



LANDSLIDE MANAGEMENT IN INDIA: A STRATEGY PAPER BY GSI

I. Preamble

The mountainous region of Himalayas and Western & Eastern Ghats of India is vulnerable to different types of landslides that can be triggered either by rainfall or earthquake. Landslides are annual recurring phenomena and cause significant impact to human life. In India, 4.2 lakh km² of hilly region in 16 states and two Union Territories, are vulnerable to landslide hazards.

For the mitigation and management of landslide risk in the country, the National Disaster Management Authority (NDMA), in consultation with the Geological Survey of India (GSI), has formulated a ***National Landslide Risk Management Strategy (NLRMS)*** guidelines in 2019 (<https://ndma.gov.in/images/guidelines/NLRMS.pdf>), which addresses all the components of landslide disaster risk reduction and management such as hazard mapping, monitoring and early warning system, awareness programmes, capacity building and training, regulations and policies, stabilization and mitigation of landslide etc. The strategy document envisages specific recommendations for GSI, States and other stakeholders, so as to avert or reduce the impact of future landslide calamities.

The recommendations in the NLRMS guidelines, if adopted and implemented by the State and user agencies, is foreseen to substantially reduce the risk associated with landslide and achieve the goal of the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 of United Nations.

Geological Survey of India (GSI), an attached office under the Ministry of Mines (MoM), is the nodal agency for landslide studies in the country. About 100 plus geoscientists of GSI are working in landslide studies from its 14 offices located in different states, including one R&D facility at Geohazards Research and Management (GHRM) Centre at Central Headquarters, Kolkata. GSI works on varied types of landslide investigations with the aim to empower the states (State Governments) and national stakeholders (e.g., NDMA) with relevant geoinformation for landslide management.

GSI's endeavor in landslide studies, work-plan and goals are oriented to:

- a. provide inputs to fulfill the United Nation's Sustainable Development Goals (SDGs), by directly contributing to the *Goal 11: Make cities and human settlements inclusive, safe, resilient, and sustainable*.
- b. achieve the objective of the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 of United Nations by providing relevant geoinformation to all the stakeholders for ... *“the substantial reduction of disaster risk and losses in lives,*

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livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries”.

- c. adopt Prime Minister’s ten agenda points on disaster risk reduction especially on “invest in risk mapping”, “leverage technology to enhance the efficiency of disaster risk management efforts”, “utilise the opportunities provided by social media and mobile technologies”, “build on local capacity and initiative”.
- d. enhance knowledge networking with resource organisations, intellectuals and individuals through creating appropriate knowledge platform and repository for effective landslide management.
- e. partnering with institutions and resource organisations for research & development, innovations and leading landslide management subject at global level.
- f. certification of landslide management excellence to the organisations, institutions, individuals who contribute significantly towards landslide management.
- g. creation of conducive environment for landslide management study, exhibition of exemplary landslide management and landslide management museum for future generation as well as for effective documentation.
- h. exploring risk transfer and risk prevention in landslide management leading to economic development as well as welfare of community.
- i. integration of landslide solutions in development activities i.e. in transport & logistics, agriculture, forestry, industries, town and country planning/urban development/ regional and master plan etc.
- j. take up need based landslide management programmes / projects.
- k. support NDMA’s Landslides Risk Management (LRM) scheme by providing geological inputs through detailed geological mapping and assessment of landslides, and also works as a peer in NDMA’s expert committee for reviewing the DPRs submitted by the States, and
- l. pursue actionable points of NDMA’s National Landslide Risk Management Strategy guidelines of 2019 (<https://ndma.gov.in/images/guidelines/NLRMS.pdf>) and to create, update and provide quality geoinformation to all relevant stakeholders in improving the coping capacity and mitigation of landslide risk.
- m. to study landslide hazards triggered by heavy and extreme precipitations

GSI’s landslide activities, right from developing methodologies to its application, aims towards achieving the ultimate goal of Disaster Risk Reduction and to build a safer and sustainable Nation. The Sendai framework on DRR focuses on developing strategies to substantially reduce disaster risks, and GSI, being the nodal agency, is entrusted to carry



forward the same in landslide sector. GSI has been continuously engaged in such service to the nation and has envisaged a detailed actionable plan for the next 10 years to achieve the desired goals for DRR in landslide hazards.

