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Landslide Hazard Management of Darjeeling Hill – A Critical Need For Inhabited.

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ABSTRACT: *Landslides are the most widespread natural disaster in Darjeeling Himalaya which increases its spatial extent day after day. For several natural causes and strong human impact on highly fragile and sensitive hill ecological landscape in form of deforestation, constructions the natural stability are accelerated out. Natural factors like rainstorms, earthquake can trigger landslides. During landslide the materials like soil, rock, vegetation, and existing construction may move very rapidly within a second where as some may take longer time to develop. The result is livelihood security lost, socio-economic condition of people destroys and a huge amount of revenue spent with untold suffer of victims after landslide occurrences. Thus it is required to identify the landslide vulnerable area in advance. To mitigate landslide hazard effectively new methodologies are required to develop. Besides structural measure some recent measure and non structural measure are also essential for better management of landslide prone hilly terrain of Darjeeling district. In the light of the prime objective of the paper is landslide hazard management of Darjeeling hill - a critical need for inhabited the present study evaluating how to minimise the landslide occurrences and its impact.*

KEY WORDS: *Afforestation, Landslide Hazard Management, Landslide Hazard Zonation, LIR Map, $NDMA_S$, $SDMA_S$.*

I. INTRODUCTION

The rapid movement of large volumes of surface materials under gravitational influences adds considerably to the range of hazards found in mountainous terrains.

– Hewitt, 1992.

Landslides are widespread phenomena and unpredictable in nature. Landslide are major hydro-geological and anthropogenic hazards that affect not only mountains areas rather it can found in mining areas, plateau river terrains, coastal areas and offshore too. The Darjeeling district is highly prone to landslide. Researchers (Ghosh, 1950; Nautiyal, 1951, 1966; Dutta *et al*, 1966; Roy and Sensharma, 1967; Basu, 1985, 1987 and 2001; Verma, 1972; Paul, 1973; Sinha, 1975; Chatterjee, 1983; Bhandari,1987; Deoja *et al*,1991; Sengupta, 1995; Agrawal *et al*, 1997; Krishna *et al*, 1997; Yudhbir, 2000; Starkel and Basu,2000; Bandyopadhyaya, 2001; Basu and De, 2003; Bera, 2004; Pal, 2006; Maiti, 2007; Basu and Bera, 2007; Ghosh, 2009; and Sarkar, 2011) carried out a demand oriented studies in hilly areas and identified the causes and consequences of major landslide occurrences phenomena and proposed some mitigation procedure to minimise its hazardous impact[1] . The Geographical extension of the district is 26^o $31^/$ N - 27^o $13^/$ N and 87^o $59^/$ E - 88^o $53^/$ E. with an area of 3149 Km^2. Geographically, the district can be divided into two broad sub region, the hills region and the plain regions. The Darjeeling hill area covers an area of 2476 Km^2 spanning 3 sub division of Kalimpong, Kurseong, Darjeeling and 13 mouzas of siliguri subdivision. The entire hilly region of the district comes under the Darjeeling Gorkha Hill Council, a semi-autonomous administrative body under the state government of West Bengal. The foothill of Darjeeling Himalayas, which comes under the Siliguri subdivision, is geographically well known as the Terai. The prime objective of the paper is landslide hazard management of Darjeeling hill - a critical need for the inhabited.

Identified Major Area of Landslide

Landslide is most common phenomena in following areas of Darjeeling hill–

(a) Areas subject to Seismic shaking.
(b) Mountainous environments with very high relative relief.
(c) Unscientific mining/land use areas.
(d) Areas of moderate relief suffering severe land degradation.
(e) Areas covered with thick sheets of loess.
(f) Areas with high rainfall and ill drainage system.

II. CLASSIFICATION OF LANDSLIDE

Classification of landslide after Varnes (1978) are given below[2]–

TABLE NO 1: Classification of Landslide

Type of movement	Type of material		
	Bedrock	Engineering soils	
		Mainly coarse	Mainly fine
Falls	Rock fall	Debris fall	Earth fall
Topples	Rock topple	Debris topple	Earth topple
Slides			
Rotational	Rock slump	Debris slump	Earth slump
Rotational (few units)	Rock block slide	Debris block slide	Earth block slide
Translational	Rock slide	Debris slide	Earth slide
Lateral spreads	Rock spread	Debris spread	Earth spread
Flows	Rock flow (Deep creep)	Debris flow (Soil creep)	Earth flow (Soil creep)
Complex	Combination of two or more principle types of movement.		

Source: Smith Keith, Environmental hazards, 4th Edition, Routledge, P. 126.

