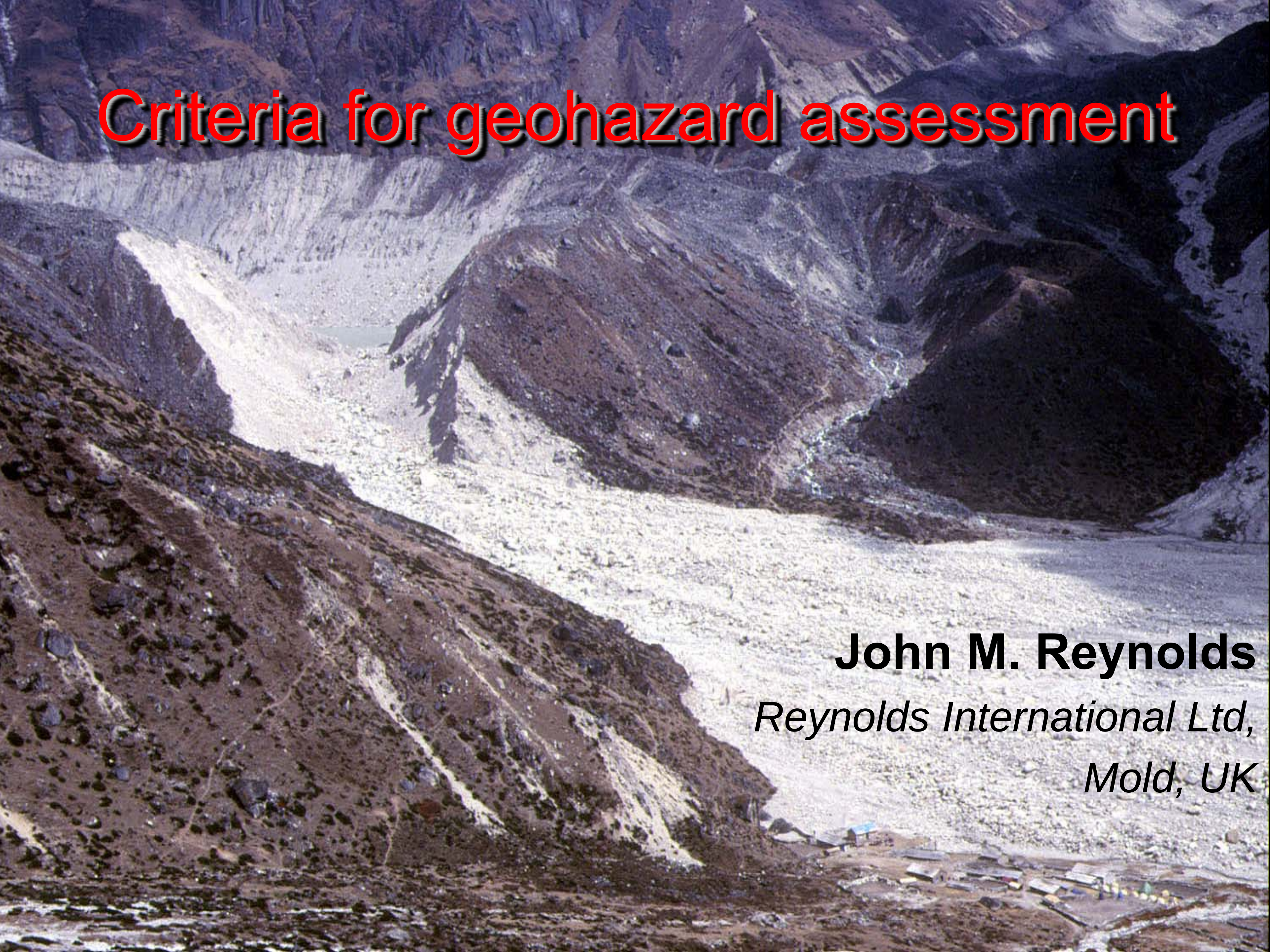
Criteria for geohazard assessment



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- Neil Glasser, Mike Hambrey, Bryn Hubbard, Richard Lucas, Duncan Quincey, and Shaun Richardson, Aberystwyth University
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- Surendra Pant, Tribhuvan University, Nepal
- Department of Hydrology & Meteorology, Kathmandu, Nepal
- Jőrg Hanisch, formerly BGR, Germany

Workshop objectives

Guidelines for the assessment of remote geohazards

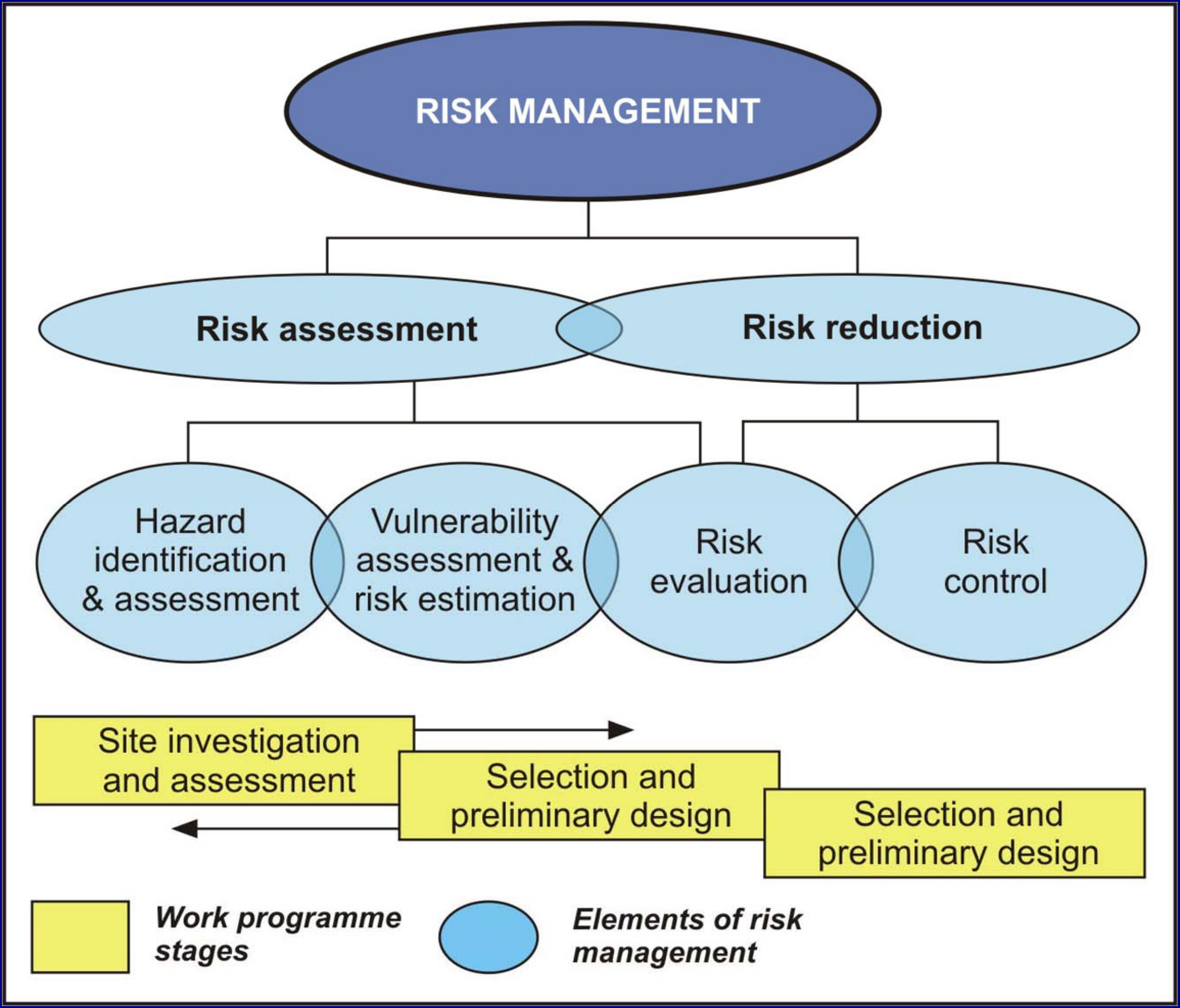
"This should be a generic and consistent approach which is regionalizable and adaptable for different types of hazards, different socio-economic environments and different availability of data"

Martin Mergali & Christian Huggel.

