सत्यमेव जयते

Training Module on

COMPREHENSIVE LANDSLIDES RISK MANAGEMENT



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Resilient India - Disaster free India

National Institute of Disaster Management (NIDM)
(Ministry of Home Affairs, Government of India)

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Training Module on
COMPREHENSIVE LANDSLIDES RISK MANAGEMENT



Impacts of Landslides on Society & Environment

August 2020

National Institute of Disaster Management (NIDM)

(Ministry of Home Affairs, Government of India)

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सत्यमेव जयते

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संदेश

हमारे देश के पहाड़ी क्षेत्रों, विशेषकर विशाल हिमालय की पर्वत श्रृंखलाओं को अक्सर भू-स्खलन के अप्रत्याशित खतरों का सामना करना पड़ता है। भू-स्खलन से होने वाले प्राकृतिक और मानव निर्मित पर्यावरण के विनाश के कारण बार-बार जान और माल की हानि से हमारे लोगों को भयानक पीड़ा सहनी पड़ती है। वर्तमान में संबद्ध लोगों और हितधारकों की क्षमता बढ़ाने के प्रति आपदा जोखिम न्यूनीकरण से जुड़ी सभी प्रमुख संरचनाओं में सर्वसम्मति है। माननीय प्रधान मंत्री के आपदा जोखिम न्यूनीकरण संबंधी 10 बिन्दु एजेंडे में भी आपदा जोखिम न्यूनीकरण के लिए स्थानीय लोगों की सूझबूझ और क्षमता को बढ़ाने पर जोर दिया गया है।

मुझे प्रसन्नता है कि राष्ट्रीय आपदा प्रबंधन संस्थान ने 28 नवंबर, 2019 को नई दिल्ली में 'भू-स्खलन जोखिम न्यूनीकरण एवं समुत्थानशीलता' विषय पर पहला अंतर्राष्ट्रीय सम्मेलन आयोजित किया था। संस्थान ने आपदा प्रबंधन अधिनियम, 2005 के अंतर्गत इसे सौंपे गए उत्तरदायित्वों के निर्वहन का निरंतर भरसक प्रयास किया है। **'व्यापक भू-स्खलन जोखिम प्रबंधन' पर प्रशिक्षण माड्यूल** की स्थापना स्थानीय समुदायों के अतिरिक्त विभिन्न हितधारकों की क्षमता संवर्धन और अंतिम व्यक्ति तक सूचना पहुँचाने के अपने लक्ष्य को प्राप्त करने के प्रति वचनबद्धता को दर्शाता है। प्रशिक्षण माड्यूल द्वारा तैयार की गई सामग्री भू-स्खलन क्षेत्र के सभी कर्मियों और शोधकर्ताओं के लिए सहायक सिद्ध होगी और इसके अलावा भू-स्खलन जोखिमों, उनके प्रभाव और उन जोखिमों / प्रभावों से बचाव / न्यूनीकरण के समुचित उपायों को समझने में अनभिज्ञ लोगों की क्षमता का विकास करके स्थानीय स्तर पर प्रकृति की संरक्षा कर इस को विकसित करने में भी सहायता मिलेगी।

भू-स्खलन के खतरे पर प्रथम प्रशिक्षण माड्यूल को विकसित करने के लिए किए गए प्रयासों के लिए मैं राष्ट्रीय आपदा प्रबंधन संस्थान को धन्यवाद देता हूं। मैं आशा करता हूं कि संस्थान भविष्य में अन्य आपदाओं पर भी इस तरह के समग्र प्रशिक्षण माड्यूल प्रस्तुत कर उनको कार्यान्वित करने की दिशा में अग्रसर होगा। देश को आपदा से लड़ने के योग्य बनाने के इसके प्रयासों के लिए मैं संस्थान को अपनी शुभकामनाएं देता हूं।

(नित्यानन्द राय)

अगस्त, 2020
नई दिल्ली।

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राष्ट्रीय आपदा प्रबंधन संस्थान
(गृह मंत्रालय, भारत सरकार)

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Foreword



The severe landslide hazard vulnerability of the mountainous states and other parts of the country is irrefutable. India has witnessed several horrendous landslide disasters which have hampered the socio-economic development and growth besides losses to lives, livelihood, environment, structures and infrastructure. Time to time landslides has questioned our capabilities to develop a culture of safety against the disasters.

National Institute of Disaster Management (NIDM) has been mandated by Disaster Management Act 2005 to develop training modules and educational materials, undertake training, research, documentation and publication for disaster risk reduction and resilience as well as promote awareness among different stakeholders for enhancing the human capacity to avoid, prevent, mitigate, prepare, respond and recover efficiently in a proactive, holistic and integrated manner. NIDM and its professional Faculty Members have made substantial contributions since inception of the National Disaster Management Authority in formulating various Guidelines, structuring and conducting Capacity Building programmes and providing technical support for numerous initiatives.

In pursuance of the mandate of DM Act 2005 and suo moto perception of the need of a comprehensive training module on one of the high ranked hydro-geological hazard, NIDM developed a training module on “Comprehensive Landslides Risk Management” in the year 2012 by Dr. Surya Parkash, faculty NIDM.

Recently the revised and updated version of the module has been prepared by Dr. Surya Parkash, Professor and Head, Geo-meteorological Risks Management Division, NIDM based on his experience gained from more than 50 training programmes on landslides, all over the country over the past ten years. The module has been designed with multi-hazards risk management approach and briefly discusses all the facets of developing culture of safety against landslides for all stakeholders in an integrated holistic manner.

Hopefully, this training module will enhance the capacity of relevant stakeholders dealing with the landslides in respective regime as well as the local community which are the very first sufferer due to the landslides.

MK Bindal

(Major General Manoj Kumar Bindal, VSM)
Executive Director,
National Institute of Disaster Management
New Delhi, India

Preface

India, the seventh-largest country in the world apropos of area, is persistently jolted by landslides of varied magnitude in hilly regions. As per available records, earliest instance of landslides in India dates back to early eighteenth century, about which not much is known. In recent past, the Alaknanda tragedy in 1970 in Garhwal Region of Uttarakhand state reminds us of the calamity of landslides. The catastrophe resulted in a trail of complete destruction along the valley for hundreds of kilometres. It engulfed a hamlet named Belakuchi, destroyed more than a dozen bridges and the debris completely submerged a large convoy of 30 buses. Another perilous disaster, which shook the heads of bureaucrats, thinkers, policymakers and professionals from different fields trading with earth science towards landslides was the infamous Malpa landslide of 1998 in the Pithoragarh district of Uttarakhand that wiped away the entire village. It also swept away a big camp that was set up to accommodate pilgrims returning from Mount Kailash-Mansarovar Yatra, killing about 210 people. Such nightmarish scenarios keep haunting the people and places of their occurrences.

The author had assisted NDMA as part of the Core Group and Drafting Committee for the Landslide Guidelines at the national level. He continues to be involved with NDMA as part of the National Task Force on Landslides Management and Working Committee of Experts on Landslides. He also severed as a member of the Task Force constituted by NDMA to formulate National Strategy for Landslide Risk Management. The experiences gained by the author from these activities have been used to compile this module for enhancing the knowledge and information related to landslides and disaster management among the different stakeholders.

NIDM was recognized as the World Centre of Excellence on Landslide Disaster Reduction {WCoE-LDR – (2011-2014)} by the Global Promotion Committee of the International Consortium on Landslides (ICL) and International Progamme on Landslides by International Strategy for Disaster Reduction (IPL-ISDR) for its contributions in the field of training and capacity development for landslide risk reduction. The author, who worked and the Leader of the WCoE-LDR at NIDM, has also been made Coordinator for the ICL's Thematic Network on Landslide Risk Management and approved as Project Leader for IPL-172 project on "Training, Documentation and Capacity Development for Landslides Risk Management" under the International Programme on Landslides. He is presently engaged in developing teaching tools for landslide risk reduction with ICL as one of the expert members.

It is believed that the present module will provide an insight to the trainees in the basic understanding about landslides and measures required for reducing the risks at different levels. The trainees are encouraged to interact with field experts and resources persons in this field to prepare themselves better for landslides risk reduction.



(Surya Parkash)
Author

Acknowledgement

At the outset, I would like to express my sincere thanks/gratitude to Major General Manoj Kumar Bindal, VSM, Executive Director, National Institute of Disaster Management (NIDM), New Delhi for his kind encouragement and support in revising and updating this module. I am also thankful to Lt. Col. D.C. Vashista, Joint Director, NIDM for extending his support. I would like to place on record the significant contributions made by different resource persons in compiling the information, database and maps related to landslides in the country. I am particularly thankful to Dr. R. K. Bhandari, Prof. Yudhbir, Shri Sanjiv Sharma, Dr. P.C. Nawani, Shri U. S. Rawat, Dr. R. K. Avasthy, Dr. Saibal Ghosh, Dr. Pankaj Jaiswal, Shri P. P. Srivastava, Shri Ishwar Singh Duhan, Shri Jog Singh Bhatia, Dr. Tapas Martha, Dr. Ravinder Singh Bora, Dr. P. K. Champati Ray, Dr. Kishor Kumar, Shri Anil Kathait, Shri Yadvendra Pandey, Shri Om Prakash Sahu for their fruitful discussions and valued contributions in preparing the manuscript of this module.

I am grateful to the reviewers namely Lt. Gen. (Retd.) N. C. Marwah, Former Member, NDMA, Shri Sanjiv Sharma, Former Dy. Director General, Geological Survey of India and Dr. Shailesh Kr. Agarwal, Executive Director, Building Materials and Technology Promotion Council (BMTPC) for their useful comments.

I sincerely acknowledge the encouragement by renowned international landslide experts, viz., Prof. Kyoji Sassa, Executive Director, International Consortium on Landslides, President ICI Dr. Peter Bobrowsky from Canada, Ms. Lynn Highland from USGS, Prof. Dwikorita Karnawati and Dr. Faisal Fathani from Indonesia, Prof. Alexander Strom from Russia, Prof. Cees van Westin from Netherlands, Dr. Fausto Guzzetti from Italy, Dr. S.H. Tabatabei from Iran, Dr. He Bin and Dr. Hiroshi Fukuoka from Japan.

It gives me immense pleasure in acknowledging the cooperation of my colleagues and supporting staff at NIDM, particularly Sh. Vikram Gurjar, Sh. S.K.Tiwari, Ms. Sonali Jain & Ms. Karanpreet Kaur. I would also like to express my sincere gratitude to faculty members and staff of disaster management centres in the different parts of the country who have helped in various manners by sharing their experiences, resources, database etc. and made valuable contributions to this effort.

Last but not the least, I would like to thank my wife Reeta and daughter Rasika, without whose consistent moral and logistic support, I would not have been able to give due attention and time to this work. I am indebted for their tolerance to bear with me when I was busy with work for the module and could not give them due attention and care.

Finally, I am grateful to the Almighty God without whose grace and kindness, I would not have been capable to carry this task successfully.



(Surya Parkash)

Module at a Glance

- Name: Comprehensive Landslides Risk Management
- Developed by: National Institute of Disaster Management (NIDM), New Delhi
- Technical Support: Geological Survey of India (GSI), Central Road Research Institute (CRRI), Advanced Technical Engineering Services (ATES), Central Building Research Institute (CBRI), Snow and Avalanches Studies Establishment (SASE), Wadia Institute of Himalayan Geology (WIHG)
- Total Number of sub-modules: 14
- Target Audience: Stakeholders in various sectors at different levels, particularly geologists, engineers (civil, mining and hydel), administrators, planners, NGOs, civil defence personnel, environmentalists etc.
- Training programme on the basis of this module requires:
    - Training Days – 5 days
    - Training Hours – 38-40 Hours
    - Trainers required: Minimum 2
    - Training Hall with sufficient number of movable chairs and tables
    - Training Materials: As mentioned inside
- Total Pages – 335 excluding annexures
- Module prepared by: Dr. Surya Parkash, Professor and Head, NIDM

Who Shall Use This Module

This module shall be used by a trainer involved in conducting courses on landslides risk management. The following individuals/organizations can be the potential users of this module:

- Geologists, Civil/Mining/Hydel Engineers, Field Professionals, Architects/ Planners, Developers, Environmentalists working in Hilly Terrains
- NDMA, SDMAs, DDMAs
- Geological Survey of India, State Departments of Geology and Mines, Academicians, Researchers and Professionals working on landslides
- Disaster Management Centres at State ATIs & SIRDs
- NGOs, CBOs, SHGs, Social Volunteers, Public Representatives
- NDRF, SDRF, QRTs, RRFs, Paramilitary and Military Establishments
- Administration, Local Bodies like Municipality and Panchayats
- NSS, NYKS, NCC, Scouts and Guides, Home Guards, Civil Defence and Fire Fighters
- Field Agencies like Border Roads, PWD, NHAI, PGCL, NHPC, THDC, NTPC, Irrigation and Flood Control etc.
- Stakeholders in Insurance, Finance, Planning, Policy, Development and Legal Sectors

How to Use this Module

The training design brief will provide users with the objectives of the course, target audience, structure, training methodologies and resource materials etc.

The chapters on pre and post training assessment will guide on how to carry out the evaluation and impact assessment of the training course with a set of questionnaires to be used and other necessary instructions. The actual training sessions will start with the sub-modules provided in the contents. However, elaborate instruction and guidelines are given for each session in each sub-module.

Trainer's Guide

The trainer/facilitator/course director may find the following tips useful for smooth conduct of the training.

General

- During the inauguration/introduction session, the trainees should be asked to switch off or keep their mobiles/cell phones in silent mode during sessions and advised to attend only the urgent calls that too by going out of the training hall.
- Participants list with names, addresses, contact numbers, emails, etc. should be circulated for verification from the trainees and for necessary corrections.
- Entire training materials and equipments should be kept ready and checked before the training.
- Clear information about lunch hours and tea breaks should be given to trainees to avert any kind of delays. They should be informed exact time for start of sessions and following day's plans.
- Every possible care should be taken regarding logistic arrangements for the trainees to make them feel comfortable during the entire course of training.

Training Specific

The following points should be taken care of:

- Except the first day, each day shall start with a recapitulation session of about 15 minutes. At the end of each day, summary of the day's proceedings shall be shared with the participants for 10 minutes.
- Group composition shall change for every activity/exercise through different methods.

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ABBREVIATIONS/ACRONYMS USED

ATES	-	Advanced Technical Engineering Services
ATI	-	Administrative Training Institute
BIS	-	Bureau of Indian Standards
BRO	-	Border Roads Organization
CBDP	-	Community Based Disaster Planning
CBLRM	-	Community Based Landslides Risk Management
CBDRM	-	Community Based Disaster Risk Management
CBO	-	Community Based Organizations
CBRI	-	Central Building Research Institute
CLRM	-	Comprehensive Landslides Risk Management
CRF	-	Calamity Relief Fund
CRRI	-	Central Roads Research Institute
DDMA	-	District Disaster Management Authority
DGBR	-	Director General Border Roads
DGCD	-	Director General Civil Defence
DGM	-	Department of Geology and Mines
DMA	-	Disaster Management Act
DMMG	-	Department of Mines, Minerals and Geology
DoS	-	Department of Space
DST	-	Department of Science & Technology
ESF	-	Emergency Support Function
GSI	-	Geological Survey of India
GFDRR	-	Global Facility for Disaster Reduction and Recovery
HVCR	-	Hazard, Vulnerability, Capacity and Risk
ICL	-	International Consortium on Landslides
ILC	-	International Landslide Centre
IMD	-	Indian Meteorology Department
IIRS	-	Indian Institute of Remote Sensing
IPL	-	International Programme on Landslides
ISDR	-	International Strategy for Disaster Reduction
ISRO	-	Indian Space Research Organization

ITBP	-	Indo Tibetan Border Police
LHZ	-	Landslides Hazard Zonation
LMP	-	Landslides Management Plan
LRM	-	Landslides Risk Management
LSN	-	Landslides Schools Network
MHA	-	Ministry of Home Affairs
MoM	-	Ministry of Mines
MoES	-	Ministry of Earth Sciences
NCCF	-	National Calamity Contingent Fund
NDMA	-	National Disaster Management Authority
NDMRC	-	National Disaster Mitigation Resource Centre
NDRF	-	National Disaster Response Force
NDRF	-	National Disaster Response Fund
NGO	-	Non Governmental Organization
NHAI	-	National Highway Authority of India
NHPC	-	National Hydro Power Corporation
NIDM	-	National Institute of Disaster Management
NTPC	-	National Thermal Power Corporation
NRSC	-	National Remote Sensing Centre
PGCL	-	Power Grid Corporation (I) Limited
PWD	-	Public Works Department
QRT	-	Quick Response Team
SASE	-	Snow and Avalanches Studies Establishment
SDMA	-	State Disaster Management Authority
SDRF	-	State Disaster Response Fund
SDRF	-	State Disaster Response Force
SOP	-	Standard Operating Procedures
THDC	-	Tehri Hydro Development Corporation
UNDP	-	United Nations Development Programme
USGS	-	United States Geological Survey
VOs	-	Voluntary Organizations
WBI	-	World Bank Institute
WIHG	-	Wadia Institute of Himalayan Geology

Glossary / Terminology related to Landslides

Abandoned: The landslide which is inactive and no longer affected by its original causes.

Acceptable Risk: A risk for which we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Active: Landslide that is currently moving or has moved in present annual cycle of seasons.

Annual Exceedance Probability (AEP): The estimated probability that an event of specified magnitude will be exceeded in any year.

Assessment: Overall process of hazard or risk identification, analysis and evaluation.

Cloud Burst: Clouds are formed when water vapours reach a height where temperature is low. Water vapours condense to form small water droplets. When nucleation of such clouds takes place, water droplets grow in size to form raindrops, depending on the thickness of clouds and low temperature, the rain is light or heavy. In case of cloud bursts, cyclonic winds virtually compress the clouds and force nucleation amounting to sudden precipitation, whereby almost entire water in the clouds is poured out.

Sudden rainfall with great velocity is called a cloud burst. It results from the condensation of stratus clouds. It does not last very long. Heavy rains on the other hand are caused by nimbus clouds which are dark grey and are suspended at a lower height.

Complex: An activity where a landslide exhibits at least two types of movement (from among fall, topple, slide, spread, or flow) in a sequence.

Consequence: The probability of loss and damage to elements at risk by a landslide event.

Controlling (Perpetuating) Factors: The factors which dictate the condition of movement as it takes place; i.e. factors which control the form, rate and duration of movement.

Danger (Threat): Natural phenomenon that could lead to loss, disadvantage, damage, injury or loss of life; it does not include any forecasting; also see Hazard.

Disaster: A serious disruption of the functioning of society, causing widespread human, material or environmental losses, which exceed the ability of affected society to cope using only its own resources.

Early Warning: Provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response.

Elements at Risk: Population, buildings and engineering works, economic activities, public utilities, other infrastructure, and environmental values in an area affected, or potentially affected by a landslide.

Exposure: People, property, systems, or other elements present in hazard zones that are thereby exposed to potential losses due to landslides.

Erosion: Process of weathering and transport of soil and rock from their natural environment or source. Agents of erosion include wind, water, ice, gravity and living organisms (bioerosion).

Estimation: The determination of hazard or risk.

Evaluation: Using values and judgments in the decision process, either explicitly or implicitly, to determine the importance of the estimated hazard or risks, and thereby identify alternatives to manage the hazards or risks.

Forecast: The definite statement or statistical estimate of the likely occurrence of a future event or conditions for a specific area.

Frequency: Probability or likelihood of occurrence of a repeating event, such as a landslide, expressed as the number of occurrences per unit time; also a measure of past occurrences per unit time.

Hazard: A condition with the potential for causing an undesirable consequence. Alternatively, the hazard is the probability a particular landslide occurs within a given time and space.

Hazard Zoning: The subdivision of the terrain in zones that are characterized by the temporal probability of occurrence of landslides of a particular size and volume, within a given period of time.

Individual Risk: The risk of fatality and/or injury to any identifiable (named) individual who lives within the zone exposed to the landslide, or who follows a particular pattern of life that might subject him/her to consequence of the landslide.

Landslides: Landslides can be simply defined as down slope movement of rock, debris and/or earth under the influence of gravity. This sudden movement of material causes extensive damage to life, economy and environment.

Landslide is the most common and universally accepted collective term for most slope movements of the mass movement type. The term has sometimes been considered unsuitable as the active part of the word denotes sliding.

Landslide Inventory: The collection or record of landslide events indicating location, classification, volume, activity, date of occurrence and other characteristics of landslide within an area.

Landslide Risk Map: The subdivision of the terrain in zones that are characterized by different probabilities of losses (physical, human, economic, environmental) that might occur due to landslides of a given type within a given period of time. The risk may be indicated either qualitatively (as high, moderate, low and no risk) or quantitatively (in numbers or economic values).

Landslide Susceptibility Map: A map showing the subdivision of the terrain in zones that have a different likelihood that landslide of a type may occur. The likelihood may be indicated either qualitatively (as high, moderate, low, and not susceptible) or quantitatively (e.g. as the density in number per square kilometres, or area affected per square kilometre).

Likelihood: Chance of an event occurring; a qualitative description of probability of a landslide.

Management: Process of hazard or risk assessment and control or treatment.

Mass Movement: It is outward or downward gravitational movement of earth material without the aid of running water as a transporting agent. It does not deny the importance of water in either its solid or liquid state as a destabilising factor nor does it exclude subsidence and other movements on flat ground.

Mass Wasting: A broader term commonly used in conjunction with the erosion cycle to refer to the mass reduction of the interfluves as opposed to the degradation by streams. In effect it must include the action of all non-linear erosional processes working on the slopes between streams.

Monitoring: The continual or frequent observation or determination of the status of activity of a landslide to identify change.

Preparatory Factors: which dispose the slope to movement; i.e. the factors which make the slope susceptible to movement without actually initiating it and thereby tending to place the slope in a marginally stable state.

Qualitative Risk Analysis: The analysis that uses descriptive words or numeric rating scales to describe likelihood, vulnerability and consequences.

Quantitative Risk Analysis: The analysis based on numerical values of probability, vulnerability and consequences.

Risk: A measure of the probability and severity of an adverse effect to individuals or populations, property or the environment.

Risk Management: The complete process of risk assessment and risk control.

Slope Failure: It refers to the process of rupture or shearing in materials rather than to a particular ground feature. Terzaghi (1950) advocated this term for slope movements on engineered slopes.

Slope Instability: It refers to the predisposition of a slope to mass movement. The condition may be recognised by analysis of stress within the slope, by various slope characteristics or by analysis of historical records of slope development.

Slope Movements: Restricts to mass movements on slopes.

Societal Risk: The risk of multiple injuries or deaths to society whole: one where society would have to carry the burden of a landslide accident causing a number of deaths, injuries, and financial, environmental and other losses.

Stability Factors: All forces determining stability are controlled or influenced by identifiable phenomena and these are referred as Stability factors. When these operate to induce instability, they are called destabilsing or causative factors. e.g. climate, slope strength, vegetation etc. Indeed there are many components of the slope system which can change independently to destablise the slope but the significance of any change is dependent on the aggregated effect of all the components. An examination of the temporal variability of factors identifies some as being passive (slow or gradually changing) e.g weathering, and transient or active (fast changing).

Triggering Factors: The factors which initiate movement; i.e. those factors which shift the slope from a marginally stable to actively unstable state.

Tolerable Risk: A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

CONTEXT

Landslides occur in all hilly terrains in response to a wide variety of terrain conditions and triggering processes like heavy rainstorms, cloudbursts, earthquakes, floods and haphazard human activities. As per an estimate more than 5000 people are buried alive under landslide debris and economic losses of the order of more than US$ 4 bn are suffered every year globally (ICL, 2010). Continent-wise, Asia suffers the maximum damages/losses due to landslides and among the Asian countries, south Asian nations are the worst sufferers and even among south Asian countries India is one of the most affected by landslides. According to the spatiotemporal assessment of Global Fatal Landslide Database (GFLD) from 2004 to 2016 by Froude and Petley (2018), globally 55, 997 people were killed in 4,862 distinct landslide events (excluding landslide events due to seismic activities). Asia, with a percentage of 75, tops the list of continents with the highest number of the landslide events.

In India, nearly 15% of its territory is prone to various degrees of landslide hazard (GSI, 2001), frequently affecting the human lives, livelihood, livestock, living places, structures, infrastructure, and natural resources in a big way. In addition to direct and indirect losses, landslides cause significant environmental damage, societal disruption and strategic concern. It is estimated that annually on an average about 300 lives are lost and costs the country an approximately Rs. 300 crores every year. Bansal and Mathur, 1976 reported that annually **Rs. 350 millions** are lost due to failure of transport and communication by the landslides. Bartarya and Valdiya, 1989 estimated that almost **50% of the landslides** occur along the roads. Valdiya, 1987 reported that the incidences of landslides increase by **25 to 345 times** due to road construction activities whereas Gupta (1990) estimated that each kilometer of road in hills require displacement of **40 to 80 thousand cubic metre** debris. Froude and Petley (2018) reported that in India 28 percent of the total landslides are as a consequence of construction activities, most by any country followed by China with only 9 percent.

Sometimes landslides occur as a consequence of other disasters like earthquakes, floods, cyclones, lightning, cloudburst, forest fires, dam/lake bursts etc. In such cases, landslide losses are normally included with the primary disaster and are not dealt separately.

With growing population, urbanization and human interventions in terms of developmental activities over unstable slopes, landslides pose an increasing risk to human lives, structures, infra-structures and environment. Changing climatic conditions like global warming, snow and glacial melting, erratic and uneven rains, extreme temperature conditions etc. are also adding to these risks to even unexpected areas. Large scale deforestation along with faulty management practices have led to high vulnerability to landslides in many regions of the country. Human activities relating to expansion on unsafe locations, unscientific mining, haphazard construction of roads, dams and river

training works ignoring natural features contribute to increased intensity of landslides. The absence of large scale landslide hazard maps leads to people being caught unaware especially when the first time landslides strike.

As individual landslides usually affect limited areas and people, damage resulting from landslide hazards were not recognized as a problem of national importance and were not addressed on a national basis. The absence of coordinated national approach to mitigating the detrimental effects of landslides resulted in a reduced ability of the States and Local Government agencies to apply the important lessons learnt, often at considerable expense, as a result, the need for a national strategy was been strongly felt and worked upon by the National Disaster Management Authority through Guidelines on Management of Landslides and Avalanches (2009), National Landslide Risk Management Strategy (2019) and National Disaster Management Plan (2019). Strengthening the process of landslide assessment, investigation, mapping and management will have far reaching effects in reducing landslide losses.

The aim of this training programme is to work in the following directions to make the hilly terrains and coastal areas free of landslide disasters.

- To promote the use of landslide risk analysis techniques to guide loss reduction efforts at the State and Local levels.
- To play a vital role in evaluating methods, setting standards, and advancing procedures and guidelines for landslide hazard maps and assessments.
- To provide tools for landslide hazards mitigation and promote basic research on monitoring techniques and aspects of landslide process mechanics.
- To improve education, training and awareness of landslide hazards and mitigation options for decision-makers, professionals, and the general public.
- To integrate and mainstream landslide risk management with development and climate change in a multi-hazard perspective involving interdisciplinary cross-sectoral partnership approach.
- To produce the implementation and management plans that will provide the practical basis for an effective national strategy that can be applied at local levels.
- To support advocacy, policy, guidelines and plans for landslides risk management at different levels among various stakeholders
- To develop workable partnerships with States, District and Local Level Governments and Non-Governmental Organizations as well as with professionals and other stakeholders.

Aim of the Course

To provide knowledge and skills related to landslides risk management to a multi-stakeholder target group which are expected to play a role in reducing landslide incidences and impacts through various kinds of activities involving social, technical, legal, financial, environmental, administrative and other such issues, aspects and dimensions at different levels/scales.

Course Objectives

At the end of the training programme, the participants will be able to:

- Define the terms/concepts in landslides risk management and provide basic information about landslides
- Describe landslide scenario and mitigation strategy with multi-hazard perspective in state
- Characterize/identify landslides indicators/precursors and related factors affecting landslide occurrence and extents
- Identify the needs, gaps and strategies in landslide databases, inventory & mapping
- Understand the Landslide Hazards, Vulnerability and Risk Assessment, Zonation, Prioritization and Communication for Landslide Risk Reduction
- Learn options for minimizing landslides risks – avoidance, prevention, mitigation (including structural and non-structural measures), preparedness, and response
- Assess landslides damages and losses in a systematic way
- Inform about planning, policy and guidelines on landslide risk management as well as roles/responsibilities/SOPs of stakeholders
- Understand cross-sectoral issues like administrative, technical, legal, financial, and social etc.
- Enlist and use Indian Standards and Codes related to landslides
- Discuss about the possible applications of technology, local resources/ skills, and traditional wisdom in landslides management – Community Based Landslides Risk Management
- Demonstrate through an exercise the process of landslide risk management
- Carry out mock drills for public safety against landslides

- Integrate and mainstream landslide risk management with development and climate change in a multi-hazard perspective with interdisciplinary cross-sectoral partnership approach

- Provide a forum for networking, linkage and coordination among different stakeholders for exchange of ideas, information, knowledge, experiences and resources on landslides risk management

Target Group

The target group for this programme would be senior officers from departments of Revenue, Disaster Management, Geology and Mines, Geological Survey of India, Town Planning, Public Works Department, Border Roads Organization, Irrigation and Flood Control, Rural and Urban Development, Hydel Sector, Building and Housing Department, State and District Development Authorities, NDRF, Police and Civil Defence, Fire Services, Environment & Forest, Roads and Bridges, Watershed Management, State Science and Technology Council, State Remote Sensing Application Centres, Professionals, and Research, Academic and Community organizations/Public Representatives etc.

The participants are expected to have varied responsibilities, academic backgrounds & experience. They are also required to be equipped with minimal level of knowledge, skills, information and experience related to landslides for taking up their tasks effectively in their organizations. They are expected to deal with disaster management during planning and implementation of developmental activities. The programme is intended to provide a comprehensive knowledge and skills in the field of landslide risk management to these participants.

Assumptions about Trainees

It is assumed that the age of trainees varies in the relevant sectors. The academic qualifications will also be variable in discipline and level of degrees They may or may not have experience/exposure to disasters prior to the training.

Why This Training?

Lack of adequate knowledge, skills and information about landslide disasters have aggravated the losses and prolonged the recovery process. Informed, skilled and trained human resources can play a significant role in landslides risk management and loss reduction. The training aims to fill this gap in a proactive mode by imparting skills, knowledge and information related to landslides management.

Training Needs

An interaction with the various concerned organizations leads to the conclusion that landslides incidences and impacts are rising due to lack of adequate trained human resources with these organizations besides the fact that affected communities are also unaware, uninformed, and unprepared. Different stakeholders as well as the affected communities need to be made aware, informed and prepared to assess the potential/impending landslides risks, minimize the risks and prepared themselves against the remnant risk.

Relevance of Objectives to Training Needs

The objectives of the training programme are formulated to cater to the training needs of different stakeholders for carrying out their tasks more effectively and efficiently in order to reduce landslides risks and manage their impacts on life, economy and environment.

Time Constraint

There will be time constraints for holding training course due to the fact that most of landslides happen during monsoon periods and the concerned officials would be busy in managing them. Hence, relevant participants shall be available only in pre and post monsoon seasons. Thus, timings for the training should preferably be fixed in pre and post monsoon period to enable to attend the training without stress of the field work.

Trainers

Senior officials from GSI, BRO and faculty members of NIDM, ATIs, research and academic institutions who have expertise in different aspects of landslide risk management.

Logistics

Boarding and lodging arrangements for 20-25 participants.

Number of Trainees

20 to 25 participants from various departments/agencies.

Venue(s) for Training

NIDM, State ATIs and GSI/DMMG training centers.

Entry Behavior

Geologists, Engineers (civil, mining, irrigation) and concerned field level officers involved in landslide studies and management. Field officials preferably with academic background in geology/geophysics/geotechnical engineering/mining engineering/highway engineering/irrigation/watershed management/remote sensing and experience or involvement in landslides risk management will be preferred.

Content defined in Relation to Objectives

- Terms and Concepts in Landslides Risk Management
- Landslides Definition, Types, Causes, Factors, Impacts
- Landslides Database, Inventory, and Zonation
- Institutional Mechanism for Landslide Management
- Policy, Guidelines and Plans for Landslides Risk Management
- Landsides Identification, Investigation, Instrumentation and Monitoring
- Early Warning, Alert and Communication Systems
- Search, Rescue and Relief for Landslide Victims
- Landslides Preparedness for Pre, During and Post Landslide Conditions (Do's and Don'ts)
- Survival Skills in Disastrous Situations
- Prevention, Mitigation and Management of Landslide
- Response to Landslides
- Damage and Loss Assessment
- Cross Cutting Issues – Administrative, Legal, Financial, Technical, Social etc.
- Mainstreaming Landslide Risk Reduction with Development and Climate Change Adaptation in Hills
- Community Based Landslides Risk Management
- Standards, Codes, Regulations, Acts, Byelaws related to Landslides
- Case Studies and Best Practices
- Handout/Exercise/Orientation Notes for Group Works, Guided Field Exercise, Role Plays and Mock Drills
- Resources, Links & Networks

Language

Language of instruction is English. All the Presentations/Demonstrations/ Drills/Exercises have been prepared in English but can be translated into local languages for understanding by layman. Interactions can be also in Hindi or any other vernacular languages depending upon the requirement of the State.

Time Frame

Training shall be held for 5 days.

Training Methods

Lectures/Interactive Discussions/Power Point Presentations/Slide Shows/ Brainstorming Discussions/Panel Discussions/Experience Sharing/Participatory Learning/Needs Assessment/Case Studies/Guided Group Exercises (Table Top and Simulation)/Hands on Exercises/Practicals/Skill Transfer/Mock Drills/ Demonstration and Exposure Visit/Guided Field Work.

Media and Equipments

Computers, LCD Projector, Screen, Laser pointer, Overhead Projectors, White board, Flip Charts and Stand, Markers, Mike and Speakers (PA system), Camera, GPS.

Performance Aids

Flip Charts, Lecture Notes/Hand-Outs of Presentations, Questionnaires, Check List, Formats for Data Collection/Templates/Exercises for Case Studies.

Training Materials

Note Pad, Pen, Folder/Bag, CD, Sketch Pens, and Flip Charts

Measures for Transfer of Learning

Each trainee shall submit an action plan to implement and impart training skills at his/her organization. Trainees will be asked to submit a short term project within one month to demonstrate their level of learning from the course and their efficiency in using the skills.

Assessment, Feedback and Validation Measures

During the course, questionnaires will be distributed to assess the level of learning of the participants. Daily session-wise evaluation will be done through recapitulation of learning of the previous day. Trainer/Facilitator will also evaluate transfer of skills during role plays, exercises and mock drills by the participants. At the end of course, a feedback evaluation form will be given to the participants to know the perception about the course. External validation

shall be done through short term projects and feedback from the head of the sponsoring agency.

Benefits

1. Pool of trained human resources who can cater to the needs for assessing landslides risks and help in managing them or reducing their risks at various levels, viz., local, district, state and national levels.
2. Reliable and credible system for landslide risk management would become available.
3. Networking and co-ordination among various stakeholders will be strong.

Cost of Training (Per Course)

Includes TA/DA for Resource Persons, Training Kit, Stationery Cost, Expenditure on Field Visit, Boarding and Lodging Charges for the Participants, Transportation Charges, Photography, Xeroxing/Binding of Reading Material/Hand Notes, Hospitality Charges for Resource Persons, Communication Charges (Mobile/ Telephone/Postage), Tutor Expenses, Miscellaneous/Contingent Charges and Administrative/Overhead Charges.

Approximate Budget

Rs. 2,000/- per participants per day

Day 1 - Learning Event for Learning Unit-1

Landslide History, Morphology and Diagnostic Features

Topic 1-1: Registration

Enabling Objectives:

- Personal & Organizational Information about trainees
- Expectations from the Course
- Experience of Participant

Contents

- Filling of Registration Form
- Compilation of registration record
- Profile of trainees/organizations

Time and Duration: 0930-1000 hrs (30 min.)

Method: Proforma for Registration

Facilitator: Training Assistant

Topic 1-2: Introduction and Inauguration

Enabling Objectives:

- Mutual Introduction of participants
- Experience Sharing
- Course Introduction
- Significance of Programme & Paradigm Shift

Contents

- Welcome to Participants
- Experience Sharing and Expectations
- Entry Behaviour
- Ground Rules
- Course Introduction
- Inaugural Address

Time and Duration: 1000-1130 hrs (90 min.)

Method: Mutual Interaction

Resource Person(s): Course Director and Guest Speaker

Learning Event for Learning Unit-1:

Basic Information on Landslides, History and Landslide Scenario

Training Objective:

- Basic Information about Landslides and Understanding about Landslides
- Understanding history and scenario of landslide disasters – global, national and state-wise

Objectives: At the end of this session, participants would be able to

- Define landslides
- Study the landslides features/morphology
- Characterize different types of landslides
- Inform about landslides scenario in the State/UT

Contents:

- Introduction to Terms/Concepts in CLRM
- Definition & Types of Landslides
- Landslide Features/Morphology

Time and Duration: 1145-1300 hrs (75 min.)

Method: Lecture, Presentation and Discussions with field examples

Topic 1-3: Topic – Landslide History and Scenario

Enabling Objectives: Learning about past landslide disasters and their impacts Landslides Distribution Scenario of the State/UT

Contents:

- History and Distribution of Landslides
- Lessons learnt from past landslides disasters

Time and Duration: 1400 -1530 hrs (90 min.)

Method: Lecture, Presentation and Discussions with field examples

Topic 1-4: Landslide Morphology and Diagnostic Features

Enabling Objectives: Learning about parts of landslides Diagnostic features of potential and relict landslides

Contents:

- History and Distribution of Landslides
- Lessons learnt from past landslides disasters

Time and Duration: 1545 -1715 hrs (90 min.)

Method: Lecture, Presentation and Discussions with field examples Summary of the Day-1: Recalling Day-1's deliberations

Time and Duration: 1715-1730 hrs (15 min.)

Method: Mutual Interaction

End of Day - 1

Day 2 - Learning Event for Learning Unit-2

Factors affecting Landslides and Landslides Hazard Zonation

Training Objective:

- Landslides Indicators/Precursors, Factors & Causes,
- Landslides Database, Inventory and Hazard Zonation
- Landslide Risk Assessment and Treatment

Session 2-1:

Topic 2-1: Recapitulation of Day-1

Enabling Objectives: Recalling the Learning from the Previous Day

Contents:

- Recapitulation by Participants
- Reference to the Reading Material

Method: Oral/Flip Chart

Time and Duration: 0930-1000 hrs (30 min.)

Session 2-2:

Topic 2-2: Identification of Landslide Indicators and Precursors

Enabling Objectives: Understanding

- Field Indicators for Slope Movements
- Precursors of Landslides

Contents:

- Enumeration of Potential Indicators for Landslides
- Observations and Interpretation of Indicators
- Case Examples from the Field Sites
- Experiences with Landslide Precursors
- Scope and Limitation of Landslide Indicators and Precursors for Safety against Landslides

Method:

Presentation and Discussion with Field Examples and Sketches

Time and Duration: 1000-1100 hrs (60 min.)

Session 2-3:

Topic 2-3: Factors Affecting Occurrence of Landslides

Enabling Objectives: Understanding Factors & their Types

Role and Relation of Different Factors with the Landslides

Content:

- Recognizing the Factors Affecting Landslides
- Classifying Factors as Preparatory, Controlling and Triggering Factors
- Discussing their Relation with Landslides using a Case Study

Method: Lecture, Presentation and Discussions with a Case Study

Time and Duration: 1115-1215 hrs (60 min.)

Session 2-4:

Topic 2-4: Factors and Causes of Landslide

Enabling Objectives: Understanding Factors and Causes Affecting
Dimensions of Landslides (LxWxD)
Velocity of Landslides & Run-out Distance
Time and Duration of Landslide Activity

Contents:
Factors, Causes and Consequences of Landslides

Method: Lecture and Discussions

Time and Duration: 1215-1300 hrs (45 min.)

Session 2-5:

Topic 2-5: Landslides Database and Inventory

Enabling Objectives: Understanding Need, Status, Gaps and Strategy for Landslides Database and Inventories Collection and Compilation of Data

Contents:

- Existing Landslides Database and Inventory
- Needs, Status, Gaps and Strategy to generate and update database – NDSS
- Template for Landslide Database
- Template for Landslide Inventory

Method: Lecture, Presentation and Discussions with Case Studies and Templates

Time and duration: 1400-1530 hrs. (90 min.)

Session 2-6:

Topic 2-6: Landslide Hazard Zonation, Risk Assessment and Treatment

Enabling Objectives: Information about LHZ
Landslide Risk Assessment
Options for Landslides Risk Treatment

Contents:

- Landslide Hazard Zonation
- BIS Code for LHZ
- A case study on LHZ
- Landslide Risk Assessment and Treatment

Method: Lecture, Presentation and Discussions with a Case Study

Time and Duration: 1545-1715 hrs (90 min.)

Summary of the Day-2
Recalling Day-2's deliberations
Mutual Interaction
1715-1730 hrs (15 min.)

End of Day-2

Day 3 - Learning Event for Learning Unit-3

Landslide Investigation, Monitoring and Remediation; Table-Top Exercises

Training Objective:

- Landslide Investigation and Instrumentation
- Landslide Monitoring and Warning system
- Landslide Remediation
- Table-Top Exercises

Session 3-1:

Topic 3-1: Recapitulation of Day-2

Enabling Objectives: Recalling the Learning of Previous Day

Contents:

- Recapitulation by Participants
- Reference to the Reading Material

Method: Oral/Flip Chart

Time and Duration: 930-1000 hrs (30 min.)

Session 3-2:

Topic 3-2: Landslide Investigation and Monitoring

Enabling Objectives: Understanding
Preliminary Investigation and Monitoring
Detailed Investigation Planning
Instrumentation and Monitoring

Contents:

- Geological Investigations
- Geophysical Investigations
- Geotechnical Investigations
- Landslide Instrumentation

Method: Lecture, Presentation and Brainstorming Discussions

Time and Duration: 1000-1100 hrs (60 min.)

Session 3-3:

Topic 3-3: Options for Landslide Remediation

Enabling Objectives: Understanding
Landslide Remediation Practices
Options for Landslide Remediation
Mitigation Methods for Different Types of Landslides
Relevant Standards and Codes for Landslide Mitigation

Contents:

- Remedial Measures
- Landslides Management Practices in India
- Mitigation Methods for Different Types of Landslides
- Biotechnical and Bioengineering Measures

Method: Lecture, Presentation and Panel Discussions

Time and Duration: 1115-1300 hrs (105 min.)

Session 3-4:

Topic 3-4: Orientation for Case Study on Landslides Management

Enabling Objectives: Understanding
Critical Issues Related LRM Activities

Contents:

- Orientation of Participants in Conducting TTE
- Information about Landslide
- Grouping of Participants – Team building
- Rules for Conducting TTE

Method: Lecture, Presentation and Discussions with a Case Study

Time and Duration: 1400-1430 hrs (30 min.)

Session 3-5:

Topic 3-5: Table Top Exercise on Landslide Management

Enabling Objectives: Conducting TTE
Facilitation, Observation and Monitoring

Contents:

- Understanding and utilization of information
- Interactions by Individuals and Discussion among the Group
- Facilitation, Observation & Monitoring of TTE
- Action Plan and Implementation Strategy for Pre, During and Post Landslide Risk Management by the Team

Method: Group Exercise (Table-Top)

Time and Duration: 1430-1630 hrs (120 min.)

Session 3-6:

Topic 3-6: Presentation and Feedback of TTE

Enabling Objectives: Comments on Technical/Managerial Content Observations on Attitudinal Aspects and Team Spirit

Contents:

- Group Presentations
- Comments and Feedback

Method: Group Presentation

Time and Duration: 1630-1715 hrs (45 min.)

Summary of Day-3 Activities and Learning

Instructions for Field Visit on the following day

1715-1730 hrs (15 min.)

End of Day-3

Day 4 - Learning Event for Learning Unit-4

Field Exposure/Exercises, Mock drill and Videos/Documentary shows

Training Objective:

Field Visit to Landslide, Conduct of Simulation Exercise/Mock Drill, Videos on Evacuation and SRR, Demonstration of S&R techniques, First-Aid and Survival-Skills

Session 4-1:

Topic 4-1: Recapitulation of Day-3

Enabling Objectives: Recalling the learning from the previous day

Contents:

- Recapitulation by Participants
- Reference to the Reading Material & Discussions

Method: Oral/Flip Chart

Time and Duration: 0930-1000 hrs (30 min.)

Session 4-2:

Topic 4-2: Field Exposure to Landslide

Enabling Objectives: Understanding

Field Identification of Landslides

Studying Landslide Features/Morphology

Observations & Data collection

Assessing Factors & Causes affecting Landslide Occurrence

Hazard, Vulnerability & Risk Assessment

Options for Risk Minimization

Contents:

- Features for Landslide Identification
- Landslide Morphology
- Landslide Characteristics & Behaviour
- Elements at Risk & their Degree of Vulnerability
- Risk Estimation, Classification, Prioritization and Communication
- Mock Drill/Simulation Exercise

Method: Exposure Visit/Guided Field Work/Simulation Exercise/Mock drill

Time and Duration: 1000-1530 hrs (330 min.)

Session 4-3:

Topic 4-3: Presentation and Feedback of Field Visit and Simulation Exercise

Enabling Objectives- Comments on Technical/Managerial Content

Observations on Attitudinal Aspects and Team Spirit

Contents:

- Group Presentations
- Comments and Feedback
- Recommendations

Method: Flip Charts, Power Point Group Presentation

Time and Duration: 1630-1715 hrs
Summary of Day-4 Activities and Learning
Following Day Plan
1715-1730 hrs (15 min.)

End of Day-4

Day 5 - Learning Event for Learning Unit-5

Community Based Disaster Risk Management, Mainstreaming Landslide Risk Reduction, Capacity Development and Emerging Issues

Training Objective:

- Community Involvement in Disaster Risk Management
- Mainstreaming Landslide Risk Reduction
- Capacity Development

Session 5-1:

Topic 5-1: Recapitulation of Day-4

Enabling Objectives: Recalling the Learning of the Previous Day

Contents:

- Recapitulation by Participants
- Reference to the Reading Material, Field Discussions and Presentations

Method: Oral / Flip Chart

Time and Duration: 930-1000 hrs (30 min.)

Session 5-2:

Topic 5-2: Community Based Disaster Risk Management

Enabling Objectives: Understanding
Role of Community in Disaster Risk Management
Tools and Technique for CBDRM
Case Study on CBDRM

Contents:

Methodology for CBDRM

Application to a Locality

Case Example

Method: Video/Slide Show on Community Involvement in Disaster Risk Reduction

Time and Duration: 1000-1030 hrs (30 min.)

Session 5-3:

Topic 5-3: Mainstreaming Landslides Risk Reduction

Enabling Objectives: Understanding

Inter-relation between Disasters and Development

Integrating Disaster Risk Reduction with Development

Contents:

- Relation between Disasters and Development
- Mainstreaming Disaster Risk Reduction
- Issues and Strategies

Method: Video/Slide Show on Mainstreaming DRR with Development

Time and Duration: 1030-1100 hrs (30 min.)

Session 5-4:

Topic 5-4:Capacity Development and Emerging Issues

Enabling Objectives: Landslide Education and Training

Landslide Awareness and Preparedness

Capacity Development

Emerging Issue

Contents:

Training and Capacity Development for Landslides Risk Reduction Emerging Issues

Method: Slide show

Time and Duration: 1115-1215 hrs (60 min.)

Session 5-5:

Topic 5-5: Networking, Linkage and Coordination

Enabling Objectives: Landslide Networks and Links

Coordination between Different Stakeholders

Contents:

- Information Landslide Knowledge Networks
- Information about Landslide Resources Networks
- Linkage and Coordination Activities

Method: Practical Demonstration on First Aid and survival Skills

Time and Duration: 1215-1300 hrs (45 min.)

Session 5-6:

Topic 5-6: A Case Study on Community Based Landslides Risk Management & LMP

Enabling Objectives: Understanding
Community Involvement in LRM
Format for LRMP

Contents:

- Aims and Objectives of CBLRM
- Methodology for Field Operation
- RRA/PRA/PLA Tools
- Context Specific Issues
- Template for LMP

Method: Lecture, Presentation and Discussions

Time and Duration: 1400-1500 hrs (60 min.)

Session 5-7:

Topic 5-7: Cross Cutting Issues and Mainstreaming DRR with Development & Climate Change

Enabling Objectives: Issues related to Discipline, Sectors, Levels, Boundaries, Policies etc.

Contents:

- Inter-disciplinary studies
- Cross-sectoral and Multi-level Approach
- Transboundary Issues
- Advocacy, Policy, Planning & Guidelines

Method: Group Discussions

Time and Duration: 1500-1600 hrs (60 min.)

Session 5-8:

Topic 5-8: Landslide Quiz

Enabling Objectives: Knowledge Check

Contents: Knowledge Check

Method: Slide Show, Question-Answers

Time and Duration: 1600-1645 hrs (45 min.)

Session 5-9:

Topic 5-9: Evaluation, feedback, certification and valediction

Contents:

Feedback from Participant

Post-training Assignment

Method: Follow-up Strategy

Time and Duration: 1645-1730 hrs (45 min.)

End of the Course

COMPREHENSIVE LANDSLIDES RISK MANAGEMENT

Introduction

Landslides occur in all hilly terrains in response to a wide variety of terrain conditions and triggering processes like heavy rainstorms, cloudbursts, earthquakes, floods, cyclones and haphazard human activities. As per an estimation based on Global Fatal Landslide database 2004-2016, India with a share of 20 percentages tops the list of countries with most fatalities due to landslide events. As landslides are frequent and widespread, the annual cumulative losses worldwide amount to tens of billions of USD in terms of lost property, environmental damage, repair works, and the maintenance of defence measures (source: Page 61, World Atlas of Natural Hazards by Bill McGuire, Paul Burton, Christopher Kilburn and Oliver Willets). The frequency of landslides is strongly influenced by the return periods of triggering events like rainfall and earthquakes.

More than 5000 people are buried alive under landslide debris and economic losses of more than 4 bn USD are suffered every year globally. Continent-wise, Asia suffers the maximum damages/losses due to landslides and among the Asian countries, South Asian nations are the worst sufferers and even among South Asian countries India is one of the most affected by landslides. The window of economic loss due to landslides may reach between 1-2% of the gross national product in many developing countries (GSI).

In India, nearly 12.6% of its territory (covering about 0.42 million sq.km.) is prone to various degrees of landslide hazard (NIDM, 2019), frequently affecting the human lives, livelihood, livestock, living places, structures, infrastructure, and natural resources in a big way. In addition to direct and indirect losses, landslides cause significant environmental damage, societal disruption and strategic concern. Landslides are spread over 19 States and 4 UTs including Himachal, Uttarakhand, Arunachal, Assam, Meghalaya, Mizoram, Manipur, Nagaland, Sikkim, Tripura, Kerala, Karnataka, Tamilnadu, Andhra Pradesh, Goa, Maharashtra, Madhya Pradesh, Chhattisgarh, West Bengal, Jammu & Kashmir, Ladakh, Andaman & Nicobar and Puducherry. The most sensitive areas are the Himalayan belt, the Nilgiris, the Western and Eastern Ghats. Landslides constitute a serious hazard that causes substantial human and financial losses in the country. Based on the general experience of landslides, a rough estimate of monetary loss is of the order of Rs. 100 Crore to Rs. 150 Crore per annum at the 2011 prices for the country as a whole (NDMA, 2019).

Landslides can happen not only in isolation but also along with or as a consequence of other disasters like earthquakes, floods, lightning, cloud-burst, forest fires, dam/lake bursts etc. In such cases, landslide losses are normally included with the primary disaster and are not dealt separately. Hence, most of the reported estimates on landslides losses are found to be quite lower than the actual impacts of landslides on the society as a whole.

With growing population and human interventions in terms of developmental activities over unstable slopes, landslides pose increasing risk to human lives, buildings, structures, infra-structures and environment. Large scale deforestation along with faulty management practices have led to high vulnerability to landslides in many regions of the country. Human activities relating to expansion on unsafe locations, unscientific mining, haphazard construction of roads, dams and river training works ignoring natural features contribute to increased intensity of landslides. Of the total landslide events recorded from 2004 to 2016 in the country 28 percentage were due to construction activities (Froude and Petley, 2018). The absence of large scale landslide hazard maps leads to people being caught unaware especially when the first time landslides strike.

As individual landslides usually affect limited local areas and residents, damage resulting from landslide hazards was not recognized as a problem of national importance and was not addressed on a national platform. The absence of coordinated national approach to mitigating the detrimental effects of landslides resulted in a reduced ability of the States and Local Government agencies to apply the important lessons learnt, often at considerable expense.

As a result, the need for a national strategy was strongly felt and worked upon by the National Disaster Management Authority through National Disaster Policy and Guidelines on Landslides. Being cognizant of the diversity of issues associated with national landslides problem that arise from both the regional considerations and of the considerable variations in the institutional capability and responsibility at regional and local levels, inputs from a wide variety of stakeholders are essential. Strengthening the process of landslide hazard assessment, investigation, mapping and management will have far reaching effects in reducing landslide losses. NIDM, the nodal agency dealing with disasters is planning to undertake such projects in order to stimulate necessary activities across the country and create a nodal platform to deliver trainings on various aspects of landslides risk management and also create a network of resource persons/experts who can contribute in this activity. It would pave way for effective decision making and planning micro level mapping for various developmental and regulatory activities in hilly terrains.

NIDM, thus, aims to work in the following directions to make the hilly terrains and coastal areas free from landslide disasters.

- To promote the use of landslide risk analysis techniques to guide loss reduction efforts at the State and Local Levels.
- To play a vital role in evaluating methods, setting standards, and advancing procedures and guidelines for landslide hazard maps and assessment.
- To provide tools for landslide hazards mitigation and promote basic research on monitoring techniques and on aspects of landslide process mechanics.
- To improve education, training and awareness of landslide hazards and mitigation options for decision makers, professionals and the general public.
- To integrate and mainstream landslide risk management with development and climate change in a multi-hazard perspective involving interdisciplinary cross-sectoral partnership approach.
- To produce the implementation and management plans that will provide the practical basis for an effective national strategy that can be applied at local levels.
- To support advocacy, policy, guidelines and plans for landslides risk management at different levels among various stakeholders.
- To develop workable partnerships with States, Districts and Local Level Governments and Non-Governmental Organizations as well as professionals and other stakeholders.

Landslide Scenario in India

Landslides are a threat to our housing and infrastructure, farms and fields, vast stretches of border roads and railway lines, hydroelectric, water supply, and transmission line projects, aerial ropeways, open cast mines, tunnels, heritage buildings and monasteries, pilgrim routes and tourist spots.

The vulnerability to landslides can be reduced by spreading culture of safety through careful landuse planning, timely and appropriate engineering intervention, conscientious maintenance of slope and connected utilities, early warning, public awareness, and preparedness. There is a need to develop the culture of quick response to manage disasters and reduce the impacts.

The Ambutia landslide, located on the tea garden clad picturesque hill slopes around the Kurseong town in the Darjeeling is probably the largest landslide in Asia. As the pressure of population grew in recent past, more and more of human settlements, roads, dams, tunnels, water reservoirs, towers and other public utilities have come up. Today the network of roads in the Himalayan region is well over 50,000 km and a large number of dams have been built here. For

example, the dam projects over the Ganga and its tributaries in the hills alone exceed two dozen. A number of tunnels, microwave, TV, transmission lines and other towers also dot the hilly areas. For example, quarrying and mining in the Doon valley has led to deforestation and development of bare lands. Jhiroli (Almora) and Chandhak (Pithoragarh) have inflicted heavy damages to slopes and the associated environment.

Landslides along NH-1A and NH-1B in Jammu & Kashmir, Rishikesh-Badrinath (pilgrimage route in Uttarakhand Himalaya), and in Darjeeling & Sikkim Himalaya, Dimapur-Imphal and Shillong-Silchar National Highways in north-eastern region have been disastrous and have caused enormous economic losses and affected the social fabric.

Landslides that had catastrophic effects in terms of life, economy and environment include Kavalappara Landslide, Kerela (2019), Idukki and Wayanad Landslide, Kerala (2018), Kodagu Landslide, Karnataka (2018), Kutrupi Landslide, Himachal Pradesh (2017), Bastari Landslide, Pithoragarh, Uttarakhand (2016), Assam Landslides (2016), Joumol Village Landslide, Manipur (2015), Malin Landslide, Maharashtra (2014), Kedarnath Landslide, Uttarakhand (2013), Kapkot Landslide, Uttarakhand (2010), Sikkim Landslide (2011), Leh Debris Flow, Ladakh (2010), Nilgiri Landslide, Tamil Nadu (2009) and La-Jhekla Debris Flow, Uttarakhand (2009), Karwar Landslide, Karnataka (2009), Sakinaka Landslide, Maharashtra (2009), Ghanvi village Landslide, Himachal Pradesh (2007), Konkan Landslide, Maharashtra (2005), Varunavat Landslide, Uttarakhand (2003), Budha Kedar Debris Flows, Uttarakhand (2001), Malpa Landslide, Uttarakhand (1998), Kaliasaur Landslide, Uttarakhand (1984), Zubza and Mao Seng-Song Landslides along Dimapur- Imphal National Highway, Sonapur Landslide along Shillong- Silchar National Highway. Other examples of devastating landslides include Amboori landslide in Thiruvanantapuram district, Kerala; Runnymede, Hospital, Glenmore, Coonoor and Karadipallam Landslides in Nilgiris district, Tamil Nadu.

Instances of co-seismic landslides particularly in the Himalayan terrain and North-eastern part of the country are not uncommon. Epicentres of strong earthquakes at Shillong (1897), Kangra (1905), Bihar-Nepal (1934), Assam (1950), Uttarkashi (1991), Chamoli (1999), Kashmir (2005) and Sikkim (2011) generated numerous co-seismic landslides over vast areas and caused loss of human lives, livestocks, and properties, and degradation of environment.

Some landslides block the drainage courses and form natural dams known as landslide dams. A few such landslide dams worth mentioning are: Gohana Gad landslide dam that blocked Birehiganga in 1893, landslide blockage on river Patalganga in 1970 led to Alaknanda tragedy, Naptha-Jhakhri landslide dam on Satluj caused huge losses to the Nathpa-Jhakhri hydroelectric project, and the landslide that blocked the river Parechhu in Tibet caused large scale floods in Himachal Pradesh in 2005 when this dam breached.

Impact of Landslide Disasters

The landslide disasters have both short term and long term impacts on society and environment. The short term impacts account for the loss of life and property at the site and the long term impacts include landscape changes that can be permanent, including loss of cultivable land and environmental impact in terms of erosion and soil loss, population shift and relocation of establishments.

The adverse impact of landslides on the environment can be categorized as change in topography of the earth's surface, alteration in quality as well as quantity of both surface and subsurface water bodies, degradation of forest cover, triggering tsunami and devastating the natural habitat of wildlife.

Like in any other disaster, the most affected are the socio-economically weaker sections of the society who inhabit the vulnerable areas. They have a meager source of livelihood, which when wiped out by a hazard, leaves them without any food and shelter. Apart from this, the injury and the casualties add to the woes of the affected families.

The frequent obstructions caused to the movement of traffic by numerous landslides during rainy season for days together, particularly in the Himalayan terrain and north-eastern region of the country, brings untold miseries to the people inhabiting the villages and townships in the landslide prone hilly terrains.

The landslides also reduce the effective life of hydroelectric and multipurpose projects by adding enormous amount of silt load to the reservoirs.

Landslide dams result in flooding of large upstream areas. Further, if the dam fails, it causes flooding and large scale devastation in downstream areas. Also, solid landslide debris can add volume and density to otherwise normal stream flow or cause channel blockages and diversions creating flood conditions or localized erosion. Landslides can also cause overtopping of dams resulting in flash floods and/or reduced capacity of reservoirs to store water. Examples are Gohna lake burst and Parechhu Lake burst.

Landslide Hazard Management in India

Earlier, landslide hazard management in India was confined to ad hoc solutions of the site specific problems and implementation of immediate remedial measures including debris removal and dumping them either down slope or into the river. One of the aims of the present training is to manage the landslide hazard through an institutional mechanism by following a systematic approach that includes both short term and long term planning and treatment of the landslide problems involving hazard, vulnerability and risk assessment approaches.

