Flash floods in the Himalayas and vulnerability analysis

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International Centre for International Centre for
Integrated Mountain Development
(ICIMOD)

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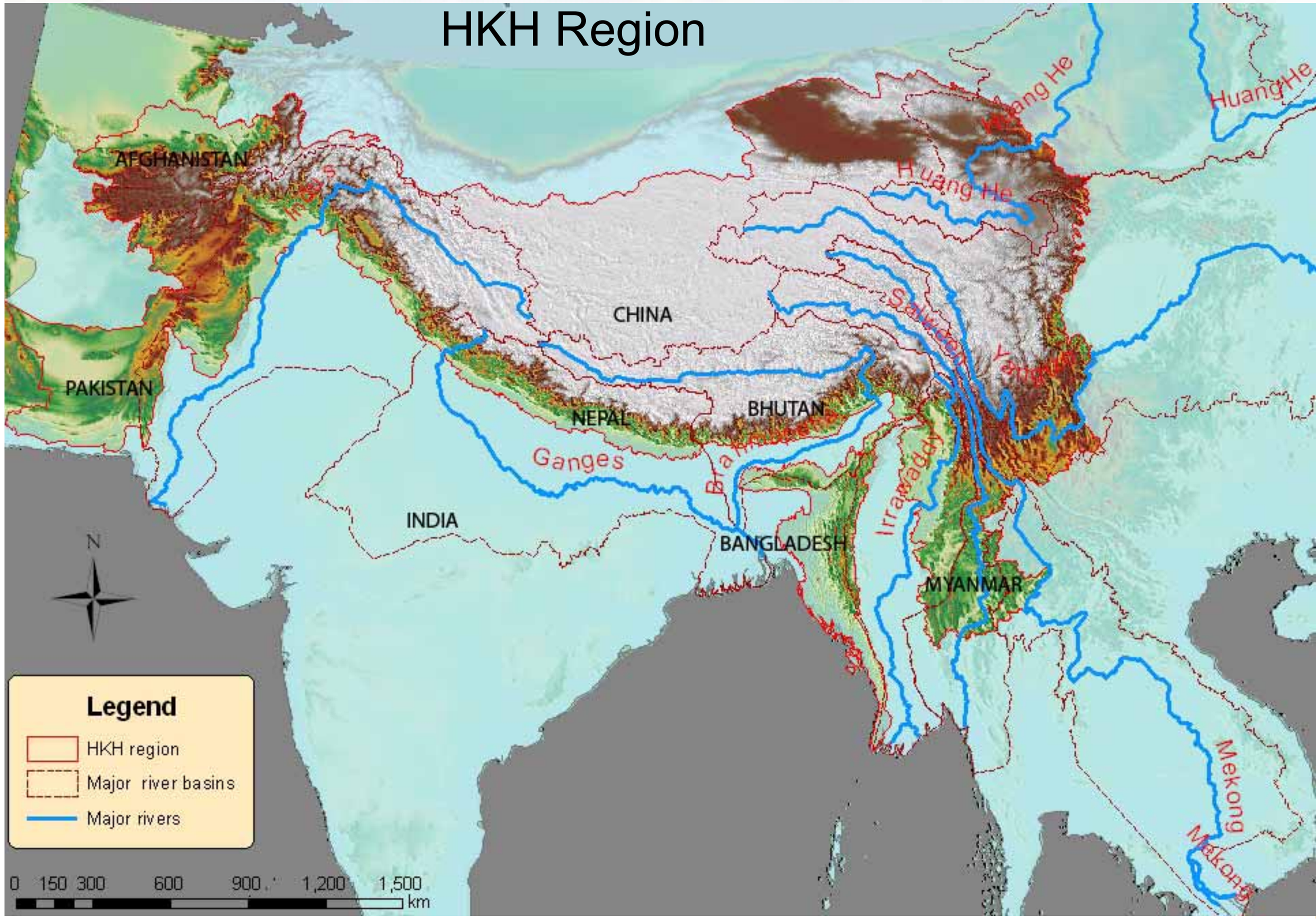
Outline

1. About ICIMOD
2. Flash floods in the Hindu Kush-Himalayan (HKH) region
3. Glacial Lake Outburst Flood (GLOF)
4. GLOF vulnerability analysis
   - Case study
5. Conclusions

1. About ICIMOD

- ICIMOD is an international independent mountain learning and knowledge centre
- committed to improving the sustainable livelihoods of mountain peoples in the extended Himalayan region.
- ICIMOD serves HKH area – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan.
- Founded in 1983, ICIMOD is based in Kathmandu, Nepal,
- **Vision**: Together with its partners and regional member countries, ICIMOD is committed to a shared vision of prosperous and secure mountain communities committed to peace, equity, and environmental sustainability.
- **Mission**: ICIMOD’s mission is to develop and provide integrated and innovative solutions, in cooperation with national, regional, and international partners, which foster action and change for overcoming mountain people’s economic, social, and physical vulnerability.

About ICIMOD



- River basins
  - Indus
  - Ganges
  - Brahmaputra
  - Irrawaddy
  - Salween
  - Mekong
  - Yangtze
  - Yellow

WATER TOWERS OF SOUTH ASIA!

Sustaining over 600 million people in the Region

Integrated Programs

- IP1: Natural Resource Management (NRM)
- IP2: Agricultural and Rural Income Diversification (ARID)
- **IP3: Water, Hazards, and Environmental Management (WHEM)**
  - 1: Water and Floods
  - 2: Climate Change and Responses
  - 3: Environmental Services
- IP4: Culture, Equity, Gender, and Governance (CEGG)
- IP5: Policy and Partnership Development (PPD)
- IP6: Information and Knowledge Management (IKM)
  - **Mountain Natural Resources Information System (MENRIS)**

Comparative Benefit of ICIMOD

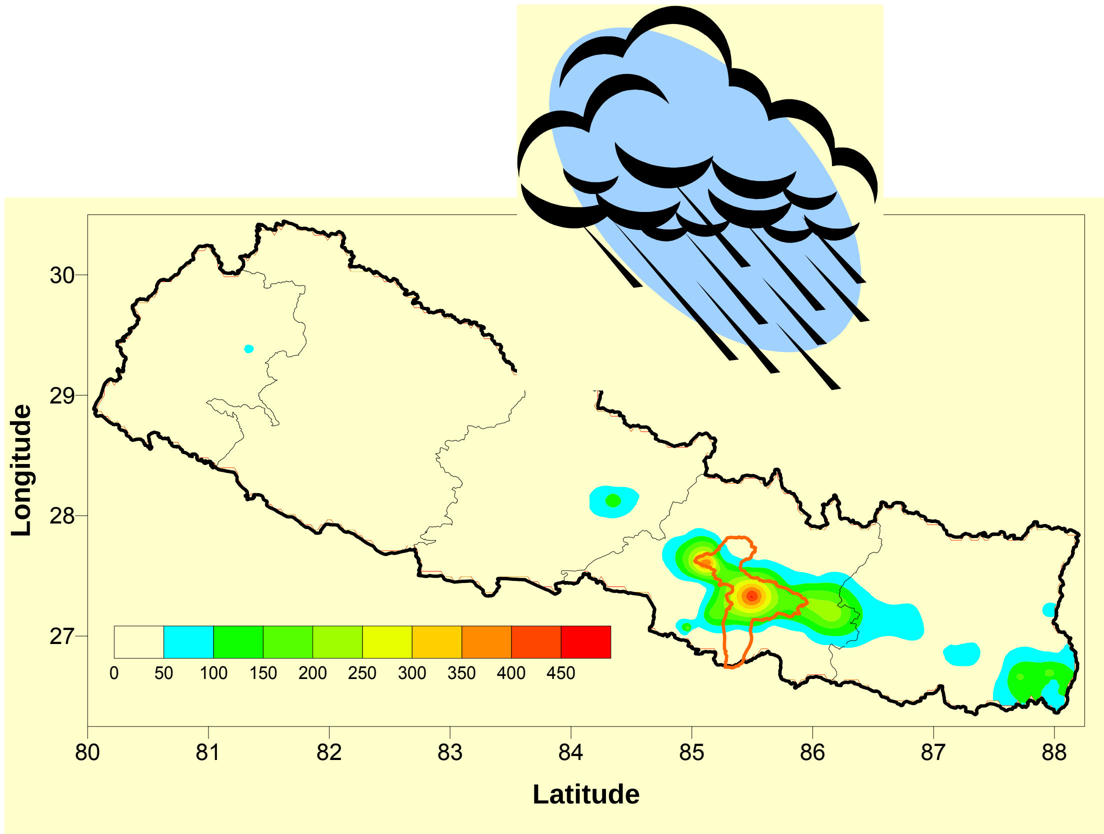
- Regional Organization
- Non-political
- Mountain related
- Transboundary Issues

