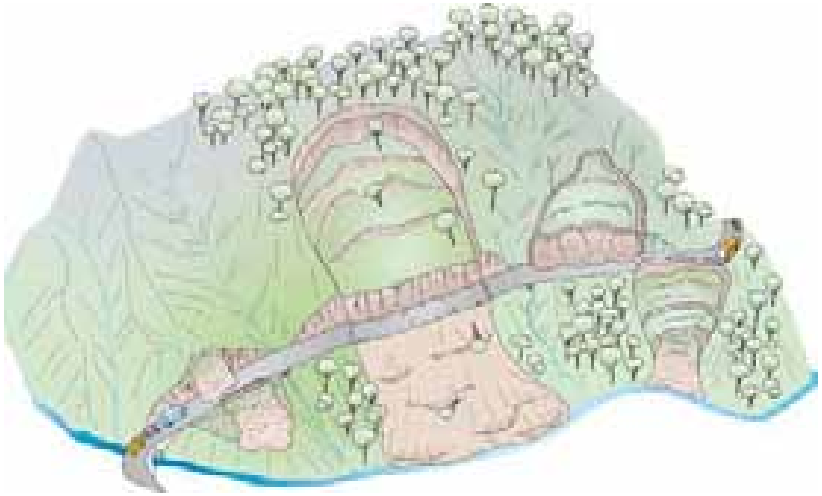
Fostering Resilience to Remote Geo-hazards

Landslide hazard and risk assessment for rural infrastructure development

Contents of Presentation



Typical landslide and debris flow hazards and their impacts in remote mountain regions

Illustrations of hazard and risk assessment from Tajikistan, Kyrgyzstan and Nepal

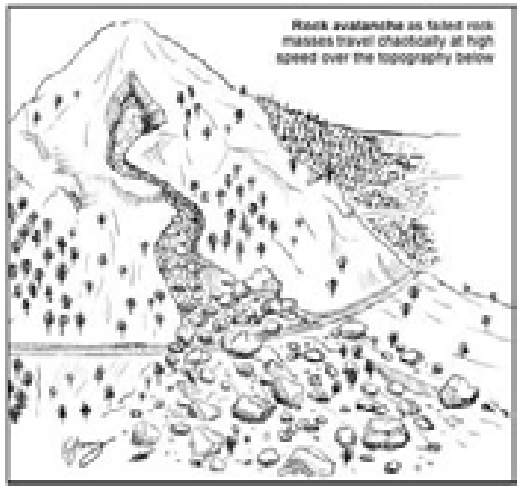
Review of mitigation options

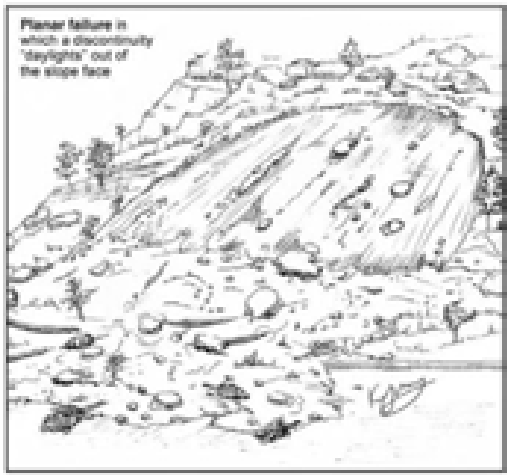
Dr Gareth Hearn

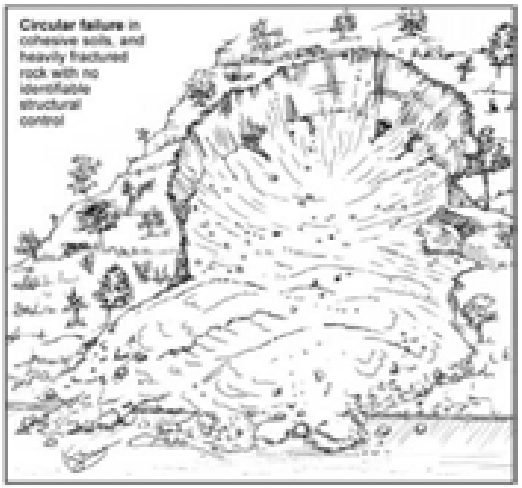
Scott Wilson Ltd, UK

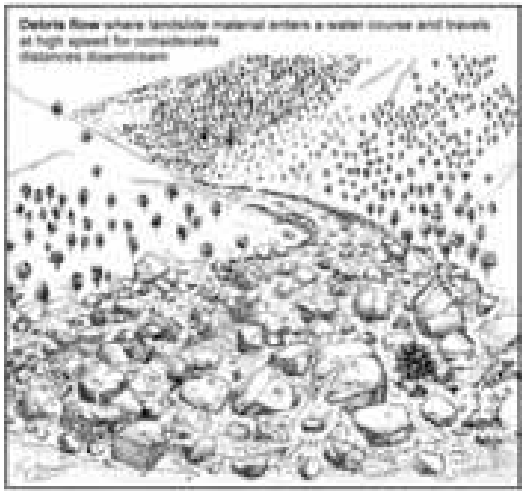
Typical landslide hazards impacting mountain infrastructure and communities

- Deep-seated landslides, either planar, rotational, wedge or complex
- Rock falls
- Rock avalanches
- Debris flows

