

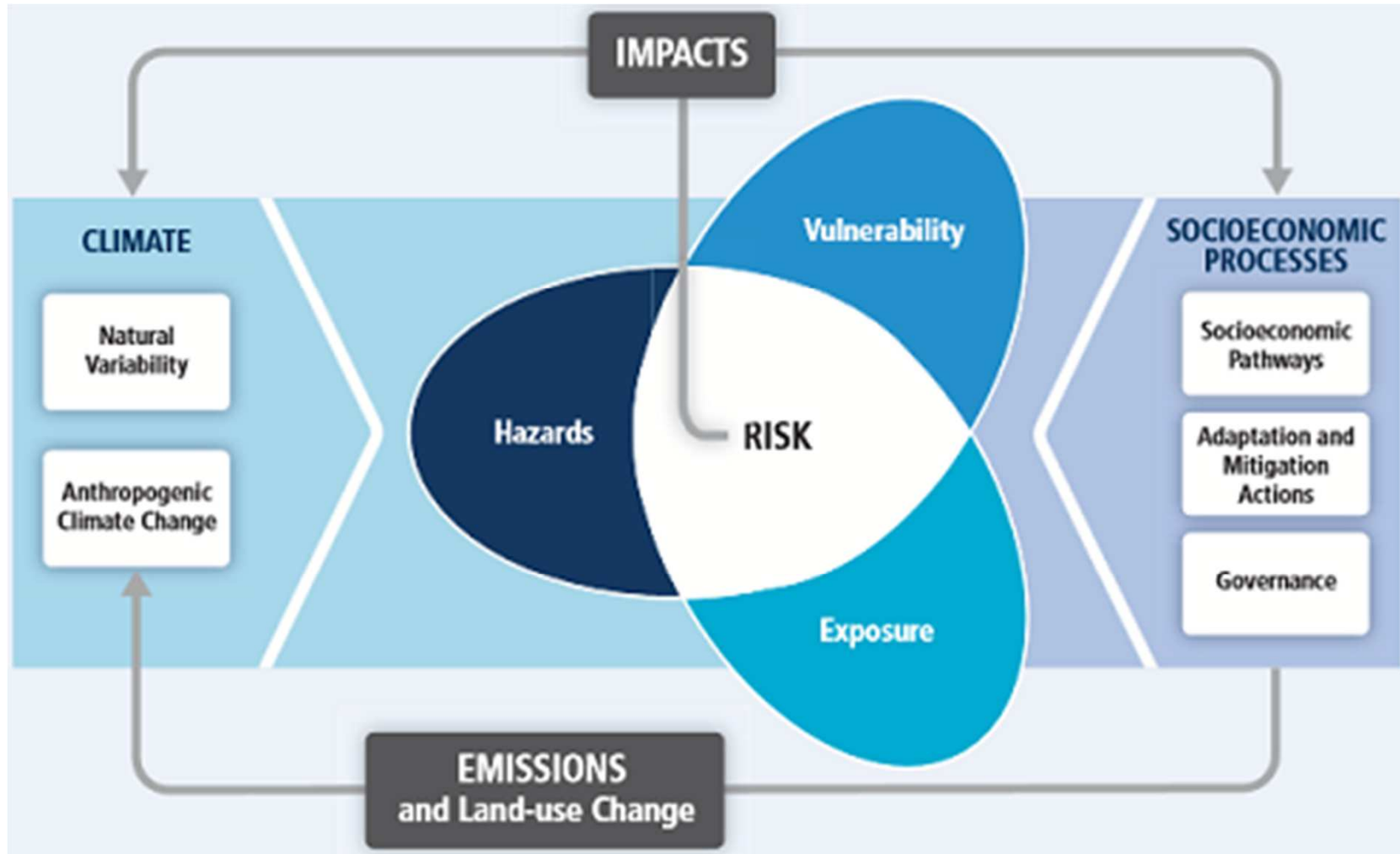
MANAGEMENT OF NATURAL HAZARDS
IN MOUNTAIN BASINS

Mitigation measures
against natural risks

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Academic year 2014/2015

Recalling what risk is...

$$\text{Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability}$$



...the possible mitigation measures

- Reduction of hazard
 - Traditional approach
 - Expensive
 - Effectiveness ? (design scenario)
 - Environmental disadvantages
- Reduction of exposure
 - The ideal solution (theoretically)
 - Socially difficult (when feasible)
 - Still few examples realized
 - Key for still undeveloped areas
- Reduction of vulnerability
 - Potentially very effective
 - Increasingly applied
 - Physical easier than social
 - «adaptation» to hazards

Structural vs non-structural measures



THE RICE UNIVERSITY AND TEXAS MEDICAL CENTER
FLOOD ALERT SYSTEM

Home Radar Rainfall Cameras Hydrology Case Studies News

350 CFS, Flat at 10:05 AM
Page Refresh Rate
 Rapid Normal

Brays Bayou Cam
07/15/2010 10:33

Gulf Act

Map depicts rainfall intensity (inches per hour) in sub-basins from the most recent 30-minute data.

