Flood protection through an integrated strategy of planning, structural and river restoration measures, an application in the Aurino river in South Tyrol

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Overview&Contents

1. analysis of the current situation in terms of retention volume naturally available within the floodplain;

2. analysis of two project designs approach which aim at improving the retention capacity of the floodplain for event exceeding 30-year flood (>HQ_{30});

3. comparison between different approaches: one is based on structural measures, the second approach is based on restoration measures (ecological values);

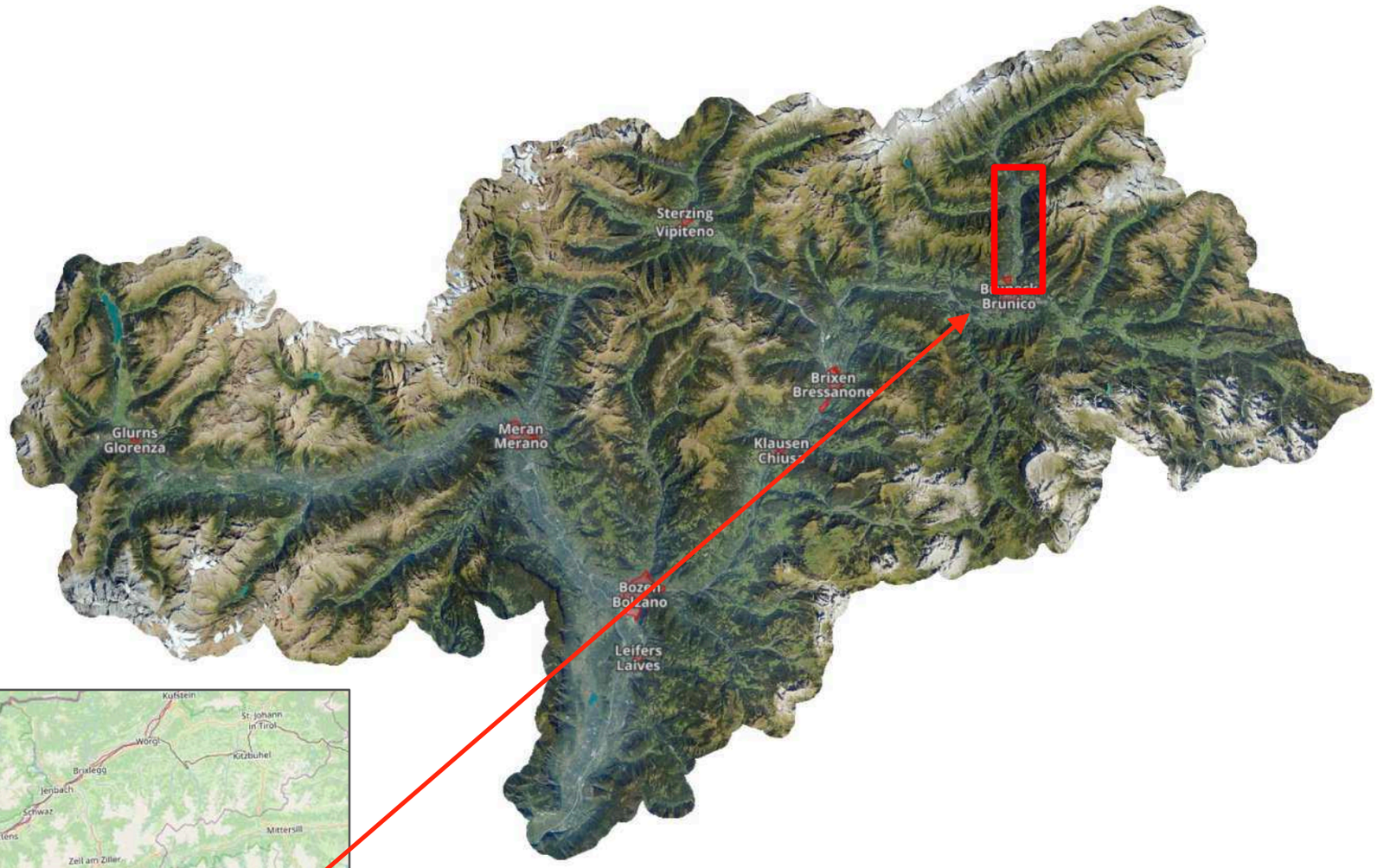
4. design methodology which allows for retention volume calculation, based on the desired protection target.

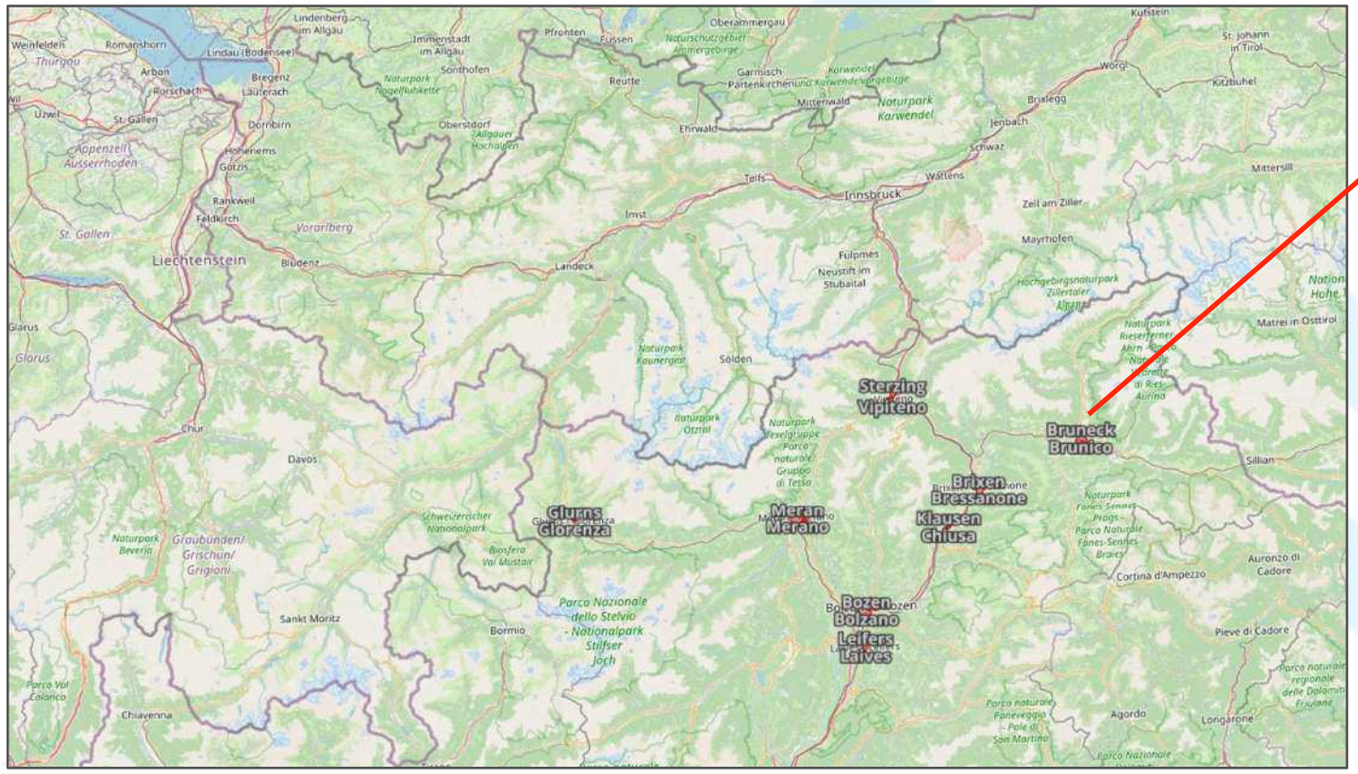
A project funded by the Civil protection agency of the Province of Bolzano

STUDY AREA

1. lower Aurino valley, located in South Tyrol;

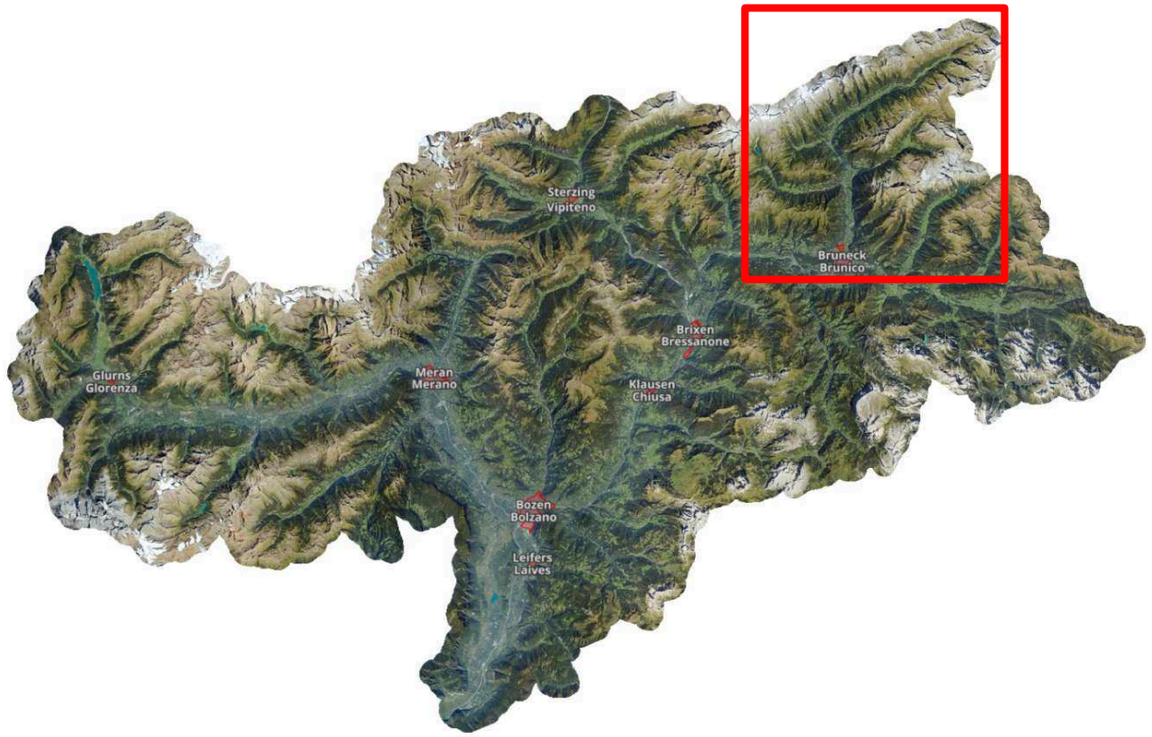
2. 16-km long reach between Campo Tures and Brunico

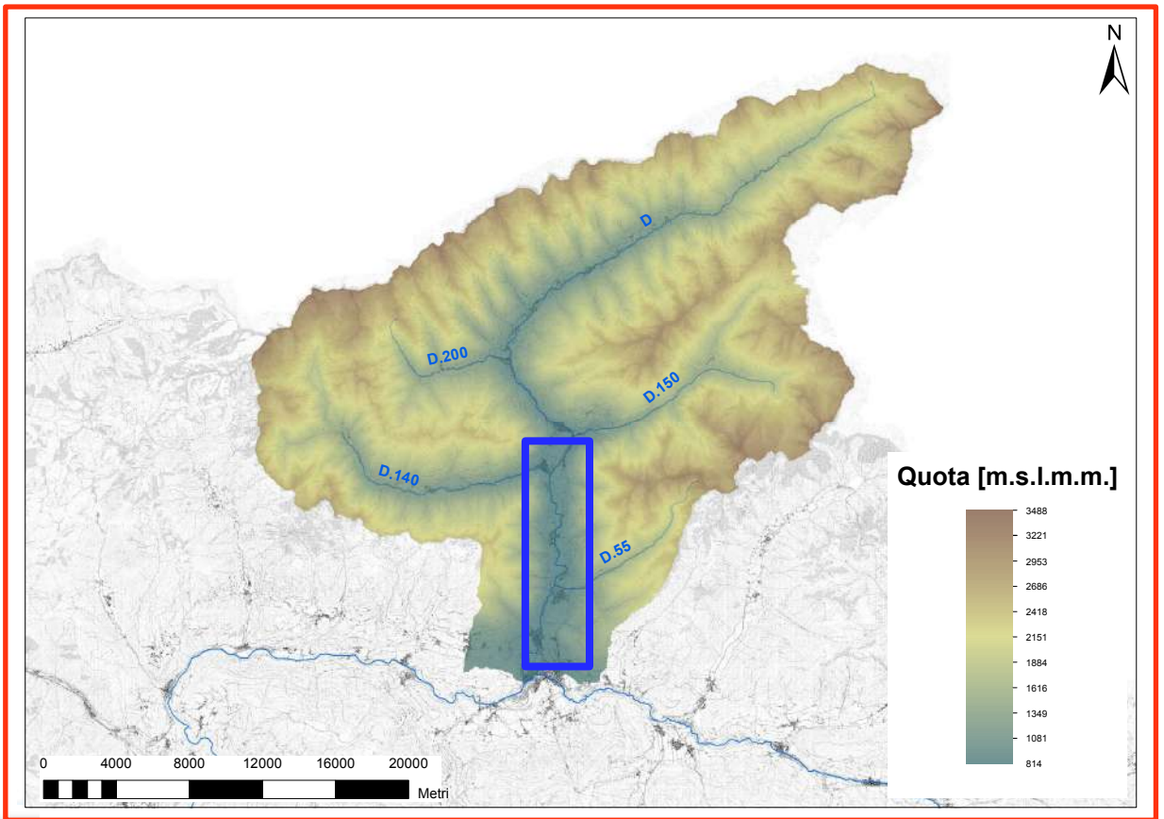


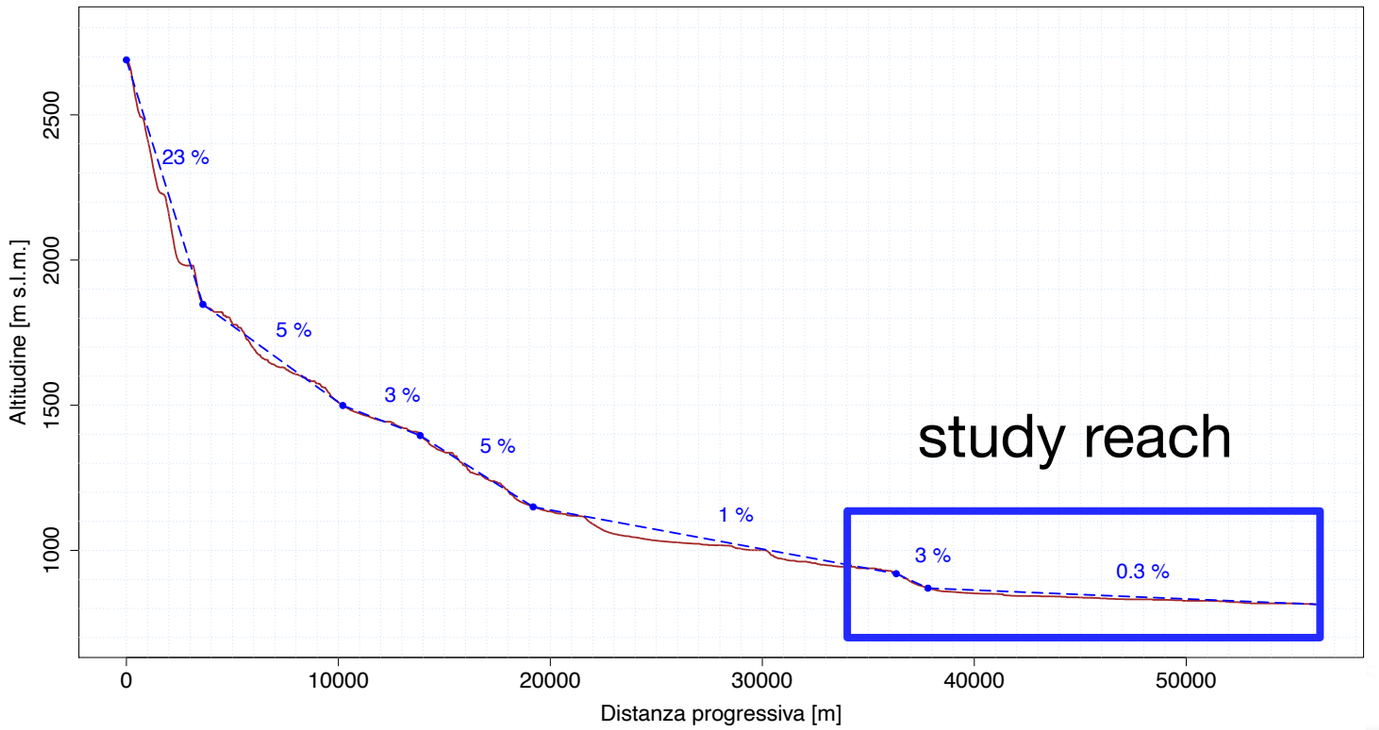


STUDY AREA

1. 16-km long reach between Campo Tures and Brunico;
2. Watershed area at the begging 419 km^2, at the end 634 km^2







RIVER RESTORATION MEASURES

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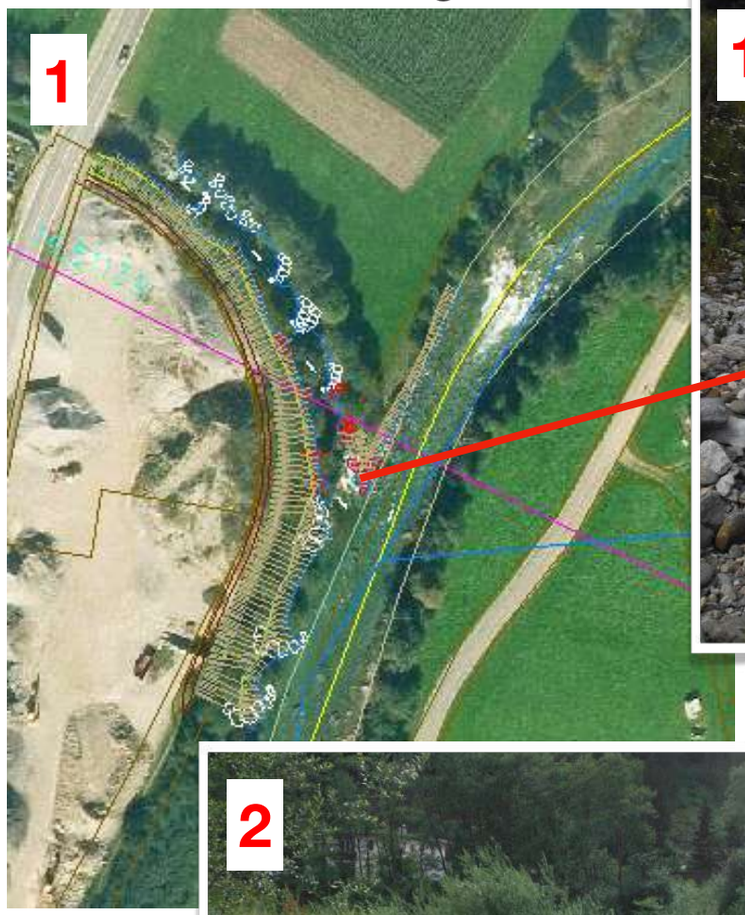

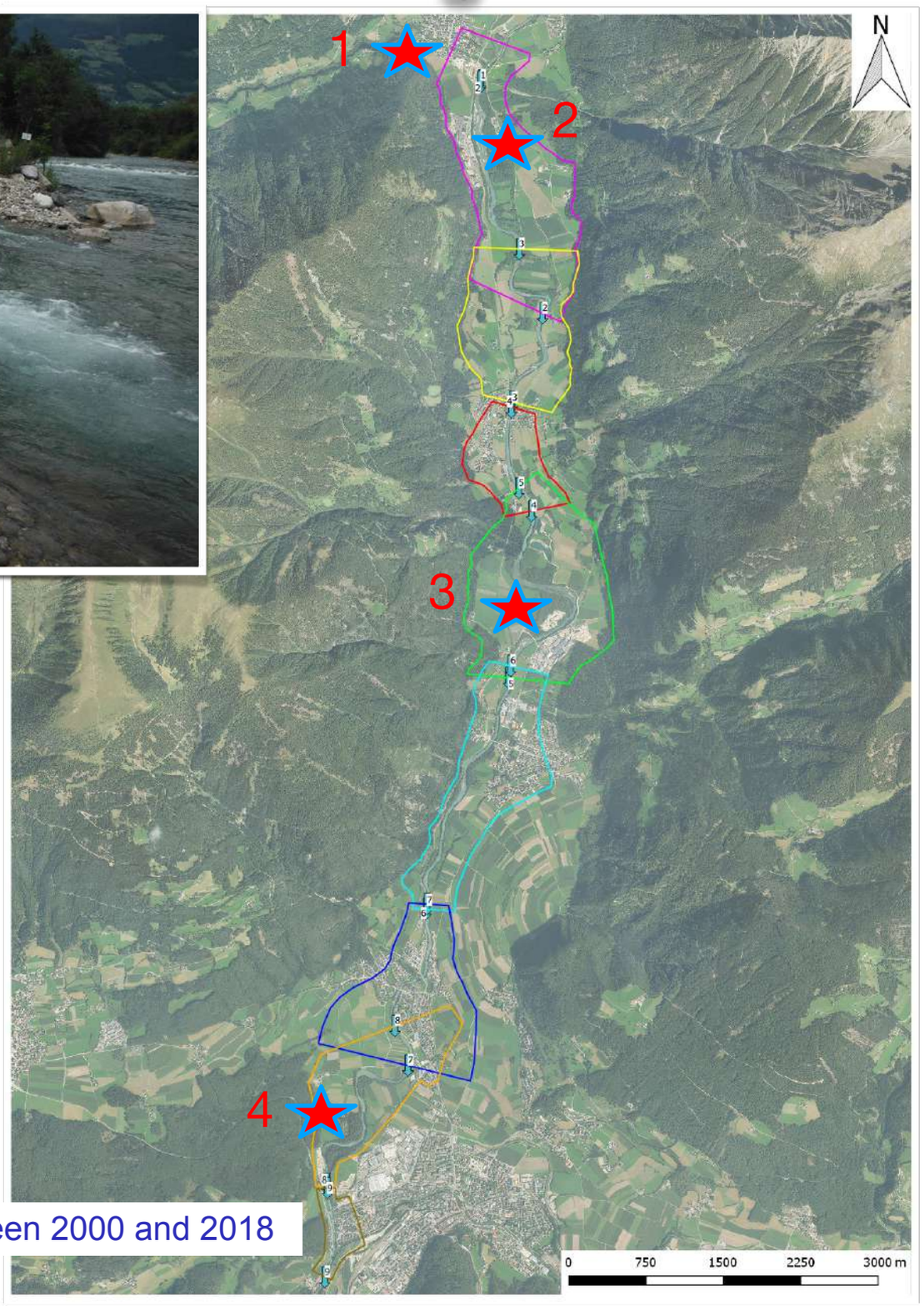

carried out by the Civil protection agency of the Province of Bolzano between 2000 and 2018

RIVER RESTORATION MEASURES

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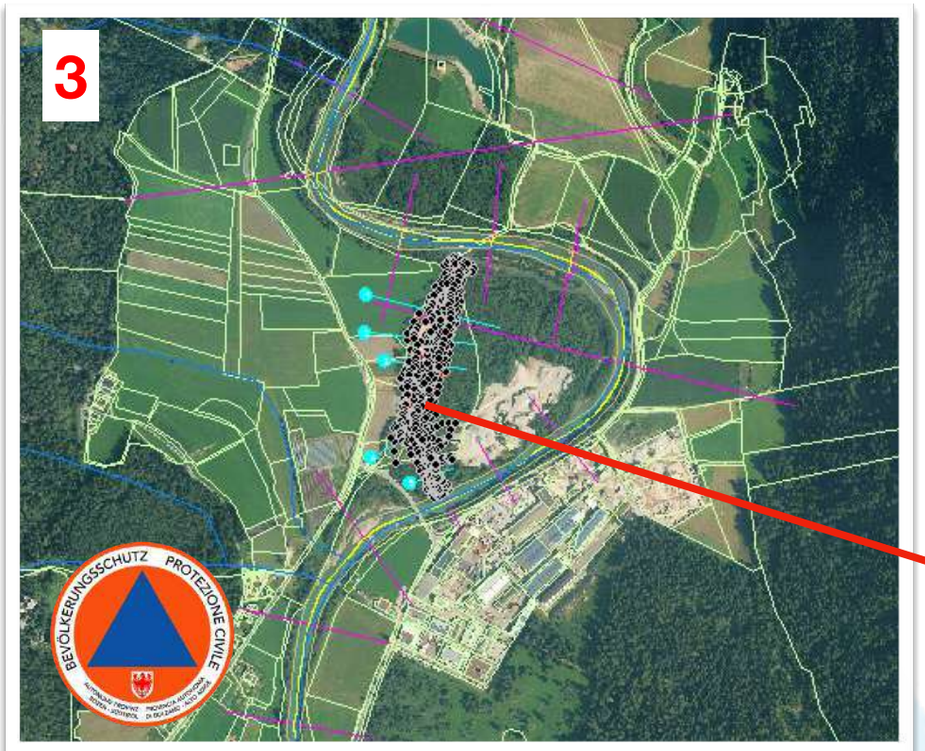

carried out by the Civil protection agency of the Province of Bolzano between 2000 and 2018

