Glacier Risks

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Possibilities and Limits of Prevention and Mitigation

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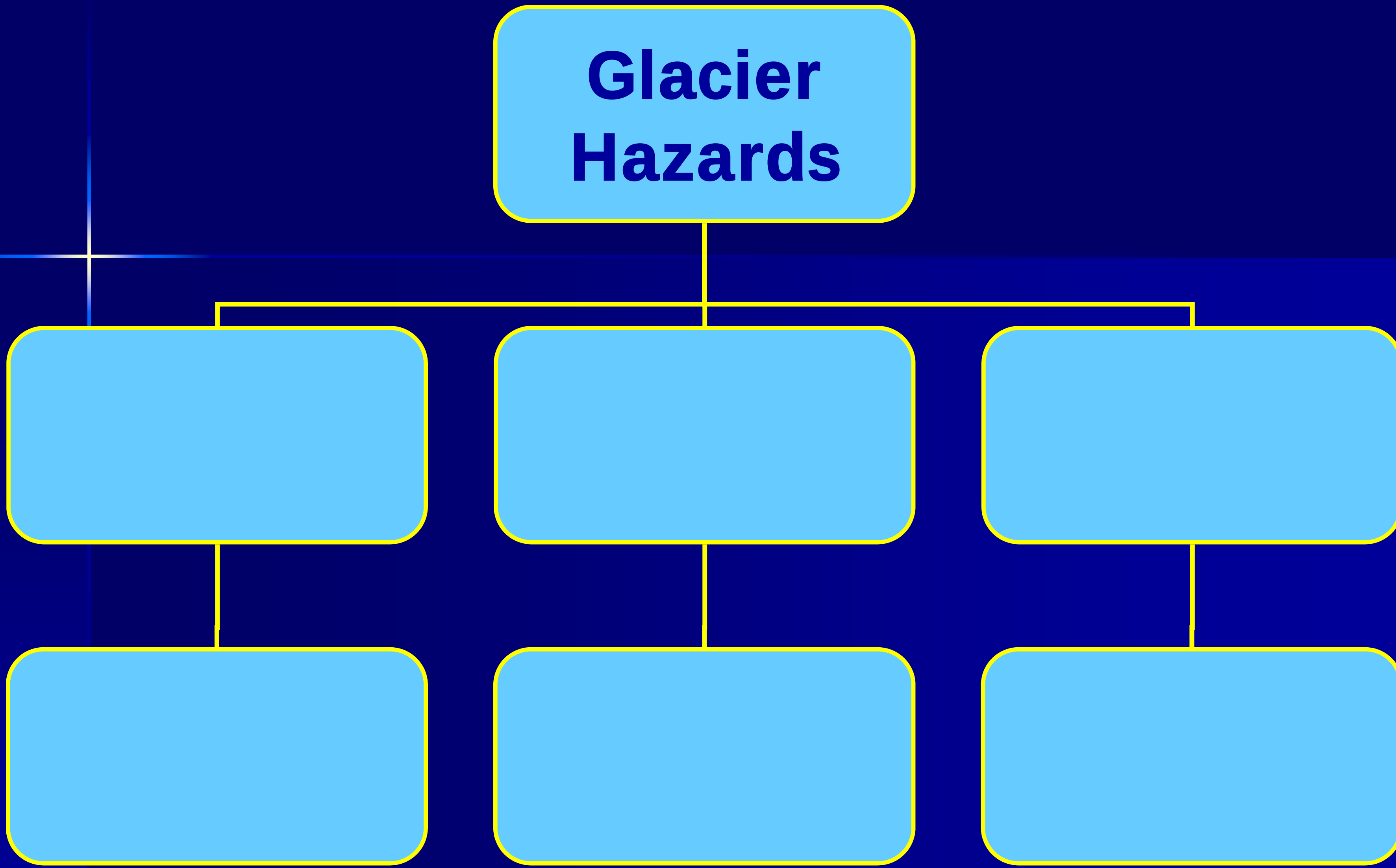
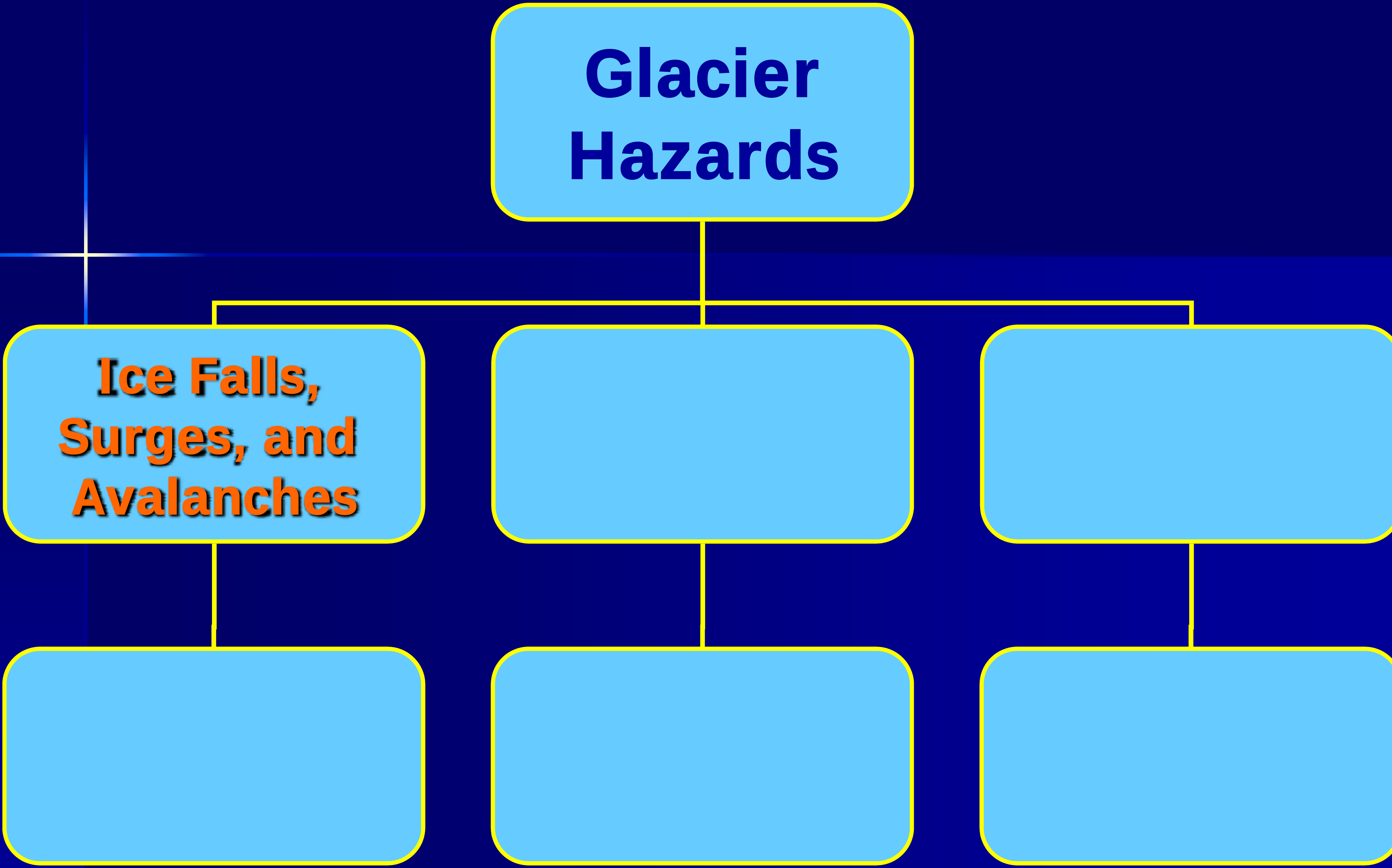
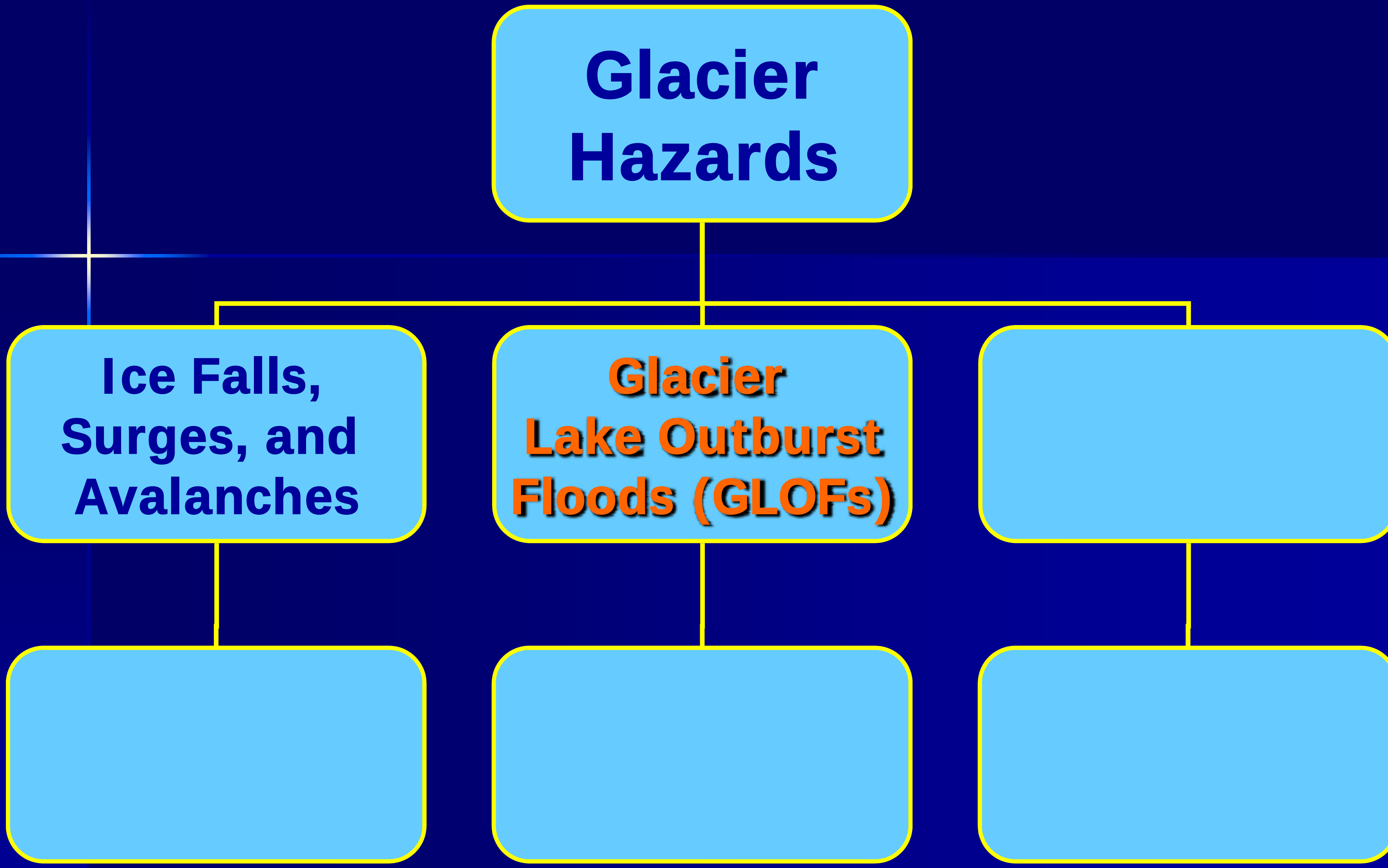
Mold, UK