III. LANDSLIDE VELOCITY SCALE AND PROBABALE DESTRUCTIVE SIGNIFICANCE

During Landslide the materials like rock, soil, vegetation and existing construction above the land sliding area may move by falling, toppling, sliding, spreading, flowing or in combination of two or more principal types of movement. Some Landslide is rapid, occurring in seconds, where as others take some minutes, hours, and week and so on. The Landslide velocity scale proposed by Cruden and Varnes (1996) are below[3]-

TABLE N0 2: Landslide Velocity Scale

Velocity Scale	Description	Velocity (mm/sec)	Typical Velocity	Probable Destructive Significance
7	Extremely Rapid	5×10^{3}	5 m/sec	Catastrophe of major violence; buildings destroyed by impact of displaced materials; many death; escape unlikely.
6	Very Rapid	5×10^{1}	3 m/min	Some lives lost; velocity too great to permit all persons to escape.
5	Rapid	5×10^{-1}	1.8 m/hr	Escape evacuation possible; structures; possessions, and equipment destroyed.
4	Moderate	5×10^{-3}	13 m/month	Some temporary and insensitive structures can be temporarily maintained.
3	Slow	5×10^{-5}	1.6 m/year	Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase.
2	Very Slow	5×10^{-7}	15 mm/year	Some parmanent structures undamaged by movement.
	Extremely Slow			Imperceptible without instruments; construction POSSIBLE WITH PRECAUTIONS

Source- Landslide Risk Management Concepts and Guidelines, Australian Geomechanics Society, Sub-Committee on Landslide Risk Management, March 2000.

IV. METHODOLOGY

The methodologies consist of three parallel processes including pre field method, field method and post field method. The pre field method was carried out for collecting primary and secondary data. Several maps such as location map, land use map, slope and soil map are also carefully used. Various publication of the central, state and local governments, books, Magazines, news paper, publication prepared by research scholars, university etc. in different field, statistics and historical document are also carefully study. In field process Observation method, Interview method (personal interview) and collection of data through questionnaires etc. has been taken for collecting primary data. Finally in the post field method all the data is compiled, maps are prepared to solve the problem.

V. BASIC CAUSES OF LANDSLIDE

Landslide is the result of two primary causes in the study area. These are−

1. Increase in driving force

The following physical and manmade factors which increase the driving force on the slope in Darjeeling hill.

1.1 Physical Factors

1.1.1 Local shocks and vibration occur from seismic activity.
1.1.2 Ill drainage system due to high rate of soil erosion.
1.1.3 Heavy precipitation in the time of monsoon period.
1.1.4 An increase of slope angle if a stream erodes the bottom of a slope.

1.2 Manmade Factors

1.2.1 Local shocks and vibration occur from the operation of heavy construction machinery.
1.2.2 An increase of slope if the slope is steepened by building work.
1.2.3 Removal of lateral support by human activity such as road construction.
1.2.4 Additional weight placed on the slope by dumping of waste or by building construction.
1.2.5 Deforestation.
1.2.6 Unscientific mining and quarrying which reduce the basal support of the slope.
1.2.7 Heavy vehicular movement is another factor which causes local shocks and vibration.

TABLE NO 3: Total Registered motor vehicles in three subdivisions (except siliguri subdivision) of the Darjeeling hill area.

Year (2003-04)	Goods vehicles	Motor car & Jeep	Motor Cycle & Scooter	C.C. Taxi	Mini Bus & Bus	Tractors	Others/ Ambulance	Total
Total	2391	7186	20799	1068	279	138	26	32015

Source: The Road and Transport Office (R.T.O).

2. Decrees in share resistance

The following physical and manmade factors reduce the share resistance on the slope in the study area.

2.1 Physical Factors

2.1.1 An increase of pore water pressure in the slope materials.
2.1.2 Pedological factor.
2.1.3 Surface and subsurface runoff.

2.2 Manmade Factors

2.2.1 Heavy land degradation by human activity.
2.2.2 Roadways construction.
2.2.3 Unscientific cultivation.
2.2.4 Population pressure.
2.2.5 Use of non-degradable materials (plastic) etc.