Hazard: *A potentially damaging physical event, phenomenon or human activity, which may cause loss of life or injury, property damage, social and economic disruption or environmental degradation.*

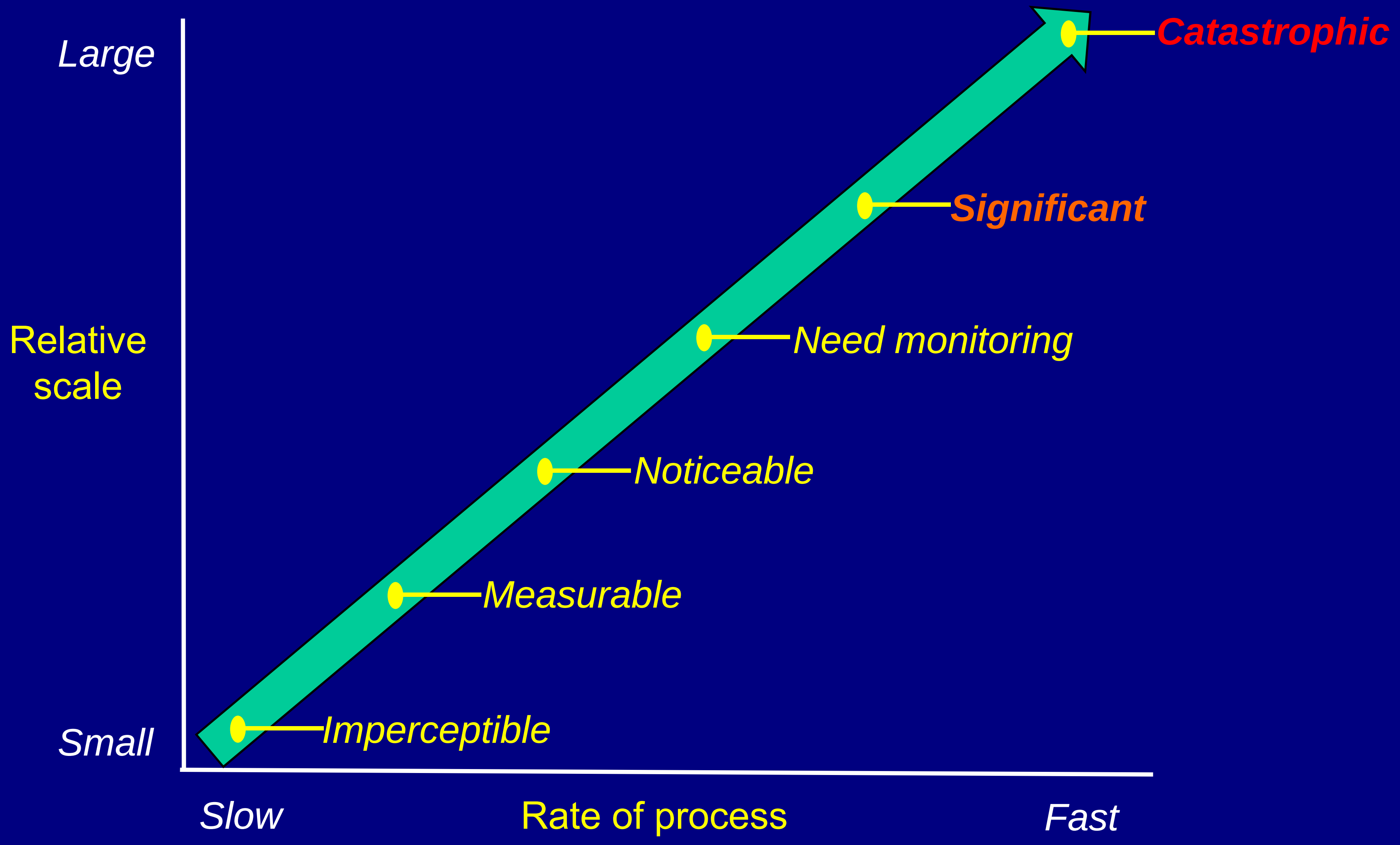
(ISDR, 2002)

RISK **= Fn[Hazard*Vulnerability]**

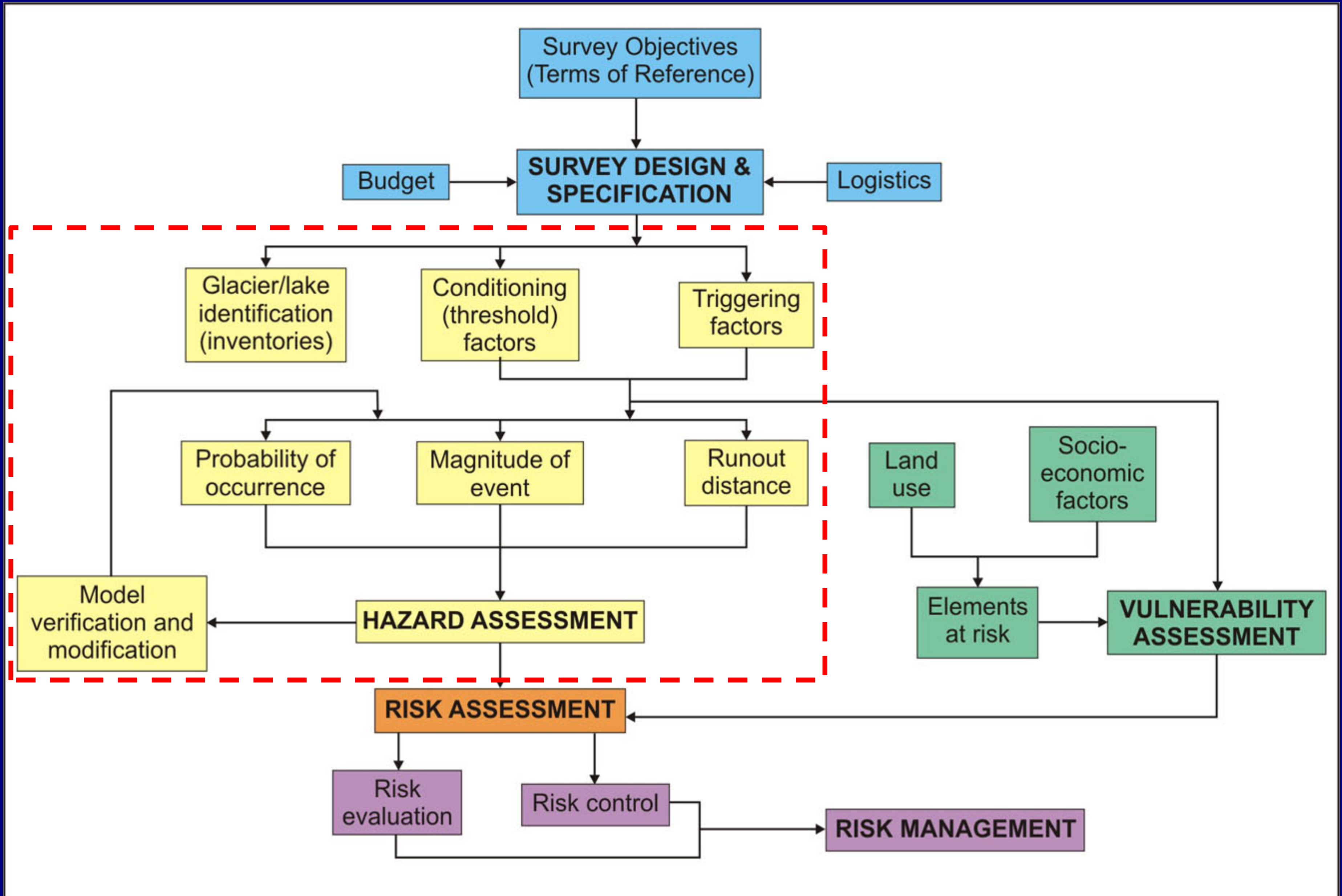


After Harris & Herbert (1994)

Definition of processes



Example project structure for glacial risk assessment and management

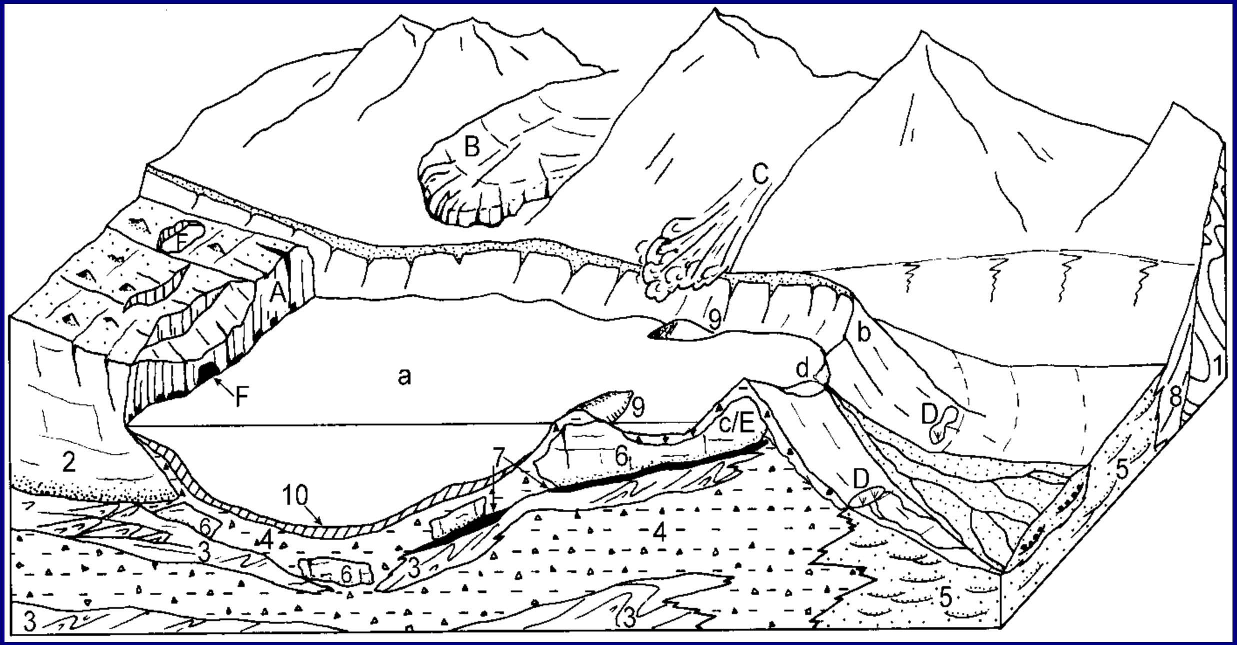


From *Guidelines for the management of glacial hazards and risks*, RGSL, 2003.