Glacier Hazards


Glacier Hazards
Ice Falls, Surges, and Avalanches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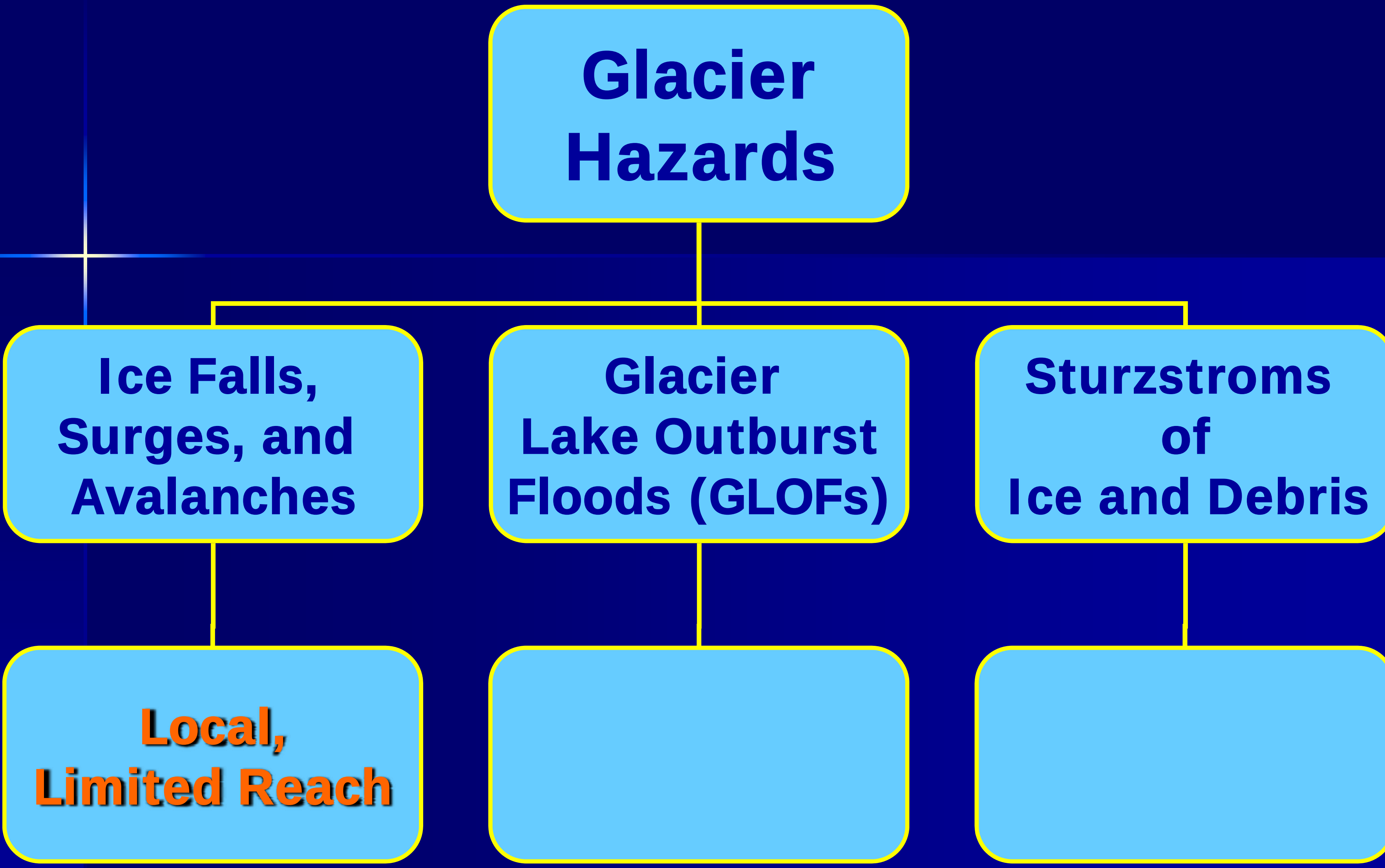
Ice Falls, Surges, and Avalanches
Glacier Lake Outburst Floods (GLOFs)