0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00 4.25 4.50 4.75 5.00

Wellcome to FAS3, the new Flood-Alert System Website!
To visit the FAS2 site, [click here.](#)



Hazard mitigation

- Mostly through structural measures
- Aims to reduce *event intensity* (flow depth/velocity/pressure; deposition depth; rock size/energy) for a range of recurrence intervals
- Based on the concepts of:
 - Prevent or decrease transport processes (*in initiation or transport zones*)
 - *Retaining volumes* upstream of vulnerable areas (*in transport zones*)
 - Increase *conveyance* within vulnerable areas (*in transport and depositional zones*)

Hazard mitigation

- Preventing transport processes in initiation areas



Rockfall protection nets



Avalanche barriers (foto SLF Davos)



Consolidation check-dams (Foto Studio Archeng)

Hazard mitigation

- Preventing landslide initiation

Slope safety factor increased by:

- Reducing pore pressure (drainage, vegetation)
- Increasing cohesion (drainage, vegetation)
- Increasing stabilizing forces/moment (concrete/metal structures)

Slope Failure Repair Options

Terracing/Benching: Making the slope more manageable by dividing it into several smaller and less steep slopes reinforced by retaining walls, friction piles, etc.

Drainage: Minimizes hydrostatic pressure buildup in the slope.

Retaining Wall: Walls that are designed to hold a substantial amount of soil behind it in place.

Friction Piles: Piles that are driven into the ground towards load bearing strata.

GeoGrid: A perpendicular mesh that works by creating lateral frictional resistance needed for slope instability.

Biotechnical Slope Stabilization: Use of plants and vegetation for slope stabilization.

Shotcrete: Mortar or concrete that is pneumatically ejected at high velocities over a grid of rebars that have been sufficiently anchored on the slope face.

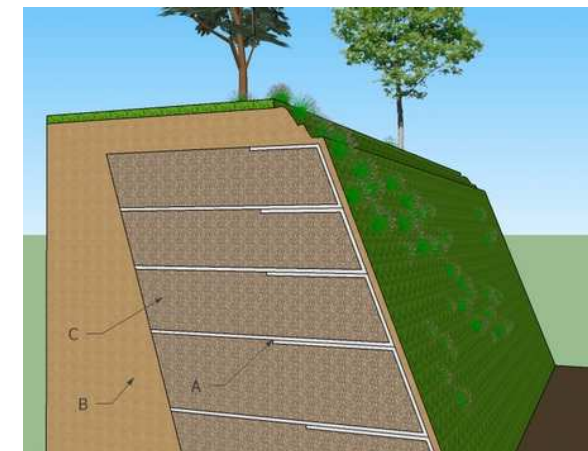
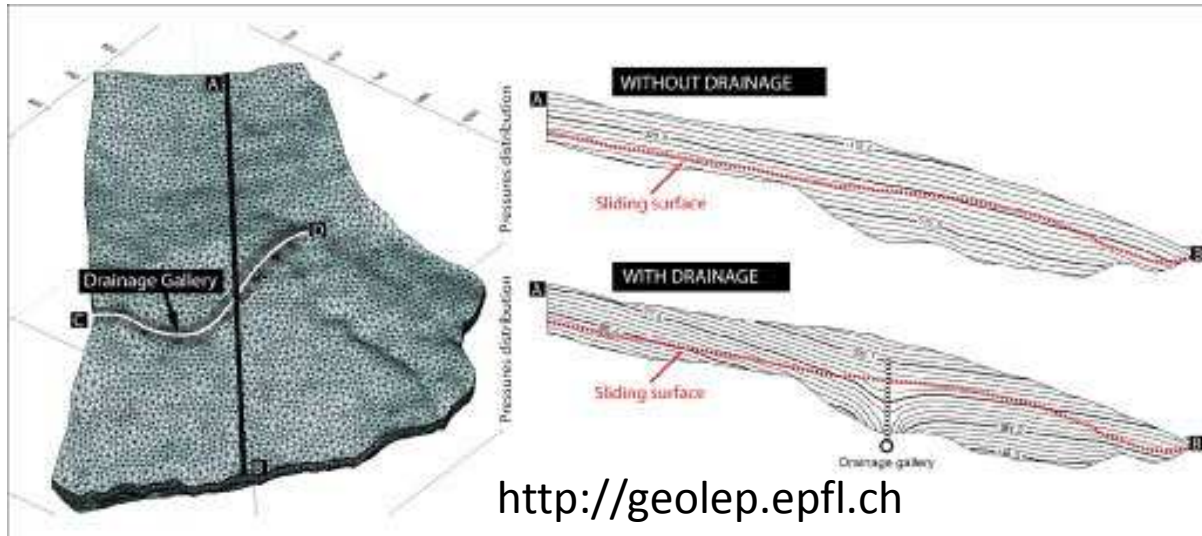
Rock Bolts: Connect the fractured and weak surface to the stronger rock layers underneath for slope stability.

