3. Specific Concerns

Engineering Geology

Several structures in mountainous regions have experienced problems because of inadequate engineering-geological inputs in terms of subsurface explorations and designs developed to match the natural processes. Before discussing examples of major problems encountered in the past, it would be useful to focus on mass wasting as recorded in Tables 1 to 13.

Table 1 describes the Himalayan System, Table 2 provides a classification of the problems of mass wasting, Table 3 shows the power of flowing water, Table 4 provides some examples of exceptionally heavy rainfall and devastating landslides that took place in India, Table 5 lists landslides in China that have killed at least 100 people, Table 6 is a list of the principal natural hazards in the Nepal Himalayas, Table 7 lists some of the most devastating earthquakes that have taken place in the Himalayan region, Table 8 lists historic earthquakes of great magnitude and effects that have taken place in Southwest China, Table 9 shows some historical earthquake events in Nepal, Table 10 shows the maximum points of 10 major rainfall events that have taken place in China, and Tables 11 to 14 record rainfall and landslide occurrences that have taken place in China.

In Nepal, a preliminary study by Karmacharya in 1989 showed that there were 176 reported cases of significant landslides in the period from 1970 to 1989. The study showed a yearly toll of 78 people dead and 100 houses destroyed. A study by Laban in Nepal (1979) showed that 47 per cent of mass movements are geological or of natural occurrence, and that the other 53 per cent of mass movements are caused by man. Therefore, conservation programmes would be best oriented to preventing or mitigating the negative impacts of grazing, terrace management, and road construction.

The following is an account of some of the main problems associated with infrastructures in the mountains.

In China, 2,136 slope failures, that occurred from 1954 to 1957 along the 848 km Baoji-Chengdu Railway, entailed renovation costs of about US $ 2,200 million (July 1987). From 1974 to 1976, more than 1,000 landslides along China's railway lines gave rise to a need of approximately US$ 2 billion for stabilisation (Li Tianchi 1990). Nine hundred and sixty-three slope failures in 1980 in southwestern China: i) interrupted railway transportation for a total of 1,565 hours; ii) resulted in direct losses of at least US$ six million, iii) led to US$ three million in costs of interrupted transportation, and iv) necessitated repair costs at US$ nine million (Li Tianchi 1990).

Similarly, in 1984, about 3,244 landslides and debris flows damaged the main highways in Would and Tianshui prefectures and destroyed 45 per cent of the bridges and culverts (Li Tianchi 1990).

In China, there were 238 railway tunnels, totalling 89 km, between 1949 and 1989. By 1989 only 191 tunnels of a total length of 23km were remaining, and the rest of the tunnels were abandoned. Since 1956, an average of 100 km of railway tunnel has been constructed each year, 154 tunnels so far have been greater than two km long, ten are longer than five km, and the largest is seven km (Chen Cehngzong n.d.).

Table 1: The Himalayan System

Group	Relief	Description
The Sub-Himalayas or Siwaliks (600m to 1,200m)	A succession of dissected hills, mostly with flat summits, forming the southernmost part of the foothills. They are characterised by a zone of intense landslides and mass wasting.	Comprised of soft tertiary sediments, sandstones, silt stones, shales, and clays prone to disintegration. It experiences the full force of the monsoon. The Siwalik Range is still thickly vegetated.
The Middle or Lower Himalayas (1,200m to 3,000m)	A tangled mass of ranges and valleys, with major rivers cutting across it, sometimes through deep gorges. It lies immediately to the north of the Main Boundary Thrust (MBT) where the Siwalik belt ends and falls in the medium to high relief zone.	This is a para-autochthonous zone consisting largely of unfossiliferous rocks. The northern slopes are gentler, densely forested, colder, and not much inhabited. The southern slopes are steep, bare, and gullied, comprised essentially of sedimentary rocks subject to weathering. Deforestation, overgrazing, and impact of the monsoon are the chief causes of denudation and mass wasting.
The Higher Himalayas (average height=5,200m; -92 peaks over 8,000m)	Lies north of the Main Central Thrust (MCT) and is characterised by a high relief zone of glaciation.	They are characterised by the serrate nature of the mountains with abundant sharp-edged features and a discordant drainage system. Comprised of granitic gneisses and other crystalline rocks. Slopes are mostly bare with debris cones and moraine walls at their base. Avalanches are recognised as a major hazard.
The Trans Himalayas (avg. altitude 4,500)	Tibetan marginal land. High altitude passes between India & Tibet are located in this region.	They are composed of fossiliferrous sediments from the pre-Cambrian to Cretaceous or even the Tertiary periods. The principal rocks include slate, sandstone, conglomerates, and limestone.

Source: Bhandari 1987

Table 2: Classification of the Problems of Mass Wasting

	Class	Problem	Effect	Economics of Control Measures and Efficiency
A.	Catastrophes	Simultaneous triggering of several landslides & other mass movements following 'cloudbursts', 'flash floods', and tectonic activity. Includes fresh slides as well as reactivation of old ones.	Landslides and breaches often create river blockades, landslide dams, and lakes. Damage is spectacular and ground movements extensive and large scale.	Problem often faced as it comes. Control measures require very heavy techno-economic inputs which are rarely available. Palliative measures are only partially effective.
B.	Repetitive slide & mass movements	Major old landslides, particularly if left neglected, enlarge themselves to assume formidable proportions. The problem is less severe for slides already in a treated state before reactivation	Slope movements are sudden, extremely large, and the ensuing subsidences usually of a very high order. Drainage of the area is severely impaired & susceptibility to erosion increases.	Massive haulage of earth and protection works essential and efficiency of the latter is intimately related to the appropriateness & adequacy of control measures and their timely execution.
C.	First time or fresh slides & mass movements	Problems on cuttings are more severe than those on natural slopes. Slides often involve subsidence at the 'crown' & heave at the toe. Planar slides are also common in certain geological formations.	Virgin natural slopes usually retain vegetation cover. Toe, rear scar, and side shear boundaries can generally be identified. Mudflows cut across colluvium.	A 'stitch in time' can generally save the slope at a nominal cost. Drainage deserves special emphasis. Vegetation should be restored to certain surface erosion problems.
D.	Block-slides & Rockfalls	Shooting boulders hurtle down the slopes and the ensuing noises trigger mass movements.	Destroys bridges, roads, and communication systems.	Often requires detouring, tunnelling, anchoring, etc, which are expensive.
E.	Creep Movement	Does not pose any serious problem.	Tilts trees, buildings, etc.	No attempts are made to arrest creep movements.

Source: Bhandari 1987

Table 3: Power of Flowing Water

Transported Rock Fragments	Size* (mm)			Velocity of Flowing Water (m/s)
Fine Sand	0.425	-	0.075	0.3
Coarse Sand	4.75	-	2.0	0.6
Fine Gravel	20.0	-	4.75	1.0
Coarse Gravel	80.0	-	20.0	1.2
Cobble	300.0	-	80.0	2.4
Boulders	> 300.0	-		> 3.0

(* IS:1498-1970)
Source: Bhandari 1987

Table 4: Exceptionally Heavy Rainfall and Devastating Landslides

Place/Area	Date	Consequences of Heavy Rainfall
Darjeeling & Jalpaiguri	3-5 Oct 1968	Widespread landslides & other mass movements caused death and devastation all over.
Uttar Pradesh	July 1970	The Alaknanda River caused considerable loss of life among pilgrims. Many bridges, houses, and an entire village were washed away.
do	Sept. 1970	Landslides and house collapses killed 223 people
Jammu & Kashmir	Feb. 1971	Widespread landslides caused disruption of traffic & communication systems.
do	Aug. 1972	Widespread landslides causing damage to life and property.
do	March 1973	Landslides cut off Kashmir Valley from the rest of the country.
Shimla (H.P.)	July 1973	Landslides cut off Shimla from the rest of the country.
North Bengal	July 1975	The Teesta, Jalldhaka, and Diana rivers were in spate. Widespread landslides and floods rendered 45,000 people homeless.
Jammu & Kashmir	Sept. 1975	Landslides killed 2 labourers and disrupted the transportation system for 3 days.
Darjeeling	June 1976	The Teesta in flood, triggering many landslides, 3 people were buried alive due to a hillock caving in.
Jammu & Kashmir	July 1977	Srinagar-Leh road was blocked due to landslides.

Source: Bhandari 1987

Table 5: Landslides in China That Have Killed At Least 100 People

No	Year	Province	Affected Area	Type of Slope Failure	Number of deaths
1	BC 186	Gansu	Would	Rock and debris avalanche	760
2	100	Hubei	Zhigui	Rock and debris avalanche	> 100
3	1310	Hubei	Zhigui	Rock and debris avalanche	3,466
4	1558	Hubei	Zhigui	Rock and debris avalanche	> 300
5	1561	Hubei	Zhigui	Rock and debris avalanche	> 1,000
6	1718	Gansu	Tongwei	Earthquake-induced landslide	40,000
7	1786	Sichuan	Luding	Flood resulting from landslide-dam-failure	100,000
8	1847	Quinghai	Beichuan	Loess and rockslide	Hundreds of deaths
9	1856	Sichuan	Qianjiang	Rockslide induced by earthquake	> 1,000
10	1870	Sichuan	Batang	Rockslide induced by earthquake	> 2,000
11	1897	Gansu	Ningyuan	Loess and rockslide	> 100
12	1917	Yunnan	Daguan	Rockslide	1,800
13	1920	Ningxia	Haiyuan	Loess landslide induced by earthquake	100,000
14	1933	Sichuan	Maowen	Flood resulting from landslide-dam failure	2,429
15	1935	Sichuan	Huili	Rock and debris slide	250
16	1943	Quinghai	Gonghe	Loess and mudstone	123
17	1951	Taiwan	Tsao-Ling	Flood caused by landslide-dam failure	154
18	1954	Xizang	Jiangzhi	Flood caused by glacier-dam failure	450
19	1964	Gansu	Lanzhou	Landslide and debris flow	137
20	1965	Yunnan	Luguan	Rock landslide	444
21	1966	Gansu	Lanshou	Landslide and debris flow	134
22	1972	Sichuan	Lugu	Debris flow	123
23	1974	Sichuan	Nanjiang	Landslide	195
24	1975	Gansu	Zhuanglong	Loess slide caused flooding along the shore of the reservoir and downstream	> 500
25	1979	Sichuan	Yaan	Debris flow	114
26	1980	Hubei	Yunnan	Rockslide and avalanche	284
27	1983	Gansu	Tongxiang	Loess landslide	277
28	1984	Yunnan	Yinmin	Debris flow	121
29	1984	Sichuan	Guanue	Debris flow	> 300
30	1987	Sichuan	Wushan	Rock avalanche	102

Source: Li Tianchi 1990

Table 6: List of Major Natural Hazards in the Nepal Himalayas

YEAR	
1934	Earthquake in Bihar and Nepal
1964	Glacial lake outburst flood along the Arun River
1968	Rockslide on 5th March and blocking of the Budhi Gandaki River # a second landslip on 17th July # a third landslip causing a flood of 5,210 cumecs on 1st August
1969	Floods along Gandak
1971	Floods along Gandak
1974	Rockslide and damming of Ankhu *Khola* at Labu *bensi* and washout of Arughat bazaar
1977	Glacial lake outburst of Nare Drangka below Amadablam
1980	Bhajang earthquake
1980	Glacial lake outburst and flood in Tamor
1981	Glacial lake outburst in head region of Bhote Sunkoshi
1981	Glacial lake outburst flood in the Barun *Khola*
1981	Damming of the Tinau River and consequently a washout downstream
1985	Glacial lake outburst of Dig Cho and washout of Namche hydropower station
1986	Rockslide and flash flood on Gandak *Khola* on 30th June
1987	Flood along the Sunkoshi River and damage to the powerhouse
1988	Flood in eastern Nepal

Source: Sharma 1988

Table 7: Devastating Earthquakes in the Himalayan Region

Place and Epicentre	Date	Richter Magnitude	Damage
Kashmir(India) (34.6°N, 4.4°E)	30 May 1885	7	Felt for over 11,000 sq.miles; 6,000 people were killed
Assam* (India)	12 June 1887	8.7	Felt for over 25,000 sq.miles; Landslides, flowslides, and ground subsidence were widespread
Kangra (India) (32.2°N, 76.5°E)	4 April 1905	8	Felt for over 1.625 million sq.miles; 2,000 people were killed
Quetta (Pakistan) (30.2°N, 67.7°E)	24 Aug. 1931	7.8	Many buildings and a railway bridge were destroyed
Nepal (26.6°N,86.8°E)	15 Jan. 1934	8.3	Extensive landslides, collapse of buildings, lateral ground spreading, ground settlement, and sand boils over an area of 4,320 sq.miles
Assam (India) (30.5°N,91.5°E)	15 Aug. 1950	8.5	Felt for over 0.42 million sq.miles; caused extensive landslides and rockfalls, fissures, and sand boils, resulting in collapse of buildings, roads, bridges, etc
Lhasa(Tibet) (30.5°N, 91.5°E)	17 Aug. 1952	7.5	55 people were killed and 157 injured; 850 buildings were destroyed
Srinagar (India)** (33.9°N, 74.7°E)	2 Sep. 1963	5.3	79 people were killed and 400 injured
Kinnaur(India)	19 Jan. 1975	6.8	Huge boulders hurtled down the hill slopes resulting in widespread damage to life, property, and the communication system

* Earthquakes also occurred in 1923, 1930, 1947, and 1957

** An earthquake also occurred in 1921.

Source: Bhandari 1987

Table 8: Historic Earthquakes of Greater Magnitude and Effects in Southwest China

Date	Approximate Epicentre	Magnitude	Effects
February 26 1713	Xundin (Yunnan)	6.5	Ground fissures, many slumps and shallow slides in the upper watershed of Xiao River.
August 2 1733	Donghuan (Yunnan)	6.75	A fault rupture 100 km long. Many landslides; one large landslide buried a village on the Daqiao River killing 40 people.
October 10 1786	Kangding-Luding (Sichuan)	7.5	Many landslides along the Dadu River and its tributaries. One huge landslide dammed the Dadu River for 10 days, causing a great flood downstream.
February 6 1973	Luhuo (Sichuan)	7.6	More than 200 landslides, a 20 km highway destroyed by landslides and rockfalls.
May 11 1974	Zhaotong (Yunnan)	7.1	Extensive rockfalls, slumps, and slides.
May 29 1976	Longling (Yunnan)	7.4	Extensive shallow slides and slumps in weathered granite rocks.
August 16 1976	Songpan (Sichuan)	7.2	170 landslides, created 3 land-slide-dam-lakes.

