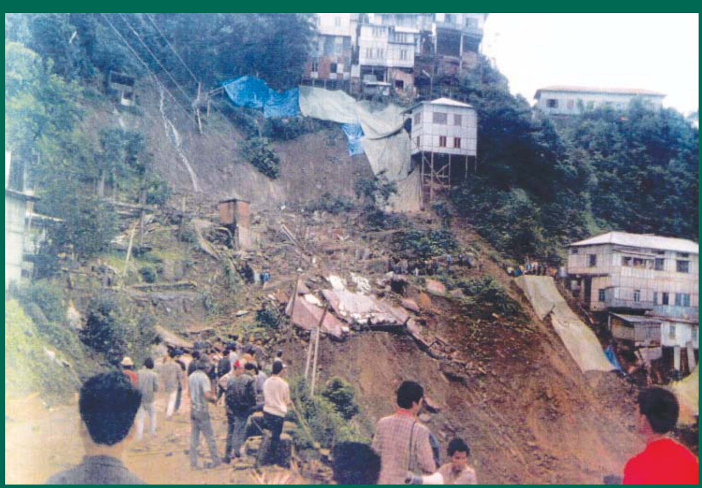
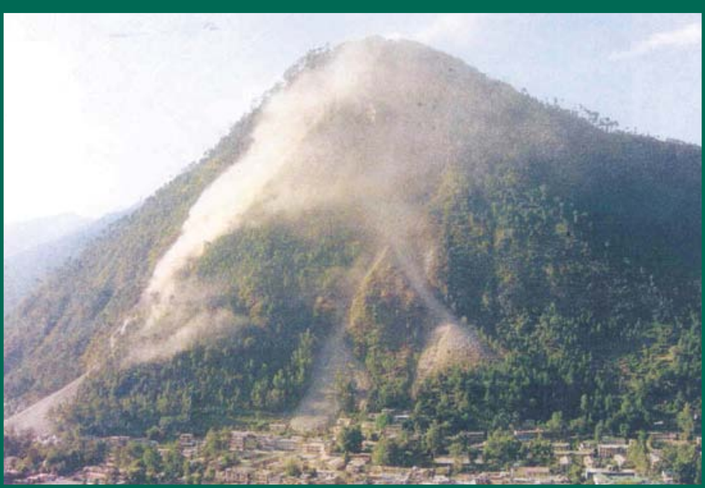
NATIONAL DISASTER MANAGEMENT GUIDELINES

MANAGEMENT OF LANDSLIDES AND SNOW AVALANCHES





June 2009

NATIONAL DISASTER MANAGEMENT AUTHORITY
GOVERNMENT OF INDIA

National Disaster Management Guidelines

Management of Landslides and Snow Avalanches

National Disaster Management Guidelines—Management of Landslides and Snow Avalanches

A publication of:

National Disaster Management Authority
Government of India
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These National Guidelines are formulated under the Chairmanship of Dr. Mohan Kanda, Hon'ble Member, NDMA, in consultation with various stakeholders, regulators, service providers, and specialists in the subject field concerned from all across the country.

National Disaster Management Guidelines

Management of Landslides and Snow Avalanches

National Disaster Management Authority
Government of India

Vision

No loss of life and property on account of landslides and snow avalanches

Mission

To minimise the impact of landslides and snow avalanches on life, property and economic activity

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Vice Chairman
National Disaster Management Authority
Government of India

FOREWORD

Our country experiences landslides year after year especially during the monsoons and periods of intense rain. This hazard affects about 15 per cent of our country covering over 0.49 million square kilometers. Landslides of different types occur frequently in the geodynamically active domains of the Himalayan and Arakan-Yoma regions, as well as in the relatively stable domains in the Meghalaya Plateau, the Western Ghats and the Nilgiri Hills. Extensive anthropogenic interference is a significant factor that increases this hazard manifold.

Though various expert committees/working groups headed by eminent people have made several useful recommendations and suggestions in the past, many of these are yet to be implemented, which is a cause for concern. These Guidelines have not only highlighted those recommendations but also indicated actions required to be taken on them, in a time-bound manner and by specified agencies.

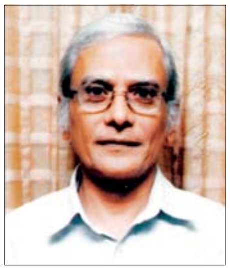
National Disaster Management Guidelines—Management of Landslides and Snow Avalanches have been formulated after a 'nine-step' process, which includes wide consultation with various central ministries/departments, states/union territories and other stakeholders, including scientific and technical institutions, non-governmental organisations and community based organisations. A draft of the document was also circulated to all the central ministries/departments, states and union territories for their feedback and all their workable suggestions have been incorporated.

These Guidelines call for a participatory approach involving all the stakeholders, in order to take forward the task of operationalising the National Vision of securing proactive and pre-disaster preparedness, and emphasising a mitigation-centric approach.

I am grateful to the members of the Extended and Core Groups who have made valuable contributions to this document. I am happy to place on record my sincere appreciation for the efforts of Dr. Mohan Kanda, Member, NDMA, who has guided and coordinated the entire exercise.

New Delhi
June 2009

General NC Vij
PVSM, UYSM, AVSM (Retd)



Member
National Disaster Management Authority
Government of India

ACKNOWLEDGEMENTS

At the outset, I express my sincere thanks to the Members of the Core Group and the Extended Group for their unrelenting cooperation in the extensive effort that went into the formulation of the *National Disaster Management Guidelines—Management of Landslides and Snow Avalanches* by the National Disaster Management Authority (NDMA).

I would like to place on record the significant contributions made by the representatives of all central ministries/departments concerned—especially the Ministry of Mines, the Geological Survey of India, the states/union territories, academic institutions, eminent professionals, the National Institute of Disaster Management and non-governmental organisations, which helped us improve the content and presentation of the document.

I would like to express my gratitude to the Vice Chairman and all the Members of the NDMA for their patient reading of various drafts, constructive criticism, guidance and suggestions in relation to the formulation of these Guidelines.

The efforts of Shri Y.P. Sharda, Director (Retd.) and Shri Sanjiv Sharma, Director, Geological Survey of India, in providing knowledge-based technical inputs to the Core Group and in drafting the document have been of special value.

I am also happy to acknowledge the support and cooperation extended by Shri H.S. Brahma, Special Secretary, NDMA along with his team, and members of my office Dr. Pavan Kumar Singh, Sarvashri G.V. Satyanarayana, M. Kankaji, S.K. Agarwal, Pratap Singh Chauhan and Narender Singh for their help in organising the various workshops and meetings and in the preparation of this document.

It is hoped that this humble effort will prove useful to the central ministries/departments and the states/union territories in formulating effective Landslide and Avalanche Management Plans that will lead to holistic and effective management of this phenomenon in the future.

New Delhi
June 2009

Dr. Mohan Kanda

Abbreviations

The following abbreviations and acronyms appear in the text and have the following meanings:

AHP	Analytical Hierarchy Process
AICTE	All India Council for Technical Education
ARMV	Accident Relief Medical Van
ASI	Archaeological Survey of India
ATI	Administrative Training Institute
BIS	Bureau of Indian Standards
BMTPC	Building Materials and Technology Promotion Council
BRO	Border Roads Organisation
CARTOSAT	Cartographic Satellite
CBO	Community Based Organisation
CBRI	Central Building Research Institute
CBSE	Central Board of Secondary Education
CDMM	Centre for Disaster Management and Mitigation, Vellore
CFI	Construction Federation of India
CLRSM	Centre for Landslide Research Studies and Management
CoA	Council of Architecture
CRF	Calamity Relief Fund
CRRI	Central Road Research Institute
CSIO	Central Scientific Instrumentation Organisation
CSR	Corporate Social Responsibility
CWC	Central Water Commission
DCR	Development Control Regulation
DDMA	District Disaster Management Authority
DEM	Digital Elevation Model
DGM	Directorate of Geology and Mining
DM	Disaster Management
DMA	Disaster Management Authority
DMP	Disaster Management Plan
DMS	Disaster Management Support
DoM	Department of Mines
DoS	Department of Space
DrISS	Doppler Radar and Infrared Satellite Sensing
DRM	Disaster Risk Management
DST	Department of Science and Technology
DTRL	Defence Terrain Research Laboratory

EO	Earth Observations
EOC	Emergency Operations Centre
EPIRB	Emergency Position-Indicating Radio Beacons
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GoI	Government of India
GPR	Ground Penetrating Radar
GPS	Global Positioning System
GSI	Geological Survey of India
HSC	Hazard Safety Cell
ICS	Incident Command System
IDRN	India Disaster Resource Network
IIA	Indian Institute of Architects
IIRS	Indian Institute of Remote Sensing
IIT	Indian Institute of Technology
IIT-K	Indian Institute of Technology – Kanpur
IIT-R	Indian Institute of Technology – Roorkee
IMD	India Meteorological Department
INTACH	Indian National Trust for Archaeological and Cultural Heritage
IRC	Indian Roads Congress
ISRO	Indian Space Research Organisation
ITC	International Institute for Geo-Information Science and Earth Observation
LHM	Landslide Hazard Management
LHZ	Landslide Hazard Zonation
LiDAR	Light Detection and Ranging
LMP	Landslide Management Plan
LP	Landslide Potential
LRA	Landslide Risk Analysis
LSZ	Landslide Susceptibility Zonation
MCI	Medical Council of India
MFR	Medical First Responder
MHA	Ministry of Home Affairs
MHRD	Ministry of Human Resource Development
MoA	Ministry of Agriculture
MoD	Ministry of Defence
MoEF	Ministry of Environment and Forests
MoES	Ministry of Earth Sciences
MoH&FW	Ministry of Health and Family Welfare
MoM	Ministry of Mines
MoR	Ministry of Railways
MoSRTH	Ministry of Shipping, Road Transport and Highways
MoWR	Ministry of Water Resources

NBC	National Building Code
NCC	National Cadet Corps
NCMRWF	National Centre for Medium Range Weather Forecasting
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NEC	National Executive Committee
NER	North Eastern Region
NGF	National Geotechnical Facility
NGO	Non-Governmental Organisation
NIDM	National Institute of Disaster Management
NIT	National Institutes of Technology
NPEEE	National Programme in Earthquake Engineering Education
NRSC	National Remote Sensing Centre
NSS	National Service Scheme
NYKS	Nehru Yuva Kendra Sangathan
PRI	Panchayati Raj Institution
PS	Persistent Scatterer
PWD	Public Works Department
QIP	Quality Improvement Programme
QRMT	Quick Response Medical Team
QRT	Quick Response Team
R&D	Research and Development
RDP	Resource Damage Potential
RDSO	Research Designs and Standards Organisation
SAR	Synthetic Aperture Radar
SASE	Snow and Avalanche Study Establishment
SDMA	State Disaster Management Authority
SDRF	State Disaster Response Force
SEC	State Executive Committee
SLHZ	Seismic Landslide Hazard Zonation
SMR	Slope Mass Rating
SMS	Short Message Service
SoI	Survey of India
SOP	Standard Operating Procedure
TAC	Technical Advisory Committee
UGC	University Grants Commission
ULB	Urban Local Body
UNDAC	United Nations Disaster Assessment and Coordination
UNDP	United Nations Development Programme
UN (OCHA)	United Nations Office for the Coordination of Humanitarian Affairs
WIHG	Wadia Institute of Himalayan Geology

Glossary of Terms

Afforestation
Systematic plantation in a deforested area to increase its forest cover.

Cloudburst
Rain storm of great intensity usually over a small area for a short duration.

Co-Seismic Landslides
Landslides triggered or induced by earthquakes.

Creep
Any extremely slow slope movements which are imperceptible except through long-period measurements.

Debris
The slope forming material that contains a significant proportion of coarse material; 20 per cent to 80 per cent of the particles are larger than 2mm; the remainder less than 2mm in size.

Debris Avalanche
A debris avalanche is an extremely rapid downward movement of rocks, soil, mud and other debris mixed with air and water.

Debris Flow
A mixture of water and clay, silt, sand and rock fragments that flows rapidly down steep slopes. A debris flow is slower than a mudflow.

Debris Slide
A debris slide is a jumble of material (clay, silt, sand and rock fragments) that moves downhill.

Deforestation
Removal of a forest by human activity.

Disaster
A catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or man-made causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of property, or damage to, and degradation of environment and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area.

Disaster Management
A continuous and integrated process of planning, organising, coordinating and implementing measures which are necessary or expedient for prevention of danger or threat of any disaster; mitigation or

reduction of risk of any disaster or its severity or consequences; capacity building; preparedness to deal with any disaster; prompt response to any threatening disaster situation or disaster; assessing the severity or magnitude of effects of any disaster; evacuation, rescue and relief; and rehabilitation and reconstruction.

Earthquake
An earthquake is a series of vibrations on the earth's surface caused by the generation of elastic (seismic) waves due to a sudden rupture within the earth during release of accumulated strain energy.

Elements at Risk
The population, properties, economic activities, including public services, etc., that are at risk in a given area.

Factor of Safety
Factor of safety for a slope or a landslide, irrespective of the shape of the failure surface, is expressed in terms of the proportion of the measured shear strength that must be mobilised to just maintain limiting equilibrium. At limit equilibrium, the factor of safety of a slope in a deterministic analysis is unity.

Fall
The more or less free and extremely rapid descent of masses of soil or rock, of any size from steep slopes or cliffs is called a fall.

Flash Flood
Very fast rise and recession with characteristics of small volume flow and high discharge, which causes high damage because of suddenness and force.

Flow
The downward movement of a loose mixture of debris, water and air that moves in a fluid like manner.

Gravity
Gravity is a constant force exerting a pull on everything on or above the earth's surface in a direction towards the centre of the planet.

Hazard
A threatening event or the probability of occurrence of a potentially damaging phenomenon (e.g., an earthquake or a large flood) within a given time period and area.

High Risk Area
Geographical area which falls under seismic zones III, IV and V, vulnerable to the potential impact of earthquakes, landslides, rock falls, and mudflows.

Landslide
Landslides are downward and outward movement of slope materials such as rock debris and earth, under the influence of gravity.

Landslide Dam
When landslides occur on the slopes of a river valley, the sliding mass may reach the bottom of the valley and cause partial or complete blockage of the river channel. This accumulated mass of landslide debris resulting in blockage of a river is commonly termed as landslide dam.

Landslide Hazard Map
Map of spatial and temporal extent of landslide hazard. It indicates those areas that are, or could be, affected by landslides, assessing the probability of such landslides occurring within a specific period of time.

Landslide Inventory
Documentation of all the known landslide incidences including stabilised, dormant, reactivated, and most recent slides.

Landslide Risk Map
A map that integrates landslide hazard, landslide vulnerability and quantification of elements at risk.

Landslide Susceptibility Map
A map that ranks slope stability of an area. It shows locations where landslides may occur in future (without a definite time frame). These maps go beyond an inventory map and depict areas that have the potential for landsliding.

Liquefaction
Liquefaction is a phenomenon in which the shear strength and stiffness of a soil is reduced by an earthquake or other rapid loading due to collapse of soil structure and temporary increase in pore-water pressure.

Local Authority
It includes panchayati raj institutions, municipalities, a district board, cantonment board, town planning authority or Zilla Parishad or any other body or authority, by whatever name called, for the time being invested by law, for rendering essential services, or, with the control and management of civic services, within a specified local area.

Mitigation
Measures aimed at reducing the risk, impact or effects of a disaster or threatening disaster situation.

Mudflow
A fast flow of a mixture primarily of the smallest silt and clay particles oversaturated with water. A mudflow has the consistency of newly mixed concrete.

Non-Structural Measures
Non-engineered measures to reduce or avoid possible impacts of hazards which include education, training, capacity development, public awareness, communication, etc.

Preparedness
The state of readiness to deal with a threatening disaster situation or disaster and the effects thereof.

Resilience
The capacity of a system to tolerate perturbation or disturbances without collapsing into a qualitatively different state, to withstand shock and rebuild whenever necessary.

Risk
The anticipated number of lives in danger, damage to property and disruption of economic activity due to a particular natural phenomenon.

Risk Assessment
The determination of the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihood, and the environment.

Risk Management
The systematic process of using administrative decisions, organisation, operational skills, and capacities to implement policies, strategies, and coping capacity of the society and communities to lessen the impact of hazards.

Seismic Hazard
In the context of engineering design seismic hazard is defined as the predicted level of ground acceleration which will be exceeded by 10 per cent over the probability of hazard at the site under construction due to occurrence of earthquake, anywhere in the region, in the next 50 years.

Seismic Retrofitting
The structural modifications to upgrade the strength, ductility and energy dissipating ability of seismically deficient or earthquake-damaged structures.

Snow Avalanche
Snow Avalanche is a slide of snow mass down a mountainside. It is a rapid, down slope movement of large detached mass of snow, ice and associated debris such as rock fragments, soil and vegetation.

Specific Risk
The expected degree of loss due to a particular natural phenomenon.

State Authority (SDMA)
State Disaster Management Authorities established under sub-section (l) of section 14 of the Disaster Management Act, 2005, and includes the disaster management authorities of union territories.

State Government
The department of the state government having administrative control of disaster management and includes the administrator of a union territory appointed by the President of India under article 239 of the Constitution.

Structural Measures

Any physical construction to reduce or avoid possible impact of hazards, which include engineering measures and construction of hazard-resistant, protective structures and infrastructure.

Vulnerability

The degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural (or man-made) phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss).

Executive Summary

Background

The prevention of loss to life and property due to natural calamities is being viewed very seriously by the Government of India. In the past, the main role played by the Government in the case of various disasters was confined mainly to post-disaster activities that included providing relief and organising rehabilitation. The Uttarkashi Earthquake of 1991, Killari Earthquake of 1993 and the devastating Malpa landslide along the Kailash-Mansarovar route in 1998 acted as an eye-opener for the Government. The need was felt for a proactive approach rather than waiting for a disaster to occur. As a part of this strategy, the Government decided to institute task forces for landslide hazard zonation, geotechnical investigations, and land use zonation and regulation. It was however the Kutch Earthquake of 26 January 2001 that led to a paradigm shift in the policies of the Government.

A review of the disaster management mechanism was carried out by the Government in June 2002 and the subject of disaster management was shifted from the Ministry of Agriculture to the Ministry of Home Affairs. The latter was declared as the nodal ministry for coordination of relief and response and overall disaster management. Subsequently, the Geological Survey of India was declared the nodal agency for landslides by the Government in January 2004. The responsibilities of the Ministry of Mines/Geological Survey of India as the nodal ministry/agency include coordinating all the activities related to landslide hazard mitigation, and monitoring the occurrence of landslides in the country. The Disaster Management Act, 2005, was enacted on 23 December 2005 and the National Disaster Management Authority, a statutory body under the chairmanship of the Prime Minister as provided for in this Act, was set up. As per the Disaster Management Act, the responsibility to cope with natural disasters is essentially that of state governments and the role of the central government is a supportive one in terms of supplementing physical and financial resources. At the state level, each state government is to set up a state disaster management authority under the chairpersonship of the chief minister. At the district level, the collector/district magistrate/deputy commissioner is the chairperson of the district disaster management authority and directs, coordinates and supervises disaster management activities.

Landslide Risk

Landslides are one of the natural hazards that affect at least 15 per cent of the land area of our country—an area which exceeds 0.49 million km^2. Landslides of different types are frequent in geodynamically active domains in the Himalayan and Arakan-Yoma belt of the North-Eastern parts of the country as well as in the relatively stable domains of the Meghalaya Plateau, Western Ghats and Nilgiri Hills. In all, 22 states and parts of the Union Territory of Pudducherry and Andaman & Nicobar Islands are affected by this hazard. The phenomenon of landslides is pronounced during the monsoon period.

For a long time landslides have had disastrous consequences causing enormous economic losses and affecting the social fabric. In 2005 alone, more than 500 human lives were lost due to this hazard in our country.

Approach to the Guidelines

In order to reduce the enormous destructive potential of landslides and to minimise the consequential losses, it is necessary that the hazard must first be recognised, the risk analysed and an appropriate strategy developed at the national level to mitigate its impact. To achieve this objective, the National Disaster Management Authority initiated a series of consultations for drafting the National Guidelines on Landslides and Snow Avalanches to guide the activities envisaged for mitigating the risk emanating from landslides at all levels. The main objectives of these Guidelines are to institutionalise the landslide hazard mitigation efforts, to make our society aware of the various aspects of landslide hazard in the country and to prepare the society to take suitable action to reduce both risks and costs associated with this hazard. The Guidelines include regulatory and non-regulatory frameworks with defined time schedules for all activities. It is envisioned that all national and state disaster management plans and policies for landslides will be formulated and implemented keeping in view the overall framework of the Guidelines.

Structure of the Guidelines

The following nine major areas have been identified for systematic and coordinated management of landslide hazards:

i) Landslide hazard, vulnerability, and risk assessment.

ii) Multi-hazard conceptualisation.

iii) Landslide remediation practice.

iv) Research and development; monitoring and early warning.

v) Knowledge network and management.

vi) Capacity building and training.

vii) Public awareness and education.

viii) Emergency preparedness and response.

ix) Regulation and enforcement.

Landslide Hazard Zonation

The above areas would need to be addressed for minimising the impact of landslides. Landslide hazard and risk assessment will be done through landslide hazard zonation mapping and geological and geotechnical investigation of vulnerable slopes and existing landslides. Building inventory databases has been considered an integral part of this exercise. Hazard zonation mapping involves:

i) Creation of landslide inventory.

ii) Selecting scales for mapping depending upon end-user requirements.

iii) Selecting landslide hazard zonation methodologies for different scales.

iv) Multi-hazard integration especially integrating seismic hazard.

v) Prioritisation of areas for landslide hazard zonation mapping.

vi) Landslide risk zonation.

Investigations for Landslide Risk Assessment

Geological and geotechnical investigations of landslide risk assessment involve a multidisciplinary approach where engineering geologists and geotechnical engineers are an integral part of the investigating team. The investigations include preliminary stage geological investigations, detailed geological investigations and geotechnical investigations. As an aid to the development of a systematic method and development of standard codes, and planning and capacity building for geological and geotechnical investigations, a few major disastrous landslides will be identified for creating pace setter examples of detailed investigations. These pace setting investigations will be carried out by assigning tasks to the identified organisations having necessary expertise and experience. The state geology and mining directorates will be made an integral part of these pilot projects as a part of capacity development.

Strategies for Landslide Risk Treatment

Landslide risk treatment is the ultimate objective of the risk management process which aims to mitigate the effects of the hazard. This encompasses a five-pronged strategy comprising:

i) Treating vulnerable slopes and existing hazardous landslides.

ii) Restricting development in landslide-prone areas.

iii) Preparing codes for excavation, construction and grading.

iv) Protecting existing developments.

v) Monitoring and warning systems.

vi) Putting in place arrangements for landslide insurance and compensation for losses.

Risk treatment of already distressed slopes includes the four broad types of landslide remediation practices for slope stabilisation, namely: control works, restraint works, slope protection works and mass improvement techniques. Mitigation measures for landslide dams have been given special attention as a large portion of the hazard prone area in the Himalayas is susceptible to the formation of such dams with disastrous possibilities. Protecting heritage structures from landslide damage has also been given due attention.

Monitoring and Forecasting of Landslides

The monitoring and forecasting of landslides, which are two of the least developed fields of landslide management practice will be given special attention as a part of mitigating the risk arising from landslide hazard. Monitoring of landslides includes:

i) Surface measurements of landslide activity.

ii) Sub-surface measurements of landslide activity.

iii) Total regime measurements.

These methods are very useful in comprehending slope movement. However, only real-time monitoring of landslides can pick up minor changes from minute to minute and helps in understanding the dynamic behaviour of a landslide. Real-time monitoring can give a sound technological basis for issuing warning signals.

Another important aspect is the development of early warning systems for landslides. Early warning is a process which involves three components:

i) Scientific and technical communities.

ii) Government authorities and civil agencies.

iii) Local communities.

In addition to the first two, the third one, i.e., involvement of local communities in the process of early warning is crucially important. An aware and vigilant community sensitised to the warning signs of impending landslides is the vital pillar for implementation of an effective early warning system. Early warning systems also comprise a scientific and technological base, mechanisms of dissemination and transmission of information, and response capability on receipt of warning information. It is imperative to execute a few pilot projects as pace setters of early warning systems which will also promote confidence in their operational capabilities.

Snow Avalanches

The issues related to snow avalanches, which affect certain areas in the Himalayas at regular intervals have also been taken up in these Guidelines along with landslides. A brief summary of the types of avalanches, their causes, their forecasting possibilities and the control strategies is presented. Since the recording of avalanche data and their clearance is chiefly carried out by the Border Roads Organisation, and forecasting and control of snow avalanches are generally dealt with by the Snow and Avalanche Studies Establishment, the management of this hazard will be a collaborative work of the National Disaster Management Authority, district administration, Border Roads Organisation, Snow and Avalanche Studies Establishment, and academic institutions active in carrying out research in this field.

Research and Development on Landslides

Landslide studies are a developing field of science. Extensive and intensive research and development activities are required to be taken up by institutions and individual experts to attain the goals set by the Guidelines. A few vitally important topics of research identified are:

i) Standardisation of landslide hazard zonation mapping and site specific studies.

ii) Understanding earthquake induced landslides and the required remedial measures.

iii) Design of surface and sub-surface drainage systems for stabilisation of slopes.

iv) Instrumentation for geotechnical investigation to conduct a detailed study of landslides.

v) Development of early warning systems.

vi) Facets of landslide dams.

vii) Run out and return period modelling of landslides.

viii) Simulation and modelling of snow avalanches.

ix) Landslides and snow avalanches in relation to global warming and climate change.

Success of research and development efforts will depend on institutionalisation 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 should be an integral part of the system.

Awareness and Preparedness

The issues related to awareness and preparedness are considered to be of crucial importance in both the pre- and post-disaster management processes. Mechanisms will be initiated for creating awareness among various stakeholders including government officials, local communities and non-governmental organisations on a sustained basis in landslide affected regions so that all the stakeholders are empowered by information and knowledge and mentally prepared to face the hazard.

Capacity Building

Capacity building is an important component of the disaster management process and is a field which needs attention. The requirement and importance of introducing appropriate capacity development interventions including capacity upgradation of institutions and organisations, education and training of stakeholders and responders, and proper documentation is included in the Guidelines. The identified institutions/organisations will be entrusted with the development of high-quality education material, textbooks, films, technical documentation, training courses, etc.

Post-disaster emergency response has been considered an integral component of mitigation efforts. The requirement of strengthening emergency response capability in landslide prone areas has been given emphasis. A coordinated response mechanism will involve emergency search and rescue, and relief; maintaining an operational incident command system; nurturing a community level disaster response mechanism; defining the involvement, role and responsibilities of all the stakeholders including the corporate sector; delineating the role of specialised paramilitary rescue teams; structuring emergency logistics; and institutionalising a loss assessment mechanism.

Adherence to Legal-Regulatory Regime

Improving the compliance regime through appropriate regulation and enforcement is vital. State governments/state disaster management authorities of landslide affected areas in consultation with the Ministry of Mines/Geological Survey of India and National Disaster Management Authority will establish the necessary techno-legal and techno-financial mechanisms to address the problem of landslide hazard in their respective states. The existing landslide related codes will be updated by review and suitable modifications. The process has to be initiated for preparation of codes on landslide risk evaluation and detailed geological investigations of landslides. The compliance regime has to be monitored and enforced for establishing model planning for towns and villages, thus ensuring safety in hazardous areas.

Development of State and District Disaster Management Plans

The Guidelines include the preparation of disaster management plans of central ministries and departments, state governments and the nodal agency in tune with the stated aims and objectives. Implementation of the Guidelines at the national level will begin with the preparation of a detailed action plan (involving programmes and activities) by the Ministry of Mines.

The National Plan will lay special emphasis on the most vulnerable groups/communities to enable and empower them to respond and recover from the impact of landslide disasters. The National Executive Committee will coordinate preparation of the national disaster management plan incorporating the disaster management plans prepared by the central ministries/departments and state governments for landslide affected states and districts, which will be approved by the National Disaster Management Authority. The plan will be in consonance with the schedule of activities in the Guidelines designed for effective landslide hazard mitigation in the country. The Ministry of Mines will keep the National Authority apprised of the progress on a regular basis. Similarly, concerned state authorities/departments will develop their state level disaster management plans and dovetail them with the national plan and keep the National Authority informed.

These activities will be initiated by the central ministries, departments and state governments, other stakeholders, and the nodal agency as parallel processes. These will be reviewed and updated by a group of experts/advisory committee to be constituted by the Ministry of Mines/nodal agency in consultation with the National Disaster Management Authority. This high level scientific and technical committee will not only serve as a think tank but also provide continuity in thought and ideas to the national landslide mitigation initiative.

Organisations Associated with Landslide Hazard Management

There is a need to set up a central organisation that will deal exclusively with all the fields of landslide management in a comprehensive manner. The central government through the Ministry of Mines will, therefore, set up a centre for landslide research, studies and management in one of the landslide prone states to ensure a wider view of landslides as a component of the environment and bring the existing pool of expertise in earth sciences (coastal stability, seismology and meteorology included) to bear upon this new initiative.

Financial Allocation for Landslide Hazard Management

The scheme of financial allocations for landslide hazard management has also been delineated. In the Five-Year and Annual Plans, the central and state ministries/departments will make specific allocations for landslide disaster management related activities. In addition 10 per cent of the Calamity Relief Fund will also be made available for the purchase of equipment for landslide preparedness and mitigation, and for rescue and relief operations. Besides these, the National Disaster Management Authority has also proposed to take up a national landslide mitigation project in the Eleventh Five-Year Plan which will aim to comprehensively deal with basic issues of landslide hazard management in the country.

Highlights of Important Recommendations

Although management of landslides requires coordinated and multi-faceted activities among many stakeholders in the total disaster management cycle, a few of the important recommendations made are listed below:

i) Developing and continuously updating the inventory of landslide incidences affecting the country.

ii) Landslide hazard zonation mapping in macro and meso scales after identification and prioritisation of the areas in consultation with the Border Roads Organisation, state governments and local communities.

iii) Taking up pilot projects in different regions of the country with a view to carry out detailed studies and monitoring of selected landslides to assess their stability status and estimate risk.

iv) Setting pace setter examples for stabilisation of slides and also setting up early warning systems depending on the risk evaluation and cost-benefit ratio.

v) Complete site specific studies of major landslides and plan treatment measures, and encourage state governments to continue these measures.

vi) Setting up of institutional mechanisms for generating awareness and preparedness about landslide hazard among various stakeholders.

vii) Enhancing landslide education, training of professionals and capacity development of organisations working in the field of landslide management.

viii) Capacity development and training to make the response regime more effective.

ix) Development of new codes and guidelines on landslide studies and revision of existing ones.

x) Establishment of an autonomous national centre for landslide research, studies and management.

Efficacy in managing landslides and avalanches in the country is expected to improve substantially after all these action points have been addressed on a priority basis with a sense of urgency and duly backed by requisite operational, legal, institutional, and financial support.

Schedule for Completion of Action Points

The time lines proposed for the implementation of various activities in the Guidelines are considered both important and desirable, especially in the case of those non-structural measures for which no clearances are required from central or other agencies. Precise schedules for structural measures will, however, be evolved in the landslide management plans that will follow at the central ministries/state level duly taking into account the availability of financial, technical and managerial resources. In case of compelling circumstances warranting a change, consultation with the National Disaster Management Authority will be undertaken, well in advance, for any adjustment, on a case to case basis.

Overview of the Guidelines

Introduction

The Guidelines on Landslides and Snow Avalanches chart out the regulatory and non-regulatory framework on the basis of which the national and state disaster management plans and policies are to be formulated and implemented. The task of mitigating landslide hazards has to be a coordinated effort of the central government, state government, local authorities, non-governmental organisations and other stakeholders including communities living in landslide-prone hilly regions. These plans will be reviewed and updated at periodic intervals and implemented through appropriate, well-coordinated and time-bound actions as laid down in these Guidelines at the national, state and local levels. As the growth of urban, semi-urban and rural centres, infrastructural developments, and other developmental activities in landslide prone areas increases, the risk of landslides will rise manifold unless mitigation issues are addressed adequately. Therefore, all agencies concerned are required to ensure implementation of these Guidelines.

Guidelines for Landslide and Snow Avalanches Disaster Management

The National Disaster Management Guidelines for Management of Landslides and Snow Avalanches include a wide range of scientific, planning, and administrative tools to address various aspects of these hazards to effectively reduce losses from them. These include nine major elements to enhance the effectiveness of managing the above hazards in the country:

Landslide Hazard, Vulnerability and Risk Assessment: This includes delineating areas susceptible to landslide hazards and status of landslide hazards in different areas and to assess the resources at risk due to these hazards as per the requirement of communities and for planning and decision making purposes. This also involves site specific studies of landslides and preparation of landslide inventory. The study of snow avalanches can also be included in this.

Multi-Hazard Conceptualisation: Integrating landslide concerns into multi-hazard disaster management plans at different levels for effective risk assessment, mitigation and response.

Landslide Remediation Practice: Encouraging implementation of successful landslide remediation and mitigation technologies, and execution of pace setter examples in mitigation and remediation strategies to build confidence amongst the affected communities. This also includes monitoring of landslides and development of early warning systems.

Research and Development; Monitoring and Early Warning: The study of landslide hazards is an area that requires active research. Unlike many other violent acts of nature, landslide hazards can be mapped out, predicted and contained, provided that a synergy of detailed plans, an aware community and scientific research are established. Research is of critical importance in managing landslides. 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; risk assessment and developing methodologies for assessing the potential co-seismic slides are some of the important fields of research that need immediate attention.

Knowledge Network and Management: Establishing an effective system for gathering information on landslides, loss assessment resulting from landslides, and the effective dissemination of technical information and maps is an essential component of the disaster management process. A web portal—the India Disaster Knowledge Network (IDKN) will be launched at the National level.

Capacity Building and Training: Developing institutional capacity and training for geoscientists, engineers, and planners is necessary for effective management of the landslide hazard. The directorates of mining and geology of the state governments require particular attention in this regard as these can be focal points of most scientific studies for landslides in the future. Risk assessment methodology, detailed site specific studies, etc., have to be standardised and existing codes for landslide related practices have to be suitably modified.

Public Awareness and Education: Effective communication of landslide hazard issues to the affected communities through education, public awareness programmes, posters, audio-visual aids, media campaigns, etc., is required.

The Components of the Landslide Disaster Management Process

Emergency Preparedness and Response: Development of coordinated landslide rapid response capability involving scientists, engineers, local authorities, the National Disaster Response Force and paramilitary forces. Rescue, relief and rehabilitation are covered in this component.

Regulation and Enforcement: Establishment of a techno-legal mechanism of landslide hazard assessment and mitigation with provisions for enforcing compliance thereof are important.

Plan for Implementation of the Guidelines

The central ministries and departments, and state governments concerned in landslide affected areas will designate nodal officers responsible for landslide management activities and for effective formulation and implementation of the disaster management plans. The policies, initiatives and activities of these agencies will address the concerns of all stakeholders involved in the development, management and maintenance of the built-up environment to ensure safety.

The implementation of the disaster management plans based on the Guidelines will incorporate the following elements:

Central Policy Statements and Plans: This will provide an overview of the resource management issues; the mode of coordination between central organisations and departments crucial for landslide hazard management; and supervise and monitor the implementation of the national disaster management plan for landslides. The National Executive Committee will prepare the national disaster management plan, based on the National Disaster Management Policy and Guidelines, and will incorporate the key elements of the plans prepared by various central ministries and departments, and state governments. Five-year and annual plans of all central ministries/departments and state governments will include disaster management components to support the activities spelt out in these plans. Remediation and mitigation practices for lifeline structures, national highways, the railway network and large civil engineering structures like major power and irrigation projects will be in direct purview of the appropriate central ministries and departments together with the involvement of local authorities.

The nodal agencies at the central and state levels will encourage all stakeholders to set up appropriate institutional mechanisms to ensure that the national landslide safety agenda is not only implemented but also closely monitored vis-à-vis specific targets. Such nodal agencies will identify appropriate agencies and institutions to develop standardised training modules, to prepare public awareness resource materials and to monitor the implementation of the disaster management plans based on these Guidelines.

State Policy and Plans: The state policy statement of landslide prone states will identify landslides as an issue, and then present objectives and policies that explain how the issue will be addressed. State plans will describe the significant management issues facing the state and then set out objectives, policies and methods (including rules) to address these issues, and also outline the results that are anticipated from their implementation. The state must ensure that their plans are consistent with national policy statements and plans. Plan provisions need to be appropriate to the geographical and community circumstances. No single policy for response to landslide disasters will fit the needs of all sites because of wide variation in geology, geomorphology, climatic conditions, and therefore types and locations of landslides. The issues and objectives among the districts threatened by slope instability may be similar, but the methods required to address the risk can be different. The state governments will also constitute disaster management teams responsible for the total disaster management cycle including mitigation, early warning, rapid response, rehabilitation and damage assessment. Response, relief and rehabilitation will be a coordinated endeavour of the disaster management teams, the central ministries and departments concerned and the local authorities.

District Plans: The district administration will understand and gather information about landslide hazards, estimate the appropriate level of risk and identify the issues for mitigation thereof. District plans for land use may be developed to minimise the risk of landslide hazard. The district administration will also create a community contingency fund for tackling post-disaster issues. Since landslides are, by and large, a localised phenomenon, district level community based preparedness plans are crucial for management of landslide disasters. The district administration will be responsible for constituting village level disaster management committees with the responsibilities of initiating and implementing disaster preparedness plans. They will include local elected representatives, government functionaries, local non-governmental organisations/community based organisations and other local groups. These committees will be responsible for identifying locally available assets and resources that can be utilised for building the capacities of the community for organising search, rescue and relief during and after disasters. Given an acceptable level of awareness, local level early warning of landslides is practicable to quite an extent.

Rules: These can be included in state plans to control various aspects of development in landslide hazard prone areas, including design, construction, location and density. These will also have provisions to ensure that the risk does not increase by unplanned urbanisation, intensified improper land-use or by new constructions in high hazard areas.

Non-Regulatory Activities: These provisions will dissuade people from putting themselves at risk due to landslides. Information, education and communication of information are the pillars of this activity. Disaster management cells will be set up with the responsibility of preparing and disseminating the landslide susceptibility maps for identifying, avoiding or mitigating the risk in vulnerable areas.

Monitoring

The plans will specify monitoring mechanisms with the following indicators:

i) Frequency of damaging landslides.

ii) Loss assessment.

iii) Mitigation methods used.

iv) Number of buildings being built on land at risk.

v) Land subject to landslide activity being set aside/purchased.

vi) The awareness level of the community.

Detailed documents need to be developed to elaborate on the monitoring mechanisms to be employed for undertaking a transparent, objective and independent review of landslide mitigation activities. Non-governmental organisations and local bodies will be involved in the monitoring process. If the monitoring process indicates that the provisions are not reducing landslide risk, the plans will be examined and may be revised and modified, if required.

To measure the effectiveness of policies and methods contained in plans, the results of monitoring will be put in the public domain. Keeping the communities informed is important because it not only lets them know about what is going on in terms of development and implementation of disaster management plans, but also raises the level of awareness about hazards in the community.

Goals and Milestones

The vision of the National Guidelines on Landslides and Snow Avalanches is that of a people sensitised to landslide hazards and pursuing mitigating steps armed with scientific, technological, planning, and policy capabilities to eliminate all avoidable losses due to landslides. The mission is to provide and encourage the use of scientific information, maps, technology, and guidance in mitigation techniques, emergency management, land use planning, and development and implementation of government policy to reduce losses from landslides throughout the country.

Implementation of the *National Disaster Management Guidelines—Management of Landslides and Snow Avalanches* will result in a number of major accomplishments, including the following:

i) Reduced losses from landslides.

ii) Greater public awareness about landslide hazards and methodologies for mitigating losses.

iii) Improved technology for landslide mitigation and remediation.

iv) Assessment and maps of landslide susceptibility in landslide-prone areas.

v) Policies to encourage landslide hazard mitigation through government agencies with the involvement of communities.

vi) Creation of national databases/inventory on landslide information.

vii) Preparation of training materials for geologists, geo-technicians, engineers, administrators, and planners.

viii) Curricula and training material for public awareness on landslide hazards.

ix) Real-time monitoring of critically hazardous landslides nationwide.

x) Establishment of a well-coordinated landslide emergency response mechanism.

Operational issues

Successful implementation of the Guidelines would require consideration of the following operational issues:

Technical/Scientific

i) Integrating landslide concerns in the development of disaster management plans at different levels i.e., national, state, district, municipal/panchayat.

ii) Networking of knowledge based institutions dealing with landslide studies for effective implementation of national landslide agenda.

iii) Innovation in the management of multi-institutional and multi-disciplinary teams.

iv) Switch-over from piecemeal remediation of landslides to simultaneous and holistic implementation of control measures.

v) Participation of the private sector and insurance sector in disaster management plans.

vi) Establishment of a disaster knowledge network (a network of networks) and a mechanism for dissemination of information at the national level.

vii) Mechanism for international linkages, cooperation and joint initiatives.

viii) Formation of expert committees for distribution of workload, evaluation of any project proposal, recommendation for funding the project, scrutiny of the project report, approval for implementation of the suggested remediation measures and assessment of the efficacy of the recommendations after their implementation.

Financial Issues

i) Criteria for disbursement of funds for servicing different areas of landslide mitigation.

ii) Building cost on preventive action and long-term maintenance of major problematic slopes in the development budget.

iii) Creating a techno-financial regime for landslide project implementation.

iv) Criteria for disbursement of landslide mitigation funds to non-governmental organisations.

Legal Issues

i) Techno-legal regime for introduction of sound slope protection, planned urbanisation, regulated land use and environment friendly land management practices.

ii) Zero tolerance against deliberate environmental violence and unhealthy construction practices.

iii) Laws governing new constructions and alteration of existing land use on problematic slopes and in landslide prone areas.

Road Map and Milestone Activities

These Guidelines will come into force with immediate effect. Keeping in view the goals, the activities required for landslide disaster management in the country have been divided into three categories which are:

i) Vital,

ii) Essential, and

iii) Desirable.

These activities have been further divided into short-term and long-term tasks depending upon the quantum of work involved, resources available, and impact of activity on disaster management.

Vital

The tasks categorised as vital are those which are absolutely essential and would form the basis for the operationalisation of other categories. These will be taken up initially and some of them may run concurrently with the activities of other categories.

Short-Term Activities

The short-term activities include preparation of status papers discussing the state-of-the-art technologies available for different aspects of landslides and landslide hazard management, which will form the basis for future studies on the subject. The topics covered may include development of uniform methodologies for landslide hazard zonation mapping on both macro and meso scales; landslide monitoring; detailed investigations of different types of landslides; landslide remediation practices; development of early warning systems including correlation between rainfall and landslide activity; and approach to awareness generation among communities, administrators, decision makers, and initial steps for capacity development at various levels.

Developing and continuously updating inventory of all landslide affected national highways, state highways, strategic transportation routes, human habitations and important civil engineering projects, and the landslide incidents impacting them.

Identification of the institutions engaged in landslide studies and disaster management at different levels, assess and upgrade their technical and resource capabilities to involve them effectively in the endeavour of landslide disaster management.

Identification and prioritisation of areas to be taken up for landslide hazard zonation mapping on macro as well as meso scales in consultation with Border Roads Organisation, state governments and local communities.