Sheet Piling: Overlapping sheet piles driven into the ground to act as retaining walls.

SINAI CONSTRUCTION

Hazard mitigation

- Preventing landslide initiation



www.ecofibre.it

Hazard mitigation

- Reducing transport processes in transport zones



Rockfall barriers (photo Geobruigg)



Rockfall retaining wall
(www.ingph.eu)



Avalanche retention
barrier
(www.eagm.eu)

Hazard mitigation

- Reducing transport processes

Reduce flow velocity

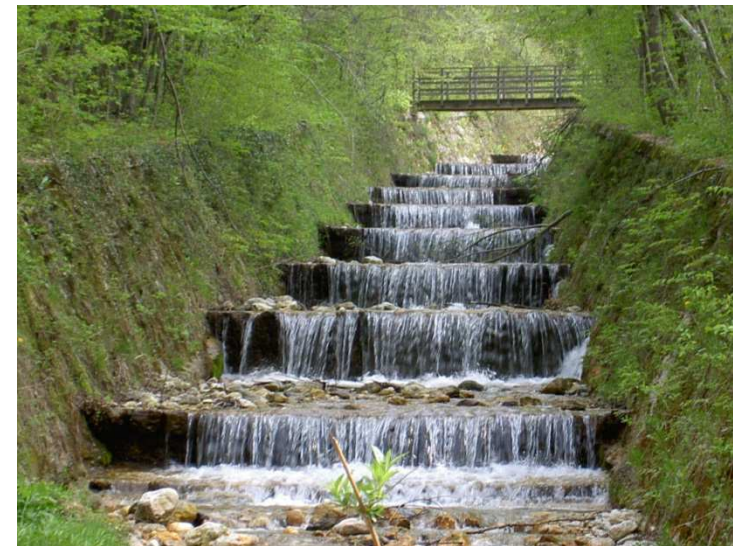
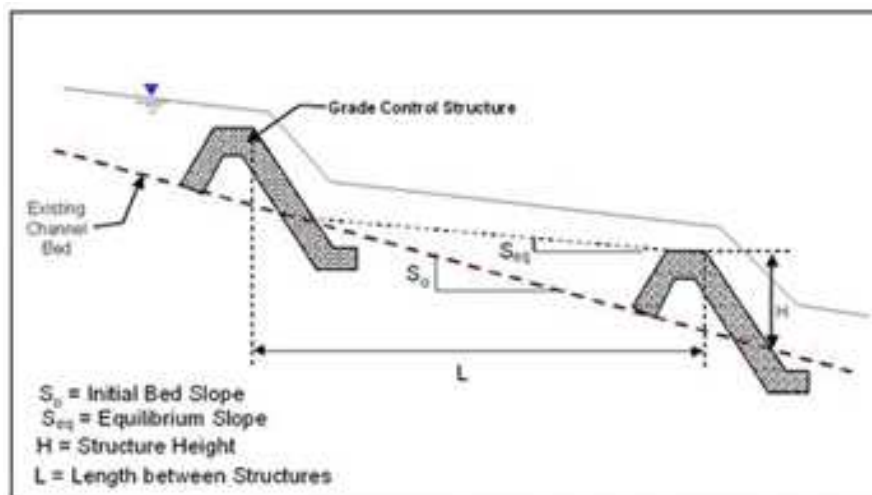


Reduce energy/bed slope



Create stable drops in the long. profile (grade-control structures)

- consolidation check-dams and bed sills



Hazard mitigation

- Reducing transport processes in the transport zone

Reduce bank/hillslope erodibility



Heavy/resistant boundary



Bank protections

- ✓ Concrete walls
- ✓ Large rocks (riprap) with or without cement
- ✓ Large wood elements (engineered wood jams)



