

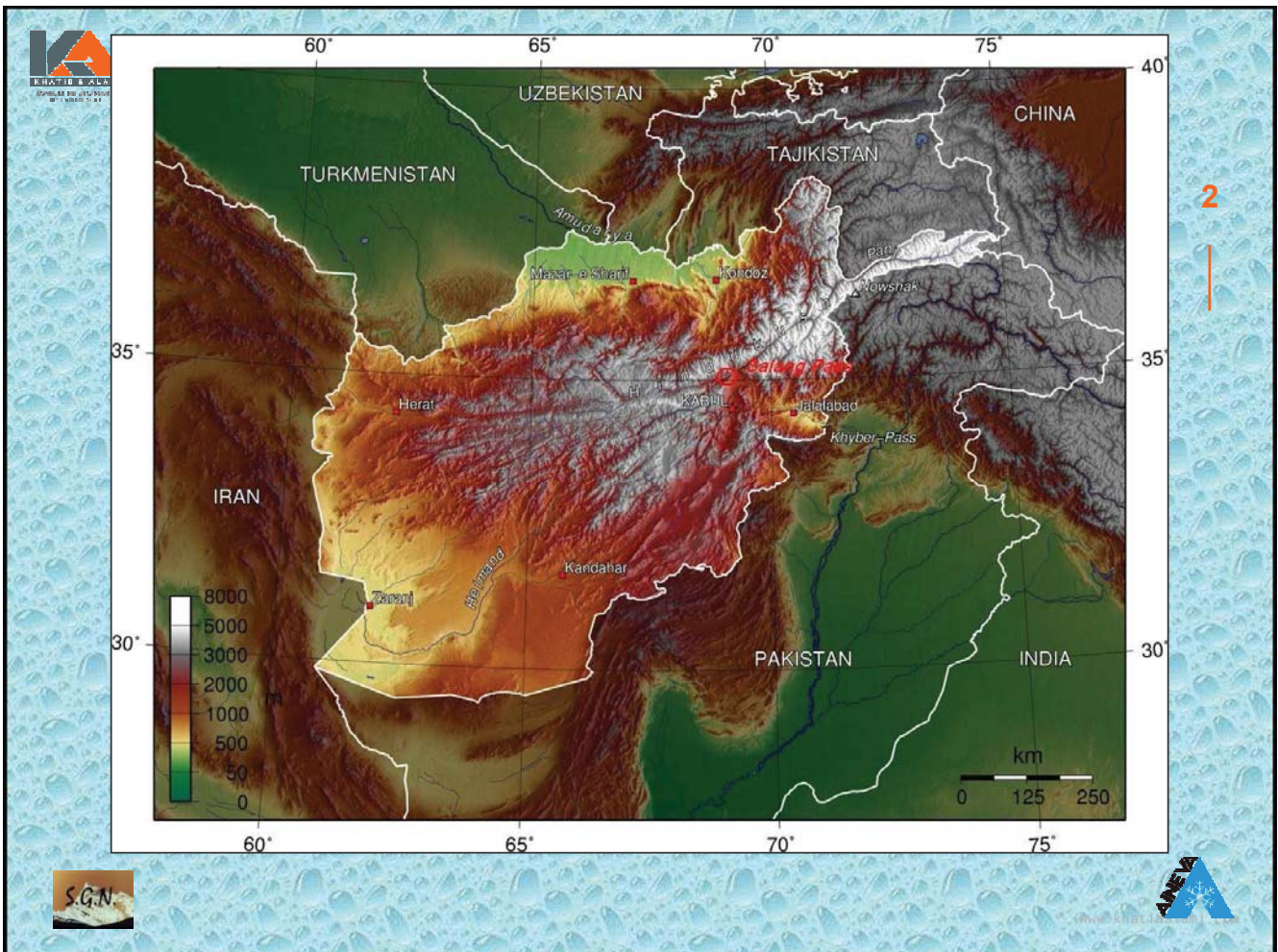
Salang Pass Afghanistan

Esempio di studio applicato
alla mitigazione
del rischio di valanga

2019

Aldo Bariffi

Bormio Maggio 2023



AFGHANISTAN

3

SUPERFICIE = 650.000 KMQ CIRCA

POPOLAZIONE = 40 MILIONI CIRCA

CLIMA CONTINENTALE

ARIDO PREVALENTE

- **ESTATE CALDA E SECCA**
- **AUTUNNO E PRIMAVERA CON PIOGGE
SPESSO ABBONDANTI E CONCENTRATE**
- **INVERNI RELATIVAMENTE BREVI E FREDDI**



AFGHANISTAN

4

**La strada del Salang Pass
collega Kabul alle province del Nord
che hanno come capoluogo Mazar el Shariff.
Dal punto di vista economico è una delle più
importanti del Paese ed è la sola che consente
l'attraversamento dell'Hindu-Kush
anche nel periodo invernale.**



AFGHANISTAN

5

**Il Passo del Salang si trova a 3.800 m. di quota.
Nei primi anni '60 del secolo scorso l'Unione
Sovietica ha costruito il tunnel del Salang,
ad un'altitudine di 3.400 metri,
che consente di evitare il Passo.**



AFGHANISTAN

6

**Lo sviluppo del Tunnel è di 2.600 metri circa
e per molti anni è stato il traforo stradale
più alto del mondo.**

**A partire dal 2015 le condizioni del Tunnel e della
strada del Salang si sono talmente deteriorate che la
WB ha deciso di avviare un progetto per la
riabilitazione della strada.**



AFGHANISTAN

7

**Nel 2017 vengono investiti 150 milioni di dollari
per la riabilitazione e la messa in sicurezza
della strada del Salang Pass.**

**Nel 2018 inizia la fase progettuale, che viene affidata
ad una importante Società di ingegneria libanese.**

**Nel 2019 viene sviluppato parallelamente
il presente studio di mitigazione
del rischio di valanga.**



AFGHANISTAN

8

Nel 2020 si conclude il progetto esecutivo.

**Nel 2021 i contingenti ONU abbandonano il Paese
e i talebani ritornano al potere.**

**Si verifica il conseguente congelamento di tutti gli
investimenti previsti.**

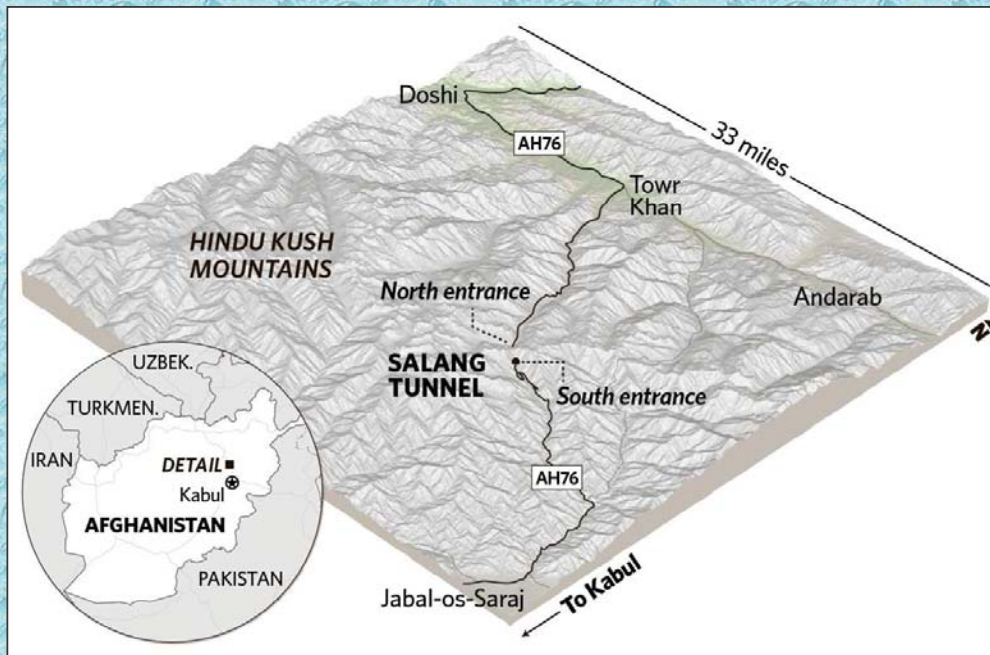
Attualmente tutti i progetti in essere sono sospesi.



The Avalanche Study

for implementation of mitigation works
has been carried out on the most critical section of Salang road
between km 32+550 and km 62+747

9



PRINCIPALI INCIDENTI CHE HANNO COINVOLTO LA STRADA DEL SALANG NEL TRATTO PIU' CRITICO

10

1980 (FEBBRAIO)
A SEGUITO DI UN INCIDENTE
UN CONVOGLIO MILITARE SOVIETICO
RIMANE BLOCCATO NEL TUNNEL
E 16 PERSONE MUOIONO
SOFFOCATE DAI GAS DI SCARICO.

PRINCIPALI INCIDENTI CHE HANNO COINVOLTO LA STRADA DEL SALANG NEL TRATTO PIU' CRITICO

11

1982 (NOVEMBRE)

**A SEGUITO DI UNA COLLISIONE SCOPPIA UN
INCENDIO NEL TUNNEL E MUOIONO CIRCA 180
PERSONE MA IL BILANCIO DEFINITIVO NON
E' STATO MAI COMUNICATO.**



PRINCIPALI INCIDENTI CHE HANNO COINVOLTO LA STRADA DEL SALANG NEL TRATTO PIU' CRITICO

12

2002 (INVERNO)

**DIVERSE VALANGHE INTERESSANO LA STRADA
DEL SALANG SUL VERSANTE SUD DEL PASSO.
SI REGISTRANO DIVERSI MORTI
ANCHE PER CONGELAMENTO E ASFISSIA.**



PRINCIPALI INCIDENTI CHE HANNO COINVOLTO LA STRADA DEL SALANG NEL TRATTO PIU' CRITICO

13

2009 (GENNAIO)
ALMENO 10 PERSONE PERDONO LA VITA
TRAVOLTE DA VALANGHE
LUNGO LA STRADA DEL SALANG.