Glacial lake hazard assessment

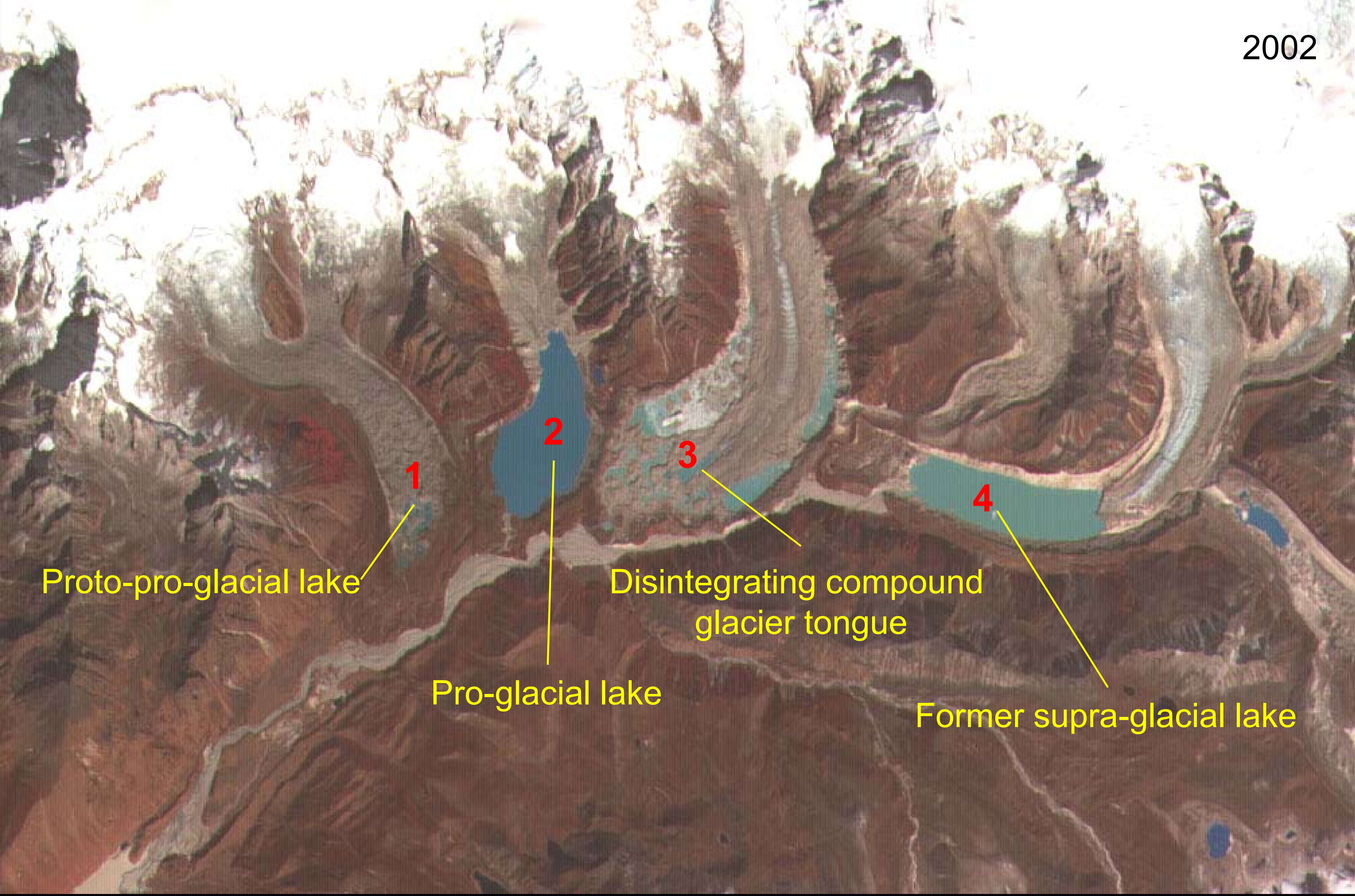
Glacial lake system approach

- Terminal moraine complex
- Stagnant debris-covered ice
- Lateral moraines
- Source glaciers
- Valley flanks & environs



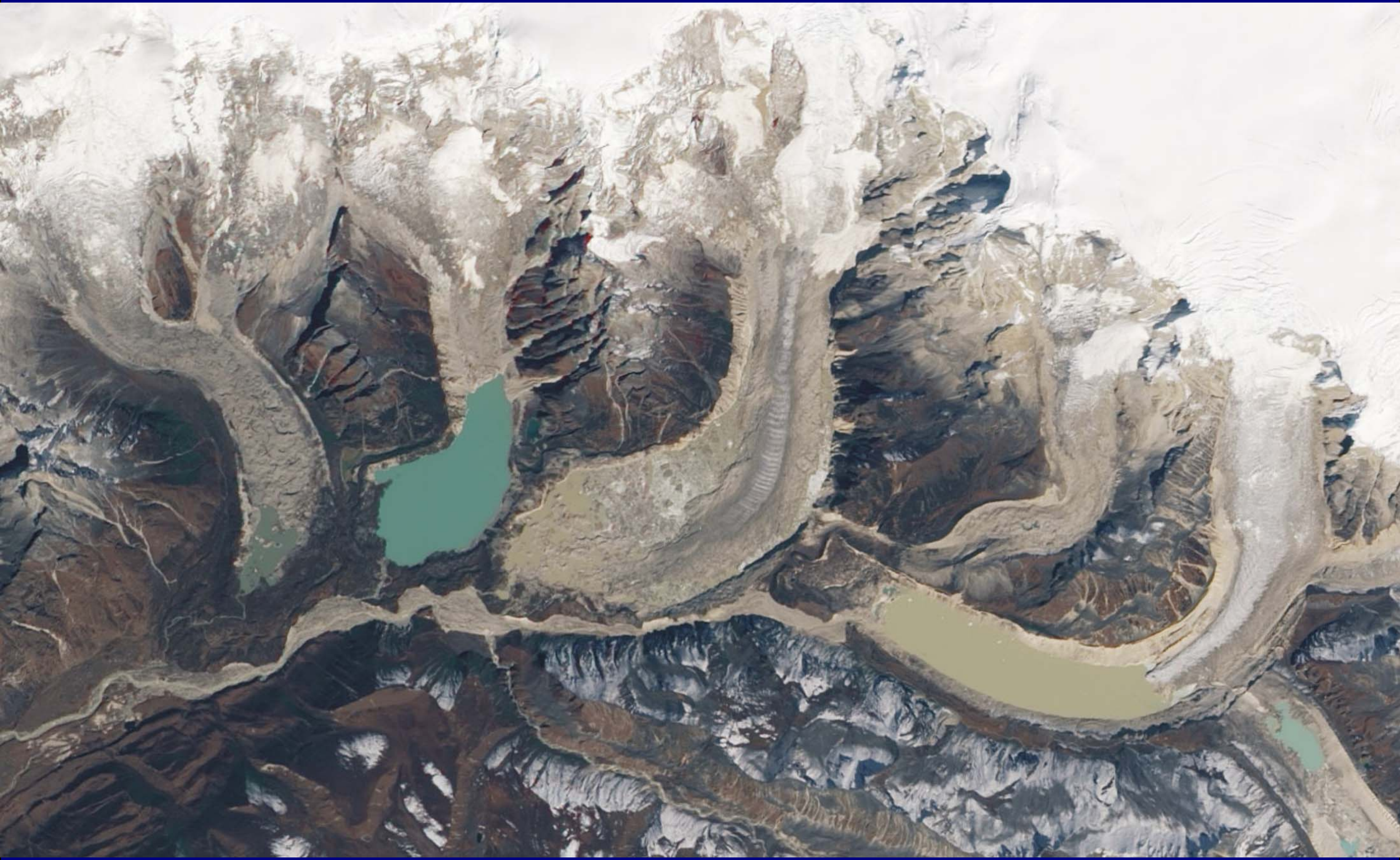
Static and temporal conditions

(Richardson & Reynolds, 2000)