Glacier Hazards

- Ice Falls, Surges, and Avalanches
- Glacier Lake Outburst Floods (GLOFs)
- Sturzstroms of Ice and Debris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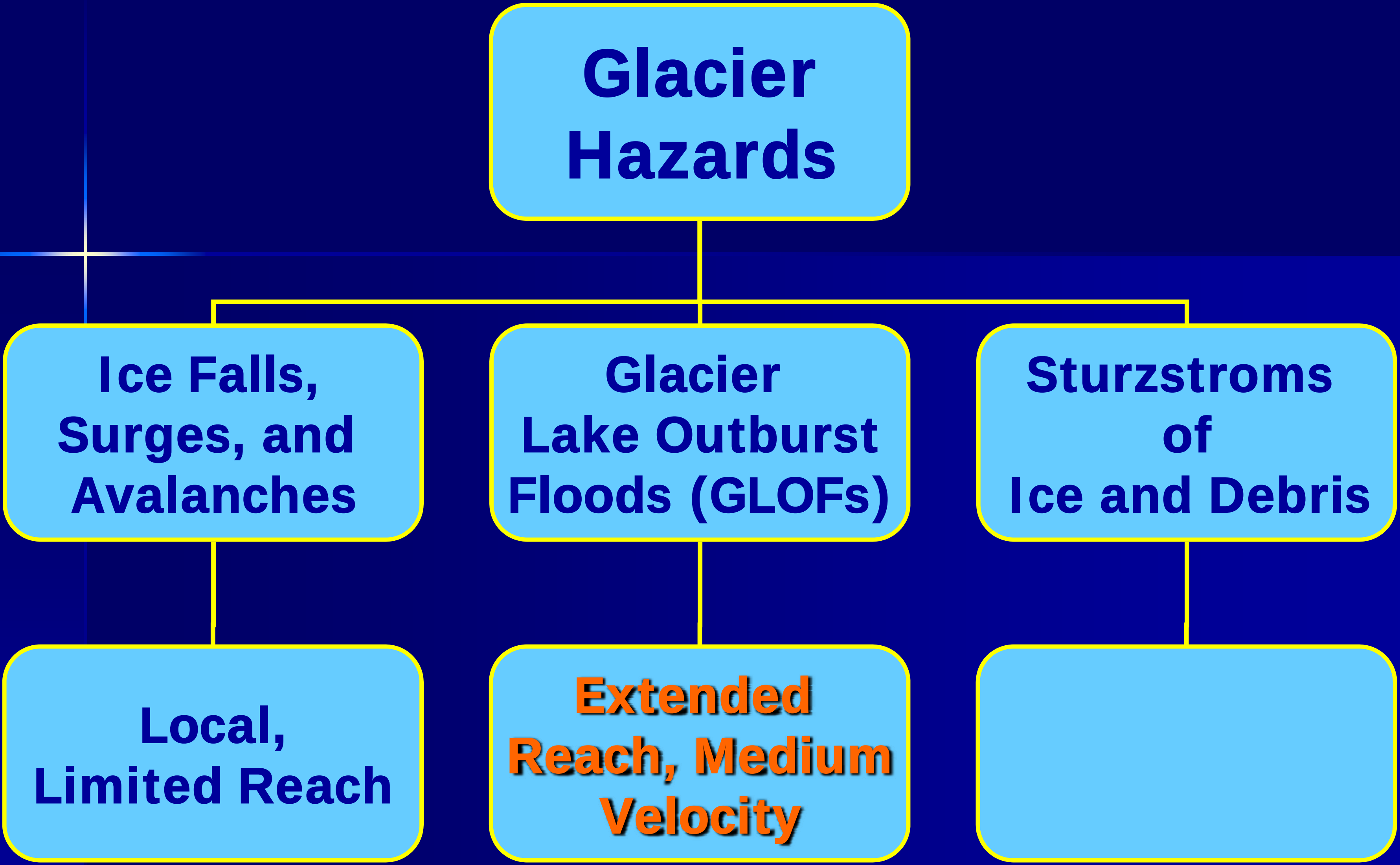
Local, Limited Reach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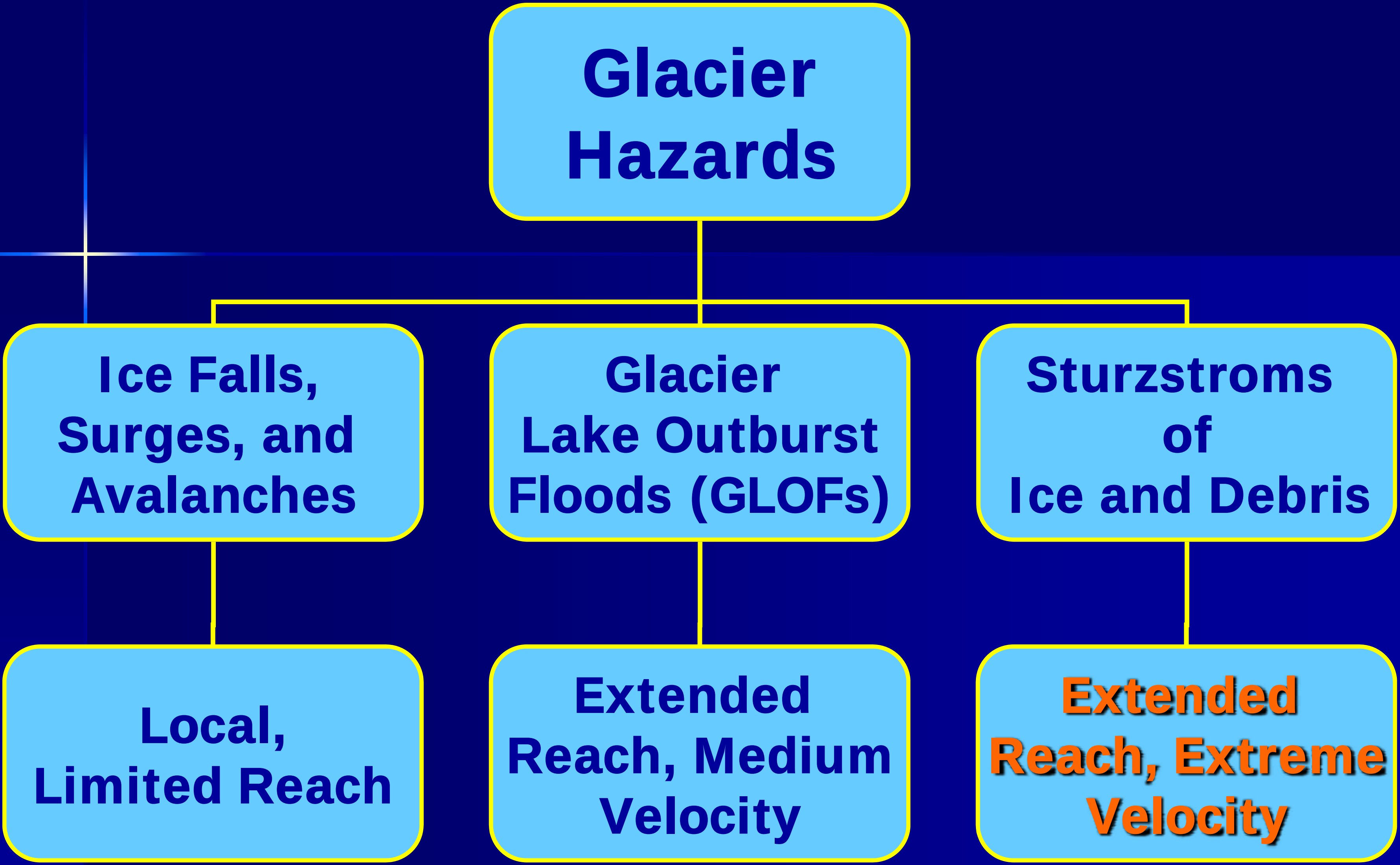
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Extended Reach, Extreme Velocity