2. Flash Floods in HKH

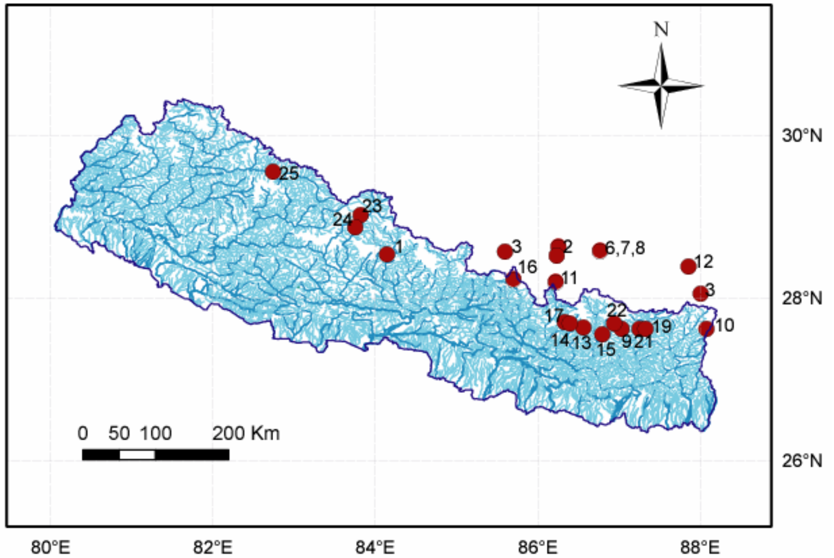
- Flash floods are
  - sudden with little lead time
  - usually violent, present high risk to life and properties
  - small scale
  - short in duration

Different Types of Flash Floods

- Intense Rainfall Flood (IRF)



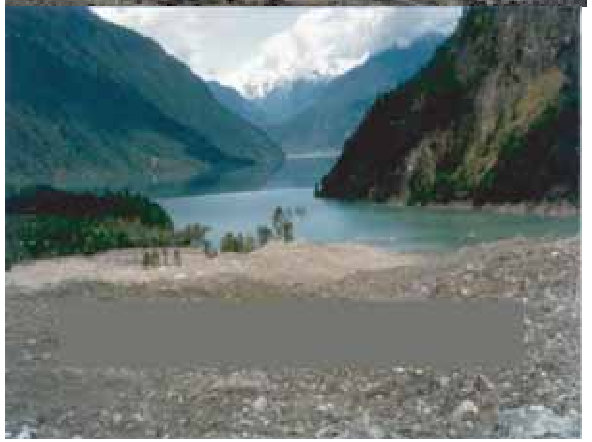
► Glacial Lake Outburst Flood (GLOF)



Landslide Dam Outburst Flood (LDOF)

Yigong landslide dam outburst flood,
Tibet, China

Damming: 9 April 2000
Outburst: 10 June 2000

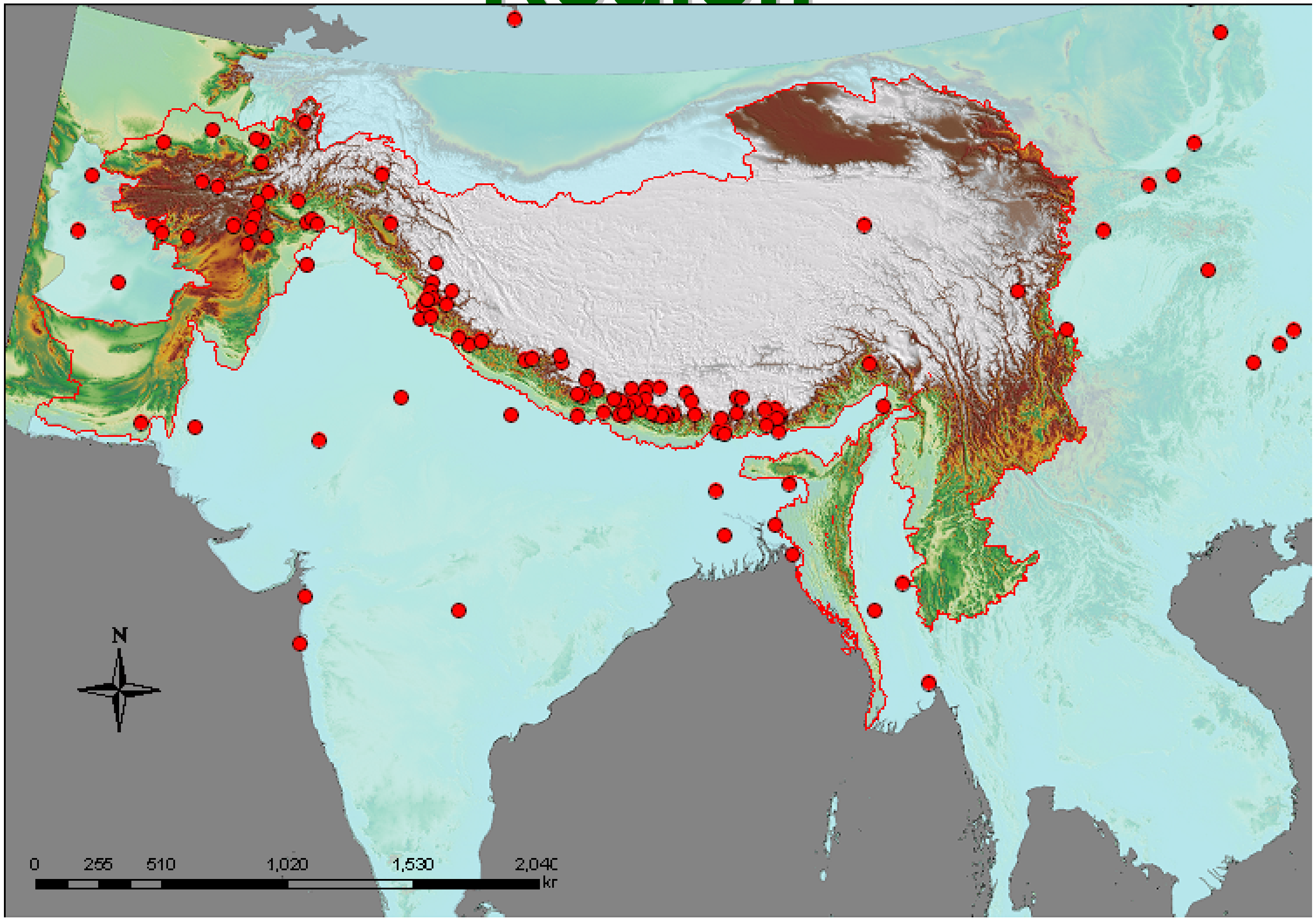


- Rapid Snow/Ice Melt Flood (RSMF)
- Ice Dammed Lake Outburst Flood (IDLOF)

Kande in Shyok
sub-basin

Common in Hindu Kush and Karakorum

Flash Flood Events In HKH Region

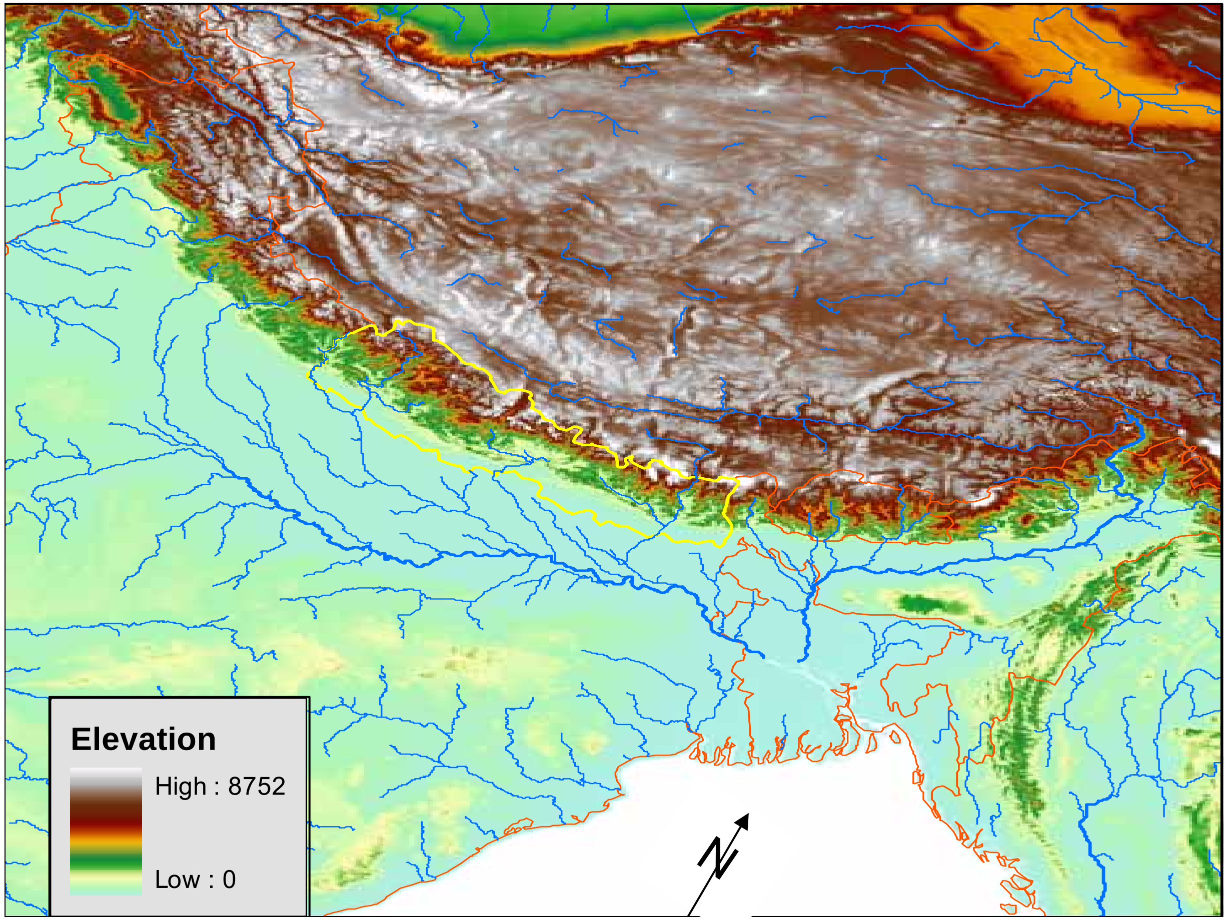


Characteristics of flash Floods

- Rapid rise and fall in water level and discharges (minutes)
- Can occur any time in the year
- Occurs mainly in headwater areas
- Highly unpredictable, difficult to forecast
- Most effective measure is early warning, community preparedness and emergency measures