Setting up an institutional mechanism for generating awareness on landslide hazards among various stakeholders, spreading landslide education, and capacity development with a view to achieving the above objectives. The exercises for awareness generation will be planned and initiated by identified agencies. The capacities of different institutions and agencies will be assessed and required measures to develop their capacities will be initiated.

Taking up pilot projects in different regions of the country with a view to carry out detailed studies and monitoring of selected landslides, assess their stability status and estimate risk. The results of these studies will help in the identification of a few landslides that can be taken up for stabilisation or setting up an early warning system in the long term.

Integrating the landslide and snow avalanche hazard concerns into the multi-hazard concept as this hazard does not find a place in the Vulnerability Atlas of India published by the Building Materials Technology Promotion Council which currently includes earthquakes, cyclones and flood hazards. This atlas should be a multi-hazard one and include landslide and snow avalanche hazards as well. Since this atlas is under revision, the matter will be taken up with the Building Materials and Technology Promotion Council to include these hazards in its latest edition.

Long-Term Activities

The practice of controlling landslides is not a systematic process in our country and therefore has not met with much success. The results of pilot studies proposed can be utilised to identify the landslides that can be taken up for stabilisation or setting up early warning systems depending on the risk evaluation and cost-benefit ratio. These studies would also serve as pace setter examples to be followed in future and also in building up confidence among various stakeholders about the effectiveness of techniques and the importance of studies.

Landslide hazard zonation mapping of the identified priority areas is required to be carried out before actual development is taken up. The priority areas are to be identified based on information from the concerned ministries and state governments.

Essential

The activities next to vital in the order of importance have been categorised as essential. The activities for accomplishing the objectives or tasks of this category have been grouped into short-term and long-term activities.

Short-Term Activities

The short-term activities include preparation of landslide hazard zonation maps of national highways, state highways, and human habitations which have been identified at risk, on macro scales, in consultation with state governments; preparation of landslide hazard zonation maps for landslide prone habitations and sites of large civil engineering projects on meso scales; taking up a comprehensive programme to investigate identified slides with a view to stabilise them; identification of heritage structures that are vulnerable to landslide hazard and making plans to preserve them; to conduct training programmes for professionals on hazard, vulnerability, risk assessment and damage assessment; promote innovations in landslide education, awareness generation among administrators and communities; and establish modern search, rescue and relief practices by introducing modern search and rescue equipment and trained personnel in landslide affected states. Creating a network of institutions capable of carrying out detailed studies and managing selected landslides effectively by applying state-of-the-art technology.

Long-Term Activities

The long-term activities included in this category are—systematic landslide hazard zonation mapping of all the river basins in hilly areas and publishing those maps in the form of an atlas; the preparation of landslide hazard zonation maps of all urban and rural habitations located in hilly terrain as identified by state governments; to complete site specific studies of major landslides and plan treatment measures, and to encourage state governments to continue these; to intensify awareness generation programmes by involving state government agencies, non-governmental organisations and community organisations; to set up monitoring systems for some high-risk and difficult to manage landslides, to attempt stabilising them after consultation with different stakeholders and detailed risk analysis and vulnerability assessment; and to plan early warning systems at selected sites that are difficult to stabilise. It is essential that the state directorates of geology and mining be associated with all the scientific and technical activities right from the beginning.

Identification and selection of roads and reservoir rim corridors for essential studies and landslide analyses is to be undertaken in order to prevent any possible loss to lifeline structures such as dams and road links. It may even involve monitoring in selected cases. A programme on bio-remedial measures will be undertaken at the grassroots level involving local communities.

Desirable

The activities that are in the desirable category are also further sub-divided into short-term and long-term sub-categories. The short-term activities include establishment of a disaster knowledge bank; development of new codes and guidelines, and revision of the existing ones. The long-term activities include development and establishment of early warning systems for selected landslides that pose high risk and are difficult to fully stabilise with designed remedial measures. A mechanism should be developed to prepare institutions to take up these exercises regularly and improve them based on feedback. Some of these activities can be taken up concurrently with essential and desired activities and some that are dependent on the results of activities categorised as vital and essential can be taken up during later phases.

1 The Context

1.1 Landslide Hazard—An Introduction

Humans have had to face the impact of natural hazards from time immemorial. Natural hazards such as earthquakes, landslides, avalanches, floods, cyclones, droughts, and volcanic eruptions of varying magnitudes have repeatedly been the cause of calamities. According to statistics, natural hazards are believed to account for up to 4 per cent of the total annual deaths world-wide, besides causing enormous economic losses and uprooting habitation. It has also been observed that casualties resulting from natural hazards are not evenly distributed throughout the world, but are more concentrated in developing countries, partly due to their higher population densities and lack of preparedness.

Landslides form a significant component of the natural disasters that affect most of the hilly regions round the globe. Recent studies on global landslide disasters indicate that some of the highest risk landslide disaster zones are located in Colombia, Tajikistan, India, China, and Nepal where the estimated number of people killed per year per 100 sq. km area was found to be more than one. Historical records indicate that the highest number of lives lost to a single landslide event were in the earthquake-triggered landslide disaster in Kansu Province of China in 1920. Another well known landslide event of the last century was an earthquake-triggered debris avalanche in 1970 on the slopes of Mt. Huascaran, Peru, which advanced with an average speed of 320 km/hr, burying the towns of Yungay and Ranrahirca, killing more than 18,000 people. Similarly, in Europe, the 1963 Vaiont reservoir slide in North-Eastern Italy, resulted in the death of 2,000 people.

Although the term landslide in the strict sense may be defined as a process involving the downward and outward movement of a part of the slope forming material due to the action of gravity, other forms of mass movements like falls, flows, topples and creeps are generally included in the term landslides. This document also considers snow avalanches as within the ambit of landslide management.

1.2 Landslide Vulnerability and Risk in India

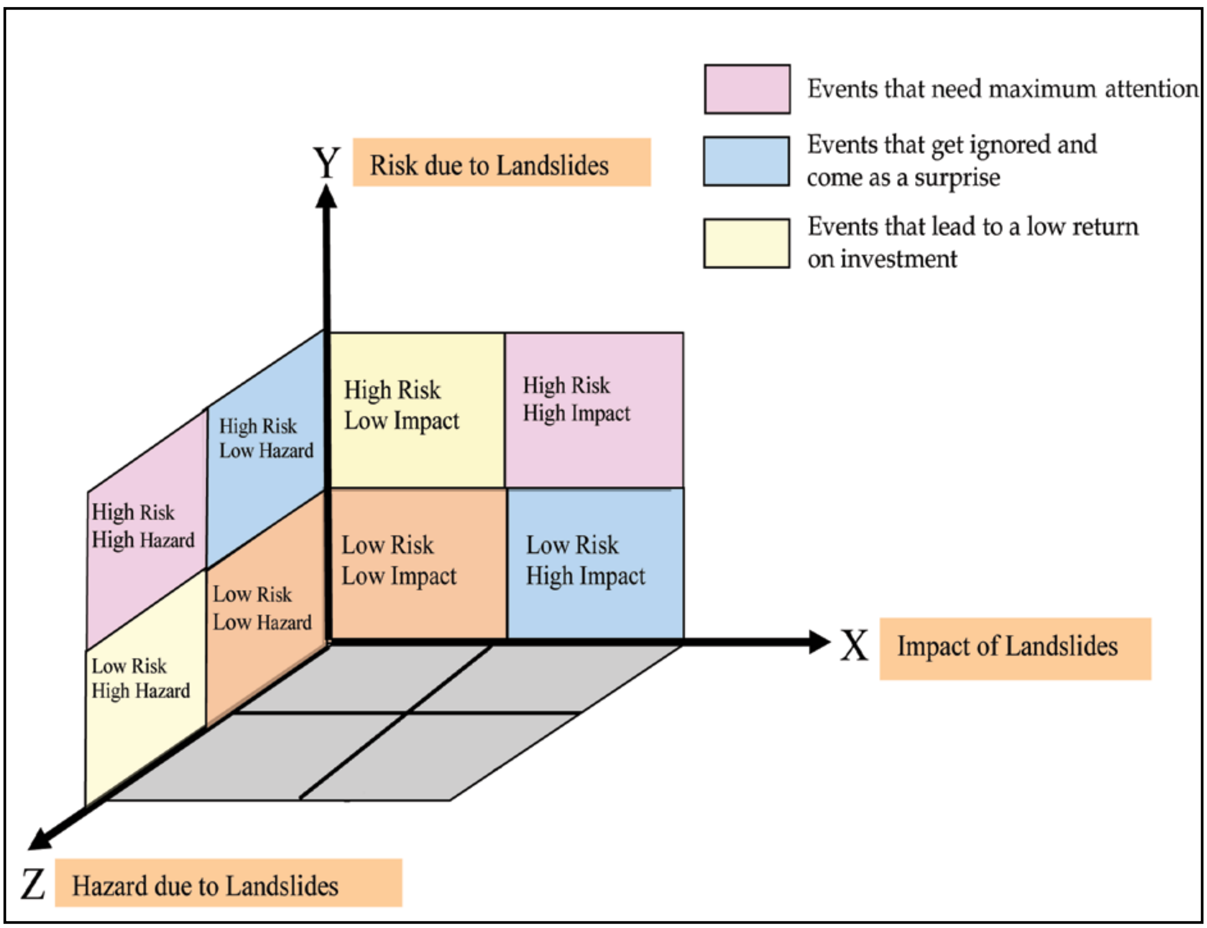
India's vulnerability to landslides is seen in the threat of landslides to our housing and infrastructure, farms and fields, vast stretches of border roads and railway lines, hydro-electric and water supply installations, transmission line projects, aerial ropeways, open cast mines, tunnels, heritage buildings and monasteries, pilgrim routes, and tourist spots. Having defined the terms landslide hazard, vulnerability, and risk, it follows that the scientific approach to dealing with the perceived threat is to first establish landslide hazard and vulnerability scenarios for reliable risk analyses.

Vulnerability to landslides can be evaluated only if we know the exposure to landslide hazard and our preparedness to face that hazard. Vulnerability will be close to nil in the case of well managed and protected slopes. It will be the maximum for unprepared populations living on slopes with a proven history of landslides. This vulnerability to landslides can be reduced by creating a culture of safety through careful land use planning, timely and appropriate engineering intervention, conscientious maintenance of slopes and connected utilities, early warning, public awareness, and preparedness. We need to develop a culture of quick response to managing disasters to reduce the impact of landslide disasters.

Once we know the landslide hazard and vulnerability profile, specific risk can be determined. The total risk is then the multiple of the specific risk (as calculated above) and elements like population, property, infrastructure, and development activities exposed to landslide hazards. The main purpose of this exercise is to visualise a relationship between landslide hazards, risk, and impact of a landslide, possibly in terms of quantified loss for safer construction (See Figure 1.1).

Landslides are a natural hazard that affect at least 15 per cent of the land area of our country, covering an area of more than 0.49 million sq. km. Landslides of different types occur frequently in the geo-dynamically active domains in the Himalayan and North-Eastern parts of the country as well as relatively stable domains in the Western Ghats and Nilgiri hills in the Southern part of the country. Besides, sporadic occurrences of landslides have been reported in the Eastern Ghats, Ranchi Plateau, and Vindhyan Plateau as well. In all, 22 States and parts of the Union Territory of Pudducherry and Andaman & Nicobar Islands of our country are affected by this hazard, mostly during the monsoons.

Figure 1.1: Visualisation of Landslide Hazard, Risk and Impact



The Himalayan mountain ranges and hilly tracts of the North-Eastern region are highly susceptible to slope instability due to the immature and rugged topography, fragile rock conditions, high seismicity resulting from proximity to the plate margins, and high rainfall. Extensive anthropogenic interference, as part of developmental activities, is another significant factor that increases this hazard manifold. As a result, the landscape in the Himalayan and North-Eastern regions is highly susceptible to reoccurrence of landslides. The Ambutia landslide, located on the picturesque tea garden clad hill slopes around the Kurseong town in Darjeeling is probably the largest such landslide in Asia.

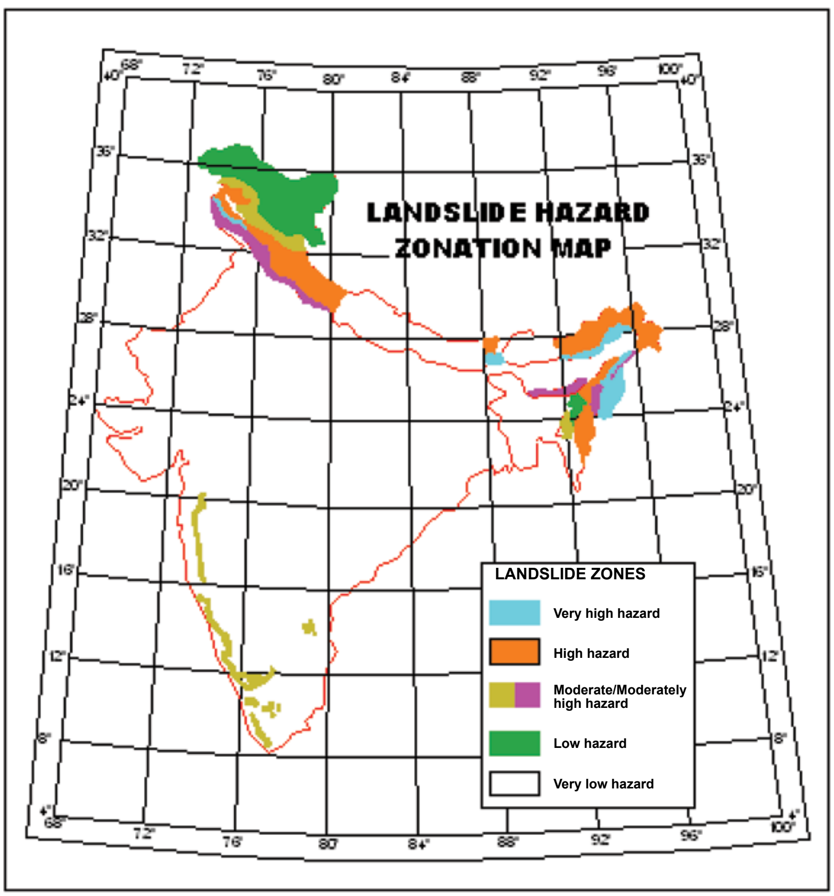
Similarly, the Western Ghats, overlooking the Konkan coast, though located in a relatively stable domain, experience the fury of this natural hazard due to steep hill slopes, overburden and high intensity rainfall. The Nilgiri hills located at the convergence zone of the Eastern Ghats and the Western Ghats bear the innumerable scars of landslides due to their location in a zone of high intensity and protracted rainfall where overburden is sensitive to over-saturation.

In addition to landslides, the snow avalanche is another natural hazard involving mass movement that is experienced at high altitudes in the Himalayan terrain during the late winter season when the snow starts melting.

Vast areas of western Sikkim, Kumaon, Garhwal, Himachal Pradesh, Kashmir, and several other hilly regions have been denuded of protective vegetal cover, which has been reduced to less than 30 per cent, which is less than half of what would be considered desirable. As the pressure of population grew rapidly, more and more human settlements, roads, dams, tunnels, water reservoirs, towers and other public utilities came up in vulnerable areas. The road network in the Himalayan region is more than 50,000 km in length. A large number of dams have been built in the Himalayan region.

There are more than 25 river dam projects on the river Ganga and its tributaries in the hills alone. A number of tunnels and towers for microwave, television, and power transmission dot the hilly areas. Quarrying and mining, for example, in the Doon valley, Jhiroli (Almora) and Chandhak (Pithoragarh) have inflicted heavy damages to the slopes and the associated environment.

Figure 1.2: Landslide Hazard Zonation Map of India (Prepared by GSI)



Landslides along the National Highway (NH) 1A and NH-1B in Jammu and Kashmir, the Rishikesh-Badrinath pilgrimage route in Uttarakhand, highways and roads in Darjeeling and Sikkim, and the Dimapur-Imphal and Shillong-Silchar National Highways in the North-Eastern region have been disastrous and have caused immense economic loss and affected the social fabric for a long time.

Landslides with catastrophic effects include the Varunavat landslide of Uttarkashi, the Malpa landslide along the Kailash-Mansarovar yatra route, the Kaliasaur landslide along the Rishikesh-Badrinath pilgrimage route, the Zubza and Mao Seng Song landslides along the Dimapur-Imphal National Highway, the Sonapur landslide along the Shillong-Silchar National Highway, the Sakinaka landslide in Mumbai, the Konkan landslides of 2005, and the Ghanvi village landslide in Himachal Pradesh in 2007.

Instances of co-seismic landslides particularly in the Himalayan and North-Eastern parts of our country are common. The Shillong earthquake of 1897, the Kangra earthquake of 1905, the Assam earthquake of 1950, the Uttarkashi earthquake of 1991, and the Chamoli earthquake of 1999 generated numerous landslides over vast areas. Similarly, the October 2005 Kashmir earthquake generated numerous landslides in both Pakistani as well as Indian territory.

In the Western Ghats, over 500 lives were lost due to landslides in the Konkan area in Maharashtra during incessant rain in 2005, which accounted for 100 lives in the Mumbai Metropolitan Area alone.

Some examples of devastating landslides in the Nilgiris include the Amboori landslide in Thiruvanantapuram district, Kerala; and the Runnymede, Hospital, Glenmore, Coonoor, and Karadipallam landslides in Nilgiri district, Tamil Nadu.

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

The Himalayan and North-Eastern regions are potential sites where landslide dams have formed at many places in the past and the potential of such occurrences in the future is high. In contrast, the peninsular shield region is tectonically stable and the potential of occurrences of landslide dams is very low.

1.3 Impact

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

Like in any other disaster, the most affected are the socio-economically weaker sections of the society who inhabit the vulnerable areas. They have meagre sources of livelihood, which when wiped out by a hazard, leaves them without any food or shelter. Apart from this, the injuries and casualties suffered add to the woes of the affected families. The biggest loss is that of private and government property, as well as damage to/destruction of infrastructure and heritage structures.

The frequent obstructions caused to the movement of traffic by numerous landslides during the rainy season, sometimes for days together, particularly in the Himalayan and North-Eastern regions of the country, bring untold misery to the people inhabiting the villages and townships in the landslide-prone hilly regions.

Landslides also reduce the effective life of, and returns from hydroelectric and multipurpose projects by adding an enormous amount of silt load to the reservoirs.

Landslide dams result in the 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 'bulk' or add volume and density to otherwise normal stream flow or cause channel blockages and diversions creating flood conditions or localised erosion. Landslides can also cause overtopping of dams resulting in flash floods and/or reduced capacity of reservoirs to store water.

1.4 Landslide Management in India

1.4.1 Current Status

Landslide hazard management in India had till now been confined to ad-hoc solutions of site specific problems and the implementation of immediate remedial measures including debris removal, and dumping of this debris either down slope or into a river. The aim of these Guidelines is to manage landslide hazard through an institutional mechanism, by following a systematic approach that includes both short-term and long-term planning after a study of the hazard, vulnerability and risk assessment.

Landslide hazard management involves measures taken to avoid or mitigate the risk posed by landslide hazards. The most important role in this process is played by the local government machinery. Once information is received 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/ dwellers to shift to safer places. Moreover, further development is avoided in such high risk zones. Mitigation strategies might not be possible in every landslide hazard prone area both due their high cost and the indifferent attitude of the public. Efforts to reduce risk are also made by road construction and maintenance agencies by implementing required treatment measures.

There is, however, a need to pre-empt disaster by making adequate information available in advance before it strikes, something that is emphasised in these Guidelines which are to be used by all states, especially those affected by multi-hazards.

1.4.2 Government Policies and Initiatives

The Government of India (GoI) has been quite concerned about the management of natural calamities since a long time. The task of Disaster Management (DM) was earlier entrusted to the Ministry of Agriculture (MoA) since only droughts and floods were considered major national natural calamities. Here too, the main focus was on post-disaster response i.e., conducting relief operations in the affected areas.

The devastating Malpa tragedy resulting from a landslide that occurred along the Kailash-Mansarovar route in the Kumaon Himalayan region in August 1998 acted as an eye-opener for the GoI as far as landslide disasters are concerned. It decided to set up task forces for Landslide Hazard Zonation (LHZ), Geotechnical Investigations and Land Use Zonation and Regulation. The Geological Survey of India (GSI) was identified as the nodal agency for LHZ while the Department of Science and Technology (DST) and the Ministry of

Environment and Forests (MoEF) were identified as nodal agencies for the other two task forces, respectively. Consequently, the Department of Mines (DoM) constituted a task force to review the existing methodologies for LHZ study, to prioritise areas/belts for its study and to recommend a plan for the preparation of macro/meso/micro LHZ maps. The task force constituted by the DoM submitted its report to the Government in September 2000.

The DST pursued the task on Geotechnical Investigations and submitted a report to the Government. The DST launched the Coordinated National Programme on Landslide Hazard Mitigation and published a document on the Status of Activities and Thrust Areas of Research in December 2003. Several projects have been sanctioned by the DST since then.

The GSI is the nodal agency for monitoring landslide activity and its mitigation.

There are many government departments and organisations which are engaged in landslide hazard studies and hazard management in the country. These include the GSI, Central Road Research Institute (CRRI), Central Building Research Institute (CBRI), Indian Institute of Technology, Roorkee (IIT-R), Wadia Institute of Himalayan Geology (WIHG), Department of Space (DoS), National Remote Sensing Centre (NRSC), Defence Terrain Research Laboratory (DTRL), Bureau of Indian Standards (BIS), some academic institutions, and individual experts. The Snow and Avalanche Study Establishment (SASE) under the Ministry of Defence (MoD) is the institution engaged in studying snow avalanches. In addition, the Border Roads Organisation (BRO) is the principal agency responsible for the construction and maintenance of roads in almost all the hilly regions of the country and DST has been funding Research and Development (R&D) activities that include different types of landslide investigations.

The earliest landslide studies in the country were carried out by the GSI. This includes the study of the Nainital landslide by Sir R.D. Oldham in 1880 and C.S. Middlemiss in 1890, and the study of the Gohana landslide in 1893 in the erstwhile Uttar Pradesh Himalayan region that resulted in the formation of a 350m high landslide dam across the Birehiganga. Till date the Department has carried out studies on more than 1,500 incidences of landslides. In the case of LHZ mapping, the GSI has prepared LHZ maps with scales of 1:50,000 and 1:25,000 covering about 45,000 sq. km in the landslide prone hilly tracts. LHZ mapping has also been carried out with similar scales, covering about 4,000 km along the important national and state highways. Besides, the GSI has also prepared detailed LHZ maps of five landslide affected townships in different parts of the country at scales of 1:5,000 and 1:10,000.

Facet based LHZ methodology was initiated at the University of Roorkee (now the Indian Institute of Technology) in the mid-eighties. The work is still continuing over different parts of the Uttarakhand Himalayan region, incorporating progressive improvements. Several institutions have adopted facet based LHZ mapping.

The CRRI's major activities include geological and geotechnical investigations of landslides, landslide hazard potential and risk analysis, instrumentation, monitoring, and prevention of landslides. The CRRI has published reports on landslide correction techniques, application of geo-textiles, deep trench drains, and promotion of jute based geo-textiles, etc. The CRRI has also prepared a partial database of over 200 landslides in different parts of the country.

The CBRI has prepared LHZ maps in parts of Garhwal, Sikkim, and the Darjeeling Himalayan region using different techniques and has also monitored some landslides. The institute has also implemented control measures at the Mussoorie bypass and the Kaliasaur landslides in the state of Uttarakhand.

The Central Scientific Instrumentation Organisation (CSIO), a national instrumentation laboratory, has installed an instrumentation network for landslide monitoring at Mansa Devi, Haridwar in 2006.

The WIHG has carried out LHZ mapping in parts of the Sutlej valley and has also monitored some landslides.

The BIS has the responsibility of developing zoning codes and guidelines related to landslide practices. It has issued guidelines related to LHZ mapping on macro-scales, construction of retaining walls and landslide control. For standardising landslide studies BIS is also in the process of developing LHZ mapping guidelines on meso scale, risk evaluation and detailed investigations.

The Landslide Hazard Atlas of India containing small scale maps was published jointly by the Building Materials and Technology Promotion Council (BMTPC) and Anna University in 2004.

The NRSC has prepared LHZ maps on a scale of 1:25,000 along various pilgrimage routes and important highways in Uttarakhand and the Himachal Himalayan region. Utilisation of the latest available remote sensing techniques and synthesisation of data on the (Geographic Information System) GIS platform were the highlights of the work. The NRSC published a two volume atlas on LHZ in 2004. The NRSC has also carried out a high resolution aerial survey of the Varunwat landslide and has provided detailed maps on the contour, slope, etc. The NRSC, GSI and International Institute for Geo-Information Science and Earth Observation (ITC) are collaborating on developing landslide risk assessment models for the North-Western and North-Eastern Himalayan regions and also the Western Ghats. A collaborative project on LHZ for NH-17 (from Mumbai to Goa) by the GSI and NRSC is in progress.

With the availability of high resolution images, it is possible for the NRSC to monitor landslides and also keep an eye on the occurrence of new landslides and formation of landslide dams in highly inaccessible areas.

The National Institute of Disaster Management (NIDM), which works under the control of the National Disaster Management Authority (NDMA), has the capability to develop training modules, formulate and implement human resource development plans, organise training programmes covering the management of natural hazards including landslides, develop educational material for DM, and provide assistance to state governments and state training institutes in the formulation of state level policies and plans for DM.

The DST has been carrying out a number of activities related to landslide management for the past 15 years. It carried out landslide hazard mapping in parts of the Sutlej Valley in Himachal Pradesh, the Kumaon and Garhwal areas in Uttarakhand, the Konkan Railway Region from Panvel to Ratnagiri, the Nilgiris, and the North-Eastern states of Manipur, Nagaland, Mizoram, Sikkim, and Arunachal Pradesh. The data/maps are in digital form and can be shared for DM activities. The DST has also developed software/brochures for the Landslide Safe Route Finder to provide safe navigation while constructing new communication lines/roads in hilly areas.

The DST has brought out many publications on landslides and related issues like the coordinated national programme on Landslide Hazard Mitigation, and a Field Manual for Landslide Investigations, etc. Periodically, it also organises awareness programmes/courses/workshops for government agencies/Non-Governmental Organisations (NGOs) and communities.

In collaboration with the International Centre for Geohazards and the Norwegian Geotechnical Institute, the DST is establishing a National Geotechnical Facility (NGF) in Dehradun. The NGF aims to have state-of-the-art facilities in geotechnical sciences and to provide a platform for building capacities in geotechnical investigations and research. This will also help in networking the institutions within the country which have facilities and technical manpower. It is expected that the NGF will provide inputs for DM related activities in designing/retrofitting underground and surface level structures.

The Central Water Commission (CWC) has been the lead agency for assessing the hazard potential of landslide dams in the country and its vicinity.

1.4.3 Landslide Studies—Methods Practiced in India

Landslide Hazard Zonation Mapping

LHZ mapping is a tool to identify those areas which are, or could be, affected by landslides and assessing the probability of such landslides occurring within a specified period of time. The preparation of a LHZ map includes the study of the regional geology and geomorphic setting, slope conditions including existing and potential instability, and land use information. Scale is an important factor of LHZ mapping. Maps of 1:1,00,000 or 1:50,000 scales are inappropriate for regional studies since these are only indicative and do not provide adequate details. Larger scale maps on 1:10,000 or 1:5,000 scale are taken up for detailed studies at the local level.

Inventory of Landslide Incidences

Unlike earthquakes or floods, landslides are localised events. But these may occur with a high frequency in a region. The basic objective for the preparation of a LHZ map is the availability of a landslide inventory database which indicates the intensity of the hazard in a given area. The preparation of landslide inventory maps and databases is a tedious procedure. A landslide inventory database requires detailed information, both present and past, about a landslide. Thus, it is very difficult to obtain a complete landslide inventory map containing information like the type and characteristics of slope failure, exact date of occurrence, triggering event that initiated the movement, etc. This lack of landslide inventory data leads to problems in validating landslide hazard maps. No organisation in our country has a sound database on landslide inventory. Taking into consideration the importance of developing a sound database on landslide inventory, the GSI has recently initiated a programme for the generation of landslide inventory maps and databases covering the landslide prone regions of our country. These can be supplemented using satellite data for updating the information and plotting in the geospatial domain.

Site Specific Study of Landslides

The purpose of site specific studies is to investigate a landslide in detail, employing both surface and sub-surface exploration techniques to establish the type of slide, causative factors leading to slope instability, stability status of the slope, monitoring of the slide to understand its dynamic behaviour, the extent of damages caused and likely to be caused due to further sliding, the mechanism of sliding and finally to suggest the most appropriate corrective measures to stabilise the slide. Geotechnical investigations, including monitoring, have been carried out at some of the landslides. These include work on the Kaliasaur landslide along NH-58 near Srinagar, the Nainital landslide at Sher Ka Danda and 9.5 Mile, B2 and Lanta Khola landslides in Sikkim, the Powari landslide at km 367 on NH-21, Kinnaur district, Himachal Pradesh, and the Patalganga landslide on NH-58 near Pipalkoti, Uttarakhand. The DST has initiated various research projects such as the ones for NH-1A Sonapur in Meghalaya, the Tirumala Hills, eight specific sites in Uttarakhand, etc.

Rock fall velocity modelling is a new kind of study for which very limited research has been done in the country. IIT-R has recently attempted it in the Nandprayag region in the Garhwal Himalayas. The velocity of a rock fall is one of the main factors which defines the degree of the risk. Slow moving landslides are not as risky, if the movement is continuous. However rock falls are one type of landslide that need to be understood with respect to their movement i.e., slow or fast and also with respect to the risks they cause to the local population. For rock fall velocity modelling, software needs to be developed and tested on accessible slopes for further research and modifications.

Research and Development

A number of organisations/institutes in India are engaged in studies of the different aspects of landslides. However, very little effort towards R&D pertaining to landslide investigation has been made so far in India. Intensive research is urgently required in order to develop innovative, eco-friendly and cost-effective measures for landslide investigation and remediation practices. These include the standardisation of landslide terminologies, methods of slope stability analysis, standardisation of guidelines for landslide hazard zonation mapping on different scales, procedure of vulnerability and risk evaluation and assessment, preparation of guidelines for risk zonation mapping, innovative techniques and/or modern technology for the construction of underground drainage networks, etc.

Snow Avalanches Studies

Snow avalanches are not landslides in a strict sense of the term, but when snow and ice slides it causes devastation, especially during inclement weather at high altitudes. Snow avalanches lead to disasters in the snow covered mountainous terrain of the Himalayas. Avalanches are transient, three dimensional, gravity driven, free surface, rapidly moving shear flows that contain a dense granular core surrounded by a cloud of airborne turbulent powder. The SASE is engaged in carrying out research activities in the field of snow avalanche forecasting and avalanche control structures. The SASE is also responsible for conducting search and rescue operations as post-disaster activities in the case of snow avalanches.

1.4.4 Landslide Remediation Practices

A comprehensive risk management strategy requires systematic approaches in planning and implementation. It includes two main categories, i.e., pre-disaster prevention strategies and post-disaster management. Pre-disaster strategies include assessment of the hazard, risk analysis through the documentation of existing events, hazard zonation mapping and the application of modern techniques that can help in preventing the activation of dangerous processes. Comprehensive hazard zonation aims at preventing settlements and infrastructural elements from being 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 sub-surface water including the development of pore pressures, nailing, bolting, anchoring, micro piling, application of geo-grids and geo-textiles and afforestation, constitute powerful elements of most geo-technical packages commonly used for improving the stability of problematic slopes and landslide sites in India.

In India, most landslides occur during the monsoon barring a few, which are caused by earthquakes. Pore water pressure plays a major role in initiating landslide events. There are also instances where toe erosion by rivers or nalas and scouring of the hill slope due to high velocity discharge of streams descending from the crown of the landslide gives rise to debris flows/ landslides. Hence, surface and sub-surface water management on the slopes or in the catchments is the most effective remediation measure for controlling many landslides. Management of surface runoff and sub-surface water is done through the construction of drainage networks. Sub-surface drainage management is hardly practiced in our country for the stabilisation of landslides. This aspect of prevention calls for immediate attention and agencies like the BRO, Public Works Department (PWDs), etc., engaged in slope stabilisation activities need to be equipped with modern technologies for the construction of sub-surface drainage networks.

Reinforcing technologies like nailing, bolting, anchoring and tie-back solutions have all provided apt solutions to a wide range of civil and mining engineering problems. Numerous successful examples of stabilisation of problematic slopes, landslides, open cast mines, tunnels, road cuttings, etc., bear ample testimony to the potential of reinforcing technologies.

Technological interventions in many cases have not been sensitive to the needs of specific sites, and there has been very little technological innovation in India in the area of landslide control. These shortcomings can be overcome only through R&D efforts in technological intervention by knowledge based institutions or organisations.

1.4.5 Slope Instrumentation, Monitoring and Landslide Prediction

Slope instrumentation for the monitoring and prediction of landslides has so far generally not been practiced in India. A few attempts have been made by some institutions but the methodology and techniques as well as the results are not uniform. Detailed slope stability analysis and landslide modelling are almost impossible without slope instrumentation generated data. Monitoring indicates the acceleration of movement and the development of pore pressures at different locations within the landslide mass. However, interpretation of the data is difficult as critical values are unknown in the absence of a documented history of previous events. It is also not practicable to monitor all landslides by the installation of instruments, considering the prohibitive cost and the huge number of landslide incidences in the country. The monitoring system of landslides can, however, be used for warning people about ensuing disaster.

1.5 Early Warning Systems for Landslides

Early warning systems elsewhere in the world have been developed by the real-time monitoring of landslides. This includes the continuous monitoring of movements, development of stresses, and pore pressures or hydrostatic pressures, and the transmission of this instrument generated data through a telemetric system at regular time intervals. At the initiation of an event, radio signals are transmitted and alarm signals are sent to the relevant authority regarding the impending danger and probable time of occurrence of a landslide. However, awareness generation and the involvement of local communities is a vital component of an early warning system, to ensure its success. Thus, in certain cases, the local communities, if properly trained and adequately motivated, can observe the movement indicators on the hill slopes and issue the necessary warnings.

Real-time monitoring may be undertaken for the development of an early warning system in the case of a few devastating, large dimension and recurring types of slides or rock falls which are very difficult to stabilise and pose a high risk. Since the ultimate goal is to find a permanent solution, i.e., to stabilise the landslide, the development of an early warning system is not the ultimate answer to this natural hazard, but only a part of the effort to mitigate its impact.

Considering the probable danger of losing instruments due to the recurrent nature of some of the conspicuous landslides and the prohibitively high cost of these instruments, an effort should be made to develop an early warning system for some of the devastating landslides where instrumentation could be proposed that would serve the twin purposes of providing a detailed slope stability analysis for suggesting the most appropriate remedial measures, or the development of an early warning system by the real-time monitoring of these landslides. The experience gained from this type of exercise will be immensely helpful for studying other landslides.

1.6 Landslide Education, Awareness and Capacity Building

The GoI has initiated a nation-wide awareness generation campaign as a part of its overall disaster risk management strategy. A steering committee for a mass media campaign has been constituted at the national level with due representation of experts from diverse communications streams. DM as a subject, including landslides, has been introduced in the school Social Science curriculum for classes VIII, IX and X by the Central Board of Secondary Education (CBSE) in all the schools affiliated to it. The same is to be done by state boards of secondary education in all disaster prone states. While the Ministry of Home Affairs (MHA) has compiled/prepared a set of resource materials on some natural hazards—developed by various organisations/institutions—for distribution and dissemination, there is an urgent requirement to develop resource materials for landslide hazards as well.

As a part of the awareness generation exercise for the landslide hazard mitigation effort, the GSI, in consultation with the MHA, initiated a programme to establish contact with various state governments in landslide affected areas and to create awareness about this hazard among the state officers and other agencies dealing with natural hazards. The contact programme in the form of a one-day interactive workshop has so far been conducted in the states of Sikkim, Uttarakhand, Jammu and Kashmir, Assam, Meghalaya, Tamil Nadu, Karnataka, Tripura, Nagaland, Himachal Pradesh, Kerala, and the Union Territory of Pudducherry. The programme consists of an audio-visual presentation and distribution of booklets and posters for creating awareness about landslide hazards, terminologies, causes, treatment measures, etc.

Another effort in landslide education involves the development of self-training software and self-certification CD-ROMS. Such efforts to produce quality resource materials are to be an ongoing process. The GSI Training Institute conducts a regular training programme on the various aspects of landslide investigations using state-of-the-art technologies.

The NIDM has the mandate to develop training modules, undertake research and documentation for DM, provide assistance in national and state level policy formulation, develop educational materials for DM, and promote awareness about hazard mitigation, preparedness, and response measures. The Indian Institute of Remote Sensing (IIRS), Dehradun also conducts courses, both short- and long-term, in the use of remote sensing data for geological hazards. The decision support centre at the NRSC also conducts a two-week course for various planners at the state and district level in the use of Earth Observations (EO) data for hazards.

The mass awareness generation programme is to be made an essential component of the disaster mitigation plan and is to be carried out in a sustained manner through the electronic and print media, interactive meets, and the distribution of handbills and posters in local languages, with the help of different NGOs and state government authorities. For this purpose a series of audio-visual resource materials has to be prepared and distributed to these organisations, for which the services of the media, private volunteers and NGOs active in the field of DM can be effectively utilised, after proper orientation.

A large number of engineers and geologists engaged in landslide hazard management do not possess the requisite expertise to manage this hazard. Therefore, landslide hazard management techniques, risk assessment and remediation practices are required to be included in the curricula of technical institutes teaching civil engineering, geology, geophysics and DM.

Professionals engaged in Landslide Hazard Management (LHM) have to be properly oriented and made aware about the latest technological developments related to landslides. Some training institutes need to be identified and entrusted with the responsibility of regularly training and orienting professionals.

1.7 The Snow Avalanche Hazard

1.7.1 Introduction

The snow avalanche, a common occurrence in snow covered mountainous regions, is a slide of snow mass down a mountainside. This is a rapid downslope movement of a large detached mass of snow, ice, and associated debris such as rocks and vegetation. Small avalanches, or sluffs, occur in large numbers, while large avalanches that may encompass slopes a kilometre or more in length with millions of tons of snow, occur infrequently but cause most of the damage. Humans have been exposed to the threat of sliding snow for as long as they have inhabited mountainous regions. A large avalanche can run for many kilometres, and result in massive destruction of forests and anything else that comes in its way.

These threats are felt in the Indian context as well. Most recently, snowfall of up to 2m occurred at many places on the higher reaches of the Pir Panjal range between 16–20 February 2005, resulting in avalanches at several places in Anantnag, Doda, Poonch, Pulwama, and Udhampur districts of Jammu and Kashmir. Over 300 people lost their lives.

1.7.2 Types of Avalanches

There are two basic types of avalanches, loose snow avalanches and slab avalanches. These are further sub-divided according to whether the snow involved is dry, damp or wet, whether the snowslide originates in a surface layer or involves the whole snow cover (slides to the ground), and whether the motion is on the ground, in the air, or mixed.

Loose snow avalanches form in snow masses with little internal cohesion among the individual snow crystals. When such snow lies in a state of unstable equilibrium on a slope steeper than its natural angle of repose, a slight disturbance sets progressively more and more snow in downhill motion. If enough momentum is generated, the sliding snow may run out onto level ground, or even ascend an opposite valley slope. Such an avalanche originates at a point and grows wider as it sweeps up more snow in its descent. The demarcation between sliding and undisturbed snow is diffuse, especially in dry snow. Though very common, most dry, loose snow avalanches are small and few achieve sufficient size to cause damage. With the onset of melting, wet loose snow avalanches become common. Most of the latter, too, are small, but they are more likely to occasionally reach destructive size, especially when confined to a gulley.

Slab avalanches originate in snow with sufficient internal cohesion to enable a snow layer, or layers, to react mechanically as a single entity. The degree of this required cohesion may range from very slight in fresh, new snow (soft slab) to very high in hard, wind drifted snow (hard slab). A slab avalanche breaks free along a characteristic fracture line, a sharp division of sliding from stable snow whose face stands perpendicular to the slope. The entire surface of unstable snow is set in motion at the same time, especially when the cohesive snow lies on top of a weak layer. A slab release may take place across an entire mountainside, with the fracture racing from slope to slope to adjacent or even distant slide paths. The mechanical conditions leading to slab avalanche formation are found in a wide variety of snow types, new and old, dry and wet. They may be induced by the nature of snow deposition (wind drifting is the prime agent of slab formation), or by internal metamorphism. Slab avalanches are often dangerous, unpredictable in behaviour, and account for most of the damage.

Avalanches composed of dry snow usually generate a dust cloud when the sliding snow is whirled into the air. Such slides, called powder snow avalanches, most frequently originate as soft slabs. Under favourable circumstances, enough snow crystals are mixed with the air to form an aerosol which behaves as a sharply bounded body of dense gas rushing down the slope ahead of the sliding snow. This wind blast can achieve high velocities, to inflict heavy destruction well beyond the normal bounds of the avalanche path.

Wet snow avalanches move more slowly than dry ones and are seldom accompanied by dust clouds. Their higher snow density can lend them enormous destructive force in spite of lower velocities. As wet slides reach their deposition zones, the interaction of sliding and stagnated snow produces a characteristic channelling.

Direct action avalanches are the immediate result of a single snow storm. They usually involve only fresh snow. Climax avalanches are caused by a series of snow storms or a culmination of weather influences. Their fall is not necessarily associated with a current storm or weather situation.

1.7.3 Causes of Snow Avalanches

Avalanches form as soon as the force of gravity on the snow cover exceeds its mechanical strength. To be caused, an avalanches needs a steep slope, snow cover, a weak layer in the snow cover, and a trigger to initiate movement. Snow avalanches may occur on any slope where enough snow is deposited in the right circumstances. Snow does not accumulate significantly on steep slopes; also, snow does not flow easily on flat slopes. Most avalanches of dangerous size therefore originate on slopes with inclinations of between 30 degrees and 45 degrees. On slopes from 45 degrees to 50 degrees, sluffs and small avalanches are common, but snow seldom accumulates to sufficient depths to generate large snow slides. Convex slopes are more susceptible to avalanches than concave slopes.

Avalanches are released (spontaneously or artificially) by an increase in stress (e.g., by fresh snow) and/or a decrease in strength (e.g., by warming or rain). Though internal metamorphism or stress development may sometimes initiate a snow rupture, avalanches are often dislodged by external triggers. Ice fall, falling cornices, earthquakes, rock falls, thermal changes, blizzards, and even other avalanches are common natural triggers. Avalanches can also be triggered by loud sounds such as shouts, machine noise, and sonic booms. In the absence of external triggers, unstable snow may revert to stability with the passage of time as long as no avalanche occurs. The rheology of snow cover is similar to that of ice as both are visco-elastic materials that exhibit creep behaviour over time. Snow deforms continually without fracturing as the load on top of it increases. However, the loading rate is critical. Heavy snow fall over a short duration leads to a greater probability of avalanche occurrence. A snow fall of 1m in one day is far more hazardous than 1m over three days.

When the snow pack becomes unstable, it is released suddenly and descends rapidly downslope, either over a wide area or concentrated in an avalanche track. Avalanches reach speeds of up to 200 km an hour and can exert forces great enough to destroy structures coming in their way and uproot or snap off large trees. It may be preceded by an 'air blast' capable of damaging constructions and forest cover.

