TECHNICAL COLLABORATION BETWEEN NBRO AND NORWEGIAN GEOTECHNICAL INSTITUTE (NGI)

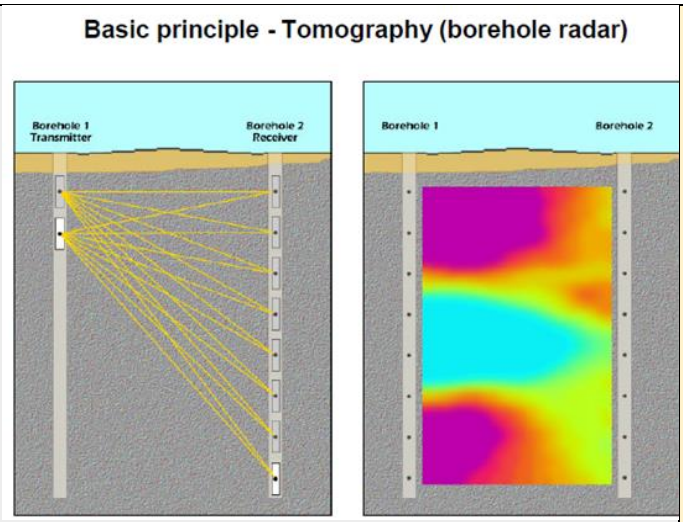
NBRO – NGI TECHNICAL collaboration program has designed to build the capacity of NBRO professionals representing various disciplines such as geotechnical engineering, engineering geology, town planning, civil engineering, etc. to mitigate the impact of landslides and other natural hazards, to effectively respond to and recover from such disaster events.

The outcome of the program activities was achieved by utilizing training and capacity building, technology transfer, knowledge sharing on disaster risk management, collaborating closely with NBRO scientists involved in various activities for upgrading and optimizing the technical expertise and adapting the program activities to suit the country context.

The specialized program activities yielded area-specific results to assist NBRO to fulfil their national mandate in landslide risk management and to serve communities better, prepare for disasters, whilst driving and supporting them to take the appropriate actions to reduce disaster risk.

Activities	**Impacts/contributions**	**Remarks** (Covered through ongoing programme and future perspectives)
Use of Remote Sensing Interferometry Synthetic Aperture Radar (SAR)	Sri Lanka is annually faced with several hydro-meteorological and geological hazards and losses, damages, social and economic impacts owing to such disasters are getting higher. SAR is used to extract topographic information from the ground surface to facilitate detection and an early action for remedy. It is an advanced remote sensing technique for monitoring the ground displacement in critical areas of the country. The capacity building carried out by NGI has helped in data extraction, analysis, and development of a digital elevation model (DEM) with a high accuracy from the satellite images for Identification of risk potential in advance to undertake measures for risk management. Currently NBRO has developed the capacity using the SAR as a tool for I. Land subsidence risk assessment in the country. A map indicating the subsidence prone areas due to karstification phenomena has been done and special guidelines for construction in such areas was possible with mapping and identification of potential risk. ii. better understanding the ground condition for taking appropriate measures for reducing the risks to infrastructures. iii. monitoring of slow moving rockfall and slow-moving mass movements with SAR sensors. Now it is possible for NBRO to take actions for risk reduction for most vulnerable communities including resettlement in safer areas. iv. for monitoring of flood events as it has the capability to generate rapid, accurate and cost-effective flood mapping. Current techniques used for flood detection cannot track or detect the cascading and progressing effects of the flood, but the SAR sensors have the penetration capacity to detect through cloudy	**Covered through ongoing programme** 1. Land Subsidence Monitoring - Matale, Hingurakgoda 2. Land subsidence caused by tunnel excavation during Uma-oya hydro-power Project **Future Perspectives** 1. Flood Propagation Detection 2. Identification of slow moving rockfall and mass movements

