Nature-based Landslide Risk Management Project in Sri Lanka (Phase II)

Final Report

September 2020

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Acknowledgments

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The final report is an output of the project "Nature Based Landslide Risk Management Project (Phase - II)" implemented by National Building Research Organisation, Ministry of Defence, Government of Sri Lanka with technical support from Asian Disaster Preparedness Center, Thailand. The project was funded by the World Bank under their Analytics and Advisory Services project in Sri Lanka on Nature-Based Landslide Risk Management (Grant no: 7191576)

Executive Summary

This report provides a summary of the outcome and achievements of the 2nd phase of the Nature Based Landslide Risk Management Project, initiated by the World Bank in Sri Lanka in May 2019. The project which was implemented through two phases since March 2018 by National Building Research Organization (NBRO), the mandated institution for landslide risk management, received technical guidance and implementation support from Asian Disaster Preparedness Center, Thailand. The primary objective of the project was to raise awareness and deepen the knowledge on the role of nature-based and hybrid solutions for landslide risk management within the country.

The Project Phase II is designed around several activities under 03 tasks:
Task A: Detailed Scoping and Mapping of Exposed Assets to assess Landslide Risk,
Task B: Site Specific Landslide Mitigation Planning
Task C: Stakeholder Consultation, Knowledge Sharing and Capacity Strengthening.
This final project completion report summarizes the achievements under each task area and the reflections while evaluating the success and way forward.

The final stakeholder workshop of the Project Phase II, was held on 25th September 2020 at the NBRO auditorium adhering to local health guidelines on the conduct of workshops/meetings in order to ensure prevention and control of COVID-19 pandemic. Only a limited number stakeholder agencies were invited to attend the meeting in person. The participants from NBRO headquarters and field officers as well as ADPC-Bangkok office, attended the meeting through online cloud-based video conferencing service - Zoom. The participants felt that the project activities had helped in deepening the technical knowledge on the application of NbS as an economical, reliable, cost effective and eco-friendly landslide risk management approach at macro level as well as for mitigating landslide risk at the local level. It also helped in gaining knowledge about possible areas of application and number of multiple benefits that NbS could offer other than improving the stability of slopes. The activities also helped in broadening the conceptual understanding about NbS as a promising strategy for increasing socio-ecological resilience, mitigating climate change impacts, protecting ecosystems & biodiversity, and improving livelihoods.

The project has shown the potential of NbS as a macro-level initiative to promote conservation practices at upper watershed areas, which can contribute positively in reducing the growth of disaster risks, while bringing together the subjects of landslide risk mitigation and climate change adaptation. At local level, project has demonstrated the capacity of NbS in addressing location specific slope stability problems and in increasing the effectiveness of structural mitigation measures. In addition, there is a good potential in considering NbS, when other conventional measures in particular the geo-engineering measures may not be feasible and cost-effective. Project has emphasized the importance of ensuring active and field level community centered approaches for addressing the location specific slope stabilization problems through NbS. Additionally, it could offer affordable and not so complex technologies, while creating new sources of income for at risk communities, thereby uplifting their socioeconomic conditions. For instance, some plant species have a high demand (as raw material/ semi-processed products/extracts) in the Ayurveda system of medicine, food & beverages industries, cosmetics & perfume industries, handicraft industry etc..
Reflections in evaluating the project success are highlighted in the Chapter 6 of the report while bringing forward a few recommendations as the way forward for future, to build on the achievements to date.

Some of the key recommendations are:

1. Using the current institutional set up and enabling policy environment, it is high time to demonstrate the advantage of NbS, their contributions, services, benefits in mitigating existing and future risk at macro level as well as at local level. NBRO to provide leadership in developing a comprehensive future roadmap to promote NbS, through collaboration with other government institutions, who have interest in application of NbS. This is to facilitate sharing of information widely and continuation of collaborative research, training and conducting awareness programs together using the expertise available with all stakeholder institutions.

2. The project has created a basis for landslide professionals to realize the potential of NbS in mitigating landslide risk and addressing site-specific slope stability related problems. It is essential to carry out on-site demonstrations of nature-based/hybrid solutions through piloting some of the mitigation planning designs in future to identify practical issues, challenges and to monitor the long-term effectiveness with the passage of time. There can be other opportunities for undertaking real field scale projects (similar to the Neluwa-Lankagama Road Project) where NbS can be integrated and such possibilities should be explored/considered by NBRO in future.

3. Project has emphasized the possibility of applying NbS to offer long term solution for reduction of shallow slope instabilities and in rehabilitation of landslide affected areas or abandoned land due to resettlement of highly vulnerable families. This is especially important as government has plans to resettle around 15,000 families in the next few years and simultaneously government should have plans for application of NbS for rehabilitation of lands susceptible to landslide hazard in order to improve the safety and the productivity of the same.

4. Explore possibilities to have more innovations and demonstrations on low cost, simple, affordable, slope stabilization techniques incorporating NbS that can be executed using local material, community knowledge with the purpose of addressing local level slope instability problems. Disseminate widely the economic benefits offered by some plant species used in NbS to create new sources of income for vulnerable local communities, thereby uplifting their socioeconomic conditions. Try to harness local wisdom in execution of such solutions as local community has better understanding of plant species, material, native inventions, indigenous technology etc. that can be applied in executing such interventions.

5. Initiate further research activities to build the knowledge base about various types of plant species (grasses, trees, herbs, shrub etc.) suitable for different climate conditions as well as appropriate for utilization in different contextual setting in terms of social, economic (which provide value additions commercially), botanical (native to specific localities and not to promote invasive species) and bio-engineering (with appropriate root architecture, mechanical and hydrological characteristics) nature.

6. Continue risk communication workshops at district level and at institution level with members of the district level risk communication network, initiated under the project. It is essential to capacitate the field level officials of the support agencies, providing them with necessary technical knowledge, awareness, landslide related risk information available with NBRO and facilitate a close association with them to make them participants in the landslide risk management process.

7. Access to funding is frequently identified as a common barrier to create commitment towards application of NbS in landslide and other disaster risk management. In order to improve the accessibility of funding, it is better to map existing financial instruments, approaches and look for possibilities for converting the NbS into investment models to attract private sector, develop blended finance and public-private partnerships, philanthropy etc. Promote utilization of by-products of NbS as raw material for pharmaceutical industries, Ayurveda treatments, production of nutraceuticals, food & beverages, cosmetics, perfume industries & toiletries, handicrafts etc.

Acronyms

ADPC:	Asian Disaster Preparedness Center
GCM:	Global Circulation Model
GOSL:	Government of Sri Lanka
GPM:	Global Precipitation Measurement
IUCN:	International Union for Conservation of Nature
NASA:	National Aeronautics and Space Administration
NbS:	Nature-based Solutions
NBRO:	National Building Research Organisation
NEM:	North East Monsoon
NEX:	NASA Earth Exchange
RCP:	Representative Concentration Pathway
RDA:	Road Development Authority
SPI:	Special Investigation Report
SSLMP:	Site Specific Landslide Mitigation Planning
SWM:	South West Monsoon
ToR:	Terms of Reference
UNEP-WCMC:	The UN Environment Programme World Conservation Monitoring Centre

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Chapter 1: Objectives, Project Task Areas and Approach Adapted in Designing Project Activities

The application of nature-based solutions (NbS) for landslide risk mitigation are now gaining increased attention world-wide as cost effective, eco-friendly and sustainable measures that can be incorporated in risk management approaches. NbS make use of natural processes and ecosystem services to address hazards such as floods, erosion and landslides. Such solutions are considered as alternatives or complements to conventional engineering or gray solutions. Further, NbS are capable of offering multiple benefits to the environment as well as to local communities such as sequestering carbon and sustaining livelihoods.

In view of the above, the World Bank launched the Analytics and Advisory Services project in Sri Lanka on Nature-based Landslide Risk Management, with the partnership of National Building Research Organization (NBRO), the mandated agency for landslide risk management in Sri Lanka. Asian Disaster Preparedness Center (ADPC), Thailand provided implementation and technical guidance for project execution. The project was implemented in two phases (Phase I – March 2018 to June 2019 and Phase II – May 2019 to September 2020.)

In the past, Sri Lanka has largely relied on engineering solutions for mitigating the landslide risk and the application of nature-based and hybrid approaches for landslide risk management was not a common practice. Although, it has been demonstrated in many countries in Asia that the risk-informed nature-based solutions can be pertinent and cost effective in reducing the occurrences and impacts of certain types of landslides, it was not so popular in Sri Lanka due to lack of confidence in application of NbS as a permanent solution. The scientific studies have confirmed the crucial role of vegetation in reducing soil erosion as well as preventing shallow landslides, by reinforcing sub-surface formations and reducing soil moisture in them. But there was a need to present the ways of adapting the principals of NbS in mitigating the landslide risk to Sri Lankan professionals. With the additional knowledge gained through the project, it is expected that the country takes initiatives to promote conservation practices at macro scale and application of nature-based solutions for solving site-specific landslide risk management problems, when and where it is appropriate. In addition, there was a need for considering application of NbS, when other measures in particular the geo-engineering measures may not be so feasible and cost-effective solution.

As the primary objective the project aims at raising awareness and deepen the knowledge on the role of nature-based and hybrid solutions for landslide risk management within the Government of Sri Lanka.

The World Bank in its terms of reference (ToR) has proposed following three task areas for implementation of the project:

- Task A: Detailed Scoping and Mapping of Exposed Assets to assess Landslide Risk
- Task B: Site Specific Landslide Mitigation Planning (SSLMP)

- Task C: Stakeholder Consultation, Knowledge Sharing and Capacity Strengthening

Having discussions with NBRO management, ADPC has identified three constraining factors that limit the risk-informed decision-making in planning and implementation of landslide mitigation activities incorporating NbS. These are:

1. Absence of an appropriate process to move from hazard analysis / assessment to landslide risk mitigation utilizing NbS as a feasible and cost-effective measure;
2. Insufficient competence in terms of procedural and methodological attributes, technical know-how, within the relevant government agencies to apply NbS as one of the appropriate landslide risk management practices;
3. Limited awareness and knowledge on the design and application aspects.

Project carried out a literature survey and the same gave a good understanding about the depth of knowledge and state of the art of technology available currently on the subject of application of NbS in landslide risk management.

A few references in these regards are:

1. Gray, D. H. & Sotir, R. B. (1996) "Biotechnical and soil bioengineering slope stabilization: A practical guide for erosion control". John Wiley & Sons, New York.
2. Howell, J. (1999) "Roadside Bio-Engineering – Reference Manual". Nepal-UK Road Maintenance Project.
3. Howell, J. H., Clark, J. E., Lawrence, C. J. & Sunward, I. (1991) "Vegetation structures for stabilizing Highway Slopes" Overseas Development Administration of UK with Department of Roads, Nepal.
4. Geotechnical Engineering Office. (2011) "Technical Guidelines on Landscape Treatment for Slopes" GEO Publication No. 1/2011, Civil Engineering and Development Department, The Government of the Hong Kong, Special Administrative Region.
5. Ghosh, C. & Bhattacharya, S. (2018) "Landslides and Erosion Control Measures by Vetiver System" In I. Pal, R. Shaw (eds.), Disaster Risk Governance in India and Cross Cutting Issues, Disaster Risk Reduction, DOI 10.1007/978-981-10-3310-0_19.

Essentially the various literature mentioned above gives an indication that there is a need for development of an appropriate process to move from hazard analysis to utilization of NbS as a cost-effective measure for landslide risk mitigation. The success of meeting the challenges in this process depends on the possibility of developing a user-tailored process covering steps such as:

- Exposure database development;
- Selection of sites where NbS can be applied as a feasible and cost-effective measure;
- Selection of appropriate plants and design interventions;
- Implementation aspects of site-specific plans and maintenance.

The project made certain progress in developing a site selection criterion at the phase 1, but the improved version of the same is needed to see the applicability of the methodology in different eco-systems and agro-climatic zones in different landslide prone districts in Sri Lanka. The project started developing a plant manual, however it needs to be expanded to suite different conditions in all landslide prone districts. Application of NbS in different agro-climatic zones need to be carried out utilizing the plants that are suitable in different contextual setting considering social, economic (plants with value

additions commercially), botanical (plants that are native to target districts and invasive species) and bio-engineering aspects.

Nature-based techniques also can be used for greening areas and for getting higher aesthetic (natural beauty) appearance of the overall slope in addition to contributions for increased stability of slopes

World Bank (2017) also has expressed the need for considering other possible multiple benefits in addition to direct benefits of mitigation of impacts of landslides using NbS, such as:

- Restoration, conservation, and management of ecosystems are crucial elements of the implementation of NbS;
- They may help decrease vulnerability to climate change while also creating multiple benefits to the environment and local communities. These include sustaining livelihoods, and sequestering carbon.

Cook (2017) provides 3 keys for scaling up nature-based solutions as a climate adaptation practice.

- Nature-based solutions are an underused climate adaptation strategy

While some research of this kind exists, countries often need place-specific assessments to identify the best opportunities to use nature-based solutions for adaptation. Governments also should consider that local and indigenous communities often have ample understanding of nature's value for people, and should seek out and include this knowledge in plans and policies.

- Embed nature-based solutions into climate adaptation planning

Nature-based solutions often work best when people use them at larger scales — across whole landscapes, ecosystems or cities. Governments are often best placed to plan climate adaptation at this scale given their access to resources and ability to make policy and coordinate among multiple actors. To be successful, they should include nature-based solutions in their adaptation planning from the start.

- Encourage investment in nature-based solutions

Communities and countries often cite access to funding as a barrier to implementing nature-based solutions, and to climate adaptation efforts overall. But, as UNEP-WCMC highlights, governments can spur investment in these approaches by reorienting their policies, subsidies and public investments. They can also better incentivize private investors to finance adaptation projects.

As per the guidance and indications provided by literature that was under reference during the literature survey as described above, the project team has taken following approaches in identifying project activities under suggested task areas in the World Bank ToR:

- Review further the existing methodology and suggest an appropriate methodology that can be used for selection of sites appropriate for implementing NbS as green solutions and hybrid solutions;
- Conduct further research on identifying different characteristics of plant species commonly available within landslide prone districts that can be used in slope stabilization and landslide risk mitigation;
- Review the plant selection criteria based on characteristics of individual plant species/clusters (root strength, hydrological significance, ecological significance and economic importance);

- Develop a ranking methodology of plant species according to their suitability for NbS using the plant selection criteria developed;
- Propose a site-specific landslide risk mitigation plan development process, incorporating NbS for creating not only safer but also more visually acceptable and ecologically sustainable slopes;
- Promote macro-level multiple benefits through NbS for reduction of impact of climate change, increase ecosystem services and promote conservation practices;
- Look for additional benefits at community level through increasing livelihood opportunities for communities while serving as landslide risk mitigation solutions;
- When proposing NbS, particularly when recommendations are made on plant species for slope stabilization, such efforts shall aim at a win-win situation where such solutions safeguard the rural livelihoods, while adequately contributing to landslide mitigation strategies;
- The experience gained in project activities, finally shall lead to development of a guideline document on site-specific landslide risk mitigation planning utilizing NbS.

The following chapters provide a summary of activities and outputs as deliverables under each activity.

References

Cook, J. (2020) 3 keys for scaling nature-based solutions for climate adaptation. Retrieved from https://www.greenbiz.com/article/3-keys-scaling-nature-based-solutions-climate-adaptation

World Bank. (2017) Implementing nature-based flood protection: Principles and implementation guidance. Washington, DC: World Bank. Retrieved from http://documents1.worldbank.org/curated/en/739421509427698706/pdf/Implementing-nature-based-flood-protection-principles-and-implementation-guidance.pdf

CHAPTER 2: Outcomes of Task A - Detailed Scoping and Mapping of Exposed Assets to Landslide Risk

This Task Report under Task A - Detailed Scoping and Mapping of Exposed Assets to Landslide Risk is divided in to four reports:

Report 1:	Report on Site-specific Landslide Susceptibility
Report 2:	Report on assessment of exposure and vulnerability of elements at risk within the impact zone of candidate sites within 04 target districts
Report 3:	Assessment of future climate scenarios within 04 target districts
Report 4:	Report on the assessment of feasibility of application of nature-based solutions for mitigating landslide risk

A summary of study finding and results are provided in the following sections.

2.1 Site-specific Landslide Susceptibility Assessment

The set of activities carried out with the aim of reducing or minimizing the adverse impacts of a hazardous event will have direct relationship with the factors that are being considered for developing hazard maps, exposure of elements at risk and vulnerability. The aim will be to minimize the influence of one or more corresponding factors in reducing the landslide hazard, exposure and/or vulnerability. Currently, NBRO uses factors such as geology, surface deposits, hydrology, slope gradient, land use, land form for evaluation of the hazard potential for developing 1:10,000 scale landslide hazard zonation maps.

NBRO provided 20 candidate sites from 04 target districts (Table 2.1) for the study under the project and the sub-report provides a detail commentary and associated analysis of the factors used for hazard zonation maps for all 20 respective sites. The above sites were located in the 04 target districts of the project and selected from the locations where NBRO had carried out Special Investigations (SPI) in the past.