LANDSLIDE HAZARD ZONATION MAP

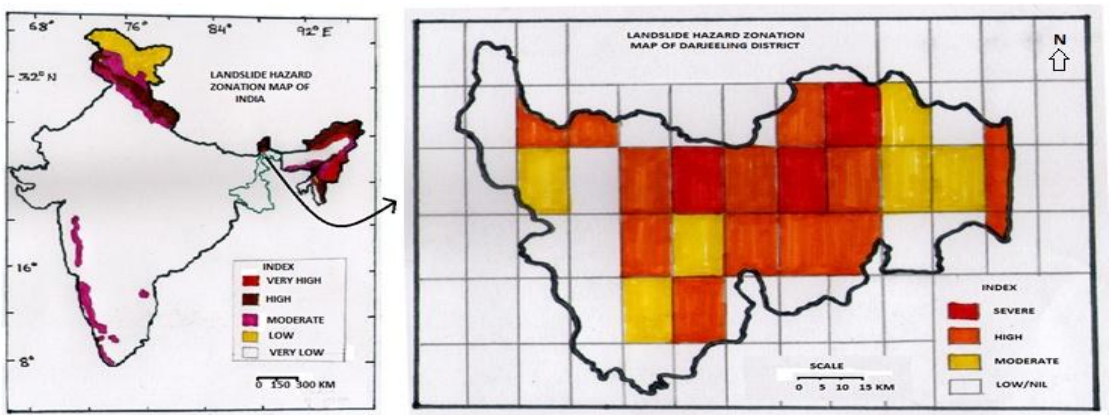

Fig: 1- Landslide Hazard Zonation Map of INDIA and Darjeeling District.

TABLE NO 4: Major Landslide in Darjeeling Hill Region during 1998-2004

YEAR	BLOCK/MUNICIPALITY	AREA	DAMAGE DODE
1998	Kurseong	Tindharia	250 houses damaged, NH-55 damaged, 10 people died.
		Sittong T.E	13 people died
1999	Kurseong	Sittong III &I GP	9 people died
		Tindharia	3 person died
2000	Sukhia pokhari	Pusumbing	2 people died
	Bijanbari	Relling Basty	1 people died
		Hathale Basty	2 people died
	Darjeeling sadar	Botanical Garden	1 people died
		Jawar Basty	1 people died
	Kurseong	Sepoydhura	2 people died
	Darjeeling Sadar	Dali	11 people died
		Harishatta	1 people died
2001	Kurseong	Rohini	2 people died
2002	Kurseong	Giddapahar	2 people died
2003	Mirik	Gayabari	24 people died
2004	Sukhia Pokhari	Mim T.E	1 people died

Source: D.M.Office, Relief Department, Darjeeling.

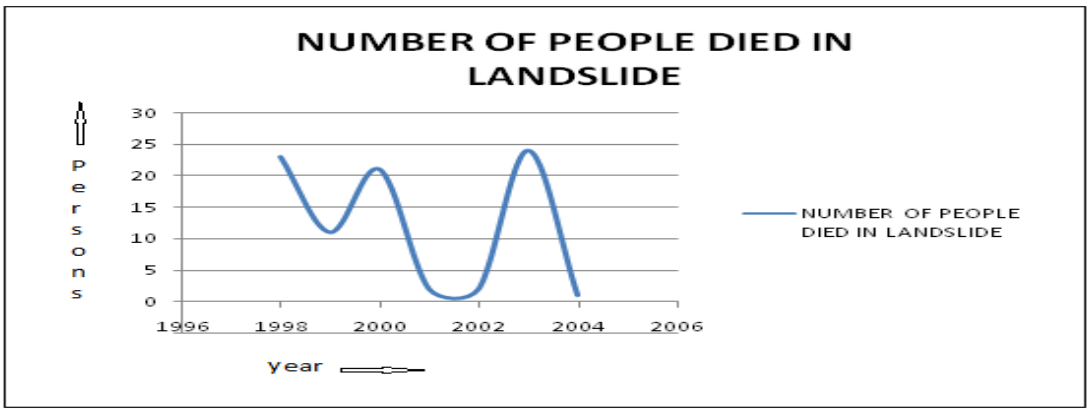

Fig: 2- Number of people died in landslide in Darjeeling district.

VI. EARLY SIGNS OF LANDSLIDE

Warning sign on landslide emerges earlier than the actual event. It is necessary to recognize these warning. These signs are-

(i) Pattern of storm-water drainage on slopes, land movement, small slides, flows, or progressively leaning trees.
(ii) One should not ignore the doors windows stick or jam for the first time or new cracks appear in plaster, tile, brick, or formations of buildings.
(iii) Landslide happens in areas where the ground or paved areas, such as streets or driveways, show slowly developing, widening cracks or where underground utility lines break or bulging ground appears at the base of a slope.
(iv) Water breaking through the ground surface in new locations is another important sign.
(v) Similarly fences, retaining walls, utility poles, or trees tilt or move.
(vi) In more advances circumstances, a faint rumbling sound can be heard that increases in volume. Unusual sounds, such as trees cracking or boulders knocking together, might indicate moving debris. Collapse pavement, mud, fallen rocks, and other indications of possible debris flow can be seen[4].