	atmospheric circumstances like fog, mist, smog, and light rain etc.	
Ground Penetrating Radar (GPR Technology)	Bore hole drilling and testing is the commonly used technique in uncovering the characteristics of sub-surface formations and detection of associated problems. However, it has limited use for investigation of some critical infrastructure foundations (such as earth dams, dikes, embankments, verifying the integrity of pile foundations, condition of archaeological infrastructure buried in subsurface formations etc) due to time constraints and cost effectiveness. A Ground Penetrating Radar (GPR) is a very useful advanced modern equipment utilized for scanning the ground below the surface and developing cross sections to indicate the prevailing below surface conditions. The principle of GPR is that a 'transmitter antenna' sends electromagnetic waves into the ground, which are then reflected and received back at the surface by the 'receiver antenna'. With this equipment the ground can be scanned up to 30 m in depth depending upon prevailing conditions at the site. The European Commission declared after testing of similar equipment from USA, Canada, Sweden, Germany, and Norway that GPR developed at the Norwegian Geotechnical Institute is the best in the world providing good resolution of the features that were evaluated. NGI through the cooperation agreement has helped in procurement of the basic GPR equipment and helped in capacity building in scientists. NGI and NBRO has implemented several projects together in Sri Lanka to transfer knowledge and know-how example detection of weaker areas in earth dams, flood dikes helped in timely repair, saved resources, and prevented unfortunate events such as dam breaking during monsoon. The discovery of the ancient city of Anuradhapura before current urban area expansion projects helped in protecting the heritage sites. GPR survey have been performed by NBRO for the purpose of geotechnical investigations at geo-hazard sites and at several upcoming infrastructure project sites in the country. NBRO is now in the process of procuring advanced borehole antennas which can be used to scan the ground between two boreholes. This process is sometimes termed Tomography (see fig. below) in which the borehole antennas are used for scanning the ground features between the boreholes using the transmitter and receiver antennas. These antennas have been especially fabricated at NGI for use by NBRO to perform geotechnical investigations at geo-hazard sites and at upcoming infrastructure projects in the country.	**Covered through ongoing programme** 1. Land Subsidence Mapping - Matale, Hingurakgoda 2. Identification of ancient fort - Anuradhapura 3. Identification of Dam leakage - Nachchaduwa Tank 4. Identification of Utility located underground - Colombo (pipeline) 5. Identification of slip surface - Ratnapura **Future Perspectives** 1. Cross borehole Tomography

		
Vulnerability assessment	Vulnerability assessment is an important tool from the planning perspective of a settlement, which helps to identify the behaviour of various elements such as houses, commercial areas, buildings, infrastructure etc. during a hazard situation. It is the responsibility of a city planner to identify all such vulnerabilities and suggest appropriate land use planning measures to minimize the impacts. Vulnerability assessment provides necessary details of the elements at risk, for a particular hazard and degree of vulnerability within a human settlement or a city. GPR and SAR surveys were found to be very useful tools in data extraction, analysis and conduct of vulnerability assessment and to enhance the accuracy of such assessment. The NGI-NBRO corporation helped in developing the capacity of NBRO for Incorporation and application of novel technologies like GPR surveys and SAR imagery in new settlement and city planning. In particular for conducting vulnerability assessment to enhance the accuracy of the assessment and come up with various mitigation options to reduce the impact of potential disasters. The successful outcome of the above is the capacity built in NBRO for application of such modern and advanced tools and possibility of NBRO to extend assistance to Urban Development Authority (UDA), Local Governments etc. in preparing development plans, preparation of building guidelines and land-use regulations to create safer settlements in future.	**Covered through ongoing programme** 1. Conduct vulnerability assessment for Matale MC area 2. Develop Vulnerability Scoring Matrix to identify vulnerable settlements 3. Discussion with UDA to incorporate the vulnerability assessment with their development plans **Future Perspectives** 1. Develop construction guidelines and land use guidelines for land subsidence risk areas.
Landslide Monitoring System 1. Installation of automated Rain Gauge System	Landslide hazard Early warning (EW) constitutes a comprehensive system, comprising several tasks such as hazard monitoring, forecasting, risk assessment, warning communication and preparedness. The NBRO as the designated government institution for landslide risk management in Sri Lanka, is involved in providing landslide EW to all 12-landslide prone administrative districts as rainfall remains to be the main triggering factor in inducing landslides. In addition, monitoring the real time rainfall on 24/7 basis during peak monsoon has	**Covered through ongoing programme** 1. Installation of automated rain gauges in Badulla and Rathnapura District 2. Installation of automated rain gauge in Hingurakgoda area