Table 2.1: List of Candidate Sites

District	No	Location	DS division	GN division	GPS coordinates	Extent of the impact area (Sq.km)
Rathnapura	1	Alupathgala, near temple	Elapatha	Weragama	6.663183°N, 80.29262°E	0.16

District	No	Location	DS division	GN division	GPS coordinates	Extent of the impact area (Sq.km)
	2	Alupathgala, Galapeelehena	Elapatha	Weragama	6.6693522^{0}N, 80.323842^{0}E	0.017
	3	Horaketiyahena, Kurahana	Niwithigala	Wanniyawatta	6.604572^{0}N, 80.510899^0 E	0.207
	4	Kalawana town	Kalawana	Thapassarakanda	6.531072^{0}N, 80.395670^{0}E	0.017
	5	Ayagama town	Ayagama	Ayagama town	6.639317^{0}N, 80.310985^{0}E	0.070
Nuwara Eliya	6	Hakgala	Nuwara Eliya	Goredihela	6.930483°N, 80.814883°E	0.090
	7	Diyanilla	Walapane	Palalpathana	7.038752^0 N, 80.857472^0 E	0.570
	8	Mahawewa	Walapane	Kumbalgamuwa	7.108333 80.85	0.160
Matale	9	Rattota public playground	Rattota	Rattota	N 7.518542; E 80.678093	0.004
	10	Maussagolla	Rattota	Maussagolla	N 7.504603; E 80.689941	0.003
	11	CEB Ukuwela power plant	Ukuwela	Raithalaawa	N 7.397121; E 80.650665	0.010
	12	Rusigama in Pallepola DS	Pallepola	Maadipola	7.684835 ˚N 80.580421 ˚E	0.170
	13	Balakaduwa Welikanda Road	Ukuwela	Balakaduwa	7.416719 ˚N 80.612096 ˚E	0.017
	14	Bowatta School-Ukuwela DS	Ukuwela	Bowaththa	N 7.417556 E 80.631278	0.007
	15	Alagumale	Matale	Dodandeniya	N 7.478310; E 80.615013	0.030

District	No	Location	DS division	GN division	GPS coordinates	Extent of the impact area (Sq.km)
Matara	16	Dissanayake Hospital Waralla	Kotapola	Kotapola South	6.27827 ˚N 80.54291 ˚E	0.016
	17	Naindawa waththa	Pasgoda	Batadura North	6.32818 ˚N 80.57121 ˚E	0.058
	18	Idigalgodakanda	Pasgoda	Rotumba north	6.238698 ˚N 80.581739 ˚E	0.207
	19	Hettikanda	Kotapola	Poddana	6.33028 ˚N 80.49480 ˚E	0.035
	20	Gallanda forest reserve	Kotapola	Pallegama North	6.20,476 ˚N 80.31,305 ˚E	0.042

For all the locations, available site-specific technical data (geological, geotechnical and hydrological) and past disaster events were collected from NBRO and other stakeholder agencies. Special Investigation (SPI) Reports done by NBRO were referred in collecting the above-mentioned information. Field visits were organized by the project team (NBRO/ ADPC) for collection of additional data needed for site-specific landslide susceptibility assessments. A drone survey was also conducted at each location. After collecting all raw data, desk studies were carried out to generate factor maps which include ortho image, digital surface model, slope map, land use map and hydrology. Annex 1 provides the report which includes a detail analysis of site-specific landslide susceptibility corresponding to all 20 candidate sites.

2.2 Assessment of Exposure and Vulnerability of Elements at Risk within the Impact Zone of Candidate Sites within 04 Target Districts

Further the project team in consultation with the NBRO team has defined an impact area (through expert judgment) and site-specific exposure maps have been derived through the same. All elements at risk within the impact zone were taken in to consideration in vulnerability assessment. Detailed scoping and mapping of exposed assets to landslide risk at each site has been carried out and all socio-economic data related to the elements at risk within the impact area were collected. All above reported data in terms of hazard exposure and vulnerability, had been used for delineating the risk potential of each site. A detail commentary and analysis in relation to exposure and vulnerability is provided in the report provided in Annex 2.

Table 2.2, Table 2.3, Table 2.4 and Table 2.5 presents no. of building units in the impact areas of twenty candidate sites.

Table 2.2: No. of building units in impact areas - Ratnapura District

No	Candidate site	Probable area of impact (Sq km)	No. of residential building units	No. of residents	No. of commercial building units	Critical infrastructure & other	Remarks
1	Alupathgala (near Weragama temple)	0.16	11	37	-	Minor roads	3 resettled buildings.
2	Alupathgala, Galapeellahena	0.017	16	50	-	Minor roads	-
3	Horaketiyahena	0.207	14	65	-	Minor roads	29 resettled building units. 1 abandoned building unit.
4	Kalawana Town	0.017	4	8	16	Tiruwanaketiya - Agalawatta Road	2 residential buildings were closed
5	Ayagama Town	0.070	1	4	18	Gavaragiriya Road	5 Abandoned buildings 1 closed building unit

Table 2.3: No. of building units in impact areas - Nuwara Eliya District

No	Candidate site	Probable area of impact (Sq km)	No. of residential building units	No. of residents	No. of commercial building units	Critical infrastructure & other	Remarks
6	Hakgala	0.090	-	-	-	400m of A005 Road	
7	Diyanilla	0.570	47	196	2	Rikillagaskada – Tannekumbura-Ragala Road	73 building units resettled

No	Candidate site	Probable area of impact (Sq km)	No. of residential building units	No. of residents	No. of commercial building units	Critical infrastructure & other	Remarks
8	Mahawewa	0.160	18	72	1	16 School building units. Minor roads	25 abandoned building unit 4 closed building units 3 closed building units 5 abandoned building units

Table 2.4: No. of building units in impact areas - Matale District

No	Candidate site	Probable area of impact (Sq km)	No. of residential building units	No. of residents	No. of commercial building units	Critical infrastructure & other	Remarks
9	Raththota public play ground	0.004	4	19	-	-	1 building unit resettled
10	Maussagolla	0.003	-	-	-	Access road to Water treatment plant of Greater Matale Water Supply Project	-
11	Ukuwela Power Plant	0.010	-	-	-	Pent house of the Power Plant	-
12	Rusigama in Pallepola	0.170	41	150+	5	Minor roads	8 closed building units
13	Balakaduwa Welikanda Road	0.017	10	44	1	Minor roads	1 abandoned building unit
14	Bowatta school	0.007	-	-	-	3 School building units	-
15	Alagumale	0.030	14	57	-	Minor roads	3 abandoned building units

No	Candidate site	Probable area of impact (Sq km)	No. of residential building units	No. of residents	No. of commercial building units	Critical infrastructure & other	Remarks
							1 closed building unit

Table 2.5: No. of building units in impact areas - Matara District

No	Candidate site	Probable area of impact (Sq km)	No. of residential building units	No. of residents	No. of commercial building units	Critical infrastructure & other	Remarks
16	Dissanayake, Ayurveda Hospital, Waralla	0.016	-	-	-	2 Hospital building units	-
17	Naindawa Watta	0.058	2	9	-	Minor road	-
18	Indigalgoda Kanda	0.207	16	58	-	Minor road	-
19	Hettikanda	0.035	3	17	-	Minor road	2 resettled building units
20	Gallassa Koratuwa	0.042	6	17	-	Minor road	1 building unit under construction

2.3 Assessment of Future Climate Scenarios within 04 Target Districts

Additionally, future climate scenarios and its influence to site-specific landslide susceptibility has been analyzed and provided in the part 3 of Task A Report. Historical rainfall data has been collected from NBRO, Department of Meteorology (NBRO maintains a network of automatic rain gauges and Department of Meteorology maintains a large network of rain gauges) and satellite-based rainfall data from Global Precipitation Measurements (GPM) Mission. Future climate scenario data (rainfall and temperature) has been taken from NASA Earth Exchange (NEX) Global Circulation Models (GCMs), which are downscaled and bias-corrected with global data. NEX data has been further bias-corrected and downscaled to suite the landslide studies using observed data collected from NBRO and Department of Meteorology. The study outcome which is reported below as a summary (Annex 3 provides detail assessment results) should help in analyzing and capturing the long-term changes in precipitation, intensity etc. due to global climate change. The outcome presented below and in Report 3 - Assessment of future climate scenarios within 04 target districts (Annex 3) will help in understanding the possible influence of future climate change induced scenarios in landslide susceptibility within 04 target districts of the project.

Rainfall projections for target landslide hazard prone Districts

- The results indicate that the Wettest GCM for intermediate emission scenario show a considerable spatial variability with the projected annual, SWM and NEM seasons in all three-time horizons.
- *Matale District* – It is likely to decrease the Annual and NEM rainfalls by 2030s. However, it is likely to increase during 2050s and 2080s. SWM rainfall is likely to continuously increase in the future.
- *Matara District* – Annual and SWM rainfalls are likely to continuously increase towards the future. NEM rainfall may slightly decease by 2030s. However, it may continuously increase during 2050s and 2080s.
- *Nuwara Eliya District* – It is likely to continuously increase the Annual and SWM season rainfalls in the future. NEM rainfall is likely to slightly decease by 2030s and it may again continuously increase during 2050s and 2080s.
- *Ratnapura District* – Annual and SWM rainfalls may continuously increase towards the future. Though, NEM rainfall may slightly decease by 2030s and it may again continuously increase during 2050s and 2080s.

Conclusions of the climate study

- The above results likely to indicate that landslide hazard occurrence may be a common phenomenon in the hilly areas of these districts towards the near, medium and distant futures. Nevertheless, since NEM rainfall may decrease by 2030s compared to the normal, less vulnerability to landslide hazards or fewer number of events can be expected in the four districts during the next decade. However, this vulnerability may again increase during 2050s and 2080s. But annual combined and SWM rainfalls may continuously increase towards the future;
- Even though, this study depicts the results for highest extreme GCM and intermediate emission scenario (RCP 4.5), it is recommended to run impact models for both highest (wettest) and lowest (driest) extreme GCMs as well as both intermediate and high emission (RCP 8.5) scenarios to understand the full range of variability to the future;
- Climate projections are not predictions of the future, but instead provide a range of possible future climate. As such, projection values should be used to guide thinking in impact assessments and planning, and users should include flexibility in their planning and adopt an adaptive management approach to allow for change as more information becomes available through appropriate observational-based monitoring, scientific research, and evaluation.

2.4 Assessment of Feasibility of Application of NbS for Mitigating Landslide Risk and Selection of Sites for Site-Specific Mitigation Planning Incorporating NbS.

Nature-based Solutions (NbS) are interventions which make use of natural processes and ecosystem services to address hazards such as floods, erosion and landslides. NbS can be completely "Green" (consisting of only ecosystem elements) or "Hybrid" (combination of ecosystem elements and conventional engineering measures). However, NbS cannot be applied to each and every site due to various reasons and project team has developed a selection criterion for selecting sites for application of NbS (including as a Hybrid solution) for mitigating the landslide risk. The 20 candidate sites were subjected to the site selection criteria give in Fig. 2.1 and 04 candidate sites have been selected for application of NbS for mitigating the landslide risk.

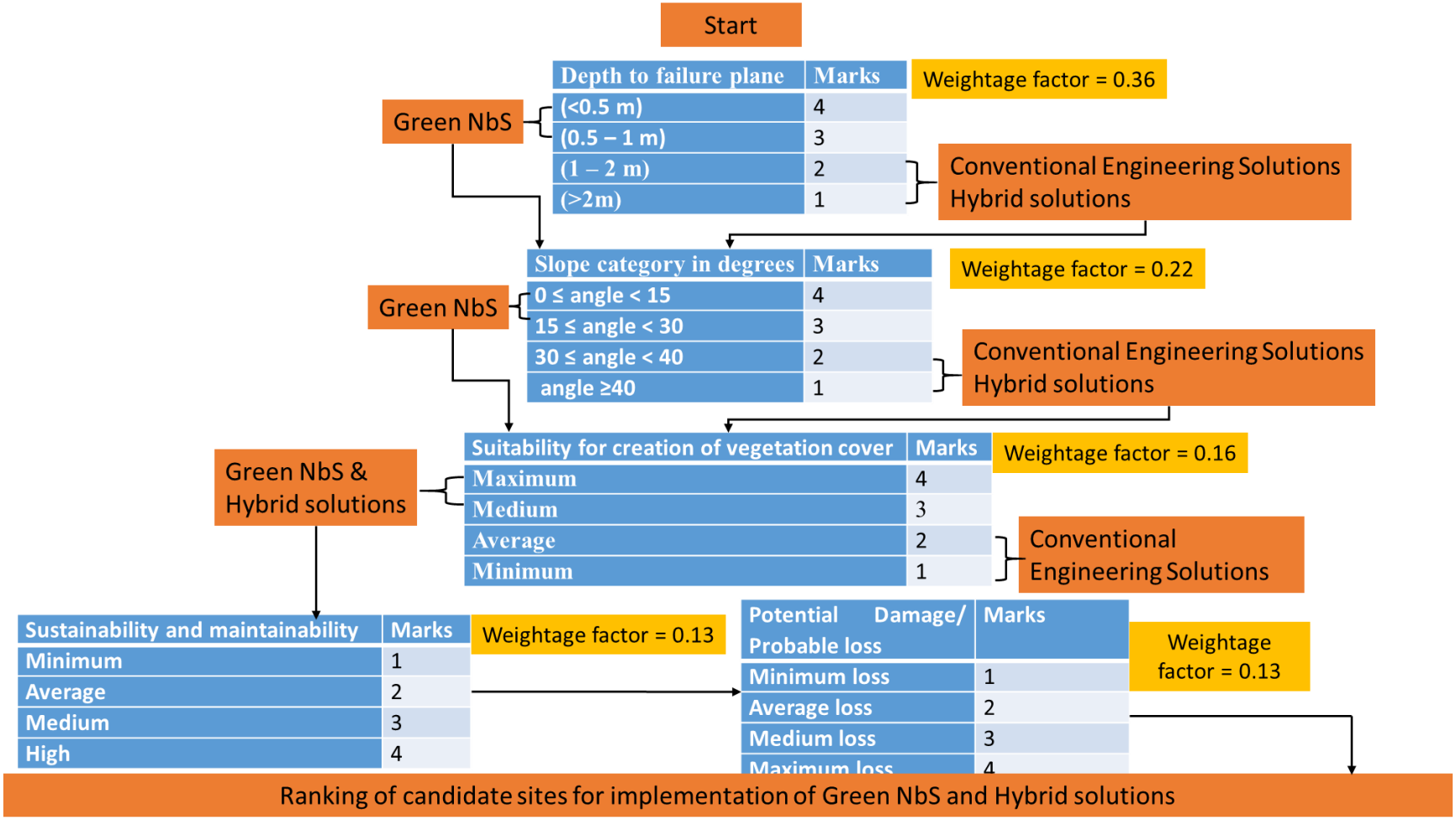

Fig. 2.1: Site selection criterion

The tables 2.6, 2.7, 2.8 and 2.9 summarizes the marks gained by each site in the target districts of Ratnapura, Nuwara Eliya, Matara and Matale respectively.

Table 2.6: Application of site selection criteria in Ratnapura District

No.	Name of site	Depth to failure plane	Slope Category	Suitability for creation of vegetation cover	Sustainability & Maintainability	Landslide Vulnerability	Final score	Remarks
1	Alupathgala (near Weragama temple)	1	2	4	1	3	1.96	
2	Alupathgala, Galapeellahena	1	2	3	3	3	2.06	
3	Horaketiyahena	1	2	3	1	3	1.80	
4	Kalawana Town	1	2	3	3	1	1.80	
5	Ayagama Town	1	2	4	3	3	2.22 *	

* site with the highest marks recorded at each district

Table 2.7: Application of site selection criteria in Nuwara Eliya District

No.	Name of site	Depth to failure plane	Slope Category	Suitability for creation of vegetation cover	Sustainability & Maintainability	Landslide Vulnerability	Final score	Remarks
1	Hakgala	1	2	4	4	2	2.22*	
2	Diyanilla	1	3	3	1	3	2.02	
3	Mahawewa	1	3	3	1	3	2.02	

* site with the highest marks recorded at each district

Table 2.8: Application of site selection criteria in Matara District

No.	Name of site	Depth to failure plane	Slope Category	Suitability for creation of vegetation cover	Sustainability & Maintainability	Landslide Vulnerability	Final score	Remarks
1	Dissanayake Ayurveda Hospital, Waralla	1	2	4	4	3	2.35 *	
2	Naindawa Watta	1	2	3	1	3	1.80	
3	Idigalgoda Kanda	1	2	3	2	3	1.93	
4	Hettikanda	1	1	3	2	3	1.71	
5	Gallassa Koratuwa	1	1	2	2	3	1.55	Probable rock fall site

* site with the highest marks recorded at each district

Table 2.9: Application of site selection criteria in Matale District

No.	Name of site	Depth to failure plane	Slope Category	Suitability for creation of vegetation cover	Sustainability & Maintainability	Landslide Vulnerability	Final score	Remarks
1	Raththota Public Play ground	1	2	3	3	3	2.06	
2	Maussagolla	2	1	1	1	3	1.62	
3	Ukuwela Power Plant	1	1	2	2	2	1.42	
4	Rusigama in Pallepola		1	2	2	3	1.19	Rock fall hazard is present
5	Balakaduwa Welikanda Road	1	1	3	2	3	1.71	
6	Bowatta school	1	1	3	4	3	2.13 *	
7	Alagumale						0	Rock fall hazard is present.