Hazard mitigation

- Retaining volumes upstream of vulnerable areas

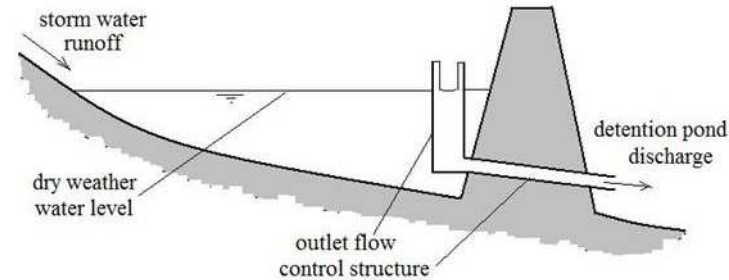
To reduce flood peak discharges



Store temporarily part of flood runoff



- ✓ Flood retention/detention basins
- ✓ Multipurpose dams (including flood attenuation)
- ✓ Allow valley floor flooding (where not urbanized...hard !)



Hazard mitigation

- Retaining volumes upstream of vulnerable areas

To reduce sediment and wood volumes transported by a flood



Trapping sediment and wood during the event in retention basins



- ✓ *Retention check-dams*
(fill up quickly ! High maintainance costs)
- ✓ *Filtering check-dams*
(trap only coarse bedload + wood, self-cleaning ?)
- ✓ *Steel nets /ropes*
(for wood only)



Hazard mitigation

How much filtering ?
The self-cleaning design



Hazard mitigation

- Retaining volumes upstream of vulnerable areas

To stop debris flow propagation



Breaking and trapping
debris flow fronts



- ✓ *Concrete/steel debris-flow check-dams*
- ✓ *Debris flow ring nets*



(photo Geobruigg)

Hazard mitigation

- Increase conveyance within vulnerable areas

Increase flow velocity
(stabilizing bed)



Reveted channel, narrow sections



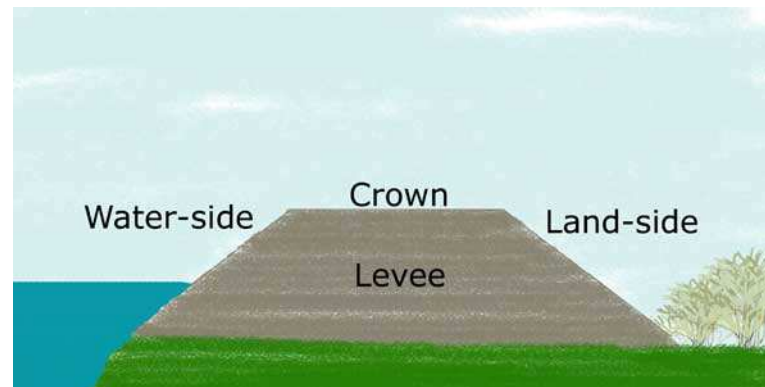
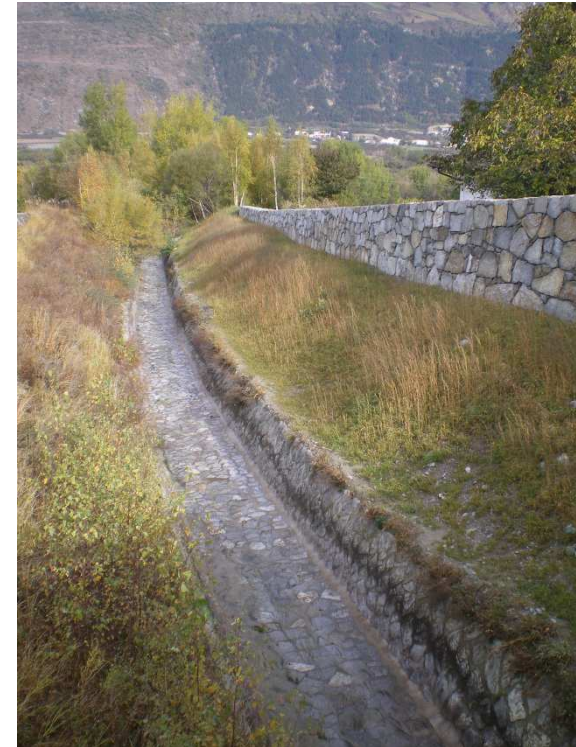
Hazard mitigation

- Increase conveyance within vulnerable areas

Prevent water or debris flows
from flooding adjacent land
(floodplain, fans)