3. Glacial Lake Outburst Flood

Himalaya the Third Pole



- Water reservoir in frozen state
- Deglaciation is widespread
- Retreating glaciers give birth to glacial lakes
- Glacial lakes might burst out causing GLOFs

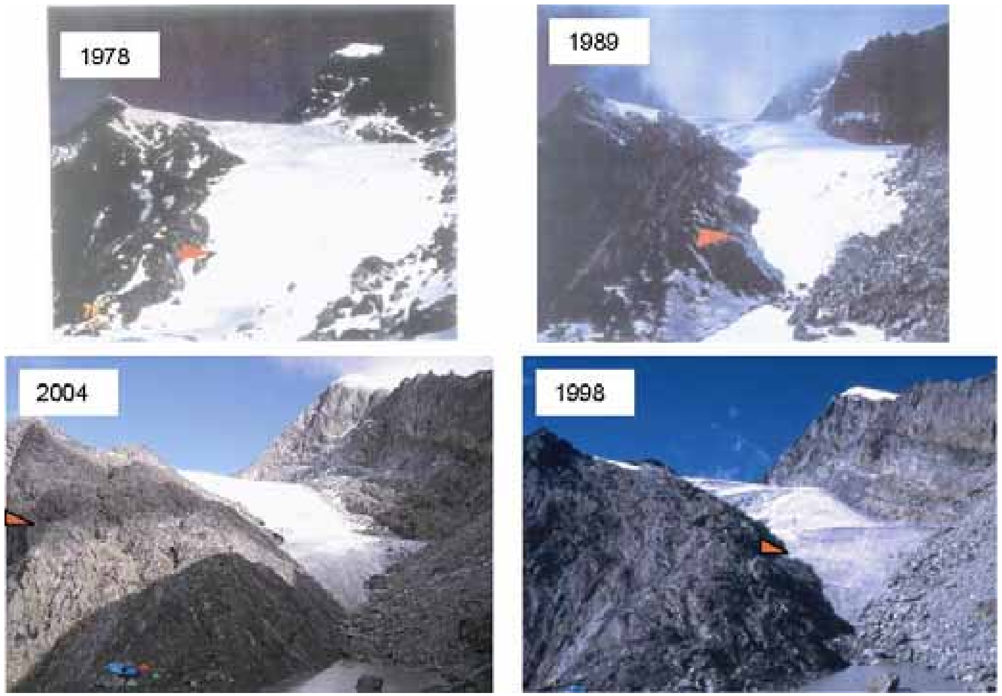
Glacier and glacial lakes in the HKH region

- There are 15,000 glaciers occupying 33,300 km^2
- There are 8863 glacial lakes occupying 796 km^2
- 26 GLOF events have occurred in the past
- There are more than 50 potentially dangerous lakes in the HKH region

Glacier and glacial lakes in Nepal

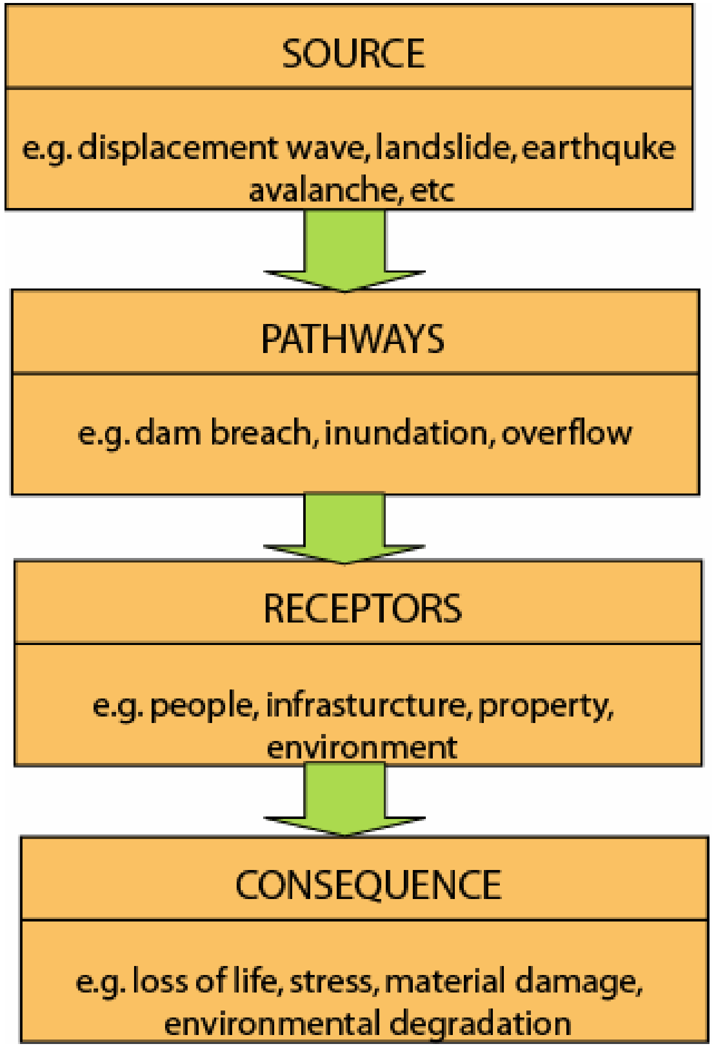
- There are more than 2300 glacial lake in Nepal
- There have been 25 GLOF events in Nepal or affecting Nepal (Shrestha and Shrestha, 2005)
- 20 glacial lakes have been identified as potential dangerous lakes (PDL; ICIMOD/UNEP, 2001)
- A GLOF carries enormous amount of water and debris and can be devastating for the downstream riparian communities

Glacier: AX010



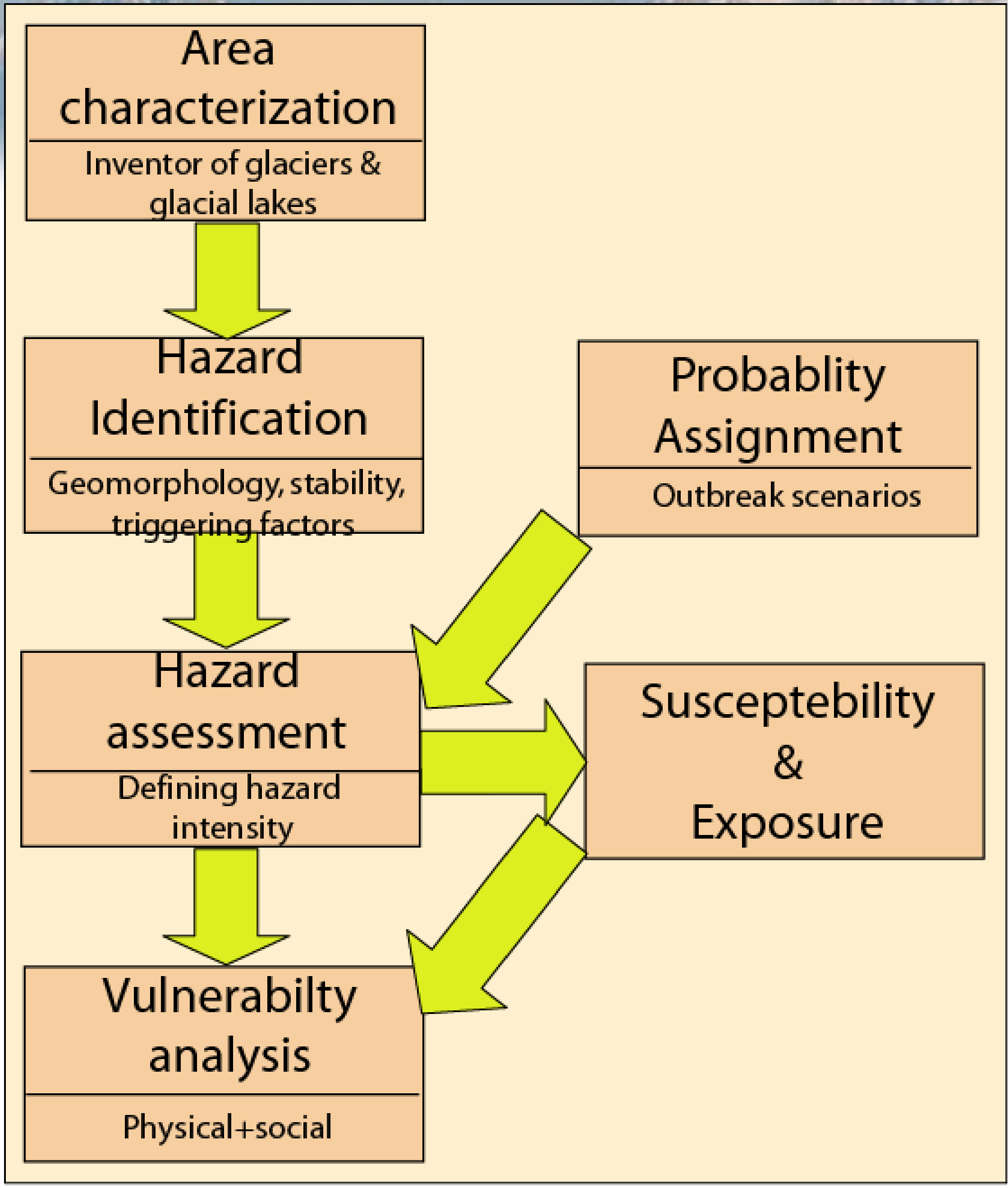
4. GLOF vulnerability analysis

Flood risk



Modified from Goulby and Samuals (2005)