* site with the highest marks recorded at each district

The above tables summarizes the assessment of 20 candidate sites which were subjected to the site selection criteria. The selected sites as candidate sites for application of NbS for mitigating the landslide risk are marked in yellow colour.

The detailed report on Assessment of feasibility of application of nature-based solutions for mitigating landslide risk and selection of sites for site specific Mitigation planning incorporating NbS is given in Annex 4 for further reference.

CHAPTER 3: Outcomes of Task B - Site Specific Landslide Risk Mitigation Plan preparation

The project team selected 04 sites using the Site Selection Criterion developed under the project as mentioned in Chapter 2. The purpose of Task B – Site-specific Landslide Risk Mitigation Plan preparation, is to demonstrate the different aspects of application of NbS and their benefits while delivering site-specific landslide risk mitigation plans for the selected 04 sites.

During the process of preparation of site-specific landslide risk management plans, the NbS were introduced to 04 selected landslide affected sites, namely (1) Dissanayake Ayurveda Hospital Site, Kotapola, (2) Sri Sumangala School, Bowatta, (3) Hakgala and (4) Ayagama Town in landslide prone districts of Matara, Matale, Nuwara Eliya and Ratnapura respectively.

The mitigation plan development for 04 selected sites, has been carried out to demonstrate the steps in the design process and to highlight the essentials in terms of problems & possible engineering and bioengineering solutions required at the site that needs consideration in proposing suitable nature-based remedial actions to mitigate the risk. It also demonstrates the possibility of various design options for landslide risk mitigation, incorporating Nature-based Solutions (NbS) in different combinations.

The Nature-based Landslide Risk Management Project Phase I project team developed a process for site-specific landslide risk mitigation plan preparation and demonstrated that landslide risk can be mitigated successfully, in a cost-effective manner when conventional engineering solutions are combined with nature-based solutions (Hybrid solutions). Hence one of the aspects considered under this task is to explore the possibility of undertaking hybrid solutions where possible to make mitigation designs planned for 04 candidate sites, more sustainable and capable of enhancing the stability conditions.

Plant species utilized in them, were selected after assessing their bioengineering characteristics in combination with ecological significance and economic importance utilizing the project developed plant selection criteria. It is a known factor that the influence of the vegetation cover expected to grow higher with the development of an effective root system. Then the root system is capable of providing additional reinforcement to sub-surface formations and thereby risk mitigation success can be ensured. Certain time period should be allowed for development of a root system to a sufficient depth and to reach considerable coverage spatially by the suggested plant species. At the meantime, an attempt was made for the suggested NbS integrated mitigation plan to help greening the slopes and enhancing the aesthetic (natural beauty) appearance of the overall slope, in addition to contributions for increased stability.

Through the landslide mitigation plan development exercise undertaken through Task B, it was possible to demonstrate several combinations of incorporating NbS in to conventional engineering practices, in terms of:

1) Green solutions,
2) Hybrid solutions and
3) The appropriateness of NbS in enhancing the aesthetics of areas where the landslide risk is mitigated through conventional engineering solutions.

NbS possess a considerable potential for addressing socio-economic vulnerabilities of communities at risk as they could offer multiple livelihood benefits for the local communities. Hence, potential economic benefits, also has been considered in proposing nature-based solutions (NbS) for mitigating the risk in selected sites. For instance, the economic benefits offered by some plant species proposed in Dissanayake Ayurveda Hospital site could create new sources of income for the hospital as the idea is to create an herbal garden full of medicinal value. This could be of some importance to even for some of the vulnerable communities in the area, as they could implement similar mitigation solutions, to enhance the stability of vulnerable slopes within their own premises. In the meantime such initiatives can bring some additional income for them and useful for uplifting their socioeconomic conditions.

The conceptual design proposed for Sri Sumangala School, Bowatta site will help in demonstrating the importance of mitigation of landslide risk through engineering measures combined with NbS. The school children can have a good idea about the appropriate low-cost landslide risk mitigation technology and ways of incorporation of NbS for enhancing the effectiveness of conventional slope stabilization measures.

There is an ongoing project utilizing engineering mitigation works at Hakgala site and as observed the unprotected earth surfaces within the stabilized area, are currently subjected to shallow land sliding and gully erosion during heavy precipitation events. Hence the proposed measures under the project were to address the observed needs and to help creating a good vegetation cover for the unprotected earth surface.

The Ayagama site is proposed to be mitigated through ongoing donor funded project initiative and proposed NbS are to be incorporated into conventional engineering designs to enhance benefits of the proposed investment by allowing the city authorities to convert the area in to an "Urban Leisure Park".

The initiatives undertaken and presented above will help in demonstrating that the combination of conventional engineering and nature-based practices can be very effective as a long-term solution for landslide risk mitigation while also offering other multiple benefits such as sustainable livelihoods, improved ecosystem services and overall enhancement of aesthetic appearance of the area in addition to enhancing the stability of vulnerable slopes. The findings of the project initiative could support the Government of Sri Lanka (GOSL) in piloting and potentially scaling up the use of nature-based and especially hybrid solutions (NbS coupled with conventional engineering solutions) for landslide risk management within the country.

The mitigation plan deigns for 04 candidate sites are given below. The detailed report on Site- Specific Landslide Risk Mitigation Plan preparation is provided in Annex 5.

3.1 Dissanayake Ayurveda Hospital Site – Green Solutions

Dissanayake Hospital at Kotapola is engaged in offering Ayurveda treatments to patients. Developing its premises into a medicinal garden will be of immense benefit to the hospital. The garden will be able to provide the majority of the needed medicine for treatments.

A well-designed medicinal garden in the hospital premises offers Green Solutions (consisting only ecosystem elements) to mitigate the current slope instabilities experienced at site. Such an intervention will offer more effective and sustainable solutions.

Hence, the landslide risk management plan for the Hospital Premises was developed making use of Green Solutions and centralizing on the main theme of "Medicinal/ Herbal Plants Garden". Proposed plant species are of medicinal values.

The surface drainage flow of the site is recommended to be improved by constructing a network of cut-off, cascaded and line drains. A cutoff drain and a toe drain is suggested to be constructed to intercept water flow coming from up slopes. Two cascade drains are suggested to dispose off the intercepted water by the cut-off drain and the toe drain. Suggested layout is shown in Fig. 3.1.

The site is divided into four segments depending on the nature of slope instabilities (Fig. 3.1). Area 1 is proposed to be developed by having a live fence consisting of large trees with stronger trunks grown along the probable flow path of the previous landslide observed at site.

Fig. 3.1: Proposed drainage lay out

Area 2 and 3 is to be improved by constructing a Vegetated Rock Wall. As per Gray & Sotir, 1996, a vegetated rock wall is a rock breast wall in which live cuttings are inserted between the rocks and also placed in the reshaped soil surface formed above the wall. The proposed design is shown in Fig. 3.2.

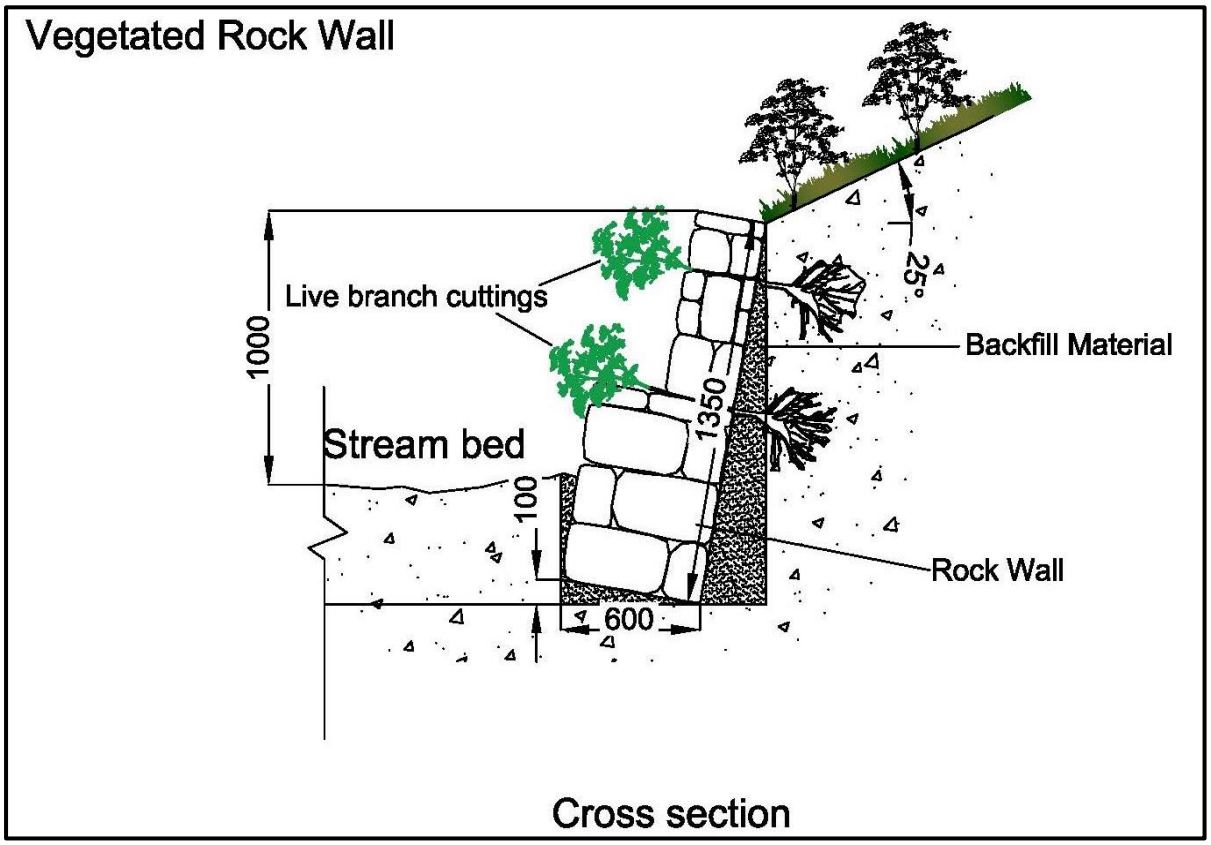

Fig. 3.2: Cross section of proposed Vegetated Rock Wall with initial sizing in mm

Area 4 is to be developed by constructing a Live Slope Grating for the upper slope area and a Vegetated Crib Wall as the toe support. Proposed designs are shown in Fig. 3.3 and Fig. 3.4.

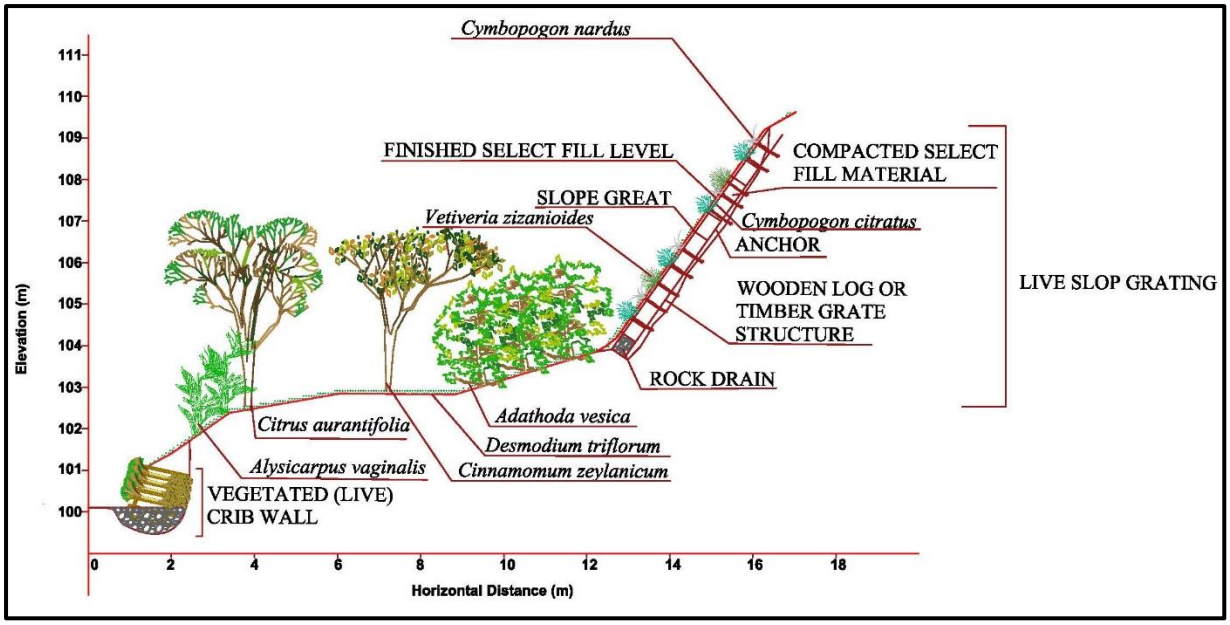

Fig. 3.3: Cross section showing proposed stabilization measures for Area 4

A live slope grating, as explained by Gray & Sotir, (1996) consists of a lattice-like array of vertical and horizontal timbers that are fastened or anchored to a steep slope. The structural members are typically wooden logs, timber or bamboo. The openings in the structure are filled with a suitable back fill material and layers of live branch cuttings.

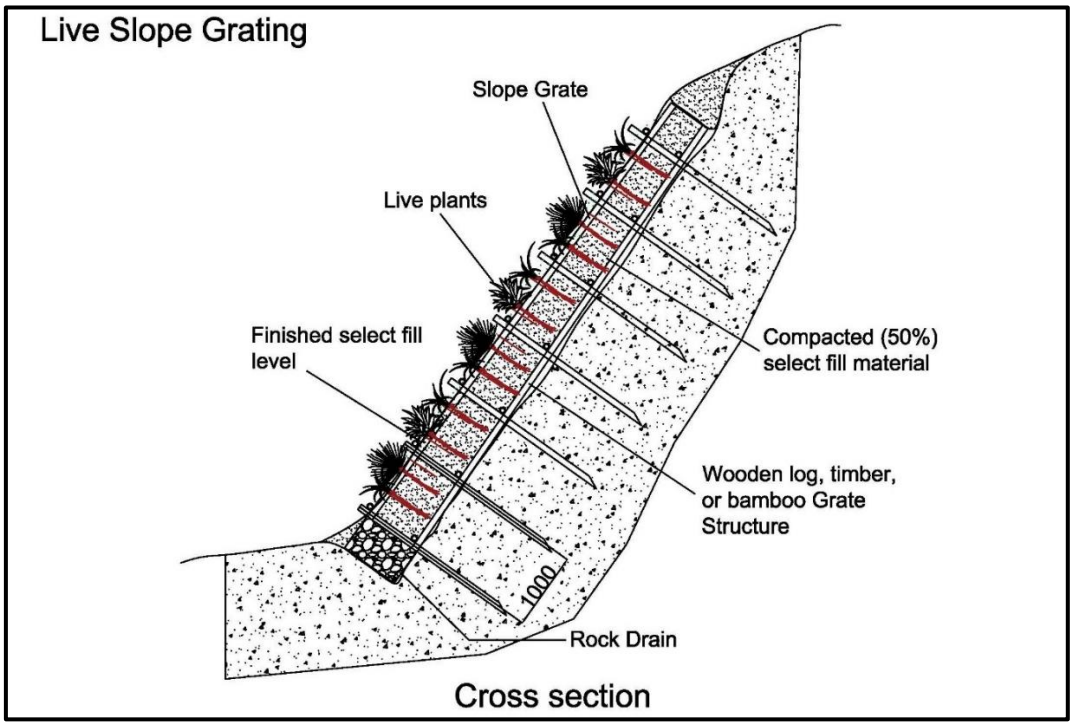

Fig. 3.4: Cross section of a live slope grating

A vegetated crib wall as explained by Gray & Sotir (1996), consists of a hollow, box-like interlocking arrangement of structural beams which are usually wooden logs, bamboo or timber members. The structure is filled with a suitable backfill material (or crib fill) and layers of live branch cuttings that root inside the crib. The structure (or crib) eventually rots away, but its function is replaced by the crib fill, which becomes indurated with roots and behaves as a coherent gravity structure itself.