Landslide hazard management involves the measures taken to avoid or mitigate the risk posed by the landslide hazard. The most important role in this process is played by the local government machinery. Once this body receives the information about the probability of landslide occurrence within its jurisdiction, it initiates steps to warn the communities living in the area about the risk involved and tries to convince landowners and building occupiers to shift to safer places. Moreover, further development is avoided in such high risk zones. The mitigation strategies might not be possible in every landslide hazard prone area both due their high cost and indifferent attitude of the public. The efforts to reduce the risk are also made by road construction and maintenance agencies by implementing the treatment measures.

There is, however, a need to pre-empt the disaster by making adequate information available in advance before it strikes and same should be emphasized by all states specially those routinely affected by multi-hazards.

Some of the organizations/agencies working in the field of landslide hazard mitigation and management in India:

- Geological Survey of India (GSI)
- Bureau of Indian Standards (BIS)
- Department of Space (DoS)
- Indian Road Congress (IRC)
- Defence Terrain Research Laboratory (DTRL)
- Central Road Research Institute (CRRI)
- National Remote Sensing Centre (NRSC)
- Indian Institute of Technology, Roorkee (IIT-R)
- Central Building Research Institute (CBRI)
- Wadia Institute of Himalayan Geology (WIHG)
- Snow and Avalanche Studies Establishment (SASE)

Landsides in Other Countries

December 16, 1920 witnessed the known deadliest landslide of all times that occurred in the district of Haiyuan, China. The havoc was consequent to an 8.5-magnitude earthquake that generated a series of 675 major loess landslides, which together caused enormous destruction by claiming over 100,000 lives, and destroyed an area of approximately 20,000 square kilometers.

In the year 1999, rainfall induced a series of flash floods and debris flows that claimed around 30,000 lives in the Vargas state of Venezula, a country in northern coast of South America. Nearly ten percent of Vargas's population was killed in that cataclysm and towns of Carmen de Uria and Cerro Grande were completely submerged under the mud bed.

In the mountains of Asia and Central and South America, as well as steep islands in the Caribbean and Southeast Asia, highest numbers of fatalities due to landslides were recorded (Ketchell, 2018). Globally, the developing countries encounter more severe consequences of landslides than developed ones. According to Dowling and Santi (2014), the number of fatalities per deadly debris flow in developing countries is 23, whereas in the developed nations it is only 6.

In Japan alone, averages of 90 lives are lost annually from debris flows (Takahashi, 1981). In 1970, a debris avalanche (a rapidly moving form of debris flow) triggered by an earthquake, completely destroyed the city of Yungay, Peru, killing an estimated 17,000 people and burying the whole city under 5m of mud and debris (Plafker and Erickson, 1978). Other countries with chronic losses from debris flows are USA, Indonesia, Tanzania, Scandinavia, Costa Rica, China, Brazil, Ireland, Romania, Japan, Bangladesh, New Zealand, Soviet Union etc.

In Canada, landslides have caused over 600 deaths cumulatively, since the middle of the 19th century. In addition, lines of communication have been severed, and the resource base has been significantly impacted. Recent studies on geographic distribution of the impact of landslides in Canada has indicated that the Canadian Cordillera, comprising about one-fifth of Canada's landmass, is most prone to damaging landslides. The southeastern Cordillera (roughly defined by the Trans-Canada Highway to the north, the Foothills to the east and the Okanagan Valley to the west) has been the site of a number of catastrophic landslides including the 1903 Frank slide, Canada's worst landslide disaster. The region, crossed by national strategic transportation corridors, has important natural resources, and has extensive areas of designated natural heritage.

The record of damaging landslide events in historical time has been compiled from existing case history documents, archival information, and information supplied by transportation companies and government agencies. The record has been assembled in a relational database. Major damaging landslide types have been identified as follows; rock avalanches, rockfalls, rainfall-triggered debris flows and debris avalanches, landslides in built slopes, and landslides in slopes consisting of glacio-lacustrine deposits. Deforming rock slopes, however, constitute a hazard that is difficult to assess.

Benefits of Good Landslide Management Practices

Good landslide management practices will help in identifying existing gaps and lessening the number of landslide events as well as after effects of the disasters. Several countries like Japan, Hong Kong, Switzerland, Australia and USA have made good attempts in prevention and management of landslide risk through various measures such as landuse patterns, and construction and development controls. Slosson and Krohen (1977) have demonstrated the benefits of good landslide management practices. An example from California as given in Table-1.

Table-1: Landslide & Flood Damages to Hillside Homes in Los Angeles County, California

Construction Dates and Legal Requirements	Number of Homes built on Hillside sites	Damaged Homes			Average Prorated Cost for Total Number of Homes Built
		Number	Percent of Total	Total Damage	
Pre-1952: No Legal requirements for soils engineering or engineering geological studies	10,000	1,040	10.00	$3,300,000	$300
1952-1963: Soil engineering studies, and preliminary engineering geological studies required	27,000	350	1.30	$2,767,000	$100
1963-1969: Extensive engineering geological and soils engineering studies required	11,000	17	0.15	$80,000	$7

A list of available guidelines/documents around the world on landslide mitigation and management is provided in annexure-1, page no. 295-296.

UNDERSTANDING LANDSLIDES

Some basic questions about landslides

- What are landslides and how do they occur?
- Disasters due to landslides and their impacts on society?
- What are characteristic features of landslides and factors influencing landslides including human factors?
- How do they function?
- Where do they occur and what factors control their timing?
- What is their human and environmental significance?
- What are the available investigation methods for landslides?
- What are the available instrumentation, monitoring and warning system for landslides?
- What are the available remedial measures for landslides hazard prevention, mitigation and management?
- How local community can help in response, mitigation and management of landslides?
- What initiatives are taken by the government in country for mitigation and management of landslides?
- Do's and don'ts for safety against landslides.

Questions about landslides and type of hazard prediction

Questions	Hazard Prediction Type
Where will the landslide(s) occur?	Spatial
When will the landslide(s) occur?	Temporal
How hazardous/unstable are the slope(s)?	Type
How much of the slope(s) will be involved?	Hazard/Instability
How much will the landslide(s) move?	Volume
How fast will the landslide(s) move?	Velocity
How far will the landslide(s) travel?	Travel distance
How far will the landslide(s) retrogress?	Retrogression limit

Training module will help trainers/planners/community to understand the landslide hazard and find answers of the above questions.

LANDSLIDES – INTRODUCTION

1.1 Introduction

Landslides are simply defined as downslope movement of rock, debris and/or earth under the influence of gravity. This sudden movement of material causes extensive damage to life, economy and environment. It is the most common and universally accepted collective term for most slope movements of massive nature. The term has sometimes been considered unsuitable as the active part of the word denotes sliding, whereas the phenomenon encompasses movements without sliding like fall, topple, flow etc.

Other terms which have been used by different stakeholders in place of landslides are mass wasting, mass movements, slope failures etc. Similarly the slope materials are also classified differently by various researchers. For example, Sharpe (1938) defined landslides as the perceptible downward sliding or falling of a relatively dry mass of earth, rock or a mixture of the two. Varnes (1978) preferred the term 'Slope Movements' as it does indicate process and defined it as a downward and outward movement of slope forming materials under the influence of gravity. Brunsden (1984) preferred the term 'mass movement' and distinguished this from mass transport as being a process which did not require a transporting medium such as air, water or ice etc. Cruden (1991) defined landslides as a movement of mass of rock, earth or debris down a slope. However, the classification of slope processes and slope materials as proposed by Cruden & Varnes (1996) has been widely accepted and is given below for the reader's reference (Table 1.1).

Table-1.1: Classification of slope processes and materials (after Cruden and Varnes, 1996)

Type of Movement		Type of Material		
Bedrock		Bedrock	Coarse Grained Soil or Debris	Fine Grained Soil
Falls		Rock Fall	Debris Fall	Earth Fall
Topples		Rock Topple	Debris Topple	Earth Topple
Slides	Rotational	Rock Slide	Debris Slide	Earth Slide
	Translational/ Wedge	Rock Slide	Debris Slide	Earth Slide

Lateral Spreads		Rock Spread	Debris Spread	Earth Spread
Flows		Rock Flow	Debris Flow	Earth Flow
Complex	Nature of movement varies with time			
Composite	Nature of movement varies in different parts of the failed slopes			

It is important to distinguish among the different types of landslides to be able to understand how to deal with each of them. The ways to identify and mitigate different types of landslides are often different.

1.2 Morphology of Landslides

Before we discuss about different types of landslides, it would be good to learn about the morphology of landslides and its various features/parts as given below (Fig. 1.1).

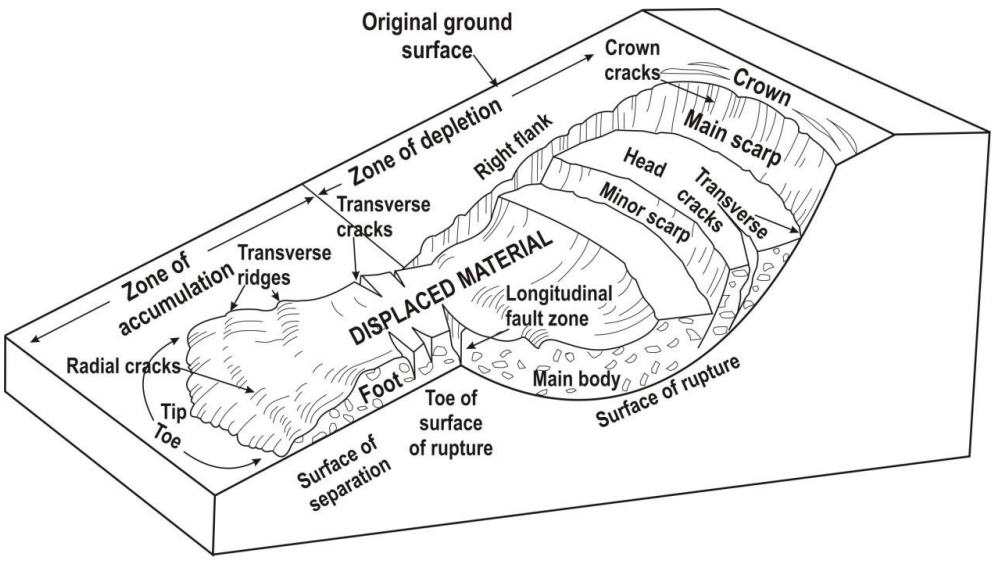


Fig. 1.1: An idealized slump-earth flow showing commonly used nomenclature for labeling the parts of a landslide (Source: IRC: SP-106-2015)

1.2.1 Parts of Landslides – Description of Features

Accumulation - The volume of the displaced material (13), which lies above the original ground surface (20) (Fig. 1.2).

Crown - The practically undisplaced material still in place and adjacent to the highest parts of the main scarp (1).

Depletion - The volume bounded by the main scarp (2), the depleted mass (17) and the original ground surface (20).

Depleted mass - The volume of the displaced material (13), which overlies the rupture surface (10) but underlies the original ground surface (20).

Displaced material - Material displaced from its original position on the slope by movement in the landslide. It forms both the depleted mass and the accumulation.

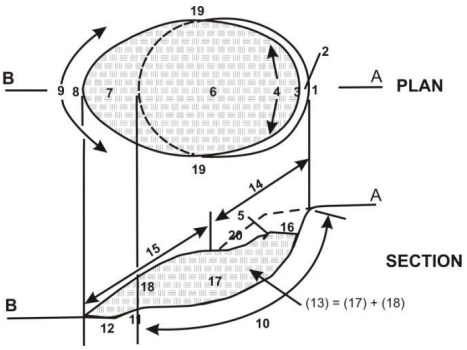


Fig. 1.2: Cross Section of an idealized slump-earth flow
(Source: IRC: SP-106-2015)

Flank - The undisplaced material adjacent to the sides of the rupture surface. Compass directions are preferable in describing the flanks, but if left and right are used, they refer to the flanks as viewed from the crown.

Foot - The portion of the landslide that has moved beyond the toe of the surface of rupture (11) and overlies the original ground surface (20).

Head - The upper parts of the landslide along the contact between the displaced material and the main scarp (2).

Main body - The part of the displaced material of the landslide that overlies the surface of rupture between the main scarp (2) and toe of the surface of rupture (11).

Main scarp - A steep surface on the undisturbed ground at the upper edge of the landslide, caused by movement of the displaced material (13) away from undisturbed ground. It is the visible part of the surface of rupture.

Minor scarp - A steep surface on the displaced material of the landslide produced by the differential movement within the displaced material.

Original ground surface - the surface of the slope that existed before the landslide took place.

Surface of separation - The part of the original ground surface (20) overlain by the foot (7) of the landslide.

Surface of rupture - The surface that forms the lower boundary of the displaced material (13) below the original ground surface (20).

Tip - The point of toe farthest (9) from the top of the landslide (3).

Toe - The lower, usually curved margin of the displaced material of a landslide, it is the most distant part from the main scarp (2).

Top - The highest point of contact between the displaced material (13) and the main scarp (2).

Toe of surface of rupture - The intersection (usually buried) between the lower part of the surface of rupture (10) of a landslide and the original ground surface (20).

Zone of accumulation - The area of landslide within which the displaced material (13) lies above the original ground surface (20).

Zone of depletion - The area of the landslide within which the displaced material (13) lies below the original ground surface (20).

1.3 Landslide Types Based on Process of Failure

Based on process types, there are five types of landslides i.e. Fall, Topple, Slide, Spread, Flow and Subsidence.

1.3.1 Fall

It is a very rapid to extremely rapid movement which starts with detachment of material from steep slopes such as cliffs, along a surface on which little or no shear displacement takes place (Fig. 1.3 and 1.4). The material then descends through the air by free falling, bouncing or rolling onto the slopes below.

- The detachment of soil or rock from a steep slope along a surface on which little or no shear displacement takes place.
- Movement is very rapid to extremely rapid.
- Free fall if slope angle exceeds 76 degrees and rolling at or below 45 degrees.

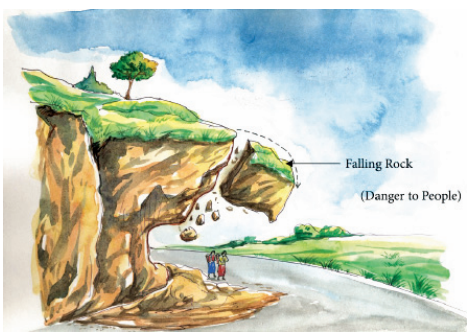


Fig. 1.3: Sketch showing mode of failure in fall



Fig. 1.4: An example of a rock fall site

However, in order to identify the potential falls and relict falls, the Table-1.2 may be referred.

Table-1.2: Diagnostic features of falls

S. No.	Potential Falls	Relict Falls
1	Steep to vertical slopes, overhanging; undercut; open cracks close to slope face.	Where rock falls have taken place these may be curved hollows, beams, bridges of rock on buttresses.
2	Dip of discontinuities towards the free slope face are vulnerable.	Look for piles of debris, loose rock mass, scree slopes, open-work rock textures in colluvium, detached boulders, massive debris in valley floors, valley dams.
3	Discontinuities with gouge or other soft infillings and interbedded materials are common locations.	If the fall material is mainly debris, then the relict may be boulders set in a redistributed matrix or colluvium.
4	Falls occur where high water pressures are possible. Melting permafrost or seasonally frozen faces are vulnerable areas.	
5	An eroded slope in debris or soil is vulnerable. Such slopes rapidly unload or weather so that boulders could fall in heavy rains or similar disturbances.	

1.3.2 Topple

Topple involves overturning of material. It is forward rotation of the slope mass about a point or axis below the centre of gravity of the displaced mass. Topples range from extremely slow to extremely rapid movements (Figs. 1.5 to 1.7).

➢ The forward rotation out of the slope of a mass or a rock about a point or axis below the centre of gravity of the displaced mass.

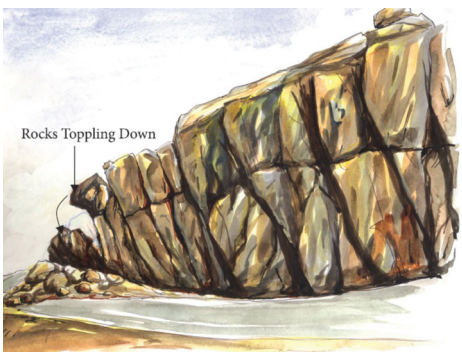


Fig. 1.5: Sketch showing the end-over-end motion of rock down a slope during toppling

- Movement is extremely slow to extremely rapid.
- Driven by gravity and sometimes by water or ice in cracks of mass.



Fig. 1.6: Field photo showing topple failure



Fig. 1.7: Toppling failure in rocks

However, in order to distinguish between potential and relict topples; some of the diagnostic features as referred in Table-1.3 can be used.

Table-1.3: Diagnostic features of topples

S. No.	Potential	Relict
1	A free face, steep slope or cliff with sufficient unloading potential.	Cliff top may be marked by residual, tension cracks, partially detached columns.
2	Sufficient height (weight) relative to the width of base to provide disturbing force.	Rock face will show open vertical cracks which may have chaotic fillings from overlying material.

3	Sufficient rock strength to allow a column to stand, usually hard or coherent rock layer overlying a weaker stratum.	Base of cliff shows disturbed strata or bulging material.
4	Strong vertical joint development which divides face into columnar units; strong jointing or unloading tension cracks parallel to face	Where a column has fallen the weathering details on the face may be less well developed; very fresh scars will be smooth.
5	Critical dip in basal materials	Debris will be very chaotic, huge boulders or partially broken columns will be scattered across the lower slopes, the texture will be coarse with open works and extensive voids.

1.3.3 Slide

Movement of material along recognizable shear surface e.g. translational and rotational slides (Figs. 1.7 to 1.8).

➢ Downslope movement of a soil or mass occurring dominantly on surfaces of or on relatively thin zones of intense shear strain.

➢ The sign of ground movement are cracks of the original ground.

Modes of Sliding:

o Translational/planar slides

o Wedge slides

o Rotational Slide

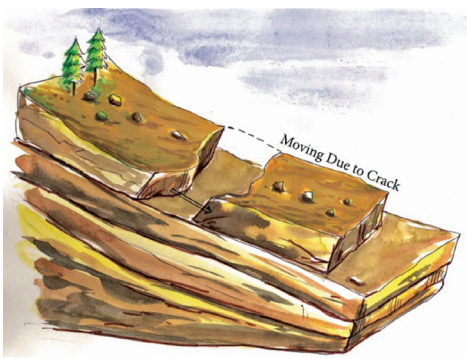


Fig. 1.8: Sketch showing movement parallel to planes of weakness and occasionally parallel to slope



Fig. 1.9: Planar rockslide



Fig. 1.10: Wedge Rockslide due to intersection of two joint planes heading towards valley

Table-1.4: Diagnostic features of rotational slides

S. No.	Potential	Relict
1	Single rotational slides require steep slopes, undercut areas, erosion by streams and the sea	Hummocky ground
2	Rise in piezometric surface or changes in water regime	Toe area recognisable as a pronounced lobe with a steep front
3	Usually, unconsolidated clays and uniform clay outcrops	Crown will have a back-tilted or horizontal surface.
4	Multiple slides commonly occur where permeable rocks overly impermeable ones	Hollows filled with washed debris and organic material, common at head
5	A weak layer is usually required to allow development of a common shear surface for multiple slides	All irregularities will be smoothed out and filled; form may be completely erased to a smooth slope, but the structure and shear surface will remain beneath the ground
6	Retrogressive unloading could generate new slides	Tension cracks may be visible at the head

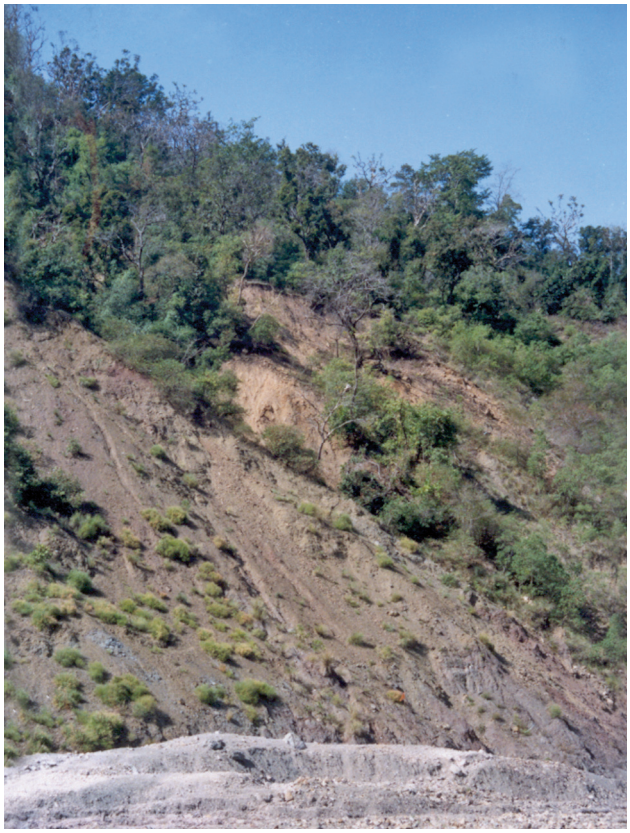


Fig. 1.11: Example of a Rotational Landslide at Chilla Tal-Valley

1.3.4 Flow

Flow is a landslide in which the individual particles travel separately within a moving mass (Figs. 1.12 to 1.14).

- ➢ Spatially continuous movement, in which surfaces of shear are short-lived, closely spaced and usually not preserved.
- ➢ Slides and flows are different depending on water content, mobility and evolution of movement.

Features for recognition of flows are:

i. Crown may have few cracks.

ii. The main scarp typically has serrated or funnel shaped upper part; is long and narrow, bare and commonly striated.

iii. Flanks are steep and irregular in the upper part; may have levees built up in the middle and lower parts.

iv. The body has flowlines, follows drainage ways, is sinuous, and it is very long compared to width.

v. The toe spreads laterally in lobes; if dry, may have steep front.

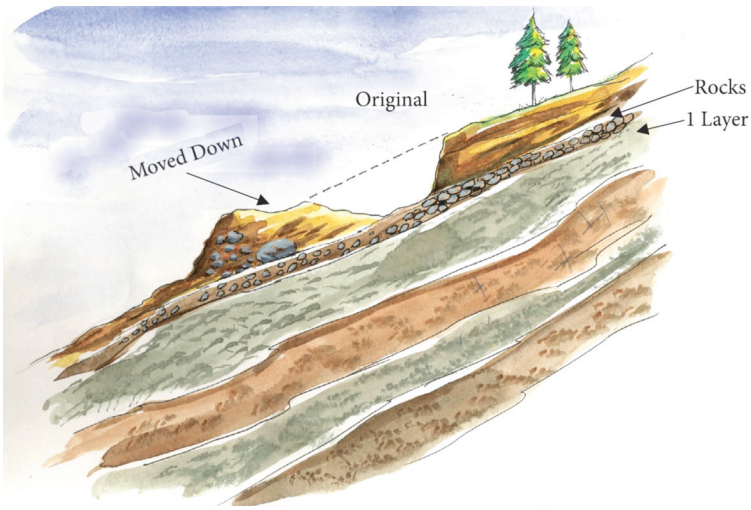


Fig. 1.12: Sketch showing Viscous to fluid-like motion of debris, often channeled

Modes of Flow:

- Open-slope debris flow
- Channeled flow



Fig. 1.13: Debris flow after a cloudburst at Balta, Uttarakhand



Fig. 1.14: Debris Flow near Sikkim Supreme Factory on NH-31 A, Sikkim

1.3.5 Spread

- Sudden movement on water-bearing seams of sand or silt overlain by homogeneous clays or loaded by fills.
- May result from liquefaction or flow of softer material (Fig. 1.15).

Modes of Spreading:

- Block Spreads
- Liquefaction spreads
- Complex spreads

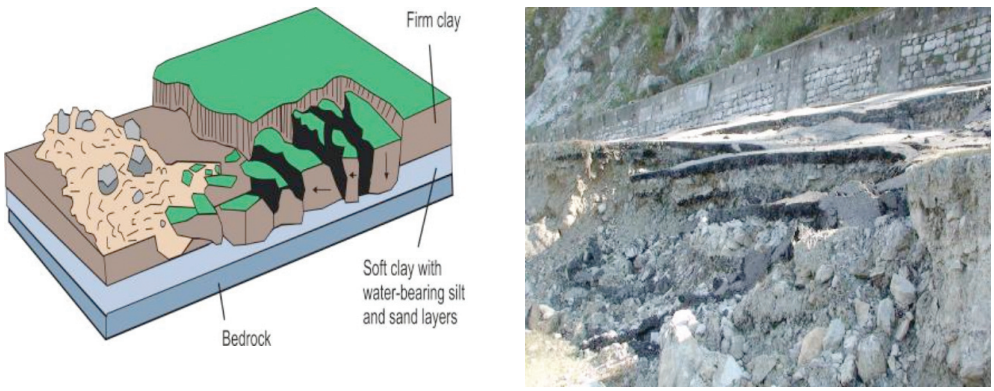


Fig. 1.15: Sketch and example of lateral spreading

- Lateral Spreading: is usually used to describe the lateral extension of a cohesive rock or soil mass over a deforming mass of softer underlying material in which the controlling basal shear surface is often not well defined.
- Rock Spreading: is the result of deep seated, plastic deformation in a rock mass, leading to extension at the surface. e.g. cambering, horsts and grabens and valley bulging.
- Soil Spreading: takes place as a result of plastic deformation in the soil mass, it occurs in response to a loss of strength, and by the application of stresses over a long period of time.

1.3.6 Slump

It is a type of rotational failure on slopes. The trees bend or fall backwards or towards the upslope, as shown in the figure 1.16.

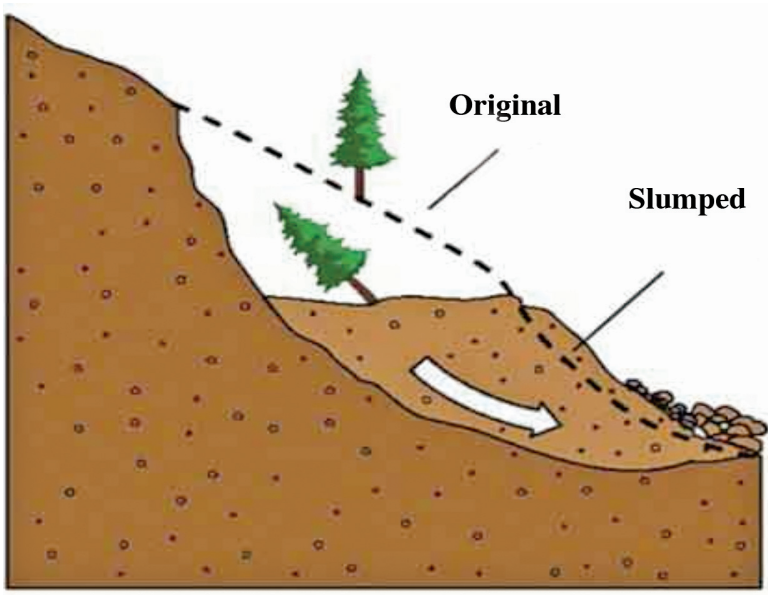


Fig. 1.16: Sketch showing slump type failure

1.3.7 Creep

Extremely slow slope movements, usually a few millimeter per year (which is imperceptible) are covered under this category (Fig. 1.17).

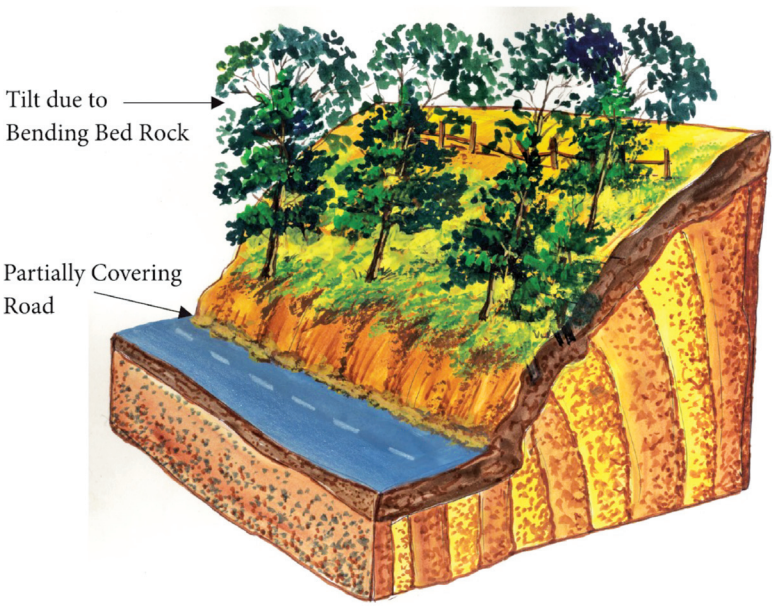


Fig. 1.17: Gradual movement of slope material during creep

However, one may find landslides that do not fall directly under any of these typical singular types of slope failures. Such landslides may be composite, complex or multi-tier. The following examples indicate these types of mixed processes.

1.3.8 Multi-tier/Multi-rotational Landslides

When more than one main scar appear in a landslide site and slope mass has more than one slip surface along which movement takes place (Fig.1.18).



Fig. 1.18: Multi-tier Rotational Landslide at Sataun, H.P.

1.3.9 Complex Landslides

Those landslides where the nature of failure process is not consistent but changes with time (Fig. 1.19). For example, a landslide that begins with rock sliding changes its nature to a rock-fall due to steepening of slopes during a failure, may again result into a debris flow due to formation of a channel during the process of past failures. Thus, it often becomes, very difficult to prevent and control such complex landslides. It requires a persistent study to understand the causes of such landslides properly. These landslides are also found to be chronic and recurring in nature. For example, Kaliasaur landslide in Alaknanda valley, Uttarakahnd displayed this type of failure.



Fig.1.19: Complex Landslide at Kaliasaur, Alaknanda Valley, Uttarakhand

1.3.10 Composite Landslides

The slopes which fail in different manners simultaneously at the same site are termed as composite landslides (Fig.1.20). These landslides display a composite nature as different parts of the landslide indicate a different process type. The types of failure vary due to changes in slope aspect, gradient, heterogeneity in slope mass, landcover, structural/tectonic controls etc. The Matli landslide in Bhagirathi valley, Uttarakhand is an example of composite landslide.

In addition to the classification based on process types and their combination, the landslides can be classified in different ways. Some of the examples of such landslide classifications proposed by different researchers are given here for better understanding of the slope failures.

According to age (Huang H. Yang, 1983), slope movements are classified into contemporary, dormant and fossil movements. Contemporary movements are generally active and relatively easily recognizable by their configuration (the



Fig. 1.20: Matli landslide exhibiting composite landslide failure

surface forms produced by mass movements are expressive) and not affected by rainwash and erosion. Dormant movements are usually covered by vegetation or disturbed by erosion so that the traces of their last movement are not easily discernible. However, the causes of their origin still remain and the movement may be renewed. Fossil movements generally developed in the Pleistocene or earlier periods, under different morphological and climatic conditions and cannot repeat themselves at present.

According to stages of slope movements, these can be divided into initial, advanced and exhausted (Huang, 1983). At the initial stage, the first signs of the disturbance of stability (equilibrium) appear and cracks develop in the upper part of the slope. In advanced stage, the loosened mass is propelled into motion and slides downslope. In the exhausted stage, the accumulation of the slide mass creates temporary stabilization (equilibrium conditions).

The degree of activity of landslides enables an assessment of the possibility of future movement. Erskine (1973) provided the following definitions on various degrees of activity. Active slopes represent those moving at the present time or within last cycle of seasons. Whereas Inactive slopes have not moved within the last cycle of seasons and are therefore, dormant. They may later renew their activity or remain dormant for so long that their features become degraded. The following table outlines the major differences between active and inactive landslides.

Table-1.5: Features indicating active and inactive landslides

S. No.	Active	Inactive
1	Scarps, terraces and crevices with sharp edges	Scarps, terraces and crevices with rounded edges
2	Crevices and depressions without secondary infilling	Crevices and depressions in filled with secondary deposits
3	Secondary mass movement on scarp faces	No secondary mass movement on scarp faces
4	Surface of rupture and marginal shear planes show fresh slickensides and striations	Surface of rupture and marginal shear planes show old or no slickensides and striations
5	Fresh fractured surfaces on blocks	Weathering on fractured surfaces of blocks
6	Disarranged drainage system; many ponds and undrained depressions	Integrated drainage system
7	Pressure ridges in contact with slide margins	Marginal fissures and abandoned levees
8	No soil development on exposed surface of rupture	Soil development on exposed surface of rupture
9	Presence of fast growing vegetation species	Presence of slow growing vegetation species
10	Distinct vegetation differences 'on' and 'off' slide	No distinction between vegetation 'on' and 'off' slide
11	Tilted trees with no new vertical growth	Tilted trees with new vertical growth above the inclined trunk
12	No new supportive, secondary tissue on trunks	New supportive, secondary tissue on trunks

1.4 Other Classifications

Besides the process based classification, the landslides have also been categorized based on velocity of landslides (Table-1.6), depth of landslides (Table-1.7) and area affected by landslides (Table-1.8).

Table-1.6: Proposed landslide velocity scale (Varnes, 1996)

Class	Description	Velocity (mm/sec)	Typical Velocity	Probable Destructive Significance
7	Extremely Rapid	≥5 x 10 3	≥5 m/ sec	Catastrophe of major violence; buildings destroyed by the impact of displaced material; many deaths; escape unlikely
6	Very Rapid	≥5 x 10 1	≥3 m/ sec	Some lives lost; velocity too great to permit all persons to escape
5	Rapid	≥ 5x 10 -1	≥1.8 m/ hr	Escape evacuation possible; structures, possessions and equipment destroyed
4	Moderate	≥5 x 10 -3	≥13 m/ month	Some temporary and insensitive structures can be temporarily maintained
3	Slow	≥5 x 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 x 10 -7	≥16mm/ year	Some permanent structures undamaged by movement
1	Extremely Slow	<5 x 10 -7	<16mm/ year	Imperceptible without instruments; construction possible with precautions

Speed of a running man is ~5 m/sec (It matches approximately with velocity of extremely rapid and rapid landslides)



Fig. 1.21: Field example of a fast moving landslide/rock fall

Table-1.7: Depth classification of landslides

S. No.	Depth of slide below surface	Class Name
1.	<1.5 m	Surficial Slide
2.	1.5 m - <5 m	Shallow Slide
3.	5 m - <20 m	Deep Slide
4.	>20 m	Very Deep Slide

Table-1.8: Magnitude classification of landslides (after USSR State Committee on Construction, 1981)

S. No.	Scale of Landslides and Mudflows	Volume of Landslides and Mudflows in m3
1.	Small	Hundreds
2.	Fairly Large	Thousands
3.	Large	Tens of thousands
4.	Very Large	Hundreds of thousands
5.	Enormous	Millions
6.	Collosal	Tens and hundreds of millions

1.5 Causative Factors for Landslides

There can be several different causative factors for the occurrence of landslides which may work individually or collectively to cause a landslide. Broadly these factors can be categorized into ground conditions, geomorphological processes, physical processes and man-made processes. A brief list of these causative factors is given in the table below.

Table-1.9: A brief list of landslide causative factors

A. GROUND CONDITIONS

- Plastic weak material
- Sensitive material
- Collapsible material
- Weathered material
- Sheared material (Fig. 1.31)
- Jointed or fissured material
- Adversely oriented structural discontinuities including faults, unconformities, flexural shears, sedimentary contacts (Figs. 1.29 & 1.31)
- Adversely oriented mass discontinuities (including bedding, schistosity, cleavage)
- Contrasts in permeability and its effects on groundwater (Figs. 1.26 & 1.27)
- Contrasts in stiffness (stiff, dense material over plastic material)

B. GEOMORPHOLOGICAL PROCESSES

- Tectonic uplift
- Volcanic uplift
- Glacial rebound
- Fluvial erosion of the slope toe
- Wave erosion of the slope toe
- Glacial erosion of the slope toe
- Erosion of the lateral margin
- Subterranean erosion (solution, piping)
- Deposition loading of slope at its crest
- Vegetation removal (by erosion, forest fire, drought)
- Ground cracks (Fig. 1.30)
- Subsidence (Fig. 1.49)

C. PHYSICAL PROCESSES

- Intense, short period rainfall
- Rapid melting of deep snow
- Prolonged high precipitation

- Rapid drawdown following floods, high tides or breaching of natural dams (Fig.1.22)
- Earthquakes
- Volcanic eruptions
- Breaching of crater lakes
- Thawing of permafrost
- Freeze and thaw weathering
- Shrink and swell weathering of expansive soils

D. MAN-MADE PROCESSES

- Excavation of the slope or its toe
- Loading of the slope or its crest
- Drawdown of reservoirs (Fig.1.22)
- Irrigation (Fig.1.23)
- Defective maintenance of drainage systems (Fig.1.24)
- Water leakage from services like water supplies, sewers, storm water drains (Fig.1.25)
- Vegetation removal (deforestation)
- Mining and quarrying in open pits or underground galleries (Fig.1.21)
- Creation of dumps of very loose waste
- Artificial vibration including traffic, pile driving, heavy machinery, blasting and explosion (Fig.1.20)
- Poor maintenance of remedial measures (Figs.1.60 & 1.61)

1.6 Classification of Conditions/Factors Responsible for Landslides

Some slopes are susceptible to landslides whereas others are comparatively stable. Many factors contribute to the instability of slopes, and these include high relief, drainage, bedrock, regolith, vegetation, climate, earthquake, paleo-features and man-made conditions. The conditions/factors governing landslides can be classified into inherent (terrain) and external as given below.

1.6.1 Inherent or Basic Conditions

- Lithology – Rock types and their physical and mechanical properties
  Structure – Fracture, folding etc
- Geomorphology
  Angle, direction, shape and other topographic attributes
- Hydrologic conditions
  Movement and distribution of surface as well as subsurface drainage

- Vegetation
  Types and density
- Soil mechanics
  Soil types and their friction angles, volumetric weight, undrained strengths

1.6.2 External Factors/conditions

External factors/conditions include precipitation, vibrations induced by earthquakes/blasting/explosion, loading or unloading of slopes etc.

These factors may actually produce two different types of changes, i.e. changes in stress conditions and in strength of materials. The different factors producing different changes are given below.

1.6.3 Factors Producing Unfavourable Changes in Conditions

Those that change stress conditions

Erosion or deposition
Fluctuation in water level
Seismic vibrations
Construction activity
Cuttings
Reservoir fluctuations
Landuse practices

Those that change strength of materials

Progressive softening of fissured clays
Disintegration of granular rocks (Freeze & thaw)
Hydration of clay minerals
Drying and cracking of clays
Loss of cementing material from coherent material by dissolution

1.6.4 Landslide's Driving Force

The principal driving force for any landslide is the gravitational force and the tendency to move this mass will be proportional to the hill slope angle. The resisting forces preventing the mass from sliding down the slope are inversely proportional to the same hill slope angle and proportional to the friction of the material. The stability of the material resting on a slope will be reduced with an increased slope angle. In addition, the resisting forces can be significantly reduced in case of rain or earthquake or other vibrations.

1.7 Identifying Landslide Areas

The identification and prediction of a landslide is essential to minimize or control the hazard. Usually this is done using costly procedures as surveying, monitoring or soil testing, which are not affordable or feasible in rural regions with almost no resources. Therefore, simpler but still effective methods have to be used to assess the stability of slopes and decide if a given location is safe for construction. The following features may be used to identify probable landslide prone areas:

- Existing or old landslides or places of known historic landslides
- Areas at the base of slopes
- Within or at the base of minor drainage hollows
- At the base or top of a fill slope
- At the base or top of a cut slope
- Any sloping ground in an area known to have a landslide problem
- V-shaped valleys, canyon bottoms, and steep stream channels
- Fan shaped areas of sediments and boulders accumulation at the outlet of canyons
- Areas with large boulders (2 to 20 cm diameter) perched on soil near fans or adjacent to creeks
- Steep hill slopes above a home or hamlets
- Logjams in streams above a home or hamlets
- Steepened road cuts, sunken or down-dropped road beds
- Areas that have been extensively disturbed by excavation into steep slopes
- Moderately steep slopes that are exposed to high water flow
- Burn areas, intensively irrigated agricultural field, canyon, hillside, mountain and other steep areas are vulnerable to landslides

1.8 Potential Landslide Risk Indicators

The following simple observations and inspection by community, municipal officials and property owners, may assist in assessing potential landslide hazards. It is important to note that some of these features can also be due to causes other than landslides, such as swelling clays.

- Saturated ground or seeps in areas that are not typically wet.
- New cracks and scarps or unusual bulges in the ground, roads or pavements (Fig.1.37)
- Movement of ancillary structures such as decks and patios in relation to a house (Fig.1.43)

- Sticking doors and windows, and visible open spaces indicating jambs and frames out of plumb (Figs. 1.33, 1.34, 1.35 & 1.38)
- Soil moving away from foundations
- Tilting or cracking of concrete floors and foundations.
- Broken water lines and other underground utilities.
- Leaning telephone poles, trees, retaining walls or fences.
- Offset fence lines or retaining walls (Fig. 1.29)
- Sunken or displaced road surfaces (Fig. 1.50)
- Rapid increase in creek water levels, possibly accompanied by increased turbidity (soil content)
- Sudden decrease in creek water levels though rain is still continuing or recently stopped
- Springs, seeps or saturated ground in areas that have not typically been wet
- Thorough cracks in walls, gaps between roof and wall etc. (Fig. 1.34 & 1.36)
- Damages to building elements (Fig. 1.39)

In most cases in the field, one may find the presence of combination of landslide

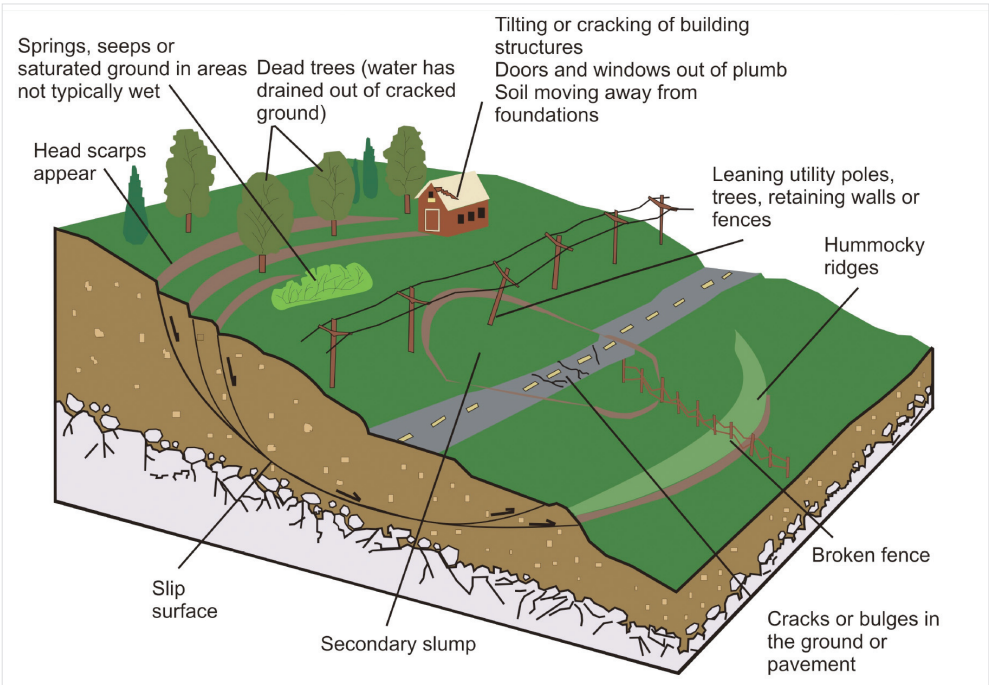


Fig. 1.22: Ground Sign of Slope Instability (Source: IRC: SP-106-2015)

risk indicators. It is important that local bodies provide a means of keeping records, preferably in written format, about the occurrence of landslides, with photographs and/or diagrams wherever possible. This will provide a means to sustain landslide knowledge through time and it is important that such landslide information be made available, in some manner, to general public.

Table-1.10: Field matrix for identifying features of landslide

	Diagnostic geomorphic feature on slope	Likely significance of feature with respect to
Possible period and character of slope movement	Fresh rock or soil surfaces	Recent or ongoing slope movement
	Groups of re-curved 'pistol butt' trees	
	Groups of toppled, jack-strawed, leaning, 'drunken' trees, pistol grip	
	Split trees, disrupted roads, fences, or other linear features	Recent or ongoing differential slope movement
	Fresh scars	Recent or ongoing movement of part of the slope
	Tension cracks, crescent-shaped or curved scarps or depressions; shallow, linear depressions: step-like benches or small scarps	Recent or ongoing continuous or intermittent slope movement
	Revegetated scars or partially revegetated strips; linear strips of even-aged vegetation or trees	Older slope movement; inactive/dormant
Possible landslide type	Fresh accumulation of rock or soil on lower slope or at base of steep slopes	Rock or soil fall, topple or slide
	Linear or fan shaped tracks of angular blocks below steep slopes	Rock fall or debris flow
	Hummocky ground, sag ponds	Earth flow; can also result from erosion of displaced material of other landslide types
	Rock or soil piled on the upslope side of trees	Channelized debris flow
	Colluvial fan or debris piles at mouth of gullies	
	Trim lines, levees along gully; no or new vegetation in gully bottoms	

	Vegetation in gullies much younger than the adjacent forest; poorly developed soils on gully sides relative to adjacent slopes	Channelized debris flow
Other possible significance	Mixed or repeated soil profiles in natural or artificial exposures	Slope movement; repeated soil profiles indicates thrusting or shearing
	Buried soil profile in natural or artificial exposures	Displaced material from landslide has buried undisturbed material
	Poorly developed soils relative to other comparable slopes	Possibly the result of slope movement
	Terracettes across slopes	Shallow slow deformation of slope; may indicate seasonally saturation or permafrost thaw
	Bulging in the lower portion of a slope	Incipient larger slope movement
	Displaced or disrupted stream channel	Slope movement into stream channel
	Numerous springs along toe of slope	Disruption of drainage due to slope movement

1.9 Effects and Consequences of Landslides

Landslide effects can be classified as direct and indirect effects as below:

Direct effects - are those first order consequences which occur during and immediately after an event, such as deaths and damage caused by landslides directly.

Indirect effects - may emerge after the landslide event and may be more or less easy to attribute directly to landslides. This includes psycho-social impacts, bereavement and evacuation.

Similarly the effects may be classified as tangible and intangible as below:

Tangible effects - are those to which it is possible to assign reasonable reliable monetary values, such as replacement of a damaged property.

Intangible - cannot be satisfactorily assessed in monetary terms. For example, loss of human lives has proved difficult to assess financially

Landslides effects can be discussed under the two basic environments – (i) built environment and (ii) natural environment. Sometimes there is intersection between them; for example agricultural lands and forest lands that are logged.

- Physical Injuries and Loss of human lives,
- Property/Infrastructural damages and economic losses,
- Affect a variety of resources like water supplies, fisheries, sewage disposal systems, forest, dams and reservoirs.

1.9.1 Effects of Landslides on Built Environment

Landslides affect manmade structures either directly or when these are located near a landslide. Residential buildings on unstable slopes may experience partial damage to complete destruction as landslides destabilize or destroy foundations, walls, floors, surrounding property, utilities such as water pipelines, power lines, communication lines, transport routes etc. Commercial structures may also face similar consequences as the residential buildings but the consequences may be greater due to disruption in business due to damage of access routes.

Fast moving landslide such as debris flows and rock falls/topples are more destructive and life-taking as they often occur without precursors or warnings, move too quickly for any safety measures to be taken, with high momentum due to their mass and velocity that can destroy anything that comes in its way; whereas slow moving landslide may only cause slight damage and its slow pace may allow relief and implementation of mitigation measures as well. However, if left unchecked, even slow landslides can completely destroy the structures over time (USGS Circular 1325). The nature of landslide movement and the fact that they may continue after days, weeks, or months preclude rebuilding on the affected area, unless mitigation measures are taken appropriately.

As the world population grows, they are increasingly vulnerable to landslides. People tend to move to new lands that might have been deemed too hazardous in the past but are now the only areas that remain for the growing population. Poor or non-existent landuse policies allow building and other constructions to take place on the land that should better be left to agriculture, parks or other such uses. Communities are not prepared to regulate unsafe buildings practices and may not have legitimate or adequate means / expertise to do so,

1.9.2 Impacts on Buildings (including residential, commercial, private, public and government)

Landslides result in development of cracks in the buildings in case of slow moving/creeping landslides but may cause collapse or complete damage/ burial of buildings in cases of sudden massive and fast moving landslides (Figs. 1.39, 1.46 & 1.48). Figure 1.63 depicts the impact of Varunawat Landslide in Uttarkashi City of Garhwal Himalaya, Uttarakhand State, where about 400 houses were affected by the occurrence of landslide.



Fig. 1.63: Landslide buries both commercial and residential buildings besides blocking the highway

1.9.3 Impact on Highways, Roads and Railways

One of the greatest consequences of landslides is its impacts on transportation industry (roads and railways) which indirectly affects large number of people in any locality (Figs. 1.40, 1.41, 1.49, 1.50, 1.52, 1.55, 1.59 & 1.60). Blockages of highways by landslides occur very commonly around the world, and many can simply be bull dozed or shoveled away. Others may require temporary diversion of traffic or even closure of road traffic or a major excavation. National/State highways and connecting roads are also very vulnerable to the impacts of landslides. A large number of landslide that occur along the roads and highway result in damage/destruction of transportation/access routes as well as pose risk to the vehicles and passengers/passers-by on the road-side. Figure 1.48 depicts the destruction of national highway to Badrinath due to Lambagar Landslide in Uttarakhand and Figure 1.40 show the impacts of a rock-fall on a bus parked close to a landslide spot near Sukhi on Bhatwari-Gangotri National Highway in Uttarkashi district, Uttarakhand.

1.9.4 Impact on Essential Services like Power, Communication, Water Supply etc.

Besides buildings and roads, the landslides also affect our essential services like power, communication and water supply etc. The rigid pipelines and structures are more badly affected compared to flexible/elastic pipes and structures. The photograph (a) below shows the inundation of a power tunnel in a hydel project (Sanjay Jal Vidyut Yojna in Satluj Valley) due to blockade of river by a landslide on the downstream side, thus, hindering the operations for power generation. The photograph (b) reveals the problems of stability of power transmission structure due to their close proximity to the crown of retrogressive landslide, thereby endangering their stability and functionality.

1.9.5 Impacts on Health and Education Sectors

Several educational and health buildings have been reported as affected by landslides in hilly areas. 18 Children between the age of 5 and 11 were killed by a landslide on 18th August 2011 in Uttarakhand while they were attending their school. Similarly hospital buildings at Shimla and Rampur in Himachal Pradesh were found affected by the landslides. Thus, safety from landslides in educational and health buildings has prime importance as these places involve vulnerable groups of people.

1.9.6 Effects on Natural Environment

Landslides may have the following impacts on natural environment:

- The morphology of earth's surface - mountain valley system, both on continents and beneath oceans, are most significantly affected by landslide due to morphological changes
- The forest and grassland cover changes
- The native wildlife, its rivers, lakes and seas.

The following landslides may occur in natural environment:

(a) Submarine Landslide is general term used to describe downslope mass movement of geologic materials from shallower to deeper regions of the oceans. Such events may produce major effects to the depth of shorelines. These types of landslide can occur in rivers, lakes and oceans. Large submarine landslides triggered by earthquakes can cause deadly tsunamis.

(b) Coastal cliff retreat or cliff erosion – Falling rocks from eroding cliffs can be especially dangerous to anyone occupying areas at the base of cliffs, or on the beaches near cliffs. Large amount of landslide material can also be destructive to aquatic life such as fish.

(c) Landslide dams are natural phenomena and these occur when a large landslide blocks the flow of river, causing a lake to form behind the blockage. Most of these dams are short-lived as the water will eventually erode the dam. Lakes created by landslide dams can last for long. But sooner or later when these natural dams breach, the stored water gets released suddenly and cause massive flooding downstream.

1.9.7 Impacts on Natural Resources and Cultural Heritage

During Varunawat landslide at Uttarkashi, more than 300 pine trees got uprooted and about 300 trees had to be cut for treating the landslide. Besides pine, number of other varieties of trees and shrubs were also affected. Therefore, it can be said that a huge loss to the natural environment and resources occur due to such landslides. Figures 1.56 and 1.57 depict the impacts of landslides at heritage structures in Uttarakhand.

1.9.8 Strategic Impact on National/Border Security

The occurrence of landslide can lead to strategic problems when it happens along our border roads with other countries. The movement of army vehicles and troupes on the ground can get hurdled by landslides (Fig. 1.44). The photograph below is depicting the situation of army movement when a landslide happened on a border road to Bhaironghati in Uttarakhand. The insurgency by terrorists and anti-social elements also rises when the army movement is restrained by landslides in border areas.

1.9.9 Economic Effects of Landslides

- Cost of repair
- Loss of property value
- Disruption of transportation routes
- Medical costs (injury)
- Water availability, quality and quantity

Direct Loss - are the most visible consequences of landslides. They may be comparatively easy to measure but they are not always the most significant outcome. They are caused by the immediate damage done to humans, resources and environment.

Indirect Loss - rise mainly through the second order consequences of landslides, such as disruption of economic and social activities in a community or onset of ill-health amongst disaster victims. These effects often outlast those of direct losses by months or even years and can be highly intangible.

1.10 Inter-relationship of Landslides with other Natural Hazards - The Multiple Hazard Effect

Earthquakes, volcanic eruptions and cloudbursts are purely independent phenomena and can induce and trigger landslides. However, one or more of the other natural hazards such as floods, glacial lake outburst floods, and landslides can occur individually or simultaneously, as one of these can cause one or more of the other hazards.

As an example, a very high magnitude undersea earthquake can induce massive landslide, which in turn would displace huge amount of water and may lead to deadly tsunami. Another example would be a volcanic eruption induced or earthquake induced landslide that blocks a river, causing water to back up behind the mass and flood the upstream area. Should the dam fail, the impounded water will be suddenly unleashed to cause flooding downstream. The flooding can then add to riverbank and coastal erosion and destabilization through rapid saturation of slopes and undercutting of cliffs and banks. It is therefore, imperative, when evaluating an area's vulnerability to landslides, to examine all other possible hazards. Thus, multiple hazard susceptibility should be produced for showing all multi-hazard events involving landslides.

1.11 Communicating Landslide Hazard

The successful compilation of natural hazard information in a format useful for non-technical users conveys the following elements in one form or the other.

- Likelihood of the occurrence of an event of a size and in a location that would cause casualties, damage, or disruption to an existing standard of safety,
- Expected location and extent of the effects of the event on the ground, structures or socio-economic activity, and
- Estimated severity of the effects on the ground, structures or socio-economic activity.

The non-technical user must be able to perceive likelihood, location and severity of the hazard so that they become aware of the danger, are able to convey the risk to others, and use the translated information directly to reduce the risk.

1.12 Landslide Warning Signs

Some simple warning signs can be placed in hazardous areas along with some information that can be used in emergency management. Some basic

information about safety tips for landslide prone areas may be posted and distributed among the public in such places.

1.13 Minimizing the Effects of Landslides

Planners and Decision Makers should learn from past tragic events and should impose stringent planning and design requirements in landslide-prone and unstable areas. These may include:

- Implementation of regional hazard and risk assessments into landuse planning policies. This ensures that appropriate processes are in place whereby new development applications are assessed with respect to slope stability issues and zoning for future development is directed towards areas with a low or very low risk of slope instability.

- Engineering and geotechnical investigation that define the landslide hazard and risk at site specific levels of investigation.

- Mapping of landslide vulnerability that can help with the development of emergency response scenarios.

The following field photographs reveal the above features.



Fig. 1.21: Blasting in road construction leads to landslides



Fig. 1.22: Improper open cast mining causes landslide



Fig. 1.23: Sudden and fast drawdown may result in subsidence/landslides



Fig. 1.24: Inappropriate irrigation practices can cause slope instability



Fig. 1.25: Ill-planned and clogged drains under culverts result in damages to roads



Fig. 1.26: Water pipelines may get ruptured and joints open up due to landslides and water leakage further aggravates the instability



Fig. 1.27: Seepage and leaching at interface between sand & clay beds



Fig. 1.28: Permeability contrasts in rocks leads to percolation and development of pore pressures



Fig. 1.29: Retaining walls get de-aligned due to landslide



Fig. 1.30: Faults are weak zones and susceptible to landslide



Fig. 1.31: Ground cracks indicating incipient slope failures



Fig. 1.32: Fold axis is the weakest plane along which movement can occur



Fig. 1.33: Land subsidence creates gap between door frame and floor



Fig. 1.34: Opening between wall and roof due to settlement



Fig. 1.35: Appearance of cracks due to differential settlement

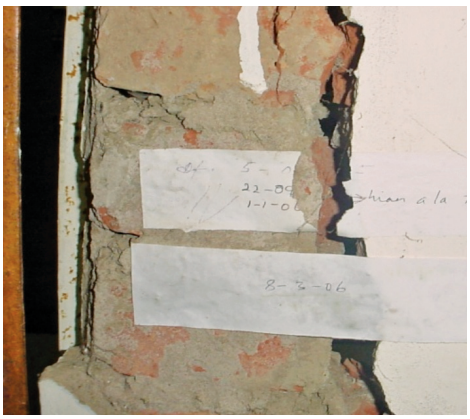


Fig. 1.36: Monitoring of wall cracks using paper slips with markings



Fig. 1.37: Cracks appear in pavement/ ground in a house wall



Fig. 1.38: Cracks extending from floor to walls due to landslides/differential settlement



Fig. 1.39: Building gets damaged due to unsound ground beneath



Fig. 1.40: Extensive damages to roads during landslide



Fig. 1.41: A huge boulder fell on a bus parked near a slide and damaged it



Fig. 1.42: Stability of towers compromised due to their proximity to slide area



Fig. 1.43: Differential settlement in pavement/floors in a house



Fig. 1.44: Army personnel face problems of damaged access route when landslide occur in border roads



Fig. 1.45: Lake created due to river damming by landslide



Fig. 1.46: Residents protect houses by using polythene sheets to prevent seepage



Fig. 1.47: Tunnel in a hydel project filled with silt-charged water after a landslide blocked river on downstream side



Fig. 1.48: Earthquake induced landslide caused damages to cluster of houses



Fig. 1.49: Complete road washed off after bursting of transient landslide dam



Fig. 1.50: Subsidence causes differential settlement and damage to road



Fig. 1.51: Petrol pump damaged leading to cut in fuel supply



Fig. 1.52: Bridge washed off due to landslide



Fig. 1.53: Landslide affects cluster of houses at foothill slopes



Fig. 1.54: Post-earthquake landslide affects UNESCO heritage toy train track adversely



Fig. 1.55: Landslide causes damage to railway track and road



Fig. 1.56: Application of net barriers to reduce the impacts of debris flow; these however need proper maintenance



Fig. 1.57: Heritage building at risk from landslides



Fig. 1.58: Historical pilgrimage sites at risk from landslides



Fig. 1.59: Passengers and traffic stranded due to landslides



Fig. 1.60: Hanging railway track; ground base washed away by landslide



Fig. 1.61: Ill-maintained culverts get damaged and cracked



Fig. 1.62: Poor implementation/ maintenance of mitigation measures caused failures

LANDSLIDES INVENTORY AND HAZARD ZONATION

2.1 Landslide Inventory

The main purpose of preparation of a landslide inventory map and the database is documentation of all the known landslide incidences including stabilized, dormant, reactivated and most recent slides. The documentation includes location, date of occurrence, triggering factors like rainfall and seismicity during the event, dimension and type of slide, volume of material dislodged, nature and extent of damages caused/may be caused by further sliding, type of triggering factor (earthquake, cloudburst, anthropogenic interference, toe erosion by streams or rivers etc.), probable causes and run-out distance. A colour photograph and sketch plan of the landslide on the date of investigation will be an additional asset of the record. Another important parameter is the collection of historical record of each slide which also gives an idea about the approximate return period of each slide. All these information pave the foundation for LHZ mapping, vulnerability assessment and risk zonation mapping.