VII. SOME MEANS OF MITIGRATION

1. RECENT MEASURE

1.1 Rescue Operation

At first, responsibility of local people should inform police, SDMA, local government body, hospitals or media any of one for quick rescue operation. The Government should take help of Para military combat force in case of large scale of hazard.

1.2 First Aids and Hospitalised Injured Peoples

The landslide victim's people are injured seriously so as early as possible provide first aids by medical and Para medical staff, if in emergency injured people are admitted in the nearby hospitals to provide them better treatment.

1.3 Removal of the Debris

The roads are blocked by the landslide debris and all transport system breakdown in hill area. Traveller, tourist, patient, children's all are waiting without food, water and medical treatment. Thus highway/roadway authority should always prepare to remove the debris materials from the road ways as early as possible.

2. STRUCTURAL MEASURE

The slope of Darjeeling hilly area may be stabilized by following positive steps-

2.1 Treatment for Slope Stabilization

The stability of a vulnerable slope may be increased either by reducing the volume at the head or by expanding the volume at the toe.

2.2 Treatment of Drainage Pattern

(a) The streams and temporary water resources particularly at the head of the slides are to be diverted from the slide area.

(b) Periodic maintenance of drainage should essential particularly in pre monsoon and monsoon period.

2.2 Afforestation

Afforestation programmed should lunched for minimize the breakdown situation of environmental equilibrium. The grass cover must not be disturbed unnecessarily in the hilly area.

2.3 Construction of Human Settlement

Due to the population pressure, increasing tourism industry the vulnerability of landslide increase day by day in Darjeeling hill. Many heritage sites in the hilly area now subjected to landslide hazard, so Indian National Trust for Archaeological and Cultural Heritage (INTACH) and State Archaeological Department should follow scientific measure to save these heritage sites. Planners, architect and engineers should design human settlement with consideration of ecologically fragile environment of the hilly area.

2.4 Engineering Construction

In landslide prone area engineers construct various kind of structural measure such as Retaining Wall, Buttress Wall, Drainage Borings, Rock Boulders, Piling Works, Hardening of Soil, Grouting, Slope Stabilization by Vegetation, Break of slip surface by Blasting, Drainage Trenches, Horizontal Drainage borings and Vertical Exploration Boring etc. But which one construction may be suitable for a particular landslide vulnerable area should be determined by skilled engineers.

2.5 Rehabilitation of Settlement

Due to landslide houses destroy, people died, and road are blocked with untold suffer of the victims, thus local government responsibility should provide rehabilitation of settlement as early as possible.

2.6 The wide expansion of Tea plantation, urbanisation should not welcome instead of forest cover.
2.7 Reducing the channel gradient by building check dams with cover of shrubby vegetation is necessary.
2.8 Unscientific cultivation and mining should be stopped.
2.9 Geo-textile method should be practice.

Landslide and Debris Flow Hazard Management issues and options, prepared for Whakatana District Council, July 2013 under the Australian Geomechanics Society (AGS) 2007 Risk Management Framework with some modification, the following guidelines (Structural) may be suitable in the study area[3]-

STRUCTURAL MEASURE

Structural measures include physical measures that eliminate or mitigate a hazard, or reduce the risk from a hazard.

Hazard Elimination

Potential measures include

(a) Re-profiling of slopes;
(b) Reducing the height of slopes and/or removing potential landslide material;
(c) Construction of earthwork buttresses to support slopes;
(d) Construction of retaining walls;
(e) Reinforcement of slopes by the installation of rock anchors etc;
(f) Prevention of material falling from slopes through the placement of concrete, wire netting etc.

These solutions may be applicable at an individual site scale.

Hazard Reduction

Potential measures include:

(i) Storm water and Ground water control through:
  (a) Diverting water flows away from landslide prone land.
  (b) Lowering groundwater levels through subsurface drains.
(ii) Vegetation Control through:
  (a) Removal or reduction of dangerous overhanging trees.
  (b) Planting of appropriate species at crest, face and base of slopes.

Risk Reduction

Potential measures include:

(i) Debris flow control structures
  (a) Debris dams
  (b) Debris nets
(ii) Debris barriers
  (a) Earth bunds
  (b) Steel posts
  (c) Flexible ring net barriers
  (d) Impact walls

3 NON STRUCTURAL MEASURE

3.1 Data Mining

To build knowledge about causes and consequences of landslide, to prepared maps and to take mitigation measure area wise data mining including landslide occurrences data, landslide intensity, vulnerability, risk analysis, surface and sub surface data is essential.