Source: Li Tianchi 1990

Table 9: Historical Earthquake Events in Nepal

Kathmandu:	1255	King Abhaya Malla's reign (1216-1255 AD). Many houses and temples collapsed, killing one-third to one-fourth of the population in Kathmandu Valley.
	1681	During King Sri Nibas Malla's reign, many houses collapsed.
	1833	August 26, intensity X (M.M.), time 11 pm. Symptom: land noises like artillery shots. Result: More than 100 houses levelled in a moment. Direction of motion: East-West.
	1833	October 4, intensity IX, lasted half a minute and destruction was as bad as that of 26 August.
	1833	October 18, intensity VIII
	1869	July 7, intensity X: tremendous shock in Kathmandu, a large portion of the population buried in the ruins.
	1934	January 15, intensity X in magnitude ------ 3,400 people died in the Kathmandu Valley alone.
	1966	May 23, intensity VIII. Event: A terrible shock: destroyed a large portion of the town.

Sources: Rana 1935 & Pandey and Chitrakar 1986

Table 10: The Maximum Points of the 10 Major Rainfalls in China

No	Location Province	Station	Date	Rainfall in mm			
				6 hrs	24 hrs	3 days	7 days
1	Jiangxi	Lu Sahan, Zhiwuyuan	Aug 17 1953		900	1073	
2	Guangdong	Taishan Zhenhai	July 12 1955	386	851	949	972
3	Guangdong	Dianbai Lidong	May 20 1957	281	858	1030	1234
4	Jiangsu	Rudong Chaoquiao	August 4 1960		822	934	
5	Hebei	Neigiu Zhang	August 4 1963	426	950	1456	2051
6	Taiwan	Taoyuan Peishih	Sept. 10-11 1963		1248	1794	
7	Taiwan	Yilan Heinliao	October 17 1976		1672	2749	
8	Henan	Biyang Linzhuang	August 7 1975	830	1060	1065	1631
9	Guangdong	Haifeng Baishinen	May 30 1977	460	884	1222	1513
10	Nei Monggol	Uxin Qui Muduo	August 1 1977		1400		

Source: Li Tianchi 1990

Table 11: Characteristic Values of Rainfall during Landslide Occurrence in Sichuan Basin (July 1982)

Location	Rainfall up to the time a landslide occurred		Rainfall up to the time landslides occurred in large numbers	
	Cumulative	Daily Rainfall (mm)	Cumulative	Daily Rainfall (mm)
Zhongzian	139.0	139.0	289.7	138.2
Yunyang			277.7	205.6
Kaixian	53.4	51.4	280.8	153.8
Liangping	177.0	177.0	289.7	102.3
Fengdu	99.0	88.0	-	-
Fengjie	113.7	47.9	218.9	10.1

Source: Li Tianchi 1990

Table 12: Typical Landslides Induced by Rainfall in Eastern Sichuan Basin (July 1982)

Name of Landslide	Location	Time Month Day	Volume (10^6m^3)	Lithology	Cumulative Rainfall (mm)	Daily Rainfall (mm)
Nanzhuba	Fengdu	7.16	0.70	mudstone	90.0	88.0
Shank	Zhougxian	7.17	18.00	mudstone	310.8	171.8
Yijian	Zhougxian	7.17	2.80	mudstone	310.8	171.8
Jipazi	Yunyang	7.18	13.00	debris	331.0	164.1
Tinabo	Yunyang	7.17	6.20	mudstone	345.7	101.6
Geling	Yunyang	7.17	9.50	mudstone	345.7	94.9
Baigou	Fengie	7.16	1.20	debris	138.3	58.5
Guadouzai	Liangping	7.28	5.62	debris	210.5	83.2

Source: Li and Li 1985 in Li Tianchi 1990

Table 13: Precipitation Levels Triggering Landslides in Gansu Province

Location	Time Day, Month, Year	Lithology	Rainfall in the Early 10 Days (mm)	Daily Rainfall (mm)
Tianshui	21.7.1978	Loess	82.9	200.0
Huixian	21.8.1981	Mudstone	284.0	120.0
Tianshui	3.8.1984	Loess	63.1	52.7

Source: Li and Li 1987 in Li Tianchi 1990

Table 14: Rainfall Thresholds for Rainfall Triggered Landslides in Different Rocks in China

Types of Landslides	Rainfall Intensity (mm/h)	Daily Rainfall (mm)	Cumulative Rainfall in One to Two Days (mm)
Small landslide of debris and loess	6.0	50.0	50-100.00
Medium landslide of debris and loess and fractured rocks	10.0	120.0	150.0-200.0
Large landslide of debris and bedrocks	15.0	150.0	>250.0

Source: As above

In northern Guatemala, a newly-paved 40 mile mountainous stretch of the Inter-American Highway was closed by landslides one week after the formal inauguration in 1957 and has since never reopened (Kojan 1978).

A detailed account of mountain road failures in Nepal from 1979 to 1993 is presented in Chapter 4. It is seen that more than 2.5 billion rupees worth of loss along these road sections has been incurred during this period.

The 806 km long Karakoram Highway, commencing from Hassanabad (475 masl) and ending at Khunjrab on the Pakistan-China border at 5,000masl has experienced numerous landslides every year.

Environmental Concern

Loss of land and topsoil caused by accelerated human activities has been the main environmental concern in mountain regions. Massive cutting of the mountain slopes and disposal of the cut material downhill in an uncontrolled manner; uncontrolled blasting of rock in large quantities for road cutting, quarrying, and mining activities; and improper water management in mountainous terrain has resulted in intensive soil loss from accelerated erosion, gullying, and landslides. Temporary benefits in one infrastructural activity have added costs either to other infrastructural activities or to the infrastructure itself. The narrow perspective of benefits often ignores the impending disasters and irreversible losses. Every kilometre of road, when constructed, may bring about a stress relief equivalent to about 100,000 to 200,000 tonnes of rock mass. An additional 1,000 tonnes of land loss from rockfalls and landslides may be added per kilometre annually in the case of unprotected cut slopes.

Experiences in northern Sikkim and Garwal in India indicate that there are two landslides every square kilometre with an additional one every six square kilometre. The mean rate of loss is in the tune of $120m^2$ per km^2 per year. The annual loss of land is about 2,500 tonnes for every square kilometre in area (Bhandari 1987).

In Nepal, in the author's experience, it is estimated that 400 to 700 cubic metres of landslides occur per kilometre per year along the mountain roads, and 3,000 to 9,000 cubic metres of landslides occur per kilometre during the construction of mountain roads in Nepal.

Soil loss is estimated at 2.87 tonnes per hectare per year in the northern Himalayan forests, whereas up to 150 tonnes per hectare per year of soil are estimated to be lost from the poorly constructed roads.

Tables 15 to 18 show sediment loads, denudation rates for Nepalese rivers, and the accepted rate of tolerable soil loss.

In Kaghan Valley and on the Karakoram Highway in Pakistan, the United Nations sponsored a very large watershed management scheme and planted millions of trees. It has not only brought about stability to slide-prone areas but has also helped immensely in checking the erosion of topsoil. This scheme has also helped increase the lifespan of the Tarbela and Mangla dam reservoir.

Figure 1 shows an eroded and cultivated landscape and Figure 2 depicts an assessment of a man-environment system. Figure 3 shows the factors causing slope stability problems and gives a common prescription for their control. Figure 4 depicts the factors causing slope stability problems and gives common treatments. Figure 5 is a schematic illustration of the pattern of interaction between man and nature in the Usambara Mountains in Tanzania. A rough calculation of the landslides and soil loss caused by mountain road construction in Nepal, as per Annex 1, based on the author's experience, shows that about 8,000 MT/ha/yr of soil loss can occur as a result of careless construction of a mountain road and, similarly, 100 MT/ha/yr of soil loss occurs as a result of careless maintenance of a poorly-constructed mountain road.

Table 15: Karnali River Sediment Load (million tonnes/year)

Types of Sediment	Nippon Koei 1966	S.M.H.A.*	Norconsolt electrowatt 1976	HPC# 1988
Suspended load	93.5	137	101	
Bedload	0	13	25	---
Total Sediment	93.5	150	126	170

Notes: (The Sediment loads of the Narayani River at Bainslotan and the Kosi at Barahchetra are 170 and 177 million tonnes per annum respectively).
The above sediment load is roughly equivalent to 1 mm removal of topsoil per year.

*: Snowy Mountain Hydroelectric Authority
#: Himalayan Power Consultants

Source: Sharma 1988

Table 16: Denudation Rate in the Sunkoshi Basin, Nepal

River	Rate of denudation mm/yr	Area of basin in sq.km.	Average sediment contribution over watershed T/ha/yr
Sapta Koshi	2.56	5,770	38
Sunkoshi	1.43	18,985	21
Arun	0.57	34,525	7.6
Sapta Koshi	1.00	59,280	15

Source: Sharma 1988

Table 17: Sediment Load in Nepalese Rivers

River	Catchment area (sq.km.)	Total annual sediment load in m³	Sediment load Tonne/ha/yr	Erosion rate Tonne/ha/yr*A
Tamur	5900	29.6×10^6	80	240
Arun	36533	34.6×10^6	15	45
Sunkosi	19230	54.2×10^6	45	135
Bagmati	585	2.6×10^6	45.5	96*B
Trisuli	4110	7.6×10^6	18.5	55
Karnali	42890	22.0×10^6	51	153

*A : Sediment delivery ratio of 33%

*B : The sediment delivery ratio of the Bagmati is taken as 50%

Laban (1978) estimates the following overall erosion rates in different areas of Nepal.

1. Churiya hill-east	7.8	-	36.8 tonnes/hectare/year
west	20	-	200
2. Mahabharat *lekh*	31.5	-	140
Central Nepal	63	-	420
3. Middle mountains	27	-	45
a) Kathmandu Valley without forest	125	-	570
b) Kathmandu Valley with forest			8
c) *Phewatal* pasture			9.2

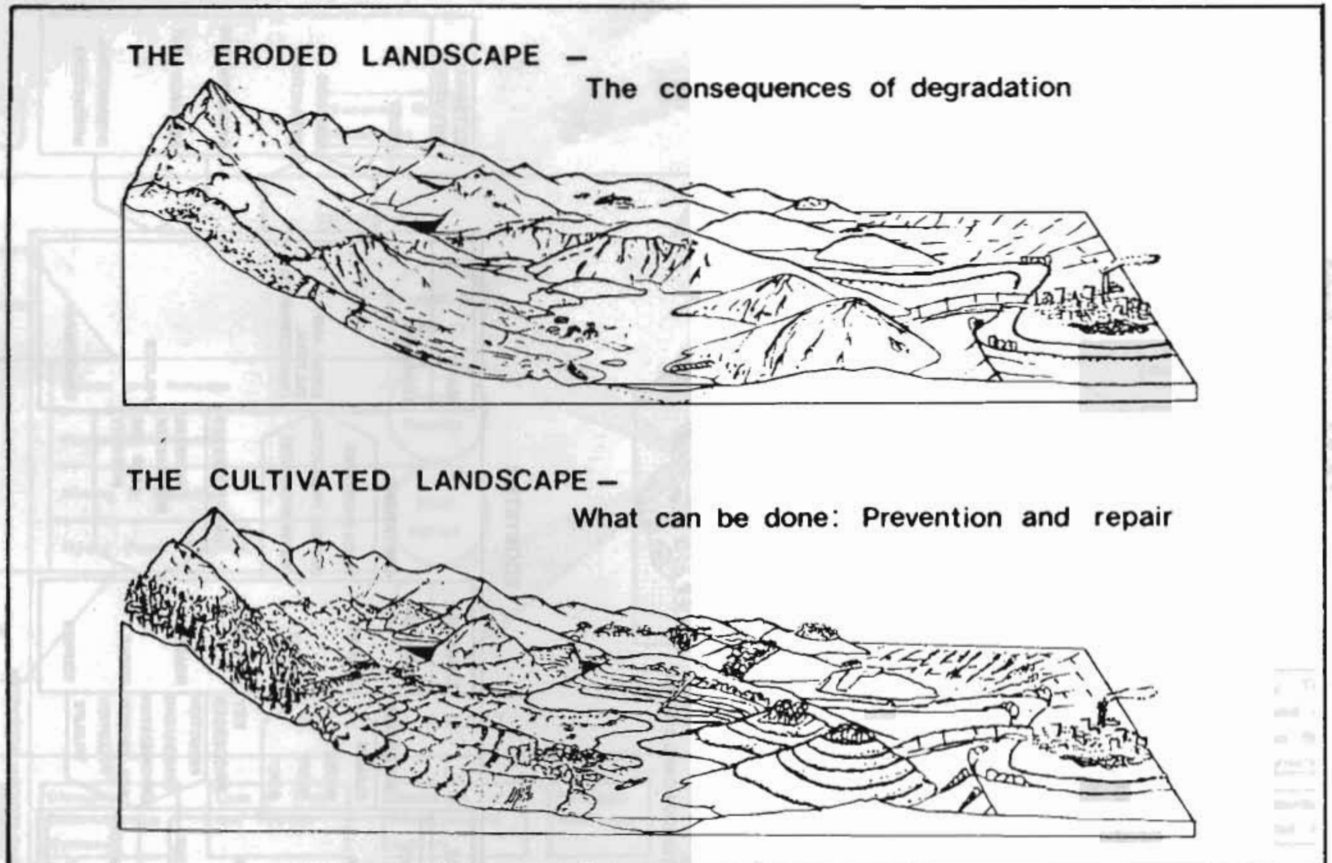
Source: Sharma 1988

Table 18: Accepted Rates of Tolerable Soil Loss

Description of location and site and condition	Rate Tonnes/ha/year	Reference
USA, under farming practices recommended by the Soil Conservation Service	2.5-12.5	Hudson 1971
East Africa	10-12.5	Hudson 1971
Probably a reasonable figure for soil loss in Nepal	10-20	