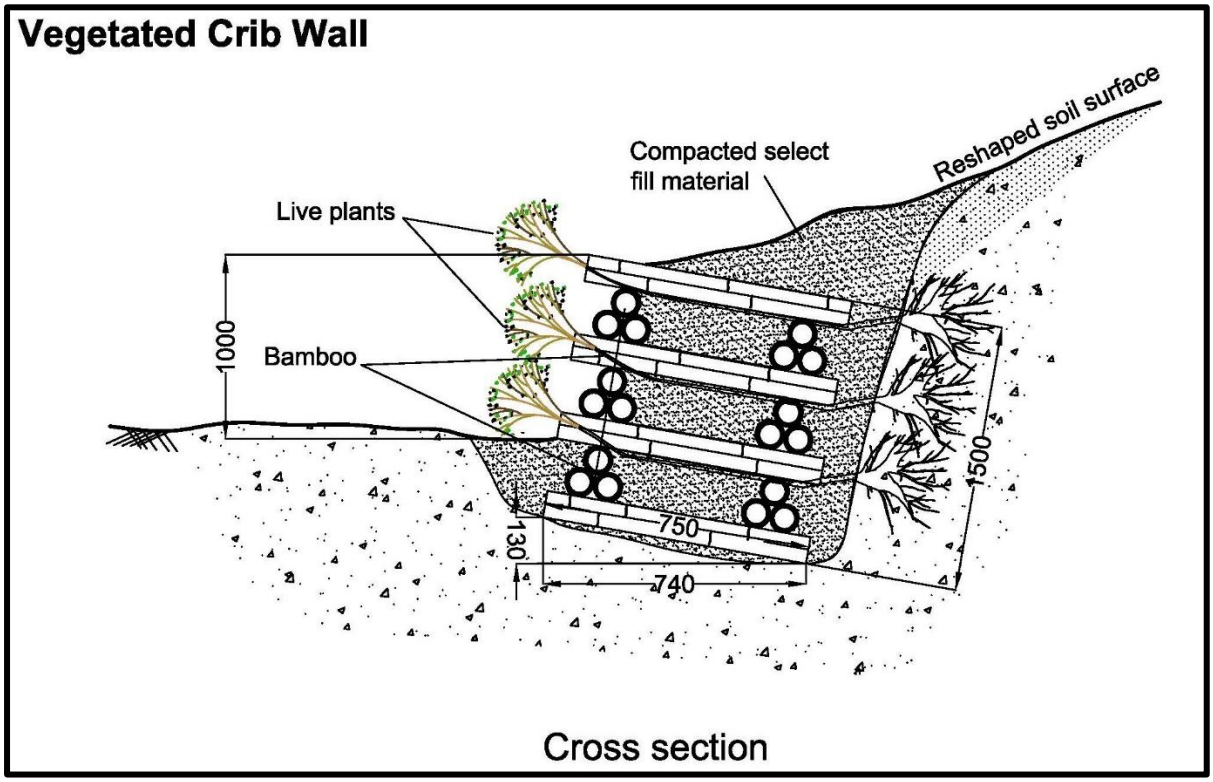

Fig 3.5: Vegetated Crib Wall made up of bamboo

Proposed list of plant species for each location are elaborated in Fig. 3.5.

3.2 Sri Sumangala School, Bowatta in Matale District – Hybrid Solutions

The site houses a school with small children learning from Grade 1 to Grade 5. A combination of nature-based solutions and conventional engineering solutions were introduced in order to mitigate the landslide risk.

It is proposed to improve the surface drainage flow inside the school premises as given in Fig. 3.6. Two cutoff drains, one toe drain and one berm drain to be constructed to intercept water flow coming from up slopes. They can be constructed as line drains.

The intercepted water will then be safely disposed out towards the storm water drainage path by the road down slope via cascade drains. The specific dimension of the drains shall be determined after carrying out a hydrological analysis of the site.

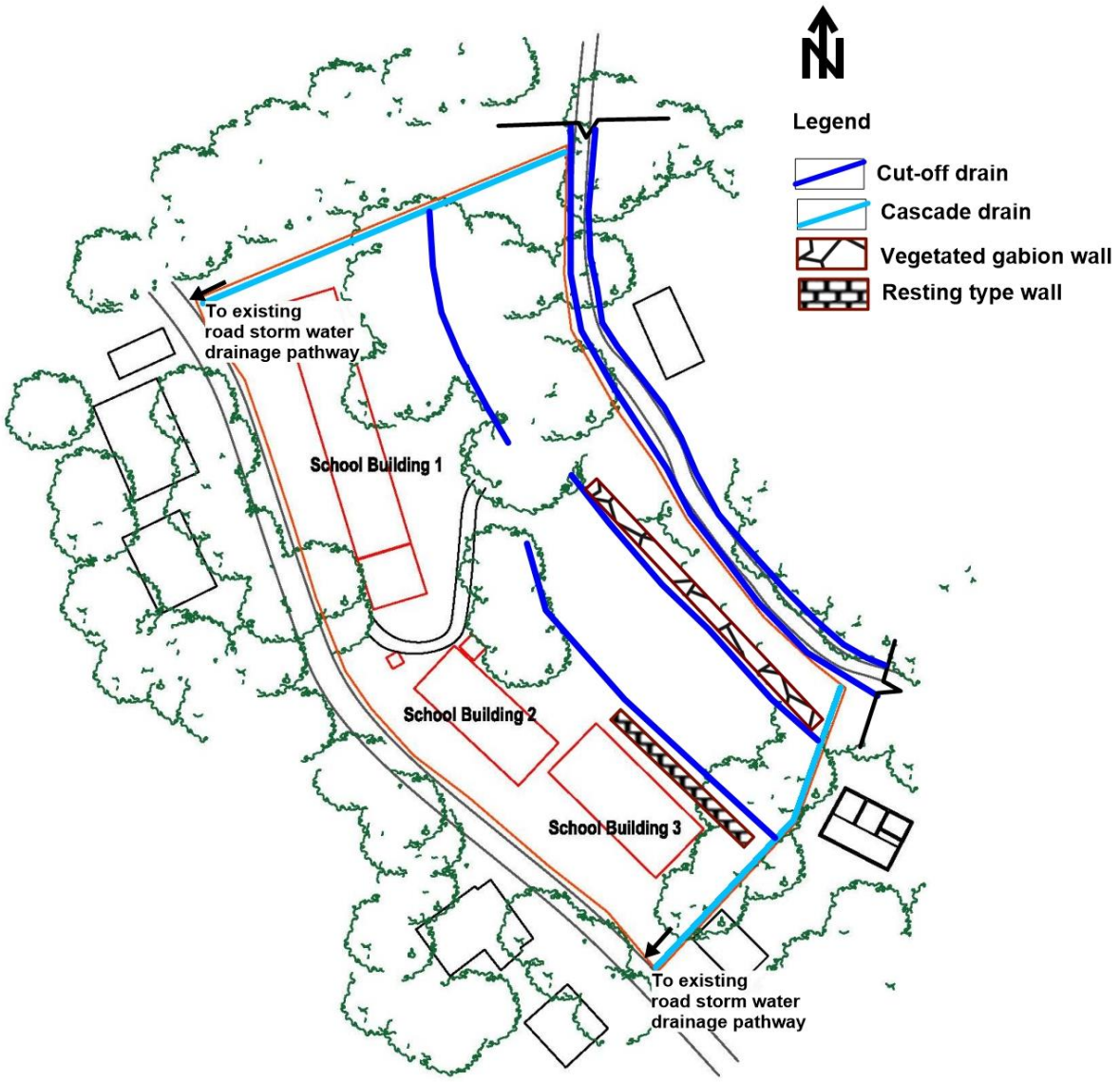

Fig. 3.6: Proposed plan

Slope instabilities were observed at Location A and Location B and the corresponding solutions for each location are given below.

Solutions for Location A

Solution 1

The upper slope just above the school playground will be strengthened by constructing a vegetated gabion as the toe support. Vegetated gabion is classified as a hybrid solution. As per Gray & Sotir (1996), they are one type of gabion walls where vegetation is incorporated. Gabions are rectangular containers fabricated from a triple twisted, hexagonal mesh of heavily galvanized steel wire. Gabions are normally

supplied folded flat and bundled together for easy handling. The empty gabion baskets are placed in position and wired to adjoining baskets in various stacking arrays or configurations. They are then filled with rocks.

The proposed vegetated gabion wall is given in Fig. 3.7.

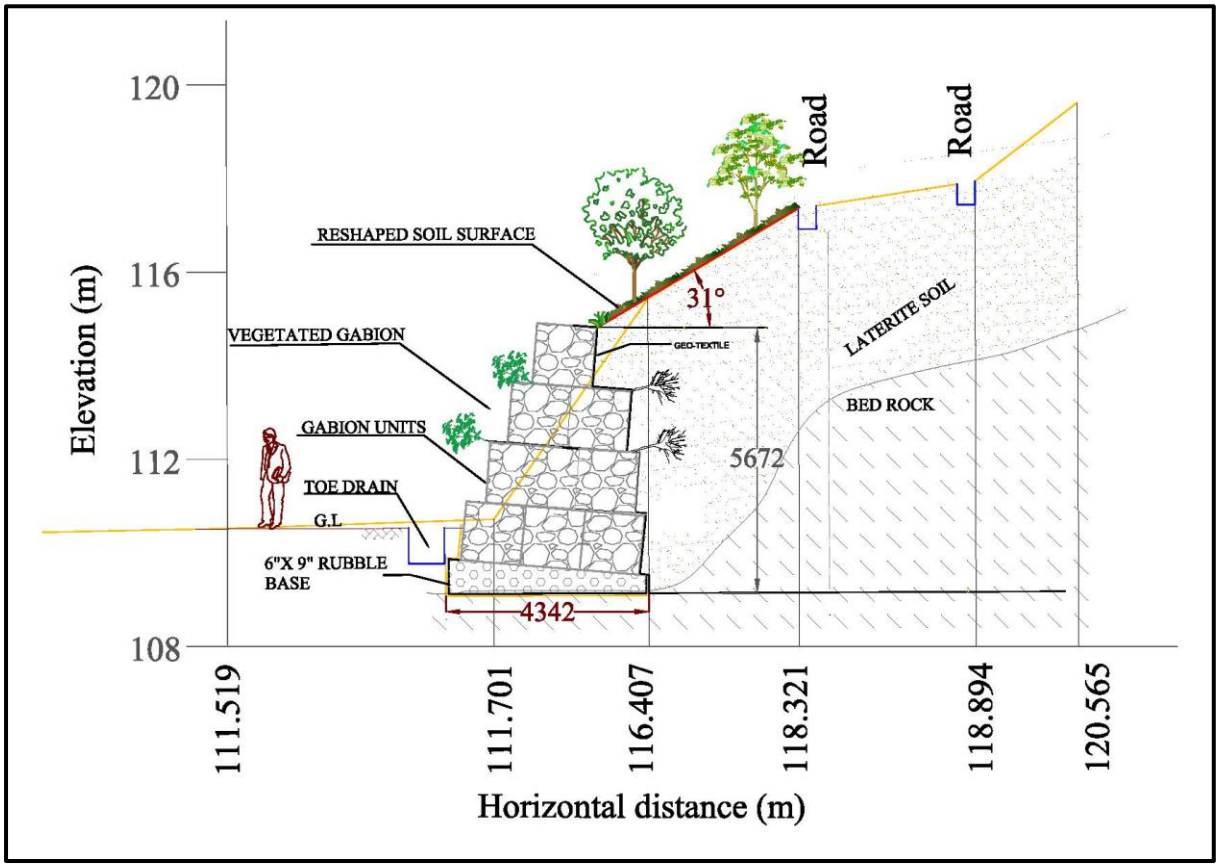

Fig. 3.7: Schematic diagram of the proposed vegetated gabion

Solution 2

Tiered Wall using TOR blocks with Bench Plantings

A second alternative solution is also developed for Location A. That is to construct a Tiered Wall using TOR blocks with bench plantings. According to Gray and Sotir, (1996), a tiered retaining wall system provides an alternative to a low toe-wall with face plantings. Shrubs and trees can be planted on the benches to screen the structure and lend a more natural appearance. This solution allows vegetation to be planted on slopes that would otherwise be too steep. Roots that permeate the backfill or slope behind the structure will also tend to reinforce and indurate the soil. Fig. 3.8 indicates the proposed Tiered Wall using TOR block with bench plantings.

Wall type

The tiered wall system is proposed to be built using "TOR" Blocks. TOR block is an innovative product made by Dr. Suttisak Soralump and his research team at Kasetsart University, Bangkok, Thailand. Fig. 3.9 describes in detail the information on "TOR" block. Its dimensions, reinforcement and how it is arranged for the construction of the retaining wall are depicted in the schematic diagram.

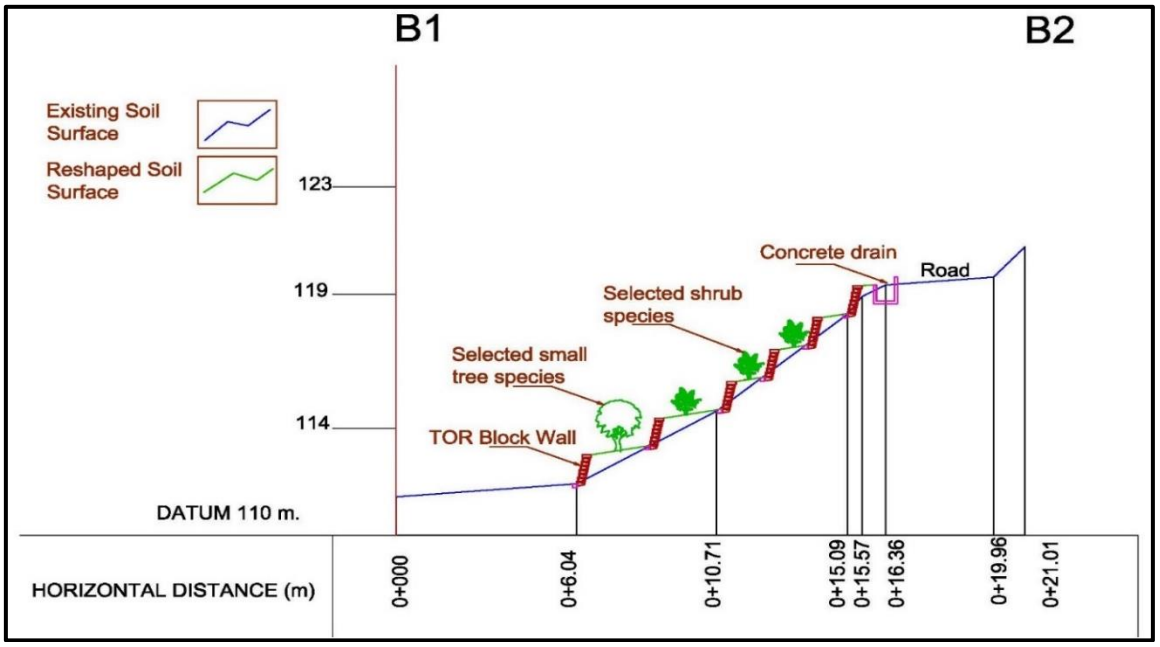

Fig. 3.8: Proposed Tiered Wall using TOR blocks with Bench Plantings

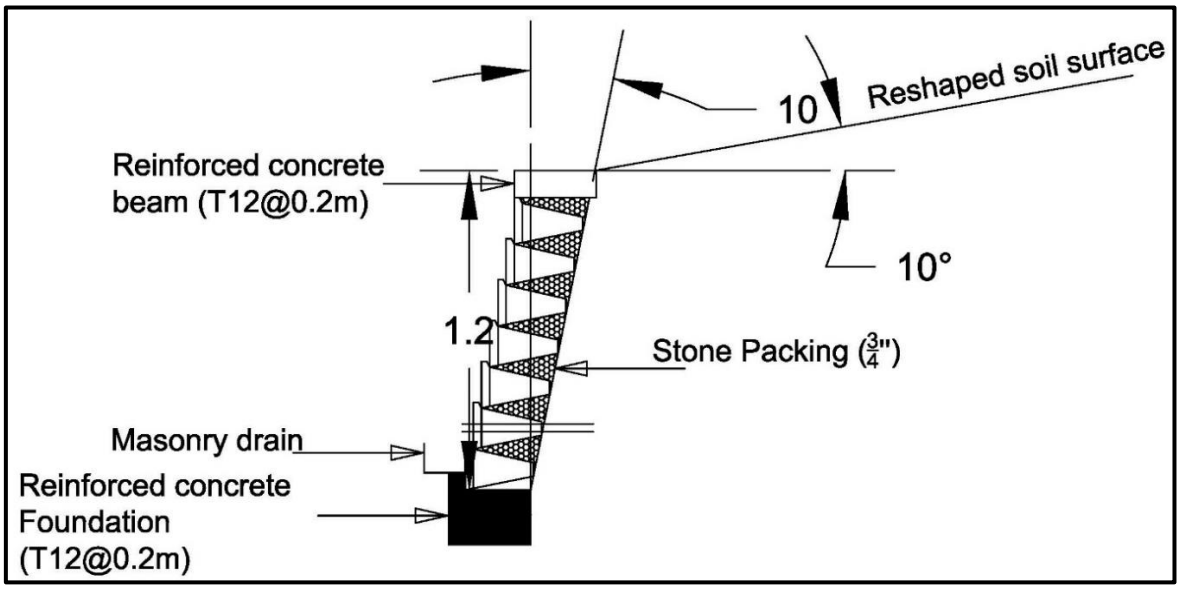

Fig. 3.9: Information on "TOR" block wall

Construction of a 1m2 using "TOR" blocks costs around $10-$15. Drainage is provided by creating weep holes at the toe blocks as seen in Fig 3.9. The spacing in between the blocks too serve as drainage paths.

Location B

An engineered retaining structure is required behind the classroom building at location B. It is proposed to construct a "Resting type Wall" as shown in the schematic diagram presented in Fig. 3.10. The wall is to be built using reinforced concrete. A conventional engineering measure needs to be adopted in this location together with drainage improvement as given in Fig. 3.4.