PRINCIPALI INCIDENTI CHE HANNO COINVOLTO LA STRADA DEL SALANG NEL TRATTO PIU' CRITICO

14

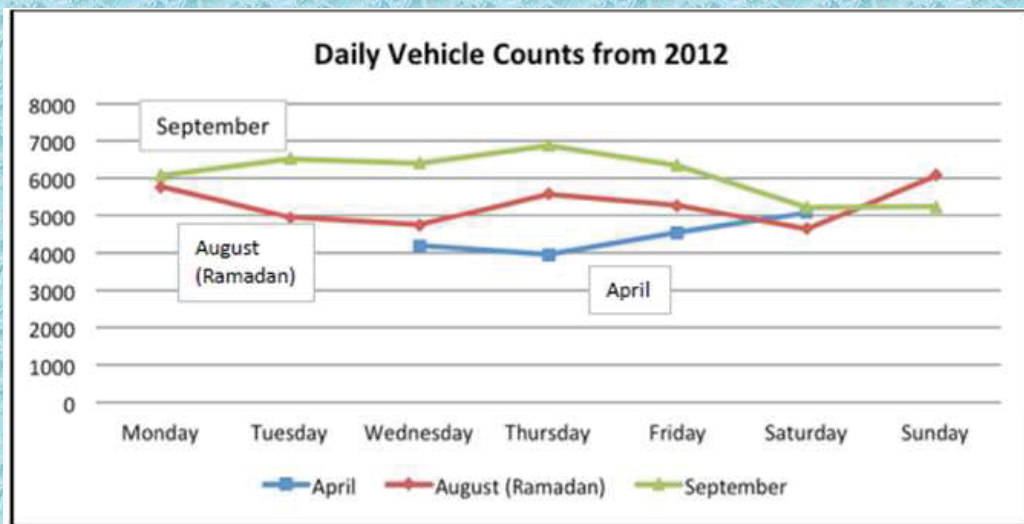
2010 (FEBBRAIO)
CIRCA 170 PERSONE
PERDONO LA VITA
LUNGO LA STRADA DEL SALANG
TRAVOLTE DALLE VALANGHE
E/O PER CONGELAMENTO E/O PER ASFISSIA.



PRINCIPALI INCIDENTI CHE HANNO COINVOLTO LA STRADA DEL SALANG NEL TRATTO PIU' CRITICO

15

2022 (DICEMBRE)
**UN'AUTOCISTERNA DI CARBURANTE
 ESPLODE NEL TUNNEL DEL SALANG.
 ALMENO 31 PERSONE PERDONO LA VITA
 E 37 ALTRE SONO RICOVERATE.**



16

Vehicle Type	Share of traffic (%)
Trucks	36
Bus	10
Cars	51
Motor bikes	3



Vehicle Type	Average length (m)	Average number of passengers
Truck	16.5	1
Bus	15	54
Car (Toyota Corolla)	4.6	5
Motorcycles	2.5	1

17

2012 – Source USAID

Purpose of travelling	Northbound (%)	Southbound (%)
Passengers	6	4
Visting Family and Friends	19	12
Other (Business, Cargo etc.)	75	84

**About 36.000 people result in moving daily
through the avalanche prone areas
known as “dead zone”**



Types of accidents

18

Hit and buried by avalanches

(first-order danger)

Hit and swept away from the highway by avalanches

(second-order danger)

Blocked in the tunnel and galleries by avalanches and suffocated/frozen

(third-order danger)

Buried by snowdrifts on the road, then suffocated and/or frozen

Blocked in the tunnel and galleries by snowdrifts and suffocated/frozen





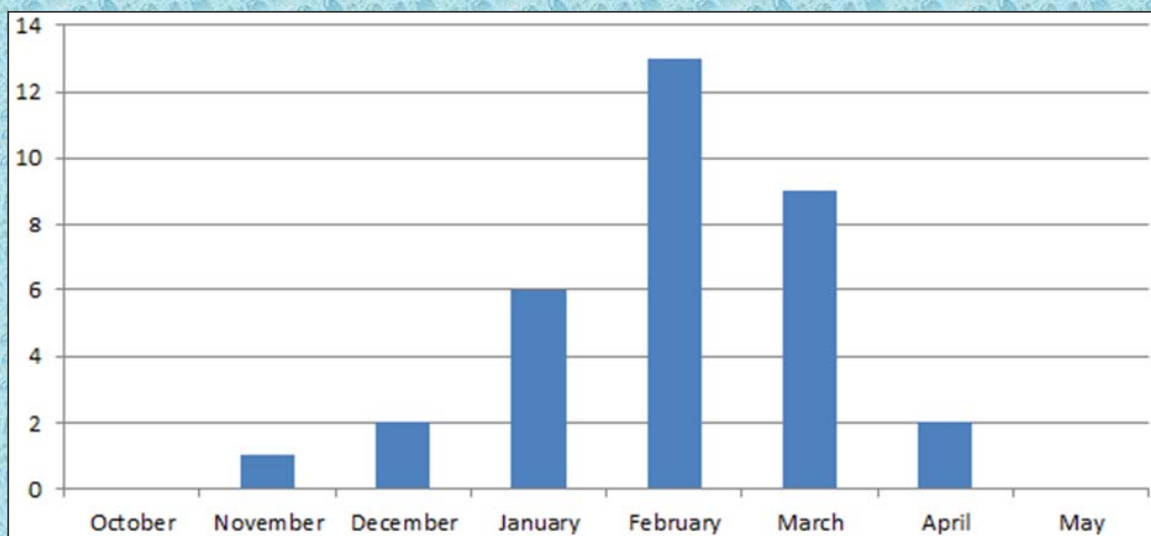
19

Period 2001-2015

Mass media sources – GRF Davos



Repartition of road closures through the winter season (period 2001-2015)



20

Mass media sources – GRF Davos



Total number of death along the Salang Road
18 - 20 deaths/winter (approximately)
means 10×10^6 USA \$ (society loss)
(1 human life in Afghanistan = 500.000 USA \$)

21

Traffic interruption for Salang Road winter closure
10 day/winter (approximately)
means 20×10^6 USA \$ (economical loss)
(2×10^6 USA \$ for each day of road closure)

Source WB – GRF - MPW



Data Collection and Analysis

- Topographic map of quadrangle 3568-3569 (2005);
- Site Visit Report – Project: Salang Pass (2017) – THRPC;
- **Final Report V15 Davos by WB (2017);**
- Site visit report (2018) - THRPC;
- Vir Geological survey (2018);
- Afghanistan Multi-hazard risk assessment (2018) – by WB and GFDRR;
- **Salang Surface Autocad (dwg format) - UTM coordinates (2019);**
- **DTM (Digital Terrain Model) with about 11 meters resolution (Tiff/Tfw format);**
- **Orthophoto by ARCGIS WEBMAP and Google Earth Pro (3D visualization);**
- Project Information Document (PID) – Appraisal Stage;
- Afghanistan Transportation Geohazards Decision Support System by World Bank;
- **Metheorological data (north Salang and south Salang);**
- **Avalanche accident reports on Salang highway;**
- Afghanistan Agromet Bulletin;
- Online metheorological data and photos;
- Afghanistan and climate change in the Hindu Kush –Himalayan region.

22



Limitations in availability data

23

Cartography

Avalanche cadastre

Weather and snow data

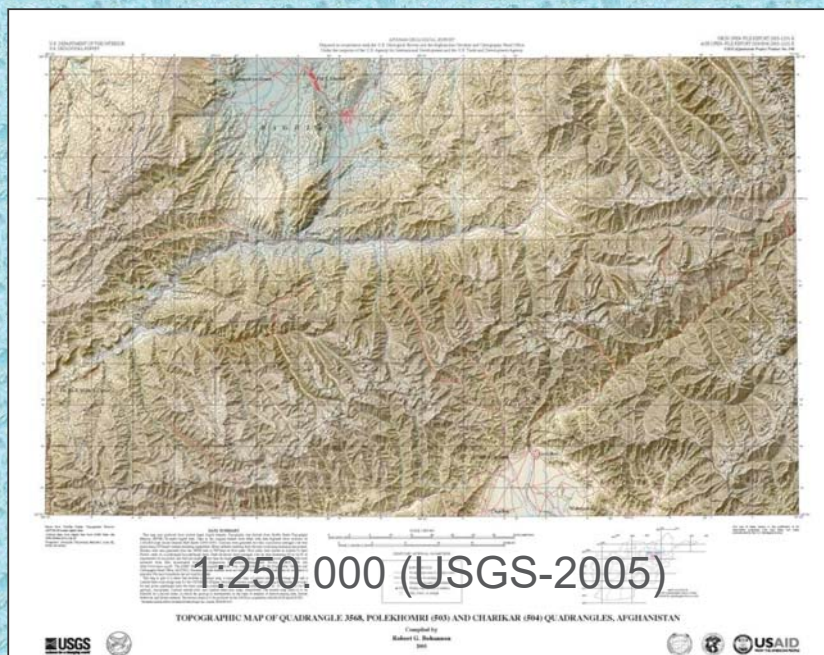
Real consistence and fiability
of any kind of informations



Limitations in availability data

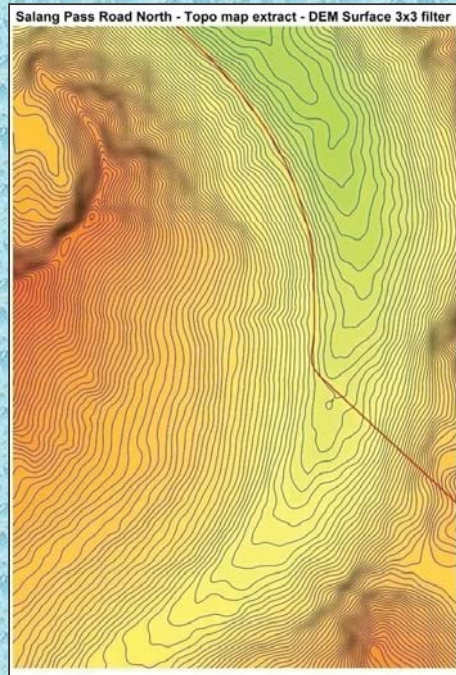
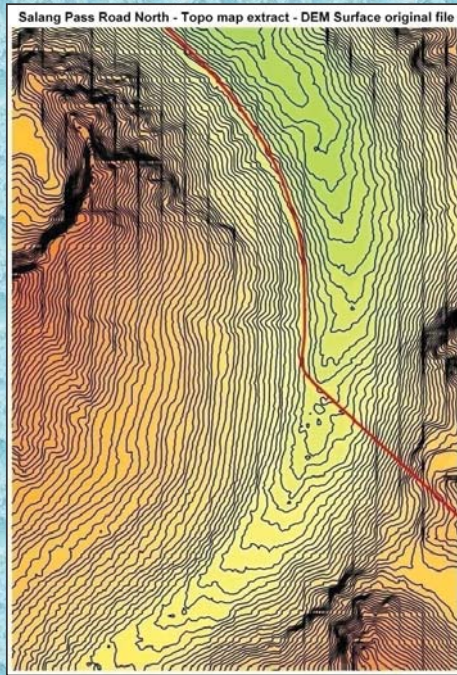
24