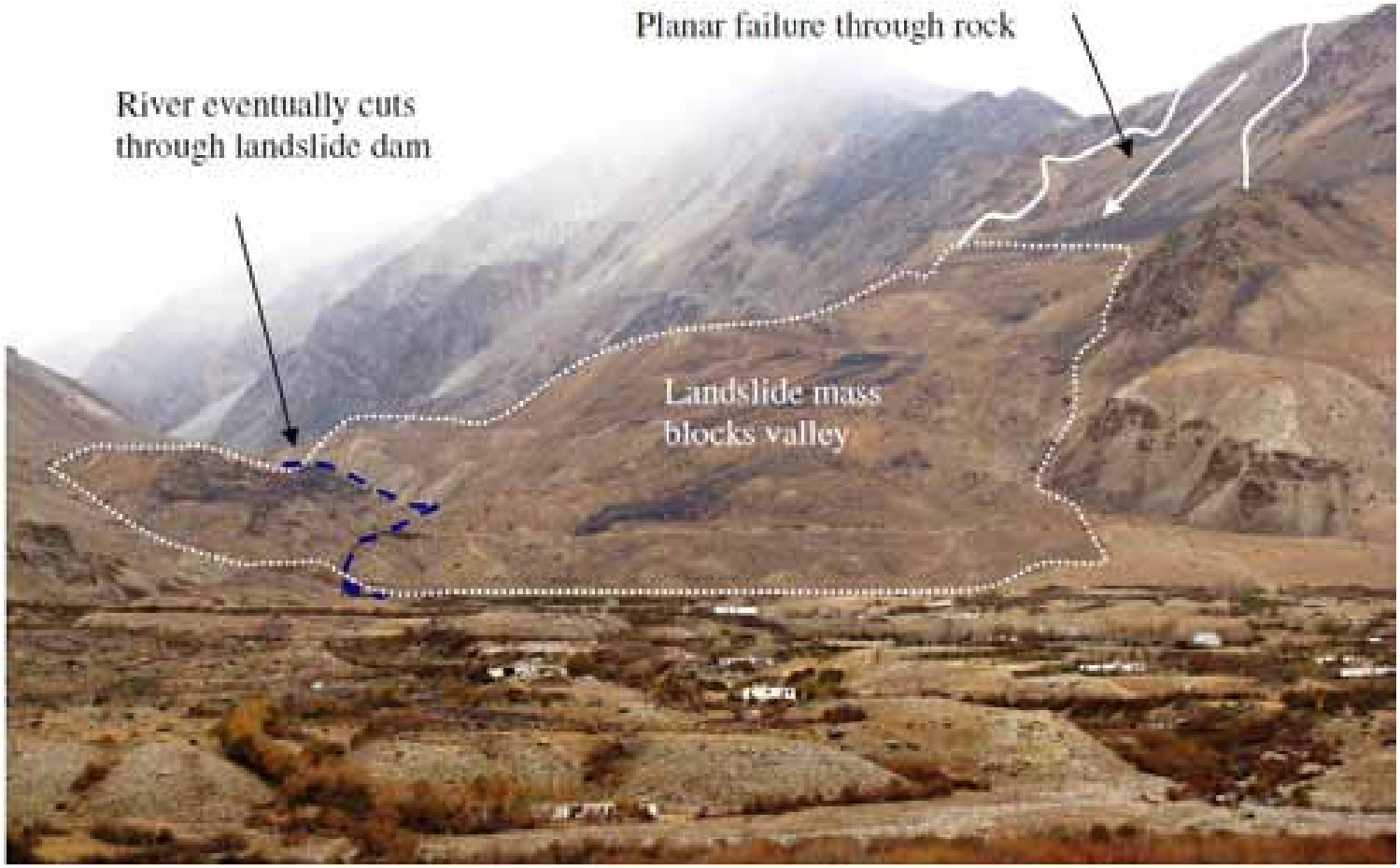




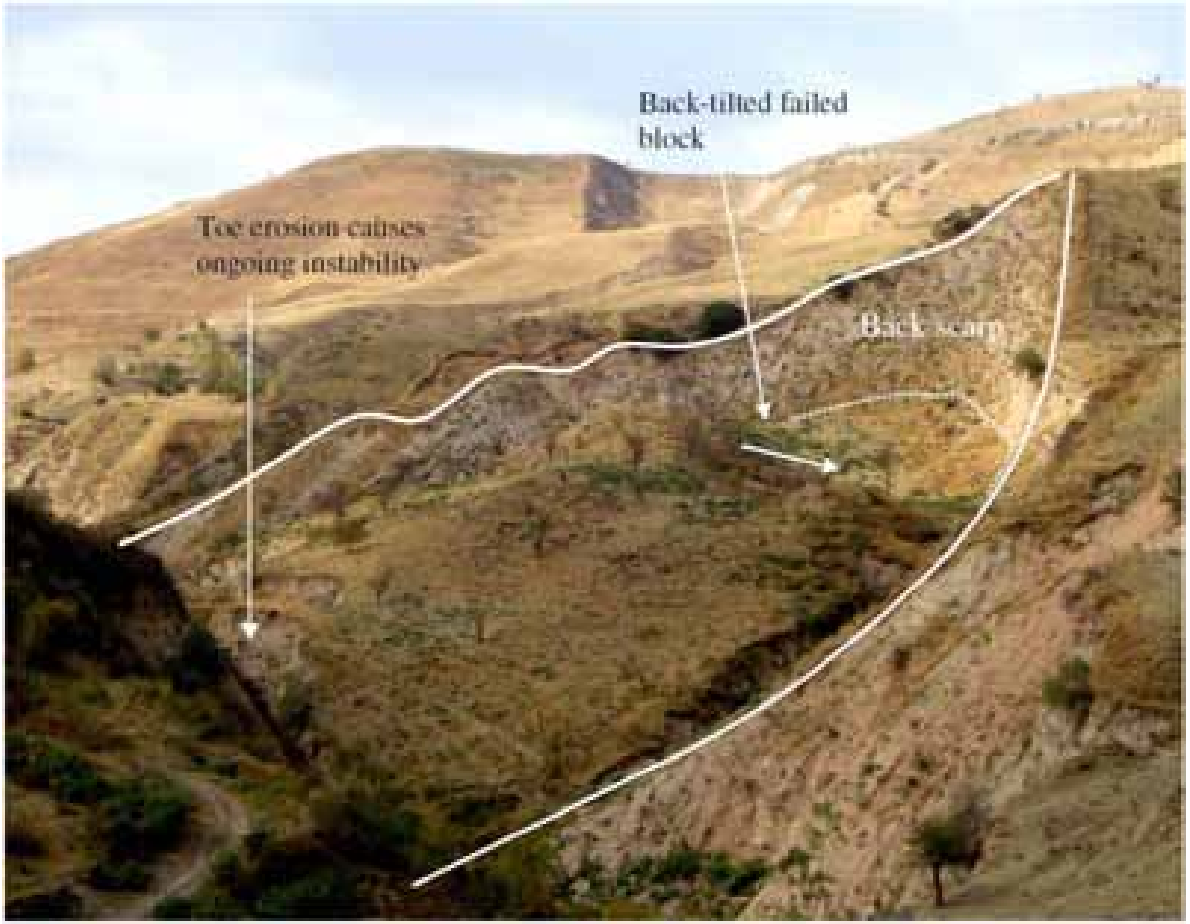




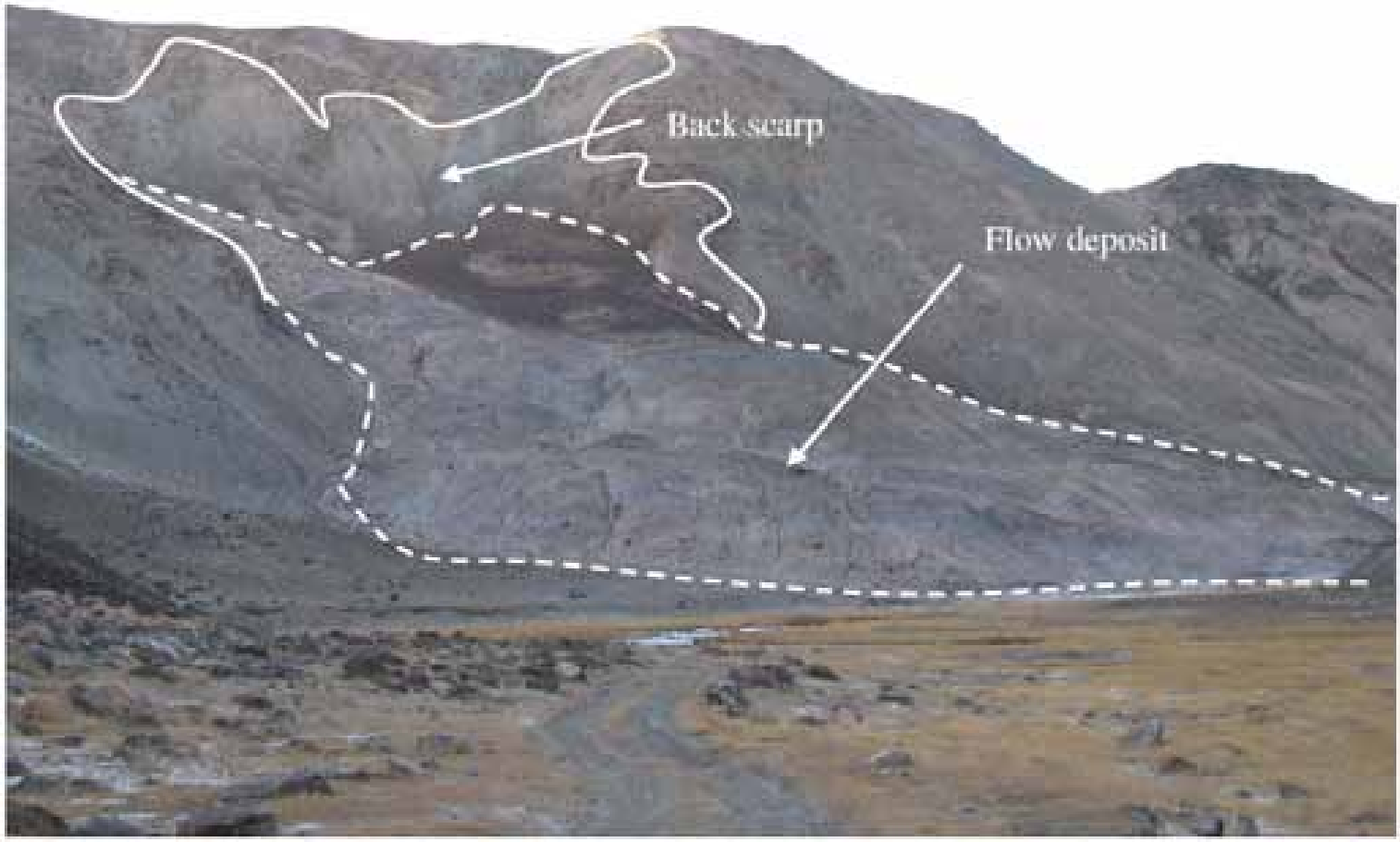
Deep-seated planar landslide



Deep-seated rotational failure

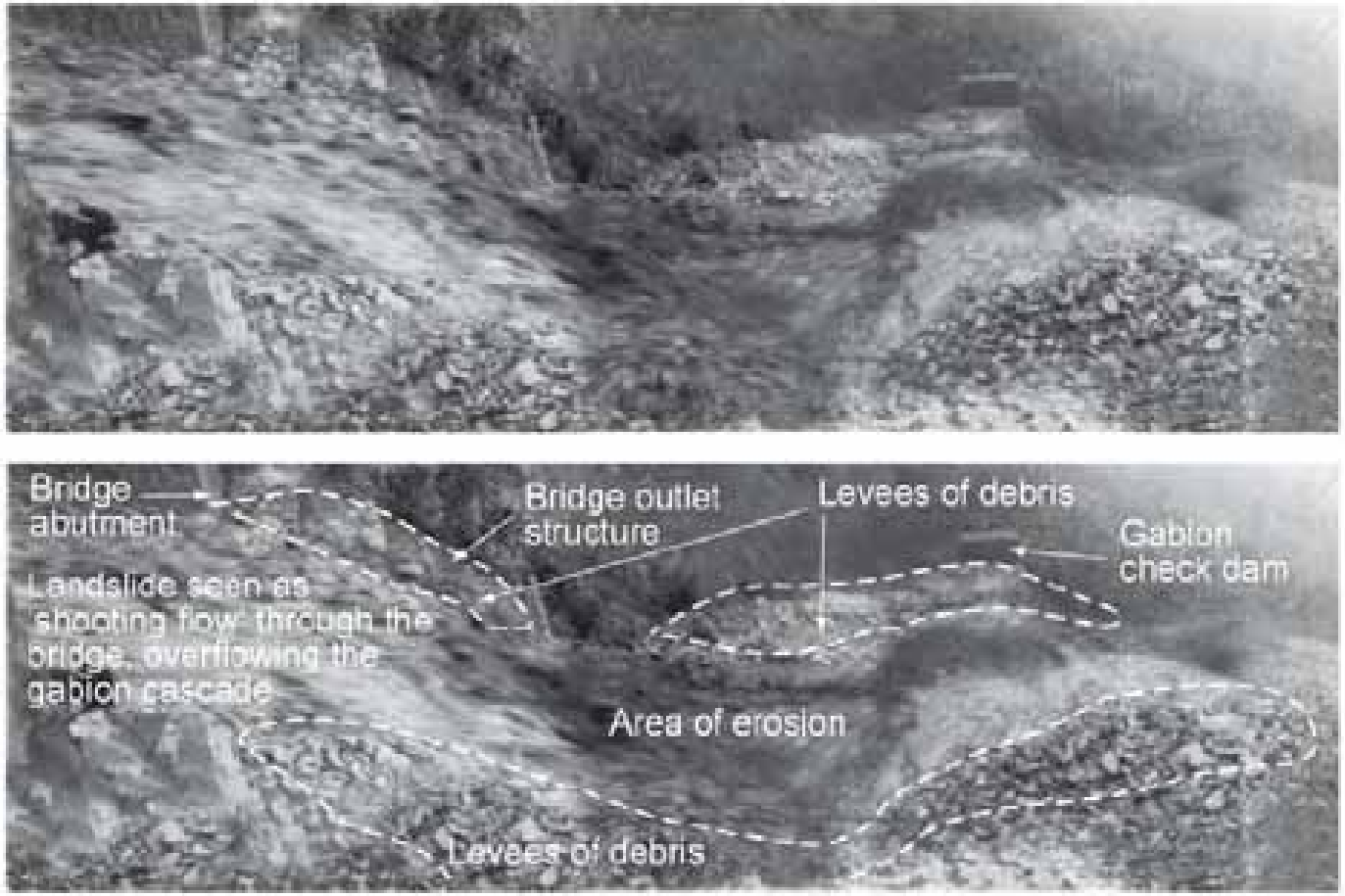


Mudflow

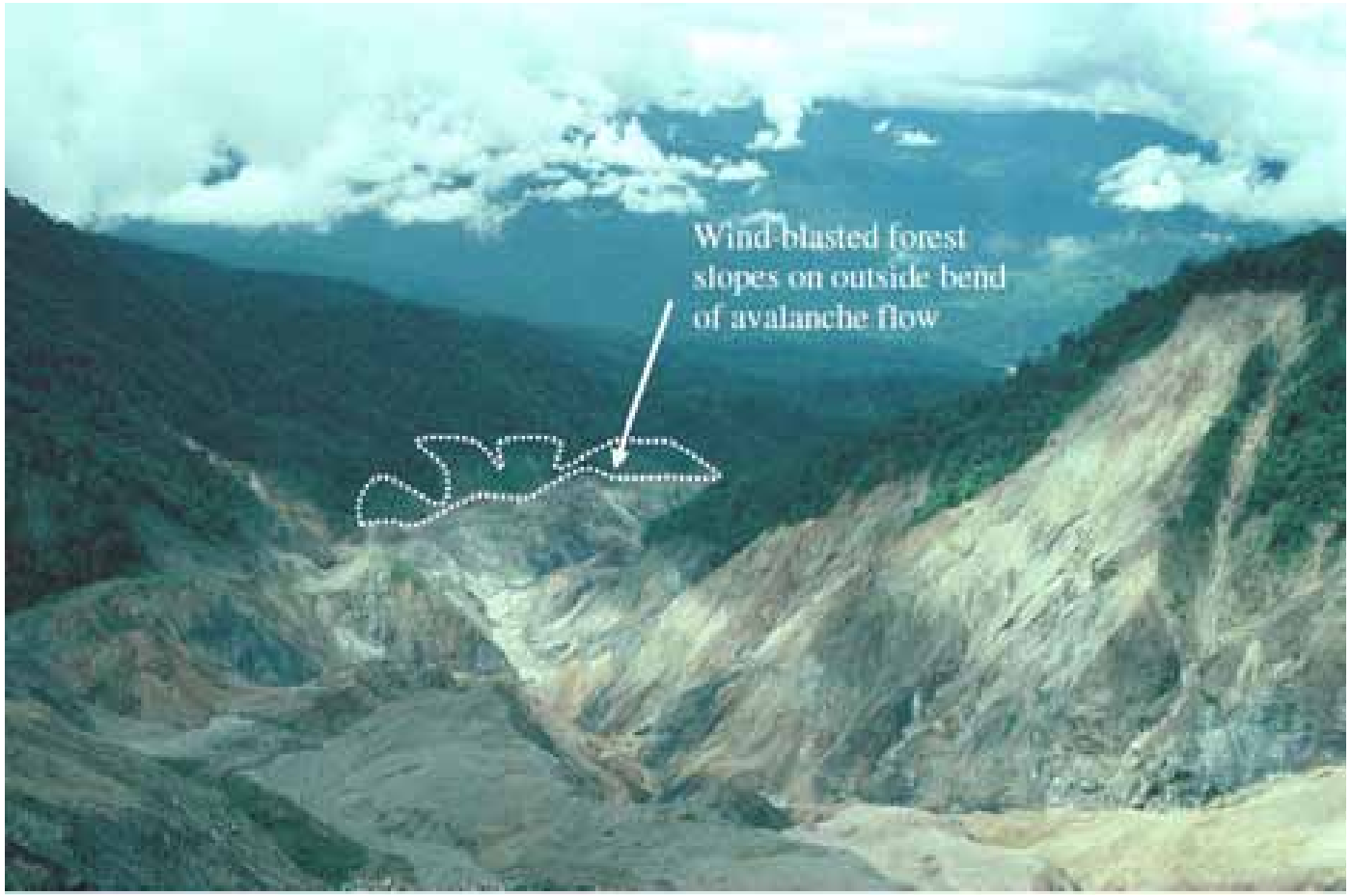


Catastrophic rock fall

Debris flow


Bridge abutment
Bridge outlet structure
Levees of debris
Gabion check dam
Landslide seen as 'shooting flow' through the bridge, overflowing the gabion cascade
Area of erosion
Levees of debris

Rock avalanche



Landslide impacts

- Injury and fatality either in the landslide source area or downstream in its flow path
- Damage to buildings in source and flow path areas
- Disruption, damage and destruction to roads and other linear infrastructure (water supply, pipelines etc)
- Damage and destruction to agricultural land and loss of forest resources
- Pollution of water courses and water supply due to sediment influx to streams and rivers

Most studies deal with identification of landslide source areas, but in mountain terrain it can be the downstream impacts that are the most severe.

Key elements in fostering resilience

- **Geo-hazard awareness**