A landslide inventory map not only shows the time and date of occurrence but approaches, ranging from digital stereo image interpretation to automatic classification based either on spectral or altitude differences, or a combination of both. The multi temporal images can be used to prepare a landslide activity map. The stereo-images are not only useful for the derivation of elevation information but also for landslide inventory mapping as it provides a 3-dimensional visualisation opportunity

Very high resolution imagery (Worldview 4, GeoEye, SkySat-1, QuickBird, IKONOS, CARTOSAT-1 and 2) are among the best options for landslide mapping from satellite images, and the number of operational sensors with similar characteristics is growing year by year. Other remote sensing approaches of landslide inventory mapping include shaded relief images produced from Light Detection and Ranging (LiDAR) DEM and Synthetic Aperture Radar (SAR) interferometry. LiDAR is an active sensor and the signal from the sensor from onboard aircraft has most of the times the capability of penetrating through the tree crowns. Thus, it provides data about subtle elevation variation of the bare ground. LiDAR data have been used to prepare landslide inventory under forest areas in hilly regions and to refine the boundaries of landslide areas prepared during field investigations. This data is not only useful for mapping

old landslides but also can improve field survey based investigation in regions with subdued morphology. SAR images are useful in identifying critical terrain elements such as faults and slope characteristics. Also subtle movement due to landslides can be picked up from interferograms generated from SAR image pair. Another advantage of SAR data over optical sensor data is its all weather monitoring ability. So, combination of SAR imagery with high resolution optical multispectral imagery is useful for monitoring debris hazard in mountainous areas. However the problems such as foreshortening and layover effects associated with SAR data in mountainous areas have to be addressed carefully.

Preparation of a comprehensive and user-friendly national landslide inventory database will be taken up paving way for continuous updating of the landslide map of India. This will be achieved by nation-wide networking of the agencies engaged in the task and would be aided by the latest tools of geomatics and followed by field checks.

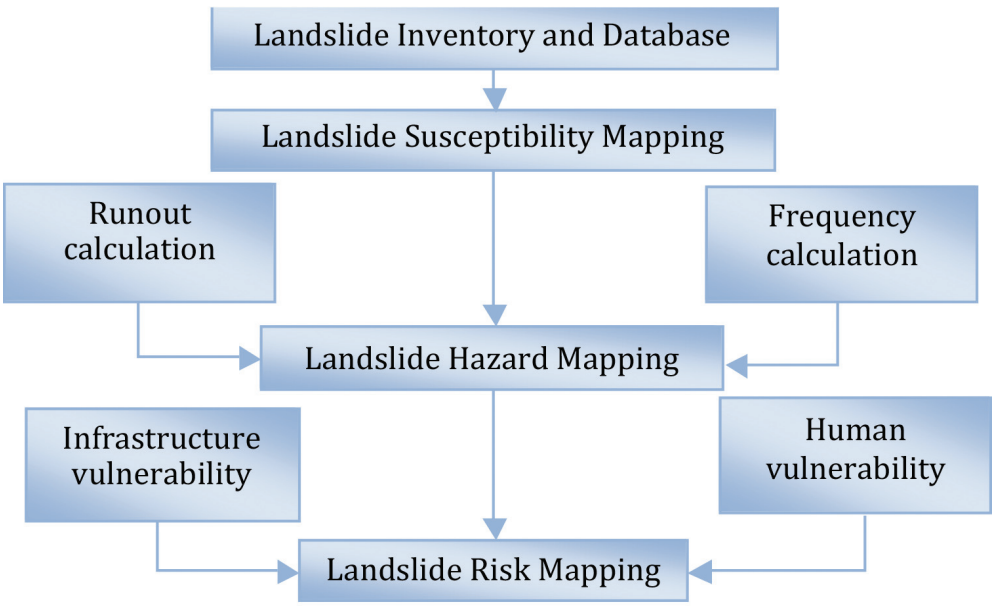


Fig. 2.1: Basic framework of hazard and risk mapping (Source: IRC: SP-106-2015)

2.2 Landslide Database

A. Location of the Slide Site

i. Name of Road
ii. Motor Road or bridle road
iii. Nearest village or town and direction and distance of the slide from it
iv. Slide developed at km (From ---- to -----)

B. General Description of the Area

i. Elevation (Height above M.S.L.)

ii. Slope on Uphill side

iii. Slope on downhill side

iv. State of erosion on slope

v. Density of vegetation (low, medium, high). Give details of trees and vegetations.

vi. Are trees tilted?

vii. Are there cultivated fields?

viii. Monthly data for average rainfall for last 3 years. Annual rainfall for last 10 years or as many years as available.

ix. Name of the nearest observatory

C. Geological Features of the Area

i. Type of rock exposed or underlying (thinly bedded, thickly bedded or massive).

ii. Attitude of beds (strike and dip)

iii. Joints, their dip and spacing. State of joint planes - favourable/ unfavourable.

iv. Structural features (folds, faults, conformities)

v. Stratigraphic position.

vi. Lithological characteristics of the rock with sequence of formation

vii. Texture of rocks

viii. If not rocky to which of the following types it pertains:

Debris (soil to rock pieces)

Soil (almost no rock pieces)

D. Drainage Features

i. Is there any nala or river flowing at the toe of the slide, if so indicate whether it was eroding the toe of the slope.

ii. Give the position of water accumulation, place of spring water, position of snow accumulation with respect to position of the road.

iii. Is any pond or lake present on hill slope?

iv. Any other remark regarding nature of hill slope affecting the stability of hill slope.

E. History & Description of the Slide during its Development

a. Sketch of Slide

Please sketch the slide showing relationship with the road and/or other land marks, take photographs from appropriate angles and in sufficient numbers to be able to generate a mosaic/composite view.

The sketch should show approximate dimensions, boundaries of the slide, position of notable cracks, position of the road, nala and river if any, water path, places of water percolation, spring water, position of road outcrops, big boulders, trees, retaining walls and other prominent structures, location of subsidence/sinking if any.

i. Date of Occurrence of slide

ii. No. of times the slide has taken place so far

iii. Duration of the road blockage due to slide

iv. Number of casualties or persons injured, if any

v. Damages to the property due to slide (houses, livestock, road, fields etc.)

   a. Number of houses completely damaged

   b. Number of houses partially damaged

   c. Number and type of livestock lost

   d. Nature of damage

   e. Occurrence of damage

   f. Progressive nature of damage - Yes/No

   g. If extension of damage has any relation with season - Yes/No

   h. If yes, whom and how observed and their details.

   i. Period of extension of damage.

vi. Method of clearance of slide mass by men and machine or by both.

vii. Time taken for clearance.

viii. Condition before occurrence of slide (dry, rains etc.)

ix. Was sinking of road noticed?

x. Slope angle

xi. Height of crown of the slide from road level

xii. Depth of toe of the slide from road level

xiii. Any other remarkable point observed during or before slide, and

xiv. Rate of movement (cm/day).

F. Causes of Slide

What you think about the cause of slide?

i. Whether it was by man (such as back cutting, blasting, excavation, changes in nature/artificial drainage etc.)

ii. Natural cause (such as river erosion, nala erosion, saturation of hill slope mass, cloud burst, glacial lake outburst flood, unfavourable nature of hill slope mass, earthquake, deforestation, disruption of drainage etc.)

iii. Any other cause noticed at the site.

Note: Generally more than one cause develops the slide but one cause may be dominating and may initiate/trigger the movement.

G. Remedial Measures

i. Whether applied - Yes/No. If yes, please state the measures, viz. :

a. Sealing of cracks.

b. Provision of retaining structures.

c. Improvement in drainage.

d. Measures for protecting river erosion

e. Chemical treatment

f. Grouting

g. Plantation etc.

What is their outcome?

ii. Has the slide area been studied for adopting remedial measures by any competent investigator? If so, give the name of organisation and the summary of the major recommendation.

iii. Indicate what measures were followed and their outcome.

H. Notes:

i. Please complete separate sheet for important slide site of your region. Mark the location of all slides of your region on the district map.

ii. Your active feeding of the information is required and will be helpful to the investigator in suggesting the corrective measures to the pertinent landslides and similar one.

iii. If you feel any problem in providing information, the respective column may be left blank, but should be followed up later. Some of the information as geological features of the area may be left for geologist, in case the field engineers are not able to fill that.

Date: ……..

Signature (Name) of Reporting Officer

Designation

Geological Survey of India (GSI) has also developed a web based "Information Sheet for Landslide Incident", that can be filled by local public in case of any landslide event in their surroundings. GSI has also framed 42-point Detailed Geoparametric attributes of landslide incidences that can be used by trained geoscientists at field (provided in annexure).

2.3 Landslide Hazard Zonation (LHZ) Mapping

The aim of LHZ, a pre-requisite for risk assessment, is to determine spatial and temporal extent of landslide hazard. In general the LHZ map divides the landslide prone hilly terrain into different zones according to their relative degree of susceptibility to landslides. It requires identification of those areas that are, or could be, affected by landslides and assessing the probability of such landslides occurring within a specific period of time. Commenting on the time domain of landslide occurrences through zonation mapping is a difficult task. Due to conceptual and operational limitations, landslide hazard zonation is stated as landslide susceptibility zonation (LSZ). Spatial prediction of landslide is termed as landslide susceptibility, which is a function of landslide and landslide related internal factors (i.e., ground characteristics). The aim is to identify places of landslide occurrence over a region on the basis of a set of physical parameters. The LSZ can formally be defined as the division of land surface into near-homogeneous zones and then ranking these according to the degrees of actual or potential hazard due to landslides. The LSZ maps do not directly incorporate time and magnitude of landslide occurrences. Since LSZ is conceptually accepted as LHZ, it is popularly used as LHZ all over India. A Landslide Risk Zonation Map integrates landslide hazard, landslide vulnerability and degree of risk.

LHZ map requires dividing an area into several zones indicating progressive levels of landslide hazard. The number of zones into which the territory is divided is generally arbitrary. Landslide hazard zoning entails mapping all possible landslides and landslide-induced hazards to the required detail. The

hazard maps are designed to limit information to the users' requirements, and present it in a form comprehensible to them. Indeed, the users' maps ought to be different from those prepared by, or for, the specialists. Graded landslide hazard maps are required by, among others, developmental planners as tools for efficient management of land and its resources. Landslide hazard maps are also essential for assessment of damage potential, and for quantification of risks. Scientific forecasting of a landslide for early warning finds its first clue in the landslide hazard map of the area.

It is necessary to understand the conditions and processes that control landslides and determine existing landslide hazard if future landslide occurrences are to be estimated. A map of existing landslides serves as the basic data resource for understanding these conditions and processes. Existing landslides and their relationship with other key parameters – nature of slope forming material, slope inclination and aspect, landcover, landuse, climate and hydrology – form the basis for hazard assessment.

An all-inclusive approach for mapping landslides, starting with the assessment of regional geologic and geomorphic setting, then focusing in to the detailed scale is recommended. A comprehensive view of the terrain is needed to identify all possible problems associated with slope conditions, including existing and potential instability. It is necessary to review the impact of geological features located beyond the boundaries of the site that could influence the status of hazard in future. There may be vital evidence of instability processes outside the area to be developed that may not be evident on the site itself, but could have a future impact on the site.

The available geological and geomorphological maps form the basic inputs for LHZ mapping. It is not at all possible to prepare all the thematic maps covering a huge area by field work. This problem can be solved with the help of aerial photographs or satellite imageries followed by limited field checks.

Preparation of maps showing landslide hazard includes:

- Generation of thematic maps by compiling and collating the observations on geology, geomorphology, landuse, landcover and distribution of landslide processes including use of local records, interpretation of aerial photographs and high-resolution imageries.
- Collection of relevant information on the existing landslide hazard and analysis of potential landslide hazard including first time slides.
- Identification of areas that could be affected by landslide hazard in future.
- Transformation of process maps into hazard maps identifying the potential for spatial impact and probability of occurrence of hazard.

2.4 Selection of Scales

Landslides related data and information have to be mapped on a scale that is appropriate for end-use purposes, to enable planners to make decisions about future landuse on or close to landslides or landslide-affected areas. At present, few local authorities have access to landslide maps on appropriate planning-level scale (i.e. approximately 1:10,000). Most of them are ignorant even about maps on 1:50,000 scale wherever these are available. While these or smaller scale maps are appropriate for regional studies, these do not provide adequate detail for planning purposes on local level which require detailed information at least up to municipal ward level. At present, very large area of the country has been mapped on 1:50,000 or 1:25,000 scales by GSI on the landslide theme. It is important that a landslide hazard map should be on a scale not markedly different from the data maps used to produce it otherwise estimation of hazard might be misleading.

Considering the importance of landslide hazard and its mapping, GoI, constituted a Task Force on LHZ Mapping in March 1999. Keeping in view the availability of topographic and geological maps in the country at present and recommendations of the Task Force, different scales suggested for preparation of LHZ maps for different purposes are given below.

MAP SCALE FOR LANDSLIDES MAPPING

- National or Regional (1:100,000 to 1:1,000,000)
- Macro-scale (1:25,000 to 1:50,000) – river basins, communication routes etc.
- Meso-scale (1:5,000 to 1:10,000) – municipalities, localities etc.,
- Site specific or theme based (1:100 to 1:1,000 or at desired large scale) – project sites, important/heritage structures, settlements etc.

(Note: Mapping on scales larger than meso should be carried out for site-specific studies and not for Zonation.)

However, it is not appropriate to carry out zonation on scales larger than 1:5000. Landslide studies are being carried out on 1:5000 and larger scales for detailed studies. A nation-wide consensus on the rationale of uniform mapping scales should be developed.

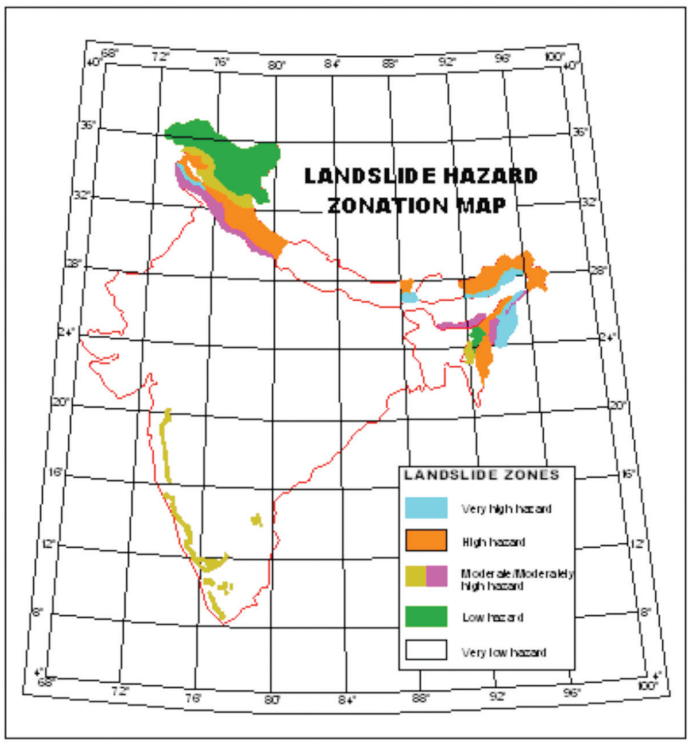


Fig. 2.2: Landslide Hazard Zonation Map of India (Source: GSI)

Table-2.1: Hazard analysis techniques in relation to mapping scales (after Soeters and Van Westen, 1996)

Type of Analysis	Technique	Characteristics	Scale of Use Recommended		
			Regional	Medium	Large
			1:50,000 - 1:1,00,000	1:25,000 - 1:50,000	1:500 - 1:5,000
Inventory	Landslides distribution analysis	Analyze distribution and classification of landslides	Yes	Yes	Yes
	Landslide activity analysis	Analyze temporal changes in landslide pattern	No	Yes	Yes
	Landslide activity analysis	Calculate landslide density in terrain units or as isopleth map	Yes	Yes	No

Heuristic	Geomorphologic analysis	Use in-field expert opinion in zonation	Yes	Yes	Yes
	Qualitative map combination	Use expert-based weight values of parameter maps	Yes	Yes	No
Statistical	Bi-variate statistical analysis	Calculate importance of contributing factor combination	No	Yes	No
	Multivariate statistical analysis	Calculate prediction formula from data matrix	No	Yes	No
	Probabilistic (Magnitude/ Frequency)	Calculate prediction from inventory and time period using power law	Yes	Yes	No
Deterministic	Safety factor analysis	Apply hydrological and slope stability models	No	No	Yes

2.5 Seismic Landslide Hazard Zonation

The principal triggers for landslides are rainfall, earthquake and anthropogenic activities. Since landslides in most areas can co-occur with other hazardous events like earthquakes, high rainfall or cloudburst, these areas can suffer from more than one hazard at a time. Therefore, it is required that risk emanating from all the hazards should be considered for assessing the total risk. It makes it necessary to integrate the landslide hazard into multi hazard concept.

The landslides triggered or induced by earthquakes are known as co-seismic landslides. Earthquake triggered slides occur either when existing landslides are activated by an earthquake or earthquake induced fresh or first time generated slides. Earthquake induced first time landslides are few but earthquake-triggered landslides are many. In a great majority of cases, landslides take place with the earthquake shock, and a few of them may also occur hours and days after the shock. It is observed that the extent of the area within which land sliding is generated tends to increase with the shock magnitude. Seismically generated landslides occur suddenly in more widespread area.

The most abundant types of earthquake-induced landslides are rock falls and slides of the slope forming material resting on steep slopes. However, almost every other type of landslide can occur due to an earthquake but landslides resulting from liquefaction are caused by a seismic event only. Other types of mass movements that can be generally related with seismic activity are:

- Rock avalanches on over-steepened slopes in weak rocks

- Mud flows, rapidly moving wet earth flows

Comprehensive research, development and field oriented studies on instrumented problematic slopes would be undertaken to improve our understanding of earthquake induced landslides. Multi-hazard and seismic micro-zonation programmes will be enriched by added focus on hither to neglected subject of earthquake induced site affected in hilly areas and their effect on slope instability.

2.6 Earthquake-Induced Landslides

A clear distinction is essential between the earthquake-triggered and earthquake induced landslides. Earthquake events are usually known to serve as a trigger for pre existing but dormant landslides to create what may be called as earthquake-triggered landslides. Strong tremors, however, hold the potential to induce new slides especially by rupture along unfavourable discontinuities and shear zones. Such slides are designated as earthquake-induced landslides. It should also be recognized that the commonest classes of the best-understood problems are flow slides due to liquefaction. The other possibilities are (a) reactivation of old, dormant or previously inactive landslides (b) acceleration of known landslides (c) triggering of rock falls (d) development of fresh, first time landslides, and (e) onset of slumping and braking up of the ground. The understanding of the whole process presupposes understanding of (a) topographic and hydrological controls, (b) geological and geotechnical controls (c) seismological controls and (d) anthropogenic controls.

- Ground surface acceleration alone is a poor measure of the effect of shaking on slope stability. Intensity is even more so. The indicators such as ground velocity, experiences on past earthquake events, and duration of shaking are considered to be better indicators of landslide susceptibility under seismic conditions. Critical acceleration of a slope is also an important factor in deciding seismic safety of a slope. The factor of safety during an earthquake may drop below one (limit equilibrium state) for a short duration of time, but the effect of failure on the slope may perhaps be negligible, and needs to be determined.

- The observation that catastrophic landslide events are a post-seismic phenomena rather than a co-seismic happening needs to be investigated. While the earthquake provides the trigger, the development of a landslide is seldom sudden, and it usually occurs after the earthquake and its after-shocks.

2.7 Measures to Reduce Landslides Hazards and/or Risks

If unacceptable levels of landslide safety are identified, it may be appropriate and required, that the professionals provide recommendations for measures to reduce landslide hazards and/or risks. Measures can be passive such as covenants or relocation of proposed buildings, or active such as stabilization or protective works. Residual risks, or those that remain should be estimated and clearly explained.

Typically, a landslide assessment report should include the following:

- Legal description of the property
- Location map or description of property relative to well known geographic features
- Objectives, method of landslide hazard or landslide risk analysis, and the level of effort
- List of background information available, collected and reviewed, and its relevance
- Terrain or physical description of the study area
- Map or plan of the property including topography, natural features, existing structures, roads, infrastructure and surface drainage
- Description of proposed residential development
- Methods and intensity of field work
- Observations of topography, geology, landslide processes and elements at risk
- If applicable, adopted level of landslide safety used for comparison
- Results of landslide assessment
- Conclusion, accompanied by supporting rationale
- Recommendations, if requested and as required, to reduce the landslide hazards and/or risks
- An estimate of the associated residual risks if the recommendations are implemented
- If required, recommendations for further work and requirements for future inspections, and by whom

- Definitions of qualitative terms, technical terms, concepts and variables
- Other information as specified in the agreement with client, or as required jurisdictional guidelines
- References, including maps and photographs
- Limitations and qualifications of the assessment and report, assumptions, error limits and uncertainties

Reports should be accompanied by drawings, figures, sketches, photos, test reports/logs, tables and other support information/data as required. Graphic information should be consistent with the information in the text. Maps or plans should delineate the areas of landslide hazards and risks in relation to existing and proposed residential development. The report should be written clearly to allow reviewers to understand the methods, information used and supporting rationale for the conclusions and recommendations, without necessarily visiting the site. A peer review of landslide assessment report, prior to its submission to the client and/or authority, is strongly encouraged as part of quality assurance/control programme.

2.8 Limitations and Qualifications of Landslides Assessment

The limitations and qualifications of a landslide assessment depend on the objectives, method of landslide hazard or risk analysis, level of effort, size of the study area, stability and geological and geotechnical complexity of the terrain, type of residential development, elements at risk, availability, quality and reliability of background information and field data, intensity of field work, experience and local experience of the professional, and whether or not a defined level of landslide safety has been adopted by the approving authority.

Although field work associated with a landslide assessment can provide reasonable coverage of the study area, field work may not cover the entire study area or all areas potentially affected by residential development. The extent of field work should be described in the report.

Many aspects of landslide assessment are qualitative and subjective based on observed, inferred and assumed conditions. Only some landslide assessments include subsurface investigations, sampling, instrumentation, monitoring and laboratory testing.

Conclusion and recommendations are based on the assumption that standard methods of residential development will be followed. Non-standard development, design and/or constructions recommendations should be clearly described. Substandard practices of construction may render the conclusion and recommendations invalid.

The life of landslide assessment report depends on the occurrence of subsequent landslides, changes in landuse, site development, neglect or discovery of previously unknown information.

Limitations and qualifications, including those associated with background information, assumptions, sources of error and range of values, should be clearly described in the report.

Levels of landslide safety are determined by society, not individuals. Therefore, for residential development, the levels must be established and adopted by the local and provincial government after consideration of a range of societal values. For example, factor of safety of a slope under static conditions must be significantly greater than 1 to accommodate earthquake loads. Acceptable factor of safety depends on the uncertainty in the analysis, the soil parameters and the magnitude and duration of seismic excitation, in addition to the potential consequences of slope failure.



Fig 2.3 Map Showing Distribution of Failed Slopes in Dunda Uttarkashi



Fig 2.4 Drainage Map of the Dunda Uttarkashi Area

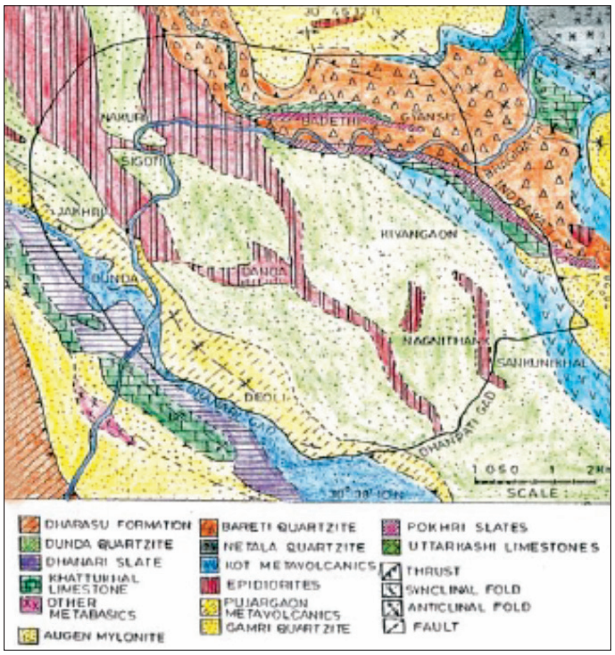


Fig 2.5 Geology Map of Dunda, Uttarkashi Area

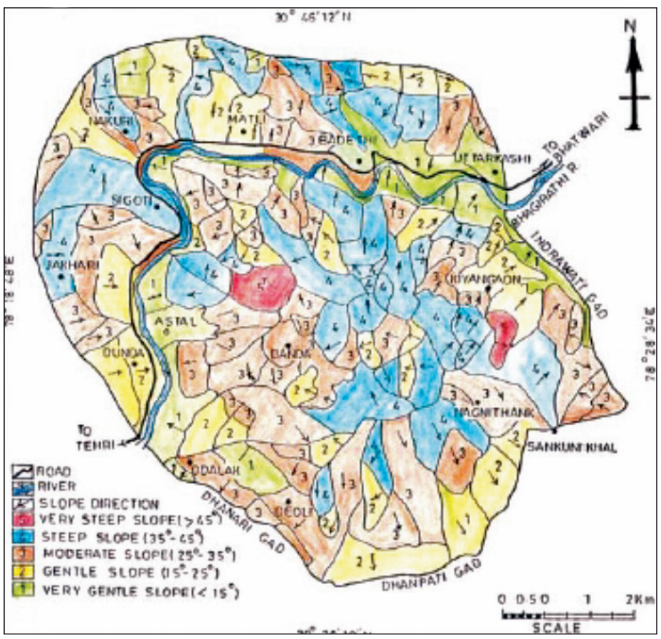


Fig. 2.6 Slope Map of the Dunda, Uttarkashi Area

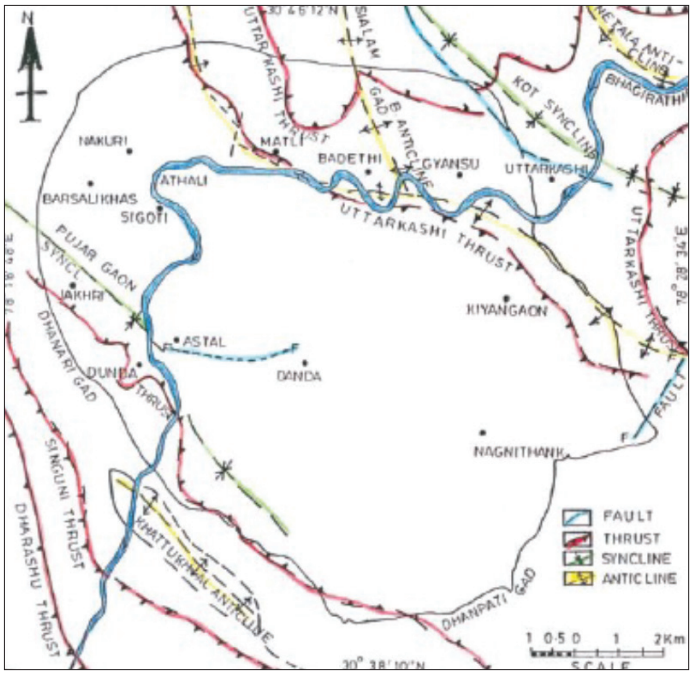


Fig. 2.7 Structure & Tectonic Map of the Dunda, Uttarkashi

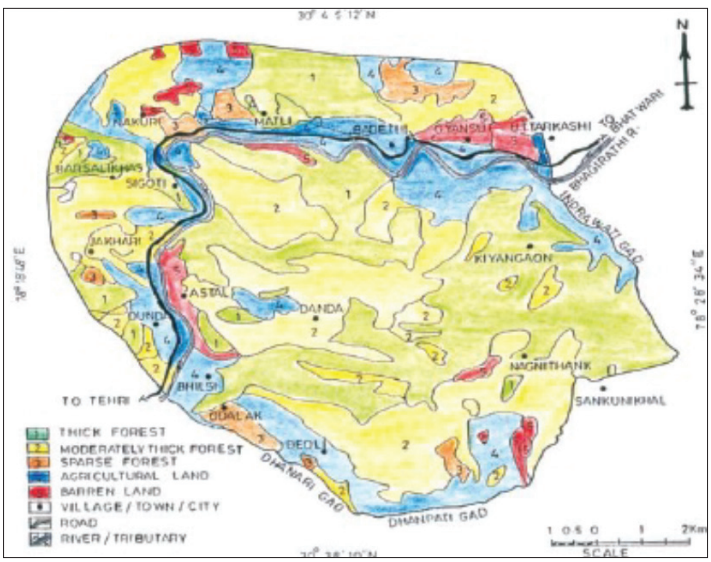


Fig. 2.8 Landuse Map of Dunda, Uttarkashi

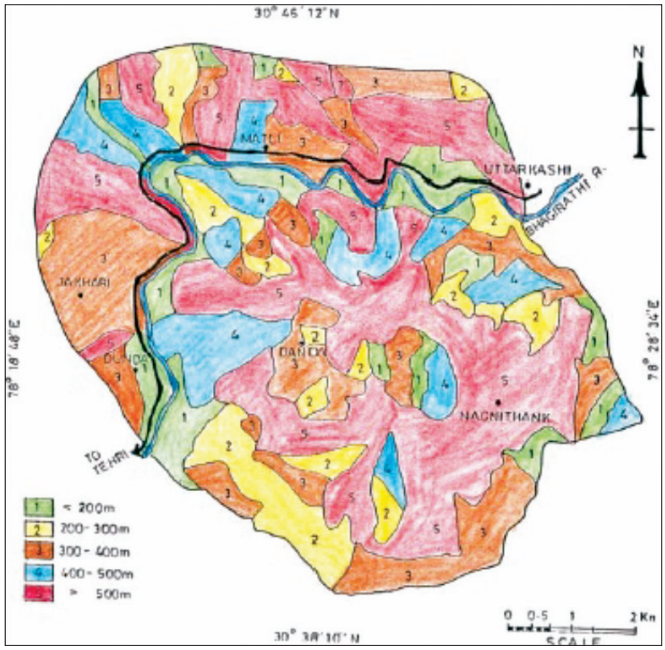


Fig. 2.9 Relative Relief Map of the Dunda, Uttarkashi

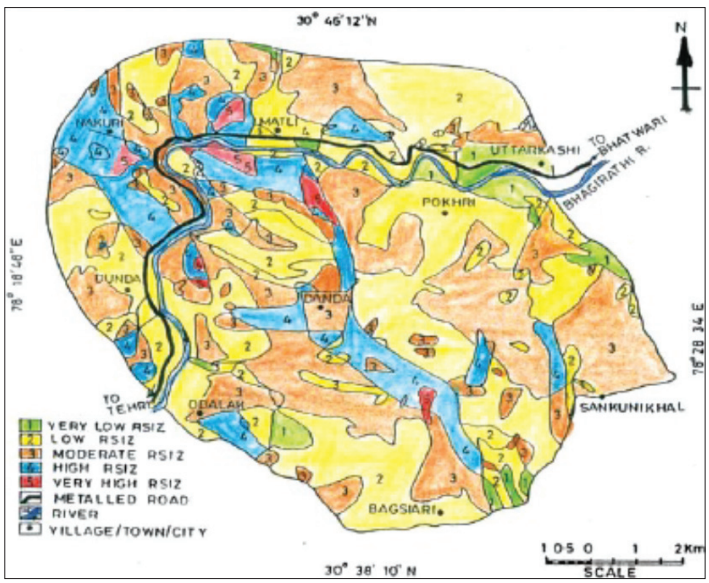


Fig. 2.10 Relative Slope Instability Zonation (Rsiz) Map of the Dunda, Uttarkashi

LANDSLIDES RISK ASSESSMENT

3.1 Introduction

Landslide is a natural process (although many a times human indulgence does contribute in endangering stability or enhancing slope instability), which occurs and recurs in some settings under certain conditions. The rising costs of landslide damages are a direct consequence of the increasing vulnerability of the people, structures and resources to the hazard. The vulnerability of people to the natural hazard is determined by the relationship between the occurrence of extreme events, the proximity of people to these occurrences, and the degree to which the people are prepared to cope with these extremes of nature.

$$Rt = (E) * (Rs) = (E) * (H \times V)$$

Where Rt is Total Risk,

E - Elements at risk,

Rs - Specific Risk,

H - Natural Hazard,

V - Vulnerability

3.2 Principles

- The past and present are keys to the future.
- The main conditions that cause landslide can be identified.
- Degree of hazard can be estimated.

3.3 Landslide Risk Assessment

Natural hazard is a condition that expresses the probability of a damaging event occurring with a specified magnitude within a defined time period and area. Risk is a measure of the probability and severity of the damaging event.

Landslide risk can be defined as the potential for adverse consequences, loss, harm or detriment to population and resources. Hence, landslide risk is a combination of the probability of occurrence of landslides and the consequences due to landslides.

Management of risk involves the complete process of risk assessment and risk control. Risk assessment, the process of risk analysis and risk evaluation, is the initial and the most important step of risk management. Conducting a risk assessment can provide information on location of hazard, value of existing land and property on hazard location, an analysis of risk to life, property and the environment that may result from natural hazard events. The complete Risk Management process comprises three components:

- Risk analysis
- Risk evaluation, and
- Risk treatment

3.3.1 Risk Analysis

Risk analysis involves the use of available information to estimate the risk to individuals or populations, property or the environment from hazard. The effects of landslide may not be limited to property damage and injury/loss of life. Other consequences may include public outrage, political effects, and loss of business confidence, social upheaval and consequential costs, such as litigation. It is important to define the site, geographic limits that may be involved in the processes that affect the site, scope of analysis, the extent and nature of the investigations that will be carried out, types of analyses that will be conducted and basis for assessment of acceptable and tolerable risks. Subsequent to hazard identification, risk estimation must be carried out.

3.3.1.1 Risk Estimation

Risk estimation may be carried out quantitatively, semi quantitatively or qualitatively. Wherever possible, the Risk Estimate should be based on a quantitative analysis, even though the results may be summarized in a qualitative terminology.

Quantitative risk estimation involves integration of the frequency analysis and consequences.

The risk can be calculated as:

R = P H * PS: H * PT: S * V * E

Where

R = Risk (annual probability of loss property value/life).

PH = Annual probability of the landslide occurring.

PS: H = Spatial probability that the landslide will reach the property/individual, taking into account the travel distance and travel direction.

PT: S = Temporal spatial probability that the individual will be present when landslide occurs. For houses and other buildings P (T: S) = 1.0. For Vehicles and other moving elements at risk1.0< P (T: S) >0.

V = Vulnerability or probability of life loss/property value loss.

E = Element at risk (the value or net present value of the property and number of people at risk).

3.3.1.2 Element at Risk

The elements at risk are those which are exposed to different level of hazards. The elements at risk can be community, engineering structures and Infrastructures, economic activities, daily services utilities and ecosystem of the area which has potential for occurrence of landslide hazard. The elements that are exposed to threat of landslides need to be appraised for existing as well as further development activites.

3.3.1.3 Vulnerability

Vulnerability may be defined as the level of potential damage, or degree of loss of resources at risk, subject to landslide occurrence of a given intensity. Vulnerability assessment involves the understanding of the interaction between a given landslide and the affected resources. Generally, the vulnerability to a particular landslide depends on the volume and velocity of sliding, the distance of transported sliding material, the resources at risk, their nature and proximity to the landslide. The assessment of vulnerability is somewhat subjective and may largely be based on the historical data of the region. However, in case of a regional scale vulnerability assessment, the resources at risk and their nature and proximity to the landslide hazard zones may be considered. The appropriate vulnerability factor may be assessed systematically based on the opinions of experts and can be expressed at a scale of 0 to 1.

A complete risk analysis involves consideration of all landslide hazards for the site (e.g. large, deep seated landslides, small slides, boulder falls, debris flows etc.) and all the elements at risk. For computing total risk, risks for each element of the hazard are summed up. Most of the approaches applied for assessing Landslides Risk Analysis have inherent limitations but risk analysis has the benefit of encouraging a systematic approach to a problem and promoting a greater understanding of consequences. The risk analysis, assessment and evaluation can be done through detailed analysis employing multi disciplinary approach. In this effort the geological and geotechnical investigations play an important role.

Landslide Risk Analysis (LRA) can be made at different stages in the decision-making process, starting from developmental planning on a regional scale to a particular site evaluation at local scale. Landslide risk assessment on a

regional scale leads to demarcation of areas with different levels of threat to risk elements. This information can be used to establish landuse plans, developmental activities and patterns of building regulations. LRA on regional scale depends on two factors: (i) the spatial probability of landslide occurrences in a region and (ii) the vulnerability of resources at risk.

The spatial probability of landslide occurrences depends on the causative factors. Hence, the LHZ maps may be used to define the landslide potential in a region.

In the present context of regional risk analysis on regional/macro/meso/large scales, the LRA can be considered as a function of landslide potential (LP) and resource damage potential (RDP). The LP and RDP can be characterized by the LHZ map and the resource maps (landuse and landcover) of the area, respectively. The LRA map can be obtained by integrating landslide susceptibility and resource damage potential at spatial level. This map can be categorized into areas of different risk zones. Therefore, risk maps essentially include landslide hazard map and elements at risk map. Landslide hazard map is generated by the integration of thematic maps, landslide incidence maps and vulnerability maps.

For site specific LRA, run-out effect analysis due to specific landslides based on travel distance analysis method can be implemented.

In risk analysis the role of remote sensing is important as it provides the necessary inputs for identifying the element at risk. The large coverage of satellite data with its temporal capability is useful for mapping the landuse/ landcover, infrastructure, settlements which are vital input for landslide risk assessments.

3.3.2 Risk Evaluation

Risk Evaluation is the final step in Risk Assessment process. The main objective of risk evaluation is usually to decide whether to accept or treat the risks and identify priorities. Risk evaluation involves making judgments about the significance and acceptability of the estimated risk. Evaluation may involve comparison of the assessed risks with other risks or with risk acceptance criteria related to financial aspects, loss of life or other values. Risk evaluation may include consideration of issues such as environmental effects, public reaction, politics, business or public confidence. While evaluating risk, it is important to distinguish between acceptable risk which society is prepared to accept as such with no regard to its management and tolerable risk which they are willing to live within the confidence that it is being properly controlled and being monitored. This applies both to property and life.

3.4 Risk Assessment Framework

3.4.1 Sliding

What is the probability of sliding?

- Rain/snow/reservoir seepage induced
- Earthquake induced
- Earthquake induced liquefaction
- Reservoir drawdown induced
- Combination of the above

Risk assessment for sliding:

- If landslide occurs, how large will it be?
- What mechanism(s) induced sliding?
- How deep is the slide (i.e. surface of rupture)?
- How much along river?
- How much normal to river?
- How far will the displaced material move?
- What will be the reservoir level?
- How much of the slide displaced material will reach the reservoir and how quickly?
- What will be volume of water displaced? Will it cause formation of a wave(s)?
- What are the expected losses?
- Will these be acceptable?
- What is the probability of secondary movement/subsequent landslide?

3.4.2 Rock Fall

Rock fall poses several hazards to the communities:

- Moving highway traffic impacted by a rock fall
- Stationary vehicle impacted by a rock fall
- Moving vehicle hits by a fallen rock
- Rock fall could block traffic causing nasty delays and diversion of traffic
- Damage to highway itself
- Pedestrians, cyclists, highway maintenance workers impacted by a rock fall

Risk assessment of the rock fall:

- What is the probability of rock fall?
- How big will the rock fall be?
- Where will the rocks impact?
- What is the number and characteristics of vehicles using the highway? (Speed and length of vehicle etc.)
- What is the probability of a moving vehicle being hit by a falling rock?
- What is the probability of a stationary vehicle being hit by a falling rock?
- What is the probability of a moving vehicle hitting a fallen rock?
- In the event that a rock impacts a vehicle, what is the probability of a fatality?
- What are the acceptable risk criteria?

3.4.3 Debris Flows

Debris flows present a hazard to urban areas as below:

- Damage to houses in the debris flow path and deposition
- Damage to urban infrastructure, e.g. roads, power and telephone lines, and drainage
- Potential for fatalities and injuries to persons who live in the houses
- Potential for fatalities and injuries to persons on the roads.

Risk assessment of debris flow:

- What is the probability of a debris flow?
- How big will the debris slide be?
- How far will the debris slide flow and what will be its flow path?
- What is the probability of a structure or person being hit by a debris slide?
- What is the vulnerability of structure and persons?
- What are the risks to property and persons?
- What is the acceptable risk criteria?

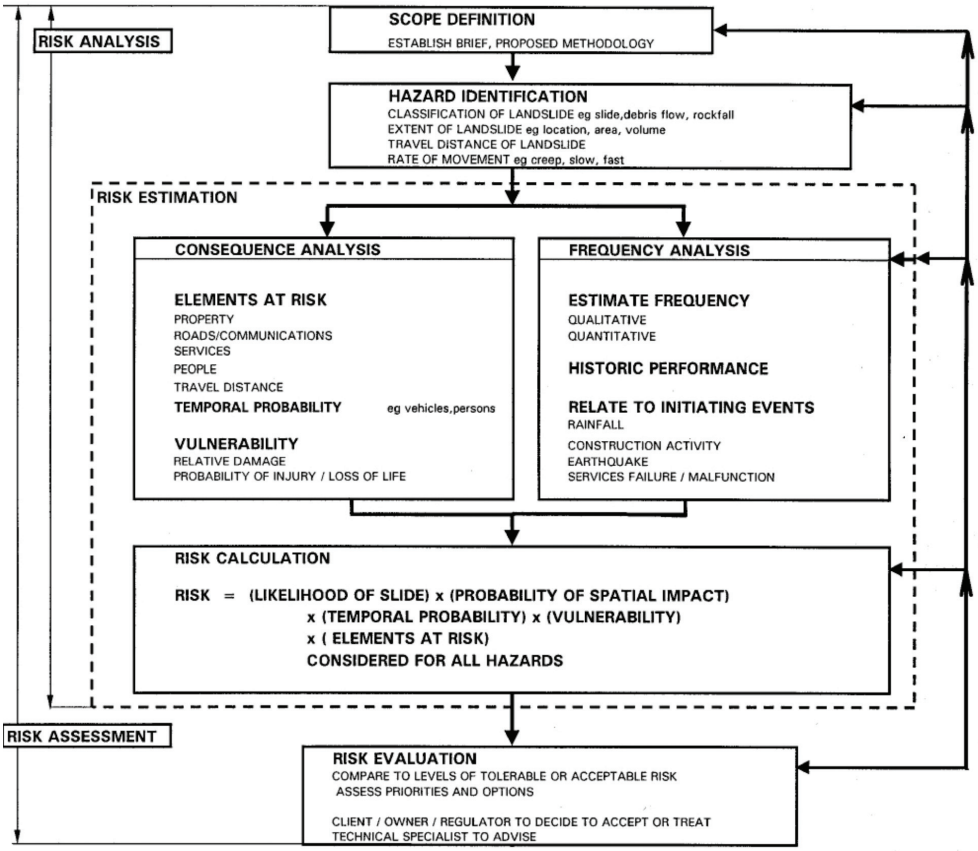


Fig. 3.1: A basic framework for landslide risk assessment
(Source: Australian Geomechanics, 2000)

LANDSLIDES RISK TREATMENT

4.1 Introduction

Risk Treatment is the ultimate aim of Risk Management and it provides the mechanism for mitigating the effect of natural hazard. Once the risk has been analysed, the strategy is to identify the options and methods for treating the risk. Some typical options would be to accept the risk, avoid the risk, reduce the likelihood, reduce the consequences, install monitoring and warning systems, transfer the risk, or, if there is sufficient uncertainty from the available data, postpone the decision. The relative costs and benefits of the options are required to be considered so that the most cost-effective solutions, consistent with the overall needs can be identified. Combination of options or alternatives may be appropriate, particularly where relatively large reduction in risk can be achieved at relatively small cost. A treatment plan for each option may be used to delineate how the option will be implemented. Each plan needs also to identify responsibilities for each stake holder during and after implementation, the extent of work required, cost estimates and programme, performance of measures and the expected outcome. Monitoring of the treatment plan and risks is needed to ensure that the plan is effective and changes in circumstances do not alter risks. It is essential to reconsider all stages of the analysis, assessment and prioritisation as the treatment plan evolves and is implemented. The results of monitoring may enable feedback for reassessment of the risks.

Landslide risk can be mitigated by five approaches used individually or in combination, to reduce or eliminate losses.

Restricting Development in Landslide-Prone Areas: Landuse planning is one of the most effective and economical ways to reduce landslide losses by avoiding the hazard and minimizing the risk. This is accomplished by removing or converting existing development or discouraging or regulating new development in unstable areas. However, in many States in our country, there are no widely accepted procedures or regulations for landslides

Codes for Excavation, Construction and Grading: Excavation, construction and grading codes have been developed in many countries for construction in landslide-prone areas. There is no nationwide uniform code to ensure standardization in India

Protecting Existing Developments: Control of surface water drainage and groundwater movement are the most widely used, and generally the most successful, slope-stabilization methods. Stability of a slope can be increased by

removing all or part of a landslide mass, or by adding earth buttresses placed at the toes of potential slope failures. Restraining walls, piles, caissons, or rock anchors, soil nailing are commonly used to prevent or control slope movement. In most cases, combinations of these measures are used.

Monitoring and Warning Systems: Monitoring and warning systems are utilized to protect lives and property, and these are not meant to prevent landslides. However, these systems often provide timely warning of slope movement to allow taking up of immediate or long-term measures that will reduce the hazard. Site-specific monitoring techniques include field observation and use of various ground motion measuring instruments, trip wires, radars, laser beams, and vibration meters. Data from these devices can be telemetered for real-time warning.

Landslide Insurance and Compensation for Losses: Landslide insurance would be a logical means to provide compensation and incentive to avoid or mitigate the hazard. Landslide insurance coverage could be made a requirement for mortgage loans. Controls on building, development, and property maintenance would need to accompany the mandatory insurance. Insurance and appropriate government intervention can work together, each complementing the other in reducing losses and compensating victims.

4.2 Mitigation Measures

Mitigation includes activities that prevent an emergency, reduce the chance of an emergency situation, or lessen the damaging effects of unavoidable emergencies. Investing in preventive mitigation steps now such as planting ground cover (low growing plants) on slopes, or installing flexible pipe fitting to avoid gas or water leaks, will help reduce the impact of landslides and mudflows in future.

4.2.1 Structural Measures

4.2.1.1 Drainage Corrections

The most important triggering mechanism for mass movements is the water infiltrating into the overburden during heavy rains and consequent increase in pore pressure within the overburden. Hence the natural way of preventing this situation is by reducing infiltration and allowing excess water to move down without hindrance. As such, the first and foremost mitigation measure is drainage correction. This involves maintenance of natural drainage channels both micro and macro in vulnerable slopes.

4.2.2 Non-Structural Measures

4.2.2.1 Proper Landuse Measures

Adopt effective landuse regulations and building codes based on scientific research through landuse planning. Also, discourage new construction or

development in identified hazard areas where appropriate remedial measures have not been implemented.

4.2.2.2 Structural Measures

Adopt remedial techniques (i.e., buttresses, shear keys, sub-drains, soil reinforcement, retaining walls, etc.) on existing landslides that are in close proximity to public structures (Rogers, 1992 for examples).

4.2.2.3 Afforestation

The afforestation programme should be properly planned so that in the process little slope modification is also done. Bounding of any sort using boulders etc. has to be avoided. The selection of suitable plant species should be such that these will with stand the existing stress conditions of the terrain.

4.2.2.4 Awareness Generation

Educate the public about signs that a landslide is imminent so that personal safety measures are taken.

Some of these signs include:

(i) Springs, seeps, or saturated ground in areas that have not typically been wet before.

(ii) New cracks or unusual bulges in the ground, street pavements or sidewalks.

(iii) Soil moving away from foundations, and ancillary structures such as decks and patios tilting and/or moving relative to the house.

(iv) Sticking doors and windows, and visible open spaces.

(v) Broken water lines and other underground utilities.

(vi) Leaning telephone poles, trees, retaining walls or fences.

(vii) Sunken or dropped-down road beds.

(viii) Rapid increase in a stream or creek water levels, possibly accompanied by increased turbidity (soil content).

(ix) Sudden decrease in creek water levels even though rain is still falling or just recently stopped.

4.3 Three Elements for Translating Technical Information to Users

i. Likelihood of the occurrence of an event of a size and location that would cause casualties, damage or disruption;

ii. Location and extent of the effects of the event on the ground, structures or socio-economic activity.

iii. Estimated severity of the effects on the ground, structures or socio-economic activity.

Translate hazard information so that nontechnical users are able to perceive likelihood, location and severity of the hazard.

4.4 Techniques for Reducing Landslide Hazards

Discouraging new developments in hazardous areas by:

- o Disclosing the hazard to real estate buyers
- o Posting warnings of potential hazards
- o Adopting utility and public facility service-area policies
- o Informing and educating the public
- o Making a public record of hazards

Removing or converting existing development through:

- o Acquiring or exchanging hazardous properties
- o Discouraging nonconforming uses
- o Reconstructing damaged areas after landslides
- o Removing unsafe structures
- o Clearing and redeveloping blighted areas before landslides

Providing financial incentives or disincentives

- o Conditioning financial assistance by the state or centre
- o Clarifying the legal liability of property owners
- o Adopting leading policies that reflect risk of loss
- o Requiring insurance related to the level of hazard

Relating to new developments in hazardous areas by:

- o Enacting grading ordinances
- o Adopting hillside development regulations
- o Amending landuse zoning districts and regulations
- o Enacting sanitary ordinances

Protecting existing developments by:

- o Controlling landslides and slumps
- o Controlling mudflows and debris flows
- o Controlling rockfalls
- o Operating monitoring, warning and evacuating systems
- o Emergency plans (life-saving, evacuation and facility specific)

LANDSLIDES INVESTIGATIONS

Investigation of Landslides

Investigation is utmost phase of landslide hazard mitigation and management. The investigation of landslides should be carried out in the following sequence.

5.1 Preliminary Investigations

5.1.1 Collection and Review of Existing Data

Landslides often occur at specific locations under certain topographic and geologic conditions. Therefore, in order to understand the topography, geology, and properties of similar landslides it is important to utilize existing data (history of the problem, records of restoration work, and data review). It is also important to understand their relationship with meteorological factors such as rainfall, period of activity, existence of any warning sign, groundwater conditions, chronology of topographic change or erosion by rivers, earthquakes, and other factors which may have a relationship with the slope deformation/ displacement surrounding the investigation site area prior to the detailed investigation.

5.1.2 Topographic Investigations

It is necessary to identify changes in the site topography. This can be accomplished by recognizing;

a) the overall topographic feature of the site;

b) understanding the topographic characteristics of the site slopes; and

c) estimating the regional geological structures of the site.

Such methods include comparing the aerial photographs of the site and vicinity taken prior to and after the sliding, and interpreting the topographic maps. These photographs can be used to understand the chronologic and topographic changes over any area. By utilizing aerial photographs, it is possible to interpret landslide phenomena and warning signs, geology and geologic structure, topography and distribution of vegetation type. For landslide investigations, it is useful to identify and interpret the distribution and continuity of knick points, gentle slopes, gullies and cracks seen in the photos to aid in preparing a photo interpretation map. The map can then be utilized in the field investigation.

Remote sensing using satellite imageries has been particularly useful for estimating the distribution of slide areas and groundwater, and vegetation at regional levels. Remote sensing can also be used for analysis of topographic characteristics in terrains susceptible to landslides

5.1.3 Field Investigations

With an assessment of the overall topographic feature and knowledge of the distinctions of movement and areal extent of the sliding blocks (viewed from the opposite hillside), a detailed field investigation plan can be developed to delineate the areal extent and a general direction of movement of the landslide zone, assess the lithologies and geologic structures, estimate the causes of the sliding, and predict future movement. The field investigation should not include just the actual landslide area, but also extend to slope limits or local drainage basin area. The field investigation should also include areas where aerial photographic interpretation is difficult or unclear, and in areas that could aid in the understanding of particular topographic features and characteristics.

5.2 Planning a Detailed Investigation Plan

A detailed investigation which will satisfy the following objectives should be planned.

- Areal extent of the slide, differentiation of moving blocks and identification of the type, direction and extent of movement; if possible, the time and duration of movement as well
- Location and shape of slide planes
- Nature of landslide blocks
- Possibility of further or future movement on slopes above the existing slide
- Possibility of further, future or accelerated sliding
- Distribution of groundwater and heterogeneity of slope mass

5.2.1 Survey Lines

The survey lines can be established on each moving block on the ground where the slide mass is expected to be thickest and where the stability analysis and plan for control works will be emphasized.

5.2.2 Exploratory Borings:

At least three borings should be done along the main survey line with one at least 5 to 10 m below the slide plane. During the early stage of the investigation, it is particularly important to have an accurate estimate of the configuration and location of the slide plane(s) for planning adequate drilling (Figs. 5.11 & 5.12).

5.2.3 Geophysical Survey

Seismic survey should be conducted along the main survey line as well as along the longitudinal survey lines, that cross the main survey line, and subsidiary survey lines. The interval of survey points for the seismic survey should be 5-10m and it should be 20-50m for the electric survey. Furthermore, to verify the results of the geophysical surveys, it is important to drill holes at the survey line intersections.

5.3 Geological Investigations

Landslide investigation and mitigation, requires mapping landslide hazards and creating a knowledge/database with the fullest appreciation of the scale and degree of reliability of the information gathered. For estimation of destructive potential of a landslide, one needs to know its expanse/spatial extent and also time span of landslide activity, its mechanism, run out distance, elements at risk and its recurrence history. For prediction of a landslide, one needs to find out where and when will it occur and how far and how fast will it move. For preparing design of control measures for managing landslides, one needs to know the type of landslide (as per classification), its possible modes of failure, the slide boundaries, the shear strength characteristics of boundary shears and how the pore pressures will vary on the slide boundaries with time. For measuring the efficacy of control measures, one would need to know the actual performance of the slope measured vis-a-vis the design performance. The plan of geotechnical investigation should clearly state its purpose.

The term geological investigation covers both surface and subsurface explorations to be carried out for determination of the extent of the landslide in all dimensions, nature and disposition of geological formations and structures in the area, physical and geotechnical characteristics of the material involved in the landslide process and factors responsible for activating the slide and severity of hazard.

5.3.1 Preliminary Stage Geological Investigations

The preliminary stage investigations involve collection of available information, desk studies as well as reconnoitory traverses in field to collect regional as well as local information and data. Extensive use of remote sensing products including high resolution CARTOSAT-1 & 2 should be done to demarcate the area likely to be affected by further sliding, understand the dynamic behaviour of slide, delineate modified slope conditions by preparing DEM etc.

Field Surveys and Investigations: The first task to be taken in the field after finishing the desk work is verifying and validating the data collected during desk studies and plan further course of work. The preliminary field surveys in the slide area should be carried out with a view to assess:

i) The dimensions, geometry and nature of the landslide and status of sliding activity

ii) The condition of the ground beyond the boundaries of the landslide

iii) Orientation, spacing and openings of all the cracks

iv) Disposition of zones of accumulation, depletion and scarp faces and distribution pattern of different size fractions in debris

v) Disposition, attitude of bedding, foliation and all other planar structures, lithological variation of rocks, state of weathering, joint/fracture spacing, openness, roughness, continuity, joints/fractures, wall alteration etc.

vi) Locations of seepages, springs, natural drainage courses and slushy ground

vii) Movement of different parts of slide during period of investigation

viii) Location of human habitations, communication corridors and other civil engineering structures

ix) Weathering profile, nature of slope forming material and of overburden, rock contact, nature of drainage, springs, scarps etc. and

x) Demarcation of Buffer zone based on the trajectory of the falling rock blocks, between the toe of the hill and the human settlements or other structures to avoid any risk during treatment of the slide.

5.3.2 Detailed Geological Investigations

The detailed geological investigations, both surface and subsurface, are required to be carried out at this stage. The extent of area to be covered by geological mapping and subsurface geological investigations are guided by the geological complexity of site. The detailed investigations at this stage should be planned and executed in close interaction between engineering geologists and geotechnical experts.

After completion of surface geological mapping, the behaviour of surface material and other features at depth are required to be explored. The subsurface explorations should aim to establish:

- Depth to bedrock or thickness of overburden and weathering limit, lithological characters of various rock units and their significance, limit of slump joints and glide cracks, if any
- Nature, condition, openings, spacings and continuity of prominent joints, slip surfaces, minor and major shear zones. etc.

- Depth to groundwater level
- Permeabilities of strata, and
- If possible, the depth and disposition of plane along which failure has taken place.

The above parameters can be determined by employing non-destructive geophysical techniques that are easily available. The geophysical exploration should be done especially in the areas covered by debris or river-borne material/ terrace deposits. Geophysical investigations including, resistivity surveys, seismic refraction surveys are helpful in determination of above parameters. With developments in electronic and software technologies, the results are becoming more and more accurate and dependable.

Ground Penetrating Radar (GPR) can be initially employed in such surveys for evaluating depth and nature of bedrock and also groundwater conditions. GPR surveys are very quick and provide results quickly. Other geophysical surveys like seismic (reflection) and resistivity surveys can follow the initial GPR Surveys.

The preliminary and detailed geological investigations of landslides constitute the bedrock on which sound geotechnical investigations must be undertaken. Detailed guidelines will be developed on diverse aspects of slope engineering for ensuring systematic geological investigations and mapping.

5.4 Geotechnical Investigations

These include mapping of problematic slopes on an appropriate scale, scientific understanding of its kinetics, elucidation of landslide boundaries, determination of representative shear strength parameters, pore pressure variations on the slide boundaries and finally evaluation of factor of safety. It is important to understand the distinction between the first time and the reactivated slides. The boundaries of the former are not known in advance and hence the investigations and mitigation measures may be different.

Geotechnical Investigation for mass movements like rapid motion landslides, multi-tier landslides, rock falls, debris flows and avalanches may throw up many other investigational requirements. There are instances of landslides changing their character. For instance, in its wetter manifestation, a landslide may partake the character of a flow and acquire rapid motion. In such cases, laws of fluid dynamics may take over from the laws of classical soil mechanics.

A good geotechnical investigation is usually driven by the leads thrown up by the large scale geomorphological map of the area. It should always begin with careful study of field evidences that can be closely observed by a trained landslide investigator. For instance, study of the slide boundaries, exposed geology, discontinuities, shear zones; water springs, aquifers, slope subsidence,

heave, cracks and behaviour of buildings/walls/floors etc., provide a sense of direction to the nature and quantum of ensuing detailed sub slope geotechnical investigations. A vigilant eye can gather much more from an exposed roadside cutting than the whole gamut of geotechnical investigation done at the expense of time and money. No amount of drilling, can replace the practice of observation and careful characterisation of fissures, slip surfaces and shear zones, joint fillings, the erratic nature of soil profiles, the sand and silt lenses, the solution cavities, the evidences of underground erosion and more, as seen in the open exposures and cuttings.

No matter how thorough is the geotechnical investigation, uncertainties would time to time call for making modifications in the design based on engineering judgment. Every geotechnical report must clearly state the assumptions made and the basis there of. It would, therefore, be a big mistake to prescribe a rigid programme of soil investigation at the outset. The best soil investigation programmes are those which advance and get modulated with every new shred of investigational information.

A geotechnical investigation often tends to get expensive and even wasteful if it does not relate closely to the slope information to be gathered and answer the specific. For instance, it has become a common practice to prescribe an extensive programme of drilling to locate basal boundary shear of a landslide even without a site visit. One must remember that even with extensive drilling, the basal boundary of a landslide may defy attention in the core logs. Imagine the savings and time effectiveness in investigation that will accrue if one were to succeed in locating traces of basal boundary shears, for example, in a road cutting.

Selection of equipment for slope investigation, drilling and in-situ testing and decision on scale, scope and type of undisturbed sampling and laboratory testing are highly specialized matters. The present tendency of making divergent un-informed choices without adequate scientific reasoning must end. There is a need to develop guidelines on this, especially for the training of geotechnical engineers engaged on landslide projects as also for the benefit of those responsible for building institutional capacities.

Deterministic analyses of slopes are two/three dimensional. The two dimensional analyses under-estimate the factor of safety and are, therefore, done where either side resistance to landslide is negligible or uncertainties are large and quick conservative designs are required for further planning. For important projects where high quality investigation is mandatory, a three dimensional analyses should be done for ensuring economy in design. Since there are uncertainties involved at various steps of investigation and design, and it is not always possible to justify single value inputs, the need and merit of probabilistic analyses of slope must also be considered.