II. NDMA's Strategy

At present two national level guidelines from NDMA are available that deal about landslide risk management: *Guidelines on Management of Landslides and Snow Avalanches*, 2009 (<https://ndma.gov.in/images/guidelines/landslidessnowavalanches.pdf>), and the *Guidelines on National Landslide Risk Management Strategy (NLRMS)*, 2019 (<https://ndma.gov.in/images/guidelines/NLRMS.pdf>). Both the documents have been formulated by NDMA in consultation with GSI.

The 2019 NLRMS guidelines outlined six strategies for landslide disaster risk reduction as under:

- a. generation of user-friendly landslide hazard maps,
- b. development of landslide monitoring and early warning system,
- c. awareness programmes,
- d. capacity building and training of stakeholders,
- e. preparation of mountain zone regulations and policies, and
- f. creation of a SPV for landslide management including stabilization & mitigation.

The strategy document is prepared to fulfil the fifth target of Sendai Framework for Disaster Risk Reduction (2015-30) i.e., *Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020*. All these strategies in NLRMS guidelines are inter-linked and collectively, if implemented, can lead to achieve the ultimate goals of landslide risk reduction.

In this regard, GSI has prepared its vision to provide landslide related geoinformation and models to stakeholders to formulate and implement their plans, policies and procedures for landslide mitigation and management with the ultimate aim for disaster risk reduction.

GSI's future landslide programs (2020-2030) are thus planned and synced with the launch of the **National Landslide Risk Mitigation Project (NLRMP) of GSI in 16 landslide prone States and in two UTs**, with 10 activity spearheads for 2020-2030. The details of specific action plans of NLRMP are enumerated in Section VI later.

However, implementation of Landslide DRR strategies comes under the ambit of the State Governments, as disaster mitigation in our country is a State-Subject. Geoscientist has a limited scope in implementing landslide mitigation schemes in a State in totality either using structural (engineering solutions) or non-structural (regulation)



measures. The role of GSI is thus restricted to landslide identification and mapping, generating baseline and thematic information on the distribution of landslide vulnerable zones (e.g., landslide susceptibility mapping), estimation of landslide hazard and risk, development of early warning, and awareness generation etc. for which GSI has already launched the above National Landslide Risk Mitigation Project (NLRMP) in multiple landslide prone States and UTs with 10 discerning activities since 2020.

Accordingly, GSI contributes significantly in the first four landslide risk management strategies (i to iv) of NDMA's NLRMS guidelines and thereby assists the State Governments in executing the National Disaster Management Plan and National Disaster Management Policy for overall landslide management and disaster risk reduction as a whole.

III. Stakeholders of GSI

At present, besides GSI, several other institutes in India are engaged in landslide studies of both fundamental and on application levels. Some of the premier institutes include National Remote Sensing Centre (NRSC) in remote sensing based studies for carrying out rapid assessment landslide geometry immediately after a disastrous event, mapping of elements-at-risk and physical damages caused by a landslide, National Institute for Rock Mechanics (NIRM) for rock slope stability modelling and analysis, IITs and Universities for fundamental research on landslides through Department of Science and Technology (DST) sponsored projects or support from UGC/CSIR fellowships, CSIR-Central Road Research Institute (CRRI)/CSIR-Central Building Research Institute (CBRI)/Wadia Institute of Himalayan Geology (WIHG)/ Defence Terrain Research Laboratory of DRDO, etc. for landslide applications in instrument-based site-specific landslide monitoring and early warning, and Indian Institute of Remote sensing (IIRS) and National Institute of Disaster management (NIDM) for landslide trainings, awareness and capacity building endeavours, etc.

GSI has a pan India presence, last-mile connectivity and has the capability, expertise and commitment of taking up almost all types of landslide investigations with intensive field inputs. The landslide related outputs of GSI are 'open file textual reports', and GIS-enabled seamless landslide susceptibility maps of landslide-prone areas, landslide inventory maps with detailed field-based geoparametric attributes. All these spatial and textual geoinformation are available on GSI's web portal (<http://bhukosh.gsi.gov.in/Bhukosh/Public>) for free downloading and use by stakeholders. The major stakeholders in this case are the State Governments, Central Departments, Universities, IITs and Research Scholars, important being NDMA, SDMA, Building Materials & Technology Promotion Council (BMTPC), NRSC, Boarder Road Organisation (BRO), etc.