Levees



Flood hazard mitigation in the Alps: evolution

- **16th – 19th century**

Masonry (retention)
check-dams



- **19th century – 1940s**

Slope and channel wooden
consolidation structures



- **1960s – 1980s**

Concrete consolidation and
retention check-dams



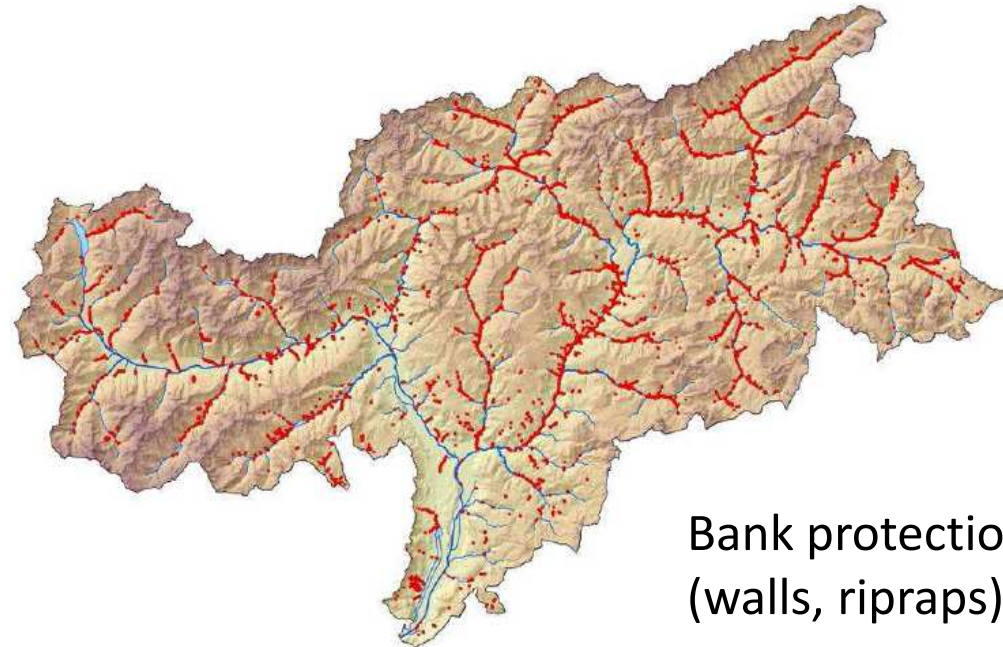
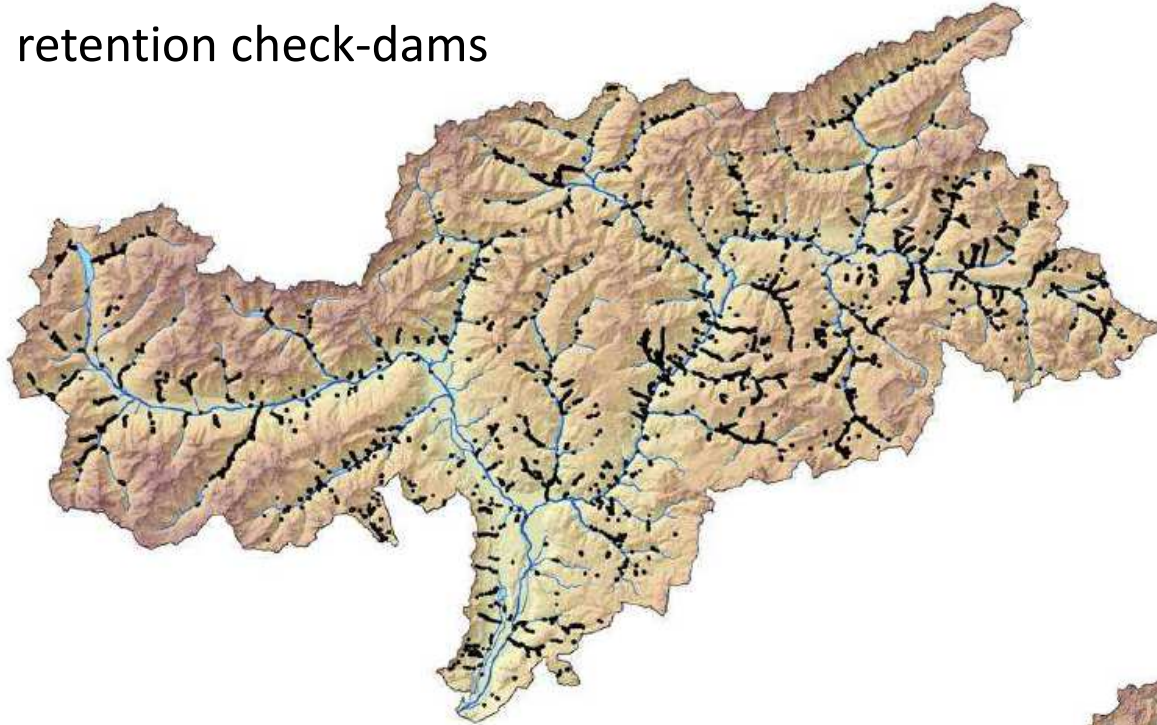
- **1990s – now**