Ice Falls and Avalanches

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Mattmark Ice Avalanche 1965

(Switzerland, courtesy: W. Häberli)

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Glacier Lake Outburst Floods

(GLOFs)

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GLOF in Brit. Columbia

(from Evans & Clague 1994)

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Dig Tsho Outburst, Nepal 1985
(WECS)

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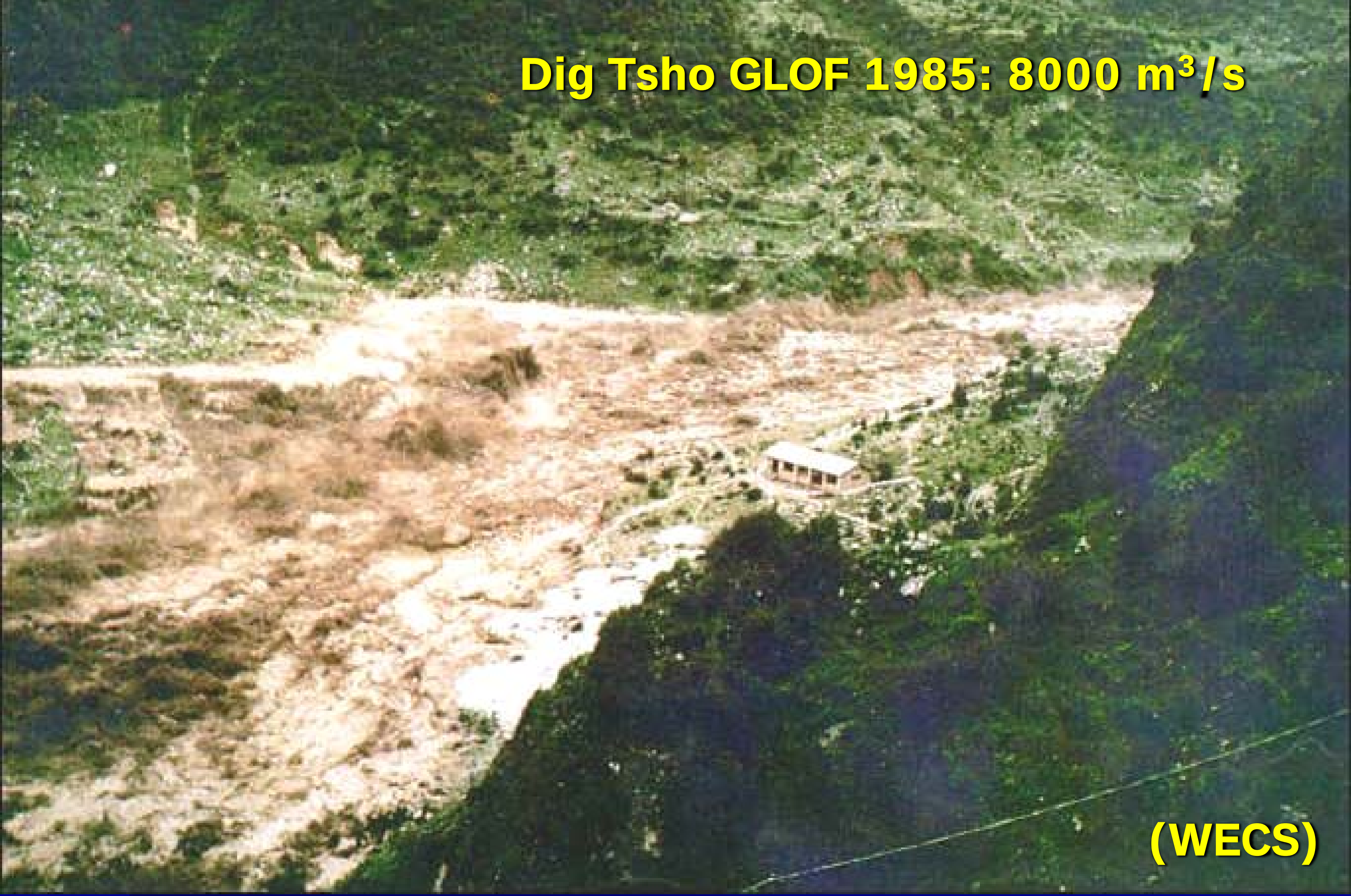
Dig Tsho GLOF 1985: 8000 m^3/s



Sturzstroms

Huascarán Sturzstrom 1970, Peruvian Andes
(Welsch & Kinzl 1979)