The complete path of an avalanche is made up of a starting zone at the top where the unstable snow breaks away from the more stable part of the snow cover, a run-out zone at the bottom where the moving snow and entrained debris stop, and a track that runs between the two zones. The air blast zone is usually in the vicinity, but not necessarily continuous with the lower track or run-out zone. In some cases it may even run way up the slope across the valley from the avalanche path.

In general the run-out zone is the critical area for land use decisions because of its otherwise attractive setting for development. Avalanches run on the same paths year after year, the danger zones often being well known in normal circumstances. Exceptionally uneventful weather intervals lasting for many years may produce exceptional avalanches which overrun their normal paths and even break new ones where none existed for centuries. Avalanche prone lands may pass many winters or even decades without a serious avalanche.

Avalanches are not confined to specific terrain features: they may follow narrow gullies or ravines for all or a part of their path, they may occur on broad, uniform slopes or even ridges and spurs. The longitudinal profiles of the paths may be concave, convex, or stepped. On stepped paths, small avalanches will often stop on a bench some distance down the tract while larger ones will run the full length of the path.

1.7.4 The Impact of Snow Avalanches

The forces generated by moderate or large avalanches can damage or destroy most man-made structures. The debris from even small avalanches is enough to block a highway or rail-road. Avalanches are extremely destructive due to the great impact forces of the rapidly moving snow and debris and the burial of areas in the run-out zone. Structures not specifically designed to withstand these impacts are generally totally destroyed. Where avalanches cross highways, passing vehicles can be swept away and destroyed, killing their occupants.

In general, land use within an avalanche area should not include buildings intended for winter and early spring occupancy. Ordinarily, use of avalanche areas in the summer does not constitute any hazard. Structures including power lines, highways, railroads, and other facilities that are placed in avalanche paths and run-out zones should be designed for expected impact even if other preventive measures are implemented.

1.7.5 Early Warning Systems against Snow Avalanche Hazards

There are two basic methods of anticipating an avalanche hazard. One is the examination of the snow cover structure for patterns of weakness, particularly those leading to slab avalanches. The second method is the analysis of the meteorological factors affecting snow depositions. In practice the two methods overlap and both are used. Emphasis on either one or the other depends on the local climate, pattern of snowfall, snow type, and avalanche characteristics. Both apply principally to winter avalanches in dry snow. Forecasting wet spring avalanches depends on knowledge of the heat input to the snow surface.

Rising temperature during a storm accompanied by rising new snow density tends to cause avalanching, while falling temperatures have the opposite effect. New snow precipitation intensity is a significant factor, as it represents the rate at which the slopes are being overloaded.

Wet snow avalanches are generated by the intrusion of percolating water (rain or snow melt) in the snow cover. The rapid rise in temperature quickly alters snow behaviour, while the water itself reduces snow strength. Water accumulating on an impervious crust provides an especially good lubricating layer for slab release. The most extensive wet snow avalanching occurs during winter rains or the first prolonged melt period in spring, when water intrudes into previously sub-freezing snow. Snowmelt due to solar radiation is the most common cause of wet snow avalanches.

Snow cover, terrain and atmospheric parameters are the major inputs for forecasting of snow avalanches. It is difficult to obtain the required information from the remote regions of the Himalayas using conventional ground based techniques, as there are several limitations due to the inaccessibility and ruggedness of the terrain, the lack of infrastructure facilities, and limited information on the region. Satellite remote sensing is the most efficient tool for these purposes, especially for large, rugged, and remote areas. For gathering the latest terrain information on avalanche-prone areas, snow cover and atmospheric parameters, optical [MODIS, AVHRR, AWiFS, WiFS, LISS-III, PAN, Cartographic Satellite (CARTOSAT), IKONOS, Quickbird] and microwave (AMSR-E, SSM/I, Radarsat, ENVISAT) imagery can be used. The latter is useful in weather conditions where cloud cover obstructs remote observation by other means.

1.7.6 Avalanche Control Strategies

The need for study of snow bound areas has increased manifold with the increasing necessity of developing communication routes, development of winter tourism, construction of hydroelectric projects and transmission lines in snow bound areas. Snow avalanches have long posed a threat to the indigenous populations of the Himalayan and Trans-Himalayan mountains. Land use intensification due to population growth, new transportation routes, defence related activities and tourism are raising this level of risk.

Obviously, the most desirable and effective protection against avalanches is to situate buildings, roads, and other valuable developmental projects in areas free from avalanches. However, as the population grows and more hazardous sites are considered for development, advanced planning and strictly enforced zoning and construction practices appear to be the best solutions. In some cases, even these are not adequate to completely eliminate the risk of avalanches, and acceptable risks must be defined, especially in the case of roads, power lines and railroads. These risks can, however, be reduced considerably if appropriate structural controls are employed.

Since avalanche prone areas can be identified, the safest and probably best mitigation procedure is to avoid construction of buildings or any type of structure involving winter use in these areas. Agricultural and recreational activities that take place during the non-avalanche months are relatively safe. Other uses that could be considered are those that do not involve permanent unprotected structures in the avalanche path or those that could be moved or closed down during high avalanche-risk periods.

Methods of avalanche control include structural terrain modification to deflect the sliding snow away from the fixed facilities to be protected, or to actually prevent the avalanche release, and the planned release of small snow slides with explosives before snow accumulation increases their destructive potential to unmanageable proportions.

Explosive techniques have been used for the deliberate release of avalanches for many years. The theory behind this technique is to cause many smaller, controlled avalanches and thus avoid large unpredictable destructive avalanches. Explosive control has been very effective in areas with easy access to avalanche starting zones and ones that can tolerate many small snow slides without causing damage. Detailed information in the form of an inventory on current and past snow-packs and avalanche conditions should be made available for this technique to be safe and effective. However, explosive control may be unfeasible in areas with human habitation.

Engineering structures for the control of snow avalanches are of the following four types:

i) Supporting structures in the starting zone built on the upper part of the avalanche path to prevent avalanches from initiating, or to retard movement before it gains momentum. Massive earth or stone walls and terraces; rigid structures made from wood, steel, aluminium, pre-stressed concrete, or a combination of these materials; and flexible supporting structures called 'snow nets' constructed of steel cables or nylon straps and held up by steel poles, are examples of these.

ii) Deflecting and retarding structures in the run-out zone to keep the moving snow of an avalanche away from structures in critical locations. These are massive structures usually made of earth, rock, or concrete located in or near the avalanche track or run-out zone.

iii) Retarding structures are usually earth mounds or large concrete structures called breakers or tripods. The additional roughness and cross currents set up by these structures usually stop all but large, dry snow avalanches.

iv) Direct protection structures are built immediately adjacent to the object to be protected, or in a few cases, incorporated into the design of the object itself. Avalanche sheds or shelters are merely roofs over roads or railroads that allow avalanches to cross the road/railroad without interrupting or threatening the traffic.

In actual practice it is common for many different types of structures to be used on a single path.

In India, the responsibility of dealing with the different aspects of avalanches rests with the SASE. The BRO, with a vast network of roads in the high altitude snow-bound areas of Leh in Jammu and Kashmir, Sikkim, Arunachal Pradesh, Himachal Pradesh, and Uttarakhand, plays a major role in the operation of snow-avalanche clearance. The BRO strives to keep vital lines of communication open in these snow-bound regions through a slew of measures like the use of modern snow cutting equipment/snow cutters/snow sweepers, conventional dozers, experienced work-force, total station survey instruments, etc. Summer snow clearance is carried out every year on a 50 km stretch across the Zojilla-Pass on the Srinagar-Leh road (the approximate road length that remains closed to traffic from mid-November to mid-May every year) and on a 100 km stretch on the Manali-Leh road across the Rohtang Pass and Baralachla Pass. These two routes have many avalanche prone zones, which are cleared with the utmost caution. In addition, it clears the Khardungla Pass at an altitude of 18,300 ft in the Ladakh region, the Nathula Pass in Sikkim, and numerous other passes in the Great Himalayas.

Moreover the BRO keeps a record of these avalanche zones and appraises the SASE about the fresh occurrence of avalanches.

The SASE and BRO will be responsible for the identification and monitoring of snow avalanches. The SASE will be responsible for the zonation of avalanche prone areas and the forecasting of snow avalanches. Central and state governments in association with the BRO will be responsible for implementing clearance and control strategies against identified snow avalanches.

[Action: The nodal ministry in consultation with the Technical Advisory Committee (TAC) and in collaboration with the SASE, BRO, central government, and state governments.]

1.7.7 Search and Rescue Operations for Snow Avalanches

Search and rescue operations mean either externally organised search and rescue services or the capabilities the affected group itself has for dealing with an avalanche emergency. The latter is known as self-rescue or companion rescue.

Even small avalanches can present a serious threat to life. As per the data available, between 55 and 65 per cent of victims buried in snow avalanches are killed and only 80 per cent of the victims remaining on the surface survive. Research indicates that the percentage of survivors depends on the response times. It varies from 92 per cent for a response times of 15 minutes to only 30 per cent for a response time of more than 35 minutes, as most of the victims die of suffocation. After two hours, most of the victims die of injuries or hypothermia.

In snow avalanches, the survivors among the victims are the first responders. For this reason, self-rescue or companion rescue is vital, more so since organised help takes time to arrive.

The chances of a buried victim being found alive and being rescued increase when victims carry and use standard avalanche equipment. The equipment used in Western countries include avalanche cords, beacons, probes, shovels and other devices like Emergency Position-Indicating Radio Beacons (EPIRB) containing the Global Positioning System (GPS), and mobile phones. A first aid kit and equipment is useful for assisting survivors who may have cuts, broken bones, or other injuries, in addition to hypothermia.

The SASE is presently not involved in carrying out search and rescue operations. Therefore, the district administration will identify organisations/ institutions that can take up programmes to educate the communities living in avalanche prone areas, to prepare them with the latest techniques of self-survival, and to equip them with simple and essential tools. Similarly, the organisations engaged in development and strategic tasks at high altitudes will be educated on initial search and rescue operations and the use of basic equipment necessary for these operations.

Quick Response Teams (QRTs) equipped with the latest rescue equipment like snow clearing tools, probes, communication capability, and medical emergency aids will be organised. These teams will have the capability to be mobilised at very short notice and reach the affected sites within the shortest possible time. The QRTs shall include trained personnel drawn from different arms of the local administration and the National Disaster Response Force (NDRF).

[Action: State Disaster Management Authorities (SDMAs) in collaboration with District Disaster Management Authorities (DDMAs), NDRF.]

1.7.8 Schedule of Activities for Snow Avalanche Control

Activity		2009		2010				2011	
		Sep	Dec	Mar	June	Sep	Dec	Mar	June
1A	Identification of Avalanche Sites and Routes							Implement	
1B	Avalanche Control						Implement		
1C	Research and Development	M*					Implement		

M*: Meetings

1.7.9 Frequency and Intensity of Landslides

The Core Group noted that there are many similarities in the factors leading to the occurrence, as also the different aspects in the management of landslides and avalanches. Also, the geographical spread, frequency and intensity of landslide occurrence is substantially greater than that of avalanches. It was therefore felt that the preceding coverage of the avalanche hazard could be read together with the rest of this document, with the understanding that, largely, the applicability of the recommendations may be taken as equal for both phenomena.

1.8 Recent Government Initiatives

The GoI has taken serious notice of the loss of life and property due to natural calamities. A review of the DM mechanism was carried out by the GoI after the Super Cyclone in Orissa in 1999 and the Kutch Earthquake in Gujarat in 2001. It was then decided to shift the subject of DM from the MoA to MHA, and the actual transfer took place in June 2002. Feeling the need for including hazard mitigation activities in the planning process for sustainable development, the GoI decided to bring about a paradigm shift in policy from relief-centric activities to an emphasis on mitigation, prevention, and preparedness as essential components in the DM process. A strategic roadmap has been drawn up for reducing the country's vulnerability to disasters and this roadmap shall be reviewed every two years. The GoI constituted a number of committees in order to assess the hazards and their risks; to develop early warning systems; to evolve techniques for hazard mitigation; to generate public awareness about the causes, effects, and safety measures to be adopted; and to undertake rescue, relief, and rehabilitation measures. At the national level, the MHA was declared as the nodal ministry for the coordination of relief, response and overall DM, and the GSI was declared as the nodal agency for landslides by the GoI in January 2004. Accordingly, the Action Plan on Landslide Hazard Risk Mitigation was formulated by the MHA, and the GSI started implementing it. Subsequently, the Disaster Management Act, 2005, (DM Act) was enacted on 23 December 2005, and the government set up the NDMA, a statutory body under the chairmanship of the Prime Minister. While the responsibility of coping with natural disasters is essentially that of the state government, the central government plays a supportive role in terms of the supplementation of physical and financial resources. At the state level, almost all state governments have set up state DM authorities under the direct control of the respective chief minister. The chief secretary of the state heads the state level executive committee, which has the overall responsibility for relief operations in the state. The DM 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 government. At the district level, it is the collector/district magistrate/deputy commissioner who exercises coordinating and supervisory powers over all the departments at the district level. For each natural disaster, the declared nodal agencies are responsible for coordinating/ undertaking studies on the processes responsible for hazards and for suggesting precautionary and preventive measures, monitoring the disasters, and developing early warning systems, etc.

1.9 National Disaster Management Policy and Guidelines

The National Disaster Management Authority has drafted the National Disaster Management Policy. The present Landslide Disaster Management Policy envisages a two-tiered system, with pre-disaster measures comprising preparedness, prevention and mitigation, and post-disaster measures comprising emergency response (rescue and relief) and rehabilitation. Unlike earthquakes and floods, landslides are localised events, induced by certain causative factors that are well understood. This hazard can be most effectively controlled or reduced to a minimum if initiatives and activities based on the most modern technological and scientific approaches are implemented through a well-coordinated institutionalised mechanism.

i) The approach to the formulation of the 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.

ii) Identification of the residual agenda in terms of operational, administrative, financial and legal issues.

iii) Identification of the destination, in terms of the goals and objectives to be attained in the short- as well as the long-term, duly prioritised as vital, essential and desirable, with timelines and milestones.

iv) Drawing up a roadmap to the destination, duly indicating the milestones to facilitate easy monitoring.

v) Putting in place an institutional mechanism that oversees the operationalisation of this roadmap.

The NDMA will play a nodal role in initiating the institutional measures for prevention, mitigation and preparedness with a view to generating a holistic, integrated and proactive approach to DM. The institutional arrangements drawn up for the implementation of DM plans assign an important role to the NDMA and the nodal agency (GSI) for coordinating and ensuring their implementation at the national, state, district, and local levels.

The National Executive Committee (NEC), statutorily mandated to assist the NDMA will be responsible for preparing the national plan based on the Policy and Guidelines. The NEC will also be responsible for getting it approved by the NDMA and then operationalising it.

The NDRF will play a pivotal role in specialised response to a threatening disaster situation or disaster. 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 its implementation.

Landslides are a significant natural hazard in the country which not only threaten the environment, human safety, infrastructure, and post-earthquake relief operations, but also have a huge impact on the national economy. This hazard deserves much greater attention in terms of multi-hazard mapping, research, scientific investigations, and effective mitigation and management practices. The Guidelines address all the varied aspects of landslide mitigation and management, adopting a holistic and integrated approach that maximises the networking of voluntary agencies, affected communities and other stakeholders.

1.10 Approach to the Guidelines

Consultations were initiated by the NDMA for the development of Guidelines for the coordinated and systematic management of landslide hazard. The main objective of the Guidelines on Landslides and Snow Avalanches is to generate awareness of the various aspects of the landslide hazard in India and to suggest suitable action to reduce both—the risks and costs associated with this hazard. Accordingly, the Guidelines envision an improved administrative response, bringing together the relevant scientific, engineering, construction, planning, and policy capabilities of the Nation to eliminate losses from landslides and other ground failure hazards.

The long-term mission of these Guidelines is to develop a strategy that encourages the use of scientific information, maps, methodology, and guidance for emergency management, land use planning, development, and implementation of public and private policy to reduce losses from landslides and other ground failure hazards. It is also important for the strategy to define the role of local, state and national level bodies in combating this hazard. In addition, the Guidelines describe the required government policies at the national and state levels, institutional arrangements, financial arrangements, and planning for safe national development.

While a good deal of work has already been done to improve management of landslides and snow avalanches, there are many areas which require special focus and emphasis in the future. Important among these are:

i) Hazard Zonation Mapping.

ii) Geological and Geotechnical Investigation.

iii) Landslide Risk Treatment.

iv) Monitoring and Forecasting of Landslides.

v) Regulation and Enforcement.

vi) Awareness and Preparedness.

vii) Capacity Development.

viii) Response.

ix) Research and Development.

x) Implementation of the Guidelines—Preparation of Landslide Management Plans.

In recognition of the need to pay special attention to these relatively weaker areas, these Guidelines have been structured into chapters that deal with these disciplines in detail and make recommendations with regard to specific action points and timelines.

2 Hazard Zonation Mapping

2.1 Introduction

Disaster mitigation efforts aim to assess the status of the hazard and identify the scientific and technological tools that can help in minimising vulnerability and risk. These mitigation efforts involve the identification of sites vulnerable to hazards, and the intensity of hazards at specific sites by preparing inventory databases, carrying out hazard zonation mapping at different scales, and selecting the sites that require detailed investigation for estimating the hazard potential and risk. This requires the utilisation of modern techniques for mapping, such as the recent developments in remote sensing, communication, and instrumentation technologies.

2.2 Landslide Inventory

The main purpose behind the preparation of a landslide inventory map and database is the documentation of all the known landslide incidences, including stabilised, dormant, reactivated, and the most recent slides. The documentation should include data about the location, date of occurrence, rainfall, and seismicity during the event, the dimension and type of the slide, the volume of material dislodged, the nature and extent of the damages caused/ likely to be caused by further sliding, the type of triggering factor (earthquake, cloudburst, anthropogenic interference, toe erosion by streams or rivers, etc.), the tentative causative factors leading to slope failure, and the limit of the run-out distance. Colour photographs of the landslide on the date of the investigation are an additional asset to the record. Another important parameter is the collection of historical records for each landslide, which would give an idea about the approximate return period of each slide. All this information forms the foundation for LHZ mapping, vulnerability assessment and risk zonation mapping. It is not possible to prepare a complete landslide inventory map and database, since that would involve the field mapping of each and every landslide incidence, which is practically impossible. However, a few countries like Australia, Italy, and New Zealand have prepared landslide inventory maps based on aerial photographs or satellite images.

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

Very high resolution imagery (QuickBird, IKONOS, CARTOSAT-1 and 2) has become the best option now for landslide mapping from satellite images, and the number of operational sensors with such characteristics is growing every year. Other remote sensing approaches of landslide inventory mapping include shaded relief images produced by Light Detection and Ranging (LiDAR), Digital Elevation Model (DEM), and Synthetic Aperture Radar (SAR) interferometry. LiDAR is an active sensor and the signal from this sensor onboard aircraft has the capability of penetrating the tree crown (most of the time) thus providing data about subtle elevation variations of the bare ground. LiDAR data have been used to prepare landslide inventories in the forest areas of hilly regions and to refine the landslide boundaries prepared during field investigations. This data is not only useful for mapping old landslides, but can also improve field survey based investigations 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 pairs. Another advantage of SAR data over optical sensor data is its all-weather monitoring ability. So, a combination of SAR imagery with high resolution optical multispectral imagery is useful for monitoring debris hazards in mountainous areas. However, problems such as foreshortening and layover effects associated with SAR data in mountainous areas have to be addressed carefully.

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

[Action: The Ministry of Mines (MoM)-GSI in collaboration with state Directorates of Geology and Mining (DGMs); WIHG; NIDM; NRSC; State Remote Sensing Centres (SRSCs); BRO.]

2.3 Landslide Hazard Zonation Mapping

The aim of LHZ mapping, which is needed for risk assessment, is to determine the spatial and temporal extent of a landslide hazard. In general the LHZ map divides the landslide prone hilly terrain into different zones according to the relative degree of susceptibility to landslides. This requires the identification of those areas that are, or could be affected by landslides, and the assessment of the probability of such landslides occurring within a specific period of time. Commenting on the time domain of landslide occurrence through zonation mapping is a difficult task. Due to conceptual and operational limitations, landslide hazard zonation is conceptually stated as Landslide Susceptibility Zonation (LSZ). The spatial prediction of landslides 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. LSZ can be formally defined as the division of the land surface into near-homogeneous zones and then ranking these according to the degree of actual or potential hazard due to landslides. The LSZ maps do not directly incorporate the time and magnitude of landslide occurrences. Since LSZ is conceptually accepted as LHZ, it is popularly referred to as LHZ all over India.

A landslide risk zonation map integrates the landslide hazard, vulnerability, and a quantification of the elements at risk. It cannot be developed unless an LHZ map is prepared. An important input for the preparation of an LHZ map is a landslide inventory database, which is not yet available in India. Thus, a landslide hazard assessment broadly involves the preparation of a landslide inventory, a landslide hazard zonation map, followed by a landslide risk zonation map.

An LHZ map requires the division of an area into several zones, indicating the progressive levels of the landslide hazard. The number of zones into which a territory is divided is generally arbitrary. Landslide hazard zonation entails the mapping of all the possible landslides and landslide-induced hazards in the required detail. The hazard maps are designed to limit the information to the users' requirements, and to present it in a form comprehensible to them. Indeed, the users' maps ought to be different from those prepared by, or for specialists. Graded landslide hazard maps are required by, among others, developmental planners as tools for the efficient management of land and its resources. Landslide hazard maps are also essential for the assessment of damage potential, and for the 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 of landslide control, and to determine existing landslide hazards if future landslide occurrence is 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 the slope forming material, slope inclination and aspect, land cover, land use, climate, and hydrology—form the basis for hazard assessment.

An all-inclusive approach to mapping landslides, starting with the assessment of the regional, geological, and geomorphological settings, and then focusing on a detailed scale is recommended. A comprehensive view of the terrain is needed to identify all the 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 the hazard in the future. There may be vital evidence of instability processes outside the area in consideration 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 possible to prepare all the thematic maps covering a huge area solely through field work. This problem can be solved with the help of aerial photographs or satellite imagery, followed by limited field checks.

The preparation of maps showing landslide hazards includes:

i) The generation of thematic maps by compiling and collating the observations on geology, geomorphology, land use, land cover, and the distribution of landslide processes, including the use of local records, interpretation of aerial photographs, and high-resolution imagery.

ii) The collection of relevant information on existing landslide hazards and the analysis of potential landslide hazards, including first time landslides.

iii) The identification of areas that could be affected by landslide hazards in future.

iv) The transformation of process maps into hazard maps identifying the potential for spatial impact and the probability of occurrence of hazards.

2.3.1 Selection of the Scale

Landslide related data and information have to be mapped at a scale that is appropriate for end-use purposes, to enable planners to make decisions about future land use on or close to landslides or landslide-affected areas. At present, few local authorities have access to landslide maps at an appropriate planning-level scale (i.e., approximately 1:10,000). Even where maps of scale 1:50,000 are available, most of them are not aware of their existence. While maps at the scale of 1:50,000 or lower are appropriate for regional studies, they are indicative only and do not provide adequate detail and information for planning purposes at the local level, such as the municipal ward level. At present, very few areas in the country have been mapped even at the scale of 1:50,000 or 1:25,000 that are preferred for regional mapping. It is important that a landslide hazard map be at a scale not markedly different from the data maps used to produce it, or else a misleading picture about the estimation of the hazard might emerge.

Considering the importance of landslide hazard and its mapping, the 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, the scales suggested for preparation of LHZ maps for different purposes are given below.

MAP SCALE FOR LANDSLIDES

- National or Regional (1:1,000,000 to 1:1,00,000)
- At the Macro-Scale (1:25,000 to 1:50,000) — river basins, communication routes, etc.
- At the Meso-Scale (1:5,000 to 1:10,000) — municipalities, localities, etc.
- Mapping at a scale larger than the meso-scale should be carried out for site-specific studies and not for zonation.

Since it is not appropriate to carry out zonation at a scale larger than 1:5,000, it is recommended that zonation studies be carried out at a scale of up to 1:5,000.

Landslide studies are being carried out at a scale of up to 1:5,000 and at even larger scales for detailed studies, depending on the size of the landslide and other requirements. A nation-wide consensus on selection of mapping scales will be reached with a view to introducing rational uniform procedures throughout the country.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the NRSC; BIS; DST; CBRI; CRRI; WIHG; IITs, universities, and other academic institutions.]

2.3.2 Landslide Hazard Zonation Methodologies

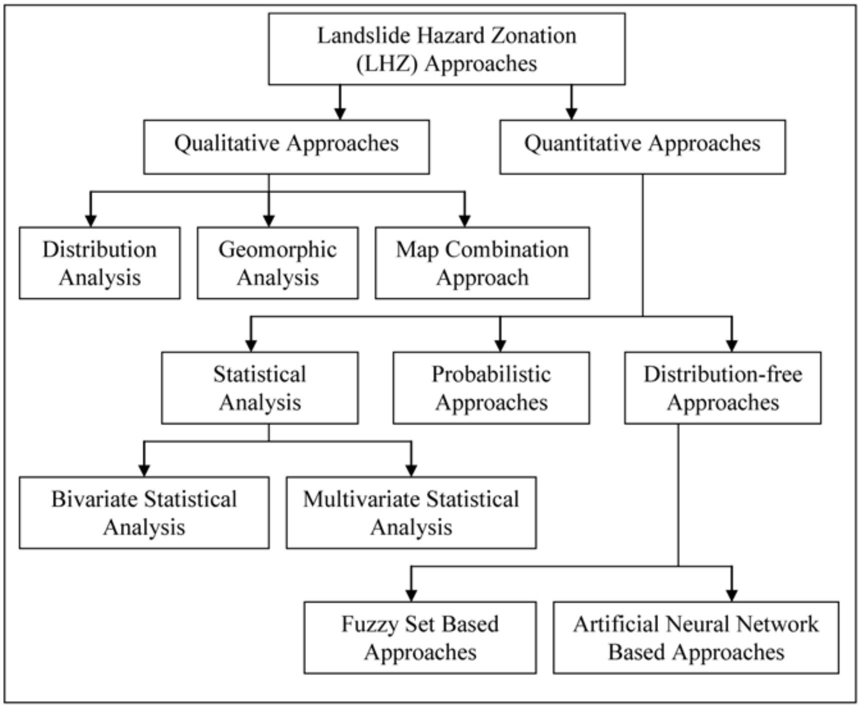
The types of hazard analysis techniques in practice generally include inventory and heuristic methods. The taxonomy of the different types of hazard zonation is given in the figure.

The LHZ maps produced by the various organisations, institutions and individuals in the country are either qualitative or semi-quantitative. In either case, landslide inventory has not been used as the basic input data. These studies have conventionally been carried out on manual interpretations of various thematic maps and their super-imposition. During recent years, the availability of a wide range of high resolution remote sensing data in digital form has been immensely helpful in the preparation, interpretation, and analysis of data in the GIS environment. As a result, it has become possible to prepare different thematic maps corresponding to different causative factors responsible for the initiation of landslides, more accurately and within a shorter period.

2.3.3 Landslide Hazard Zonation Mapping at the Macro Scale

Different institutions and individuals have in the past carried out LHZ mapping at the macro scale following their own methodologies. Keeping in view the requirement of maintaining uniformity, the task force appointed for this purpose constituted by the GoI suggested that in order to carry out LHZ mapping at the macro scale, it is required that a uniform standardised methodology be adopted throughout India. Keeping in view the availability of methodologies and requirements of the work, it is suggested that the BIS guidelines,

Figure 2.1: Taxonomy of Landslide Hazard Zonation



although having some lacunae, may be adopted with certain modifications for carrying out LHZ mapping at the macro scale.

Approaches to landslide hazard mapping being used by different agencies in India are at variance with each other. The ongoing mapping programmes should continue to make the best use of the prevailing state-of-the-art technologies, at the same time making a determined effort to arrive at national level recommendations through a process of workshops and rigorous peer review. This will also hasten the revision of the related BIS Code.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the NRSC; BIS; DST; CBRI; CRRI; WIHG; IITs, universities, and other academic institutions.]

The BIS will critically review and revise its guidelines on LHZ mapping, taking full advantage of the experiences of the GSI and other agencies in this field. This will be achieved within the next two years. Subsequently, these will be revised every five years. Till the existing BIS methodology is revised and codified, the present guidelines should be relied upon.

[Action: The BIS in collaboration with the GSI; IITs, universities, and other academic institutions.]

The GSI, based on its experience of LHZ mapping, has slightly modified the parameters and weighting procedures included in the BIS guidelines. It is carrying out LHZ mapping at the macro scale using this modified methodology.

2.3.4 Landslide Hazard Zonation Mapping at the Meso Scale

The preparation of LHZ maps at the meso scale is yet to be practiced in India. There is neither a code nor a standard methodology for LHZ mapping at the meso scale. There are a few instances when it was attempted by the GSI, in the Nainital area, Mirik, and Gangtok, following the BIS guidelines on macro scale mapping. A review of these maps indicates that the overburden that forms considerable slope forming material in the case of the Himalayas has not been taken into consideration. Therefore, the assessment made of slope-stability status may not be realistic. Keeping this in view and considering the requirement of standardisation of methodology for LHZ mapping at the meso scale, a methodology synthesising both Slope Mass Rating (SMR) techniques and BIS guidelines for LHZ mapping at the macro scale has been suggested to the BIS and is under the process of codification.

For LHZ mapping at the meso scale, two additional factors have been added to the list for macro scale LHZ mapping. The following geo-environmental parameters/causative factors that induce slope instability have been considered for LHZ mapping at the meso scale:

It is recommended that the slope facet map, slope morphometry map and relative relief map be prepared from the Digital Elevation Module (DEM), as these maps can be prepared more accurately and within a shorter time period than with the widely practiced manual method.

Remote-sensing data should be extensively utilised in the preparation of LHZ maps. The main contribution of EO data is to provide morphological, land use, and geological details to assist in determining the process and causes of landslide failures. Satellite data essentially provides information on geomorphology, lineament, broad lithology, land use/land cover, drainage, infrastructure, incidence of landslides based on the terrain, the spatial extent of landslides, and slope details. All this information can be derived at the scale of 1:50,000 or 1:25,000, using different visible IRS data, especially IRS-P6, LISS-IV, and LISS-III. The CARTOSAT-1 data which has stereo capability can be used to generate the DEM for the area and this can be used to derive the slope facet, morphology, and angle. The CARTOSAT-2 data with high resolution (of more than one meter) can be used for understanding the individual landslide morphology. GIS techniques are increasingly used for regional analysis and prediction. Geospatial standards need to evolved for coding the thematic data generated under the LHZ programme.

Table 2.1: Geo-Environmental Parameters for Slope Instability/LHZ

1.	Lithology	7.	Hydrological conditions
2.	Structure	8.	Slope erosion
3.	Slope morphometry	9.	Rainfall
4.	Relative relief	10.	Landslide inventory
5.	Land cover	11.	Seismicity
6.	Land use	12.	Geotechnical properties of the slope material

The NRSC has evolved standards for LHZ mapping in Uttarakhand and Himachal Pradesh and these need to be evaluated for adoption into the national standards. There are various methods for integrating the geospatial data in the GIS environment. All these models need to be evaluated before adopting an appropriate model for the generation of LHZ maps. A customised software in the GIS environment can be developed by integrating the various thematic data.

Landslide susceptibility can also be determined through the deterministic method, which is followed in smaller areas at larger scales (larger than 1:10,000). These methods are process-based and give more detailed results, expressing the hazard in terms of the factor of safety to each mapping unit. The deterministic method can quantitatively represent landslide processes by considering the detailed physical and dynamic in-situ parameters of the slope forming material, and can easily be used to retrieve temporal probability information by modelling different groundwater scenarios caused by different rainfall events (the triggering factor). The deterministic methods depend highly on a large number of detailed site-specific geotechnical and groundwater parameters, otherwise their results are oversimplified. That is why, for medium scale (of 1:25,000 to 1:50,000) analysis in a large area, the use of such deterministic methods may not be feasible. Deterministic models are also difficult to represent as 2D GIS spatial data products because they consider depth wise data variability for the calculation of the factor of safety. That is why, for hazard assessment of bigger areas on a medium scale, empirical methods based on various statistical and mathematical techniques are followed.

In medium scale landslide susceptibility analysis, knowledge-driven/heuristic and data-driven empirical methods are prevalent. The knowledge-driven methods are mostly qualitative (direct), but semi-quantitative (indirect) methods based on heuristics are also followed. The data-driven methods are mostly statistical (bivariate and multivariate), while a few are mathematical (artificial neural network).

The knowledge-driven/heuristic direct approaches to spatial prediction of landslide susceptibility involve detailed geomorphological mapping using uniquely coded polygons, which are evaluated one by one by an expert to assess the type and degree of the hazard. The indirect heuristic approach utilises data integration techniques, including qualitative parameter combination, in which the analyst assigns weight values to a series of terrain parameters and to each class within each parameter. The relative importance of each terrain parameter as a predisposing determining factor of slope instability is quantitatively determined by a pair-wise comparison using the so-called Analytical Hierarchy Process (AHP). In direct heuristic methods, the use of detailed geomorphological factor maps in general has raised the overall accuracy of the susceptibility maps, though the accuracy of such direct qualitative models depends largely on the experience of the expert using the method. In the indirect heuristic methods, however, similar weight values are considered for all locations within the same factor. The addition of such unique weight values tends to 'flatten out' the results of indirect methods. Thus, the main limitations of the knowledge-driven methods are the subjectivity involved both in the direct mapping as well as in the assignment of weights in the indirect method, and the general non-availability of any quantitative technique of model validation.

Among the quantitative methods, the application of bivariate statistics (e.g., the weight of evidence method) in landslide spatial prediction is common and it needs to be weighed in light of the following limitations because of misapplication by many researchers, which include:

i) Generalisation by assuming that landslides happen under the same combination of factors throughout the study area, ignoring the fact that each landslide type has its own set of causal factors, and should be analysed individually.

ii) Lack of suitable expert opinion on different landslide types and processes and on landslides of different periods, which may be inevitable if these methods are solely applied by GIS experts, and not by earth scientists.

Bivariate or multivariate methods may be found to be statistically suitable to predict future landslides at medium scales (of 1:25,000 to 1:50,000), but logical explanations of the results or outputs and exact knowledge about the dependencies of causal parameters with the target are sometimes absent in these types of methods. Since these methods are mostly based on various statistical data treatments focused mainly on the objective elimination or reduction of errors and uncertainty in prediction, the aspects of data quality, reasoned selection of input parameters and inherent fuzziness of some data on geofactors, etc., are frequently overlooked. Multivariate methods, in spite of limitations and pitfalls in application, are used nowadays as among the most feasible quantitative tools for assessing different levels of landslide susceptibility. For example, when a set of independent variables include both good and bad predictors (the latter having no clear physical relationship with mass movement processes), a step-wise regression technique in multivariate statistics is followed with an aim to eliminate statistically non-significant factors, but sometimes the output of these analyses may generate unreliable and meaningless results. In a similar way, the Artificial Neural Network (ANN)—a mathematical technique—is also used for the spatial prediction of landslide hazards. The ANN method is not sensitive to any statistical distribution of data, and can integrate both continuous as well as categorical data sets. The ANN methods are adaptive and generic in nature. They are construed to handle imperfect or incomplete data sets and can capture non-linear and complex interactions among the variables of a system. Since ANN is almost independent of the quality of the input variable; there are chances of getting an unexpected quality in results which can sometimes be highly abstract and misleading. Like other multivariate techniques, in the ANN method also, the internal processes which train the input data set and minimise statistical errors and uncertainties are difficult to follow.

The final landslide map generated should be user friendly and simple enough to be easily comprehended by planners and other users.

The most important inputs required for carrying LHZ mapping at both the macro and meso scale are topographical and geological maps, remote sensing products, and seismological data in the case of seismogenic landslides. Repositories of these are the Survey of India (SoI), GSI, NRSC, and India Meteorological Department (IMD). These agencies will be made an integral part of any effort in this direction so that the work does not suffer for want of these vital inputs, and additional demands can also be serviced.

The IMD and CWC will have to increase the network density of rain gauge stations (with particular reference to major landslide susceptibility locations) and seismic observatories in hilly regions. The SoI should also take up the task of generating topographic/contour maps at the scale of 1:5,000 or 1:10,000 for the landslide affected hilly regions of India. A mechanism will be put in place so that the seismic and rainfall data are communicated to the national landslide hazard database centre on a real-time basis.

[Action: The SoI in collaboration with the IMD; MoM-GSI; NRSC; CWC.]

2.3.5 Seismic Landslide Hazard Zonation (SLHZ)

The principal triggers for landslides are rainfall, earthquake and anthropogenic activities. Since landslides in most areas of the country can co-occur with other hazardous events like earthquakes, high rainfall or cloudbursts, these areas can suffer from more than one hazard at a time. Therefore it is necessary that the risk emanating from all these hazards be considered while assessing the total risk. This makes it necessary to integrate the landslide hazard into the multi-hazard concept. It is observed that the Vulnerability Atlas of India prepared by BMTPC does not include the landslide hazard while assessing the vulnerability of various locales. It is therefore necessary that the landslide hazard is incorporated into such attempts to get the true status of the vulnerability of the area.

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

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

i) Rock avalanches that originate on over-steepened slopes with weak rocks.

ii) Mud flows and rapidly moving wet earth flows that can be initiated by earthquake tremors.

Comprehensive research, development and field-oriented studies on problematic slopes with the help of instruments should be undertaken to improve our understanding of earthquake induced landslides. Multi-hazard and seismic micro-zonation programmes would be enriched by an added focus on the hitherto neglected subject of earthquake-induced landslides in hilly areas and their effects on slope instability.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the IMD; DST; Centre for Disaster Management and Mitigation, Vellore (CDMM); WIHG; IITs, universities, and other academic institutions.]

2.3.6 Prioritisation of Areas for LHZ Mapping

The areas susceptible to landslides are the Himalayan belt, the Naga-Arakan range, the southern margin of the Shillong Plateau, parts of the Western and Eastern Ghats, the Nilgiris, and the Ranchi Plateau, aggregating 0.49 million sq. km. These will have to be mapped for the preparation of LHZ maps at scales of 1:25,000 or 1:50,000.

It is further estimated that the area around 150 towns, 1,500 villages and 6,000 km of road corridors would need to be covered at the macro and meso scale. The work related to LHZ mapping at both the macro and meso scale will be taken up in two phases. In the first phase the areas proposed to be covered are as follows:

At the Macro Scale

i) Keeping in view the immediate civilian and strategic demands, areas along specified road corridors in the Himalayas and the North-Eastern Region (NER).

ii) Critical transportation corridors in the Western Ghats and Nilgiris.

iii) Critical areas with inhabited towns, villages, pilgrim centres, and pilgrim routes in the Western and Eastern Himalayas.

The identified areas for macro scale LHZ mapping are proposed to be completed during the first phase by 2013. The mapping will be done by various institutions, of which a major portion will be done by the GSI. It is proposed that in the second phase, the macro scale LHZ mapping may be taken up district- or basin-wise in the Lesser and Outer Himalayas, the NER and the Nilgiris in the areas not covered in the first phase. Subsequently, the LHZ mapping can be extended to difficult areas in the Higher Himalayas and the interior areas of the NER. Depending upon the availability of resources, the second phase will extend up to 2020 or beyond. The national priorities will be reviewed and mapping methodologies improved as the work progresses.

[Action: SDMAs/state governments in collaboration with the TAC; MoM-GSI; NRSC; DST; BRO; WIHG; Panchayati Raj Institutions (PRIs); CRRI.]

At the Meso Scale

- Areas around urban agglomerations, including those having high growth potential in the Himalayas and the NER.
- Critical transportation corridors in the Western Ghats.
- Critical areas in the Nilgiris having high growth/development potential.
- Areas with a high potential for the siting of hydroelectric power structures in the Himalayas and the NER.

Areas within the above categories deserve more or less the same priority. Within these categories are around 100 towns/pilgrim centres and 1,000 villages in the Western Himalayas along with about 50 towns/pilgrims centres and 50 villages in the NER. The road and rail network in the Himalayas, the NER, the Western Ghats and Nilgiris may add up to 10,000 km. The areas in the Western Himalayas and the NER having high hydroelectric power potential could add up to a total catchment area of around 20,000 sq. km. However, this component can be taken up in the first phase based on demand from hydropower developers or state governments.

The locations requiring studies at the meso scale shall be identified in consultation with state governments and other agencies, prioritised and taken up for LHZ mapping in a phased manner, depending upon the availability of resources. In the second phase of LHZ mapping at the meso scale, the areas not covered during the first phase will be taken up. The work carried out in this phase will extend up to 2020 or beyond, depending on the resources available.

[Action: SDMAs/state governments in collaboration with the TAC; MoM-GSI; NRSC; DST; BRO; WIHG; PRIs; CRRI.]

2.4 Landslide Risk Assessment

A natural hazard is 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 human populations and other things of value to humans, due to landslide occurrence. Hence, landslide risk is a combination of the probability of landslide occurrence and its consequences.

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

i) Risk analysis.

ii) Risk evaluation.

iii) Risk treatment.

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

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 summarised in qualitative terminology.

A complete risk analysis involves the consideration of all landslide hazards for the site (e.g., large, deep seated landsliding, smaller landslides, boulder falls, debris flows) and all the elements at risk. For total risk the risk for each hazard and for each element is summed up. Most of the approaches applied for carrying out Landslide Risk Analysis (LRA) have inherent limitations, but risk analysis has the benefit of encouraging a systematic approach to a problem and promoting greater understanding of the consequences. Risk analysis, assessment, and evaluation can be done through a multidisciplinary approach. In this effort, geological and geotechnical investigations play an important role.

LRA can be done at different stages in the decision-making process, starting from developmental planning on a regional scale to the evaluation of a particular site on a local scale. Landslide risk assessment on the regional scale leads to the demarcation of areas with different levels of threat to elements at risk. This information can be used to establish land use plans, developmental activities and patterns of building regulations. LRA on the regional scale depends on two factors:

i) The spatial probability of landslide occurrence in a region.

ii) The vulnerability of the resources at risk.

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

Vulnerability may be defined as the level of potential damage, or the degree of loss of resources at risk when subjected to a landslide occurrence of a given intensity. Vulnerability assessment involves the understanding of the interaction between a given landslide and the affected resources. Generally, vulnerability to a particular landslide may depend on the volume and velocity of sliding, the distance travelled by the sliding material, the resources at risk, and 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 the case of regional scale vulnerability assessment, the resources at risk and their nature and proximity to landslide hazard zones will be considered. The appropriate vulnerability factor may be assessed systematically based on the opinion of experts, and can be expressed on a scale of 0 to 1.

In the present context of regional risk analysis at regional/macro/meso scales, LRA can be considered as a function of Landslide Potential (LP) and Resource Damage Potential (RDP). The LP and RDP can be characterised by the LHZ map and the resource map (i.e., land use and land cover map) of the area, respectively. The LRA map can be obtained by integrating landslide susceptibility and resource damage potential at the spatial level. This map can be categorised into different risk zones. Risk zonation maps, therefore, essentially include the LHZ map, vulnerability map and elements at risk map. The LHZ map is generated by the integration of thematic maps and landslide incidence maps (Figure 2.1).

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

In risk analysis, the role of remote sensing is important to provide the necessary inputs for identifying the elements at risk. The large coverage of satellite data with its temporal capability is useful for mapping land use/land cover, infrastructure and settlements, which are vital inputs for LRAs.