Cartography



Limitations in availability data

Cartography



Limitations in availability data

Cartography



Limitations in availability data

Avalanche cadastre

27



Limitations in availability data

Avalanche cadastre

28



Limitations in availability data

Avalanche cadastre

29



Limitations in availability data

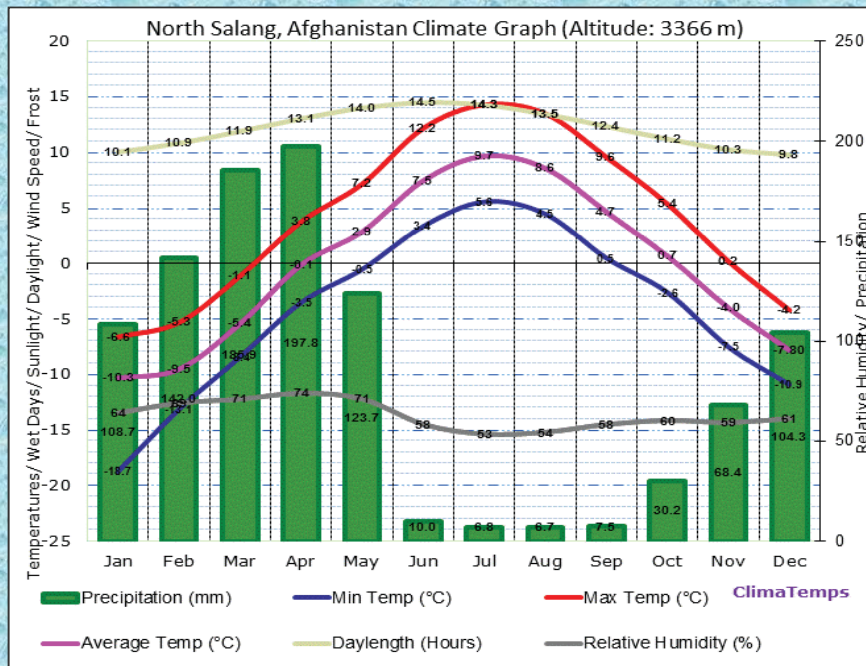
Avalanche cadastre

30



Limitations in availability data Weather and snow data

31



The study has been developed by the follow steps

32

Cartographic map elaboration

such as DEM, Aspect Map and Slope map with avalanche location

Risk assessment and priorities

using the canadian ATES methodology
(Avalanche Terrain Exposure Scale)

Location and thipology of suggested mitigation works

and avalanche sheets documentation

Preliminary Report – Meeting 1 in Kabul (presentation)



The study has been developed by the follow steps

33

On site visit

to calibrate the preliminary data elaboration and Report

Avalanche Simulations

performed by Aval 1D along critical sections

Location and thipology of suggested mitigation works

Final Report – Meeting 2 in Kabul (presentation and discussion)

Analysis of Benefit/Cost Ratio of suggested mitigation works

Meeting 3 in Davos



The study has been developed by the follow steps

34

Snow and Avalanche Data Set for galleries calculation

and Design Recommandations

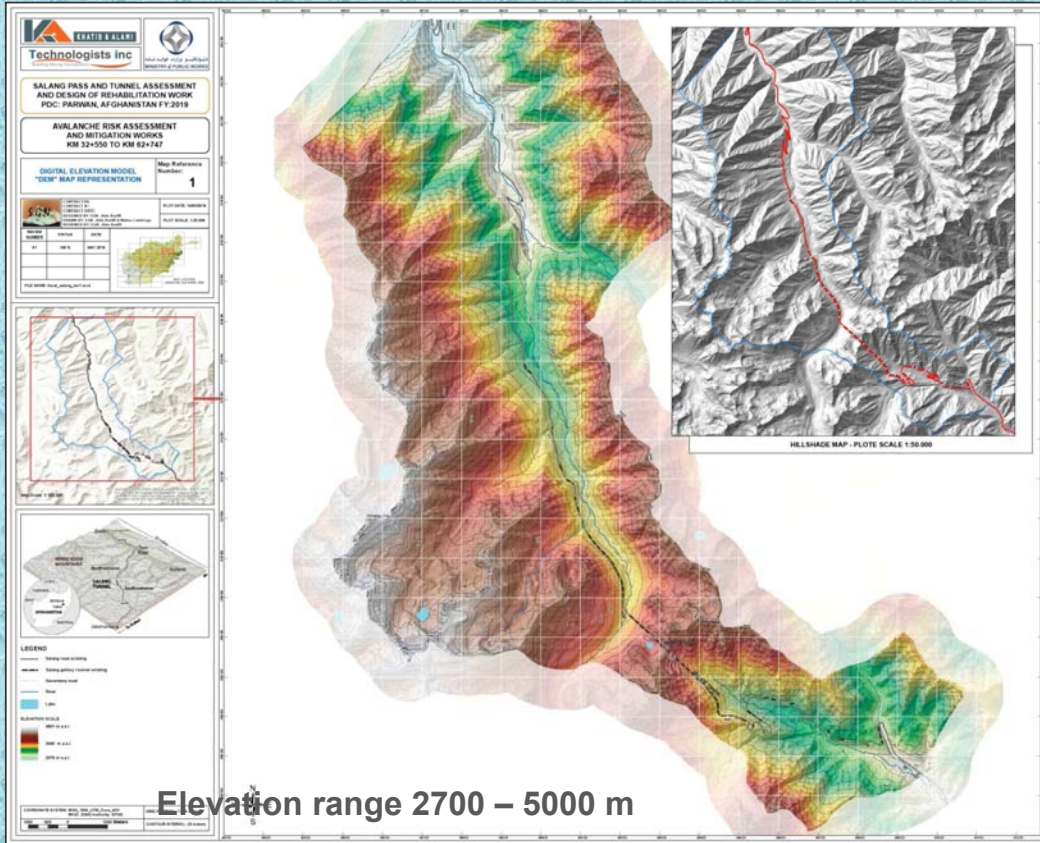
(Swiss Guideline 2007)

Final Report (updating)

Meeting 4 in Kabul (presentation)



DTM 1:25.000 (about 150 Km²)

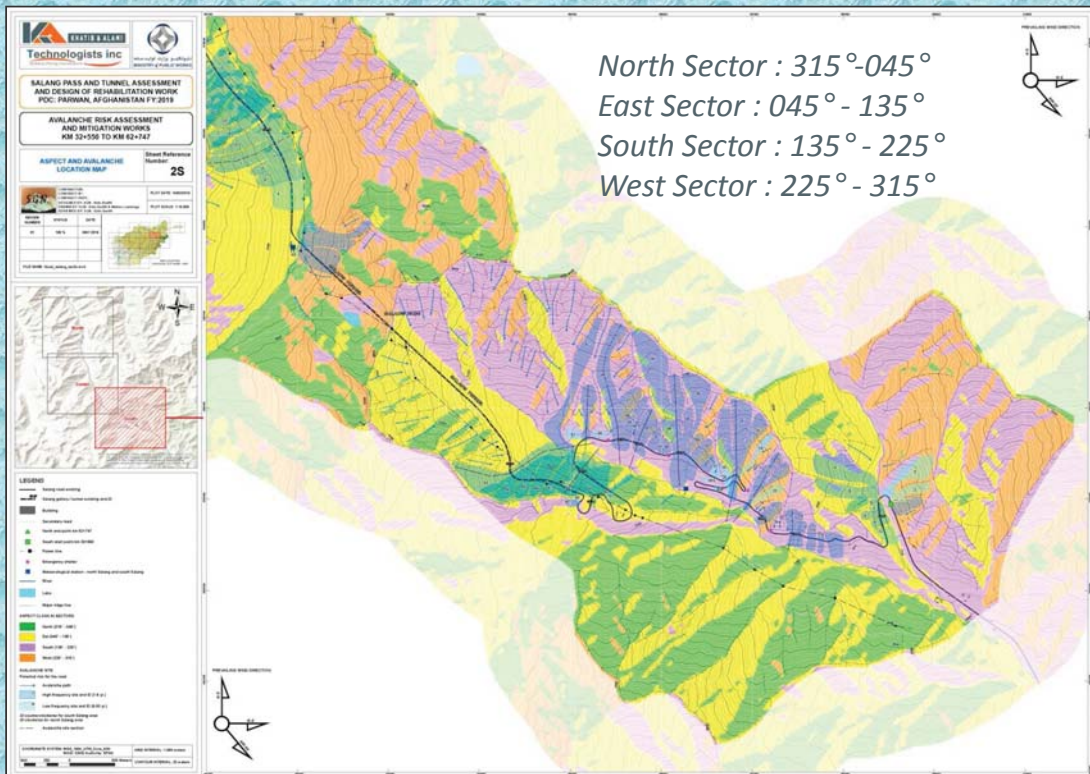


35

Elevation range 2700 – 5000 m



Aspect Map 1:10.000



36

North Sector : 315°-045°
 East Sector : 045° - 135°
 South Sector : 135° - 225°
 West Sector : 225° - 315°