The Karmadon Sturzstrom-Disaster in Kaukasus 2002

Photo: Alexander Polkvoy

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25.09.2002
Alexander Polkvoy
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25.09.2002
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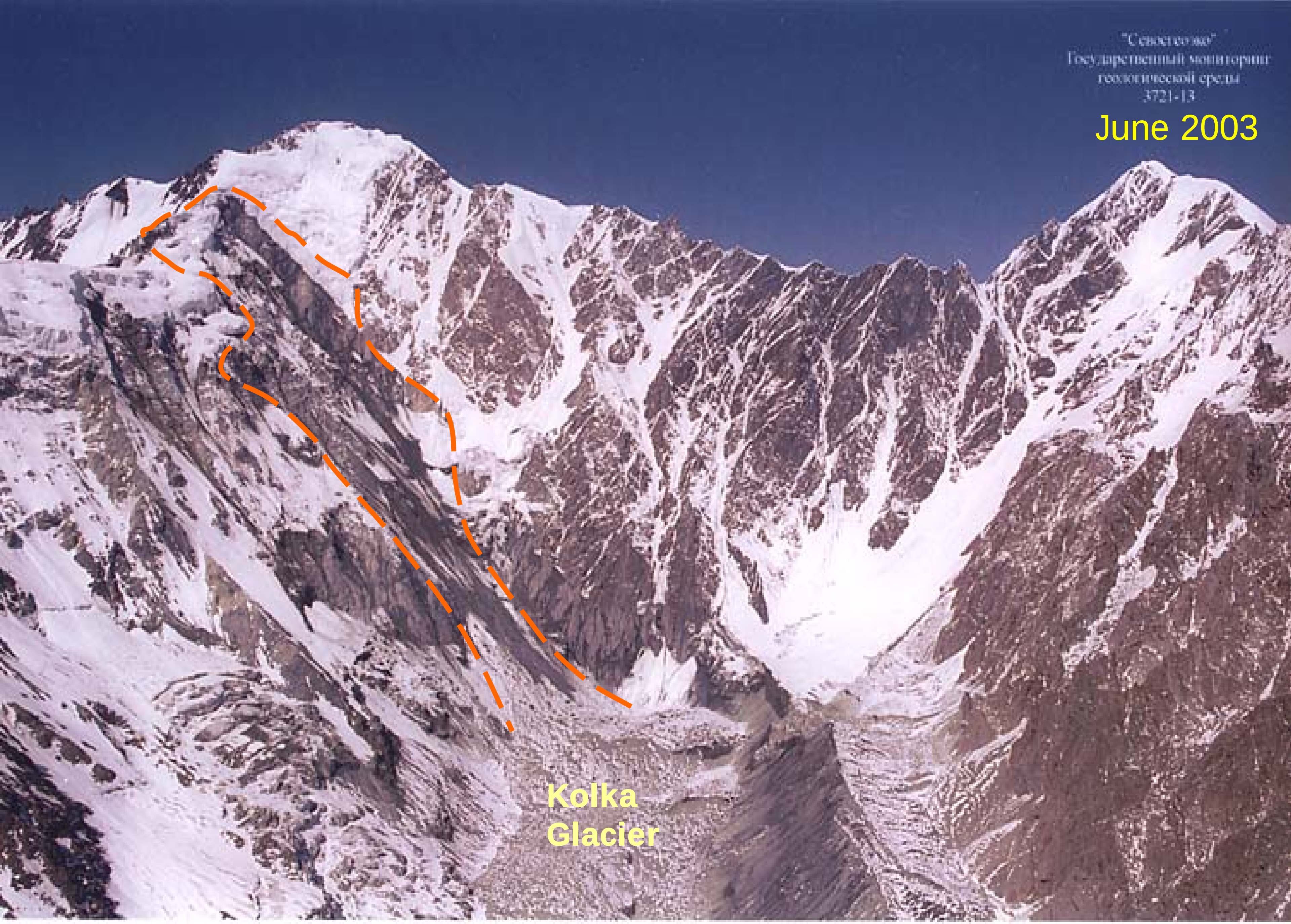
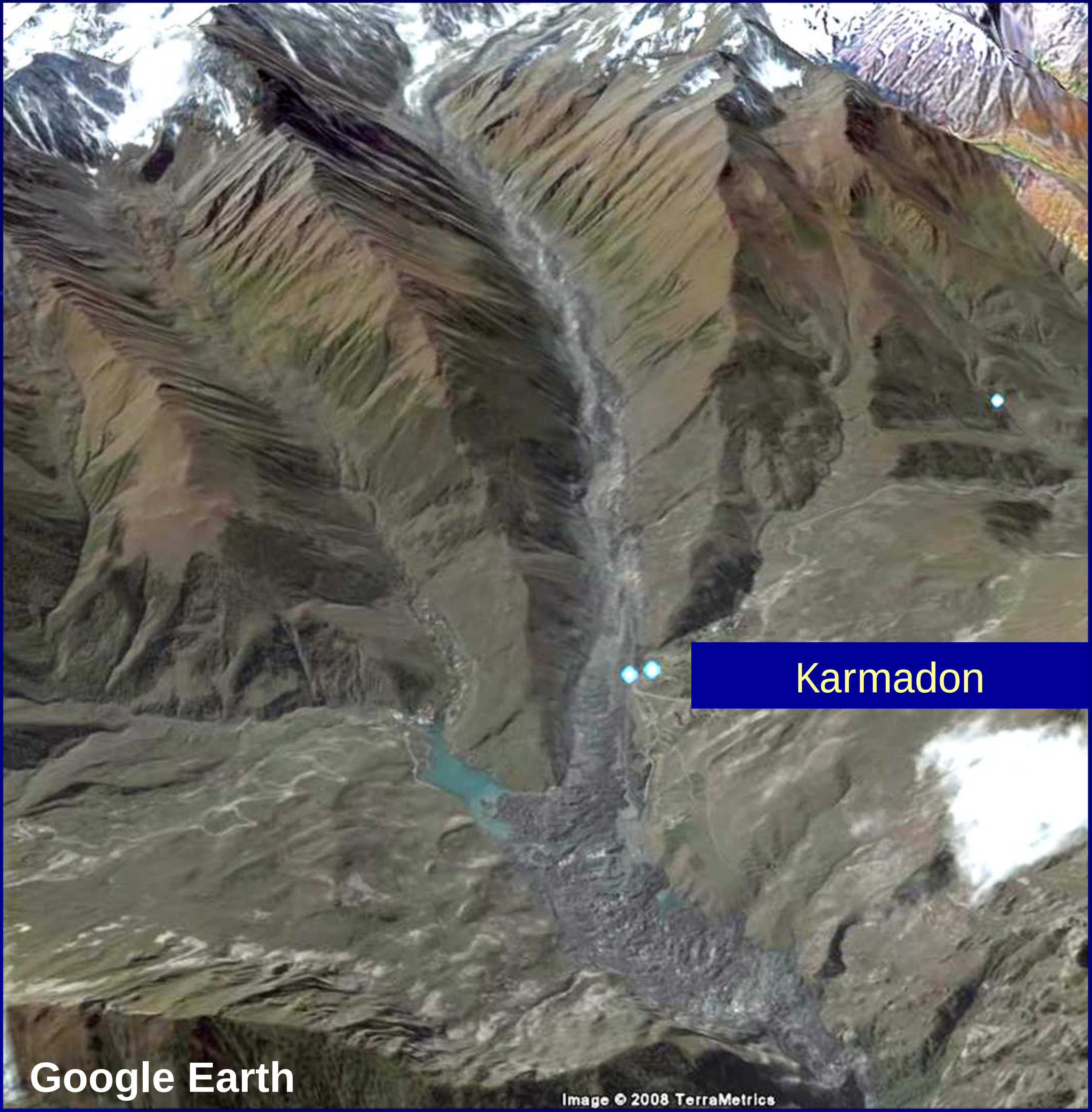


Рис. Вершины Джимарай, Шау, стенка обвала. 26.06.03 г.


22.09.2002
Mean Velocity
300 km/h
Alexander Polkvoy



End of Karmadon Sturzstrom

Conclusion:

Glacier Risks are to

90 % Debris-Flow Risks

Risks

consist of two components:

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- **Hazard**
  (probability of a major natural event to happen)

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consist of two components:

- **Hazard**
  (probability of a major natural event to happen)

- **Vulnerability**
  (potential casualties and/or major values at risk)

In Engineering Geology:

Risk = Hazard x Vulnerability

Hazard →

Vulnerability ↓	0	1	2	3
0	0	0	0	0
1	0	1	2	3
2	0	2	4	6
3	0	3	6	**9**

Risk = Hazard x Vulnerability

What can be done against these horrific threats?

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Mitigation

- Improved monitoring systems

Mitigation

- Improved monitoring systems
- Improved early warning and warning systems

Mitigation

- Improved monitoring systems
- Improved early warning and warning systems
- Improved mapping methods of hazards and risks

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Mitigation

- Displacement of roads and bridges

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- Debris-flow deflection walls

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Mitigation

- Displacement of roads and bridges
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- Widened channels through villages

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Mitigation

- Displacement of roads and bridges
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- Preparedness of population