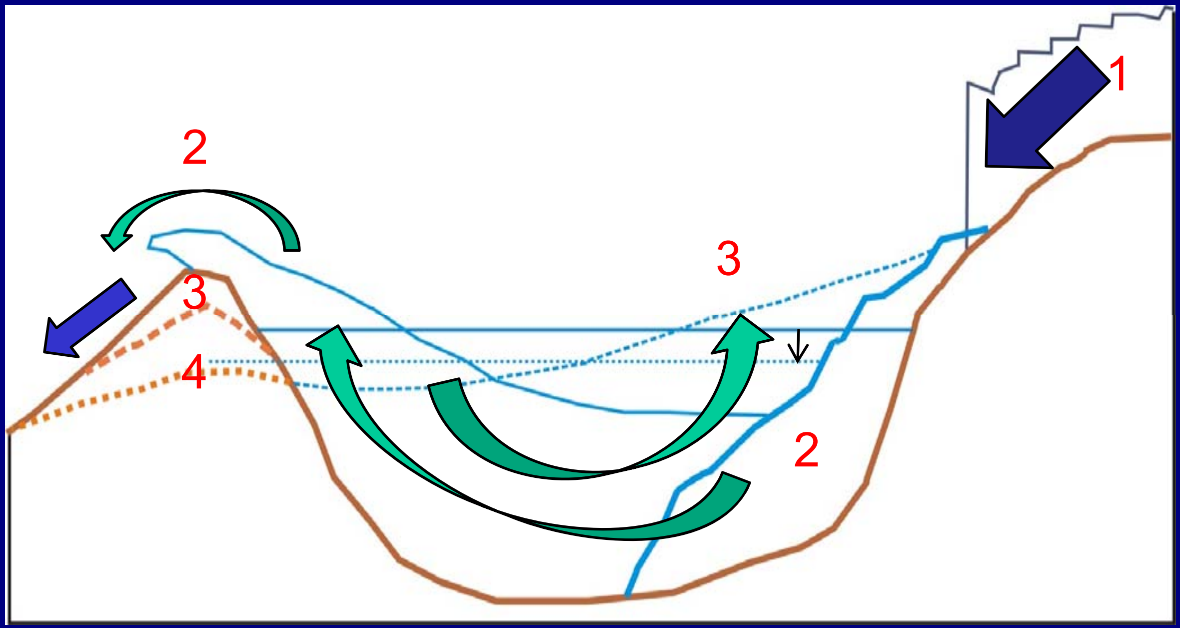
Lunana lakes, northern Bhutan

Lunana lakes, northern Bhutan



28th October 2009

Multi-phase events



1. Avalanche into lake
2. Displacement wave overtops moraine with some discharge
3. Runback of wave and re-surge forwards with regressive erosion of moraine
4. Breach of moraine and lowering of lake level ...

- Hydrograph will show initial surge from overtopping wave (2);
- Reduction in flow during the runback stage (3), with a further pulse when the re-surge occurs perhaps with increased base flow;
- Breach of moraine occurs and main lowering of lake level (4) ...

Relationships

Parameter	Affects
Lake depth near breach point	Peak flow rate
Breach mechanism	Peak flow rate
Breach dimensions	Peak flow rate & flood duration
Lake volume	Flood duration

??Implications for flood modelling??

Hazard assessment – Multi-Criteria Analysis

ID	Parameter affecting hazard\Score*	0	2	10	50
	Volume of lake	N/A	Low	Mod.	Large
	Lake level relative to freeboard	No dam	Low	Mod.	Full
	Seepage evident through dam	None	Min.	Mod.	Large
	Ice-cored moraine dam +/- thermokarst features	N/A	Min.	Partial	>Mod.
	Calving activity from ice cliff	N/A	Low	Mod.	Large
	Ice/rock avalanche risk	N/A	Low	Mod.	Large
	Supra- / englacial drainage	None	Low	Mod.	Large
	Compound risk present	None	Slight	Mod.	Large

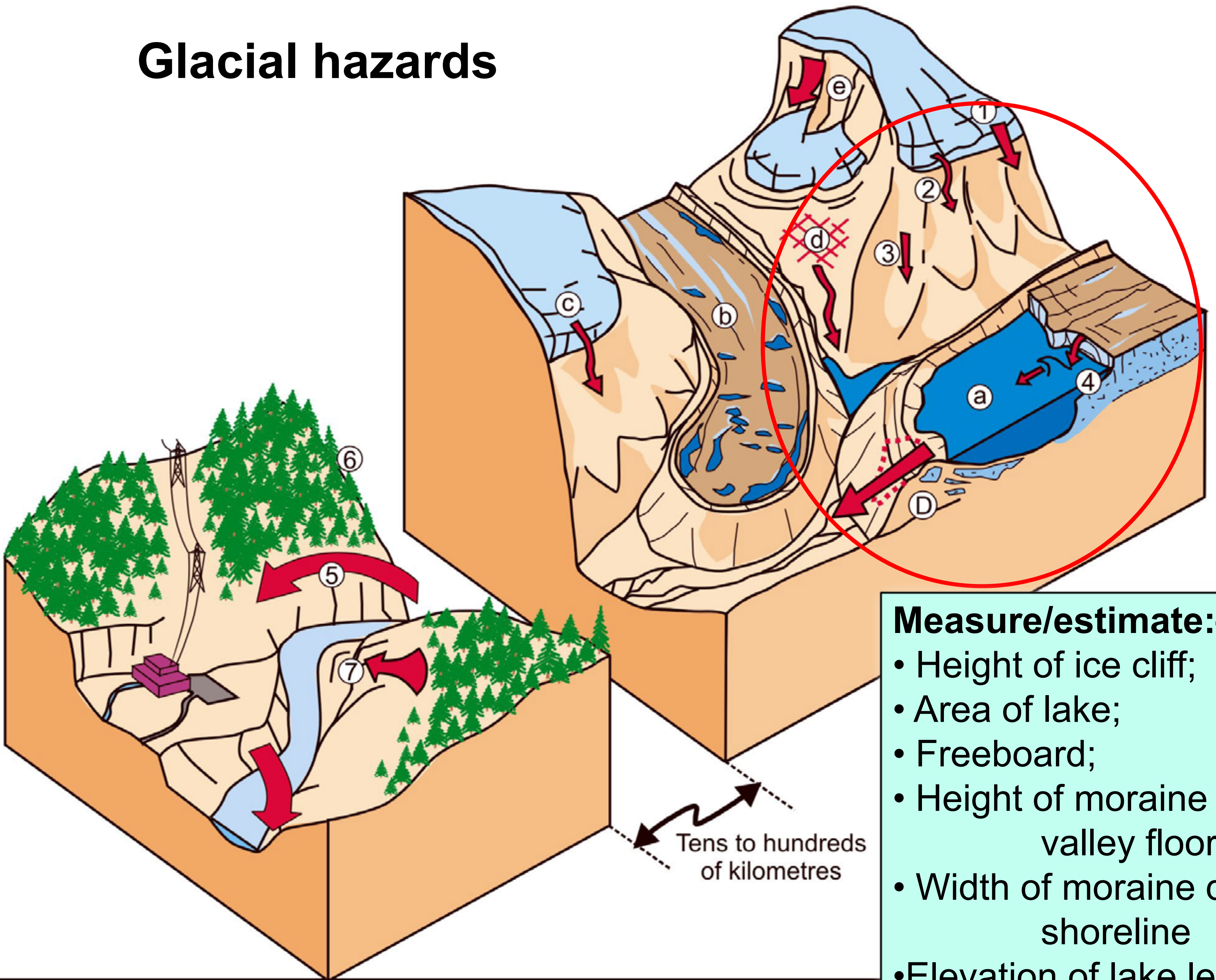
Threshold parameter *Trigger potential parameter*

**Criteria for each score can be defined*

Zero	Medium hazard	Serious	**High**	**Very high**
		>>> An outburst can occur at any time>>>		

(Modified from Dyce and Reynolds, 1998)