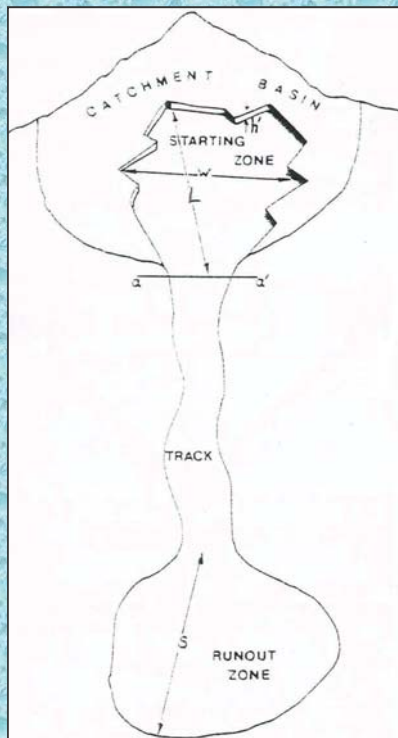
Aspect Map 1:10.000 (detail)



37



Slope and Avalanche Location Map 1:10.000



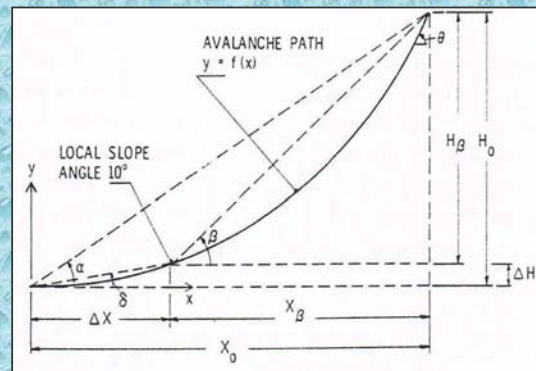
Original CAA (degree)

Adapted (degree)

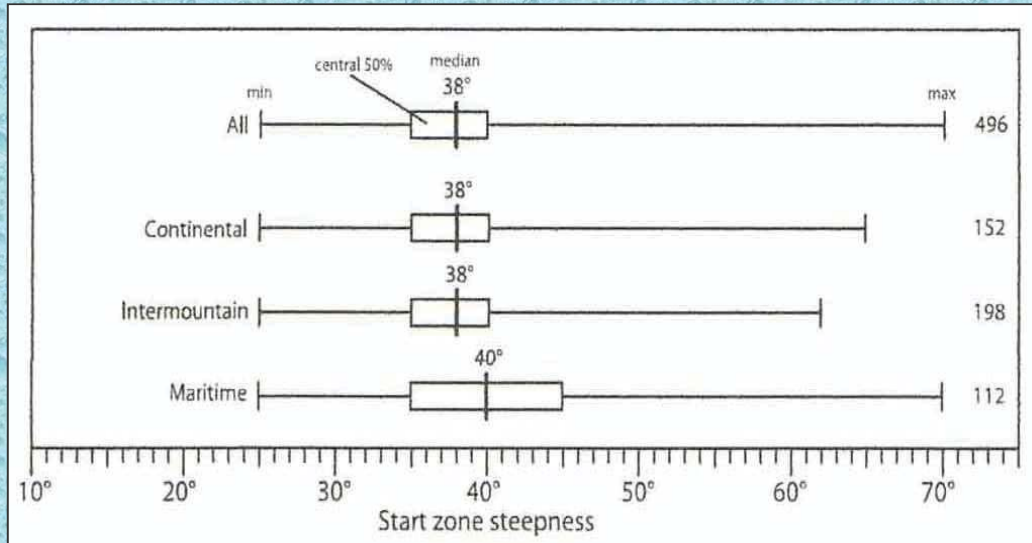
38

- 0-19.9/61-90
- 20-24.9/56-60.9
- 25-29.9/51-55.9
- 30-34.9/46-50.9
- 35-45.9

- 0-11.9 (runout zone)
- 12-19.9/60-90 (avalanche track)
- 20-27.9/52-59.9 (avalanche track)
- 28-32.9/45-51.9 (release zone LF)
- 33-44.9 (release zone HF)



Slope and Avalanche Location Map 1:10.000

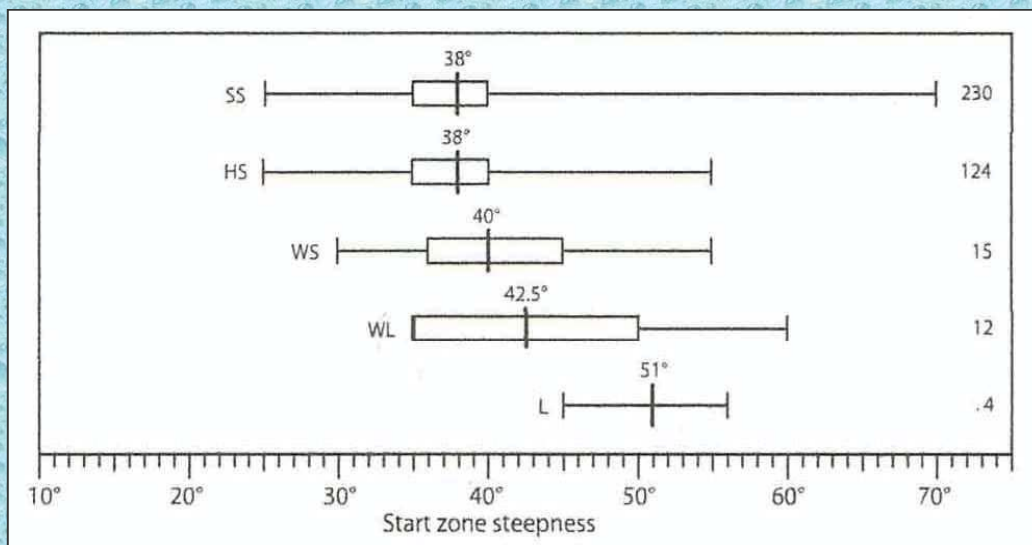


39

Start zone steepness in different climate region
 and number of avalanches considered
 "Closer look at avalanche type and slope angles
 Source: the avalanche review 2009



Slope and Avalanche Location Map 1:10.000

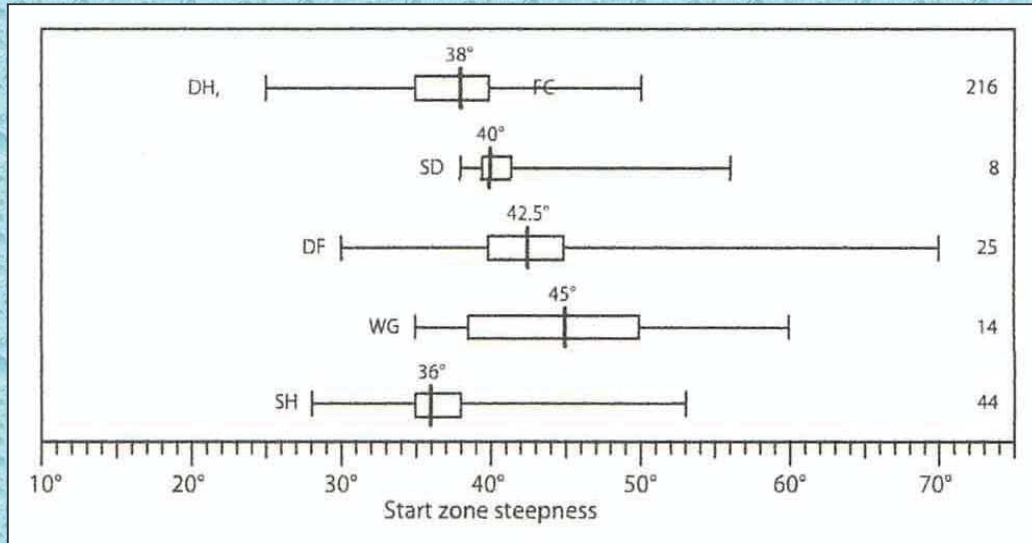


40

Start zone steepness for different avalanche type
 and number of avalanches considered
 SS=soft slab; HS=hard slab; WS=wet slab; WL=wet loose; L=dry loose
 Source: the avalanche review 2009



Slope and Avalanche Location Map 1:10.000

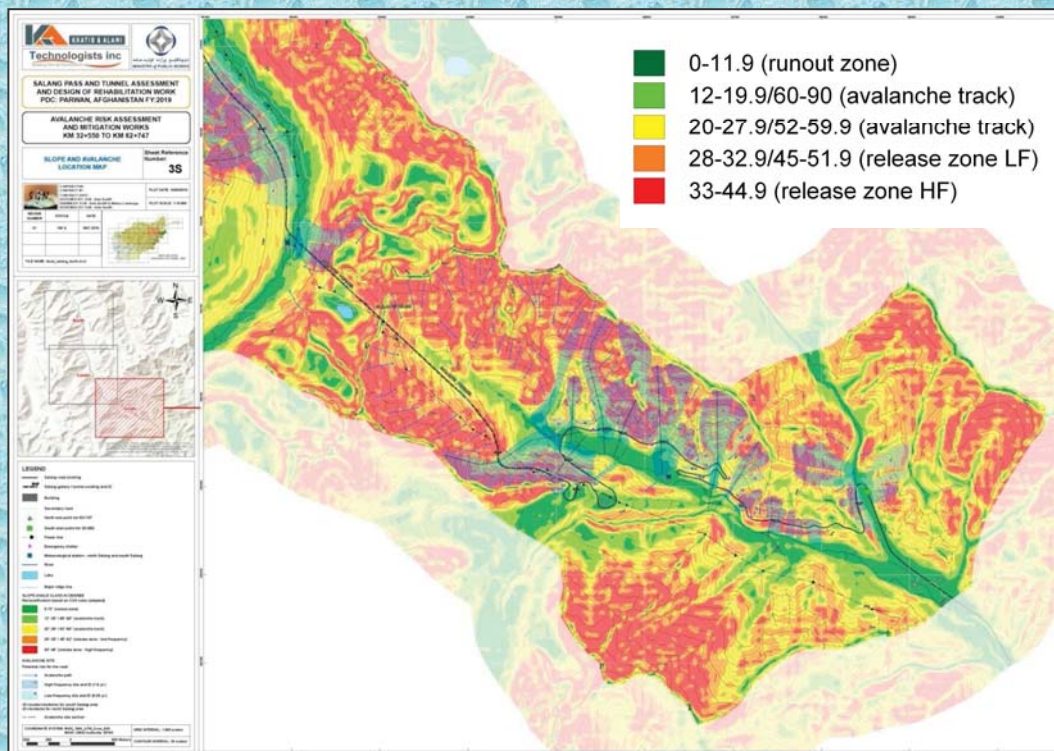


41

Start zone steepness for weak layer grain type and number of avalanches considered
 DH, FC = dept hoar or faceted grains; SD = stellar dendrites;
 DF = decomposing forms; WG = wet grains; SH = surface hoar
 Source: the avalanche review 2009