Framework for GLOF Vulnerability Analysis



Colombo et al. (2002)

Area characterization

- Selection of area under question
- Inventory of glaciers and glacial lakes
- Lake development trend
- Lake volume
- Surrounding environment

Hazard Identification

- Collecting information about the physical process
  - Hydrology
  - Ice calving
  - Buried ice in the moraine dam
- Dam properties
  - Stability
  - Karst areas
  - piping
- Triggering mechanism
  - Ice avalanche
  - landslide

Hazard Assessment

- Dam bre
  - Dam
- Downstr
  - Flood
- Flood m

Vulnerability Analysis

- **Susceptibility and exposure**
- **Physical vulnerability**
  - Lithology
  - Channel slope
  - River meandering
  - Land use
- **Social Vulnerability**
  - Accessibility
  - Health
  - Communication
  - Emergency response system
  - Economic diversity
  - Awareness, attitude …
- **Total Vulnerability**

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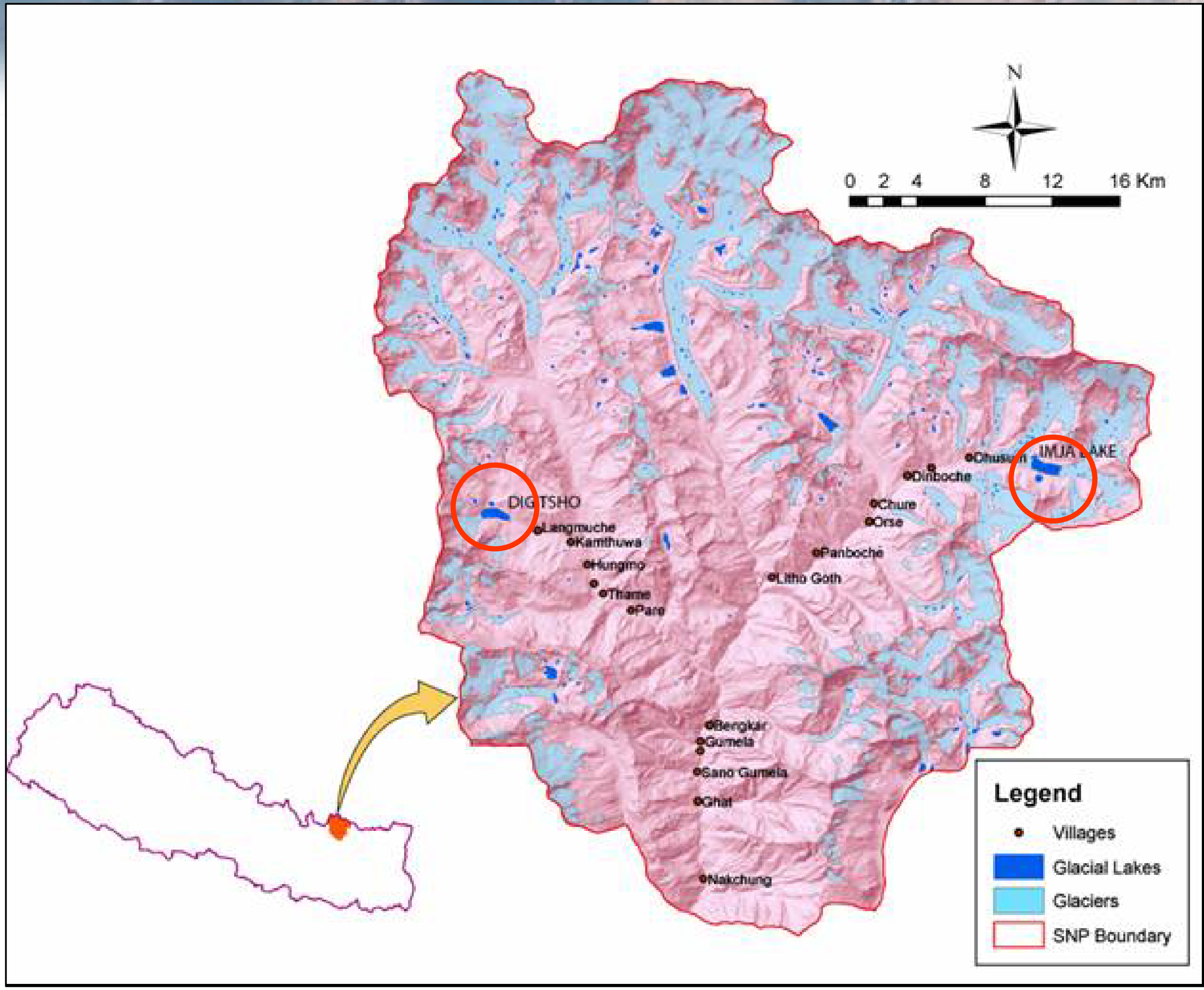
Case Study
Imja GLOF

Study Area

Sagarmatha National park (SNP) and its Buffer Zone



The Imja Glacial Lake

Imja Lake Development

15 December 1962 (Corona image)
Area – 27,916 sqm.

15 October 1975 (Landsat MSS)
Area – 309,573 sqm.

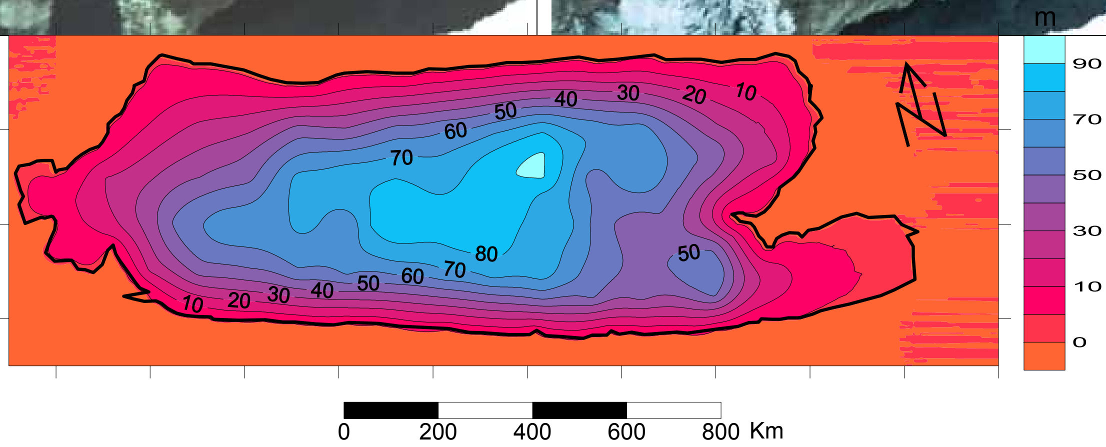
22 September 1992 (Landsat5 TM)
Area – 635,945 sqm.

02 December 1983 (Space Shuttle)
Area – 568,824 sqm.

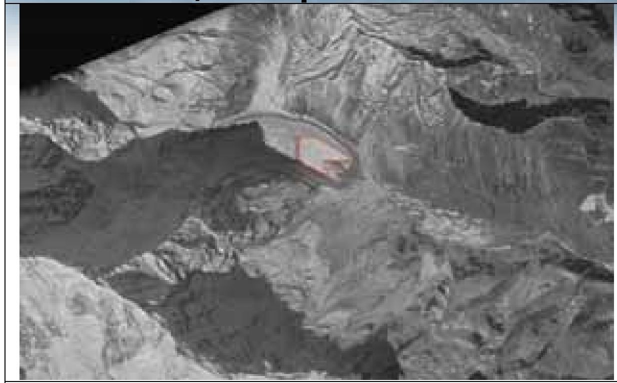
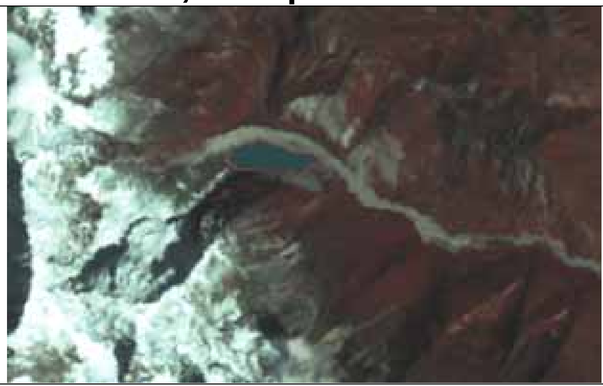
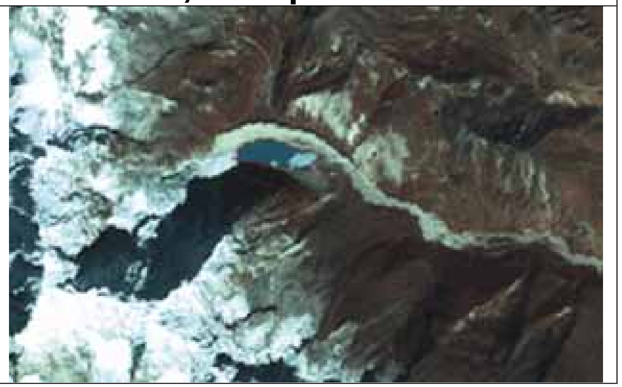
11 December 1989 (Landsat5 TM)
Area – 633,214 sqm