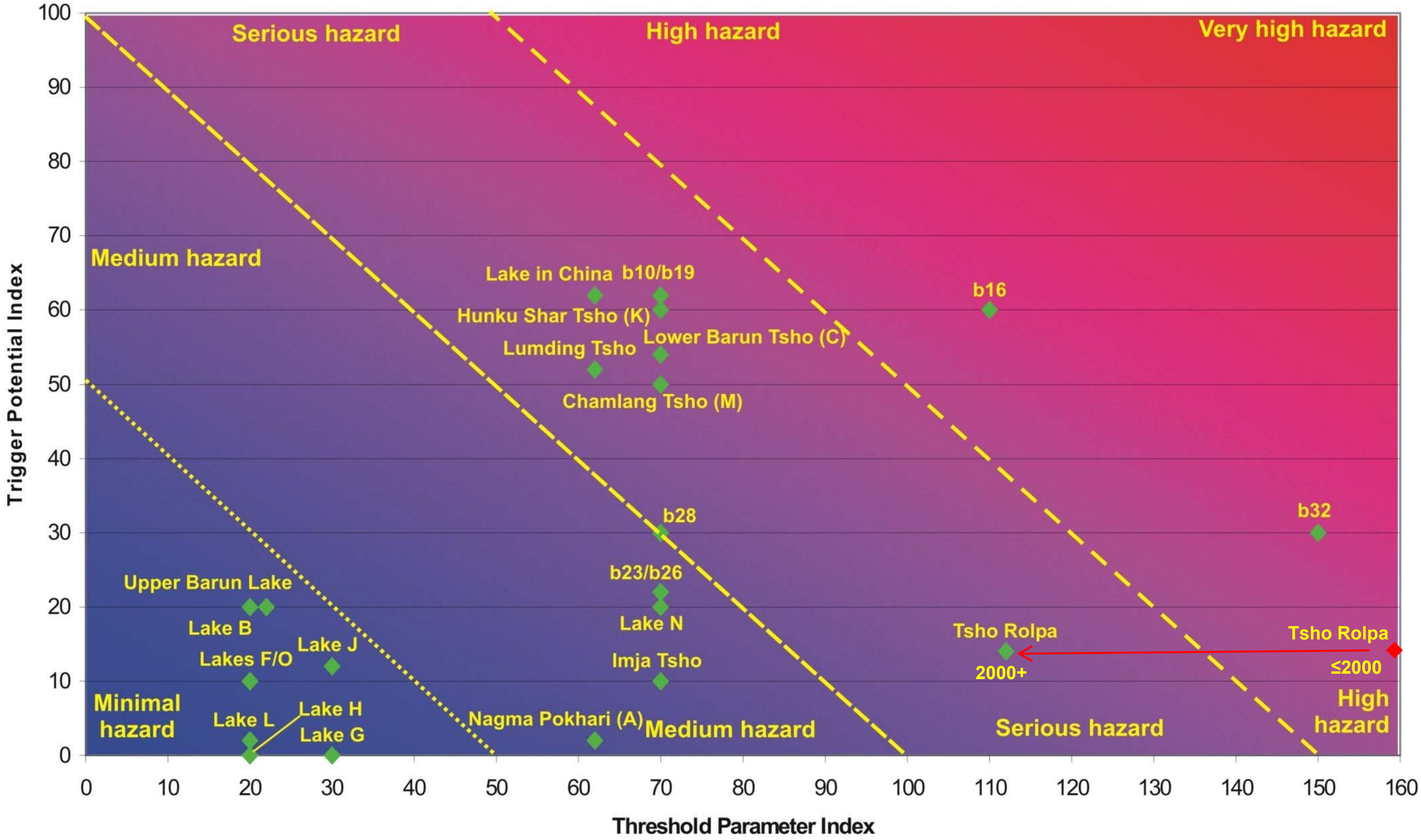
Glacial hazards



Measure/estimate:–

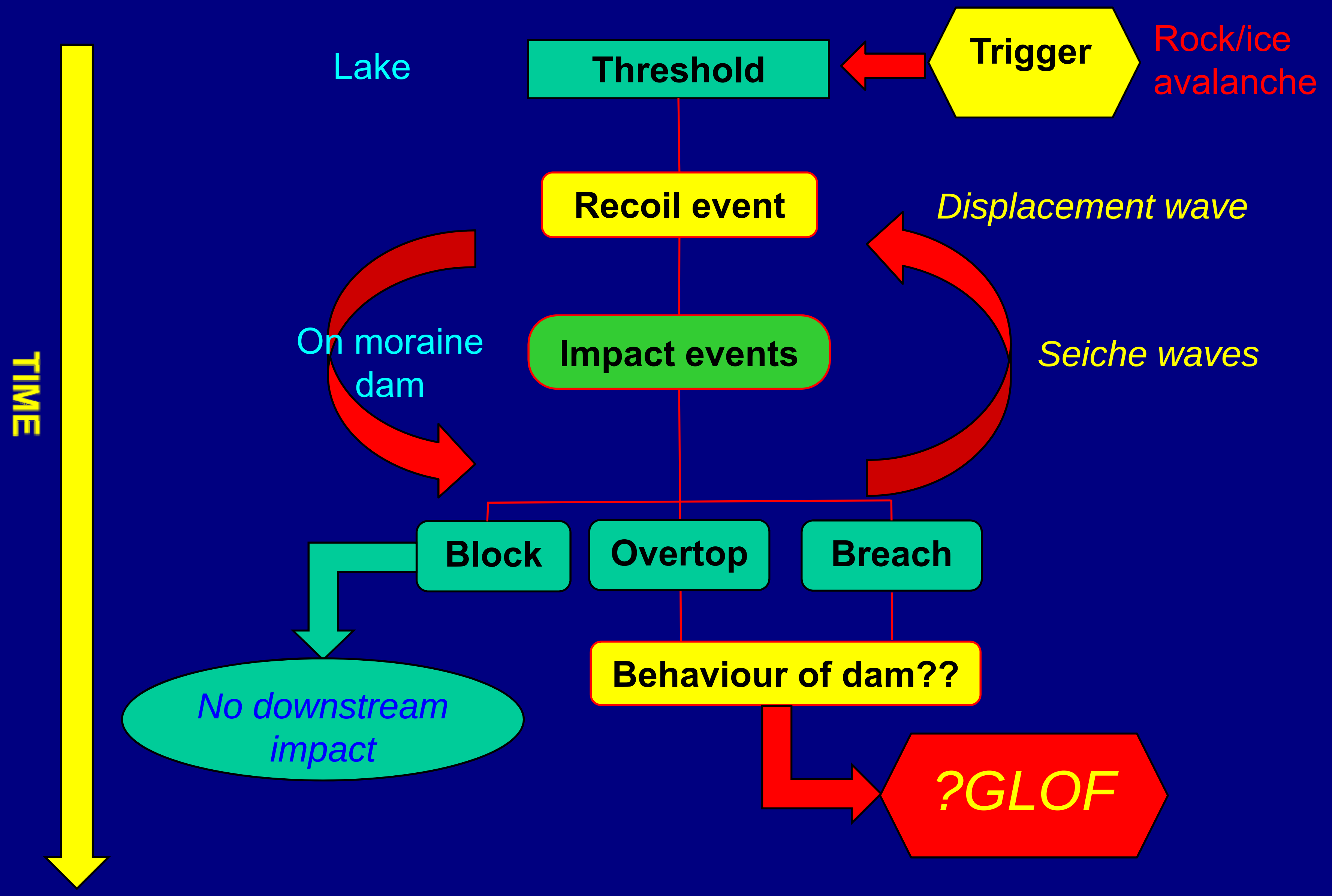
- Height of ice cliff;
- Area of lake;
- Freeboard;
- Height of moraine above valley floor
- Width of moraine dam at shoreline
- Elevation of lake level relative to adjacent valley floor

Multi-Criteria Analysis for northeast Nepal



(RGSL, 2007)

Hazard event development



Hazard assessment – Multi-Criteria Analysis

ID	Parameter affecting hazard\Score*	0	2	10	25	50
	Parameter 1	N/A	Low	Med.		
	Parameter 2	No dam	Low	Med.		
	Parameter 3	None	Min.	Med.	Mod.	Large
	Parameter 4	N/A	Min.	Partial	Med.	>Mod.
	Parameter 1	N/A	Low	Med.	Mod.	Large
	Parameter 2	N/A	Low	Med.	Mod.	Large
	Parameter 3	None				
	Parameter 4	None				

Threshold parameter *Trigger poten…*

**Criteria for each score can be defined*

Can also be done also for **vulnerability** rating

Identify and define your threshold parameters

Establish your weightings and your criteria

Identify and define your trigger parameters

Can be defined qualitatively (estimated)or quantitatively (measured)

Zero	Medium hazard	Serious	High	Very high
		A hazardous process can occur at any time>>>		