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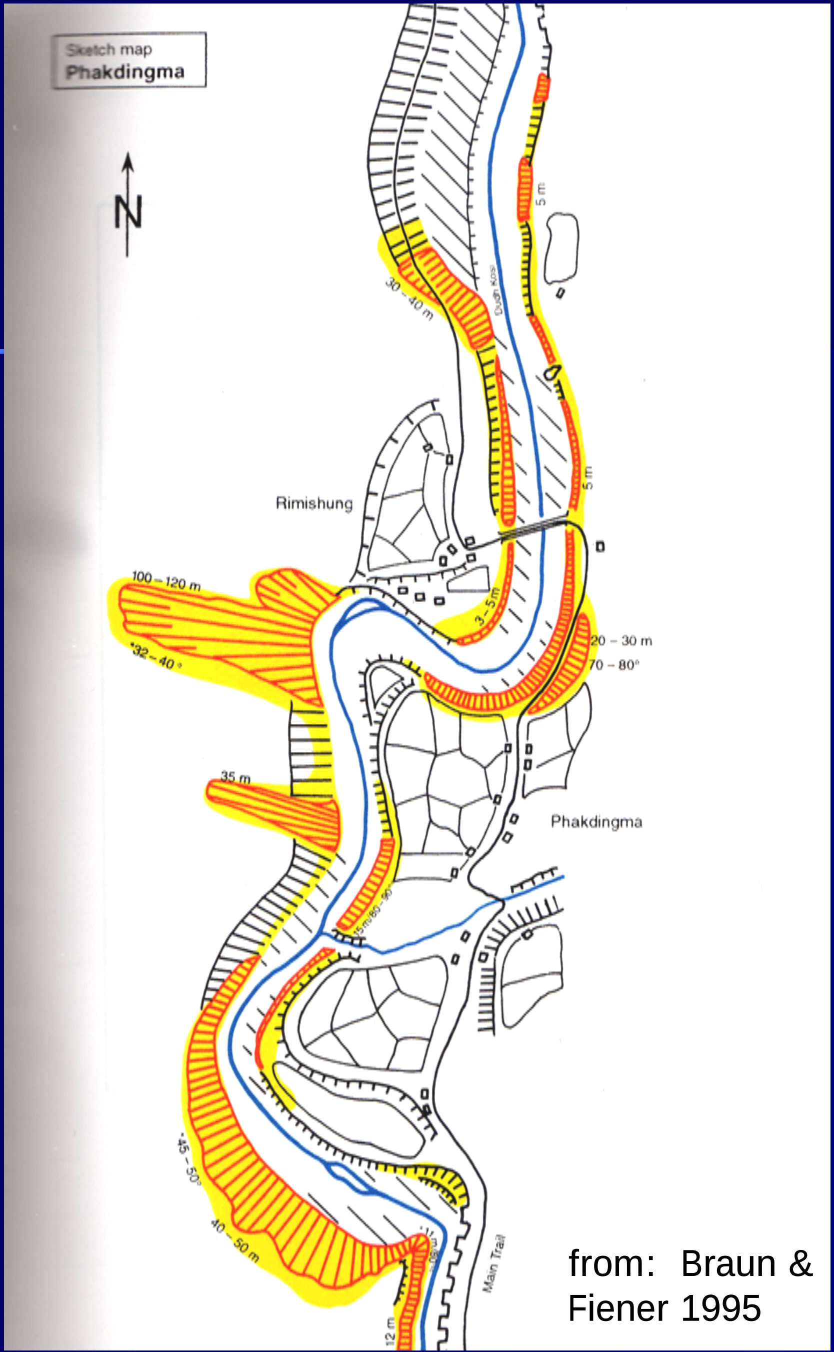

from: Braun & Fiener 1995

Example of GLOF risk mapping along a Himalayan valley

Glacier Hazard Prevention Strategies

Glacier Hazard Prevention Strategies

Prevent Initiation of GLOFs

Glacier Hazard Prevention Strategies

- Prevent Initiation of GLOFs
- Prevent GLOFs and Sturzstroms from reaching areas of high vulnerability

Prevention of Initiation of GLOFs

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Prevention of Initiation of GLOFs

Lowering of lake level by

- siphoning
- tunneling
- trenching

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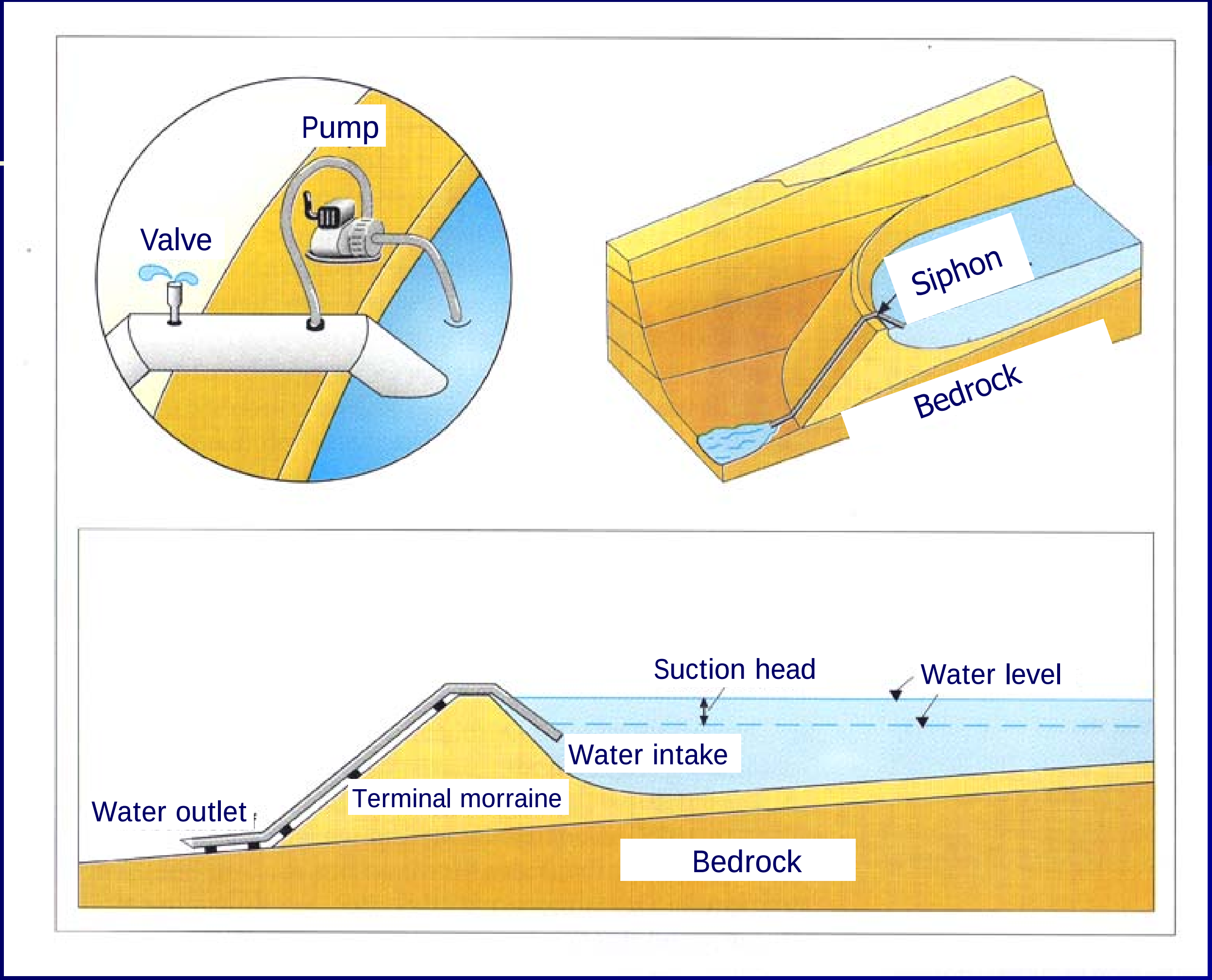
Siphoning of glacier lakes



Principle of hydraulic syphon

from Grabs & Hanisch (1993)

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APPENDIX

Calculation of the possible suction head of a site with the following parameters (according to charts of physical constants and data from SGHP Yearbooks 1987-1990):

Geographic latitude	$\phi = 28°$
Altitude	$h = 4500$ m
Atmospheric pressure	$Pa = 57\,500$ to $60\,000$ Pa (-17 to $+6$°C) $\pm 10\%$
Water temperature	$t = 4$°C
Vapour pressure at 4°C	$Pv = 839$ Pa
Density of the water	$= 1000$ kg m^{-3}
Local gravity	$g(28°) = (g(0°) - 3.0865 \times 10^{-6} \times h)$ m s^{-2} $= 9.766$ m s^{-2}
Loss by friction (estimated)	$f = 5\%$

The formula for the maximum suction head is

$$z = \frac{Pa - Pv}{\rho g}(1 - f)$$

$$z = \frac{57.500\ \text{Pa} - 839\ \text{Pa}}{1000\ \text{kg m}^{-3} \times 9.766\ \text{m s}^{-2}} \times 0.95$$

$(Pa = N\ m^{-2};\ N = kg\ m\ s^{-2})$

$$z = \frac{56.661\ \text{kg m s}^{-2}\ \text{m}^{-2}}{1000\ \text{kg m}^{-3} \times 9.766\ \text{m s}^{-2}} \times 0.95$$

$z = 5.51$ m $\pm$ 10% (for $t = -17$°C)