30 October 2000 (Landsat7 ETM+)
Area – 775,065 sqm.

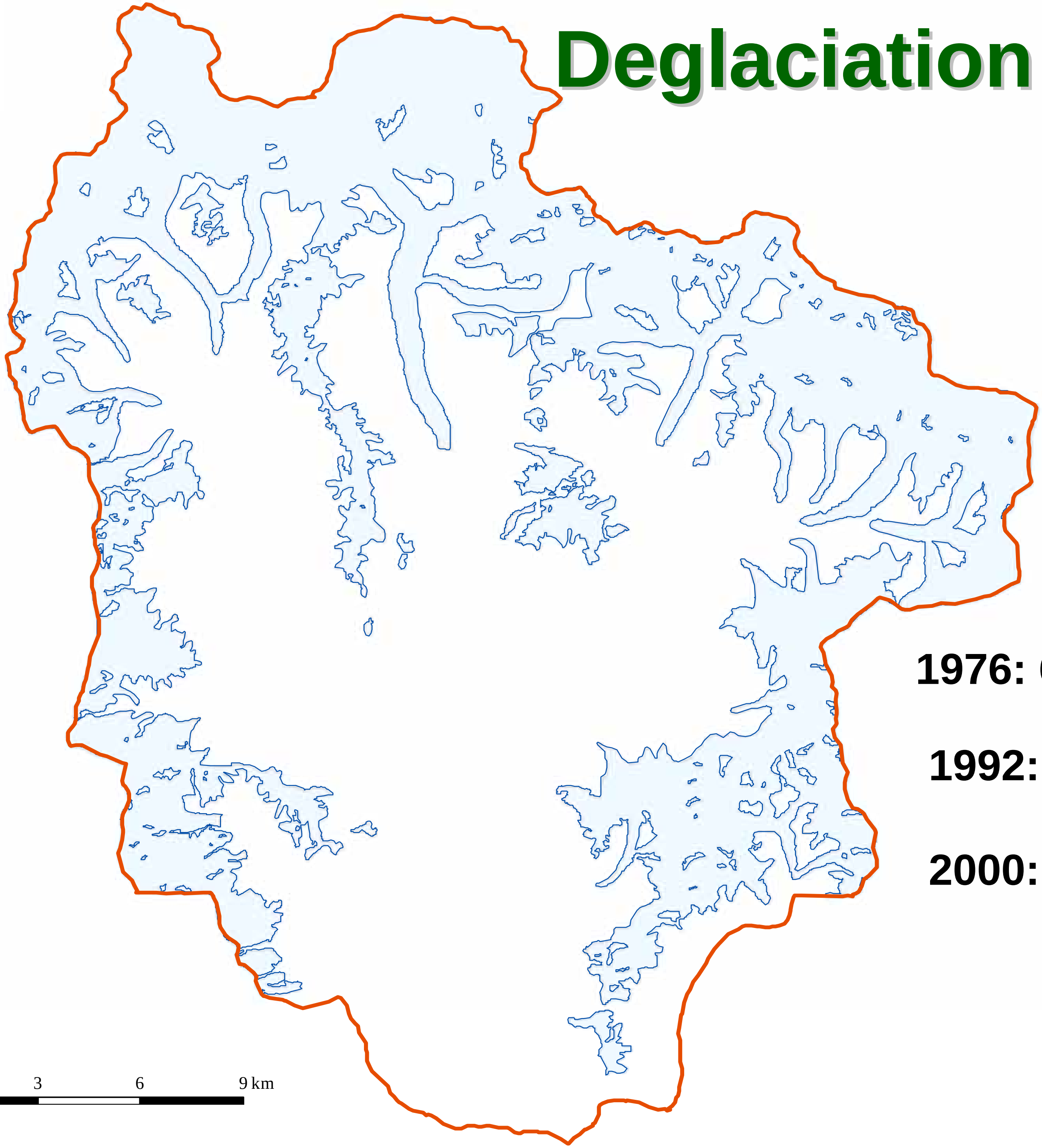
According to GEN/DHM ground survey of 2001 the surface area is 0.86 sq km



Dig Tsho Lake Development

15 December 1962 (Corona image) **Area – 201,172 sqm.**	**15 October 1975 (Landsat MSS)** **Area – 334,861 sqm.**	**11 December 1989 (Landsat5 TM)** **Area – 315,865 sqm**
		
02 December 1983 (Space Shuttle) **Area – 597,923 sqm.**	**22 September 1992 (Landsat5 TM)** **Area – 376,575 sqm.**	**30 October 2000 (Landsat7 ETM+)** **Area – 361,867 sqm.**
		

Deglaciation in SNP



1976: 612.94 km^2

1992: 606.69 km^2

2000: 583.29 km^2

Methodology

- Geometric and topographic information
  - Topographic info from DEM (Dept. of Survey)
  - Geometric info extracted using HEC GeoRAS
  - Stream centreline and banks digitized using IKONUS images
- Lake information
  - Bathymetric survey of 2001
  - Moraine topography: survey of 1994 and 2001
  - Dig Tsho- data from literature (area and max depth)

Methodology (contd.)

- Breach Simulation
  - NWS BREACH
  - Geometric data from 1994 & 2001 survey (Imja) and DEM (Dig Tsho)
  - Geotechnical info from literature (mainly Tsho Rolpa case study)

Parameters/Input Data	Values for GLOF Simulation		Unit
	Dig Tsho	Imja	
Lake surface area	0.4	0.86	km^2
Lake maximum depth	42.9	90	m
Dam top elevation	4395	5030	m a.s.l.
Dam bottom elevation	4360	4960	m a.s.l.
Dam inside slope	1:0.47	1:8	
Dam outside slope	1:1.7	1:6	
Dam width	210	600	m
Dam length	600	650	m
d50	1	1	mm
d90	300	300	mm
d30	0.1	0.1	mm
d90/30	3000	3000	
Unit Weight	2000	2000	$kg\ m^{-2}$
Porosity	0.4	0.4	
Manning's n of outer core of the dam	0.15	0.15	
Internal Friction Angle (ø)	34	34	
Cohesiveness	0	0	

Methodology (contd.)

- Flood Routing
  - NWS FLOODWAVE
  - NWS BREACH output hydrograph - upper boundary condition
  - Routing up to SNP buffer zone border (Dig Tsho ~35 km; Imja ~45 km)
- Flood Map
  - NWS FLOODWAVE result → HEC GeoRAS
  - Inundation area and depth of inundation
- GLOF Vulnerability Assessment
  - Method of RGSL (2003)
  - Input: topography (slope), geology and geomorphology (compactness), hydrology (river meandering) and land use

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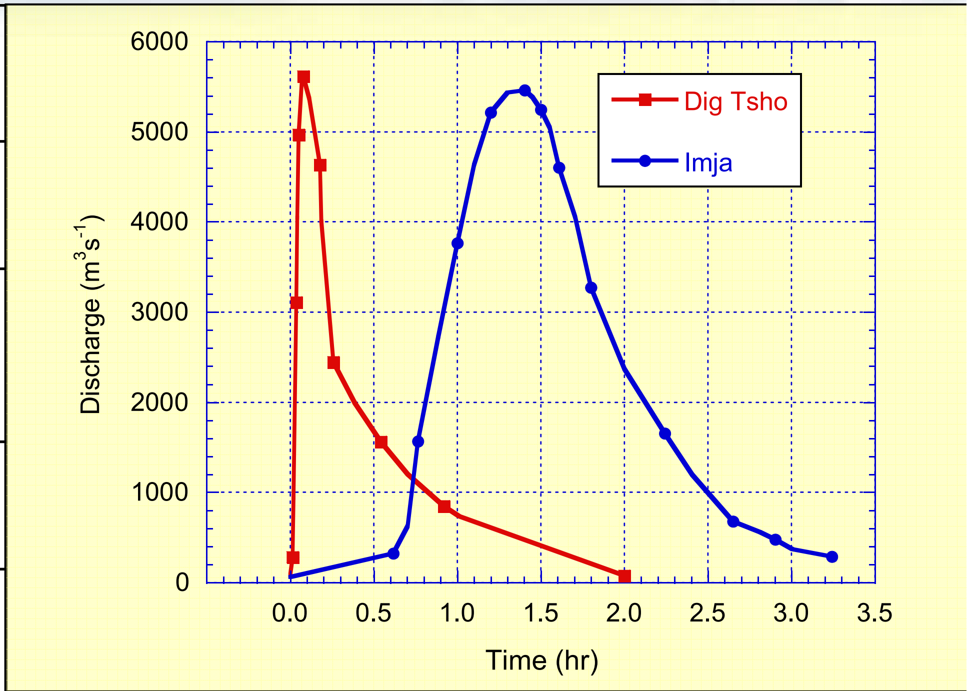
Results