	proven to be quite useful in issuing landslide early warning. The landslide EW is issued by the landslide early warning center (LEWC) at NBRO when rainfall intensities reach certain threshold values. The NBRO LEWC has defined and established threshold limits and warning levels for each district. Currently landslide EW is issued through the Emergency Operations Centre (EOC) of the Disaster Management Center (DMC), which is the main focal point responsible for coordinating early warning dissemination to the public. The DMC is in constant coordination with all technical agencies, local governments, public administration, and media for timely dissemination of hazard warnings. As a pilot several automated rain gauges were installed in identified locations in partnership with NGI to enhance the current rainfall monitoring system. The installed high-capacity automatic rain gauges can monitor the rainfall, soil moisture, temperature and other parameters which are relevant to assess the ground conditions in problematic areas and send regular updates to NBRO. Realizing the importance and based on the achievements thro' NGI collaboration, subsequently NBRO has developed a system of Automated rain gauges to cover most of the landslide prone areas with nearly 300 Automated rain gauges. Through this initiative now NBRO could obtain real time data and fast dissemination of landslide early warning for evacuations. This is an economical and effective way to ensure life safety and reduce property losses.	for monitoring land subsidence **Future Perspectives** 1. Install additional sensors (Water level meter/ tilt sensors) and monitoring impact of land subsidence in Hingurakgoda area
Flow Path Simulation – DAN 3D	To make risk management programs more meaningful and cost effective the programs should target the high-risk settlements through a comparative assessment of risk potential. Currently identification of landslide prone areas with high-risk potential and implementation of proper and effective landslide risk reduction interventions to minimize the risk, have become an essential priority for the country. Landslide hazard mapping will provide a good understanding of the landslide susceptibility, but it will give only an indication about In-situ hazard. For a comprehensive landslide hazard assessment, there are two processes that should be evaluated for incorporation of location specific susceptibility or in-situ hazard with the potential extended hazard due to movement of landslide material along the slope and it is to understand the point of initiation and run-out. The initiation process consists of a slope failure along a critical surface which produces the detachment of a volume of material from the landslide scarp. Following this detachment, the material moves downslope until stopping at its maximum run-out distance. The NGI has provided the capacity for NBRO scientists to account for the processes of initiation and run-out both and to conduct a very comprehensive landslide hazard assessment using a DAN 3D which is a statistical based computer programme. That is usually capable of	**Covered through ongoing programme** 1. Conduct a workshop and share knowledge on the application **Future Perspectives** 1. Flow path simulation

	generating landslide/debris flow paths. The NGI shared the techniques and provided capacity and knowledge on flow path simulation using DAN 3D to enhance the capacity of NBRO scientists. This software can be used to model the regional landslide hazard assessment and to evaluate predictability of landslide events. DAN 3D is a statistical based computer programme capable of generating landslide/debris flow paths. The NGI shares the techniques and knowledge on flow path simulation using DAN 3D to enhance the capacity of NBRO officials. This software can be used to model the regional landslide hazard assessment and to evaluate predictability of landslide events. Landslide runout area assessments were conducted covering four divisional secretariats of Badulla district(Badulla DSD, Hali Ela DSD, Haputhale DSD and Haldummulla DSD) after the training and currently NBRO uses data for creating awareness of communities living in the flow path and mitigating the risk. Currently NBRO uses this methodology to predict landslide flow path and run off for high risk areas and large landslides for evacuation and resettlement people from possible affected areas.	
Drone Technology for Landslide Risk Monitoring 1. High-speed computer facilities for drone data monitoring 2. Agisoft for cloud processing 3. Drone	Technology advancements can assist in disaster preparedness and emergency response functions greatly and NBRO is grateful to NGI for resource inputs for capacity enhancement in Drone technology applications. The use of the Drone technology has helped NBRO to help national agencies in managing emergencies, while enhanced capacity at NBRO itself is helpful for fulfilling its own mandate in landslide risk management. The NGI delivered a high-speed computer system and capacity built in Agisoft application provides an opportunity for NBRO scientists to process the high-resolution aerial imagery taken from Drones with RGB or multi spectral cameras. Following analysis and outputs can be generated from this application which are useful for decision making on disaster management. • Dense point cloud generation and automatic classification • DSM/ DTM generation • Elevation contour line generation • True orthomosaic generation in user defined projections	**Future Perspectives** It is proposed that NGI continue to build the capacity through a few pilot projects that utilizes the technology for disaster preparedness, response and further scaling-up as Drone technology has many positive uses in disaster management such as. • Time series comparison analysis to monitor rock fall movement/ slow mass movement/ construction monitoring/ progress monitoring • LiDAR survey. This high accuracy 3D information can be used for analysis of landslide events and flood modelling. • Thermal Comfortability Assessment/ heat index. • NDVI generation
Oil-water contamination (Water Quality assessment in	The capital of the northern Province, Jaffna, depends on four main groundwater aquifers for water consumption based on the water capacity and quality of the water. Of these four aquifers, Chunnakam aquifer has high capacity and acceptable quality water for	