Risk Evaluation: Risk evaluation is the final step in the risk assessment process. The main objectives of risk evaluation are usually to decide whether to accept or to treat the risks, and to identify priorities. Risk evaluation involves making judgments about the significance and acceptability of the estimated risk. Evaluation may involve a comparison of the risks assessed with other risks or with risk acceptance criteria related to financial aspects, loss of life or other values. Risk evaluation may include the 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 that society is prepared to accept without regard to its management, and tolerable risk that it is willing to live with in the confidence that it is being properly controlled and monitored. This applies to loss of property and life.

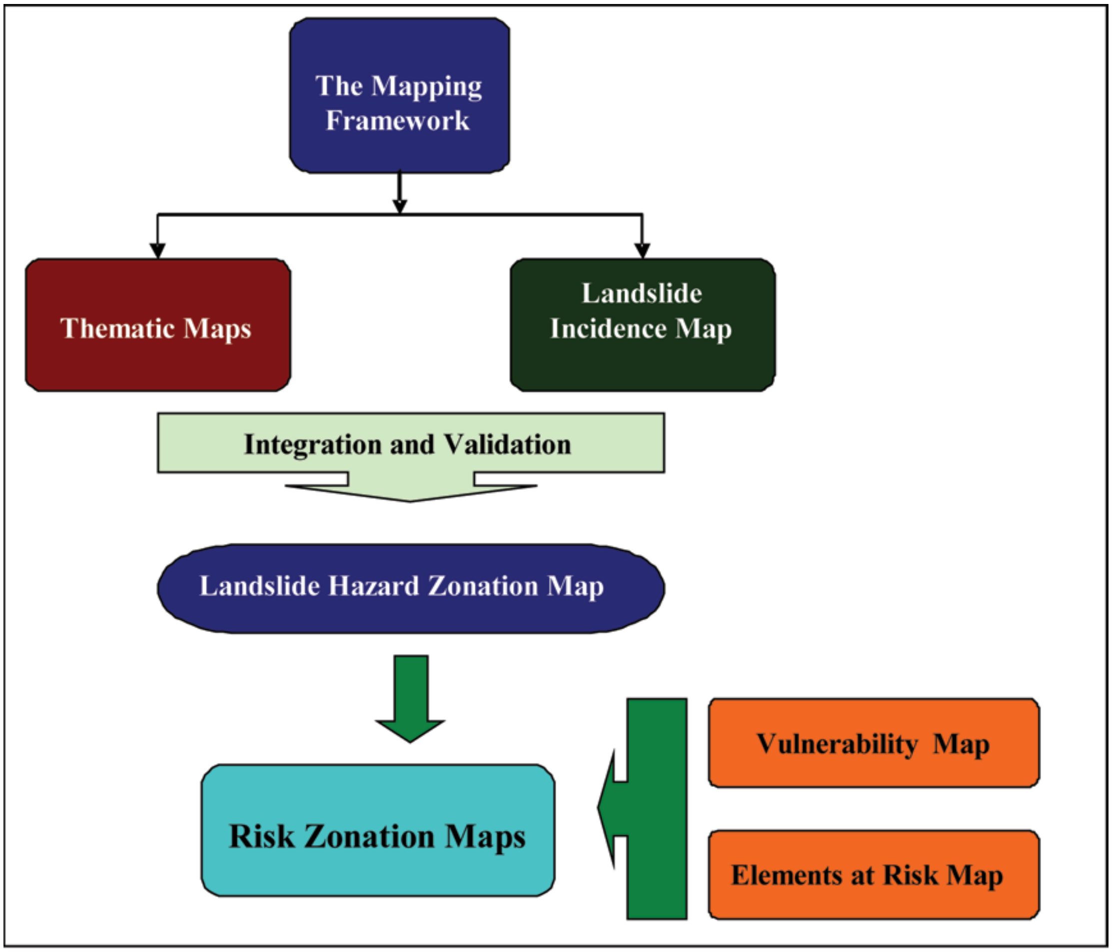
2.4.1 Landslide Risk Zonation

Landslide risk zonation has so far not been attempted in India. Most of the organisations and institutes in our country carry out LHZ mapping which is significantly different from landslide risk zonation. The four data inputs required for risk zonation are environmental factors, triggering factors, historic landslide occurrence and elements at risk.

The historic information on landslide occurrence is by far the most important input as it gives insight into the frequency of the events, the types of landslides, and the volume and extent of damage. Landslide inventory maps, derived from historical archives, field data collection, interviews of the affected community and image interpretation are essential. As all this data is not readily available, quantitative landslide risk assessment becomes very difficult.

Information on triggering factors consists of earthquake and rainfall records, which have to be converted into magnitude-frequency relations of those aspects that actually trigger landslides, e.g., earthquake acceleration or groundwater depth.

Figure 2.2: Landslide Management Maps and Procedures

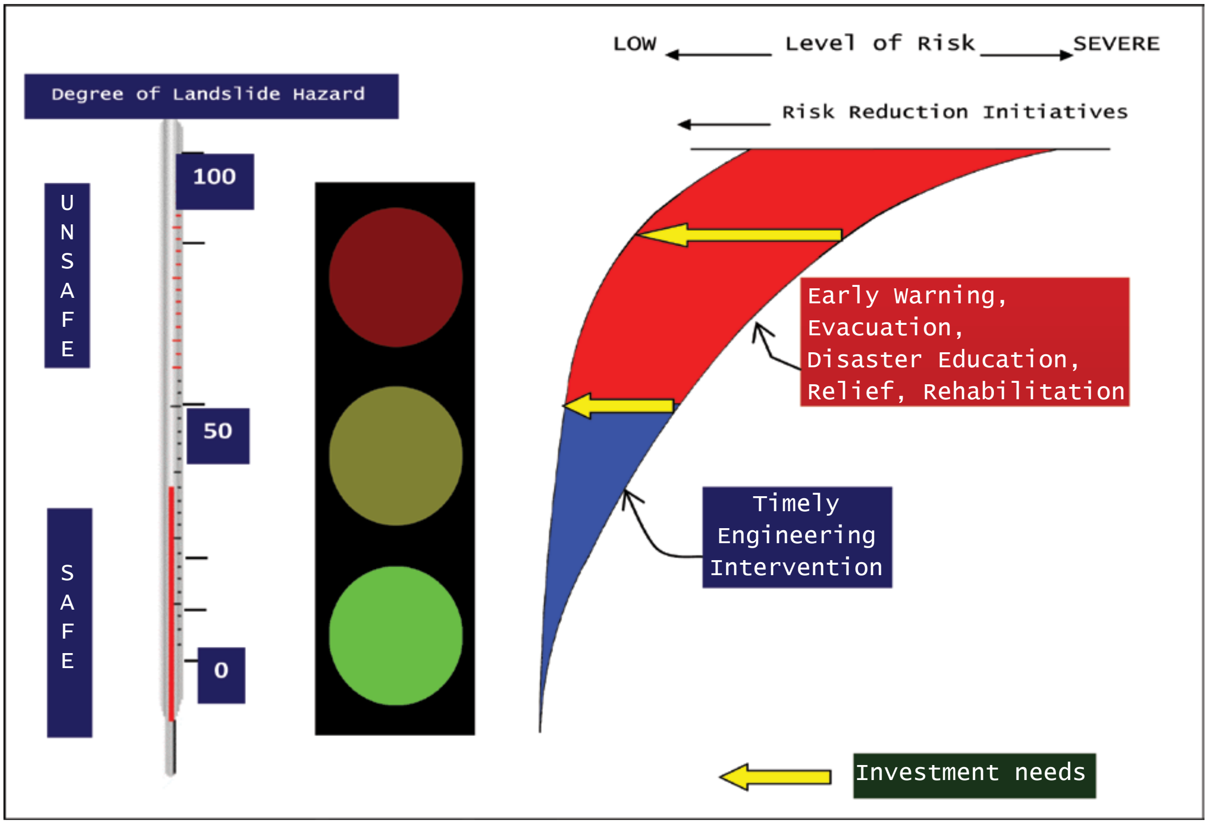


These parameters are very site specific and can only be modelled properly using deterministic models, which require considerable input on the geotechnical characterisation of the terrain (soil depth, cohesion, friction angle, and permeability). Temporal probability is determined either by correlating the data on landslide occurrence with that of triggering factors, or through dynamic modelling. On the other hand, the spatial probability can be obtained either through dynamic modelling or by analysing the relation between the locations of past landslide events with a set of environmental factors.

Investment decisions are taken depending upon the level of risk and the corresponding risk reduction initiatives (Figure 2.3). Considering the importance of landslide risk zonation mapping, a proposal has been recently drawn up by the BIS to frame guidelines for landslide risk zonation mapping, and the GSI along with some members of the sectional committee on the Hill Development Council of the BIS have been requested to prepare the draft guidelines.

[Action: The BIS in collaboration with the MoM-GSI.]

Figure 2.3: Guidelines For Investment In Landslide Management



2.5 Schedule of Activities for LHZ Mapping

Activity		2009 Sep	2009 Dec	2010 Mar	2010 Jun	2010 Sep	2010 Dec	2011 Dec	2013 Dec	2014 Mar	2014 Jun	2014 Sep
2A	Developing and Updating the Landslide Inventory							Implement				
2B	Standardisation of LHZ Methodology by the BIS			Implement								
2C	Identification and Prioritisation of Areas	M*	M*	M*					Implement			
2D	Identification of Institutions/Organisations	M*						Implement				
2E	LHZ Mapping (Macro and Meso Scale) (First Phase)						Implement					
2F	LHZ Mapping (Macro and Meso Scale) (Second Phase)										Implement	

M*: Meetings

3 Geological and Geotechnical Investigations

3.1 Introduction

A landslide is one natural disaster that can be predicted and managed if its development is monitored and a detailed analysis carried out to determine the factors responsible for its activation. For understanding landslides, we need to know the plausible slide boundaries, mode of failure, shear strength variation along slide boundaries and spatial variation of pore water suction or pore water pressure, possible causes of slope instability, and the factors responsible for triggering the movement. This can be achieved through detailed scientific investigation of a slope or landslide in a multi-disciplinary domain, where engineering geologists and geotechnical engineers play an important and highly inter-related role. Sound geotechnical investigation followed by sound data analysis is fundamental to the entire range of tasks from slope characterisation to slope engineering. Good slope geotechnology is not possible without essential hydro-geological, seismo-tectonic and anthropogenic inputs for slope analysis. Slope geotechnology therefore has an expansive and specialised scope. A landslide investigation team will naturally be regarded as incomplete without an experienced engineering geologist and an equally experienced geotechnical engineer. The methodology to be followed for carrying out detailed analysis depends on the geological, geomorphological and climatic conditions at the site affected by the landslide. As the geo-environmental conditions, causative factors and triggering agents responsible for inducing slope instability vary from site to site, it is not possible to lay firm guidelines for landslide investigation and treatment. However, broad guidelines can be formulated that define the minimum investigation to be carried out at a site to obtain data required for a fairly realistic analysis.

3.2 Geological Investigations

Landslide investigation and mitigation requires mapping of landslide hazards and creation of a knowledge database with the fullest appreciation of the scale and degree of reliability of information gathered. For estimating the destructive potential of a landslide, one needs to know its expanse/spatial extent and also the time scale of landslide activity, mechanism, run-out distance, elements at risk en route, and its recurrence history. For landslide prediction one needs to find out when and where it will occur, and how far and how fast it will move. For the design of control measures for landslide management, one needs to know the landslide type (its classification), the different possible modes of failure, the location of the landslide boundaries, the operating shear strength characteristics of the boundary shears, and how the pore pressures will vary on the landslide boundaries with time.

The term geological investigation covers both surface and sub-surface explorations to be carried out to determine the extent of the landslide in all dimensions, nature and disposition of geological formations, structures in the area, physical and geotechnical characteristics of the material involved in the landslide process, factors responsible for activating the landslide, and the severity of the hazard. The extent of geological investigation should be planned keeping the above factors in view.

The geological investigation of landslides can be divided into different stages and these investigations proceed sequentially from one stage to the other with some overlap. The different stages of investigation are:

i) Preliminary geological investigation.

ii) Detailed geological investigation.

iii) Geotechnical investigation.

iv) Treatment implementation stage investigation.

v) Post-implementation stage investigation/ monitoring.

3.2.1 Preliminary Stage Geological Investigation

The preliminary stage investigation involves collection of available information, desk study as well as initial reconnoitering traverses in the field to collect regional as well as local information and data.

Extensive use of remote sensing products including high resolution CARTOSAT-1 and 2 should be made to demarcate the area likely to be affected by further landsliding, understand the dynamic behaviour of the landslide, delineate the modified slope conditions by preparing DEM, etc.

Field Surveys and Investigations: The first task to be taken up in the field after finishing the desk work is to verify and validate the data collected and to plan the further course of work. Preliminary field surveys in the landslide area should be carried out with a view to assess:

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

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

iii) The orientation, spacing and openings of all the cracks.

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

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

vi) The locations of seepage, springs, natural drainage courses, and slushy ground.

vii) The movement of different parts of the landslide during the investigation period.

viii) The location of human habitation, communication corridors and other civil engineering structures.

ix) The weathering profile, nature of the slope forming material, study of overburden and rock contact, nature of drainage, springs, scarps, etc.

x) The demarcation of the 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 factor during landslide treatment.

3.2.2 Detailed Geological Investigations

The detailed geological investigations, both surface as well as sub-surface, which are required to be carried out at this stage shall be in addition to the studies already carried out. The extent of the area to be covered by geological mapping and the extent of the sub-surface geological investigations required are to be guided by the geological complexity of the site. Detailed investigations at this stage should be planned and executed in close cooperation and interaction between engineering geologists and geotechnical engineers.

After the completion of surface geological mapping, the behaviour of surface material and other in-depth features need to be explored. The sub-surface explorations required for this should aim to establish:

i) The depth to bedrock or thickness of the overburden, and weathering limit. The lithological characters of various rock units and their significance. The limits of slump joints and glide cracks, if any.

ii) The nature, spacing, and continuity of prominent joints, slip surface, minor and major shear zones, etc.

iii) The depth of the groundwater table.

iv) The permeability of strata.

v) If possible, the depth and disposition of the plane along which the failure has taken place.

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

Ground Penetrating Radar (GPR) can initially be employed in such surveys for evaluating the depth and nature of bedrock and ground water conditions as well. GPR surveys provide quick results. Other geophysical surveys like seismic (reflection) and resistivity surveys can follow the initial GPR Surveys.

The preliminary and detailed geological investigation of landslides constitutes the foundation on which sound geotechnical investigation must be built. Detailed guidelines will be developed for ensuring systematic geological investigation and mapping.

[Action: The BIS in collaboration with the MoM-GSI; DST; IITs, universities and other academic institutions.]

3.3 Geotechnical Investigations

The geotechnical investigation of a landslide includes mapping of the problematic slope at the appropriate scale, scientific understanding of its kinetics, elucidation of the landslide boundaries, determination of representative shear strength parameters and pore pressure variations on the landslide boundaries, and finally, the evaluation of the safety factor. It is important to understand the distinction between first time and reactivated slides. The boundaries of first time slides are not known in advance while reactivated slides generally have predefined boundaries which are sometimes modified due to further sliding.

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

A good geotechnical slope investigation is usually driven by the leads thrown up by a large scale geomorphological map of the area. It should always begin with a careful study of the field evidence by a trained landslide investigator. For instance, the study of the landslide boundaries, exposed lithologies, discontinuities, shear zones, water springs, aquifers, slope subsidence, heave, cracks, behaviour of buildings, etc., can provide a sense of direction to the nature and quantum of the ensuing detailed sub-slope geotechnical investigation.

Guidelines will be developed to usher in the culture of sound geotechnical investigation suited to different geological settings and anthropogenic situations. Systematic scientific geotechnical investigation will become an essential component of any important landslide management initiative. The training of professionals, writing of field manuals, and introduction of appropriate tools and techniques for investigation will be accorded priority. The guidelines will emphasise the importance of fashioning geotechnical investigations on hard field evidence and the previous history of the slope. The importance of arriving at critical slope profiles, elucidation of the possible modes of failure, and purpose oriented field and laboratory testing and instrumentation for the validation of design assumptions will be highlighted to improve the health of current engineering practices. Engineering geologists and geotechnical engineers will be jointly trained to raise the standards of investigation and data analysis. All major landslide remediation works will be linked intimately with the findings of geotechnical reports.

[Action: The BIS in collaboration with the NIDM; DST; CDMM; MoM-GSI; CBRI; CRRI; WIHG; CoA; IITs, universities and other academic institutions.]

No matter how thorough the geotechnical investigation, uncertainties involved would always call for making design assumptions based on engineering judgment. Every geotechnical report must clearly state the assumptions made and the basis thereof. 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 are modulated as the investigations advance and new information emerges.

A geotechnical investigation often tends to become expensive and even wasteful if it does not relate closely to the slope information required and specific questions that need answers. For instance, in many cases an extensive programme of drilling is prescribed to locate the 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. Considerable savings of both time and money could be achieved if one were to succeed in locating traces of basal boundary shears in, for example, road side cutting.

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

The private sector can play a major role in improving the national capacity for quality geotechnical investigations and will be encouraged to do so through professional bodies like the Indian Geotechnical Society (IGS).

[Action: The DST in collaboration with the TAC; IGS; engineering project authorities.]

The deterministic analysis of a slope can be either two dimensional or three dimensional. A two dimensional analysis underestimates the factor of safety and is therefore done either where side resistance to landsliding is negligible or uncertainties are large and quick, and conservative designs are required for further planning. For important projects where high quality investigation is mandatory, a three dimensional analysis 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 for and merit of a probabilistic analysis of the slope must also be considered.

The deterministic analysis could either be in terms of effective stress or in terms of total stress.

There is a need to develop guidelines for scientific analysis of slopes and landslides in terms of total and effective stress, as the ground situation demands. Every report will specifically point out the assumptions made and the limitations of the data used in slope analysis and design. The guidelines must clearly focus on hitherto neglected but vital aspects such as techniques of undisturbed sampling of shear zones and boundary shears and the evaluation of shear strength parameters using an appropriate stress path.

[Action: The BIS in collaboration with the CDMM; Council of Architecture (CoA); IITs, universities and other academic institutions.]

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

For the ultimate objective of an investigation to be achieved, the coupling between the study of landslides through remote sensing such as satellite imagery 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.

The geotechnical investigation of landslides, which in their wetter manifestations take on the character of a flow, calls for a different kind of investigation. In most such cases the laws of fluid mechanics tend to take over from the laws of soil mechanics. The major difference lies in the short-lived nature of slip surfaces and the kinetics of mass movement. The classical methods of slope analysis or back analysis may no longer remain valid.

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

Geotechnical investigations for such a set of problems fall in a specialised domain and must be critically examined by investigators.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the IMD; DST; CDMM; IITs, universities and other academic institutions.]

3.3.1 Culture of the Observational Method of Design and Construction

The phenomena involved in slope engineering are indeed complex and the observational method is the best approach to deal with issues of slope stability. Recourse to the observational method provides a powerful defence against the uncertainties and complexities of slope processes as they unfold, as the observations pro-actively aid the modification of the design as one proceeds.

In this context the current practices in the country need to be reformed as they do not even insist on adequate and timely slope investigation before the design gets finalised and slopes get treated. Very often, the initial neglect of a slope failure or landslide eventually grows into a major problem calling for urgent attention. The problem becomes too dangerous to be left untreated and tight project schedules usually do not allow the time normally required for systematic investigation and slope treatment. Professionals usually succumb to such pressures and evolve a scheme of slope treatment without even basic information on the landslide boundaries, various possible modes of failure, causative factors, operating shear strength parameters and spatial piezometric variations. This amounts to treatment of slopes without diagnosing the causes responsible for inducing instability.

There is an urgent need to sensitise professionals on how to handle slope failures and their remediation, as well as landslide emergencies and uncertainties by making efficient use of the observational method and the power of engineering judgment. The culture of the observational method of design and construction will be promoted with training on the development of contingency plans.

[Action: The NIDM in collaboration with the CDMM; CoA; IITs, universities and other academic institutions.]

The present tendering process normally does not allow designs to be altered as uncertainties melt and assumptions change with more field data becoming available. Unless financial managers allow the flexibility necessary to revise geotechnical investigation and design as the work proceeds, the culture of the observational method of design and construction will continue to elude us. No professional will be ready to speak about the error of engineering judgment and its ensuing negative impact on the health of the project unless the system appreciates these limitations and allows for more freedom.

Despite the best geotechnical investigation, several questions always remain unanswered. It should, therefore, be normal practice to check the validity of design assumptions and monitor slope behaviour concurrently with the investigation and implementation of slope stability treatment. Such an approach will help in boosting confidence in the designs and dealing with uncertainties, and getting a premonition of any impending slope failure.

Uncertainties on the account of inherently aleatory, epistemic uncertainties due to instrumentation and human limitations during landslide investigations are also understandable and can be minimised through the use of appropriate technologies. What is unacceptable however is the remediation and management of landslides, ignoring the need for scientific investigation and reliable diagnosis.

3.4 Earthquake-Induced Landslides

A clear distinction is essential between earthquake-triggered and earthquake-induced landslides. Earthquake events are usually known to serve as a trigger for pre-existing but dormant landslides, causing earthquake-triggered landslides. Strong tremors, however, also hold the potential for inducing new slides, especially by rupture along unfavourable discontinuities and shear zones. Such slides are designated as earthquake-induced landslides. It should also be recognised that the commonest class of the best-understood problems are flow slides due to liquefaction. Other possibilities are:

i) Reactivation of old, dormant or previously inactive landslides.

ii) Acceleration of known landslides.

iii) Triggering of rock falls.

iv) Development of fresh, first time landslides.

v) Onset of slumping and breaking up of the ground.

To understand the entire process, prior understanding is required of:

i) Topographic and hydrological controls.

ii) Geological and geotechnical controls.

iii) Seismological controls.

iv) Anthropogenic controls.

Ground surface acceleration alone is a poor measure of the effect of shaking on slope stability. The intensity is even more so. Indicators such as ground velocity, experience of past earthquake events, and the duration of shaking are considered to be better indicators of landslide susceptibility under seismic conditions. The critical acceleration of a slope is also an important factor in gauging the 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 post-seismic rather than co-seismic phenomena needs to be investigated. While earthquakes provide the trigger, the development of a landslide is seldom sudden, and it usually occurs after the earthquake and its after-shocks.

3.5 Pilot Project for the Investigation of Major Landslides

A few major landslides will be identified for creating pace setter practical examples of systematic and scientific geotechnical investigations which will include detailed geological and geotechnical mapping at the scale of 1:500 or 1:1,000. The identification and investigation will be done by assigning tasks to organisations or institutions identified as having multi-disciplinary expertise and experience. These organisations will not only aid in the development of a systematic method but also assist in the development of standard codes, and planning for capacity building for geological and geotechnical investigations.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; BRO; CBRI; CRRI; DST; CDMM; WIHG; BIS; IITs, universities and other academic institutions.]

On a long-term basis, a comprehensive programme to investigate disruptive landslides is needed. This will involve the identification of all the devastating landslides in the country and the initiation of site specific studies for some of them (at least 10 in number) in a standardised format. This will give impetus to complete site-specific studies of all high-risk landslides and the formulation of realistic treatment plans.

3.6 Schedule of Activities for Geological and Geotechnical Investigations

Activity		2009		2010				2011	
		Sep	Dec	Mar	June	Sep	Dec	Mar	June
3A	Identification of Landslides and Prioritisation	M*	M*					Implement	
3B	Identification of Institutions/Organisations	M*					Implement		
3C	Initiation of Mission Mode Research Projects in Priority Areas and Introduction of Scientific Landslide Investigation	M*	M*				Implement		
3D	Detailed Landslide Investigation					Implement			
3E	Development of Guidelines/Codes to Introduce Sound Geotechnical Investigation Practices in Landslide Management	M*		Implement					
3F	Development of Guidelines/Codes on the Observational Method of Design and Construction in Landslide Prone Areas	M*		Implement					
3G	Development of Guidelines/Codes for the Siting of Human Settlements and Infrastructure in Landslide Prone Areas	M*		Implement					

M*: Meetings

4 Landslide Risk Treatment

4.1 Introduction

Risk treatment is the ultimate aim of risk management which helps in mitigating the effects of a 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 available options need to be considered so that the most cost-effective solutions, consistent with the overall needs, can be identified. A combination of options or alternatives may be appropriate, particularly where a relatively large reduction in risk can be achieved at a relatively small cost. A treatment plan for each option may be used to delineate how the option will be implemented. The plan also needs to identify the responsibilities of each stakeholder during and after implementation, the extent of work required, cost estimates, the implementation programme, performance evaluation of the measures, and the expected outcome. Monitoring of the treatment plan and the risks involved is needed to ensure that the plan is effective and changes in circumstances do not alter the risks. It is essential to reconsider all the stages of 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 through five approaches, used individually or in combination, to reduce or eliminate losses.

Restricting Development in Landslide-Prone Areas: Land use planning is one of the most effective and economical ways of reducing losses due to landslides by avoiding the hazard and minimising the risk. This is accomplished by removing or converting existing developments, or discouraging or regulating new development in unstable areas. However, in many states of India, there are no widely accepted procedures or regulations with regard to 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 uniform code to ensure standardisation in India.

Protecting Existing Developments: The improvement of surface water and groundwater drainage is the most widely used and generally the most successful slope-stabilisation method. The stability of a slope can be increased by removing all or part of a landslide mass, or by adding earth buttresses at the toe of potential slope failures. Restraining walls, piles, caissons, rock anchors, or soil nailing, are commonly used to prevent or control slope movement. In most cases, a combination of these measures is used.

Monitoring and Warning Systems: Monitoring and warning systems are utilised to protect lives and property, not to prevent landslides. However, these systems often provide warning of slope movement in time to allow the construction of physical measures that can reduce the immediate or long-term hazard. Site-specific monitoring techniques include field observations with various ground motion measuring instruments such as trip wires, radar, laser beams, and vibration meters, etc. 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 an 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 the victims.

4.2 Landslide Remediation Practices

Already distressed slopes require immediate landslide remediation intervention. Landslides can be triggered by various factors such as excessive rainfall, earthquakes and human interference. Besides shallow erosion or reduction of shear strength caused by seasonal rainfall, anthropogenic activities such as the adding of excessive weight above the slope, and excavation on the slope or at the foot of the slope contribute towards landslide occurrence on a large scale. Different factors may combine to generate instability, which in many cases may occur after the lapse of some time. Mostly it may not be possible to reconstruct the evolution of the landslide process except in cases where the site is well-instrumented. It may also be nearly impossible to stabilise a failed slope until the morphology of the slide is understood, the causes responsible for inducing instability determined, and the resultant risk assessed, analysed and addressed adequately. This can be achieved through detailed geological and geotechnical investigation. Therefore, it is necessary to conduct detailed investigations for the planning of remediation measures, as the extent and nature of the stabilisation to be implemented will depend mainly on the results of detailed investigation carried out at the affected site.

Depending upon the nature and purpose of the work, degree of risk, and cost effectiveness of the remediation measures, the slope stabilisation methods generally include works involving modification of the natural landslide conditions such as topography, geology, ground water, and other conditions that indirectly control portions of the entire landslide movement. These include drainage improvement works, soil/debris removal works, buttress filling works and river training works.

Drainage works include both—surface and sub-surface drainage works. Surface drainage improvement works are implemented to minimise the infiltration of rain water that builds up pore pressure. These include two major components, i.e., drainage collection works and drainage channel works. Surface drainage measures, comprising lined catchwater drains above the crown of a slide, lined contour drains at different levels of the slide mass, and lined cascading chute drains, are provided to intercept and divert rain water from the upslope and slide surface to reduce infiltration and the development of pore water pressure substantially. The purpose of sub-surface drainage improvement works is to remove the ground water from within the landslide mass. These include shallow and deep sub-surface drainage control works depending upon the nature of the slide. Sub-surface drainage works may include intercept under drains, interceptor trench drains, horizontal gravity drains, drainage wells and drainage tunnels.

Soil/debris removal works are treatment measures that yield the most reliable results and generally can be expected to be very effective in the case of small to medium sized landslides. The soil/debris removal or offloading of the slide mass is generally undertaken from the crown portion downwards and in this process, benches or berms are created at appropriate intervals depending on the properties of the material.

In the case of fill works, a buttress fill is placed at the lower portions of the landslide in order to provide a counterweight to the landslide mass. It is most effective if the soil generated by the soil removal works is used.

Scouring and erosion of the channel bank or toe of a slope reduces the stability of the slope and often tends to induce landslide activity. In such cases, check dams, groundsils and bank protection can be constructed to prevent further erosion. If required, deflection spurs are provided on the upstream of the affected slope.

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

Once treatment measures have been implemented on a landslide, the treated slopes are required to be protected against the effects of atmospheric elements like rain, snowfall, etc. This requires minimising the direct exposure of a treated slope to natural atmospheric processes, which can be achieved by providing a protective covering to the treated slope. The covering commonly provided to slopes includes afforestation, which not only provides effective covering to slopes but also improves the shear strength of the material through root networks. Vegetation can also be used directly to help stabilise slopes using biotechnical methods, commonly referred to as slope bio-engineering. These methods, originally pioneered in Europe, involve aggressive planting of carefully selected plants and the construction of engineered structures using live materials that will increase in strength over 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.

4.2.1 Landmass Improvement Techniques

The stabilisation of hill slopes is also achieved by improving the mechanical characteristics of potentially unstable ground by means of two different approaches:

i) The insertion of reinforcement elements into the ground.

ii) The improvement of the mechanical characteristics of the ground volume affected by landslides through chemical, thermal or mechanical treatment.

Reinforcement technology has found wide application in measures for slope protection. This can be achieved by the installation 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 chemical grouting, depending upon the properties of the material.

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

Identified hazardous landslides will be prioritised and treatment measures implemented after detailed investigations. The implementation measures will be supervised by trained representatives of investigating teams and monitored for their efficacy.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; BRO; CBRI; CRRI; DST; CDMM; IITs, universities and other academic institutions.]

4.3 Strengthening of Buildings and Safety of Critical Facilities from Slides

One of the major concerns of disaster managers in India is the prevention of deaths due to the collapse of buildings due to landslides, earthquakes, or cyclones. We deal with a huge existing housing stock of questionable safety and every year we add substantially to that housing stock a mix of engineered and non-engineered constructions, on already overstressed slopes. We also have a growing stock of formal and informal housing, multi-storied buildings, heritage buildings, bridges, flyovers, and other infrastructure vulnerable to landslides.

Non-engineered buildings may collapse due to a large number of causative factors acting individually or in league with one another. The super-structure of a building may fail because of the inadequacy of the design, lack of ductility of structural members and connections, absence of shear walls in framed buildings, neglect of soil structure interaction effects, use of inappropriate design assumptions, incorrect choice of construction materials, and faulty construction.

Even structurally safe buildings may collapse if their foundations sink, tilt, uplift, and move down a slope. Failure of the foundation may also be caused by the liquefaction of the underlying soil deposit, inadequate foundation, subsidence due to a collapse of the soil-structure of filled-up areas, inappropriate choice of foundation, and shoddy foundation construction.

Strengthening of a building (retrofitting) means upgrading it to the required design level to prevent its collapse, while some damage to its super-structure and foundation may still occur. The upgrading aims at improving the design of buildings to bring them in line with the provisions in the prevailing BIS design codes.

The vulnerability of building foundations to landslides is an issue on which there is a lack of sensitivity, absence of initiative and subdued professional appreciation. No amount of retrofitting of a superstructure can render a building safe if its foundations or the slope on which it rests are vulnerable.

The safety of critical facilities like hospitals, police stations, schools, etc., against landslides must be ensured under the worst combination of forces, including an earthquake tremor. All new critical facilities should be safeguarded against multiple hazards, including landslides. Mainstreaming disaster risk reduction in this way would ensure that all the critical facilities serve a disaster reduction function.

Government buildings, hospitals, schools, archaeological monuments, nuclear structures, dams, highways, bridges, and commercial establishments are critical to the national economy and compete for priority depending on their relative importance in a given situation. Equal attention must also be paid to the safety of other infrastructure such as water pipelines, sewerage networks, oil pipelines, electrical supply lines, flyovers, underpasses, metro/rail networks, etc.

Their disruption could make disaster management a difficult task.

4.4 Mitigation Measures for Landslide Dams

When landslides occur on the slope of a river valley, the sliding mass may reach the bottom of the valley and cause partial or complete blockage of the river channel. This accumulated mass of landslide debris resulting in blockage of a river is commonly termed as a landslide dam. The most common type of mass movements that result in the formation of landslide dams are rock and debris avalanches, rock and soil slumps and slides, and mud, debris, and earth flows.

The formation of a landslide dam is a complex geodynamic process involving interaction between the river system and the landslide process. The geomorphic factors involved in the landslide damming process are the watershed area, landslide velocity, nature of the valley slopes, and width of the valley.

Landslide dams, in general, have been observed to form in tectonically active areas where the valleys are narrow, its slopes are steep, and geomorphological processes are active. The sites vulnerable to the formation of landslide dams are characterised by narrow river valleys with steep slopes requiring a relatively less volume of debris mass for blockage to occur, and the occurrence of landslides that cause the movement of huge volumes of dislodged mass at moderate to high speed within a short span of time. The formation of landslide dams the world over is more frequent in tectonically active areas of crustal shortening where the rapid uplift of land has provoked the formation of both large scale slope movements, and deeply incised and narrow valleys. In the case of India, the Himalayan region and NER which are tectonically active and have a concentration of tectonic stresses, great fault systems and frequent earthquakes, are areas where landslide dams have been formed at numerous locales in the past. Compared to the Himalayas and the NER, the peninsular shield region is tectonically stable and the potential of landslide dam occurrence is very low.

Landslide dams generally occur in areas receiving high and/or excessive rainfall, rapid snowmelt and experience moderate to high magnitude earthquakes.

The immediate impact of landslide dams is the pondage of water resulting in the submergence of large upstream areas. The sudden collapse of the dam body can result in disastrous flash floods in the lower reaches of the river valley. These may cause a catastrophic loss of human lives, settlements, and infrastructural development that are located nearby in both upstream and downstream areas of the landslide dam. The severity of the disaster depends on the height of the damming structure and the quantity of water impounded.

If the landslide dam does not fail immediately or soon after its formation and tends to get stabilised, then the deposition of the water-borne sediment load and debris mass from the valley sides into the dammed lake basin results in river bed aggradation which may lead to the formation of deltas or even changing of the river course. In general, the formation and breaching of landslide dams takes place within a short span of time; hence its hazard impact is disastrous both in upstream and downstream areas. The hazard potential is maximum when it is not possible to provide an outlet for the controlled release of water. In the present scenario, it is difficult to identify each and every site along river courses that has a high probability of landslide dam formation. Studies would have to be carried out to identify probable sites, especially in those areas which have a history of landslide dam formation, and measures for the prevention thereof would have to be taken.

In the case of landslide dam formation, the aim of the mitigation effort is to minimise losses in case a breach occurs. Considering the immediate danger of the dam breaching immediately after its formation, both short-term and long-term remedial measures are to be contemplated to save life and property. The immediate measures will include:

i) In case a report of landslide dam formation after heavy rainfall/strong earthquake/ rapid snowmelt in hilly areas is received, the vulnerable areas will be reconnoitred immediately, if required by helicopter, to see whether more such landslide dams have been formed or not. For inaccessible areas and trans-boundary rivers, the vulnerable areas will be monitored by the NRSC through satellites on a real-time basis. If such an occurrence is noticed, the situation will be monitored continuously and information about the developments will be communicated immediately to the designated authorities such as the MHA, NDMA and the concerned SDMAs.

   [Action: The CWC in collaboration with the NRSC; MHA; SDMAs; BRO; IMD.]

ii) The SDMAs will establish and activate the warning and communications systems immediately so that information reaches the last post on a real-time basis and proper action is taken by all players involved in an effort to save lives and minimise the loss to property and infrastructural elements.

   [Action: The SDMAs in collaboration with the BRO.]

iii) Satellite data will be consulted for understanding the nature of damming. The pre- and post-occurrence satellite data would be useful in understanding the cause of impounding, extent and the areas affected. This becomes an important tool in inaccessible areas. Periodic monitoring will be done using satellite data to understand the breaching, etc.

iv) A team of experts will reach the affected site as soon as possible to monitor the situation, assess the stability status of the structure and landslide activity, and changes in water level in the impounded lake. The teams will implement the required initial measures to the extent possible immediately. One of the immediate tasks will be to establish a communications link between the site and the designated authorities. This would help the authorities to take appropriate decisions related to preparedness and response whenever required. If, however, overflow from the dammed lake has already begun, or the dammed body is collapsing, then urgent preventive measures to prevent losses in downstream areas due to the bursting of the landslide dam will have to be adopted on an emergency basis. The status of landslide activity will be evaluated and if possible, attempts will be made to release the impounded water in a controlled way by creating an outlet. However, the stability of the structure, changes in water level and status of landslide activity will be monitored continuously.

   [Action: The CWC in collaboration with the MoM-GSI; BRO.]

v) If the landslide dam is found to exist without any immediate threat of failure, then actions involving preparedness in the eventuality of an outburst of the landslide dam, or dam stabilisation, depending upon site conditions, will be formulated.

vi) Removal measures: If there is negligible risk of outburst then the landslide dam can be excavated or blown out with explosives after assessing the probable impact on downstream areas, or the dam can be left as it is without taking any immediate measures. The partial removal of the blockage will be in a phased manner to the extent that the threat to downstream areas is minimal.

vii) Monitoring the stability status of the landslide dam, even if it is apparently found to be stabilised, and the water level behaviour, will be continued for longer periods. This can be done through earth observation systems and by installing automatic telemetric water level recorders at site. Similarly, hydrological observations will be continued by installing automatic telemetric rain and discharge gauges for both the upstream and downstream areas of the site.

[Action: The CWC.]

viii) Assessing the stability of the dam and the possibility of its failure due to overtopping, piping, heaving, floods, impact of new landslides, impact of earthquake, etc., through detailed field investigations and testing of the materials forming the dam.

ix) Evolving remedial measures on the basis of the probable causes and mechanism of the collapse of the dammed body in advance. These should be checked for their efficiency and implemented as soon as site conditions are permissible.

x) For assessing the flood hazard posed by the dam in the event of its breaching by a landslide, Dam Break Analysis will be conducted for identifying vulnerable areas. Communities living in such areas will be kept in a state of alert as long as the threat of flash floods exists.

[Action: The CWC in collaboration with the SDMAs; District Administration.]

The management of landslide dam related disasters has also been dealt with in the *National Disaster Management Guidelines: Management of Floods*, in section 1.11, p.6.

The lead for these assessment and mitigation efforts will be taken by the CWC/Ministry of Water Resources (MoWR) in collaboration with the GSI, NRSC and the respective state governments.

[Action: The CWC in collaboration with the MoM-GSI; NRSC; SDMAs.]

4.5 Human Settlements in Landslide Prone Areas

The planning and design of human settlements in landslide prone areas is a task usually left to town planners, architects, and engineers. Simple geological considerations are increasingly being appreciated in the siting of human settlements. Architects are generally aware of the special consideration that goes into the design of human settlements in the hills vis-à-vis those in the plains. They, however, need to be educated on the importance and highly specialised nature of landslide investigation, mapping and analysis, which has an impact on both safety and economy.

Human settlements must be viewed not only from the perspective of their landslide vulnerability, but also from the perspective of the hazards that they create or exacerbate.

There is a need to look closely at human settlements, especially those being built on problematic slopes by the community. Mitigation measures, particularly in ecologically fragile hilly areas, will become much more expensive if new settlements continue to be built without recourse to proper slope investigation and timely protective action, ignoring well known professional practices in landslide risk management.

Projects like the Prime Minister's Grameen Sadak Yojna and the Jawaharlal Nehru National Urban Renewal Mission, envisaging wide coverage and huge investment, provide a great opportunity for improving the safety of constructions against landslides in hilly areas.

Site selection for housing, human settlements and other infrastructure in hilly areas will be done by a highly competent multi-disciplinary team of experts aiming to preserve the texture of the place and its cultural fabric, maintaining balance between natural and anthropogenic factors. These Guidelines aim to remove the points of conflict between the growing developmental compulsions of sluggish economies in the hilly areas and the applicable techno-financial and techno-legal regimes. A casual approach to site selection and planning will be discouraged to facilitate well-informed decision making based on systematically conducted investigations.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the SDMAs; MoM-GSI; MoEF; Archaeological Survey of India (ASI); CoA.]

The experiences with human settlements in hilly regions, especially in the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Uttar Pradesh, Arunanchal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Assam, Goa, Karnataka, Kerala, Maharashtra, Tamil Nadu, and the Union Territories of Puducherry and the Andaman and Nicobar group of islands, tell us that the problems of human settlements in mountain regions are those of staggering imbalances in growth patterns, varying levels of natural hazards, environmental degradation, the degree of deforestation, high cost of construction, paucity of building materials, uneasy access to appropriate technologies, economic backwardness, lack of entrepreneurship, and the slow pace of social change.

The growing population density, fuelled in some places by increasing tourism, has generated an additional pressure of human settlements on the already fragile slopes. The techno-legal regime will be tightened to strictly regulate new construction, in accordance with approved development plans.

Numerous human settlements are frequently seen on valley floors, particularly alongside rivers and close to their tributaries, as also around lakes and water bodies. Many of these locations are highly prone and vulnerable to the multiple hazards of landslides, earthquakes, floods, and cloudbursts.

Indiscriminate quarrying and mining operations for construction material have also become a cause for serious concern in the hills, and will be strictly regulated.

4.6 Protection of Heritage Structures

The protection of cultural heritage from natural hazards is an issue of worldwide concern, both in developed as well as in developing countries. The damage caused to heritage structures by natural disasters is increasing as both the vulnerability of rapidly developing urban areas and the consequences of climate change tend to amplify the effects caused by their occurrence. Within this framework, landslides represent a major threat, both to the safety of people and the preservation of the built environment, including many important heritage sites of national, international, cultural, or natural value. Although the concept of preservation has already taken hold in many countries, the situation is more serious in developing countries where awareness of the unique value represented by cultural heritage and the economic, scientific, and technical means for mitigating landslide hazard are limited.

The safety of many of our heritage buildings as well as lifeline structures stands visibly threatened by landslides and other types of disasters. In many cases the slopes supporting them are neglected. In some other cases only piecemeal efforts are being made to contain the problem, with partial success.

Close interaction with agencies like the ASI, Indian National Trust for Archaeological and Cultural Heritage (INTACH) and archaeological departments of the states will be developed to prepare lists of structures/sites which are at risk due to landslides/ slope stability problems, and to prioritise them. Based on this priority list, further studies and works for hazard mitigation will be taken up by the appropriate authorities in collaboration with the ASI, INTACH and the archeological departments of the state governments.

[Action: The ASI in collaboration with the INTACH; state governments.; SDMAs; CoA.]