  - Institutional level
  - community level
- **Geo-hazard preparedness**
  - Institutional level
  - Community level

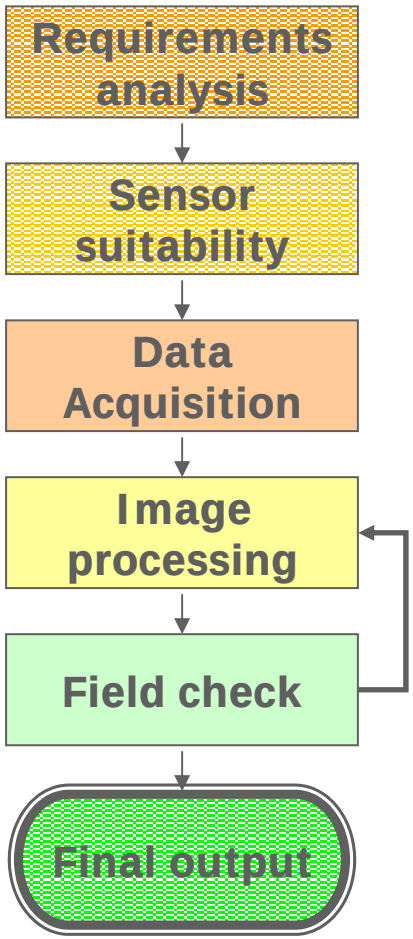
- Where are existing geo-hazards located?
- What are the triggers for future landslides and ground movements?
- Where are potential future geo-hazard locations?
- What actions can be taken to mitigate the risk from geo-hazards?
- What actions or inactions increase the risk posed by geo-hazards?
- What monitoring can be undertaken to provide early warning?
- How can emergency response systems be optimised so that recovery from geo-hazard events is maximised?

Where are the existing landslides?

Client: DFID

Indicators of landslides and potentially unstable slopes	Description and comments	Method				
		Optical satellite Imagery[1]		Aerial Photo-graphy		Field
		Resolution		Scale		
		Low	High	1:40k	1:20k	
Active Landslides						
Tension cracks	Often orientated in an arc and commonly continuous with vertical displacement		✓		✓	✓
Slip scarps	Steps across terraces and other slopes		✓	✓	✓	✓
Disturbed/displaced terracing	Lines of vertically/laterally displaced terracing often mark the margins of ground movement		✓	✓	✓	✓
Hummocky ground	Slope surface is irregular and often formed by a series of low amplitude hummocks		✓		✓	✓
Cracking to structures and paved surfaces	Can be due to settlement of fill and foundations, so supporting evidence is required, unless extensive				✓	✓
Dislocation of drainage structures	Either directly observed or seen as seepages		✓		✓	✓
Springs and seepages	Creating marshy ground		✓	✓	✓	✓
Trees leaning or with curved trunks	Wind, steep slopes and slope movement can cause leaning tree trunks, careful interpretation required					✓
Relict Landslides						
Spoon-shaped landforms	Steep upper scarp often semi-circular, lower-angled, possibly tongue-shaped deposit		✓	✓	✓	✓
Chaotic debris forming landslide deposits	Boulders often protrude above the surface		✓	✓	✓	✓
Hummocky ground	Slope surface is irregular and often formed by a series of low amplitude hummocks		✓		✓	✓
Immature soil profile, indicates disturbed ground	Normal weathering profile is replaced by a structureless, and usually loose taluvium soil					✓
Disturbed or uncharacteristic vegetation pattern	Could be related to land use, so needs to be interpreted with care		✓		✓	✓