$z = 5.75$ m $\pm$ 10% (for $t = +6$°C)

Limitations of hydaulic siphons:

- Suction head
- Volume of drained water

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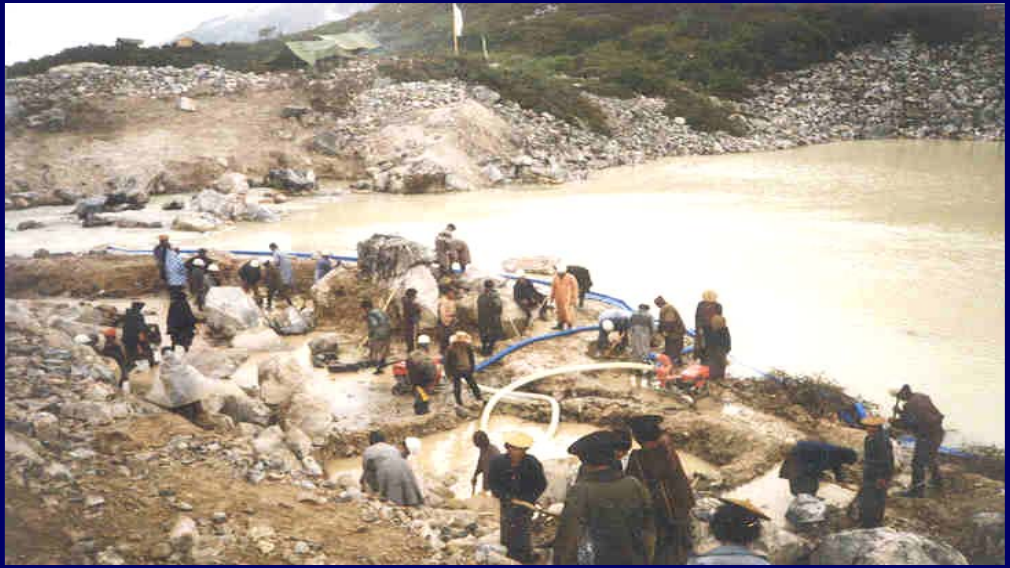
Tsho Rolpa, 4500 m, Nepal



Hydraulic siphons in Peru

Lake level lowering by drainage tunnel, Peru

Courtesy: John M. Reynolds

Trenching: Tsho Rolpa, 4500 m, Nepal

- Channel completed 2000
- Water level reduced by 3.5 m
- Costs ~ US$ 3 million

Gate at Tsho Rolpa (Nepal)

Disaster of Quebrada los Cedrs, Peru 1949

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Failed mitigation works in Peru 1949

Lliboutry et al. 1977

- Lake level lowered by 15 m by trenching
- Collapse of glacier snout which before had been under buoyancy

Lliboutry et al. 1977

- Displacement wave rushing through trench
- Breaching of morraine by regressive erosion
- GLOF killing several hundred people

Special method to control the spillway

Emergency Agency Almaty, Kazakhstan

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Drastic protection measures

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GLOF Front in Kazakhstan

Court.: Kazselezaschita, Almaty

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GLOF Front in Kazakhstan

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Medeo Debris-Flow Protection Dam, upstream Almaty, Kazakhstan

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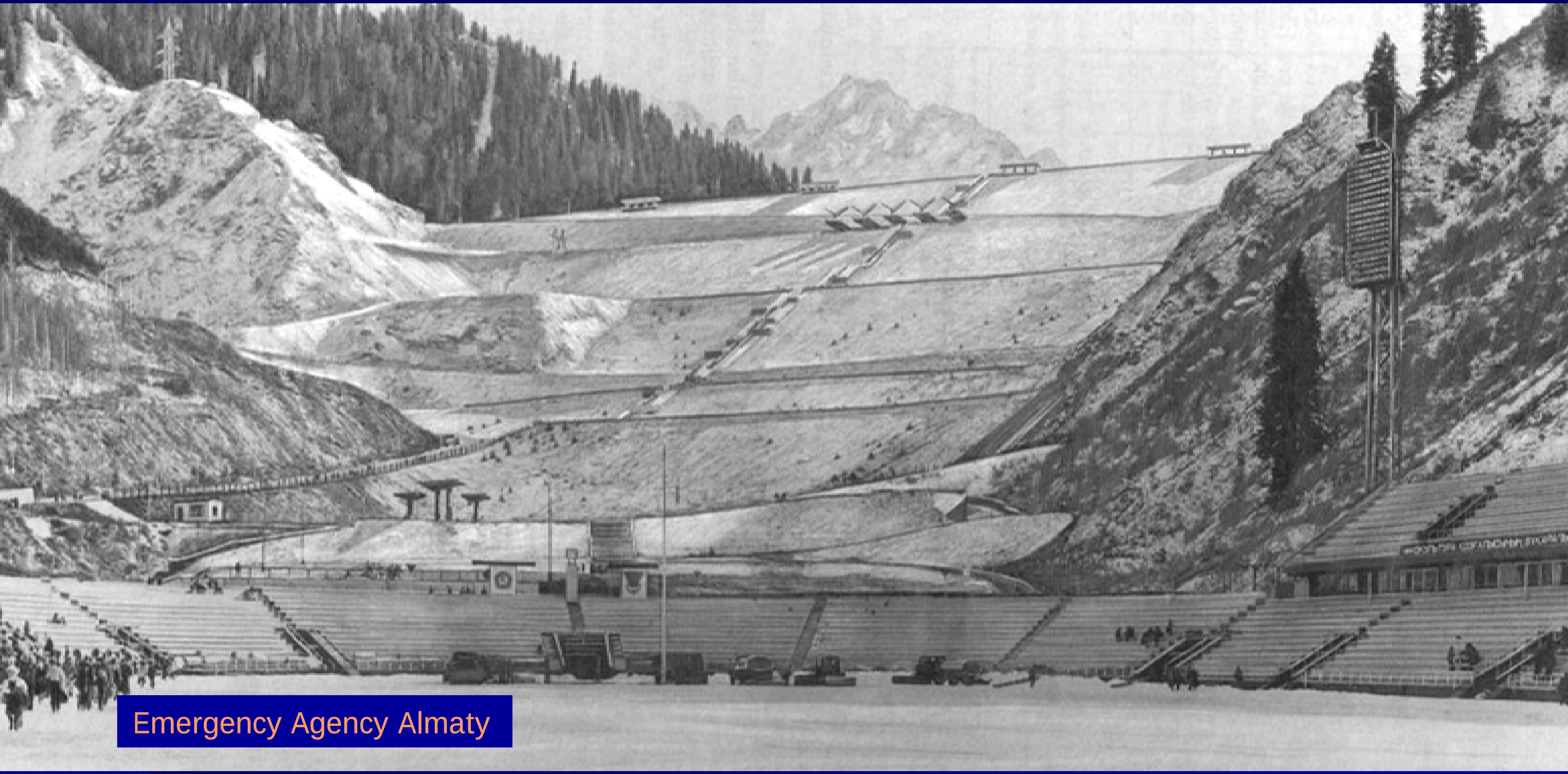
Medeo Debris-Flow Protection Dam



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Emergency Agency Almaty

Medeo Debris-Flow Protection Dam under Construction 1972

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Medeo Debris-Flow Protection Dam under Construction 1972