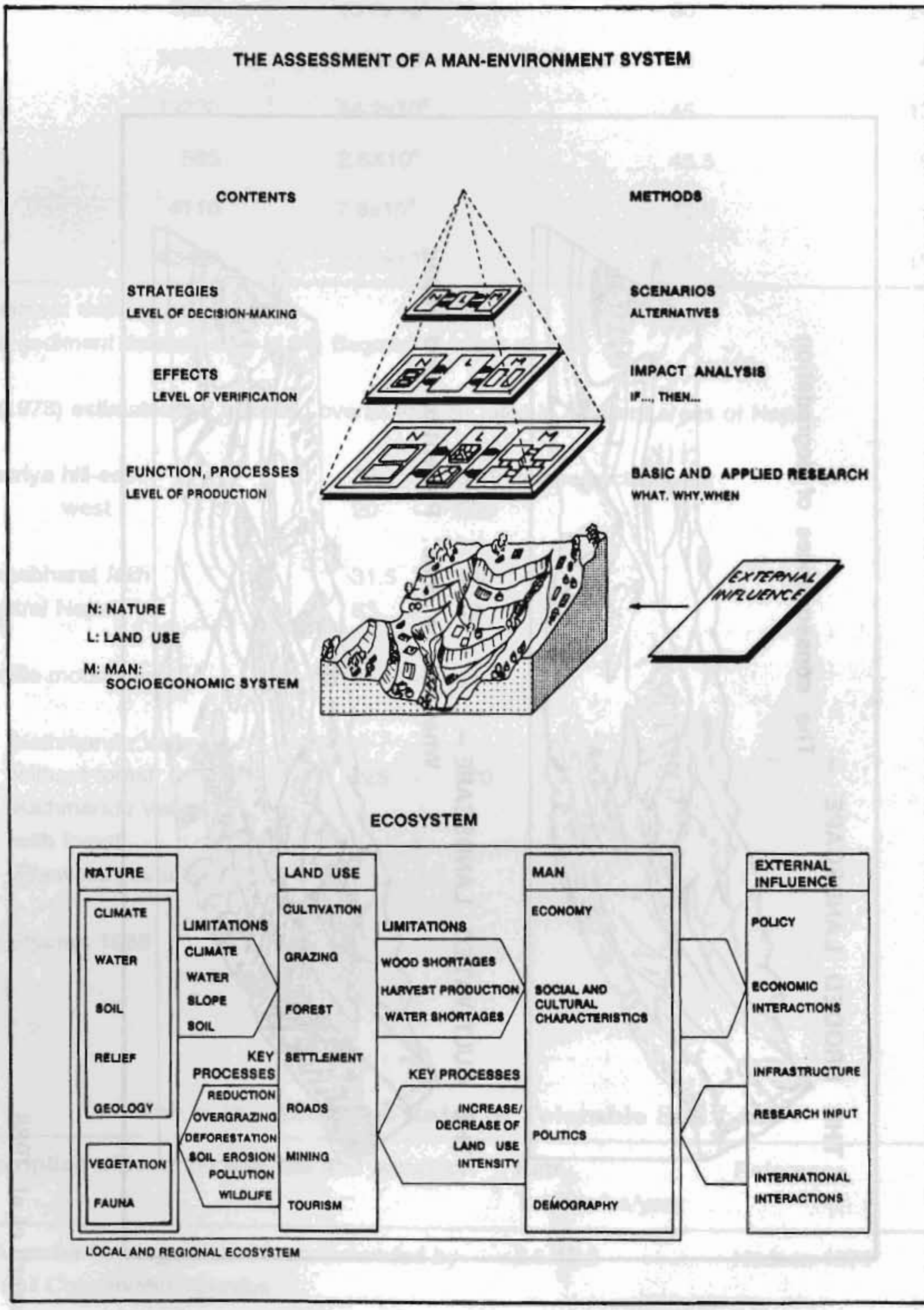
Source: Laban 1979

Figure 1: The Eroded and the Cultivated Landscape



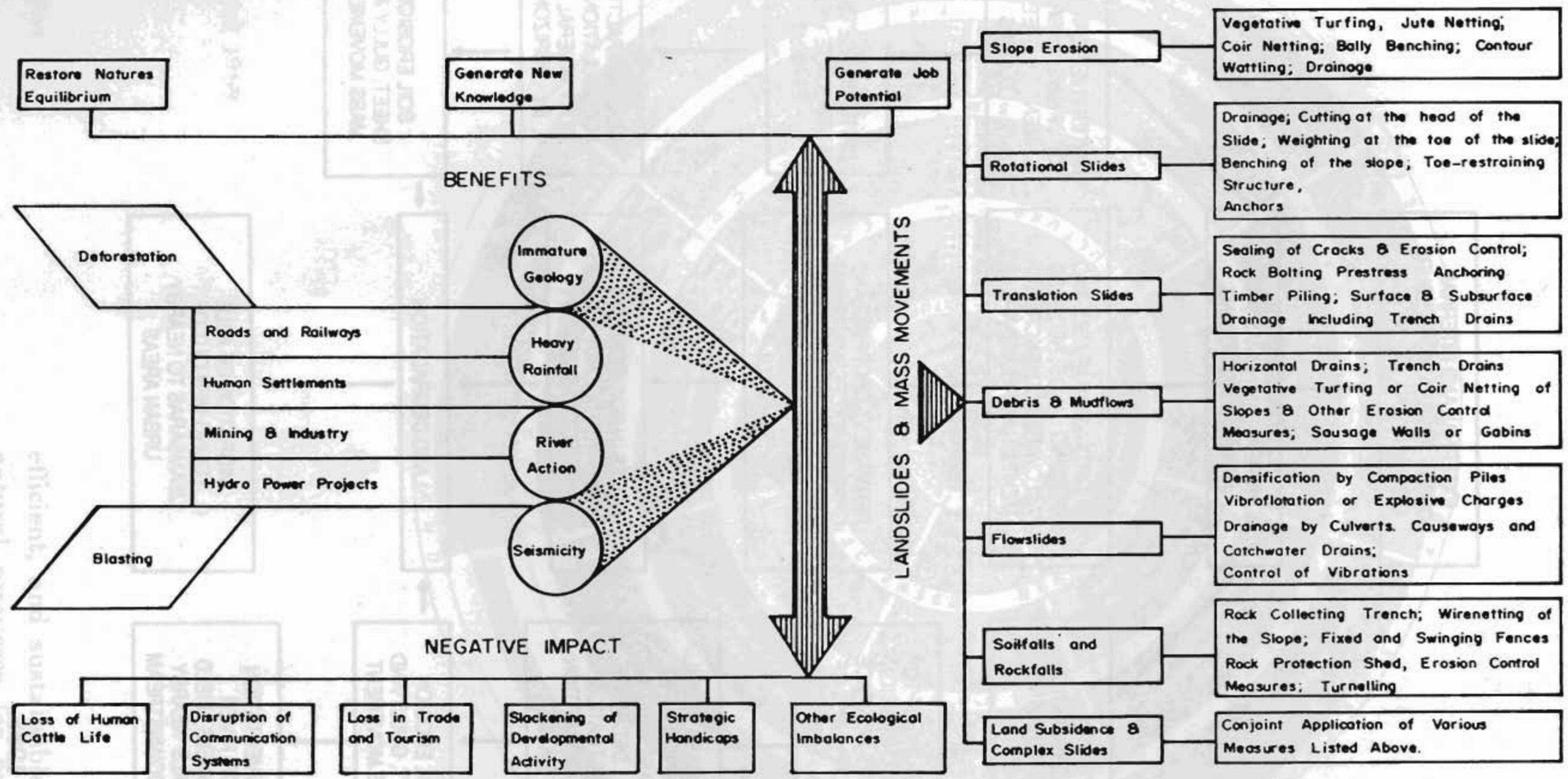
Source: Messerli et al. 1988

Figure 2: The Assessment of a Man-environment System



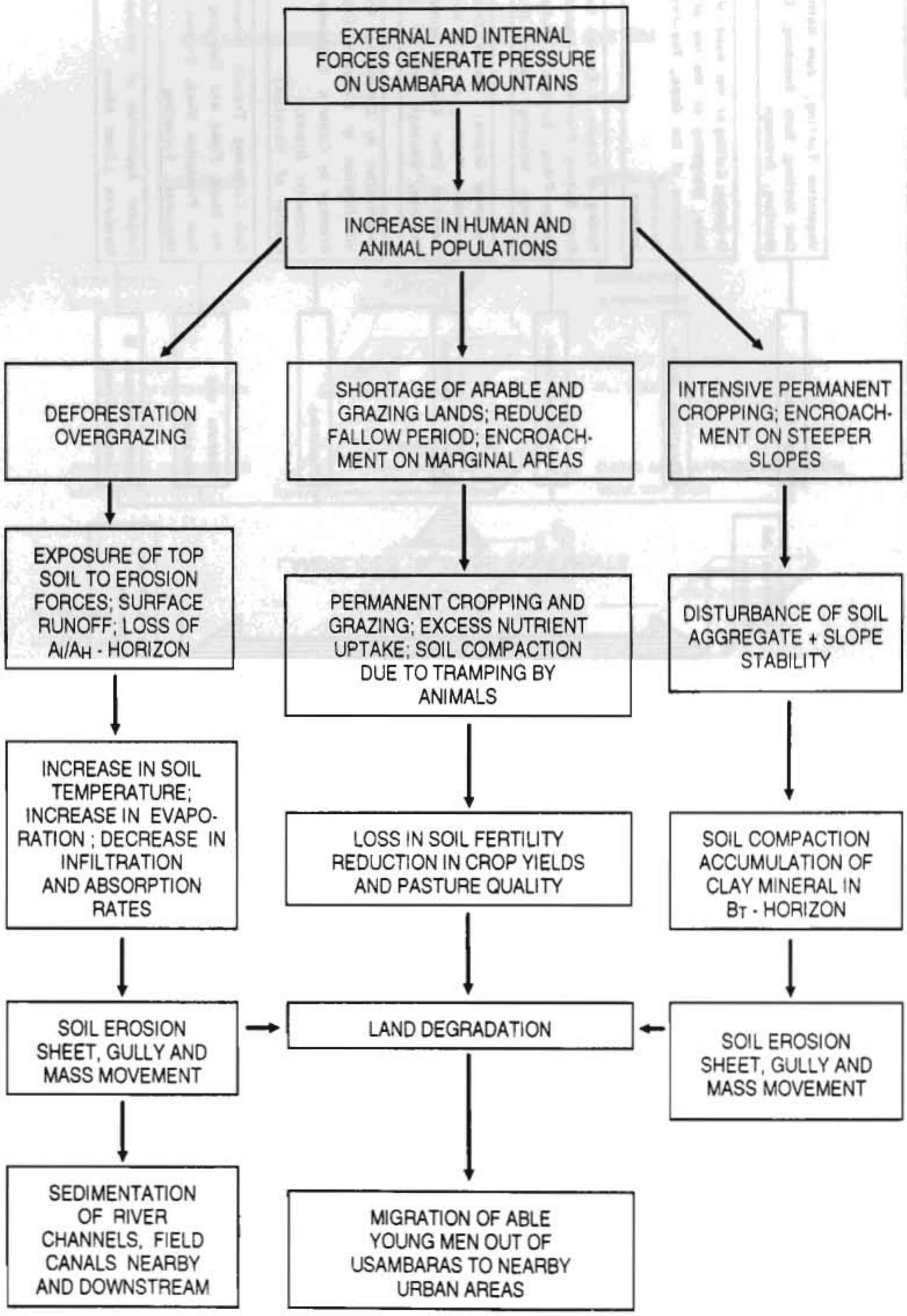
Source: Messerli et al. 1988

Figure 3: Factors Causing Slope Stability Problems and a Common Prescription for Their Control