Bathymetry&Photogrammetry

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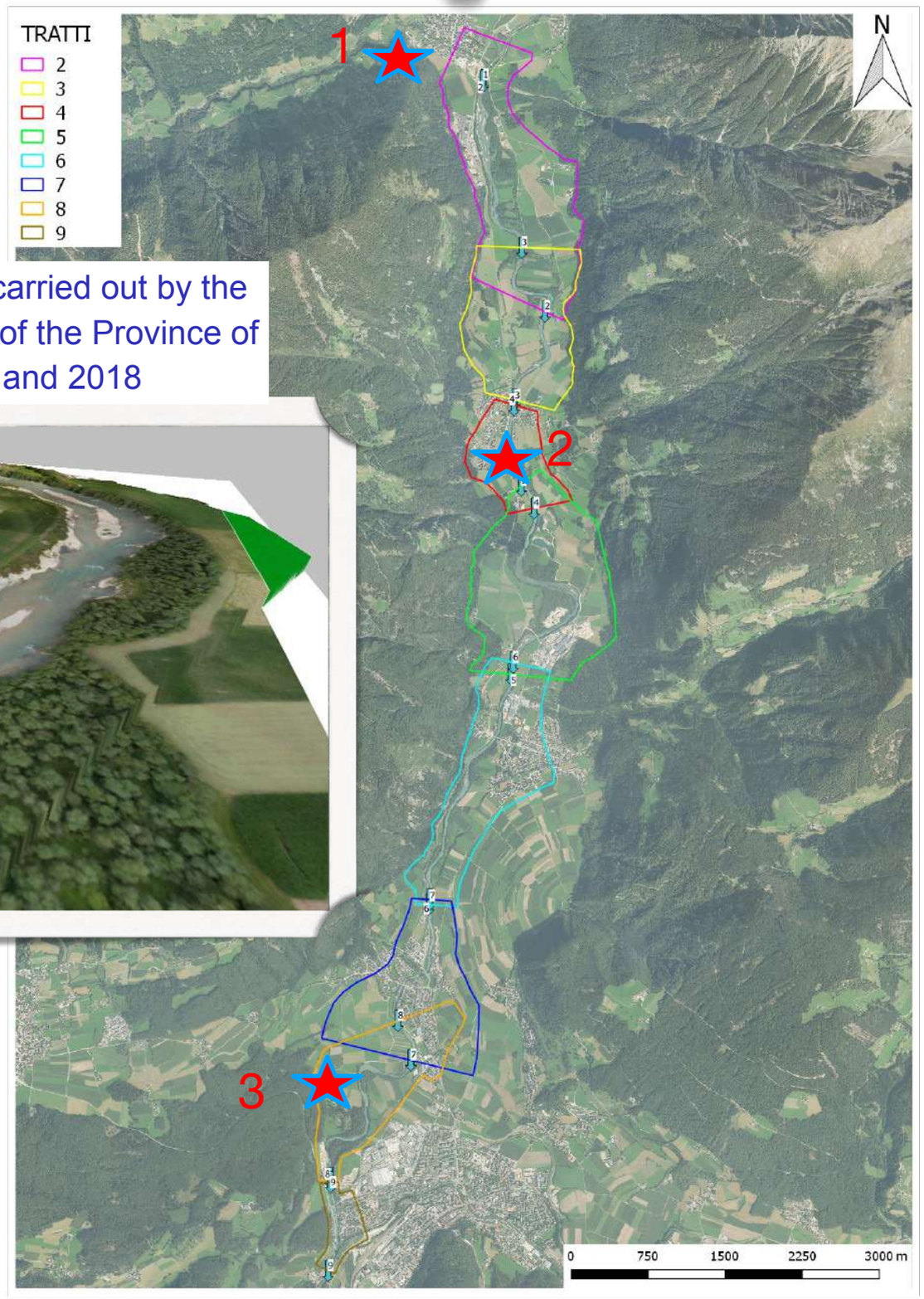
Restoration measures carried out by the Civil protection agency of the Province of Bolzano between 2000 and 2018



RETENTION AREAS

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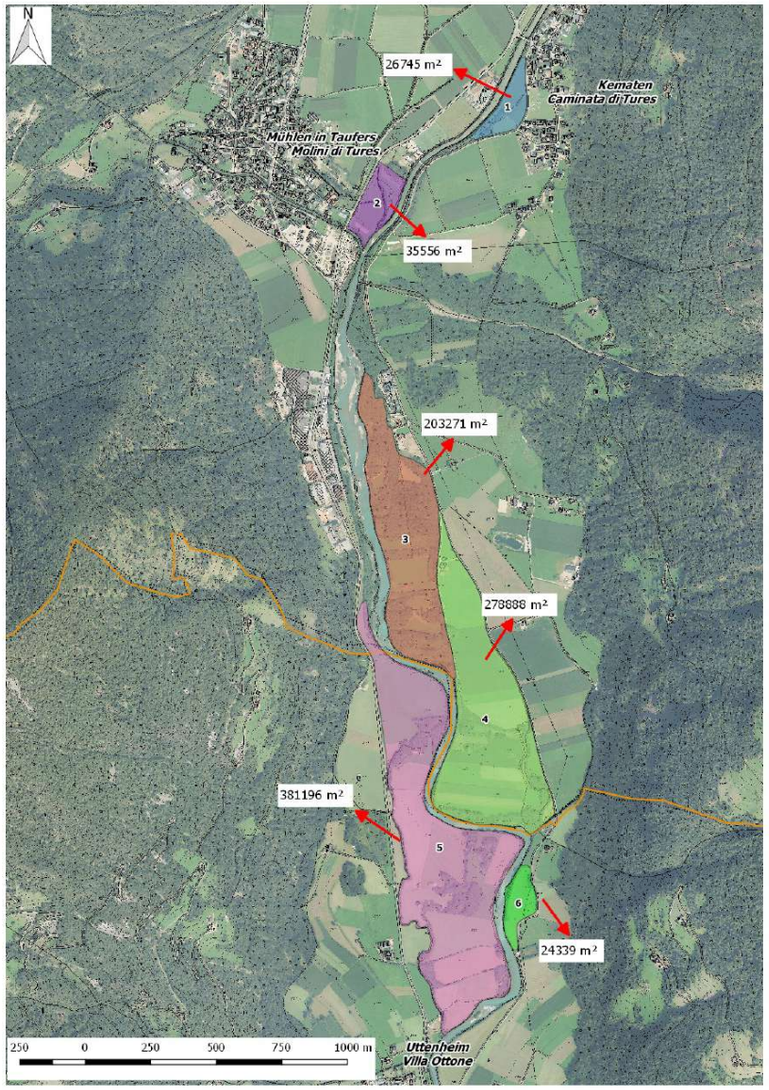
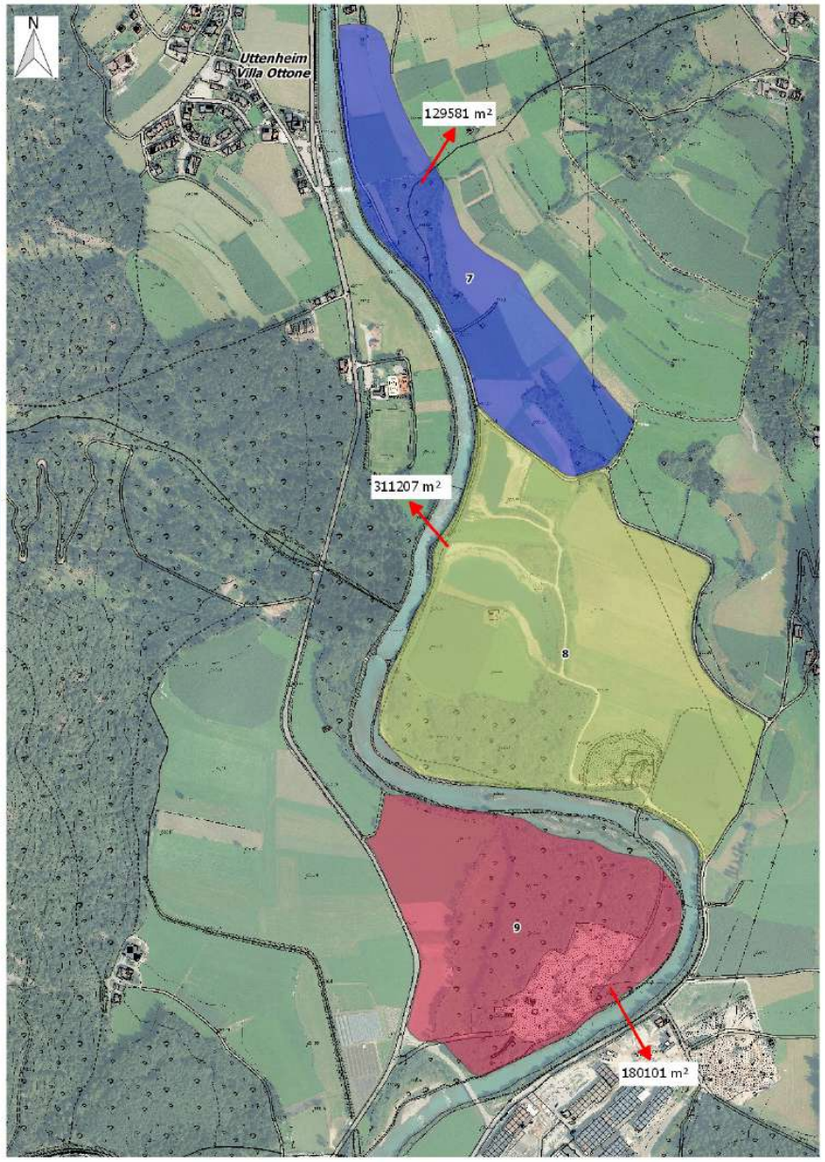
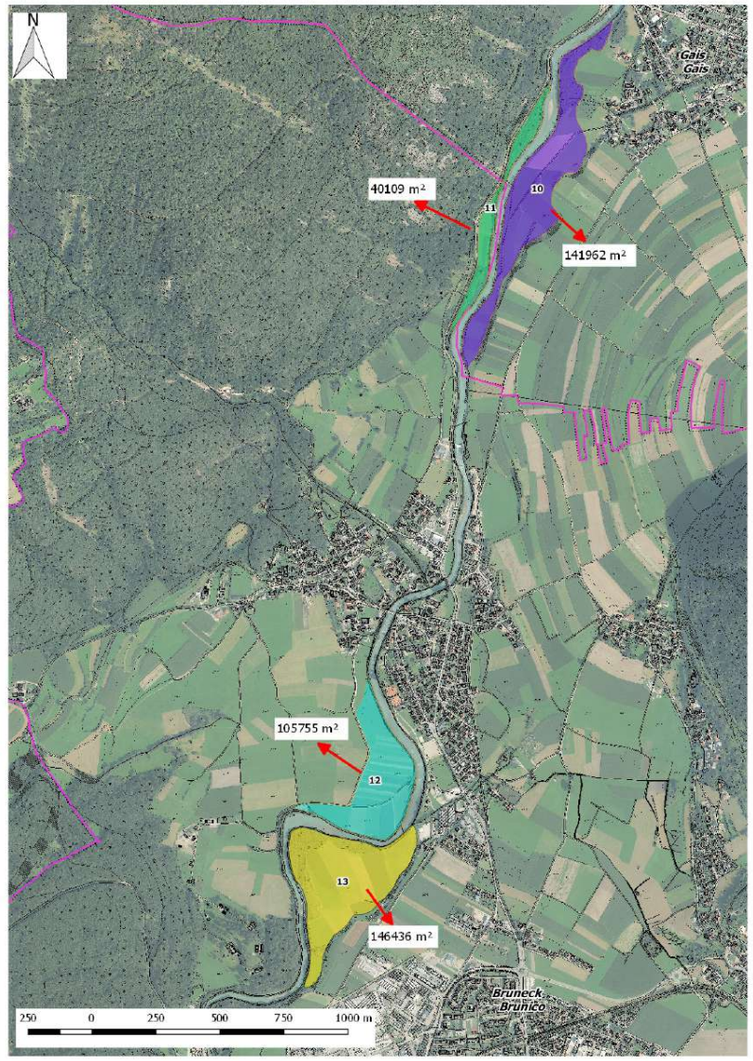
Total area ~ 200 ha

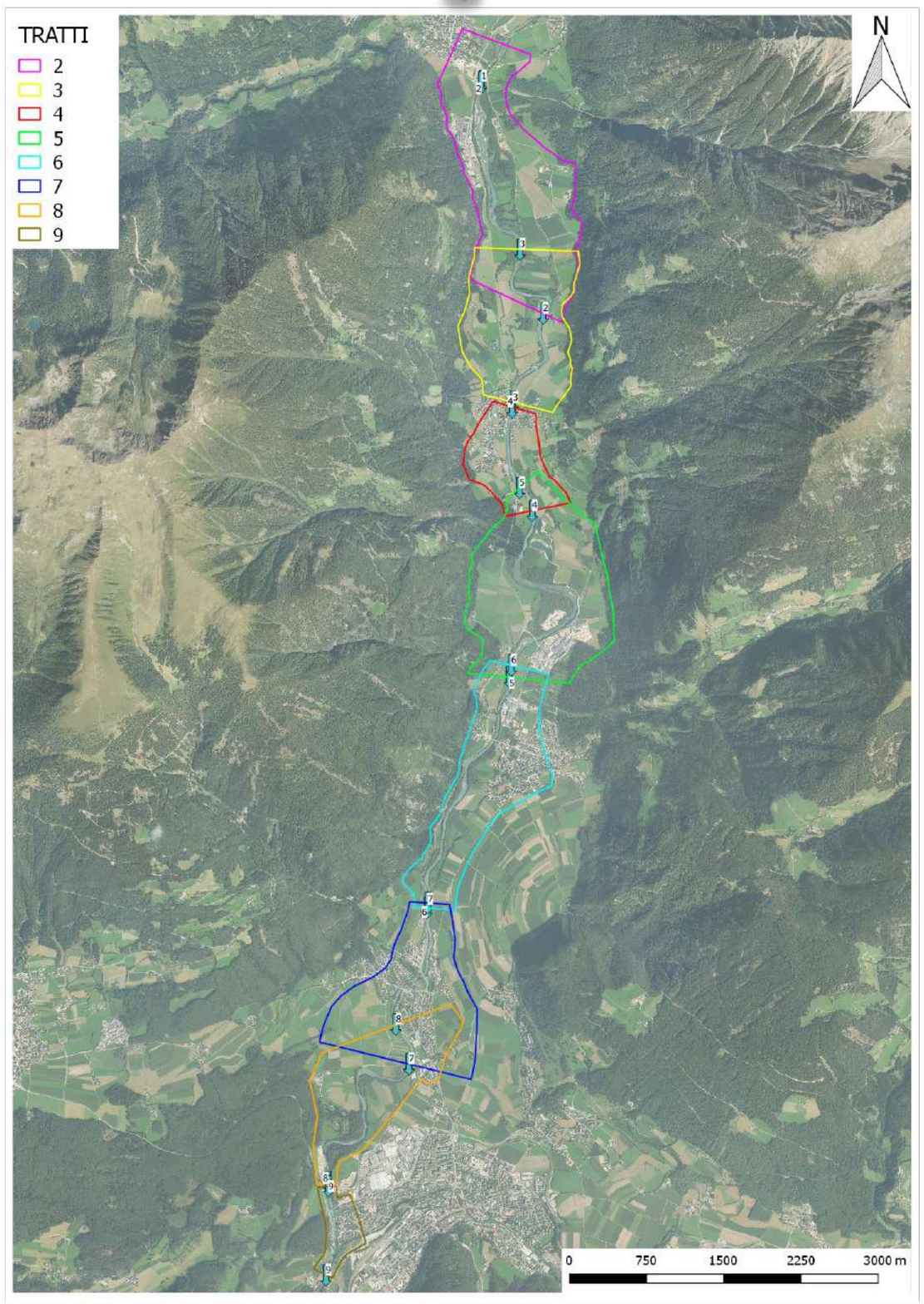






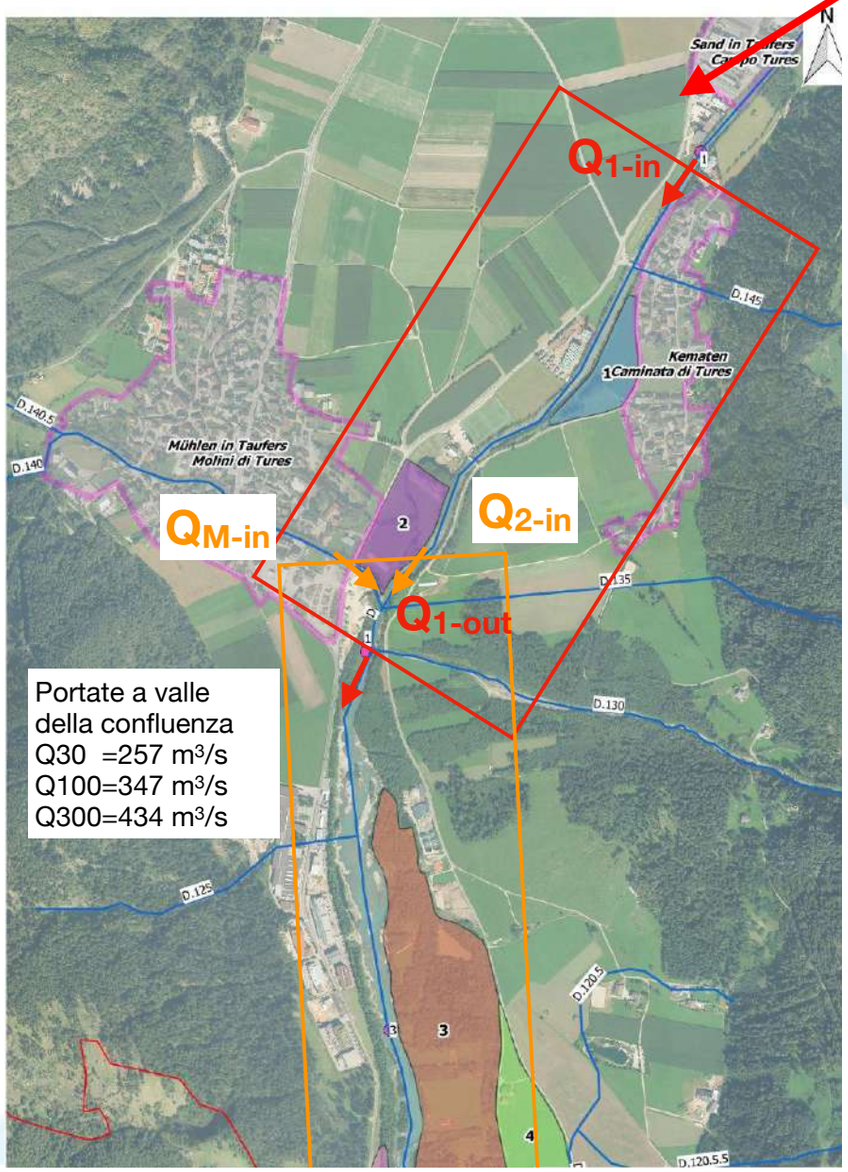
MODELLING APPROACH

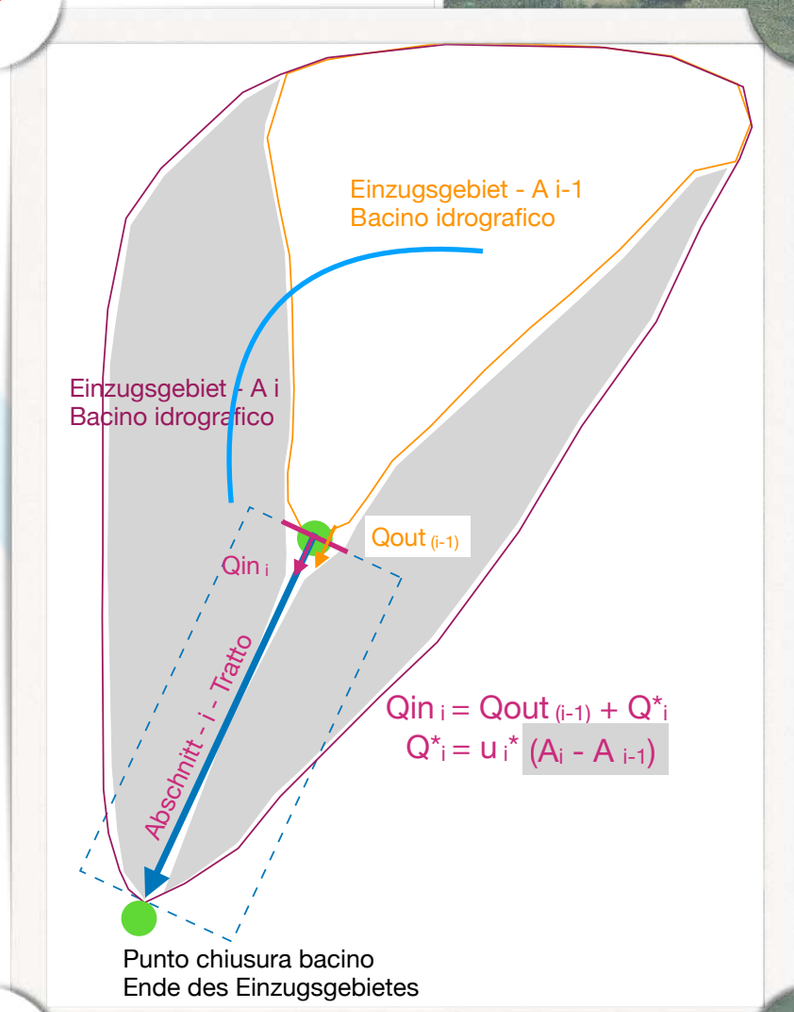
1. 2D-hydraulic model - module BASEMD;
2. multi-domain approach due to the length od the study reach - 16 km; overlapping domains.
3. Accounting for the contribution of lateral tributaries through additional inflow boundary;
4. Accounting for the contribution of the inter-basin area as “lumped inflow” at the upstream boundary
5. Setting up cross-control sections to quantify discharge at point of interest

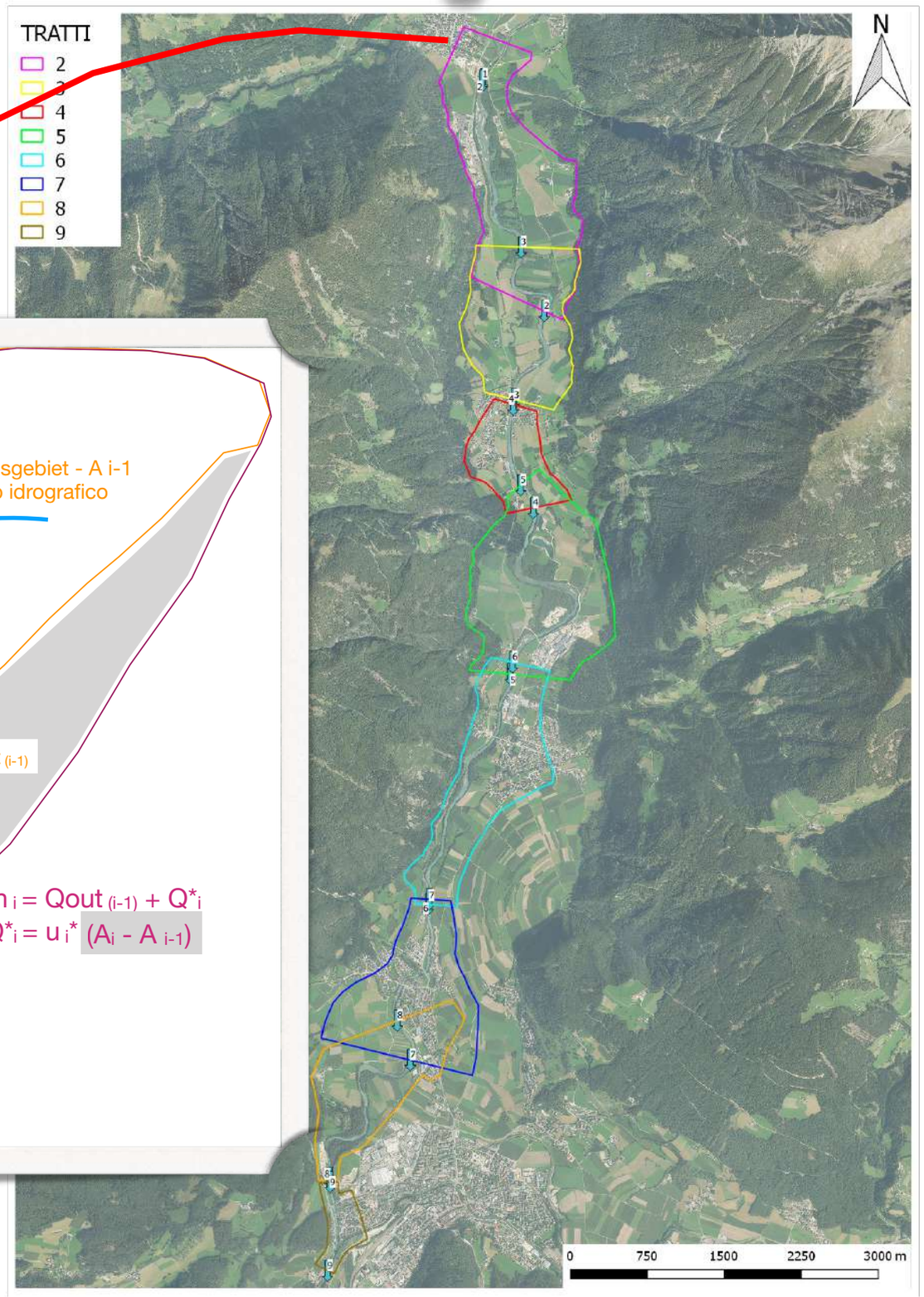


MODELLING APPROACH

		TR30	TR100	TR300	tipologia
Tratto 1	$Q_{1\text{-}in}$	241	313	385	picco
Tratto 2	$Q_{2\text{-}in}$	$Q_{1\text{-}out}$	$Q_{1\text{-}out}$	$Q_{1\text{-}out}$	picco
	$Q_{M\text{-}in}$	16	34	49	costante