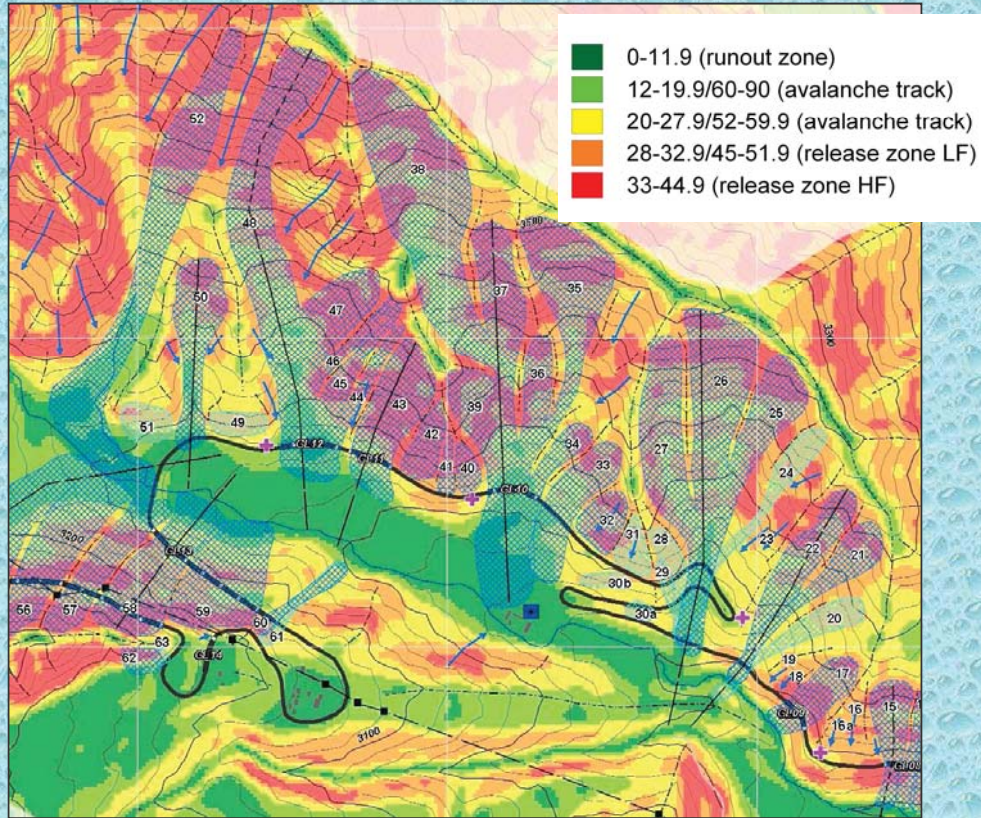
Slope and Avalanche Location Map 1:10.000



42



Slope and Avalanche Location Map 1:10.000 (detail)



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Reference table for avalanche assessment risk and priority (CAA) ATES (Avalanche Terrain Exposures Scale) – Adapted Technical Model

Parameters	Priority 1	Priority 2	Priority 3
Slope angle	33°-45° (red class– HF) (+3)	Mix (red/orange class)	28°-33° (orange class-LF)
Aspect of the slope and snow drift accumulation	E - N	SE	W
Morphology of the slope	channelled	irregular	open slope
Extension of release zone	> 25.000 mq	10.000-25.000 mq	< 10.000 mq
Mean elevation of the release zone	> 3.500 m	3.000-3.500 m	< 3.000 m (+3)
Documented events or mitigation suggestions	Yes	not clear	No
	If provided by R.M.S. (+5)		If provided by R.M.S. (+5)
Release zone crosses the road	Yes	No but very close to it	No
Track zone crosses the road	Yes	Yes but with a long way	No
Run-out zone crosses the road	No	Yes	Yes
Dangerous slopes downstream of the road	Yes (+3)	No	No
Possible obstruction of gallery/tunnel entry and exit	Yes	uncertain	No
Avalanche can interest road in different part along the same track	Yes	occasional	No
Management control is required for road closure (Artificial Aval. Release)	No	No	Yes (+3)
Check control for avalanche occurrences is required at least for a winter season before planning the works	No	Desirable	Yes (+3)
Traffic exposure time (estimation)	long	medium	short
Benefit/Cost/ ratio (estimation)	high (+3)	medium	low

Reference table for avalanche assessment risk and priority (CAA) ATES (Avalanche Terrain Exposures Scale) – Adapted Technical Model

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BC Ratio what is it?

46

BC Ratio rappresenta il rapporto Beneficio/Costo.
 Generalmente quando il rapporto è uguale o maggiore di 1
 l'intervento è giustificato.

Il beneficio può essere rappresentato dalle vite umane salvate per anno o dalle perdite economiche evitate.
 Il costo è l'investimento necessario rapportato all'anno per ottenere il beneficio prefisso.

Facciamo un esempio pratico.



BC Ratio what is it?

47

Supponiamo di conoscere il tasso di mortalità registrata lungo una sezione stradale pari a 2 morti ogni 10 anni.

Il tasso di mortalità è dunque 0.2 morti/anno.
Ciò si traduce in un costo annuale per la società di
 $500.000 \times 0.2 = 100.000$ USA \$ (Afghanistan)

Supponiamo di prevedere la realizzazione di una galleria come intervento di mitigazione/protezione.

I parametri che ci servono sono i seguenti:

- costo dell'opera (15.000 USA \$/ml in Afghanistan);
- vita tecnica dell'opera (50 anni);
- costo di manutenzione annuo (1% dell'investimento).

Se abbiamo 200 metri di strada da proteggere il costo annuo dell'opera sarà di 90.000 USA \$



BC Ratio what is it?

48

In questo esempio abbiamo quindi
 $100.000/90.000 = 1.1$ circa

$B/C > 1 =$ intervento giustificato

Se abbiamo sufficienti elementi è possibile anche calcolare analiticamente la mortalità annua relativa ad un determinato tratto stradale interessato da un fenomeno valanghivo.

In genere tale approccio è utile per confermare il dato registrato o osservato.



BC Ratio what is it?

49

Il calcolo analitico richiede le seguenti informazioni:

- Tempo di ritorno della valanga (in anni);
- Segmento di strada interessato dalla valanga (in Km);
- Velocità media del veicolo che attraversa la zona a rischio (in Km/h);
 - Numero medio di veicoli che transitano in 24 ore;
- Tipologia di veicoli (% di auto, mezzi pesanti, bus);
 - Media degli occupanti per ciascun veicolo.

Questo sostanzialmente è l'approccio europeo.

Nell'approccio canadese e neozelandese

si prende in considerazione anche il caso di blocco del traffico.

Si introduce allora anche il parametro legato alla lunghezza del veicolo e al tempo di attesa previsto per l'intervento di sgombero neve/soccorso.

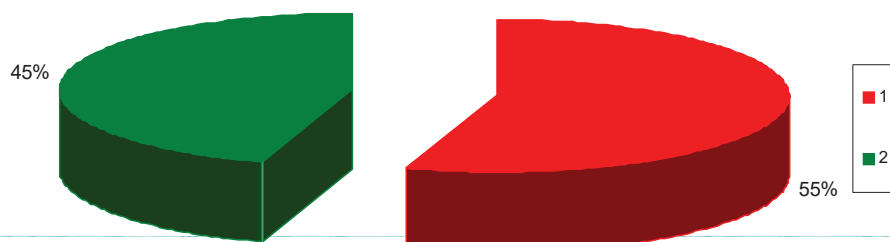
Ciò si riflette su un valore di B maggiore rispetto all'approccio europeo e quindi con risultati più conservativi.



Salang road under study

- 1 = road length prone to avalanche danger in ordinary scenery
2 = road length not prone to avalanche danger in ordinary scenery

50



*Salang road section between km 32+550 and 62+747
(in percentage)*

Red (1) = 16,592 m = 55% (without existing galleries)

Green (2) = 13,605 m = 45%

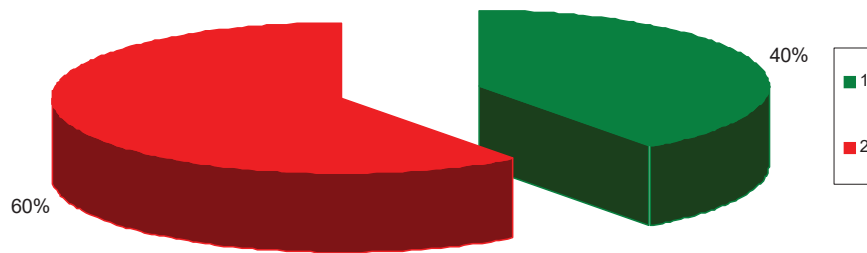
Total = 30,197 m = 100%



Salang road section prone to avalanche danger

1 = critical section protected by existing galleries
2 = critical section prone to avalanche danger in ordinary scenery

51



Salang road section between km 32+550 and 62+747
(in percentage)

Into the 55% of road prone to avalanche danger:

green (1) = 6,632 m = 40%

red (2) = 9,960 m = 60%

Salang tunnel is not taken into account



List of suggested mitigation measures

52

Mitigation measures include one or a combination
of the following solutions

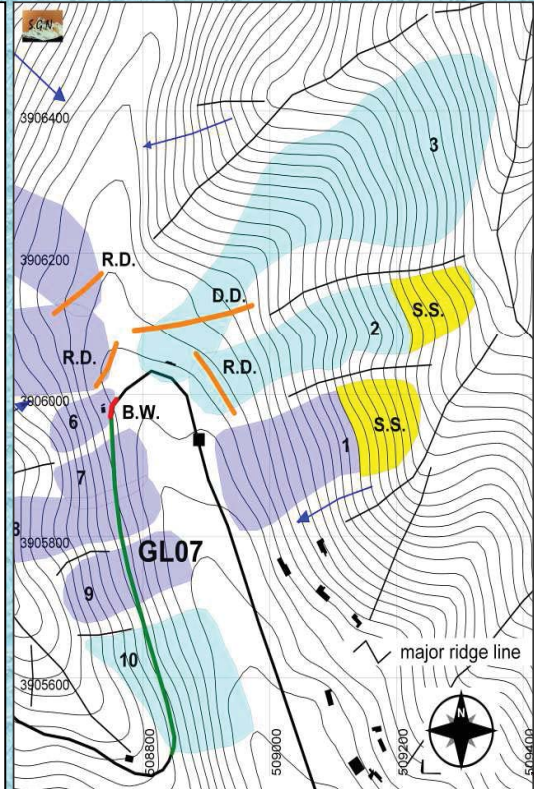
- A) new galleries or extension of existing galleries (GLN);
- B) deflection and retention dams (D.D. – R.D.);
- C) snow supporting structures (S.S.);
- D) breast walls and guide walls (B.W. – G.W.);
- E) snow wind fences (S.W.F.);
- F) artificial avalanche release (A.R.);
- G) automatic weather stations (A.W.S. – F.C.);
- H) emergency shelters (E.S.).