Summary of selected satellite data



- Landsat 7 ETM

+ cost (<<1$/km^2), spectral resolution (R G B, NIR, MIR, TIR, Pan

- spatial resolution (15m Pan, 30 MS, 60m TIR)

- SPOTv

+ cost ($4/km^2), spatial resolution (2.5m – 20m)

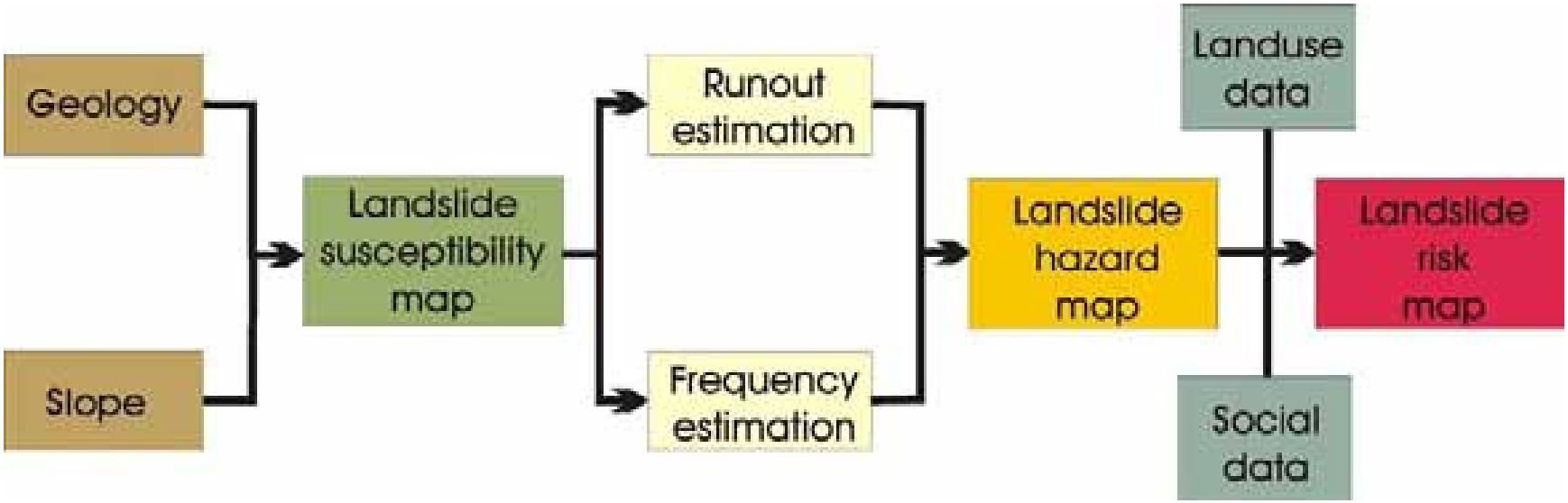
- spectral resolution (R G NIR, SWIR, Pan)

- IKONOS/QUICKBIRD

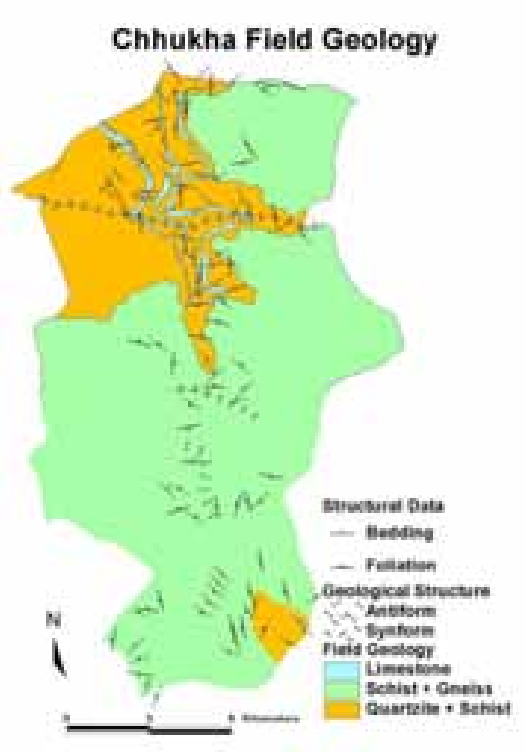
+ spatial resolution (1m Pan, 4m MS)

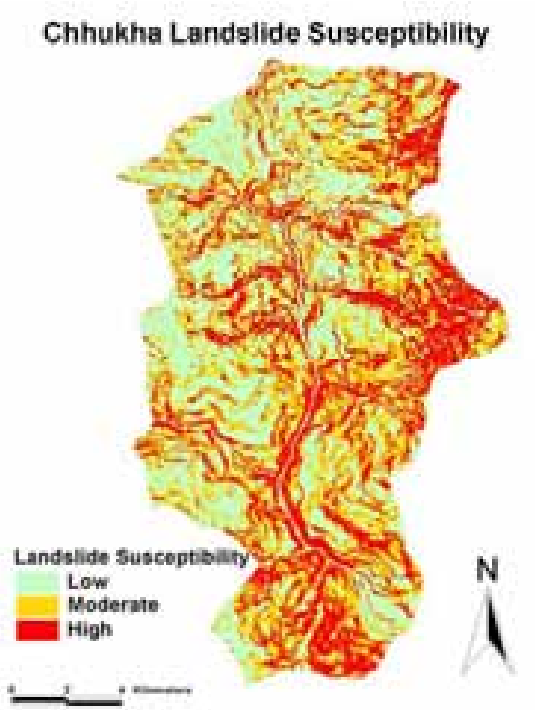
- cost ($20/km^2), spectral resolution (R G B, NIR, Pan)

Where are the potential future landslides? Landslide susceptibility, hazard and risk