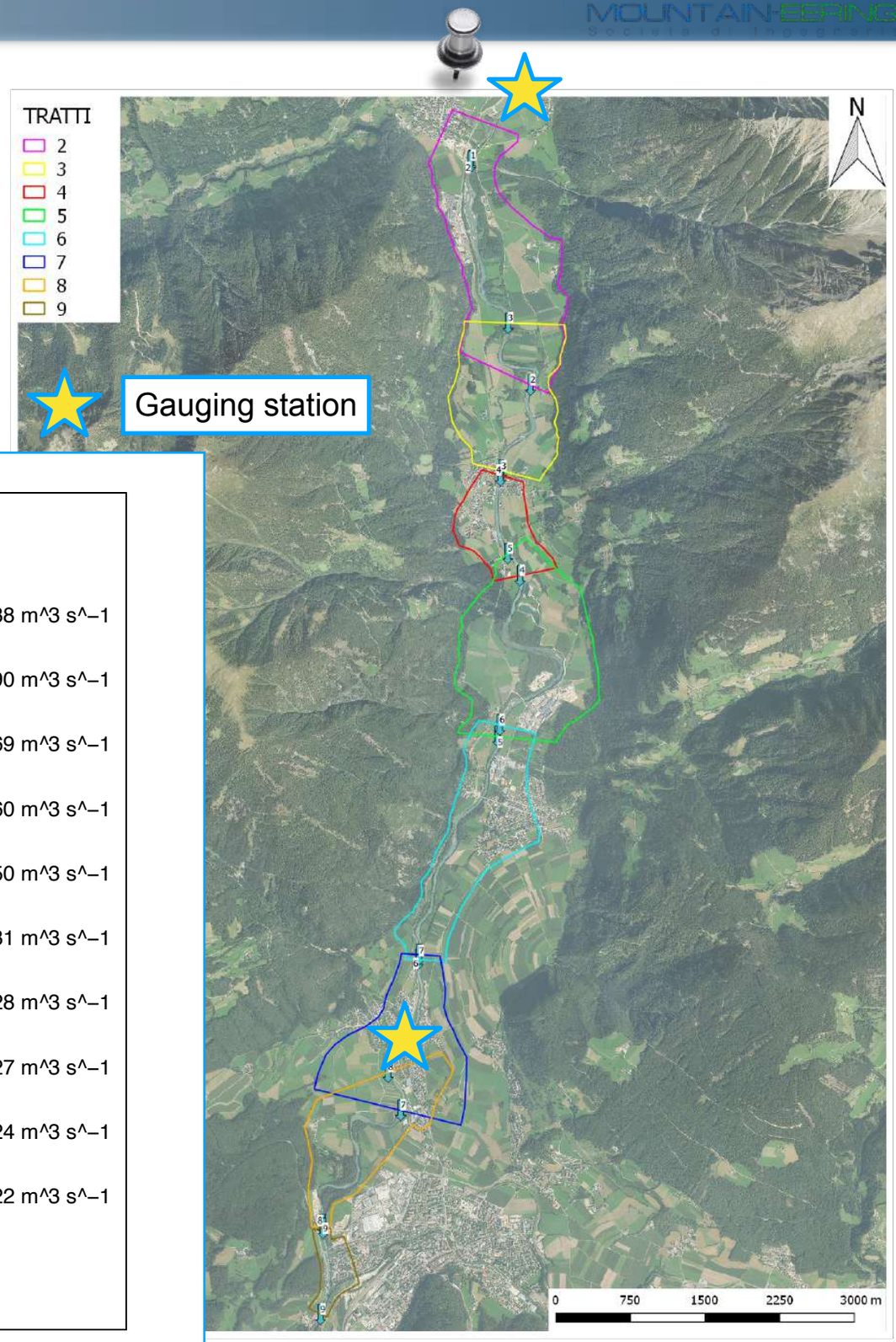


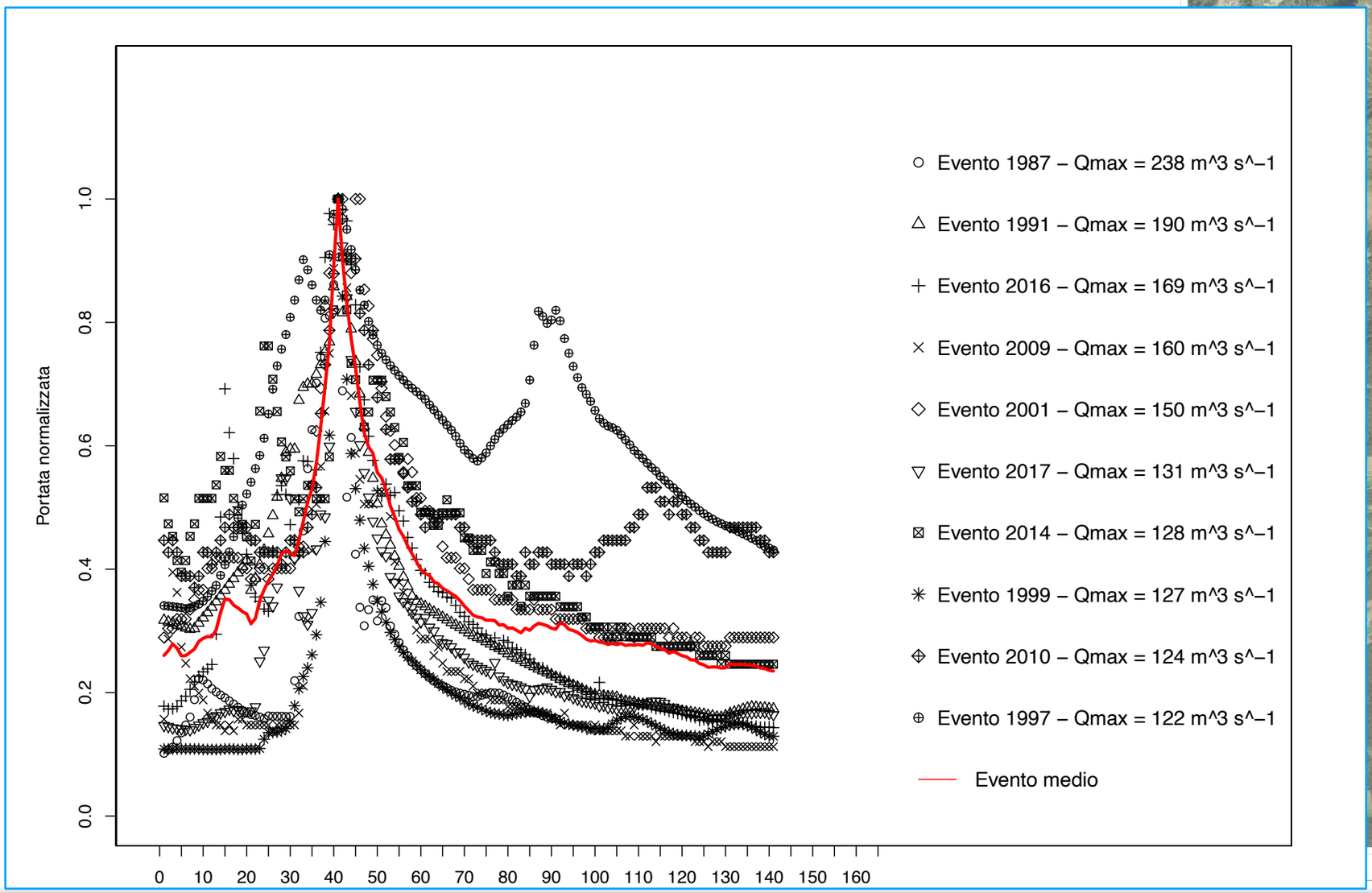




HYDROLOGICAL ANALYSIS

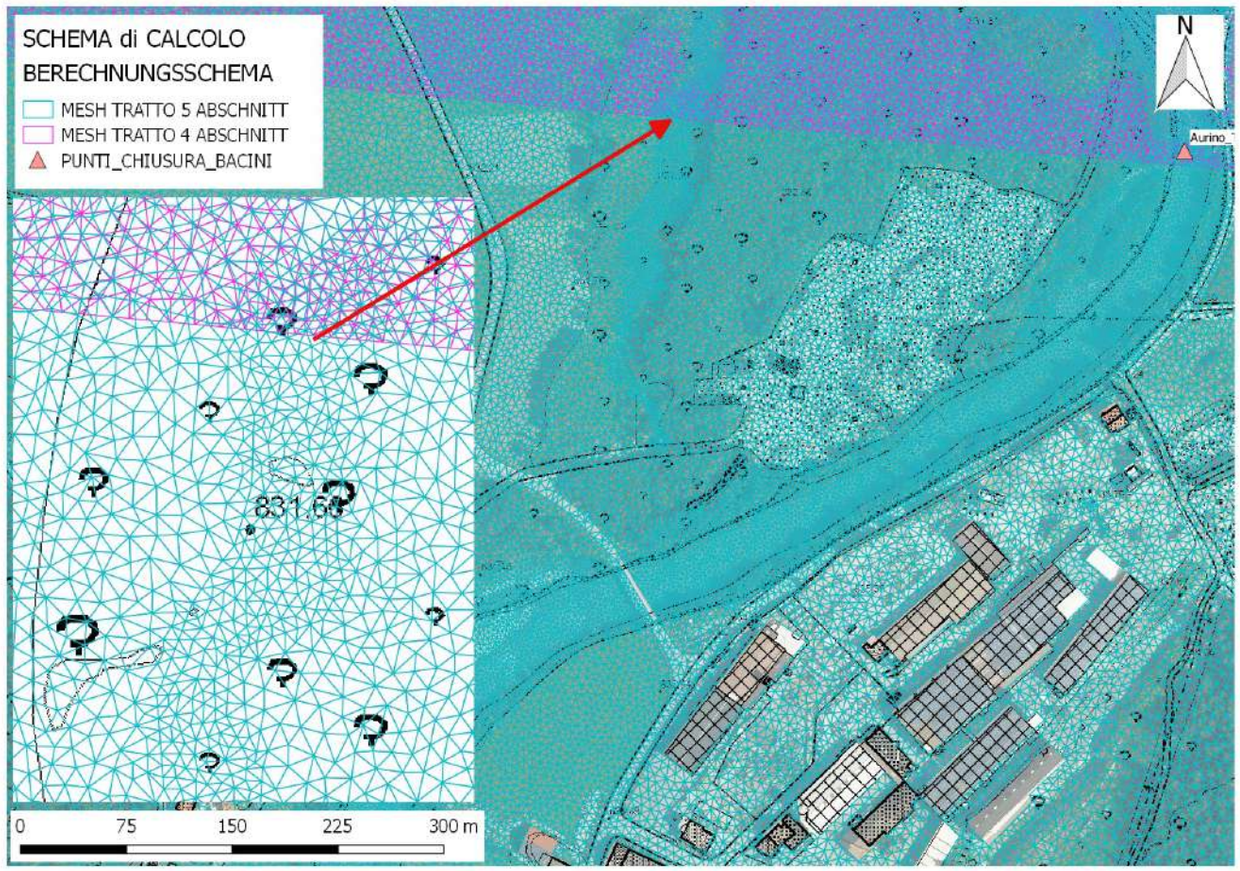
1. Statistical analysis of discharge values to estimate 30-year flood (due to ~ 30-year time serie)
2. Consistency to PZP (Hazard maps) for floods with a return interval higher than 30 year (100, 300), based on unit discharge coefficient.

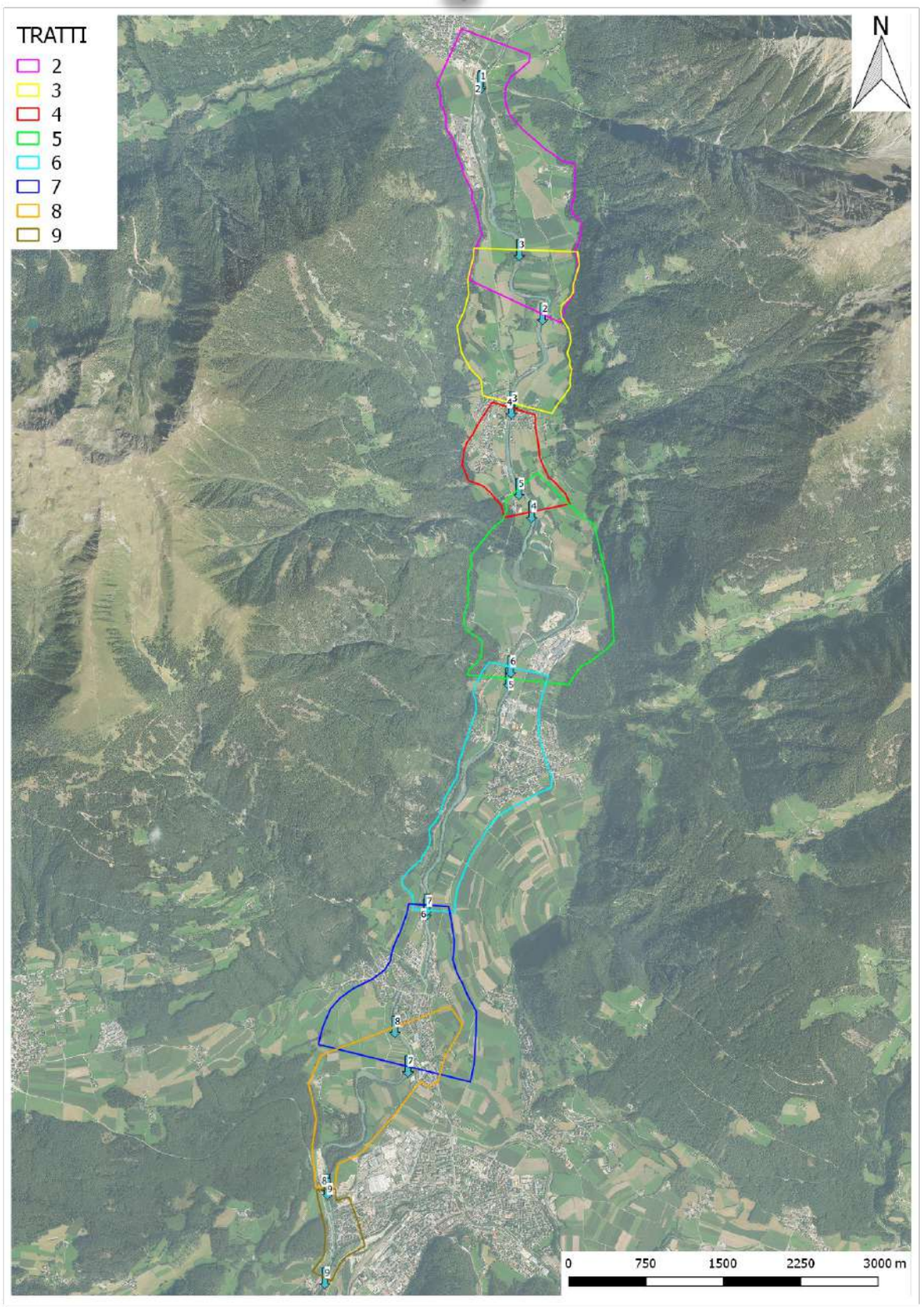




COMPUTATIONAL DOMAINS

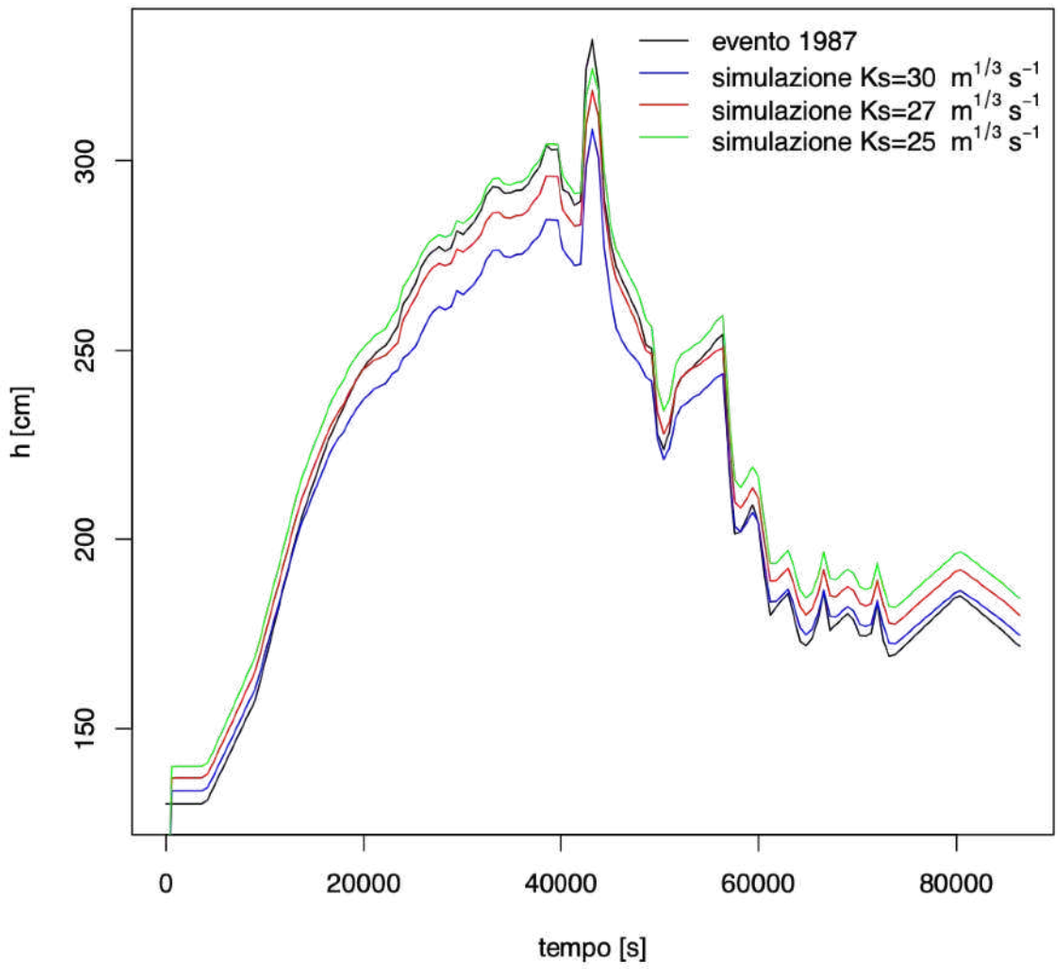
1. The computational mesh was refined, in villages, around buildings, roads and bridges.
2. Model calibration through historical events.
3. IC run with a constant discharge
4. BC inflow hydrograph + h-q relation outflow section