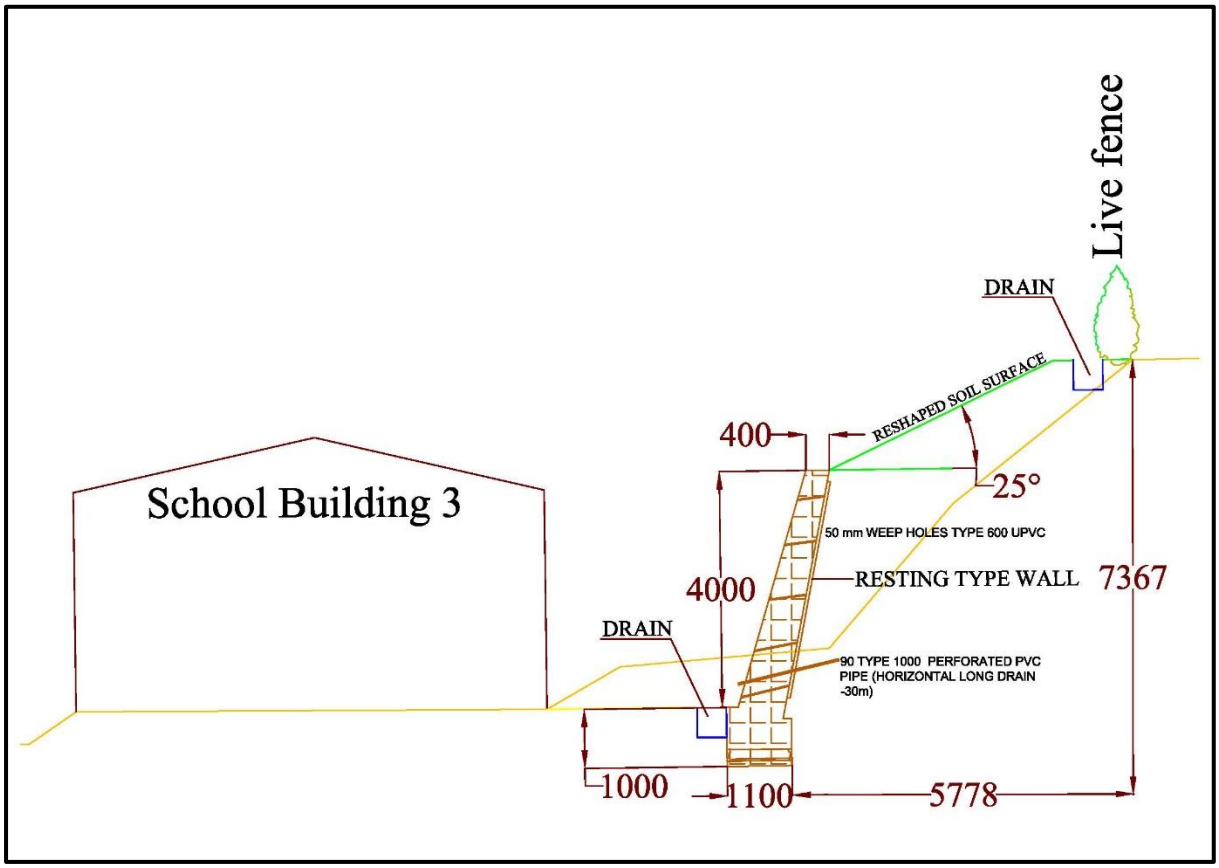

Fig. 3.10: Schematic diagram of the proposed Resting type Wall

3.3: Hakgala in Nuwara Eliya District – Greening & Improving Aesthetics

Conventional engineering solutions were already introduced at site to mitigate the slope instabilities. The main objective of the introduction of NbS at site is for greening the area and for getting higher aesthetic (natural beauty) appearance. (Blending conventional engineering solutions with the existing ecological setup). A group of plant species with good bioengineering characteristics and compatible with the site ecological setup is proposed (Annex 5). Fig 3.11, 3.12, 3.13 & 3.14 show layout plans showing spatial locations of proposed plant species.

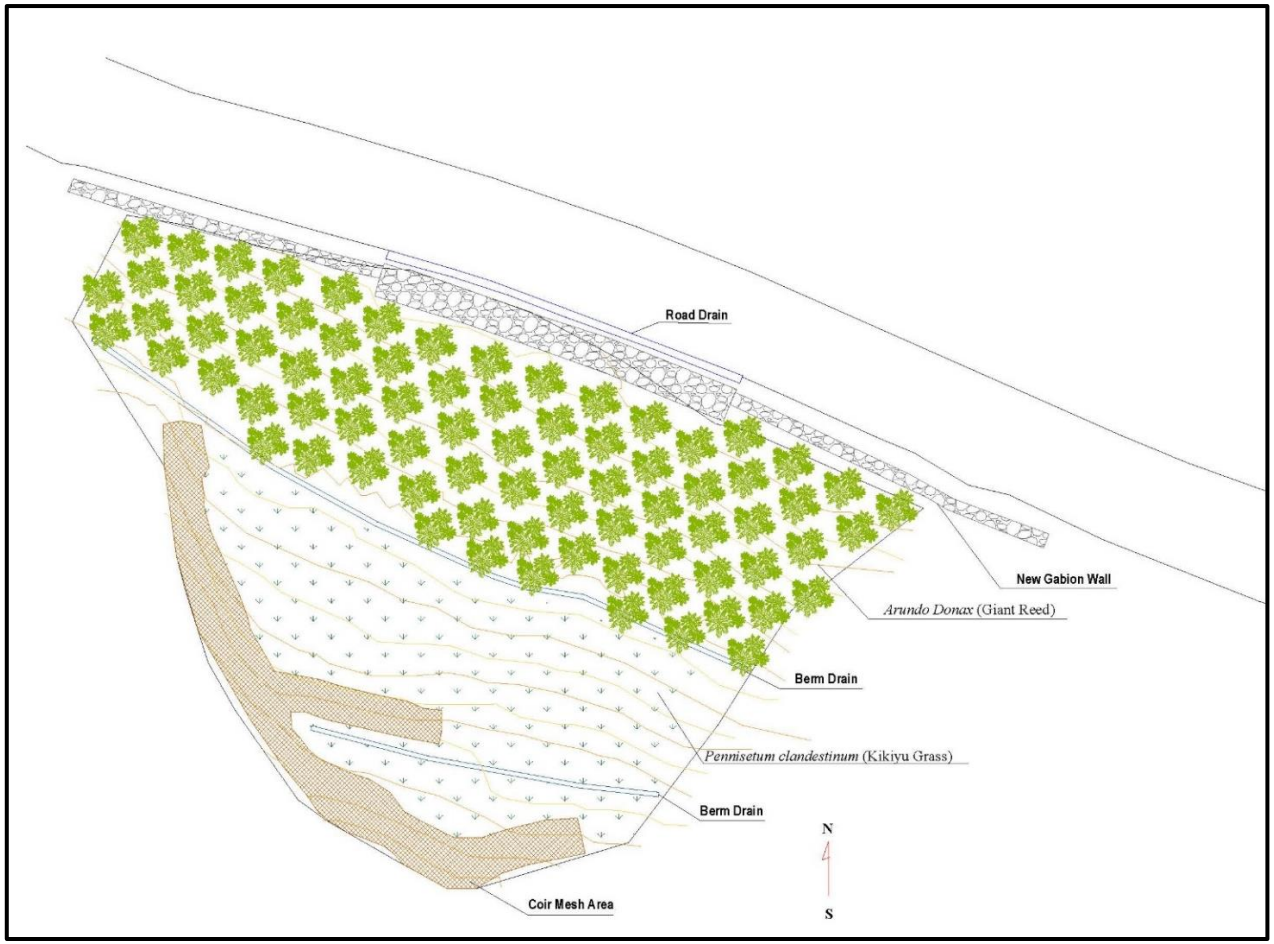

Fig. 3.11: Plan view of section between culvert 75-6 and 75-7

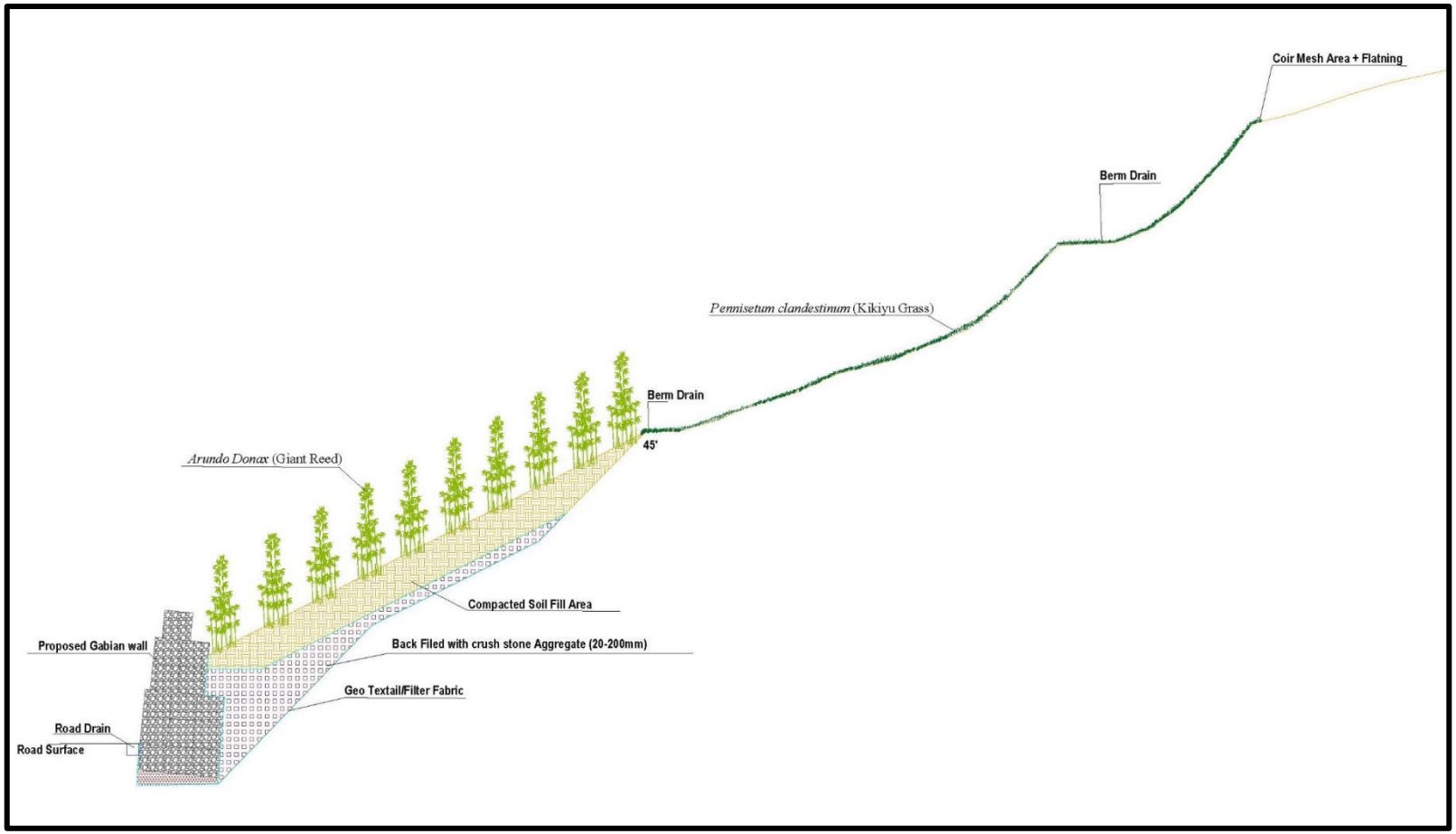

Fig. 3.12: Side Elevation view of section between culvert 75-6 and 75-7

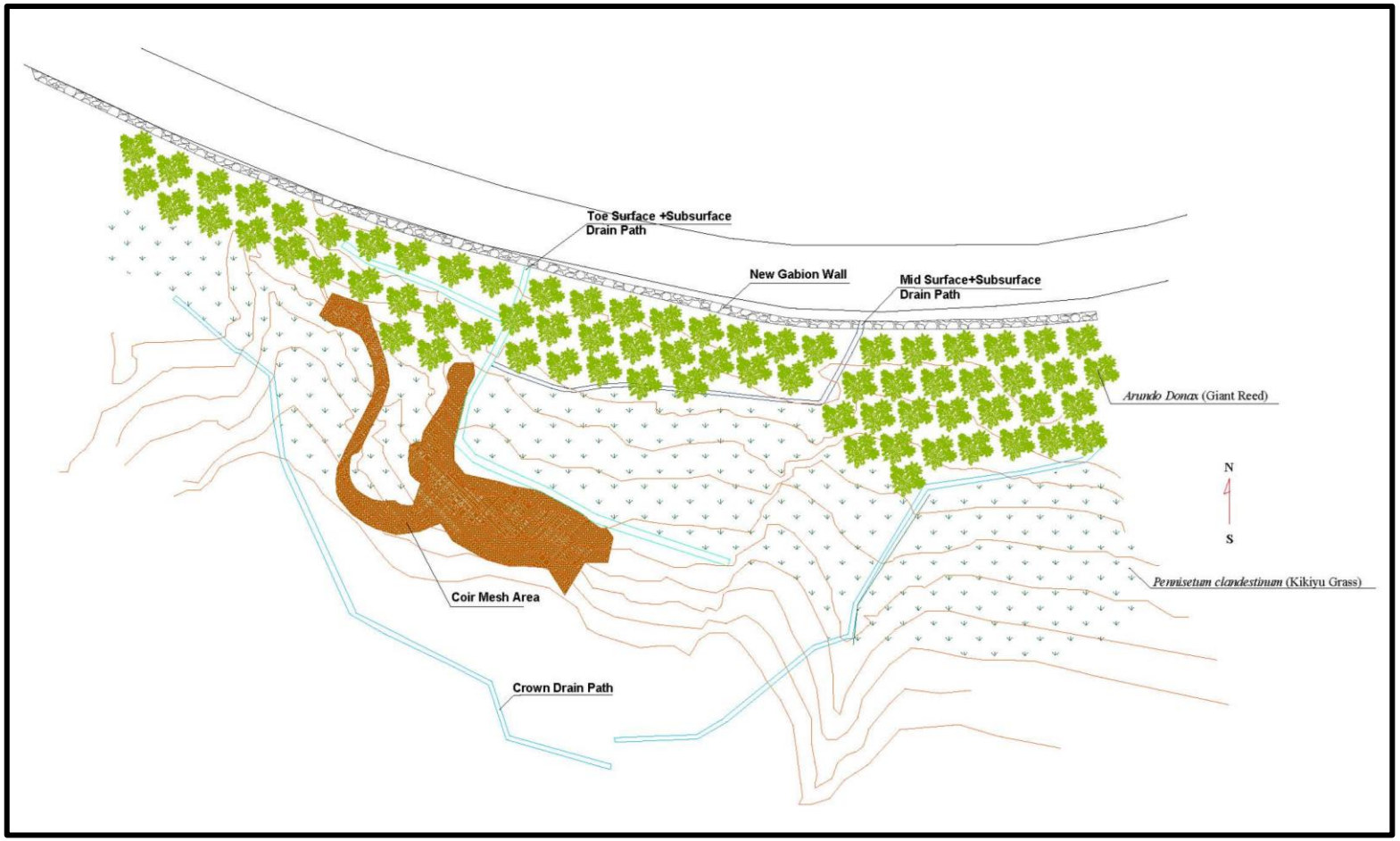

Fig. 3.13: Plan view of section between culvert 75-7 and 75-8

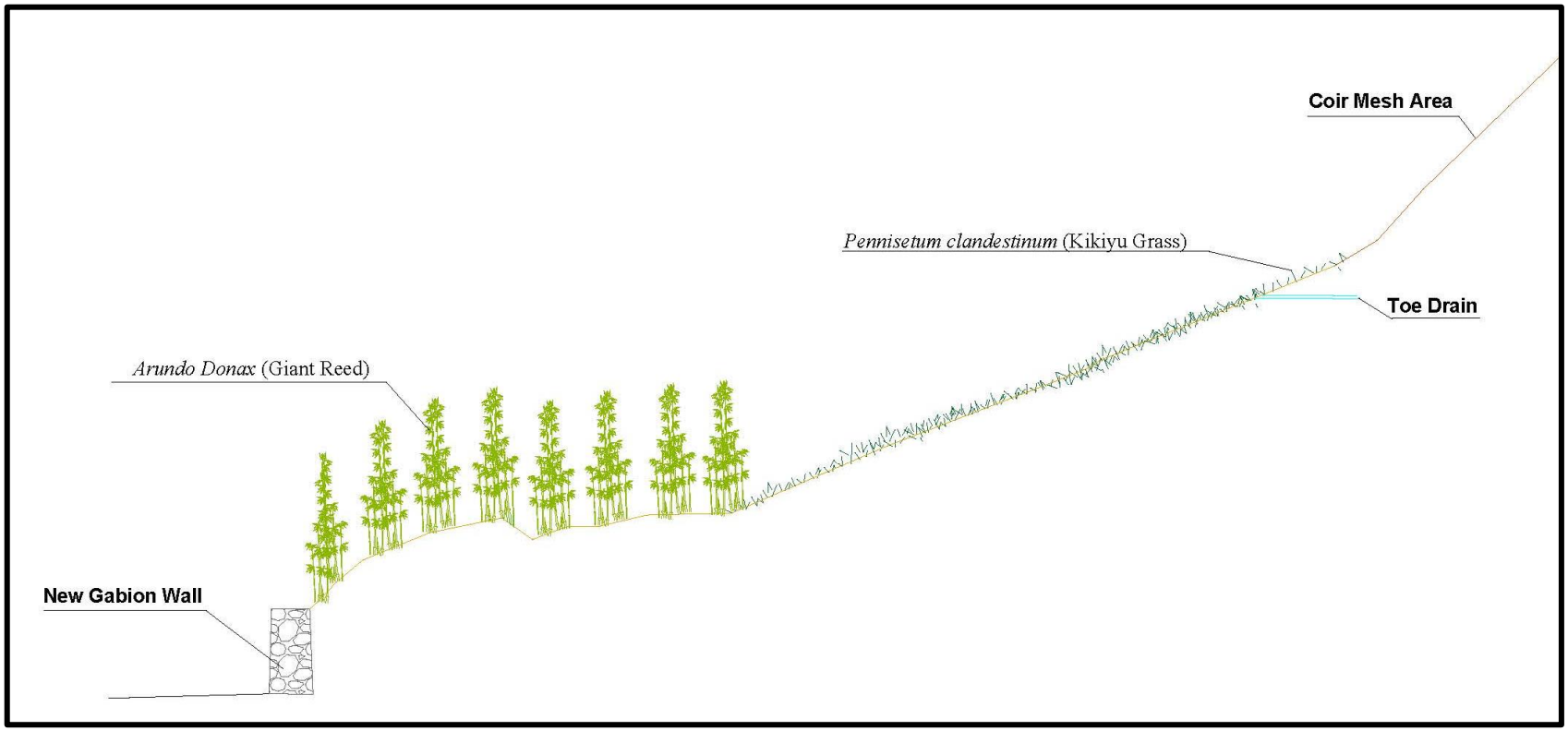

Fig. 3.14: Side Elevation view of section between culvert 75-7 and 75-8

3.4: Ayagama in Ratnapura District - Greening & Improving Aesthetics

As in the previous site, conventional engineering solutions were already introduced at this site to mitigate the slope instabilities. The main objective of the introduction of NbS at site is for greening the area and for getting higher aesthetic (natural beauty) appearance. (Blending conventional engineering solutions with the existing ecological setup). A group of plant species with good bioengineering characteristics and compatible with the site ecological setup is proposed (Annex 5).