Concrete/steel filtering check-dams and
Boulder/wood check-dams/ramps for consolidation



Flood hazard mitigation in South Tyrol

About 64000 consolidation and retention check-dams

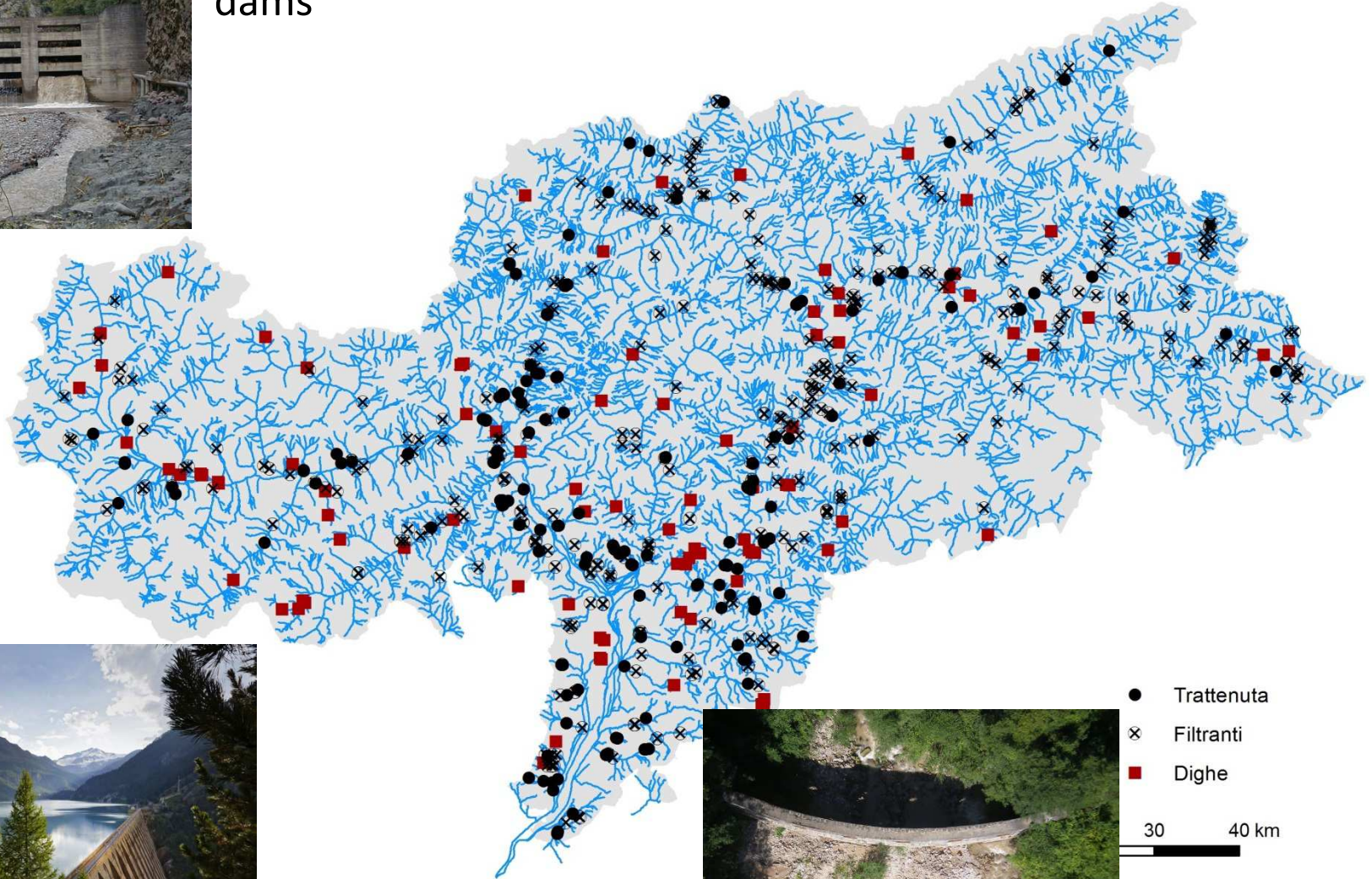


Bank protections
(walls, ripraps)

South Tyrol: sediment disconnections



Filtering (open) check-dams



Dams



Retention check-dam



- Trattenuta
- × Filtranti
- Dighe

30 40 km

Structural measures and their risks !