Define your grade boundaries

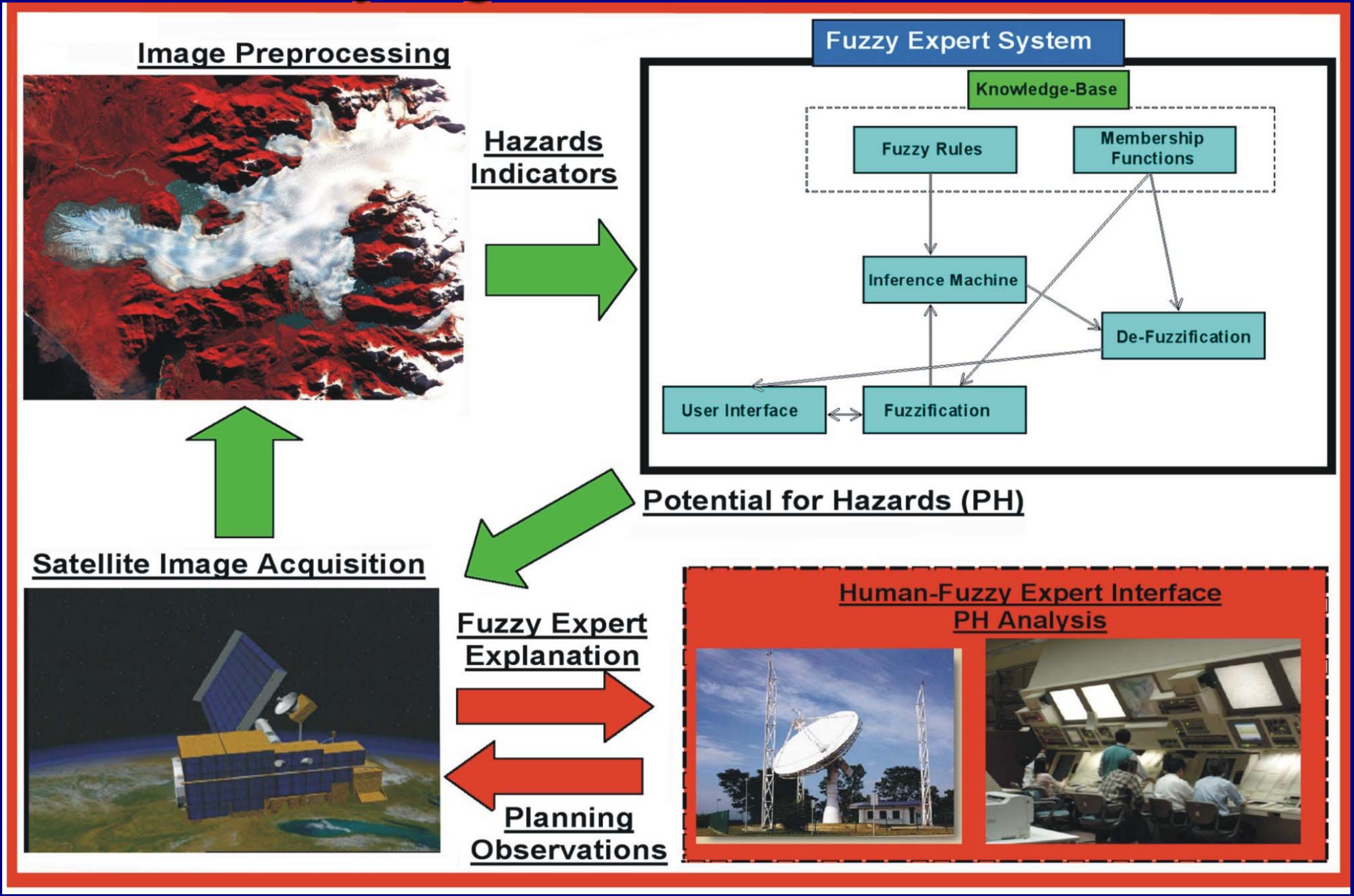
Hazard assessment – fuzzy logic

- The MCA approach introduced the notion of using multiple objective parameters to determine a hazard rating.

- With satellite imagery, GIS and AI software elements available, it should be possible to develop a system that automatically measures, defines and maps designated parameters and provides an output suitable for hazard managers (Kargel *et al.* 2009).

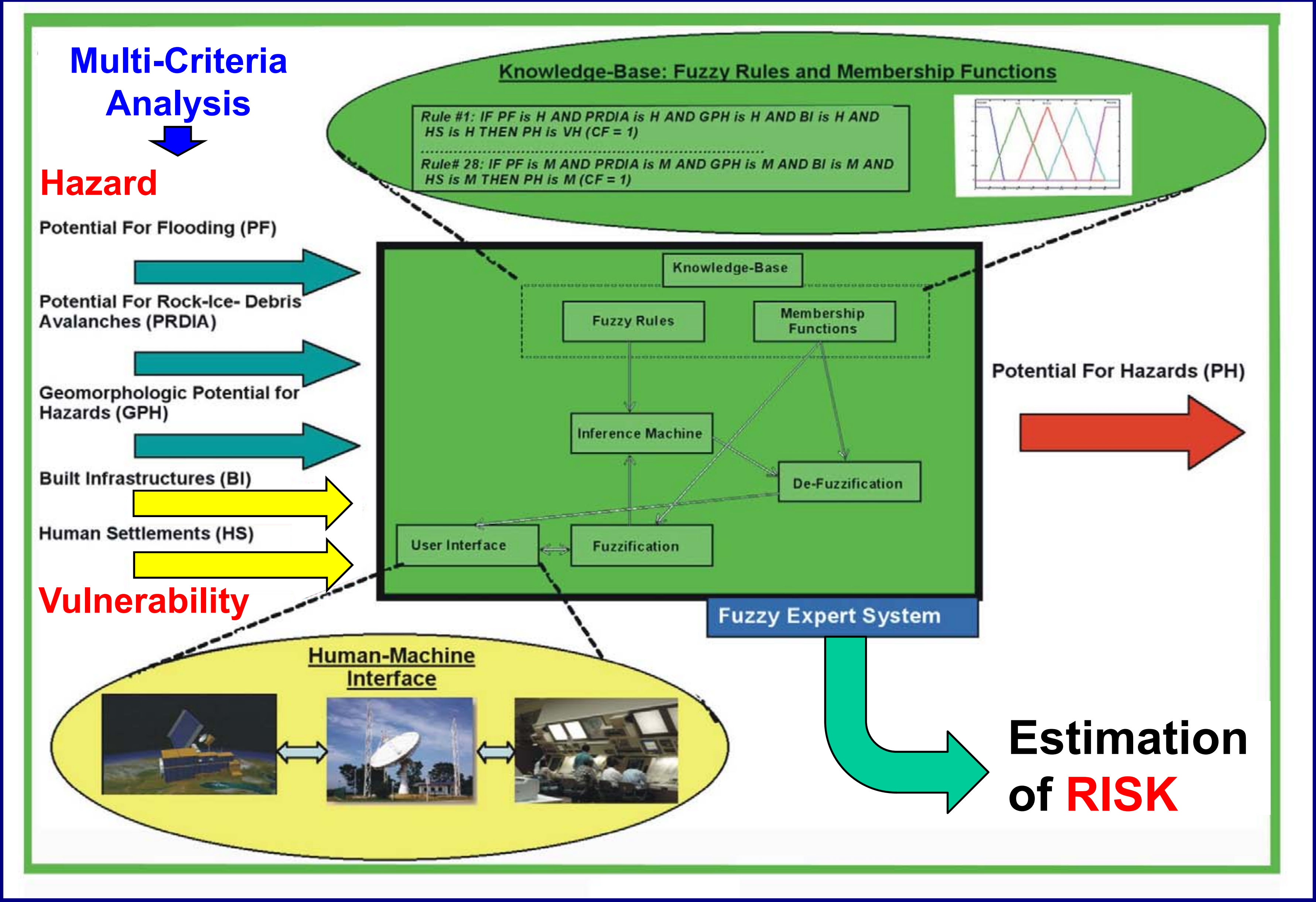
- Start to be able to use these systems for hazard monitoring and short-onset identification of forthcoming geohazard events (e.g. by identifying pre-cursor changes in run-off water colour, *etc*.)

Fuzzy logic hazard assessment

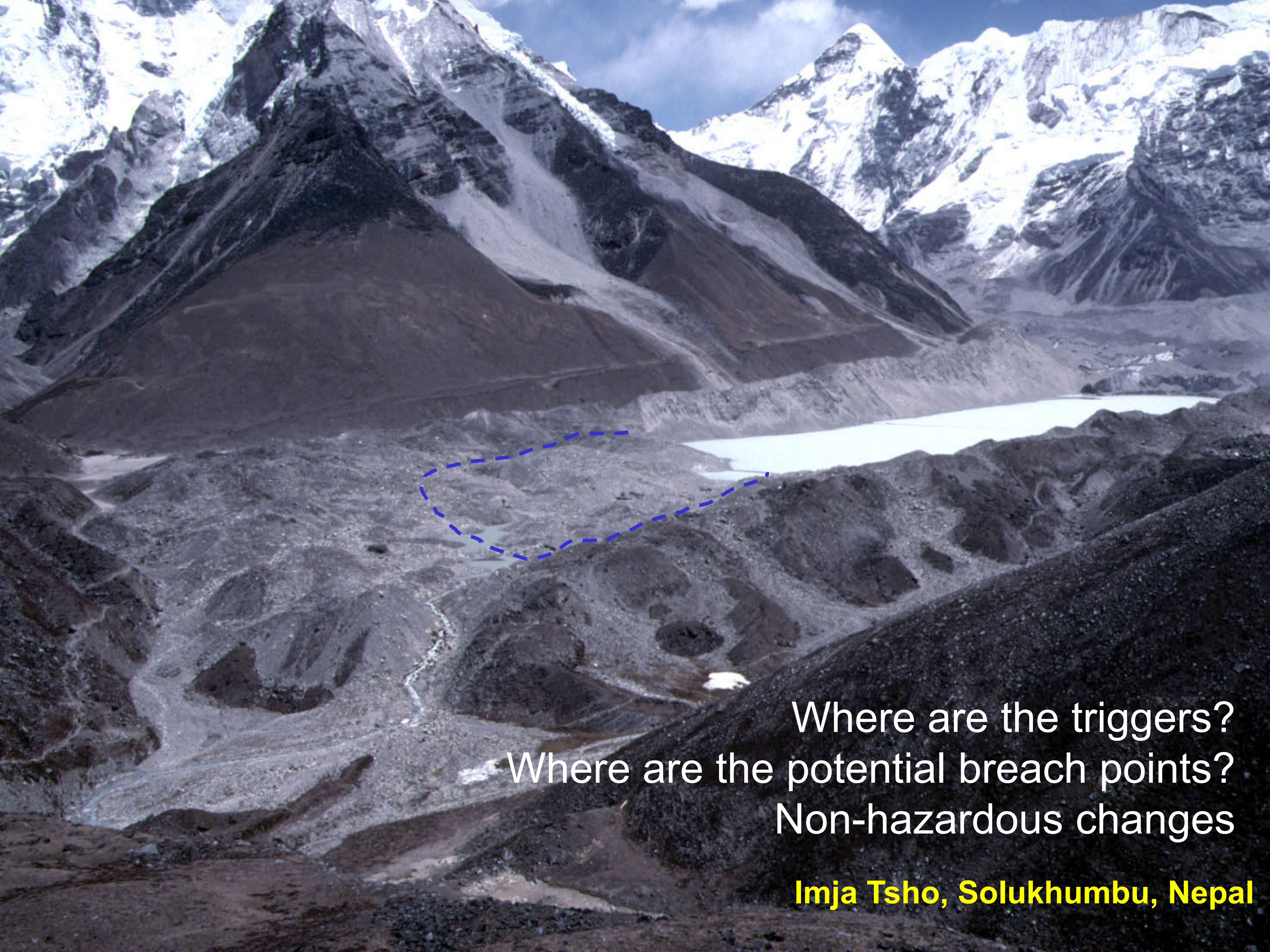


Kargel *et al.* (in press) Fig 7a.