Deterministic analyses could either be in terms of effective stress or in terms of total stress. The unhealthy practice of ignoring this essential requirement must stop. There is a need to develop guidelines for scientific analyses of slopes and landslides in terms of total and effective stresses as the demand of ground situation. Every report will specifically point out assumptions made and limitation of the data for slope analyses and design. The efforts must clearly focus on neglected but vital aspects such as techniques of undisturbed sampling of shear zones and boundary shears and evaluation of shear strength parameters using appropriate stress path. It is often meaningless to spend money on tests such as Standard Penetration Test (SPT) and Dynamic Core Penetration Test (DCPT) in drill holes or unconfined compression tests in a laboratory. Since shear strength is not a unique property of a soil sample, laboratory tests without obtaining representative high quality undisturbed samples and without right selection of test could also be misleading. Besides, one must remember that soils are normally non-homogeneous and anisotropic and their non-linear behaviour is greatly influenced by their stress-strain history and structure.

Most landslides being the result of poor slope and sub-slope drainage, detailed hydrological studies of the catchments associated with landslides are essential. In the areas of complex landforms with water streams, springs and ill defined overland flow; radioisotope studies are often useful to map subterranean water flow while investigating the causative factors of a landslide.

For achieving the objectives of an investigation, the coupling between study of landslides through remote sensing and ground surveys should be logical and strong. Landslide investigation without remote sensing is often blind. By the same logic, landslide investigation without ground studies and validation is lame.

Landslides in meta-stable deposits of granular (sandy) nature, especially in the high rainfall areas, tend to liquefy due to an earthquake shock or external vibration. Similarly earthquake-induced landslides could be co-seismic or post-seismic.

Reference to geotechnical reports prepared for different civil and infrastructure development projects at or close to the location of a landslide will serve the triple purpose of consolidating the available body of geotechnical information, pinpointing the inconsistencies, inadequacies and gap areas and provide a cost-effective and sound basis for deciding the geotechnical scope of a landslide investigation.

5.6 Softwares for Landslide Study

A wide range of softwares are available for the evaluation and assessment of different parameters of the landslide hazards. Some of the softwares are mentioned below:

Software	Purposes
ArcGIS	Geospatial data management, processing and analysis of data, generation of different thematic layers/maps and their analysis, spatial and temporal modeling, sharing of the outcomes
ArcView	
ERDAS IMAGINE	
ILWIS	
OpenJUMP (open source)	
QGIS (open source)	
GRASS GIS (open source)	
SAGA GIS (open source)	
TRIGRS	
Global Mapper	
AutoCAD	
Flow – r	Susceptible mapping of debris flow
Titan 2D	Mass flows such as debris avalanches and landslides
Rockyfor3d	Windows application that explicitly and realistically integrates the barrier effect of trees on falling rocks.
SHALSTAB	Digital terrain model for mapping shallow landslide potential
GeoStudio	Modeling slope stability, ground deformation, and heat and mass transfers in soil and rock
GEO5	Geotechnical analysis
FLAC 2D	
PLAXIS3D	
Midas GTS NX 3D	
LAND-SE	Landslide susceptible evaluation



Fig. 5.1: Triaxial Test apparatus for evaluating strength parameters



Fig. 5.2: Stress Path Triaxial Test System



Fig. 5.3: Computer Controlled Consolidometer



Fig. 5.4: Laser Particle Size Analyser



Fig. 5.5: Computer Controlled Triaxial Test Equipment

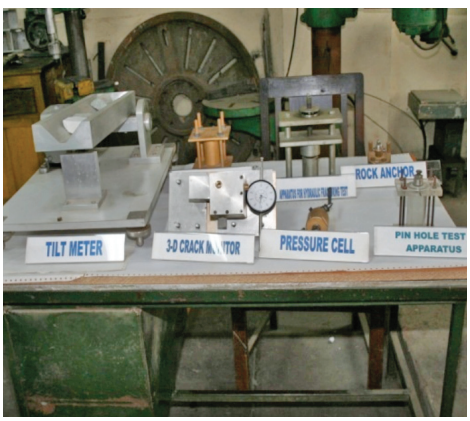


Fig. 5.6: Indigenous instruments (Tiltmeter, Crackmeter, Pressure Cells) for slope monitoring



Fig. 5.7: Triaxial Testing equipment for strength parameters of rocks



Fig. 5.8: Compressive strength test equipment for rocks



Fig. 5.9: Indigenous Open stand-pipe type piezometer



Fig. 5.10: Electrical Strain Gauge Equipment



Fig. 5.11: Use of bore hole camera to study bore wall



Fig. 5.12: Core logs to study lithology/ rockmass

LANDSLIDES INSTRUMENTATION, MONITORING AND EARLY WARNING

6.1 Slope Instrumentation, Monitoring and Landslide Prediction

Slope instrumentation for monitoring and prediction of landslide has so far not been a general practice in India. A few attempts have been made by some institutions but the methodology and techniques as well as the results are not uniform. Thus, the efficacy of slope monitoring through instrumentation has remained a non starter. The detailed slope stability analysis and modeling of a landslide are almost impossible without instrument generated data. Monitoring indicates acceleration of movement and development of pore pressures at different locations within the slide mass. Interpretation of data is difficult as critical values are unknown unless there is documented history of previous events. It is not practicable to monitor all the landslides by the installation of instruments. The monitoring system of landslide can also be used for alerting the people about impending disaster.

6.2 Early Warning Against Landslides

The Early Warning Systems elsewhere in the world have been developed by Real Time Automated Monitoring of landslides. These include monitoring the movements, development of stresses, development of pore pressures or hydrostatic pressures continuously and transmission of instrument generated data through telemetric system at regular time intervals. At the initiation of an event, the radio signals are transmitted through public media for affected masses and stakeholders and alarm signs are sent to the relevant authority on probable time of occurrence and impending dangers of the landslide. Generating awareness and involvement of local communities is a vital component of an early warning system and to be successful it is necessary that local communities are associated with it. In certain cases the local communities, if properly trained and adequately motivated can observe the movement indicators on the hill slopes and issue necessary warnings.

The Real Time Automated Monitoring for the development of an Early Warning System may be undertaken for a few devastating, large dimension and recurring types of slides or rock falls which are very difficult to stabilize and pose high risk. Since the ultimate goal is to find out a permanent solution to stabilize the slide, the development of Early Warning System is not the ultimate answer to this natural hazard, but it is a part of the effort to mitigate its impact.

Considering the probable danger of losing costly instruments due to recurrent nature of some conspicuous landslides an effort may be made to develop the early warning system that would serve the twin purpose of deriving detailed slope stability analysis for suggesting remedial measures of devastating landslides and development of an early warning system by real time monitoring of landslides. The experience from such an exercise will immensely help in the study of other landslides.

6.2.1 Monitoring of Landslides

Monitoring of landslides consists of:

- Selection of specific location depending upon the type of movement, location and hazard and risk factor of slope failure.
- Selection of monitoring methods and frequency of data collection.
- Data processing and methods of presentation/communication of results.

Methods generally used for monitoring landslide can be divided into surface and subsurface measurements of the landslide activity and total regime measurements.

6.2.1.1 Surface Measurements of Landslide Activity

Simple method of monitoring is installation of a few survey pillars within the landslide zone and on its periphery and linked with a few reference pillars installed on undisturbed and stable ground. Periodic observations of the relative position and top level of survey pillars particularly in pre-monsoon, during high rainfall and post-monsoon periods give a fairly good idea about the extent and rate of surface movement of the slide, amount of subsidence and also surface stress variations. The rainfall data, particularly the intensity of rainfall should be collected from the nearby rain gauge station and an effort may be made to correlate the intensity of rainfall data with the time of initiation of the mobilization event. Measurement of cracks on surface of the slope and their development provides very useful input in slope stability analyses.

6.2.1.2 Subsurface Measurements of Landslide Activity

Subsurface measurements of landslide activity are carried by installing different types of instruments in boreholes drilled at various identified locations. The shallow subsurface movements including creep are measured by installing flexible casings in boreholes and observing their behaviour; SGI rod Inclinometers; Kirby's T-pegs and Strain Probes. The movements at deeper depths are monitored through Chain Deflect meters, Single or Multi Drill hole Extensometers; Single and Multi Point Wire Extensometers; Pipe Strain Meters and Insert Type Pipe Strain Meters. However, Slope Indicators and Inclinometers are most extensively used instruments used for monitoring the subsurface movements in landslides. Geophysical method of measuring pulse

electromagnetic emissions identifies the zones of high stress concentration in the body of the slide. The measurements can be taken in the inclinometer boreholes.

6.2.1.3 Total Regime Measurements

The total regime measurements include recording groundwater fluctuations, the principal cause of sliding, yield of water and consequent development of pore pressure in the slide material. The behaviour of groundwater in the slide area can be measured and monitored by installing piezometers at different depths in the boreholes. Of the various types of piezometers, the most commonly used are Hydraulic, Pneumatic and Electrical Piezometers. Of late, Tensiometers are in use for measuring pore water pressures.

Recording of rainfall is required to develop correlation between rainfall, slope movements and pore pressures in the slide mass and also impact of these on initiation of slide activity. The rainfall should be measured by installing automatic rain gauges at the slide location.

6.2.2 Real Time Automated Monitoring of Landslide

Simple monitoring of landslides, with or without instrumentation, cannot detect changes during initiation of the mobilization event while the real time automated monitoring of landslides can continuously pick up even minor changes enabling transmission of warning signal just at the time of initiation of slide movement. The continuous data provided by real time automated monitoring through a remote station permits better understanding of dynamic behaviour of a landslide. With the rapid advances made in electronics and communication technology, it has become possible to monitor the behaviour of a landslide continuously and transmit data to processing locations on real time basis. All the instruments are connected to data loggers located in the vicinity of the site or sites being monitored. The data loggers are connected to data processing stations through telemetry systems that can transmit data to processing stations in real-time. The data thus obtained can be processed automatically and immediately with the help of computers installed with necessary softwares. The results thus obtained can be utilised in issuing warnings as well for updation of records.

Recently, the remote sensing application tools, including High Resolution Satellite Imagery, Light Detection and Ranging (LIDAR), Synthetic Aperture Radar (SAR), Persistent Scatterer (PS), Synthetic Aperture Radar, Differential Interferometery techniques for correlations between landslide morphology, motion and topographic analysis are used in some countries for landslide monitoring. It has facilitated predictive modeling and risk analysis of landslides.

These and related studies demonstrate the rich potential of new technologies in landslide studies. Clearly, the advances during the past two decades in the fields

of remote sensing, digital image processing, GPS, and GIS has revolutionized the study of landslides and improved the knowledge and capabilities of geoscientists and civil engineers in monitoring and management of landslides. Use of GPS, in particular, can play an important role in monitoring landslide-prone areas for signs of current movement, and provide near real-time warning of motion on slides that can endanger lives and property. With the advent of multi-antenna GPS instruments, the cost of monitoring using GPS has reduced substantially. High resolution imagery and topographic mapping can lead to improved understanding of landslide mechanism and hazard prediction. Continued research into methods of data collection, processing, and synthesis is needed to realize the full potential of these technologies for worldwide use in coming decades.

Real time landslide monitoring is a costly procedure involving high amount of risk of losing the expensive instruments due to active nature of the slide, landslides having the potential to collapse catastrophically and threatening lives and property, should be identified and monitored on real-time basis.

6.2.3 Landslide Early Warning in India

The first Wireless Sensor Network (WSN) based real-time Landslide Warning System in the country was established in 2009 at Amrita Vishwa Vidyapeetham in district Munnar,Kerala. The unique attributes of the WSN system established were:

- The ability to mimic biological systems where the high accuracy and reliability of the whole sensor network is achieved through proper interaction among low-cost sensors placed close to each other.
- The sensor network can dynamically configure itself in the event of any nodal failure, thereby forming a self-healing and self-organizing network.
- The landslide detection system's signals are available online, enabling researchers to study the signal variations and patterns on a real-time basis.
- The system is capable of achieving globally optimal decisions without the need to send all the collected data to a fusion center.

After the successful execution of the WSN system in Kerala, the Amrita University at the instance of Government of India and in collaboration with Sikkim State Disaster Management Authority, established new IoT (Internet of Things) system for landslides around Chandmari Village, East Sikkim. Co-funded by the Ministry of Earth Science (MoES), the monitoring system consists of network of 200 sensors in 150 acres of area that can measure geophysical and hydrological parameters like seismic activity, rainfall and pore pressure.

Indian Institute of Technology, Mandi (Himachal Pradesh), successfully developed an indigenously built low-cost landslide monitoring and warning

system. A total of 10 such systems have been deployed along Mandi-Joginder Nagar and Mandi-Kullu highways. The system costs around INR 20,000, and can record weather parameters and soil properties that can be scrutinized online on a website in both tabular and graphical formats. On detection of any significant soil movement the system is capable of altering the vehicular road traffic through blinkers,installed along the road. The blinkers appear/come online for 10-15 seconds with audiovisual signals each time soil movement is observed and recorded at the deployment site.

CSIR-Central Scientific Instruments Organisation (CSIR-CSIO) and Defence Terrain Research Laboratory (DTRL), DRDO have also contributed in the field of landslide early warning in India. CSIR-CSIO installed instrumentation network of five sensors (Rain Guage, Inclinometer, Tiltmeter, Crack meter and Earth pressure cell) to monitor the landslide site at Mansa Devi (Haridwar, Uttarakhand) and to predict the probability of slope failure. DTRL, under DRDO has developed landslide early warning system using statistical analysis of sensor's (in-place inclinometers, vibrating wire piezometers, tipping bucket rain gauge and extensometers) data at Tangni landslide in Uttarakhand.

6.3 Investigation of Surface Deformation

The investigation of surface deformation is conducted to define the boundaries of the landslide, its size, level of activity and directions of the movement, and to determine individual moving blocks of the main slide. The presence of scarps and transverse cracks are useful for determining whether the landslide is a potential threat.

Instrumentation for surface deformation includes extensometers and ground tiltmeters, whereas movement determination is achieved by transverse survey, grid survey and laser survey from the opposite bank and movement determination can be accomplished with the help of aerial photographs and GPS.

a) Extensometer

The extensometer (Fig.6.4) is used to measure relative movement from two points. The extensometers are generally installed across the main scarp, at transverse crack and transverse ridges near the toe or front portion of the slide and parallel to the suspected slide movement. By arranging a series of interconnecting extensometers from the main scarp to the toe of a complex landslide that has many moving slide blocks, the resulting data could aid in clearly delineating the individual slide blocks. Measurements has to be accurate to within 0.2 mm and the magnitude of the movement and daily rainfall data should be included to establish the relationship between the measurable movement and the precipitation/infiltration.

b) Tiltmeter

The ground tiltmeter (Fig. 5.6) is useful for determining the deformation at the head and toe portions and sometimes along the flanks of the landslide, or to assess the possibility of future deformation. Commonly, a level type tiltmeter is used. The tiltmeter is capable of measuring the N-S and E-W components. The magnitude of tilting and tilt directions can be read directly from the instrument panel. Furthermore, in order to determine the characteristics of the deformation, the results are shown chronologically along with the daily rainfall totals. The relationship between the magnitude of tilting and the cumulative effect of tilting, rainfall totals and groundwater levels should be depicted as plots.

c) Differential Settlement Gauge (Fig.6.3)

Settlement monitoring is essential to evaluate the possible problems and for risk management related to ground displacement on surface or underground constructions. Differential settlement gauge is a hydraulic system that can be used to monitor vertical displacement.

d) Crackmeter

Crackmeter are used to monitor the displacement across surface cracks and joints (Fig. 6.6). These are simple and low-cost devices, installed by grouting, bolting, or bonding two threaded anchors (with ball joints) on opposite sides of the cracks or joints and then attaching the ends of the gauge with the anchors.

Simple Method to Measure Movements

One of the simplest methods to determine landslide movement is to drive wooden stakes across a tension crack along the direction of slide movement. Thereafter, using saw, horizontal boards are attached to the stakes. After a lapse of time increase in space between the sawed portions of the boards is the measure of movement across the tension crack.

Determination of Movement by Surveying (Transverse Survey, Grid Survey, Laser Survey from the opposite bank, Movement Determination by Aerial Photographs, and GPS).

Transverse Survey:

This survey method involves laying of transverse survey lines across the landslide block and along these survey lines close-spaced survey stakes are put. The survey stations are to be established both within the slide and outside; the latter should be on a stable ground.

Grid Survey:

This survey method involves constructing grid lines across the entire landslide as well as over the stable ground outside the landslide. The survey stakes are driven at the intersection of grid lines.

Laser Survey from the Opposite Bank:

A control point (Fig. 6.14) is established at a suitable location on the opposite bank on stable ground, and survey stakes are positioned within the slide (Figs. 6.8, 6.9, 6.10 & 6.13). It is most effective where the movement is large.

Movement determination by Aerial Photographs:

For landslides with a large component of movement, study of aerial photographs is very useful, and if the aerial photographs are taken at an interval of a year or two, an accurate assessment of movement can be made.

GPS:

Global Positioning System is the state of the art technology that uses signals from satellites to mark the position of a point in the field. By taking multiple locations from GPS a three-dimensional figure of the slide can be deciphered. Use of GPS has been of immense help in some recent landslide investigations (Figs. 6.5, 6.11 & 6.12).

Automating Survey System

Not very long ago, measurements of slope deformation were performed manually. But, recently, automatic survey systems using data loggers and computers is largely been adopted (Figs. 6.15 to 6.18). The typical instrument set-up has been designed for easy installation in the field; it is weatherproof, durable, maintenance-friendly and economical. Besides, through remote controled study in real time and rapid geographical data processing, it is possible to use long term data of multiple attributes for quick and effective early warning of slide activity, thereby reducing landslide hazard.

Further, by deploying advanced technologies in information based constructions systems and adopting real time safety control measures at the construction site facilitates planning through construction stage.

There are three main advantages in using the automated survey system.

i. Surveillance of conditions of landslide failure: Issuance and cancellation of landslide watching and warning announcements based on the velocity of movement, piezometric pressure and variation in the rainfall amounts and prediction and forecasting of the landslide failure.

ii. Understanding of conditions of the landslide deformation: Chronological measurements of movement velocity; determination of the slide plane depth; and determination of the relationship between the slope deformation and factors of slide occurrence (pore water pressure against the slide plane, critical pore water pressure related to the time of sliding, rainfall and snowmelt).

iii. Effectiveness in determining landslide control works: Measurement of the amount of earth movement and pore water pressure; measurement of the earth pressure affected by piles and collection wells; and assessment of effectiveness of construction.

6.4 Investigation of Geologic Structure

Generally, this is accomplished by exploratory borings; however in cases where the bedrock distribution is ambiguous or a better understanding of the regional geologic structure is needed, geophysical exploration (seismic and electrical surveys) is added to the boring data.

A) Borings

In most cases the drilling is done using NX (76 mm) size bits. The cores obtained from the borings are stored in specially designed core boxes and are logged. It is suggested that the core logs contain photographs of cores and include details on geology and soil, e.g., color; hardness; lithology; degree of weathering; alterations and fractures; attitudes (strikes and dips) of bedding and joints; boring conditions; and percentage of core recovery; along with initial and stabilized groundwater levels.

Geologic assessment based on the boring data should include a discussion on the differentiation of moving earth blocks, semi-moving earth, and stable ground. Clays within the slide plane generally have high moisture content, are highly sticky and plastic and are often associated with abrasion scars and slickensides. During drilling, squeezed earth could occur near slide plane. Slopes where advanced relaxation of the bedrock formation has occurred will often exhibit gentler slopes than those of the unaffected bedrock zone. Formations can bend or form a kink near the lower limit of that zone, and could develop into a slide plane. In translational dip slope slides, the slide plane in many instances will develop along a thin, weak bed of mudstone, tuff bed or coal seam sandwiched between hard and competent beds. Borings can sometimes easily miss these thin beds. Therefore, the possible existences of slide planes along these weak beds typically consist of about 10cm, and must be considered even though the boring may not indicate their presence.

Furthermore, using the data from the borings, the following information must be assessed or determined:

- Evaluation of slide plane
- Groundwater level measurements
- Groundwater logging
- Groundwater tracer tests

- Standard penetration tests, Horizontal loading tests, in-situ tests such as in-situ permeability tests
- Sampling for soil tests
- Geophysical logging

B) Geophysical Surveys

Geophysical surveys (seismic and electric surveys) aid in visualizing the subsurface conditions like dimension and nature of slide material, lithology, structure and other geological characteristics of the enclosing rocks and the presence and extent of water bodies. In the seismic method, P-wave refraction technique is more commonly used than S-wave and P-wave shallow refraction techniques. Generally, the Electric surveys employ specific resistance method and are applied to determine the distribution of aquifers and to understand the geologic structures. These surveys include the geotomography method. In some countries, a natural radioactivity survey is used to determine the locations of small scale fracture zones and cracks.

6.5 Evaluation of Slide Plane/Monitoring of Sub-surface Movements

Determination of the slide plane for actively moving landslides utilizes the fact that the rates of movement differ significantly along the slide plane. Depending on the need for surveying accuracy and magnitude of movement, the appropriate instrumentation is selected from the following representative instruments:

a) Pipe strain gauge

b) Inclinometer

c) Multi-layer movement meter

d) Other Methods

a) Pipe Strain Gauge

PVC pipes with strain gauges are inserted into the pre drilled boreholes, the movement causes the pipes to bend and their shift is estimated by the change in the strain. The accuracy of the strain gauge can be increased by reducing the intervals of the gauge. However, it is acceptable to widen the space upto 1m for investigations involving very thick slide materials and where it is difficult to handle the survey extension wires. The two lowest strain gauges must be anchored into the bedrock below the slide plane so that data of the stable formation is also obtained. Furthermore, annular space between the borehole and the pipe must be filled with concrete during the gauge installation. It should be seen that the instruments last for at least one to two years.

b) Inclinometer (Figs. 6.1 & 6.2)

A grooved casing is inserted into the borehole extending into the bedrock formation, and an adequate quality of grout put into the borehole to ensure that the casing has a positive contact with the borehole. By lowering a probe equipped with a tilt sensor, deformation in the casing can be detected and movement of a landslide can be determined. An accurate measurement is possible where the deformation of a landslide is relatively small. As the landslide movement increases, the borehole and casing will bend making insertion of the probe difficult or will exceed the tilt detection limit of the instrument.

c) Multi-Layer Movement Meter

A set of wires are inserted and anchored at different depths in a borehole. Using a simple ruler, the magnitude of displacement of each wire segment can be measured directly. It is possible to install 20 to 30 wires per borehole. This method is not suitable for landslides with small displacement and is most effective where the slide movement is so large that other instruments do not work. Applying the same principle, a vertical extensometer can be formulated by fixing a wire on the bedrock at the bottom of the borehole.

d) Other Methods

Other methods to evaluate the slide plane include: slide plane detection probe; creep wells; and sounding penetration tests.

6.6 Groundwater Investigation

Investigation of groundwater, which is a driving force of sliding, includes determining ground water level, pore water pressure, groundwater logging, groundwater tracing test, pumping test, water quality analysis, electrical survey, geothermal survey, and geophysical logging (electric logging and radioactive logging). Based on the results of the above measurements and tests, groundwater control works can be planned, designed and deployed.

a) Groundwater Level Observation

As a general rule, groundwater levels should be measured in all the boreholes. In some of the more important boreholes, continuous rainfall data should be obtained by installing automatic recorders to determine the correlation between the slide movement and rainfall and groundwater level, and also collect data on the groundwater distribution and its movement regime.

b) Pore Water Pressure

Groundwater levels in boreholes will often reflect seepage from highly fractured formations or indicate the water level of a predominant aquifer. Therefore, for stability analysis, it is best to measure pore water pressure

along the slide plane. Sometimes it is difficult to accurately estimate the depth of the slide plane. In such cases it is desirable to install piezometers (Fig. 5.9) in the beds with low seepage or low shear strength. The standard piezometers forlandslide investigations must be open piezometer water level type and should be durable..

c) Groundwater Logging

Flow of groundwater and flow directions can be determined by computing the increase in specific resistance of groundwater in flow over a period of time. The measurements should be continued afterlowering specific resistance of groundwater by injecting a salt solution into the borehole. There should be at least two borings for groundwater logging at the head portion of the landslide where abundant groundwater is expected. The measurement results should be recorded in the borehole core logs, and the relationship between the location of groundwater flow and bed, and magnitude and variation of specific resistance of groundwater should be discussed. Furthermore, the results of the analysis should be recorded along with the cross sections in order to understand the overall groundwater flow.

d) Groundwater Tracer Tests

Tracers such as a soluble dye or inorganic chemicals (NaCl) are injected into a borehole. Water samples are then collected chronologically from springs, other boreholes, wells and ponds within or outside the landslide, and are analyzed for the tracer to estimate the groundwater flow direction(s) and permeability. This data is used for basic information for developing the design of dewatering works.

e) Drawdown Test

In order to estimate the yield and to calculate the coefficient of permeability, water within a borehole is pumped to certain levels after raising the boring casing every 2 to 3 m. A time-recovery curve can then be plotted using Jacob's and other formulae, and thus the coefficient of permeability is determined.

f) Water Quality Tests

Water quality testing is an effective method to examine the distribution of the groundwater regime and flow directions where landslides are very large and the groundwater system is expected to be complicated. Specific tests include determination of water temperature, Cl-, SO42-, HCO3-, Na+, K+, Ca2+, and Mg2+ content, pH, alkalinity, electrical conductivity, SiO2 etc. The test results are classified according to the chemical composition.

g) Geothermal Investigation

Considering the fact that geothermal investigations are influenced by prevailing local air temperatures and depending on the location of the site, there might be distinct variations in summer and winter temperatures. In such locations good results could be obtained for shallow groundwater regimes. The procedure involves conducting geothermal investigations separately during two extreme periods both near groundwater veins and in non-groundwater areas.

6.7 Geotechnical Investigations (Soil and Rock Mechanic Tests)

In order to conduct slope stability analyses and to design appropriate control measures for landslides, physical properties such as strength, location and depth of slide plane and stable ground areas must be determined. Generally, the following tests are performed: physical tests, Standard Penetration Tests, soil and rock mechanic tests (unconfined compression, tri-axial compression, box shear, ring shear, and in-situ shear (along the slide plane)). In order to obtain the earth reaction coefficient for the design of the restraint works, there is currently a tendency to conduct more horizontal loading tests and plate loading tests to determine the modules of deformation. Furthermore, the intensity and degree of alteration of the slide plane clays are evaluated by X-ray diffraction methods. The results could also been applied to analyze the origin of the slide plane.

6.8 Early Warning Systems for Landslides

In a holistic sense, the term early warning includes the whole range of actions and operations right from stages of planning and instrumentation of problematic slopes and landslides to their monitoring, analyses, fixing of early warning alert thresholds, decision making, dissemination of early warning alerts and constant improvements in early warning practices through sustained location-specific feedback and new researches. The impact of these landslides can be mitigated or minimized, if the communities threatened by them, are forewarned about impending disaster and are prepared to face them.

There is no standard ready-made package or system for early warnings but all instrumentations, tools, equipments, and observations and data processing systems are available in multiple choices. These are necessarily to be fashioned to suit a particular slope or a landslide according to its type, magnitude, hazard potential and the purpose of early warning alert. Usually, the hazard detection and early warning systems for different types of landslides are different. For example, planning for instrumentation and early warning for a pre-existing (repetitive) landslide will be very different from the scheme for early warning against an anticipated first time landslide. Likewise early warning scheme for mass movements such as a debris flow or a rock fall will be very different from a block slide or a classical landslide with discrete boundary shears. The task of

evolving early warning system in a given situation will necessarily have to be assigned to experts.

An early warning is a process involving following components:

i. **Scientific & Technical Communities:** These are responsible for studying and monitoring natural events to provide models, which can be used to forecast events in terms of intensity, time, and geographical span.

ii. **Government Authorities and Civil Agencies:** These are responsible for establishing operations, frameworks related to preparedness and response in case of events.

iii. **Local Communities:** The local communities must understand the nature of the hazards, their possible intensities and ranges, and react according to existing guidelines provided by the institutions identified by the authorities.

People- centered early warning systems empower the communities to prepare for and confront the fury of natural hazards. These bring safety, security and peace of mind to people. The effective early warning systems can provide resilience to natural hazards and protect economic assets and ensure developmental gains.

A complete and effective early warning system comprises four inter-related elements:

i. Risk knowledge: Prior knowledge of risk faced by communities.

ii. Monitoring and warning service: Technical and warning services for these risks.

iii. Dissemination and communication: Dissemination of easy to understand warnings to those at risk.

iv. Response capability: Knowledge, awareness and preparedness to act.

A weakness or failure in any one of above could result in failure of the whole system.

There is a notion among non-professionals that early warning systems for slope failures and landslides are always sophisticated and expensive. The fact however is that in many situations, simple, inexpensive and easily perceptible or measurable indicators can provide premonition of an impending slope failure. Monitoring of rainfall, surface and subsurface slope movements, slope subsidence, slope heave, development and widening of cracks, tilting of trees and poles, sudden oozing out of water or drying of water springs, sub slope piping, under slope erosion, sudden fall of boulders, cracking of building floors

etc. often provide irrefutable evidence of unsatisfactory slope behaviour. Randomly picked isolated observations of this kind do not convey much but when all such evidence are collected, analysed and synthesized, early warning alerts do not remain a fantasy.

In the past, simple devices commonly used for early warning against landslides were: (1) wire or special switches, actuated by the pressure of moving debris coupled with a decision-support system that would release early warning alerts, (2) electrical switch poles – which turn to an upright position upon displacement, (3) photo-electrical barriers, especially for a rapidly moving debris flow or earth flow, (4) pulsed radar for snow avalanches, (5) fiber optic sensors and technology, (6) acoustic emission technology, (7) auto-actuated photographic systems and (8) GPS observations.

While the capabilities exist at global level to identify areas of occurrence of landslides, the capability of predicting as when these would occur is still being developed. The signs of impending landslide can often be detected at an early stage and used for warning the communities at risk. It is possible to predict the time of landslide occurrence, provided the slopes are monitored continuously. Advances in monitoring technology, particularly in real time transmission of information have helped in developing the technique of short-term prediction. More examples of same are rare. Best instance of this is an early warning system established for Yangtze River valley in China that monitors using 70 stations employing over 300 professionals. The network protects a population of 300,000 and so far has forecast 217 landslides and avoided estimated economic losses of US$ 27 million.

Remote sensing, the Global Positioning System (GPS), and Geographic Information Systems (GIS) are now mature and robust technologies that can be used to monitor landslides and landslide prone areas with greater accuracy than could be accomplished previously with field reconnaissance alone. Recent studies that have used these tools, including high-resolution satellite imagery, light detection and ranging radar (LIDAR). High resolution imagery and topographic mapping can lead to improved understanding of landslide mechanics and hazard prediction. Continued research into the methods of data collection, processing, and synthesis is needed to realize the full promise of these technologies for global use in the coming decades.

Radar is one of the outputs of technological advances that can be used in monitoring the landslide effectively. Radar can be used for monitoring avalanche movement, detection of crevasses, measuring the thickness of snow on the road to facilitate their clearance operations and aiding search for avalanche victims.

Recent developments in remote sensing of weather information have provided the capability for more timely and spatially accurate assessments and warnings of weather-related hazards. Remote sensing of rainfall using Doppler Radar and Infrared Satellite sensing (DrISS) can provide information on rainfall with a spatial and temporal resolution that is potentially useful for near real-time landslide hazard assessment and warning. Thresholds of rainfall intensity and duration for triggering of landslides have been developed for many regions worldwide using ground-based rainfall measurements and documentation of landslides. Rainfall thresholds have been applied for regional real-time landslide warning system. However, techniques for analyzing the temporal variation in slope stability on a local scale during the course of a storm with interval rainfall input are now being developed. The automatic weather station developed by ISRO can also be deployed in remote areas for collecting meteorological details and transmitting them through the different networks like VSAT, VPN etc.

A great majority of dormant landslides often turn active and become catastrophic during the monsoon season and high intensity short duration rainfall events.. The short term observation on rainfall is enough to underscore the importance of reliable and continuous rainfall measurements and real time analyses of rainfall data and should be arranged preferably at all major landslide sites. Rainfall information will be utilized for developing indicators for landslide alert especially for high landslide hazard areas prone to high intensity short duration rainfalls. For example, the eastern Himalayan region gets very heavy monsoon rainfall punctuated with occasional cloud bursts where the rainfall intensities are in the range of 300mm per day to 1000 mm/day (in general, the more the intensity, the lesser is its duration). One study developed on this observation in 1980s led to linking of landslide with the corresponding rainfall event coefficient (ratio of the rainfall of an event to the mean annual rainfall at the location). The findings reveal that event coefficients exceeding 20% will trigger heavy landslide at all times. Very high probability of landslides was projected where event coefficients were 10-20%. The probability of landslides was rated very low when the event coefficient fell below 5%. The above inference is suggestive of the nature of advanced studies to be undertaken. It is important to encourage such studies and make them more scientific and systematic. Statistical correlation between rainfall and corresponding slope surface, subsurface movements, development of pore water pressure measurements within the slope provide good insight into the slope behaviour.

Early warning thresholds for a well studied seasonal (repetitive) rain-induced landslide on discrete boundary shears with known pore pressure variations on the slide boundaries are extremely reliable. Such early warning thresholds usually take advantage of the unique, linear relationship between factor of safety (in terms of effective stress) and the pore water pressure (considered in terms of ratio). Since inter-relationships between rainfall intensity, slope

surface and sub slope movements and pore pressures provide powerful means for reliable landslide forecasting, studies for these should be encouraged. Rainfall and the associated slope behavioural information will be utilized for developing indicators for landslide alert especially for high landslide hazard areas known to succumb to high intensity short duration rainfalls. In cases where no such information is available, a warning of a general nature and low reliability may still be possible through study of rainfall records in the backdrop of landslide history.

Prediction of landslides is possible and research and development work on it deserves to be encouraged. Attempts to predict landslides have so far been based on time-dependent displacement behaviour of slides, generally in the tertiary stage of tertiary creep. Increasing availability of high-resolution geospatial maps and powerful slope instrumentation techniques can make real-time prediction of landslides possible.

Based on available information inputs when a decision for early warning is taken, the early warning dissemination strategy will be same as the one prescribed for other disasters. Operations such as post early warning interfacing with communities, press and media are common to all types of disasters. Integrated early warning dissemination systems will be evolved.

Even with the best of early warning systems, results will still be catastrophic if early warning signals are not properly interpreted and communities are not educated and trained on how to respond to the early warning alerts in real time. There should be an easily understandable manual clearly bringing out what is to be done when an early warning system flashes such an alert. Quite often the early warning alert may be lost in panic and confusion, if people are not aware of the response that must follow such alerts.

Studies are being carried out in many countries to establish the correlation between the intensity of rainfall and initiation of slides in different regions. Once threshold values of rainfall which will initiate landside in a particular area is established, same can be the basis to issue early warning. The correlations can be established with the help of past records as well as monitoring. In our country, IMD and NCMRWF are believed to have developed the capability to forecast the amount of rainfall an area is likely to receive 3-5 days in advance. Collaborative efforts in this field should be pushed. Depending on the success of this study, some more landslide prone areas may be selected for developing the early warning system.

Public response to a forecast is another difficult area. If the people are not educated, they may interpret the same forecast differently. If not fully aware of the lethal consequences, they will generally take warnings lightly. Disaster education must eliminate such possibilities.

6.9 Dissemination and Communication

Dissemination and communication mechanisms, as far as early warning systems are concerned, must be operational, robust and available round the clock. These should be designed to the needs of a wide range of threats for user communities. The dissemination of the information must be based on clear protocols and procedures and supported by an adequate telecommunication infrastructure. At the national level, effective dissemination and communication mechanisms are required to ensure timely dissemination of information to the authorities and communities at risk even in the most remote areas of the country. Each area may require different technological infrastructure to allow effective dissemination of messages. To ensure that all systems work smoothly in tandem, these will be based on internationally agreed standards.

At the national level, the effectiveness of warnings depends on their timely and effective dissemination to all at risk, not only through operational telecommunication systems but also through non-technical social networks. The later is very important in poor communities that lack technological advanced communication systems. Effective dissemination requires the establishment of a chain of command, in advance, in order to manage warning issuance and dissemination and ensure that the information is understood by those who need it and reaches all affected locations in the country. It is all the more important in case of landslides as these are localized events and can occur in remote locations.

A typical warning dissemination chain involves channeling warnings from technical and scientific sources through government decision makers and the media to multiple receivers who may also function as onward disseminators. Such users include emergency services, security agencies, operators of utilities, information and communication services, other economic service providers, NGOs, voluntary agencies and vulnerable communities. In a system with integrated disaster management structures, the principal agencies responsible for issuing warnings and the processes for their issuance will be established by prior agreement. Various players are involved in generating warnings, including the private sector in developed countries and civil defence in others. To be effective, early warning activities must cover all relevant areas in the country equally. In order to reach all those who need to take action, there is a need to design warnings for particular groups of stakeholders, such as different language groups, people with disabilities, and tourists. Worldwide, public broadcast media remains the most widely used mode. The better systems for warning dissemination are those which are used in daily life and with which users are most familiar. The role of community-based and grassroots organisations, as well as NGOs and other players in disseminating warnings are pivotal.



Fig. 6.1: Inclinometer used for monitoring subsurface displacement



Fig. 6.2: Inclinometer installed to identify depth of slip surface



Fig. 6.3: Differential settlement Gauge for monitoring vertical movement



Fig. 6.4: Piped Wire Extensometer for measuring slope displacement



Fig. 6.5: Geodetic surveying for studying spatial movements in slopes



Fig. 6.6: Crack meter to study crack propagation and extension

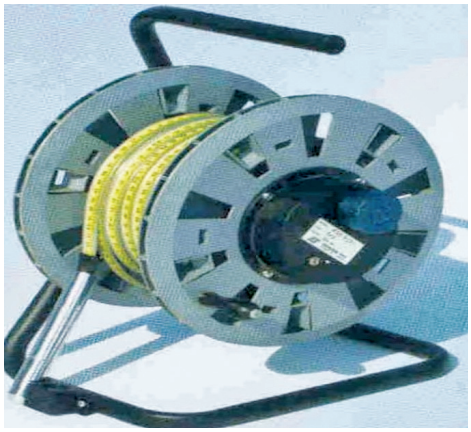


Fig. 6.7: Water Level Indicator



Fig. 6.8: Peg markers used for monitoring slope movements



Fig. 6.9: Total station with GPS and Prisms for slope monitoring



Fig. 6.10: Slope stability radar



Fig. 6.11: Total Station, GPS and Prisms



Fig. 6.12: Hand held GPS and Total Station



Fig. 6.13: Reflecting stickers used to monitor surficial slope displacements



Fig. 6.14: Permanent Station used to monitor movement using peg markers



Fig. 6.15: Solar panels used for power supply in automated monitoring system



Fig. 6.16: An automated landslide monitoring with recording system



Fig. 6.17: Remote Real time Automated Monitoring System for landslide



Fig. 6.18: Video Camera and Landslide Alert system with power backup

LANDSLIDES REMEDIATION

7.1 Landslide Remediation Practices

A comprehensive risk management strategy requires systematic approach in planning and implementation the concepts and measures. The risk management comprises pre-disaster prevention strategies and post-disaster management. The pre-disaster strategies include assessment of the hazard, analysis of risk through documentation of existing events, hazard zonation mapping and application of modern techniques that can help in preventing the activation of dangerous processes. Comprehensive Hazard Zonation aims at preventing settlements, infrastructural elements to be located in vulnerable areas and also prescribing, to some extent, the appropriate treatment measures required at vulnerable locations.

Remediation practices, including slope geometry correction, providing protection to the toe of slope by retaining structures, management of the surface and subsurface water including development of pore pressures, nailing, bolting, anchoring, micro piling, application of geo-grids and geo-textiles and afforestation, constitute powerful elements of most geotechnical packages commonly used for improving stability of problematic slopes and landslides in India.

In our country, most of the landslides occur during the monsoon period barring a few which owe their origin to earthquake. Pore water pressure plays a major role initiating landslide events. There are also instances where toe erosion by rivers or nalas and scouring of hill slope due to high velocity discharge of streams descending from the crown of the landslide gives rise to debris flow/ slide. Hence, surface and sub-surface water management on the slopes or in the catchments forms the most effective remediation measure for controlling many landslides. Management of surface runoff and subsurface water is done through the development of drainage networks. Subsurface drainage management is hardly practiced in our country for stabilization of landslides. This aspect of landslide stabilization calls for immediate attention and the agencies like BRO, PWDs etc. engaged in slope stabilization activities must be well equipped with the modern technology to develop construct subsurface drainage network.

Reinforcing technologies like nailing, bolting, anchoring and tie back have provided apt solutions to bewildering varieties of civil and mining engineering problems. Numerous successful examples of stabilization of problematic slopes, landslides, open cast mines, tunnels, road cuttings etc., bear ample testimony to the great potential, the reinforcing technologies hold.

It is however, somewhat disappointing that the technological interventions in many cases have not always been quite sensitive to the real needs of the specific sites. There have been very little technological innovations in the area of landslide control in India. Research and development in the technological interventions by some knowledge based institutions or organizations in our country may be the only answer to overcome such shortcomings.

Already distressed slopes require immediate remediation. Landslides can be triggered by various factors like excessive rainfall, earthquakes and interference by man. Besides shallow erosion or reduction of shear strength caused by seasonal rainfall, the anthropogenic activities such as adding excessive weight above the slope, carrying excavations on the slope or at the foot of the slope resulting from developmental activities contribute towards large scale occurrence of landslide. However, sometimes different factors combine together to generate instability and in many cases these appear after some time. Many a times, it is not possible to reconstruct the evolution of the landslide process except in cases where site is well-instrumented. It may also be mentioned that it is nearly impossible to stabilize a failed slope until its morphology is well understood, causes responsible for inducing instability determined and the resultant risk assessed, analyzed and adequately addressed. Therefore, it is necessary to conduct detailed geological and geotechnical investigations for planning remediation measures.

Depending upon the nature and purpose of work, degree of risk, cost effectiveness of the remediation measures, slope stabilization methods generally include modifications of the natural conditions of landslides such as topography, geology, groundwater etc. that directly or indirectly control portions of or the entire landslide. These generally include drainage control works, soil/debris removal works, buttress fill works and river training works.

The drainage control measures include both surface and sub-surface drainage works. The surface drainage control works are implemented to minimize the infiltration of rain water that builds up pore pressure. The surface drainage controlling comprises drainage collection and drainage channel works. The surface drainage measures comprise lining catchwater drains above the crown of a slide, lining contour drain on different levels of the slide mass, lining cascading chute drain to intercept and divert rain water from the upslope and slide surface and to reduce infiltration and development of pore water pressure substantially. The purpose of subsurface drainage control works is to lesson or remove the impact of groundwater within the landslide mass. The subsurface drainage control works include shallow and deep subsurface drainage control works depending up on the nature of the slide. The sub-surface drainage works may include intercepting under drains, interceptor trench drains, horizontal gravity drains, drainage wells and drainage tunnels.

Soil/debris removal or offloading of the slide mass is generally very effective for small to medium sized landslides. The work is generally undertaken from the crown portion downwards and depending on the properties of the material; benches or berms are created at appropriate intervals.

In case of fill works, buttress fill is placed at the lower portions of the slide as counterweight to the landslide mass. It is more effective if the removed soil is used.

Scouring and erosion of channel bank or toe of a slope reduces its stability and often tends to induce slide activity. In such a case, check dams and bank protection can be erected to prevent further erosion. If required, deflection spurs are provided upstream.

Provisions of restraining structures rely directly on the construction of structural elements with a view to improve the stability of sliding mass. These include pile works that act as keys to tie together the moving landslide and the stable ground. The anchors and bolt works utilise the tensile force of anchor bodies embedded through the slide mass and into stable earth and construction of retaining and breast walls to prevent smaller and secondary landslides that often occur along the toe portion of the larger landslides.

Once treatment measures have been implemented, the treated slopes are required to be protected against the effects of atmospheric elements, like rain and snowfall. This requires minimizing direct exposure of a treated slope to the natural atmospheric agencies and can be achieved by providing a protective covering to the treated slope. The common practice is afforestation that not only provides effective covering to the slopes but also improves the shear strength of the material through network of plant roots. Vegetation can also be directly used to help stabilize slopes using biotechnical methods, commonly referred to as slope bio-engineering. These methods, originally pioneered in Europe, involve aggressive planting of carefully selected varieties and the construction of engineered structures using live materials whose strength will increase with time. Vegetation can also be effective on steep slopes, where it intercepts precipitation and reduces both runoff and excessive infiltration.

Shotcreting with or without a chain link fabric wire-mesh is very effective in protecting slopes with weathered rocks. Drainage holes can be provided along with shotcreting. Covering the slope surface with geo-fabrics made of natural as well as synthetic material is also commonly used in slope protection works.

NDMA has developed a template for preparation of Detailed Project Report (DPR) for Site-specific Landslide Risk Mitigation to facilitate State in execution of landslide mitigation projects in a better way. https://ndma.gov.in/images/guidelines/landslide-dpr-template.pdf

7.2 Mass Improvement Techniques

The stabilisation of the hill slopes can be achieved by improving the mechanical characteristics of the potentially unstable ground by:

- inserting reinforcement elements into the ground, and
- improving the mechanical characteristics of the ground through chemical, thermal or mechanical treatment.

In measures for slope protection, the reinforcement technology is finding wide application. This involves creation of large diameter wells supported by one or more crowns of consolidated and possibly reinforced earth columns, anchors, networks of micro piles, nailing and grouting with cement or depending upon the properties of the material, chemical grouting can be used.

The improvement of the mechanical characteristics of the ground can also be done through thermal treatment of potentially unstable hillsides made up of clayey materials or by using electro-osmotic treatment in case of homogenous clayey ground.

Table-7.1: A brief list of landslide remedial measures

A. Modification of Slope Geometry
• Removing material from the area driving the landslide (with possible substitution by lightweight fill) • Adding material to the area maintaining stability (counterweight berm or fill) • Reducing general slope angle • Slope stitching using timber or cement concrete (Figs. 7.1, 7.2 & 7.18)
B. Drainage
• Surface drains (Figs. 7.13 to 7.15) to divert water from flowing onto the slide area (collecting ditches and pipes); for example French Drains (Fig. 7.53) • Shallow or deep trench drains filled with free draining geo-materials (coarse granular fills and geo-synthetics) • Buttress counter forts of coarse grained materials (hydrological effect) • Vertical (small diameter) boreholes with pumping or self draining • Vertical (large diameter) wells with gravity draining • Sub-horizontal or sub-vertical boreholes • Drainage tunnels, galleries or adits • Vacuum dewatering • Drainage by siphoning • Electro-osmotic dewatering • Vegetation planting (hydrological effect)

C. Retaining/Restraining Structures

- Gravity retaining walls
- Crib block walls (Fig. 7.18)
- Gabion walls
- Passive piles, piers and caissons
- Cast in-situ reinforced concrete walls
- Reinforced earth retaining structures with strip/sheet polymer/ metallic reinforcement elements/geosynthetic and geotextiles (Figs. 7.3, 7.4, 7.6, 7.44 & 7.45)
- Buttress counter forts of coarse grained material (mechanical effect)
- Retention nets/meshes for rock slope faces
- Rowck fall attenuation or stopping systems (rock trap ditches, benches, fences and walls)
- Protective rock/concrete block against erosion
- Drum Diaphragm Wall or Tyre Walls

D. Internal Slope Reinforcement

- Rock bolts
- Micro piles
- Soil nailing
- Anchors (pre-stressed or not)
- Grouting
- Stone or lime/cement columns
- Heat treatment
- Freezing
- Electro-osmotic anchors
- Biotechnical measures like planting vetiver grass or using jute/coir mats
- Mulching

7.3 Mitigations Methods for Various Types of Landslide Hazards

The simplest means of dealing with landslides is to avoid construction on steep slopes and existing landslides. However, this is not always practical. Regulating landuse and development to ensure that construction does not reduce slope stability is another approach. In cases where landslides affect existing structures or cannot be avoided, physical controls can be used. In some cases, monitoring and warning systems allow residents to evacuate temporarily during times when the probability of landslide activity is high.

7.3.1 Physical Mitigation Methods for Slides & Slumps

1. **Drainage**
    - a. **Surface drainage (Figs. 7.13 to 7.16)**
        - i. Ditches
        - ii. Regrading (Fig. 7.59)
        - iii. Surface/crack sealing (Fig. 7.48)
    - b. **Subsurface drainage**
        - i. Horizontal drains (Figs. 7.7 & 7.8)
        - ii. Vertical drains/wells (Figs. 7.11 & 7.12)
        - iii. Trench drains/interceptors, cut-off drains/counterforts (Fig. 7.10)
        - iv. Drainage galleries or tunnels (Fig. 7.9)
        - v. Blanket drains
        - vi. Electro-osmosis
        - vii. Blasting
        - viii. subsurface barriers
2. **Excavation or Regrading of Slope**
    - i. Total removal of landslide mass
    - ii. Regrading of slope
    - iii. Excavation to unload the upper part of landslide
    - iv. Excavation and replacement of the toe with other material
3. **Restraining Structures**
    - i. Retaining walls (Figs. 7.19, 7.20, 7.23, 7.25 to 7.30)
    - ii. Piles
    - iii. Buttresses and counterweight fills (Fig. 7.19)
    - iv. Tie rods and anchors (Fig. 7.57)
    - v. Rock bolts/anchors/dowels
4. **Vegetation (Fig. 7.60)**
5. **Soil Hardening**
    - i. Chemical treatment
    - ii. Freezing
    - iii. Thermal treatment
    - iv. Grouting

7.3.1.1 Site Leveling

Smoothening the topography of the slide surface can prevent surface water from ponding or connecting with the groundwater. Any depressions on the slope that might retain stagnant water must be removed. Infilling and sealing large cracks in the soil surface by grading the soil mass are beneficial and prevent surface water from reaching the failure plane.

7.3.1.2 Drainage Techniques

Groundwater is the most important single contributor to landslide initiation and its continuation. Not surprisingly, therefore, controlling drainage is the most effective element of slope stabilization scheme, for both existing and potential landslides. Drainage is effective because it increases the stability of the soil and reduces the weight of the sliding mass. Drainage can be either surface or subsurface. Surface drainage measures require minimal design and costs and have substantial stability benefits. These are recommended on any potential or existing slide.

The two objectives of surface drainage are to prevent erosion of the face, reducing the potential for surface slumping, and to prevent infiltration of water into the soil, thereby reducing ground-water pressures. Subsurface drainage also is effective but can be relatively expensive. It is therefore essential that groundwater be identified as a cause of the slide before subsurface methods are developed. The various methods of drainage are:

Ditches and Drains

Surface drainage can be either through surface ditches or shallow subsurface drains. Surface drainage is especially important at the head of the slide, where a system of cutoff ditches that cross the headwall of the slide, and lateral drains to lead runoff around the edge of the slide are effective. Ditch gradient should be at least 2 percent, to ensure rapid flow away from the unstable area.

The simplest type of subsurface drain is the lateral trench constructed above an unstable slope. Drainage trenches are economical only for shallow soils overlying bedrock or hard impermeable till. The trenches should be excavated to the base of the shallow soil to intercept any groundwater flow along the failure plane. These are backfilled with coarse gravel to prevent sloughing of the ditch sidewalls. It is more useful if drainpipes are now and then backfilled with coarse gravel.

Drainpipes

Horizontal drainpipe is a widely used device for landslide prevention in highway construction. It is most effective when installed during initial excavation. Because of the long lag times to lower groundwater levels, the drains are

effective only if the pipe is carefully installed, failure surface intersected and the pipe actually drains the soil. As most slopes have varying soil and hydraulic and geometric conditions, drainage systems must be individually designed. After drilling has been done up to the desired depth and the casing installed, the latter is cleared of soil and sections of slotted PVC drainpipe are covered with filter cloth and pushed into the casing and coupled together. The casing is then withdrawn and screen is installed over the end of the drain. Drain holes must be thoroughly cleaned of drill cuttings and mud. Uncleaned holes may be only 25 percent effective.

In clay soils, the full change in groundwater tables can take up to 5 years, with 50 percent of the improvement taking place in the first year. Once water tables are lowered in clay soils, the change is fairly permanent; however, seasonal fluctuations can occur: rainfall will not alter the groundwater level in the slope provided the drains do not clog. In sandy soils, the groundwater level will lower within a few months but will also fluctuate with rainfall.

Straw Wattles and Straw Bales

Straw wattles, also known as straw worms, bio-logs, straw noodles, or straw tubes, are cylinders made up of compressed, weed-free straw (wheat or rice), 20 to 30 centimeters in diameter and 7 to 9 meters long. These are encased in jute, nylon, or other photodegradable materials and have an average weight of 16 kilograms. These are installed in a shallow trench forming a continuous barrier along the contour (across the slope) to intercept water running down a slope. Straw wattles should be effective for a period of 1 to 2 years if these can be installed on slopes up to 70 percent; however, their effectiveness diminishes greatly on slopes steeper than 50 percent. Soils can be shallow but not less than, say, 8 inches. Straw wattles increase infiltration, add roughness, reduce erosion, and add short-term protection on slopes where permanent vegetation will be established to provide long-term erosion control. Straw bales, easily obtainable in most areas globally, are portable, and have a modular-type application for slope erosion and drainage control.

Retaining Walls

For all types of retaining walls, adequate drainage through the structure is essential because very high groundwater pressure can build up behind any retaining wall, leading to its failure. Drainage can be provided simply with a coarse backfill and foundation material.

Timber Crib

Timber crib walls (Fig. 7.18) are box structures built of interlocking logs and backfilled with coarse aggregate. These work by intersecting the critical sliding surface, thus forcing the potential failure surface to a deeper, less critical depth. The structure must be able to withstand: (1) shearing, (2) overturning,

and (3) sliding at the base. It must, therefore, be strongly built by burying to sufficient depth and extending beyond the critical failure plane. Crib walls are only effective where the volume of soil to be stabilized is relatively small. These are most efficient where a thin layer of unstable soil overlies a deeper, more stable layer of soil. Crib wall structures should have a volume equal to 10 to 15 percent of the volume of the soil to be stabilized. This relatively small volume provides little counterweight support at the toe; therefore, virtually the entire resistance to failure comes from the strength of the crib.

Steel Bin Wall

A steel bin wall is made from corrugated galvanized steel components bolted together to form a box and then filled with earth. The stability of a gravity wall is due to the weight of the wall itself, perhaps aided by the weight of soil in front of the wall. The bulk of the weight is from the contained soil, not the steel, and this should be kept in mind when the foundation is prepared. Large walls must be individually engineered, with load and foundation requirements calculated. Structural and civil engineering design charts provide stringer (horizontal member) specifications and height-to-width ratios for typical loading conditions. The widths of walls vary from 2 to 5 meters and are one-half to three-fifths the height of the wall. To provide additional sliding resistance, the foot of the wall is usually 0.5 to 1.0 meter below grade, although the design should not rely on the additional toe support, as it can erode or be removed inadvertently. The factor of safety is improved if the wall is at a 1:6 slope. Fill material must be well drained and compacted, preferably in 20-centimeter lifts. Material behind the wall also should be well drained and moderately compacted.

Reinforced Earth Wall

Reinforced Earth is a patented system for constructing fills at very steep to vertical angles without the use of supporting structures at the face of the fill. The system uses horizontal layers of flexible metal strips within the fill to form a composite earth-metal system with high strength.

Gabion Walls

Gabions are wire mesh, boxlike containers filled with cobble-sized rock that are 10 to 20 centimeters size. A gabion retaining wall (Figs. 7.13, 7.25 & 7.28) can also be constructed from stacked gabions. Gabion walls usually are inexpensive and are simple and quick to construct. Due to their flexibility, these can withstand foundation movement, and do not require elaborate foundation preparation. Because of their coarse fill, these are very permeable and thus provide excellent drainage. Gabion walls work because the friction between the individual gabion rows is very high, as is the friction between the basal row and the soil underneath. When failure occurs, it is almost always in

the foundation soil itself. Three-tiered walls up to 2.5 meters high can usually be constructed without consulting any detailed engineering analysis. Higher walls are very heavy by nature due to their added bulk and need larger base foundations and possibly counterforts for bracing of the wall. A counterfort is a buttress bonded to the rear of walls and is designed to improve stability. Gabion walls built on clay soils require counterforts, which can be constructed as gabion headers extending from the front of the wall to beyond the slip circle. The counterforts serve as both structural components and as drains. Design charts are available for various combinations of hill slope angle and retaining-wall height.

Piles

Large-diameter piles can be placed into the toe of a slope to form a closely spaced vertical pile wall. Pile walls are normally used as a pre-excavation restraint system—the cut slope excavation takes place in front. Whereas large-diameter concrete pile and culvert pile walls have been used successfully on highways, wood or steel piles that are small in diameter have not. For most earth or rock movement, wood piles are not adequate to provide enough shearing resistance. These are suitable only where the volume of soil to be stabilized is small. On average, one wood pile is necessary for every 50 cubic meters of soil, which is not sufficient for large stabilization projects. Too few piles can result in toppling and (or) breakage by the moving mass of soil, as well as by soil movement between the piles.

A major limitation when log piles are used is depth, as many failure surfaces lie below the height of the piles. Wood piles are the best for shallow soil failures over deeper stable soils. The piles should extend well below the potential failure surface and be firmly driven into firm subsoil. If the depth of placement is not sufficient to allow the piles to act as a cantilever system, then the piles must be tied back with an additional anchor system.

7.3.2 Debris-Flow Mitigation

This section describes some simple mitigation methods for debris-flow hazards for homeowners, businesses, and others. A short section on erosion and fire control is included since erosion, fire, and subsequent debris flows and flooding are interrelated hazards.

Physical Mitigation Methods for Debris Flows and Debris Avalanches

1. **Source-Area Stabilisation**
    a. Check Dams (Fig. 7.17)
    b. Revegetation

2. **Energy Dissipation and Flow Control**
    a. Check Dams (Fig. 7.42)
    b. Deflection Walls
    c. Debris Basins (Fig. 7.40)
    d. Debris Fences (Fig. 1.53)
    e. Deflection Dams
    f. Channelisation
3. **Direct Protection**
    a. Impact spreading walls
    b. Stem walls
    c. Vegetation barriers

7.3.2.1 Check Dams

These are small, sediment-storage dams built in the channels of steep gullies to stabilize their bed. These are commonly used in Europe and Japan to control channelized debris-flow frequency and volume. A less common use of check dams is to control raveling and shallow slides in the source area of debris slides. Check dams are expensive to construct and therefore are usually built only where important installations or wildlife habitat, such as a camp or unique spawning area, lie downslope. Channelized debris flows are associated with channel gradients over 25 degrees and obtain most of their volume by scouring the channel bed. Check dams serve three purposes when installed in the channels:

- Mitigate the incidence of failure by reducing the channel gradient in the upper channel.
- Reduce the volume of channel-stored material by preventing down cutting of the channel with subsequent gully sidewall destabilization and by providing toe support to the gully slopes.
- Store debris-flow sediment, when installed in the lower part of the channel.

When installed on debris slides, the dams store raveled material, which eventually creates small terraces on the slide, reducing the surface slope. Check dams can be constructed of reinforced concrete or of log cribs. Concrete mortared rock dams do not usually exceed 8 m in height, whereas log crib

dams must not exceed 2 m. The spacing of dams depends on channel gradient and dam height. For example, a 2 m high dam in a 20-degree channel with 10-degree sloping channel infill will be spaced every 12 m. Lateral stream erosion and scour by spillway water are the main drawbacks.

How to Prevent Check Dam Failure

During construction, the concrete wing walls and log crib ends must be tied securely into the canyon wall and streambed to withstand backfill pressures and lateral scour. Wing walls should slope at about 70 percent and extend a minimum of 1–2 meters into the banks. The foundation of the dam should have a minimum width of one-third the total height of the dam and be deeper than any scour holes likely to develop.

Backfilling the dam, rather than allowing it to fill naturally, reduces the dynamic loading on the structure and results in a more stable design. The slope of the backfill should be less than one-half the channel gradient. Dams that have been back-filled will usually survive a debris flow; the backfill material will not be scoured during or after a torrent.

7.3.2.2 Strengthening Slopes for Erosion/Debris Flows

Erosion may cause the steepening and lengthening of gullies and resulting in loosening of soil, plants, rocks, and boulders, which can intensify the effects of debris flows. Keeping an area free of excess fuel for fires can also help in the mitigation of debris flows, as burnt slopes become more vulnerable to the effects of debris-flow initiation and erosion. Loss of vegetation that holds soil in place and physical and chemical changes to the soil that result from intense heat and burning by fires make this soil more prone to debris flows.