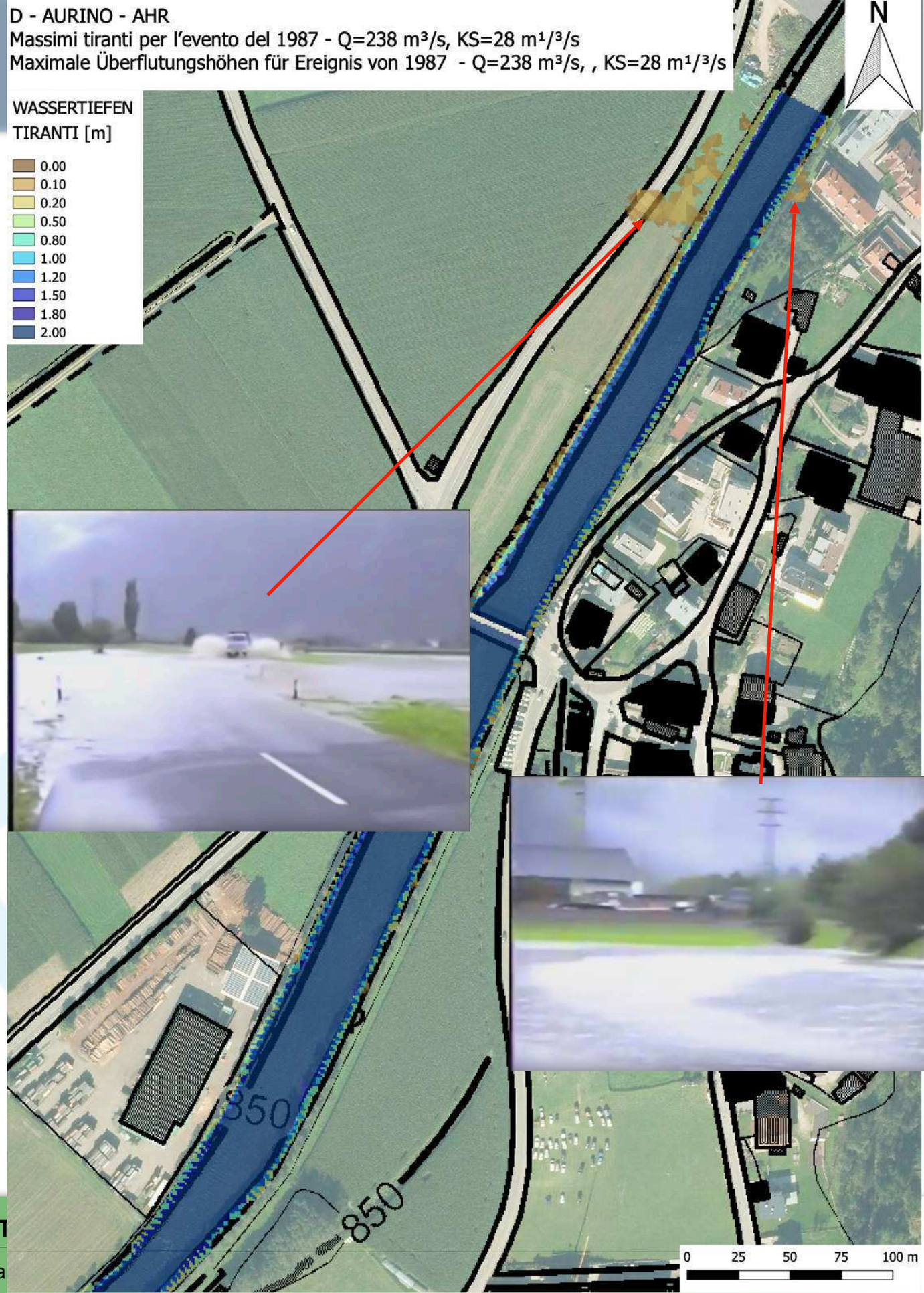




Hydraulic model calibration

through a comparison with 1987 - historical event

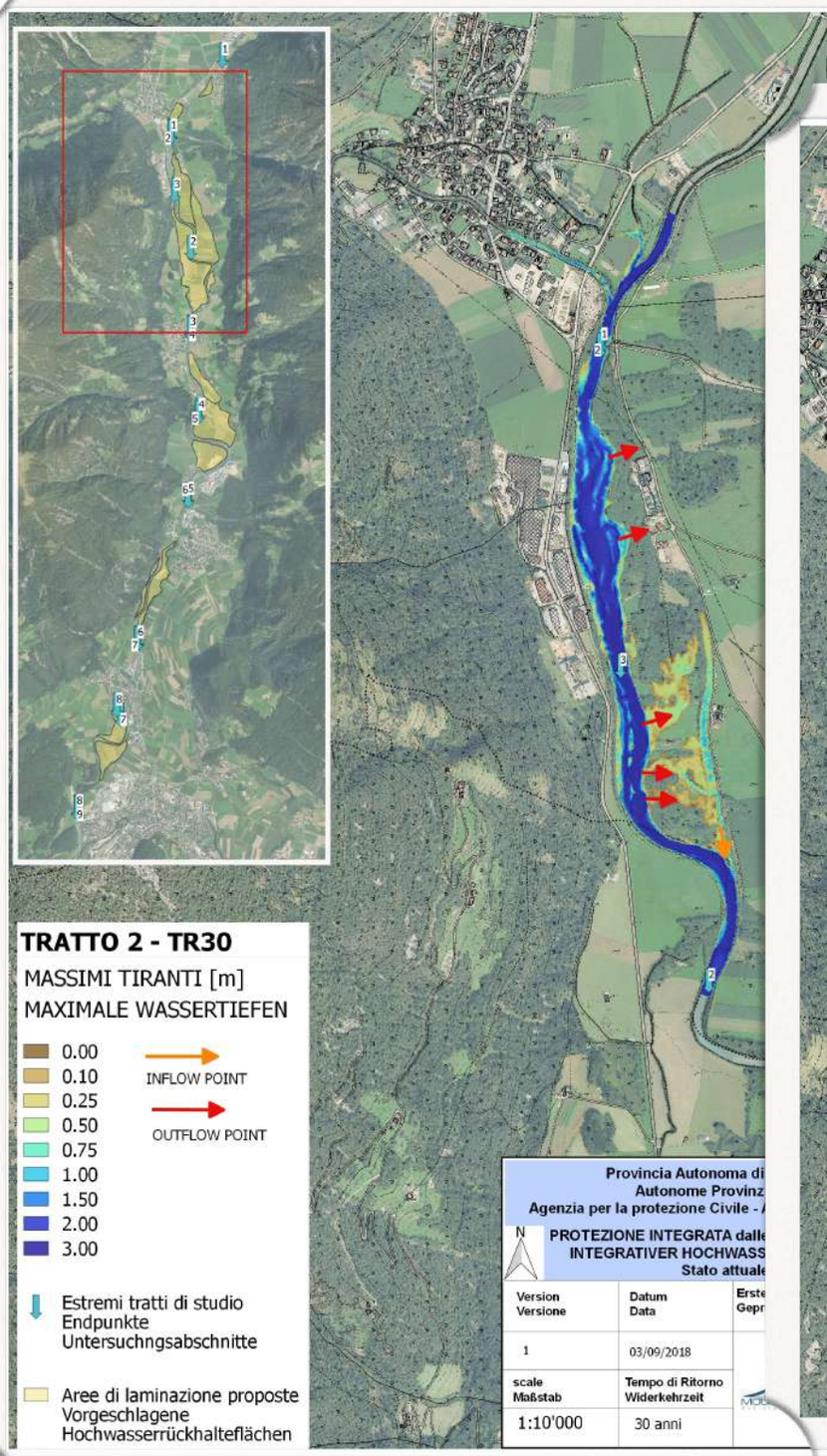




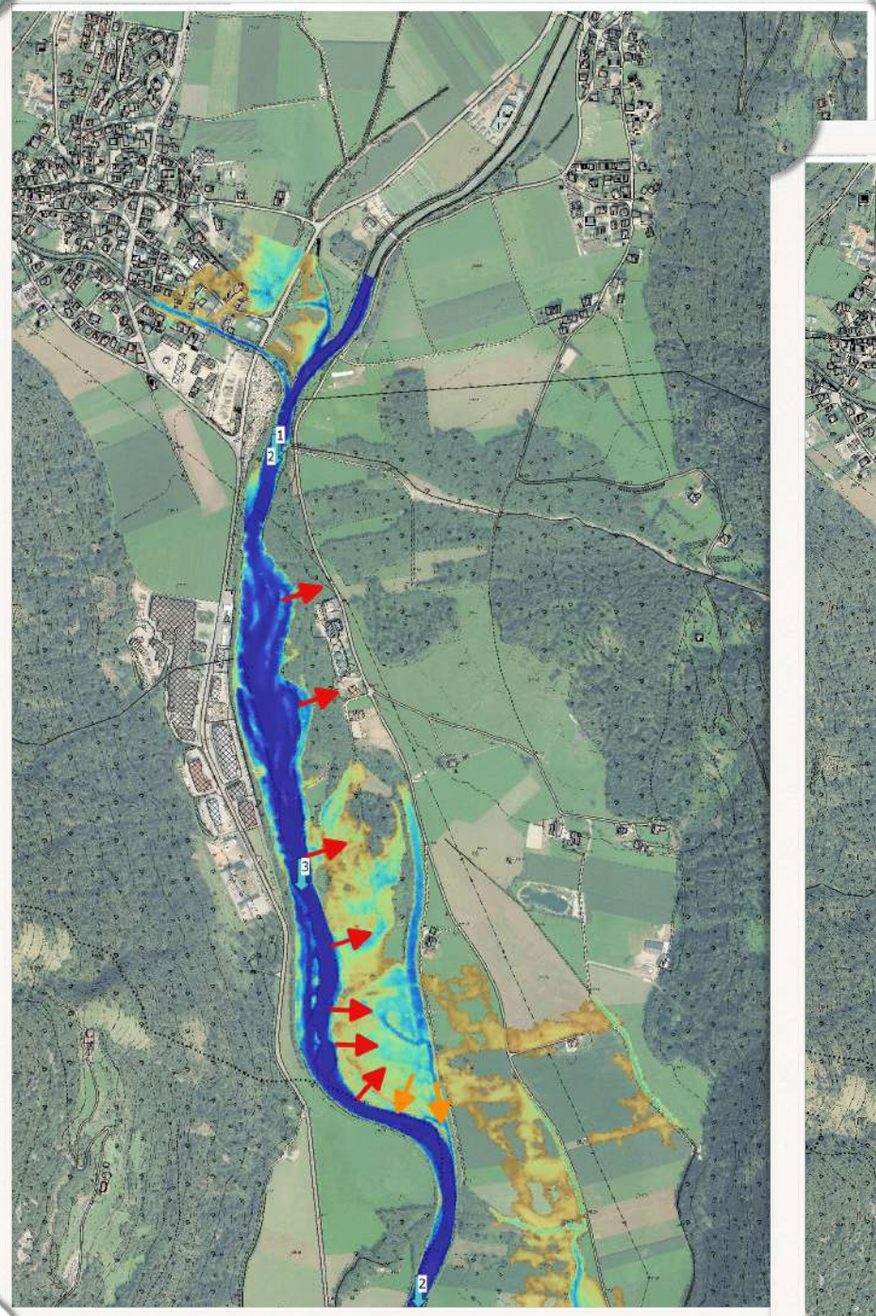
BASEMENT SIMULATIONS WERE RUN TO EVALUATE THE CURRENT NATURAL STORAGE CAPACITY OF THE VALLEY FLOOR

Results current situation - domain 2

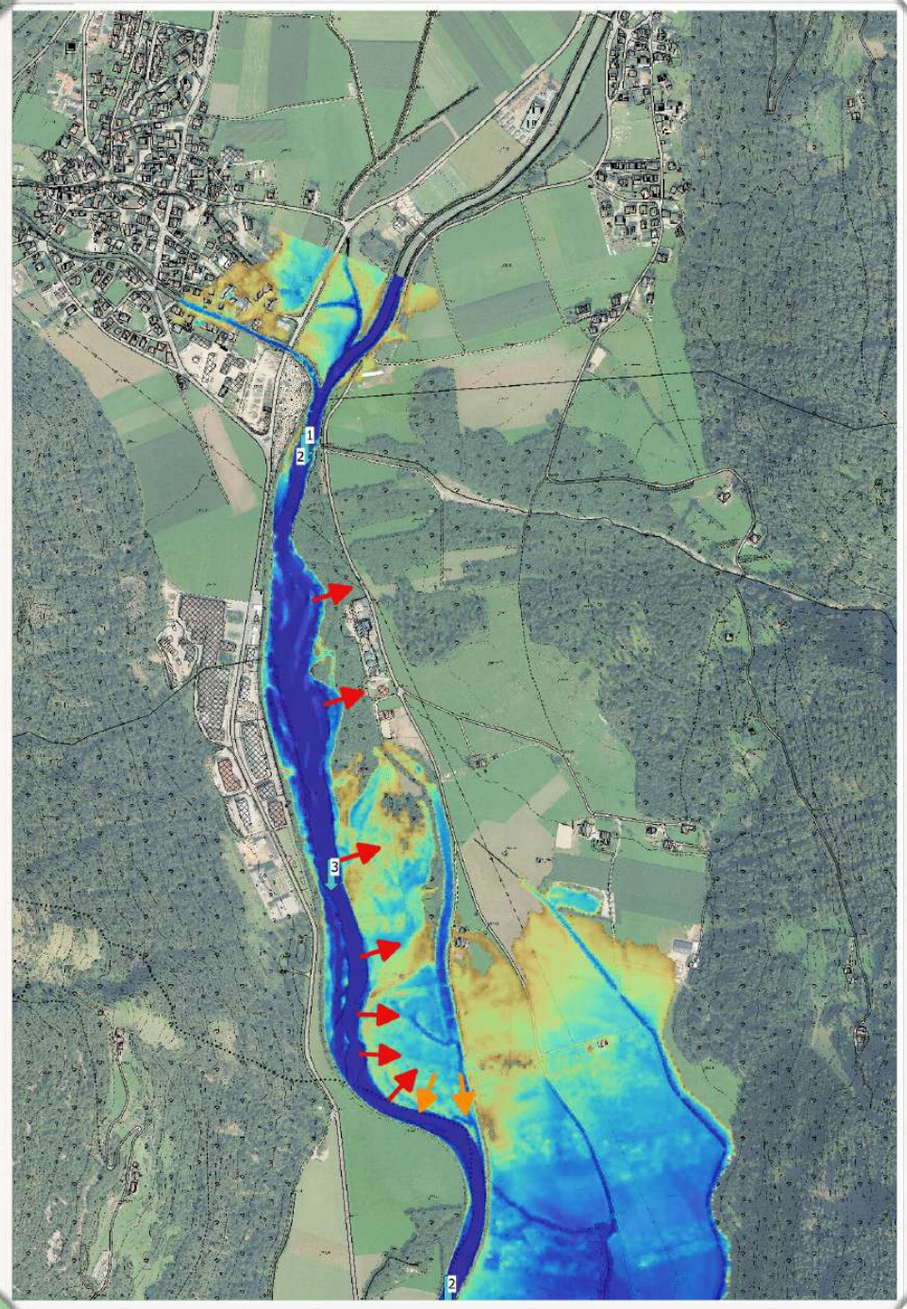
TR30



TR100

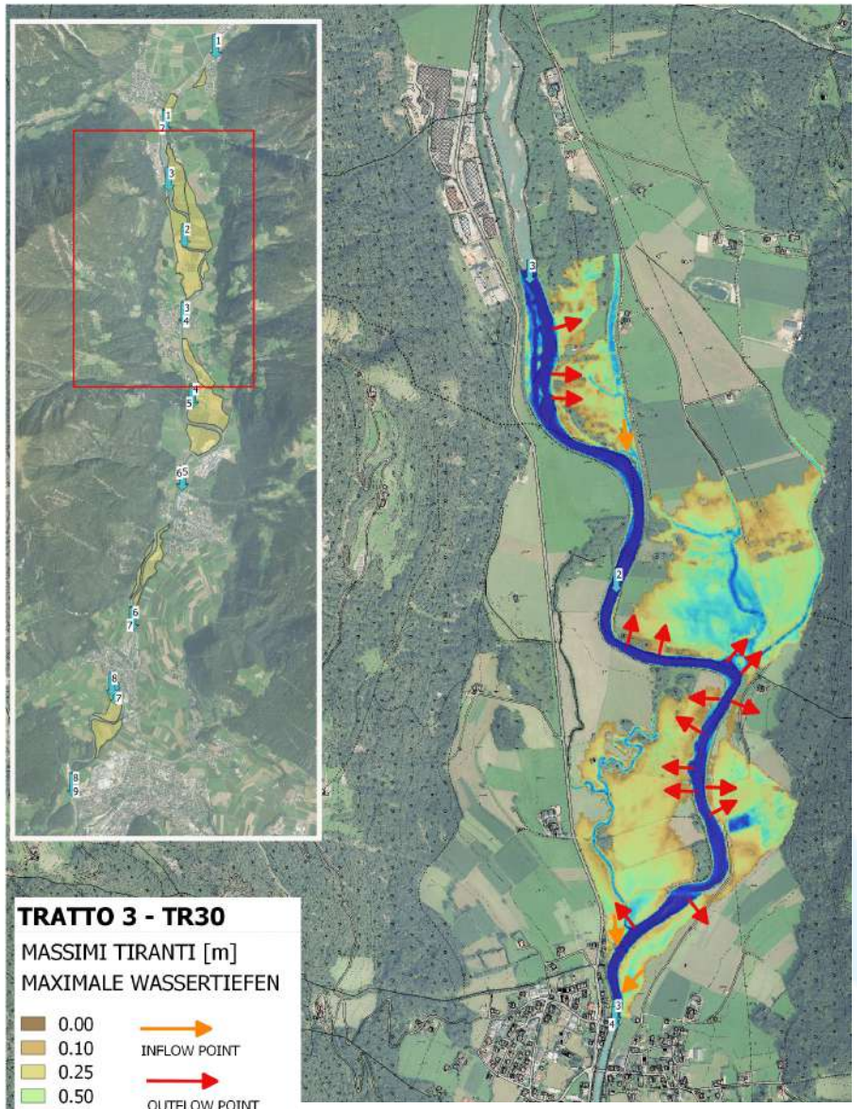


TR300

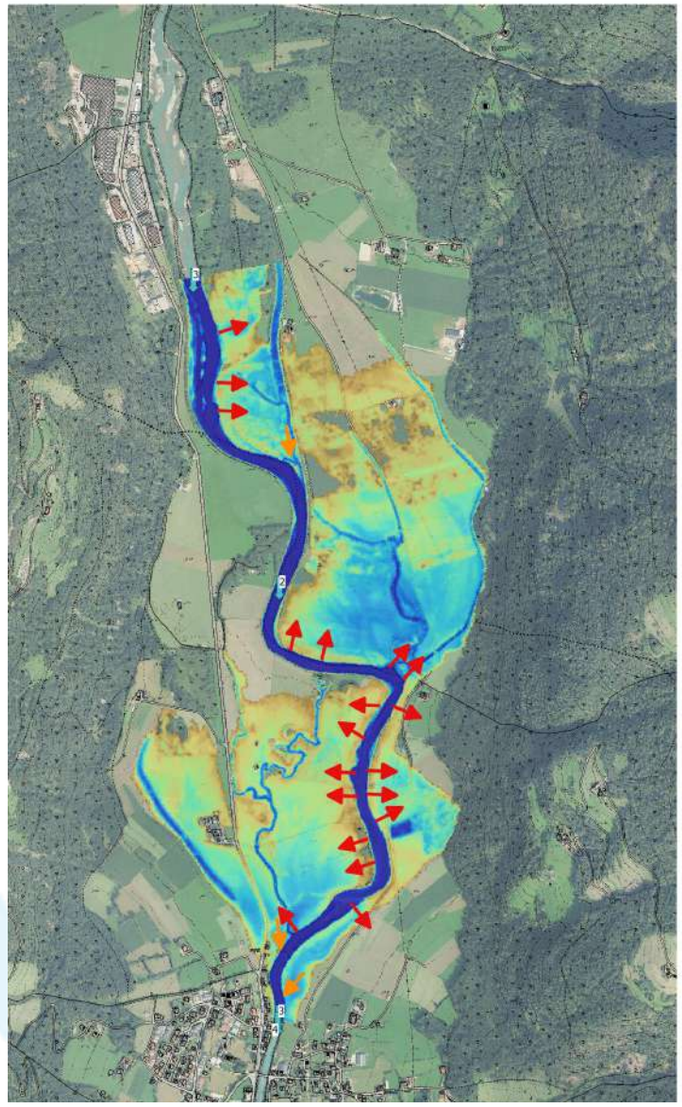


Results current situation - domain 3

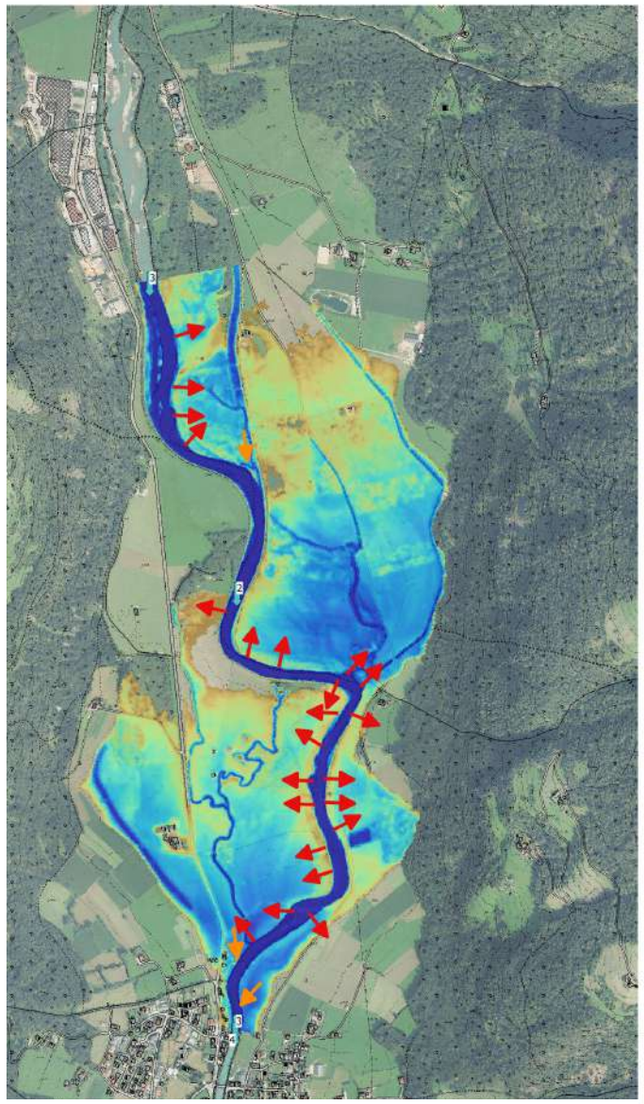
TR30



TR100



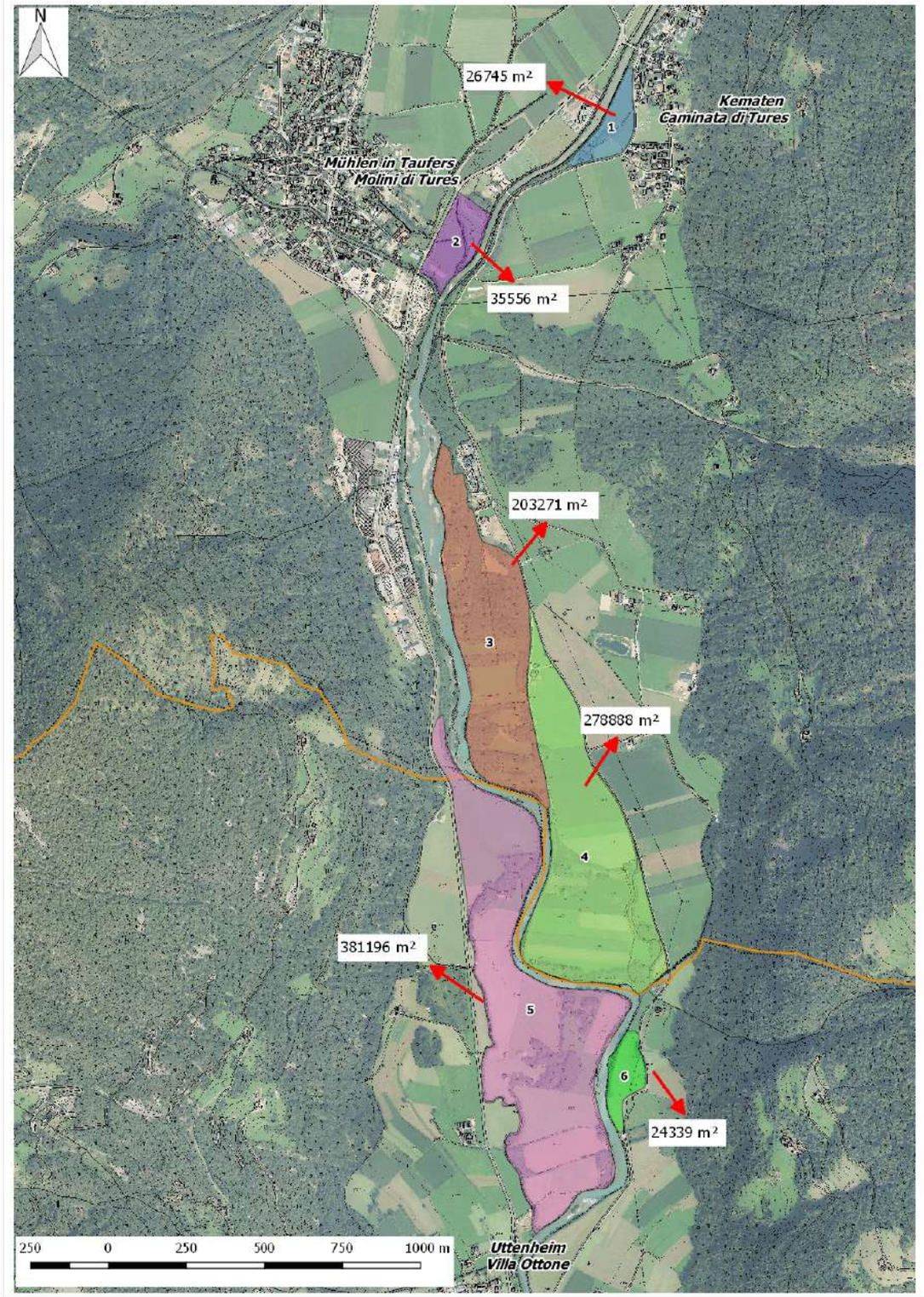
TR300



Uttenheim Nord - Uttenheim (Tratto Nord PZP Gais)

EFFECTIVE NATURAL STORAGE CAPACITY of the RETENTION AREAS

Area di ritenzione	Volume TR30 [m^3]	Volume TR100 [m^3]	Volume TR300 [m^3]
1	0	9582	15295
2	3765	11179	26340
3	33664	98746	125138
4	86093	168573	319710
5	64359	131303	198564
6	6164	10606	13979
7	0	254	17566
8	15503	31175	62990
9	45927	91616	175199
10	30700	76552	112280
11	19174	35034	45568
12	19897	26485	37070
13	21236	32466	40451
TOTALE ritenzione	346'482	723'571	1'190'150
TOTALE esondato [$10^6 m^3$]	0.4	1.1	2.1
TOTALE ritenzione [%]	93	67	56



Volumes computed by comparing the outflow hydrograph to the inflow hydrograph;

EFFECTIVE NATURAL STORAGE CAPACITY of the RETENTION AREAS

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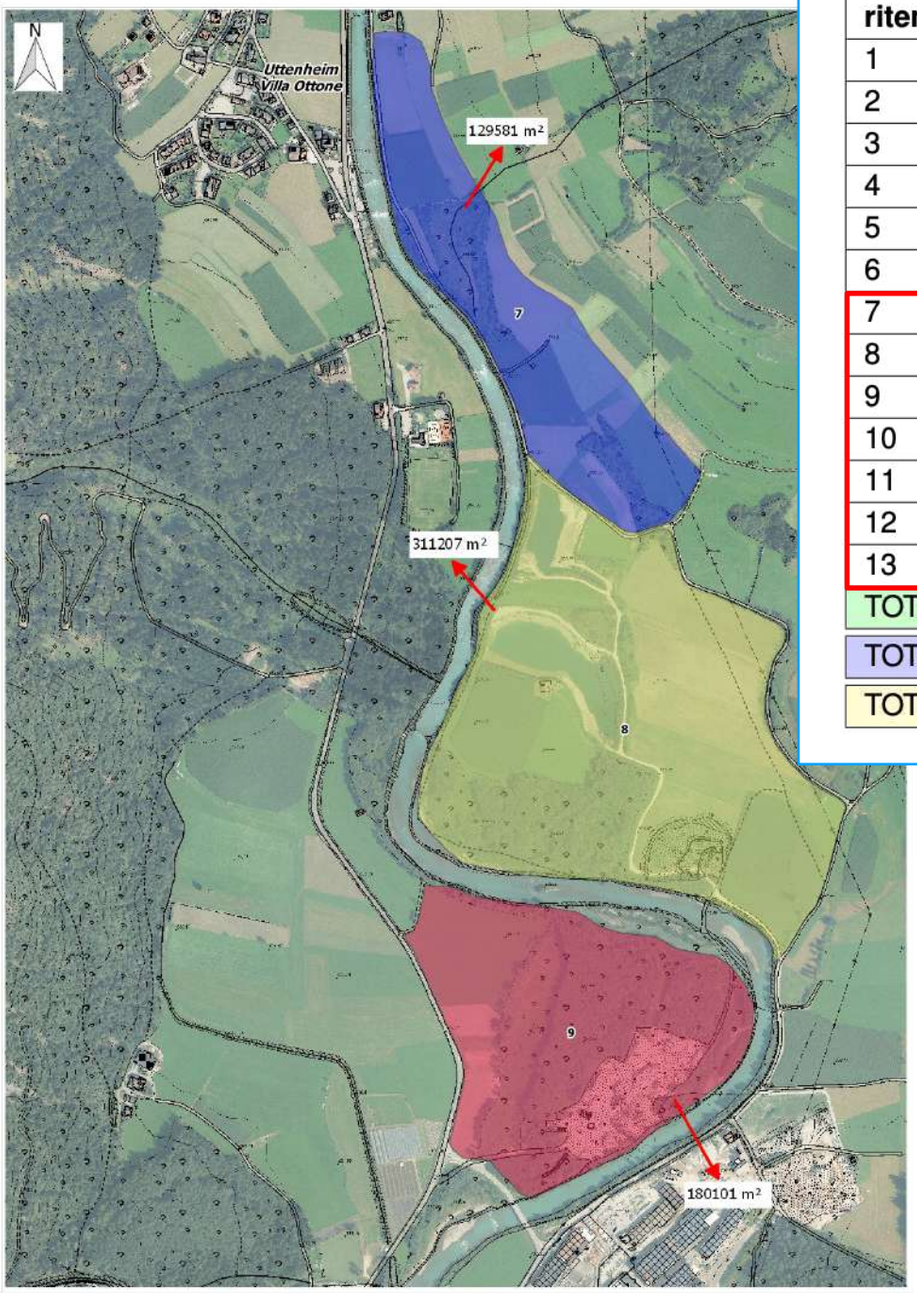
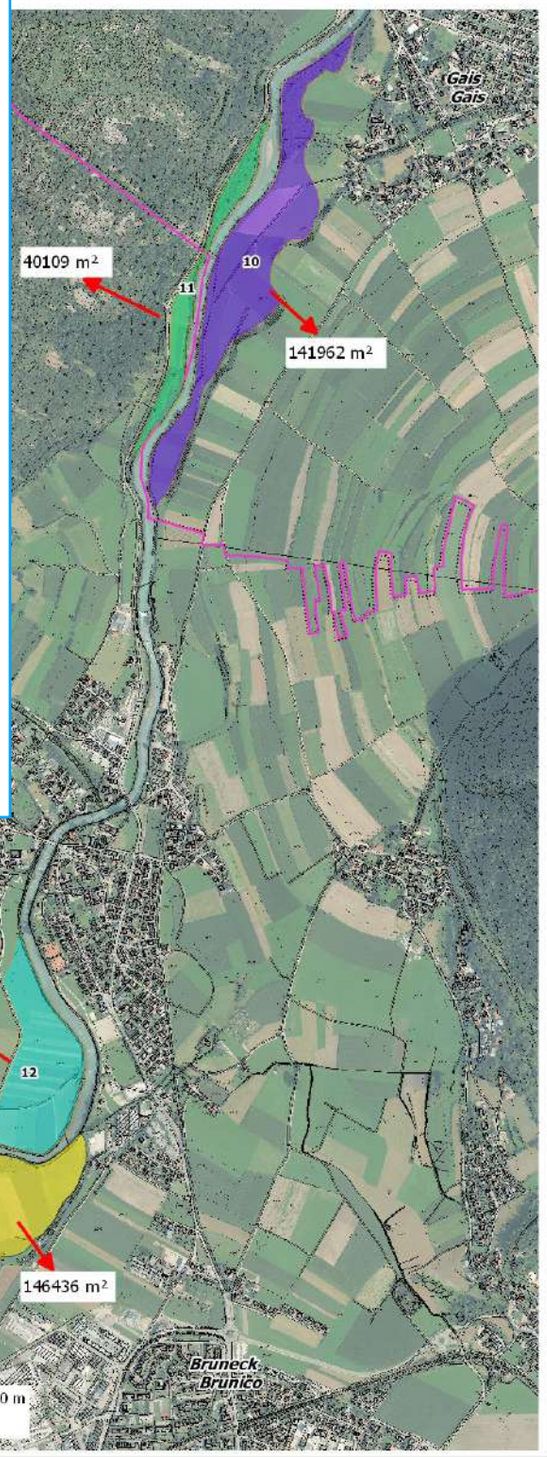