Fuzzy logic risk assessment



Modified from Kargel *et al.* (in press) Fig 7b.


Where are the triggers?
Where are the potential breach points?
Non-hazardous changes
Imja Tsho, Solukhumbu, Nepal

Guidelines for glacial hazards & risks

- Integrated guidelines for holistic glacial hazard assessment and risk management
  - *Site investigation techniques*
  - *Hazard assessment, vulnerability assessment*
  - *Introducing objectivity into assessments*
  - *Risk reduction techniques*
- Concentrates on glacial lakes, but with broader application to other hazard types
- Technical sections for use by practitioners
  - *Geophysics*
  - *Geotechnics*
- Strategic risk management aspects for decision makers
- Available on line at: Or see me for a copy.

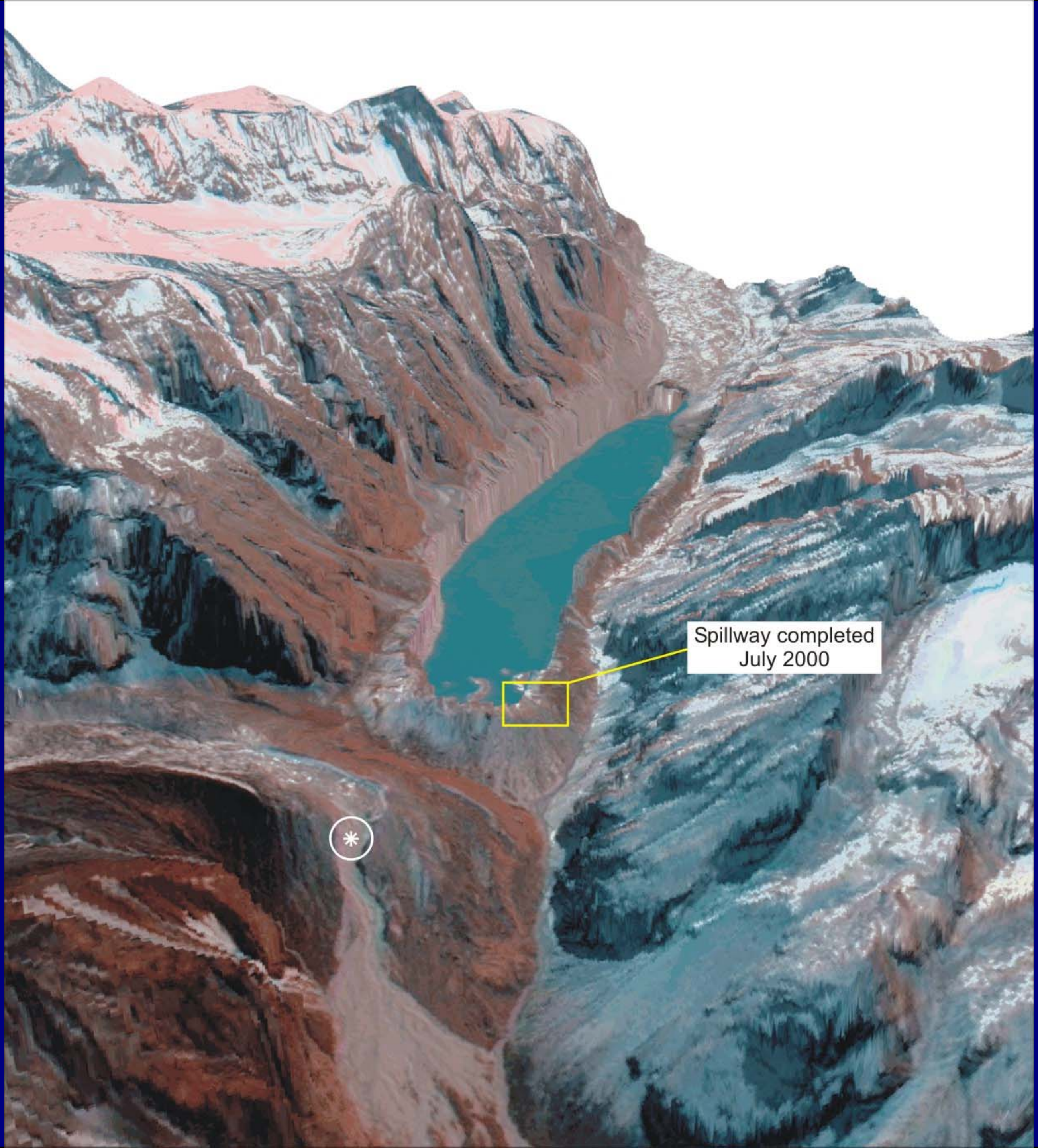
  www.geologyuk.com/mountain_hazards_group/dfid.htm

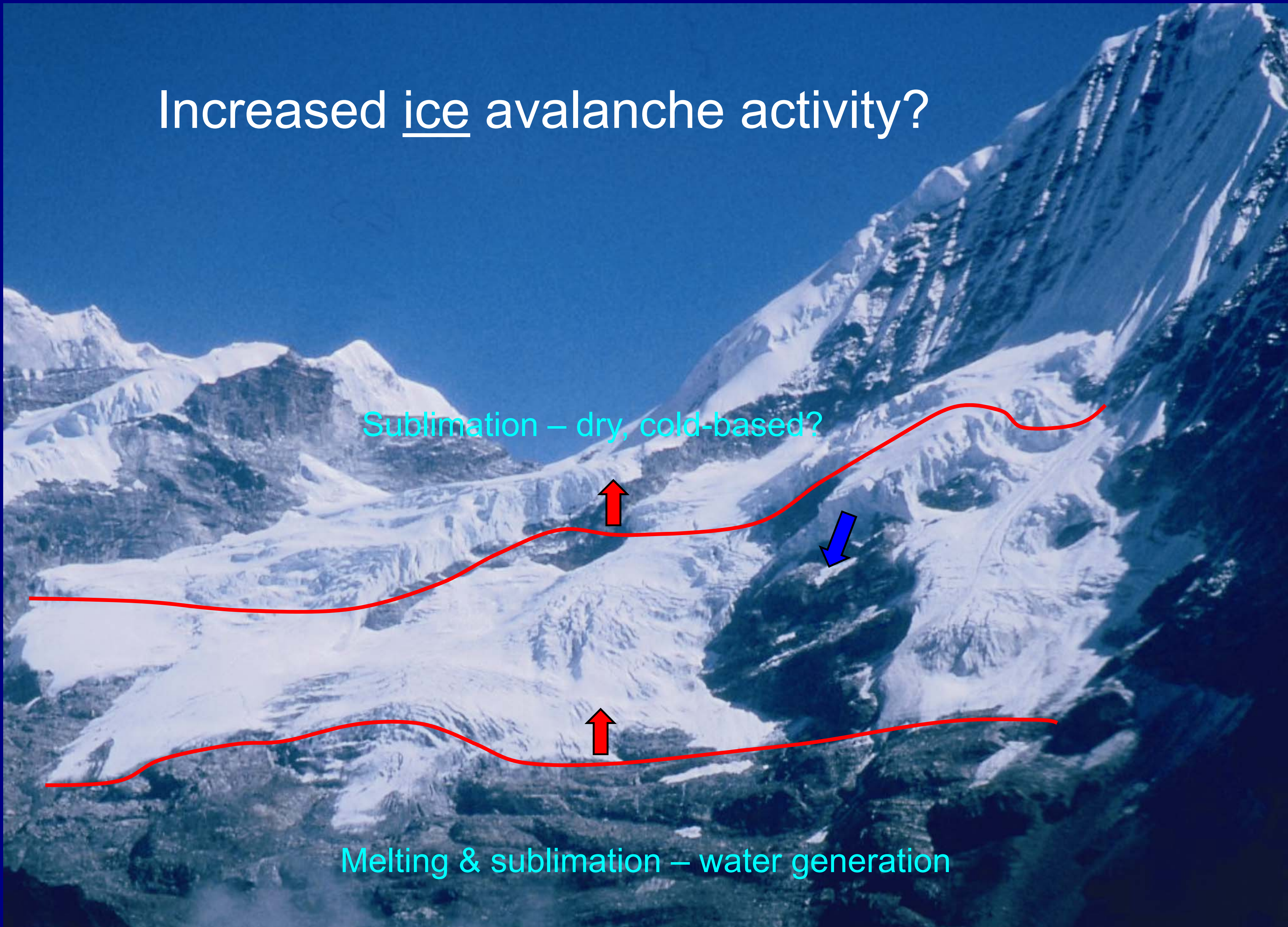
Changing hazards as a consequence of climate change

- Down wasting and receding glaciers
- Changes in melt water run-off – quantities and timing
- Changes in precipitation – quantities and timing
- Thawing permafrost
- Rise in boundary between cold-based and temperate ice regimes
- Increased lake temperatures and more rapid ablation of glacier cliffs that terminate in lakes
- Others??

How do we measure these and with what precision?

What are the gaps in our baseline data?