Moreover, the site is within close proximity to Ayagama town and it is served as a commercial/ administration center for the general public. Hence, project team members decided that it would be better to create a usable urban space on completion of the landslide risk mitigation. Therefore, considering above facts and in consultation with NBRO senior professionals, it was proposed to include setting up an "Urban Leisure Park" in to the landslide risk mitigation plan incorporating NbS.

Fig 3.15 shows the proposed landscape layout plan of the proposed "Urban Leisure Park".

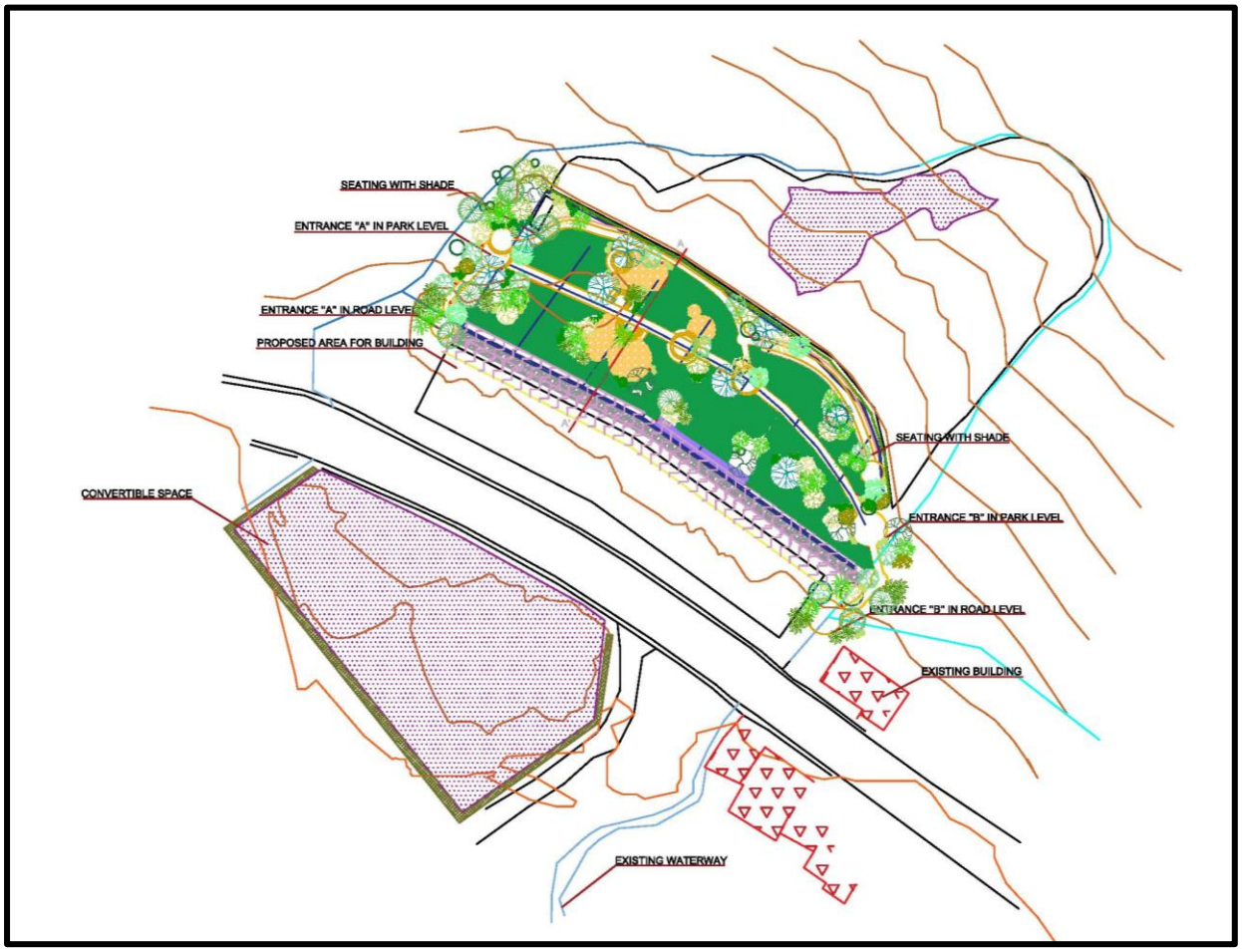

Fig. 3.15: Plan View of Urban Leisure Park

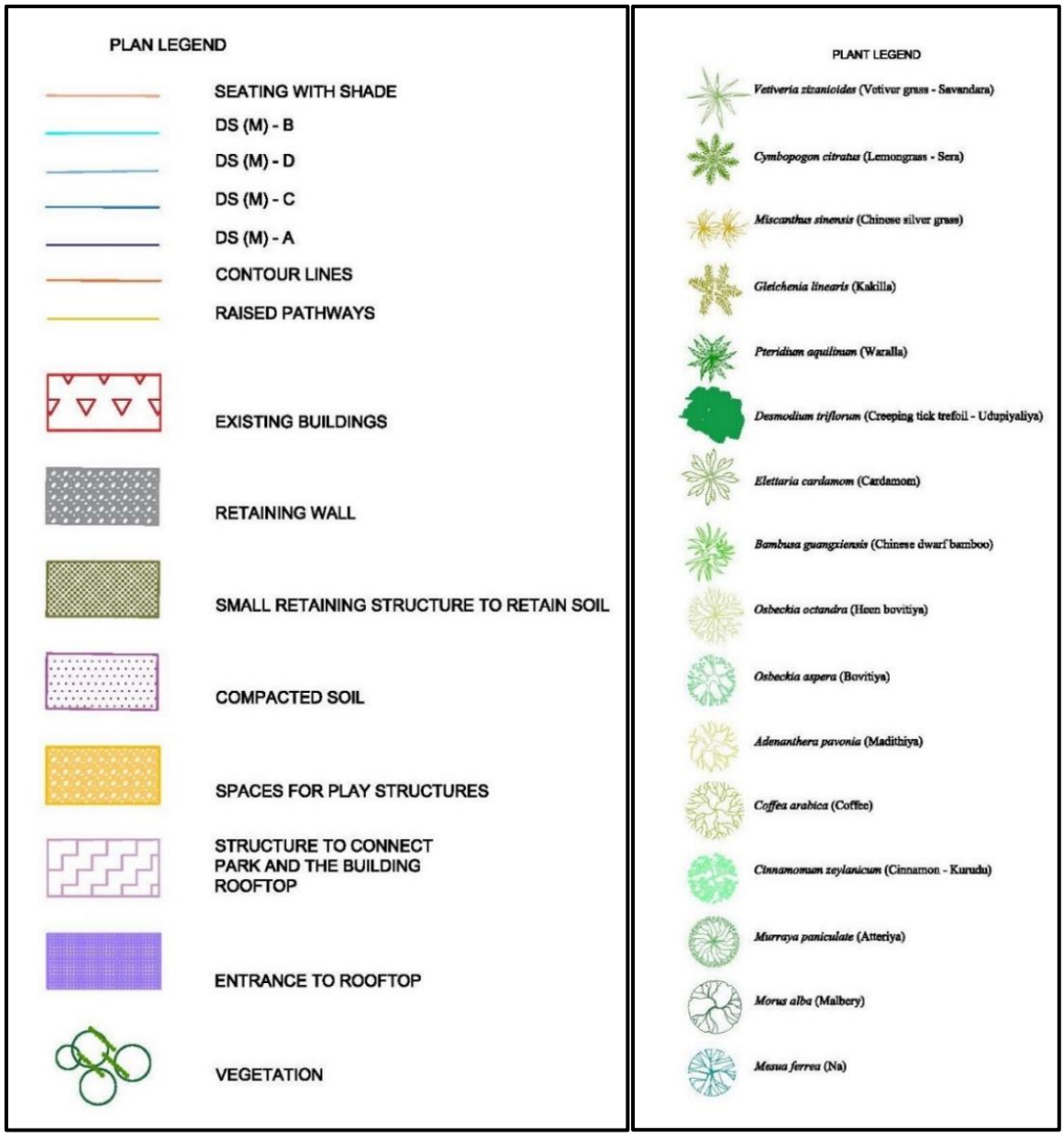

Fig. 3.16: Description of legends

3.5 Development of Guidance Document on application of Nature-based Solutions for Site Specific Landslide Risk Mitigation Planning (SSLMP)

The document is expected to serve as a guidance manual on application of nature-based (as well as hybrid) solutions for Site Specific Landslide Risk Mitigation Planning. It is developed with the main purpose of providing guidance to professionals involved in landslide risk management activities including scientific staff at NBRO, other practitioners and staff at relevant local authorities.

The document provides guidance in designing, implementation and monitoring the effect of nature-based solutions for landslide and erosion risk reduction under a range of physical conditions. Some of them are associated with measures involving a vegetation cover to make the appearance of slopes as natural as possible, and help in creating not only safer but also more visually acceptable and ecologically sustainable slopes. The nature-based and especially hybrid solutions presented in the guide are chosen specifically to suit Sri Lanka's need for landslide risk reduction.

In addition, it is expected to provide nature-based solutions to reduce the impact of climate change, increase ecosystem services, and promote conservation practices. It also discusses about the possible multiple benefits at community level through livelihood opportunities for vulnerable communities while serving as landslide risk mitigation solutions.

Guidance Document on Use of Nature-based Solutions for Site-specific Landslide Risk Mitigation is included in Annex 6.

References

Gray, D. H. & Sotir, R. B. (1996) *Biotechnical and soil bioengineering slope stabilization: A practical guide for erosion control*. John Wiley & Sons, New York.

CHAPTER 4: Outcomes of Task C - Stakeholder Consultation, Knowledge Sharing and Capacity Strengthening

Landslide risk mitigation professionals in Sri Lanka are familiar with the process adapted in undertaking structural as well as non-structural mitigation solutions. They have more confidence in application of conventional engineering solutions for various locations with high landslide risk. However, such applications are not feasible for every location with landslide threat. Such techniques are fit enough for improving the strength characteristics of sub-soil formations in certain instances. However, when taking in to account the cost benefits, environmental suitability, ecological aspects etc., there is certain limitations in effective application of conventional engineering solutions. It is important to convince the professionals that combined efforts involving geo-engineering and nature-based solutions can give rise to stability of the slope as well as contribute positively in meeting cost effectiveness, enhancing the aesthetics of the environment and reducing ecological impacts.

The activities planned under Task C, were lined up to meet the objectives of the project to raise awareness and deepen the knowledge within the agencies of the Government of Sri Lanka (GOSL) on the role of nature-based solutions for landslide risk management. In addition, it was necessary to use the planned activities for capacitating landslide professionals further with required knowledge to overcome the confidence barrier by convincing them about the possibility of mitigating the landslide risks cost-effectively when conventional engineering solutions are combined with NbS.

This report summarizes, the different activities carried out under Task C and their achievements. Task C was comprised of a set of activities under 05 sub-tasks, namely:
(01) Training & Capacity building program;
(02) National & International forums for experience sharing;
(03) Risk communication workshops at District level;
(04) Initiation of a national level policy roundtable and
(05) Interventions for dissemination of project experience via international publications.

A summary of the activities undertaken are given below. The full report on Task C – Stakeholder Consultation, Knowledge Sharing and Capacity Strengthening, is provided under Annex 7.

4.1 Training & Capacity Building Program

Training workshop on "Landslide susceptibility mapping by integrating climate change impacts scenarios" from 2 to 4 December 2019

In this three-day training session, participants were introduced to evidence-based landslide susceptibility mapping techniques. Bivariate statistical analysis can be used to produce landslide susceptibility map. This procedure is well known in landslide hazard analysis and usually used for delineating the landslide susceptibility and risk for the purpose of different physical and development planning interventions in district or local government levels. This susceptibility statistical analysis relies on the accuracy of landslide inventories and of factor maps such as soil map, land use map, slope map, rainfall distribution map, etc.. Satellite imagery can be used to identify previous landslide locations and can aid in improving the landslide inventory. This type of mapping can cover larger as well as smaller

areas (at local government level) and can be an alternative methodology to that of currently adapted by NBRO for preparation of 1:10,000 scale maps. It is a faster and a costeffective method.

Training workshop on "Root testing and modeling of effects of vegetation in strengthening sub-soil formations and in improving slope stability" on 21 October 2019

The technical workshop on root testing and modeling of effects of vegetation in strengthening sub-soil formations, was organized for NBRO scientist with the aim of providing some of the answers to the technical issues that the project team came across while carrying out laboratory testing of roots and incorporating the test results in computer modeling. The session included the following subject areas:

- What kind of roots (and parts of the root system) is most appropriate to be taken into account when considering the vegetation effect in stabilizing sub-surface soil formations?
- How to arrive at a representative value of root tensile strength or root cohesion for a particular plant species when considering tensile testing results?
- What factors must be considered in incorporation of parameters such as root suction/ soil suction into slope stability modelling?
- What other improvements can be done to the current methodology of root testing and modeling of vegetation effect in improving slope stability?

Workshop for familiarization of the content of the Guidance Document on use of Nature-based Solutions for Landslide Risk Management on 21 October 2019

This workshop was conducted mainly to introduce the content of the Guidance Document on use of Nature-based Solutions for Landslide Risk Management, drafted under phase 1. Under phase 2, the content of the Guidance Document was enriched with new subject areas, based on the feedback received at the workshop.

Lecture on "How beneficial medicinal plants for Nature-based landslide risk management?" On 27 May 2020 through Zoom facility

Plant species are a major element in nature-based techniques which are adopted in order to mitigate the landslide risk. But it is important to look for different varieties of plant species which can be applied in designing nature-based solutions and also provides other multiple benefits. Medicinal/ Herbal plants are one such variety that can provide NbS for mitigating landslides as well as capable of providing livelihood opportunities for community living in risk prone areas.

This lecture highlighted the benefits of medicinal plants and advantages in applying them in NbS. The workshop covered the following main subject areas:

i. Types of medicinal/herbal plants which fall under plant community categories of Grasses, Herbs, Shrubs and Trees (Small/Medium/Large).
ii. Root characteristics (effective rooting depth, root architecture, strength)
iii. Evapotranspiration capacity
iv. Rainfall interception capacity via its foliage/canopy
v. Ecological Significance (Native-Endemic/ Exotic-Introduced/ Invasive)
vi. Economic benefits

4.2 National & International Forums for Experience Sharing

Organization of the special session on Nature-Based Landslide Risk Management at the 10th NBRO Annual Research Symposium

Project team organized a special session on Nature-Based Landslide Risk Management at the 10th Annual Research Symposium of National Building Research Organization (NBRO) "Equitable Resilience'' theme. The symposium was held at the Hotel Galadari, Colombo on 17th and 18th December 2019.

Organization of a Thematic Session titled "Nature-based Solutions (NbS) for managing disaster risks" at the International Symposium on Multi-Hazard Early Warning and Disaster Risk Reduction

A thematic session titled "Nature-based Solutions (NbS) for managing disaster risks" was scheduled to be held on 18th March 2020 as a part of the International Symposium. A panel of several international subject experts were scheduled to make presentations based on their international experience. However due to the prevailing COVID-19 pandemic situation, the organizers of the "International Symposium on Multi-Hazard Early Warning and Disaster Risk Reduction" was compelled to postpone it, until further notice, including the project-initiated event. Provisions will be made to organize the session, in a future date when the situation becomes conducive for organization of the said International Symposium.