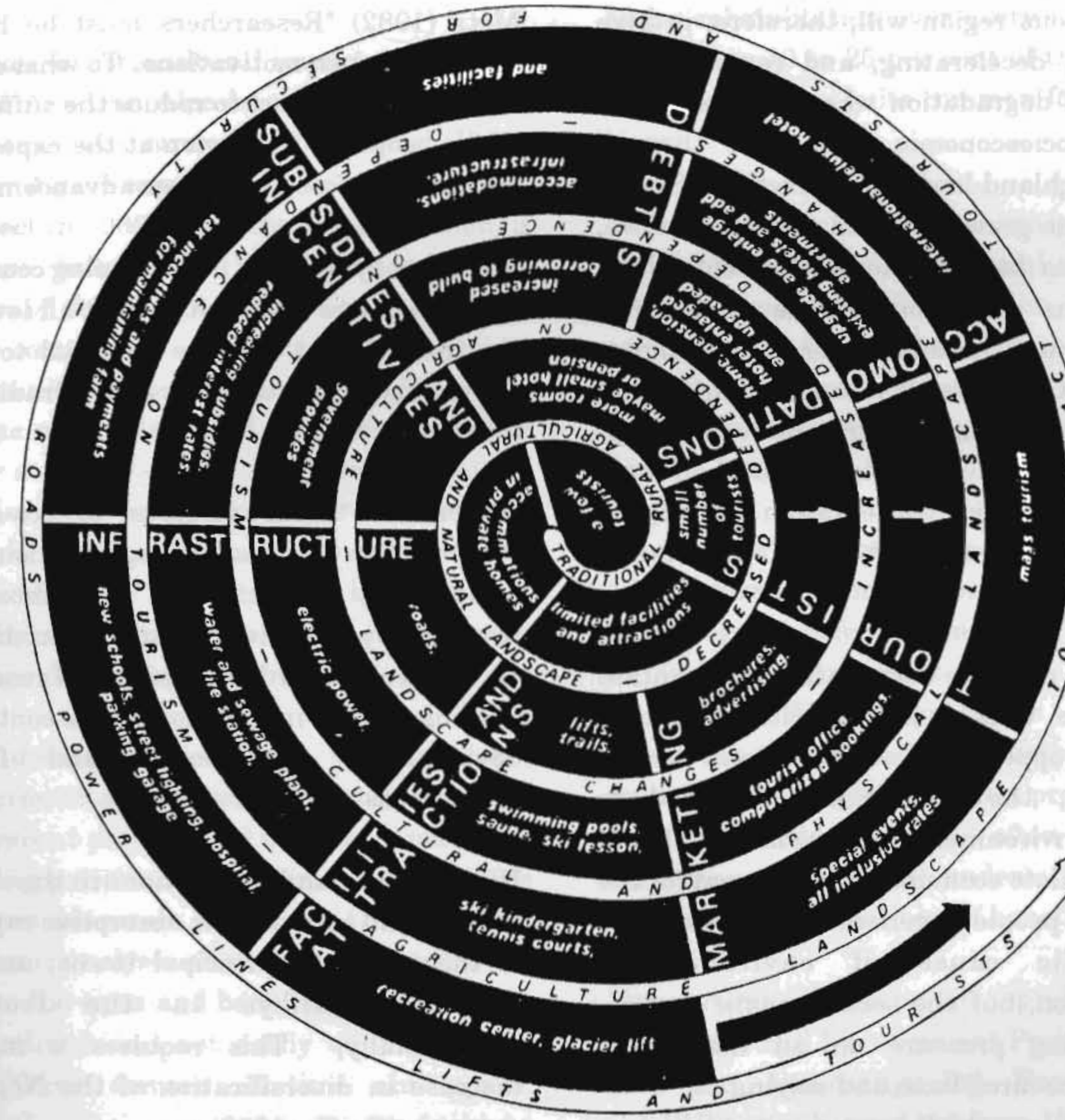
Source: Bhandari 1987

Figure 4: Schematic Illustration of the Pattern of Interaction between Man and Nature in the Usambara Mountains



Source: Ezaza 1988

Figure 5: Spiral of Economic and Infrastructural Growth and Landscape Change under the Influence of Tourism



Source: Kariel 1989

Socioeconomics

Development is seen as improvement in the quality of human life through rational, efficient, and sustainable use of available natural resources for present and future generations. Since mountains are highly vulnerable to degradation caused by increasing human activities, the rate of degradation may accelerate. Resources in the interdependant highlands and lowlands may be exhausted in the absence of management strategies and policies to minimise land degradation. The development of a mountainous region will, therefore, involve arresting, decelerating, and reversing the process of degradation wherever possible to enable socioeconomic upliftment through proper highland-lowland interactions. Equity and income growth, within this perspective, would thus become the societal objectives. The plains and mountainous areas of a country must therefore interact to optimise this objective through resource-sharing and ecology-optimising programmes. Development programmes should be based on long-term, integrated conservation strategies, rather than on short-term "piece-meal" projects.

Land and resource degradation in mountain areas are closely linked with restricted economic opportunities for the local people. Therefore, the programmes designed to reduce environmental degradation should also stimulate economic improvement for the mountain people in general. Poverty may be the basic cause of environmental degradation, but the socioeconomic system, by exerting pressure on an inadequate natural resource base and relying on "over-thinning" as well as limited budget allocations, are counterproductive in the long run.

Ensuring a balanced income-equity-income cycle is a complex task which requires vision, information systems, inculcation of motives rather than incentive-addictions, rationalisation of resource-sharing, an integrated ecosystem, transparency, commitment from planners and decision-makers, and participant action research at local levels.

Donor programmes over-emphasise the environmental crisis but appear only minimally committed to significant output. Failure to address the issue of long-term reliance on subsidies simply results in maintenance of the status quo. To quote Metz (1982) "Researchers must be honest about their own motivations. To what extent are we willing to act to reduce the sufferings of the people of the region at the expense of our own comfort and career advancement?"

Soft State syndromes in developing countries do not indicate a commitment at all levels to the institutional changes essential to meet the challenges of scarcities and of traditional practices.

The emotive "doom and gloom" or "eco-crisis" view of the Himalayan region should be replaced by "reduction of the imbalance produced by excessive pressure of production on resources" and "optimisation of resource-sharing and eco-integration for the continued development of present and future generations".

Highland-lowland interactions in the case of Nepal could increase the absorptive capacity of the *terai,* the principal towns, and the principal valleys in the foothills substantially. This requires a marked increase in diversification of the Nepalese economy (Griffin 1988).

In pursuit of a balanced ecosystem, it is essential to understand the impact of differential forest coverage between the highlands and lowlands. For the middle hills of Nepal, at least, it is argued that most forest land can no longer be converted to other uses without deleterious impacts, because virtually all the remaining forest is needed to sustain the subsistence economy (Griffin 1988). Forests in the mountains have to be seen as a "renewable resource" rather than in the traditional concept of a "convertible resource". Siltation of fertile land in the lowland and the rampant behaviour of river courses in the lowlands are consequences of accelerated erosion and runoff from the mountains.

The case of sociocultural impacts of tourism in the Austrian Alps is a lesson for Nepal. The study was carried out by Kariel (1989) in four Alpine communities in a west-to-east transect in 1986. To quote the conclusion, *a balance between the values, needs, and desires of the local population and tourists is being attained....acculturated to tourism, community residents have, in many respects, become modernised and integrated with the wider society of their country and the world, yet, in many respects, they retain unique cultural characteristics and a traditional way of life.* Figure 5 shows a Spiral of Economic and Infrastructural Growth and Landscape Change under the Influence of Tourism.

Once development strategy, policies, plans, and priorities are established, socioeconomic analysis at project level becomes a matter of refining priorities and optimising the usage of given resources. Traditional methods of economic analysis alone are not adequate to assess the costs and benefits, most of which are indirect and not easily quantifiable in the larger domain of time and space. Several criteria may be necessary for right decision making. (Table 19 is an example of decision-making for selection of a road alignment in the mountains.)

A thorough treatment of cost variables is crucial if the economic analysis of a project is to be sensitive to realistic cost estimates. Experiences in mountain areas throughout the world provide numerous examples of the critical role of landslides in determining the cost and performance of engineering projects. Road cost studies in Nepal have shown that the as-built costs are six to eleven times the original estimated costs and 1.5 to 2 times the original costs when all costs are expressed in base year prices (Deoja 1989).

Major rehabilitation over every four to five years costs 10 to 25 per cent of the original costs, and this is quite common for roads in Nepal.

Sectoral approaches; donor agency priorities and targets; nature of technical assistance; recipient country's desperation to accept anything rather than nothing; the indifference of local bureaucrats in defining their own needs; over-qualified experts; donor bureaucracies, computer jargon, burgeoning environmental wisdom; local bureaucrats' aspirations to go on shopping trips to foreign countries under training and technology transfer programmes; and above all lack of commitment to the pursuit of meaningful development have tended to produce a surge of ineffective and small research and implementation programmes. Feasibility studies are often number-crunching exercises with underestimations of cost and overestimations of benefit.

Two rural development projects, the Integrated Hill Development Project (IHDP) and the Lamosangu-Jiri Road Project (LSJRP), were carried out from 1975 to 1990 in the districts north-east of Kathmandu, Nepal, with Swiss assistance, aimed at rural development with explicit consideration of ecological, economic, and sociocultural aspects. Rs 1009.7 million at 1990 prices (Swiss Franc=Nrs 18 in 1989/90) were invested in these two projects, for a district with an area of 2,500 sq. km. and a population of 172,000 (1990), during the fifteen-year (1975-1990) period. Out of the Rs 1009.7 million, the road sector expenditure was Rs 611.4 million.

Table 19: Decision-making on Choice of Alignment

Final Selection of Best Alternative

Attributes		Initial cost	Maintenance cost	Duration of construction	Design life	Hazards and risks	Economic returns	Environmental impacts	Strategic or other considerations	Total rating	Rank
Relative importance		10%	10%	10%	10%	20%	15%	15%	10%	100%	
Alignment I	Relative rating	82	100	100	100	50	79	89	60	79.5	2
	Weighted rating	8.2	10.0	10.0	10.0	10.0	11.9	13.4	6.0		
Alignment II	Relative rating	70	90	100	100	44	56	73	100	74.2	3
	Weighted rating	7.0	9.0	10.0	10.0	8.8	8.4	11.0	10.0		
Alignment III	Relative rating	100	88	100	100	100	100	100	80	96.8	1
	Weighted rating	10.0	8.8	10.0	10.0	20.0	15	15	8.0		

Source: Deoja et al. 1991

The Impact Status Study carried out by the Swiss Development Cooperation (SDC) in 1990 indicated that, although transportation costs were greatly reduced, the economic effects were different from those expected (Dhakwa 1990). The visible impacts of the two projects were physical infrastructures such as roads, schools, health posts, and drinking water schemes, which were beyond the region's financial resources and skills to maintain. Households situated more than 20 km from the road actually felt no change, or a deterioration in economic conditions. Although the study did indicate some improvements, the quantification and validation of significant improvements brought about by projects are not yet established.

It is thus clear that, in other remote mountain areas, with fewer comparative advantages in terms of location, proximity to the capital, and favourable terrain, significant benefits from road projects alone are not likely to occur in less than 20 years from the beginning of a project. Economic justification for road projects in remote mountain areas would, therefore, be possible only if investment costs can be reduced. This requires lower standards and participatory programmes. Perhaps practical skills rather than high-sounding qualifications are needed here? Perhaps indigenous manpower would be more useful than imported manpower? Perhaps we should assert that there is a felt need encompassing a larger hinterland surrounding roads.

Engineering

Since most mountainous areas have subsistence economies, the trade-off between the rigour of mountain-specific engineering, which usually demands much more investigation and technological application, and affordablility under conditions of local participation, is a dilemma. Experiences from the plains' area-oriented, routine engineering practices applied to mountain infrastructures have shown that so-called, low-cost engineering methods have often turned out to be failures, and high maintenance costs' outputs usually involve serious cost overruns by the time the project is completed.

Mountain roads constructed in Nepal so far have provided examples of alignment relocations that have no regard for natural hazards. Road geometry is often non-commensurate with effective horizontal and vertical alignment and vehicle horsepower to weight ratio, terrain, traffic, and life-cycle costs. Guidelines, such as those given in Tables 20 and 21, are valuable for mountain-specific roads. Table 22 provides guidelines on selection of retaining walls through consideration of hazards, costs, and technology.

Careless road cross-section designs have led to excessive back-cutting, unnecessary foundation excavations into the rock for the retaining walls, unstable outslopes, unduly high retaining walls as a result of front battering, below capacity culverts, unprotected outlets of culverts, indiscriminate blasting and spoil disposal, and constricted and low-level bridges.

Figures 6 to 16 present examples of proper cross-section designs, cost-saving techniques, and environmentally-controlled constructions for mountain roads.

The lifespan of a bridge is generally not related to return period flood and probability of exceedence. For example, a bridge has to be designed for 952 years return-period flood if it is to serve with a 90 per cent probability that the flood will not exceed the bridge in 100 years.