7.3.2.3 Debris-flow Basins

The catchment basins are commonly built at the base of slopes where debris flows are frequent. These are used especially in areas where the debris must be contained so that soil and debris are stopped from flowing into sensitive ocean or river shorelines areas or where there are structures at the base of the slope that are vulnerable to debris-flow damage. These basins will eventually fill with the debris-flow deposits and must be emptied periodically or these will overflow. Commonly, heavy duty dump trucks and power shovels are needed to empty the debris and carry it away. However, small basins can be emptied manually. These should be designed to be able to contain the maximum flow volumes of an area to prevent overtopping during a flow event.

7.3.2.4 Debris Flow Retaining Walls

These structures can be of various materials. These are designed to stop the accumulation of debris, either by blocking its flow or diverting it around the

vulnerable area. These structures should be carefully designed as any deflection of material may be unintentionally redirected to additional vulnerable areas.

7.3.3 Rock Slope Stabilization/Mitigation Techniques

Rockfalls range from a few fist-sized rocks to large cliff sections and boulders which, depending on size and shape, can roll and bounce downslopes, landing in areas at great distances from the fall lines. Recreation areas such as beaches near cliffs, parks, and open spaces may be affected by rockfall. Thus people are exposed to these hazards especially those who tend to venture too near the edges of cliffs and rocky slopes, can add pressure to already weak overhangs and cause rockfalls to land on people or structures below or sustain injuries themselves. Whether hiking, camping, walking, or working around cliffs or rock faces, very often, people encounter the hazard without warning. A variety of engineering techniques can be implemented to help mitigate the effects of rockfalls, and some of these are discussed here. In some cases, more than one type of engineered solution is the best.

Physical Mitigation Methods for Rockfalls

1. **Stabilisation**
    a. Excavation
    b. Benching
    c. Scaling and trimming
    d. Rock bolts/anchors/dowels (Figs. 7.31 to 7.36 & 7.57)
    e. Chains and cables (Fig. 7.46)
    f. Anchored mesh nets (Fig. 7.21)
    g. Shotcrete (Fig. 7.43)
    h. Buttresses
    i. Dentition
2. **Protection**
    a. Rock-trap ditches
    b. Catch nets and fences (Fig. 7.49)
    c. Catch walls
    d. Rock sheds or tunnels (Figs. 7.37 & 7.39)

7.3.3.1 Excavation of Rock/Benches

Horizontal benches excavated into a rock face are among the most effective kinds of protection measures for rockfall. In addition to intercepting rockfall, benches reduce tensional forces in the surface rock and reduce surface erosion rates. These also reduce the rate of occurrence of rockfall. However, these have little or no effect on potential deep-seated rock failure. Bench faces can be constructed steeper than the overall slope angle, as rocks that fall will likely to remain on them. Vertical bench-face angles should be avoided, as tension cracks, dangerous overhangs, and excessive rockfall can result. The placing of bench faces should be stopped at the base of weaker rock layers, fractured rock zones, or water-bearing zones. A minimum width of 4 m is recommended for the benches, and all benches should have drainage ditches to divert water away from the slope.

7.3.3.2 Scaling and Trimming

Loose, unstable, and (or) overhanging blocks of rock, which may pose a danger to passing traffic and (or) pedestrians, can be removed by scaling or trimming. Scaling is the removal of loose blocks by the use of hand-held pry bars and small explosive charges. Trimming involves some drilling and light blasting by explosives, followed by scaling, to remove larger areas of overhanging or potentially dangerous rock. Scaling and trimming can be reduced bycontrolled blasting, but it is not always feasible. Overhanging rock is either removed or trimmed back to a stable part of the face. Scaling operations are usually carried out by workers suspended by ropes or other means, using pry bars, jacks, and explosives. These can be time-consuming and expensive (sometimes dangerous) and on active slopes may need to be repeated, say every few years, or as need has to be. Scaling is highly skilled work and can sometimes be dangerous; scaling crews should be trained and the work performed by professionals.

7.3.3.3 Shotcrete and Gunite

Shotcrete and gunite are types of concrete that are applied by air jet directly onto the surface of an unstable rock face. Shotcrete is an all-inclusive term to describe the spraying of concrete or mortar either by a dry or a wet-mix process. Gunite refers only to the dry-mix process in which the dry cementing mixture is blown through a hose to the nozzle, where the water is injected immediately before application. This is a rapid and relatively uncomplicated method commonly used to provide surface reinforcement between blocks of rock and also to reduce weathering and surface scaling. Shotcrete contains aggregate up to 2 cm in size and is more commonly used than gunite, which has smaller aggregate. Both materials can be applied rapidly by air jet so that large areas can be covered in a short time.

7.3.3.4 Anchors, Bolts, and Dowels

These are tools composed of steel rods or cables that reinforce and tie together a rock face to improve its stability. Anchors are post-tensioned members used to support large blocks of rock, whereas bolts are shorter and support surface rock. Dowels are similar to bolts but are not post-tensioned. Reinforcing a rock slope with steel requires a specialist's knowledge of rock stability analysis, of grouting techniques, and of testing procedures. Determination of orientation of the potential failure surfaces is crucial to a successful anchor system and requires considerable amount of engineering experience.

7.3.3.5 Safe Catching Techniques

7.3.3.5.1 Catch Ditches

Wide catch ditches are effective in containing rockfall, but the ditches must be designed taking into account the cliff geometry taken into account, and it is advised to consult a professional about specifications. The bottom of the catchment ditch should be covered with loose earth to prevent falling rock from bouncing or shattering into pieces or shards. If there is not enough space to construct as wide a ditch as is specified, then a combina¬tion of smaller ditches with a gabion or rock wall along their downhill edges can be used.

7.3.3.5.2 Cable, Mesh, Fencing, and Rock Curtains

Cable lashing and wire nets are simple, low-cost methods for protecting a road or path from rockfall. For large, unstable blocks, strands of metal cable are wrapped around the blocks and anchored to the slope. Where the rock is too fractured to be restrained by individual cables, cable nets are used. Wire mesh (closely spaced interwoven wires) can be used to prevent smaller rocks, less than 0.75 meter in size, from falling. The standard mesh is double-twisted gabion wire mesh or a heavy gage metal chain link. The mesh is either loosely draped over a uniform rock face or bolted or otherwise firmly secured where the cliff face is irregular and the mesh cannot make close contact with the rock. Bolting the mesh to the rock face can prevent rock from becoming dislodged and provides overall stability of the slope or rock face. Wire mesh also is useful on steep soil cuts, especially beneath talus slopes.

Catch nets made of cable and wire mesh can be constructed to catch falling rock at the bottom of gullies and slopes. When suspended from an anchored cable, the mesh forms a flexible barrier to dissipate the energy of the falling rock and will usually stop boulders up to 1 m in diameter, if properly secured. Additionally, catch nets can be used in conjunction with roadside catch ditches.

Rock fences are fairly easy to install and can restrain small rocks from falling onto roads but do not stop rocks that bounce out over the top of the fence

barrier. Rock curtains are more effective in directing rocks down to a catch ditch or other catching structure, by preventing them from bouncing outward onto the highway or structures below.

7.3.3.6 Retaining Walls

Retaining walls can work much like those described for soil slope-stabilization techniques in keeping rockfall debris out of an area. These are similar to rockfall fences but are in most cases more substantial and stronger. Retaining walls can be made out of steel, concrete, timbers, or other materials and must be anchored properly so as not to tip over during rockfalls. Different codes and practiced are available on retaining structures in the country, some are mentioned in annexure.

7.3.3.7 Rock Sheds/Shelters (Figs. 7.50)

These shed/shelters are built over roads, railways, and sometimes structures to shield the area from rockfall and rock avalanches. Shed structures are either open ended or completely envelope the rockfall area in a concrete or steel (or other material) structure that will deflect rockfall away from the road, railway, or structure.

7.3.3.8 Rock Ledge Reinforcement (Fig. 7.54)

These are used only for unique situations; hence the works must be carefully engineered and should be structurally strong.

7.3.4 Soil Nailing

Soil nailing essentially involves reinforcing and strengthening of existing grounds by installing closely-spaced steel bars, called nails, into the hill slope. A soil-nailed system can override local weaknesses in the ground through stress redistribution and is less vulnerable than unsupported cuts to undetected adverse ground and groundwater conditions that have not been accounted for in the slope stability analysis.

7.3.5 Slope Stabilization Using Vegetation

Seeding with grasses and legumes reduces surface erosion, which can under certain conditions lead to landslides. Plating with shrubs adds vegetative cover and stronger root systems, which in turn enhances slope stability. If not checked in time, surface erosion and small, shallow failures can lead to larger problems that cannot be controlled. The terms “bioengineering” and “biotechnical” slope stabilization refer to use of vegetation as slope protection to arrest and prevent slope failure.

Planning is required for the successful implementation of a revegetation programme. Before undertaking seeding, a person with local experience should be consulted. Involvement of local knowledgeable persons may be extremely beneficial. Seed application should begin immediately following a disturbance, at a minimum of approximately 6 weeks before periods of drought or damaging frost. Controlling surface water drainage, removing cut-bank overhangs, reducing slope angles, and benching — all should be done before seeding begins.

7.3.6 Mulching

Mulch (Fig. 7.51) is nonliving material spread over soil surface to provide protection from surface erosion by rain and retention of soil moisture. Various types of mulches are work — straw, grass fibres, wood fibres, seaweed and paper products.

7.3.7 Biotechnical Slope Protection

This is used to reduce the environmental consequences of landslide mitigation measures. Usually, conventional earth retaining structures made of steel or concrete are neither aesthetic, nor environment friendly. These traditional hard remedial measures are increasingly being supplanted by vegetated composite soil/structure bodies. Common biotechnical systems include geonets anchored by soil nails that hold in place soil seeded with grass and geocells with seeded soils in the interstices.

Research has been done on using plants to stabilize soils to mitigate landslides. One of the most promising types of plants is Vetiver (Chrysopogon zizanioides) (Fig. 7.60), a type of fast growing perennial grass with strong stems and dense and deep root system that works very well in many different environments, to stabilize slopes. It provides a practical and inexpensive way to minimize landslides.

The other plant species that can be used in various biotechnical slope stabilization techniques are Broom grass (Thysanolaena maxima), Durva grass (Cynodon dactylon), Napier grass (Pennisetum purpureum), Kans grass (Saccharum spontaneum), Bamboo (Bambusoideae), Giant cane (Arundo donax), Cottonwood (Populus deltoides), Malabar nut (Adhatoda vasica), Male fern (Dryopteris filixmas), Artemesia (Artemisia spp.), Coconut tree fibre (Cocos nucifera), Weeping willow (Salix babylonica), Mulberry (Morus alba), five-leaved chaste tree (Vitex negundo), Ghogar tree (Garuga pinnata), Coral tree (Erythrina variegata), Tiger's milk spruce (Sapium insigne) etc.

Biotechnical slope protection consist of basiclly two elements: biotechnical stabilization and bio-engineering stabilization, both of which entail the use of live materials. Biotechnical vegetation stabilization uses mechanical elements (structures) in combination with biological elements (plants) to prevent and

arrest slope failures. Both mechanical and biological elements must function together in a complimentary manner.

7.3.8 Bio-Engineering Measures for Stabilization of Surficial Landslides

Bio-engineering can be defined as the use of live plants or plant parts in controlling soil erosion and mass movement to fulfill engineering functions. The living plant materials are used as the main structural components or reinforcements in the soil mantle. These provide immediate reinforcement. Secondary stabilization occurs as a result of adventitious roots that develop along the length of the buried stems. Finally, vegetation that is seeded or planted provides mechanical and hydrological support to the soil.

If employed carefully, bio-engineering can prevent minor problems transforming into larger, complex ones. Vegetation affects the surficial stability of slopes in significant ways. The stabilizing or protective benefits of vegetation depend both on the type of vegetation and slope degradation process. In case of mass stability, the protective benefits of woody vegetation range from mechanical reinforcement and restraint by the roots and stems to modification of slope hydrology as a result of soil moisture extraction via evapo-transpiration.

- Catching material that is moving down a slope.
- Armouring the slope against surface erosion (runoff and splash).
- Supporting the slope by propping from the base.
- Reinforcing the soil by increasing its shear strength.
- Draining a slope depending on the pattern and density of the vegetation.
- Limiting the extent of slope failure by binding soil.
- Improving soil and micro-catchments so as to encourage regeneration.

Bio-engineering is often used as part of a broad design, in conjunction with a number of standard civil engineering measures. These include check dams, prop walls, toe walls, wire bolsters, jute netting etc. However, it is stressed that bio-engineering should always be used as part of the overall design when resolving any particular slope problem. It must always be integrated in such a way that it complements and enhances other measures. As a key component in off-road engineering, vegetation is environmentally sound and it finds practical application in several environmental mitigation measures. In hilly regions, roads are an inseparable part of the slopes. These must be fully integrated into the landscape so as to make them sustainable. Bio-engineering techniques offer the best way of blending roads into the landscape and limiting damage to surrounding agricultural, horticultural and forest land. These allow the restoration of something of the original vegetation and ecosystems, and

particularly of tipping sites and spoil dumps. These offer social and economic benefits for poor rural farmers through both implementation and later productivity.

Some bio-engineering techniques used to stabilize the slope are mentioned below:

Table-7.2: Bio-engineering techniques used to stabilized the slope

Technique	Application	Description	Vegetation Example
Wattle fencing	Over-steepened slopes where vegetation cannot naturally establish live bank protection	Long cuttings (e.g. willow) laid horizontally and supported with larger vertical plant stakes or rebar. Behind the fence soil is filled; it creates a series of terraces.	Broom grass (Thysanolaena maxima), Napier grass (Pennisetum purpureum)
Bamboo fencing	Soil creep or surface erosion on a slope	Live bamboo pegs are installed to trap loose sediments on the slope, to improve the conditions for growing vegetation, and to reduce the rate of surface runoff.	Bamboo (Bambusoideae)
Palisades	Adjacent to a stream or river where the natural vegetation has been removed	Large posts of a tree such as cottonwood are sunk in trenches at some distance in the back from edge of the stream.	Cottonwood (Populus deltoides), Bamboo (Bambusoideae)
Brush layering	Stabilizing shallow earth slumps and loose soil slopes and gullies	Benches are excavated in the slope, willow branches are laid at a slight angle on the benches; branches are covered with soil, with just the tips sticking out.	Woody plants of different species (e.g., Willow (Salix tetrasperma), Alder (Alnus), Populus, Garuga (Burseraceae), Malabar nut (Justicia adhatoda), Five leaved chaste tree (Vitex negundo)

Brush mattress	To hinder the slope erosion	A layer of interlaced live branches are placed on a bank face or slope to provide a living protective covering against erosion.	Silky Willow (Salix sericea), Arrowwood (Viburnum dentatum), Buttonbush (Cephalanthus occidentalis)
Coconut fiber fascines	Stabilizing the base of a stream bank or shoreline.	Fascines (fibre "log rolls") are placed along the base of a bank; these collect sediment and help to stabilize the bank; riparian vegetation may then be planted in and alongside the roll.	Coconut tree fibre (Cocos nucifera)
Pre-vegetated mats	Lakeshores and wetlands	Plants are grown on mats made up of a slow biodegrading material, such as coconut fibre; thereafter, mats are simply placed on the slope.	Fibres of different species e.g. Coconut tree fibre (Cocos nucifera)
Live gravel bar staking	Artificial large gravel bars amid braided streams (caused by upstream resource activities)	Using an excavator, live stakes are inserted in the gravel bar to start recolonization of natural vegetation, and return to a single stream channel.	Smooth Willow (Salix glauca), Sandbar willows (Salix exigua and S. sessilifolia)
Jute netting	For stabilizing moderate to steep slopes of 350–80°	Woven jute net is used to protect the bare slope from of soil detachment and reduce the velocity of surface run-off.	Jute (Corchorus)

7.3.9 Landslide Dam Mitigation

As previously mentioned, failure of landslide dams lead to primary hazard of floods (downstream). When the natural dams break due to overtopping or due to the increased lateral pressure on the dam, water and slurry gush out and flash floods occur. The following measures can be undertaken by local communities/stakeholders:

1. Diversion of inflow water before it reaches the lake formed by the landslide dam.

This can be done by diverting water from the stream into other reservoir(s) or to some irrigation system. Although this is usually a temporary measure, diversion may slow the filling of the lake to allow application of a long-term solution.

2. Temporary drainage from the impoundment by pumps or siphons

The rising water level can be controlled temporarily by means of pumps or siphons, causing the water to flow through lower points of the dam. This also is a short-term (less than 1 to 2 years) measure that provides time for more extensive, long-term solutions.

3. Construction of an erosion-resistant spillway

The most common method of stabilizing a landslide dam is to construct an erosion-resistant open-channel spillway either across the dam or an adjacent abutment. When the overtopping by water occurs, flow is controlled by the spillway in much the same way that emergency spillways are constructed on engineered dams to control water level. An additional advantage of this type of spillway is that it allows for the lowering of the water level behind the dam, which helps lessen the upstream flooding caused by landslide dams.

Spillways are not always successful in preventing dam breaching and downstream flooding; these sometimes fail due to retrogressive erosion (erosion from the spillway outlet to its intake) caused by high-velocity outlet flow. To prevent erosion by minimizing flow velocity, the spillway should be wide and shallow. If possible, it should be lined with erosion-resistant materials (commonly riprap), especially at the outlet. Often, check dams are installed along steeper grades of the spillway to prevent/reduce erosion. Spillways that fail due to erosion may still be partially successful because they have limited the total volume of the water behind the dam, thus reducing total discharge even if the dam breaches entirely.

Open-channel spillways across the landslide dam commonly are excavated by bulldozers; however, draglines, backhoes, explosives, and hand labour — all have been used. Excavation can be dangerous in rough terrains, so an access road has to be constructed.

4. Drainage tunnel through an abutment (Fig. 7.38)

A long-term method of preventing overtopping and breaching of a landslide dam is construction of a diversion tunnel through an adjacent dam abutment. Because large landslide dams commonly occur in mountain canyons, these usually have bedrock abutments; thus rock-tunneling methods are commonly used. The landslide mass/debris may be left as it is, as it is too massive to remove. However, it may be monitored with instrumentation.

5. Control Blasting

The control blasting after appropriate inception of the site to breach the landslide formed dam and allowing the discharge of the accumulated water through least resistant path can also eliminate the potential disaster from landslides dammed lake. Such intervention was carried out by the NDMA for the landslide formed dam on river Phuktal in Kargil district of Ladakh.



Fig. 7.1: Slope stitching technique for preventing surficial failures



Fig. 7.2: Slope stitching technique for preventing surficial failures



Fig. 7.3: Application of Geosynthetic mats for slope stability



Fig. 7.4: Geosynthetic Grids used for slope protection and vegetative growth



Fig. 7.5: Jute mats used for slope stabilization and vegetative growth



Fig. 7.6: Slope protection with geogrid helps prevent surficial rock failures



Fig. 7.7: Flexible drain pipe system used to dispose water from landslide



Fig. 7.8: PVC pipes to drain out water from unstable slopes



Fig. 7.9: Drainage Gallery/Tunnels to collect and dispose subsurface water



Fig. 7.10: Underground pipes collect sub-surface water from landslide site



Fig. 7.11: Underground covered water well for subsurface drainage



Fig. 7.12: Open well structure for collecting water from subsurface



Fig. 7.13: Boulder Gabion wall with surficial drainage system



Fig. 7.14: Surface lined drains to dispose water properly

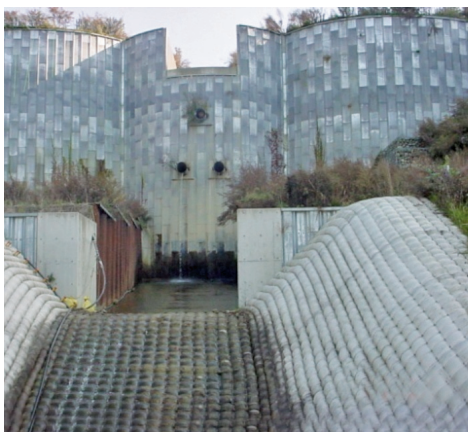


Fig. 7.15: Arch type wall structure and drainage system used for stabilizing slopes



Fig. 7.16: Well lined surface drains at a landslide site



Fig. 7.17: Debris Control Structures and Mechanism



Fig. 7.18 Timber stitching for preventing slope failure



Fig. 7.19: Sand bags used as retaining structures for preventing landslide impacts



Fig. 7.20: Block masonry retaining wall with weep holes



Fig.7.21: Net fencing to hinder rockfall movement downside



Fig. 7.22: Multiple remedial measures for stabilizing landslide site



Fig. 7.23: Empty bitumen drums filled with debris act as retaining wall



Fig. 7.24: Wire crated shotcreting



Fig. 7.25: Gabion wall made of boulders and wire baskets



Fig. 7.26: Boulder masonry walls with joints to adjust minor deformations



Fig. 7.27: Banded Random Boulder wall without masonry



Fig. 7.28: Random Boulder Gabion Wall with wire crates



Fig. 7.29: Random Rubble Boulder Masonry Wall



Fig. 7.30: Stone masonry wall with weep holes and drain pipe



Fig. 7.31: Nailing for slope reinforcement



Fig. 7.32: Steel anchors and mesh used as preventive measure



Fig. 7.33: Multi-bar reinforcement with an instrument to record wall pressure



Fig. 7.34: Rock bolting and shot creting for slope stabilization



Fig. 7.35: Rock anchors with tie beams made of reinforced concrete



Fig. 7.36: Rock bolting for slope reinforcement



Fig. 7.37: Tunnel to avert recurring and chronic landslide along highways



Fig. 7.38: Snow Gallery to avoid avalanches and debris flows along roads



Fig. 7.39: Tin Roof sheds to prevent direct impacts of rock fall



Fig. 7.40: Debris Catch Traps to avoid impacts of debris flows



Fig. 7.41: Fencing with metallic nets and girdles to support net, prevents damages to road, vehicles and passers



Fig. 7.42: Boulder wall barriers to arrest falling boulders and reduce impacts of debris flows



Fig. 7.43: Shotcreting with wire mesh and weep holes



Fig. 7.44: Geosynthetic sheets used for stabilizing slopes

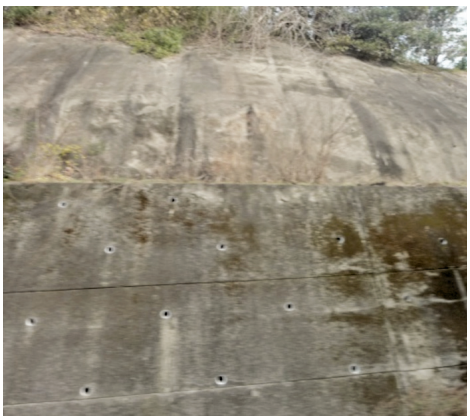


Fig. 7.45: Application of geosynthetics for slope stabilization



Fig. 7.46: Chain and cable type ring nets for preventing rock/boulder fall



Fig. 7.47: Drum wall for mitigating landslide



Fig. 7.48: Sealing of cracks with impervious material on top and pervious materials beneath the surface



Fig. 7.49: Catch nets for restraining rock fall



Fig. 7.50: Example of an open rock shed



Fig. 7.51: Rice husk drains



Fig. 7.52: Trespassing rock slide area



Fig. 7.53: French drains



Fig. 7.54: A reinforced rock ledge



Fig. 7.55: Use of polythene sheets to prevent water percolation



Fig. 7.56: Net Fencing to avoid the impacts of sliding on road and traffic



Fig. 7.57: Rock Bolting



Fig. 7.58: Rockfall blocking road



Fig. 7.59: Benching, retaining structures, drainage and plantation



Fig. 7.60: Vetiver plantation for slope stabilization



Fig. 7.61: Bamboo fencing for slope stabilization (ICIMOD)

RESPONSE TO LANDSLIDE DISASTERS



Fig 8.1: Resource personnel engaged in response to Landslide Disaster

8.1 Standard Operating Procedures for Responding to Landslides Disasters

All over the world, it has been experienced that a prompt, well-coordinated and effective response mounted in the aftermath of disasters not only minimizes loss of life and property but also facilitates early recovery. The important ingredients of an effective response system are integrated institutional arrangements, state of the art forecasting and early warning systems, failsafe communication system, rapid evacuation of threatened communities, quick deployment of specialized response forces and coordination and synergy among various agencies at various levels in dealing with any disaster. Most importantly, all the agencies and their functionaries must clearly understand their roles and responsibilities and specific actions they have to take for responding to disaster or threatening disaster situations.

The objectives of SOPs are:

a) To provide, in a concise and convenient form, a list of major executive actions involved in responding to natural disasters and necessary measures for preparedness, response and relief required to be taken;

b) To ensure that all concerned Ministries, Departments and Organisations of the Government of India, State Governments and District Administrations know the precise measures required from them at each stage and also to ensure that all actions are closely and continuously coordinated; and

c) To indicate various actions which would be required by the State Governments/UT Administrations within their sphere of responsibilities so that they may prepare and review the Contingency Action Plans accordingly.

The instructions contained in this SOP should not be regarded as exhaustive in terms of all the actions that might be considered necessary.

The SOP encompasses the following five phases of disaster management for effective and efficient response to natural disasters.

(i) **Preparedness Phase** – This will include taking all necessary measures for planning, capacity building and other preparedness so as to be in a state of readiness to respond, in the event of a natural disaster. This stage will also include development of search & rescue teams, mobilization of resources and taking measures in terms of equipping, providing training, conducting mock drills/exercises etc.

(ii) **Early Warning Phase** – This will include all necessary measures to provide timely, qualitative and quantitative warnings to the disaster managers to enable them to take preemptive measures for preventing loss of life and reducing loss/damage to the property. In the event of a natural disaster or imminent threat thereof, all the concerned agencies will be informed/ notified for initiating immediate necessary follow up action.

(iii) **Response Phase** – This will include all necessary measures to provide immediate succor to the affected people by undertaking search, rescue and evacuation measures.

(iv) **Relief Phase** - This will include all necessary measures to provide immediate relief and succor to the affected people in terms of their essential needs of food, drinking water, health & hygiene, clothing and shelter.

(v) **Restoration Stage** – This will include all necessary measures to stabilize the situation and restore the utilities.

This SOP does not cover long-term measures needed either for mitigation or for rehabilitation/recovery of the affected people and reconstruction of the area.

8.1.1 Standard Operating Procedure of GSI

Geological Survey of India, being a part of National Disaster Management Plan 2016, adopted following Standard Operating Procedure for landslides.

PRE-DISASTER ACTIVITIES		
Activities	**Time Period**	**Objectives/Outcome**
Landslide Susceptibility Zonation (LSZ) on Macro Scale (1:25,000/50,000) as per BIS guidelines	Annually in Field Season Programmes (FSP). Prioritization of areas for Susceptibility Zonation will be done by a committee of experts in GSI with inputs from various stakeholders.	Report with LSZ Map to facilitate the planners and settlers to understand the slope stability potential of the land parcels for a larger area in fragile hilly or mountainous terrains for use, development and deciding on protection measures to ameliorate the stability conditions.
Landslide Susceptibility Zonation on Meso Scale (1:5000/10,000)	Annually in Field Season Programmes. Prioritization of areas as above.	Report with LSZ Map depicting the stability status of the existing thickly populated townships/important civil engineering structures, proposed expansion schemes for urban development, new construction sites of townships in the landslide prone hilly terrain etc through much detailed stability investigations.
Monitoring of a few conspicuous landslides	Annually in Field Season Programmes on the basis of assessment of GSI and specific request of stake holders.	Development of Forecast and Early Warning systems of specific hazardous landslides.
Development of Early Warning System	Activity in pilot studies scale taken up in annually FSP.	Development of early warning systems on local and regional scales.

POST- DISASTER ACTIVITIES (RESPONSE TO DISASTER)		
Immediate response - Reconnoitory (Level-1)	Field-based ground appraisal will be taken up within 15 days of the event. Study is expected to be completed within 1 month and submission of preliminary report within 7 days after completion of field studies.	Study includes rapid assessment of damages, preliminary identification of landslides, their broad typology, identification of stretches of affected roads/ accessibility corridors and if possible, tentative identification of probable safer slopes for temporary rehabilitation. Another objective of this study is to delineate vulnerable tracts and to assess quantum of work to be taken up for the 2nd level appraisal.
Response study – Preliminary/ feasibility & multi-thematic (Level-2)	To be initiated within 1-2 months of the disaster. The total time period of this study is 6 months to 1 year including submission of reports to the stakeholders.	The main objectives of the first level of response are: • To update the existing macro-scale landslide inventory database of the area, and preparation of an event-based landslide inventory (Landslide inventory mapping- the most fundamental tool to convert susceptibility maps into hazard and risk maps which are essential for any landslide management and mitigation planning). • To evaluate tentatively the geogenic causes of this geo-hazard. • To identify the susceptible locations for fresh mass wasting and failures.

		• Preliminary assessment on effective mitigation measures for restoration of roads/accessibility tracks along NH and SH. • Preliminary evaluation of the proposal of realignment of NH and/or SH wherever essential for suggesting further more detailed site specific studies geological/ geotechnical studies. • To preliminarily identify safer and stable locations for rehabilitation/ relocation of settlement and for taking up detailed and site specific geological/geotechnical investigation in future.
Response study – Detailed site specific (Leve-3)	In annual Field Season Programmes. Prioritization of areas on the basis of level-1 and 2 studies and requests from State Governments.	Main aim is to identify activity, extent, causes and failure mechanisms of such landslides for effectively suggesting the slope protection measures; to suggest suitable and stable sites for houses buildings, suggesting realignment of roads and for preparing the foundation for constructing some critical infrastructures (e.g., bridges, rope ways, transmission tower etc.).

8.2 Emergency Operations Centre (EOC)

The EOCs/Control Rooms at National, State and District levels will be the nerve centres for coordination and management of disasters. The objectives of the EOCs shall be to provide centralized direction and control of any or all of the following functions:

- Receiving and processing disaster alerts and warnings from nodal agencies and other sources and communicate the same to all designated authorities.
- Monitoring emergency operations.
- Facilitating Coordination among primary and secondary ESF Ministry/ Departments/Agencies.
- Requisitioning additional resources during the disaster phase.
- Issuing disaster/incident specific information and instructions specific to all concerned.
- Consolidation, analysis, and dissemination of damage, loss and needs assessment data.
- Forwarding of consolidated reports to all designated authorities.

8.2.1 Location of EOC

The EOC will be set up at a suitable location and the building should be disaster resistant so as to withstand the impact of disasters and remain functional during the emergency phase.

8.2.2 Communication Network of EOCs

Under the National Communication Plan being implemented by the Government of India, the EOCs at all the three levels shall have a fail proof communication network with triple redundancy of NICNET of NIC, POLNET of Police and SPACENET of ISRO in addition to the terrestrial and satellite based communication to ensure voice, data and video transfer. Under the network, the EOCs/Control Rooms of all States will be directly connected with the NEOC/Control Room of MHA at the National level. The district EOCs/Control Rooms will be connected with the respective State EOCs/Control Room. All these control rooms will function on 24x7 basis and will be functional round the year. Suitable personnel will be selected, imparted training in the operation of Control Rooms, and posted to man these EOCs/Control Rooms.

8.3 National Disaster Response Force (NDRF)

For specialized response to both natural and manmade disasters/emergencies, NDRF has been constituted. It comprises 12 Battalions drawn from Central Para-Military Forces. Each NDRF Battalion has 18 Specialized Search & Rescue Teams including doctors, paramedics and dogs squad.

The general direction and control of NDRF is vested with NDMA while the command and supervision of the Force is vested in Director General of Civil Defence and NDRF appointed by the Central Government.

8.3.1 State Disaster Response Force (SDRF)

State Governments/SDMAs shall be primarily responsible for taking preparedness measures and building response capacity as per their vulnerability to various natural disasters and constitute State Disaster Response Forces on the pattern of NDRF.

8.4 National Disaster Mitigation Resource Centres (NDMRCs)

The NDMRCs will be co-located with the NDRF Battalions. These will also serve as repositories for NDMR bricks of relief stores for the disaster affected people, in each of the twelve NDRF locations. These will cater to the emergent requirements especially for the first 72-96 hours. These stores will supplement the reserves maintained by respective states/UTs.

In addition, these centres will assist in organising mock drills and capacity development programmes. During disasters, they will act as facilitators to the states/UTs in deployment of central resources and provide much needed additional link to the centre.

8.4.1 State Disaster Mitigation Resource Centres (SDRMCs)

State Government shall also set up Resource Centres based on their requirements to pre-position essential supplies. The States shall be responsible to constantly evaluate their own capabilities to handle that situation and project the anticipated requirements for the central resources well in time. Memorandum of Understanding may be entered into by the neighbouring States for assisting each other during natural calamity. Inter-State assistance and cooperation shall be encouraged.

8.5 Other Disaster Response Services/Organisations

In addition to NDRF at national level and SDRF at state levels, the provisions have been made to strengthen the Fire and Emergency Services as well as Civil Defence to reduce the deployment of armed forces during disaster times.

8.5.1 Fire & Emergency Services

The Fire Services in the States/UTs will be strengthened and will be made multi-hazard response units. These will be appropriately equipped depending upon their location and area of operation.

8.5.2 Civil Defence

Civil Defence volunteers will be enrolled for voluntary services in accordance with the provisions of the Civil Defence Act. The services of CD volunteers should be utilized during response to natural disasters. Civil Defence training

institutions at the National and State levels will be set up/upgraded to cater to the training of Civil Defence volunteers in relevant areas of disaster response.

8.5.3 Armed Forces

Establishment of NDRF should progressively reduce deployment of the Armed Forces, which would be requisitioned only when the situation is beyond the coping capacity of State Government and NDRF.

8.5.4 Emergency Support Functions (ESFs)

Disaster response is a multi-agency function. There will be one Lead or Primary Agency which will be responsible for managing and coordinating the response while other agencies will support and provide assistance in managing the incident. Each ESF will be headed by a lead Ministry/organisation responsible for coordinating the delivery of goods and services to the disaster area, and supported by numerous other organizations. These ESFs will form integral part of the Emergency Operation Centres (EOCs) and each ESF should coordinate its activities from the allocated EOC. Extension teams and workers of each ESF will be required to coordinate the response procedures at the disaster affected site.

8.6 Pre-Contract for Essential Commodities

All the State Governments will ensure storage and availability of essential commodities including medicine in the vulnerable districts well before the onset of monsoon and cyclone periods. They will also enter into pre-contract with the suppliers of essential commodities, medicines, tents and boats etc. on an annual basis for supply of these items at pre-decided rates within stipulated time framework.

8.7 District Level Preparedness for Response

8.7.1 Vulnerability Assessment

Each district will make its vulnerability assessment and identify potential hazards. While making such assessment, the risk involved and capacity to respond will be taken into account. The local community will be informed about their vulnerability to potential hazard/disasters through the representatives of Panchayati Raj Institutions/Local Self-Government and NGOs.

8.7.2 Contact Details

A comprehensive directory of officers involved in disaster management at various levels will be prepared for National and State levels giving their names, addresses, telephone numbers, mobile numbers, email addresses and fax numbers. Such a directory will be widely circulated and updated periodically.

8.7.3 Review

Annual review of the preparedness measures will be done at the National, State, District and sub-Divisional levels. This will ensure that all loose ends are tied up so that response during natural disasters is efficient, effective and timely. The review will also include rearrangements for essential commodities required for response and relief on emergent basis. The decentralization of authority is an important feature of good management of natural disasters. As such, the States will also review their resources and preparedness in their annual meetings, the present levels of delegation of powers to the Relief Commissioners, Additional Relief Commissioners and District Magistrates.

8.7.4 Mock Drills

Search and Rescue Teams at National and State Levels will carry out mock drills on various disasters' situations annually. Mock Drills for floods will be carried before the monsoon periods, i.e., in May-June and for cyclones these will be carried out tentatively in March and September.

For earthquakes, landslides etc., such drills can be done in March itself. At the district and State levels, mock exercises will be carried out for testing the effectiveness of all the preparedness machinery including manpower and equipments.

8.8 Resource Inventory – IDRN

Government of India has launched India Disaster Resource Network (IDRN), which is a web enabled resource inventory for disaster management. The State Governments will ensure that necessary entries have been made in the web-portal and updated at-least once in a month by the designated District Authorities.

8.9 National Crisis Management Committee (NCMC)

1. On direction of the Cabinet Secretary, meeting of the NCMC shall be convened.
2. NCMC will take stock of the situation.
3. It shall give necessary directions to NEC, MHA, other Central Ministries/ Departments/Agencies and State Governments.

8.10 National Executive Committee (NEC)

1. JS (DM), MHA shall take order from Union Home Secretary for convening the meeting of NEC.
2. NEC shall assess the situation and give directions to the concerned

Ministries/Departments of the Govt. of India, the State Governments and the State Disaster management Authorities regarding measures to be taken by them in response to any specific threatening disaster situation or disaster.

3. NEC shall coordinate responses of various agencies.

4. It shall depute a team of officials to visit the affected States for on the spot assessment of the situation and coordinate with State Governments.

5. It shall mobilize resources and dispatch them to concerned States.

6. It shall monitor and review the situation on a regular basis.

8.11 Role of the Nodal and Other Central Ministries/Departments

1. On activation of national ESF Plan, the concerned Ministry/Department shall depute the designated officials to NEOC for coordination of response measures.

2. Ministries/Departments shall coordinate with their counterparts and make assessment of immediate needs in their respective sectors.

3. Ministries/Departments shall provide resources both in terms of men and material for assistance of the States on request of NEC.

8.12 State Level

Following shall be the sequence of action at the State level:

8.12.1 State Emergency Operation Centre (SEOC)

1. On receipt of information either from NEOC/DEOC or from Early Warning Agencies or any other reliable sources, State Emergency Operation Centre shall be fully activated as per laid down protocol.

2. SEOC shall issue alerts/warning to all designated authorities at State and Districts levels including Public Information to AIR/Doordarshan/Press.

3. SEOC shall send First Information Report to NEOC, MHA and thereafter Daily Situation Report till situation normalizes.

4. SEOC shall collect all relevant information and appraise the status to the designated decision making authorities.

5. It shall arrange Meetings of SEC.

6. It shall activate ESFs of State if the situation so demands.

8.12.2 State Disaster Management Authority (SDMA)

1. Meeting of the SDMA shall be convened on the direction of Chief Minister.
2. SDMA will take stock of the situation.
3. SDMA shall give necessary directions to SEC, Deptt. of Disaster Management and other Departments/agencies of the State Government and concerned DDMAs.
4. SDMA shall decide on Inter-State assistance and cooperation.

8.12.3 State Executive Committee (SEC)

1. Secretary (DM) shall convene the meeting of SEC.
2. SEC shall assess the situation and give directions to the concerned Departments/agencies of State Governments and DDMAs concerned regarding measures to be taken by them in response to any specific threatening disaster situation or disaster.
3. SEC shall coordinate responses of various agencies.
4. SEC shall requisition NDRF or Armed Forces if the situation so demands.
5. SEC may depute a team of officials to visit the affected Districts for on the spot assessment of the situation and supervising the response & relief measures.
6. SEC shall mobilize resources and dispatch them to concerned Districts.
7. SEC shall monitor and review the situation on a regular basis.
8. SEC shall keep the NEC and NDMA informed of the situation.
9. SEC shall constantly evaluate their own capabilities to handle that situation and project the anticipated requirements for the central resources well in time.
10. SEC shall deploy State level Incident Command Team on the request of the DDMA as and when required.
11. In the event of calamity of severe nature, the SEC will consider appointment of Senior Officers, delegate powers and assign specific areas for timely and effective, efficient management of disasters.
12. SEC will also take necessary steps to pool the resources for better management of crisis situations. This includes the pooling of food grains funds and other resources available in the districts under various Government schemes. However, these resources will be reimbursed to the respective schemes/Departments once the situation becomes normal.

8.12.4 Role of Other Departments/Agencies

1. On activation of State ESF Plan, the concerned Department/Agency shall depute the designated officials to SEOC for coordination of response measures.
2. Departments/Agencies shall coordinate with their National counterparts and mobilize central assistance, such as specialized manpower, equipments, materials etc. to meet immediate needs in their respective sectors.
3. Departments/Agencies shall provide resources both in terms of men and material for assistance to the DDMAs.

8.13 District Level

Following shall be the sequence of action at the District level:

8.13.1 District Emergency Operation Centre (DEOC)

On receipt of information either from NEOC/SEOC or from Early Warning agencies or field functionaries from Sub-divisions, Blocks, Tehsils or any other reliable sources, District Emergency Operation Centre shall be activated fully as per laid down protocol.

- DEOC shall issue alerts/warning to all designated authorities at the District level.
- DEOC shall send First Information Report to SEOC and NEOC, MHA and thereafter Daily Situation Report till situation normalizes.
- DEOC shall collect all relevant information and appraise the status to the designated decision making authorities.
- DEOC shall maintain all records and documents related to the response.

It shall activate ESFs of District if the situation so demands.

8.13.2 District Disaster Management Authority (DDMA)

1. DDMA shall assess the situation and give directions to the concerned Line Departments/Agencies at the District level regarding measures to be taken by them in response to any specific threatening disaster situation or disaster.
2. DDMA shall take such other action as may be necessary for coordinated response to natural disasters. These may include the following:
   a) Assessing situations based on reports received from various sources and giving directions to different agencies for immediate response, relief and restoration of critical infrastructure.

b) Reviewing resources and capacities of different agencies to deal with the situations and giving directions for pooling available manpower, equipments and resources available with different agencies for speedy and effective response.

c) Requisitioning assistance from NDRF / Armed Forces / other specialized agencies, if necessary.

d) Coordinating with civil society and Non-Governmental Organizations for supplementing the efforts of government agencies.

e) Monitoring and reviewing the situations on a regular basis.

8.14 First Response

In disasters where there are no early warning signals available, the community members will be the first responder. However, immediate support and assistance shall be available from other important first responders like the police, State Disaster Response Force (SDRFs), Fire and Medical Services.

Other important responders will be the Civil Defence, Home Guards and youth organizations such as NCC, NSS and NYKS drawn from local units.

8.14.1 First Information Report

DEOC shall send First Information Report immediately to SEOC, NEOC and all designated authorities/agencies. FIR shall invariably give an account of the severity of the disaster, damage & loss caused, locally available capacities and priority. The FIR shall briefly summarize,

i. Severity of the disaster

ii. Actions being taken locally

iii. Local coping capacities (including locally available resources)

iv. Immediate priorities for external relief required and approximate quantities for the same

v. Best logistic means for delivering relief

vi. Forecast of possible future developments including new risks.

The First Information Report on occurrence of natural calamity shall be sent to SEOC, NEOC and MHA, Government of India within a maximum of 24 hours of occurrence of calamity.

8.14.2 Daily Situation Report

A standardized form for reporting of situation report on daily basis has been prepared for the District, State and National levels. This format will be used uniformly for all the States. The State Governments shall submit situation report to the MHA on six hourly basis during first three days thereafter daily till the situation becomes normal.

8.14.3 Air Dropping of Food in Inaccessible Areas

Airdropping of food and essential commodities shall be undertaken in inaccessible areas. The State Governments/district authorities will liaise with Air Force Authorities and the NEC, Ministry of Home Affairs, Government of India for requisitioning the helicopters.

The agencies for preparing food packets for airdropping and items as well quantity to be included in the food packets will be communicated by the district administration in advance.

8.14.4 Rapid Damage Assessment

Rescue & relief operations shall be based on ground assessment of damage and losses. Preliminary assessment shall be carried out immediately within 24 hours for planning the response. Teams shall be constituted of officials drawn from various sectors to make assessment on the basis of on the spot visits, aerial surveys and information collected from primary and secondary sources.

8.14.5 Immediate Repair of Infrastructure

The Departments/Agencies of the State Governments responsible for various infrastructural facilities such as electricity, drinking water, telecommunication etc shall repair the damage caused by the disaster and will take immediate steps to restore damaged essential services so that rescue & relief operations are conducted smoothly.

8.14.6 Disposal of Dead Bodies

The State Government/District authorities shall earmark authorities responsible for disposal of bodies in the event of mass causalities. The process of identification and handing over to next of kin shall be followed. Mass burial/ disposal of bodies shall be done as a last resort. Local religious & cultural practices shall be honoured while disposing dead bodies.

8.14.7 Disposal of Carcasses

The State Government/District authorities shall earmark authorities responsible for disposal of carcasses in event of mass destruction. The process to be followed for mass disposal of carcasses shall be decided by Department of Animal Husbandry.

8.14.8 Information and Media Management

During disaster situations, the dissemination of accurate information through electronic and print media is very important. Regular press briefings shall be made by District Magistrate/Collector or his authorized representative at pre-designated time as a single source of information from Government.

8.14.9 Relief

In the aftermath of disasters the affected people must be looked after for their safety, security and the well being and provided food, water, shelter, clothing, medical care etc. so as to ensure that the affected people live with dignity. State Governments shall be responsible for providing prompt and adequate relief assistance to the victims of disasters. The minimum standards of relief shall be laid down by the NDMA and by the SDMAs in terms of sections 12 and 19 respectively of DM Act 2005.

8.14.10 Food & Nutrition

People affected by disasters may be deprived of food and therefore food aid shall be provided to sustain life. The following measures shall be under taken:

1. Where necessary free distributions of food shall be made to those who need the food most.
2. The food distribution will be discontinued as soon as possible.
3. Wherever possible dry rations shall be provided for home cooking.
4. Community Kitchen for mass feeding shall be organised only for an initial short period following a major disaster particularly where affected people do not have the means to cook.
5. While providing food assistance, local food practices shall be kept in mind and commodities being provided must be carefully chosen, in consultation with the affected population.
6. Foods must be of good quality, safe to consume, and appropriate and acceptable to recipients.
7. Rations for general food distributions shall be adopted to bridge the gap between the affected population's requirements and their own food resources.
8. Food distributed should be of appropriate quality and fit for human consumption.
9. Food should be stored, prepared and consumed in a safe and appropriate manner at both household and community levels.

10. Food should be distributed in a responsive, transparent, equitable manner.

11. NGOs, CBOs and other social organizations should be involved for supplementing the efforts of the Government.

12. The nutritional needs of the population should be met and malnutrition and micronutrient deficiencies identified at risk groups should be also addressed.

8.14.11 Water

Water supply is invariably affected in natural disasters. Safe drinking water might not be available particularly in hydro-meteorological disasters.

The following measures shall be taken by the State Governments/district administrations:

1. The State Governments shall identify alternative sources of water and make necessary arrangements for supply to the affected population.

2. The State Governments shall ensure that affected people have adequate facilities and supplies to collect, store and use sufficient quantities of water for drinking, cooking and personal hygiene.

3. It shall be ensured that drinking water supplied conforms to the prescribed quality standards.

4. It shall be ensured that water made available for personal and domestic hygiene should not cause any risk to health.

8.14.12 Health

During post disaster phase many factors increase the risk of diseases and epidemics. These include poverty, insecurity, overcrowding, inadequate quantity and quality of water, poor environmental and sanitary conditions, inadequate shelter and food supply.

8.14.13 Medical Response

Medical response has to be quick and effective. The execution of medical response plans and deployment of medical resources warrant special attention at the State and District levels in most of the situations. The following measures shall be taken by the States/Districts:

1. A mechanism for quick identification of factors affecting the health of the affected people shall be established for surveillance and reporting.

2. An assessment of the health and nutritional status of the affected population shall be done by experts with experience of emergencies, if possible, local knowledge.

3. The voluntary deployment of the nearest medical resources to the disaster site, irrespective of the administrative boundaries, will be warranted.
4. Mobile medical hospitals and other resources available with the Central Government shall be provided to the States/UTs.
5. Adequate supply of medicines, disinfectants etc. shall be made.
6. Where necessary inoculation shall be done.
7. Vaccination of the children & pregnant women shall be undertaken.
8. Vector-borne diseases are a major cause of sickness and death in many disaster situations. Vector control measures shall be undertaken.
9. Water borne diseases may cause sickness and deaths and therefore adequate measures shall be taken to prevent such outbreaks.

8.14.14 Mental Health Services

Disasters cause tremendous mental trauma to the survivors. Psychosocial support and mental health services should be made available immediately in the aftermath of disaster so as to reduce the stress and trauma of the affected community and facilitate speedy recovery. The following measures shall be undertaken by States/UTs:

1. A Nodal Mental Health Officer shall be designated for each affected District.
2. Rapid needs assessment of psycho-social support shall be carried out by the Nodal Officer/Health Department.
3. Trained man power for psycho-social and mental health services shall be mobilized and deputed for psycho-social first aid and transfer of critically ill persons to referral hospitals.
4. Psycho-social first aid shall be given to the affected community/ population by the trained community level workers and relief and rescue workers.
5. Psycho-social first aid givers shall be sensitized to local, cultural, traditional and ethical values and practices.
6. Psycho-social support and mental health Services shall be arranged in relief camps set-up in the post disaster phase.
7. Where large number of disaster victims have to be provided psychosocial support a referral system for long term treatment shall be followed.
8. The services of NGOs and CBOs may be requisitioned for providing psycho-social support and mental health services to the survivors of the disasters.

9. Community practices such as mass prayers: religious discourse etc. should be organized with preventive and promotive mental health services.

8.14.15 Clothings & Utensils

During disasters, people lose their clothings and utensils. The following measures shall be taken by State/District authorities:

1. The people affected by the disaster shall be provided with sufficient clothings, blankets etc. to ensure their dignity, safety and well-being.
2. Each disaster-affected household shall be provided with cooking and eating utensils.

8.14.16 Shelter

In a major disaster a large number of people are rendered homeless. In such situations shelter becomes a critical factor for survival of the affected people in the initial stages of a disaster. Further, shelter becomes essential for safety and security and for protection from the adverse climatic conditions.

Shelter is also important for human dignity and for sustaining family and community life in difficult circumstances. The following measures shall be taken by State/District authorities for providing shelter to the affected people:

1. Disaster affected people who have lost their dwelling units or where such units have been rendered damaged/useless shall be provided sufficient covered space for shelter.
2. Disaster affected households shall be provided access to appropriate means such as artificial lighting to ensure personal security.
3. Disaster-affected households shall be provided with necessary tools, equipment and materials for repair, reconstruction and maintenance for safe use of their shelter.

8.14.17 Relief Camp

The following steps shall be taken for setting up relief camps in the affected areas:

1. Adequate numbers of buildings or open space shall be identified where relief camps can be set up during emergency.
2. The use of premises of educational institutions for setting up relief camps shall be discouraged.
3. One member of the Incident Command Team of the district trained in running and management of relief camps will be deputed for management of relief camps.

4. The requirements for operation of relief camps shall be worked out in detail in advance.
5. Agencies to supply the necessary stores will be identified in the pre-disaster phase.
6. The temporary relief camps will have adequate provision of drinking water and bathing, sanitation and essential health-care facilities.
7. Adequate security arrangements shall be made by local police.
8. Adequate lighting arrangements shall be made in the camp area including at water points, toilets and other common areas.
9. Wherever feasible, special task forces from amongst the disaster affected families will be set up to explore the possibility of provision of food through community kitchens, provision of education through the restoration of schools and anganwadis.
10. Efficient governance systems like entitlement cards, identification cards, bank accounts for cash transfers etc shall be developed.

8.14.18 Sanitation and Hygiene

Sanitation services are crucial to prevent an outbreak of epidemics in post disaster phase. Therefore, a constant monitoring of any such possibilities will be necessary. It should be ensured that disaster-affected households have access to sufficient hygiene measures. Soap, detergents, sanitary napkins and other sanitary items should be made available to ensure personal hygiene, health, dignity and well-being. In the relief camps, toilets should be sited, designed, constructed and maintained in such a way as to be comfortable, hygienic and safe to use.

8.14.19 Provision of Intermediate Shelters

In the case of devastating disasters, where extreme weather conditions can be life-threatening or when the period of stay in temporary shelters is likely to be long and uncertain, the construction of intermediate shelters with suitable sanitary facilities will be undertaken to ensure a reasonable quality of life to the affected people. Such shelters shall be designed to be cost effective and as per local needs.

8.14.20 Management of Relief Supplies

Speedy supplies of relief materials shall be ensured in relief operations. A supply chain management system shall be developed. Standard Protocols shall be put in place for ensuring the procurement, packaging, transportation, storage and distribution of relief items. A mechanism shall be developed for receiving donations in cash or kind and their distribution.

8.14.21 Transparency in Relief

SDMAs/DDMAs shall take all appropriate measures for transparency in the relief operations. Affected people shall be apprised of the nature and quantum of relief admissible to them. Proper formats will be developed to acknowledge the receipt of relief materials and their further distribution.

8.15 Landslide Alerts and Warnings

Geological Survey of India issues alerts and warnings to all designated authorities and agencies of the Central Government and State Governments/ District Administration for landslides in the following categories.

Category IV: Landslides of small dimensions that occur away from habitations and do not affect either humans or their possessions. These may occur near infrastructural installations, agricultural and forestlands and may not affect them in a significant manner. These slides may include small incidents that block communication routes for short periods or do not affect the society in a significant manner. - YELLOW

Category III: Landslides which are fairly large and affect infrastructural installations like strategic and important highways and roads, rail routes and other civil installations like various appurtenant structures of hydroelectric and irrigation projects. The landslides that enter large water bodies like reservoirs of hydroelectric projects and could damage some of components of these projects. ORANGE

Category II: The landslides that may occur on the fringes of inhabited areas and result in limited loss of life and property. Landslides which result in blockade of courses of relatively smaller natural drainages and if the blockade is of relatively smaller dimensions its impact would be of a lower order. Although a threat potential is there, it may not be immediate. ORANGE

Category I: Landslides of large dimensions that are located over or in close vicinity of inhabited areas like urban settlements or fairly large rural settlements. Activity on these slides can result in loss of human lives, dwellings on large scale. These slides may also inflict heavy losses on urban infrastructure. The slides that block busy pilgrimage routes during peak times resulting in hardships to thousands of pilgrims and sometimes resulting in loss of human lives. Landslides which result in blockade of courses of relatively large natural drainages and if the blockade is fairly large it could lead to formation of a very large reservoir of water behind it. Formation of a large landslide dam could result in sudden flooding of areas located upstream. Abrupt breaching of landslide dam would suddenly release enormous quantities of water in the downstream areas leading to flash floods that could result in loss of life and damage to property on large scale. RED

8.16 FORMAT FOR FIRST INFORMATION REPORT ON OCCURRENCE OF NATURAL CALAMITY

(To be sent to MHA, Government of India within maximum of 24 hours of occurrence of

Calamity)

From: State ---------- Date of Report ----------

To

JS (DM), MHA (fax : _____ ; email :_____)

I/c National Integrated Operations Centre, MHA (fax: _____; email:_____)

a. Nature of Calamity

b. Date and time of occurrence

c. Affected area (number and names of affected districts)

d. Population affected (approx.)

e. Number of Persons

- □ Dead
- □ Missing
- □ Injured

f. Animals

- □ Affected
- □ Lost

g. Crops affected and area (approx.)

h. Number of houses damaged

i. Damage to public property

j. Relief measures undertaken in brief

k. Immediate response & relief assistance required and the best logistical means of delivering that relief from State/National

l. Forecast of possible future developments including new risks

m. Any other relevant information



Fig. 8.2: Fire Guards and Civil Defence personnel extricating a dead body



Fig. 8.3: Community volunteers searching and recovering bodies buried under debris



Fig. 8.4: Bull dozer clearing landslide debris from the road



Fig. 8.5: Fire Guards and Civil Defence personnel extricating a dead body



Fig. 8.6: Labour and Bull dozer kept for clearing debris, buried by the landslide



Fig. 8.7: People and livestock under huge mass of rock debris



Fig. 8.8: Steep and negative slope -a challenges to landslide managers



Fig. 8.9: JCB clearing debris



Fig. 8.10: Bull dozer used for road clearance



Fig. 8.11: JCB and Loader used for removing and disposing landslide debris



Fig. 8.12: Community workers rescuing children buried under landslide



Fig. 8.13: First responders trying to help landslide victims



Fig. 8.14: Tree logs being used to make temporary bridge in landslide affected area



Fig. 8.15: Searching for buried people in bad weather conditions



Fig. 8.16: Mechanical breaking and removal of big boulders



Fig. 8.17: Bulldozer clearing landslide debris from road side



Fig. 8.18: Failure of retaining structures due to weak foundation



Fig. 8.19: Inspecting the damage by landslide in a residential area



Fig. 8.20: Community and Civil Defence acting together for search & rescue



Fig. 8.21: Removing debris and searching children buried underneath



Fig. 8.22: People trying to trespass a landslide



Fig. 8.23: First Aid Vehicle (108) to assist disaster victims



Fig. 8.24: Road washed off by landslide makes access/operations difficult for rescue & relief



Fig. 8.25: Rescuers helping people cross a damaged bridge and road



Fig. 8.26: Local leaders visiting a landslide affected area



Fig. 8.27: Local leaders along with civil administration people visiting a landslide affected site



Fig. 8.28: Water supply by tanks after water pipe lines got disrupted by landslide



Fig. 8.29: Local people assisting in disposal of dead bodies



Fig. 8.30: Canine search for locating human bodies under landslide debris



Fig. 8.31: Shortage of Gas and Fuel supply due to road disruption by landslide

8.17 Rapid Damage and Loss Assessment

Disaster brings in its wake damages to life, property, infrastructure, economy and environment. For adequate and effective response to disasters it is of paramount importance to assess the extent of physical harm to assets, property and infrastructure which render them less valuable or less effective.

The objective of Rapid Assessment is to determine the precise nature and extent of damage so that Rescue and Relief measures are undertaken in the affected area. The rapid damage assessment has following major components:

i. Geographical area impacted

ii. Structural damage to buildings, Housing stocks, establishment etc.

iii. Damage to roads & bridges, public buildings, shops, workshops, stalls etc.

iv. Damage to water supply lines, electricity supply lines, public utilities etc.

v. Damage to agricultural crops, livestock, etc.

Tools for Rapid Assessment

- Arial surveys
- Photographs, video graphs of the affected area
- Satellite imageries
- Field reports
- TV/Press coverage
- Visual Inspection Checklist
- Camera
- Laptop
- Notebook
- GIS Map
- GPS
- Compass
- Charging apparatus and electric supply for camera, GPS, laptop etc.

8.18 Proforma for Rapid Damage Assessment Report (Radar) of a Landslide

Rapid Damage Assessment Report				
Date of Survey:		**Time:**		
Venue:				
State:	**District:**	**Block:**	**Tehsil:**	**Village:**

A. Event Details				
	Geographical Location (Longitude, Latitude, Altitude)			
	Event Type (Slide/Flow/Fall/Subsidence)			
	Magnitude of Disaster (Scale & Level)			
	Response (Community/Agency)			
	Chronology of events – (Time of Initiation, Period/Duration of activity, Sequence of activity, cause of disaster and consequences as well as response); Association with impacts of any other hazard like earthquake, thunderstorm, lightning, flash floods etc., if any should be mentioned			
	Total Number of Villages/Towns/Cities Affected in the surveyed area:			
	Total Population Affected (males/females/children):			
	Number of Families Affected:			
B. Social Impacts on Life				
	Humans	Deaths	Male	
			Female	
			Children	
			Physically or Mentally impaired	
		Injured		
		Buried/Missing		
		Homeless		
		Orphans	Male	
			Female	
	Livestock (Cows/Goats/Sheep/Hens & Chickens/Mules etc.)			
	Quantity of dead animals (Heads)		Average replacement cost (Rs.)	Total value of damages (Rs.)