3.2 Hazard Zonation Mapping

To minimise vulnerability and risk of landslide Hazard zonation mapping at different scale with the help of modern techniques for mapping such as remote sensing, inventory data base and instrumentation technologies is necessary. The inventory data base means-all the known landslide incidence. Site specific all the information of inventory data base helps to provide landslide hazard zonation (LHZ) mapping, vulnerability assessment and risk zonation mapping. This map also has shown the landslide prone hilly region into different zones according to the relative degree of susceptibility to landslides. The landslide susceptibility zonation (LSZ) mapping is define as the division of landslide occurrence near homogeneous zones and the ranking is done according to the degree of the actual or potential hazard due to the landslide.

3.3 Geological and Geo tectonic Investigation

Engineers mainly geologist, hydro-geologist, geotechnical engineers play a vital role. Before investigation it is need to know about spatial extent, historical data base, landslide type, shear strength characteristics, pore pressure variety, how far and how fast movement of debris took place etc. The term geological investigation covers both surface and sub surface attributes. The geological and geotechnical investigation took place in three stages i.e. (i) preliminary stage, (ii) geotechnical investigation stage and (iii) detailed geological investigation stage. In the preliminary stage the geological engineers should observe, investing and gather historical data base, remote sensing data (CARTOSAT-1 and 2), and field survey data. During the field survey he must notice the lithological characteristics of rocks, joints and fracture zone, weathering process and its dominant factor, location of spring, seepage, and nature of drainage pattern, vegetation cover, slope characteristics, and finally the location of human settlement. Before detailed geological investigation the geotechnical investigation should must done. Geotechnical investigation includes slope analysis; tend to liquefy rock due to an earthquake shock etc. Co-seismic and post seismic landslide should be carefully investigated. The Indian Geotechnical Society (IGS) plays a vital role in this manner. Detailed investigation includes both surface and sub surface investigation. After surface investigation sub surface data including depth of bed rock, weathering limits, slip surface, permeability of strata, and depth of ground water table should be carefully investigate by the geologist.

Picture – 1and 2

3.4 Landslide Risk Treatment

Landslide risk treatment is the ultimate procedure of risk management. Landslide risk may be mitigated through five approaches used individually or combined to overcome or reduce losses. These ares-

(a) Restricting Development in Landslide Prone Areas- in India, there are no rules and regulation in this regard.

(b) Codes for Excavation, Construction and Grading - in India there is no uniform code to ensure standardisation about the construction in landslide prone areas.

(c) Protection of Existing Development - individually or in combined retaining wall, rock anchors, and soil nailing are commonly used to control mass movement in the hill areas.

(d) Monitoring and Warning System - Site specific monitoring techniques including field observation and remote sensing observation of landslide prone area are suitable for real time warning.

(e) Landslide Insurance and Compensation for Losses - landslide insurance is the way to provide compensation to the landslide victims. Landslide insurance coverage could be made a requirement for mortgage loans.

Picture – 3 and 4

3.5 Rules, Regulation and Enforcement

In India there is no uniform rules and regulation about construction of building and dams, hydro electricity generation, mining, deforestation, land use pattern, tourism in the landslide prone hilly terrain. I am sorry to say some dishonest and corrupted political leader and government officer issued licence to the builders, planners, mining agencies, hydro electricity generating companies without considering the disturbance of environmental equilibrium and their further effect in the hilly terrain of study area.

The government allocated fund is too short and government representative declared lot of funds to the inhabited victim's family after damaged done in any type of hazard. But now all of us should have to change our narrow political profitable view/mind. We all know natural disaster cannot be delaminated by human effort but the losses may be minimised by allocating this fund before hazard by scientific improvement of land use pattern in the slide prone hilly terrain.