Levees and check-dams failure are commonly observed during extreme events



Structural measures



«safety feeling»



construction in potentially hazardous areas



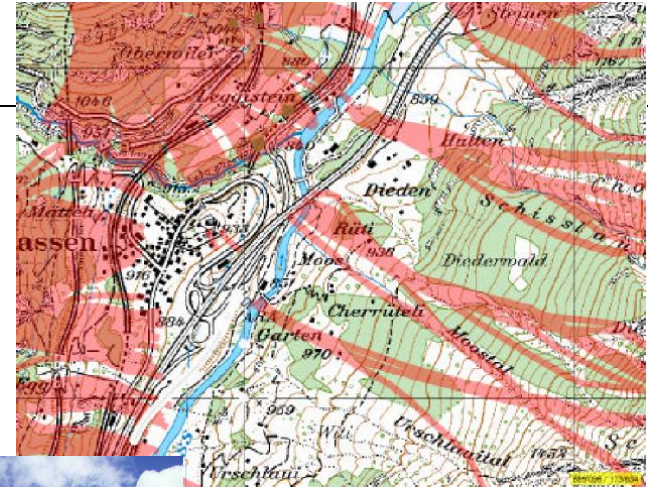
High residual risks
(in case of failure of underdesign)



Reduction of exposure

- Land use planning and insurance plans for future developments

➔ Based on hazard maps



- Relocation of buildings/towns

➔ Where possible/
socially accepted

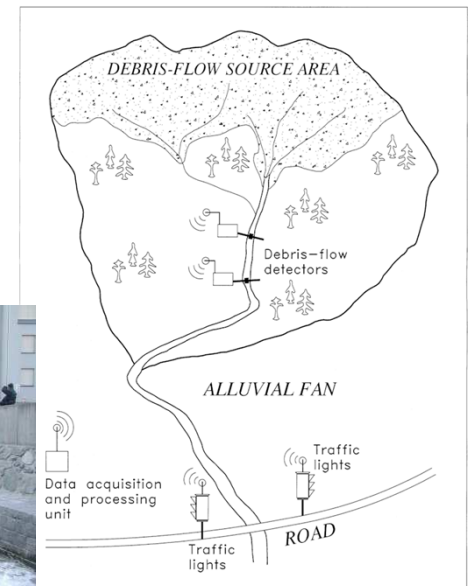


- Early-warning systems (for traffic/people)

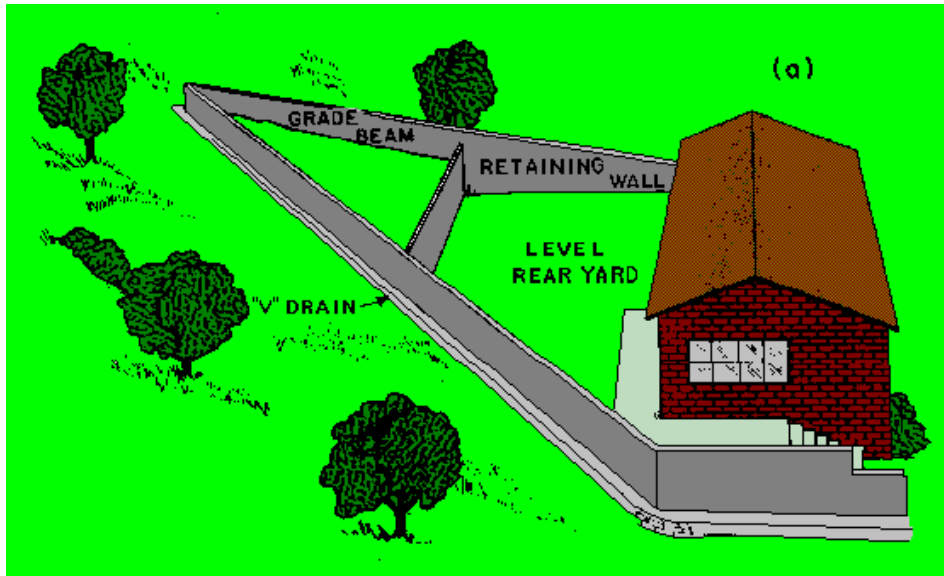
➔ Lead time is short
in small mountain basins