Jaffna-Chunnakam)	drinking and other usages. Due to this high capacity and good quality, water supplies are drawn from this area for drinking and other usages. However, in the recent past, when water supplies were generated from this area a Fuel smell had been continuously observed in Chunnakam water intake site. The intake site is located very close to the Chunnakam fossil fuel power station. Through the field assessment and analysis, conducted by the NGI scientists along with NBRO staff, around the intake well and the adjacent wells a significant amount of oil contamination has been discovered. This not only provided an enhanced capacity for NBRO to carry out similar environmental assessments in the country, but also to find ways to address the problem by the authorities.	
Participation in RECLAIM network	NBRO has been participating in the RECLAIM network events actively in the past, together with the Norwegian Geotechnical Institute (NGI), and ADPC-Thailand for Sharing its own project outputs/experiences with other Asian countries. NBRO proposes to continue organizing annual meetings of this regional platform on landslide risk management for experience-sharing by experts from countries across the region and to undertake pilot demonstration activities for improving the early warning and preparedness practices in high-risk landslide prone areas. Sri Lanka has experienced a high number of landslide events during the past few years resulting in devastating impacts in terms of loss of lives and property damages and continues to benefit from participating in this regional platform.	**Future Perspective** NBRO proposes to continue organizing annual meetings of this regional platform on landslide risk management for experience-sharing
Training & capacity building,	This initiative was one of the most important and helped to build the professional and technical capacities on various disciplines including landslide risk reduction activities as elaborated above	
NGI arranged visits to Norwegian institutions, laboratories etc.	Get the exposure on a world recognised laboratory complex and apply the technology innovations to ongoing development activities. This was helped in redesigning the NBRO laboratory complex, which will be established in the NBRO new building complex which is under construction at present.	
NGI participation in NBRO Annual symposium	NBRO is looking for opportunities to develop itself into a knowledge management hub in landslide risk management not only at national level but also both in the region and internationally. NBRO, with the support from various national and international agencies, organizes an annual symposium to share the research outcomes, project experience and advance technological approaches with the Sri Lankan research community. The purpose is to share and to benefit from the experience of the practitioners and professionals involved in various thematic areas in landslide other multi-hazard risk management. NGI was invited to provide a keynote speech in the annual symposium in 2018 by Dr. Farrokh Nadim. Dr. Rajinder Bhasin attended the symposium in 2019 and contributed through important key issues and the solutions pertaining to landslide risk management using his involvement in various projects in Norway and Internationally. Both have	

	shared their experience in Asia and Norway and presented good practices.	
Donation of equipment by NGI	The attempts made by NGI for sharing the latest technologies with the NBRO officers and provide adequate technical training on how to use the equipment was very useful. Some of the donations made by NGI helped NBRO to meet the capital infrastructure needs in terms of latest equipment and getting technical guidance for application. NBRO scientists put them in to action and use them in different projects mentioned above to serve the country better.	