C. Damage to Buildings/Structures (Residential, Government and Commercial)				
	Number of totally destroyed	Number of partially Damaged	Average replacement cost per unit	Total value damages
D. Damages to Agricultural field				
	Damages to Agricultural assets	No. of totally destroyed	No. of partially destroyed	Total value of damages
	Damages to crops	Quantity of affected areas (Hectares)	No. of totally destroyed (Kilograms)	Total value of damages
D. Landscape Changes/Ground Failures/Environmental Impacts				
E. Impacts on Infrastructure				
		Number of totally destroyed	Number of partially Damaged	Average replacement cost per unit	Total value damages
	Transportation (Vehicles/Roads/ Bridle path/ Bridges/Footpath)				
	Communication (Wireless/Phone/ Mobile/Internet / Pager)				
	Drinking Water Supply				
	Power Supply				
	Sewerage and Sanitation				
F. Projects/Activities Affected				
		Area destroyed (hectare)		Average replacement cost per unit	Total value damages
	Hydel/Projects				
	Grain Grinders (Gharats)				
	Other Projects				

G. Total Losses (Approx.)	
	Tangible (in rupees)
	Intangible (in brief description)
H. Additional Information	
	Name & Signatures of the Survey Team with designation & duties performed Team Leader (Overall Damage Assessment) JE/AE, PWD (assessed buildings/structures) AE/JE, Irrigation (Infra-structures) District Geologist (ground failures) Section Officer, Revenue (Impacts on life)
	Note: A local map, hand-held GPS, measuring tape, digital camera, RDAR Proforma and notebook with a pen, pencil & eraser should be carried by the team and data/information may be fed in excel sheet after completion at the NIC Office for use by various authorities and public dissemination on a web portal.
	Photos/Sketches/Maps showing extent and distribution of damages **Note:** North and scale may be marked on the map

8.19 Search and Rescue Skills

Searching and Locating: A set of techniques and procedures whose purpose is to obtain a response or indication of the presence of live victims within a landslide.

Composition of Search Team: A squad leader with 5 or more rescuers.

Squad Leader: He/she will be responsible for developing the search plan, drawing diagrams, keeping documentation and making recommendations to the Incident Commander.

Rescuers: To carry out the search operation physically or as outlined by the squad leader.

Basic Tools: Probing Radar, Radio equipment to communicate with team members and Command Post, Walkie-talkies, Work site marking supplies, Flags, Cones etc.

Warning and alert devices: Megaphone, Whistle, Hammer, Flags, Horn etc.

Reconnaissance and Vision: Binoculars, Camera, Flashlight, Search Diagrams, Technical search equipment, pen, board etc.

Steps for Searching and Locating

- Compile and analyse available information; secure the scene
- Inspect and evaluate the worksite
- Rescue victims with easy access on or near the surface
- Select the area for searching
- Select the proper tools for searching
- Conduct an appropriate search pattern
- Initiate pre-hospital treatment for the victims
- Confirm the presence and location of potential victims with resources, information and equipment available

8.19.1 Search Modalities

Hasty Search/Primary – It is conducted to quickly detect the presence of survivors on the surface. Hasty search accomplishes the following: rapid detection of victims, set priorities.

Extensive (Grid) Search/Secondary – This type of search is conducted in a methodical manner to pinpoint the exact location of victims. It is designed to cover the entire assigned area carefully and in detail. An extensive or grid search accomplishes the following: a thorough systematic search, redundant checks, and use of alternate search resources.

8.19.2 Search Methods

Physical Search – These operations do not require specialists or unique, expensive equipment. These only require senses and some established procedures. This search tactic is the first and sometimes, the only search method used by local rescuers who do not possess technical or canine search resources.

Canine Search – It uses the acute sense of smell among dogs, especially trained to detect live humans. Certified canine teams with highly specialized dogs (Fig.8.30) provide the best way to locate trapped victims in a large area in the shortest time. They are able to access the areas too small or too unstable for humans to enter. Canines can be used for hasty and extensive operations. A thorough site search with 2 well-trained dogs has a high probability of conclusive results. The search dogs are trained to detect those victims that are still alive. Rescuers should coordinate their activities with that of canine team during their search operation.

Technical Search – It requires highly trained personnel and specialized equipment for sound and temperature detection, video, vibration etc. It can be carried out using specially manufactured or locally improvised equipment.

8.20 Basic Rescue Skills

8.20.1 Knot Tying

Although there are other knots and hitches in rescue work, the ones mentioned here are the most common and should be learned if you are passionate to be a good rescue worker. Lives may depend on your being able to tie the right knot securely at the moment it is needed in light or dark, rain or shine. The use of natural fibre rope must be discouraged for the rescue of human lives. For most other operations, natural fibre rope will suffice. Beware of ropes or straps that have been in the sun for some time; this may have weakened them. The important knots are simple figure eight knot, reef knot, clove hitch, figure eight-on-a-bight, sheet bend, bowline, round turn and two half hitches, timber hitch etc.

8.20.2 Emergency Handling of Casualties

The prime purpose of all rescue work is to arrange medical help as quickly as possible and get the injured people out of danger. When there are many casualties, the aim becomes one of trying to ensure the best use of time to effectively help the most people. This decision-making process is called "triage." In triage, those responding to the incident are called upon to examine all casualties quickly and rank them according to the level of need for both first aid and transportation to medical help. In any rescue or multiple casualty situations, confusion may be evident. It is essential that individuals assigned the job of helping injured people should remain calm and act quickly but carefully, always remain attentive to potential hazards to either themselves or other people in the area. In any situation where you suspect a possible head or spinal injury, if the life of the person is not under immediate threat, seek the help of specialists. If it is essential to move the casualty, and if one's life is not in danger, maintain normal anatomical alignment (nose, belly button, inside of ankles). If the person is not in this position, get the help of qualified personnel.

Try to establish quickly how many casualties are there in the incident. Go to the nearest casualty, provided it is safe, and check for responsiveness. If the person does not answer or respond to attempts to wake him/her, check to see if the person is breathing. The aim is to keep the person alive until medical help arrives. One should not waste time dealing with minor injuries until all casualties have been found and stabilized.

If the person is not breathing, try to find someone nearby who is able to do artificial respiration until help gets there. If the casualty is bleeding severely,

apply a pressure bandage before moving to the next casualty. Remember, time is valuable. Give first aid for life-threatening conditions quickly and go to the next casualty.

8.20.3 One-rescuer Methods

Never move the casualty any further than needed. Scan the escape routes to determine the best method and route to carry the casualty. If one is alone and must move the casualty quickly, try one of the following rescue carries: human crutch, drag carry, blanket drag, pick-a-back, removal downstairs, firefighter's crawl etc.

8.20.4 Two-rescuer Methods

If there are two people to do the carrying, try one of these emergency methods: chair lift, two-hand seat carry, or four-hand seat carry method.

8.20.5 Multi-rescuer Methods

If there are more than two people to do the job, there are a number of different methods that can be used to carry casualties. These include blanket lift, three-person lift and carry, improvised stretchers, blanket and poles stretcher, stretchers from found materials, blanketing stretchers, lashing casualty to stretcher, carrying stretchers etc.

8.21 Five Stages of Rescue

No hard and fast rules can be laid down for rescue work but, generally speaking, five stages of rescue are followed by trained rescue parties.

Stage 1- Reconnaissance and dealing with surface casualties

Examine the site. Deal with surface casualties. Gather all possible information about other occupants of the building.

Stage 2 - Location and removal of lightly-trapped casualties

Immediate search-accessible areas for casualties, who can be rescued with minimal effort. Maintain contact with casualties inside who can be seen or heard but who cannot be moved immediately.

Note: The use of trained air-scenting dogs can greatly increase the likelihood of finding trapped and conscious or unconscious casualties. Dogs used in this fashion should not be worn collars or harnesses that might trap itself when moving through debris. The paws should be checked regularly for injuries.

Stage 3- Exploration of likely survival points

Search the ruins and rescue all persons who can be seen or heard. This may include a calling and listening period.

Stage 4 - Further exploration and selected debris removal

Search farther into the ruins where the chances of trapped people remaining alive seem remote. This may include removing debris from the more likely places where casualties may be located.

Stage 5- Systematic debris removal

Strip selected areas of debris until all supposed casualties are accounted for. This includes removal of the dead bodies and detached body parts. Identify buildings that have already been searched by using spray paint or signs. This method can also be used to mark buildings that may contain bodies.

8.22 Some Do's and Don'ts

Practice in the dark

To be a good rescue worker one should master all skills outlined in this booklet. One should be able to do them in the dark. Practice tying knots blindfolded and in cramped quarters.

What should be done before an emergency

- Volunteer to get involved with your municipality's implementation of an Emergency Plan. One should call local authorities and let them know he is interested.
- Make a family emergency plan.
- Prepare a family emergency kit in case one need to evacuate the premises.
- Get first aid training.
- Know a list of emergency telephone numbers.
- Get all the safety equipment (gloves, safety glasses, helmet, work boots, anti-dust mask) for protection ready

What to do

- Think before you act and be careful.
- Warn or have somebody warn the authorities about the damages and the number of casualties in your sector.
- Do a reconnaissance before starting the work. This will not amount to wasting of invaluable time..
- Walk as closely to the wall as possible when on damaged stairs and upper floors.

- Use gloves when removing debris by hand.
- Be careful how you move debris from the vicinity of a casualty.
- Protect a casualty from falling debris and dust by using blankets, tarpaulins, corrugated iron sheets, etc.
- Keep off wreckage as much as possible; leave it undisturbed or the neutral voids may be destroyed by further collapse.
- Be careful how you remove debris and obstacles, especially from voids, to prevent further collapse.
- Exercise great care when using sharp tools in debris.
- It is often necessary to use props or struts to strengthen a floor loaded with debris before passing over or working underneath it.
- In situations where the number of casualties is greater than the help available, do not waste time. Use your resources wisely.
- Examine a casualty before removal and give first aid for all life-threatening conditions.
- Free the nose and mouth of a casualty from dust and grit to ease breathing.
- Keep the casualty warm to slow the progress of shock.
- Make sure that the stretcher is properly blanketed so that the casualty has maximum amount of warmth and comfort.
- Use appropriate procedures to carry a stretcher over debris and obstacles. Keep a list of all casualties handled.

Don't

- Move an injured person without rendering first aid unless the casualty is in immediate danger.
- Smoke or light a matches stick in case there is a gas leak.
- Crawl over debris or disturb parts of the damaged structure unless you are compelled to do so by circumstances.
- Pull timber out of the wreckage indiscriminately to cause further collapse.
- Enter any site without informing the other members of your party or, if possible, without a companion to help in case of accident.

- Touch loose electrical wiring.
- Throw debris aimlessly - you may have to move it again.

8.23 Safety in Rescue Operation

Rescue operations are the most complex and difficult activities that first responder teams face in the line of duty. There may be numerous factors affecting safety during a rescue operation. Every rescuer should follow some basic safety rules like:

- **Personal Protective Equipment**: Anyone entering the area must be wearing all required personal protective equipment.
- **Hygiene**: To reduce as much as possible the contamination or contagion, one must wash his/her hands with soap and water before and after entering the work area; before and after eating and before and after using baths/toilets.
- **Safety Officer**: During the rescue work, one individual from the team will be designated safety officer. He/She will be in-charge of all safety related matters and will have the authority to partially or completely halt all activities if needed.
- **Group Safety**: Each instructor and team leader will also be responsible for the safety of personnel in the respective groups. Should one observe any unsafe action or condition, or an emergency, the safety officer should be alerted immediately. For this purpose, everyone will have an emergency whistle to use in an emergency.
- **Whistle Signals**: The safety officer will use the whistle to give alarm signals and alerts in the work area using the following signal system
    - o One long signal – stop all work and listen for instructions
    - o One long, one short – continue working
    - o Three short signals – alarm signal, evacuate the area immediately to a previously designated safety zone
- **Safety Zone**: The safety officer will establish a safety zone near the work area. The safety zone will be used in case of any emergency requiring evacuation of the work area.
- **Emergency Medical Services**: A first aid kit and a means of communications must be made available to ensure EMS arrival within 15 minutes, should the need ever rise.
- **Drinking Water**: During rescue work, the rescuers must carry a canteen or drinking water, to prevent dehydration.

- **Team safety**: All operations involving use of tools and equipment must be conducted in pairs, so that one person can use the tools/equipment while the other acts as a safety lookout. The person for safety lookout will use the signal system in which one tap on shoulder means to stop working, and two taps means to continue.
    - o The Rescue Team Leader is responsible for the safety of his team members
    - o When there is no designated safety officer in CSSR team, every team member must remain acutely aware of safety at all times and look out for each other
    - o Every CSSR team members are responsible for giving warning about and preventing unsafe actions and/or conditions during all phases of a CSSR operation

8.24 Safety is Everyone's Responsibility

Victim Management – The following concepts and procedures should be applied starting from the moment the search is initiated until the last victim is found.

Precautions during a search

- Never make inappropriate comments and keep a positive note. Always assume someone is listening to you (may be the victim?)
- The victim is in the worst possible position and fighting to stay alive, and one can enhance their chances of survival by being positive about the possibility of finding and extricating them.
- You may be first person whom the victim is able to communicate with: therefore, it is important to project a sense of confidence and hope.

Steps for initial contact with a located victim

- Identify and overcome language barriers
- Identify yourself as a rescuer, projecting confidence and calm in your voice and choice of words
- Obtain the following information: Name, Adult or Child, Type and extent of injury, Hydration Status, Warmth, Degree of Confinement
- Provide emergency medical help as quickly as possible
- Ask about other potential victims and their condition
- Inform the victim of rescue operations

- Inform the victim if one has to leave for short periods
- Provide protection as much as possible from the environment
- Consider direct or indirect interventions of a relative or friend etc.

8.25 First Aid

First Aid is the temporary help given to an injured or a sick person before professional medical treatment: It may also be termed as an emergency care offered to a victim of sudden illness or injury until more skillful help is available. This timely assistance, comprising of simple medical techniques, is most critical to the victims and may, often, save life and improve vitals. Any layperson can be trained to administer first aid, which can be carried out using minimal equipments. Basic training in first aid skills should be taught in school, in work places and, in general, be learnt by all, as it is mandatory to our modern and stressful life. Also, it is equally important to know what not to do in such situations.

There are several conditions that require first aid.

"First aid" is a catch-all phrase that refers to two distinctly different categories of medical needs.

- Emergency first aid is the first positive response to an injury, illness or life-threatening (or limb-threatening) medical emergency. In this case more advanced medical care will follow. This type of first aid includes CPR, clearing an airway obstruction, responding to anaphylactic shock, splinting a broken bone, and severe bleeding control.
- Non-emergency first aid is the treatment for minor medical needs. We may or may not seek more advanced medical care after the initial response. This includes taking over-the-counter medications for minor pain or allergies, cleaning and bandaging cuts or abrasions, and minor bleeding control.

When you reach the victim, do the following:

- Assessment of the injured
- Is the person alive?
- Can she/he be removed from the site?
- Quick Triage

  (First attend to the one who is most likely to survive)

Lifting and Extracting injured people:

- Unless the accident site becomes unsafe or further damage likely, do not move the victim
- Do not retrieve if further damage is likely by one's action
- Let injured arm hang free
- One should lock his/her arms under those of the injured to lift.
- Stabilize neck

Assessment of the Injured

- Check Pulse
- See Skin Color
- Assess level of consciousness (AVPU: A-Alert, V-Response to vocal stimuli, P-Response to painful stimuli, U-Unresponsive)

Seriously Injured Ones – ABCDE:

A – Airways

B – Breathing

C – Circulation

D – Disability (Neurological and others)

E – Exposure and Temperature Control

Halt further damage/injury; do no harm.

Airways – Look and Listen

- Look for vomitus/foreign bodies (in mouth and throat)
- Look for breathing efforts
- Listen for abnormal sound
- HEIMLICH's maneuvers to clear foreign body from the wind pipe (trachea)
- Lift the chin
- Do not bend/tilt the neck unnecessarily

Breathing:

- Make sure that victim can breath
- Look for rib fracture
- Close open chest wound
- Mouth to mouth respiration

Circulation:

- Check pulse
- See colour
- Check for bleeding (may be internal?)
- Control bleeding
    - o No Tourniquet
    - o Direct Pressure (Wound, Pressure point, Elevate the injured part)
- Control bleeding
- Check for fractured ribs
- For shock (Head down and legs up/raised)
- Do not remove the stuck sharp objects from the body before you can stop bleeding
- Tourniquets have done more harm than good

Stabilization

- Neck/spine stabilization (most important)
- Any trauma above the upper chest and neck should be considered as Cervical Spine Injury unless proved otherwise in the hospital
- May not have external/neurological signs of injury
- Place victims in most comfortable/neutral position
- Utmost care to be taken during shifting/transfer
- Reassure the victim that help is at hand

Environment Control

- Halt further injury (damage)

- Prevent hypo/hyper-thermia
- Prevent suffocation/drowning
- Do not feed the victim.

Expert Resuscitation

- Suction
- Intubation
- Oxygen Therapy
- Medication
- Control of bleeding
- Cardio Pulmonary Resuscitation (CPR)
- Defibrillation
- Stabilization

Transportation

- Identify priority cases
- Get appropriate transport (vehicle)
- Appropriate personnel
- Closest versus Most appropriate centre
- Transport in “recovery position’
- Stabilize

(Caution – Transporting unconscious patients on his back without proper attention to his airways is a major cause of death due to ill-care)

First Aid for fractures

Spine Fracture:

- Move victims with great care. Will need many people
- Rolled towel can be used as a collar support
- Keep person’s spine as straight as possible
- Can strap him/her to a plank

Pelvic Bones fracture:

- Triangular Bandage
- Put pad between thigh

Fractured Arms:

- Sling and strap to his body

Legs fracture:

- Splint (with bamboo etc.)
- Splint to other leg

Survival Skills

- Avoid/Prevent
- Escape
- Communicate
- One should not become a victim himself/herself while rescuing

If injured and if you are fairly conscious:

- Try to make oneself comfortable
- Be calm, do not panic
- Breath normally
- Move as little as possible
- Keep control on heart rate, BP, Oxygen demand, blood loss, conserve energy, remain conscious longer

If injured, compress over the bleeding site. Cooperate with rescue team. Ensure your safety first and then help others if you can.

Things to learn

- Patient in “Recovery Position”
- Vessel Compression\HEIMLICH Maneuver
- Mouth to mouth artificial respiration\CPR

8.26 Relief

8.26.1 Financial Mechanisms

The Fifteenth Finance Commission recommended creating the mitigation funds at both national and state levels in the form of a National Disaster Mitigation Funds (NDMF) and State Disaster Mitigation Funds (SDMF), in accordance with the Disaster Management Act beyond the existing disaster response funds. These mitigation funds shall be used for those local level and community-based interventions which reduce the risks and promote environment-friendly settlements and livelihood practices. The mitigation and response fund together was termed as National Disaster Risk Management Fund (NDRMF) and State Disaster Risk Management Funds (SDRMF). The existing cost-sharing patterns between the center and states were retained in present finance commission.

The 14th Finance Commission followed the methodology of the previous commission (FC-XII) to determine the SDRF corpus for each state and allocated an amount of Rs.61,219 crore. The constitution of District Disaster Response Funds (DDRFs) was left for the states and no separate grants were recommended for financing DDRFs. The 14th Finance Commission provided provision for states to utilize 10% of the SDRF for those occurrences which they considered as "disaster" and are not in the list of notified disasters. It also recommended ensuring other sources of funding for the NDRF such as private contributions and to accord tax exemption to those contributors.

The 13th Finance Commission (2010 – 2015) constituted by the President on 13th November 2007, to give recommendations on specified aspects of Centre State Fiscal relations, has submitted its report to the President on 30th December 2009. Para 8 of the Terms of Reference (ToR) pertains to review of the present arrangements as regards financing disaster management with reference to the National Calamity Contingency Fund and the Calamity Relief Fund and the funds envisaged in the DM Act 2005.

The commission reviewed the existing arrangement of financing relief expenditure in light of the DM Act 2005 and recommended merger of the National Calamity Contingency Fund (NCCF) into National Disaster Response Fund (NDRF) as well as the merger of Calamity Relief Fund (CRF) into State Disaster Response Fund (SDRF) with effect from 1st April 2010 and transfer of the balances in the existing funds into the new funds (please refer MHA notification and MoF Guidelines on NDRF and SDRF for more information).

The commission has assessed the relief expenditure requirements of all States/UTs and recommended that 75% of the SDRF requirement for general category States and 90% for the special category States/UTs (NE States, Sikkim, Uttarakhand, Himachal Pradesh, Jammu and Kashmir) be met by the Centre through a grant to the States.

FC-XII found considerable justification in widening the list of calamities covered under the scheme (FC-XII added landslides, avalanches, cloudburst and pest attacks in the existing list of six disasters – cyclone, drought, earthquake, fire, flood and hailstorm). FC-XII recommended that other disasters including chemical and industrial, as also air/railway accidents, may continue to be taken care by the respective ministries.

The claim on the NCCF is made through a memorandum submitted by the State Government, which is assessed by a central team deputed for the purpose. The report of the team is assessed by an inter-ministerial group (IMG), which makes recommendations to the high level committee (HLC) for release. The assistance from NCCF is only for immediate relief and rehabilitation and not for any reconstruction of assets or restoration of damaged infrastructure. In order to finance post-disaster reconstruction which is not covered under NCCF, Additional Central Assistance (ACA) has been given to States in recent years, particularly for Gujrat earthquake 2001, Tsunami 2004, Kashmir earthquake 2005 and Kosi flood 2008. In the year 2008-09, Rs. 645 Crore has been released to 10 States under ACA for long term reconstruction of assets.

The High Level Committee (HLC) will be constituted with Finance Minister, Agriculture Minister, Home Minister and Deputy Chairman of Planning Commission as members. HLC is serviced by the DM Division of MHA. Upon the approval of HLC, Ministry of Finance will release assistance from NDRF to the States.

Although the DM Act uses terms like 'substantial loss of life, or human suffering, damage to and destruction of property and nature or magnitude as to be beyond the coping capacity of the community of affected area; it however does not quantify these terms.

As per DMA, NDMA shall recommend minimum standards for relief in terms of facilities in relief camps, relief to widows and orphans, ex gratia assistance on account of loss of life and damage to houses and restoration of means of livelihood. The executive powers with regard to calamity relief as well as powers to ensure compliance with directions in carrying out the relief measures are vested with SEC.

Section 46 and 47 of DM Act 2005 deal with the constitution of National Disaster Response Fund (NDRF) and National Disaster Mitigation Fund (NDMF). NDRF shall be administered by the NEC to meet the expenses for emergency response, relief, and rehabilitation in accordance with the guidelines laid down by the Central Government in consultation with NDMA. Fund for Pooled Procurement –of relief material on short notice often comes with an associated premium pricing and may adversely impact quality. An initial grant of Rs. 250 Crore, in the form of revolving fund, has been provided to National Disaster Response

Force for the purpose. NDMF is to fund projects exclusively for the purpose of mitigation and is to be administered by NDMA. Similar provisions have been made for the State and District Disaster Response and Mitigation Funds. Disaster Mitigation should be a part of plan process and the expenditure therein be met out of the plan resources of the respective ministries of the Union and the States. Second Administrative Reforms Commission recommended that disaster mitigation plans should be included in the development plans. The 11th Five year Plan Document emphasized on mainstreaming disaster management into development planning. Every development should include elements of impact assessment, risk reduction and `does no harm' approach. The State Governments need to give priority to hazard identification and risk assessment in their plans and schemes.

The best methodology to assess the requirements of SDRF would be to base it upon Hazard-Vulnerability-Risk Profile of the States, as it would be a good indicator of the disasters a state may face. However, there are no reliable exercises that map the states on such a scale. In its absence, expenditure based approach would continue to be adopted. The existing list of natural disasters covers most of the prevalent events. However, for very specific events that could even be man-made and require high level of funding, but may have low chance of occurrence, financing of relief arrangements is left out to SDRFs.

The Public Liability Insurance Act (PLI), 1991, notified presently for specified quantities of 179 explosives, toxic and highly reactive chemicals, establishes the principle of liability for enterprises engaged in hazardous activities. Setting up of Environmental Relief Fund (ERF) under the Act in 2008 has further strengthened its provisions. As on 31st March 2009, the ERF has a corpus of Rs. 285 Crores. The legal framework therefore, provides another source of relief for financing man-made disasters.

Effective disaster response requires trained manpower to deal with complex situations wherein effective and speedy handling can reduce the impact of a disaster on human lives and property. It is necessary to continuously undertake measures to build capacity amongst those handling response and creating awareness amongst people. An additional grant of Rs. 525 Crore has been recommended on the basis of the overall size of the SDRF of a state. This amount may be used for taking up activities for building capacity in the administrative machinery for better handling of disaster response and for preparation of district and state level disaster management plans as envisaged in the DM Act.

LANDSLIDES EDUCATION, TRAINING AND CAPACITY ENHANCEMENT

9.1 Landslide Education

Landslide education will address multifaceted aspects of landslide management, especially preparedness, mitigation and response efforts. In this regard, case histories of actual past disastrous landslides can be used as valuable inputs for disaster education in general, and landslides in particular.

The development of high-quality education materials, textbooks, field training and high standard of teaching at all levels should be given due emphasis. Education and training programmes should be designed, with greater focus on development of capacity and skills of trainers and teachers. Science and technology courses designed by the experts and designated institutions should be introduced to orient all target groups including school teachers, NGOs and private volunteers and other professionals engaged in disaster management.

9.1.1 Education of Professionals

The knowledge institutions and universities should focus attention on landslide education through revision of syllabi, enlarging the scope of teaching earth sciences, civil engineering and allied disciplines with practical bias and through crafting of new educational programmes. The curriculum in earth sciences, engineering geology, seismology, geotechnical engineering, structural engineering and architectural aspects needs special attention. Another possible intervention is training of professional engineers and architects to ensure that classroom teaching benefits professional practice. A large number of professionals require training and retraining; endeavour should be to enhance on priority the quality of teaching, of text books, of training kits, etc. in the field of landslide education.

The country need to create a breed of professionals who can appreciate the importance of correct diagnosis before slope treatment. Geomorphologists have to perceive both macro and micro geomorphology and use it in slope analyses to deliver a message that present practices of dismembering slope into factors such as relative relief and slope erosion. Engineering geologists should discuss micro-geological details controlling a landslide, and not just stop at broad description of lithology. A geotechnical engineer needs the education to realize that the orthodox soil mechanics has long been replaced by modern

soil mechanics arming him with concepts, tools and techniques that can help characterize and analyse a landslide reliably. The landslide managers need the education they should insist on a scientific, systematic slope investigation and that ad-hoc measures without sound investigation may prove to be a costly waste.

There is a need to educate professionals in damage and loss assessment due to landslides and create simple tools and uniform procedures by which objective assessment becomes possible.

Technical institutes, polytechnics and universities located in vulnerable areas should develop adequate technical expertise on the various subjects related to landslide management. The State Governments, if required, in association with the University Grants Commission (UGC), Department of Science and Technology (DST), Ministry of Human Resources Development (MHRD), All India Council for Technical Education (AICTE) etc will introduce short term Quality Improvement Programmes (QIP) for teachers and professionals engaged in teaching the subjects related to landslides. The new technical programmes on the lines similar to those launched by various Central Ministries for college teachers, geoscientists, civil engineers, town planners etc. for developing the additional capacities in landslide management should also be taken up. The GoI should address the gap between the requirement and availability of quality teachers conversant with natural hazards, especially with the landslide assessment and mitigation techniques.

The subject of disaster medicine covers trauma care, epidemic control, emergency medical care by paramedics and emergency medical technicians, telemedicine etc. DM related medical education will receive due attention in the undergraduate level, so that graduating doctors are able to handle emergencies with greater confidence. All architecture and civil engineering graduates should be taught in detail about all aspects of landslides and related hazards in hilly areas of the country. These educational efforts should encapsulate improving the knowledge and skills of human resources by reviewing and updating the curricula periodically, upgrading the facilities, and institutionalising the desired capacity building mechanisms in mitigating this hazard. The mainstreaming of landslide management in development planning will be supplemented with the development of the requisite infrastructure in technical and professional institutions, improved laboratories and libraries in identified R&D institutions. These measures should enable these institutions to undertake research and execute pilot projects on different aspects of landslides employing latest technology and set pace setter examples that will build confidence amongst geo-scientists, geo-technical engineers and communities regarding management of landslides. The results of such studies should also help to develop and update the technical documents that may form important part of resource materials prepared for training programme on education, sensitisation and training.

9.1.2 Community Education and Awareness

The need for community education cannot be over-emphasized since it is usually the first responder to a disaster and their role in containing damage could be of prime significance. It is necessary that the government and the communities together evolve joint action plan aiming at spreading of community awareness and development of community leadership. Such awareness will enable communities in ensuring safer constructions. Investments in Disaster Education, Public Awareness, Community Leadership Development, Disaster Education of unemployed youth, physically challenged, elderly, women and school children should be encouraged.

9.2 Training

The geologists from Geological Survey of India (GSI) and State Directorate of Geology and Mining (DGMs) should be involved in landslide hazard mitigation programmes and studies after proper training in landslide affected States. A large number of engineers are involved in the construction activities at the civil engineering and infrastructural project sites in landslide affected areas. Such training programmes should be offered to these professionals as well. The training modules may include both in-class and on-field training.

9.2.1 Training of Professionals

Geologists, engineers and other professionals related to the field of landslide will be exposed to latest developments in the domain of landslide investigations and



Fig. 10.1: People engrossed in Village Level Community Based Training on Disaster Management

management being evolved globally on regular basis so that well trained manpower conversant with latest technological advances is available in the country to manage the hazard effectively. This can be done by sending these professionals abroad regularly to acquire theoretical knowledge as well as practical experience on application of latest and more effective techniques. The training programmes will be systematically planned and executed with extensive interdisciplinary exposures for engendering a trained manpower tuned to holistic management of landslides.

These training programmes should be pilot tested, critically evaluated, upgraded, documented, and peer reviewed at regular intervals. The training modules will be continuously updated based on the evaluation and feedback from participants.

In the initial phases, training may be imparted to all engineers, geologists, geophysicists, hydrologists from DGMs and other departments involved in developmental activities in hilly regions, especially in the ULBs and PRIs of such States. In particular, the design directorates, if any, in the State Departments will ensure that they have architects and engineers with background in landslide-safe design and construction. Those who undergo the 'Training of Trainers' programme will be responsible for training the professionals through the network of professional societies. Minimum acceptable standards of safety, as enumerated in the BIS codes, will be disseminated through professional organisations and the training requirements will be integrated with the licensing criteria.

9.2.2 Recommended Areas Requiring Training

- Geomorphological, geotechnical, hydro-geological and GIS based LHM with perception of mapping scales
- Geotechnical investigation of landslides with particular reference to characterization of slopes, elucidation of landslide boundaries, representative undisturbed sampling from shear zones, handling of samples, simulated stress-path testing and stability analyses in terms of total and effective stresses
- Techniques of monitoring slope surface and sub slope movements and movement rates and cross linkage with rainfall record, piezometric profiles and behaviour of buildings and structures on the slope
- Slope modeling
- GIS based landslide hazard, vulnerability and risk assessments
- Slope kinetics, site effects and earthquake induced landslides in seismic micro-zonation and risk assessment

- Instrumentation of slopes, landslides and avalanches, and early warning
- Design of landslides and avalanche control measures with particular reference to choice of technologies
- Training of first responders in search, rescue and medicare
- Training of communities and local bodies
- Training for visual, print and electronic media in the science of disasters for improved and more objective reporting

9.3 Capacity Enhancement

Mechanism should be developed to identify institutions active in the field of landslides, assess capabilities, enhance and strengthen capacities in terms of expertise, knowledge and resources for effective management of landslide hazard. Main areas requiring capacity development in the context of landslide disaster management are as follows:

- Establishment of a nation-wide organized vibrant pro-active, systematic and scientific institutional mechanism that would replace the current piecemeal, ad-hoc, less recognized and poorly appreciated landslide management practices.
- Enhancement of expertise and capacities of knowledge centres in different parts of the country for dependable and timely geomorphological, geotechnical and hydro-geological investigations and for scientific design and speedy and effective implementation of control measures.

Strengthening a few objectively identified institutions, their units and departments in all states and union territories to redefine and enlarge their respective mandates/roles to provide/support pre and post landslide routine/ specialized functions.

9.4 Awareness

As a part of awareness generation exercise of landslide hazard mitigation effort, GSI, in consultation with the MHA, initiated a programme to establish contact with various State Governments of landslide affected states and create awareness about this natural hazard among the state officers and other agencies dealing with natural hazards. The programme included audio-visual presentation and distribution of booklet and posters for creating awareness about landslide hazards, familiarising landslide terminologies, causes, treatment measures etc. GSI Training Institute conducts training programme on regular basis on various aspects of landslide investigations.

NIDM has the mandate to develop training modules, undertake research and documentation in disaster management; provide assistance in national and State level policy formulation; develop educational materials for disaster management and promote awareness for hazard mitigation, preparedness and response measures. Indian Institute of Remote Sensing (IIRS), Dehradun also conducts both short and long term courses especially orienting the people in the usage of remote sensing data for geological hazards. The Decision support centre at NRSA conducts a two weeks course for various planners at State and District level in the usage of Earth Observation data for hazards.

The mass awareness generation programme is to be made essential component of disaster mitigation plan and should be carried out as sustained effort through electronic and print media, interactive meets and distribution of handbills and posters in local languages. Different NGOs, State Government Authorities have also to undertake exhaustive programmes for mass awareness generation. A series of audio- visual resource material on this aspect has to be prepared and distributed to the above mentioned organizations for this purpose. The services of media, private volunteers and NGO's active in the field of disaster related work can be effectively utilized for this purpose after proper orientation.

Large number of engineers and geologists engaged in landslide hazard management do not possess requisite expertise to manage this hazard. Landslide hazard management techniques, risk assessment and remediation practices are required to be included in the curriculum of technical institutes teaching civil engineering, geology, geophysics and disaster management.

Local communities aware about landslide hazards and their locales, would be in a better position, both physically and psychologically to face its consequences. Since landslides are frequent, sudden and cause disasters that affect localized areas resulting in segregated losses, these do not receive appropriate attention due to transitory nature and short-lived human memory. Hence, the level of awareness about landslides has been quite low compared to other disasters like earthquakes, floods and cyclones. In our country's hilly terrain, cumulative losses due to landslides are much higher than any other disaster. Thus, there is an immediate need to educate people about landslides so as to reduce the associated risk/losses.

State Governments/State Disaster Management Authorities (SDMAs) of landslide affected state will, in collaboration with the GSI and other key stakeholders, make special efforts to mobilize communities to carry out landslide mitigation efforts. Electronic and print media will also be associated in the endeavor to create greater public awareness about landslide hazard and the importance of landuse zoning practices. Comprehensive awareness campaigns targeting different groups of people living in landslide prone areas will be carried out systematically. These campaigns will emphasise on the prevalent landslide risk and vulnerability of the areas as well as highlight the roles and responsibilities

of communities and stakeholders in addressing this risk. These will also focus on the specific role that each institution/organization or community will play in order to mitigate the effects of landslides.

9.5 Creation of Public Awareness on Landslide Risk Reduction

Handbooks, posters and handbills containing status of landslide hazard should be distributed and details of landslide indicators along with precautions to be adopted and suggestive measures should be displayed near the landslide prone sites. All above documents should be translated into local and regional languages. Short video films on the landslide risk, vulnerability and importance of preparedness and mitigation measures should be prepared for the benefit of local public. The electronic and print media should also be made integral part of the campaigns.

Communities need to be alerted and made aware of:

- the major disaster threat perceptions in the localities of immediate concern, and the projected disaster scenarios (landslide included)
- the possible landslide hazard distribution scenarios and major known landslide spots and identified elements at risk
- the lessons learnt from the past landslide disasters in the areas and from their (mis)management, if any
- the precursors and early indicators that can avert landslide disaster
- the roads, housing, schools etc. exposed to landslide risk
- the role and responsibility of the government and local bodies before, during and after a disaster
- the expected roles and responsibilities of communities and people at large before, during and after a disaster; the responsibility the residents and communities are willing to shoulder in choosing to live or do business in high risk areas
- the role of public sector, NGOs and other voluntary organizations
- whether the construction materials, design and construction conform to prevalent building codes and establish engineering practices

9.5.1 Awareness Drives for Specific Target Groups

One of the most challenging tasks in landslides preparedness and mitigation is the sensitization of all stakeholders, and educating and training them to participate in landslide preparedness and mitigation efforts. If the community recognizes the importance of landslides safety vis-à-vis developmental activities, tremendous gains can be achieved in landslide risk reduction.

Big construction companies and contractors engaged in infrastructure development in the hilly regions will undertake campaigns to sensitise their members on the risk and vulnerability resulting from landslides in various parts of the country so that necessary attention to prevent this hazard and mitigation measures are included in designs and construction in vulnerable areas.

A comprehensive awareness campaign should be developed and implemented for following safe practices before, during and after a landslide. The campaign should also highlight the risks and vulnerability of the states and the roles/ responsibilities of all communities and stakeholders in addressing the risk.

Public awareness campaigns should be conducted at the national, state and district centres and in high risk areas for disseminating information on landslide risk management among all stakeholders. Case studies documenting the major landslides should be prepared and used for creating greater public awareness among professional and critical stakeholders. Landslide risk management should be done by applying available knowledge and customizing the same through R & D for specific situations and generating new adaptive techniques.

9.6 Landslide Preparedness

DM plans for landslide prone areas should be systematically developed such that stakeholders are able to address landslide risk. These plans should be region specific and should consider the risk profile and the special characteristics of a particular geographic area. Preparedness should include the formulation of family and community contingency plans. Mock drills should be conducted in offices, schools and industrial units etc. and in the neighbourhood of the sites vulnerable to landslides.

The people operating in the mountainous regions will be sensitized about the landslide hazard. They would be advised to remain vigilant and respond effectively in emergency situations.

An exercise in real sense is a focused practice that puts the participants in a simulated situation to function in the capacity that would be expected of them in a real event. Its purpose is to promote preparedness by testing policies and plans and training personnel.

Exercises should be conducted to evaluate an organization's capability to execute one or more portions of its response or contingency plans. Many successful responses to emergencies over the years have demonstrated that exercising pays huge dividends.

Comprehensive exercise programme involves five main types of activities, viz. orientation seminar, drill, tabletop exercises, functional exercises and full-scale exercises.

As per the specific situation these exercises will be conducted to assess the preparedness for all the hazards present in the district rather than for individual hazards.

9.6.1 Medical Preparedness

The disaster management plans related to medical preparedness developed at the state and district levels will be same as in other hazards. The principal aim of the medical management plan will be to improve emergency medical preparedness and emergency medical response. In case of landslide hazard, the medical preparedness should focus on likely injuries resulting from landslides including psycho-social trauma. It should address the need for surveillance and for planning and rehearsing for disaster preparedness through mock exercises.

Since Medical Management Plans include all disasters existing in the area, there is a need to create greater awareness in all medical teams and the medical community at large about all the hazards and types of injuries that can be inflicted especially by landslides.

All public health facilities will develop their own DM plans, with the scope for enhancing their surge capacity in the event of disaster. Training exercises and mock drills will be carried out regularly by doctors and paramedical staff. The medical preparedness plans will also include identification of trained trauma and psycho-social care teams, with nursing and paramedical staff. In high-risk landslide areas, mobile hospitals and Quick Reaction Medical Teams (QRMTs) should be developed as part of the overall disaster health-care delivery system of the states to manage patients with minor injuries at the incident site itself.

The State Governments will identify the hospitals, team of doctors and para-medics including mental health and psycho-social service provider at sub-divisional and district levels, who will be deployed at short notice. Their names, addresses, telephone numbers, mobile numbers, email etc. will be made available to the district and state control rooms. The list will be updated annually. The stock of medicines, accessories and equipment for each of identified teams at the district and sub-divisions will be assessed and updated in advance as per needs.

9.6.2 Animal Care

Animals both domestic as well as wild are exposed to the effects of natural and man-made disasters. It is necessary to devise appropriate measures to protect animals and find means to shelter and feed them during disasters and their aftermath, through a community effort, to the extent possible. It is pertinent to note that many communities have shown compassion to animals during disasters, and these efforts need to be formalized in the preparedness plans of the Departments of Animal Husbandry at the Centre and the States.

9.7 Preparedness Plan for Landslides

Landslides are a serious geologic hazard that causes thousands of deaths and injuries each year throughout the world. Often associated with periods of heavy rainfall or rapid snow melt, landslides are capable of rapid movement with enormous destructive capacity. Earthquakes, floods, cloudbursts, prolonged precipitation can also trigger landslides. Landslide preparedness involves individuals knowing about the hazard potential where they live and taking various steps to reduce the personal risk from this geologic phenomenon. Landslide usually strike without warning. The force of rocks, soil, or other debris moving down a slope can devastate anything in its path. Following steps should be taken to keep one in readiness:

9.7.1 Pre-disaster Preparedness

If one is at risk from landslides, one should:

- Develop an evacuation plan. If home could be damaged in a landslide, one should know where to go. Making plans at the last minute can be upsetting, create confusion, and waste precious time. Contact local authorities to learn about the emergency response and evacuation plans for the area and develop own emergency plans for family and business.
- Familiarize with the land around, it will help in assessment of risk.
- Watch the patterns of storm water drainage on slopes near homes, especially the places where runoff water converges, increasing flow over soil covered slopes. Watch the hillsides around your home for any signs of land movement, such as small landslides or debris flows, or progressively tilting trees.

Noticing small changes could alert to an increased threat of a landslide:

- Discuss landslides and debris flows with members of household. Everyone should know what to do to stay safe if one occurs.
- Be aware that, landslide insurance is generally, not available; however, in some cases, debris flow damage may be covered by flood insurance policies.
- Get a Ground Assessment of your property.
- Seek specific information on areas vulnerable to land sliding from a geologist. Consult a professional engineering geologist or a geotechnical expert for opinions and advice on landslide problems and on corrective measures you can take.
- Minimize home hazards. One can reduce the potential impacts of land movement by taking steps to remove oneself from harm's way.

- Plant ground cover on slopes and build retaining walls. In mudflow areas, build channels or deflection wall to direct the flow around buildings. (Remember: If one build walls to divert debris flow and the flow lands on a neighbour's property, one may be liable for damages). .
- Build away from steep slopes.
- Build away from the bottoms or mouths of steep ravines and drainage facilities.

Learn to recognize the landslide warning signs:

- Doors or windows stick or jam for the first time.
- New cracks appear in plaster, tile, brick, or foundations.
- Outside walls, walks, or stairs begin pulling away from the building.
- Slowly developing, widening cracks appear on the ground or on paved areas such as streets or driveways.
- Underground utility lines break.
- Bulging ground/wall appears at the base of a slope.
- New holes or bare spots on hillsides
- Water breaks through the ground surface in new locations.
- New springs appear or sudden disappearance of existing springs
- Muddy water in creeks, rivers.
- Fences, retaining walls, utility poles, or trees tilt or move.
- Faint rumbling sound that increases in volume as the landslide nears. The ground slopes downward in one specific direction and may begin shifting in that direction.

Make evacuation plans:

- Plan at least two evacuation routes since roads may become blocked or closed.
- Develop an emergency communication plan.
- In case family members are separated from one another during a landslide or mudflow (this is a real possibility during the day when adults are at work and children at school), have a plan for getting back together.
- Develop a family plan that includes out-of-locality family contact number, place to join up if family members are separated, decide the safe routes

to leave for secure place, and locations of utility shut-offs. After a disaster, it's often easier to call long distance. Made sure everyone knows the name, address, and phone number of the contact person.

- Keep ready emergency supplies like Food, Water, First aid kit, Flashlights and batteries, Battery-operated radios, Special medications/eye care products.
- Prepare an evacuation kit that includes Cash (small bills and change), Important documents (Birth certificates, insurance policies, marriage certificates, mortgage documents), games, toys for children.
- Purchase supplies to protect your home. It may include Hammer, Nails, Plywood, Rain Gauge, Sand, Sandbags, Shovel.
- Listen to the radio or watch television for information and instructions from local officials.
- Respect the power of the potential landslide. Remember, landslides move quickly, can cause damage and kill people.

Insurance:

- The local insurance companies can cover mudflow and Landslide risks under natural calamities.

Landslide Preparedness and Prevention for Oceanside Residents:

- With last winter's heavy rains, the ocean-side and the coast parts may suffer devastating landslides.
- As you face another potentially wet winter, the Coastal States should initiate an educational programme regarding Landslide Preparedness and Prevention for Oceanside residents.
- While all landslide damage cannot be prevented, home and business owners should consult disaster management professionals for preventive measures to make their property safer.
- As it is the owner's responsibility to protect the stability of his/her property, he/she should take this opportunity to learn how to protect own property and recognize potential landslide risks.
- Eliminate litter and dead and dry plants.
- Inspect slopes for increases in cracks, holes and other changes.
- Contact local public works department for information on protection measures.

What to do during a landslide:

- Take cover under a sturdy table or desk if inside the house when landslide is moving.
- If outside, try to get out of the path of landslide or debris flow; Run to the nearest high ground in a direction away from the path of landslide.
- If rocks or debris are approaching you, run the nearest shelter such as group of trees or big and heavy rock mass that is unlikely to move with slide.

What to do after a landslide:

- Stay away from the slide area – There may be danger of additional slides.
- Go to established meeting point and follow instructions by the assigned responsible person.
- Check for injured and trapped persons near the slide, without entering the slide area directly. Direct rescuers to their locations.
- Help a neighbour who may require special assistance – infants, elderly people and people with disabilities. People who care for them or who have large families may need additional assistance in emergency situations.
- Give first aid to victim, if you are trained.
- Listen to local radio or television for the latest emergency information.
- Watch for flooding, which may occur after a landslide or debris flow. Floods sometimes follow landslides and debris flows because they may both be started by the same event.
- 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.
- Check the building foundation, chimney and surrounding land for damage, it may help to assess the safety of the area.
- Replant damaged ground as soon as possible since erosion caused by loss of ground cover can lead to flash flooding.
- Seek the advice of landslide expert for evaluating hazards or designing corrective techniques to reduce landslide risks. A professional would be able to advise you ways to prevent or reduce landslide risk, without creating further hazard.

9.7.2 People-centric Landslide Early Warning System

The local community should be made aware of the environment where they dwell, the hazard present and ways to monitor them for timely response as they are the first responders in case of any disaster. People-centric Landslide Early Warning System will facilitate the community in remote areas to manage the risk by empowering themselves and will also build a resilient society.

Geological Survey of India in collaboration with Government of West Bengal deployed a People-centric Landslide Early Warning System (LEWS) on 07th September, 2018 at Giddapahar Village in Kurseong Block, Darjeeling District, West Bengal. The four inter-related key elements i.e., (i) risk knowledge, (ii) monitoring, analysis, and warning generation, (iii) dissemination and communication of the warning and (iv) preparedness for timely response, required for an effective early warning system is managed by the community in People-centric LEWS. The system established in Giddapahar Village bank on rainfall threshold model and local landslide risk knowledge for generating warning. The community monitors the rainfall, analyse its threshold value and exceedance, generate warning and communicate to the local community and Block Administration, and take decision of evacuation, if required.

9.8 Survival Skills

Live by Your Wits, but for Now, Learn Basic Skills

Without training in basic skills for surviving and evading on the battlefield or after disaster, ones chances of living in evasion situation are slight.

Learn these basic skills now, not when you are headed for or are in survival situation. How one decides to equip oneself before deployment will impact on whether or not he/she survive. One need to know about the environment to which he/she is going, and must practice basic skills geared to that environment. For instance, if one is going to a desert, he/she needs to know how to get water in the desert.

Practice basic survival skills during all training programmes and exercises. Survival training reduces fear of the unknown and gives self-confidence. It teaches to live by own wits.

Train Yourself to Survive

There is need to train to survive. But don't make the mistake of thinking that being in a survival situation would be fun. Wilderness Survival is not a game, there are no reward challenges, and there is no immunity. How does one think he/she would fare in a survival situation? Could he/she build a shelter? Could he/she forage for food and purify water? In real life one would not have luxury

items, one would not don't get tarps and matches and camping supplies. In real life one may not have any tools except his/her own two hands. If one is stranded in the wilderness would he/she end up a survivor?

Don't worry about those questions. Instead take action and educate yourself on survival techniques. Nature is unforgiving and you must be prepared to fight to stay alive.

Expand the meaning of each letter of the word survival. Study and remember what each letter signifies because you may someday need Survival.

S — Size up the Situation (Surroundings, Physical Condition, Equipment)

U — Use All Your Senses, Undue Haste Makes Waste

R — Remember Where You Are

V — Vanquish Fear and Panic

I — Improvise

V — Value Living

A — Act Like The Natives

L — Live by Your Wits, But for Now, Learn Basic Skills

MAINSTREAMING LANDSLIDES RISK REDUCTION IN DEVELOPMENT

10.1 Initiatives on Development and Disaster Risk Reduction

The Central Government, State Governments, Public Sector Units and Private Entrepreneurs in the country are engaged in some kind of developmental activities which can enhance or reduce the disaster risks. Thus, development may have either positive or negative impacts on disaster risks. Similarly disasters also provide an opportunity to learn from our mistakes and help us identify good as well as bad practices. The destruction during disasters demolishes the non-resilient structures whereas the disaster resilient one remains safe and functional. Post disaster reconstruction and redevelopment should, therefore, promote application of disaster resilient features more in practice for safer sustainable development. Mainstreaming DRR is one such initiative taken by Government of India to develop a culture of prevention and mitigation into the development process. Major developmental programmes of the Government of India which may have wider impacts on DRR are discussed briefly. **Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS)** under **MGNREG Act** assure financial relief to the needy families in drought affected areas. MGNREGA serves the larger objective of enhancing agricultural productivity because the first priority under MGNREGA is given to projects aimed at water conservation. Such schemes can be easily integrated with relief programmes to increase the availability of funds for relief expenditure. Similarly **Pradhan Mantri Gramin Awaas Yozana (PMGAY)** accomplished useful relief works in terms of providing housing to the affected families. 10% of the annual allocation under PMGAY is earmarked for this purpose. Likewise allocation (5%) is also made under the **Accelerated Rural Water Supply Programme (ARWSP). National Rural Health Mission** provides broad based improvement in health care for rural population. **Rashtriya Swasthya Bima Yojana** is a new and important innovation providing the population below poverty line with an insurance policy covering hospital treatment for a defined set of conditions with government meeting the premium. **Bharat Nirman Programme** focuses on the provision of key elements of rural infrastructure such as irrigation, rural electrification, rural roads, rural drinking water supply, sanitation, housing for the poor, and rural connectivity via community IT services. **Rashtriya Krishi Vikas Yojana (RKVY)** incentivizes State governments to prepare district level agricultural plans that take account of local conditions. **Swarna Jayanti Shahari Rozgar Yojana (SJSRY)** to provide gainful employment to the urban

unemployed (below poverty line) as well as Urban Poverty Alleviation and Slum Development to improve. **Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT)** seeks to provide central assistance for urban infrastructure development linked to a process of reforms at the city and urban local body level which would make these bodies more financially viable, and ultimately capable of financing the investment needed in urban areas. **National Highways Development Programme (NHDP)** include four laning of the Golden Quadrilateral and the North-South, East-West Corridors; 4/6 laning of 10000km of national highway connecting State capitals and places of tourist importance with the national network (implemented by NHAI). **Special Accelerated Road Development Programme for the North East Region (SARDP-NE)** is presently under implementation for providing road connectivity to all State capitals and district headquarters in the NER. The 11th plan outlined a broad approach based on Integrated Energy Policy formulated earlier by the Planning Commission. **National Food Security Mission** launched in 11th Plan aims at increasing production of cereals and pulses. **Pradhan Mantri Gram Sadak Yojana (PMGSY)** extends rural connectivity. PMGSY aims to provide reliable road connectivity to all habitations with 1000+ population (500+ Population in Hilly regions). **Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY)** has ambitious plans to extend rural electrification to hitherto unserved rural areas. RGGVY aims not only at household electrification but also at energization of pumpsets. **Accelerated Power Development and Reform Programme (APDRP)** aims at reducing aggregate technical and commercial losses. **Mid-Day Meal Scheme and the Sarva Shiksha Abhiyan (SSA)** brought additional children to schools. **Accelerated Irrigation Benefit Programme (AIBP)** incentivizes States to complete projects in a time bound manner. **Command Area Development Programme (CADP)** was modified in 10th Plan to include water management. A model **Participatory Irrigation Management (PIM) Act** has been circulated to States to promote PIM to improve irrigation water distribution to all farmers, including the tail enders. Under the **Environment (Protection) Act 1986**, the Central government can intervene where the water table falls (otherwise as per Easement Act of 1882, the ownership rights of groundwater rest with the owner of the land). **River Conservation Programme** to ensure that river flows are adequate to provide water of at least bathing quality standards. A comprehensive action plan for Yamuna and Ganges (Ganga Action Plan) has been prepared. Similarly **National Lake Conservation Plan (NLCP)** for conservation of 46 lakes in 13 States has been taken up through 31 projects (e.g. Dal Lake Conservation Project). **A National Action Plan on Climate Change** and **Clean Development Mechanism (CDM)** are being prepared. The 13th Finance commission recommended for creation of a National Disaster Response reserve (NDRR) with a corpus of Rs. 250 Crore as Revolving Fund to meet the immediate requirement of relief material/equipment after a disaster. The purpose of creating **National Disaster Response Reserve (NDRR)** is to mitigate the sufferings of the victims of the

disaster which are beyond the coping capacity of the States. The Government of India approved the creation of NDRR on 26.9.2014. **Aapda Mitra Scheme** for the duration of 2 years, i.e, for financial year 2016-2017 and the financial year of 2017-2018 was launched with aim to train community volunteers in disaster response in the 30 most flood-prone districts of 25 states in India.

It is estimated that the earth's surface temperature has risen by 0.6±0.2ºC over the 20th century. In the last 50 years, the rise has been 0.13±0.07°C per decade and the recent years have been warmest since 1860, the year from which regular instrumental records are available. Recognizing the importance of climate change issues, the Prime Minister established a **Council on Climate Change** under his chairmanship in June 2007 to coordinate national action for assessment, adaptation and mitigation of climate change. An action plan for adaptation to climate change would require (i) action in the area of agricultural research to evolve varieties that can cope with likely climate changes, (ii) action to cope with likely increase in water stress, (iii) action to be able to cope with a greater frequency in natural disasters. In 1997, the Kyoto Protocol under **United Nations Framework Convention on Climate Change (UNFCC)** was adopted. **Bali Action Plan** was commenced after the 13th **Conference of Parties** at Bali in December 2007 to enable the full, effective and sustained implementation of the Convention through long-term cooperative action. With a share of just 4% of global emissions, any amount of mitigation by India will not affect climate change. **National Environment Policy** of 2006 requires 'equal per capita entitlements of global environment resources to all countries'. India's per capita emissions never exceed the per capita emissions of the industrialized countries. This formulation focuses on per capita emissions rather than total emissions as the relevant variable, and also provides industrial countries with an incentive to reduce their level of emissions as quickly as possible. With urbanization and concentration of population in metropolitan cities, more and more people are becoming vulnerable to locational disasters.

The 10th Five Year Plan (2002-07), prepared in the backdrop of Orissa Super cyclone, Gujarat earthquake, and the end of IDNDR, recognized disaster management as a development issue for the first time. The plan devoted a separate chapter to disaster management and made a number of important prescriptions to mainstream DRR into the process of development. The prescriptions of 10th Plan can be broadly divided into 3 categories: (i) Policy guidelines at macro level that would inform and guide preparation and implementation of development plan across sectors; (ii) Operational guidelines for integrating DM practices into development; (iii) Specific development schemes for prevention and mitigation of disasters.

The plan called for a 'multi-pronged strategy for total risk management, comprising prevention, preparedness, response and recovery, on one hand and for initiating development efforts aimed towards DRR and mitigation on the other hand' to achieve sustainable development. The plan suggested

development of SOPs for dealing with humanitarian and relief assistance from non-government sources.

- Building disaster prevention and preparedness in development planning by introducing a rigorous process of vulnerability analysis and risk assessment, maintaining data base and resource inventories at all levels, developing infra-structure for mitigation and establishing Disaster Knowledge Network for use of disaster managers, decision makers, community and so on.
- Encouraging community level initiatives for disaster preparedness by involving people at grass root level, particularly those who are vulnerable.
- Developing appropriate zonal regulations, design standards, building codes, and performance specifications for safe construction.
- Inclusion of disaster mitigation analysis in all development schemes in vulnerable areas and building disaster mitigation components into all development projects.

The 10th Plan recommended creation of faculties in disaster management in all 28 States, in addition to community mobilization, human resource development, establishment of control rooms and forging international cooperation in disaster management. A Central Sector Plan Scheme, the National Disaster Mitigation Programme (NDMP), has been implemented since 1993-94. The scheme mainly provided training and capacity building of government functionaries and other stakeholders to manage disasters effectively. This scheme was transferred from Ministry of Agriculture to Ministry of Home Affairs in June 2002. The allocation of this scheme was raised from Rs. 6.30 Crore in 8th Plan to Rs. 16.32 Crore in 9th Plan and to Rs. 30.77 Crore in 10th Plan. Presently there are 30 Disaster Management Centre (DMC) in States/UTs besides NIDM at national level, who undertake research, consultancy and documentation for disaster management. NIDM has been set up for training, capacity building, research and documentation on various natural and manmade disasters. A comprehensive human resource plan for DM has also been prepared. 30 DMCs run in the States/UTs and 6 Centres of Excellence are allocated Rs. 30 Lakh and Rs. 25 Lakh per annum respectively. The total financial allocation is Rs. 25 Crore over a period of 5 years from 2007 to 2012. The allocation of Rs. 21.90 Crore to the training institutions during 10th Five Year Plan was mainly used on NIDM which incurred an expenditure of Rs. 11.56 Crore. Nearly 71,000 persons have been trained under the programme.

The FC-XIV restricted creation of National Disaster Mitigation Fund (NDMF) to existing arrangements on the financing of the already constituted funds. The objective of creation of National Disaster Mitigation Fund (NDMF) is for the projects exclusively for the purpose of mitigation which is being served by the existing Centrally Sponsored Schemes/Central Sector (CS) Schemes.

Additionally, the Ministry of Finance (MoF) made a provision of 10% of total outlay for all CSS schemes, [except for schemes which emanate from legislation (eg. MGNREGA)], as flexi fund.

The Fifteenth Finance Commission recommended creating the mitigation funds at both national and state levels in the form of a National Disaster Mitigation Funds (NDMF) and State Disaster Mitigation Funds (SDMF), in accordance with the Disaster Management Act beyond the existing disaster response funds. These mitigation funds shall be used for those local level and community-based interventions which reduce the risks and promote environment-friendly settlements and livelihood practices. The mitigation and response fund together were termed as National Disaster Risk Management Fund (NDRMF) and State Disaster Risk Management Funds (SDRMF). The existing cost-sharing patterns between the centre and states were retained in the present finance commission. States have been allocated Rs. 28,983 crore for SDRMF in 2020-21. The shared of SDRF and SDMF in the total amount will be 80 percent and 20 percent respectively. The mitigation and response fund allocated at the national level is Rs. 12,390 crore. However, the funds under NDRF and NDMF are non-interchangeable but there is flexibility for re-allocation within the three sub-windows of NDRF, subject to the condition that the reallocated amount shall not exceed 10 percent of the amount earmarked for that sub-window.

The revised version of National Building Code was published in 2016, taking into consideration the natural hazard and risks of various regions of the country. The **National Programme for Capacity Building of Engineers in Earthquake Risk Management (NPCBEERM)** aims to train 10000 engineer and NPCBAERM aims to train 10000 architects on safe construction techniques and practices. MHA implemented Disaster Risk Management (DRM) programme (2002-2009) in 176 (earlier 169) multi-hazard districts and 38 cities in 17 States. The DRM programme ended in June 2009. It had a multi-donor resource framework of USD 41 million and was the largest CBDRM programme in the world. One of the sub-components of DRM programme was **Urban Earthquake vulnerability Reduction Project (UEVRP)** implemented in 38 cities with over half a million population in seismic zone III, IV and V across India. It was completed in December 2009. Under this programme, DM plans are being prepared from village to district; DM teams are being constituted and training is imparted on various aspects of DM at all levels. Subsequent to DRM Programme, Disaster Risk Reduction (DRR) Programme (2009-2013), implemented in 26 states, 78 districts, and 56 cities, which aimed to strengthen the state and district disaster management authorities and city administrations to undertake DRR activities as outlined in the National Disaster Management Act, 2005. DRR programme was followed by the GoI-UNDP Programme for “Enhancing Institutional and Community Resilience to Disasters and Climate Change (2013-2017)”. It was implemented to provide technical support to strengthen capacities of government, communities and institutions to fast-track implementation of

the planning frameworks on Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA). The project was implemented in 10 states, across the country with an outlay of $ 6.235 million.

MHA-USAID and UNDP collaborate for Project on 'Climate Risk Management in Urban Areas through disaster preparedness and mitigation'. The first phase of the USAID funded component covered a four year period of 2012-2016 and covered 8 urban areas viz. Bhubaneswar, Gangtok, Madurai, Navi Mumbai, Shimla, Trivandrum, Vijayawada and Visakhapatnam. The second phase of the collaboration titled "Developing Resilience Cities through Risk Reduction to Disasters and Climate Change" with an outlay of 2.5 million USD, initiated in 2016 will conclude in 2020 and is being implemented in six cities viz. Navi Mumbai, Shimla, Vijayawada, Vishakhapatnam, Cuttack and Shilong.