The thematic session will have three main objectives:

Objective 1: Sharing of evidence of effective NbS (e.g. Ecosystem-based Disaster Risk Reduction, Ecosystem-based Adaptation, Ecological Restoration, Climate Risk Management and Climate Adaptation Services, Green Infrastructure, etc.) to address global societal challenges of climate change, disaster risk, food & water security and economic & social development in countries in the region.

Objective 2: Relating evidences of NbS to policy decisions at national scale to ensure effectiveness through tools and methods to support planning, implementing as well as monitoring & evaluation.

Objective 3: Strategy to scale-up and scale-out NbS by linking Science, Practice and Policy - opportunities and both institutional and financial challenges.

4.3 Risk Communication Workshops at District Level

NBRO started implementing the Landslide Hazard Mapping Program (LHMP) since early nineties, to understand the contextual setting, demarcate the probable areas of occurrence of landslides, and determine the hazard parameters. NBRO uses state-of-the-art technology for landslide susceptibility mapping to identify areas prone to landslide phenomena. Subsequently NBRO has taken initiative to extend the program to risk mapping in order to estimate the probable risk associated with landslides to devise the most appropriate risk management options. As a part of the same, an exposure assessment has been carried out, which involves the analysis of exposure characteristics of all the elements at risk present within the area. The analyzed characteristics include elements of the human system, the built environment, (infrastructure & critical facilities etc.) and land use types (agriculture). In addition, they

have carried out a vulnerability assessment for the same elements. Combination of the levels of hazard, exposure and vulnerability provide the degree of risk in a given area.

It is necessary to conceptualize that the landslide disaster is a result of a set of incremental actions which lead to landslide risk accumulation. One of the notable factors for growth of risk in recent times is the rapid increase in anthropogenic interventions, which are being carried out by the population with a limited understanding of risk. It is necessary to elevate the knowledge on the landslide risk so that they will have a correct perception on landslide disaster risk and make them understand that it is a dynamic compound event. Hence risk reduction measures should be integrated as a part of development planning and resilience building processes at all levels. That is an essential factor in resilience building and making the communities and infrastructure safe.

There is a current framework that is in operation at district level. It is the District Coordinating Committee under the chairmanship of the District Secretary. But that is meant for coordinating mainly response activities and to some level in increasing the preparedness. Hence, NBRO under the project has developed a District level Risk Communication Framework, which is a support structure or system that comprised of agencies that are closely associated with NBRO in undertaking various development activities. This framework is expected to support the landslide risk management interventions and building resilience.

The membership of the framework consists of agencies such as Urban Development Authority (UDA), Provincial Road Development Authority (PRDA), Irrigation Department, Forest Department, Education Department, National Disaster Relief Services Center (NDRSC), Disaster Management Center (DMC), GN officers, Land Use Policy Planning Development (LUPPD), Survey Department, Water Board, Agriculture Department, National Housing Development Authority (NHDA), Plantation Human Development Trust (PHDT), Local Authorities, Leaders of village level disaster management committees and Estate sector representatives. This framework can be used as a vehicle for having a dialogue and communicating the risk & risk reduction interventions, if meetings can be organized frequently.

The project has initiated such meetings at district level for risk communication. The Structure of the meetings is as follows;

- Presentation of district level landslide disaster situation, which is a result of a set of incremental actions that leads to landslide risk accumulation;
- Introducing the NBRO database comprised of data related to landslide hazard & risk mapping, special investigations in slope instabilities & landslide susceptibility and discussion with participants the ways to improve interactions with the stakeholder community;
- Presentation of simple technology and mitigation solutions including NbS that can be promoted at the community level.

The recommended actions in future based on the comments made by the participants are:

- Setting up of the framework and organization of district level risk communication workshops. They both are very useful initiatives by NBRO and should be continued in future to have a regular dialogue with agencies involved in development interventions;
- Participants would like to have a better understanding on landslide risk mitigation solutions that can be used at the community level. In particular they would like to know simple cost-effective solutions that can bring multiple benefits to community;

- Participants suggested to have more demonstrations at the community level to create more know-how and demonstrate the effectiveness;
- Participants wanted NBRO to organize institution level workshops to brief them on the NBRO database and explain how to use the available data effectively;
- Participants suggested NBRO to organize school programs to create awareness on possible nature-based mitigation solutions that community can undertake with multiple benefits;
- Another suggestion by participants was to develop awareness material in Sinhala/Tamil especially targeting community, school children, skill artisans etc.

4.4 National Level Policy Roundtable

The project team, under the phase I of the project, carried out an assessment of existing policies, relevant legal, regulatory and institutional frameworks to understand the degree of relevance of the same to the subject area of nature-based solutions and the applicability of the same for the purpose of landslide risk management.

The study revealed that there were number of relevant policies and several key agencies responsible for undertaking various relevant actions as per their mandates. However, there were number of overlapping areas. Therefore, for promoting application of nature-based solutions as one of the options for landslide risk management, the most appropriate action would be to undertake a collaborative approach. When adapting such a strategy it was suggested that NBRO work with number of like-minded key institutions in order to have collaborations in joint research programs, capacity building, and awareness raising in promoting nature-based solutions.

The project team organized a workshop to disseminate the findings under phase I, but it was felt subsequently that it is useful to organize a forum with a few key institutions, to have a better and close dialogue and map out future possible collaborative actions.

Considering the importance of having such a forum for promoting nature-based solutions, a Policy Roundtable discussion was organized by National Building Research Organization (NBRO) in partnership with the World Bank and Asian Disaster Preparedness Center (ADPC) on 31st January, 2020 in Mövenpick Hotel Colombo 03.

Recommendations of the national level policy dialogue roundtable are:

- All the agencies have shown commitment to create a better disaster risk governance system, that can enhance preparedness for early actions in mitigating the risk and a better recovery that prevents the emergence of new risks;
- Take action to convert this roundtable in to a structured forum to have a process to promote macro-level multiple benefits of NbS for reduction of impact of climate change, improvement of ecosystem services, promotion of conservation practices, in addition to disaster risk management;
- Having recognized the mandate and its specialized role in the context of landslide risk management, NBRO to take the lead in convening the forum as an informal/formal forum and develop a collaborative action plan for joint research, training, awareness raising etc. on the subject;
- The partner agencies will provide their technical expertise, contributing to achieve the overarching goal of "reduced occurrence and impacts of landslides through the risk informed nature-based solutions and macro level benefits";

- NBRO to take the lead in formulating an Operational Plan with a specific time duration (i.e. for 3-year period) with annual Action Plans. Identify and assign clear roles to the key technical agencies that have already expressed their commitment. The agencies who were present in the discussion agreed to discuss the operation plans in detail and respective contributions;
- These Annual Plans will be of significant importance in negotiating resources from the Consolidated Fund of the Treasury. It is also suggested to involve National Planning Department in this process in future so that their support will pave the way for funding the actions on Nature-based Landslide Risk Management.

4.5 Dissemination of Project Experience via International Publications

The project team took the initiative to develop following technical papers and book chapters and decided for publication in the proceedings of the respective international forums.

- Policy brief on "**Nature-based Solutions for Landslide Risk Management**"- submitted to the World Bank
- Technical paper on "**Site suitability analysis for nature-based landslide risk mitigation**"- The Paper has been accepted for publication at the 5th World Landslide Forum, Kyoto, Japan in the Full Colour Book on Understanding and Reducing Landslide Risk.
- Book Chapter on **"Plant selection criterion on for nature-based landslide risk management"**- The Book Chapter was accepted for publication in the book volume Multi – Hazard Early Warning and Disaster Risk Reduction at the International Symposium on Multi Hazard Early Warning and Disaster Risk Reduction.
- Book Chapter on "**Policy recommendations for establishing a long-term landslide risk management strategy for Sri Lanka**". The Book Chapter has been accepted for publication in the book volume Multi – Hazard Early Warning and Disaster Risk Reduction at the International Symposium on Multi Hazard Early Warning and Disaster Risk Reduction.
- Technical paper on **"Effects of root tensile strength of vegetation on slope stability"-** The Paper has been accepted for publication at the "International Conference on Geotechnical Engineering" which will be held in Colombo, Sri Lanka on 6-7 December 2021.
- Paper on "**Guidance Document on use of Nature-based Solutions for Landslide Risk Reduction**" - 10th Annual Research Symposium – 2019 of NBRO.

CHAPTER 5: Summary of The Proceedings of the Final Stakeholder Workshop

The final stakeholder workshop of the Nature Based Landslide Risk Management Project – Phase II, was organized at NBRO Auditorium on 25th September 2020 upon the completion of project activities. The workshop was held adhering to local health guidelines in conduct of workshops/meetings in order to ensuring prevention and control of COVID-19. Hence, only a limited number of participants from stakeholder agencies were invited to attend the meeting. Others (namely the participants from NBRO headquarters and field officers as well as ADPC-Bangkok office), attended the meeting through online cloud-based video conferencing service Zoom. The purpose of the meeting was to brief the stakeholders about the project activities and to present the outcomes and achievements of the project. Around 45 participants attended the event along with the World Bank (WB), National Building Research Organization (NBRO) - the project implementing agency and Asian Disaster Preparedness Center (ADPC), Thailand – the technical partner of the project. There were representatives from seven stakeholder organizations. Namely, Plantation Human Development Trust (PHDT), Sri Lanka Railways, Mahaweli Authority, Road Development Authority (RDA), Climate Resilience Improvement Project (CRIP), Forest Department, Urban Development Authority (UDA) and Irrigation Department.

Eng. (Dr.) Asiri Karunawardena, Director General of National Building Research Organisation (DG-NBRO), welcoming the participants of the final stakeholder workshop, stated that due to escalation of landslide events and associated impacts in terms of deaths, property damages & socio-economic impacts, the Government of Sri Lanka (GOSL) is compelled to take various initiatives to reduce the devastating impacts in the future. As the national focal point in landslide risk management, NBRO works in collaboration with various national level agencies and NBRO decided to invite key agencies to share the outcome of the project. He thanked the representatives present at the meeting, for their participation. He also thanked the World Bank for initiating this important project and for their funding assistance. He stressed on the fact that with landslide disasters becoming increasingly frequent in Sri Lanka, the importance of undertaking risk mitigation interventions in a cost-effective manner is growing. In the past Sri Lanka has largely relied on engineering solutions in landslide risk management and this project helped NBRO to introduce additional measures through the application of nature-based and hybrid (engineering in combination with nature-based) approaches. There are advantages in applying NbS when considering factors such as affordability and other multiple benefits to the environment and towards vulnerable communities. The other advantage is the possibility of application of NbS to increase the effectiveness of conventional engineering measures and to provide better aesthetic appearance through blending with the surrounding environment. At macro level, NbS offer multiple benefits for reduction of climate change impacts, improvement in ecosystem services and for promotion of conservation practices.

DG-NBRO also felt that the study undertaken by the project team on available policies, approaches/solutions in terms of the legal, regulatory and institutional arrangements also provided a set of good recommendations. He stated that NBRO would take them positively and take necessary actions for creating an enabling environment for application of nature-based landslide management solutions in the future. He also stated that the Guidance Document on "Nature Based Solutions for mitigation of Landslide risk at site-specific level" is one of the very important outcomes of this project. DG-NBRO at the conclusion stated that in his view the Analytics and Advisory Services Project, funded

by the World Bank, has achieved its objectives largely as the project has very much helped in raising the awareness on the subject and deepening the knowledge within the country on the role of nature-based solutions for landslide risk management. He thanked ADPC for the valuable support extended and for technical guidance provided as NBRO will see every opportunity in future for using the nature-based measures introduced by the project in mitigating the landslide risk in the country.

Ms. Priyanka Dissanayake, Disaster Risk Management Specialist from the World Bank, delivering a short message stated that the World Bank had decided to fund this Analytics and Advisory Services project to provide more options for mitigating landslides by increasing the knowledge within the country on the role of nature-based solutions for landslide risk management. World Bank is happy to hear that NBRO consider this type of mitigation measures are of importance and plan to apply NbS for landslide risk management in future. This sort of green initiatives is becoming more popular worldwide due to the fact that such initiatives offer multiple benefits for reduction of impact of climate change, increase ecosystem services, promote more conservation practices and ensure sustainability of environment. On the other hand, it can offer cost effective solutions at community level and can be used for achieving multiple benefits in creating even livelihood options for communities living in landslide prone areas. She thanked NBRO for taking the initiative to implement the project and also thanked ADPC team for their technical assistance. She promised to report the success and achievements to the World Bank management, with a very positive note as the project was implemented under challenging circumstances due to COVID-19 pandemic. She also felt that it is more important if NBRO could extend assistance in future to create more knowledge at the community level and help creating awareness on the cost-effective solutions that the project has presented.

Mr. N.M.S.I. Arambepola, Team Leader of the project, made a presentation highlighting the approach taken by the project in designing the project activities, providing a summary of final project outcomes and achievements. The project demonstrated the process of utilizing exposure databases covering high landslide risk areas in four (04) districts, namely Nuwara Eliya, Matale, Ratnapura and Matara for the assessment of landslide associated risks. At the end, the project delivered site-specific landslide mitigation plans for 04 selected sites from 04 target districts through application of NbS and hybrid solutions, where they are most appropriate. Project had taken special interest in capacity building and knowledge networking. Project also tried to present possible additional benefits at community level through increasing livelihood opportunities for communities while serving as landslide risk mitigation solutions. Study also tried to capture the outcome of NbS applications that could be useful in promoting macro-level multiple benefits through NbS for reduction of impact of climate change, increase ecosystem services and promote conservation practices. Commenting on the development of a Guidance Document on application of Nature-based Solutions for Site Specific Landslide Risk Mitigation Planning (SSLMP), he stated that the document is expected to serve as a guidance manual on application of nature-based (as well as hybrid) solutions for Site Specific Landslide Risk Mitigation Planning. It was developed with the main purpose of providing guidance to professionals involved in landslide risk management activities including scientific staff at NBRO, other practitioners and staff at relevant local authorities. Mr. Arambepola briefed about the district level risk communication framework, which is a new structure, comprised of agencies that are closely associated with NBRO in activities that support the landslide risk management interventions. It can be a support structure to the main framework already functional at the district level as the District disaster management committee. It is headed by the district secretary. The proposed structure would importantly work with operational level agencies to help them in analyzing risks and associated decision makings. He also thanked NBRO for the assistance provided to the project team in implementing the project and cooperation extended. He also thanked

World Bank for providing an opportunity to work with NBRO for undertaking this important project not only beneficial for Sri Lanka but also for the region.

Dr. Udeni P. Nawagamuwa, Consultant of ADPC gave a summary on capacity building initiatives as well as the initiatives undertaken for Stakeholder Consultation, Knowledge Sharing and Awareness Raising. He stated that the project initiated 04 capacity building initiatives including 03 workshops and an online lecture. He briefed about the National level Policy Dialogue Roundtable, which should help in creating a better disaster risk governance system that can enhance preparedness for early actions on mitigating the risk and a better recovery that prevents the emergence of new risks through the application of NbS. He also gave a list of project-initiated publications and technical sessions, intended for dissemination of project outcome widely, through national and international symposia.

Dr. Anurudda Karunarathna, Consultant of ADPC gave a presentation on the project approach and initiatives taken for providing necessary know-how and technical guidance in selecting plant species for use in nature-based landslide risk management. Dr. Karunarathna gave a detailed account of research studies carried out for analyzing different aspects of plant species that can be used in slope stabilization and landslide risk mitigation. The project had taken steps to devise a plant selection criterion based on characteristics of individual plant species such as root strength, hydrological significance, ecological significance and economic importance. Further, he described in detail the ranking methodology of plant species which would be very helpful in selecting plants according to their suitability for use in NbS.

Mr. Chinthaka Ganepola, Project Engineer from ADPC made a detailed presentation on the approach taken in Site-specific Landslide Mitigation Plan preparation. He presented a detailed methodology adapted by the project in ranking the sites for application of green solutions and hybrid solutions in combination with conventional engineering solutions using several criteria. Mr. Ganepola presented the approach used in conducting detail risk assessment in sites selected for site specific landslide mitigation plan development. Mr. Ganepola provided in his presentation the process undertaken in developing a site-specific landslide risk mitigation plan. He presented site-specific solutions and mitigation plans for selected sites from each district. He also detailed out the approach for verification of the design of the site-specific landslide mitigation plan through computer modelling and simulation studies. Mr. Ganepola also presented the detailed implementation plan and work plan for each site. He stated that the initiatives undertaken would help in demonstrating that the combination of conventional engineering and nature-based practices could be very effective as a long-term solution for landslide risk mitigation while also offering other multiple benefits such as sustainable livelihoods, improved ecosystem services and overall enhancement of aesthetic appearance of the area in addition to enhancing the stability of slopes susceptible to landslide hazard. As per the views expressed by Mr. Ganepola, the findings of the project initiative could support the Government of Sri Lanka (GoSL) in piloting and potentially scaling up the use of nature-based and especially hybrid solutions for landslide risk management in future.