4.7 Schedule of Activities for Risk Treatment

Activity		2009		2010				2011	
		Sep	Dec	Mar	Jun	Sep	Dec	Mar	Jun
4A	Identification of Landslides and Prioritisation	M*	M*					Implement	
4B	Identification of Institutions/Organisations	M*						Implement	
4C	Creation of Best Practice Examples of Slope Stabilisation through the Protection of a few Selected Important Heritage and Life Line Buildings and Strategic Roads from Landslide and Avalanche Disasters	M*					Implement		
4D	Landslide Remediation Practices						Implement		

M* : Meetings

5 Landslide Monitoring and Forecasting

5.1 Introduction

Monitoring is an important component of landslide investigation/studies that includes the measurement and analysis of landslide dynamics as well as changes in the factors that cause landslides. It is also necessary some times to undertake post-stabilisation monitoring of a landslide to evaluate the efficacy of the remedial measures implemented. Most landslide monitoring programmes include real-time, continuous (or at relatively close intervals) measurement of the temporal and spatial variability of mass movements at and beneath the surface, micro-topography, soil moisture, ground water levels, and precipitation. Typically, these measurements are collected at a central data recording and transmission point on the site. This data is often used in landslide warning systems in high-risk areas.

Landslide monitoring is generally not practiced in our country. Considering the incidence of a huge number of landslides in the Himalayas, NER, Western Ghats and Nilgiri hills in South India, it is not possible to undertake monitoring of each individual landslide. Therefore, a few landslides will be identified for monitoring and early warning.

5.2 Monitoring of Landslides

The monitoring of landslide movements consists of:

i) Selecting a specific location depending upon the type of movement, location, hazard, and risk value of slope failure.

ii) Selection of monitoring methods and frequency of data collection.

iii) Data processing and methods of result presentation.

Methods generally used for monitoring landslides can be divided into surface and sub-surface measurements of the landslide activity, and total regime measurements.

5.2.1 Surface Measurements of Landslide Activity

A simple method of monitoring is through the installation of a few survey pillars within the landslide zone and on its periphery, 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 the pre-monsoons, and during high rainfall and post-monsoon periods give a fairly good idea about the extent and rate of surface movement of the landslide, the amount of subsidence, and also surface stress variations. The rainfall data, particularly the intensity of the rainfall should be collected from nearby rain gauge stations and an effort may be made to correlate the intensity of rainfall data with the time of initiation of the mobilisation event. The measurement of cracks on the slope surface and their development provides a very useful input for slope stability analysis.

5.2.2 Sub-Surface Measurements of Landslide Activity

Sub-surface measurements of landslide activity are carried out by installing different types of instruments in boreholes drilled at various identified locations. The shallow sub-surface movements, including creep are measured by installing flexible casings in boreholes and observing their behaviour—through SGI rod inclinometers, Kirby's T-pegs, and strain probes. 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 the most extensively used instruments used for monitoring sub-surface movements in landslides.

The geophysical method of measuring pulse electromagnetic emissions identifies zones of high stress concentration in the body of the landslide. The measurements can be taken in with inclinometer boreholes.

5.2.3 Total Regime Measurements

Total regime measurements include recording fluctuations in the behaviour of ground water, which is most often the principal cause of landsliding. The purpose of these observations is to record changes in ground water levels, yield of water and the consequent development of pore pressure in the landslide material. The behaviour of ground water in the landslide area can be measured and monitored by installing piezometers at different depths in the boreholes. Various types of piezometers are used, of which hydraulic piezometers, pneumatic piezometers and electrical piezometers are the most commonly used. Of late, tensometers are used for the measurement of pore water pressure in many countries.

Rainfall records are required to develop correlations between rainfall, slope movement and pore pressures in the landslide mass and also the impact of these on the initiation of landslide activity. The rainfall should be measured by installing automatic rain gauges at the landslide locations.

5.2.4 Real-Time Monitoring of Landslides

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

Increasingly, remote sensing application tools, including High Resolution Satellite Imagery, LiDAR, Synthetic Aperture Radar (SAR), Persistent Scatterer (PS), and differential interferometery techniques for the correlation between landslide morphology, motion and topographic analysis are used in some countries for landslide monitoring. This has facilitated predictive modelling and risk analysis of landslides.

These and related studies demonstrate the high potential of using new technologies for landslide studies. Clearly, the advances of the past two decades in remote sensing, digital image processing, GPS, and GIS are revolutionising the study of landslides and improving the ability of scientific and government agencies to monitor and manage landslide-prone areas. In particular, GPS can play an important role in monitoring landslide-prone areas for signs of current movement, and provide near real-time warning on motion of landslides that can endanger life and property. With the advent of multi-antenna GPS instruments, the cost of monitoring with GPS has come down substantially. High resolution imagery and topographic mapping can lead to an improved understanding of landslide mechanics and hazard prediction. Continued research into methods of data collection, processing, and synthesis is needed to realise the full potential of these technologies for worldwide use in the coming decades.

Real-time monitoring of landslides has generally not been practised in India till recently. As real-time monitoring of landslide is a costly procedure involving a high amount of risk of losing expensive instruments due to the active nature of the landslide, only landslides having the potential to collapse catastrophically with a threat to life and property should be identified and monitored on a real-time basis.

5.3 Early Warning Systems for Landslides

In a holistic sense, the term early warning includes the whole range of actions and operations right from planning and instrumentation of problematic slopes and landslides to their monitoring, analysis, fixing of early warning alert thresholds, decision making, dissemination of early warning alerts and continuous improvement in early warning practices through sustained location-specific feedback and new research. The effects of landslides can be mitigated to some extent or minimised in certain cases, if the communities threatened by them are forewarned about the impending disaster and are prepared to face them.

There are no standard readymade packages or systems for early warning but all the instrumentation, tools, equipment, observation, and data processing systems are available in a range of varieties. They are necessarily to be fashioned to suit a particular slope or a landslide according to the type, magnitude, hazard potential of the landslide, and the purpose of the early warning alert. Hazard detection and early warning systems for different types of landslides are also usually different. For example, planning for instrumentation and early warning for a pre-existing (repetitive) landslide will be very different from the schemes for early warning against anticipated first time landslides. Likewise, early warning schemes for mass movements such as debris flows or rock falls will be very different from those for a block slide or classical landslide with discrete boundary shears. The task of evolving an early warning system in a given situation will necessarily have to be assigned to experts.

Early warning is a process which involves three components:

Scientific and 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.

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

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

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

i) Risk knowledge: Prior knowledge of the risks faced by communities.
ii) Monitoring and warning services: 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.

The weakness or failure of any one of them could result in the failure of the entire system.

5.3.1 Risk Knowledge

The development of effective warnings depends on the generation of accurate risk scenarios showing the potential impact of hazards on vulnerable groups. The acceptable levels of risk to communities can be a factor in determining whether and when warnings are to be issued to communities. The determination of this factor requires capabilities of analysis not only of the hazards, but also the vulnerabilities to the hazards, and the consequential risks.

The development of early warning systems requires access to high-quality data on the magnitude, duration, location, and timing of hazard events to be able to extract information on hazard frequency and severity from observational data sets. This requires:

i) Continuous, systematic and consistent observation of the parameters related to the hazard.
ii) Proper arrangements for data storage.
iii) Capacities to locate and retrieve the required data and freely disseminate the same to public users.
iv) Sufficient dedicated resources to support these activities.

It is necessary that in addition to gathering data on risk factors, the risk assessment exercises should involve local communities to determine their perceived risks and concerns as well as their existing preparedness. Participatory risk assessment also allows for the formal integration of traditional knowledge into risk assessment and early warning systems.

The main challenges for the development of early warning systems for landslides include:

i) Establishing and maintaining monitoring, observational, and data management systems at identified locations.
ii) Constructing a history of the hazard at selected locations.
iii) Obtaining systematic social and environmental data for vulnerability assessment.

5.3.2 Monitoring and Warning Systems

The disaster management network has to harness the local knowledge based warning systems for landslide hazards. The monitoring of hazardous locales by educated, aware, and sensitised communities is the most valuable and reliable information base for developing an effective early warning system. Local committees or groups have to be identified and trained to discern early warning signs, gather information and disseminate them to the appropriate DM cells.

There have been marked improvements in the quality, timeliness and lead time of hazard warnings, mainly driven by scientific and technological advances. This is particularly due to rapid advances in computer systems and communications technology. There have been continuous improvements in the accuracy and reliability of monitoring instruments, and in integrated observation networks, particularly through the use of remote sensing techniques. In turn, these have supported research on hazard phenomena, modelling and forecasting methods and warning systems. While the capabilities for identifying areas of landslide hazard occurrence exist at the global level, the capabilities for predicting the time of its occurrence are still developing. The signs of an impending disaster can often be detected at an early stage and used for warning. It may be possible to predict the time of occurrence of a landslide in some cases, provided the slopes are monitored.

As discussed above, identifying the incipient instability of slopes and early warning of ensuing landslides is possible through systematic mapping, slope instrumentation, monitoring and real-time data analysis. Modern technology offers a number of high resolution instruments that can capture, monitor and transmit data for real-time analysis and forecasting.

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 instruments can be used for easily measurable indicators that can provide premonitions of impending slope failure. Monitoring of rainfall, surface and sub-surface 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 boulder falls, cracking of building floors, and other such events often provide irrefutable evidence of unsatisfactory slope behaviour. Randomly picked isolated observations of this kind do not convey much but when all such evidence is collected, analysed, and connected with other inputs, early warning alerts become possible.

Guidelines and field manuals will be formulated and workshops and training programmes organised for different target groups. Actual projects will be encouraged to create pace setter examples of early warning as well as for training professionals on the projects.

[Action: The DST in collaboration with the NIDM; WIHG; CDMM; IITs, universities, and other academic institutions.]

Simple devices commonly used for early warning against landslides in the recent past are:

i) Wire or special switches, actuated by the pressure of moving debris coupled to a decision-support system that releases early warning alerts.

ii) Electrical switch poles which turn to an upright position upon displacement.

iii) Photo-electrical barriers, especially for rapidly moving debris flows or earth flows.

iv) Pulsed radar for snow avalanches.

v) Fibre optic sensors and technology.

vi) Acoustic emission technology.

vii) Auto-actuated photographic systems.

viii) GPS observations.

Projects will be encouraged to develop appropriate technologies as well as to effectively utilise the available state-of-the-art technologies to facilitate quality monitoring in a cost-effective manner, aiming at real-time early warning.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; SDMAs; CSIO; WIHG; IITs, universities, and other academic institutions.]

While capabilities exist at the global level to identify areas of landslide occurrence, the capability of predicting their occurrence is still developing. The signs of impeding landslides can often be detected at an early stage and used for warning affected communities. The time of landslide occurrence is possible to predict provided the slopes are monitored continuously. Advances in monitoring technology, particularly in real-time transmission of information have enhanced the techniques of short-term prediction, and examples of the same are available in limited numbers. The best example of this is the early warning system established for the Yangtze River valley in China that uses 70 stations, employing over 300 professionals for monitoring. The network protects a population of 3,00,000 and has so far forecast 217 landslides and avoided estimated economic losses of US$ 27 million.

Remote sensing, GPS, and GIS are now mature 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 have used these tools, including high-resolution satellite imagery, and LiDAR. High resolution imagery and topographic mapping can lead to an improved understanding of landslide mechanics and hazard prediction. Continued research into methods of data collection, processing and synthesis is needed to realise the full promise of these technologies for use worldwide in the coming decades.

Radar is one of the technological advances that can be used for monitoring landslides effectively. Some applications of radar include monitoring of avalanche movement, detection of crevasses in geological formations, measuring the thickness of snow on roads to facilitate snow clearance operations and aiding the 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 measurement and documentation of landslides. Rainfall thresholds have been applied for regional real-time landslide warning systems. However, techniques for analysing 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 the Indian Space Research Organisation (ISRO) can also be deployed in remote areas for collecting meteorological parameters and transmitting the same through different networks like VSAT, VPN, etc.

A great majority of dormant landslides often turn active and violent during the monsoon season, and high intensity short duration rainfall events are generally responsible for triggering catastrophic landslides. This single observation is enough to underscore the importance of reliable and continuous rainfall measurements and real-time analysis of rainfall data, preferably at all major landslide sites. Rainfall information will be utilised for developing indicators for landslide alerts, especially for high landslide hazard areas prone to cloudbursts and high intensity short duration rainfalls. For example, the eastern Himalayas get very heavy monsoon rainfall punctuated with occasional cloudbursts with rainfall intensities in the range of 300 mm per day to 1,000 mm per day (the higher the rainfall intensity, the lesser its duration). One study developed on this observation in the 1980s led to the linking of landsliding with the corresponding rainfall event coefficient (ratio of the rainfall of an event to the mean annual rainfall at the location). The findings revealed that event coefficients exceeding 20 per cent trigger heavy landslides at all times. A very high probability of landslides was projected for event coefficients of 10–20 per cent. The probability of landslides was rated as very low when the event coefficient fell below 5 per cent. The above study is only suggestive of the nature of advanced studies to be undertaken, and it is important to encourage such studies and make them more scientific and systematic. The statistical correlation between rainfall and the corresponding slope surface and sub-surface movements, and the measurement of pore water pressure development within the slope provide a good insight into slope behaviour.

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

Since the inter-relationship between rainfall intensity, slope surface and sub-slope movements, and pore pressures provide a powerful means for reliable landslide forecasting, studies regarding this will be encouraged. Rainfall and the associated slope behavioural information will be utilised for developing indicators for landslide alerts, especially for high landslide hazard areas known to succumb to cloudbursts and high intensity short duration rainfall. In cases where no such information is available, a warning of a general nature and low reliability may still be possible through the study of rainfall records in the backdrop of the previous landslide history.

[Action: The MoM in consultation with the TAC and in collaboration with the IMD; MoM-GSI; DST; CWC; IITs, universities, and other academic institutions.]

The prediction of landslides is possible and R&D work on it deserves to be encouraged. Attempts to predict landslides have so far been based on the time-dependent displacement behaviour of landslides, generally in the tertiary stage of the creep. The increasing availability of high resolution geospatial maps and powerful slope instrumentation techniques make real-time landslide prediction possible.

R&D projects on landslide prediction will be encouraged. One major research programme on landslide prediction and early warning installations with the provision of comprehensive scientific study and geotechnical instrumentation will be undertaken to create pace setter examples.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the CSIO; CDMM; CBRI; CRRI; IITs, universities, and other academic institutions.]

Once a decision for early warning is taken based on the available information inputs, the early warning dissemination strategy will be common to that prescribed for other types of disasters. Operations such as post early warning interfacing with communities, press, and the media are common to all types of disasters. Integrated early warning dissemination systems will be evolved. Technologies are available where a Short Message Service (SMS) can be simultaneously translated into 14 languages.

Even with the best of early warning systems, the 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 early warning alerts in real-time. There should be an easily understandable manual clearly bringing out what to do in case 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 the threshold values of rainfall at which landslides are initiated in a particular area are known, the same can be used as a basis for issuing early warnings if the amount of rainfall in that particular area can be forecast. The correlations can be established with the help of past records as well as monitoring. In our country, the IMD and National Centre for Medium Range Weather Forecasting (NCMRWF) have developed the capability of forecasting the amount of rainfall an area is likely to receive 3–5 days in advance. Collaborative efforts in this field can be made to establish the rainfall thresholds required to initiate landslides in some pilot areas. Once these are established, they can serve as early warning systems for those particular areas. Depending on the success of this study, some more landslide prone areas may be selected for developing early warning systems.

Public response to a forecast is another difficult area. If the people are not educated, they will 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.

5.3.3 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 meet the needs of a wide range of different threats and different user communities.

The dissemination of information must be based on clear protocols and procedures and supported by an adequate telecommunications 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 in even the most remote areas of the country. Each area may require different technological infrastructure to allow for the effective dissemination of messages. To ensure that all systems work smoothly in tandem, they 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, particularly through operational telecommunications systems, but also through non-technical social networks. The latter are very important in poor communities that lack modern communication systems. Effective dissemination requires the establishment of a chain of command in advance, to manage warning issuance and dissemination, to ensure that information provided can be understood by those who need it and it reaches all the affected locations in the country. It is more important in the case of landslides as they are localised events and can occur in remote locations.

A typical warning dissemination chain involves channelling of 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 sector in others. To be effective, early warning activities must equally cover all the relevant areas in the country. 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. The public broadcast media remain the most widely used mode worldwide, which is appropriate as the best systems for warning dissemination are those used everyday and with which the users are most familiar. The role of community-based and grassroots organisations, as well as NGOs and other players in disseminating warnings is pivotal.

5.3.4 Response Capability

Response to early warnings involves activating coping mechanisms (mainly for the orderly movement of people away from locales at risk, seeking shelter, and safely securing assets) before a disaster strikes. In contrast, the post-disaster response implies the wider range of recovery, rehabilitation and reconstruction efforts in the aftermath of the disaster. However, both are a 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 therefore warning systems will include preparedness strategies and plans to ensure an effective response to warning messages.

Warnings trigger a variety of responses from different agencies at various levels, which must be coordinated. A number of governmental agencies, including various ministries, institutions, national disaster management institutions, and municipal and local administration authorities, are responsible for coordinating disaster preparedness. People are more likely to listen to and act upon warnings when they have been educated about their risks and warning reaction plans are in place.

5.4 Pilot Studies for Instrument Based Early Warning

A few landslides will be identified for instrumentation based early warning in consultation with state governments and other Central Government agencies like the BRO. It will be a multi-disciplinary and multi-institutional approach. Efforts will be made to integrate local communities and the concerned state governments in this endeavour. Projects aimed at early warning against major landslides will be encouraged, taking advantage of the fact that unlike many other disasters, early warnings against landslides are possible with the present state-of-the-art technologies.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the SDMAs; BRO; MoM-GSI; DST; District Administrations; IITs, universities, and other academic institutions.]

Pilot projects will also be launched to arrive at early warning thresholds through the correlation between rainfall intensity and landslide initiation. In this case, three to four areas in different parts of the country, like the Western Himalayas, Eastern Himalayas or the NER and the Western Ghats or Nilgiris, where the density of landslide incidence and rainfall are high, can be selected in consultation with either the IMD or NCMRWF. The latter has developed weather forecasting capability for particular areas within grids of 150 km by 150 km, three to five days in advance. These grids are being redefined to blocks of 100 km by 100 km. The rainfall threshold values needed for landslide activation in the particular pilot areas will be established through earlier records and continued monitoring. The results of these observations will be matched with the weather forecasts made by the above organisations. Once these correlations are established, the forecasts issued by the IMD or NCMRWF will be utilised for issuing early warnings for possible landslide occurrence in those particular areas.

[Action: The IMD in collaboration with the NCMRWF; MoM-GSI; DST; CDMM; CBRI; CWC; IITs, universities, and other academic institutions.]

For correlating rainfall intensity and landslide initiation to develop forecast capabilities, 20 pre-determined landslide locations will be monitored initially with automatic rain gauges by different agencies. This national initiative will be closely coupled and eventually integrated into the ongoing programme of expansion of the automatic rain gauge network of the IMD.

[Action: The IMD in collaboration with the MoM-GSI; DST; CDMM; CBRI; CWC; IITs, universities, and other academic institutions.]

Both the pilot projects of developing early warning systems for specific landslides or specific areas may take about five years to complete. Depending upon the results of these pilot studies, more areas will be taken up for the development of such systems.

5.5 Schedule of Activities for Landslide Monitoring and Forecasting

Activity		2009		2010				2011	
		Sep	Dec	Mar	Jun	Sep	Dec	Mar	Jun
5A	Identification of Landslides and Prioritisation	M*	M*					Implement	
5B	Identification of Institutions/Organisations	M*						Implement	
5C	Development and Establishment of Early Warning Systems at Selected Major Landslides and Avalanches	M*						Implement	
5D	Dissemination and Communication						Implement		

M* : Meetings

6 Regulation and Enforcement

6.1 Introduction

The state governments/SDMAs of landslide affected areas in consultation with the NDMA will establish the necessary techno-legal and techno-financial mechanisms to address the problem of landslide hazards in their respective states. This is to ensure that all stakeholders like builders, architects, engineers, and government departments responsible for regulation and enforcement adopt landslide safe land use practices and provide for safety norms as far as slope stability is concerned in landslide affected areas in particular and hilly areas in general.

[Action: State governments/SDMAs; district administrations; the CoA.]

6.2 Model Town Planning and Land Use Bye-Laws

In recognition of the importance of a techno-legal framework for regulating the built environment, the MHA constituted a national level expert group to recommend modifications to the existing regulations to ensure structural safety.

This group recommended modifications to the town and country planning acts, land use 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 prescribed regulatory, quality control and compliance mechanisms. The MHA has circulated these model bye-laws to the state governments for a review of the bye-laws currently in force and for ensuring their adoption after revision.

The following codes and guidelines related to landslides have been finalised and published by the BIS.

i) IS 14496 (Part 2): 1998 Guidelines for the preparation of LHZ maps in mountainous terrain: Part 2: Macro Zonation.

ii) IS 14458: Guidelines for Retaining Walls for Hilly Areas.

   a. Part 1: Selection of the Type of Walls.

   b. Part 2: Design of Retaining/Breast Walls.

   c. Part 3: Construction of Dry Stone Walls.

iii) IS 14680:1999: Guidelines for Landslide Control.

iv) IS 14804:2000: Guidelines for Siting, Design and Selection of Materials for Residential Buildings in Hilly Areas.

v) National Building Code (NBC) 2005.

Part 2: Macro Zonation, dealing with guidelines for the preparation of LHZ maps in mountainous terrain is under revision and the guidelines for LHZ mapping at the meso-scale are under preparation.

It is essential that the above codes are critically examined and urgently reviewed by peers in the context of global and indigenous research as well as the growing pool of knowledge and experience gained in pursuing indigenous mapping programmes. Once the initial revisions are carried out in the next two years, the BIS will revise/revalidate these every five years or earlier, if necessary.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the BIS.]

It is also felt that there should be codes/ guidelines in the case of landslides risk evaluation and the detailed geological investigation of landslides.

In case of hydropower projects in hilly terrain, all the agencies involved, whether in the private or public sector, need to follow these guidelines for the preparation of landslide susceptibility, hazard and risk analysis and risk analysis maps, and to obtain clearance from the concerned authorities before initiating the project.

Model Village Planning and Land Use Bye-Laws

To ensure structural safety at the village level in mountainous terrains, a techno-legal framework akin to town planning bye-laws needs to be developed, which will translate and codify landslide concerns into village development.

Appropriate legislation may be considered for the enactment for future safe and planned development in towns and villages affected by landslide hazard.

6.3 Indian Standard Codes

The non-availability of the latest codes, guidelines and standards has been frequently cited as one of the major constraints responsible for the poor implementation of codal provisions. Considering the overriding interest of public safety, the BIS will place all Indian standards related to landslides in the public domain including the Internet for free download.

[Action: The BIS.]

A periodic revision of the codes and standards relating to landslides will be undertaken by drafting groups within a fixed time-frame of five years or even earlier on a priority basis.

Other than the 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, Road Transport and Highways (MoSRTH), Research Designs and Standards Organisation (RDSO), and Ministry of Railways (MoR). Codes developed by these organisations will also be updated and made consistent with current state-of-the-art techniques on landslide safety. These agencies also have a number of internal memos for the regulation of construction practices, the review of which will also be undertaken at the earliest.

[Action: The BIS.]

The nodal agency and the BIS will ensure that the relevant national code writing bodies prepare action plans to carry out regular revisions of the existing codes and for soliciting draft provisions for discussion on new codes to be developed.

The BIS is the nodal agency for preparing codes related to landslide studies, procedures and other safety related codes. Many codes and guidelines are in place, some are under revision and others still need to be formulated.

The BIS will ensure the finalisation and formulation of all pending codes and guidelines within the next two years.

[Action: The BIS.]

6.4 Techno-Legal Regime

The techno-legal regime for landslide risk management will cover both technical and legal issues together for the effective regulation, implementation and management of landslide risks.

All future developmental activities will be regulated by codal provisions which will prescribe all the disaster resistant features. India does not have any major provisions or good enforcement systems to ensure disaster resistant construction for landslides. It should be emphasised that it is not disasters that cause loss of life and property, but badly planned and/or adversely located structures. This can be dealt with by adopting a techno-legal regime through the introduction of disaster resistant planning features in development and building regulations.

The DM Act, 2005 has clearly defined the institutional and coordination mechanisms at the national, state, district and local levels, and provides for the establishment of a Disaster Mitigation Fund and Disaster Response Fund at these levels. The Act also provides for legal powers and penalties. The provisions included in the Act are valid throughout the country.

The state governments/SDMAs will adopt the model techno-legal framework for ensuring compliance with land use zoning and landslide safety issues in all development activities and plans. State governments will update the urban and land use regulations by amending them to incorporate multi-hazard safety requirements. They will also review, revise and update the town and country planning Acts, land use and zoning regulations, building bye-laws, and DCRs, and this process will be repeated at regular intervals.

[Action: State governments in collaboration with the SDMAs; district administrations.]

6.5 Licensing and Certification

All professionals dealing with the safety aspects of slopes in hilly areas will be trained and sensitised through a capacity building process initially, and certified through a licensing process after this. 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 will also be subject to this certification.

The NDMA and the nodal agency, in collaboration with the relevant ministries and departments of the GoI will evolve an appropriate techno-legal framework for making the licensing of professionals mandatory.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the central ministries.]

In the case of architects and town planners, the statutory body for registering architects, namely the Council of Architecture (CoA) and the professional body that coordinates with architects, namely the Indian Institute of Architects (IIA), will be responsible for the registration, training and upgradation of the skills of architects and town planners in landslide safety and construction.

[Action: All India Council for Technical Education (AICTE) in collaboration with IITs, universities and other academic institutions; the CoA; IIA; urban planners.]

6.6 Compliance Review

A sound compliance regime is required to ensure the effectiveness of legal provisions. It is most important that monitoring, verification and compliance arrangements are in place both at the national and state levels.

All land use and developmental plans in hilly areas will go through a mandatory compliance review by professionals of the Urban Local Bodies (ULBs) and PRIs to which these are to be submitted for approval. Major projects and critical structures will be put through a mandatory compliance review by qualified external agencies.

[Action: District administrations in collaboration with urban planners; ULBs; CoA; IIA; PRIs.]

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 land use plans in hilly areas for their compliance with safety requirements in accordance with the DCRs. This scrutiny will be applicable to all construction habitations and structures in both urban and rural areas. State governments, in consultation with their State Executive Committee (SEC) and Hazard Safety Cells (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 ensuring compliance with the bye-laws. MoM, in consultation with GSI, and the state governments, and other agencies concerned, will develop a checklist of items to be verified and the method for such verification at national level consultative workshops and use them as training inputs.

The area selected for the expansion of human settlements, industrial clusters, and other important projects in hilly areas will be assessed by regarding the status of slope stability by accredited agencies or professionals for their safety. A procedure will be developed by the state government/SDMA concerned for undertaking this assessment by accredited agencies for ensuring safety.

6.7 Technical Audits and Monitoring

All existing habitations and important structures located in vulnerable areas and facing high risk from unstable slopes will be monitored by ULBs. The slope stability assessment reports and treatment requirements, if needed, will be scrutinised for compliance with regulations as per the specifications of the model techno-legal regime. In the case of major projects, these aspects will be subjected to detailed technical evaluation before granting construction permissions.

6.8 Techno-Financial Regime

The Guidelines issued by the NDMA will form the basis for the formulation of plans for mitigation projects at the national, state and district levels. These mitigation projects will be duly prioritised and approved by the NDMA. The Planning Commission will include these DM plans in the Five-Year and Annual Plans of the ministries and departments of the GoI, as well as in the state plans.

[Action: The nodal ministry in consultation with the TAC and in collaboration with central ministries; state governments; the Planning Commission.]

After the occurrence of a disastrous landslide, the centre 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. The 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 on the government. Risk transfer mechanisms have been found to be fairly successful in some countries. Therefore, the insurance sector will be encouraged to promote such mechanisms in the future.

For this, the NDMA will develop a national risk avoidance, risk sharing, and risk transfer strategy, on the lines used for other disasters, using the experiences of micro-level initiatives in some states and global best practices, in consultation with financial institutions, insurance companies, and reinsurance agencies.

Financial institutions will 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 the Indira Awas Yojana), and all large-scale housing schemes will be made to comply with the landslide safety regime. The NDMA will assist MoM in coordinating with the central ministries/departments concerned and the concerned state governments for ensuring compliance to this aspect by financial institutions.

The approval and disbursement of funds from banks and other financial institutions to industrial units will also be linked to compliance with slope stability norms by these units.

6.9 Schedule for Regulation and Enforcement

The schedule of activities for regulation and enforcement is given in the table below. All activities will be institutionalised and continue beyond December 2010.

Activity		2009		2010				2011	
		Sep	Dec	Mar	Jun	Sep	Dec	Mar	Jun
6A	Review and Update of Town Planning and Land Use Bye-Laws						Implement		
6B	Review and Update of Indian Standard Codes						Implement		
6C	Regulation of Further Development in Hilly Areas						Implement		
6D	Development of Risk Transfer Mechanisms	M*	M*	M*	M*	M*	M*	Implement	

M*: Meetings

7 Awareness and Preparedness

7.1 Awareness

Local communities that are aware about the disastrous effects of landslide hazard and the hazardous locales in their area would be in a better position, both physically and psychologically, to face its consequences. Since landslides are frequent and sudden, and cause disasters that affect localised areas resulting in segregated losses, these do not receive appropriate attention due to their 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. Cumulatively, losses due to landslides are much higher in India than any other disaster in hilly terrain. Thus, there is an immediate need to educate people about landslides to reduce the associated risk and losses.

State governments/SDMAs of landslide affected areas, in collaboration with the nodal agency and other key stakeholders, will make special efforts to mobilise communities to carry out landslide mitigation efforts. Electronic and print media will also be associated in the endeavour to create greater public awareness about landslide hazard and importance of land use zoning practices. Organisations and institutions like the GSI, NIDM, IITs, CDDM, and other knowledge-based institutions including some NGOs will be entrusted with the responsibility of preparing material for awareness generation campaigns pertaining to the landslide prone states in the country in a scheduled manner.

[Action: SDMAs/state governments; the MoM-GSI; NIDM; CDMM; IITs, universities and other academic institutions; PTI; DAVP; Prasar Bharati; private broadcasters.]

Comprehensive awareness campaigns targeting different groups of people living in landslide prone areas will be carried out systematically. These campaigns will emphasise 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/organisation or community will play in order to mitigate the effects of landslides.

[Action: SDMAs/state governments; the MoM-GSI in collaboration with academic institutions and the media.]

7.1.1 Creation of Public Awareness on Landslide Risk Reduction

Handbooks, posters, and handbills containing the status of landslide hazards will be distributed, and details of landslide indicators along with precautions to be adopted and suggestive measures will be displayed near landslide prone sites. All the above documents will be translated into local and regional languages. Short video films on landslide risk, vulnerability, and importance of preparedness and mitigation measures will be prepared for the general public. The electronic and print media will also be made an integral part of the campaigns.

[Action: SDMAs/state governments; the MoM-GSI in collaboration with academic institutions and the media.]

Communities need to be alerted and made aware of:

i) What are the major disaster threat perceptions in the localities of immediate concern to them, and what are the projected likely disaster scenarios (landslide included)?

ii) What are the possible landslide hazard distribution scenarios and major known landslide spots and identified elements at risk in the area?

iii) What are the lessons to be learned from past landslide disasters in the area and from their (mis)management?

iv) What are the precursors and early indicators that can avert a landslide disaster?

v) What are the elements like roads, housing, schools etc., exposed to landslide risk?

vi) What is the role and responsibility of the government and local bodies before, during and after a disaster?

vii) What are the expected roles and responsibilities of communities and people at large—before, during and after a disaster? How much responsibility are the residents and communities willing to assume in choosing to live or do business in high risk areas?

viii) What are the roles of the public sector, corporate sector, NGOs and other voluntary organisations?

ix) Does the building material, design and construction conform to prevalent building codes and established engineering practices?

7.1.2 Awareness Drives for Specific Target Groups

One of the most challenging tasks in landslide preparedness and mitigation is the sensitisation of all the stakeholders, and educating and training them to participate in landslide preparedness and mitigation efforts. If the community recognises the importance of landslide safety vis-à-vis developmental activities, tremendous gains can be achieved in landslide risk reduction.

The nodal agency along with state governments, some selected institutions collaborating with local bodies, urban planners, and NGOs, will initiate programmes to sensitise decision makers and other important functionaries in undertaking mitigation measures in landslide affected areas. The contents and structure of the resource material will be reviewed and revised, depending on the results of earlier programmes. Large construction companies and contractors engaged in infrastructure development in hilly regions in various parts of the country will undertake campaigns to sensitise their members to the risk and vulnerability resulting from landslides so that necessary attention is paid to this hazard and mitigation measures are included in design and construction in vulnerable areas.

[Action: SDMAs/state governments; the MoM-GSI; district administrations; NGOs.]

State governments/SDMAs, in collaboration with the nodal agency, NGOs, and other identified agencies, will organise awareness programmes on the various aspects of landslide management for specific target groups of stakeholders, elected representatives, civil servants, members of local authorities, school administrators, members of management boards of educational institutions and hospitals, school children, representatives of the corporate sector, the media, etc.

[Action: SDMAs/state governments; the MoM-GSI; district administrations; NGOs.]

A comprehensive awareness campaign will be developed and implemented for following safe practices before, during, and after a landslide. The campaign will also highlight the risks and vulnerability of the states and the roles/ responsibilities of all the communities and stakeholders in addressing the risk.

The GSI, the nodal agency, will maintain a list of resource personnel and organisations capable of conducting awareness generation campaigns, which will be updated from time to time.

[Action: The MoM-GSI.]

Public awareness campaigns will 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 major landslides will be prepared and used for creating greater public awareness among professional and critical stakeholders. Landslide risk management will be done by applying available knowledge and customising the same through R&D for specific situations, and by generating new adaptive techniques.

State governments/SDMAs and professional bodies will organise knowledge and experience sharing workshops for societal benefit. These will also support private agencies to develop their capacities to assess, predict, and monitor landslides as well as implement appropriate remedial measures.

[Action: SDMAs/state governments in collaboration with the GSI.]

The NDRF will continue with its familiarisation and community awareness programme on response and relief in the landslide affected regions. These efforts will be strengthened.

7.2 Landslide Preparedness

DM plans for landslide prone areas will be systematically developed to prepare the stakeholders in addressing landslide risk. These plans will be region specific and will consider the risk profile and special characteristics of a particular geographic area. Preparedness will include the formulation of family and community contingency plans.

Mock drills will be conducted in offices, schools, industrial units, etc., and in the neighbourhood of sites vulnerable to landslides.

[Action: The nodal ministry in consultation with the TAC and in collaboration with SDMAs; district administrations.]

The employees of the GoI as well as major private transport companies operating in mountainous regions will be sensitised to the landslide hazard of the area. They will be advised to remain vigilant and respond effectively in emergency situations.

7.2.1 Community Preparedness

Local authorities like gram panchayats, with the help of NGOs and volunteer groups from within the community will prepare and implement community based DM plans. A database of these groups, their contact details, and fields of specialisation will be created and maintained at the district and state levels. The state governments/SDMAs will set up appropriate disaster management mechanisms to act as links between the state government/SDMA and different organisations.

[Action: DDMAs/SDMAs in collaboration with PRIs and NGOs.]

The comprehensive exercise programme followed by the Federal Emergency Management Agency (FEMA) of the USA is a good example of effective emergency preparedness. It includes progressively complex exercises, each one building on the previous one, until the exercises are as close to reality as possible.

An exercise in the 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 are conducted to evaluate an organisation'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 conducting exercises pays huge dividends.

A comprehensive exercise programme involves five main types of activities, viz., orientation seminar, drill, tabletop exercises, functional exercises, and full-scale exercises.

Exercise programmes for each disaster prone district will be developed and made an essential part of the preparedness programme. The entire cycle of an exercise programme from orientation seminar to full scale exercise takes about 18 to 24 months. Complete exercises in disaster prone districts will be conducted at least once in four years after careful planning so that grey areas in the preparedness programme are identified and efforts are made to make the necessary modifications. As per the specific situation, these exercises will be conducted to assess preparedness for all the hazards present in the district rather than for individual hazards.

[Action: State governments/SDMAs.]

7.2.2 Medical Preparedness

The Disaster Management Plans (DMPs) related to medical preparedness developed at the state and district levels will be the same as in other hazards. The principal aim of the medical management plan will be to improve emergency medical preparedness and response, which have been dealt with in the Guidelines for Medical Preparedness and Mass Casualty Management, issued by the NDMA. In the case of landslide hazard, medical preparedness will focus on likely injuries resulting from landslides, including psycho-social trauma. It will address the need for surveillance, and for planning and rehearsing mock exercises and drills for disaster preparedness.

Since the medical management plan will include all existing disasters in the area, there is a need to create greater awareness among all the medical teams and the medical community at large about the hazards and types of injuries that can be inflicted, especially by landslides.

Medical First Responders (MFRs) for administering first aid and resuscitation measures at the incident site and during the transportation of casualties, will be identified and trained. All members of the medical and paramedical teams will conduct regular exercises based on the Standard Operating Procedures (SOPs) laid down by the respective Disaster Management Authority (DMAs) as part of their DM plans.

[Action: SDMAs in collaboration with the state health and medical departments, and private hospitals.]

All public health facilities will develop their own DM plans, with arrangements 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 the 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) will 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.

[Action: SDMAs/DDMAs in collaboration with the state health and medical departments and private hospitals.]

7.3 Schedule for Awareness and Preparedness Activities

Landslides, unlike other natural disasters, occur as isolated incidents and hence have to be treated individually. Therefore, awareness campaigns, plans, timelines and schedules will be developed separately and implemented independently in accordance with the defined time frame. However, in the case of preparedness, a comprehensive plan that takes into consideration all the disasters the area is prone to, needs to be formulated and implemented.

Activity		2009		2010				2011	
		Sep	Dec	Mar	Jun	Sep	Dec	Mar	Jun
7A	Development of Awareness Generation Material	M*	M*				Implement		
7B	Carrying Out of Landslide Disaster Awareness Programmes at all Levels	M*						Implement	
7C	Sensitisation of Different Stakeholders	M*	M*					Implement	
7D**	Emergency Plans and Exercise Programmes	M*						Implement	
7E	EOCs						Implement		
7F	Streamlining of NGOs and Volunteer Groups	M*	M*					Implement	
7G	National and State Landslide Disaster Management Plans	M*	M*					Implement	
7H	District to Community Level Preparedness Plans	M*	M*					Implement	
7I	Medical Preparedness	M*	M*					Implement	

M*: Meetings

** : Common for all Disasters

8 Capacity Development (Including Education, Training and Documentation)

8.1 Introduction

Capacity development efforts are an essential part of the strategy to fight landslide disasters. A realistic national capacity building programme, commensurate with the intensity and extent of the hazard in India will be evolved and implemented, keeping in view the available resources. This programme of resource enhancement will encompass all institutions/organisations/ individuals that have a role in any part of the DM cycle.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI.]

Technicians, administrators, and rescue workers who have been well trained and oriented to act during emergency situations contribute significantly in reducing the impact of disasters.

The target groups identified for capacity development will include scientific and technical institutions, elected representatives, government officials, professionals in the electronic and print media, town/urban planners in hilly regions, infrastructure development companies, engineers, architects, and builders, NGOs, private volunteers, and other Community Based Organisations (CBOs), social activists, social scientists, school teachers, and school children.

[Action: The SDMAs/DDMAs; BRO; CoA; NGOs; central and state education departments; IITs, universities and other academic institutions.]

Capacity development is a challenging task that aims at preparing all the stakeholders psychologically, socially, and technically to participate in the management of landslide disasters, and can be successful only if all the stakeholders participate actively in this exercise, which will include capacity upgradation, landslide education, training, research and development, and documentation.

India has a global presence in DM and the GoI is a member of various international organisations in the field of disaster response and relief.

It has linkages with foreign organisations like the United Nations Office for the Coordination of Humanitarian Affairs [UN (OCHA)], United Nations Development Programme (UNDP), and the United Nations Disaster Assessment and Coordination (UNDAC) team. Efforts will be made to develop these relations and utilise them in building institutional and individual capacities in the field of landslide disaster management as practised elsewhere and also to participate in internationally coordinated programmes in landslide research. India will participate in the international effort at improving the quality of preparedness and response in liaison with international organisations.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; MoES; DST.]

8.2 Landslide Education

Landslides are inevitable events, having been a part of human history over the centuries. But landslide incidence has increased alarmingly due to extensive anthropogenic interference for developmental activities in the once stable hilly regions. The structures we build trigger landslides, which in turn destroy these structures.

We must learn to understand that humans become victims of nature's fury when the natural equilibrium is disturbed. There are several causative factors, other than anthropogenic interference, that give rise to slope instability. Looking at a landslide, experienced eyes can visualise to some extent the causative factors leading to slope distress. We need to educate professionals involved in landslide management so that the gap between theory and practice is bridged. Anthropogenic factors fuel landslides and that should be made clear to architects, planners, engineers, and builders, especially in landslide prone areas. Educating decision makers, local authorities, NGOs, communities, the media, and other stakeholders is as important.

The affected state governments will make sincere efforts to strengthen the field of natural disaster education in general, and landslide education in particular, by incorporating the best available technical and non-technical inputs on landslide safety in educational curricula at the secondary and senior secondary levels in all schools. Landslide education will address the multifaceted aspects of landslide management, especially preparedness, mitigation, and response efforts. In this regard, case histories of past disastrous landslides will be used as valuable inputs for disaster education in general, and landslide education in particular.

[Action: The SDMAs/state governments; the MHRD.]

Disaster related curricula have already been introduced in class VIII, IX and X levels in CBSE schools. The education boards of states with hilly terrains will develop similar content in their curricula.

The state governments/SDMAs, in collaboration with their respective boards of secondary education, will ensure that the subject of disaster safety and disaster preparedness is introduced at the senior secondary level (Class XI and XII) and at the undergraduate level in technical and non-technical disciplines as well, and that landslides form an integral part of disaster education.

[Action: SDMAs/state governments; the MHRD.]

The development of high-quality educational material, textbooks, field training, and a high standard of teaching at all levels will be given due emphasis. Education and training programmes will be designed with greater focus on the development of the capacity and skills of trainers and teachers. Science and technology courses designed by experts and designated institutions will be introduced to orient all target groups, including school teachers, NGOs, private volunteers, and other professionals engaged in disaster management.

The central and state governments will encourage knowledge institutions to undertake research, teaching, and training, which will further contribute to improving landslide education in India.

[Action: Central ministries in collaboration with NDMA; SDMAs/state governments.]

8.2.1 Education of Professionals

It is time for knowledge institutions and universities to give focused attention to landslide education through the revision of syllabi, enlarging the scope of teaching earth sciences and allied disciplines with a practical bias, and through the crafting of new educational programmes. The curricula in earth sciences, engineering geology, seismology, geotechnical engineering, structural engineering, and architectural aspects needs special attention. It would help to learn from the MHRD's National Programme in Earthquake Engineering Education (NPEEE). Another area requiring intervention is the training of professional engineers and architects to ensure that classroom teaching benefits professional practice. A large number of professionals require training and retraining. The endeavour will be to prioritise the enhancement of the quality of teaching, text books, training kits, etc., in the field of landslide education.

We need to create a breed of professionals who will appreciate the importance of correct diagnosis before slope treatment. Engineering geologists will have to discuss the micro-geological details controlling a landslide, and not just stop at a broad description of the lithology. A geotechnical engineer needs education to realise that orthodox soil mechanics has long been replaced by modern soil mechanics, with concepts, tools and techniques that can help characterise and analyse a landslide more reliably. Landslide managers need the education that will make them insist on a scientific, systematic slope investigation, realising that ad hoc measures without sound investigation may prove to be a costly waste.