IV. Strategy & Action Plan

GSI's strategy and action plan is aimed to meet the requirement of the country in landslide DRR includes both R&D as well as its application as operational programs for landslide risk management. For R&D, GSI collaborates with several National and International institutes of repute such as British Geological Survey (BGS); ITC, The Netherlands; Natural Resources Canada (NRCan); CNR-IRPI, Italy; Defence Terrain Research Lab (DTRL/ DRDO); National Remote Sensing Centre (NRSC/ISRO) etc. Recently GSI has accomplished researches focusing on development of more advanced tools and techniques for landslide risk assessment, including development of regional landslide early warning system, debris flow modelling, measuring ground deformation using satellite data as well as studying landslides using state-of-the-art ground-based instrumentations, etc. This advanced knowledge acquired is helping the country to deal with landslide hazards in a more efficient way by enabling us for a better landslide DRR regime.

GHRM centre, in collaboration with BGS and CNR-IRPI (e.g., LANDSLIP Project), has developed methods for generating landslide forecasts and is expected to launch country's first-ever experimental daily landslide forecast bulletin for Darjeeling District by 2020 monsoon. Similar attempts in experimental mode in 2-3 more terrains are planned in the next 2-5 years for constraining the model parameters. By 2025, GSI intends to apply regional landslide forecast in an operation mode in other vulnerable districts of the country, for which it has a vision to develop a state of the art landslide warning centre at GHRM Centre, GSI, Kolkata, similar to Tsunami warning centre of Indian National Centre for Ocean Information Services (INCOIS), MoES at Hyderabad. With this endeavor, GSI plans to provide much needed landslide forecast information to the State Government for their decision support in planning and effectively implementing risk mitigation strategies. Since landslide forecasting and early warning require multi-institutional inputs, GSI will be collaborating with Indian Meteorological Department (IMD)/ National Centre for Medium Range Weather Forecasting (NCMRWF)/National Remote Sensing Centre (NRSC) and State Disaster Management Authorities in this endeavor.

Regional landslide susceptibility maps are the baseline information needed for formulating any landslide management plans as envisaged in NDMA's NLRMS guidelines such as allocating resources in landslide vulnerable areas, adopting land use zoning regulations, implementation of building codes, prioritizing insurances against disaster effect, targeting population for awareness programmes and capacity building, ranking districts in terms of landslide hazard, preparation of disaster score card for States/UTs, etc.,

GSI, through its flagship ***National Landslide Susceptibility Mapping (NLSM)*** program, has already mapped 3.57 lakh km² area (85% of the total target). Out of the above completed target, landslide susceptibility maps of 2.55 lakh km² (61% of the total target)

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have already been uploaded in GSI's web portal for viewing and downloading by all stakeholders. The above spatial database also contains 52,146 active landslide polygons with their locational attributes, basic geometry information, typology, etc., and 25,184 field validated landslide point data with 41 geoparametric attributes. These GIS enabled susceptibility maps and landslide inventory spread over 16 landslide prone states and two UTs are of high significance for use by stakeholders in planning landslide risk mitigation programmes, framing land use zoning regulations and integration in their respective disaster management plans. In this direction, The Secretary, Ministry of Mines has communicated to all the Chief Secretaries of the hill states for making optimal use of the above GSI data and information available on web-portal vide DO letter dated 12th May 2020. The rest of the NLSM outputs will be placed on public domain in phases after the completion of NLSM of Arunachal Pradesh by 2022. In addition, GSI also carries out landslide contact programmes in States to highlight the importance and applicability of such vital data.

As landslide being an individual phenomenon and generally affects a small section of a society, unlike flood/draught or earthquake, the pre-disaster prevention covering all individuals, remains a challenge. These complexities of landslide, in fact, limit the efficacy of implementation of any landslide management strategies for DRR. Realising the gravity of this issue, GSI made significant attempt in developing and implementing a people centric landslide Early Warning system in collaboration with SDMA/State Government. One such system is deployed in Giddapahar village in Darjeeling District, West Bengal. By 2030, GSI will be implementing similar projects in conjunction with the Regional Landslide EWS in phases to intensify such system in vulnerable villages.