Example of Analysis – Annex 1 – Avalanche sheet reports

Avalanche site (South Salang pass)		Location (UTM coordinates and/or chainage)		Priorita 2	
ID # 02		508871.4549 E – 3905990.5297 N		Priorita 3	
Scenario (HF or LF) and hazard (estimated road length affected by avalanche in meters)			90		
HF (high frequency) = 1-5 y			LF (low frequency) = 5-30 y		
Damage potential description					
Avalanches can reach the road.					
Release area (sq. meter, degree, aspect, m.a.s.l.)					
Mean area	Mean slope	Mean aspect	Mean elevation	Max elevation	
17,000	30	W	2880	2970	
Avalanche site description					
Wide morphological basin with regular terrain. The road location is in the runoff avalanche zone.					
Documented events and source					
No special report on documented events but suggestion of mitigation works (O&M Dpt/MOPW). During on-site visit (April 2019) the road maintenance service confirmed avalanche occurrence coming from this avalanche site.					
Existing protections/mitigation measures					
Not existing					
Suggested protections/mitigations works by S.G.N.					
Construction of a retention dam in the last part of the slope, close to the road and snow supporting structures in the upper release area to reduce the volume of potential avalanche and to minimize the probability for avalanche to reach the road in high frequency events.					
Mitigation works, design recommendations and approximate cost (US\$)					
Retention Dam (priority 2)					
Topographic survey in the runoff zone where the dam is foreseen.					
Geological/geotechnical survey to detect nature of the soil and morphology.					
Location of the northern start of the dam (UTM coordinates and elevation): 508883.1691E – 3906057.7168N – 2748 m.					
On-Site check to establish and calibrate the best location and the transect of the dam.					
It's possible to foresee a length of about 100 meters for the retention dam.					
Design recommendations:					
H max = 10-12 m					
V = 170 mc/ml = 170 x 100 = 17,000 mc (estimated)					
Estimated cost: 10/mc = 10*17,000 = 170,000					
Remodelling of the morphology in the uphill side of the slope, behind the dam to create a basin.					
Snow supporting structures (priority 3):					
Topographic survey in the release area for planning the correct alignment of the structures and the number of rows in accordance to the Switzerland guidelines.					
Geological/geotechnical survey in the release area to define the nature of the soil.					
Snow supporting structures can be in rigid steel or in ring nets (snow-net).					
Design recommendations:					
for the height of the structures we suggest to assume a reference HK=400 cm for a return time of 50 years.					
It's possible to foresee about 300 meters of snow supporting structures in 6-7 rows.					
It's better that each row doesn't exceed 80-100 meters in length. Otherwise provide for an interruption.					
Estimated cost: 1,500/m = 1,500*300 = 450,000					
Comment					
The topographic survey for snow supporting structures must be extended to the main ridges around and up the release zone. It's better to realize first the retention dam and only after the snow supporting structures, so it's possible to observe the effect of the R.D. on the avalanche occurrence in ordinary scenery.					
It's possible to use here snow supporting structures with only one anchorage, like snow umbrella structures with a Dk=3.60 m					



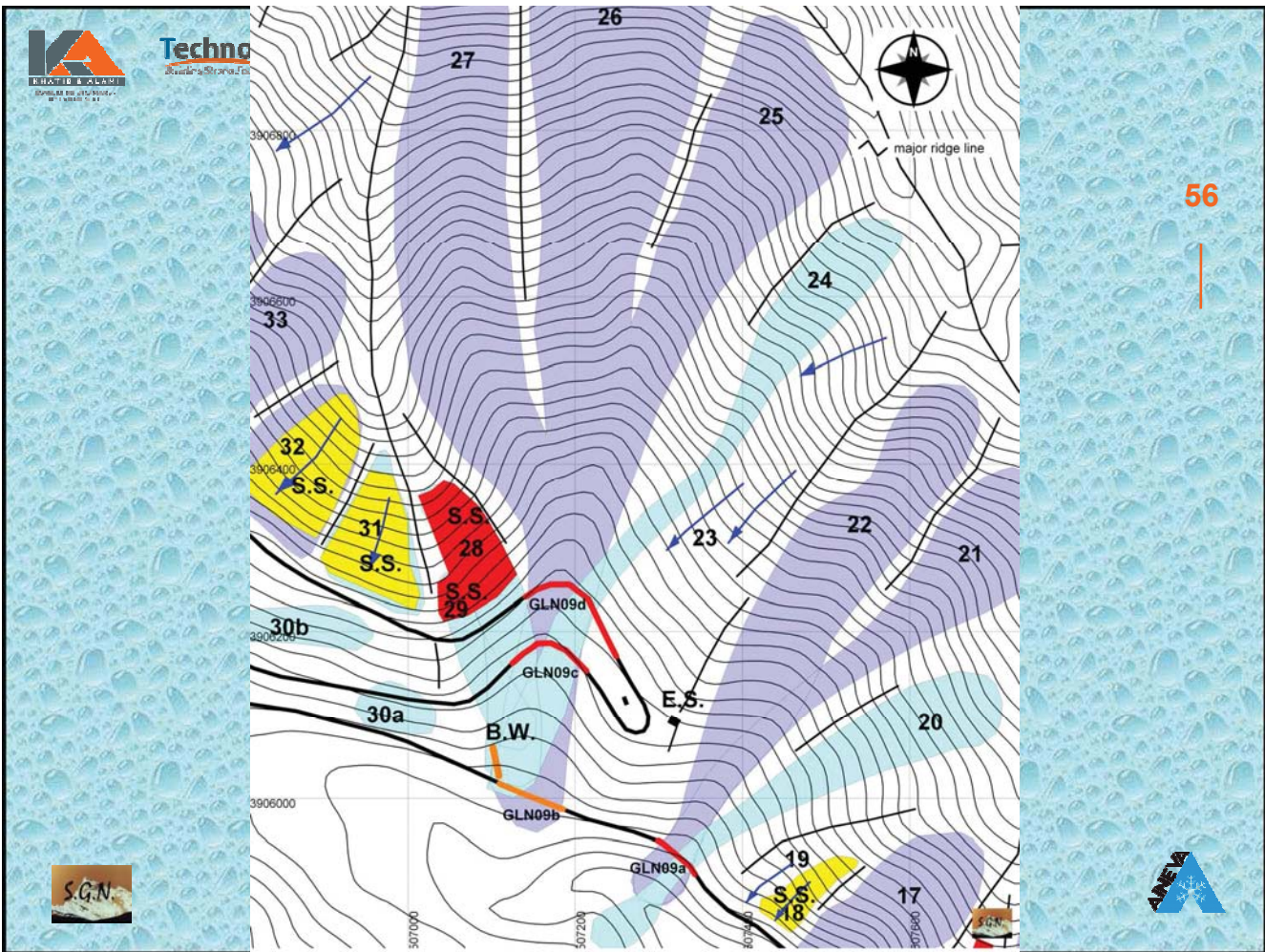
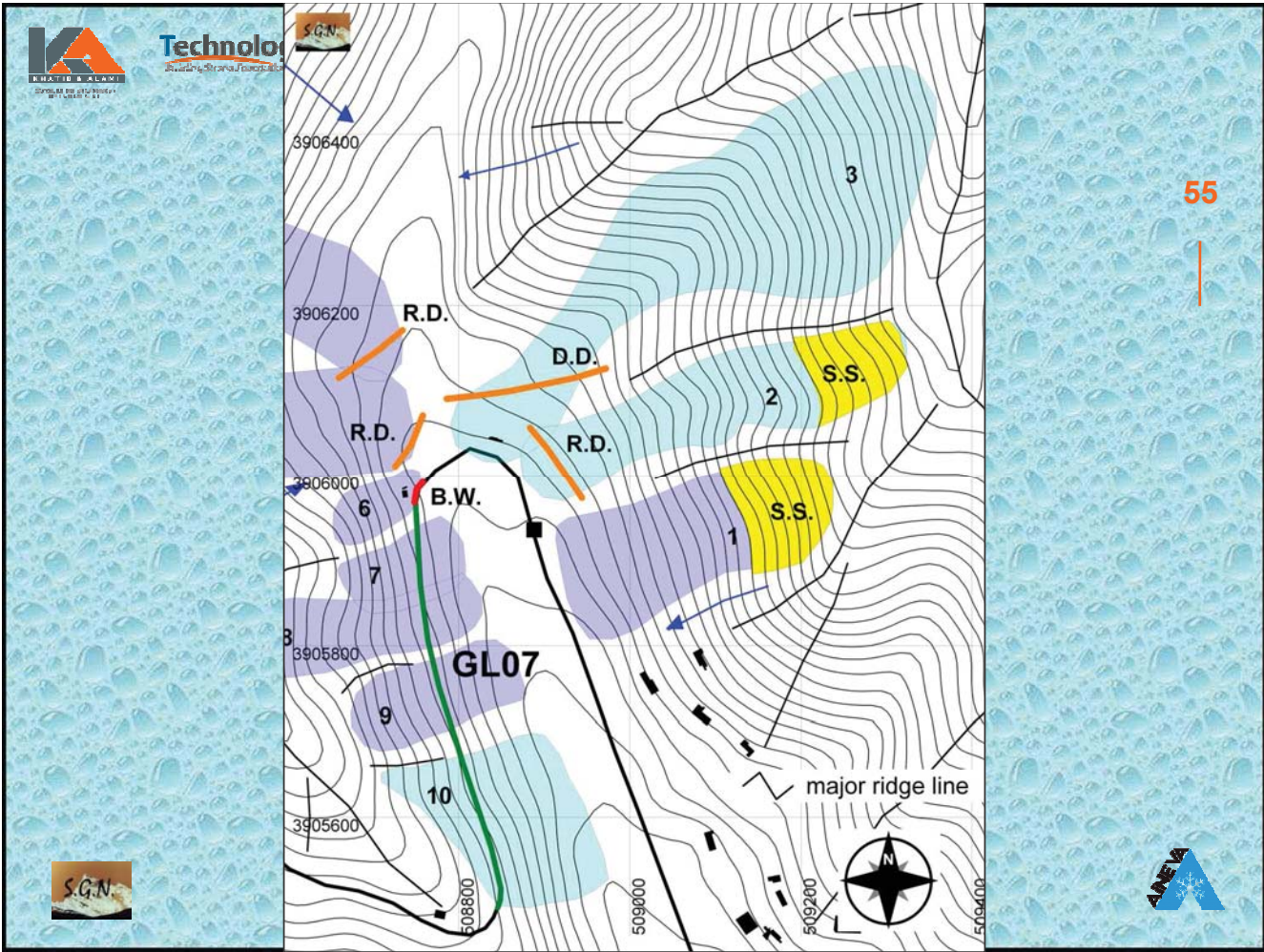
53