Self-education programmes by the effective use of multi-media based knowledge products need to be encouraged and prioritised. This will accordingly be taken up for implementation.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the NIDM; University Grants Commission (UGC); Prasar Bharati; private broadcasters; IITs, universities, and other academic institutions.]

We need to educate our 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 will develop adequate technical expertise on the various subjects related to landslide management. The state governments, if required, in association with the UGC, DST, MHRD, AICTE, etc., will introduce short-term Quality Improvement Programmes (QIPs) for teachers and professionals engaged in teaching subjects related to landslides. The new technical programmes, similar to those launched by various central ministries for college teachers, geoscientists, civil engineers, town planners, etc., for developing additional capacities in landslide management will also be taken up. The GoI will have to address the gap between the requirement and availability of qualified teachers conversant with natural hazards, especially with landslide assessment and mitigation techniques. All such training programmes will include evaluation and certification of trainees.

[Action: SDMAs/state DGMs; state governments; the MHRD; IITs, universities, and other academic institutions.]

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 at the undergraduate level, so that graduating doctors are able to handle emergencies with greater confidence.

The NDMA in consultation with the Ministry of Health and Family Welfare (MoH&FW), Medical Council of India (MCI) and other related agencies, will facilitate the introduction of subjects related to DM in the undergraduate medical curriculum.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the MHRD; MoH&FW; MCI.]

All architecture and civil engineering graduates will be taught in detail about all the aspects of landslides and related hazards in the hilly regions of India. These educational efforts will aim to improve 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, and improved laboratories and libraries in identified R&D institutions. These measures will enable these institutions to undertake research and execute pilot projects on the different aspects of landslides employing the latest technology, and to set pace setter examples that will build confidence amongst geoscientists, geo-technical engineers, and communities, with regard to landslide management. The results of these studies will also help to develop and update technical documents that will form an important part of the resource material prepared for training programmes on education, sensitisation, and training. The disaster management plans of the central ministries and departments concerned and the state governments will address these requirements in right earnest.

[Action: The AICTE in collaboration with IITs, universities and other academic institutions; the CoA.]

The curricula of IITs, National Institutes of Technology (NITs), engineering and architecture colleges, polytechnics, and universities will be suitably modified to incorporate basic knowledge about landslides and the techniques employed to control them. The NDMA along with the nodal agency will facilitate this process in collaboration with the MHRD, AICTE, CoA, and professional bodies of town planners to incorporate landslide education in their curricula.

[Action: The nodal ministry in consultation with the TAC and in collaboration with IITs, universities, and other academic institutions; the MoM-GSI; MHRD; AICTE; CoA.]

8.2.2 Community Education

The need for community education cannot be over-emphasised since the community is usually the first responder to a disaster and its role in containing damage is of prime significance. It is necessary that the government and communities involved, evolve a joint action plan together, aiming at spreading community awareness and developing community leadership. Such awareness will enable communities to ensure safer constructions.

Investments in disaster education, public awareness, community leadership development, and disaster education of unemployed youth, physically challenged, elderly, women, and school children will be encouraged.

[Action: The SDMAs in collaboration with the DDMAs; NGOs.]

8.3 Training

The NDMA and the nodal agency, viz., the GSI along with other knowledge institutions, with a view to popularising landslide education and giving momentum to research activities in India, will identify a number of leading technical institutes and earth science departments of universities which support such activities. Such institutions will also offer the services of experienced faculty members to participate in the activities specified in the Guidelines.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; NIDM; IITs, universities, and other academic institutions.]

The GSI and NIDM with the help of other knowledge based national institutions and the states' Administrative Training Institutes (ATIs) have been identified and entrusted with the responsibility of training administrative personnel from all central ministries and departments and state governments on the different aspects of landslides. As per the requirements, these organisations will evolve an action plan jointly in collaboration with the ATIs and other technical institutions to offer a comprehensive curriculum on landslide management in the form of training modules for the various target groups. The design, development, and delivery of the same will be initiated by October 2008.

The DGMs in landslide affected states have a significant number of geoscientists. Many of these will be involved in landslide hazard mitigation programmes and studies after proper training.

[Action: The SDMAs in collaboration with state DGMs.]

A large number of diploma holders are involved in construction activities at civil engineering and infrastructural project sites in landslide affected areas. Such training programmes will be offered to these professionals as well. The training modules will include both classroom and on-field training. The state governments will also evolve a formal framework for the certification of such professionals and adopt certification practices through short-term courses. Certification through online short-term courses and self-certification aids like CD-ROMs developed on similar lines as those developed by the CDMM can also be considered.

[Action: State governments in collaboration with the SDMAs.]

8.3.1 Training of Professionals

Geologists, geotechnical engineers, and professionals from other disciplines involved in landslide hazard investigation and management need to be kept updated with the latest global developments in this field, so that a well-trained workforce conversant with the latest technological advances is available to manage the hazard effectively. This can be done by sending these professionals abroad regularly to gain theoretical knowledge as well as practical experience on the application of the latest and most effective techniques. The training programmes will be systematically planned and executed, with extensive interdisciplinary exposure for generating a workforce trained in holistic landslide management.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the NIDM; MoM-GSI; IITs, universities, and other academic institutions.]

The GSI and NIDM in consultation with reputed knowledge institutions will develop comprehensive programmes for creating trainers from among trained faculty members of engineering and architecture colleges, and other professionals. The state governments/ SDMAs will identify potential trainers to develop training programmes at different levels. These training programmes will be pilot tested, critically evaluated, upgraded, documented, and peer reviewed at regular intervals. The training modules will be continuously updated based on evaluation and feedback from the participants.

[Action: The MoM-GSI in collaboration with the NIDM; IITs, universities, and other academic institutions; SDMAs; AICTE; CoA.]

In the initial phases, training will be imparted to all officers of landslide affected states, like engineers, geologists, geophysicists, and hydrologists from the 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 in the state departments, if any, will ensure that they have architects and engineers with a background in landslide-safe design and construction. Those who have undergone the 'Training of Trainers' programme will be responsible for training professionals through the network of professional societies. A timetable will be drawn up for these training programmes to give architects and engineers the opportunity to upgrade their skills in the required areas. The minimum acceptable standards of safety, as enumerated in the BIS codes, will be disseminated through professional organisations, and the training requirements will be integrated into the licensing criteria.

Landslide disaster management related search and rescue operations involve certain specialised activities and require expertise in areas like mountaineering, rock climbing, heli-slithering, heli-rescue, and trained dog squad capabilities. Specialised training modules for these will be developed by the NDRF in collaboration with national and international organisations working in this field. All NDRF battalions in landslide affected regions will be trained in these modules.

[Action: State governments in collaboration with the SDMAs; DDMAs; state DGMs.]

8.4 Capacity Upgradation

A mechanism will be developed to identify institutions active in the field of landslides, assess their capabilities, and enhance and strengthen

Areas where Training is Required

i) Geomorphological, geotechnical, hydro-geological and GIS based LHM with perception of mapping scales.

ii) Geotechnical investigation of landslides with particular reference to the characterisation of slopes, elucidation of landslide boundaries, representative undisturbed sampling from shear zones, handling of samples, simulated stress-path testing and stability analysis in terms of total and effective stresses.

iii) Techniques for monitoring slope surface and sub-slope movements, movement rates, and cross-linkage with rainfall records, piezometric profiles, and behaviour of buildings and structures on the slope.

iv) Slope modelling.

v) GIS based landslide hazard, vulnerability, and risk assessments.

vi) Slope kinetics, site effects, and earthquake induced landslides in seismic micro-zonation and risk assessment.

vii) Instrumentation of slopes, landslides, and avalanches, and early warning.

viii) Design of landslides and avalanche control measures with particular reference to the choice of technologies.

ix) Training of first responders in search, rescue and medical care.

x) Training of communities and local bodies.

xi) Training of visual, print and electronic media in the science of disaster management for improved and more objective reporting.

their capacities in terms of expertise, knowledge, and resources for the effective management of landslide hazards. The main areas requiring capacity development in the context of landslide disaster management are as follows:

i) The establishment of a nation-wide, organised, vibrant, pro-active, systematic, and scientific institutional mechanism that will replace the current piecemeal, ad hoc, and poorly recognised and appreciated landslide management practices.
ii) The 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.
iii) The strengthening of a few identified institutions, their units and departments in all states and union territories. If possible, their respective mandates/roles in providing/supporting pre- and post-landslide routine/specialised functions are to be redefined and enlarged.

[Action: The TAC in collaboration with the MoM-GSI.]

8.5 Documentation

The NDMA and GSI will facilitate the preparation of films, manuals, and other material targeting various stakeholders to inculcate landslide safety by following land zoning regulations. State governments will provide landslide safety material in multiple formats and languages, so that different groups of stakeholders can have the requisite information. The NDMA, GSI, NIDM and state governments/SDMAs will set up websites and portals to disseminate information related to landslide safety. 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 the natural and built environment.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; NIDM; SDMAs; DAVP; NGOs; IITs, universities, and other academic institutions.]

The state governments will assist specialists in the subject from academia and industry to prepare technical documents on landslides, which will provide technical specifications for the expansion of human settlements in hilly areas, and simple techniques for assessing landslide hazards 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.

[Action: The SDMAs in collaboration with the CoA; IITs, universities, and other academic institutions.]

The implementation of these Guidelines requires the participation of a wide spectrum of professionals.

The GSI and other knowledge institutions like the NIDM, IITs, NITs, and other professional bodies will generate and maintain a directory of landslide management professionals in India, containing their brief bio-data, and make this available to the state governments/SDMAs.

[Action: The MoM-GSI in collaboration with the NIDM; CBRI; CRRI; IITs, universities, and other academic institutions.]

The 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 prepared in the past have now become difficult to access or are out of print. The GSI will launch a special initiative to digitise these documents from various sources and archive them in electronic format in the data bank proposed for this purpose, giving due recognition to the source. The NDMA will help the GSI in obtaining these rare documents from the available sources.

[Action: The MoM-GSI in collaboration with the NIDM; CBRI; CRRI; DST; BRO; IITs, universities, and other academic institutions.]

8.6 Schedule of Activities for Capacity Development

Activity		2009		2010				2011	
		Sep	Dec	Mar	Jun	Sep	Dec	Mar	Jun
8A	Education in Schools and Colleges						Implement		
8B	Development of Knowledge Products, including Video films and Auto-Certification CD-ROMs for Different Target Groups, including School Children	M*			Implement				
8C	Technical Education						Implement		
8D	Training of Professionals	M*	M*				Implement		
8E	Upgradation of Institutions/Organisations	M*	M*				Implement		
8F	Documentation and Dissemination	M*	M*				Implement		
8G	Establishment of a Landslide Disaster Knowledge Network, to be Coupled with the National Disaster Knowledge Network	M*			Implement				
8H	Creation of a Network of Institutions with the Capacity and Expertise to Manage Landslides and Demonstrate Applications of State of the Art Technology in Stabilising Selected Major Landslides	M*			Implement				

M*: Meetings

9 Response

9.1 Introduction

The management and control of the adverse consequences of future landslide incidence will require coordinated, prompt, and effective response systems at the central and state government levels, and especially at the district and the community levels in the landslide affected areas. Since many components of the 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 the available resources.

Depending on the magnitude of the landslide and scale of the 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 different agencies like central government ministries and departments, state governments, district administrations, ULBs, PRIs, and other stakeholders for an effective post-landslide response.

[Action: Central ministries in collaboration with state governments/SDMAs; DDMAs; ULBs, PRIs]

Since some earthquakes trigger landslides, the IMD will immediately communicate the occurrence of an earthquake along with preliminary details to the SDMAs and GSI for initial assessment of earthquake induced landslides and dissemination of the appropriate alerts.

[Action: The IMD in collaboration with the SDMAs; MoM-GSI; NRSC.]

The preliminary assessment of the severity of the landslide is based on its magnitude and the amount of loss it inflicts on infrastructural elements and habitations.

Agencies like the BRO/state PWDs, state DGMs, forest departments, municipal/panchayat bodies will immediately communicate information on the occurrence of a landslide along with preliminary details like its location, magnitude, damage caused, etc., to the district emergency centre or district disaster management control room. These designated bodies will communicate this information to the state disaster management commissioner for onward transmission to primary nodes like the nodal agency, viz., the GSI and other nodes like the MHA and NRSC identified for this disaster. This will help the nodal agency, other central government departments, and state governments to undertake field observations for making an accurate assessment and planning follow-up action.

[Action: State governments in collaboration with state DGMs; BRO; MoEF; DoS-NRSC; DDMAs; State Resource Centres; NDRF; MoM-GSI; MHA; PRIs.]

The DM plans prepared by all the agencies concerned will incorporate detailed guidelines for their activities related to the impact of the landslide. The response component of the DM plans will consider the rapid deployment of the designated people, supplies, and logistics to the disaster site, with the functions of each functionary clearly defined. Each of the teams will be required to vacate the site as soon as their job is over because considering the nature of the hazard during the rainy season it is possible that they may be required at another site within a short duration. These plans will prescribe appropriate coordination mechanisms among all the agencies working in the affected areas.

9.2 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 local communities before the state machinery and specialised search and rescue teams arrive.

Trained and equipped teams consisting of local people will be set up in landslide prone areas to respond effectively in the event of a disaster.

[Action: DDMAs in collaboration with PRIs.]

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.

[Action: SDMAs in collaboration with the NDRF; PRIs; district administrations.]

The workforce employed by the organisations engaged in maintaining roads and highways located in hilly regions will also be trained in initial search and rescue operations and equipped with modern search and rescue equipment. 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), 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.

[Action: SDMAs in collaboration with the NCC; NSS; NYKS.]

9.3 Emergency Relief

Trained community level teams will assist in planning and setting up emergency shelters, providing relief to the affected people, identifying missing people, and addressing the needs of emergency medical care, water supply and sanitation, food and temporary shelter, etc., of the affected community.

These teams will also establish communication with the district authorities for arranging the evacuation of stranded people, particularly for vulnerable sections. Members of these teams will be made aware of the specific requirements of the disaster affected communities. These teams will also assist the government in identifying the most vulnerable people who may need special assistance when stranded following a large landslide on a highway, etc.

[Action: SDMAs/ DDMAs; district administrations.]

9.4 Incident Command System

All response activities will be undertaken at the local level through a suitably devised Incident Command System (ICS) and coordinated by the local administration through an Emergency Operations Centre (EOC). State governments will commission and maintain EOCs at appropriate levels for the coordination of human resources, relief supplies, and equipment.

[Action: State governments/SDMAs; district administrations; PRIs.]

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. GIS maps available with other sources, such as the district and municipal planning departments, will be compiled considering their potential application after a disaster. The state governments/SDMAs will undertake the training of personnel involved in the ICS. Any unusual occurrence should be immediately reported by the community to the authorities, so that its cognisance is taken care of.

[Action: State governments/SDMAs.]

9.5 Community Based Disaster Response

The DDMAs will coordinate with organisations like NGOs, voluntary agencies, self-help groups, youth organisations, women's groups, civil defence, home guards, and the community at large that normally volunteer their services in post-disaster situations.

The state government/SDMAs will utilise 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.

[Action: DDMAs in collaboration with the home guards; NGOs; NYKS.]

Natural disasters of large magnitude draw overwhelming humanitarian support from individuals and organisations. The relief and response activities carried out by such organisations will be coordinated and shall comply with the norms prescribed by the appropriate authorities.

After a disastrous landslide incidence, accurate information will be provided on the extent of the losses and details of the response activities through the electronic and print media. State governments will utilise different types of media, especially print, radio, television, internet, and SMS to disseminate timely and accurate information.

9.6 Role of Private and Corporate Sectors

The state governments will facilitate the involvement of the corporate and private sector and utilise their services and resources if offered to the government during the immediate post-disaster situation. The India Disaster Resource Network (IDRN) will be maintained and updated regularly so that locally available resources are utilised effectively in the case of emergencies.

The corporate sector, as a part of the Corporate Social Responsibility (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 for the movement of relief supplies. For instance, the Construction Federation of India (CFI) has set up the IDRN, which lists equipment and resources by type and the function performed, along with contact addresses of the controlling officers. The IDRN is a live system and is updated every quarter at both the district and state levels. These can be mobilised promptly at the time of emergency as part of the response. The state governments and district authorities will develop appropriate mechanisms to receive and optimally utilise all such assistance.

[Action: SDMAs.]

9.7 Specialised Teams for Response

The Central Government has set up eight NDRF battalions for providing rapid response to disasters. All 144 teams of the NDRF will be specially equipped and trained in landslide, avalanche and collapsed structure search and rescue operations. The NDRF battalions will also be provided with communication equipment like satellite phones for establishing continuous connectivity in every part of the country where landslides or other disasters can occur.

[Action: The NDRF.]

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 law and order, assisting in search and rescue, and in the transportation and certification of casualties. In case the landslide causes traffic disruptions for a long duration, the traffic police will 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, rescue and evacuation, protection of assets in evacuated areas, and management of relief camps and aid distribution centres.

To augment the capacities of the states, all state governments will raise from within their armed police force, an adequate strength of personnel for the State Disaster Response Force (SDRF) capable of responding to disaster situations. In addition, the police, fire services, home guards and civil defence need to be strengthened and upgraded to have adequate capacity to respond effectively to disasters.

[Action: State governments/SDMAs.]

The training and implementation of emergency response will be planned keeping in view the fact that the type of rescue operation varies with the nature of the landslide.

Snow avalanche search and rescue is a specialised technique involving probes, avalanche transceivers, trained avalanche dogs, etc. This also includes emergency on the spot first aid. Institutionalisation of avalanche search and rescue operations will be collaborative work involving the local administration, NDMA, and mountaineering institutes in the country. Local communities and NDRF personnel will be trained for search and rescue operations.

9.7.1 Civil Defence

In any disaster, the affected community has a major role to play, both as victim and necessarily as the first responder, as outside help only comes later. Having realised the significance of this, the GoI has already decided to revamp the civil defence set-up in the country. Civil defence, which was set up in the context of war to cover only important towns (225 in number), will now be utilised for disaster management as well. Each district of the country will now have a civil defence set-up which will cover the entire district. There will be about 18 persons employed on a full-time basis in each district, out of which eight will be trainers entrusted with the duty of training volunteers and wardens for response in DM.

Though the amendment of the Civil Defence Act to include DM in its charter of duties is in process, the GoI has already included this duty through an executive order.

All the revamping proposals will be implemented in a phased manner. In the first phase (year 2008-09) 40 major civil defence towns have been identified which will now cover entire districts concerned. Equipment for training and response has already been decided on and is in the process of being procured and distributed to the concerned 40 towns/districts. Till such time as the revamping takes final shape, the states should start using the existing set-up for recruiting and training more volunteers in large numbers and spreading awareness on the different aspects of DM. The NDMA is also in the process of preparing a comprehensive curriculum for civil defence training at different levels in DM. This curriculum will be circulated by the end of January 2009.

The state governments/SDMAs and DDMAs will coordinate the human resources of the civil defence set-up as well as those of other agencies for performing/responding to various disaster related activities.

[Action: State governments/SDMAs; DDMAs.]

9.7.2 Trigger Based Categorisation

The MHA in consultation with the nodal agency has developed a colour coded categorisation of landslide stages for triggering appropriate alerts within the government machinery. Three colour coded stages (red, orange, and yellow) were defined on the basis of dimension, location, and damages caused by the landslide. The nodal agency and other knowledge institutions in coordination with the state governments will take up the geotechnical investigation of landslides falling within the high alert red category stage and suggest appropriate remedial measures. Landslides in this category are of large dimensions that have occurred at or in the close vicinity of urban settlements or fairly large rural settlements, inflicting heavy loss of human life and/or urban infrastructure. This also includes landslides that block busy pilgrimage routes during the peak season, resulting in hardship to thousands of pilgrims, and landslides which result in blocking courses of relatively large natural drainages with or without the formation of landslide dams. Landslides of small or moderate dimension located at the fringes or away from human habitation and causing limited loss/damage are categorised under the medium and low alert, viz., yellow and orange categories, respectively. The management of these shall be taken up by the district and state administrations. The GSI and other knowledge based organisations will provide assistance to state governments, and train professionals on a need basis for geotechnical studies and remedial measures. However, the details of all landslide occurrences have to be communicated to the nodal agency for the maintenance of a national database.

9.8 Emergency Logistics

Specialised heavy earthmoving and search and rescue equipment are required immediately after a landslide to clear debris and carry out search and rescue operations of trapped people in huge masses of debris.

State governments will compile a list of such equipment, identify their suppliers, and enter into long-term agreements for their mobilisation and deployment in the event of a landslide disaster. The IDRN, which is a web based inventory of information on emergency equipment and response personnel available in every district, will be revised and updated every three months. A mechanism for deploying the required equipment at very short notice in case of the occurrence of a disastrous landslide will be in place.

[Action: State governments/SDMAs.]

The provision of temporary shelters and basic amenities for stranded travellers would require pre-planning. The DM plans at the state and district levels will address this issue in detail. It is also being considered that semi-permanent shelters with basic amenities be established at certain critical locations that are affected by landslides that frequently result in people getting stranded for long periods.

[Action: SDMAs in collaboration with the DDMAs.]

In the event of a large number of casualties, the respective states will develop systems for the proper identification of the deceased, recording the details of victims and handing over bodies to their kin as quickly as possible.

9.8.1 Emergency Medical Response

Whenever required, a prompt and efficient emergency medical response will be provided by QRMTs, mobile field hospitals, Accident Relief Medical Vans (ARMVs) and heli-ambulances that are in place for other disasters like earthquakes.

They 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. Resuscitation, triage and medical evacuation of victims who require hospitalisation will be done in accordance with the SOPs.

[Action: SDMAs in collaboration with the state medical and health departments and private hospitals.]

The emergency medical plan will be operationalised immediately on receiving information from a landslide affected location. Hospitals will create capacity for the anticipated number of beds by discharging non-critical patients, and mobilising doctors and support staff, additional orthopaedic equipment and supplies at short notice in landslide affected areas, during the rainy season when the majority of landslides occur. After the occurrence of a disastrous landslide, an information centre will be set up for disseminating accurate information to public, relatives of victims, and the media at the district level in case the number of casualties is high.

The medical response to disaster situations has been delineated in detail in the *National Disaster Management Guidelines: Medical Preparedness and Mass Causality Management*, section 5.1, p. 49.

9.9 Damage and Loss Assessment

It is very important to assess the losses resulting from a landslide as this is an important factor in deciding whether it is economical to treat it or not. Landslide-loss data are generally categorised 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 landslide or from flooding caused by the breach of a natural dam formed due to the obstruction of natural drainage due to landsliding.

Some examples of indirect landslide losses are:

i) The loss of industrial, agricultural, and forest productivity; and tourist revenues as a result of damage to land or facilities, or interruption of transportation systems.

ii) Reduced real estate values in areas threatened by landslides.

iii) The loss of tax revenues on properties devalued as the result of landslides.

iv) Measures that are required to be taken to prevent or mitigate additional landslide damage.

v) Adverse effects on water quality in streams and irrigation facilities outside the landslide area.

vi) The loss of human or animal productivity because of injury, death, or psychological trauma.

vii) Secondary physical effects, such as landslide-caused flooding, for which losses are both direct and indirect.

Indirect costs may exceed direct costs. Unfortunately, most indirect costs are difficult to evaluate and thus often ignored or when estimated, are too conservative. More often, however, as financial information is often of a discreet nature and in many instances, not in the public domain, people and entities prefer to keep their losses a private matter.

Currently, damage assessment in the case of natural disasters in many countries is done using aerial photography, videography, and ground checks. This is not regular practice in India. With the recent advances made in remote sensing technology, it has become possible to use it effectively even for the assessment of damages resulting from landslides. In order to be able to use EO data for landslide damage assessment, the following criteria must be fulfilled:

i) High temporal and high spatial resolution products should be made available.

ii) Images should be taken at the time of the disaster or a few days after the event. These can support relief efforts effectively.

This will be satisfied partly by existing and planned high resolution stereo optical and SAR systems. In cases where the damage is extensive, either by a single large event or by many smaller events spread over a large area, there is a need for very high resolution images before and after the disaster. These can be used to supplement the data obtained from airborne and ground exercises.

9.10 Schedules for Response Activities

All the response activities outlined above require detailed planning and comprehensive workforce mobilisation. The schedule for the same is given on the next page.

Activity		2009		2010				2011	
		Sep	**Dec**	**Mar**	**Jun**	**Sep**	**Dec**	**Mar**	**Jun**
9A	Trigger-Based Categorisation					Implement			
9B	Response Plans for Different Trigger Levels					Implement			
9C	Incident Command System					Implement			
9D	Other Emergency Response Teams	M*					Implement		
9E	Emergency Equipment and Logistics	M*	M*				Implement		
9F	Loss Assessment	M*	M*				Implement		

M*: Meetings

10 Research and Development

10.1 Introduction

Research and development in the field of landslides has attracted very little attention in India, while the same is gaining momentum globally. Intense R&D activities are required to be taken up by institutions and individual experts in order to achieve the goal of effective LHM in the country.

Central ministries, state governments, and funding agencies will encourage, promote, and support R&D activities to address current challenges, offer solutions, and develop new investigation techniques, with the application of the latest developments in remote sensing, communications, and instrumentation technologies.

[Action: SDMAs in collaboration with the MoES; MoM-GSI; DST; DoS-NRSC; central ministries; state governments.]

These R&D activities will also strive for the development of new cost-effective treatment measures required to stabilise unstable slopes and the development of economical and effective early warning systems wherever necessary. Education in landslide management will be meaningful only if the students are exposed to the latest technological developments and are made aware of local landslide problems and the lessons learnt from past experiences.

The nodal agency and respective state governments will constitute multi-institutional and multi-disciplinary teams for carrying out post-landslide field investigations to assess the hazard potential and estimate the risk involved. They will also document the lessons and disseminate the same to target audiences within the state and recommend cost effective practical measures. The nodal agency will oversee the progress of these efforts in a systematic manner.

[Action: The MoM-GSI in collaboration with the SDMAs; state governments; DST; CBRI; CRRI; IITs, universities, and other academic institutions.]

10.2 Research Issues

There are a number of important areas of research which need to be addressed that will lead to the standardisation of investigating and operating procedures, more reliable LHZ mapping, vulnerability assessment and risk analysis, cost effective landslide stabilisation, user friendly multi-hazard mapping, damage assessment, and the introduction of state-of-the-art technology. A considerable amount of R&D work is needed to develop a basic understanding of various types of landslides in India, their causative factors, and mechanisms of development, with particular reference to anthropogenic factors.

10.2.1 Standardisation

Some institutes and organisations carry out both LHZ mapping and site specific studies of landslides. However, there is no uniformity in the methodology, selection of the scale of LHZ mapping and usage of landslide terminology. As a result, a lot of confusion is created among geoscientists. Standardisation of the terminology and classification of landslides, thematic mapping scales and the introduction of mapping methodologies for different scales will be accorded priority. Scientific and systematic approaches for the site specific study of landslides and procedures of ground validation of LHZ maps are equally important, as is the development of scientific approaches to integrating the landslide hazard into multi-hazard mapping.

R&D activities will be intensified to standardise 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 landslides, and procedures for the ground validation of LHZ maps will be prepared immediately.

[Action: The nodal ministry in consultation with the TAC and in collaboration with BIS; IITs, universities, and other academic institutions.]

A research programme will be undertaken by knowledge based organisations/institutes of India for developing a scientific approach of integrating the landslide hazard into multi-hazard mapping.

[Action: The nodal ministry in consultation with the TAC and in collaboration with DST; IITs, universities, and other academic institutions.]

10.2.2 Earthquake-Induced Landslides

An improved understanding of earthquake-induced landslides will call for research on the estimation of site effects in different geomorphological settings. Research to enhance the understanding of the reactivation of old and recent landslides and initiation of first time earthquake-triggered landslides will be encouraged. Other topics of research may include run-out effects of flow slides resulting from earthquake liquefaction.

A research programme will be developed so that this aspect of landslide investigation is understood and appropriate remedial measures may be undertaken before an earthquake strikes. Knowledge based institutes, like IIT-R, IIT Kanpur (IIT-K), etc., will be encouraged to take up such programmes.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the DST; IITs, universities, and other academic institutions.]

10.2.3 Design of Surface and Sub-Surface Drainage Systems

In India the rainwater from the landslide surface is generally drained out through surface drainage systems comprising lined catch water drains, contour drains, and chute drains (often of the cascading type). In the absence of any data about the catchment characteristics of a particular slope, the design of these drains is generally done on the basis of the expert's knowledge. On the other hand, sub-surface water management of the landslide mass or distressed hill slope is rarely practiced in our country. As a result, some of the slides requiring only sub-surface drainage arrangement for stabilisation are provided with other makeshift remedial measures, triggering the landslide instead of containing it. Moreover, there is no systematic approach or established mechanism to test the efficacy of the implemented surface drainage measures.

Efforts will be directed towards R&D in scientific and innovative designs of surface and sub-surface drainage systems, which is the most important component of landslide stabilisation measures.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the DST; IITs, universities, and other academic institutions.]

10.2.4 Instrumentation for Geotechnical Investigation

In the context of scientific research, geotechnical instrumentation is primarily needed to unfold the mechanism of a landslide, collect evidence and data for reliable slope analysis and engineering, and remove uncertainties by validating assumptions and checking the efficacy of control works.

10.2.5 Development of Early Warning Systems

There are many major landslides located either along busy road corridors or close to thickly populated townships/important civil engineering structures that require a huge amount of treatment cost.

Such landslides will be selected for early warning through a consultative mechanism in association with state governments and local bodies. The development of appropriate early warning systems may be undertaken for such identified landslides. Knowledge based institutes/organisations with expertise and experience in this area will be encouraged to take the lead. The development of early warning systems by real-time monitoring of some selected landslides may be undertaken with a view to firming up both the early warning technology and early warning thresholds. Correspondence between rainfall thresholds and landsliding will be developed for selected areas based on in-depth scientific studies.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the DST; state governments/SDMAs; district administrations; IITs, universities, and other academic institutions.]

10.2.6 Landslide Dams

Dams generated by landslides are mainly reported in the narrow valleys of the Himalayan mountainous terrain. These may cause devastation by flash floods due to sudden breaching. Except for 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, preliminary investigation cannot be taken up immediately after their formation.

A mechanism must be developed by which the information regarding the formation of a landslide dam may be communicated to the relevant authorities in the shortest possible time. It is proposed that the NRSC be entrusted with this task.

[Action: The NRSC.]

The following aspects of landslide dams can be taken up for R&D:

i) Dam break analysis.

ii) Methodologies for providing controlled outlets for dewatering the created reservoir.

iii) Procedure of risk assessment.

iv) Procedure for identification of potential sites of formation of landslide dams and monitoring techniques.

10.2.7 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 requirements for the development of run-out and return period modelling of landslides is to map the landslides, identify the causes and mechanism of failure, establish correlation between triggering agents and the initiation of slope failure, determine shear strength parameters of the slope forming material, assess the hazards, vulnerability, and elements at risk, etc. In some countries like Italy, New Zealand, and the USA, this type of modelling is done for individual slides as it cannot be successfully done for a vast area affected by numerous landslides in the absence of a reliable historical landslide inventory database. Since expertise in this area is not available within the country, an R&D programme will be taken up in collaboration with international institutes having expertise in this field like the ITC, The Netherlands.

[Action: The nodal ministry in consultation with the TAC and in collaboration with IITs, universities, and other academic institutions.]

10.2.8 Snow Avalanches

Simulation, snow cover modelling, avalanche forecasting, snow cover parameter monitoring using optical imagery and microwave data, and the development of virtual reality based snow cover variability visualisation are some of the fields of active research. R&D on these and other related fields will be promoted.

The SASE, in collaboration with knowledge institutions and the NDMA, will visualise, design, and implement R&D programmes for snow avalanche studies.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the SASE; IMD; DST; IITs, universities, and other academic institutions.]

10.2.9 Emerging Concerns

Global warming and climate change are the most critical areas of concern that can have significant consequences on natural hazards including landslides and snow avalanches.

The fragile mountain systems in India, where most of the landslides occur, are exposed to increasing risks due to climate change. In the coming decades, the negative impact of climate change will be exacerbated if mounting human-induced pressures and unplanned urbanisation grows unchecked.

Whereas the whole range of issues connected with climate change, including policies and operation strategies, are beyond the scope of this document, the unfolding consequences of climate change, insofar as mitigation of landslide hazards are concerned, deserve urgent attention. Rich global experience, especially in understanding and managing uncertain weather patterns and landsliding, 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.

Research programmes to study this aspect will be encouraged.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the DST; IMD; IITs, universities, and other academic institutions.]

10.3 Important R&D Activities

R&D areas of importance are listed below. This list is only suggestive and will be reviewed from time to time in the backdrop of emerging national priorities.

i) The refinement of methodologies for carrying out LHZ mapping both at the macro and meso scale, in order to give a realistic picture of the hazard.

ii) Systematic scientific methods of landslide hazard vulnerability assessment and risk evaluation on the GIS platform.

iii) The integration of landslide hazards into user-friendly multi-hazard mapping. Projection of multi-hazard risk scenarios.

iv) The revisiting of past major landslide disasters for scientific post-mortems and documentation of the lessons learnt.

v) The application of recent technological developments in the fields of instrumentation, remote sensing, software and communication technologies for landslide studies.

vi) The development of simple, quick, and effective methodologies for assessing direct as well as indirect losses due to the occurrence of landslides.

vii) The quantification of environmental degradation, anthropogenic impact, cost of loss of land, agricultural produce, livelihood, and traffic delays.

viii) The establishment of best practice examples of deterministic and probabilistic modelling methodologies for conducting detailed stability analysis of complex natural and man-made slopes and active landslides.

ix) The scientific design of surface and sub-surface drainage systems, technology for their speedy installation, and evaluation of their efficacy.

x) The development of innovative techniques of landslide control, especially the mechanised construction of complex sub-surface drainage networks.

xi) The development of light rugged geotechnical investigational equipment suitable for rugged and inaccessible areas.

xii) The development of cheap and reliable instrumentation techniques for slope monitoring and installation of early warning systems.

xiii) The systematisation of search and rescue operations, and the development of effective equipment for the same.

xiv) The development of simple and easy to install instrumentation and slope monitoring equipment for real-time early warning, including early warning thresholds and criteria.

xv) The development of a predictive understanding of landslide processes and triggering mechanisms.

xvi) Regional real-time landslide warning systems based on threshold values of rainfall; real-time monitoring and establishment of early warning systems in the case of landslides that pose a substantial risk to developmental gains.

xvii) The development of methodologies for assessing potential co-seismic landslides.

xviii) Fundamental mechanisms of earthquake-induced and earthquake-triggered landslides.

xix) Remediation practices based on multi-disciplinary field investigations suitable for local conditions.

xx) Methodology for the identification of potential sites of landslide dams.

xxi) Fashioning of landslide rescue operations according to their typology.

xxii) Reservoir induced landslides, coastal landslides, submarine slumping, and tsunami related landslides.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; DST; CBRI, CRRI, CDMM; BRO; NRSC; IMD; CWC; state governments; IITs, universities, and other academic institutions.]

Besides, post-disaster scenario analysis and simulation modelling are extremely useful for undertaking long-term disaster management programmes and for strengthening preparedness, mitigation, and response efforts against landslide hazards. Risk assessment and scenario projections require data for all the 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 NDMA, with the support of the nodal agency, the GSI, will encourage the development of standardised methodologies for landslide risk assessment and scenario development. It will also support studies to collect data and required knowledge, develop state-of-the-art literature and reports, select topics and evolve a procedure for undertaking pilot projects related to detailed investigations for stabilising major hazardous landslides, and the development of early warning systems.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; DST; NIDM; BIS; IITs, universities, and other academic institutions.]

The quantification of the landslide risk for a specified area requires detailed information on a number of factors, namely, topography, geomorphology, geology, climatic conditions, land use practices, land cover patterns, and characteristics of surface slope forming material. The reliability of landslide hazard maps will depend on the accuracy of the 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. LHZ maps will be prepared based on advanced research studies carried out by knowledge institutions, to include earthquake induced landslides in areas with high seismic risk.

Studies will be undertaken to evolve procedures so that investigations, maps and drawings of landslides in different geographical regions of the country are easily available to users in a form that can be easily comprehended.

There is an urgent need to develop mechanisms to transfer the results of R&D efforts to the public domain so that these can be utilised by scientists/technologists engaged in LHM operations.

The success of all these efforts will depend on the prior presence of a system with streamlined procedures for the speedy funding of priority/fast track projects. The mechanism for the evaluation of project proposals, periodic reviews, and final reviews will be an integral part of the system.

10.4 Areas Requiring Special Attention

There are many issues in landslide disaster management, which are detailed in this document at various places and require special attention from planners and implementing agencies. The gap issues have been identified and these will be bridged in the near future in a planned manner. These issues include:

i) The effective management of landslide disasters in India would require detailed studies using state-of-the-art technologies, which is not practiced at present, and needs to be encouraged.

ii) The practice of real-time monitoring of potentially threatening landslides is required to avert disasters by early warning. This is currently absent in India.

iii) In current landslide disaster management practice, the investigating and implementing agencies are generally different. This results in fragmented accountability and communication gaps. Therefore, it will be ensured that the recommendations of the investigating agency will be carried out by the implementing agency in close association or consultation with the former.

iv) Partial implementation of stability measures are understandably ineffective, and this results in the reoccurrence of landslides in general. Every landslide management project must ensure the full implementation of treatment measures in a single working season and take recourse to monitoring their efficacy in the post-implementation stage.

v) The process of data collection is required to be systematised. Sharing of data among institutions engaged in landslide studies, landslide disaster management and communities at large will be encouraged through effective networking.

vi) The culture of the observational method of design and construction will be promoted to help engineers and builders effectively deal with uncertainties. The method helps in the modulation of designs based on actual ground realities as the work progresses.

vii) The culture of monitoring the efficacy of control measures will be promoted to enhance the confidence level in design and add value to it if the situation so demands.

viii) Good guidelines are not available on information and material for courses and training. The GSI, NIDM and other knowledge institutions will be encouraged to bridge this gap.

ix) There is a lack of an extensive network of rain gauges in country. Due to this it is very difficult to attempt correlation between rainfall and landslide activity. Proper coordination with the IMD is needed for installing a network of automatic rain gauges at desired locations. In this connection it is necessary that a pilot project of 20 conspicuous landslides in different regions of the country, preferably located in proximity to important townships or thickly populated localities, is taken up initially for rain gauge installation, and if possible, installation of at least two piezometers. The results and lessons learnt will be disseminated to all concerned in three-four years. The installation of automatic rain gauges required for this has to be integrated with the proposed programme of the IMD for installing automatic rain gauges at pre-selected locations in the country. The IMD will also provide daily rainfall data from existing rain gauges on a daily basis to the data centre for landslides so that the same can be utilised by agencies or individuals engaged in such studies. The concerned institutions will be identified.

x) Initially, five landslides will be identified for detailed study. It is proposed that organisations/institutions engaged in landslide studies, government or private, be identified/selected and given the responsibility for this work in coordination with the BRO and the respective state governments.

xi) Material and human resources available in the country will be identified so that studies that are to be taken up in relevant fields are properly planned and realistic capacity building programmes designed.

xii) The gaps between the landslide management systems being practiced in India and those being followed internationally will be identified and attempts will be made by all agencies engaged in landslide disaster management in the country to bridge these gaps so that the latest systems practiced elsewhere are also followed in India.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the SDMAs; MoM-GSI; IMD; DST; NIDM; BRO; NRSC; CWC; IITs, universities, and other academic institutions.]

11 Implementation of the Guidelines—Preparation of Landslide Management Plans

11.1 Plans

Comprehensive DM plans will be prepared at the national, state and district levels. At the national level, the DM plan will focus on various aspects of DM including preparedness, mitigation and response. These plans will clearly identify the roles of key stakeholders for each disaster level and also include assessments of their own response capacities.

In accordance with the various disaster specific guidelines laid down by the NDMA, the NEC will prepare a National Disaster Management Plan, incorporating the DM plans prepared by the central ministries/departments and state governments for landslide affected states and districts.

This plan, to be approved by the NDMA, will include various aspects of landslide management. The main features to be included in the plan are:

i) Preparation of state and district level DM plans with the aim of managing landslide hazard.

ii) Revision of town planning bye-laws and adoption of model land use bye-laws in hilly areas.

iii) Wide dissemination of model land use practices in hilly areas.

iv) Training of trainers in professional and technical institutions.

v) Training of professionals like engineers and geologists for landslide mapping, investigation techniques, analysis, and observational practices.

vi) Launching public awareness campaigns on landslide hazard and risk reduction, and sensitising all stakeholders on landslide hazard mitigation.

vii) Establishing appropriate mechanisms for compliance reviews of all land use bye-laws in hilly areas.

viii) Preparing an inventory of existing landslides, active or inactive, in India.

ix) Developing an inventory of the existing built environment in areas around existing landslides and in high hazard zones as per the LHZ maps.

x) Assessing the status of risk and vulnerability of the existing built environment.

xi) Preparation of DM plans by educational and health institutes/organisations, government offices, etc., and carrying out mock drills for enhancing preparedness in vulnerable areas.

xii) Strengthening the EOC network.

xiii) Streamlining the mobilisation of communities, government agencies, the corporate sector, and other stakeholders.

xiv) Preparing community and village level DM plans, with specific reference to the management of landslides.

xv) Developing simple and effective information and warning dissemination systems that can reach affected communities in far flung areas clearly and in time.

xvi) Introducing landslide safety education in schools, colleges and universities.

xvii) Strengthening landslide safety R&D in professional technical institutions.

xviii) Preparing documentation on the lessons learnt from previous landslide incidences, and their wide dissemination.

xix) Preparing an action plan for upgrading the capabilities of organisations and institutions involved in landslide disaster management studies with clear roadmaps and milestones.

xx) Developing appropriate risk transfer instruments by collaborating with insurance companies and financial institutions.

xxi) Operationalising the SDRF battalions in the states.

xxii) Enforcing and monitoring the compliance of land use and town planning bye-laws, and other safety regulations in landslide prone hilly areas.

[Action: Central ministries in collaboration with the NEC; state governments.]

The time lines proposed for the implementation of various activities in the Guidelines are considered both important and desirable, especially in the case of those non-structural measures for which no clearance is required from central or other agencies. Precise schedules for structural measures will, however, have to be evolved in the landslide management plans that will be followed at the central ministries/state levels, duly taking into account the availability of financial, technical, and managerial resources. In case of compelling circumstances warranting a change, consultation with the NDMA will be undertaken well in advance for any adjustment, on a case to case basis.

11.2 Plans of Central Ministries and Departments

The central ministries and departments concerned will prepare their DM plans which will be in accordance with the National Guidelines on the preparation of state disaster management plans and shall cover all aspects of the disaster cycle for every disaster, including landslides.

These plans will clearly indicate the actions to be taken, the allocation of tasks among the various functionaries, the SOPs to be followed, the methodology for carrying out the tasks specified and the time lines for their execution. Mock drills will be carried out to test the efficacy of implementation of these plans by the agencies falling within the purview of various ministries/departments and other stakeholders at regular intervals.

[Action: The MHA in collaboration with central ministries; the MoM-GSI.]