3.6 Awareness

There is an immediate need to aware local people about the landslide to reduce losses. The State Government, Uttarbanga Unnyan Parisod, Gorkha Hill Council, Organisation like NDMA, IIT-Kharagpur, Local Schools, Local Hospital, Soldiers, Electronic and print media each and every body should lunch comprehensive awareness programme and campaign for the inhabited of landslide prone study areas. They do and highlight the following points-

(a) They distribute handbills, poster in their regional language about the site specific details of landslide and what is the lesson they should learned from the past few landslide phenomena.
(b) They prepared and display short video film, power point documentary for the local public about the importance of preparedness and mitigation method adopted by them before, during, and after the landslide disaster.
(c) The National Disaster Management Authority should lunch power point presentation for Government organisation, School and Hospital organisation, Soldiers, $NGO_{s,}$ Local nodal agencies, Local club, and local people- What is the role and responsibility before, during and after the landslide disaster.
(d) The land use planner, urban planner should make understand the local people about the importance of land use planning. The scientist and engineer should arranged awareness camp to increase geological, geo-hydrological investigation practice for contractor. They also make understand local people about the importance and use of eco-friendly building materials in landslide prone area.
(e) The North Bengal University and colleges under this university should aware and encourage the student and research scholars to research about the new method to mitigate landslide in the hilly terrain of Darjeeling district.
(f) The North Bengal Medical College associated with local hospitals should aware and trained the Doctors, Nurse, all hospital staffs and locals how to response in emergency period, what is the primary duty of them etc.
(g) Develop awareness among the inhabited about the disadvantage of non-biodegradable materials.

(h) Media has a strong communication which reaches all level of society. Government should take help of media for awareness programme in the form of commercial advertise, short documentary films, news analysis by expert etc. among inhabited, tourist and also it can reach grass root level of society.

3.7 Landslide Monitoring and Forecasting

In India generally landslide monitoring are not practiced. To monitoring landslide involves some steps-

(a) Selecting some specific type of site.
(b) Data gathering and processing.
(c) Analysis data to understand the future result in the specific study area.

For landslide monitoring engineers should take surface and sub surface measurement. Surface monitoring are done with few survey pillar in the landslide zone and observed the rate of surface movement in pre monsoon, monsoon and post monsoon period. While sub surface movement particularly shallow movement measured by installing flexible casings in boreholes through SGI rod inclinometers, Kirby's T-pegs etc. and deep surface movement are measured by chain deflect meters, single and multi point wire extensometers, insert type pipe strain meters etc. For little bit changes of landslide prone region the real time monitoring data is also essential.

The early warning system can reduce the maximum losses of landslide hazard. It may possible with the inter cooperation of inhabitant, government authorities, scientific and technical communities, remote sensing techniques, media and state disaster management authorities.

3.8 Human manpower Development/ Capacity Building

The challenging role of urban planners, geologist, geotechnical engineers, NGO_S, rescue workers, social scientist, social workers, media and technicians are important to improve capacity building to fight against any natural calamities. For human man power development or capacity building following step are necessary-

(a) In the hilly terrain unscientific construction trigger landslide. In west Bengal some board of elementary/secondary education (Class vi-x) introduced disaster education and its preparedness. But all board of elementary/ secondary education could not introduce it. Though the syllabus is only text base not practically lunched thus they are not mentally and physically prepared what is the role of them during and after the time of hazard.
(b) Large sections of the society are detached from the school so government should arrange community education programme free of cost for 10 to 15 days. The specialist like the staff of NDMA/SDMA should arranged training cum education programme for inhabited like elderly, woman, youth, physically challenged etc.
(c) The staffs of NDMA/SDMA are too short so their quick responses are not satisfactory. Thus inhabited individuals, youth clubs, NGO_S should encourage by the government to improve capacity building among them to fight/self help during and after the landslide hazard.
(d) Another important step is up gradation of capacity building among the NDMA/SDMA staffs, urban planners, architect, geological and geotechnical engineers, communication media staffs, and decision makers of government bodies.

3.9 Proper Land use Planning

Unscientific land use of study area also causes landslide several time. The study area belonged to geologically sensitive zone of India. But deforestation, urbanization, industrialization, maximum use of resource, heavy building construction and engineering structural work etc. increases the landslide vulnerability in the study area day after day. Thus, proper scientific land use planning and Ban on non-biodegradable materials is necessary.

3.10 Landslide Management Education From School Level

Landslide management including geo climatic region, landslide characteristics, landslide vulnerable zone, their participation in the times of landslide etc. of their own particular area should be taken as an academic compulsory subject for the local children's from primary school level education.

3.11 Village wise Training Programmed

Government should organize village wise training programmed in the study area for younger/elderly people- "What is the procedure to rescue yourself, your family, and your neighborhood in the time of landslide".

3.12 National and International Co- operative Landslide Insurance Programmed

Landslide insurance is an important loss sharing strategy. It provides financial assistance to landslide victims. Government has to classify RISK ZONE AREA and also LANDSLIDE INSURANCE RATE MAP (LIRM) for insurance rating to individual properties.