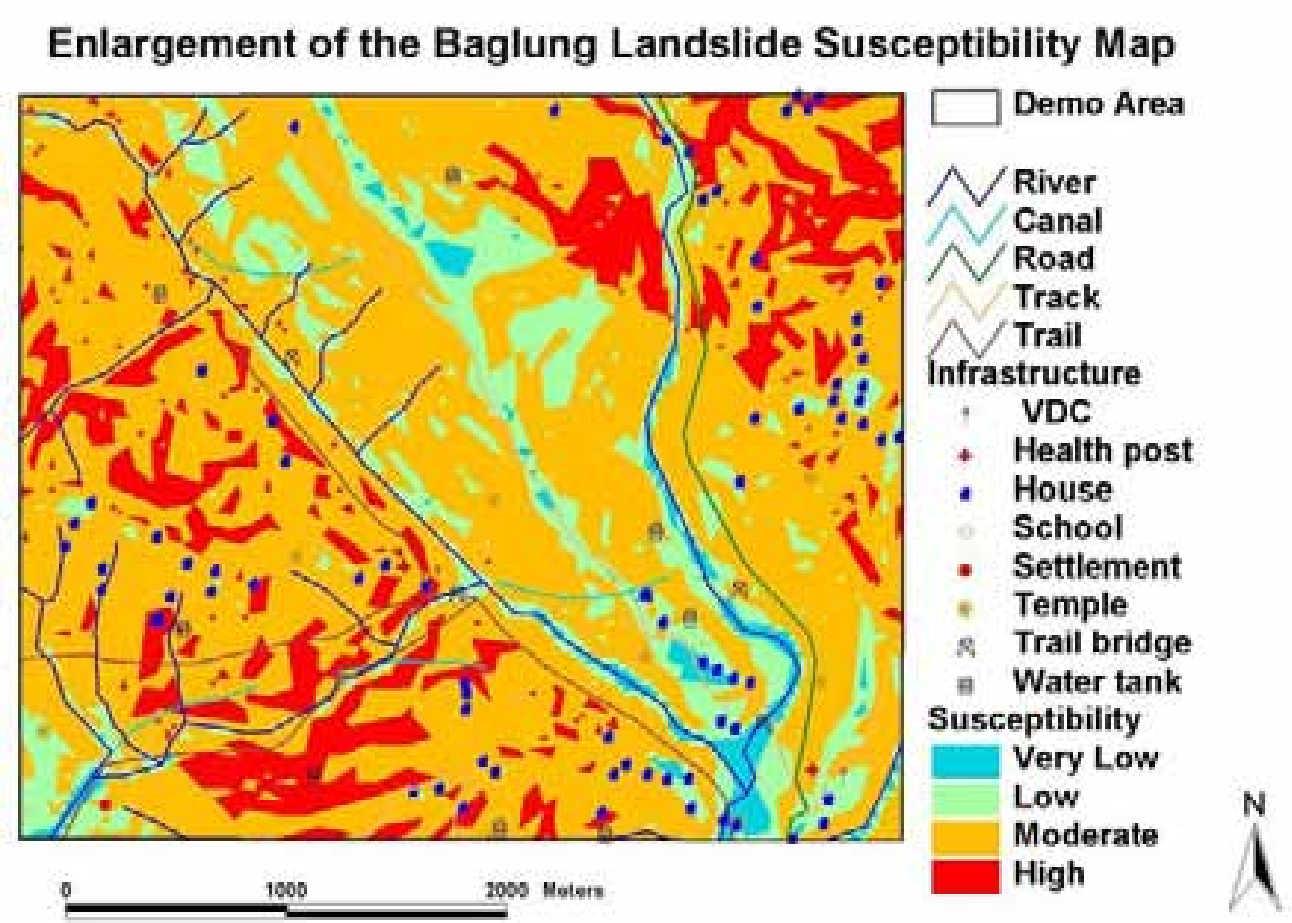
Simple susceptibility map based on geology and slope angle