Table 20: Recommended Geometric Standards for Mountain Roads

DESIGN PARAMETERS	AADT > 2000	AADT 1000 – 2000				AADT 500 – 1000				AADT 200–500				AADT 50 – 200				AADT < 50				REMARKS
	VF VG CS RS	VF	VG	CS	RS	VF	VG	CS	RS	VF	VG	CS	RS	VF	VG	CS	RS					
1) DESIGN SPEED, KPH		60	50	40	50	50	40	40	50	50	40	30	40	40	30	30	40	40	25	25	30	1) *ALMOST IMPOSSIBLE TO PROVIDE REQUIRED SIGHT DISTANCE FOR SINGLE – LANE ROAD IN THE HILLY AREAS EITHER PROVIDE DOUBLE-LANE AT CURVES OR DRASTICALLY REDUCE THE SPEED, PROVIDE MIRRORS OR BLOW HORN. 2) FOR TRAFFIC LESS THAN 200 AADT AND AT SECTIONS OF LESS THAN 5% LONG. GRADE, AND PAVED AND SEALED AREAS, OUTSLOPING OF ROAD AT 3 – 4% MAY BE FOLLOWED TO REDUCE FORMATION WIDTH AND CUT VOLUME
2) TRAFFIC LANES, NO		2	2	2	2	2	2	2	2	2	1+	1+		1	1	1	1	1	1	1	1	
3) CARRIAGE WAY WIDTH M		7	7	7	7	7	6	6	6	7	4–6	4–6	4–6	3.75	3.75	3.75	3.75	3.5	3.5	3.5	3.5	
4) SHOULDER WIDTH, GN EACH, SIDE, M		1	1	1	1	1	1	1	1	1	0.75	0.75	0.75	0.75	0.50	0.50	0.50	0.5	0.5	0.5	0.5	
5) DRAIN, M		1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	
6) MINIMUM ROADWAY WIDTH AT APEX OF SWITCHBACKS/HAIR PIN BENDS		–	11.5	11.5	11.5	–	11.5	11.5	11.5	–	9	9	9	–	7.5	7.5	7.5	6.5	6.5	6.5	6.5	
7) TOTAL FORMATION WIDTH IN M		10–10.5	10–13	10–13	10–13	10–10.5	9–13	9–13	9–13	10–10.5	6.5–10	6.5–10	6.5–10	6.25–7	5.5–9.0	5.5–9.0	5.5–9.0	5.5–8.0	5.0–8.0	5.0–8.0	5.0–8.0	
8) RULING GRADIENT %	HIGH STANDARDS, MAY JUSTIFY TUNNELS, CROSSING A RIVER MORE THAN ONCE, ETC. EXTENSIVE STUDY REQUIRED	3	4	6	5	4	6	6	4	4	6	6	5	4	7	7	6	4	7	7	6	
9) MAXIUM GRADIENT %		8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	
10) EXCEPTIONAL GRADIENT %		–	10	10	10	–	10	10	10	–	10	10	10	–	12	12	12	–	12	12	12	
11) GRADE COMPENSATION AT CURVE %																						
12) MAXIUM LENGTH OF MAXIUM GRADIENT, M		100	100	100	100	100	60	60	60	100	60	60	60	100	60	60	60	100	60	60	60	
13) MAXIUM LENGTH OF EXCEPTIONAL GRADIENT, M																						
14) MINIMUM LENGTH OF RECOVERY, AFTER MAXIMUM OR EXCEPTIONAL GRADE, AS SPECIFIED		← 200 – 150M M@ @4% →				← 200 M@ 3%		150M @ 4% →		← 150 M@4% →												
15) MINIMUM STOPPING SIGHT DISTANCE, M		90	60	45	60	60	45	45	60	60	45	30	45	45	30	30	45	45	25	25	30*	
16) MINIMUM OFFSET FROM CENTRE LINE TO INSIDE EDGE OF CUT AT 1.2 M HT		14	6.5	5.5	6.5	6.5	5.5	5.5	6.5	6.5	5.5	4.5	5.5	20	16	16	20	20	13	13	16	
17) SUPER-RELEVATION, M		$e\ \frac{v^2}{127R} = f$ —								10% ; f 0.14 for 60 KPH to 0.19 for 20 KPH —												
18) VERTICAL CURVE		— FORMULAE —																				
19) MINIMUM RADIUS OF HORIZ. CURVE, M		120	75	45	75	75	45	45	75	75	45	25	45	45	25	25	45	45	20	20	25	
20) EXTRA WIDENING OF PAVEMENT AT CURVES, M		–	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	

ADDT = Average Annual Daily Traffic
VF = Valley – flat
VG = Valley – gorge
CS = Climb Section
RS = Ridge Section

Table 21: Indicative Quantities of Major Items of Hill Road for Height of Cut Limited to Less than 12m and Low-risk Designs of Cross-sections

HILL SLOPE deg.	AV. SLOPE deg.	CUT SLOPE deg.	H:V	ROAD WIDTH m.	RATIO CUT	RATIO FILL	CUT HT. m.	FILL HT. m.	HT. OF RTG. WALL m.	CUT VOL. 1000 cu.m.	FILL VOL 1000 cu.m.	RETG. WALL VOLUME 1000 cu.m.	BREAST WALL VOLUME 1000 cu.m.	CULVERT No./Type	REMARK
										PER KM. QUANTITIES					
LOW HAZARD AREAS															
0-14	7	45	1:1	6.50	.60	.40	.55	.42		1.06	.55			5/HP + 2/Box	HP = Humc Pipe
15-24	20	45	1:1	6.50	.60	.40	2.23	3.48		4.35	4.53			5/HP + 1/Box	
25-34	30	56.30	1:1.5	6.50	1	0	6.10		1.78	19.84	0			7/HP + 1/Box	
35-44	40	63.40	1:2	6.50	.90	.10	8.47		2.34	24.77	.12	2.20		7/HP + 1/Box	
45-54	50	76	1:4	6.50	.70	.30	7.72		3.82	17.55	1.42	5.16		6/HP + 1/Box	Rock or hard soil
55-64	60	80.50	1:6	6.50	.70	.30	11.10		4.62	25.25	1.77	7.26		6/HP + 1/Box	Rock or hard soil
0-14	7	45	1:1	10	.60	.40	.84	.65		2.52	1.30			5/HP + 2/Box	
15-24	20	45	1:1	10	.60	.40	3.43	5.36		10.30	10.72			5/HP + 1/Box	
25-34	30	56.30	1:1.5	10	1	0	9.39		1.78	46.95	0			7/HP + 1/Box	
35-44	40	63.40	1:2	10	.90	.10	13.03		2.57	58.62	.30	2.59		7/HP + 1/Box	
45-54	50	76	1:4	10	.70	.30	11.87		4.77	41.54	3.36	7.70		6/HP + 1/Box	Rock or hard soil
55-64	60	80.50	1:6	10	.60	.40	14.63		7.13	43.90	7.43	16.41		6/HP + 1/Box	Rock or hard soil
MEDIUM HAZARD AREAS															
0-14	7	45	1:1	6.50	.60	.40	.55	.42		1.06	.55			5/HP + 3/Box	
15-24	20	45	1:1	6.50	.60	.40	2.23	3.48		4.35	4.53			5/HP + 3/Box	
25-34	30	56.30	1:1.5	6.50	.90	.10	5.49		2.09	16.07	.09	1.83		8/HP + 1/Box	
35-44	30	71.60	1:3	6.50	.80	.20	6.05		2.77	15.74	.50	2.95	8.52	8/HP + 1/Box	
45-54	50	76	1:4	6.50	.60	.40	6.61		4.41	12.90	2.53	6.67	9.87	8/HP + 1/Box	
55-64	60	80.50	1:6	6.50	.50	.50	7.93		6.21	12.88	4.90	12.47		8/HP + 1/Box	
0-14	7	45	1:1	8	.60	.40	.67	.52		1.61	.83			5/HP + 3/Box	
15-24	20	45	1:1	8	.60	.40	2.75	4.29		6.59	6.86			5/HP + 3/Box	
25-34	30	71.60	1:1	8	.80	.20	4.57		2.54	14.64	.57	2.54	5.43	8/HP + 1/Box	
35-44	40	71.60	1:3	8	.70	.30	6.52		3.51	18.25	1.70	4.44	9.63	8/HP + 1/Box	
45-54	50	76	1:3	8	.50	.50	6.78		5.68	13.57	5.98	10.59	10.29	8/HP + 1/Box	
55-64	60	80.50	1:6	8	.50	.50	9.76		7.13	19.51	7.43	16.11		8/HP + 1/Box	

Table 21: Indicative Quantities of Major Items of Hill Road for Height of Cut Limited to Less than 12m and Low-risk Designs of Cross-sections (continued...)

HILL SLOPE deg.	AV. SLOPE deg.	CUT SLOPE DEG.	CUT SLOPE H:V	ROAD WIDTH m.	RATIO CUT	RATIO FILL	CUT HT m.	FILL HT	HT.OF RTG WALL m.	PER KM QUANTITIES: CUT VOL 1000 cu.m.	FILL VOL. 1000 cu.m.	RETG WALL VOLUME 1000 cu.m.	BREAST WALL VOLUME 1000 cu.m.	CULVERT No./Type	REMARK
HIGH HAZARD AREAS															
0-14	7	45	1:1	6.50	.60	.40	.55	.42		1.06	.55			5/HP+3/Box	
15-24	20	45	1:1	6.50	.60	.40	2.23	3.48		4.35	4.53			5/HP+3/Box	
25-34	30	71.60	1:3	6.50	.70	.30	3.25		2.71	7.40	.85	2.83	3.21	9/HP+2/Box	
35-44	40	71.60	1:3	6.50	.70	.30	5.30		3.21	12.05	1.12	3.79	6.86	9/HP+2/Box	
45-54	50	76	1:4	6.50	.40	.60	4.41		5.59	5.73	5.68	10.28	5.12	9/HP+2/Box	
55-64	60	80.50	1:6	6.50	.40	.60	6.34		7.01	8.24	7.06	15.60		9/HP+2/Box	
0-14	7	45	1:1	10	.60	40	.84	.65		2.52	1.30			5/HP+3/Box	
15-24	20	45	1:1	10	.60	.40	3.43	5.36		10.30	10.72			5/HP+3/Box	
25-34	30	71.60	1:3	10	.70	.30	5.00			17.51	2.02	3.79	6.26	9/HP+2/Box	
35-44	40	71.60	1:3	10	.70	.30	8.15			28.52	2.66	5.38	14.04	9/HP+2/Box	
45-54	50	76	1:4	10	.40	.60	6.78			13.57	13.45	17.73	10.29	9/HP+2/Box	
55-64	60	80.50	1:6	10	.40	.60	9.76			19.51	16.72	28.09		9/HP+2/Box	

Notes:

1. Provide vegetative measures for erosion control in Low Hazard Areas.
2. Provide biotechnical and engineering works for erosion, gully, and minor slides in Medium Hazard Areas.
3. Provide specific landslide stabilisation measures based on detailed investigation and analysis for High Hazard Areas.

Source: Deoja et al. 1992

Table 22: Selection of the Retaining Walls

WALL TYPE									CONSTRUCTION MATERIAL				
BY MECHANICS	BY STRUCTURAL MATERIAL	HEIGHT OF WALL M	HILL SLOPE DEGREE	HAZARD LEVEL	FILL SLOPE	CONSTRUCTION TIME	LIFE OF WALL YEARS	FOUNDATION MATERIAL	BACKFILL MATERIAL	STRUCTURE	EQUIPMENT REQUIRED	AESTHETICS REQUIRED	INITIAL COST
GRAVITY	DRYSTONE MASONRY	1-8	<35	L	<35	SHORT	≤20	GOOD	GOOD	HARD, RECTANGULAR STONE BLOCKS	PORTABLE COMPACTER	GOOD	LOW COST
GRAVITY	DRYSTONE MASONRY	1-5	<35	H	<35	SHORT	≤5	FAIR	GOOD TO FAIR	HARD, RECTANGULAR STONE BLOCKS	PORTABLE COMPACTER	GOOD	LOW COST
GRAVITY	GABION	1-10	<60	L,H	<35	SHORT	≤20	FAIR	GOOD TO FAIR.	HARD STONE BLOCKS OR BOULDERS, G.D. WIRE	PORTABLE COMPACTER	GOOD	MEDIUM COST
GRAVITY	RCC CRIB	1-10	<35	L,H	<35	SHORT	≤20	FAIR	GOOD TO FAIR	PRECAST RCC CRIBS	PROTABLE COMPACTER	GOOD	LOW COST
GRAVITY	DRUM WALL	≤2.5	<35	L,H	<35	SHORT	<5	FAIR	FAIR	EMPTY BITUMEN DRUMS	TAMPER	POOR	VERY LOW COST
GRAVITY	CEMENT MASONRY	1-10	ANY	L	<35	AS REQUIRED	>20	GOOD	GOOD	CEMENT, SAND, WATER		FAIR	HIGH COST EXCEPT FOR BENCHING ROCKS
GRAVITY	DRYSTONE MASONRY WITH SANDS OF CEMENT MASONRY	4-8	<15	L	<20	AS REQUIRED	<20	GOOD TO FAIR	GOOD TO FAIR	PARTIAL CEMENT, SAND, AND WATER	PORTABLE COMPACTER	FAIR	MEDIUM COST
GRAVITY	REINFORCED CONCRETE	>8	<40	L	<35	AS REQUIRED	<20	GOOD TO FAIR	GOOD	CEMENT, SAND, WATER, AGGREGATES, STEEL FORM WORK	CONCRETE MIXER, VIBRATOR, TRUCKS	FAIR	MEDIUM COST
REINFORCED EARTH	GABION MASONRY FOR FACING AND GABION MESH OR GEOTEXTILE FOR EARTH REINFORCEMENT	1-10	<35	L	<35		<20	GOOD TO FAIR	FAIR	STONE, GIWIRE, PROPREITRARY MANUFACTURED PRODUCTS	COMPACTOR	FAIR	MEDIUM COST

Source:

1. Other wall types, such as anchored walls, may be considered depending on unusual problems, site coditions, and available materials and equipment.
2. Comparative cost calculation and environmental considerations may be required for final decisions in case of major walls.