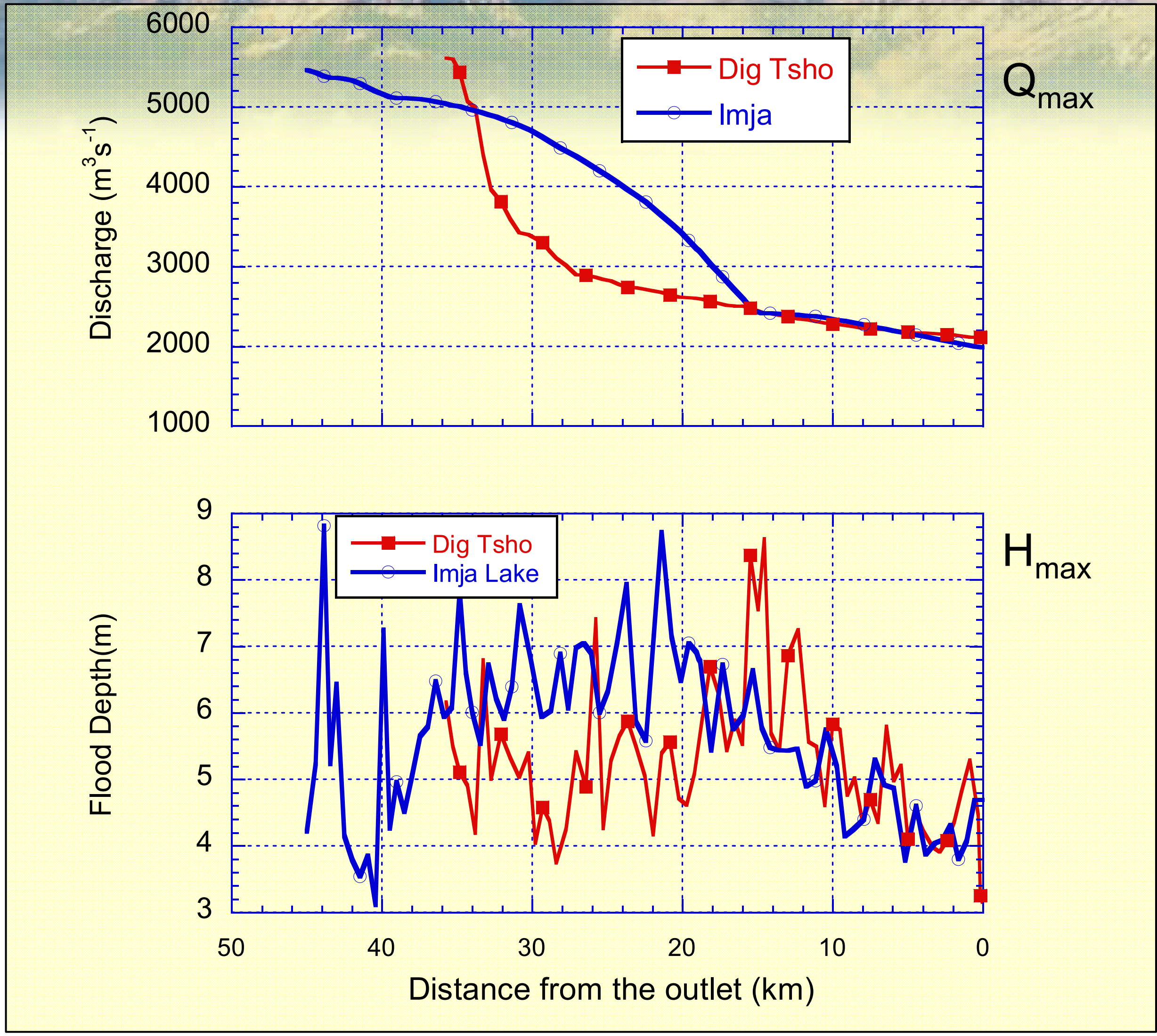
Main output of NWS BREACH

Breach Output	Unit	Dig Tsho	Imja
Maximum Outflow (Q_{max})	m^3s^{-1}	5613	5463
Duration of the Outflow (T_{out})	hr	2.0	3.2
Initial Water Level	m a.s.l.	4395.0	5030.6
Final Water Level	m a.s.l.	4373.6	4982.3
Final Depth of the Breach	m	35.0	65.2
Final Width of the Top of the Breach	m	231.0	300.5



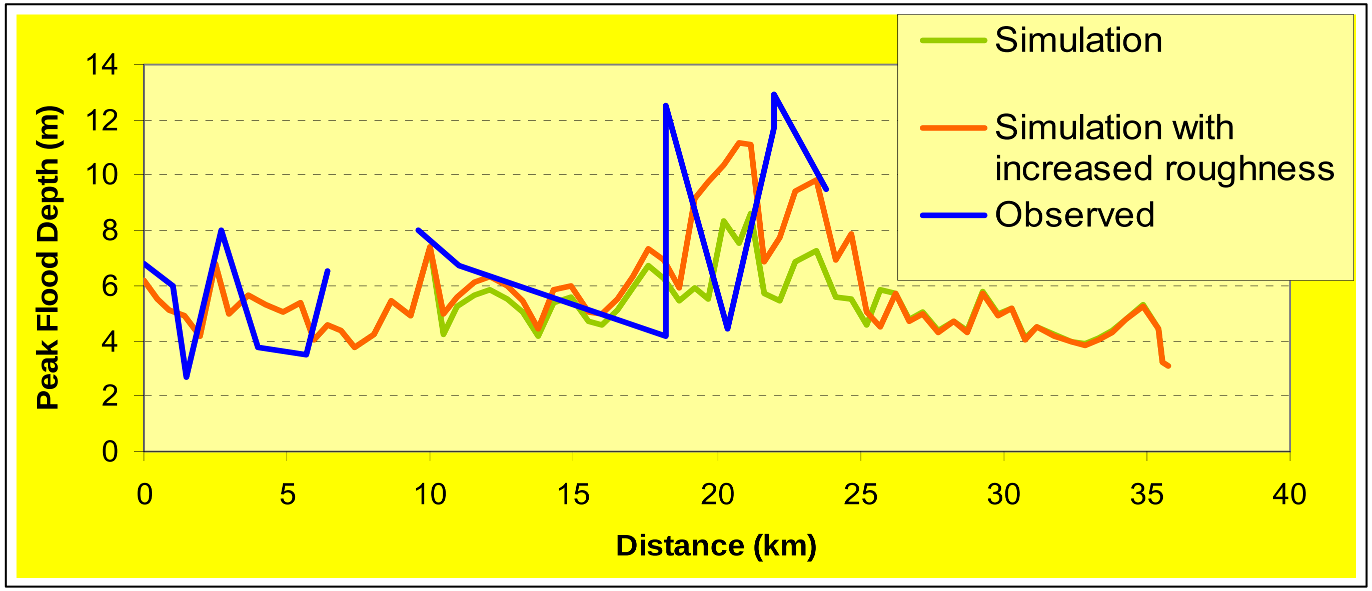
Shrestha et al., 2006

Results (contd.)