The role of concerned State/ UT authorities and local communities are essential not only in the preparedness and mitigation phases of disaster management, but, also in the emergency situations during the event. In order to sensitize the State Administrations and to make people aware of the landslide phenomenon and related disasters, GSI often carries out landslide awareness programmes in collaboration with State Governments with an aim to increase the coping capacity of the stakeholders in fighting/ tackling the landslide hazard. In past, GSI has been carrying out such programs in regional, state, district, taluka and even up to village level. Recently, GSI is also using Bhumisamvad platform to conduct such awareness programmes in landslide prone States effectively.

For specific developmental planning, large scale (meso/micro-scale) maps are required. GSI has been carrying out (suo-moto or on request from stakeholders) large scale landslide susceptibility mapping on selective stretches of road corridors and in and around important vulnerable settlements. NDMA's NLRMS guidelines highlighted 47 such sectors in India where such large-scale studies are needed. In addition, GSI from its NLSM database has also identified 100 additional sectors. Besides, the State priorities and local assessments are also given due importance in formulating the project. These reports are



submitted to the State Governments for making their use in developmental planning. ***A more rigorous attempt is needed to sensitize the State agencies on the importance and use of such large-scale maps.*** Their judicious use will certainly lead to better management of slopes and land-use practices in hilly areas. GSI's future activity in coming decade will prioritize preparation of meso scale maps of all such identified sectors so that the concerned State Governments can use them for local level infrastructure planning.

In similar line, GSI renders services to support NDMA's LRM scheme. GSI carries out the geological investigation of landslides and help the State Governments to prepare the Detailed Project Reports (DPRs) on landslide treatment for submission to NDMA for part funding.

V. GSI's Contribution in landslide studies and management

GSI's contribution to landslide studies dates back to 1880 with the study of problem of slope stability in Nainital, Uttarakhand by Sir R.D. Oldham. Since then a lot of work has been done by GSI towards the sustainable development of the country. All these studies have been compiled by GSI in the form of a Compendium of landslides and published as GSI's 'Special Publication' series. Apart from the above, other success stories include

- Preparation of landslide susceptibility maps at different scales to provide information on landslide vulnerability of hill slopes for regional and specific land use planning. Some of its maps such as meso-scale landslide susceptibility map of Nainital, Uttarakhand and macro-scale landslide susceptibility map of Nilgiri District, Tamil Nadu are included in the landslide disaster management planning by the respective state governments. The NLSM data product is being used in the TN-SMART mobile app, which has been introduced by the Tamil Nadu Disaster Management Authority to disseminate alert and it would be linked to an alarm system to all registered members.
- From 2014 onwards, with the launch of NLSM Programme, the susceptibility mapping is now being carried out in GIS using Weighted Multi-class index overlay method. The outputs – a digital national landslide susceptibility database and inventory are made available through GSI's Bhukosh web portal for wider dissemination and use. More than 1500 registered users have already downloaded these baseline geospatial databases from GSI's portal.
- Another most valuable contribution of GSI is the post-disaster rapid geotechnical assessment of landslides and preparation of detailed inventory of landslides. In the recent times, GSI has made notable contributions in this field, namely in assessment of 2013 Uttarakhand disaster and 2018 Kerala landslide disaster by including field-based



vital geoscientific inputs. GSI initiated the post-disaster slope stability assessment in 2013 in the five worst affected districts of Uttarakhand viz., Uttarkashi, Rudraprayag, Chamoli, Bageshwar and Pithoragarh, including development of Kedarnath restoration plan. The summary of these works are available in the GSI's Special Publication No 107 on 'Landslide compendium of Northwestern Himalayas'. Similarly, in the aftermath of 2018 Kerala landslide, GSI immediately responded and carried out the post disaster landslide studies in the state of Kerala and Karnataka, including assessment of villages under landslide risk. In these studies, more than 2500 landslides and 60 villages have been geotechnically assessed. The reports were duly submitted to the respective State Governments for execution of the recommendations. Such reports with field based geoscientific inputs form basic tool for decision making.