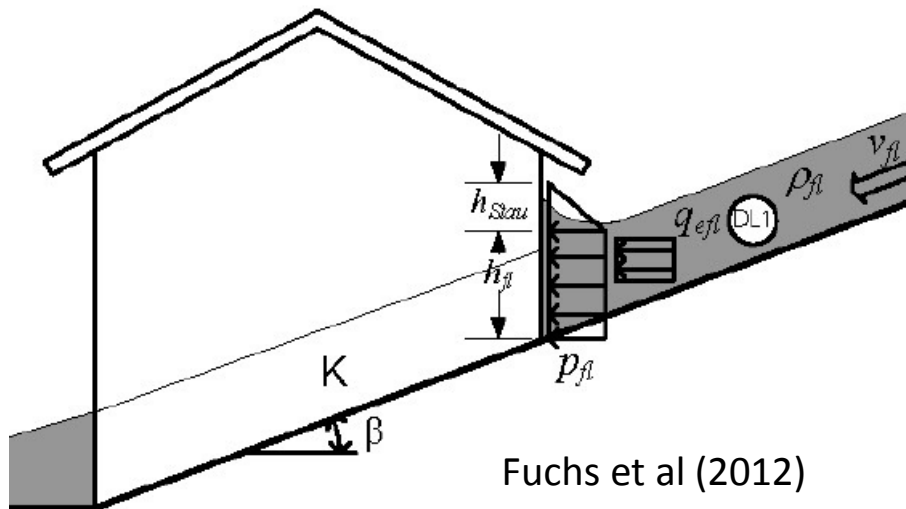
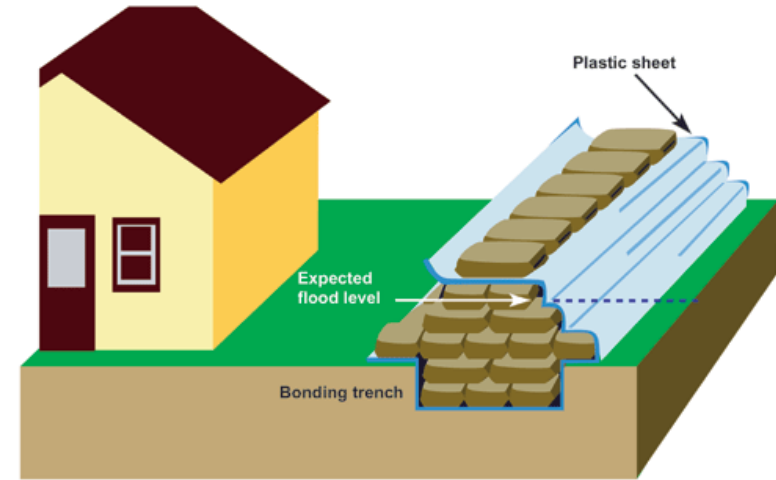
Arattano & Marchi (2008)



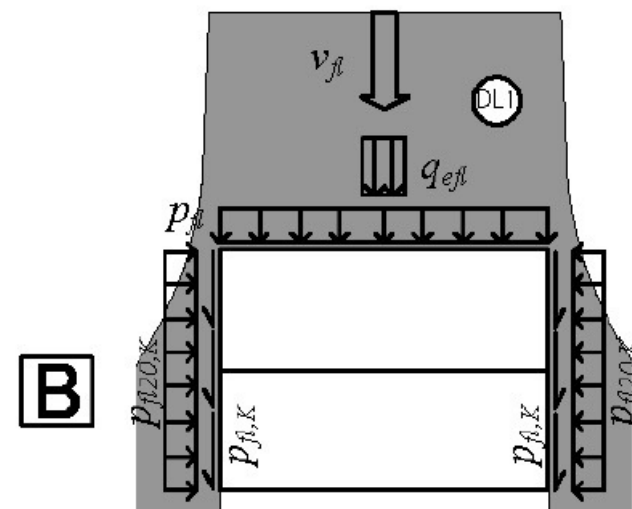
Reduction of (physical) vulnerability



Floodproofing – cross-section of a sandbag dyke



Fuchs et al (2012)



Reduction of (physical) vulnerability

Local structural protection measure	Type of measure	Effective for		Suitable for	
		Avalanche	Flood	Upgrade	New building
Foundation	Base plate foundation	(x)	x	-	x
Basement	Waterproofed concrete	-	x	-	x
	Enhancement (raising) of light shafts above flood level (flow depth), sealing of all wall penetrations	(x)	x	x	x
	Backflow flaps in sewage pipes	-	x	(x)	x
First (and second) floor	Reinforcement of the supporting structure (walls, ceilings, ...)	x	x	(x)	x
Roof	Reinforcement of the roof, avoidance of eaves	x	-	(x)	x
Building openings	Decrease of the amount and area of windows and implementation of avalanche safe windows and/or heavy shutters	x	(x)	x	x

Fuchs et al (2012)