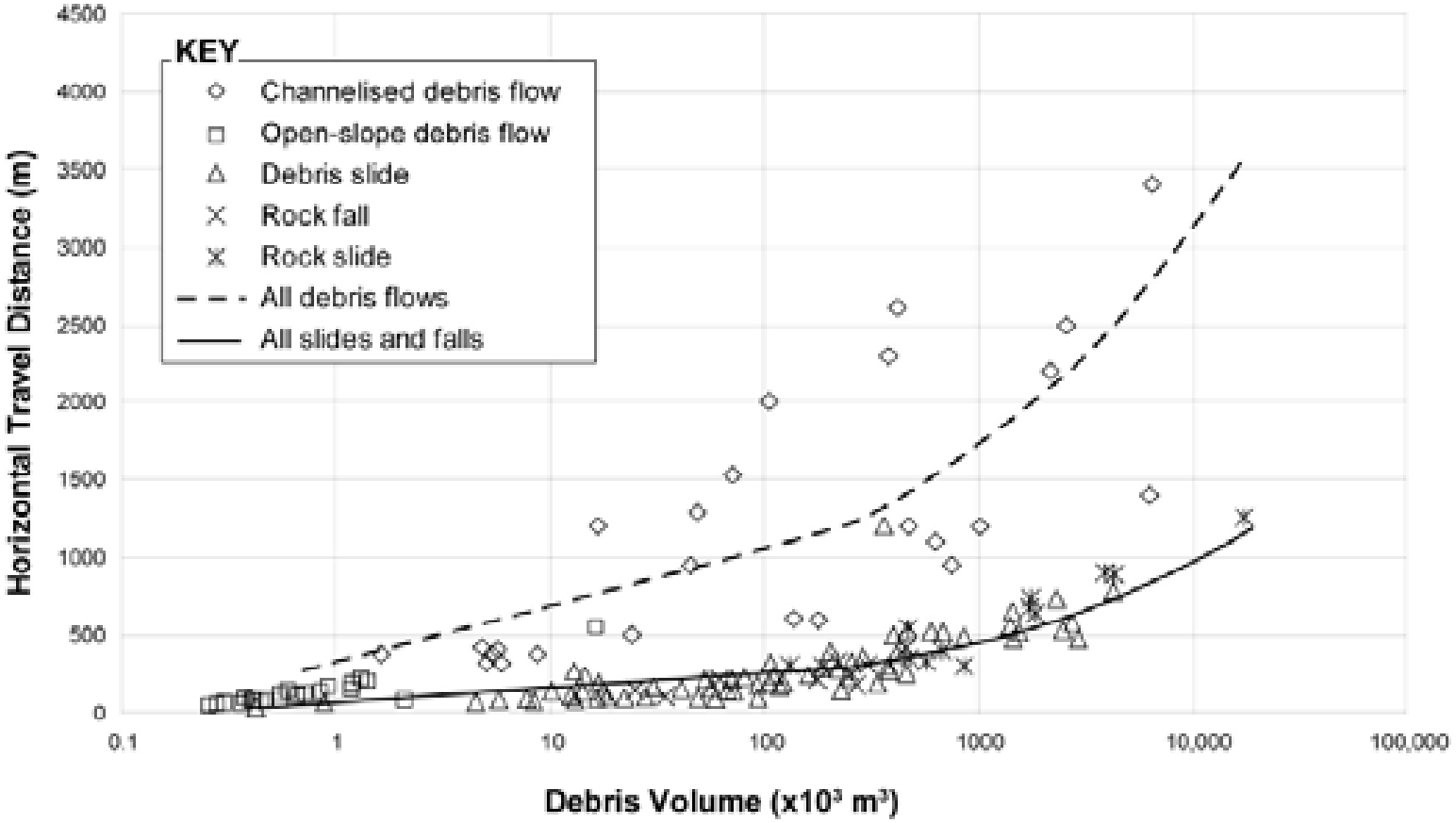
Client: DFID

Detailed susceptibility map, showing infrastructure



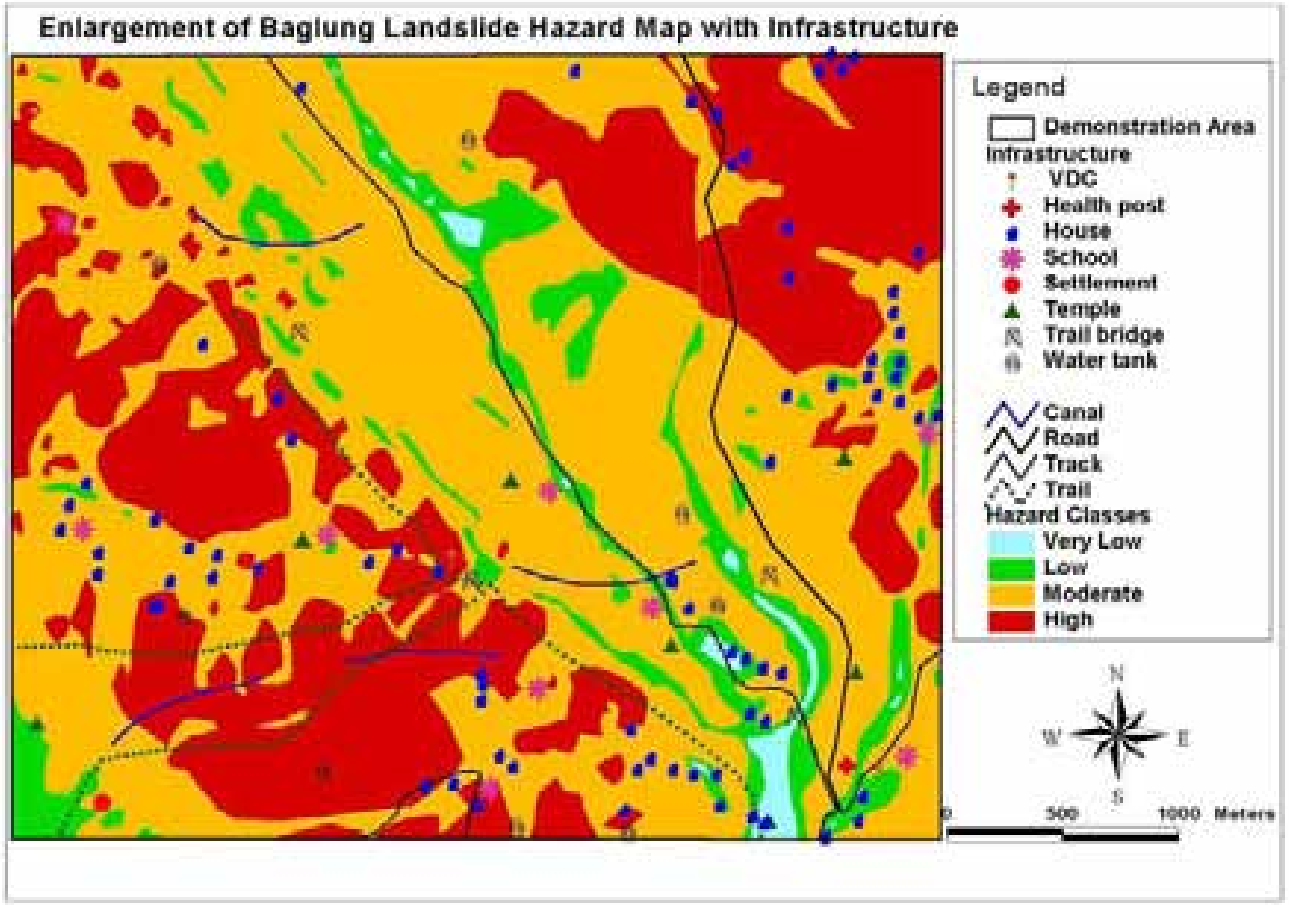
Client: DFID

Correlation between landslide volume and runout distance



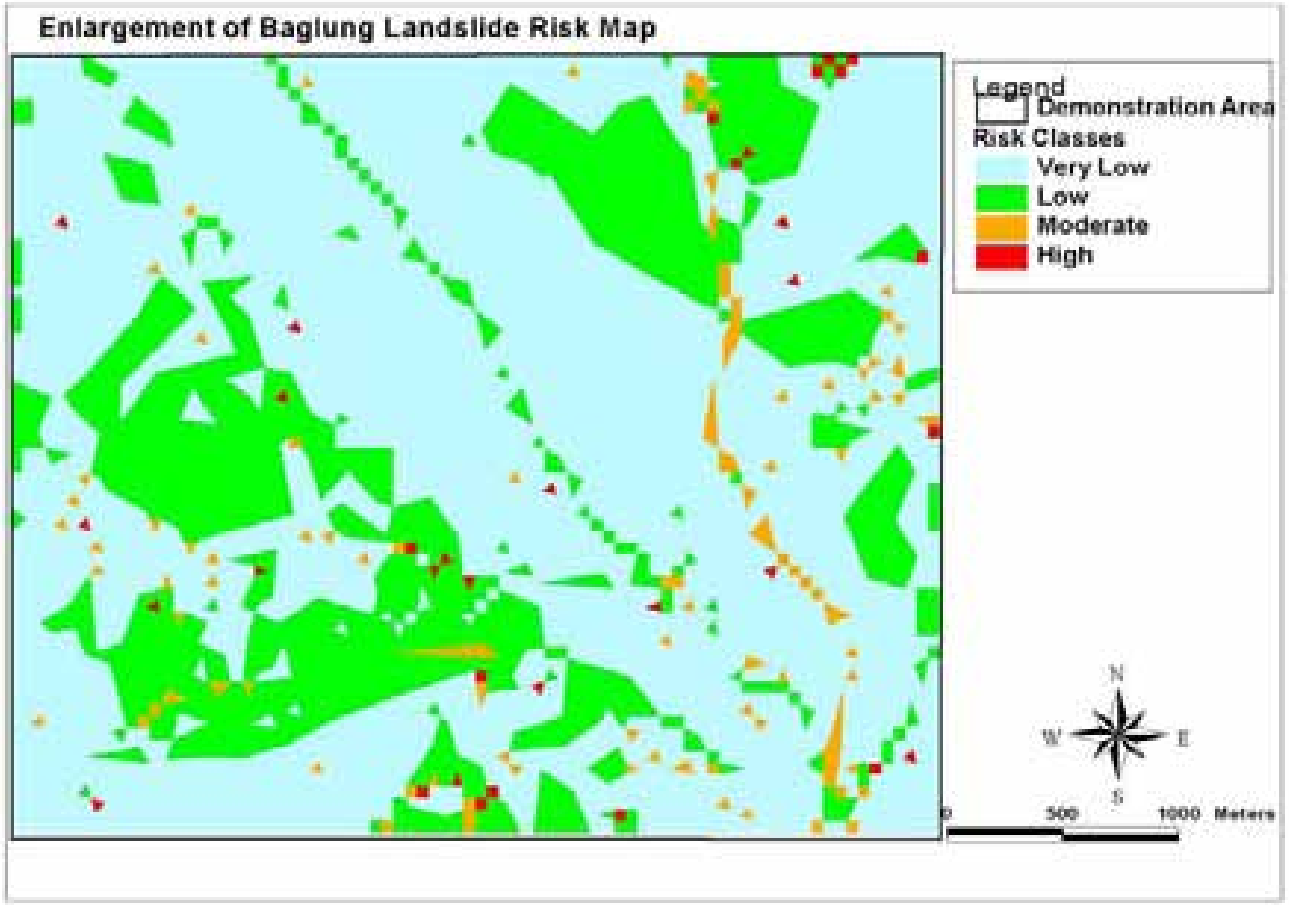
Client: DFID

Development of a hazard map showing extent of predicted runout from high susceptibility areas