DM plans will necessarily address worst case scenarios and cover various aspects of management like response, risk situation, awareness, information, and communication. Since some disasters may transcend geographic boundaries, these plans will also recognise the importance of effective networking and coordination of different levels of the response mechanisms.

The responsibilities for managing location specific landslides often rests with the ministries (Table 12.1) and departments of the central and state governments, local authorities, public sector undertakings, and the corporate sector. Inter-ministerial coordination will go a long way in providing holistic perception and concerted effort in mitigating landslide hazards.

11.3 Plans of State Governments

In addition to preparing their DM plans, the state governments with areas affected by landslides will also encourage the preparation of community preparedness plans to address their own special features, outline the linkages of the various state support systems, and the jurisdictions of each of these departments.

The GoI has initiated the GoI-UNDP Programme on Disaster Risk Management (DRM) to encourage the development of district, block, taluka/tehsil, and village DM plans, which will be further strengthened. The existing plans will be modified, wherever required, in order to streamline and optimise the response systems. These DM plans will be widely disseminated among various stakeholders for creating greater public awareness. These plans must indicate the responsible departments for carrying out specific tasks along with time lines for their implementation. It is required that the state DGMs be made an integral part of these plans as these are likely to play an important role in the management of landslides as well as other natural disasters.

[Action: State governments/SDMAs.]

Authorities in charge of educational institutions will prepare landslide preparedness plans and conduct mock drills in landslide affected areas. In many cases frequent landsliding activity results in travellers getting stranded. They may get exposed to harsh weather due to the non-availability of shelters at isolated locations. The plans should therefore include the identification of such locations for the construction and maintenance of shelters, at least during the periods when landslides occur frequently.

The DM plans will comply with the National Guidelines on the preparation of state disaster management plans and the guidelines of the SDMA, if any, and incorporate all the features of the EOCs including their establishment and operation.

[Action: State governments/SDMAs.]

11.4 Disaster Management Plans of the Nodal Agency

The responsibilities of the GSI as the nodal agency include coordinating all activities related to landslide hazard mitigation, monitoring the occurrence of landslides anywhere in India with the assistance of various departments of the central and state governments, coordinating and carrying out preliminary investigations of these incidences, reporting the same to various designated functionaries in the GoI and state governments, and carrying out LHZ mapping and other relevant studies.

The GSI will set up a secretariat at an appropriate place for the purpose of coordinating nationwide activities, carrying out landslide studies in different fields related to landslides either independently as departmental programmes or in collaboration with other agencies in studies that require multi-disciplinary and multi-institutional inputs.

[Action: The MoM-GSI.]

The GSI maintains a primary node of the Disaster Management Support (DMS) network that provides continuous connectivity with states vulnerable to natural disasters. This system would

Table 11.1: Roles of the Central Government Ministries and the Need for Inter-Ministerial Coordination in the Context of Landslide Management and Environmental Protection

Ministry of Environment and Forests	Concerned with the protection of the lithosphere as a component of the environment, and is responsible for putting in place policies, strategies, and action plans to protect mountainous landscapes and the associated environment.
Ministry of Mines	The GSI specifically addresses landslides.
Ministry of Home Affairs	The nodal ministry responsible for disaster management as a whole.
Ministry of Defence	The SASE and Defence Terrain Research Laboratory deal with snow avalanches and landslides.
Ministry of Power and Energy	The National Thermal Power Corporation and National Hydroelectric Power Corporation face landslides on many of their project sites.
Ministry of Urban Development and Poverty Alleviation	Responsible for projects connected with housing and human settlement. The CPWD and BMTPC deal with construction and hazard maps in landslide prone areas.
Ministry of Surface Transport	The BRO deals with snow avalanches and landslides along roads and highways. The IRC has a committee on DM.
Ministry of Water Resources	Responsible for the development of water resources and especially responsible for landslide dam related problems.
Ministry of Railways	Landslides affecting the railway network.
Ministry of Science and Technology	The DST promotes R&D on the diverse aspects of landslides, climate change, etc. The Department of Earth Sciences and laboratories of the CSIR are also engaged in the study of diverse aspects of landslide mitigation.
Ministry of Earth Sciences	Newly constituted ministry responsible for earthquakes, landslides, rainfall, and coastal disasters.
Ministry of Culture	Responsible for the protection of archaeological monuments, cultural and natural heritage threatened by landslides.
Ministry of Tourism	Responsible for the development of tourism in ecologically fragile areas.

help in the communication of disaster related information on a real-time basis. The availability of information on a real-time basis would also help the GSI to send officers or coordinate with geoscientists of the DGMs of landslide affected states to carry out preliminary investigations of landslides occurring in any part of the country on an emergency basis and communicate reports to the designated authorities. The GSI will develop an effective information system in consultation with states affected by landslide hazard so that all information regarding landslide occurrence is communicated to the DMS control room of the GSI on a real-time basis so that necessary action is initiated. The SOPs have already been developed for this purpose by the MHA in consultation with the department.

The GSI, along with the primary node of the DMS network, will set up a data management facility where all the data related to landslides, including inventory will be stored and made available to bona fide users.

[Action: The MoM-GSI.]

As the nodal agency for landslide management, the MoM-GSI will prepare its Landslide Management Plan (LMP) based on the guidelines laid down by the NDMA.

The various aspects of the LMP prepared by other central ministries/departments, state governments and other stakeholder groups will be considered in the LMP prepared by the GSI. The GSI, in consultation with the NDMA, will also prepare a comprehensive plan for the upgradation of the capabilities of the department with a clear roadmap and milestones.

[Action: The MoM-GSI.]

The GSI, as the nodal agency for landslides in the country, will be assisted by all the concerned agencies involved in landslide management.

11.5 Implementation of Landslide Management Plans

11.5.1 Institutional Mechanisms

The development and implementation of disaster plans will be a coordinated programme of the NDMA, GSI as the nodal agency, and the national, state, district, and local administrations.

The capacity and potential of other government organisations, knowledge institutions and academic institutions will be harnessed and incorporated into the national landslide hazard mitigation endeavour.

[Action: The MoM-GSI in collaboration with SDMAs; DDMAs; district administrations; local administration.]

The NEC includes the secretary to the GoI of the ministry or department having administrative control of DM, as well as the chairperson and secretaries to the GoI in the Ministries/Departments of Agriculture, Atomic Energy, Defence, Drinking Water Supply, Environment and Forests, Finance (Expenditure), Health, Power, Rural Development, Science and Technology, Space, Communications, Urban Development, Water Resources, and the Chief of the Integrated Defence Staff of the Chiefs of Staff Committee as members. The NEC as the executive committee of the NDMA is statutorily mandated to assist the Authority in the discharge of its functions and ensure compliance of the directions issued by the central government, and in preparing the National Plan and getting it approved from the NDMA and performing such other functions as may be required by the NDMA. The NEC will be responsible for preparing the National Plan on the basis of these Guidelines, getting it approved by the NDMA, and subsequently for its operationalisation. The NEC will also require a department or an agency of the government to make available human or material resources for handling threatening disasters, emergency response, and for rescue and relief. In the event of a disaster threat or actual disaster it will coordinate the response and perform such functions as may be required by the NDMA.

[Action: NDRF in collaboration with the GSI; BRO.]

The National Disaster Response Force (NDRF) mandated by the DM Act, 2005, will address, in close collaboration with all other field level agencies, all concerns regarding the response to the threat of landslide disaster or other disasters if and when these arise or occur.

[Action: NDRF.]

The general superintendency, direction and control of this force shall be vested in and exercised by the NDMA and the command and supervision of the force shall vest in an officer to be appointed by the Central Government as the Director General of the NDRF.

The NDRF personnel will be equipped with the most modern search and rescue equipment and will undergo landslide specific training to be able to effectively deal with diverse types of landslides and other mass movements and familiarise themselves with the case records of some of the major landslide events.

[Action: The NEC in collaboration with the NDRF.]

The role of the GSI, the nodal agency in the management of landslide hazards, will be to maintain a liaison with the NDMA, MHA, central and state government agencies and to coordinate and facilitate landslide DM programmes through the NDMA. Besides, the GSI will continue with landslide investigations in various states and union territories under its annual field season programmes, keeping in mind the overall framework of these Guidelines.

The BRO, DTRL, SASE, GSI, and other institutions dealing with landslides and other mass movements will suitably improve their capacity to meet present as well as future challenges in the landslide sector, including the modernisation of investigation and mapping methodologies, and application of satellite, information, and communications technologies.

[Action: The BRO; DTRL; MoM-GSI; SASE; CBRI; CRRI; CDMM; NRSC; ISRO; Department of Information Technology.]

In case a major landslide disaster occurs, the DM departments/commissioners in the states concerned will deal with the rescue and relief operations.

[Action: State governments in collaboration with the district administrations.]

The state governments will establish SDMAs, headed by the respective chief minister in landslide affected states to lay down policies and plans for DM in the state. The SDMA will approve the state plan in accordance with the guidelines laid down by the NDMA, coordinate the implementation of the state plan, recommend the provision of funds for mitigation and preparedness measures and review the developmental plans of the different departments of the state to ensure the integration of prevention, awareness, preparedness, and mitigation measures.

[Action: State governments/SDMAs.]

The state governments will constitute State Executive Committees (SECs) to assist the SDMA in performing its functions. The SEC will be headed by the chief secretary to the state government and will coordinate and monitor the implementation of the national policy, the national plan, and the state plan. It will also provide information to the NDMA relating to different aspects of DM.

At the district level, the District Disaster Management Authority (DDMA) headed by the district magistrate, with the elected representative of the local authority as the co-chairperson, will act as the planning, coordinating and implementing body for DM and take all necessary measures for the purposes of DM in the district in accordance with the guidelines laid down by the NDMA and SDMA.

DDMAs will prepare the district DM plans including the response plan for the district, and will coordinate and monitor the implementation of the national policy, state policy, national plan, state plan, and district plan and ensure that the guidelines for prevention, mitigation, preparedness, and response measures laid down by the NDMA and SDMA are followed by all departments of the government at the district level and also by the local authorities in the district.

[Action: The DDMAs.]

Local bodies include PRIs and ULBs such as municipal corporations, municipalities, district and cantonment boards, and town planning authorities responsible for the control and management of civic services.

These bodies will ensure DM capacity building of their officers and employees, carry out relief, rehabilitation and reconstruction activities in the affected areas, and will prepare DM plans in consonance with the guidelines of the NDMA, SDMAs and DDMAs.

[Action: State governments in collaboration with district administrations; local bodies.]

The planned building of multi-disciplinary teams, especially in landslide prone areas and their effective networking and empowerment will substantially add to the national effort in achieving a paradigm shift from a relief-centric approach to landslide prevention, mitigation and management. Special attention will be paid to the modernisation of investigation and mapping methodologies, and application of satellite, information and communications technologies.

11.5.2 Centre for Landslide Research, Studies and Management

A national level Centre for Landslide Research Studies and Management (CLRSM) will be established by the MoM as a premier geo-hazard institute with state-of-the art facilities, which would eventually grow into a national centre of excellence. It will be fully autonomous in its functioning, similar to that of a national laboratory of the Council of Scientific and Industrial Research with full operational freedom and an independent budget. It will operate within a framework of specified rules. The CLRSM will be headed by an eminent landslide expert with a proven track record.

This initiative will help in ensuring a wider view of landslides as a component of the environment and bringing the existing pool of expertise in earth sciences, including coastal stability, seismology, and meteorology, to bear upon this new initiative.

The national centre will be serviced by a nation-wide chain of actual as well as virtual sub-centres (field offices) to ensure adequate national coverage, information flow, community participation, networking, and feedback. It will also foster, promote and sustain a scientific culture in the management of slopes and landslides aiming for a paradigm shift in the culture of safety. It will aim to galvanise the existing scattered pool of scientific and technological expertise, especially in subjects such as earth sciences, meteorology, coastal protection, seismology, space research, information and communications technology, and urban development. Other areas of concern to be addressed by the centre will be to learn lessons from past landslides, and arranging for high quality education, research, training, and documentation. To begin with, sub-centres (field offices) will, as far as possible, be located in one of the existing knowledge institutions to be identified in consultation with the state government. The network could be gradually expanded in tune with the dynamics of felt needs. The establishment of virtual sub-centres will be encouraged to serve as clearing houses of information. The national capacity building initiative of the central and state governments would make adequate funding provisions to ensure a critical mass of staffing and infrastructure in the field offices. The CLRSM will nurture the field offices, eventually making them financially self-supporting within the time frame of one decade.

In the field of geotechnical investigation and research, the CLRSM will coordinate and collaborate with the National Geotechnical Facility (NGF) being established by the DST at Dehradun, and with the Indian Geotechnical Society.

[Action: The MoM.]

A high level scientific and Technical Advisory Committee (TAC) which will be chaired by the Secretary, MoM, will be constituted by the MoM in consultation with the NDMA to serve as a think tank to nurse the landslide sector with cutting edge science and technology, fresh ideas and stimulus.

It will also make recommendations to the GoI on various aspects of the CLRSM, including its formation, location, aims and objects, funding, functioning, and autonomy.

[Action: The MoM.]

The TAC will comprise top professionals drawn from multi-speciality streams connected with landslide mitigation and management, and it will address research, human resource and capacity development, landslide mapping, investigation, mitigation, and the control, preservation, and protection of slopes as a component of the environment.

It will also provide full support to the human resource development and training functions delegated to the NIDM.

[Action: The MoM in collaboration with the MoES.]

The Secretary, Ministry of Earth Sciences, Director General, GSI, Secretary, DST and Executive Director of the NIDM will be ex-officio members of both CLRSM and TAC.

[Action: MoM in collaboration with the MoES; GSI; DST; NIDM.]

Effective management of landslide disasters requires the integration and translation of landslide concerns into developmental planning. Some of the issues that need serious consideration are listed in table 11.2 on the next page.

11.5.3 Implementation and Monitoring

The LMPs prepared by the central ministries, departments concerned, state governments, district authorities, rural bodies, urban local bodies, and other stakeholders in accordance with these Guidelines will be implemented by them in accordance with in-built schedules.

These plans will indicate clearly the structure of the monitoring system and the reports to be generated at various levels together with the agency to which the report is to be sent, its format and the frequency/timing.

[Action: Central ministries in collaboration with state governments; district administrations; PRIs; ULBs.]

Table 11.2 Integration of Landslide Management with Developmental Planning

i) The creation of a vibrant network of agencies and knowledge institutions dealing with landslide studies for effective implementation of the national landslide management agenda.

ii) Empowerment of multi-institutional and multi-disciplinary teams.

iii) Switch-over from piecemeal remediation of landslides to a holistic implementation of control measures.

iv) Discard outmoded approaches in landslide remediation and switch-over to state-of-the-art technology based landslide control.

v) Mobilisation and participation of the private sector and insurance sector.

vi) Streamlining procedures for speedy funding of priority/fast track projects.

vii) Switch-over from conventional bureaucratic benchmarking and project progress evaluation to peer-centric progress review, evaluation and mid-course correction.

viii) Seeding the concept of landslide prevention and opportunity costs in the administrative management of landslides.

11.6 Financial Arrangements for Landslide Management

11.6.1 Mainstreaming of Disaster Management in Developmental Plans

The central and state ministries/departments will mainstream disaster management efforts in their developmental plans.

In the annual expenditure plans, specific allocations will be made for carrying out disaster awareness programmes, maintaining preparedness and for undertaking mitigation efforts. Wherever necessary and feasible, the corporate sector should also be involved in supporting landslide risk management efforts as part of CSR.

[Action: Central ministries in collaboration with state governments; NDMA.]

11.6.2 Plans of Central Ministries/Departments

A working group on DM, constituted for the first time by the Planning Commission, has made several recommendations in this regard, the incorporation of which in the Eleventh Five-Year Plan will significantly facilitate the funding of plans (as well as mitigation projects) made on the basis of these guidelines by the central ministries/departments and state governments.

The various measures for landslide management recommended in the Guidelines will be funded by the central ministries/departments and state governments concerned by making provisions in their Five-Year and annual plans. Additional funds will also be made available through special mitigation projects to be formulated and implemented by the state governments/SDMAs under the overall guidance and supervision of the NDMA. Besides this, 10 per cent of the Calamity Relief Fund (CRF) could also be utilised for the purchase of equipment for landslide preparedness and mitigation, and for rescue and relief operations.

[Action: SDMAs in collaboration with central ministries.]

11.6.3 State Plans

Landslide management schemes would be planned, funded, executed, and maintained by the state governments themselves as per their own priorities. Central plan assistance would be in the form of block loans and grants and would not be tied to any sector or project. Allocations for the landslide sector within the overall plan outlay would have to be made by the state governments themselves.

The various measures for landslide management recommended in these Guidelines will be included by the respective state governments in their own plans.

[Action: State governments.]

11.6.4 Centrally Sponsored/Central Sector Schemes

The role of the central government is advisory, promotional and facilitative in nature. Even though the MoM/GSI, DST, NRSC, and other organisations do undertake landslide hazard assessment and other landslide management related activities, the overall allocation for these schemes is far too little to have an impact on landslide management in India.

On specific requests from the state governments, the MoM/GSI will include some of the schemes recommended in the Guidelines for funding under these schemes, provided that sufficient funds are available.

[Action: The MoM-GSI.]

11.6.5 District Planning and Development Council Funds

From the funds available with the District Planning and Development Council in landslide prone areas, a part will be allocated for the implementation of landslide management schemes in the districts.

[Action: SDMAs.]

11.6.6 National Landslide Mitigation Project

The NDMA has proposed to take up a National Landslide Mitigation Project in the Eleventh Five-Year plan whose aims and objectives will be developed and finalised in due course. In a broader sense, it will consider the following issues:

i) Assessment of the risk and vulnerabilities associated with landslide disasters.

ii) Reduction in the degree of risk, severity or consequences of landslides, and their mitigation.

iii) Setting pace setter examples for geological and geotechnical investigations of landslides and also for efficacy of landslide treatment measures.

iv) Establishment of monitoring and early warning systems for a few selected landslides.

v) Capacity development of institutes/organisations enhancing the capabilities of communities and training of functionaries.

vi) Identification of institutes/organisations and entrusting them with the implementation of R&D programmes.

vii) Enhancing the promptness and efficacy of response to impending threats of landslides, or their actual occurrence.

viii) Ensuring that proper arrangements are made for organising rescue, relief and rehabilitation works.

ix) Improving the quality and increasing the speed of rehabilitation and reconstruction processes.

x) Spreading awareness with a stress on preparedness, and providing advice and training to the agencies involved in the management of landslides.

12 Summary of Action Points

Chapter 1: The Context

Landslides are a significant natural hazard for India. They not only threaten the environment, human safety, infrastructure, and post-earthquake relief operations but also have a huge impact on the national economy. They deserve much greater attention in terms of multi-hazard mapping, research, scientific investigations, and effective mitigation and management practices. The Guidelines address all the varied aspects of landslide mitigation and management and adopt a holistic and integrated approach that maximises the networking of voluntary agencies, affected communities and other stakeholders.

1) Avalanche Control Strategies

The SASE and BRO will be responsible for the identification and monitoring of snow avalanches. The SASE will be responsible for the zonation of avalanche prone areas and the forecasting of snow avalanches. Central and state governments in association with the BRO will be responsible for implementing clearance and control strategies against identified snow avalanches. [Action: The nodal ministry in consultation with the TAC and in collaboration with the SASE, BRO, central government, and state governments] (Section 1.7.6).

2) Search and Rescue Operations

The SASE is presently not involved in carrying out search and rescue operations. Therefore, the district administration will identify organisations/institutions that can take up programmes to educate the communities living in avalanche prone areas, to prepare them with the latest techniques of self-survival, and to equip them with simple and essential tools. Similarly, the organisations engaged in development and strategic tasks at high altitudes will be educated on initial search and rescue operations and the use of basic equipment necessary for these operations.QRTs equipped with the latest rescue equipment like snow clearing tools, probes, communication capability, and medical emergency aids will be organised. These teams will have the capability to be mobilised at very short notice and reach the affected sites within the shortest possible time. The QRTs shall include trained personnel drawn from different arms of the local administration and the NDRF. [Action: SDMAs in collaboration with DDMAs, NDRF] (Section 1.7.7).

Chapter 2: Hazard Zonation Mapping

3) Landslide Inventory

The preparation of a comprehensive and user-friendly national landslide inventory database will be taken up, paving the way for continuous updating of the landslide map of India. This will be achieved by a nation-wide networking of the agencies engaged in the task and would be aided by the latest geomatic tools, followed by field checks. [Action: The MoM-GSI in collaboration with state DGMs; WIHG; NIDM; NRSC; SRSCs; BRO] (Section 2.2).

4) LHZ Mapping

i) Landslide studies are being carried out at a scale of up to 1:5,000 and at even larger scales for detailed studies, depending on the size of the landslide and other requirements. A nation-wide consensus on selection of mapping scales will be reached with a view to introducing rational uniform procedures throughout the country. [Action: The nodal ministry in consultation with the TAC and in collaboration with the NRSC; BIS; DST; CBRI; CRRI; WIHG; IITs, universities, and other academic institutions] (Section 2.3.1).

ii) Approaches to landslide hazard mapping being used by different agencies in India are at variance with each other. The ongoing mapping programmes should continue to make the best use of the prevailing state-of-the-art technologies, at the same time making a determined effort to arrive at national level recommendations through a process of workshops and rigorous peer review. [Action: The nodal ministry in consultation with the TAC and in collaboration with the NRSC; BIS; DST; CBRI; CRRI; WIHG; IITs, universities, and other academic institutions] (Section 2.3.3).

iii) The BIS will critically review and revise its guidelines on LHZ mapping, taking full advantage of the experiences of the GSI and other agencies in this field. This will be achieved within the next two years. Subsequently, these will be revised every five years. [Action: The BIS in collaboration with the GSI; IITs, universities, and other academic institutions] (Section 2.3.3).

iv) The most important inputs required for carrying LHZ mapping at both the macro and meso scale are topographical and geological maps, remote sensing products, and seismological data in the case of seismogenic landslides. Repositories of these are the SoI, GSI, NRSC, and IMD. These agencies will be made an integral part of any effort in this direction so that the work does not suffer for want of these vital inputs, and additional demands can also be serviced. The IMD and CWC will have to increase the network density of rain gauge stations (with particular reference to major landslide susceptibility locations) and seismic observatories in hilly regions. The SoI should also take up the task of generating topographic/contour maps at the scale of 1:5,000 or 1:10,000 for the landslide affected hilly regions of India. A mechanism will be put in place so that the seismic and rainfall data are communicated to the national landslide hazard database centre on a real-time basis. [Action: The SoI in collaboration with the IMD; MoM-GSI; NRSC; CWC] (Section 2.3.4).

5) Seismic Landslide Hazard Zonation

Comprehensive research, development and field-oriented studies on problematic slopes with the help of instruments should be undertaken to improve our understanding of earthquake induced landslides. Multi-hazard and seismic micro-zonation programmes would be enriched by an added focus on the hitherto neglected subject of earthquake-induced landslides in hilly areas and their effects on slope instability. [Action: The nodal ministry in consultation with the TAC and in collaboration with the IMD; DST; CDMM; WIHG; IITs, universities, and other academic institutions] (Section 2.3.5).

6) Prioritisation of Areas for LHZ Mapping

i) The identified areas for macro scale LHZ mapping are proposed to be completed during the first phase by 2013. The mapping will be done by various institutions, of which a major portion will be done by the GSI. It is proposed that in the second phase, the macro scale LHZ mapping may be taken up district- or basin-wise in the Lesser and Outer Himalayas, the NER and the Nilgiris in the areas not covered in the first phase. Subsequently, the LHZ mapping can be extended to difficult areas in the Higher Himalayas and the interior areas of the NER. Depending upon the availability of resources, the second phase will extend up to 2020 or beyond. The national priorities will be reviewed and mapping methodologies improved as the work progresses. [Action: SDMAs/state governments in collaboration with the TAC; MoM-GSI; NRSC; DST; BRO; WIHG; PRIs; CRRI] (Section 2.3.6).

ii) The locations requiring studies at the meso scale shall be identified in consultation with state governments and other agencies, prioritised and taken up for LHZ mapping in a phased manner, depending upon the availability of resources. In the second phase of LHZ mapping at the meso scale, the areas not covered during the first phase will be taken up. The work carried out in this phase will extend up to 2020 or beyond, depending on the resources available. [Action: SDMAs/state governments in collaboration with the TAC; MoM-GSI; NRSC; DST; BRO; WIHG; PRIs; CRRI] (Section 2.3.6).

iii) Considering the importance of landslide risk zonation mapping, a proposal has been recently drawn up by the BIS to frame guidelines for landslide risk zonation mapping, and the GSI along with some members of the sectional committee on the Hill Development Council of the BIS have been requested to prepare the draft guidelines. [Action: The BIS in collaboration with the MoM-GSI] (Section 2.4.1).

Chapter 3: Geological and Geotechnical Investigations

7) Geological Investigations

The preliminary and detailed geological investigation of landslides constitutes the foundation on which sound geotechnical investigation must be built. Detailed guidelines will be developed for ensuring systematic geological investigation and mapping. [Action: The BIS in collaboration with the MoM-GSI; DST; IITs, universities and other academic institutions] (Section 3.2.2).

8) Geotechnical Investigation

i) Guidelines will be developed to usher in the culture of sound geotechnical investigation suited to different geological settings and anthropogenic situations. Systematic scientific geotechnical investigation will become an essential component of any important landslide management initiative. The training of professionals, writing of field manuals, and introduction of appropriate tools and techniques for investigation will be accorded priority. The guidelines will emphasise the importance of fashioning geotechnical investigations on hard field evidence and the previous history of the slope. The importance of arriving at critical slope profiles, elucidation of the possible modes of failure, and purpose oriented field and laboratory testing and instrumentation for the validation of design assumptions will be highlighted to improve the health of current engineering practices. Engineering geologists and geotechnical engineers will be jointly trained to raise the standards of investigation and data analysis. All major landslide remediation works will be linked intimately with the findings of geotechnical reports. [Action: The BIS in collaboration with the NIDM; DST; CDMM; MoM-GSI; CBRI; CRRI; WIHG; CoA; IITs, universities and other academic institutions] (Section 3.3)

ii) The private sector can play a major role in improving the national capacity for quality geotechnical investigations and will be encouraged to do so through professional bodies like the Indian Geotechnical Society (IGS). [Action: The DST in collaboration with the TAC; IGS; engineering project authorities] (Section 3.3).

iii) There is a need to develop guidelines for scientific analysis of slopes and landslides in terms of total and effective stress, as the ground situation demands. Every report will specifically point out the assumptions made and the limitations of the data used in slope analysis and design. [Action: The BIS in collaboration with the CDMM; CoA; IITs, universities and other academic institutions] (Section 3.3).

iv) Geotechnical investigations for such a set of problems fall in a specialised domain and must be critically examined by investigators. [Action: The nodal ministry in consultation with the TAC and in collaboration with the IMD; DST; CDMM; IITs, universities and other academic institutions] (Section 3.3).

9) Culture of the Observational Method of Design and Construction

There is an urgent need to sensitise professionals on how to handle slope failures and their remediation, as well as landslide emergencies and uncertainties by making efficient use of the observational method and the power of engineering judgment. The culture of the observational method of design and construction will be promoted with training on the development of contingency plans. [Action: The NIDM in collaboration with the CDMM; CoA; IITs, universities and other academic institutions] (Section 3.3.1).

10) Pilot Projects for the Investigation of Major Landslides

A few major landslides will be identified for creating pace setter practical examples of systematic and scientific geotechnical investigations which will include detailed geological and geotechnical mapping at the scale of 1:500 or 1:1,000. The identification and investigation will be done by assigning tasks to organisations or institutions identified as having multi-disciplinary expertise and experience. These organisations will not only aid in the development of a systematic method but also assist in the development of standard codes, and planning for capacity building for geological and geotechnical investigations. [Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; BRO; CBRI; CRRI; DST; CDMM; WIHG; BIS; IITs, universities and other academic institutions] (Section 3.5).

Chapter 4: Landslide Risk Treatment

11) Landmass Improvement Techniques

Identified hazardous landslides will be prioritised and treatment measures implemented after detailed investigations. The implementation measures will be supervised by trained representatives of investigating teams and monitored for their efficacy. [Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; BRO; CBRI; CRRI; DST; CDMM; IITs, universities and other academic institutions] (Section 4.2.1).

12) Mitigation Measures for Landslide Dams

i) In case a report of landslide dam formation after heavy rainfall/strong earthquake/rapid snowmelt in hilly areas is received, the vulnerable areas will be reconnoitred immediately, if required by helicopter, to see whether more such landslide dams have been formed or not. For inaccessible areas and trans-boundary rivers, the vulnerable areas will be monitored by the NRSC through satellites on a real-time basis. If such an occurrence is noticed, the situation will be monitored continuously and information about the developments will be communicated immediately to the designated authorities such as the MHA, NDMA and the concerned SDMAs. [Action: The CWC in collaboration with the NRSC; MHA; SDMAs; BRO; IMD] (Section 4.4).

ii) The SDMAs will establish and activate the warning and communications systems immediately so that information reaches the last post on a real-time basis and proper action is taken by all players involved in an effort to save lives and minimise the loss to property and infrastructural elements. [Action: The SDMAs in collaboration with the BRO] (Section 4.4).

iii) A team of experts will reach the affected site as soon as possible to monitor the situation, assess the stability status of the structure and landslide activity, and changes in water level in the impounded lake. The teams will implement the required initial measures to the extent possible immediately. [Action: The CWC in collaboration with the MoM-GSI; BRO] (Section 4.4).

iv) Monitoring the stability status of the landslide dam, even if it is apparently found to be stabilised, and the water level behaviour, will be continued for longer periods. [Action: The CWC] (Section 4.4).

v) For assessing the flood hazard posed by the dam in the event of its breaching by a landslide, Dam Break Analysis will be conducted for identifying vulnerable areas. Communities living in such areas will be kept in a state of alert as long as the threat of flash floods exists. [Action: The CWC in collaboration with the SDMAs; District Administration] (Section 4.4).

vi) The lead for these assessment and mitigation efforts will be taken by the CWC/MoWR in collaboration with the GSI, NRSC and the respective state governments. [Action: The CWC in collaboration with the MoM-GSI; NRSC; SDMAs] (Section 4.4).

13) Human Settlements in Landslide Prone Areas

Site selection for housing, human settlements and other infrastructure in hilly areas will be done by a highly competent multi-disciplinary team of experts aiming to preserve the texture of the place and its cultural fabric, maintaining balance between natural and anthropogenic factors. [Action: The nodal ministry in consultation with the TAC and in collaboration with the SDMAs; MoM-GSI; MoEF; ASI; CoA] (Section 4.5).

14) Protection of Heritage Structures

Close interaction with agencies like the ASI, INTACH and archaeological departments of the states will be developed to prepare lists of structures/sites which are at risk due to landslides/slope stability problems, and to prioritise them. Based on this priority list, further studies and works for hazard mitigation will be taken up by the appropriate authorities in collaboration with the ASI, INTACH and the archeological departments of the state governments. [Action: The ASI in collaboration with the INTACH; state governments; SDMAs; CoA] (Section 4.6).

Chapter 5: Landslide Monitoring and Forecasting

15) Monitoring and Warning Systems

i) Guidelines and field manuals will be formulated and workshops and training programmes organised for different target groups. Actual projects will be encouraged to create pace setter examples of early warning as well as for training professionals on the projects. [Action: The DST in collaboration with the NIDM; WIHG; CDMM; IITs, universities, and other academic institutions] (Section 5.3.2).

ii) Projects will be encouraged to develop appropriate technologies as well as to effectively utilise the available state-of-the-art technologies to facilitate quality monitoring in a cost-effective manner, aiming at real-time early warning. [Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; SDMAs; CSIO; WIHG; IITs, universities, and other academic institutions] (Section 5.3.2).

iii) Since the inter-relationship between rainfall intensity, slope surface and sub-slope movements, and pore pressures provide a powerful means for reliable landslide forecasting, studies regarding this will be encouraged. Rainfall and the associated slope behavioural information will be utilised for developing indicators for landslide alerts, especially for high landslide hazard areas known to succumb to cloudbursts and high intensity short duration rainfall. [Action: The MoM in consultation with the TAC and in collaboration with the IMD; MoM-GSI; DST; CWC; IITs, universities, and other academic institutions] (Section 5.3.2).

iv) R&D projects on landslide prediction will be encouraged. One major research programme on landslide prediction and early warning installations with the provision of comprehensive scientific study and geotechnical instrumentation will be undertaken to create pace setter examples. [Action: The nodal ministry in consultation with the TAC and in collaboration with the CSIO; CDMM; CBRI; CRRI; IITs, universities, and other academic institutions] (Section 5.3.2).

16) Pilot Studies for Instrument Based Early Warning

i) A few landslides will be identified for instrumentation based early warning in consultation with state governments and other Central Government agencies like the BRO. It will be a multi-disciplinary and multi-institutional approach. Efforts will be made to integrate local communities and the concerned state governments in this endeavour. Projects aimed at early warning against major landslides will be encouraged, taking advantage of the fact that unlike many other disasters, early warnings against landslides are possible with the present state-of-the-art technologies. [Action: The nodal ministry in consultation with the TAC and in collaboration with the SDMAs; BRO; MoM-GSI; DST; District Administrations; IITs, universities, and other academic institutions] (Section 5.4).

ii) Pilot projects will also be launched to arrive at early warning thresholds through the correlation between rainfall intensity and landslide initiation. In this case, three to four areas in different parts of the country, like the Western Himalayas, Eastern Himalayas or the NER and the Western Ghats or Nilgiris, where the density of landslide incidence and rainfall are high, can be selected in consultation with either the IMD or NCMRWF. The latter has developed weather forecasting capability for particular areas within grids of 150 km by 150 km, three to five days in advance. These grids are being redefined to blocks of 100 km by 100 km. The rainfall threshold values needed for landslide activation in the particular pilot areas will be established through earlier records and continued monitoring. The results of these observations will be matched with the weather forecasts made by the above organisations. Once these correlations are established, the forecasts issued by the IMD or NCMRWF will be utilised for issuing early warnings for possible landslide occurrence in those particular areas. [Action: The IMD in collaboration with the NCMRWF; MoM-GSI; DST; CDMM; CBRI; CWC; IITs, universities, and other academic institutions.] (Section 5.4).

iii) For correlating rainfall intensity and landslide initiation to develop forecast capabilities, 20 pre-determined landslide locations will be monitored initially with automatic rain gauges by different agencies. This national initiative will be closely coupled and eventually integrated into the ongoing programme of expansion of the automatic rain gauge network of the IMD. [Action: The IMD in collaboration with the MoM-GSI; DST; CDMM; CBRI; CWC; IITs, universities, and other academic institutions.] (Section 5.4).

Chapter 6: Regulation and Enforcement

17) Introduction

The state governments/SDMAs of landslide affected areas in consultation with the NDMA will establish the necessary techno-legal and techno-financial mechanisms to address the problem of landslide hazards in their respective states. This is to ensure that all stakeholders like builders, architects, engineers, and government departments responsible for regulation and enforcement adopt landslide safe land use practices and provide for safety norms as far as slope stability is concerned in landslide affected areas in particular and hilly areas in general. [Action: State governments/ SDMAs; district administrations; the CoA] (Section 6.1).

18) Model Town Planning and Land Use Bye-Laws

It is essential that the above codes are critically examined and urgently reviewed by peers in the context of global and indigenous research as well as the growing pool of knowledge and experience gained in pursuing indigenous mapping programmes. Once the initial revisions are carried out in the next two years, the BIS will revise/revalidate these every five years or earlier, if necessary. [Action: The nodal ministry in consultation with the TAC and in collaboration with the BIS] (Section 6.2).

19) Indian Standard Codes

i) The BIS will place all Indian standards related to landslides in the public domain including the Internet for free download. [Action: The BIS] (Section 6.3).

ii) A periodic revision of the codes and standards relating to landslides will be undertaken by drafting groups within a fixed time-frame of five years or even earlier on a priority basis. [Action: The BIS] (Section 6.3).

iii) The BIS will ensure the finalisation and formulation of all pending codes and guidelines within the next two years. [Action: The BIS] (Section 6.3).

20) Techno-Legal Regime

The state governments/SDMAs will adopt the model techno-legal framework for ensuring compliance with land use zoning and landslide safety issues in all development activities and plans. [Action: State governments in collaboration with the SDMAs; district administrations] (Section 6.4).

21) Licensing and Certification

i) The NDMA and the nodal agency, in collaboration with the relevant ministries and departments of the GoI will evolve an appropriate techno-legal framework for making the licensing of professionals mandatory. [Action: The nodal ministry in consultation with the TAC and in collaboration with the central ministries] (Section 6.5).

ii) In the case of architects and town planners, the statutory body for registering architects, namely the CoA and the professional body that coordinates with architects, namely the IIA, will be responsible for the registration, training and upgradation of the skills of architects and town planners in landslide safety and construction. [Action: AICTE in collaboration with IITs, universities and other academic institutions; the CoA; IIA; urban planners] (Section 6.5).

22) Compliance Review

All land use and developmental plans in hilly areas will go through a mandatory compliance review by professionals of ULBs and PRIs to which these are to be submitted for approval. [Action: District administrations in collaboration with urban planners; ULBs; CoA; IIA; PRIs] (Section 6.6).

23) Techno-Financial Regime

The Guidelines issued by the NDMA will form the basis for the formulation of plans for mitigation projects at the national, state and district levels. These mitigation projects will be duly prioritised and approved by the NDMA. The Planning Commission will include these DM plans in the Five-Year and Annual Plans of the ministries and departments of the GoI, as well as in the state plans. [Action: The nodal ministry in consultation with the TAC and in collaboration with central ministries; state governments; the Planning Commission] (Section 6.8).

Chapter 7: Awareness and Preparedness

24) Awareness

i) State governments/SDMAs of landslide affected areas, in collaboration with the nodal agency and other key stakeholders, will make special efforts to mobilise communities to carry out landslide mitigation efforts. Electronic and print media will also be associated in the endeavour to create greater public awareness about landslide hazard and importance of land use zoning practices. Organisations and institutions like the GSI, NIDM, IITs, CDDM, and other knowledge-based institutions including some NGOs will be entrusted with the responsibility of preparing material for awareness generation campaigns pertaining to the landslide prone states in the country in a scheduled manner. [Action: SDMAs/state governments; the MoM-GSI; NIDM; CDMM; IITs, universities and other academic institutions; PTI; DAVP; Prasar Bharati; private broadcasters] (Section 7.1).

ii) Comprehensive awareness campaigns targeting different groups of people living in landslide prone areas will be carried out systematically. [Action: SDMAs/state governments; the MoM-GSI in collaboration with academic institutions and the media] (Section 7.1).

25) Creation of Public Awareness on Landslide Risk Reduction

Handbooks, posters, and handbills containing the status of landslide hazards will be distributed, and details of landslide indicators along with precautions to be adopted and suggestive measures will be displayed near landslide prone sites. All the above documents will be translated into local and regional languages. Short video films on landslide risk, vulnerability, and importance of preparedness and mitigation measures will be prepared for the general public. The electronic and print media will also be made an integral part of the campaigns. [Action: SDMAs/state governments; the MoM-GSI in collaboration with academic institutions and the media] (Section 7.1.1).

26) Awareness Drives for Specific Target Groups

i) The nodal agency along with state governments, some selected institutions collaborating with local bodies, urban planners, and NGOs, will initiate programmes to sensitise decision makers and other important functionaries in undertaking mitigation measures in landslide affected areas. [Action: SDMAs/state governments; the MoM-GSI; district administrations; NGOs] (Section 7.1.2).

ii) State governments/SDMAs, in collaboration with the nodal agency, NGOs, and other identified agencies, will organise awareness programmes on the various aspects of landslide management for specific target groups of stakeholders, elected representatives, civil servants, members of local authorities, school administrators, members of management boards of educational institutions and hospitals, school children, representatives of the corporate sector, the media, etc. [Action: SDMAs/state governments; the MoM-GSI; district administrations; NGOs] (Section 7.1.2).

iii) The GSI, the nodal agency, will maintain a list of resource personnel and organisations capable of conducting awareness generation campaigns, which will be updated from time to time. [Action: The MoM-GSI] (Section 7.1.2).

iv) State governments/SDMAs and professional bodies will organise knowledge and experience sharing workshops for societal benefit. These will also support private agencies to develop their capacities to assess, predict, and monitor landslides as well as implement appropriate remedial measures. [Action: SDMAs/state governments in collaboration with the GSI] (Section 7.1.2).

27) Landslide Preparedness

i) Mock drills will be conducted in offices, schools, industrial units, etc., and in the neighbourhood of sites vulnerable to landslides. [Action: The nodal ministry in consultation with the TAC and in collaboration with SDMAs; district administrations] (Section 7.2).

ii) Local authorities like gram panchayats, with the help of NGOs and volunteer groups from within the community will prepare and implement community based DM plans. A database of these groups, their contact details, and fields of specialisation will be created and maintained at the district and state levels. [Action: DDMAs/SDMAs in collaboration with PRIs and NGOs] (Section 7.2.1).

iii) Exercise programmes for each disaster prone district will be developed and made an essential part of the preparedness programme. The entire cycle of an exercise programme from orientation seminar to full scale exercise takes about 18 to 24 months. Complete exercises in disaster prone districts will be conducted at least once in four years after careful planning so that grey areas in the preparedness programme are identified and efforts are made to make the necessary modifications. [Action: State governments/SDMAs] (Section 7.2.1).

28) Medical Preparedness

i) MFRs for administering first aid and resuscitation measures at the incident site and during the transportation of casualties, will be identified and trained. All members of the medical and paramedical teams will conduct regular exercises based on the SOPs laid down by the respective DMAs as part of their DM plans. [Action: SDMAs in collaboration with the state health and medical departments, and private hospitals] (Section 7.2.2).

ii) In high-risk landslide areas, mobile hospitals and QRMTs will 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. [Action: SDMAs/DDMAs in collaboration with the state health and medical departments and private hospitals] (Section 7.2.2).

Chapter 8: Capacity Development (Including Education, Training and Documentation)

29) Introduction

i) A realistic national capacity building programme, commensurate with the intensity and extent of the hazard in India will be evolved and implemented, keeping in view the available resources. This programme of resource enhancement will encompass all institutions/organisations/individuals that have a role in any part of the DM cycle. [Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI. (Section 8.1).

ii) The target groups identified for capacity development will include scientific and technical institutions, elected representatives, government officials, professionals in the electronic and print media, town/urban planners in hilly regions, infrastructure development companies, engineers, architects, and builders, NGOs, private volunteers, and other CBOs, social activists, social scientists, school teachers, and school children. [Action: The SDMAs/DDMAs; BRO; CoA; NGOs; central and state education departments; IITs, universities and other academic institutions] (Section 8.1).

iii) India has linkages with foreign organisations like UN (OCHA), UNDP, and the UNDAC team. Efforts will be made to develop these relations and utilise them in building institutional and individual capacities in the field of landslide disaster management as practised elsewhere and also to participate in internationally coordinated programmes in landslide research. India will participate in the international effort at improving the quality of preparedness and response in liaison with international organisations. [Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; MoES; DST] (Section 8.1).