GoI-USAID Disaster Management Support Project was signed in 2003 and extended upto 2015. The total outlay of the project was USD 4.715 million (comprising of USD 420,000 for training studies, USD 500,000 for equipment and USD 3.795 million for technical assistance) and USD 5 million to integrate DRR and Climate Change.

A 12 Battalion strong NDRF (three each from the BSF and CRPF and two each from CISF, ITBP and SSB) has been set-up comprising 144 specialized response teams on various types of disasters of which 72 teams are for NBC disasters. Each Battalion provides 18 self contained specialist search and rescue teams of 45 personnel each including engineers, technicians, electricians, dog squads, doctors and paramedics. The total strength of each Battalion is 1,149. Four Training Centres will be set up in Kolkata, Latur, Bhanu and NISA (Hyderabad) by respective paramilitary forces to train personnel from NDRF Battalions of respective forces. A national level Disaster Management Academy at Nagpur will be setup to provide Training of Trainers and to meet other national/ international commitments. National Disaster Mitigation Resource Centre (NDMRC), co-located with NDRF, serve as repositories of relief stores for 25,000 affected people in each of the Battalion locations. These will cater to emergent requirements especially for the first 72 – 96 hours. At Kolkata and Chandigarh, additional bricks of stores for 50,000 people each will be kept for high altitude areas.

National Fire Service College (NFSC), Nagpur is mandated to train personnel in all spheres of fire engineering. A scheme for upgradation of NFSC was launched in June 2010 to meet the requirements of specialized professional training in all aspects of emergency management, especially fire. **National Civil Defence College (NCDC)**, Nagpur is one of the main centres for disaster relief and management training and a nodal centre for CBRN emergency response. The college has been upgraded to an Institution of Excellence to train a professional cadre of trainers for disaster response and recovery management.

The **Civil Defence (CD)** set-up is being revamped to strengthen local efforts for disaster preparedness and effective response. GoI has launched a CSS in April 2009 with an outlay of Rs.100 Crore during 11th Plan for revamping CD setup in the country. Similarly Fire Services are also being strengthened/modernized to convert them in multi-hazard response force. A scheme for strengthening Fire and Emergency Services was launched in 2009 with an outlay of Rs. 200 Crore in the 11th Plan. DG NDRF&CD office is the implementing agency. It includes procure of items, awareness generation/school safety programme, ToT on search, rescue and fire fighting, fire hazard and risk analysis, project management and monitoring. A grant of Rs. 87,519 is allocated to Urban Local Bodies, a portion of which is available for revamping of fire services within their respective jurisdiction. All municipal corporations with a population of over one million (2001 census) must put in place fire hazard response and mitigation plan for their respective areas. An addition fund of Rs. 472 Crore has been allocated to 7 States (Andhra, Haryana, Mizoram, Orissa, Tripura, U.P., and West Bengal).

The 10th Plan has set into motion the process of shift in focus from response centric approach to prevention, mitigation and preparedness approach – as a means to avert or soften the impact of future emergencies. The 11th Plan aims at consolidating the process by giving impetus to projects/programmes that develop and nurture culture of safety and the integration of prevention and mitigation in development. Hazard identification and risk assessment must be bound by uniformly followed procedures, fine tuned to local conditions. In the absence of such procedures, any sporadic activity based on some ad hoc procedures carries the potential of doing more harm than good. Conceptualization of damage scenarios requires quality scientific studies in a multi-disciplinary environment, and generation of new data, besides filling data gaps. The data gaps, assumptions made, and their implications should be clearly brought out. Data sharing among the various data generators needs to be addressed. All schemes getting Plan funds will be treated as national assets and data would be made available without any pre-condition for use for DM authorities and others. High resolution geospatial database to facilitate temporal analysis of future assessment impact studies in area and also enable integration of all other assessment studies, to evolve a national database. The reliability of hazard, vulnerability and risk assessment will depend upon the quality of maps and other investigation data and various uncertainties involved due to inadequacy of data and other factors. All major stages of development, namely planning, site investigations and designs, are subject to a process of rigorous peer review and accordingly certified.

Mainstreaming DM into development essentially means looking critically at each activity that is being planned, not only from the perspective of reducing the vulnerability of that activity, but also from the perspective of minimizing

that activity's potential contribution to the hazard. Every development plan should incorporate elements of impact assessment, risk reduction and the 'do not harm' approach. All schemes for generating basic input data for hazard and vulnerability impact analysis should be taken up. Projects/schemes which yield multiplier effect for the greatest good of the largest number will deserve priority. Choice of appropriate technology, best practices and early warning systems for disaster management. Stand-alone disaster management projects such as mitigation projects, awareness programmes, capacity building projects, CBDM projects, upgrading early warning systems, fail-safe disaster management communication network, micro-zoning and so on, to be taken up. Mainstreaming DRR into already approved projects in sectors of education, housing, infrastructure, urban development and the like. Some school buildings need to be identified which will be used as relief centres and buildings so designed that they withstand the impact of disasters and also have adequate capacity to provide space as relief centres. Such schools should be equipped with essential services which assume great important at the time of a disaster.

National Landslide Mitigation Project to strengthen the structural and non-structural landslide mitigation efforts and reduce the landslide risk and vulnerability in the hilly districts prone to landslides and mudflows. Expanded Disaster Risk Mitigation Project to strengthen structural and non-structural disaster proneness and mitigation efforts to reduce the risk and vulnerability in the disaster prone districts with community participation. Information, Education and Communication (IEC) programme for disaster risk and vulnerability reduction, disaster preparedness, structural and non-structural mitigation efforts and disaster response by developing ICT materials, print and electronic media products, campaigns, exhibitions etc. India needs to adopt a proactive approach for providing necessary support to the neighbouring countries through multi-lateral cooperation and involvement of regional organizations.

- **Vulnerability Assessment Scheme** – Gujarat has undertaken vulnerability analysis of different parts of the State to different forms of disasters. Such an analysis is urgently required to be carried out by other States too.
- **National Disaster Communication Network (NDCN)** for dedicated communication and IT support for proactive disaster support functions including for early warning and forecasting.
- **National Earthquake Risk Mitigation Project** for strengthening structural and non-structural earthquake mitigation efforts and reducing vulnerability and risk in high risk districts.
- **National Flood Mitigation Project** has multi-objectives including effective preparedness and improved promptness and capability, strengthening community capacity, and reduction in consequences of floods.

- Completely new infrastructure to be built for 6 Battalions @ Rs. 80 Crore per Bn and existing infrastructure to be upgraded for the 2 Battalions @ Rs. 25 Crore per Bn.
- Micro-zonation of major cities to carried out. The high risk cities in seismic zone V and IV to prepare strategies to reduce earthquake risk and vulnerability.
- NDMA/MHA to take mitigation projects for DRR and also undertake special studies and research programmes.
- NDMA got the **National Policy on Disaster Management** approved from the Cabinet on 22 October 2009. It has also issued more than a score of guidelines on Landslides and Avalanches, Cyclones, Earthquake, Chemical Disasters, Drought, Urban Floods, Tsunami, Biological, Chemical (terrorism), Chemical (Industrial), Nuclear disasters and on role of Civil defence, NGOs, Medical Preparedness, Incident Response System, Psycho-social support, Training Regime for Disaster Response, Institutional Strengthening and Capacity Building for DRR, State Disaster Management Plan etc.

STANDARDS, BYELAWS AND GUIDELINES

11.1 Model Town Planning and Landuse Bye-Laws

In recognition of the importance of a techno-legal framework for regulating the already built environment, the Ministry of Home Affairs (MHA), Govt. of India had constituted a national level expert group to recommend modifications in existing regulations to ensure structural safety. The group recommended modifications in the town and country planning Acts, landuse and Zoning regulations, Development Control Regulations (DCRs) and Building Bye-laws and developed a set of model Bye-laws which are technically rigorous and conform to globally accepted norms. They also prescribe regulatory, quality control and compliance mechanisms. MHA has circulated these Model Bye-Laws to the state governments for review of the byelaws currently in force and for ensuring their adoption after revision. The State Governments will review and adopt the Model Town Planning Bye-Law.

Bureau of Indian Standards (BIS) has finalized and published following Codes and Guidelines related to landslide:

- IS 14496 (Part 2): 1998 Guidelines for preparation of LHZ maps in mountainous terrain: Part 2 Macro Zonation
- IS 14458: Guidelines for Retaining Wall for Hill Areas

  Part 1: Selection of Type of Walls

  Part 2: Design of retaining/breast walls

  Part 3: Construction of Dry stone walls
- IS 14680:1999 : Guidelines for Landslide Control

  IS 14804:2000 : Guidelines for Siting, Design and Selection of Materials for residential buildings in Hilly Areas
- National Building Code (NBC) 2016

The Part 2 Macro Zonation dealing with guidelines for preparation of LHZ maps in mountainous terrain is under revision and guidelines for LHZ mapping on meso-scales are under preparation.

It is also felt that there should be codes/guidelines in case of landslides risk evaluation and detailed geological investigations of landslides.

In case of hydro projects in hilly terrains, all the agencies involved, including private and public sectors, require to follow these guidelines for preparation of LSM, LHZ map and risk analysis maps and obtain clearance from the concerned authority before initiating the project.

Indian Road Congress (IRC), an apex body of Highway Engineers in the country also published certain guidelines on landslides mitigation and management apropos Indian highways and roads. Following guidelines are prepared by the IRC on the subject:

- IRC: SP-106-2015, Engineering Guidelines on Landslide Mitigation Measures for Indian Roads
- HRB SR No.21, 2012, State-of-the-Art-Report: Use of Jute Geotextiles in Road Construction and Prevention of Soil Erosion/Landslides
- HRB SR No.15, 1995, State-of-the-Art-Report: Landslide Correction Techniques

Building Materials and Technology Promotion Council (BMTPC), established in July 1990 by the erstwhile Ministry of Urban Development, Government of India, bring out third addition of its Vulnerability Atlas of India in 2019 which includes hazard maps of earthquakes, wind/cyclones, floods, landslides, thunderstorms and vulnerability risk tables based in latest available data. The atlas provides State-wise hazard maps and district wise damage risk tables for the whole country. The information and data given in the Atlas can be utilised by the Institutions and Disaster Management organizations for preparing damage scenarios in individual recurrence of hazards and for developing methodologies for mitigation and prevention.

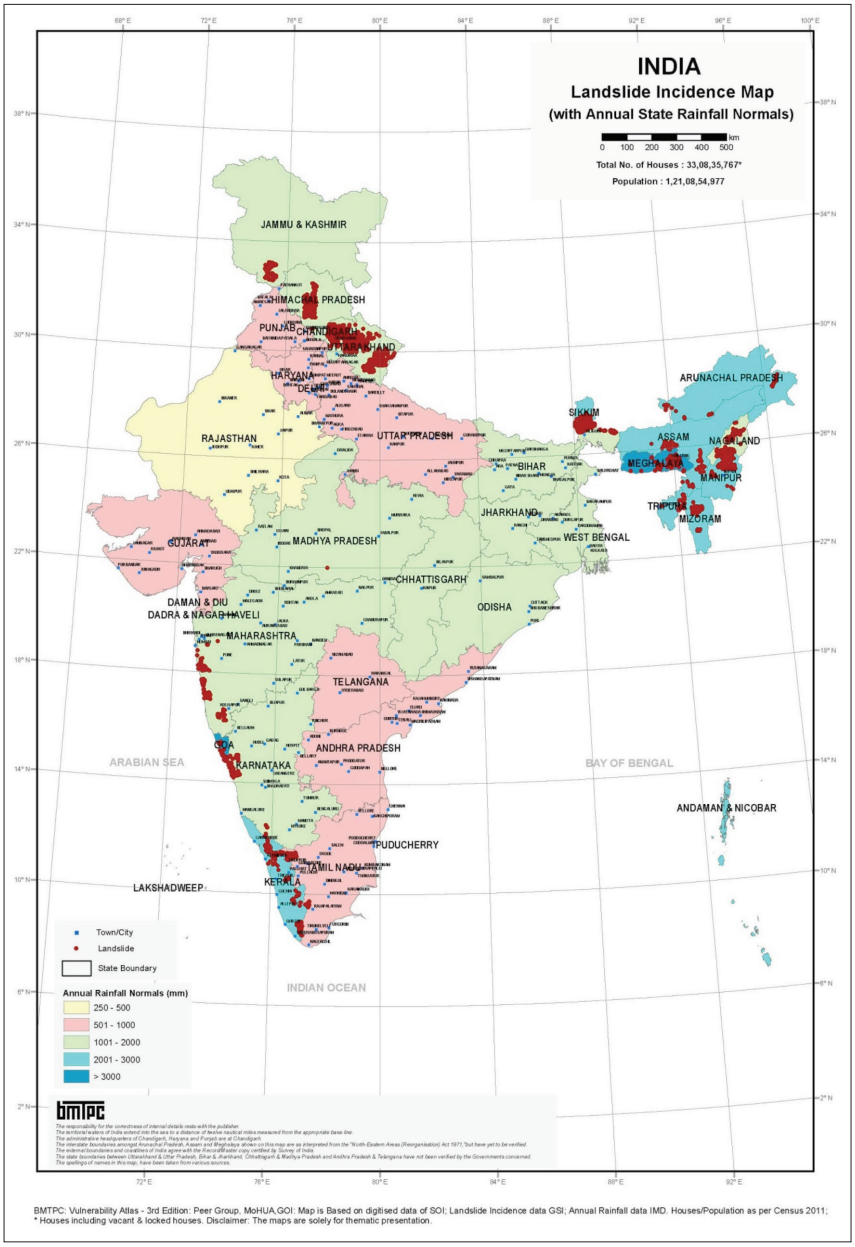


Fig. 11.1: Landslide Incidence Map prepared by BMTPC

11.2 Model Village Planning and Landuse Bye-Laws

To ensure structural safety on village level in mountainous terrains, a techno-legal framework, akin to town planning bye laws, needs to be developed which will translate and codify the landslide concerns into village development.

Appropriate legislation may be considered for enactment for future safe and planned development in towns and villages affected by landslide hazard.

Other than BIS, there are a number of other bodies that develop design codes and guidelines in the country, e.g., the Indian Roads Congress (IRC), Ministry of Shipping (MoS), Ministry of Road Transport and Highways (MoRTH), Research, Designs and Standards Organisation (RDSO), Ministry of Railways (MoR). Codes developed by these organisations should also be updated and made consistent with the current state-of-the-art techniques on landslide safety. These agencies also have a number of internal memos for regulation of construction practices, the review of which should also be undertaken.

11.3 Techno-legal Regime

The techno-legal regime for landslide risk management should cover both technical and legal issues together for effective regulation, implementation and management of landslides risks.

All future developmental activities should be regulated by codal provisions which should have all the disaster resistant features. India does not have any major provisions or good enforcement systems to take care of disaster resistant constructions for landslides. As is known, hazards do not kill people; it is the badly planned and/or adversely located structures that result in damage to property and life. This can be dealt with by adopting a techno-legal regime through introduction of disaster resistant planning features in the development and building regulations.

The DM Act 2005 has clearly defined the institutional and coordination mechanisms at national, state, district and local levels and provides for establishment of Disaster Mitigation Fund and Disaster Response Fund at national, state, and district levels. The Act also provides for legal powers and penalties. The provisions included in the act shall be valid throughout the country.

State Governments should update the urban and landuse regulations by making amendments to incorporate multi-hazard safety requirements. State Governments should review, revise and update the Town and Country Planning Acts, Landuse and Zoning Regulations, Building Bye-Laws and DCRs, and this process will be repeated at regular intervals.

11.4 Licensing and Certification

All professionals dealing with safety aspects of slopes in hilly areas should be trained and sensitized through a capacity building process initially and certified through a licensing process after initial period. Such certification requirements, in accordance with the criteria evolved by the model techno-legal regime, will

be incorporated in the DCRs. Engineering Geologists and Engineers working with the GoI and State Government organisations should also be subject to this certification.

11.5 Compliance Review

There is a need for a sound compliance regime to ensure the effectiveness of legal provisions. It is most important that monitoring, verification and compliance arrangements are in place both at national and state levels.

All landuse and developmental plans in hilly areas will go through a mandatory compliance review by the professionals of the ULBs and PRIs to which these are to be submitted for approval. The major projects and critical structures will be put through a mandatory compliance review by qualified external agencies.

The model techno-legal regime recommended by the expert group set up by the MHA will be incorporated in the DCRs to enforce the scrutiny of developmental and landuse plans in hilly areas for their compliance to safety in accordance with the requirements under the DCRs. This scrutiny will be applicable to all construction habitations and structures in both urban and rural areas. The state governments, in consultation with their SEMCs and HSCs, will ensure that the bodies responsible for compliance are equipped with qualified professionals to undertake general compliance reviews. These professionals, who may be government employees or accredited private practitioners, will be trained specifically in the compliance of the bye-laws.

The area selected for expansion of human settlements, industrial clusters and other important projects in hilly areas should be assessed regarding the status of slope stability by accredited agencies or professional for safety of these.

11.6 Technical Audits and Monitoring

All existing habitations and important structures located in vulnerable areas and facing high risk from unstable slopes should be monitored by the ULBs. The slope stability assessment reports and treatment requirements, if needed, should be scrutinised for regulation compliance as per the specifications of the model techno-legal regime. In case of major projects, these aspects should be subjected to detailed technical evaluations before granting the construction permissions.

11.7 Techno-financial Regime

After occurrence of a disastrous landslide, the Central and State governments provide funds for immediate relief and rehabilitation. This process does not adequately cover the requirements for reconstruction of damaged structures and land especially those that are privately owned. Expenditure incurred by the GoI in the provision of funds for relief, rehabilitation and reconstruction

is increasing manifold due to the rapidly increasing risk profile of the country. In most countries, risk transfer through insurance has been adopted as a step towards providing adequate compensation for the loss of property caused by disasters. Such a mechanism reduces the financial burden of the government. Risk transfer mechanisms have been found to be fairly successful in some countries. Therefore, the insurance sector will be encouraged in our country also to promote such mechanisms in the future.

Financial institutions should consider the compliance of safety aspects as far as slope stability issues are concerned before offering construction loans in hilly areas. The housing development programmes supported by the GoI and state governments (like Pradhan Mantri Gramin Awaas Yojana), and all large-scale housing schemes will be made to comply with landslide safety regime.

The approval and disbursement of funds from banks and other financial institutions to industrial units will also be linked to the compliance with slope stability norms by these units.

11.7.1 Financial Allocations for Landslide Management

Central and State ministries/departments will mainstream disaster management efforts in their developmental plans. Accordingly in annual plans, specific allocations will be made for carrying out disaster awareness, preparedness and mitigation efforts. Corporate sector can also be involved to support landslide risk management efforts as a part of Corporate Social Responsibility (CSR).

11.8 Integration of Landslide Management with Development Planning

- Creating a vibrant network of agencies and knowledge based institutions dealing with landslide studies for effective implementation of national landslide agenda
- Empowerment of multi-institutional multi-disciplinary teams
- Switch-over from piecemeal remediation of landslides to holistic implementation of control measures
- Management of change from outmoded approaches in landslide remediation to state-of-the-art technology based landslide control
- Mobilization of private sector and Insurance sector participation
- Streamlining of procedures for speedy funding of priority/fast track projects

- Switchover from conventional bureaucratic benchmarking and project progress evaluation to peer-centric progress review, evaluation and mid-course correction
- Seeding the concept of landslide prevention, and opportunity costs in administrative management of landslides

11.9 Recent Government Initiatives

GoI has constituted a number of Disaster Management bodies at national, state, district and sub-district levels to assess the hazard and its risk and to develop early warning systems, evolve techniques for hazard mitigation, generate public awareness about the causes, effects and safety measures to be adopted and to undertake rescue, relief and rehabilitation measures. At national level, the Ministry of Home affairs was declared as the Nodal Ministry for coordination of relief and response and overall disaster management and Geological Survey of India, an attached office of the Ministry of Mines, declared as nodal agency for landslides management by the GoI in January 2004. Accordingly an Action Plan on Landslide Hazard Risk Mitigation was formulated by MHA and GSI started its implement ion. Subsequently, the National Disaster Management Act 2005 came into being 23rd December 2005 and the government set up National Disaster Management Authority (NDMA), a statutory body under the chairmanship of Prime Minister as provided for in this Act. The responsibility to cope with natural disaster is essentially that of state government. The role of central government is supportive in terms of supplementation of physical and financial resources. At state level, each state government has set up Disaster Management Authority under the direct control of the Chief Minister. The Chief Secretary of the State heads a State level committee which has overall responsibility for the relief operations in the state. The Relief Commissioners who are in charge of the relief and rehabilitation measures in the wake of natural and other disasters in their states function under the overall direction and control of the state level committee. At district level, it is the Collector/District Magistrate/Deputy Commissioner who exercises coordinating and supervising powers over all the departments at district level. For every natural disaster, the declared nodal agencies are responsible for coordinating/undertaking studies for processes responsible for hazard and suggesting precautionary and preventive measures, monitoring the disasters, developing early warning systems etc.

National Landslide Susceptibility Mapping (NLSM) programme was launched by GSI in year 2014 with an aim to cover the 0.42 million sq. km landslide prone areas of the country. The objectives of the programme are to create a dynamic National Landslide Susceptibility Geodatabase; to prepare GIS – based seamless Landslide Susceptibility Maps of India on 1:50,000 scale and to prepare a nation-wide repository on GIS-based Landslide Inventory. The states targeted for preparation of susceptibility map are given in figure below:

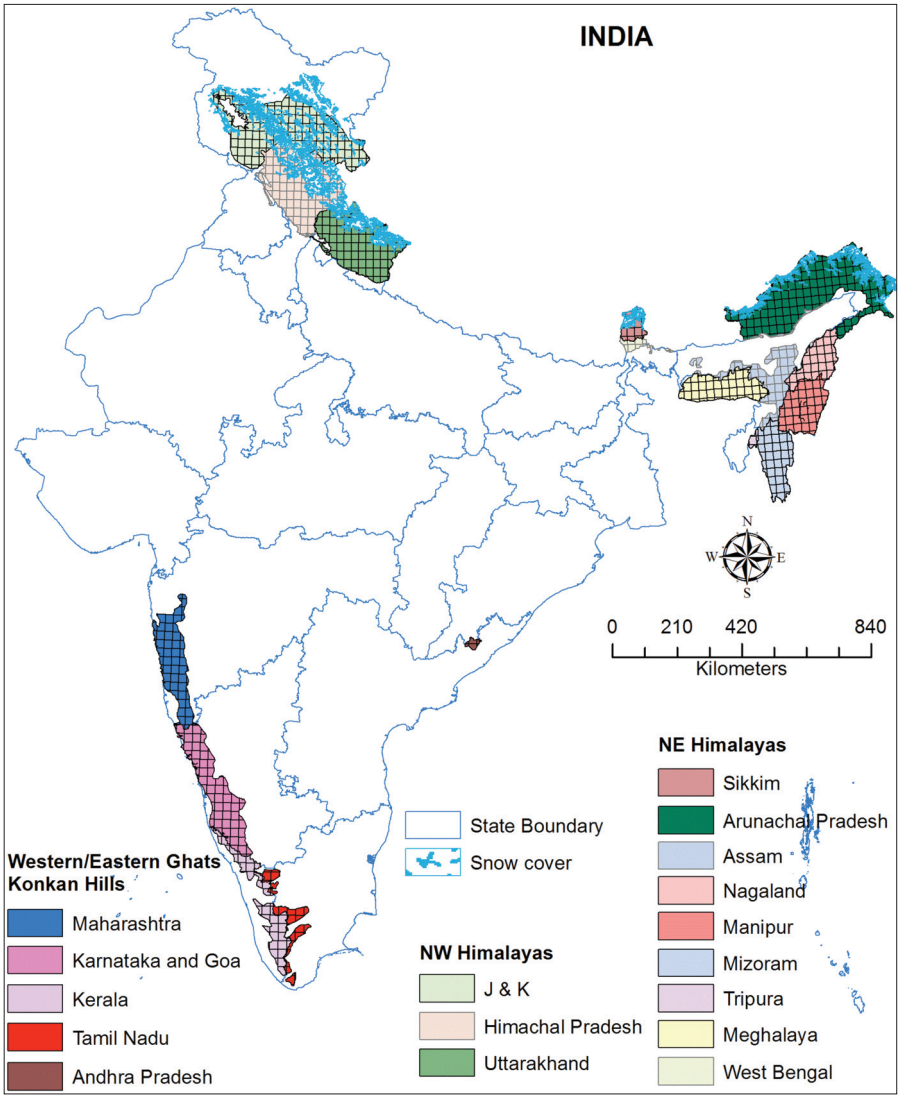


Fig. 11.2 : States covered for susceptibility mapping under NLSM Programme

11.9.1 Technical Committees

Technical Advisory Committee (TAC) for Landslide Mitigation and Management in India was constituted vide the Gazette of India Notification dated 25th September 2012. The TAC is to act as an "Apex Body" of the Government of India and is to serve as "Think-tank" to nurse landslide sector with cutting edge science and technology, fresh ideas and stimulus. Secretary, MoM is the Chairman and several Secretaries of other crucial Ministries of Central and State Governments are made Members of the TAC. The committee would look

into all matters pertaining to landslide mitigation and management including a) recommending suitable techniques and scale for landslide hazard mapping, b) monitoring of landslides, c) research and development, d) human resource planning and e) capacity development.

11.9.2 National Collaboration

MoU between GSI and NRSC on landslide studies

NRSC and GSI signed MoU on 20th December 2013, concerning event-based landslide inventory mapping and landslide susceptibility/hazard zonation in the landslide vulnerable areas of India.

MoU between GSI and DTRL on landslide studies

To develop technology for an Early Warning System of a landslide based on instrumentation and empirical relation of rainfall and ground displacement, a MoU was signed on 5th September 2014 between GSI and DTRL.

11.9.3 International Collaboration

GSI-NRSC-ITC collaboration on landslides

To carry out advanced research in landslide domain joint collaboration among GSI, NRSC and ITC, The Netherlands was initiated in the year 2007.

GSI-NRCan, Canada collaboration on landslides

Geological Survey of India and Geological Survey of Canada collaborated to develop an early warning system by installing instruments in slide area and monitor their movement through real time analysis between 2003 and 2008. In 2012, the umbrella MoU between Natural Resources, Canada and MoM/GSI was extended for another 5-year Term till 2017 to carry out/continue landslide monitoring and early warning studies in some selected landslide sites in India using satellite-based (using RADARSAT 2 and RISAT II data) SAR Interfermetry techniques.

GSI-BGS, United Kingdom, Collaboration on Landslide

GSI and British Geological survey (BGS) of Natural Environment Research Council of UK of the Natural Environment Research Council of UK signed a MoU in 2017, valid for four years, for sharing of information and knowledge to enable collaborative research in the field of Earth Sciences, Mineral Prospecting and Disaster management. Project 'LANDSLIP- Landslide Multi-Hazard Risk Assessment, Preparedness and Early Warning in South Asia: Integrating Meteorology, Landscape and Society' was initiated under the collaboration to develop effective integration tools for Landslide Multi-Hazard Risk Assessment, Preparedness and Early Warning.

11.10 National Disaster Management Policy and Guidelines

National Disaster Management Authority has formulated National Disaster Management Policy. The present Landslide Disaster Management Policy envisages a two tier measures which pre-disaster measures comprising preparedness, prevention and mitigation and post-disaster measures comprising emergency response (rescue & relief) and rehabilitation. Unlike earthquakes and floods, landslides are localized events and are induced by some causative factors, which are well understood. This hazard can be most effectively controlled or reduced if initiatives and activities are based on the most modern technological and scientific approaches and the policy implemented through a well coordinated institutionalized mechanism.

The approach to formulation of guidelines comprises a participatory and consultative process. The basic concepts of this exercise include:

- An exhaustive review, disaster-wise, of the actions/steps taken so far by various agencies including the central ministries and departments, states, academic, scientific and technical institutions, NGOs etc.
- Identification of the residual agenda in terms of operational, administrative, financial and legal issues.
- Identification of the destination, in terms of goals and objectives, to be attained, in the short, as well as long term, duly prioritized as vital, essential and desirable with timelines and milestones.
- Drawing up of a roadmap to the destination duly indicating the milestones to facilitate easy monitoring.
- Putting in place an institutional mechanism that oversees the operationalisation of this roadmap.

NDMA will play a nodal role in initiating the institutional measures for prevention, mitigation and preparedness with a view to generate a holistic, integrated and proactive approach to Disaster Management.

The NEC, statutorily mandated to assist the NDMA will be responsible for preparing the national plan based on the policy and guidelines. NEC will also be responsible for getting it approved by the NDMA and then operationalising it.

The National Disaster Response Force (NDRF) will play a pivotal role in specialised response to a threatening disaster situation or disasters. The general superintendence, direction and control of this force will be vested in and exercised by the NDMA.

At the State level, the SDMAs, established by the state governments to lay down policies and plans for DM in the state will, inter-alia approve the state plan in accordance with the guidelines laid down by the NDMA and coordinate the implementation of the state plan.

Landslide is a very significant natural hazard in the country which not only threatens environment, human safety, infrastructure and post earthquake relief operations but also hugely impacts the national economy. It deserves much greater attention in terms of multi-hazard mapping, research, scientific investigations and effective mitigation and management practices. The Guidelines addresses varied aspects of landslide mitigation and management and adopts a holistic and integrated approach that maximizes the networking of voluntary agencies, affected communities and other stakeholders.

11.10.1 National Risk Management Strategy

NDMA constituted a Task Force for the formulation of national and local level strategy for landslide risk reduction. The strategy document is also fulfilling the fifth target of Sendai Framework for Disaster Risk Reduction (2015-30) i.e., Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020. Strategy document addresses all the components of landslide disaster risk reduction and management such as hazard mapping, monitoring and early warning system, awareness programmes, capacity building and training, regulations and policies, stabilization and mitigation of landslide etc. This strategy document envisages specific recommendations for the concerned nodal Agency, Ministries/Departments, States and other stakeholders, so as to avert or reduce the impact of future landslide calamities.

COMMUNITY BASED ACTION PLAN FOR MULTI-HAZARD RISK MANAGEMENT

Lessons learnt from recent disasters have made it apparent that no strategy may be successful in disaster risk reduction until and unless the affected communities are made an integral part of the management process and come forward to act proactively for risk assessment, prevention, mitigation, preparedness and emergency response. The communities in Garhwal Himalaya suffered major earthquakes (Uttarkashi-1991 and Chamoli-1999), landslides and debris flow (Malpa and Ukhimath-1998, Phata-2001, Budhakedar-2002, Varunawat-2003, Lambagar-2004, Dhanaulti-2005, Dharchula-2006, Syaldhar-2007, Sukhidang-2008, Munsiyari-2009, Bhagirathi Valley-2012, Kedarnath-2013), flash floods (Alaknanda-1970 and Bhagirathi-1978), major forest fires occur almost every year, hailstorms and lightning etc. Hence, they became very sensitive to such disastrous events that caused heavy loss of lives, economy and environment. Such losses are rising due to increase in frequency and severity of disasters and rampant unscientific developments in vulnerable locations. During the last one decade, the interventions made by the governmental and non-governmental organizations through various efforts like Disaster Risk Management Project by United Nations Development Programme and Ministry of Home Affairs, Government of India as well as pilot projects on disaster management undertaken by local community based organizations have built the communities' capacity to prepare themselves against disasters and reduce the risks by appropriate planning, development and management at local levels. It is believed that an aware, informed and prepared community is better able to avert, prevent and react to disasters than otherwise. With this background, an effort was made to empower communities through training and field demonstrations to initiate local actions for multi-hazard risk management through the inhabitants of 50 villages in Rudraprayag District in Uttarakhand State, Garhwal Himalaya. The chapter elaborates the activities undertaken in developing the methodology for community based disaster risk management, the process of operation, the outcome and its sustenance.

12.1 Introduction

No part of the earth is free from natural hazards that adversely affect the life, economy and environment. But these hazardous events become catastrophic and termed as disasters when they strike any built environment & affect population that is not prepared against these hazards. Thus, disasters of any

kind may inflict the safety and quality of life in a society. Despite all the scientific and technological innovations, it has been difficult to reduce the impacts of these disasters. Governmental or institutional interventions for disaster management do not succeed due to lack of considerations for community dynamics, perceptions and priorities in local context. Rather the frequency and intensity of disasters appears to have increased due to rise in population density, occupation of hazardous areas, unplanned/fast developments, human fault and hostile actions, neglect of unforeseen hazards and so on.

Since most of our concerns are anthropocentric and relate to development of a sustainable environment for its survival, most hazards in remote and unpopulated areas are not cared for and all our efforts focus towards disaster management of populated and built areas. India's most population (about 70%) lives in villages and hence, the present attempt is primarily oriented towards a rural community to reduce disaster risks.

Disasters are linked not only to hazardous events but also to the vulnerabilities of the exposed elements and capacities within the society to cope with them. Thus, there are three major operating factors that influence the degree of disaster in any area i.e. hazard factor (magnitude, frequency, time of occurrence, duration & extent), vulnerability of different elements exposed to hazards (degree/duration of exposure, proximity to hazardous sources, degree of vulnerability and its value) and the capacities (techno-economic status, socio-political system & coping mechanisms). The paper focuses on possible methods of hazard identification and assessment by the community in its locality, by virtue of their natural experiences with these disasters in the past/present that affect their lives, livelihood, livestock and living places.

A history of these disasters and their impacts on community, its resources and environment is recorded through a community meeting for spatio-temporal assessment of all the hazards and depicted in a sketch called community based multi-hazard assessment plan. The sketch shows not only the hazards (indicating the place and year of occurrence) but also the physiographic details, natural & social resources, infrastructure and community facilities. The second step in the approach relates to collection of information and data on different elements (physical, human, livestock, environment etc.) in a presentable form i.e. Tables or Charts, thus, providing an idea of degree of vulnerabilities of different elements to all the hazards collectively as well as individually. In the third step, capacities within the community in terms of skills, resources, knowledge & information to face or cope with the disaster are evaluated. These three steps give a very good assessment of the potential risks due to possible disasters in any locality and an action plan is then prepared to prevent, mitigate or manage these potential disasters for reducing the risks/losses.

The planning strategy was then worked out on the basis of the aforementioned three steps. The fourth step (first in the planning strategy) makes an attempt towards hazard management i.e. to explore if the hazard can be avoided, prevented, mitigated, or monitored. The community looks for various options/ alternatives that can be applied using the local skills, resources, knowledge and techniques. In the fifth step, an attempt to strengthen the existing vulnerable elements or reduce their degree of vulnerabilities through the use of anti-disaster or disaster resistant technologies will be promoted or encouraged. The last step, which envisages that despite all the efforts, disaster may continue to inflict upon the society, ensures that the community is aware and prepared to face the remnant disasters in a planned way rather than being caught suddenly in a rash manner. It assumes that an informed, aware and prepared community will be better able to cope with disasters than otherwise.

12.2 Why Community Based Disaster Risk Management?

The need for a Community Based Disaster Risk Management (CBDRM) can be highlighted by pointing out the shortcomings in the existing approach and stating the advantages of CBDRM.

12.2.1 Shortcomings in the existing approach

a. Same plan regardless of the regional characteristics is implemented/ imposed everywhere.

b. Local/indigenous knowledge, experience, skills, resources and techniques are not given due importance. Rather external resources and techniques are proposed to be utilized.

c. Negligence about local cultural instincts and heritage.

d. Prioritisation is decided by an outsider and not the stakeholders or the community itself.

e. Local community does not have any information about the disaster management plans for their area and the role of different sectors in helping the community during disasters.

12.2.2 Advantages of Community Based Disaster Risk Management

a. Feelings of coordination and self belonging to the society are developed. As the plan is prepared in local laymen's language, it is better understood by the community (including the illiterates).

b. Local geo-climatic and socio-economic characteristics get attention of the people in development and disaster management.

c. Local initiatives begin and community provides assistance to the executing agencies involved in disaster management.

d. There is exchange of knowledge, information, skills & techniques between the community and the experts involved from outside.

e. Community comes forward to put its ideas and suggestion for selection of appropriate programmes suitable to their locality and society.

f. Community can keep a watch/monitor the quality of works being done in its locality. It will also generate a sense of responsibility among the community.

g. It will lead to capacity building of the community on issues of disaster safe developmental activities.

12.3 Development, Testing & Application of Community Methodology

The inception of the idea that CBDRM would be rational and beneficial for the society, led to development of a suitable methodology for use by the community in its aim to reduce disaster risks. Although several scientific and technological methodologies exist for hazard identification, assessment, monitoring and control; yet the community is barely involved or benefited by their application. Therefore, an attempt has been made to involve and use the community's experiences and knowledge in dealing with the issues of disaster assessment and management while applying scientific principles of disaster management in a broader sense.

Basically, six steps were identified — three of which involve assessment of hazards, vulnerability and capacity within a locality and the other three steps deal with action planning for modification or management of the first three issues. A tool called participatory learning and action (PLA) was applied during development of the said methodology to make it practical and easier for the community to adopt. The draft of this approach was taken to an interior village and discussed with the community there about its objectives and usage. The village community took keen interest in the proposed activity and carried out the whole task without much difficulty in less than two days at a community gathering. The results of this test were quite encouraging and hence, it was planned to extend the methodology to the community in other villages through a training of master facilitators from the members of task forces for disaster management in these villages.

The format of the methodology was designed in a way so that it can cover all the necessary steps in community based action planning for disaster risk management. However, the format was kept in an open style so that the community should be able to add or alter any information necessary to make it more effective and relevant as and when required. After drafting the plan, it was proposed that it should be presented before the community through a gathering of all the villagers and then tested and reviewed. The work plan and

schedules of these plans were made available for public information. Further, the roles, responsibilities and operational procedures of the community members involved in planning, testing, review, implementation, monitoring and evaluation were also well defined.

12.4 Procedure for using Methodology for CBDRM

At the onset of this process, some key actions are required to be taken by the community to initiate the work in an organised and systematic way. It involves formation of task forces and supporting groups, their affiliation with village development committee, community mobilization and disasters related sensitization. In the present case, such task forces for disaster management were formed at village levels through Disaster Risk Management Programme of United Nations Development Programme (UNDP) and Ministry of Home Affairs (MHA), Government of India.

A dedicated village level disaster risk management committee should gather necessary information about disasters and their impacts in their locality to sensitize people through awareness campaigns. In order to involve the whole community in the process of disaster assessment and preparation of plan for disaster management, it would be essential that people are made aware about the impacts of hazards and need for preparedness to reduce losses. Community mobilization or motivation can be done through street plays, drama, songs, skits, posters, meetings, interactions, Sandesh Yatras (Message trips) and video documentaries etc. It should gain confidence among community and involve all the stakeholders in drafting, testing, review, monitoring, revision, implementation and evaluation of CBDRM plan.

12.4.1 Drafting the Plan

It involves the following activities:

- Disaster Campaign and Community Mobilisation/sensitization
- Information about locality, community and the environment
- Multi-Hazard Identification & Assessment
- Vulnerability and Capacity Assessment
- Risk Categorization and Prioritization
- Existing protection systems and safety/risk management plan
- Where are gaps in our protection and safety? — Identify what is not being done
- What options are available and what action can be taken? — Brainstorming alternatives

12.4.2 Testing and Review

- What is practically feasible and acceptable? Evaluate Actions
- Who else is doing this? — Coordinate with others
- How the implementation priorities will be set? — Define Action Plan
- Who administers the plan and implements actions? —- Develop a Strategy
- How the actions will be done?
- When the actions will be started and completed?
- Monitoring and Evaluation scheme? — Adopt and Monitor

12.4.3 Implementation Strategy

Through the process of plan preparation, community determines the WHY, WHAT and WHERE of the plan; WHY damages occur, WHAT you want to do to achieve your goals, and WHERE in the community you want to implement the measures to reduce losses. To ensure that the plan will be implemented effectively, the following additional questions like WHO, WHEN and HOW should be answered.

WHO? Who will lead the implementation efforts? — Establish Implementation Committee. A committee responsible for managing the implementation activities must be assigned. It will be responsible for ensuring that project/ plan continues to make progress. He should dedicate a significant amount of time to this task and should have the ability to obtain assistance from others.

WHEN? When will these activities be implemented, and in what order? A proper Implementation Schedule should be prepared defining top priorities, vital, essential and desirable actions with place, time and duration. Some activities may be implemented simultaneously. The following pre-requisites must be met to initiate ground actions.

- Identify all implementation tasks.
- Determine needed order of completion.
- Coordinate with other community activities and determine any special scheduling needs (e.g., seasonal climatic conditions).
- Determine start date and completion date.

HOW? How will community fund the implementation of envisaged actions. An appropriate budget and potential source(s) of funding should be identified. Identification of suitable technical and financial assistance sources is also

important. Sometimes, the implementation of actions may require permits or approvals, which should be discussed at planning stage. The number of human resources, the time and skills required to execute the work should also be pre-determined.

12.5 Risk Assessment Process

It includes information pertaining to population density/distribution, age distribution, mobility, vulnerable groups, and emergency resources etc. Environmental information includes water sources, climatic conditions, landforms, fauna and flora.

12.5.1 Compilation of Data/Information Related to Past, Existing and Potential Disasters

Before embarking upon the spatial assessment on a chart or a sheet of paper, it is advisable that a list of the past, existing and potential disasters that have affected or may affect the life, economy and environment in the locality is prepared. The list would serve as a basis for indicating the affected or susceptible elements and collection of necessary information on these disasters and their impacts on the community which will ultimately help in planning and management.

The planning committee can identify hazards in the community by using the following methods:

a. Involve the whole committee in the planning process.

b. Research the history of previous hazards in the community. Consult local historical records, old newspapers, local administration etc, for evidence of previous emergencies.

c. Ensure both 'natural' and 'man-made' hazards are identified. Be completely objective.

d. Brainstorm, using the complete planning committee, to ensure that no hazard has been overlooked.

e. Draw information from emergencies in other comparable communities and localities.

f. Consider hazards identified by higher level planning committees.

The output of this step is a list of hazards, including those which have no history of occurrence in the locality. List hazards randomly; do not attempt to rank them at this stage.

12.5.2 Preparation of Multi-hazard Risk Management Sketch of the Locality

Based on knowledge and experiences of local people, an attempt is made to depict the village boundaries, physiographic features, natural resources, social or individual resources, community facilities, infrastructure and hazards of all kinds. Such a sketch displays a very good picture of the resources, hazards and the development in the locality. Following steps are taken to achieve this goal:

i. Village territory (boundaries) and physiography (drainages, ridges, valleys, slopes, lake, ground cracks, landforms, rivers etc.)

ii. Natural Resources — Forests, Mines, Water sources such as falls, springs, lakes, medicinal plants

iii. Social/Individual Resources or properties — Human population, live-stocks, Agricultural fields, Cowsheds, Watermills, Open lands, Building sites, Houses, shops, factories

iv. Community Facilities — Panchayat Bhawan, Community Centre, Temples, Schools, Society or Govt. Offices, Police Station, Forest Post

v. Infrastructure/Basic Amenities — Roads, Hospitals, Electric lines, telecommunication (phones, WLL, mobiles, wireless, Post office), Water pipelines

vi. List of disasters (past, existing and potential). All the information and data on the past disasters and their impacts are collected in a tabular form. The table provides the community a complete idea of the damages suffered by them in previous disasters and the degree of potential risks from future disasters. The details of lives lost, livelihood, resources, environment etc. are well illustrated through this exercise

vii. Hazardous areas/Susceptible zones — indicate areas that are or may be affected by any hazardous event and put a symbol for that disaster e.g. landslide, earthquake, forest fires, hailstorms

viii. Risk management features indicating existing preventive and mitigative measures, safe/unsafe shelters and routes, evacuation scheme, proposed development and disaster resistant features

Note: Mark north direction on the village sketch and use standard legends (wherever possible) for different features on the sketch.

12.5.3 Hazard Analysis & Disaster Sensitive Periods/Seasons

Hazard analysis is that part of the planning process which identifies and describes hazards and their effects upon the community. The analysis involves: identifying

hazards; describing hazards (their frequency, distribution and impacts); describe effects (susceptible zones, vulnerable persons & properties, likely facilities and services to be affected and the potential problems), describing community and environment (vulnerability and capacity assessment); Prioritizing hazards; and determining planning objectives and scope for prevention, mitigation, preparedness, response and recovery. Hazard analysis provides the basis for emergency planning and arrangements.

Temporal analysis of the data on disasters will also reflect the vulnerable periods of the year that may be more sensitive to a particular disaster compared to other periods. Accordingly strategies for prevention, mitigation or preparedness can be planned.

12.5.4 Disaster History

Since most of the information gets collected during the last step, the same can be used to write a history of disasters in the locality. The community can add versions of people's experiences with the disasters and the lessons learnt or problems faced prior, during or after the disasters. This will be quite useful to record lessons learnt, good and bad practices as well as to avoid any mis-happenings.

12.5.5 Vulnerability & Capacity Assessment

Vulnerability analysis is done by assessing the proportions of each group as part of the whole population, identifying any specific localities where there are concentrations of vulnerable people or other elements, e.g. schools, temples, in proximity to a hazard source. For each group identified, problems which might be expected under emergency conditions are noted. Community information also provides data on those groups in the community that have specialist skills or knowledge which may be useful in emergency management.

In order to bring a sense of belonging to the document by every individual in the community and to evaluate overall vulnerabilities and capacities, detailed information from each household/family should be suggested. The basic information gathered from each household include a reference to the households, the name of its family head, income levels and sources, age groups and physical/mental health conditions, skills/trainings in disasters management, emergency facilities and so on. Among the data on households, an attempt was made to identify insecure and vulnerable people who will need special and urgent attention in case a disaster strikes.

After an analysis of human and livestock vulnerabilities is completed, the next most important vulnerability concern is structural vulnerability of buildings. It is often seen that the impacts of disasters become high due to structural collapses particularly during earthquakes, landslides and floods. Thus, an

attempt is made to collect data pertaining to vulnerability of buildings in the locality. It depends on the type of structure, year of construction (age of building), design and construction practice, and so on. Besides considering the vulnerability aspect, it also deals with the capacities within the structure that may be used for safety, search and Rescue during disaster times. A mention of emergency requirements during disaster times would be helpful.

Just like people and livestock in households, prepare a separate list of vulnerable buildings so that utmost care can be taken of the people who are resident in such buildings or may get affected by damage or collapse of these vulnerable buildings. The list should be available at Emergency Resources & Operations Centre (EROC) and distributed to responsible members of the task force and supporting groups. It will help them to take quick actions in saving lives as the information would be useful in locating the potential structures that may suffer severe damages during a disaster.

The community can also prepare a sketch map showing the various life line and critical facilities as well as basic amenities available in the village or in the vicinity of the village that can be affected or utilized during a disaster. The contact details of the emergency personnel during emergency should be made known to the community.

12.6 Risk Categorization and Prioritization

Prioritising hazards enables a planning committee to concentrate efforts on those hazards which may have the greatest effect on the community. Prioritization can be assisted by using certain tools, e.g. 'Matrix Analysis', and 'Hazard Scoring & Ranking System'.

Based on the cumulative risk determined on the basis of degree of severity of the hazards and the class of vulnerability of different elements, the various levels of risk can be defined as acceptable, tolerable, adaptable, and non-acceptable or intolerable risks. The categorization will also help prioritizing the focus of disaster risk management actions as vital, essential and desirables within a given span of time.

12.7 Action Plan for Multi-Hazard Risk Management

The procedure for use of CBDRM methodology involves application of the maps, information and data obtained through the process of risk assessment for management of risks/losses in the locality in a way so that disaster incidences as well as the impacts can be minimized.

12.7.1 Hazard Avoidance and Prevention Plan

It may involve the following activities.

- Hazard Zonation — Incentive Zoning and Performance Zoning

- Regulating Development Controls/standards
- Enforcement of Building codes/byelaws
- Promotion of Disaster Resistant Technologies
- Awareness and Dissemination of Safety Guidelines
- Awareness Campaign about hazards & their impacts
- Structural Mitigation Measures
- Non-structural or Regulatory Measures
- Loss Sharing Measures

12.7.2 Hazard Mitigation & Vulnerability Reduction Plan

Disasters that cannot be avoided or prevented are considered for mitigation and vulnerability reduction planning. Activities, often long-term, which aim to reduce the impact of a hazard on vulnerable communities, and address the related vulnerable conditions and their underlying causes are known as mitigation. Mitigation planning may include:

- Reducing the frequency, severity, duration, extent of hazards by various possible means
- Diversification of incomes/livelihood alternatives
- Food and Water security
- Training for community in disaster planning and management
- Disaster Resistant Housing programmes, Building Codes and Byelaws
- Advocacy to government and community
- Environmental protection

12.7.3 Preparedness Plan

The disaster preparedness aims to:

- Ensure that appropriate systems are in place to provide prompt and effective assistance to disaster victims.
- Prepare the community to handle the disaster in the first 48-72 hours or so when outside help has not reached and the local administration is itself affected by the disaster.

It includes Community awareness/education, disaster plans, training/test exercises, emergency communications, Evacuation plans, Public information, Warning systems, Resource inventories, Provision of special resources.

The planning committee will need to determine whether any specialist functions will be required to be performed in support of the main community plan. These functions may include medical, communications, search & rescue, welfare, transport, engineering, and agriculture.

12.7.4 Establishment of Emergency Resources and Operations Centre

- List of Skilled and Trained Human Resources in and around village.
- Available Emergency Resources — List and Storage.
- Information & Data on past, existing and potential disasters.
- A copy of the community based disaster management plan, its schedules and progress with time.
- Training materials for disaster management.
- Active stockpiling of emergency resources (This approach for providing supplies usually is more effective than the massive, post-disaster influx of supplies. It also does not tie up capital on stocks that may have a limited shelf life or never be used).
- Facilities for collection and maintenance of disaster funds.
- Disaster Reduction Day/Week Celebrations.

12.7.5 Warning, Drills and Exercises

Methods used for disseminating the warning may include media messages, door knocks, community networks, audible and/or visual signals. Consideration should be given to warning special needs groups like deaf, dumb and blind.

a. The stages of evacuation which are: warning; withdrawal; shelter; reunion; and return;

b. Identification of: sites suitable as assembly areas; sites suitable as evacuation centres; evacuation routes between the above; organisations responsible for conducting and assisting with the evacuation; registration teams;

c. Organisations responsible for arranging and coordinating transport; and

d. Organisations responsible for operating evacuation centres.

12.7.6 Response Plan (with Local Capacities)

Response is the activation and implementation of operational systems which includes activating and staffing the Emergency Resources and Operations Centre (EROC), activating the communications system, collecting, processing, and disseminating information, alerting support organisations, preparing and disseminating warnings and other public information, activating liaison arrangements, coordinating and deploying resources and arranging outside assistance, and providing assistance to other areas. The response plan should include information on:

- Reflex Action to disaster and information
- Emergency Communication and Transportation
- Search, Rescue, Emergency Relief & First Aid
- Safe/alternate routes for evacuation
- Safe Accommodation, Temporary Shelters with basic amenities like food, water, light, ventilation (air), communication, health facilities (medicines), sanitation etc.
- Security of private properties and weaker sections particularly young women and children
- Carcass disposal, disinfectant spray and immunization
- Consolation to the victims
- Rapid Damage Assessment and Relief Distribution
- Repair, Restrengthening, Retrofitting, Reconstruction, Resettlement, Rehabilitation, Recovery, Redevelopment.

12.7.7 Do's and Don'ts

In order to respond properly to disasters, it is vital to know how to react to disasters. The task forces will identify these do's and don'ts for each hazard and make the community aware and prepared with this information. In order to make it more effective, practical rehearsals can be conducted with different target groups for ensuring the right kind of response by all. The necessary information regarding this is available from the District Authorities and the State Emergency Operation Centre at free of cost.

12.7.8 Emergency Communication and Transportation Plan

Since immediately after the disaster happens, one need to communicate with others who can be at risk or who can help; communication strategy should

be prepared to trigger the Incident Command System (adopted recently by Government of India for Disaster Risk Management). Most often, the routine communication systems fail during such disasters, therefore, alternative arrangements that can be depended upon during disaster should be made. Transportation is also affected during disasters. So it becomes difficult to reach to the victims in time. An alternative emergency route and conveyance method can be thought of for operations during such emergencies.

A list of important individuals, authorities and offices related to disaster risk management should be kept ready along with their names, designation, addresses (both official and residential), phone numbers, mobile, fax, email etc. in easily accessible manner.

12.7.9 Search, Rescue, and Relief

A separate group of people can be assigned the task for carrying out search, rescue and relief operation during any disaster. Persons with background in army, civil defense, home guards or police can be helpful in doing such activities. Nurses and medical practitioners can guide and help in emergency relief and first aid to the victims.

12.7.10 Evacuation Plan, Safe Accommodations & Sites for Temporary Shelters

Since a large population of the village may be affected during disasters, a sketch of the village territory showing safer buildings and sites should be prepared during plan formulation to indicate the places and the routes to the community to be used during disaster periods. The plan map should not only show the evacuation routes but also indicates the routes that may be used by outsiders for providing relief to the victims. The access route is connected to main road. The evacuation routes are normally the alternate footpaths leading to an area away from the vulnerable structures and susceptible locations.

12.7.11 Consolation Team

The consolation teams may consist of respected aged persons, religious priests, school teachers or community leaders. Generally, there is a panic and trauma during and after the disaster. Victims need to be properly consoled and inspiration from local known person gives them more solace compared to outsiders.

12.7.12 Disposal of Corpses & Carcasses

Proper disposal of dead bodies at the earliest possible time is essential to avoid outbreak of any epidemic in the disaster affected area. A group of persons may be assigned this duty and trained in proper recording and disposal of dead bodies, particularly from the inhabited areas.

12.7.13 Immunization and Infection Control

Due to large number of deaths and injuries during disasters, the potential of getting affected by any contagious disease are very high. To control this, a team should be dedicated to immunize people and livestock against possible diseases and those affected by such diseases should be treated under control and given a separate facility.

12.7.14 Water and Sanitation

Drinking water supply may be affected during disasters. The water may be polluted by sewerage damage or due to some other reasons. Necessary precautions should be taken to keep a check on water quality and in case it is found polluted, proper treatment of the water sources and supplies should be done. Any leakage of drinking water supply that may occur during disaster should be immediately checked. Proper sanitation should be planned around temporary shelters where large number of people may reside together temporarily.

12.7.15 Rapid Damage Assessment & Relief Distribution

Appropriate objective kind of rapid damage assessment criteria should be well set for assessing the degree of damages and distribution of relief to the affected people. A team consisting of reliable, honest and justified persons can be kept ready for this kind of work.

12.7.16 Rehabilitation Plan

This is the phase in which the community is back on the normal life process and in fact is fine tuning their resources to deal with other emergencies. They are thus also in a position to provide help to some other disaster affected area in the manner that they received help and assistance.

- Shelter Rehabilitation
- Livelihood Rehabilitation
- Psycho-social Rehabilitation

12.7.17 Recovery and Redevelopment Plan

Recovery is restoration of the community structure and facilities, and support provided to affected people. It may include providing short-term emergency accommodation, counseling emotionally-affected people, establishing and managing emergency financial relief schemes, repairing or replacing damaged public utilities, services, and assets, surveying and assessing damage to public and private property.

Rapid steps must be taken to establish a system of continuous contact with the families stricken by the disaster. A system of this kind makes it possible to:

- Collect information on requirements,
- Route instructions and information,
- Distribute where necessary the means of survival (clothing, blankets, food, etc.).
- Transport and highway maintenance; communications and information,
- Water supply and sanitation,
- Health,
- Public law and order.

The mid-term and long term recovery plan will include:

- Relief and Compensation
- Repair, Restrengthening, Retrofitting and Reconstruction
- Resettlement and Relocation
- Loaning, Insurance and Tax Exemptions

The redevelopment plan of the locality should include the lessons learnt from the disasters, thereby discouraging the bad practices and encouraging the good practices for redevelopment in the affected area.

12.8 Limitations in Implementation of CBDRM Methodology

The experience of local community can help in developing a formally structured information infrastructure. Implementing such a process, however, will not be so simple. It will take time and commitment on the part of all those involved because there are some sources of frustration that will need to be addressed before it can become a reality. For example, a recurring view was expressed by the village community that they had 'heard it all before' at various times, but nothing practical had ever eventuated. They are looking for a worked-through example that they can follow and the resources to do it. It cannot be achieved in any meeting, training or workshop; it can only be achieved on the ground in a real-world situation. The lack of communication reaching both top-down and bottom-up at the village level was also seen as a major source of frustration, and consequently a major hurdle. For a process that is all about information and improving the effectiveness with which it may be disseminated and used, the sharing of information about the process is critical — and that depends on communication.

Another frustration revolves around a stated lack of coordination and cooperation between the people and agencies that should be working together to improve community safety. This was seen as part of the power and political processes that tend to build barriers, rather than bridges. Frustration also relates to the perceived lack of resources — human, financial and technical. This is probably a universal frustration for all disaster managers. Typically, they are allocated only limited resources as well as limited time because a vested senior group seem to hold a different view (a disaster is unlikely to happen during their term in office, so why spend too much money on a disaster management system that does not bring significant political/economic gains with it). This may be a simplistic and cynical view, but it seems to correlate well with reality. These are not just technical issues but also socio-economic issues. Fortunately, frustrations can be overcome through strong will and determination by the public, even those as seemingly intractable as the ones identified here.

These established foundations are very sound indeed, and provide an excellent base on which to build an appropriate and sustainable information infrastructure may address issues from the village level to the level of the district and beyond. There are undoubtedly frustrations and problems that will need to be addressed along the way; however, it is clear that the communities are committed to embarking on this journey for a safer sustainable environment.

Another limitation of CBDRM lies in the fact that the local knowledge at the level of community cannot always be sufficient to assess large scale phenomena especially if their origin lies away from the zone of perception of the community or if it results from an exceptional situation (e.g. flooding due to bursting of a landslide dam on upstream side of the community). Therefore, the logic of the concept should clearly indicate the possibility of integrating information received from outside the community (national/state/district level disaster warning centers), even if it is of scientific origin and not expressed in terms to which the community is used to, as another major contribution to the re-assessment of a hazardous situation.

12.9 Conclusions

The successful application of this methodology in more than 50 villages by the community itself is evidently a good indicator of the acceptability and practicability of the approach as well as its outcome in the forms of large amounts of actual data and information generated through the process. The approach seems more rational and context specific for socio-cultural as well as geo-climatic condition. Its participatory nature and learning dynamics helps in deeper penetration of the efforts among the community.

It is essential that local capacities be strengthened to assess and manage disaster risks as well as to utilize indigenous knowledge, resources, skills, information and ideas. The approach considers varied factors like age, gender,

geographic location, caste, ethnicity, literacy, community structure/dynamics, local politics, economic disparities and decision making in this process. These factors when accounted in disaster risk management strategies and action plan become a great asset in execution and implementation at ground level by the affected community.

If the methodology is applied in other areas in a similar fashion, it will have, no doubt, a very large database on disasters and a culture of aware and prepared communities in all villages. The approach is open for further modifications to suit to specific requirements of any area/community as is permitted in any context specific approach. Technical and financial support from outsiders will further boost the efforts of these villagers in fully implementing their strategies for disaster risk management at local levels.

EMERGING ISSUES

13.1 Climate Change

The climate change and its adverse impacts on temperature and precipitation will further flame the quotient of landslide disasters and will be constantly challenging our strategies of landslides risks reduction and resilience. An increase in the frequency of extreme weather related phenomenon and alteration in timing and periodicity of rainfall, degradation rate of glaciers, and amplification in incidences of wildfire will significantly augment the risk of landslides in many vulnerable countries. The impact of climate change at each level will amplify the magnitude and number of landslide incidents and thus more human settlements, structures and infrastructures will be exposed to its destructive impacts.

13.2 Research Issues

There are several important areas of research which need to be addressed leading to standardization of investigation and operating procedures, more reliable LHZ mapping, vulnerability assessment and risk analyses, cost effective landslide stabilization, user friendly multi-hazard mapping, damage assessment and introduction of the state of the art technology. Considerable amount of research and development work is needed to develop basic understanding of various types of landslides in India, their causative factors and mechanisms of development with particular reference to anthropogenic factors.