Source: Deoja et al. 1992

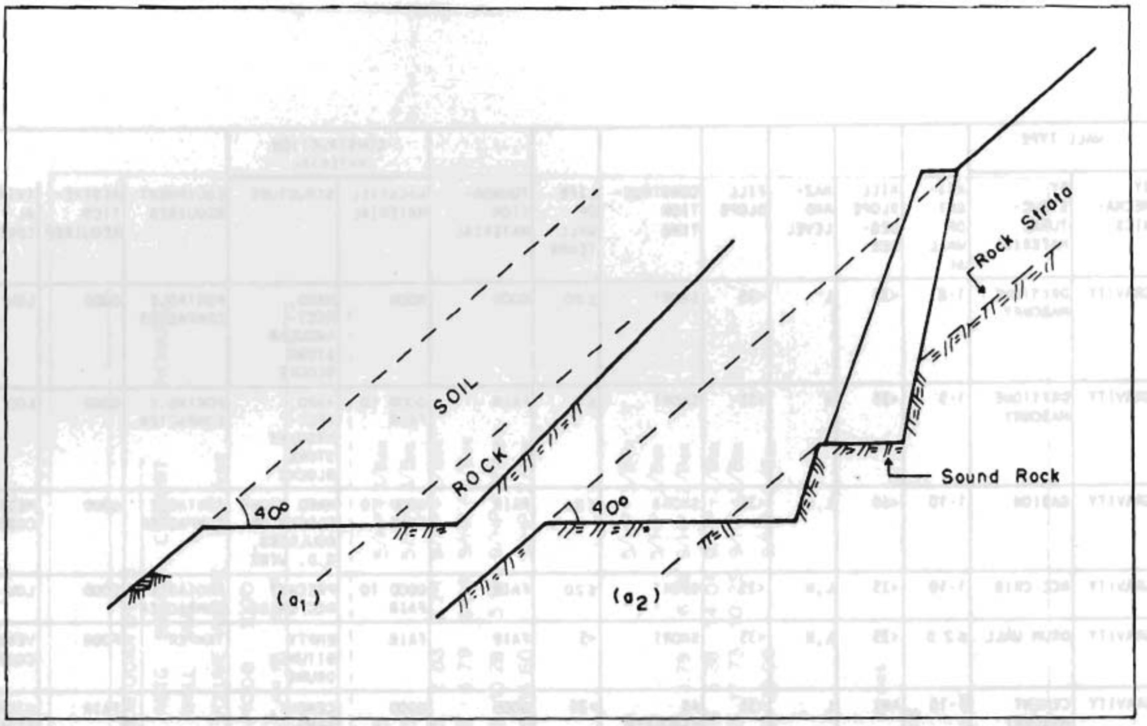


Figure 6. **In rocky areas, where excavation is difficult and expensive, the centre line shifts towards the valley and reduces the height of cut and volume of excavation to a great extent.**

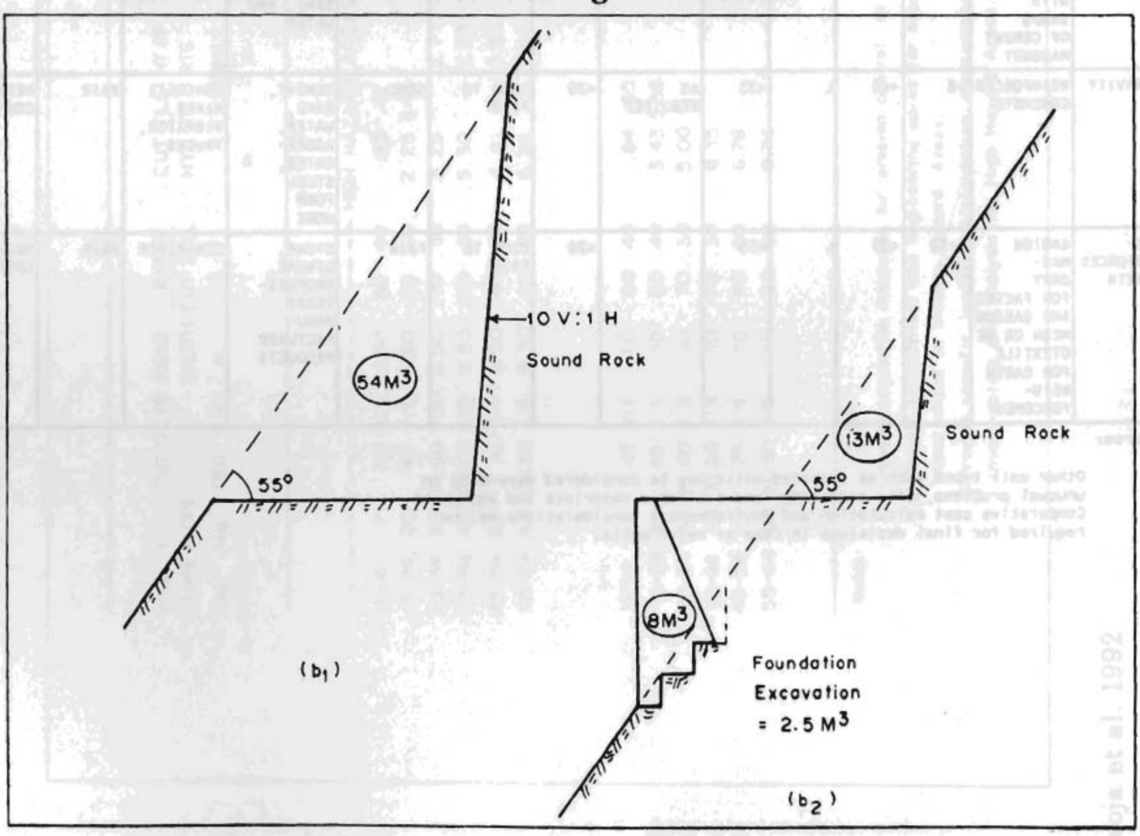


Figure 7. **A breast wall founded on the sound rock supports the cut slope and greatly reduces the amount of excavation. Cut height is much smaller and hazards and risks are reduced significantly.**

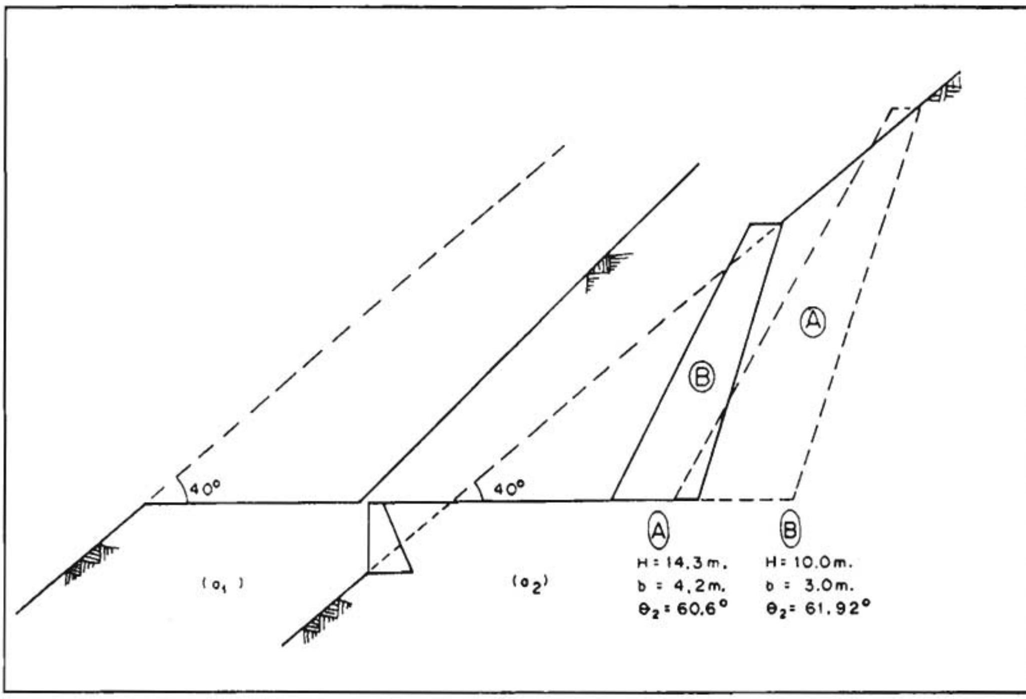


Figure 8. **Minimising height of cut on steep slopes is possible by providing breast walls and shifting the centre line horizontally as shown in the figure to the right.**

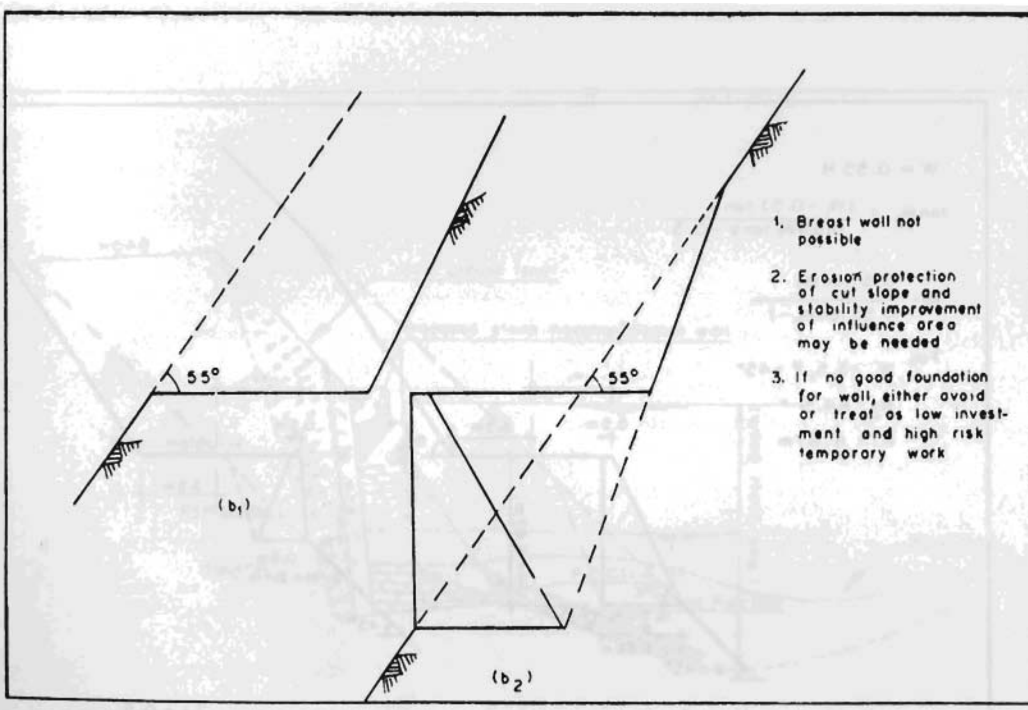


Figure 9. **On very steep slopes, breast wall construction is not feasible. By shifting the centre line horizontally and providing a back-battered retaining wall towards the downhill side of the road, the volume of excavation is reduced.**

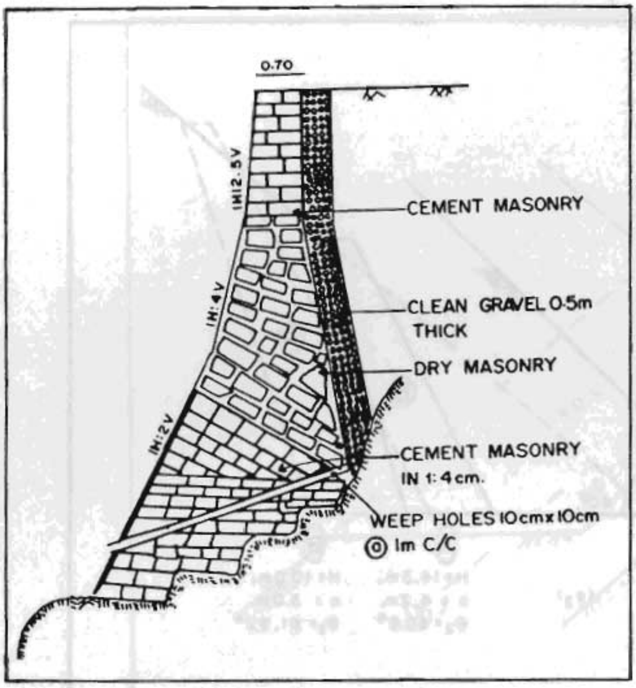


Figure 10. A Composite wall (consisting of dry masonry and cement masonry) is suitable and economical whenever the foundation is sound.