30) Landslide Education

i) The affected state governments will make sincere efforts to strengthen the field of natural disaster education in general, and landslide education in particular, by incorporating the best available technical and non-technical inputs on landslide safety in educational curricula at the secondary and senior secondary levels in all schools. [Action: The SDMAs/state governments; the MHRD] (Section 8.2).

ii) The state governments/SDMAs, in collaboration with their respective boards of secondary education, will ensure that the subject of disaster safety and disaster preparedness is introduced at the senior secondary level (Class XI and XII) and at the undergraduate level in technical and non-technical disciplines as well, and that landslides form an integral part of disaster education. [Action: SDMAs/state governments; the MHRD] (Section 8.2).

iii) The central and state governments will encourage knowledge institutions to undertake research, teaching, and training, which will further contribute to improving landslide education in India. [Action: Central ministries in collaboration with NDMA; SDMAs/ state governments] (Section 8.2).

31) Education of Professionals

i) Self-education programmes by the effective use of multi-media based knowledge products need to be encouraged and prioritised. This will accordingly be taken up for implementation. [Action: The nodal ministry in consultation with the TAC and in collaboration with the NIDM; UGC; Prasar Bharati; private broadcasters; IITs, universities, and other academic institutions] (Section 8.2.1).

ii) Technical institutes, polytechnics, and universities located in vulnerable areas will develop adequate technical expertise on the various subjects related to landslide management. [Action: SDMAs/state DGMs; state governments; the MHRD; IITs, universities, and other academic institutions] (Section 8.2.1).

iii) The NDMA in consultation with MoH&FW, MCI and other related agencies, will facilitate the introduction of subjects related to DM in the undergraduate medical curriculum. [Action: The nodal ministry in consultation with the TAC and in collaboration with the MHRD; MoH&FW; MCI] (Section 8.2.1).

iv) All architecture and civil engineering graduates will be taught in detail about all the aspects of landslides and related hazards in the hilly regions of India. [Action: The AICTE in collaboration with IITs, universities and other academic institutions; the CoA] (Section 8.2.1).

v) The curricula of IITs, NITs, engineering and architecture colleges, polytechnics, and universities will be suitably modified to incorporate basic knowledge about landslides and the techniques employed to control them. The NDMA along with the nodal agency will facilitate this process in collaboration with the MHRD, AICTE, CoA, and professional bodies of town planners to incorporate landslide education in their curricula. [Action: The nodal ministry in consultation with the TAC and in collaboration with IITs, universities, and other academic institutions; the MoM-GSI; MHRD; AICTE; CoA] (Section 8.2.1).

32) Community Education

Investments in disaster education, public awareness, community leadership development, and disaster education of unemployed youth, physically challenged, elderly, women, and school children will be encouraged. [Action: The SDMAs in collaboration with the DDMAs; NGOs] (Section 8.2.2).

33) Training

i) The NDMA and the nodal agency, viz., the GSI along with other knowledge institutions, with a view to popularising landslide education and giving momentum to research activities in India, will identify a number of leading technical institutes and earth science departments of universities which support such activities. Such institutions will also offer the services of experienced faculty members to participate in the activities specified in the Guidelines. [Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; NIDM; IITs, universities, and other academic institutions] (Section 8.3).

ii) The DGMs in landslide affected states have a significant number of geoscientists. Many of these will be involved in landslide hazard mitigation programmes and studies after proper training. [Action: The SDMAs in collaboration with state DGMs] (Section 8.3).

iii) The state governments will also evolve a formal framework for the certification of such professionals and adopt certification practices through short-term courses. [Action: State governments in collaboration with the SDMAs] (Section 8.3).

34) Training of Professionals

i) Geologists, geotechnical engineers, and professionals from other disciplines involved in landslide hazard investigation and management need to be kept updated with the latest global developments in this field, so that a well-trained workforce conversant with the latest technological advances is available to manage the hazard effectively. [Action: The nodal ministry in consultation with the TAC and in collaboration with the NIDM; MoM-GSI; IITs, universities, and other academic institutions] (Section 8.3.1).

ii) The GSI and NIDM in consultation with reputed knowledge institutions will develop comprehensive programmes for creating trainers from among trained faculty members of engineering and architecture colleges, and other professionals. The state governments/SDMAs will identify potential trainers to develop training programmes at different levels. [Action: The MoM-GSI in collaboration with the NIDM; IITs, universities, and other academic institutions; SDMAs; AICTE; CoA] (Section 8.3.1).

iii) In the initial phases, training will be imparted to all officers of landslide affected states, like engineers, geologists, geophysicists, and hydrologists from the DGMs and other departments involved in developmental activities in hilly regions, especially in the ULBs and PRIs of such states. [Action: State governments in collaboration with the SDMAs; DDMAs; state DGMs] (Section 8.3.1).

35) Capacity Upgradation

i) A mechanism will be developed to identify institutions active in the field of landslides, assess their capabilities, and enhance and strengthen their capacities in terms of expertise, knowledge, and resources for the effective management of landslide hazards. The main areas requiring capacity development in the context of landslide disaster management are as follows:

a. The establishment of a nation-wide, organised, vibrant, pro-active, systematic, and scientific institutional mechanism that will replace the current piecemeal, ad hoc, and poorly recognised and appreciated landslide management practices.

b. The 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.

c. The strengthening of a few identified institutions, their units and departments in all states and union territories. If possible, their respective mandates/roles in providing/supporting pre- and post-landslide routine/specialised functions are to be redefined and enlarged. [Action: The TAC in collaboration with the MoM-GSI] (Section 8.4).

36) Documentation

i) The NDMA and GSI will facilitate the preparation of films, manuals, and other material targeting various stakeholders to inculcate landslide safety by following land zoning regulations. State governments will provide landslide safety material in multiple formats and languages, so that different groups of stakeholders can have the requisite information. The NDMA, GSI, NIDM and state governments/SDMAs will set up websites and portals to disseminate information related to landslide safety. [Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; NIDM; SDMAs; DAVP; NGOs; IITs, universities, and other academic institutions] (Section 8.5).

ii) The state governments will assist specialists in the subject from academia and industry to prepare technical documents on landslides, which will provide technical specifications for the expansion of human settlements in hilly areas, and simple techniques for assessing landslide hazards in other areas. [Action: The SDMAs in collaboration with the CoA; IITs, universities, and other academic institutions] (Section 8.5).

iii) The GSI and other knowledge institutions like the NIDM, IITs, NITs, and other professional bodies will generate and maintain a directory of landslide management professionals in India, containing their brief bio-data, and make this available to the state governments/SDMAs. [Action: The MoM-GSI in collaboration with the NIDM; CBRI; CRRI; IITs, universities, and other academic institutions] (Section 8.5).

iv) The GSI along with other institutions will undertake the task of documenting the history of landslide studies and other related activities in India. [Action: The MoM-GSI in collaboration with the NIDM; CBRI; CRRI; DST; BRO; IITs, universities, and other academic institutions] (Section 8.5).

Chapter 9: Response

37) Introduction

i) Systems will be institutionalised by the DMAs at various levels for coordination between different agencies like central government ministries and departments, state governments, district administrations, ULBs, PRIs, and other stakeholders for an effective post-landslide response. [Action: Central ministries in collaboration with state governments/SDMAs; DDMAs; ULBs, PRIs] (Section 9.1).

ii) The IMD will immediately communicate the occurrence of an earthquake along with preliminary details to the SDMAs and GSI for initial assessment of earthquake induced landslides and dissemination of the appropriate alerts. [Action: The IMD in collaboration with the SDMAs; MoM-GSI; NRSC] (Section 9.1).

iii) Agencies like the BRO/state PWDs, state DGMs, forest departments, municipal/panchayat bodies will immediately communicate information on the occurrence of a landslide along with preliminary details like its location, magnitude, damage caused, etc., to the district emergency centre or district disaster management control room. These designated bodies will communicate this information to the state disaster management commissioner for onward transmission to primary nodes like the nodal agency, viz., the GSI and other nodes like the MHA and NRSC identified for this disaster. [Action: State governments in collaboration with state DGMs; BRO; MoEF; DoS-NRSC; DDMAs; State Resource Centres; NDRF; MoM-GSI; MHA; PRIs] (Section 9.1).

38) Emergency Search and Rescue

i) Trained and equipped teams consisting of local people will be set up in landslide prone areas to respond effectively in the event of a disaster. [Action: DDMAs in collaboration with PRIs] (Section 9.2).

ii) 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. [Action: SDMAs in collaboration with the NDRF; PRIs; district administrations] (Section 9.2).

iii) Youth organisations such as the NCC, NSS, and NYKS will provide support services to the response teams at the local level under the overall guidance and supervision of the local administration. [Action: SDMAs in collaboration with the NCC; NSS; NYKS] (Section 9.2).

39) Emergency Relief

Trained community level teams will assist in planning and setting up emergency shelters, providing relief to the affected people, identifying missing people, and addressing the needs of emergency medical care, water supply and sanitation, food and temporary shelter, etc., of the affected community. [Action: SDMAs/ DDMAs; district administrations] (Section 9.3).

40) Incident Command System

i) All response activities will be undertaken at the local level through a suitably devised ICS and coordinated by the local administration through an EOC. State governments will commission and maintain EOCs at appropriate levels for the coordination of human resources, relief supplies, and equipment. [Action: State governments/SDMAs; district administrations; PRIs] (Section 9.4).

ii) The state governments/SDMAs will undertake the training of personnel involved in the ICS. [Action: State governments/SDMAs] (Section 9.4).

41) Community Based Disaster Response

The DDMAs will coordinate with organisations like NGOs, voluntary agencies, self-help groups, youth organisations, women's groups, civil defence, home guards, and the community at large that normally volunteer their services in post-disaster situations. [Action: DDMAs in collaboration with the home guards; NGOs; NYKS] (Section 9.5).

42) Role of Private and Corporate Sector

The state governments will facilitate the involvement of the corporate and private sector and utilise their services and resources if offered to the government during the immediate post-disaster situation. The IDRN will be maintained and updated regularly so that locally available resources are utilised effectively in the case of emergencies. [Action: SDMAs] (Section 9.6).

43) Specialised Teams for Response

i) All 144 teams of the NDRF will be specially equipped and trained in landslide, avalanche and collapsed structure search and rescue operations. [Action: The NDRF] (Section 9.7).

ii) To augment the capacities of the states, all state governments will raise from within their armed police force, an adequate strength of personnel for the SDRF capable of responding to disaster situations. [Action: State governments/SDMAs] (Section 9.7).

iii) The state governments/SDMAs and DDMAs will coordinate the human resources of the civil defence set-up as well as those of other agencies for performing/responding to various disaster related activities. [Action: State governments/SDMAs; DDMAs] (Section 9.7.1).

44) Emergency Logistics

i) State governments will compile a list of such equipment, identify their suppliers, and enter into long-term agreements for their mobilisation and deployment in the event of a landslide disaster. [Action: State governments/SDMAs] (Section 9.8).

ii) The provision of temporary shelters and basic amenities for stranded travellers would require pre-planning. The DM plans at the state and district levels will address this issue in detail. [Action: SDMAs in collaboration with the DDMAs] (Section 9.8).

45) Emergency Medical Response

Whenever required, a prompt and efficient emergency medical response will be provided by QRMTs, mobile field hospitals, ARMVs and heli-ambulances that are in place for other disasters like earthquakes. [Action: SDMAs in collaboration with the state medical and health departments and private hospitals] (Section 9.8.1).

Chapter 10: Research and Development

46) Introduction

i) Central ministries, state governments, and funding agencies will encourage, promote, and support R&D activities to address current challenges, offer solutions, and develop new investigation techniques, with the application of the latest developments in remote sensing, communications, and instrumentation technologies. [Action: SDMAs in collaboration with the MoES; MoM-GSI; DST; DoS-NRSC; central ministries; state governments] (Section 10.1).

ii) The nodal agency and respective state governments will constitute multi-institutional and multi-disciplinary teams for carrying out post-landslide field investigations to assess the hazard potential and estimate the risk involved. They will also document the lessons and disseminate the same to target audiences within the state and recommend cost effective practical measures. The nodal agency will oversee the progress of these efforts in a systematic manner. [Action: The MoM-GSI in collaboration with the SDMAs; state governments; DST; CBRI; CRRI; IITs, universities, and other academic institutions] (Section 10.1).

47) Standardisation

i) R&D activities will be intensified to standardise 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 landslides, and procedures for the ground validation of LHZ maps will be prepared immediately. [Action: The nodal ministry in consultation with the TAC and in collaboration with BIS; IITs, universities, and other academic institutions] (Section 10.2.1).

ii) A research programme will be undertaken by knowledge based organisations/institutes of India for developing a scientific approach of integrating the landslide hazard into multi-hazard mapping. [Action: The nodal ministry in consultation with the TAC and in collaboration with DST; IITs, universities, and other academic institutions] (Section 10.2.1).

48) Earthquake-Induced Landslides

A research programme will be developed so that this aspect of landslide investigation is understood and appropriate remedial measures may be undertaken before an earthquake strikes. Knowledge based institutes, like IIT-R, IIT-K, etc., will be encouraged to take up such programmes. [Action: The nodal ministry in consultation with the TAC and in collaboration with the DST; IITs, universities, and other academic institutions] (Section 10.2.2).

49) Design of Surface and Sub-Surface Drainage Systems

Efforts will be directed towards R&D in scientific and innovative designs of surface and sub-surface drainage systems, which is the most important component of landslide stabilisation measures. [Action: The nodal ministry in consultation with the TAC and in collaboration with the DST; IITs, universities, and other academic institutions] (Section 10.2.3).

50) Development of Early Warning Systems

Landslides for early warning will be selected through a consultative mechanism in association with state governments and local bodies. The development of appropriate early warning systems may be undertaken for such identified landslides. Knowledge based institutes/organisations with expertise and experience in this area will be encouraged to take the lead. [Action: The nodal ministry in consultation with the TAC and in collaboration with the DST; state governments/SDMAs; district administrations; IITs, universities, and other academic institutions] (Section 10.2.5).

51) Landslide Dams

A mechanism must be developed by which the information regarding the formation of a landslide dam may be communicated to the relevant authorities in the shortest possible time. It is proposed that the NRSC be entrusted with this task. [Action: The NRSC] (Section 10.2.6).

52) Run-out and Return Period Modelling of Landslides

An R&D programme will be taken up in collaboration with international institutes having expertise in this field like the ITC, The Netherlands. [Action: The nodal ministry in consultation with the TAC and in collaboration with IITs, universities, and other academic institutions] (Section 10.2.7).

53) Snow Avalanches

The SASE, in collaboration with knowledge institutions and the NDMA, will visualise, design, and implement R&D programmes for snow avalanche studies. [Action: The nodal ministry in consultation with the TAC and in collaboration with the SASE; IMD; DST; IITs, universities, and other academic institutions] (Section 10.2.8).

54) Emerging Concerns

Global warming and climate change are the most critical areas of concern that can have significant consequences on natural hazards including landslides and snow avalanches. Research programmes to study this aspect will be encouraged. [Action: The nodal ministry in consultation with the TAC and in collaboration with the DST; IMD; IITs, universities, and other academic institutions] (Section 10.2.9).

55) Important Research and Development Activities

i) R&D areas of importance are listed below. This list is only suggestive and will be reviewed from time to time in the backdrop of emerging national priorities.

a. The refinement of methodologies for carrying out LHZ mapping both at the macro and meso scale, in order to give a realistic picture of the hazard.

b. Systematic scientific methods of landslide hazard vulnerability assessment and risk evaluation on the GIS platform.

c. The integration of landslide hazards into user-friendly multi-hazard mapping. Projection of multi-hazard risk scenarios.

d. The revisiting of past major landslide disasters for scientific post-mortems and documentation of the lessons learnt.

e. The application of recent technological developments in the fields of instrumentation, remote sensing, software and communication technologies for landslide studies.

f. The development of simple, quick, and effective methodologies for assessing direct as well as indirect losses due to the occurrence of landslides.

g. The quantification of environmental degradation, anthropogenic impact, cost of loss of land, agricultural produce, livelihood, and traffic delays.

h. The establishment of best practice examples of deterministic and probabilistic modelling methodologies for conducting detailed stability analysis of complex natural and man-made slopes and active landslides.

i. The scientific design of surface and sub-surface drainage systems, technology for their speedy installation, and evaluation of their efficacy.

j. The development of innovative techniques of landslide control, especially the mechanised construction of complex sub-surface drainage networks.

k. The development of light rugged geotechnical investigational equipment suitable for rugged and inaccessible areas.

l. The development of cheap and reliable instrumentation techniques for slope monitoring and installation of early warning systems

m. The systematisation of search and rescue operations, and the development of effective equipment for the same.

n. The development of simple and easy to install instrumentation and slope monitoring equipment for real-time early warning, including early warning thresholds and criteria.

o. The development of a predictive understanding of landslide processes and triggering mechanisms.

p. Regional real-time landslide warning systems based on threshold values of rainfall; real-time monitoring and establishment of early warning systems in the case of landslides that pose a substantial risk to developmental gains.

q. The development of methodologies for assessing potential co-seismic landslides.

r. Fundamental mechanisms of earthquake-induced and earthquake-triggered landslides.

s. Remediation practices based on multi-disciplinary field investigations suitable for local conditions.

t. Methodology for the identification of potential sites of landslide dams.

u. Fashioning of landslide rescue operations according to their typology.

v. Reservoir induced landslides, coastal landslides, submarine slumping, and tsunami related landslides.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; DST; CBRI, CRRI, CDMM; BRO; NRSC; IMD; CWC; state governments; IITs, universities, and other academic institutions] (Section 10.3)

ii) The NDMA, with the support of the nodal agency, the GSI, will encourage the development of standardised methodologies for landslide risk assessment and scenario development. It will also support studies to collect data and required knowledge, develop state-of-the-art literature and reports, select topics and evolve a procedure for undertaking pilot projects related to detailed investigations for stabilising major hazardous landslides, and the development of early warning systems. [Action: The nodal ministry in consultation with the TAC and in collaboration with the MoM-GSI; DST; NIDM; BIS; IITs, universities, and other academic institutions] (Section 10.3).

56) Areas Requiring Special Attention

i) The gap issues have been identified and these will be bridged in the near future in a planned manner. These issues include:

a. The effective management of landslide disasters in India would require detailed studies using state-of-the-art technologies, which is not practiced at present, and needs to be encouraged.

b. The practice of real-time monitoring of potentially threatening landslides is required to avert disasters by early warning. This is currently absent in India.

c. In current landslide disaster management practice, the investigating and implementing agencies are generally different. This results in fragmented accountability and communication gaps. Therefore, it will be ensured that the recommendations of the investigating agency will be carried out by the implementing agency in close association or consultation with the former.

d. Partial implementation of stability measures are understandably ineffective, and this results in the reoccurrence of landslides in general. Every landslide management project must ensure the full implementation of treatment measures in a single working season and take recourse to monitoring their efficacy in the post-implementation stage.

e. The process of data collection is required to be systematised. Sharing of data among institutions engaged in landslide studies, landslide disaster management and communities at large will be encouraged through effective networking.

f. The culture of the observational method of design and construction will be promoted to help engineers and builders effectively deal with uncertainties. The method helps in the modulation of designs based on actual ground realities as the work progresses.

g. The culture of monitoring the efficacy of control measures will be promoted to enhance the confidence level in design and add value to it if the situation so demands.

h. Good guidelines are not available on information and material for courses and training. The GSI, NIDM and other knowledge institutions will be encouraged to bridge this gap.

i. There is a lack of an extensive network of rain gauges in country. Due to this it is very difficult to attempt correlation between rainfall and landslide activity. Proper coordination with the IMD is needed for installing a network of automatic rain gauges at desired locations. In this connection it is necessary that a pilot project of 20 conspicuous landslides in different regions of the country, preferably located in proximity to important townships or thickly populated localities, is taken up initially for rain gauge installation, and if possible, installation of at least two piezometers. The results and lessons learnt will be disseminated to all concerned in three-four years. The installation of automatic rain gauges required for this has to be integrated with the proposed programme of the IMD for installing automatic rain gauges at pre-selected locations in the country. The IMD will also provide daily rainfall data from existing rain gauges on a daily basis to the data centre for landslides so that the same can be utilised by agencies or individuals engaged in such studies. The concerned institutions will be identified.

j. Initially, five landslides will be identified for detailed study. It is proposed that organisations/ institutions engaged in landslide studies, government or private, be identified/selected and given the responsibility for this work in coordination with the BRO and the respective state governments.

k. Material and human resources available in the country will be identified so that studies that are to be taken up in relevant fields are properly planned and realistic capacity building programmes designed.

l. The gaps between the landslide management systems being practiced in India and those being followed internationally will be identified and attempts will be made by all agencies engaged in landslide disaster management in the country to bridge these gaps so that the latest systems practiced elsewhere are also followed in India.

[Action: The nodal ministry in consultation with the TAC and in collaboration with the SDMAs; MoM-GSI; IMD; DST; NIDM; BRO; NRSC; CWC; IITs, universities, and other academic institutions] (Section 10.4).

Chapter 11: Implementation of the Guidelines—Preparation of Landslide Management Plans

57) Plans

In accordance with the various disaster specific guidelines laid down by NDMA, NEC will prepare a National Disaster Management Plan, incorporating the DM plans prepared by the central ministries/ departments and state governments for landslide affected states and districts. [Action: Central ministries in collaboration with the NEC; state governments] (Section 11.1).

58) Plans of Central Ministries and Departments

The central ministries and departments concerned will prepare their DM plans which will be in accordance with the National Guidelines on the preparation of state disaster management plans and shall cover all aspects of the disaster cycle for every disaster, including landslides. [Action: MHA in collaboration with central ministries; the MoM-GSI] (Section 11.2).

59) Plans of State Governments

i) In addition to preparing their DM plans, the state governments with areas affected by landslides will also encourage the preparation of community preparedness plans to address their own special features, outline the linkages of the various state support systems, and the jurisdictions of each of these departments. [Action: State governments/SDMAs] (Section 11.3).

ii) The DM plans will comply with the National Guidelines on the preparation of state disaster management plans and the guidelines of the SDMA, if any, and incorporate all the features of the EOCs including their establishment and operation. [Action: State governments/SDMAs] (Section 11.3).

60) Disaster Management Plans of the Nodal Agency

i) The GSI will setup a secretariat at an appropriate place for the purpose of coordinating nationwide activities, carrying out landslide studies in different fields related to landslides either independently as departmental programmes or in collaboration with other agencies in studies that require multi-disciplinary and multi-institutional inputs. [Action: The MoM-GSI] (Section 11.4).

ii) The GSI, along with the primary node of the DMS network will set up a data management facility where all the data related to landslides including inventory will be stored and made available to bona fide users. [Action: The MoM-GSI] (Section 11.4).

iii) As the nodal agency for landslide management, the MoM-GSI will prepare its LMP based on the guidelines laid down by the NDMA. [Action: The MoM-GSI] (Section 11.4).

61) Institutional Mechanisms

i) The development and implementation of disaster plans will be a coordinated programme of the NDMA, GSI as the nodal agency, and the national, state, district, and local administrations. [Action: The MoM-GSI in collaboration with SDMAs; DDMAs; district administrations; local administration] (Section 11.5.1)

ii) The NEC will be responsible for preparing the National Plan on the basis of these Guidelines, getting it approved by the NDMA, and subsequently for its operationalisation. [Action: NDRF in collaboration with the GSI; BRO] (Section 11.5.1)

iii) The NDRF mandated by the DM Act, 2005, will address, in close collaboration with all other field level agencies, all concerns regarding the response to the threat of landslide disaster or other disasters if and when these arise or occur. [Action: NDRF] (Section 11.5.1)

iv) The NDRF personnel will be equipped with the most modern search and rescue equipments and will undergo landslide specific training to be able to effectively deal with diverse types of landslides and other mass movements and familiarise themselves with the case records of some of the major landslide events. [Action: The NEC in collaboration with the NDRF] (Section 11.5.1).

v) The BRO, DTRL, SASE, GSI, and other institutions dealing with landslides and other mass movements will suitably improve their capacity to meet present as well as future challenges in the landslide sector, including the modernisation of investigation and mapping methodologies, and application of satellite, information, and communications technologies. [Action: The BRO; DTRL; MoM-GSI; SASE; CBRI; CRRI; CDMM; NRSC; ISRO; Department of Information Technology] (Section 11.5.1).

vi) In case a major landslide disaster occurs, the DM departments/commissioners in the states concerned will deal with the rescue and relief operations. [Action: State governments in collaboration with district administrations] (Section 11.5.1).

vii) The state governments will establish SDMAs, headed by the respective chief minister in landslide affected states to lay down policies and plans for DM in the state. [Action: State governments/SDMAs] (Section 11.5.1).

viii) At the district level, the DDMA headed by the district magistrate, with the elected representative of the local authority as the co-chairperson, will act as the planning, coordinating and implementing body for DM and take all necessary measures for the purposes of DM in the district in accordance with the guidelines laid down by the NDMA and SDMA. [Action: The DDMAs] (Section 11.5.1).

ix) These (local) bodies will ensure DM capacity building of their officers and employees, carry out relief, rehabilitation and reconstruction activities in the affected areas, and will prepare DM plans in consonance with the guidelines of the NDMA, SDMAs and DDMAs. [Action: State governments in collaboration with district administrations; local bodies] (Section 11.5.1).

62) **Centre for Landslide Research, Studies and Management**

i) A national level CLRSM will be established by the MoM as a premier geo-hazard institute with state-of-the art facilities, which would eventually grow into a national centre of excellence. It will be fully autonomous in its functioning, similar to that of a national laboratory of the Council of Scientific and Industrial Research with full operational freedom and an independent budget. It will operate within a framework of specified rules. The CLRSM will be headed by an eminent landslide expert with a proven track record. [Action: The MoM] (Section 11.5.2).

ii) A high level TAC which will be chaired by the Secretary, MoM, will be constituted by the MoM in consultation with the NDMA to serve as a think tank to nurse the landslide sector with cutting edge science and technology, fresh ideas and stimulus. [Action: The MoM] (Section 11.5.2).

iii) The TAC will comprise top professionals drawn from multi-speciality streams connected with landslide mitigation and management, and it will address research, human resource and capacity development, landslide mapping, investigation, mitigation, and the control, preservation, and protection of slopes as a component of the environment. [Action: The MoM in collaboration with The MoES] (Section 11.5.2).

iv) The Secretary, Ministry of Earth Sciences; Director General, GSI; Secretary, DST; and Executive Director of the NIDM will be ex-officio members of both CLRSM and TAC. [Action: The MoM in collaboration with the MoES; GSI; DST; NIDM] (Section 11.5.2).

63) **Implementation and Monitoring**

The LMPs prepared by the central ministries, departments concerned, state governments, district authorities, rural bodies, urban local bodies, and other stakeholders in accordance with these Guidelines will be implemented by them in accordance with in-built schedules. [Action: Central ministries in collaboration with state governments; district administrations; PRIs; ULBs] (Section 11.5.3).

64) Mainstreaming of Disaster Management in Developmental Plans

i) The central and state ministries/ departments will mainstream disaster management efforts in their developmental plans. [Action: Central ministries in collaboration with state governments; NDMA] (Section 11.6.1).

ii) Plans of Central Ministries/ Departments

The various measures for landslide management recommended in the Guidelines will be funded by the central ministries/departments and state governments concerned by making provisions in their Five-Year and annual plans. Additional funds will also be made available through special mitigation projects to be formulated and implemented by the state governments/SDMAs under the overall guidance and supervision of the NDMA. Besides this, 10 per cent of the CRF could also be utilised for the purchase of equipment for landslide preparedness and mitigation, and for rescue and relief operations. [Action: SDMAs in collaboration with central ministries] (Section 11.6.2).

iii) State Plans

The various measures for landslide management recommended in these Guidelines will be included by the respective state governments in their own plans. [Action: State governments] (Section 11.6.3).

iv) Centrally Sponsored/Central Sector Schemes

On specific requests from the state governments the MoM/GSI will include some of the schemes recommended in the Guidelines for funding under these schemes, provided that sufficient funds are available. [Action: The MoM-GSI] (Section 11.6.4).

v) District Planning and Development Council Funds

From the funds available with the District Planning and Development Council in landslide prone areas, a part will be allocated for the implementation of landslide management schemes in the districts. [Action: SDMAs] (Section 11.6.5).

Publications Consulted

The drafting of these guidelines involved extensive consultation of research papers published by many individuals, hazard management literature in the form of open file reports, and hazard management guidelines of various countries like the United States of America, Canada, Australia, New Zealand, Austria, etc. Some of the consulted reports are listed below. Authors, compilers and editors of the documents consulted are gratefully acknowledged.

Caution—Avalanches!, Ed. Swiss Federal Institute for Snow and Avalanche Research SLF, Davos, 2005
Documentation of Mountain Disasters, Eds. Hübl J., Kienholz H. and Loipersberger A., International Research Society INTERPRAEVENT, Klagenfurt, Austria, 2002

Draft—Guidelines for assessing planning policy and consent requirements for landslide prone land, Compiled by Saunders, W & P. Glassey, GNS Science Miscellaneous Series 7, 2007

Guidelines for Legislated Landslide Assessments for Proposed Residential Development in British Columbia, The Association of Professional Engineers and Geoscientists of British Columbia, March, 2006

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

National Disaster Management Guidelines: Management of Earthquakes, National Disaster Management Authority, Government of India, 2007

National Disaster Management Guidelines: Medical Preparedness and Mass Casualty Management, National Disaster Management Authority, Government of India, 2007

National Disaster Management Guidelines: Management of Floods, National Disaster Management Authority, Government of India, 2008

National Landslide Hazards Mitigation Strategy—A Framework for Loss Reduction, Elliot C. Spiker and Paula L. Gori, Circular 1244, USGS, 2003

National Landslide Hazards Mitigation Strategy—A Framework for Loss Reduction, Elliot C. Spiker and Paula L. Gori, Open-File Report 00-450, USGS, 2000

Report of the Task Force on Landslide Hazard Zonation, Ministry of Mines, Government of India, September 2000

The ABCs of Avalanche Safety, Sue A. Ferguson and Edward R. LaChapelle, Mountaineers Books, 2003

UN-ISDR Global Survey of Early Warning Systems, United Nations, 2006

Annexures

Annexure-I

Major Landslides in India

Date/Year	District/State	Remarks
1867 and 1880	Nainital, Uttarakhand	Two major landslides on the Sher-ka-Danda slope in Nainital. The 1880 landslide took place due to rainfall and an earth tremor, destroying buildings. This landslide permanently filled a portion of the Naini lake.
1893	Alaknanda, Uttarakhand	Floods in the Birehi Ganga river near its confluence with the Alaknanda river triggered landslides, causing major blockage of the river with a 10-13 m afflux. A girder bridge was bypassed and another one was destroyed.
October 1893	Gohana, Uttarakhand	The Gohana landslide which hurtled down from a height of a few thousand meters into the Birehi Ganga, a tributary of the Alaknanda river, filled the river bed up to a height of 350 m.The lake formed was 25 km by 2 km. The landslide dam was breached in 1970, raising the water level by 50 m at Srinagar. Two days later, the river water level rose by 4 m at Haridwar.
1913 to 1993	At km 138 along NH 1A (from Jammu to Srinagar), J&K	Nashri landslide is an old and notorious landslide causing disruption and road blockage at regular intervals. Often, many vehicles and equipment are buried in the huge debris generated.
September 1968	Maling landslide, H.P.	A bridge was washed out. The landslide is still active.
1968	Rishi-Ganga, Uttarakhand	The Rishi Ganga river in Garhwal was blocked up to a height of 40 m due to a landslide at Reni village. The dam was breached in 1970, causing extensive damage.
3-5 October 1968	Darjeeling and Jalpaiguri, W.B.	Widespread landslides and other mass movement causing death and devastation.
October 1968	Ambootia Landslide, Kurseong subdivision, Darjeeling District, W.B.	High landslide vulnerability with recurring threat of landsliding. Heavy landslide activity in 2003 and 2008, affecting Mamring village.

July 1970	Patal Ganga, Uttarakhand	Narrow constriction of the Patal Ganga, a tributary of the Alaknanda river. The Patal Ganga got choked and a reservoir more than 60 m deep was created. The bursting of this choked reservoir resulted in flash floods in the Alaknanda river, triggering many landslides.
February 1971	Jammu & Kashmir	Widespread landslides caused disruption of traffic and communications systems along NH-1A.
1971	Kanauldiagad, Uttarakhand	A major landslide on the bank of the Kanauldiagad, a tributary of the Bhagirathi river upstream from Uttarkashi, formed a debris cone which impounded water to a height of 30 m. Its breaching caused flash floods downstream.
July 1973	Shimla, H.P.	A landslide cut Shimla town off from the rest of the country.
July 1975	North of West Bengal	Widespread landslides and floods rendered 45,000 people homeless in the areas of Teesta, Jaldhaka, and Diana.
September 1975	Jammu & Kashmir	Landslides killed two labourers and disrupted the transportation system for three days.
June 1976	Darjeeling, W.B.	Floods in Teesta triggered many landslides. Three people were buried alive due to the caving-in of a hillock.
July 1977	Jammu & Kashmir	The Srinagar-Leh road was blocked due to landslides.
August 1978	Uttarkashi, Uttarakhand	The Kanauldia Gad, a tributary joining the Bhagirati river upstream from Uttarkashi in the Uttaranchal formed a debris cone across the main river, impounding the river to a height of 30 m. Its breaching caused flash floods, creating havoc. A 1.5 km long, 20 m deep lake was left behind as a result of the partial failure of the landslide dam.
1920, 1952, 1963, 1964, 1965, 1968, 1969, 1970, 1971, 1972 and 1985	Kaliasaur, Uttarakhand	This was one of the most persistent and regularly occurring landslides along the Rishikesh-Badrinath road.
December 1982	Solding Nallah, H.P.	At Solding Nallah, three bridges have collapsed in the last decade due to landslides. About 1.5 km of NH-22 vanished.
March 1989	Nathpa, H.P.	At Nathpa, about 500 m of road was damaged. The landslide is still active, frequently blocking the road.
October 1990	The Nilgiris, T.N.	36 people were killed and several injured. Several buildings and roads were damaged, and communications disrupted.

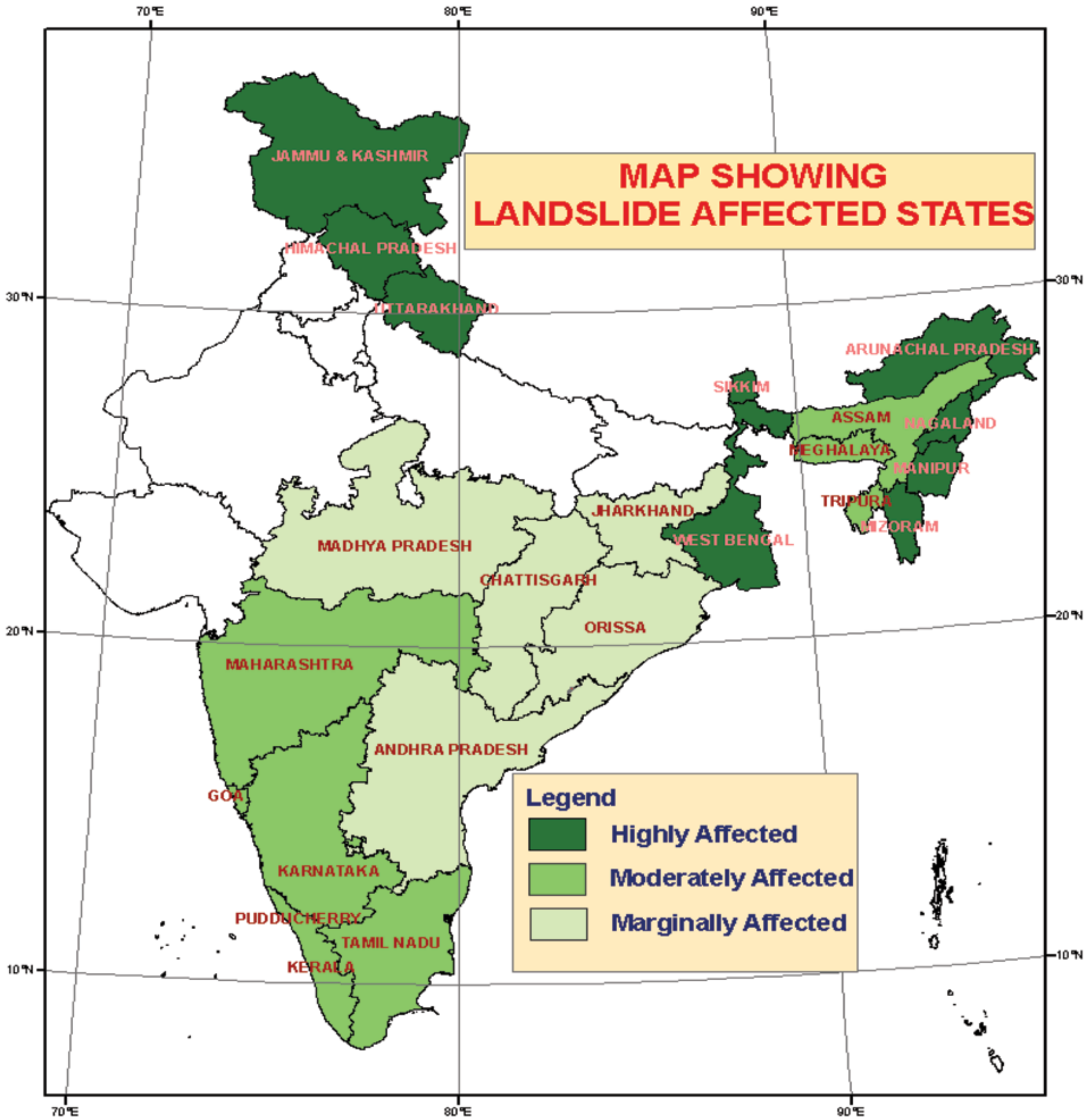
July 1991	Assam	300 people were killed, roads and buildings worth lakhs of rupees damaged.
November 1992	The Nilgiris, T.N.	The road network and buildings were damaged. Damage estimated at Rs. 50 lakh.
1993	Jhakri, H.P.	About half a km of road was completely damaged and landslide debris blocked the river Sutlej. Traffic was restored after two months.
June 1993	Aizwal, Mizoram	Four people were buried by debris.
July 1993	Itanagar, Arunachal Pradesh	25 people were buried alive, 2 km of road damaged.
August 1993	Kalimpong, W.B.	40 people were killed, heavy loss of property.
August 1993	Kohima, Nagaland	200 houses were destroyed, 500 people killed, a 5 km stretch of road was damaged.
October 1993	Marapplam, the Nilgiris, T.N.	40 people were killed, property worth several lakhs of rupees damaged.
January 1994	Jammu & Kashmir	NH-1A severely damaged by landslides.
June 1994	Varundh Ghat, Konkan Coast	20 people were killed, the road damaged to a length of 1 km.
May 1995	Aizwal, Mizoram	25 people were killed and the road severely damaged.
June 1995	Malori, Jammu & Kashmir	Six people were killed, NH-1B damaged.
September 1995	Kullu, H.P.	22 people were killed and several injured and about 1 km of road destroyed.
14 August 1998	Okhimath, Uttarakhand	69 people were killed due to several landslides.
18 August 1998	Malpa, Kali river, Uttarakhand	210 people were killed. The heap of debris created was about 15 m high. The village was wiped out in the event.
24 September 2003	Varunavat Parvat, Uttarkashi, Uttarakhand	A massive landslide started on 24 September 2003, following incessant rains in the area, causing the burial of numerous buildings, hotels, and government offices located at the foot of the hill slopes. This landslide affected 3,000 people and the loss of property was to the tune of Rs. 50 crore.
5 July 2004	Badrinath, Chamoli District, Uttarakhand	16 persons killed, 200 odd pilgrims stranded, 800 shopkeepers and 2,300 villagers trapped as cloudburst triggered massive landslides washed away nearly 200 metre of road on the Joshimath-Badrinath road cutting off Badrinath area.

16-20 February 2005	Anantnag, Doda, Poonch, Pulwama, and Udhampur Districts, Jammu & Kashmir	Avalanches at several places. Over 300 people lost their lives.
10 May 2005	Itanagar, Arunachal Pradesh	Nine people were killed and loss of property resulted.
26 May 2005	Mokokchung, Nagaland	12 persons were killed, two injured and six houses damaged. The places affected were Tongdentsuyong, Alongmenward, Aongza.
June 2005	Nogli and Rampur, H.P.	Severe damage was caused to 70 to 80 m of the road due to heavy rain and flash floods.
June 2005	Rampur, H.P.	The junction of the HPSEB Rest House road and NH-22 near Chuhabagh area of Rampur Town was affected due to a landslide resulting from rainfall.
29-30 June 2005	Govindghat, Chamoli, Uttarakhand	A cloudburst/landslide occurred in which a huge quantity of debris and rock boulders were brought down along a seasonal *nala*. 11 people were killed and property lost.
July 2005	Mumbai, Maharashtra	Caused death and loss of property in Mumbai. Four deaths on the Belapur-Kharagpur road, 14 deaths at Nerul, and 100 deaths at Sakinaka and Tardeo.
July 2005	Satara District Maharashtra	Within Satara, places affected were Bhilar, Gadalwadi, Met Gutad, and Tapola.
July 2005	Raigad, Maharashtra	Within Raigad, places affected by landslides were at Dasgaon (36 deaths), Rohan (15 deaths), Jui (96 deaths), and Kondivate (34 deaths). Also, damage was caused to roads and other structures.
August 2005	Ratnagiri District, Maharashtra	Places affected were Mandangad, Chiplun, Sangameshwar talukas. Destabilisation of slopes affecting man-made features.
13 November 2006	The Nilgiris - Coimbatore, T.N.	Between Burliar and Mettupalayam on NH-67, the road was washed off due to landslide.
September 2006	Doda, Jammu & Kashmir	Between Ramsu and Batote, there were many minor slope failures and landslides due to heavy rains.
7 August 2006	Betul, M.P.	At km 837/22 of the Betu–Itarsi section of the Central Railway, a rock slide occurred 5 km north of Maramjhiri Railway station, bringing down 100 m3 of rock material. This resulted in blockage of rail traffic.
19 July 2006	Darjeeling, W.B.	A landslide occurred due to incessant rainfall, 21 houses and property worth Rs. 25 lakhs was damaged.

20 July 2006	Darjeeling, W.B.	Debris slide within the Ging Ladenla Hatta village caused the destruction of three dwelling units.
30 August 2006	Darjeeling, W.B.	Due to incessant rain, a landslide occurred causing the loss of two lives, damage to eight houses, and loss of property to the tune of Rs. 36 lakh.
3 July 2006	Gajpati, Orissa	In Minjri and Jingirtala village, Gumma block of Gajpati district in Orissa, a landslide occurred due to prolonged heavy rainfall, and unplanned civil structures on hill slopes blocking the *nala* flow led to debris/mud flow. Seven people died and seven to eight houses were buried under debris.
August 2006	Araku valley, Paderu, Andhra Pradesh	Massive landslides occurred in Vishakhapattanam district, Andhra Pradesh, at several places. 18 lives were lost and damage was caused to 10-15 dwelling units.
14 August 2007	Dharla Village, H.P.	A landslide led to the burial of the entire village. 14 houses and one primary health centre were buried under the debris. 60 lives were lost.
6 September 2007	Village Baram/Sialdhar, Dharchula, Pithoragarh district, Uttarakhand	A landslide due to excessive rainfall resulted in 15 fatalities and loss of livestock.
14 June 2008	Parampure District, Arunachal Pradesh	17 people were killed in a series of landslides preceded by heavy rainfall.

Annexure-II

Map Showing Landslide Affected States



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