3.13 Shelter

After the massive landslide houses are totally destroyed, the people are homeless. So Government should declare all nearby schools as a shelter.

3.14 Preparedness

Landslide is frequently occurred every year in the study area. The involvement and preparedness of individuals, community, government authorities, medical team and there also the quick response of them minimize the socio economic losses and untold pains of victims.

(a) Individual's preparedness involves saving himself and your family during and after the hazard by awareness or some training.

(b) Government authorities' preparedness includes local gram panchayats, different department of State government, police, State Disaster Management Authorities ($SDMA_S$) etc. Government should quickly provide first aids, food, water, safety and rehabilitation of settlement for victims.

(c) Community preparedness including NGO_s, local clubs, media etc.

(d) All medical and Para-medical team, ambulance and driver should quick response in emergency first aids/treatment.

Landslide and Debris Flow Hazard Management issues and options, prepared for Whakatana District Council, July 2013 under the Australian Geomechanics Society (AGS) 2007 Risk Management Framework with some modification, the following guidelines (Non-Structural) may be suitable in the study area[3]-

NON-STRUCTURAL MEASURES

Non-structural measures are risk reduction measures. They do not alter the likelihood of hazard occurring, but contribute towards addressing some, or all, of the consequences.

Information

Potential measures include

(a) Research, scoping studies, hazard vulnerability studies, risk assessments to inform decision making;
(b) Monitoring of existing landslides by technical specialists;
(c) Lifeline engineering projects to assess vulnerability of lifelines and develop contingency and response plans;
(d) Education programmes to improve knowledge and promote awareness;
(e) Advice and advocacy e.g. keeping up to date best practice guidelines on mitigation measures and contact information for qualified experts;
(f) LIMs to provide information on location and/or characteristics of known hazards;
(g) PIMs to provide information on location and/or characteristics of known hazards.

All of these measures should be applicable in the study areas.

Warning Systems

Potential measures include:

(a) Landowner education on natural warning signs and self evacuation;
(b) Low Level Early warning systems;
(c) Regular monitoring and assessment of risk areas by qualified staff
(d) Active monitoring of rainfall forecasts and radar during events to detect any potential issues
(e) High Level Early warning systems - Low Level Early warning systems plus
(f) Forwarding of all severe weather warnings to residents in risk areas (email and text alert)
(g) Deployment of mobile radar to monitor areas of concern during major events
(h) Installation of wire sensors to measure land movement in all areas of high risk
(i) Rainfall sensors in all catchments

(i) Low level event system

(a) Visual observation by residents in risk areas

(ii) High level event system

(a) Sensors connected to alarms placed in all areas with a high risk of potential landslide/debris flow
(b) Staff deployed to monitor specific sites during heavy rainfall events and warn residents if movement in slope detected
(c) Evacuation procedures, including both formal and self evacuation.

Development Control

Potential measures include:

(i) Enabling District and Regional Plan rules to manage development in hazard areas, such as:
(a) Allowing existing activities to continue but only within the existing building envelope;
(b) Allowing alterations or re-development where risk is reduced;
(c) Allowing properly designed protection works to be undertaken without resource consent or streamlined consent procedures;
(d) Providing best practice guidelines to assist landowners with risk mitigation;
(e) Allowing vulnerable uses to be replaced with less vulnerable uses (e.g. residential use replaced by non-habitable use).

(ii) Restrictive District Plan zoning and rules to manage development in hazard areas, such as:
(a) Requiring resource consent for extensions and relocations, and any works on sites within hazard zones;
(b) Not allowing intensification by further subdivision within hazard zones;
(c) Not allowing new vulnerable land uses to establish within hazard zones.

(iii) Restrictive Regional Plan rules to manage development in hazard areas, such as:
(a) Requiring existing activities to cease by a specified date unless resource consent is obtained, which would require risk to be reduced to an acceptable level?
(b) Not allowing reoccupation of sites that have been rendered uninhabitable by a hazard event unless resource consent to re-establish is granted, which would require risk to be reduced to an acceptable level.
(c) Allowing life-time occupation of a site by current occupants and requiring resource consent for reoccupation by others, which would require risk to be reduced to an acceptable level.

Development Retreat

Potential measures include:

(a) Acquire / purchase properties that have unacceptably high risk and enable relocation to sites with acceptable risk.

