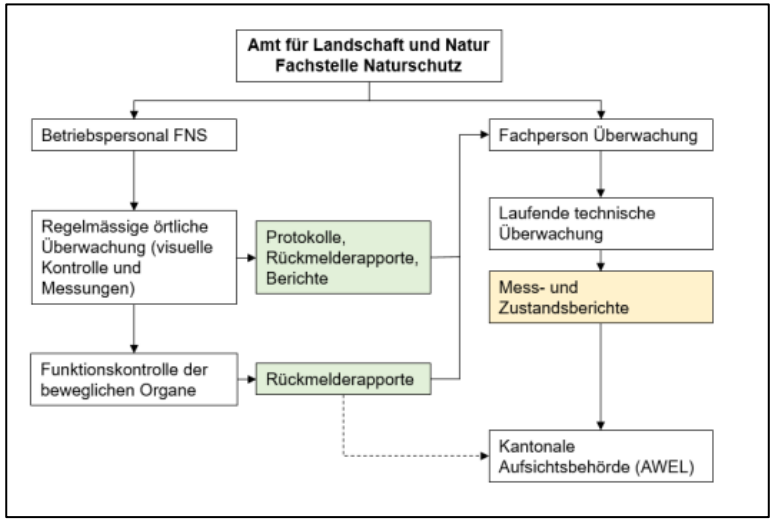
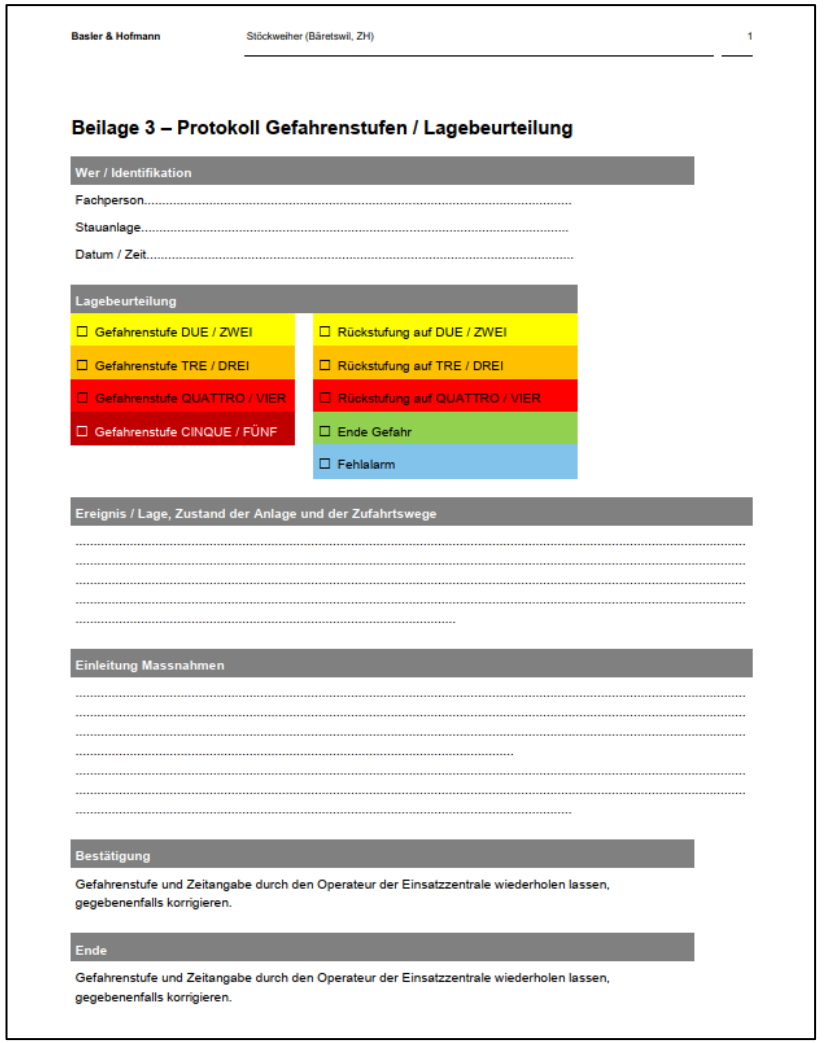
Measures taken

- Stöckweiher:
  - No possibility to reduce intensity below required threshold at building at the foot of the dam
  - Subjection to WRFO
  - ➢ Development of Monitoring & Emergency Regulations





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Beilage 3 – Protokoll Gefahrenstufen / Lagebeurteilung

Wer / Identifikation

Fachperson.....

Stauanlage.....

Datum / Zeit.....

Lagebeurteilung

☐ Gefahrenstufe DUE / ZWEI	☐ Rückstufung auf DUE / ZWEI
☐ Gefahrenstufe TRE / DREI	☐ Rückstufung auf TRE / DREI
☐ Gefahrenstufe QUATTRO / VIER	☐ Rückstufung auf QUATTRO / VIER
☐ Gefahrenstufe CINQUE / FÜNF	☐ Ende Gefahr
	☐ Fehlalarm

Ereignis / Lage, Zustand der Anlage und der Zufahrtswege

.....

Einleitung Massnahmen

.....

Bestätigung

Gefahrenstufe und Zeitangabe durch den Operateur der Einsatzzentrale wiederholen lassen, gegebenenfalls korrigieren.

Ende

Gefahrenstufe und Zeitangabe durch den Operateur der Einsatzzentrale wiederholen lassen, gegebenenfalls korrigieren.

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Outlook

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Outlook

- **Free** data and software
  - Land Coverage, Elevation (swissALTI3d), BASEbreach, BASEmesh with QGIS, BASEMENT, Paraview)
- Efficient mesh generation due to automation
- Valuable and reliable information regarding flood wave propagation and risk potential
- Basis for the planning of mitigation measures for small dams regarding WRFO
  - Comparison of costs of measures vs. costs with WRFO
  - In many cases, moderate measures can guarantee safety of retaining structures with minimal expense while preserving the use as nature reserve

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Thank you!

Basler & Hofmann, Esslingen

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