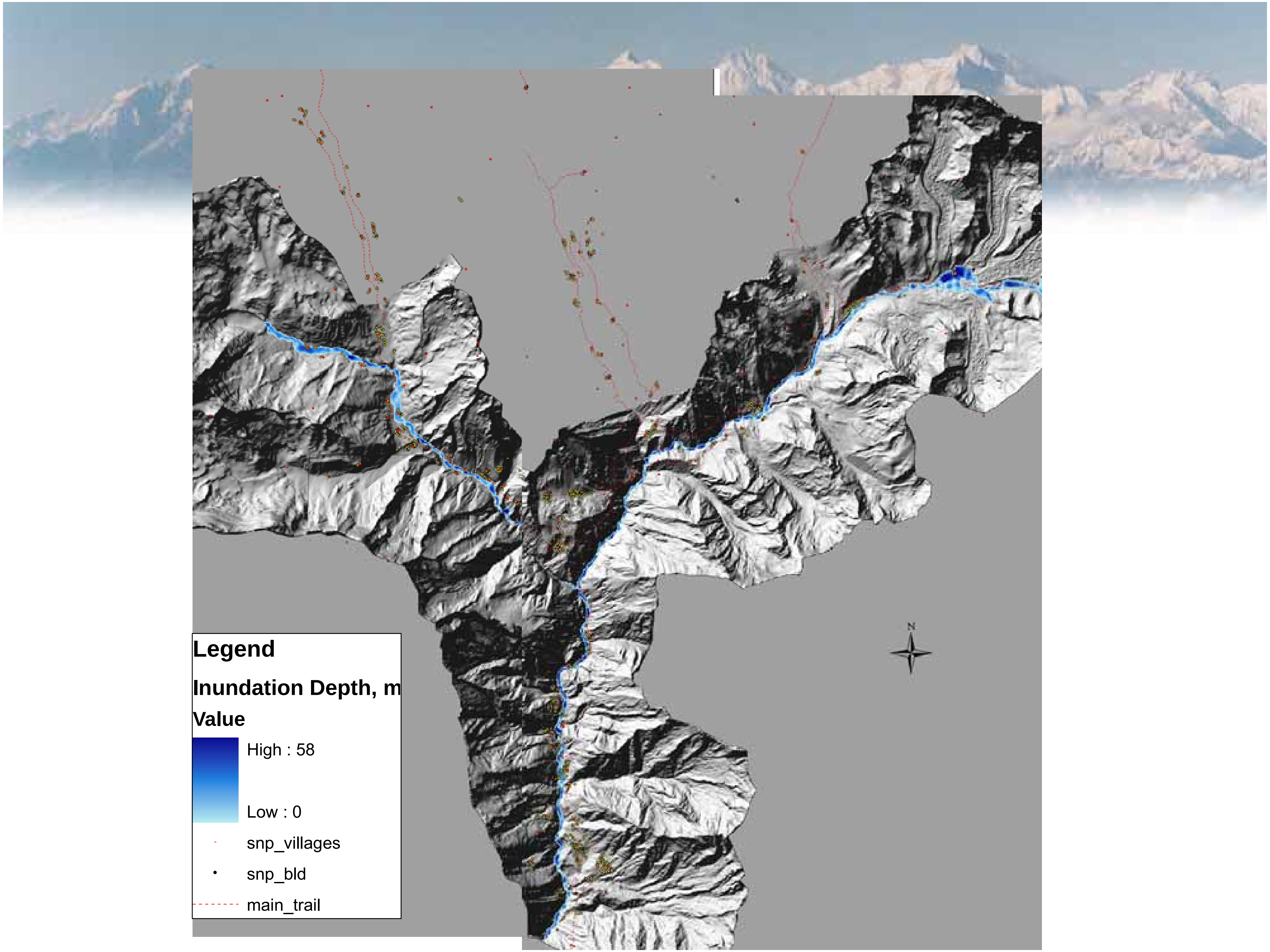


Shrestha et al., 2006

Results (contd.)
Comparison with measured flood depth



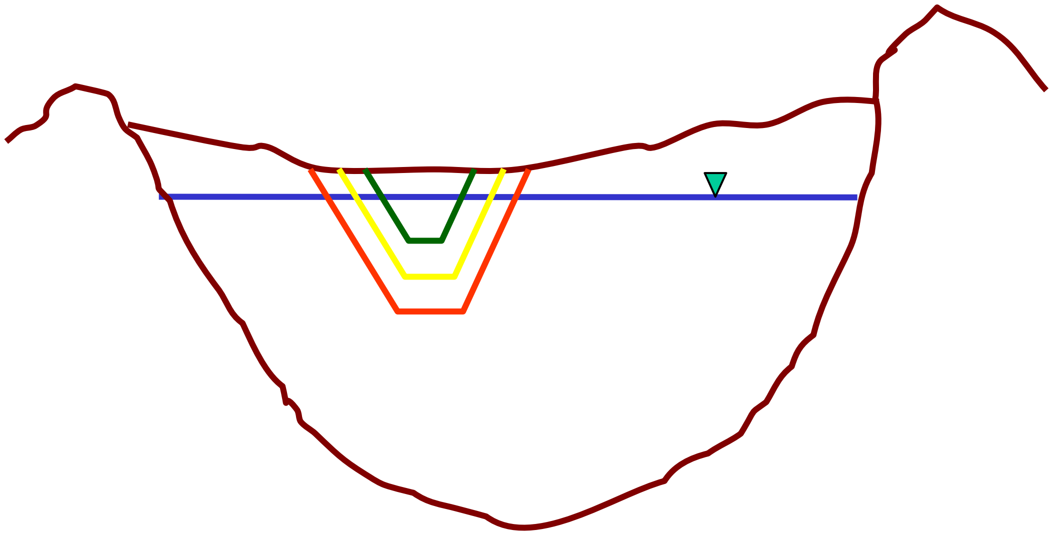
Shrestha et al., 2006

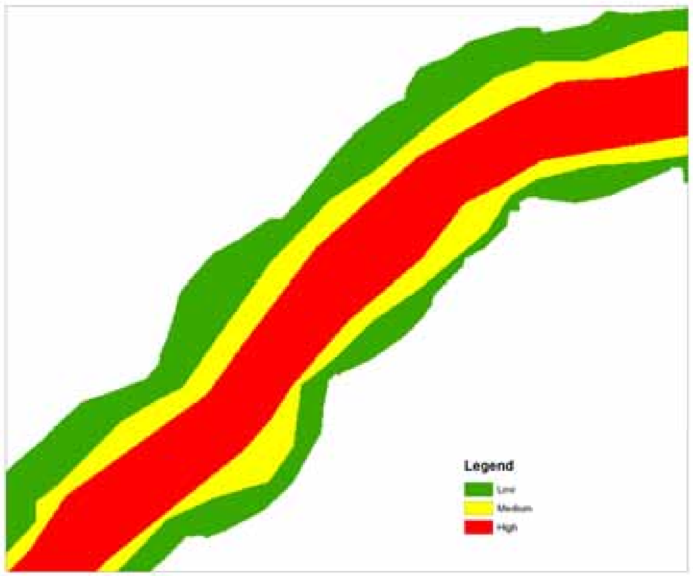

Legend
Inundation Depth, m
Value
High : 58
Low : 0
snp_villages
snp_bld
main_trail
N

Results (contd.)

Imja lake			
Place	Time (min)	Elevation (m a.s.l.)	Maximum Flood Depth (m)
Imja lake outlet	0.0	5458	
Dhumsum	6.0	5419	3.92
Syalja goth	7.2	5409	5.06
Dinboche	8.4	5401	5.81
Chure	10.8	5387	8.12
Orse	12.0	5382	5.77
Panboche	14.4	5374	6.76
Litho goth	18.0	5356	7.79
Confluence	22.8	5329	8.68
Bengkar	25.2	5316	9.29
Gumela	26.4	5315	8.47
Thulo Gumela	27.6	5310	7.76
Sano Gumela	28.8	5304	8.01
Ghat	30.0	5297	8.13
Nakchung	33.6	5275	5.71