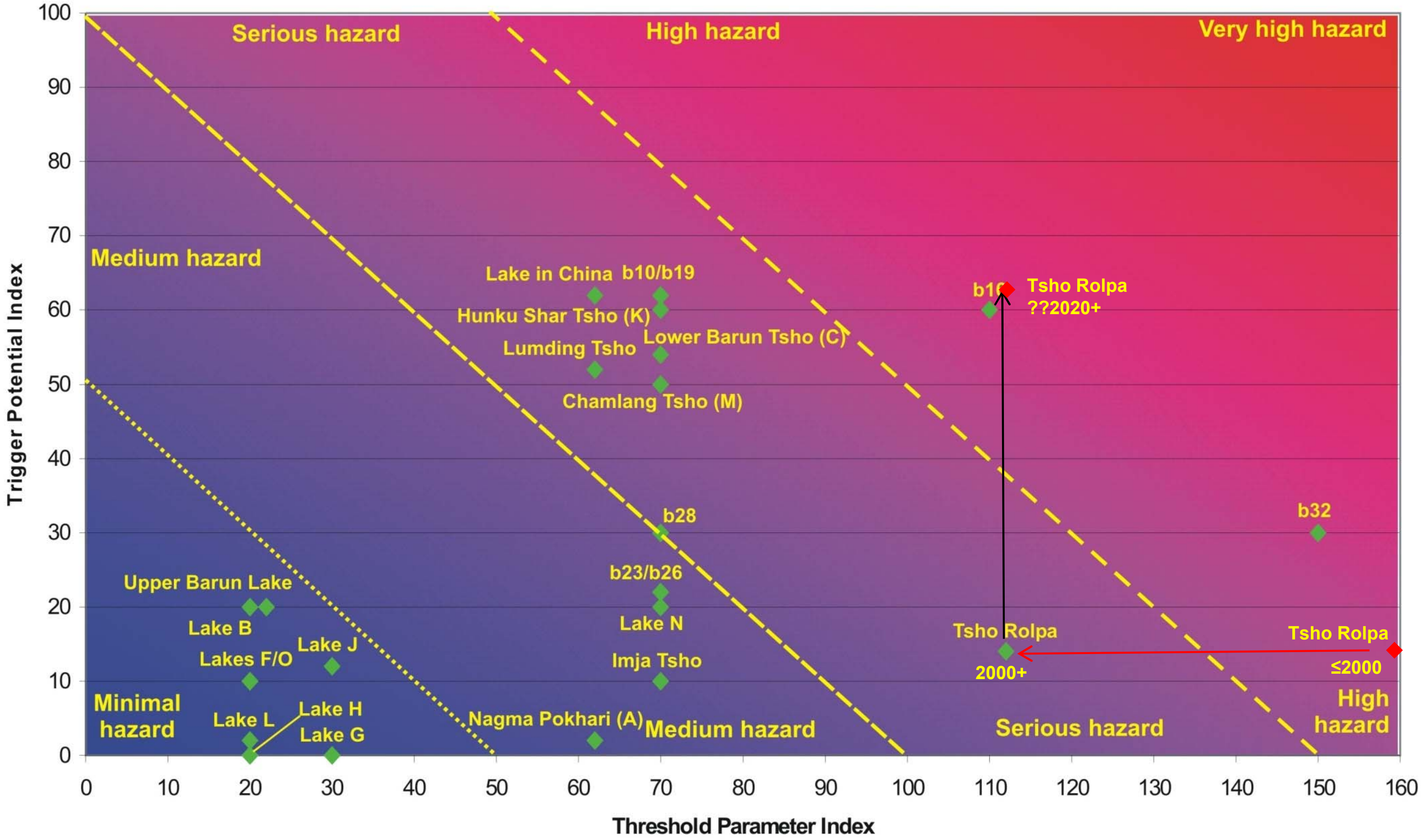

Spillway completed
July 2000


Increased ice avalanche activity?
Sublimation – dry, cold-based?
Melting & sublimation – water generation

Climate-induced change in ice loss from sublimation to sliding?

Change in nature of the local trigger mechanism to impact on the local glacial lake.

Multi-Criteria Analysis for northeast Nepal



Change in degree of hazard with climate change????

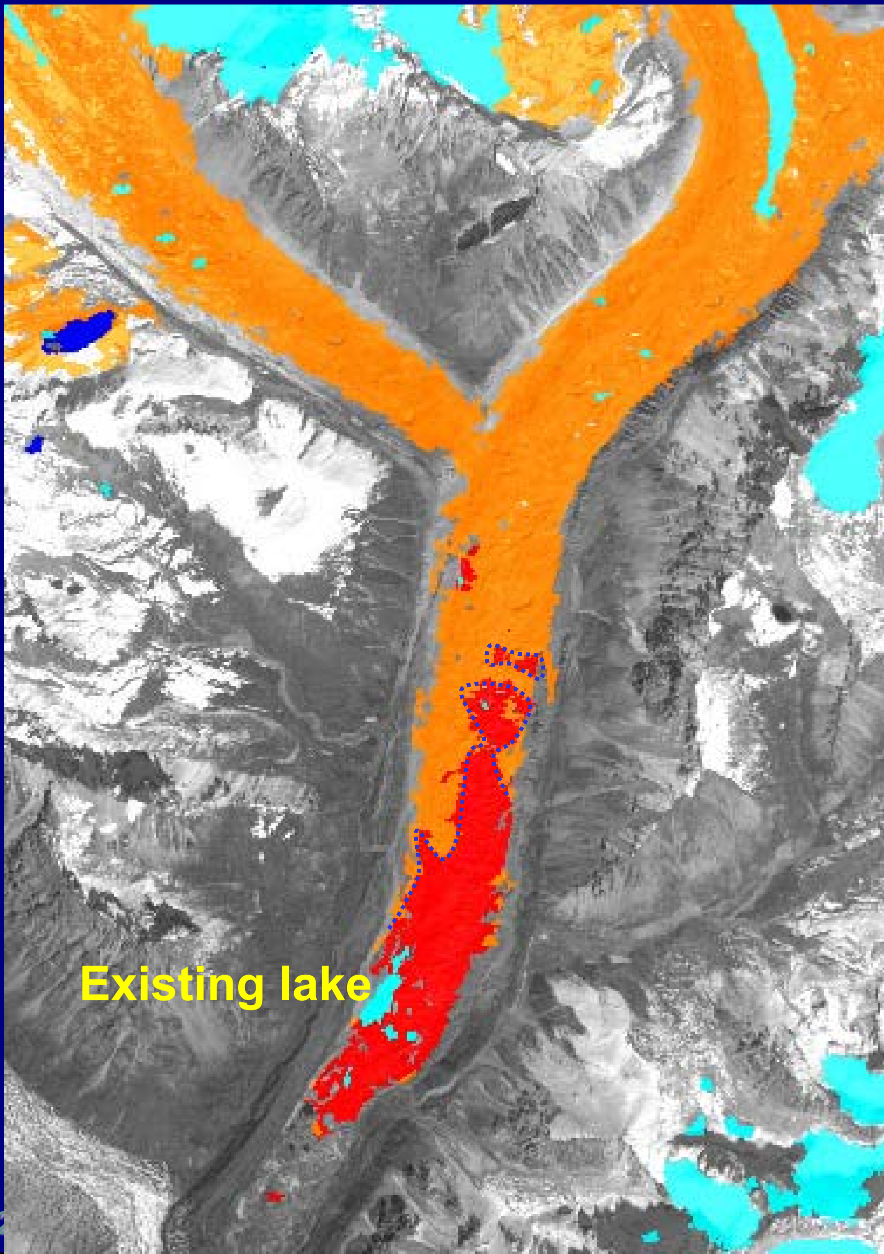
(RGSL, 2007)


Safuna, Cordillera Blanca, Peru
De-buttressing & rock avalanche
Ice avalanches

Potential buoyancy of submerged ice?

Tsho Rolpa, Rolwaling, Nepal

Mapping existing lakes at risk and predicting where lakes might form



Defining areas of potential lake formation following the 2 Rule:

- Red < 2 - *new lake*
- Orange 2-6 - *ponds (transient)*
- Cyan >6 - *no ponds*

Repeat assessment after a gap of several years will reveal changes in actual and potential lake areas and indicate the rates of glacier surface deflation and increases in potential lake areas.

Reynolds (2000)

Image courtesy of D. Quincey

Further questions for breakout groups ...

<u>Consider the following</u>:

- How will your geohazard system alter with climate change/time?
- How will you measure those changes and rates of change?
- What techniques will you use – remote sensing, ground-based, *etc*.?
- What resolution do you need to give you the necessary level of confidence in defining the potentially hazardous process?
- Will any parameters change their relative importance within your system?
- Having defined your geohazard and its degree of seriousness, how will you disseminate this information and to whom?
- What gaps are there in the baseline data to determine any of the above?
- What processes do we not yet understand sufficiently?
- How do we incorporate monitoring and Early Warning Systems?
- Within what management framework should these systems exist and who takes the responsibility for them?
- How do you raise awareness of the geohazard without causing alarm?
- How do these hazard estimates fit into warning evaluation schemes such as those using established Criteria-Development Matrix methods?
- And, ...????


Glacial hazards – her future?
Thank you
for your attention
Reynolds International Ltd, UK