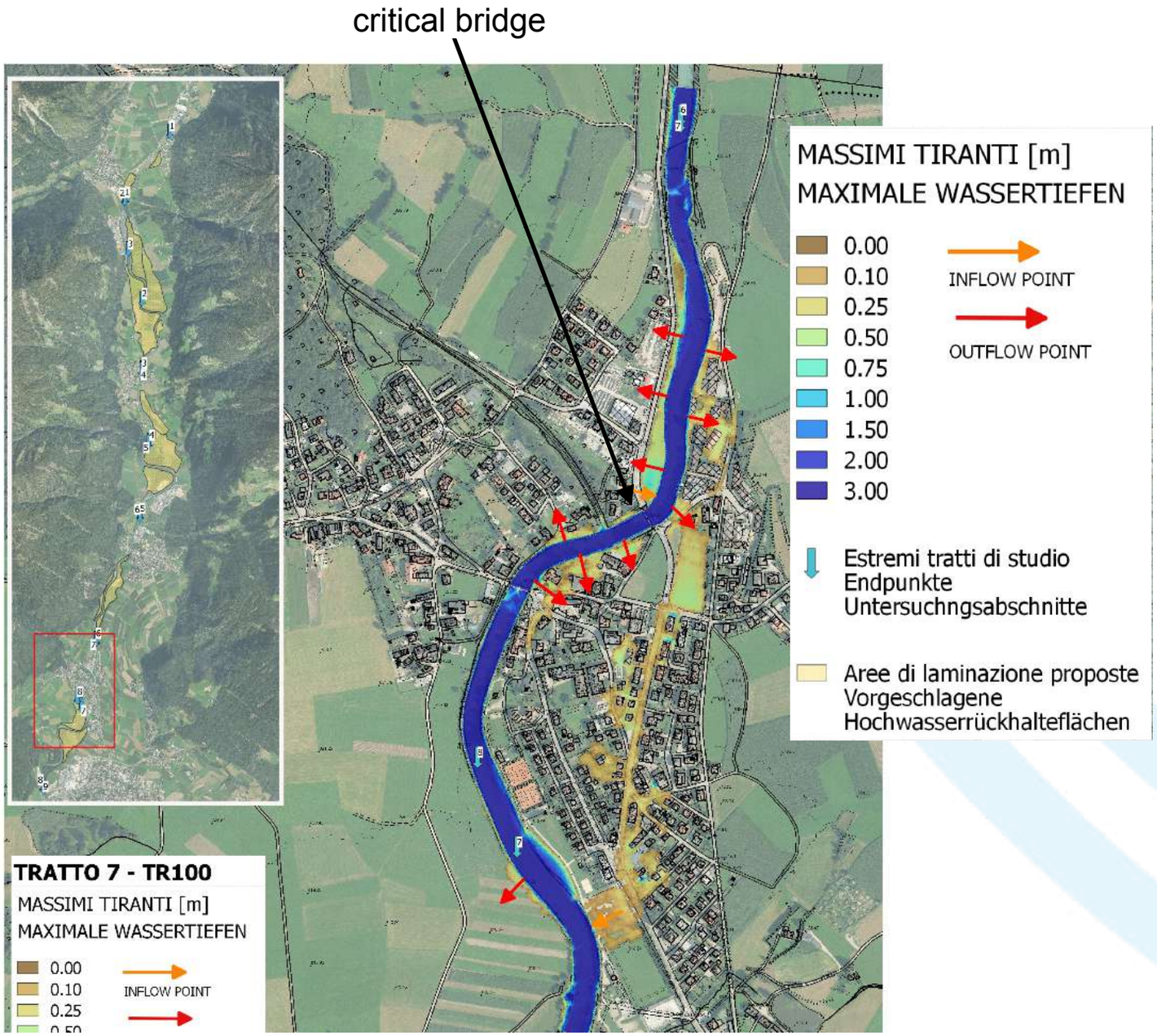
Volumes computed by comparing the outflow hydrograph to the inflow hydrograph;

Through the EFFECTIVE NATURAL STORAGE CAPACITY of the VALLEY FLOOR almost all the volume related to a 30-year flood can be retained, roughly 2/3 of a 100-year flood and roughly half of the 300-year flood

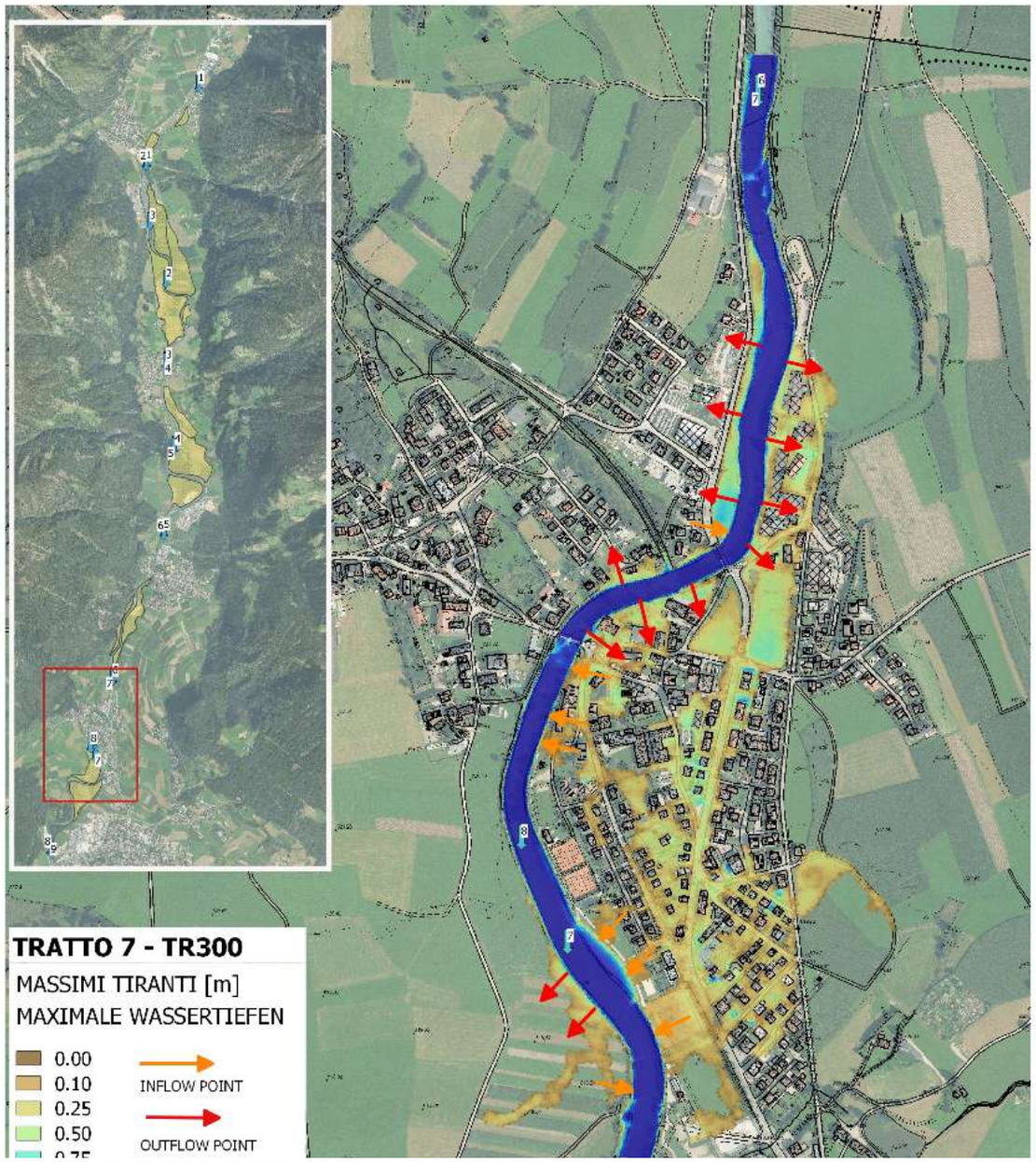
Planning instruments can help to preserve rural areas from urbanization, keeping them available for flood risk mitigation

However PART of the risk still persists

RESULTS ACCOUNTING FOR NATURAL RETENTION AREAS



RESULTS NOT ACCOUNTING FOR NATURAL RETENTION AREAS



S. Giorgio: Buwal values - hazard overview

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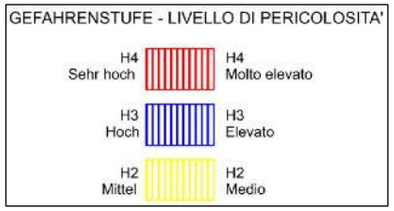
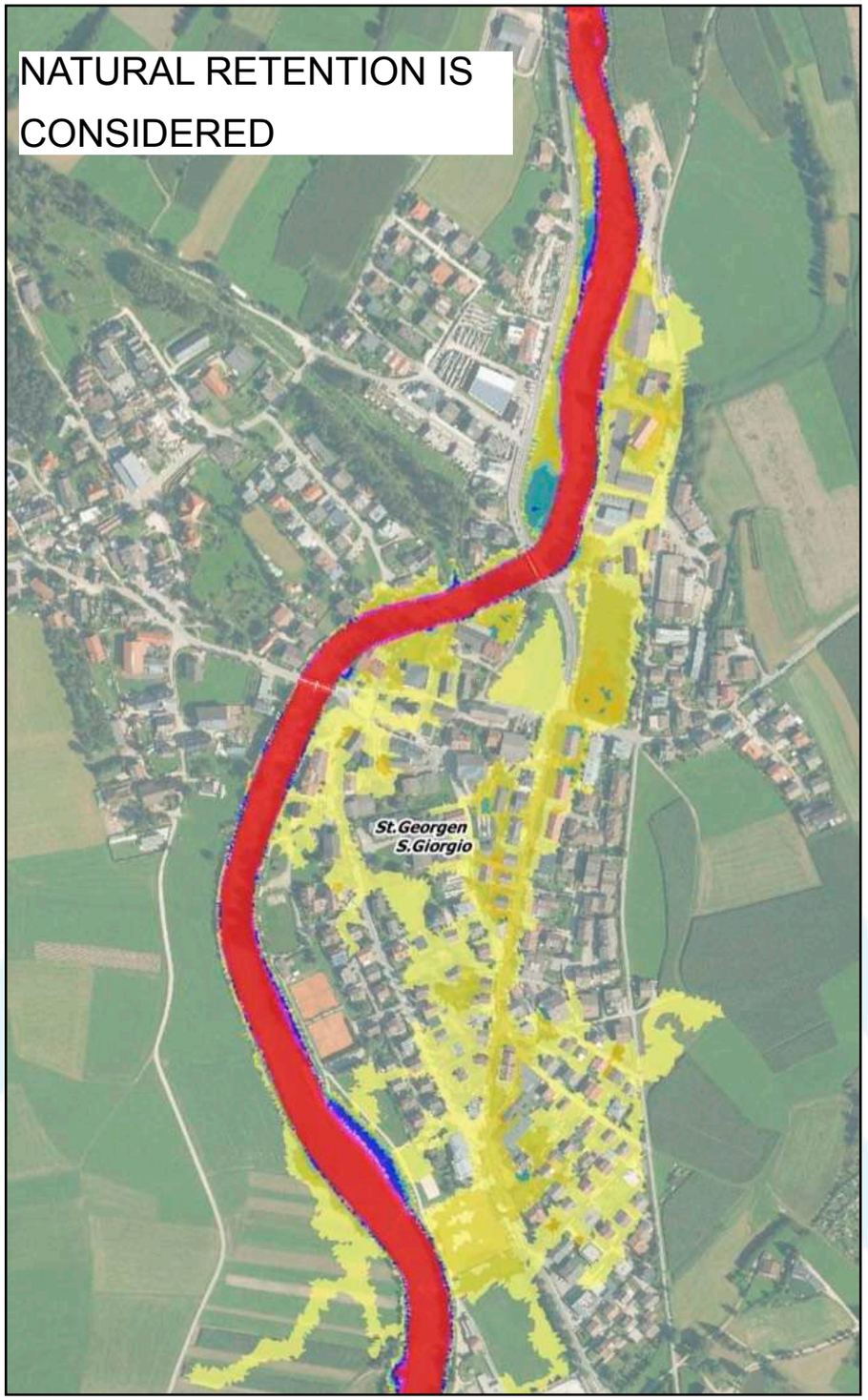
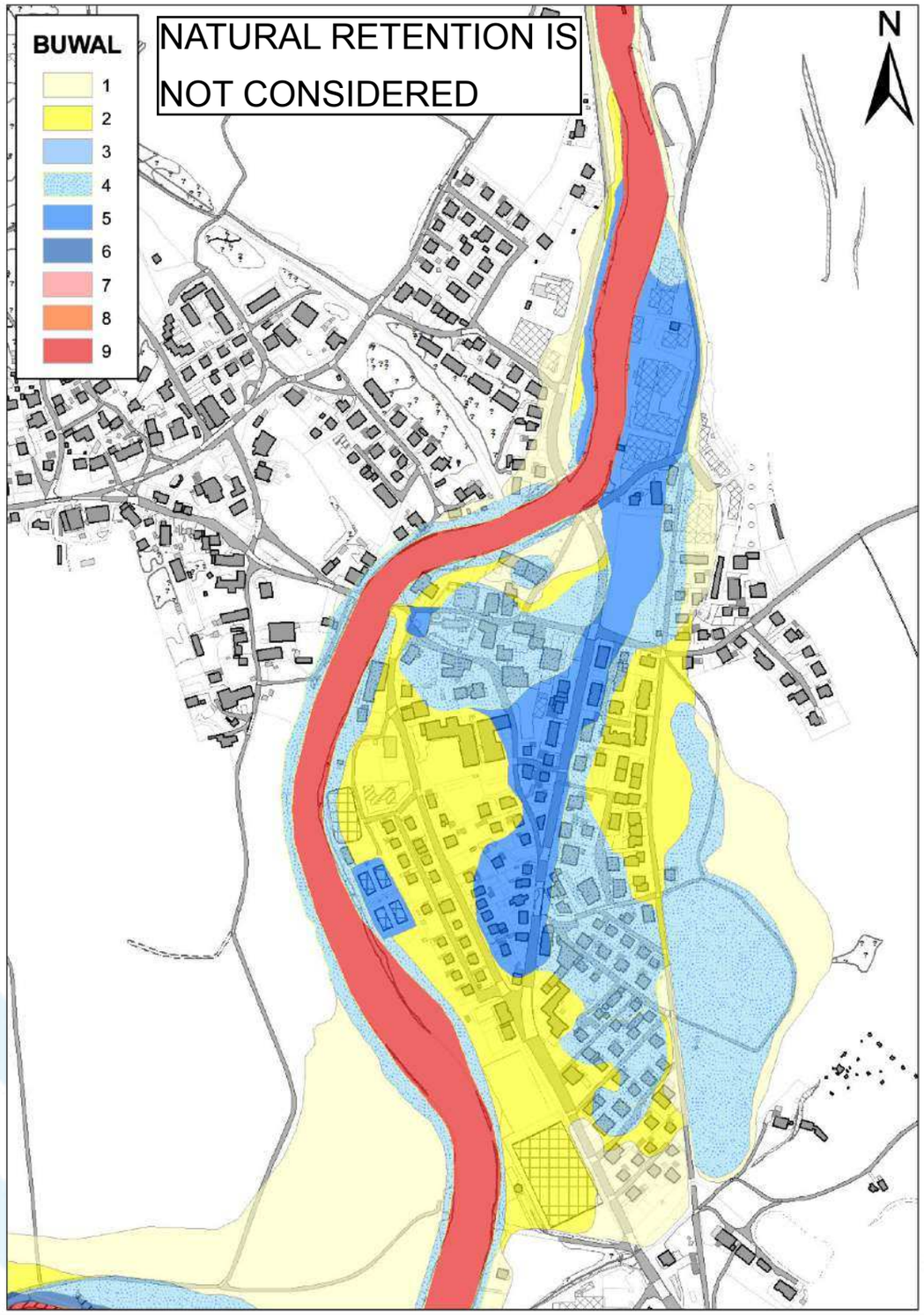






PROJECT:

OBJECTIVES

1. **Reducing the hydraulic hazard** in San Giorgio by retaining water upstream in lamination areas, in order to eliminate high hazard zones (blue areas in the previous figure)

2. **Restoring river** areas near the Aurino stream where possible

→ We need to

1. **keep** the currently **floodable areas free of settlements** → measures to be introduced in the urban plans of the municipalities involved

2. **Cut the peak** discharge for Q_{100} and Q_{300}

3. **retain a larger volume upstream** (with respect to natural state)

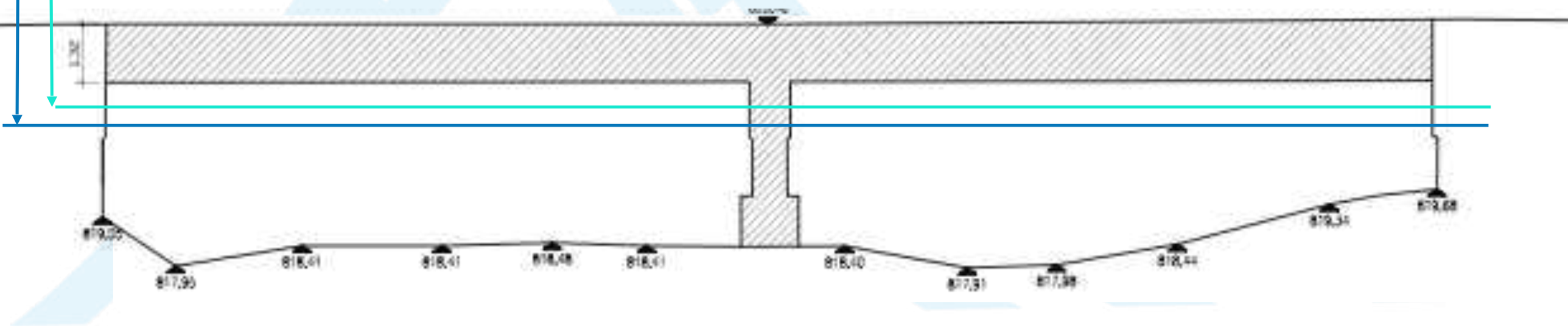
S. Giorgio: critical bridge

Depending on the freeboard values to be achieved at the critical bridge, different volumes of water must be laminated upstream, as shown in the table below

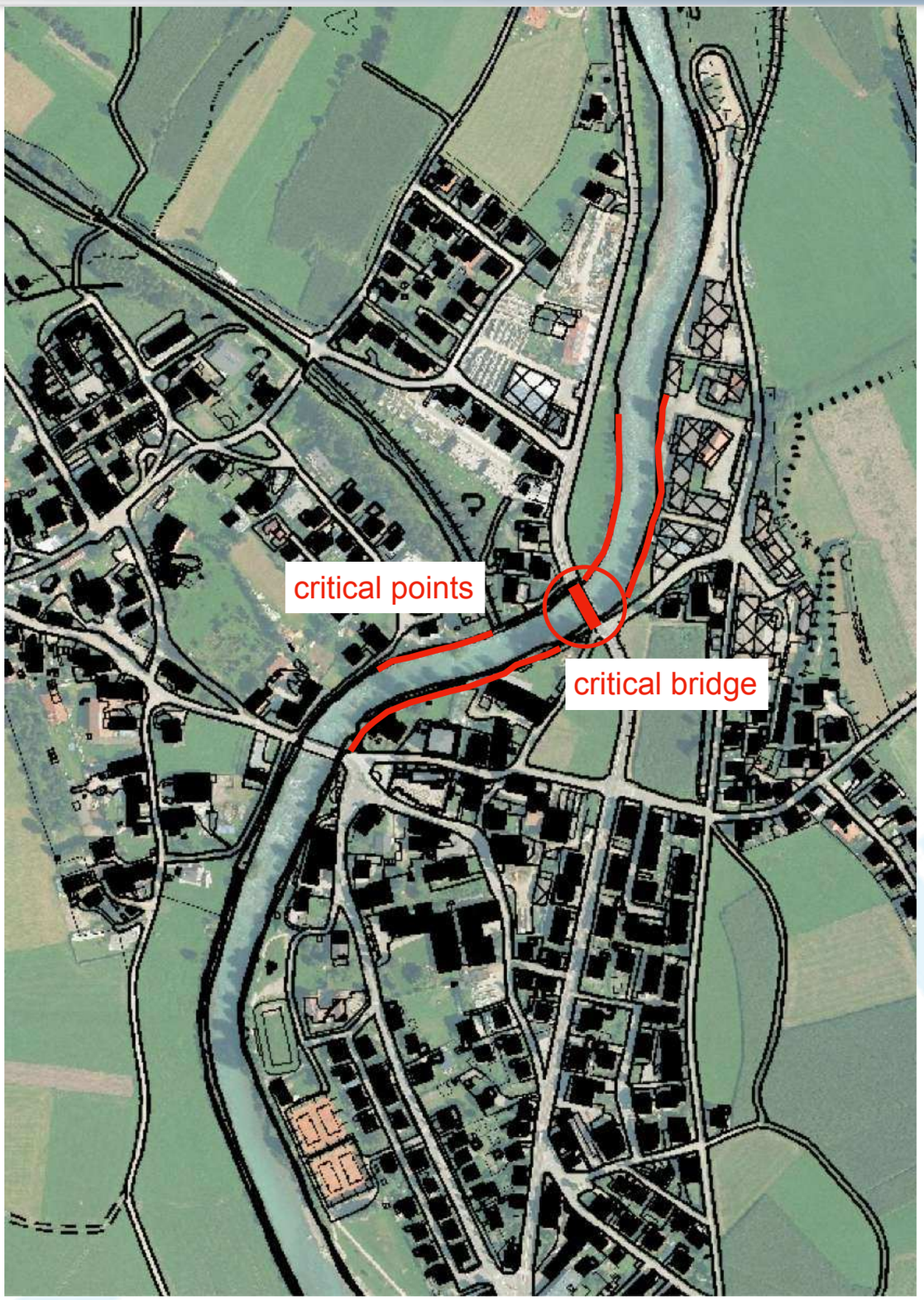
Q* is the discharge that provides the desired freeboard value at the bridge section

Q* [mc/s]	quota media wse [m s.l.m.]	franco medio [m]	ΔQ TR100 [mc/s]	ΔQ TR300 [mc/s]	t* TR100 [ore]	t* TR300 [ore]	V_LAM TR100 [mc]	V_LAM TR300 [mc]
178	820.9	1	139	192	15.7	22.2	3366400	5896890
191	821	0.9	126	179	13.3	18.5	2686800	4951390
201	821.1	0.8	116	169	11.5	16.5	2238140	4319100
220	821.25	0.65	97	150	8.8	13.7	1546780	3277350
241	821.41	0.49	76	129	6.5	10.7	969995	2353400
248	821.45	0.45	69	122	5.8	9.7	814480	2097310
249	821.45	0.45	68	121	5.83	9.67	792882	2061910
282	821.65	0.25						

calculation without bridge deck



S. Giorgio: method for calculating volumes to be laminated



Let Q* be the discharge that provides the desired freeboard in the bridge section, which is the main critical point

e.g. $Q^* = 248\ m^3/s$ corresponding to a 45 cm freeboard ~ $Q_{30} = 249\ m^3/s$