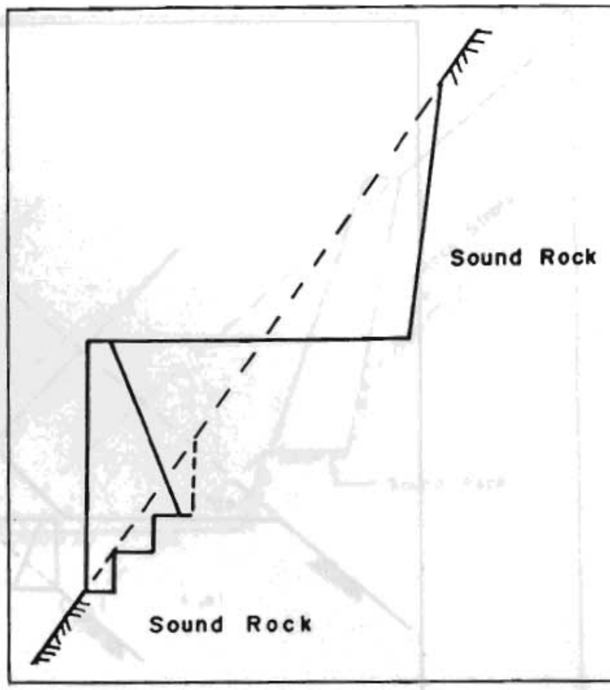


Figure 11. A Cement masonry wall can be constructed economically in rocky areas because benching of the foundation is possible and the backfill wedge may also be smaller.

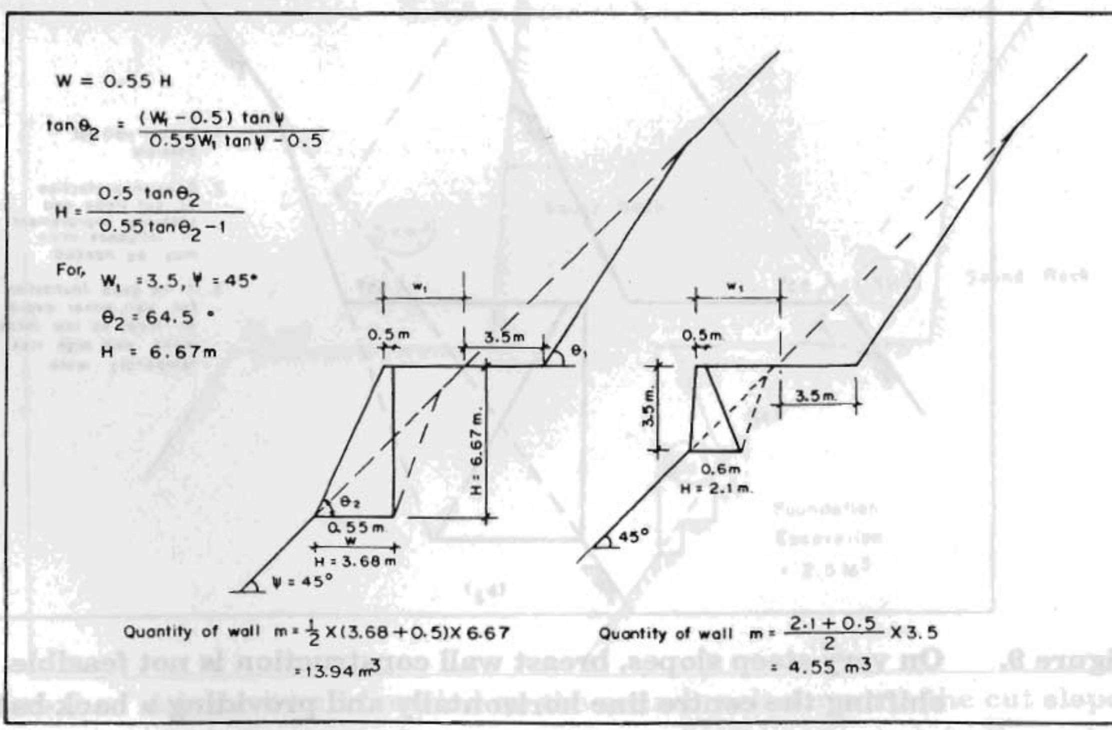


Figure 12. A Back-battered, Front-battered Retaining Wall

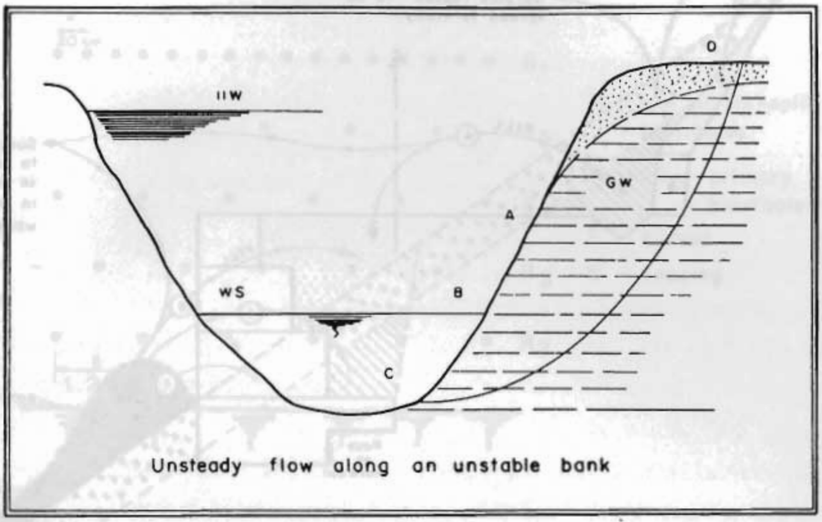


Figure 13. A high water table in the bank slope, due to change in flood level, weakens the bank

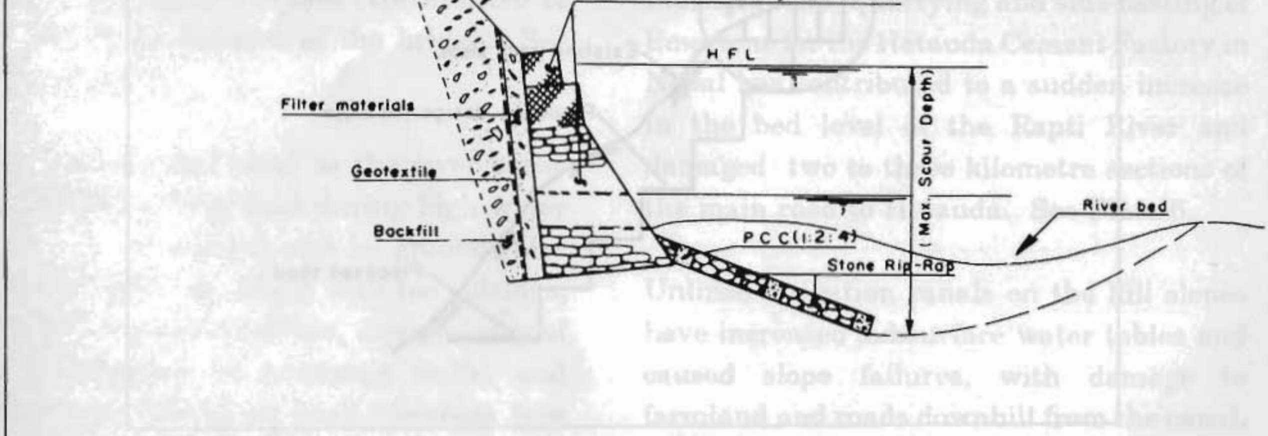


Figure 14. River training with proper backfill drainage, foundation depth, and apron

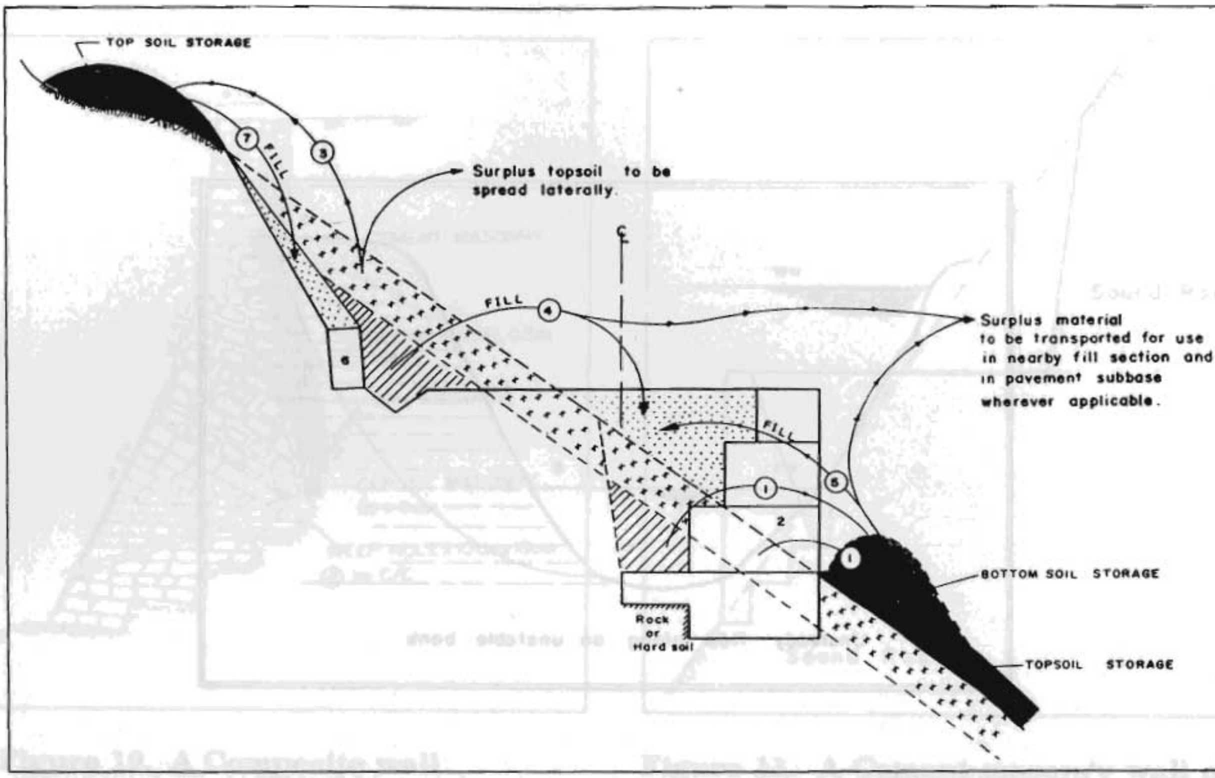


Figure 15. An environmentally-sound construction method

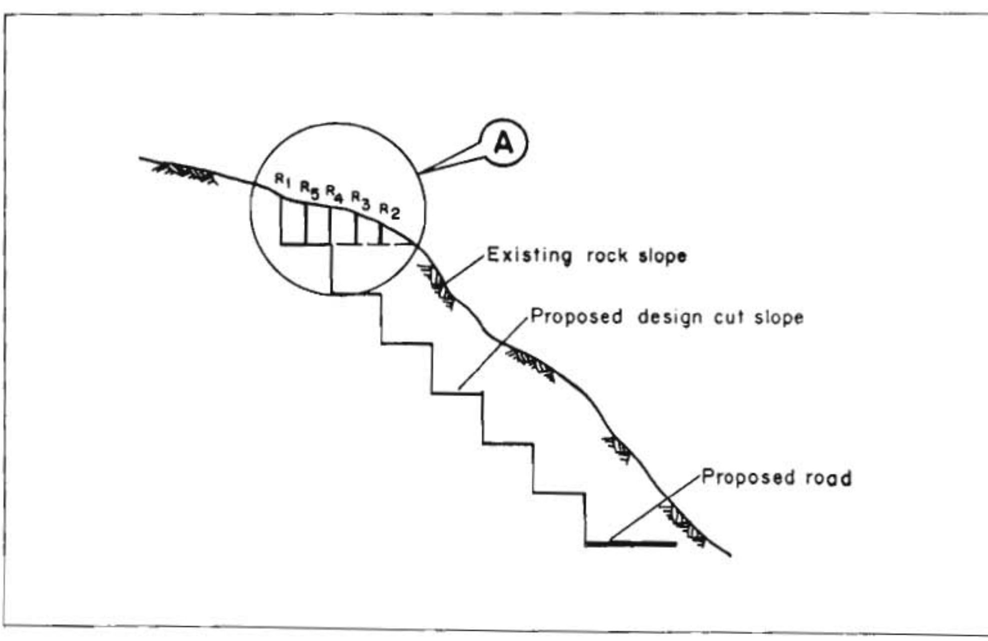


Figure 16a. An illustrative diagram for pre-split blasting

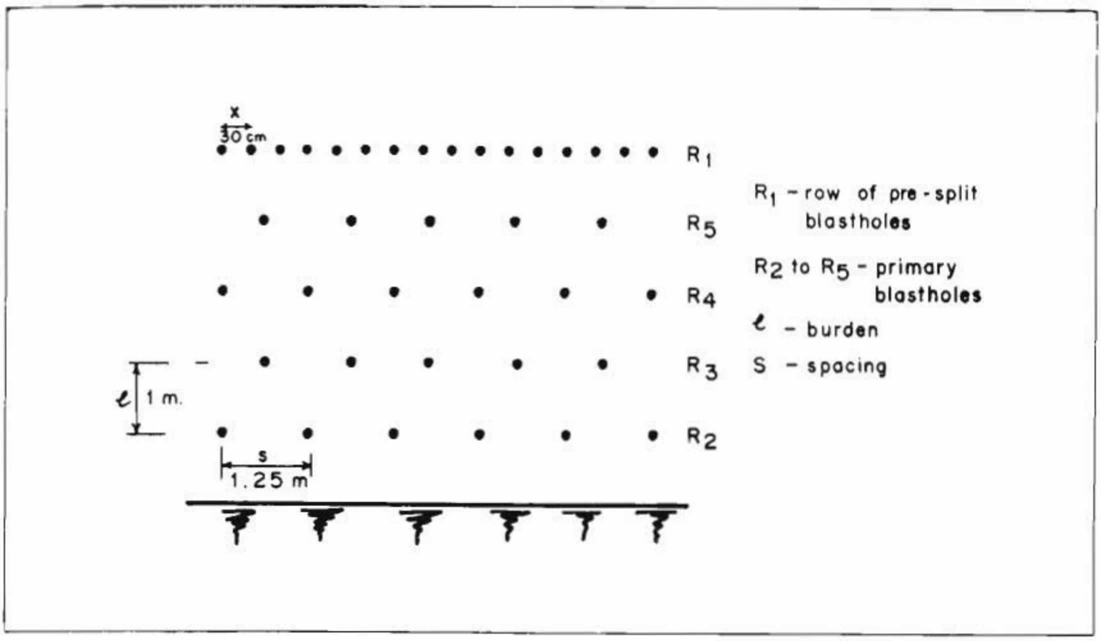


Figure 16b. Plan view of 16a: a staggered pattern of blasting

Lack of proper drainage behind retaining walls has caused early failures of retaining walls. See Plate 1.