13.3 Standardisation

Some Institutes and Organisations are carrying out both LHZ mapping and site specific studies of landslides. However, there is no uniformity in the methodology, selection of scale of LHZ mapping and usages of landslide terminologies. As a result, a lot of confusion is created among the geoscientists. Standardization of the terminology and classification of landslides, thematic mapping scales and introduction of mapping methodologies for different scales will be accorded priority. Scientific and systematic approaches for site specific study of landslide and procedure of ground validation of LHZ maps are equally important, and so is the development of scientific approach of integrating landslide hazard into multi-hazard mapping. R&D activities will be intensified to standardize the terminology and classification of landslides, thematic mapping scales and to develop uniform methodologies for different scales. Scientific and systematic approaches for site specific study of landslide and procedure of ground validation of LHZ maps will be prepared immediately.

A research programme will be undertaken by the knowledge based organizations/ institutes of our country for developing scientific approach of integrating landslide hazard into multi-hazard mapping.

13.4 Earthquake Induced Landslides

Improved understanding of earthquake-induced landslides will call for research on estimation of site effects in different geological and geomorphological settings. Research to enhance the understanding of reactivation of old and recent landslides and initiation of first time landslides triggered by earthquake will be encouraged. Other topics of research may include run-out effects of flow slides resulting from earthquake liquefaction.

13.5 Design of Surface and Subsurface Drainage Systems

In India the rainwater from the slide surface is generally drained out through surface drainage system comprising lined catch water drains, contour drain and chute drain (often cascading type). In absence of any data about the catchment characteristics of a particular slope, the design of these drains is generally done on the basis of expert's knowledge. On the other hand, the subsurface water management from the slide mass or distressed hill slope is rarely practiced in our country. As a result, some of the slides requiring only subsurface drainage arrangement for stabilisation are provided with other makeshift remedial measures triggering the slide instead of containing the slide. Moreover, there is no systematic approach or established mechanism to test the efficacy of the implemented surface drainage measure. Effort should be directed towards research and development of scientific and innovative design of surface and subsurface drainage systems, which are the most important component of landslide stabilization measures.

13.6 Instrumentation for Geotechnical Investigation

In the context of scientific research, geotechnical instrumentation is primarily needed to unfold the mechanism of a landslide, collect evidences and data for its reliable slope analyses and engineering and remove uncertainties by validating assumptions and checking efficacy of control works.

13.7 Development of Early Warning System

There are many major landslides located either along the busy road corridors or close to thickly populated townships/important civil engineering structures that require huge cost of treatment. Such landslides for early warning will be selected through a consultative mechanism in association with state governments and local bodies. Development of appropriate Early Warning Systems may be undertaken for such identified slides. Development of Early Warning System by real time monitoring of some selected slide may be undertaken with a view to

firming up both the early warning technology and the early warning thresholds. Correspondence between rainfall thresholds and landslide should be developed for selected areas based on in-depth scientific studies.

13.8 Landslide Dams

Dams generated by landslides are mainly reported in the narrow valleys of mountainous terrain. These may cause devastation by flash floods due to sudden breaching. Barring some preliminary investigation of a limited number of such dams, systematic geotechnical investigation has not so far been attempted. Besides, there is no established mechanism by which the incidence of such dams can be reported to the appropriate authorities immediately after their formation. As a result, the preliminary investigation cannot be taken up immediately after their formation.

The following aspects of landslide dams can be taken up for R&D:

- Dam break analysis
- Methodologies for providing controlled outlet for dewatering the created reservoir
- Procedure of risk assessment
- Procedure for identification of potential sites of formation of landslide dams and monitoring technique.

13.9 Run-out and Return Period Modelling of Landslides

This is one of the most important fields of landslide studies where extensive R & D is required. The basic requirement for development of Run out and Return period modeling of landslides is to map all the slides, identify causes and mechanism of failure, establish correlation between triggering agents and initiation of slope failure, determine shear strength parameters of the slope forming materials, assessment of hazards, vulnerability and elements at risk etc. In some countries like Italy, New Zealand, USA, this type of modeling has been done for an individual slide but it could not be successfully done for a vast area affected by numerous slides in absence of reliable historic landslide inventory database.

13.10 Emerging Concerns

Presently global warming and climate change are the most critical fields of concern that can have significant consequences on natural hazards including landslides and snow avalanche.

The “fragile” mountain systems in the country, where most of the landslides occur, are being exposed to increasing risks due to climate change. In the

coming decades, the negative impact of climate change will be exacerbated if the mounting human-induced pressures and unplanned urbanization do not get checked.

Whereas the whole range of issues connected with climate change including policies and operation strategies are beyond the scope of this document, unfolding consequences of climate change, insofar as mitigation of landslide hazards are concerned, deserve urgent attention. Rich global experience, especially on understanding and managing uncertain weather patterns and landslide, glacial lake outbursts, landslide dam bursts and community-centric risk reduction measures for human safety, should help speed up our own programmes with innovation and added emphasis on landslide hazard mitigation, early warning and quick response to disasters and long term socio-economic risk reduction.

13.11 Priorities for R & D

The R & D problems of importance are listed below. This is only suggestive and will be reviewed from time to time in the back drop of emerging national priorities.

- Refinement of methodologies for carrying LHZ both on Macro and Meso scales in order to bring out a realistic picture of the hazard.
- Systematic scientific methods of landslide hazard, vulnerability assessment and risk evaluation on GIS platform.
- Integration of landslide hazards into user-friendly multi-hazard mapping. Projection of multi-hazard risk scenarios.
- Revisiting of past major landslide disasters for scientific post-mortem and documentation of lessons learnt.
- Application of recent technological developments in the fields of instrumentation, remote sensing, software and communication technologies for landslide studies.
- Development of simple, quick and effective methodologies for assessing direct as well as indirect losses due to occurrence of landslides.
- Quantification of environmental degradation, anthropogenic impact, cost of loss of land, agriculture produce, livelihood and traffic delays.
- Establishing best practice examples of deterministic and probabilistic modeling methodologies for conducting detailed stability analyses of complex natural and manmade slopes and active landslides.
- Scientific design of surface and subsurface drainage systems, technology for their speedy installation and evaluation of their efficacy.

- Development of innovative techniques for landslide control especially mechanized construction of complex subsurface drainage networks.
- Development of light rugged geotechnical investigational equipment suitable for rugged and inaccessible areas.
- Development of cheap and reliable instrumentation techniques for slope monitoring and installing early warning systems.
- Systematizing the search and rescue operations and developing effective equipment for same.
- Development of simple and easy to install instrumentation and slope monitoring for real time early warning including early warning thresholds and criteria.
- Developing a predictive understanding of landslide processes and triggering mechanism.
- Regional real-time landslide warning systems based on threshold values of rainfall; Real-time monitoring and establishing early warning systems in case of landslides that pose substantial risk to developmental gains;
- Developing methodologies for assessing the potential co-seismic slides.
- Fundamental mechanisms of earthquake-induced and earthquake-triggered landslides.
- Remediation practices based on multi-disciplinary field investigations and suitable for local conditions.
- Methodology for identification of potential sites for landslide dams.
- Fashioning landslide rescue operations to their typology.
- Reservoir induced landslides, coastal landslides, submarine slumping and tsunami.

Besides, post-disaster scenario analysis and simulation modeling are extremely useful for undertaking long-term disaster management programmes and for strengthening preparedness, mitigation and response efforts against landslide hazard. Risk assessment and scenario projections require data for all landslide prone areas and major landslides located in different environs in different parts of the country affecting existing human habitations, environment, infrastructure and economic activities.

The quantification of landslide risk for a specified area requires detailed information for a number of factors, namely, topography, geomorphology, geology, climatic conditions, landuse practices, land cover pattern, characteristics of surface slope forming materials. The reliability of landslide

hazard maps will depend on the accuracy of base maps and the approach followed in their GIS based integration and subsequent validation. Freshly occurring landslides and the reactivation of existing and old landslides on account of earthquakes will be studied. The LHZ maps will be prepared based on advanced research studies carried out by knowledge institutions to include the earthquake induced landslides in areas with high seismic risk.

Studies will be undertaken to evolve procedure so that investigations, maps and drawings of landslide in different geographical regions of the country are easily available to users in the form that can be easily comprehended.

There is urgent need to develop mechanism to transfer the results of R&D efforts to public domain so that these can be utilized by scientists/technologists engaged in operations.

The success of all these efforts will depend on a prior presence of a system with streamlined procedures for speedy funding of priority/fast track projects. The mechanism for evaluation of project proposals, periodic reviews and final reviews will be integral part of the system.

13.12 Documentation

It will include preparation of films, manuals and other documents targeting various stakeholders to inculcate landslide safety by following land zoning regulations. State governments will provide landslide safety materials in multiple formats and languages, so that different groups of stakeholders can gather requisite information. This information will include specific details on the landslide risk and vulnerability of the states, landslide management basics and landslide risk mitigation for the safety of natural and built environment.

State Governments will assist subject specialists from academia and industry to prepare technical documents on landslides, which will emphasize technical specifications for expansion of human settlements in hilly areas and simple techniques for assessing landslide hazard in other areas. National and regional libraries and information centres will be encouraged to build repositories of technical resources (books, reports, journals, electronic documents etc.) related to landslides.

Generate and maintain a directory of landslide management professionals in India, containing their brief bio-data and make these available to users.

GSI along with other institutions will undertake the task of documenting the history of landslide studies and other related activities in India. A number of documents on landslide investigations that have been carried out in the past have now become difficult to access or are out of print. GSI will launch a special initiative to digitise these documents from various sources and save the archives on electronic formats in the data bank proposed for this purpose giving due recognition to the source.

13.13 Response Capability

Responses to early warnings involve activating coping mechanisms (mainly for orderly movement of people away from risk locales, seeking shelter and safely securing assets) before a disaster strikes. In contrast, post-disaster response implies the wider range of relief, restoration, recovery, rehabilitation and reconstruction efforts in the aftermath of disasters. However, both are part of disaster preparedness and employ common emergency procedures. Warnings of hazard events must be issued with clear instructions about the most appropriate actions to be taken to avoid losses as far as possible. The success of early warning depends on the extent to which it triggers effective response measures and warning systems will include preparedness strategies and plans to ensure effective response to warning messages. The warnings trigger a variety of responses from different agencies at various levels, which must be coordinated. A number of governmental agencies, including various ministries, national disaster management institutions, municipal and local administration authorities are responsible for coordinating disaster preparedness. People are more likely to listen and act upon warnings when they have been educated about their risks and warning-reaction plans are in place.

The management and control of the adverse consequences of future landslide incidences will require coordinated, prompt and effective response systems at the Central and State Governments, and especially at the district and the community levels in the areas affected by landslides. Since many of the components of response initiatives are the same for different types of disasters, systems need to be developed considering the multi-hazard scenario of various regions in order to optimally utilise available resources.

Depending on the magnitude of the landslide and scale of required response, the corresponding role players will be identified and mobilised at the district, state or national levels. Systems will be institutionalised by the DMAs, at various levels, for coordination between the different agencies like Central Government Ministries and Departments, State Governments, District Administrations, ULBs, PRIs and other stakeholders for effective post-landslide response.

The preliminary assessment of severity of the landslides is based on its magnitude and the amount of loss it inflicts on the infrastructural elements and habitations. Agencies like the BRO/State PWDs, State Directorates of Mining and Geology, Forest Department, Municipal/Panchayat body would immediately communicate information of the occurrence of a landslide along with preliminary details like its location, magnitude and damage caused etc. to the District Emergency Centre or District Disaster Management Control Room. This will help to undertake field observation for making an accurate assessment and follow-up actions.

The Disaster Management (DM) plans prepared by all concerned agencies will incorporate detailed guidelines for their activities related to the impact of landslide. The response component of the DM plans will consider the rapid deployment of designated people, supplies and logistics to the site of disaster with function of each functionary clearly defined. The individual teams will be required to vacate the site as soon as their job is over because considering the nature of hazard during the rainy season it is possible that they may be required at another site within short duration. These plans will prescribe appropriate coordination mechanisms among all the agencies working in the affected areas.

13.13.1 Emergency Search and Rescue

The community in the affected neighbourhood is always the first responder after any disaster. Experience has shown that initially over 80 per cent of search and rescue operations are carried out by the local communities before the state machinery and specialized search and rescue teams arrive. Thus, trained and equipped teams consisting of local people will be set up in landslide prone areas to respond effectively in the event of disaster.

Community level teams will be developed in each district with basic training in search and rescue. Training modules will be developed for trainers of community level search and rescue teams by district authorities with the help of the NDRF training institutes. The manpower employed by the organizations engaged in maintaining the roads located in hilly regions will also be trained in initial search and rescue operations and equipped with modern search and rescue equipments. On the ground, if required, the NDRF Battalions will also assist the state government/district authorities in training communities for which they will be sensitised. They will be further assisted by the Civil Defence, Home Guards, Fire Services and NGOs. State Governments will develop procedures for formally recognising and certifying such trained search and rescue team members; they will also provide suitable indemnity to community level team members for their actions in the course of emergency response following a landslide disaster. Youth organisations such as the National Cadet Corps (NCC) and National Service Scheme (NSS) and Nehru Yuva Kendra Sangathan (NYKS) will provide support services to the response teams at the local level under the overall guidance and supervision of the local administration.

13.13.2 Emergency Relief

Trained community level teams should assist in planning and setting up emergency shelters, distributing relief among the affected people, identifying missing people and addressing the needs of emergency medical care, water supply and sanitation, food and temporary shelters etc. of the affected community. These teams should also establish communication with district authorities for arranging evacuation of stranded people, particularly for vulnerable sections. Members of these teams must be made aware of the specific requirements of

the disaster affected communities. These teams may also assist the government in identifying the most vulnerable people who may need special assistance when stranded following a large landslide on a highway or in a habitation.

13.13.3 Incident Command System (ICS)

All response activities should be undertaken at the local level through a suitably devised Incident Command System (ICS) coordinated by the local administration through the EOC. State Governments will commission and maintain Emergency Operation Centres (EOCs) at appropriate levels for the coordination of human resources, relief supplies and equipment. Standard Operating Procedures (SOPs) for the EOCs will be developed by State Governments and integrated within the framework of the ICS, which will take advantage of modern technologies and tools, such as GIS maps, scenarios and simulation models for effectively responding to disasters. Geographical Information System (GIS) maps available with other sources, such as the district and municipal planning departments will be compiled considering their potential application after a disaster. Any unusual occurrence should be immediately reported by the community to the authorities, so that its cognizance is taken.

13.13.4 Community Based Disaster Response

The DDMAs should coordinate with the organisations, like NGOs, voluntary agencies, self help groups, youth organisations, women's groups, civil defence, home guards and community at large who normally volunteer their services in post disaster situations. The State Government/SDMAs will utilize and allocate these human resources for performing various response activities as per their capabilities. State Governments will interact with these agencies to understand and plan their roles in the command chain of the ICS and incorporate them in the DM plans.

Large magnitude natural disasters draw overwhelming humanitarian support from different stakeholders. The relief and response activities carried out by such stakeholders will coordinate and comply with the norms prescribed by the appropriate authorities.

After disastrous landslide incidence, accurate information will be provided on the extent of the losses and the details of the response activities through electronic and print media. State Governments will utilise different types of media, especially print, radio, television, internet and Short Messaging Service (SMS) to disseminate timely and accurate information.

13.13.5 Role of Private and Corporate Sectors

The State Governments should facilitate the involvement of the corporate and private sector and utilize their services and resources if offered to the government

during the immediate post disaster situation. IDRN should be maintained and updated regularly so that locally available resources are utilized effectively in case of emergency. The corporate sector, as a part of the CSR effort, can provide, inter-alia, the services of hospitals, power and telecommunication, relief supplies, search and rescue equipment, earthmoving equipment, and transport and logistics of movement of relief supplies. The IDRN is a live system and is updated every quarter both at district and state levels. These can be mobilised promptly at the time of emergency as a component of response. The state governments and district authorities will develop appropriate mechanisms to receive and optimally utilise all such assistance.

13.13.6 Specialised Teams for Response

The Central Government has set up twelve NDRF Battalions for providing rapid response to disasters. The NDRF Battalions are provided with communication equipment like satellite phones for establishing continuous connectivity in every part of the country where landslide or other disasters can occur.

The fire services in the ULBs of various states are being used as an emergency-cum-fire services force. The fire services will be trained adequately so that they can respond to different disasters promptly in addition to managing fires.

The police play a very important role after a disaster by maintaining security, law and order, assisting in search and rescue, and in the transportation and certification of casualties. In case the landslide disrupts traffic for a longer duration, traffic police can play an important role by regulating and controlling the flow of traffic movement.

The Home Guards serve as an auxiliary arm of the police force and support the district administration in various tasks. The Civil Defence is being reoriented to assist in handling DM. Members of these organisations will be trained in tasks like search and rescue and evacuation, protection of assets in evacuated areas, and management of relief camps and aid distribution centres.

Training and implementation of emergency response should be planned keeping in view that type of rescue operations varies with the nature of landslides.

13.14 Trigger Based Categorisation

Ministry of Home Affairs, GoI, in consultation with the GSI has developed a colour coded categorization of stages of landslide for triggering appropriate alerts within the Government machinery. Three colour (Red, Orange and Yellow) coded stages were defined on the basis of dimension, location and damages caused by the landslide. GSI and other knowledge based institutions in coordination with state governments will take up the geotechnical investigation of the landslides falling within the high alert red category stage and suggest appropriate remedial measures. Landslides in this category are of large dimensions that

are located over or in close vicinity of urban settlements or fairly large rural settlements inflicting heavy losses to human lives or urban infrastructure. This also includes landslides that block busy pilgrimage routes during peak times resulting in hardships to thousands of pilgrims and landslides which result in blockage of courses of relatively large natural drainages with or without formation of landslide dams. The small or moderate dimension landslides located at the fringes or away from human habitation and causing limited loss/ damage have been categorized under the medium and low alert, viz. yellow and orange. These shall be taken up by the District and State administration. GSI and other knowledge based organisation will provide assistance and train professionals on need basis to state government for geotechnical studies and remedial measures.

13.15 Emergency Logistics

Specialised heavy earthmoving equipment and search/rescue equipment are required immediately after a landslide to clear debris and to carry out search/ rescue of trapped people from huge mass of debris. A list of such equipments and identify suppliers of such specialized equipments should be compiled to enter into long-term agreements for their mobilisation and deployment in the event of a landslide disaster. India Disaster Resource Network (IDRN), which is a web based resource inventory of information on emergency equipment and response personnel available in every district, should be revised and updated every three months. A mechanism of deploying required equipment at a very short notice in case of occurrence of a disastrous slide should be in place.

The provision of providing temporary shelters and basic amenities for travelers stranded on communication routes would require pre-planning. The DM plans at the state and district levels should address this issue in details. It is also being considered that semi permanent shelters with basic amenities would be established at certain critical locations that are affected by landslides frequently resulting in people getting stranded for long periods.

In the event of large number of casualties, respective states will develop systems for proper identification of the deceased, recording the details of victims and handing over the bodies to their kith and kin as quickly as possible.

13.16 Emergency Medical Response

In case of requirement, prompt and efficient emergency medical response will be provided by QRMTs, mobile field hospitals, ARMVs and heli-ambulances that will be in place for other disasters like earthquake. These will be activated to reach the landslide affected locations immediately, along with dressing material, splints, portable X-ray machines, mobile operation theatres, resuscitation equipment and life-saving drugs, etc.

The emergency medical plan will be operationalised immediately on receiving information from the landslide affected locations. Hospitals in the affected areas will create a capacity for the required number of beds by discharging non-critical patients and mobilize doctors and support staff, additional orthopedic equipment and supplies at short notice in landslide affected areas, at least during rainy season when majority of landslide occur. After the occurrence of a disastrous landslide, an Information Centre should be set up for disseminating accurate information to public, relatives of victims and media at district level in case the number of casualties is high.

13.17 Loss and Damage Assessment

It is very important to assess the losses resulting from a landslide as this would be an important factor to decide whether it is economical to treat it or not. Landslide-losses data are generally categorized as either direct or indirect. Losses can occur in a geographic region collectively (many, possibly intermingled, landslides that may affect lifelines and public safety, as well as individual buildings) or as a single, isolated event that affects a small geographic area, such as a highway or residential structures.

Direct costs include the repair, replacement, or maintenance resulting from damage to property or installations within the boundaries of the landslides or from flooding caused by breach of natural dam formed due to obstruction of natural drainage due to landslide.

Some examples of indirect landslide losses are:

- Loss of industrial, agricultural and forest productivity and tourist revenues as a result of damage to land or facilities or interruption of transportation systems;
- Reduced real estate values in areas threatened by landslides;
- Loss of tax revenues on properties devalued as the result of landslides;
- Measures that are required to be taken, to prevent or mitigate additional landslide damage;
- Adverse effects on water quality in streams and irrigation facilities outside the landslide;
- Loss of human or animal productivity because of injury, death, or psychological trauma; and
- Secondary physical effects, such as landslide-caused flooding, or for which losses are both direct and indirect.

Indirect costs may exceed direct ones; unfortunately, most indirect costs are difficult to evaluate and thus are often ignored or, when estimated, are too

conservative. More often, however, monetary information, being of a discreet nature and in many instances, not public domain, people and entities prefer to leave their losses a private matter.

Currently, the damage assessment in case of natural disasters in many countries is done using aerial photography, videography and ground checks. With recent advances made in remote sensing technology it has become possible to use it effectively even for assessment of damages resulting from landslides. In order to be able to use Earth Observation (EO) data for landslide damage assessment, following criteria should be fulfilled:

- High temporal and high spatial resolution products should be available.
- Images are taken at the time of disaster or within a few days after the event. These can support the relief efforts effectively.

This will be satisfied partly by existing and planned high resolution stereo optical and SAR systems. In cases where damage is extensive, either by a single large event or by many large events spread over a large area, there is need of very high resolution images before and after the disaster. These can be used to supplement the data obtained from airborne and ground exercises.

13.18 Areas Requiring Special Attention

- Effective management of landslide hazard in the country would require detailed studies using state-of-the-art technologies.
- Introduction of the practice of real time monitoring of potentially threatening landslides to avert disasters by early warning.
- In the current landslide hazard management practice, investigating agency and implementing agency are generally different. This results in fragmented accountability and communication gap. Therefore, it will be ensured that the recommendations of the investigating agency will be implemented in close association or consultation with it.
- Partial implementation of stability measures are understandably ineffective and results in reoccurrence of landslide in general, results in reoccurrence of landslide. Every landslide management project will ensure full implementation of treatment measures in a single working season and take recourse to monitoring of their efficacy during post implementation stage.
- The process of data collection is required to be systematized. The system of data sharing among the institutions engaged in landslide studies, landslide hazard management and communities at large will be encouraged through effective networking.

- The culture of observational method of design and construction will be promoted to help engineers and builders dealing with uncertainties effectively. The method helps in modulation of designs based on actual measurements as the work progresses.
- Culture of monitoring the efficacy of control measures will be promoted to add to the confidence level in design and add value to it, if a situation so demands.
- There is lack of extensive network of rain gauges in country. Due to this it is very difficult to attempt the correlations between rainfall and landslide activity. A proper coordination with the IMD is required to be developed for installation of a network of automatic rain gauges at desired locations. The IMD will also provide daily rainfall data of existing rain gauges on daily basis to data center for landslides so that same can also be utilized by the agencies or individuals engaged in such studies. The concerned institutions will be identified.
- It is proposed that organizations/institutions engaged in landslide studies, government or private, should be identified/selected and given the responsibility for this work in co-ordination with the BRO and respective state governments.
- The resources and resource persons available in the country will be identified so that studies to be taken up in different fields are planned and realistic capacity building programmes are designed.
- The gap between the landslide management systems being practiced in the country and those being followed internationally will be identified and attempts will be made by all agencies engaged in landslide hazard management in the country, to bridge these gaps so that latest systems followed elsewhere are also followed in the country.
- Establishment of a national-wide institutional mechanism that would transform the current piecemeal, ad hoc, less recognized and poorly appreciated landslide management practices into an organized vibrant pro-active, systematic and scientific routine.
- Enhancement of expertise and capacities of knowledge centres in different parts of the country for dependable and timely geomorphological, geotechnical and hydro-geological investigations and for scientific design and speed-effective- implementation of control measures.
- Strengthening of a few objectively identified existing knowledge institutions or their units and departments in every state and union territory, if willing to redefine and enlarge their respective mandates/ roles to provide/support pre and post landslide routine/specialized functions.

GROUP EXERCISES FOCUSSING ON LESSONS LEARNT FROM PAST DISASTERS AND GOOD/ BAD PRACTICES

14.1 Table Top Exercise

Objectives of the Table Top Exercise

- To create sensitization about the landslide disasters.
- To assess the needs and capabilities to handle the disaster.
- To evaluate inter-agency coordination & gaps for improvement

Orientation/Preview

- Disaster Scenario (facilitator)
- Stakeholders
- Conduct of Exercise
- Observer & Evaluator's comments
- Conclusion

Disaster Scenario

You have a landslide located along a national highway; very close to the district headquarter. The upper part of slopes fall under Forest Region and the lower slopes are occupied by private residential and commercial buildings, government colony and a mosque (community place). The slide area is evident by the exposed scar and the slide debris but the authorities are scared that it may pose a great risk to lives and structures located at foot-slopes. You are asked to assess the situation and provide adequate measures with action plan to prevent and mitigation the envisaged risks. How would you proceed ahead and tackle this situation?

14.2 Varunawat Landslide, Uttarkashi — A Case Study

Salient Features

Location: At km 150 from Rishikesh on Uttarkashi — Gangotri National Highway (NH-108); Latitude: 30°44'10.8"N; Longitude: 78°26'23.0"E (Toposheet No. 53J/6); Altitude: 1680m a.m.s.l.

Elevation: 1680 m (at Crown); 1170m (at road level); Relative Relief: 510m

Average Slope Gradient: 39°;

Date of initiation of last major occurrence: Sept. 24, 2003

History of Slide: Not well recorded, dates back to about more than 2 decades. Recurrent slide

Type of Material involved in movement: Overburden, rock pieces/boulders of phyllites and quartzites — predominantly debris

Type of failure: Rotational in upper part, free fall followed by skidding, rolling, bouncing and sliding along three different tracks.

Direction of sliding/failure: SW on right flank, southern in the middle and SE on left flank

State of Activity: Intermittently Active since last several years but continuously active for a period of about one month from Sept. 24 – Oct. 24, 2003;

Style of Activity: Widening/Retrogressive

Depth of sliding: >20m; Volume of Displaced/Accumulated Mass (LxWxD): 15000 cu.m. (?)

Area affected by failed slopes: approx. 2 sq.km.

Population affected: 2,911

Landslide Precursors: Tilting of trees, development and propagation of new cracks, minor failure activities, rolling topography, presence of old cracks (widening and deepening), extension of old escarpment, increase in pore water pressure and seepage pressure, seismic vibration causing fatigue and failure

of rocks, presence of old landslide zone, potential growth of some new plant species or younger plants in unstable/failing zones

IMPACTS:

Economic Losses:

Damage to buildings – 362 (includes both residential & commercial); 63 houses damaged, 274 houses evacuated for safety. 132 out of 362 were commercial bldgs. and 232 were residential or residential cum commercial (55 Kutcha and 175 Pucca bldgs)

Infrastructure (road, power, telephone and drainage lines) – Damage to a section of national highway (500m road), power supply lines and telecom facilities, traffic disruption

Economic Activities – 2,911 people lost their homes and jobs

Environmental Losses: Loss of trees, Dust clouds, Pollution

Social Impacts:

Closure of educational institutions for several days; Hindrance in cultural activities like Ramlila Programmes

Total Estimated Loss: Approx. Rs. 300 Crore





Fig. 14.1 A View of landslide on the day when landslide engulfed the hotel seen above

14.3 Case Study on Malpa Landslide

Malpa Landslide Tragedy

Location: Right bank of River Kali, Distt.: Pithoragarh

On the fateful night b/n 17th and 18th August 1998, a huge mass of rock got detached, broke into myriad of pieces and hurtled down the slope. The rock avalanche so created killed 210 people including 60 pilgrims. The heap of debris so created was about 15m high and these included rock pieces as big as 5m. The estimated velocity was 30m/sec. Before the disaster, the hillslopes surrounding Malpa looked green, virtually without any visible signs of instability. When the landslide happened, the whole village was wiped out.

Disaster Scenario

A catastrophic landslide has occurred last night (1 am) at Malpa. Several pilgrims (who were resting at that site) are buried along with some local residents of the village. Most of buildings at landslides have been destroyed and carried away/buried by the slide. District headquarter is 100km away.

You have received this report at 4 am from a villager. How would you respond to the situation?



Fig. 14.2 An artist's recapitulation of rockfall area before the disaster happened



Fig. 14.3 Photograph of rockfall area after the disaster

ESTIMATION OF INDIRECT LANDSLIDE LOSSES (A case study of Kaliasaur Landslide, Kumar et al 2012)

Kaliasaur Landslide is one of the notorious landslides that was first initiated in the year 1920 at kilometer-147 on National Highway-58, Uttarakhand and is still threatening community and the highway. A study was carried out by Central Road Research Institute to estimate the cost of the indirect landslide losses related to the highway closure during September-October, 2010. A unit cost estimation method was used in the study which is applicable whenever a unit variable is known (i.e. no. of days an area is affected) and the associated unit cost (i.e. loss per day) can be determined. A general equation for this approach is as follows:

Detour cost= (Extra operating costs in detouring + Extra fuel used* Fuel price) *Number of travellers affected.

Commuters had to follow detours that take longer travel distance to reach the destination in case of road closure. In 2010 due to closure of NH-58 at KM 147, travellers were forced to travel through Khedakhal- Kandai road (28 km). Required parameters for above equation were estimated and the total detouring cost for 45 days were calculated which was Rs. 2,45,43,180. This indirect cost of detour is still a low estimate as it does not include other business ramifications from loss of access to local resources and an associated loss of business at local shops, restaurants, tourist sites, and hotels. This example of the indirect cost of the detour illustrates a relatively straightforward simple application of the unit cost method for highway closure impacts in Kaliasaur area.

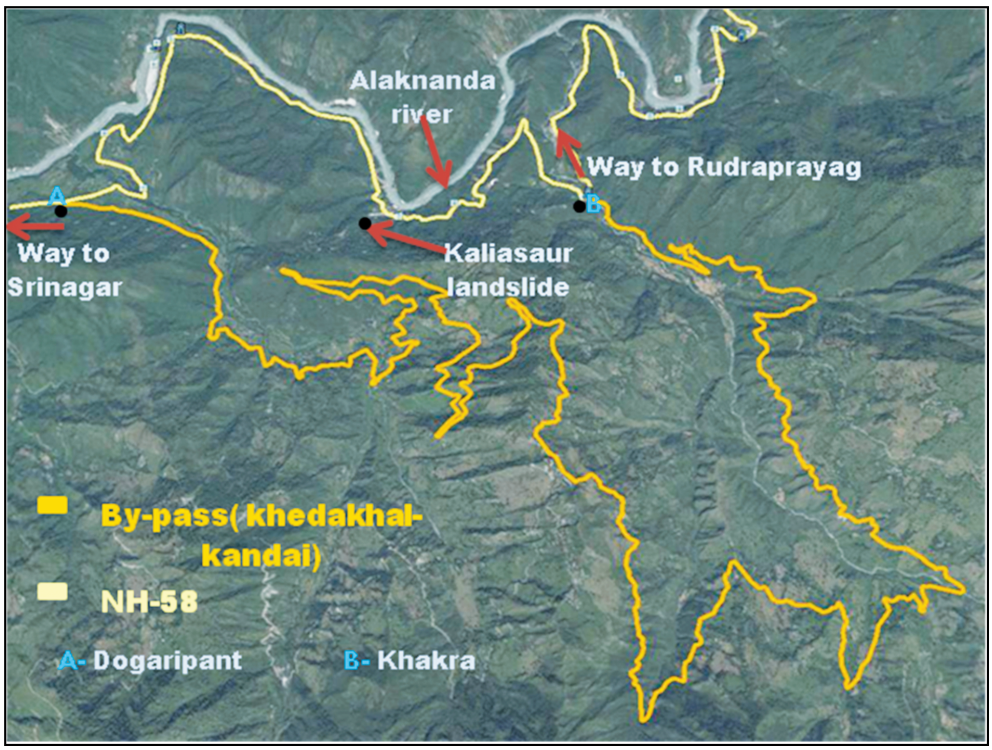


Fig. 14.4 Fig Map showing detour route used during road closure (Source: CRRI)

14.4 Case Study on Guinsaugon Landslide, Philipines

Introduction

A rapid and long-traveling landslide occurred on 17th February, 2006 in a rural area of Leyte Island, Philippine. The Landslide engulfed the Guinsaugon village

including a church. The 4m deep landslide covered 3 square kilometer, killing more than 1200 persons (154 fatalities and 990 people disappeared in the debris) and displacing 18,000 people. The estimated volume of landslide is 2.1x107 m3. The horizontal distance from the top of landslide and the toe of landslide deposit is around 4km.

The area had already been identified as risk prone and predictions of disaster were made prior to the event.



Fig. 14.5: Guinsaugon Landslide, Philipines

Timeline: Guinaugon had been evacuated a week prior (on 10/2/06 due to heavy rains), but when rains temporarily stopped, villagers returned (due to a break in rains between 11/2/06 and 16/2/06) and became the victims.

- An earthquake of magnitude 2.6 hit just prior to slide.
- Slide occurred at 10am and recurred at 10pm.
- Mudslides blocked the tributaries of river and caused fear of flooding.



Fig. 14.6: River Tributaries Blocked by Mudslide

Actions

S&R operations started within 3hrs of the disaster.

Relief efforts began including flying in response teams, tents, blankets, water, communication equipments, food, medical and psycho-social care

11 villages evacuated as preventive measure

PWD clears road (blocked by slide) for relief operations

Flood warning issued to neighbouring areas

NGOs start coordination and relief operations

Landslide Experts arrive to determine causes and guide response/recovery actions (including a Japanese and Philippine joint team of 22 scientists and engineers)

Who's Doing What Where Database

Schools used as evacuation centres

Construction of housing in permanent relocation areas underway.

Situational Challenges (due to disaster circumstances, weather, topography, geographical remoteness etc.)

Debate over cause of slide: Illegal logging, heavy rains, small earthquake, planting of non-native coconut trees with shallow roots without adequate erosion protection.

Landslide blocked roads so that only point of rescue was by boat from sea.

S&R efforts were hampered because rescuers were in danger in the shifting mud, blocked roads, collapsed bridges and severed communication lines.

Continued rains hampered relief efforts. Tributaries blocked by landslide caused fear of flooding.

Construction was time consuming due to lack of safe land and numerous official procedures for land acquisition.

Rescue hampered due to threat of additional landslides.

During the first day, area was accessible only by air.

Unstable ground impeded movement of heavy machinery, rescuers had to dig manually making relief effort harder and slower.

Absence of light led to suspension of rescue at night on day-1 (first 24hrs are critical in saving lives).

Heavy clouds impeded the arrival of helicopters, and more rain came in next 48hrs after disaster.

People were buried upto 40m deep in mud and it was hard to rescue them.

Cracks were seen in the area where slopes have failed.

Internal Resources or Infrastructure Challenges *(logistic, financial, personnel, physical, technological, informational, infrastructure resources constraints)*

- Vulnerable buildings and siting conditions
- Scale of destruction hampered efforts
- The closest airport became congested due to numerous flights arriving for relief. The location of airport w.r.t. disaster area was not adequate (flying time was more and time to travel by land to reach site was also more)

The evacuation centres were overcrowded, compounded by poor water/ sanitation facilities, with inadequate number of latrines, no proper disposal of garbage & waste, less supply of water for bath and cleaning, children (1/3) and women uncared.

Lack of political will during relief effort slowed the government response.

Large no. of organization involved in response complicated the relief effort.

What Went Right?

More efforts to coordinate relief organizations to make operations effective.

Efforts to learn from disaster to prevent and respond better to future disasters.

Technology like thermal imaging equipment, canine units was used to make more effective rescue & relief effort.

Latrines were designed in consultation with locals.

Who's Doing What Where Database made to coordinate efforts and prevent duplication.

Specialized task forces formed for coordination and focus on logistics, supply management, environmental health and children in emergency.

Surrounding susceptible areas were pre-emptively evacuated to avoid any further sufferings.

What Went Wrong?

The needs assessment took several days to complete and the results were not shared timely, affecting SRR efforts.

Not enough effort was made to prevent the disaster. Although the danger was recognized in advance but the government failed to do anything about it.

When the area was evacuated prior to disaster, the residents did not clearly understand the magnitude of danger or when they should return. However, pre-emptive evacuation was a good preventive move, if it was supported by return instruction as well.

Sphere standards of relief were not followed.

Lessons Learnt

An assessment should be made in such areas where landslides are known to occur, regarding the ground condition to determine if it is safe for people to stay or should be evacuated. The residents in Guinsaugon had returned because it had stopped raining and it was considered safe to return, but no-one made an objective assessment of the area. An expert should be in-charge of advising when to evacuate and/or when to return.

First 24-48hrs after disaster are important and critical for survival of victims. It was hampered due to bad weather and road conditions.

Establishment of a permanent relief centre close to disaster prone areas (but not so close that it may also be subject to damage during disaster) would accelerate the response. An effective layout for the centre to access the goods and supplies for SRR.

Technology and timing are two logistic strategy foci that work effectively. There should be an agile strategy to meet the immediate and changing demands of SRR.

NGOs are critical to relief efforts. They are more local, on the ground, continuously carry out needs assessment and are able to adjust their response based on latest needs. They are also able to build on existing connection in communities and quickly obtain funds.

It is important to share the learning from each disaster so when disaster strikes again, the response improves.

Predisaster trainings on community based disaster preparedness in pre-identified areas by NGOs helped the disaster response.

Socio-psychological services need to be continued to help residents cope and heal from their incredible loss.

Medium and long term plans should include relocation plans, community based disaster preparedness, continued psycho-social support, construction of houses and community facilities, and livelihood programmes.

Players/Actors/Stakeholders

Civil Administration

Red Cross

Local Government

Mines & Geology Department

SDRF

Army/Police/Civil Defence/Home Guards

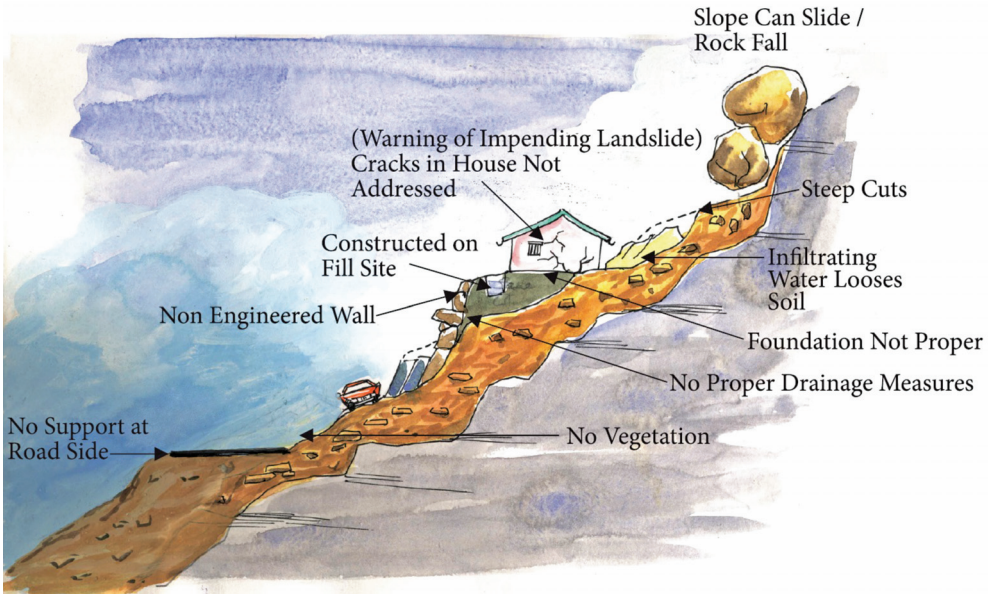
NGO

Locals

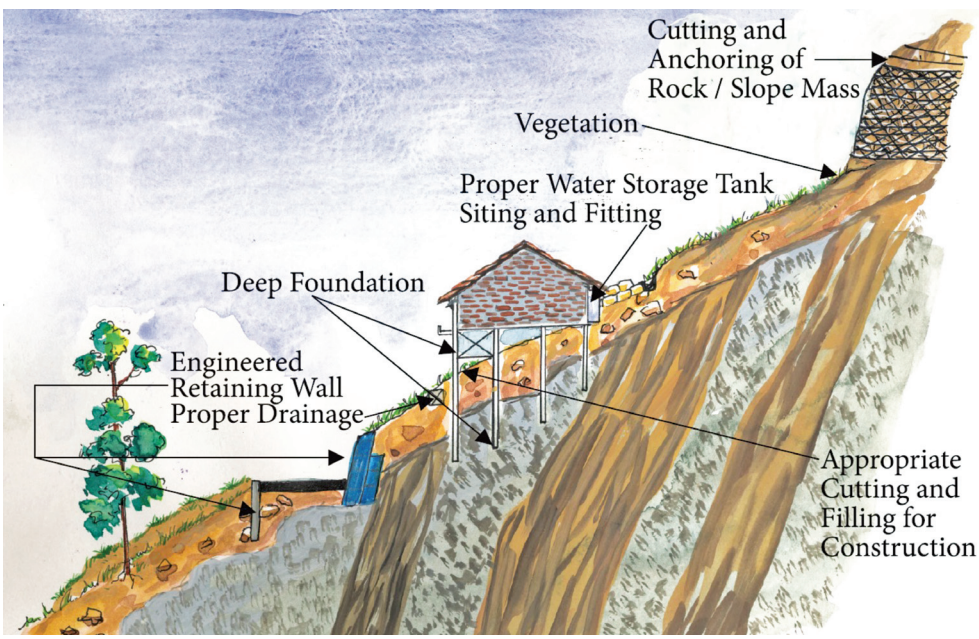
National and International NGOs

UN Agencies: OCHA, UNDP, UNICEF, UNDAC

Hill Side Construction Practice



A) Example of Bad Practice



B) Example of Good Practice

(Modified after Australian Geomechanics Society, 2007)

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The drafting of the training module involved extensive consultation of research papers, books and reports published by many individuals and institutions/ universities/organizations in India and abroad. Some of the consulted reports are listed below. Authors, compilers and editors of the documents consulted are gratefully acknowledged.

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3. Detailed Geo-parametric Attributes of a Landslide

(To be used by trained geoscientists at field)

42-point Detailed Geoparametric attributes of landslide incidences

No.	Field	Description
1.	**Slide No. (LS.No.)**	**State/district/toposheet/year/serial no.**
2.	State	Name
3.	District	Name
4.	Toposheet	No.
5.	Name of the slide	Maximum 20 character
6.	NH/SH/Locality	National Highway/State Highway/Name of nearest village or locality (Maximum 50 character)
7.	Latitude	Lat in decimal degree (using WGS 1984 Datum)
8.	Longitude	Long in decimal degree (using WGS 1984 Datum)
9.	Length	m
10.	Width	m
11.	Height	m
12.	Area	m^2
13.	Depth	m
14.	Volume	m^3
15.	Run out distance	m
16.	Type of Material	Rock/soil/debris/rock-cum-debris/debris-cum-rock
17.	Type of movement	Falls/Topple/Slide/Subsidence/Flows/Lateral Spread/Creep
18.	Rate of movement	Extremely Rapid, Very Rapid, rapid, moderate, slow, very slow, extremely slow
19.	Activity	Active/Reactivated/Suspended/Dormant/ Abandoned/Stabilized/Relict
20.	Distribution	Advancing/Retrogressive/Widening/Enlarging/ Confined/Diminishing/Moving
21.	Style	Complex/Successive/Multiple/Single
22.	Failure mechanism	Shallow planar failure/Deep planar failure/ Shallow Rotational failure/Deep rotational failure
23.	History	Date of initiation & subsequent reactivations (date/year)

24.	Geomorphology	Topography, landform, processes (Maximum 100 character)
25.	Geology	Lithological description (100 character)
26.	Structure	Details of discontinuity in whole circle (eg: J1: 50°:150°)
27.	Land use/Land cover	Barren/cultivated/forest/rural/urban/ anthropogenic activity/any other (Maximum 50 character)
28.	Hydrological condition	Dry/Wet/Dripping/Flowing
29.	Triggering Factor	Rainfall in mm/Earthquake (intensity in Richter scale)/lake bursting/Anthropogenic factors like road cutting, blasting etc. (Maximum 50 character)
30.	Death of persons	Numbers
31.	People affected	Numbers
32.	Live stock loss	Cattle death
33.	Communication	Road/Rail/transmission line (blocked/damaged)
34.	Infrastructure	Numbers of houses/building/dam/barrages damaged
35.	Agriculture/ forest/Barren	(Maximum 50 character)
36.	Geo-scientific Causes	Piping/reduction of strength on super-saturation/toe erosion by stream/gully erosion/ Anthropogenic activities (unplanned cutting of slope, unplanned construction, loading at head region, afforestation, adverse cultivation pattern /combination of above
37.	Remedial measures	(Maximum 200 character)
38.	Remarks, if any	If any (Maximum 200 character)
39.	Photos, Sketch of Plan & section of the slide	Affected by landslide – quantity/type of cultivation Send in jpg format
40.	Summary/ Abstract	(within 1000 character)
41.	Pdf	Soft copy of landslide report/source data, if available
42.	Landslide category	I, II, III

4. Some of the International Programmes for Landslides

Programme Name	University/ Country	Contact Details
CERG-C Specialization certificate for the assessment and management of geological and climate related risk	Université de Genève, Geneva, Switzerland	Email: cerg@unige.ch Phone: +41 22 3796602 Fax: +41 22 3793210 Web Link: https://www.unige.ch/sciences/terre/CERG-C/about/mission/
Summer School on Historic and Prehistoric Landslides	University of Padova, Italy	Email: landslideschool@gmail.com Link: http://landslideschool.eu/#home-block-nine
LARAM – Landslide Risk Assessment and Mitigation	University of Salerno, Italy	Email: laram@unisa.it Link: http://www.laram.unisa.it/index
iRAll – International Research Association on Large Landslides	State Key Laboratory of Geohazard Prevention and Geoenvironment Protection (Chengdu University of Technology), China	Tel: (+86) 028-84073193 Link: http://irall.sklgp.cdut.edu.cn/

5. Web Resources for Videos Related to Landslides

What are landslides and how are they caused?: This clip explains the chain of events that causes mudslides. Taken from the show "When nature strikes back: landslides" available on FirstScience.tv.

Download in full from: http://firstscience.tv/landslides.htm

http://www.youtube.com/watch?v=HiNwmj5ALZs&feature=player_embedded#!

When Nature Strikes Back: Landslides (Full Program) http://www.youtube.com/watch?v=Vd7eHG2b_tQ&feature=related

Landslide hits east Cairo shanty town in Egypt: A massive rockslide has hit a crowded Cairo shanty town, sending rocks and boulders crashed down onto dozens of houses.

http://www.youtube.com/watch?v=uCDhgtWH6t4&feature=player_embedded

Raw Video: Dramatic Mudslides in Italy: Around 200 residents of a southern Italian town were evacuated after an enormous landslide split the side of a hill.

http://www.youtube.com/watch?v=zl7_OMqOZbo

Dramatic amateur footage of deadly mudslide in Colombia: Rescue workers resumed their search and rescue efforts after up to 30 people were buried by a mudslide near the town of Giraldo in northwestern Colombia. Authorities had reported that the strong rainy season caused flooding and made many roads unusable across Colombia. The magnitude of the mudslide was making rescue operations very difficult. Amateur video shows the slide as it tumbled down, wiping out several homes.

http://www.youtube.com/watch?feature=fvwp&NR=1&v=BKTG58Bpziw

Mudslide Vancouver Hope BC June 29 2011 Canada: An extensive mudslide has Highway 1 closed in both directions at Popkum Road in the Hope area. The slide happened approximately 100 meters from the Herring Island exit this morning. It measures 25 feet deep and 200 feet long. Search and rescue crews had little to show after a ground search of a 60-metre wide mudslide on the Trans-Canada Highway between Chilliwack and Hope. In June 2000, a mudslide ripped the same stretch of highway between Chilliwack and Hope. No injuries were reported and both westbound and eastbound lanes were cleared within a day. In January 2002, a more devastating mudslide — provoked by a winter storm — struck the Trans-Canada Highway and surrounding areas in Hope and Chilliwack. According to previous reports, the storm and ensuing slide caused hundreds of thousands of dollars of damage to roads, homes and businesses in the area.

http://www.youtube.com/watch?v=S0kKtmkMgJM&feature=related

Raw Video on **Mudslides Destroy Homes in Bolivia** : A mudslide swallowed at least 50 houses and displaced 600 people in Bolivian capital La Paz. The landslides were caused by the presence of subterranean water.

http://www.youtube.com/watch?v=EzOk_lxk4Ww&feature=player_embedded

Mudslides, Flooding Kill 84 in Brazil: After days of heavy, flooding rains throughout Brazil, it is mudslides that rescue workers are now fighting against. Dozens are dead, another 30 remain missing. Officials estimate 54,000 people are displaced from their homes.

http://www.youtube.com/watch?v=HA7YtAojmU0&feature=relmfu

Frank Slide: Largest Landslide in History

http://www.youtube.com/watch?v=B-C3MCI1H7A&feature=related

Giant Sink Hole/Landslide Caught On Camera In Canada: This footage is from around Ontario, Canada.

http://www.youtube.com/watch?v=fbKDgF8CvmQ&feature=related

Massive Landslide Caught on Tape

http://www.youtube.com/watch?v=XC9AqJlaCj4&feature=related

Landslides in Svizzira, Switzerland http://www.youtube.com/watch?v=zGHCiXWR4DE&feature=relmfu

Quick Clay Landslide at Rissa - 1978 (English Commentary): On the 29th of April 1978, a quick clay landslide devastated large areas of the rural district of Rissa I mid-Norway. One person died whilst 13 farms; 2 homes; a cabin and a community centre were taken by the clay masses.

http://www.youtube.com/watch?v=3q-qfNlEP4A&feature=related

Raw Video: **Deadly Landslide Hits Train in Italy** — A landslide hit and derailed a train in northern Italy on Monday, killing 11 people and leaving some 30 injured.

http://www.youtube.com/watch?v=ktxDjqQIouw&feature=player_embedded

Raw Video: **Landslide Kills 6 in China** — A landslide in China's southwest killed at least six people and damaged a bridge that is a key link for reconstruction in areas hit by a devastating earthquake.

http://www.youtube.com/watch?v=3nAlQxOrQxs&feature=relmfu

Raw Video: **Landslide Buries Chinese Village**: A state media report says a massive landslide in northern China partially has buried a village and killed at least 23 people, and that rescuers are seeking survivors.

http://www.youtube.com/watch?v=3nAlQxOrQxs&feature=relmfu

Tibet to Nepal road with landslides - freaking scary 2: This is the continuation of my other video post "Tibet to Nepal road with landslide – freaking scary" where you can actually see the landslide "live". Bulldozer to the rescue, then continuing on, stumbling upon other landslides,

http://www.youtube.com/watch?v=mxoAUG9nmhE&feature=related

Landslides in La Rinidad, Benguet Particularly in Buyagan and in Puguis: Landslides In La Trinidad, Benguet Particularly In Buyagan and In Puguis During Typhoon Pepeng, This Devastating Disaster Have Claimed Many Lives, Most Are Them Are Families and Only Few Survived.

http://www.youtube.com/watch?v=weGGWdw7UHc&feature=related

Huge rock slide into lake! - shatters in half on the way down

http://www.youtube.com/watch?v=PFAGPYbgqlM&feature=related

Half Dome rock fall, 5/27/11, Yosemite Valley: from top of Washington Column. Large blocks came all the way down the Death Slabs - would have been fatal for anyone approaching the NW base.

http://www.youtube.com/watch?v=xGzU_sQrMsk&feature=related

Landslide in Japan - The following of website: http://www.kkr.mlit.go.jp/plan/2004-jisuberi-0810/index.html other http://www.ajiko.co.jp/bousai/nara/nara.htm (picture & 3D video)

Giant Landslip hits village. Caught live on camera - Movie of an giant Landslip hitting an village in Italy

http://www.youtube.com/watch?v=MQvNm-Swdb8&feature=related

Rock Slide As It Happens - Coffee Creek - Kootenays: TMTV News - Nelson BC Canada (UNEDITED) A rock slide as it happens on Highway 31 at Coffee Creek north of Nelson BC closed the highway for several hours. Boulders come crashing down onto the highway while filming.

http://www.youtube.com/watch?v=B4RYtNJpdLY&feature=related

Huge rockfall on Mount Rainier: Smaller and larger rockfalls happened during the day about hourly. Around 4pm a huge part of Nisqually Cleaver fell down, creating a fast river of rock and snow.

It was the biggest that day.

http://www.youtube.com/watch?v=fzRhLs5GkYs&feature=related

Malaysia Landslide: Landslide occurs at Seaside Malaysia on 1993 year, this video was taken on the spot at that time. That year, I received a call by the owner of a tin mine (the element tin, not tin as in cans...). He said that his mine, which had been running for a few decades, was about to collapse. I rushed to the scene with my video camera and waited for a few hours. Finally, I took this valuable footage. Although the footage lasted only a few minutes, it is horribly exciting enough. I hope that this video can let you all appreciate the consequence of ruining our environment."

http://www.youtube.com/watch?v=H6Ma0SVjMHA

http://www.youtube.com/watch?v=hMnAfY5H-8E&feature=player_embedded# (link to TV program in USA)

Extreme landslide caught on camera VIDEO: http://www.youtube.com/watch?v=kNrmczkpcPU&feature=related

Raw Video: **Many Missing After Mexican Landslide**: Rescue efforts continued on Wednesday in a town in Mexico's Oaxaca state, after the area was hit by landslide caused by torrential rains.

http://www.youtube.com/watch?v=yZUxIfltlT4&feature=player_embedded

Italy 16.02.2010: **Impressive landslide caught on video** — Italien Erdrutsch auf video - Italy http://croazia-alloggi-privati.info

http://www.taramtamtam.com/Urlaub-Reisen/Reiseangebote.php?c=Italien&lid=101

The landslide, which caused power failure, could have been caused by heavy rains in the region, initial reports say.

http://www.youtube.com/watch?v=R__3DYQCVnA&feature=related

Heyelan - Land slide

http://www.youtube.com/watch?v=F31ywRvtNkY&feature=related

Heyelan-Land Slide 2

http://www.youtube.com/watch?v=KmjcBb_tR2k&feature=relmfu

Land Slide-Heyelan-3

http://www.youtube.com/watch?v=9mI-TAL6SDc&feature=relmfu

Destroyed in seconds, The Frank Slide - 1903- The community of Frank NWT is obliterated on April 29, 1903

http://www.youtube.com/watch?v=cb_0D1epHcU&feature=related

Awesome Landslide: Glad you weren't driving on this Tennessee road when the cliff came down

http://www.youtube.com/watch?v=LeaX0ueZD-g&feature=related

Outrunning a Landslide: In Portland, Oregon, two men find themselves battling for their lives as a landslide hits their vehicle... and pushes it down the side of a mountain. They have to outrun the deluge of dirt and mud in order to survive. (from Discovery Channel's "Against the Elements")

http://www.youtube.com/watch?v=K1qY8nPqcCw&feature=related

Mount St. Helens Disintegrates in Enormous Landslide: Is any distance away from a volcano safe? Find out when an eruption causes one of the largest landslides in recorded history on Mount St. Helens. Unbelievable footage is studied and explained. (from Discovery Channel's "Raging Planet")

http://www.youtube.com/watch?v=UK--hvgP2uY&feature=fvwrel

Landslide Repair: The machine has arrived to repair our landslide that happened in January. The "spider" handled the 25 foot drop with little problems.

http://www.youtube.com/watch?v=O_XIXeLITdw&feature=related

!!Landslide In California!!

http://www.youtube.com/watch?v=pCMMwQmUjHI&feature=related

Oliver Mudslide: Six families are homeless, after a massive wall of mud, water and debris rushed down a hillside just south of Oliver, in the Southern Okanagan. Homeowners heard the roar of the hillside giving way, and went door to door. Amazingly everyone got out alive — and no one was injured. Emergency technicians surveyed the damage, and with rain in the forecast, they're concerned more slides could be triggered. Highway 97 is buried in meters of mud, and is expected to be closed for days. Homeowners affected by the slide will receive money from the Provincial Government's Disaster Assistance Plan.

http://www.youtube.com/watch?v=6YA1W4z_3kg&feature=related

Mudslide - June 2 2011, Keystone Colorado

http://www.youtube.com/watch?v=CyY3bCV8K-M&feature=related

Varunawat Land slide in 2003: Varunawat landslide clip, Uttarkashi www.drm.dmuttarkashi.com

http://www.youtube.com/watch?v=IamLdh2O8Iw&feature=related

Varunawat land Slide in 2003(2): www.drm.dmuttarkashi.com Varunawat landslide on district Uttarkashi (uttarakhand) india

http://www.youtube.com/watch?v=Z95nQw6Tzio&feature=relmfu

Live Landslide at Manali - Leh Highway: The landslide occurred between Sissu and Koksar in the Manali-Leh Highway. Huge pieces of rock started falling from the cliff above.

http://www.youtube.com/watch?v=6Hi_Osg2dY4&feature=related

Landslide shot live near Dalhousie: Very recent landslide shot live while coming down from Dalhousie. this is about 15 kms down from Dalhousie enroute Pathankot. while we reached a small part of the mountain had fallen completely disrupting trafiic and rendering them immobile. While I stood there, there was this whole mountain which came sliding down and honestly it was a lifetime experience bringing in mixed feelings of surprise...joy...and fear...the roads are albeit good such things keep on happening during monsoon...keep visiting Dalhousie...it makes for an exciting holiday.....no tie up with Himachal tourism.

http://www.youtube.com/watch?v=Vc6ouosXk0Q&feature=related

Most epic Landslides caught on camera 2010 - 2019

https://www.youtube.com/watch?v=d0-mBo_kblA

What causes a landslide? | Natural Disasters: In this video many causes of landslides are investigated. These mass movements of earth occur when gravity overcomes the frictional forces keeping layers of rock in place on a slope, resulting in planes of land moving and falling.

https://www.youtube.com/watch?v=RCxvbosa4fU

Massive landslide in Himachal Pradesh caught live!!

https://www.youtube.com/watch?v=66RZX9_Z4OQ

Deadliest landslides at Karnali Highway,a most dangerous Highway in Nepal

https://www.youtube.com/watch?v=f9dbo-iWVvA

People swept away by mudslide as mountainside collapses in Bolivia: A mudslide in Bolivia was captured on camera as people attempted to traverse a track on foot in an area of the mountains north-east of Sucre. The disaster came after a third successive day of heavy rain in the area, and there was no immediate report of casualties.

A day earlier another mudslide buried vehicles in the same area, killing at least 11 people. Tonnes of earth and mud collapsed on to a mountain highway near a spot known as El Choro on Saturday. The mountainside gave way as cars were lined up to make their way along a muddy patch of road.

https://www.youtube.com/watch?v=jjeCDYvGJS8

Mudslide barrels through Swiss town: A mudslide in Grugnay, Switzerland was captured on video rushing past houses and taking over a road. No injuries were reported.

https://www.youtube.com/watch?v=791o4LPqJWc

LANDSLIDE - The Dr. Binocs Show | Best Learning Videos For Kids | Peekaboo Kidz

Think you know what a landslide is? Did you know there are different kinds? If you want to learn why they happen, and where they are most likely to occur, come join us on the journey with Dr. Binocs

https://www.youtube.com/watch?v=krJLnXpemtQ

Nature's Fury | Landslides

https://www.youtube.com/watch?v=e8SecJjhb0I

A Documentary on Kailasaur Landslide: Vulnerability of Road Related Infrastructures & Facilities against Natural Hazards in Hilly Regions-A Documentary on Kailasaur Landslide

https://www.youtube.com/watch?v=y1YsJGk75Vs

Dart Landslide January 2014: Geologist Simon Cox explains some of the processes and features of the landslide, including some mysterious 'dust bubbles' at the base of a mud waterfall.

https://www.youtube.com/watch?v=Y6vs_lnBqwY

Lake burst one

https://www.youtube.com/watch?v=cgGnIM5clmM

Mass Wasting and Landslides - Types, Components, Causes and Prone Areas

https://www.youtube.com/watch?v=MpsRJ9LRabg

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