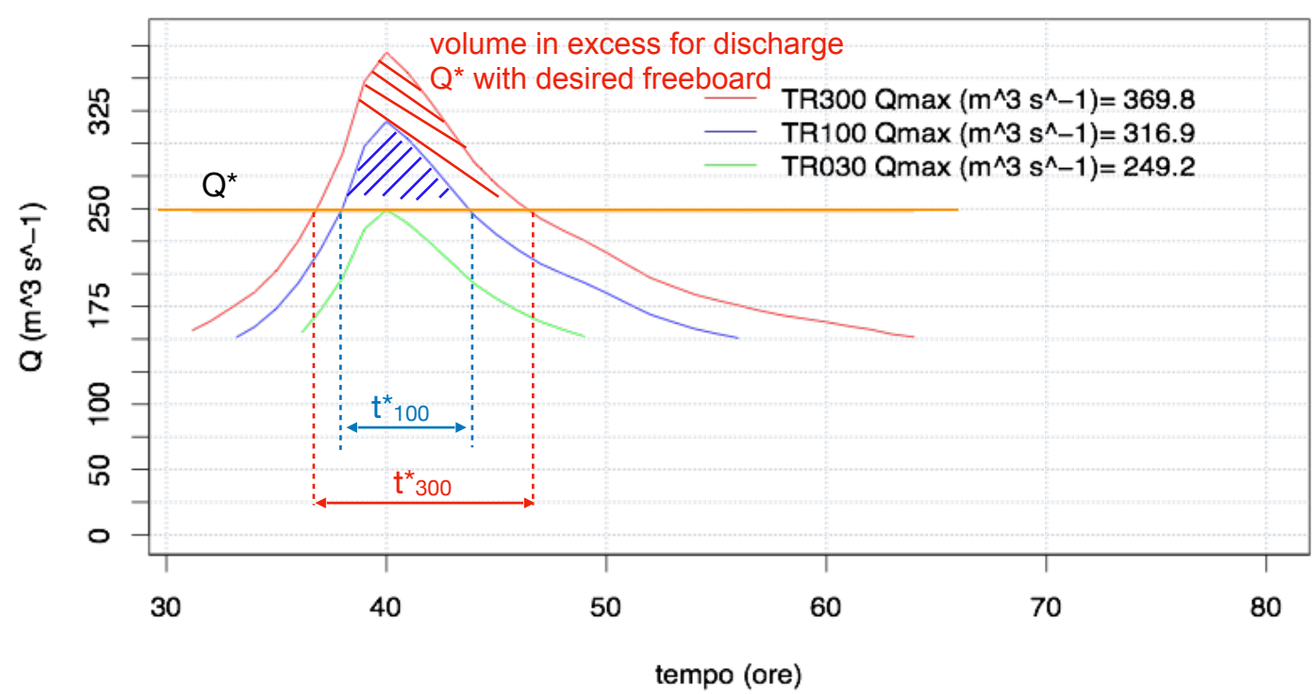
t^* = time for which $Q > Q^*$

$t^*_{100} = 5.8\ h$

$t^*_{300} = 9.7\ h$

$V^*_{100} = 814480\ m^3 \sim 0.8\ Ml\ m^3$

$V^*_{300} = 2097310\ m^3 \sim 2.1\ Ml\ m^3$



S. Giorgio – Alternative 1

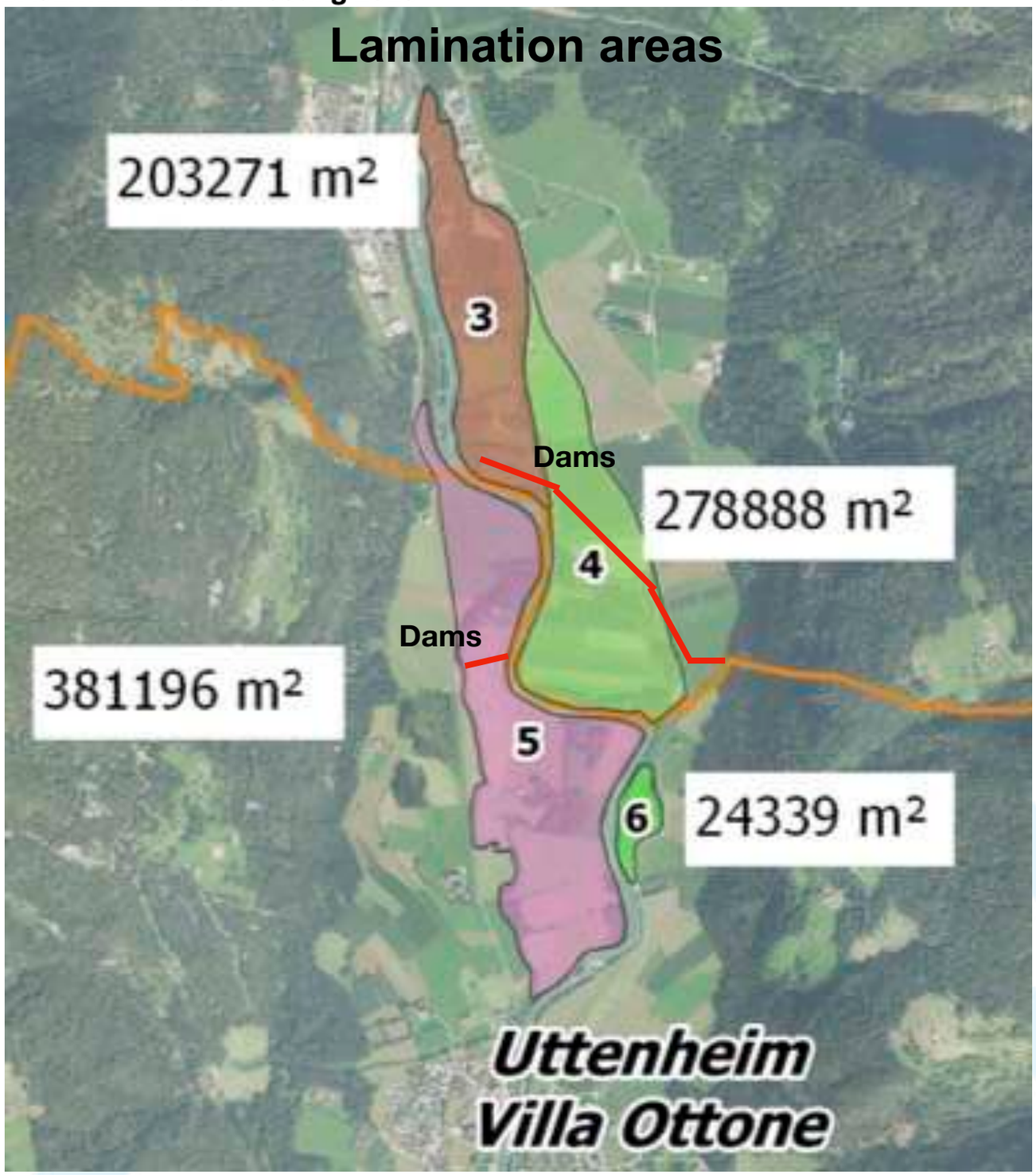
OBJECTIVES

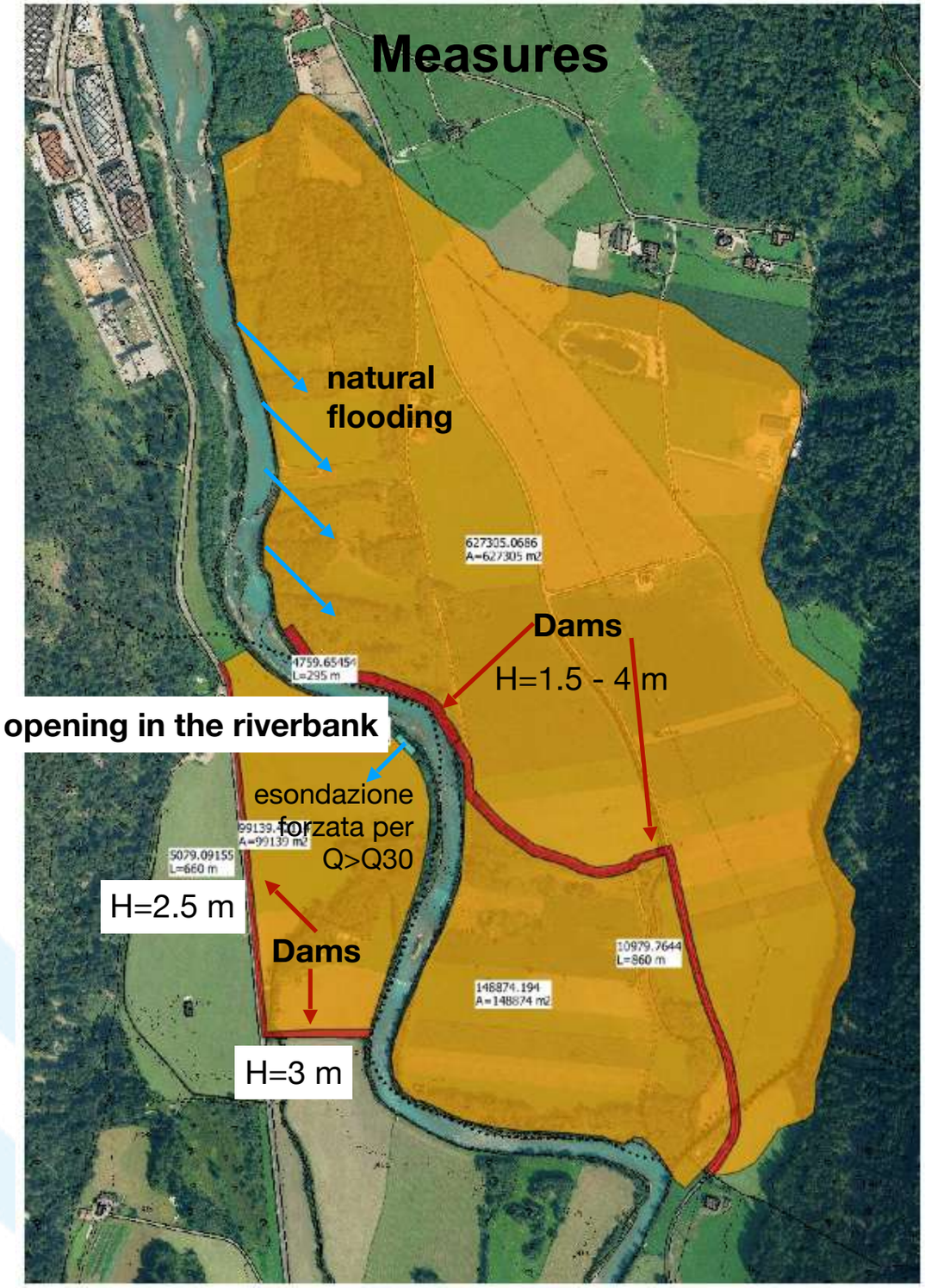
1. Peak discharge at S. Giorgio considering natural lamination for Q_{100} = 317 m^3/s and Q_{300} = 370 m^3/s
2. Design discharge: 1-100-year flood
3. Cut the peak to Q* = 248 / 249 m^3/s
4. Retention 0.8 Ml m^3 upstream

RESULTS

1. Peak discharge at S. Giorgio considering lamination in Variante 1 for Q_{100} = 284 m^3/s and Q_{300} = 323 m^3/s
2. Difference with the current state: Q_{100} = 33 m^3/s; Q_{300} = 47 m^3/s
3. Retained upstream 0.6 Ml m^3 TR100; 1 Ml m^3 TR300
4. Peak discharge at S. Giorgio without natural lamination: Q_{30} = 263 m^3/s; Q_{100} = 370 m^3/s; Q_{300} = 466 m^3/s

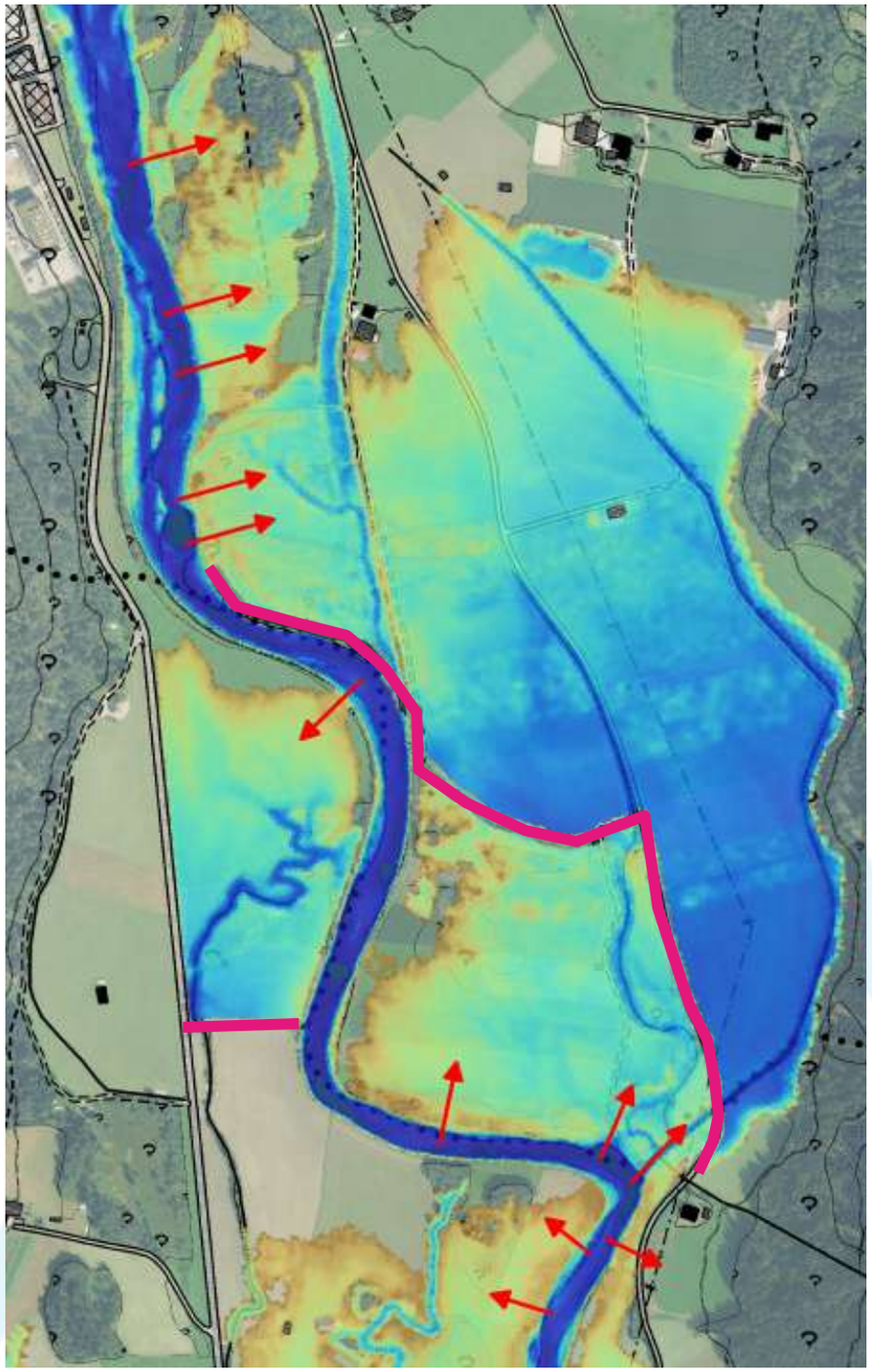
AREAS 3, 4, 5 - STRUCTURAL MEASURES

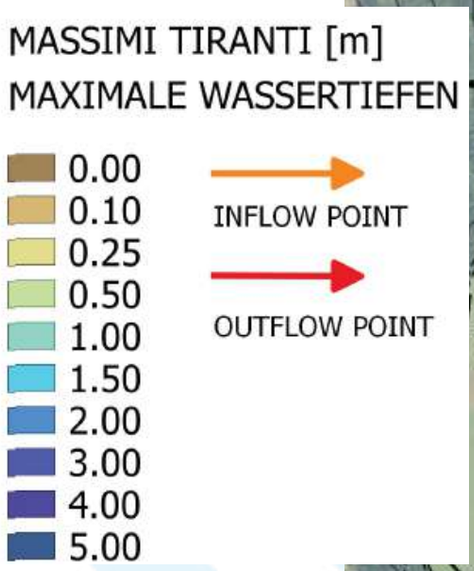




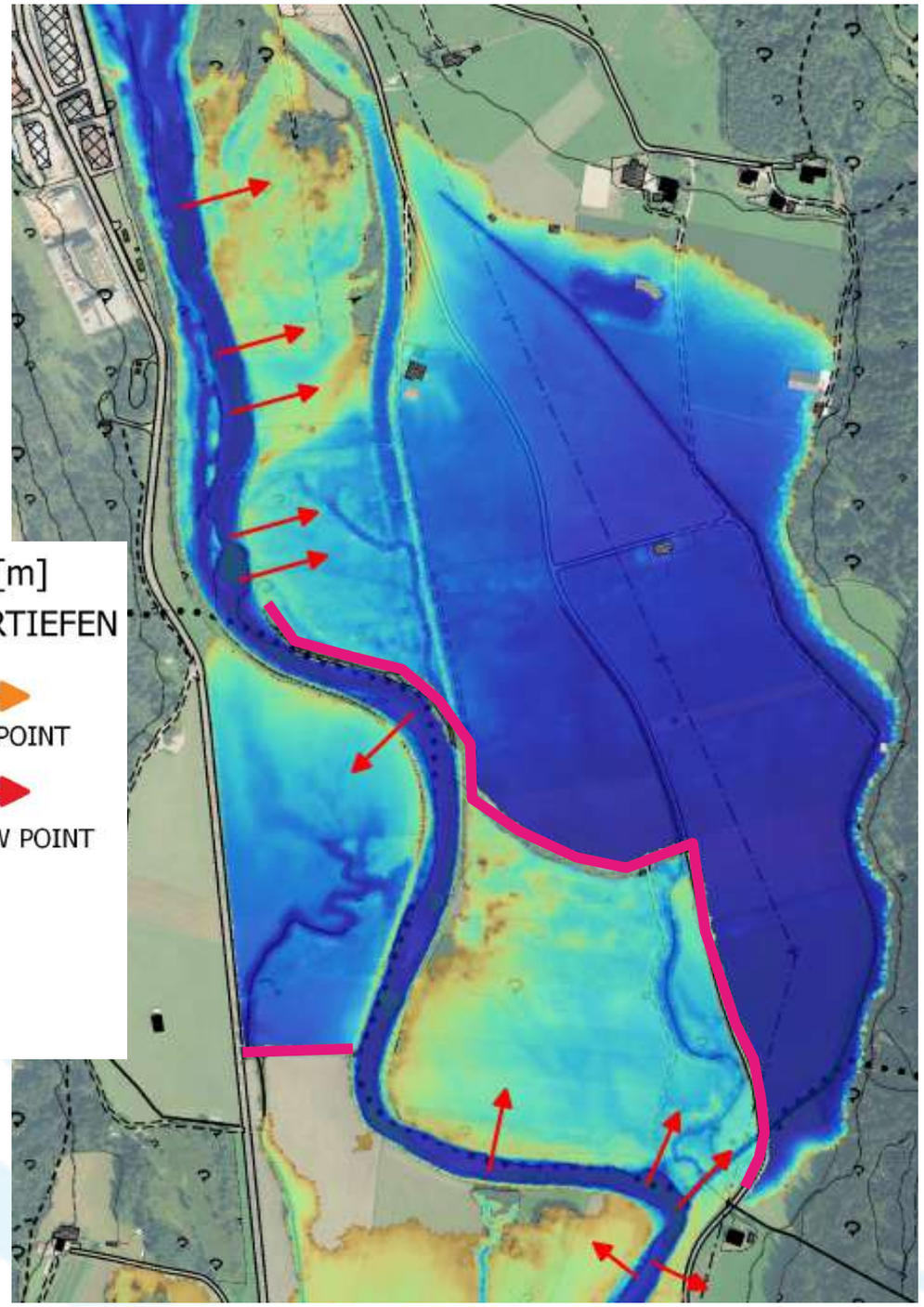
AREAS 3, 4, 5 - STRUCTURAL MEASURES

TR100

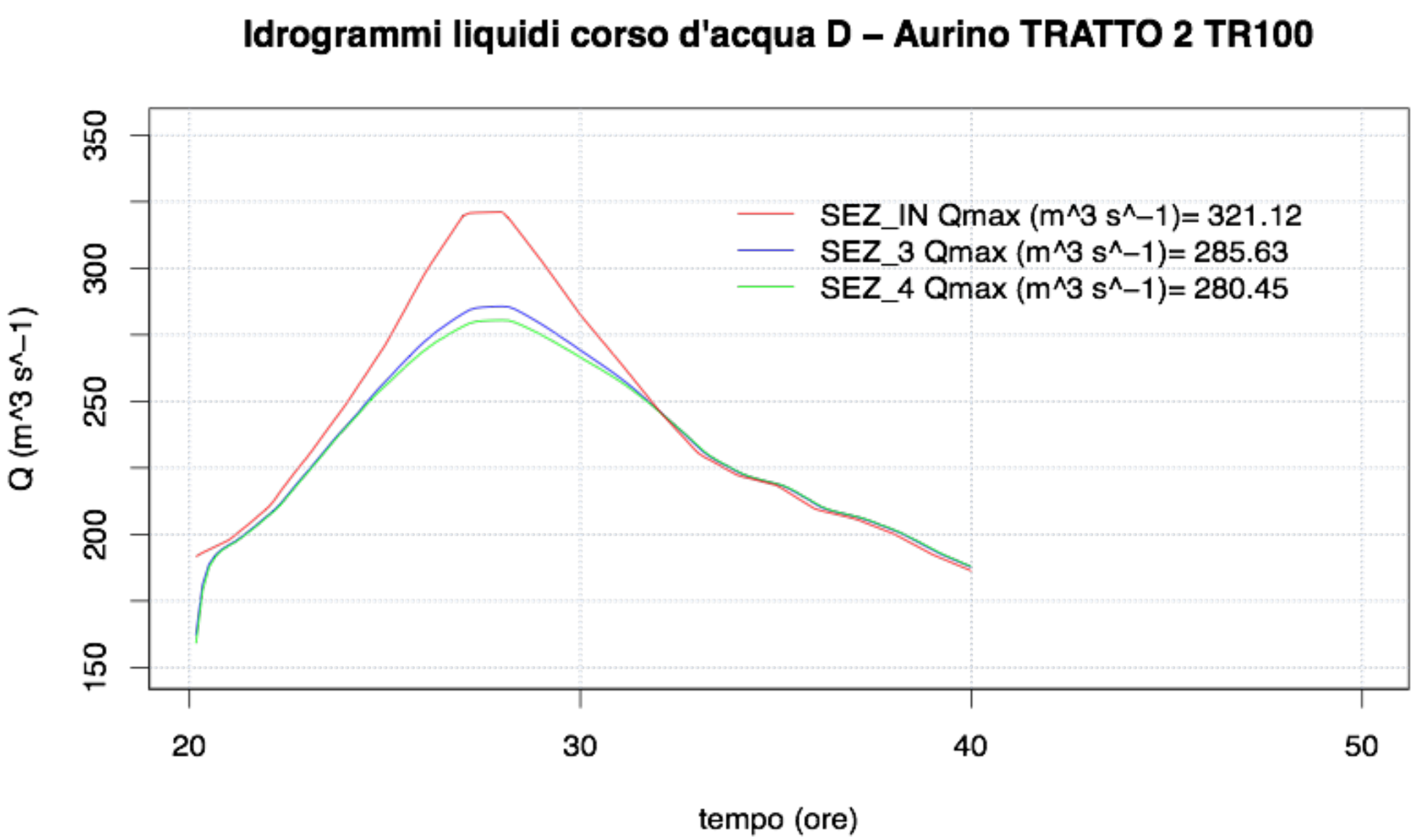




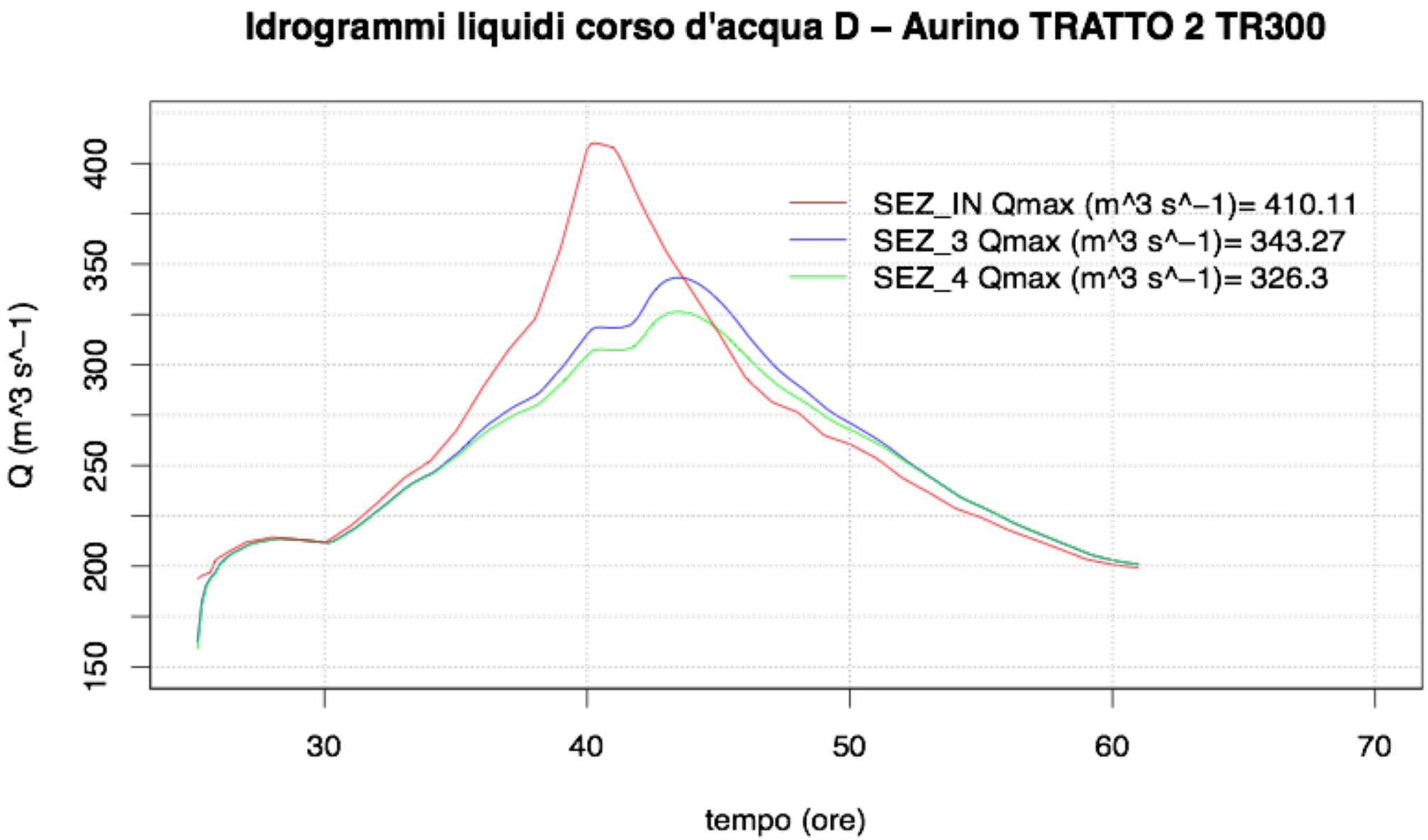
TR300



- peak decrease 1-100-year flood between upstream and downstream of the intervention area