3.15 National and Inter-State Ministry Co-operation

The need for inter ministerial coordination in the context of landslide management and environmental protection is essential. The department of ministry and their activity after the landslide are following below[5]-

TABLE NO 5: National and Inter-State Ministry Co-operation

NAME OF MINISTRY	CO-OPERATIVE ACTIVITY
Ministry of Environment and Forests	Concerned with the protection of the lithosphere as a component of the environment, and is responsible for putting in place policies, strategies, and action plans to protect mountainous landscapes and the associated environment**.**
Ministry of Mines	The GSI specifically addresses landslides.
Ministry of Home Affairs	The nodal ministry responsible for disaster management as a whole.
Ministry of Defence	The SASE and Defence Terrain Research Laboratory deal with snow avalanches and landslides.
Ministry of Power and Energy	The National Thermal Power Corporation and National Hydroelectric Power Corporation faces landslides on many of their project sites.
Ministry of Urban Development and Poverty Alleviation	Responsible for projects connected with housing and human settlement. The CPWD and BMTPC deal with construction and hazard maps in landslide prone areas.
Ministry of Surface	The BRO deals with snow avalanches and landslides along roads and highways. The

Transport	IRC has a committee on DM.
Ministry of Water Resources	Responsible for the development of water resources and especially responsible for landslide dam related problems.
Ministry of Railways	Landslides affecting the railway network.
Ministry of Science and Technology	The DST promotes R&D on the diverse aspects of landslides, climate change, etc. The Department of Earth Sciences and laboratories of the CSIR are also engaged in the study of diverse aspects of landslide mitigation.
Ministry of Earth Sciences	Newly constituted ministry responsible for earthquakes, landslides, rainfall, and coastal disasters.
Ministry of Culture	Responsible for the protection of archaeological monuments, cultural and natural heritage threatened by landslides.
Ministry of Tourism	Responsible for the development of tourism in ecologically fragile areas.

Source: National disaster management guideline, Management of landslide and snow avalanches, June 2009.

3.16 Research and Development

Central, state government, U.G.C., other governmental and nongovernmental organization should allocated sufficient scholarship for scholars, researchers, teachers, inhabited planners, architect, cartographers, remote sensing engineers, GIS analyzers and rescue workers for following reason-

(a) The Engineers/Cartographers/Planners/Rescue Worker should research on/to-
   (i) Develop geological and geotechnical investigation instrument.
   (ii) Develop early warning system.
   (iii) Develop ideal plan and blue print for dam and hydro electricity power station construction.
   (iv) Develop model of management tools and techniques.
   (v) Development of rescue tolls and techniques.
   (vi) Development of real time monitoring system.
   (vii) Develop cheap techniques of quick communication among the inhabitants including grass root level.

(b) The Geographers/Environment scientist/ Soil scientist/ Geologist/ climatologist/ Botanist/ Geo Physics scientist/ Hydrologist/ Other scholars and researchers should research on/to-
   (i) Find out the characteristics of landslide in a particular area.
   (ii) Eco friendly land use pattern, mining, building materials use, tourism etc.
   (iii) Surface and sub surface drainage pattern.
   (iv) Slope, fracture zone, soil erosion etc.
   (v) Vegetation cover.
   (vi) Anthropogenic activity.
   (vii) Fluvial characteristics.
   (viii) Earthquake introduced landslide.
   (ix) Environmental pollution and degradation etc.

VIII. CONCLUSION

At the conclusion the question arise what should do the inhabited during and after the landslide.
The following steps may be followed during landslide-

(i) Stay alert and awake.
(ii) Alert your family and neighbor and follow your pre evacuation plan.

The following steps may be followed after landslide-

(i) Stay away from the slide area. There may be danger of additional slides.
(ii) Check for injured and trapped persons near the slide, without entering the direct slide area.
(iii) Help a neighbour who may require special assistance–infants, elderly people, and people with disabilities.
(iv) Listen to local radio or television stations for the latest emergency information.
(v) Inform the local Government and $SDMA_s$.
(vi) Look for and report broken utility lines to appropriate authorities. Reporting potential hazards will get the utilities turned off as quickly as possible, preventing further hazard and injury.
(vii) Check the building foundation, chimney, and surrounding land for damage. Damage to foundations, chimneys, or surrounding land may help you assess the safety of the area.

Despite advances of science and technology losses continue in forms of human suffering, life and property loss, environmental degradation etc. We cannot eliminate landslide but we want to minimize its impact by human effort. In near future due to lack of our awareness and unscientific land use newly landslide prone area develop and existing landslide zone become more hazardous and one day total Darjeeling hill may convert into highly landslide prone region. Due to land resource shortage and over population pressure we cannot evict the inhabited from the hills. So all of us should beware about the alarming problem and should respect and follow all mitigation measure to save ourselves and our beautiful Queen of hills.

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