Client: DFID

Development of risk map based on land use and infrastructure replacement value



Client: DFID

Landslide resilience strategies (in decreasing order of preference)

- Avoidance (through landslide mapping and susceptibility mapping in advance of infrastructure planning and relocation in the case of existing infrastructure and communities) – but there may be few options in steep terrain and relocating communities involves complex resettlement issues)
- Stabilisation (through earthworks, drainage, retaining walls and anchorage systems) – but there is a limit to what is practicably and economically feasible
- Protection (protect the infrastructure or community from rock falls and landslide runout) – but there is a limit to what is practicably and economically feasible
- Accept risk but introduce emergency evacuation and response plans – need to be implemented by statutory authorities and at community level and are often under-resourced and may be based on lack of adequate information and emergency communication systems

SEACAP 21: Sustainable Slope Stabilisation, Laos

Client: DFID

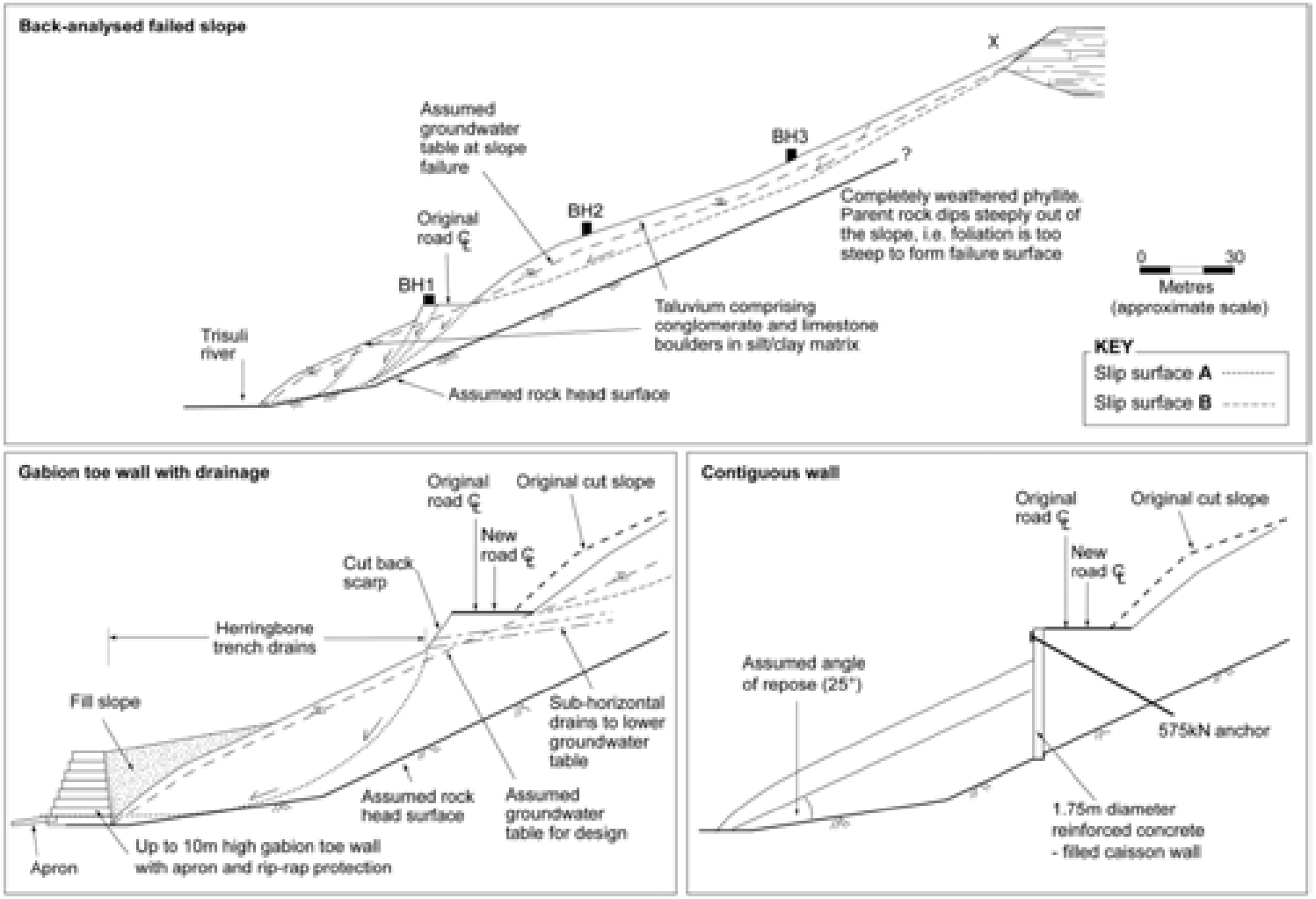
- **Slope stabilisation trials**
- **Field mapping**
- **Ground investigations**
- **Design, construction implementation and performance monitoring**
- Feasibility study
- Mainstreaming and Trainer-training

Winner of Sustainability Category of Ground Engineering Awards, 2010

Bio-engineering measures for erosion control and shallow slope stabilisation

Hand-applied shotcrete, grass planting, fascines and live cuttings (truncheons)

Soil slope stabilisation



Disaster hazard mitigation project, Kyrgyz Republic (landslides, floods and earthquakes)

Kutman Kul Landslide Dam

2840m asl, 75 million m^3 landslide volume

4 million m^3 lake volume, 450,000 m^2 lake surface area

Conclusions from the Kyrgyz project in relation to landslide preparedness

Recommendations and guidance for:

- Clear definition of the functions and co-ordination of the Ministry of Emergencies and other ministries in disaster response;
- The need for a hazard database to prioritise preparedness and response and the provision of resources at central, regional and local level to deliver this response;
- Revised regulations on involuntary resettlement to make them sustainable and not punitive towards households and communities affected;
- *The need to formulate and adopt legal instruments for earthquake-resistant construction and the enforcement of building codes;*
- Greater integration both internally and externally by the Ministry of Emergencies, including greater interface with NGOs operating in the disaster risk reduction sector;
- Exchange of information between ministries and the cascading of hazard information from central, through regional, to local level.

Client: IDA/ADB/ME, KR

Conclusions

Fostering resilience is reliant on the following:

- Good knowledge base of landslide locations and slopes susceptible to landslide initiation and runout
- Good dissemination of this knowledge to all levels, including community level
- Integration of this knowledge into infrastructure planning and management and community resettlement plans
- Targeted and sustainable investment in landslide risk reduction (stabilisation, protection, relocation and preparedness)
- Good knowledge of landslide triggers, for example rainfall and earthquake magnitudes
- Workable and affordable monitoring schemes and effective communication systems to publicise early warning
- Rehersed evacuation and emergency response plans