Column-type bridge piers constructed on the bridges across torrential rivers near confluences with other rivers, are impacted by horizontal forces from the overtopping water and the flowing trees and logs. High flexural and shear stresses transmitted to the pier cause failures of the bridge. See Plates 2 and 3.

Road beds located close to the river cause submergence of the road during high water flows; the subsequent rise in groundwater tables below roads, along with toe cuttings, is seen to cause subsidence, undermining of the foundations of retaining walls, and subsequent failures in road elements (see Plates 4 and 5)

Barrages for irrigation works in the rapidly aggrading rivers are seen to have suffered from inadequate clearances. Construction and operation of barrages and weirs, without regard to the bridges downstream, have changed the river regime, affecting adversely the stability of the bridges.

Low cost for one infrastructure has proved to be high cost for another infrastructure. The indiscriminate quarrying and side-casting of limestone for the Hetauda Cement Factory in Nepal has contributed to a sudden increase in the bed level of the Rapti River and damaged two to three kilometre sections of the main road to Hetauda. See Plate 6.

Unlined irrigation canals on the hill slopes have increased subsurface water tables and caused slope failures, with damage to farmland and roads downhill from the canal.

Improperly designed river training works for mountain roads following the river have resulted in frequent failures and rehabilitation works leading to a waste of scarce resources. See Plate 7.

Sand quarrying in the river bed for building construction has resulted in accelerated foundation scour and failures of several bridges on the urban road in the Kathmandu Valley.

Oftentimes designs are inconsistent with the true life of the structure. For example, the life of a bridge superstructure could easily be 50 to 100 years, whereas the probability of failure by scour or outburst floods in 25 years, 50 years, and 100 years for the bridge designed for a 100 years' return period flood comes to 23 per cent, 40 per cent, and 63 per cent respectively. There may be situations in which there is no justification for designing the superstructure for 100 years' life when there is a high (23%) probability of failure by foundation scour in 25 years. Thus, the choice of design is a trade-off between extra costs and extra life.

Ultimately, it is a question of risk, which is the "probability of failure times the worth of loss". Under investment constraints, it would be wiser to accept a higher probability of failure for a low-cost structure than design a high-cost structure.

Table 23 presents an example of guidelines for conservation-oriented activities during the various project cycles of a mountain road project.

Planning, Decision-making, and Communication Gap

Effective development of infrastructures in the mountainous region starts with development strategies, national policies, national plans, and sectoral priorities - which must be prepared with regard to survival of mountain-specific concerns.

Figure 17 is a model for planning and implementation of mountain infrastructures.

Table 23: Outlines for Conservation-oriented Hill Roads

Project Cycle	Major Road	Medium Road	Minor Road
Pre-feasibility project identification, project preparation, pre-appraisal	1. Preliminary hazard assessment 2. Preliminary hazard- based costing 3. IEE 4. Comparison of alternatives 5. Selection criteria and weighting	1. Preliminary hazard assessment 2. Preliminary hazard-based costing 3. IEE 4. Comparison of alternatives 5. Selection criteria and weighting	1. Walk over survey and report by local level technicians, NGOs, and social workers under expert guidance
Feasibility project appraisal budgets and negotiations	1. Hazard mapping 2. Assessment of risks to and from roads 3. EIA 4. Mitigatory measures 5. Cost estimate based on historical records, mitigatory measures, and risk analysis 6. Decision criteria	1. Preliminary hazard assessment/hazard mapping 2. Hazard-based costing 3. EIA 4. Peoples' participatory action plans 5. Decision criteria	1. Walk over survey and report by local level technicians, NGOs, and social workers under expert guidance

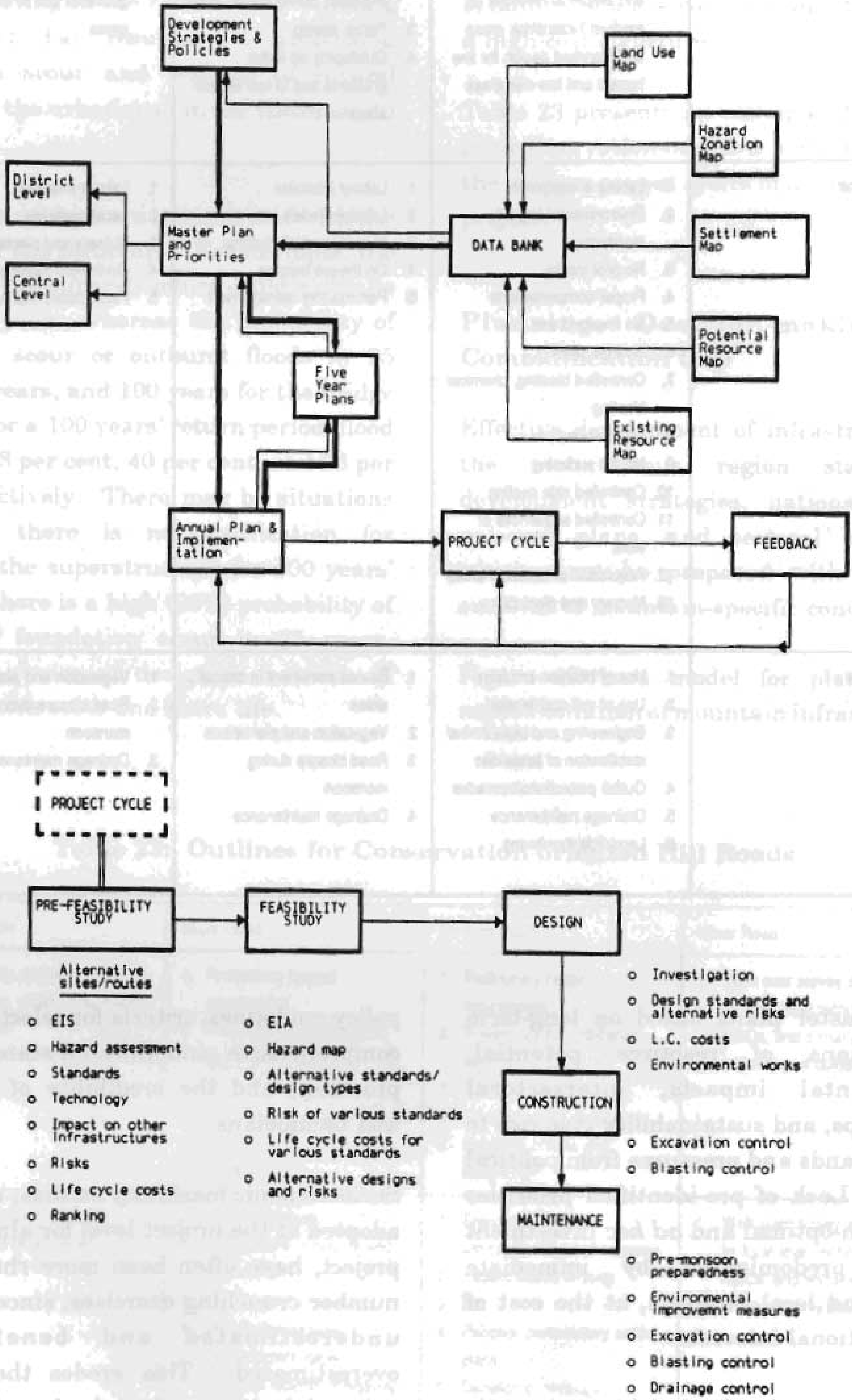
Project Cycle	Major Road	Medium Road	Minor Road
Detailed design	1. Detailed investigations 2. Rigorous designing for high hazard and high risk sites and empirical methods for medium hazard/risk areas and standard design for low hazard and low-risk areas	1. Flexible geometrics 2. Empirical and standard designs to be continually improved during construction 3. Partial paving 4. Outsloping on flatter gradients and in low erosion areas	1. Thumb rule, standard designs, practical examples 2. Outsloping on flatter gradients and in low erosion areas
Constructions	1. Labour & equipment 2. Environmental Impact monitoring 3. No pilot tracks 4. Proper compensations 5. No firewood use 6. No side casting 7. Controlled blasting, chemical blasting 8. Soil stabilisation 9. No dirt surfacing 10. Controlled side casting 11. Controlled sequences of work 12. Acquisition of unstable areas 13. Nursery and plantations	1. Labour intensive 2. Local materials 3. Nursery and plantations 4. On-the-job training 5. Participatory management	1. Labour intensive 2. Local materials 3. Nursery and plantations 4. On-the-job training 5. Participatory management
Maintenance	1. Use of bitumen emulsion 2. Use of soil stabilisation 3. Engineering and biotechnical stabilisation of landslides 4. Outfall protections/cascades 5. Drainage maintenance 6. Landslide monitoring	1. Sealed pavement in critical areas 2. Vegetation and plantations 3. Road closure during monsoon 4. Drainage maintenance	1. Vegetation and plantations 2. Road closure during monsoon 3. Drainage maintenance

Lack of master plans based on long-term considerations of resource potential, environmental impacts, intersectoral relationships, and sustainability give rise to undue demands and pressures from political interests. Lack of pre-identified priorities leads to non-optimal and *ad hoc* investment decisions predominated by immediate concerns and local interests, at the cost of broader national interests.

At the project level, decision-making is greatly influenced by the availability of policy guidelines, criteria for selection of site, comprehensive guidelines on standards and practices, and the credibility of engineers and technicians.

Socioeconomic feasibility studies, religiously adopted at the project level for almost every project, have often been more rhetoric and number crunching exercises, since costs are underestimated and benefits are overestimated. This erodes the faith of political decision-makers in the reliability of technical proposals.

Figure 17: Planning and Implementation Model for Mountain-specific Infrastructural Development



Source: Author

Wide variations in standards, technology, costs, and feasibilities among several road projects of a similar nature, depending upon the technicians involved, and the time factors allowed, have created confusion in decision-making. Without reference to comprehensive guidelines on the requisite level of standards of investigation, designs, cost-estimating, construction practices, and maintenance inputs, in relation to practical levels of fund allocation and implementational capabilities, there is no basis either for the engineers' and/or the technicians' justifications nor for the confidence of the politicians or decision-makers in the technicians. Subjectivity, compromises, and pressure-based decisions thus become inevitable.

Technical proposals, with a single alternative and single criterion, such as cost/feasibility studies alone, tend to impose a decision and take away the decision-makers' authority to choose and realise the consequences of his or her choice. Such a situation is desirable neither from the perspective of the professional integrity of the technicians nor from the decision-makers' prerogatives of choosing and understanding the risks involved in the decision.

Life of a structure is another issue confounding many, including politicians. The difference between the design life of a road and the analysis period of a road project is not clear to many. A particular road is comprised of many elements, e.g., road formation from hill excavation and/or fills; pavements; retaining walls; breast walls; drains; culverts; bridges; slope stabilisation vegetation or plantation, and physical structures such as drilled drains, rock bolts, retaining structures, and river-training works. The life of different components can vary. Bridges normally last for over 50 years, provided foundation failure does not occur as a result of heavy, high return-period floods. Culverts and retaining walls have lasted more than 20 years on many roads. Drains, biotechnical erosion control, and other minor elements could have less than five years' life. However, improper design and construction, and once in five to ten years' floods in Nepal, have caused considerable damage. Without proper awareness programmes, on the issue of costs and environmental problems, for villagers and for political leaders, engineers and technicians will continue to be subject to *ad hoc* decisions.

Bureaucrats, technicians and/or engineers, and politicians often speak different languages in the process of planning and during the implementational decisions related to infrastructures. The absence of a common language, or a mechanism to link them, arising from unclear goals and objectives, unreliability of feasibility studies and technical solutions, absence of comprehensive technical guidelines, lack of understanding of each other's concerns, and lack of commitment to broader interests have resulted in an overall loss of credibility. Engineers and technicians, mostly being at lower echelons of the decision-making hierarchy, have the most to lose.