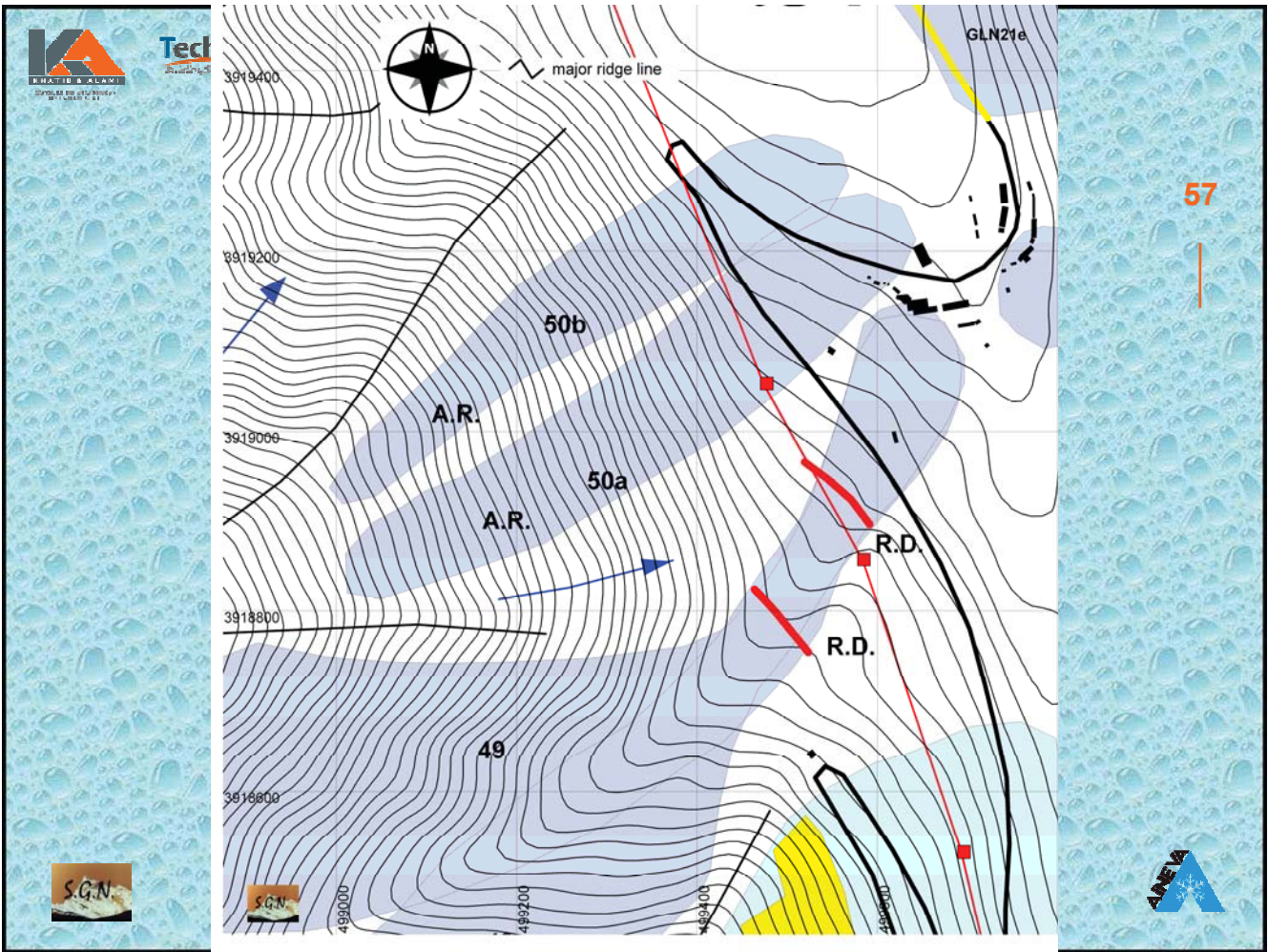


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17,000	30	W	2880	2970	
Avalanche site description					
Wide morphological basin with regular terrain. The road location is in the runoff avalanche zone.					
Documented events and source					
No special report on documented events but suggestion of mitigation works (O&M Dpt/MOPW). During on-site visit (April 2019) the road maintenance service confirmed avalanche occurrence coming from this avalanche site.					
Existing protections/mitigation measures					
Not existing					
Suggested protections/mitigations works by S.G.N.					
Construction of a retention dam in the last part of the slope, close to the road and snow supporting structures in the upper release area to reduce the volume of potential avalanche and to minimize the probability for avalanche to reach the road in high frequency events.					
Mitigation works, design recommendations and approximate cost (US\$)					
Retention Dam (priority 2)					
Topographic survey in the runoff zone where the dam is foreseen.					
Geological/geotechnical survey to detect nature of the soil and morphology.					
Location of the northern start of the dam (UTM coordinates and elevation): 508883.1691E – 3906057.7168N – 2748 m.					
On-Site check to establish and calibrate the best location and the transect of the dam.					
It's possible to foresee a length of about 100 meters for the retention dam.					
Design recommendations:					
H max = 10-12 m					
V = 170 mc/ml = 170 x 100 = 17,000 mc (estimated)					
Estimated cost: 10/mc = 10*17,000 = 170,000					
Remodelling of the morphology in the uphill side of the slope, behind the dam to create a basin.					
Snow supporting structures (priority 3):					
Topographic survey in the release area for planning the correct alignment of the structures and the number of rows in accordance to the Switzerland guidelines.					
Geological/geotechnical survey in the release area to define the nature of the soil.					
Snow supporting structures can be in rigid steel or in ring nets (snow-net).					
Design recommendation:					
for the height of the structures we suggest to assume a reference HK=400 cm for a return time of 50 years.					
It's possible to foresee about 300 meters of snow supporting structures in 6-7 rows.					
It's better that each row doesn't exceed 80-100 meters in length. Otherwise provide for an interruption.					
Estimated cost: 1,500/m = 1,500*300 = 450,000					
Comment					
The topographic survey for snow supporting structures must be extended to the main ridges around and up the release zone. Specific avalanche simulation are required.					
It's better to realize first the retention dam and only after the snow supporting structures, so it's possible to observe the effect of the R.D. on the avalanche occurrence in ordinary scenery.					
It's possible to use here snow supporting structures with only one anchorage, like snow umbrella structures with a Dk=3.60 m but a winter calibration is recommended.					

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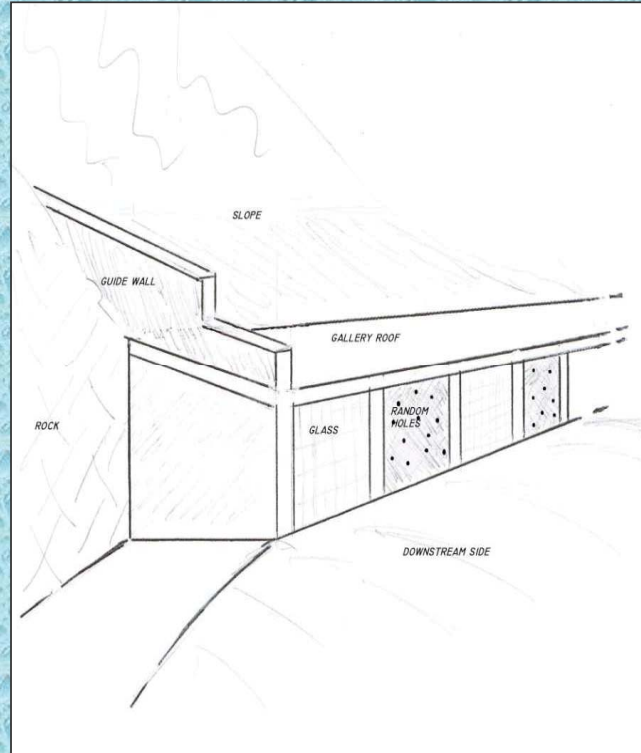
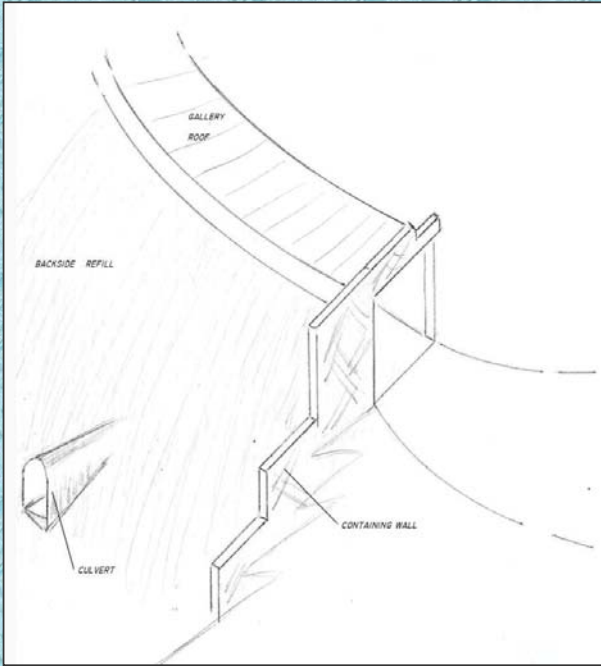
Technologists inc
 Ingegneria Strutturale e Geotecnica