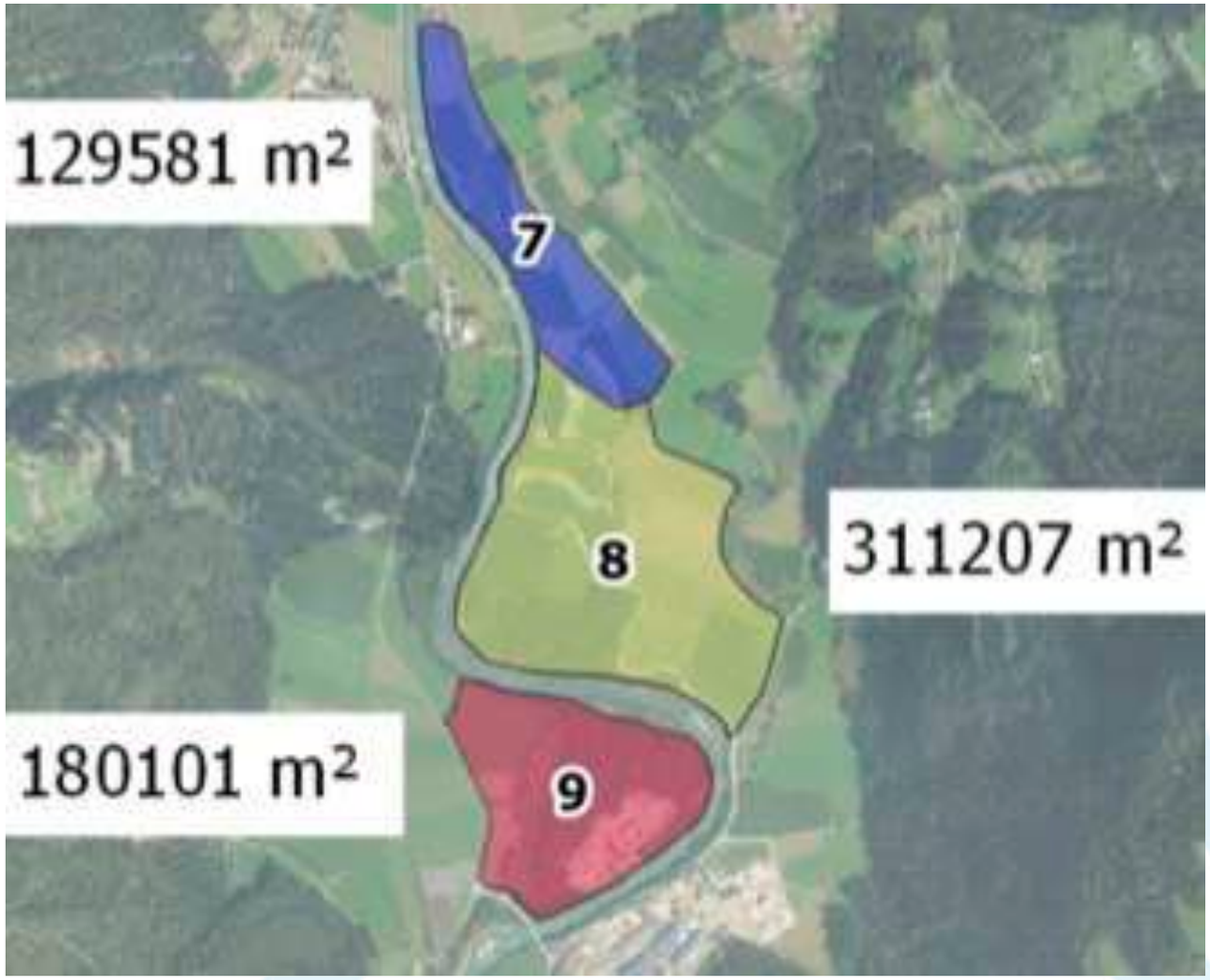


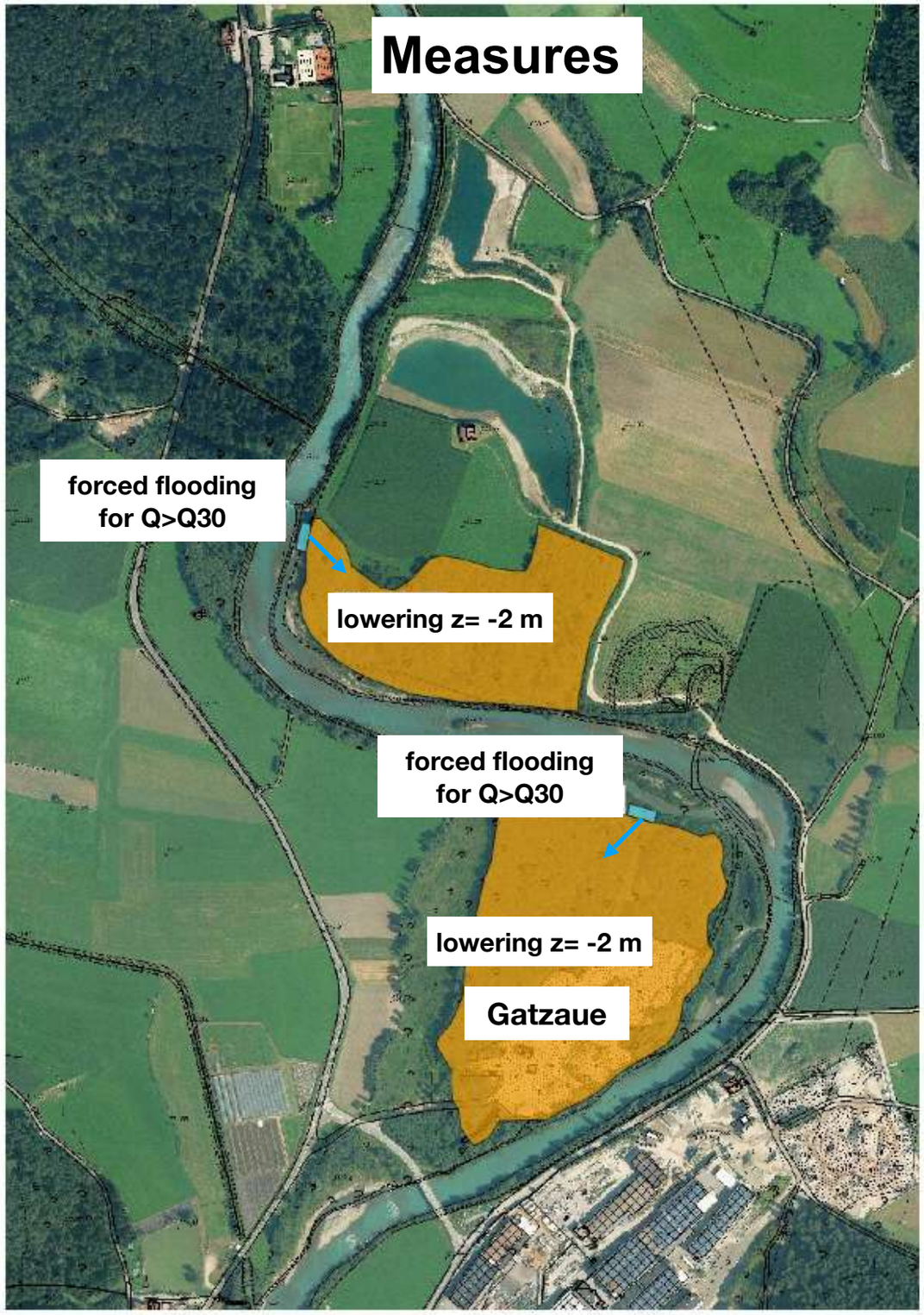
- peak decrease 1-300-year flood between upstream and downstream of the intervention area

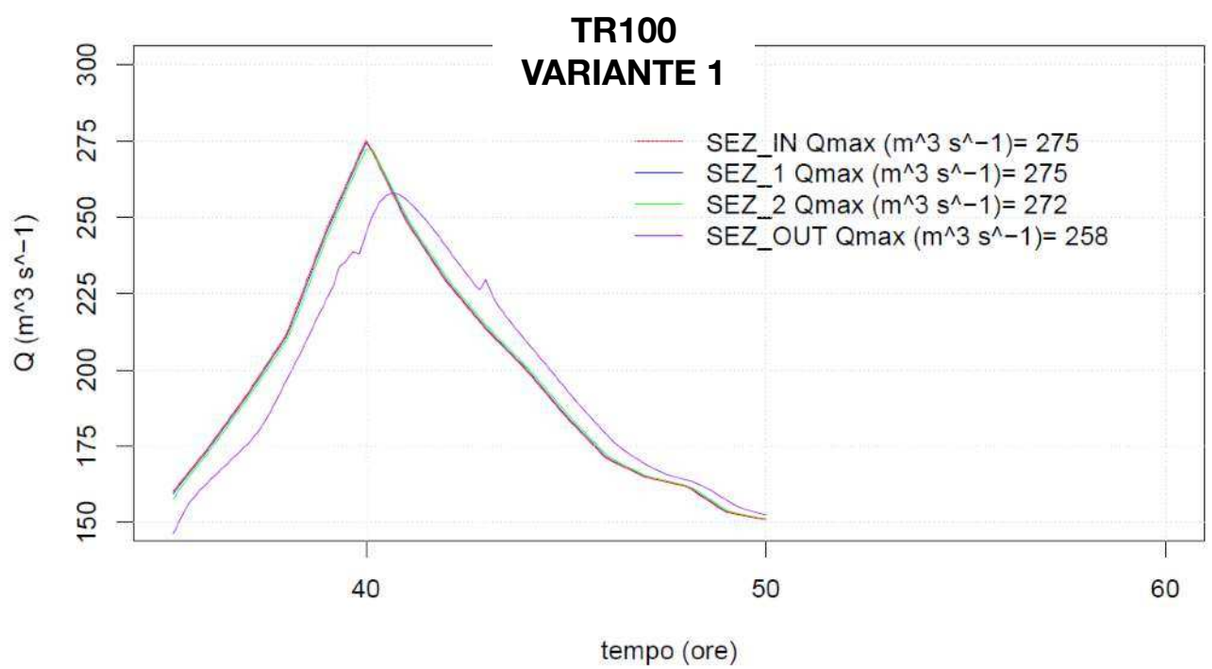


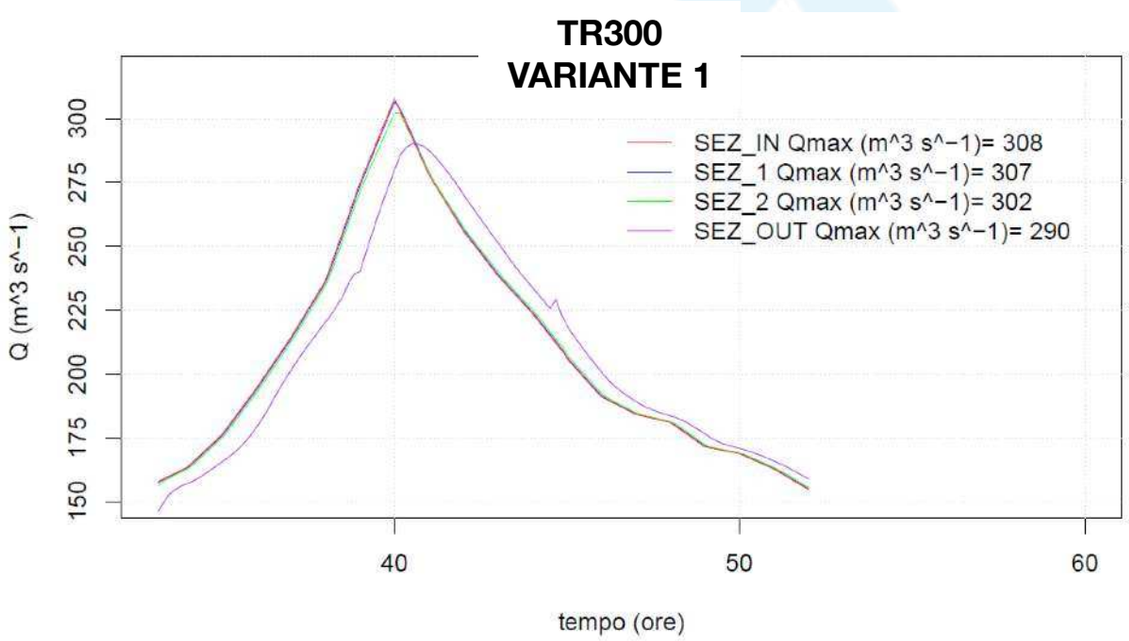
AREAS 8, 9 - STRUCTURAL MEASURES

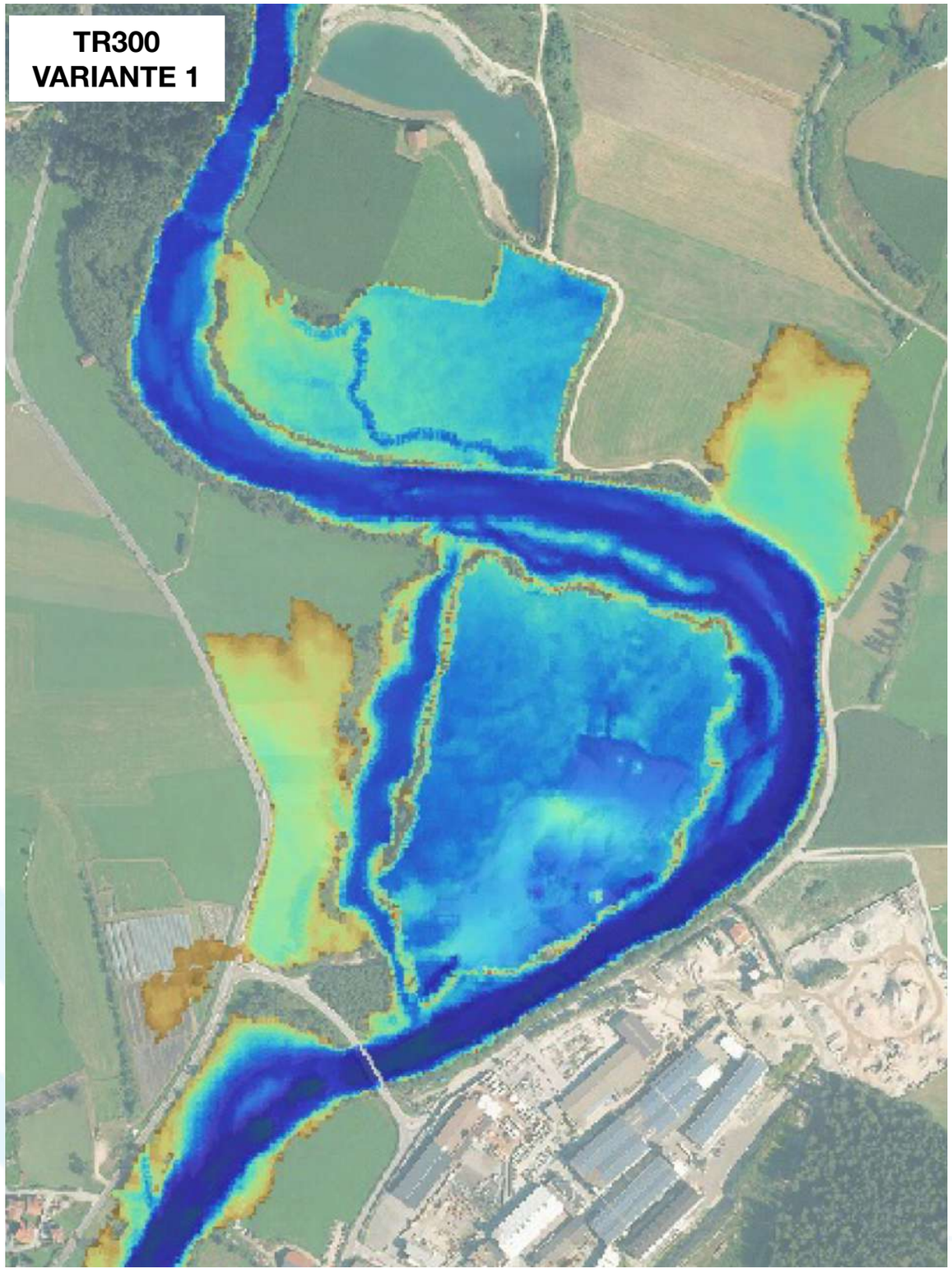
Lamination areas






TR100
VARIANTE 1
SEZ_IN Qmax (m^3 s^−1)= 275
SEZ_1 Qmax (m^3 s^−1)= 275
SEZ_2 Qmax (m^3 s^−1)= 272
SEZ_OUT Qmax (m^3 s^−1)= 258
Q (m^3 s^−1)
150
175
200
225
250
275
300
40
50
60
tempo (ore)


TR300
VARIANTE 1
SEZ_IN Qmax (m^3 s^−1)= 308
SEZ_1 Qmax (m^3 s^−1)= 307
SEZ_2 Qmax (m^3 s^−1)= 302
SEZ_OUT Qmax (m^3 s^−1)= 290
Q (m^3 s^−1)
150
175
200
225
250
275
300
40
50
60
tempo (ore)


TR300
VARIANTE 1

PROJECT: ALTERNATIVE 2

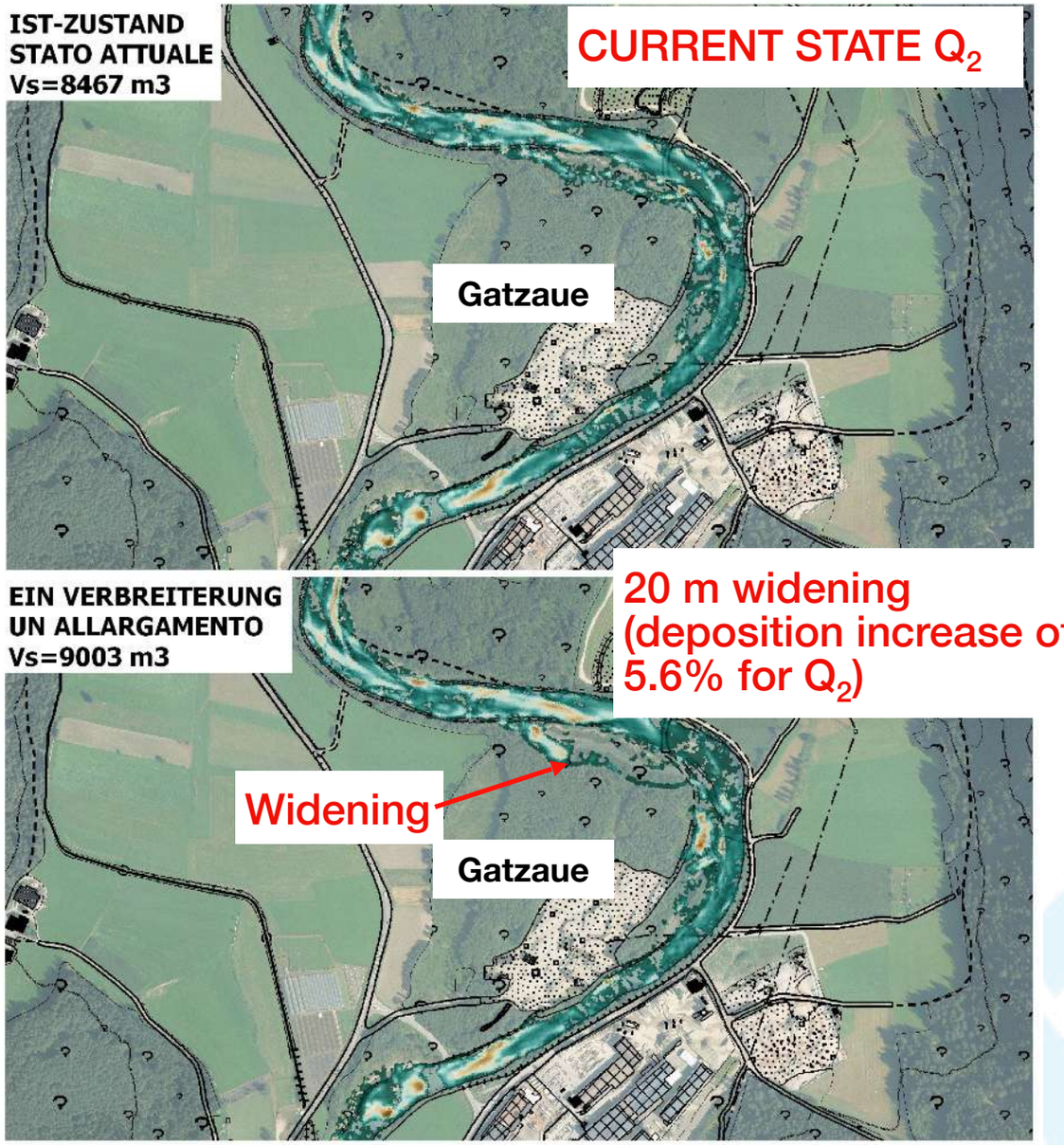
OBJECTIVES

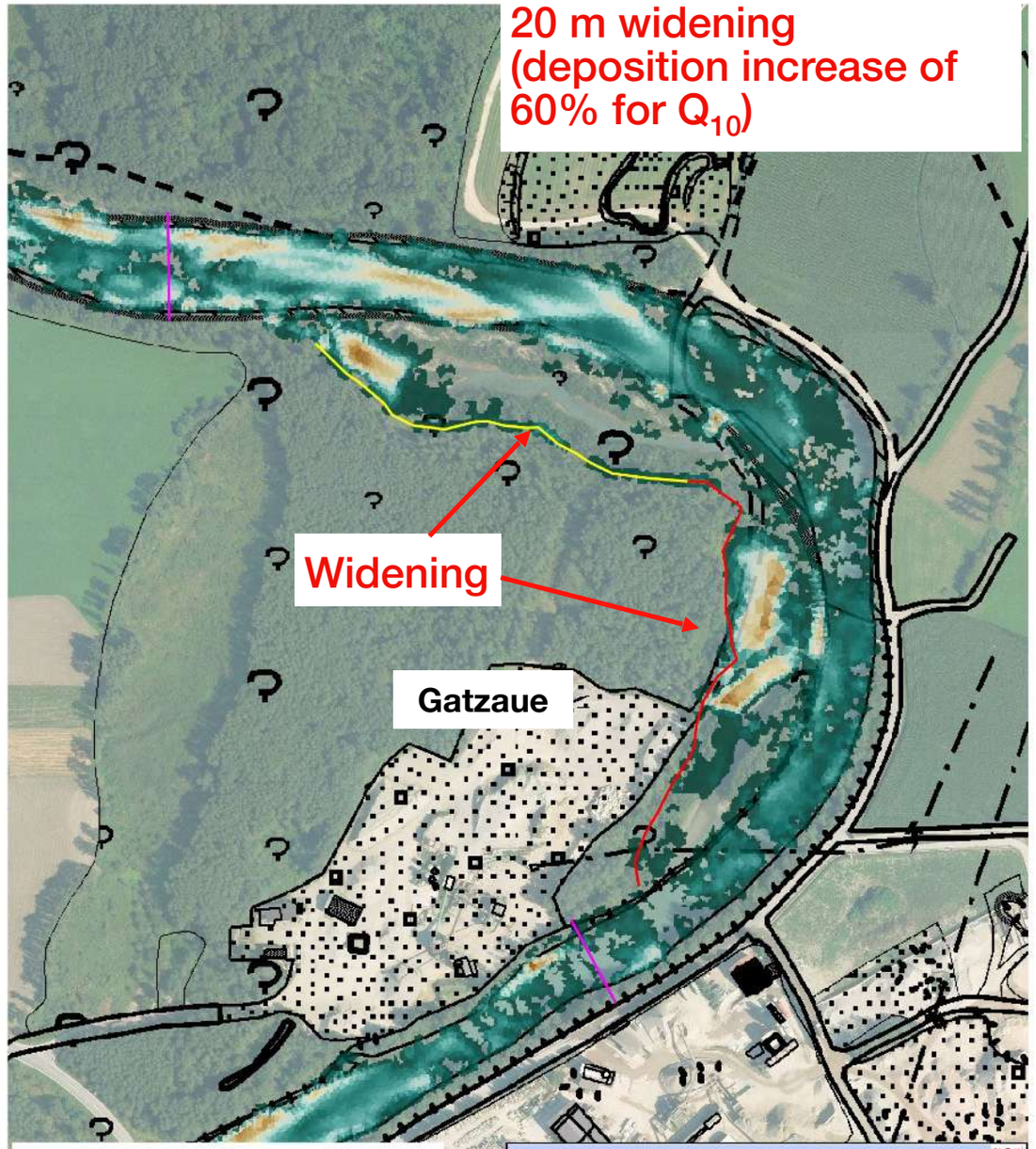
1. Complementing structural with restoration measures
2. Restoring the Gatzaue area in order to increase the frequency of flooding of alders and help to recharge the water table
3. Compare the lamination capacity of area 9 obtained in Variante 1