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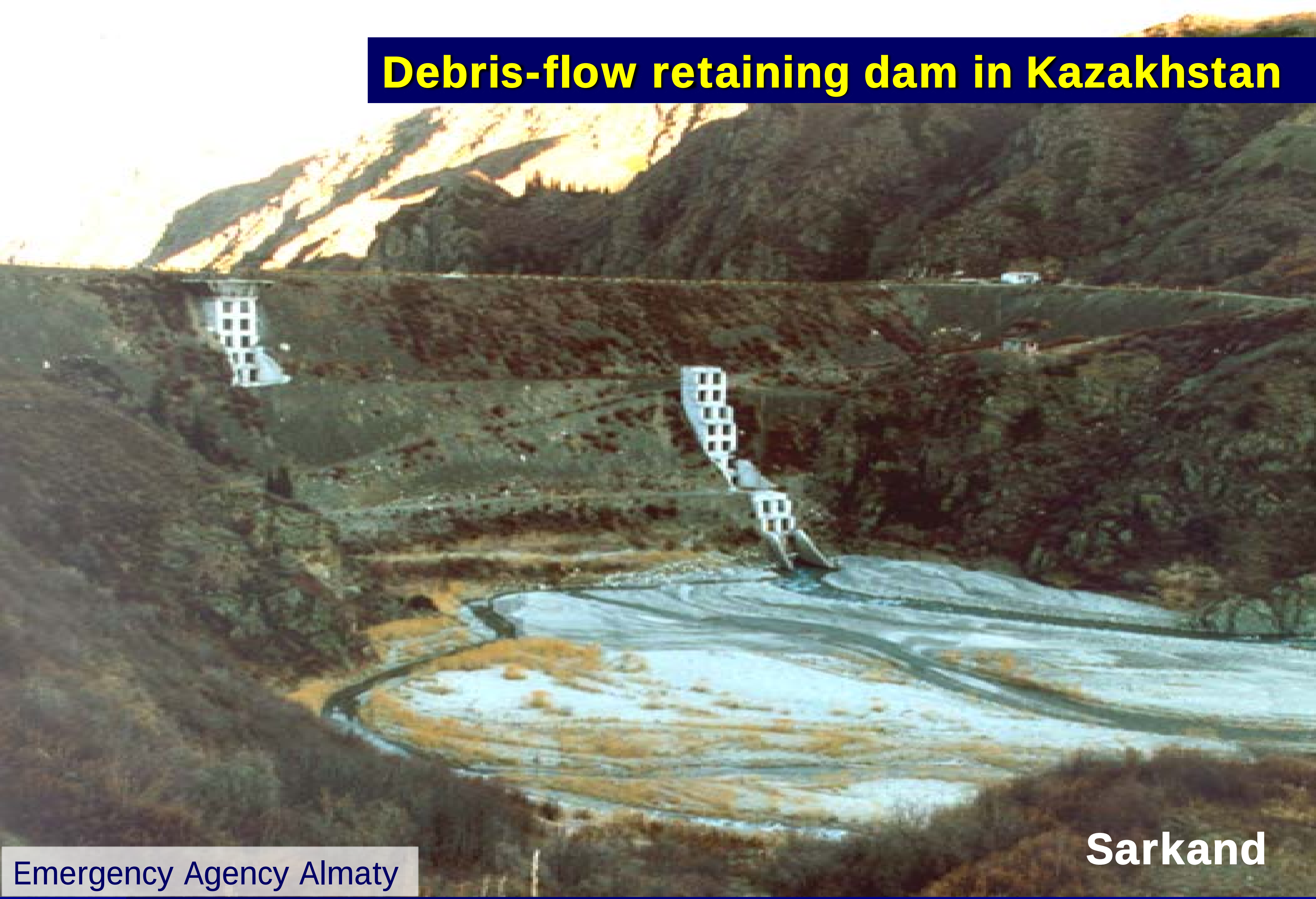
Debris-flow retaining dam in Kazakhstan




Talgar
Emergency Agency Almaty

Flexible debris-flow retaining dam in Kazakhstan

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Switzerland, Geobrugg

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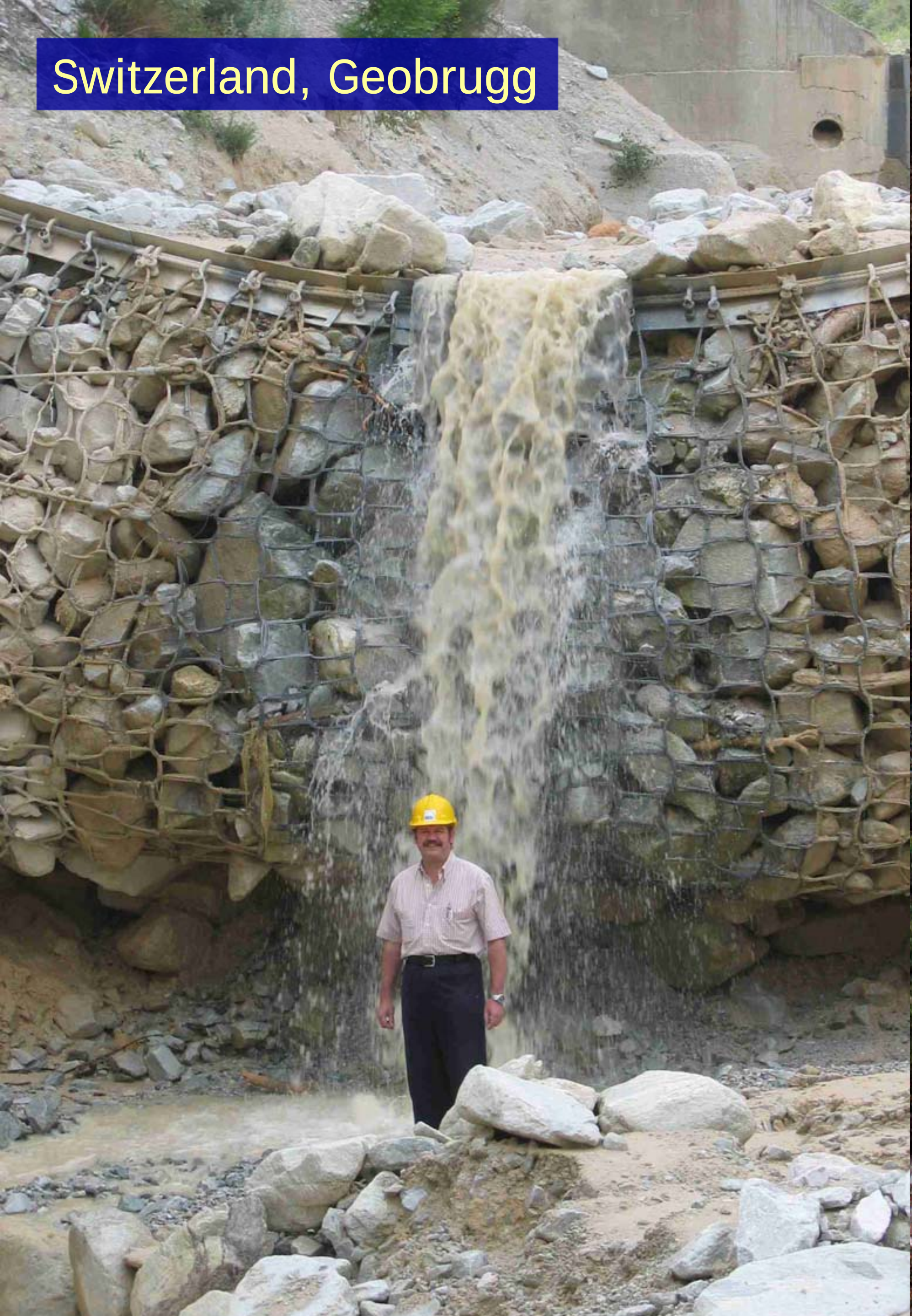
Switzerland, Geobrugg


Kazakhstan, Emergency Agency

Conclusions

- Most of the glacier hazards cannot be totally prevented

- GLOF-prevention strategies can either

  - try to prevent the outburst

  - prevent the consequent debris flow from reaching areas of high vulnerability

Conclusions

- Any mitigation measure needs careful assessment of risk (vulnerability of travel path)

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Thank you very much!

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