Suggested mitigation measures (gallery and deflection/retention dams)

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Suggested solution for drifting snow and daylight



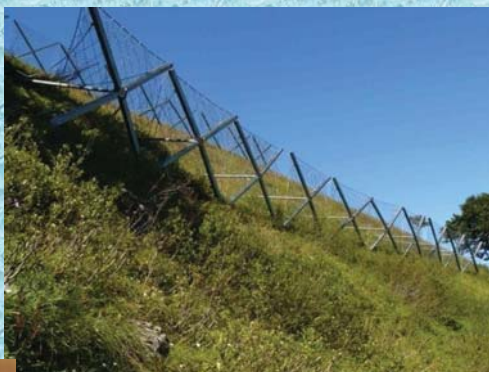
Exemple of culvert in the backside gallery refilling



Suggested mitigation measures (S.S.S.)

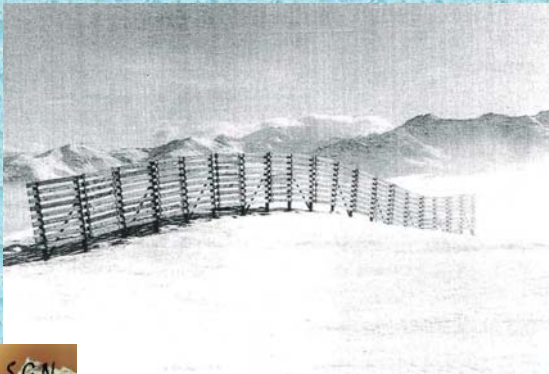
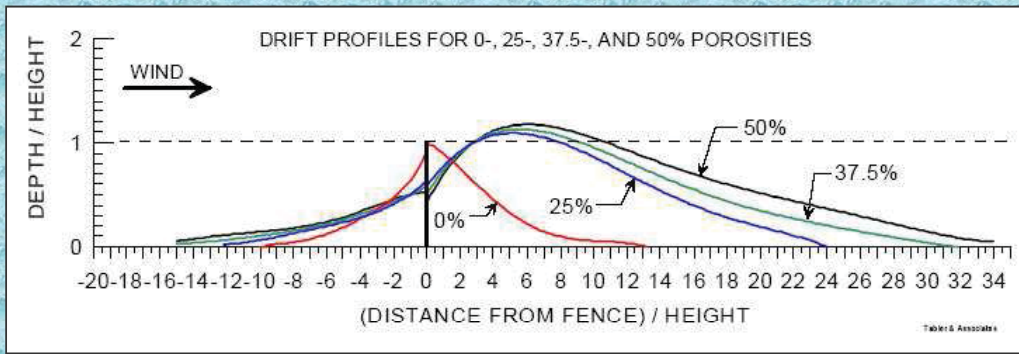


60



Suggested mitigation measures (snow wind fences and porosity)

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S.G.N.



ANETA

Suggested mitigation measures (breast wall)

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S.G.N.

ANETA

Suggested mitigation measures (Gaz.Ex. – Automatic Weather Station)



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S.G.N



Suggested mitigation measures (Emergency Shelter) – Salang Road



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S.G.N



on site visit

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to calibrate the preliminary data elaboration
supported by RMS

limitations

mainly due to time constraints
to limited mobility
and sometimes to unclear or unknown informations



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Salang Road – South side





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Salang Road – South side



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Salang Road – North side





69



Salang Road – North side



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Salang Road – North side





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Salang Road – North side



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Salang Road – North side

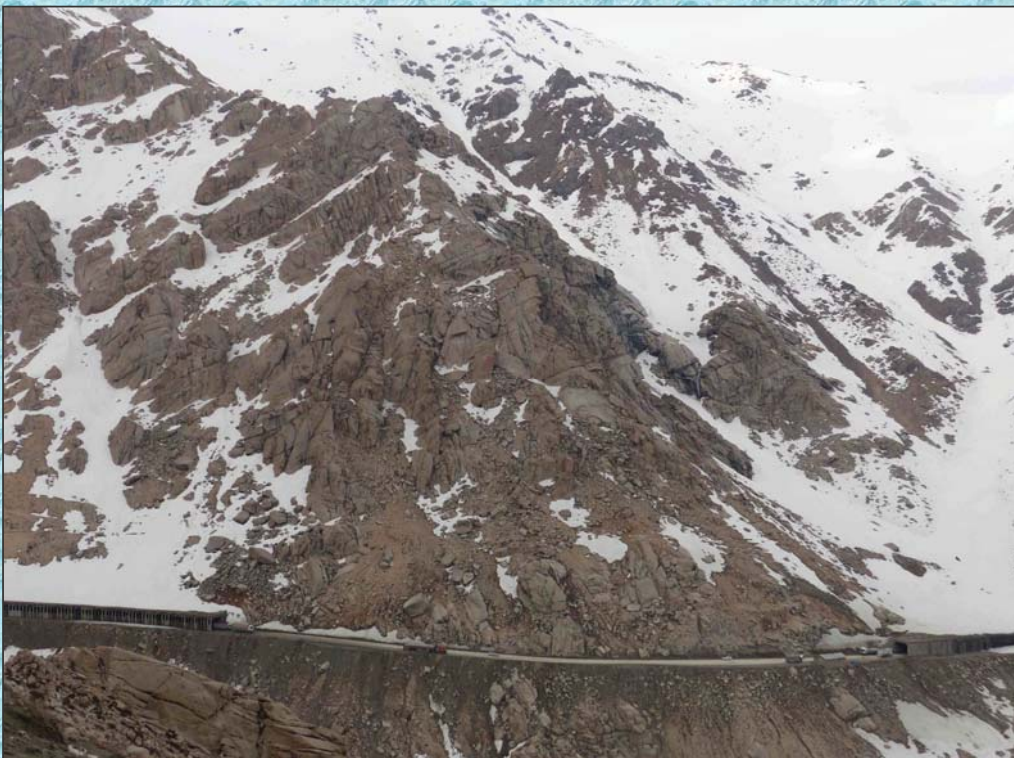




73



Salang Road – North side



74



Salang Road – South side





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Salang Road – South side



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Salang Road – South side





77



Salang Road – South side



Final suggested strategies

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Year 1-2

- Rehabilitation of existing road, galleries and tunnel;
- Implementation of the warning avalanche service (to manage temporary avalanche mitigation measures, as the artificial avalanche release and snowstorm forecast, as far as extreme local meteorological situations);
- Installation of automatic weather stations (**priority 1**);
- Rehabilitation of emergency shelters (**priority 1**);
- Construction of the critical connections between the existing galleries and some extensions of the existing ones, as foreseen in the avalanche study (**priority 1**);
- Check for avalanche sites that require additional snow data and information taking into account also the mobile artificial release.



Final suggested strategies

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Year 3-5

- New check and reassessment of the other suggested mitigation / protection works, based on new data and additional information acquired by artificial mobile release and by new Automatic Weather Stations and by the avalanche warning service, for a final decision on construction of other mitigation / protection works envisaged in priorities 1 and 2.



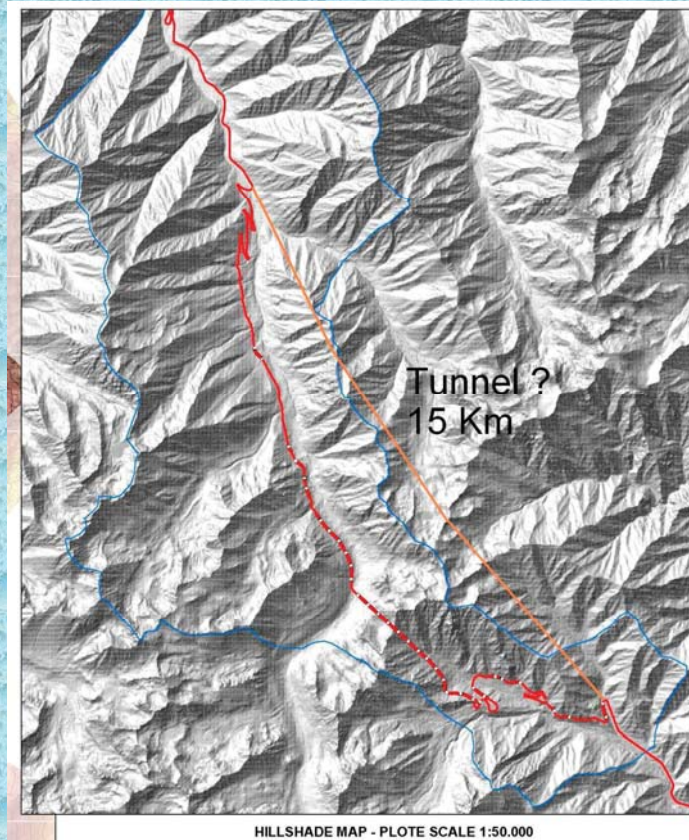
Conclusions

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Suggested strategies will surely remarkably reduce of about 50% the casualties for avalanche accidents along the Salang Road. This could be a good compromise to minimize the negative economic and social consequences.

At the same time and as a long term goal, we also suggest to carry out a feasibility study about the possibility to build a long tunnel (15 Km), that would solve definitely the avalanche problems in the most critical Salang Road section.





HILLSHADE MAP - PLOTE SCALE 1:50.000

THANK YOU

*Per eventuali approfondimenti
sugli aspetti progettuali delle gallerie
e sui parametri di calcolo
si rimanda all'articolo
pubblicato sulla rivista AINEVA n.94*