→ we need to:

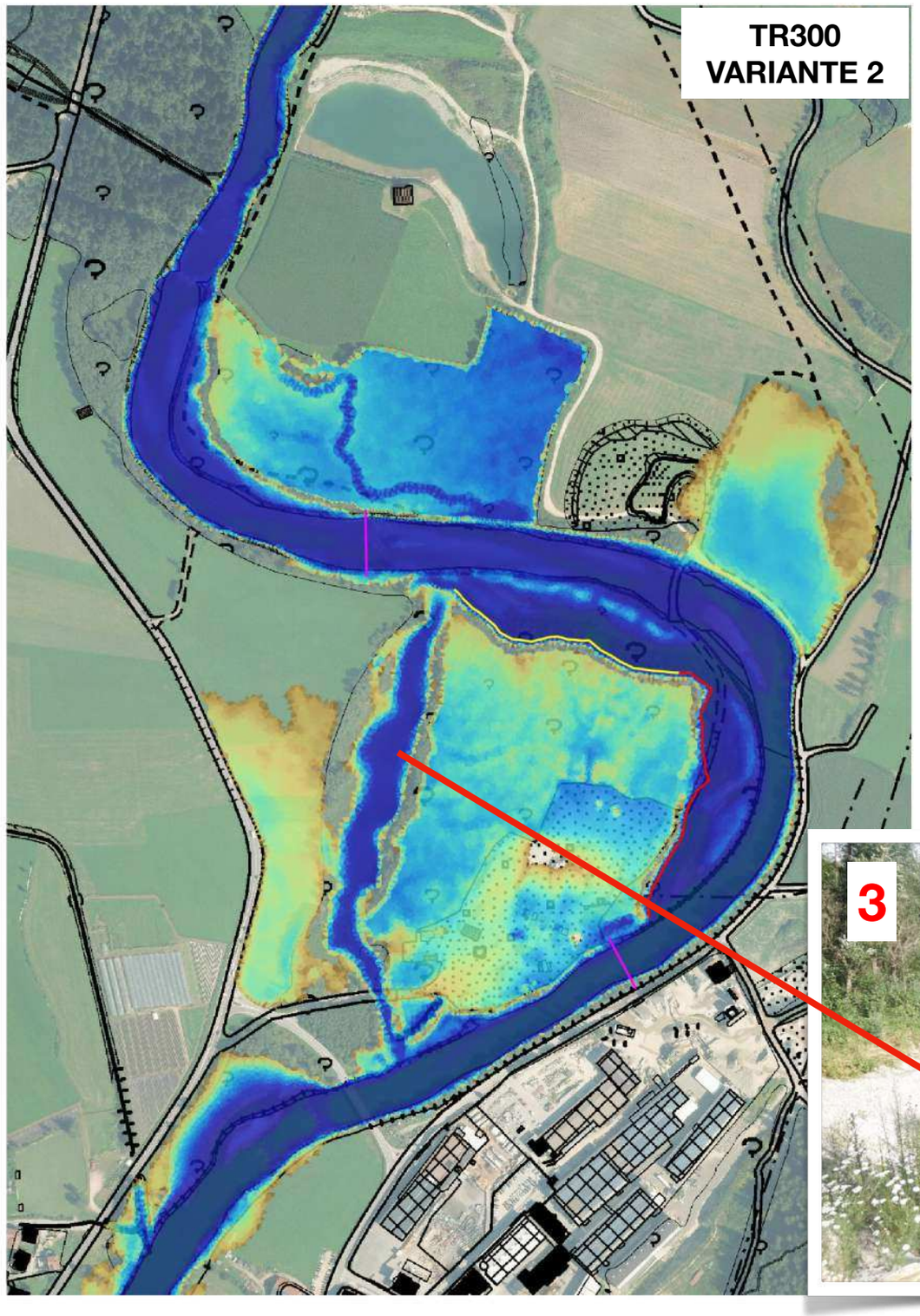
1. identify the morphological trend of the Aurino (erosion or deposition) in the Gatzaue area → simulations with bedload for Q_2 with average sediment diameter D of 10 mm
2. increase deposition trend by two section widenings → simulations with bedload for Q_2, Q_5 and Q_{10} with D=10 mm
3. set replenishment of the riverbed in the Gatzaue area, according to the pattern of deposits obtained previously → simulations without bedload with replenishment and widening for Q_{30}, Q_{100} e Q_{300}

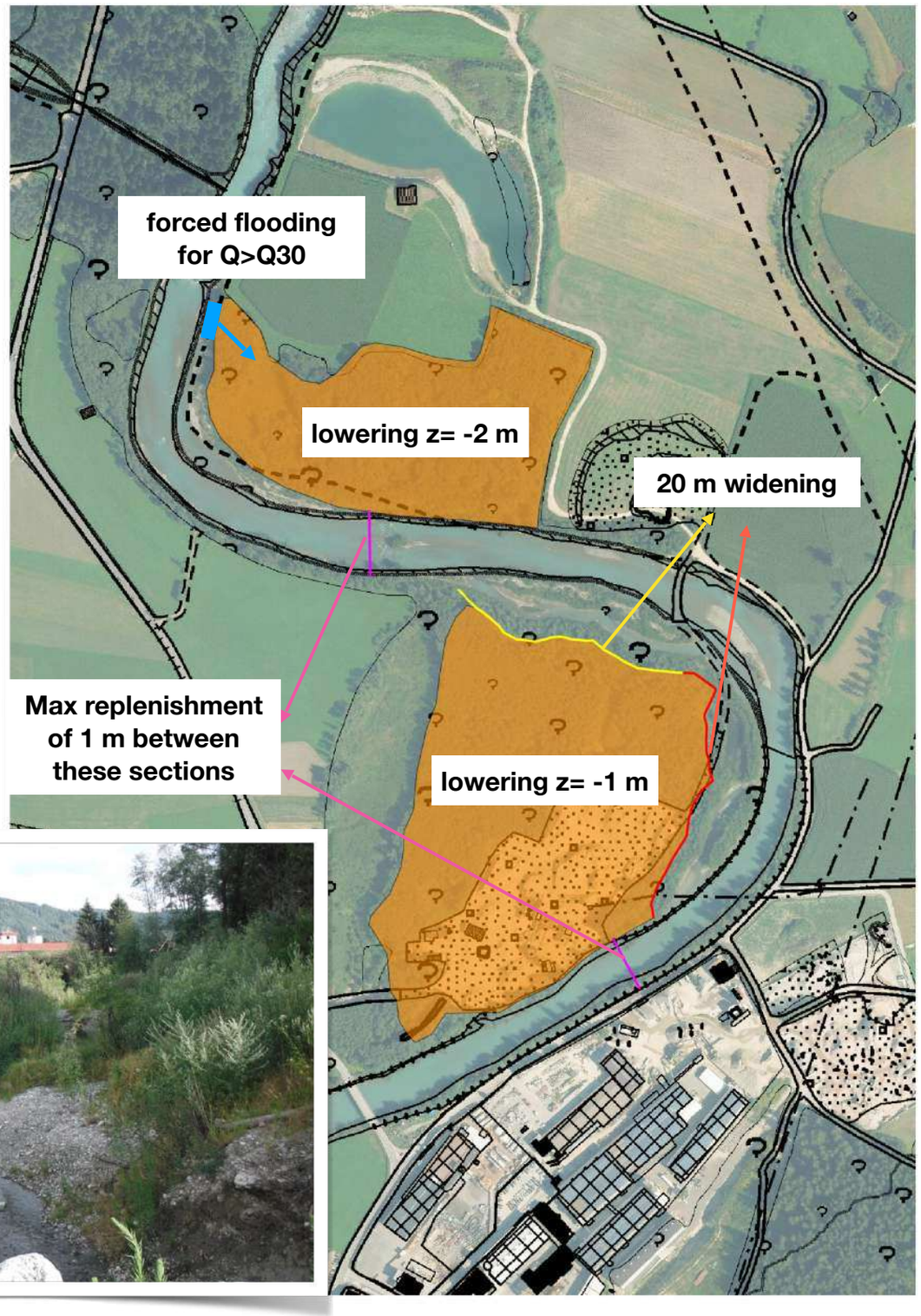
ALTERNATIVE 2 – WORK STEPS



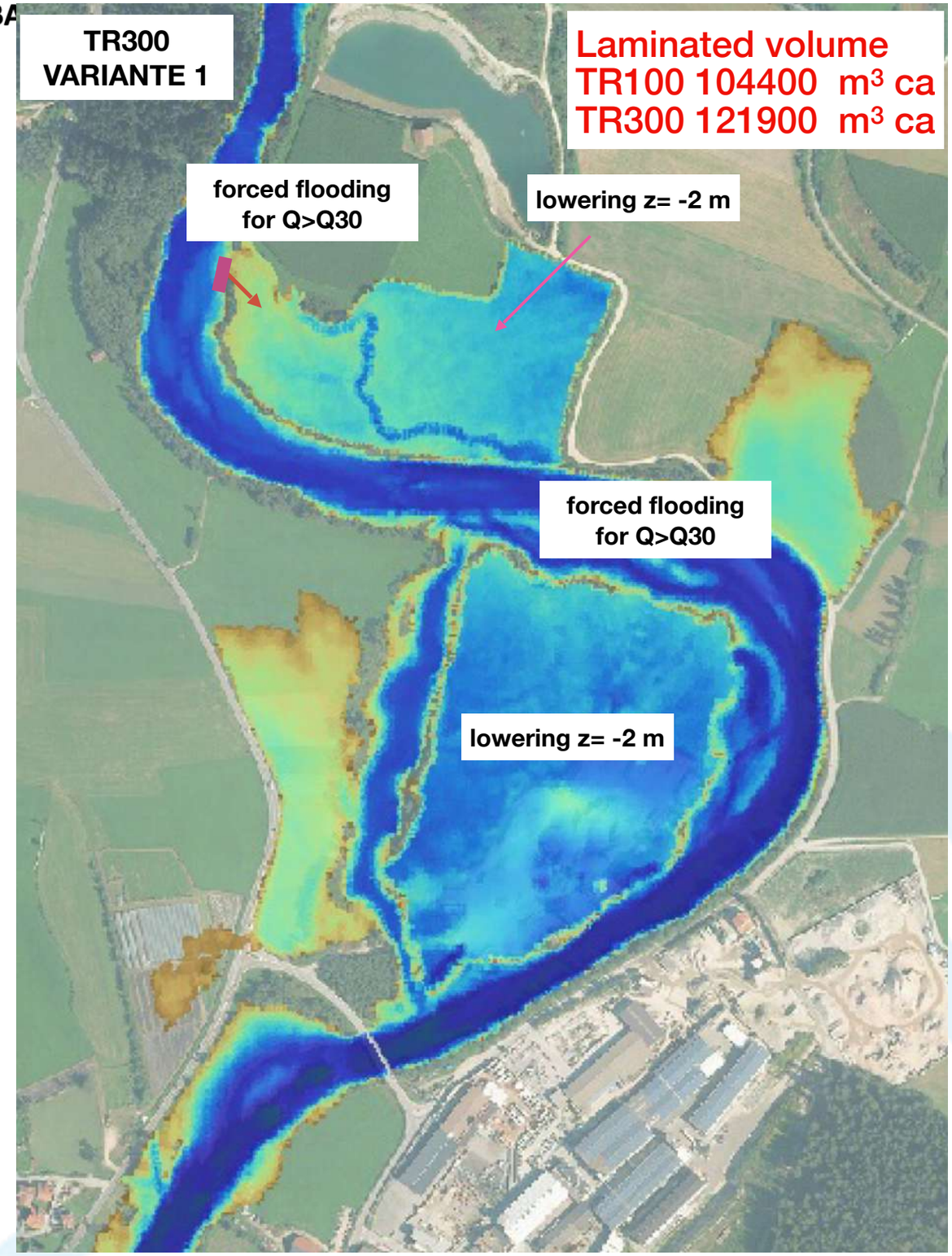


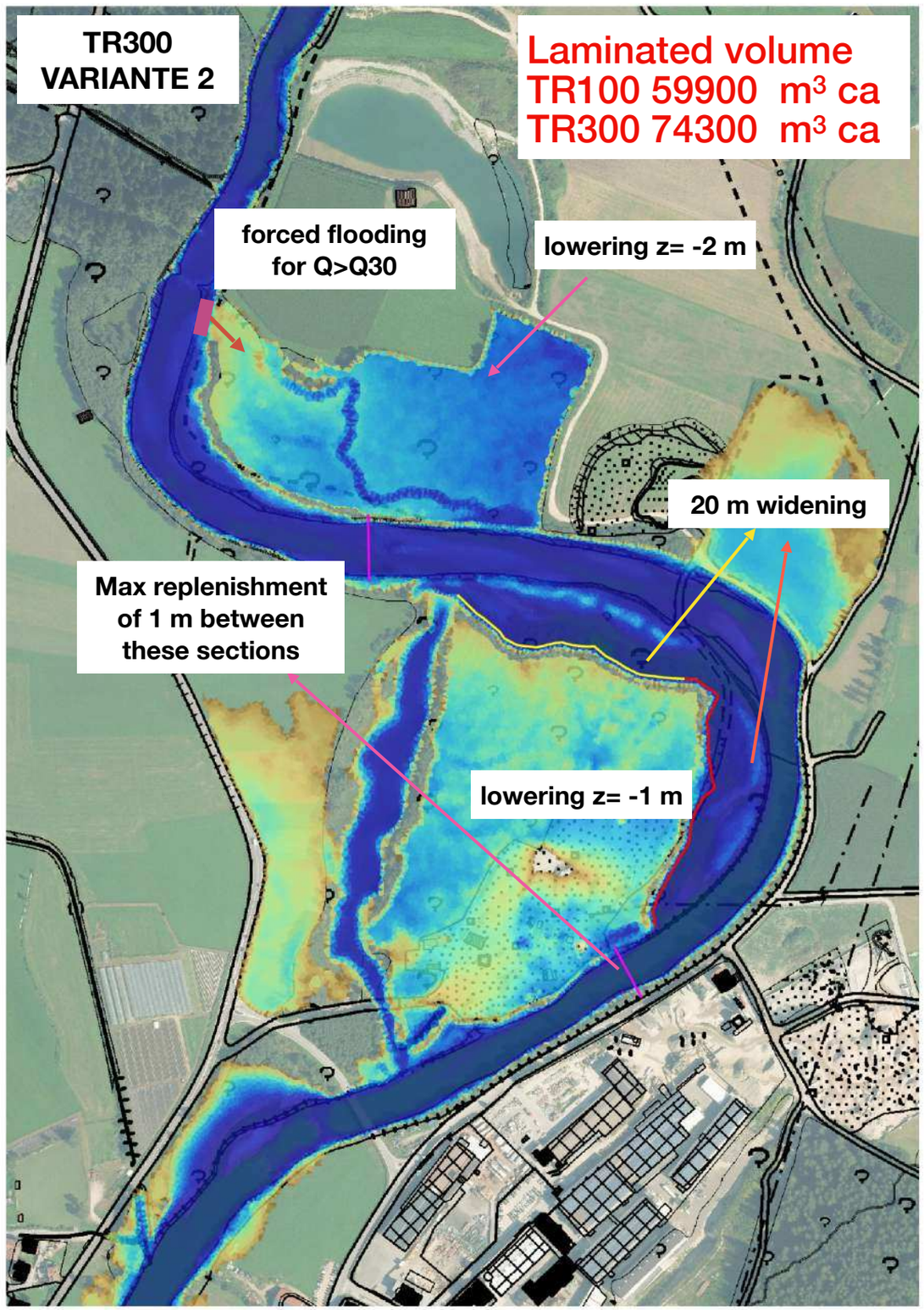
ALTERNATIVE 2 - RESTORATION MEASURES





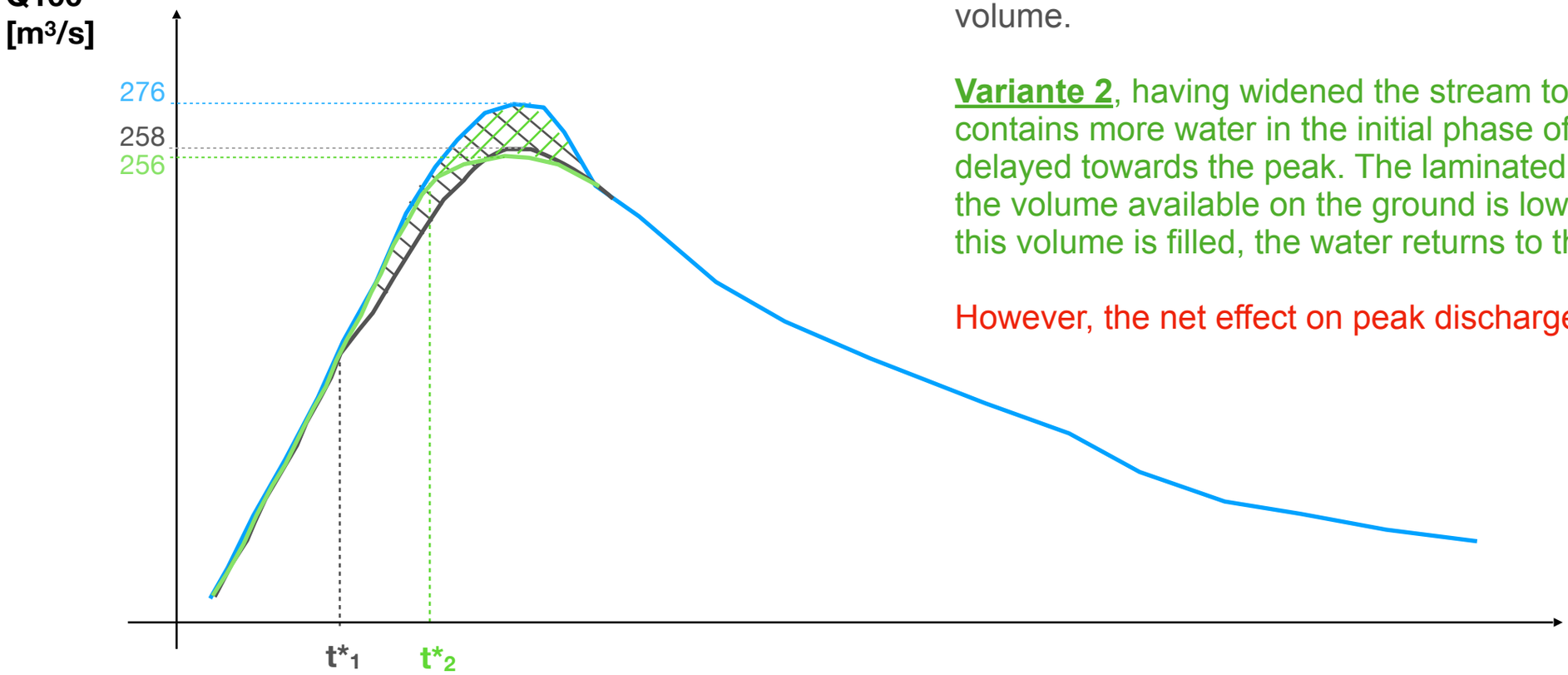
ALTERNATIVE 2 - RESTORATION MEASURES





ALTERNATIVE 1 vs ALTERNATIVE 2

ALTERNATIVE	V_laminated TR100	V_laminated TR300	Q_in TR100	Q_out TR100	Q_in TR300	Q_out TR300
1	104400	121900	276	258	308	290
2	59900	74300	276	256	308	291



Interventions work differently.

Variante 1 starts to laminate sooner because the stream is narrower; having a larger volume at ground level (lowering the ground by 2 m can hold more volume), it laminates a larger volume.

Variante 2, having widened the stream to favour deposition, contains more water in the initial phase of the flood; the overflow is delayed towards the peak. The laminated volume is less because the volume available on the ground is lower (1 m lowering); once this volume is filled, the water returns to the riverbed.

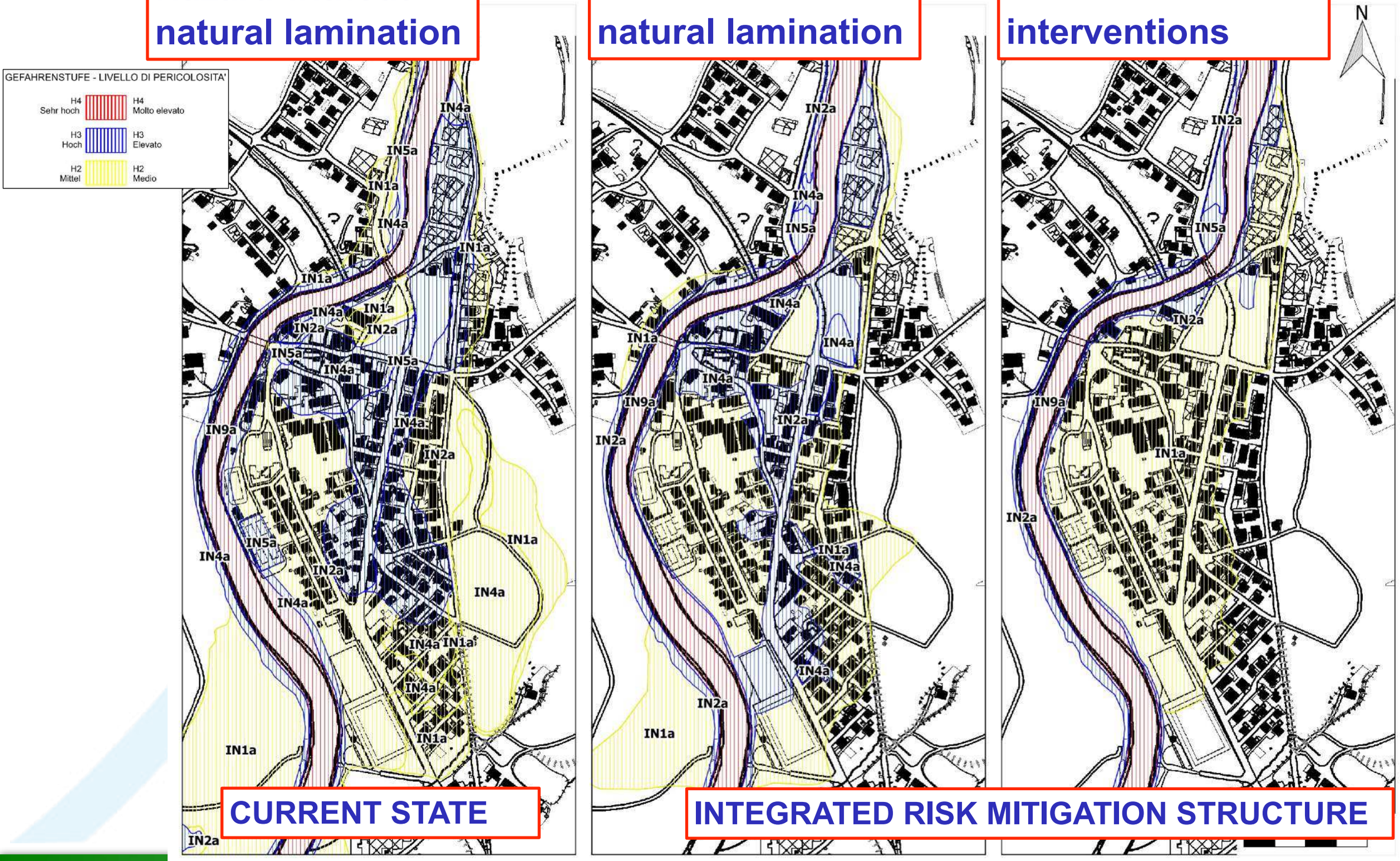
However, the net effect on peak discharge lamination is similar

CONCLUSIONS

Hazard without natural lamination

Hazard with natural lamination

Hazard with interventions



CURRENT STATE

INTEGRATED RISK MITIGATION STRUCTURE