- GSI has assisted many agencies such as Border Road Organisation, PWDs, Indian Railways, THDC Ltd, Central Water Commission, etc. for detailed site-specific geological mapping of landslides on scale 1:1000/2000 for suggesting suitable remedial measures. Notable examples include 2003 Varunavat Parwat landslide in Uttarkashi where GSI provided the geological and geotechnical data input for design of the support and strengthening measures. THDC Ltd. Executed the treatment under the overall supervision of GSI. In similar line, currently, GSI renders services to support NDMA's LRM scheme. Some of the recently concluded studies include Tawang monastery landslide in Arunachal Pradesh, Ramlhun landslide in Mizoram, Legislative assembly Complex landslide in Nagaland, etc.
- In 2018, GSI stepped into community-science approach for landslide DRR. For the first time in India, a people-centric Landslide Early Warning System has been deployed by GSI on 07 September, 2018 at Giddapahar Village in Kurseong Block, Darjeeling District, West Bengal on an experimental basis. It is a joint effort of GSI and Govt. of West Bengal. The aim of the project was to develop an early warning set-up where community plays an important role in the management of landslide warning and to act in sufficient time and in an appropriate manner to reduce the risk to life. Such system will not only enhance the coping capacity of the community at risk, who are actually the first responder in case of disaster, but will also build a resilient society.
- GSI maintains a dedicated thread-link on Landslide hazard within GSI web portal (www.gsi.gov.in). The webpage contains notes on landslide awareness programmes, project details, NLSM digital database, publication, metadata of government funded landslide projects, do and don'ts in case of landslide, etc. GSI regularly updates the landslide database of the entire country through the Bhukosh and Landslide hazard web page of GSI web portal.



VI. Future endeavour and strengthening landslide DRR in next 10 years

As indicated in Section II above, GSI has planned its future activities in line of its commitment as a 'Nodal' agency for landslide studies and to fulfil the country's demand to implement landslide risk mitigation strategies for next 10 years by launching the **National Landslide Risk Mitigation Project (NLRMP)** in multiple landslide prone States and UTs with 10 following discerning landslide studies and activities. The following are the 10 core future programs of GSI under **NLRMP** for 2020-2030 in line of the requirement of NDMA and society as a whole by drawing up required number of resources, envisaging defined targets, achievements and deliverables.

Sl. No.	Major Activity	Target	Implementation Period	Status
1.	Establishment of Landslide Early Warning Infrastructure at Geohazards Research and Management (GHRM) Centre, Kolkata	Operationalisation of Landslide Early Warning Control Centre	2020-2021	In Progress
2.	Launching of Regional Landslide Early Warning System (Experimental mode) in phases	10 Landslide-prone States	2020-2024	Commenced w.e.f. 01.07.2020
3.	Launching of Regional Landslide Early Warning System (Operational mode) in phases	16 Landslide-prone States and two landslide prone UTs	2025-2030	-
4.	Landslide Risk Assessment and Exposure Vulnerability Mapping in vulnerable districts	75 vulnerable districts spread over vulnerable States	2020-2024	In Progress
5.	Meso scale (1:10,000) Landslide Hazard Mapping in prioritised areas	200 sites (each ~ 30 km ²) spread in vulnerable States	2020-2024	In Progress
6.	Site Specific Landslide Investigations for mitigation and remedy	100 active landslides spread in vulnerable States	2020-2024	In Progress
7.	Completion of remaining target of landslide susceptibility mapping – NLSM targets (Arunachal Pradesh)	0.7 lakh km ²	2020-2022	In Progress
8.	Updation of NLSM database and National Landslide Inventory	4.2 lakh km ²	2020-2030	In Progress

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9.	Research Projects on InSAR modeling, Earthquake induced landslides, and debris flow modeling	Three Research Projects	2020-2023	Planning Stage
10.	Targeted Landslide Awareness Programmes in landslide prone States/ Districts to help the first responders	All landslide prone States and UT	2020-2030	In Progress

Under Section 18 of the Disaster Management Act 2005, the State Authority has the responsibility for laying down policies and plans for disaster management in the State. This also includes preparedness, and mitigation of landslide problems. GSI has been providing requisite data support to State Governments in landslide sector. It is now important to have more coordinated efforts between Centre and State/executing agencies such as GSI and SDMAs/Highway Authority/Railways/ PWDs, etc. for judiciously using the available landslide geoinformation in landslide disaster management planning to implement the landslide DRR in India more effectively. The platform of Technical Advisory Committee (TAC) for landslide mitigation and management in India, for which the Secretary, Mines is the chairman, should be mandatorily used for this purpose to strengthen the linkage.

Attempt will be made to make use of the landslide geoinformation mandatory in the hill area development projects. This will lead to safe hill construction and ultimately will make people's life safer from landslide hazards. GSI is committed to provide the required data and technology supports, expertise and training to SDMAs and District Disaster Management Centres to carry forward the above mission.