Dambreak flood scenarios



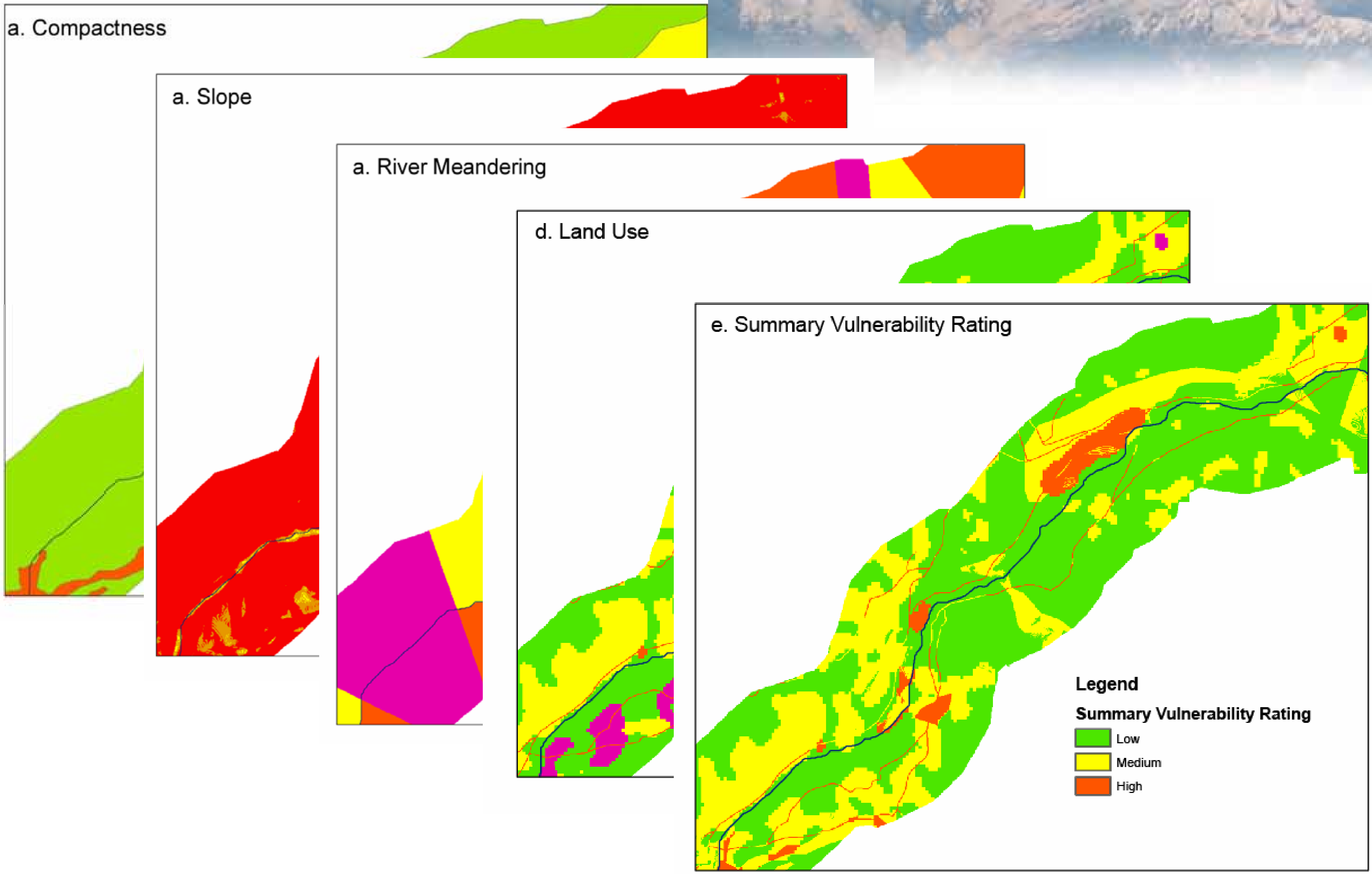


Methodology (contd.)
GLOF vulnerability rating scheme

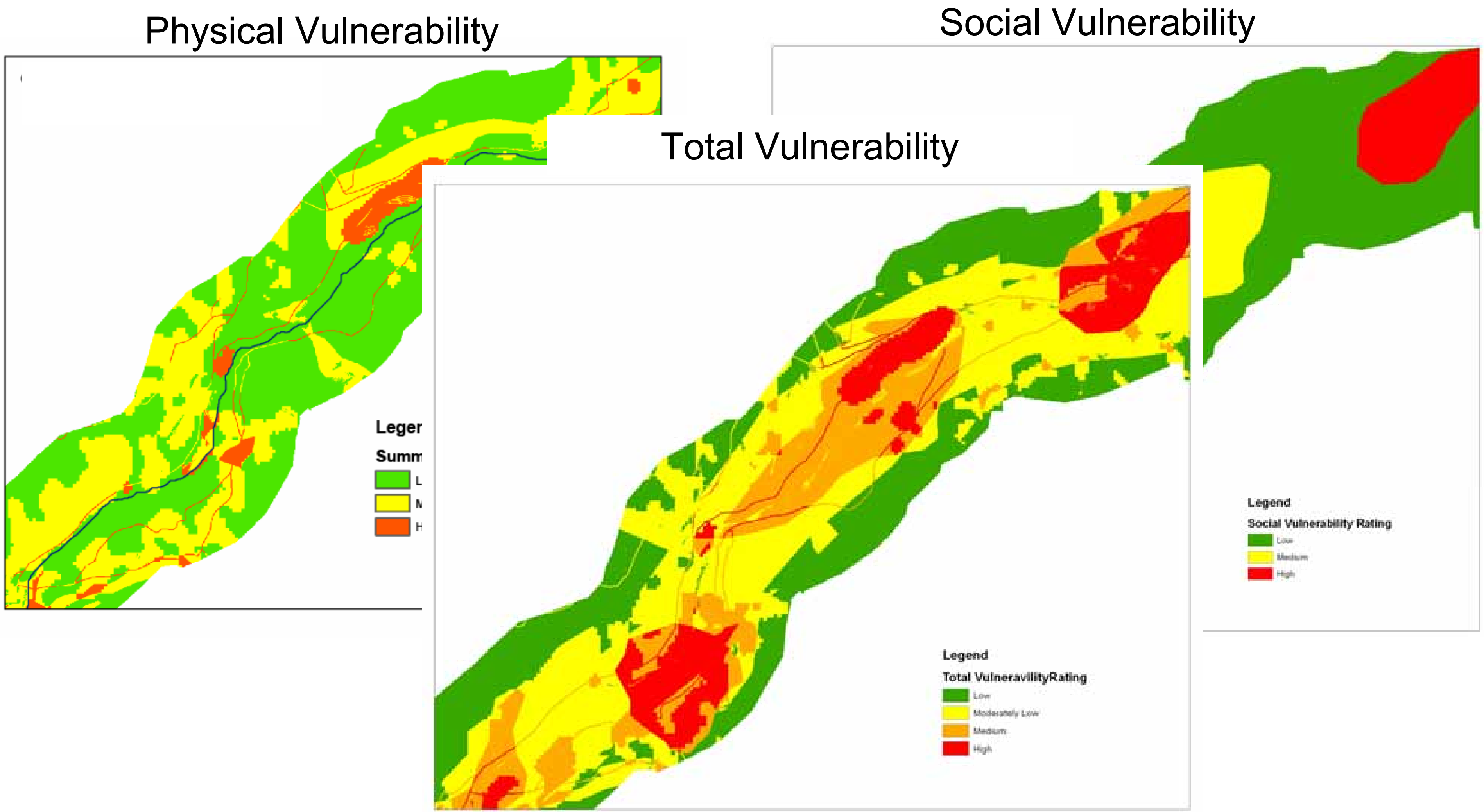
Vulnerability Rating Maps	Scoring Criteria	Vulnerability Index Score	Weighting
Map 1: Compactness	Glacial Deposit	1	2
	Cohesive Sediment	2	
	Loose Sediment	3	
Map 2: Slope map	0-2°	1	1
	2-11°	2	
	>11°	3	
Map 3: River Meandering	Inside bend of a meander	1	1
	Straight	2	
	Outside bend of a meander	3	
Map 4: Land Use	Scrub/forest, no human activities	0	3
	Pasture	1	
	Agriculture, commercial forestry	2	
	Infrastructure	2.5	
	Settlement	3	

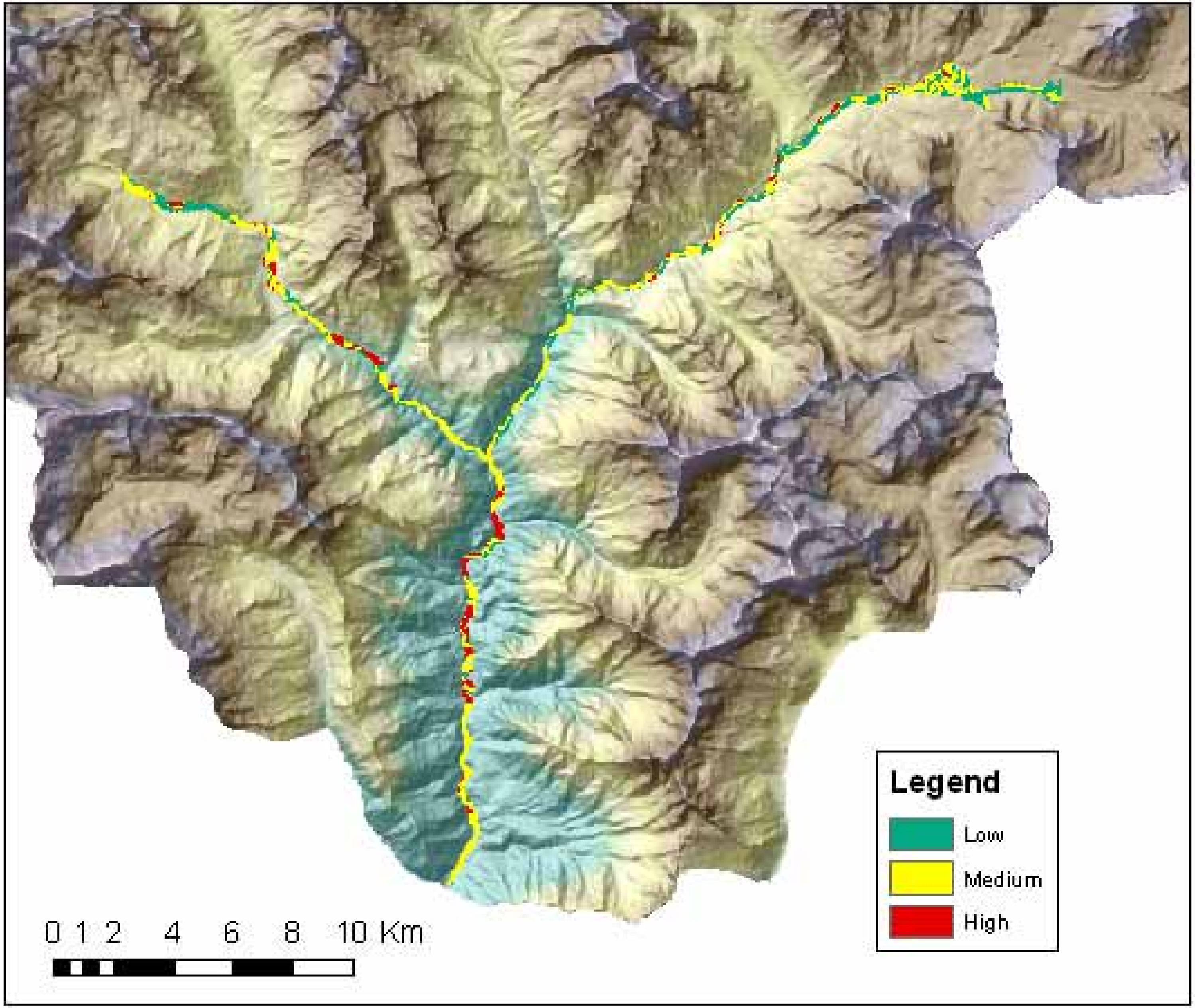
RGSL (2003)

Vulnerability Analysis



Total vulnerability




Legend
Low
Medium
High
0 1 2 4 6 8 10 Km

Conclusion

- HKH region is highly prone to flash floods
- Capacity to manage the risk of flash flood is low
- ICIMOD is supporting capacity building
- FHM is important as a DS tool
- Attempt to use GIS and hydrodynamic modeling to simulate GLOF impact in Himalayan catchment
- GLOF vulnerability analysis
  - Physical + Social vulnerability
  - Community involvement
- Results- input for early warning system (EWS)
- Several limitation: data, appropriate tool, ownership, etc
- But most important thing is how the information is transferred to the communities

Thank you