Mr. Lilanka Kankanamge, Project Engineer from NBRO presented the application of the project outcome in designing measures for improving stability of slopes in Neluwa - Lankagama road which runs through Sinharaja Tropical Rain Forest. The basic idea was to present the ongoing NBRO efforts for application of Nature-based solutions to demonstrate how NBRO will be planning to use the knowledge gained through the project in real project situation in future. He presented several mitigation options and many of the designs had been done integrating low cost, simple slope stabilization technologies combined

with various types of plant species. The project would be undertaken by the Road Development Authority. NBRO would be providing technical guidance and would help in monitoring the effectiveness.

Following main points were highlighted at the discussion session:

- The studies carried out under Phase I and Phase II of the project had provided sufficient evidence to convince landslide risk management professionals that NbS could become one of the cost effective and viable solutions for landslide risk management. It could be implemented as green solutions and as hybrid solutions to increase the effectiveness of conventional engineering measures. It was further highlighted that NbS had the potential to provide multiple benefits at macro-level such as climate change adaptation, improved ecosystem services etc. However, there is a priority need for undertaking real scale demonstrations to understand operational problems, difficulties, challenges etc. in implementing such projects. There is a need to have rates for different elements included in NbS. It is necessary to establish quantities in terms of material, manpower involvements, machinery etc. through real scale project implementations in order to get an idea of possible rates that could be worked out. Different companies used to provide rates for different components but a combined rate cannot be calculated using such rates.

- It is necessary to explore possibilities for undertaking NbS for various types of slope stability problems using different available material as conventional engineering practices may not be affordable to general community although they might offer better results. For example, Road Development Authority (RDA) had done a tire retaining wall at Udu Pussalawa area to mitigate unstable road section sometimes ago and it is necessary to try such interventions in future. A good aesthetic view of the mitigated slope can be achieved by introducing plant species. It would be better if economically beneficial plants can be introduced so that there would be avenues for creating income generating options for vulnerable communities.

- There could be many supplementary nature-based solutions to different geo-technical problems. For example, live cuttings of different pant species driven in to sub-surface formations could be an alternative solution for soil nailing. However, the ground situation should be understood to use such solutions in an appropriate way. It is useful to involve universities in this connection as they usually do lot of routine research and such research outcomes and results could be made available to public. NBRO should join hands with universities to undertake such research in future.

- Main idea of NbS is to provide a long-term solution to stabilize slopes with the aid of vegetation and thereby mitigation of risk. However, it is necessary to give a certain period for plant species to grow and develop its root system. Then only they will be capable of supporting any type of stability functions. Therefore, there is a need to implement an intermediate solution such as bamboo crib walls, ToR block walls, vegetated slope gratings, bamboo mats etc. When the effect of the undertaken intermediate solution diminishes gradually, vegetation would take over the function of stability. It is necessary to have a research program to investigate effectiveness of such an approach.

- There is a need to pay more attention to the selection process of suitable plant species to be utilized in NbS. There is a known history of some plants such as Savandara (Vetiver), lemon grass etc. with a good root system. The selected plants should be native (not invasive) and therefore there is a need to add more plants in to the plant manual developed under the project and effort should be

made to find out plants that are suitable for dry and wet climates as it should be possible to use them in all landslide prone areas of the country.

- Selecting appropriate alternative material also should be a part of research. For instance, for ToR blocks it is necessary to use different combinations of soil; cement ratios to see optimum combinations. There might be a possibility of using clay rich material available in termite mounds as villages have a belief that it is better for construction of a stronger wall and have been using it for adobe house construction often. Instead of bamboo, it would be better to select some different other native tree varieties for crib walls, gratings etc. Suitability of species such as "Bata, Milla, Kaduru, Atthana, Kittul, Puwak, Coconut" etc. which could be obtained from the area should be explored. It might be helpful if we can tap in to local wisdom by talking to villages as they might be able to give lots of ideas in this connection. It would also help in building some ownership of the community towards implemented NbS measures.

- When using NbS and low-cost simple technology there might be some failures and therefore better to start experimenting them in low risk areas first. Also, it is useful to leave a maintenance period and also some budget for maintenance and repair by factoring the weather changes in to it.

- It is necessary to educate the media about the purpose of introducing the low-cost simple technology instead of conventional expensive measures and possibility of failures. Otherwise, misleading reports by them would give a negative impact. This could always happen in a project like Neluwa - Lankagama road which runs through Sinharaja Tropical Rain Forest. It would be better to develop confidence in NbS measures, before applying such solutions in a larger area in order to avoid any negative impacts with the safety.

- It is necessary for NBRO to come up with training programs and demonstrations on application of NbS for slope stabilization for the benefit of stakeholders. It would be better to have community level demonstrations on low cost, simple technology slope stabilization measures that could be used in stabilizing vulnerable areas where risk is not very high. NBRO should target practitioners, skill workers like masons, carpenters, community members, NBRO should also develop awareness material even a Manual explaining the process, material that can be used, plant species that can be introduced in different places.

Concluding Remarks

Ms. Priyanka Dissanayake, Disaster Risk Management Specialist from the World Bank thanked NBRO, ADPC and project team for successful completion of the project despite the many challenges, the project had to undergo. She was particularly impressed with the plan that NBRO had presented for undertaking slope stabilization work in Neluwa - Lankagama road which runs through Sinharaja Tropical Rain Forest. It is a good indication that NBRO had taken the application of NbS seriously as a suitable option for mitigating landslide risk in future. The initiative taken by the project team for finding solutions that could be used at community level which also had a possibility of providing economic benefits is a very impressive outcome. She would try to conceptualize such needs that should be considered for future programming, in particular community level initiatives, training and awareness programs etc. and forward a concept note soon for the attention of the World Bank country office.

Dr. Senaka Basnayake, Project Director making his concluding remarks through the online platform Zoom, thanked Mr. Suranga Kahandawa & Ms. Priyanka Dissanayake from the World Bank and Eng. (Dr.) Asiri Karunawardena, Mr. Kishan Sugathapala and others from NBRO, for the opportunity provided to work in a theme that is gaining popularity in many countries in Asia. He said the project team today tried to present the work done under the Nature Based Landslide Risk Management project, which was a continuation of the work started under phase I, nearly two years ago. He stated that the project had achieved substantial outcomes such as the site-specific mitigation plan development for 6 sites, preparation of plant manual, development of a site selection criteria & a plant selection criteria and a guidance document on site-specific landslide risk mitigation planning incorporating NbS. The project team started work with 32 plant species but due to time factor and COVID-19 pandemic situation, could not move further. Landslides areas are located in wet as well as in dry zone of Sri Lanka. Hence, it is essential to build a good database of plants, which can be used in all areas. ADPC hope that NBRO would continue the research and try to add more and more plants into database in the future. The project team did a substantial work to demonstrate various NbS applications through mitigation plan preparation. Now, NBRO could take forward the good work started under the project and could promote NbS for mitigating the risk in other landslide prone areas. The Neluwa - Lankagama road which runs through Sinharaja Tropical Rain Forest project is a good opportunity and NBRO should try to find more opportunities of similar nature. The World Bank and other funding agencies always look for this sort of good opportunities for funding and he believed that NBRO would be able to succeed. Further, he stated that ADPC would extend help to NBRO, whenever needed. Dr. Senaka thanked the project team including NBRO staff involved in the project for successful completion of the project work on time.

Mr. Kishan Sugathapala, Director NBRO, delivering his concluding remarks thanked the World Bank for initiating this kind of project, which is a priority need for the country. NBRO started undertaking mitigation work in the year 2011 at Peradeniya town in Kandy district and made good progress in undertaking several mitigation projects using conventional geo-engineering measures to date. This is a good project initiative, which gave opportunities to try different types of mitigation solutions and it is useful as it could offer solutions for mitigating landslide risk in larger areas as well as at local level. He stated that NBRO scientists made use of training programs initiated under the project as well as actively got involved in mitigation plan preparation. This project provided theoretical knowledge as well as practical experience which could be used in future projects. NBRO is now undertaking several big scale projects in the road sector, reducing the landslide risk in schools and other critical facilities. Hence there is a good possibility of using NbS to increase the effectiveness of conventional engineering mitigation measures. NBRO always looked for opportunities for collaborative work and would come up with a good training program for the benefit of other stakeholder agencies. NBRO had already started some resilient housing demonstrations at the district level and perhaps there are opportunities to apply some of the simple technology introduced by the project team for mitigating slopes in housing projects in particular in resettlement projects. The Neluwa - Lankagama road project is a good opening and NBRO is very much thankful to Road Development Authority for providing this opportunity for designing mitigation solutions for slopes susceptible to landslide hazard along the road.

NBRO would take this as a pilot demonstration project, where they would be able to apply NbS as a real full-scale project. From the mitigation solutions suggested for stabilizing slopes susceptible to landslide hazard at Lankagama road, around 80% consist of nature-based solutions. Only for high risk areas, some conventional solutions have been proposed. NBRO plans to provide technical guidance and follow up monitoring assistance to RDA during construction. NBRO has understood the potential in application of NbS and would closely work with other stakeholder agencies to promote this as a concept. However

as one agency could not do everything, it would be better to have a collaborative approach. As suggested, NBRO would try to undertake awareness programs on NbS and perhaps would start w a program for the organizations, which would be involved in the Neluwa - Lankagama road project such as Sri Lanka Army, RDA, community members, media etc. He thanked ADPC for technical assistance in implementing the project and project team members, consultants, NBRO staff involved in the project for their invaluable contributions, which was a major factor for the successful completion of the project.

CHAPTER 6: Reflections in Evaluating Success and Recommendations for Way Forward

The project was initiated at a time when landslide risk mitigation professionals in the country had largely relied on conventional engineering solutions for mitigating the landslide risk and the application of nature-based and hybrid approaches for landslide risk management was not a common practice. The NbS was not popular among the relevant professionals in Sri Lanka due to the lack of confidence in application NbS as a reliable solution. The aim of the project, primarily was to create more awareness on the nature-based solutions that could be used in mitigating the landslide risk in the country and deepening the technical knowledge on the possibility of application of NbS as an economical, reliable, cost effective and eco-friendly hazard risk management approach, which also could offer number of other multiple benefits. At the completion of nearly two years of project work, it is essential to look back, evaluate the success and see what can be recommended for future as the way forward.

6.1 Reflections in evaluating success

- This is a good initiative that can offer benefits at macro level as well as at local level.

- Project has shown the potential for initiatives to promote conservation practices at upper watershed areas, which can contribute positively in reducing the growth of hazard risk. At macro level NbS could bring together Landslide Risk Mitigation and Climate Change Adaptation. In the same way, it is worthwhile to note the usefulness in nature-based practices in ecosystem resilience building sustaining environment and conservation of forest land. The country should be able to take necessary steps to halt deforestation in future and to replace the unproductive land uses found in slopes in upper catchment areas with the nature-based practices such as forest and suitable non-forest cultivations.

- At the local level, project has demonstrated the capacity of NbS in solving site-specific landslide risk management problems, improving the location specific slope stability problems, when and where it is appropriate. In addition, there is a good potential in considering the application of NbS, when other measures in particular the geo-engineering measures may not be so feasible and cost-effective.

- Essentially the project fulfilled a priority need by developing an appropriate process to move from hazard analysis to landslide risk mitigation, and proposing utilization of NbS as one of the cost-effective measures to mitigate landslide risk. The success of meeting the challenges in this process depends on the possibility of developing user-tailored process covering steps such as exposure database development, selection of sites where NbS can be applied as a feasible and cost-effective measure, selection of appropriate plants, design of NbS incorporated mitigation plans, implementation of site-specific plans and post implementation maintenance plans. The project has made positive contributions in this regard.

- When NbS is applied for stabilization of slopes susceptible to landslide hazard in major highways and in urban and semi-urban areas as a hybrid solution, such solutions provide improvements to the performance of conventional engineering measures and in increasing the effectiveness of same. The project has highlighted the contributions of NbS in enhancement of aesthetic appearance of

the areas stabilized through conventional engineering practices in addition to contributions in stability improvement.

- Project has emphasized the possibility of applying NbS to offer long term solution for reduction of shallow slope instabilities and in rehabilitation of landslide affected areas or abandoned land due to resettlement of highly vulnerable families. This is especially important as government has plans to resettle around 15,000 families in the next few years and simultaneously government should have plans for rehabilitation of land susceptible to landslide hazard to improve the safety and the productivity.

- Disaster risk management should be everybody's business and government should have plans to make it a reality. For that government should develop a better risk governance framework and ways to attract assistance from non-government sources. It is useful in initiating clear policy directives, procedures and appropriate practices towards creating an enabling environment for building resilient communities. Such a framework should provide guidance for early identification and initiation of risk treatment options in advance. But often such interventions are smeared by challenges associated with complexity, uncertainty and ambiguity. Risk mitigation and preparedness practices should be made an integral part of the development process rather than shouldering the responsibility for managing risk along. The government should share the responsibility in this connection with other likeminded non-government agencies, local governments, community members and private sector.

- Policy Roundtable discussion was initiated by the project to improve the dialogue between NBRO and those Agencies, who have a direct role in promoting NbS. The roundtable participants made a request for NBRO to take the lead role in initiating multi-partner programs, collaborations in research, capacity building and awareness creation. This discussion can be used as a vehicle for future dialogue by converting the roundtable in to a structured forum to have a process to promote NbS with the purpose of achieving multiple benefits at macro level such as reduction of impact of climate change, increase ecosystem services, and promote conservation practices, in addition to landslide risk management.

- Project has emphasized the importance for ensuring active and field level community centered approaches for addressing location specific slope stabilization problems through NbS. It can be an acceptable solution to communities at risk, when implemented utilizing affordable and not so complex technologies.

- It is better to disseminate widely the economic benefits offered by some plant species used in NbS to create new sources of income for vulnerable local communities, there by uplifting their socioeconomic conditions. For instance, some plant species have a high demand (as raw material/ semi-processed products/ extracts) in the Ayurveda system of medicine, in some industries, in handicraft etc.

- Access to funding is frequently identified as a common barrier to create commitment towards application of NbS in landslide and other disaster risk management. To improve the accessibility of funding, it is better to map existing financial instruments & approaches and look for possibilities for converting the NbS in to investment models to attract private sector in order to develop blended finance and public-private partnerships, philanthropy etc.

- Project has highlighted the possibilities of converting NbS in to investment models to attract private sector working with perfume & pharmaceutical industries, production of nutraceuticals, food & beverages, cosmetics, perfume & toiletries, handicraft industry etc.

6.2 Recommendations for Way Forward

- It is necessary to have on-site demonstrations of nature-based/hybrid solutions through piloting some of the mitigation planning designs in future to identify practical issues, challenges and to monitor the effectiveness with the passage of time. There can be other opportunities for undertaking real field scale projects where NbS can be integrated and such possibilities should be considered by NBRO in future.

- There is a need to conduct post-implementation monitoring programs in demonstration pilot sites for collecting information on the behavior of slopes after incorporating NbS to validate model results. This research should be done through instrumentation capable of obtaining information related to post-implementation behavior of slopes.

- Continue research on different plant species through field and laboratory investigations in order to update the plant manual with more additions. The database should be comprised of plant species suitable for different climate conditions as well as appropriate for utilization in different contextual setting in terms of social, economic (which provide value additions commercially), botanical (native to specific localities and not to promote invasive species) and bio-engineering (with appropriate root architecture, mechanical and hydrological characteristics) nature.

- More research on low cost, simple, affordable slope stabilization techniques incorporating NbS that can be executed using local material. Create community awareness on the methods of construction of such slope protection measures utilizing simple technology with freely available material and integrating NbS. It could be fulfilled by initiating community level demonstration projects to create acceptance of NbS as a risk mitigation option, which will have indirect economic benefits while contributing in building resilience. It is essential to harness local wisdom in execution of such solutions as local community has better understanding of plant species, material, native inventions, indigenous technology etc. that can be applied in executing such interventions.

- Look for possibilities for converting the NbS in to investment models to attract private sector, dealing with tourism, pharmaceutical industries, production of nutraceuticals, food & beverages, cosmetics, perfume industries & toiletries, making handicrafts etc.

- NBRO should provide leadership to develop a long-term program to promote NbS, through collaboration with other government institutions, who have interest in application of NbS. This is to facilitate sharing of information widely and continuation of collaborative research, training and conducting awareness programs together using the expertise available with other institutions.

- Joint research with universities and other interested non-academic institutions to have more innovative solutions for reducing landslide risk that can be practiced at community level, or in low risk areas. Purpose should be to introduce innovative approaches for landslide risk mitigation.

- Continue risk communication workshops at district level and at the institution level with members of the district level risk communication framework, initiated under the project. It is essential to support them with necessary technical assistance, knowledge, know-how etc. and to provide landslide related risk information available with NBRO.

- Create more awareness material to promote NbS as an effective landslide risk management option. It would be better to translate the "Guidance Document on Use of Nature-based Solutions for Site Specific Landslide Risk Mitigation" into local languages, and distribute it widely to create more awareness on the subject.

Annexures

Annex 1: Task A Report 1: Report on Site-specific landslide susceptibility

Annex 2: Task A Report 2: Assessment of exposure and vulnerability of elements at risk within the impact zone of candidate sites within 04 target districts

Annex 3: Task A Report 3: Assessment of Future Climate Scenarios within 04 Target Districts

Annex 4: Task A Report 4: Assessment of Candidate Sites for application of Nature-based Solutions

Annex 5: Task B Report: Site-specific Landslide Risk Mitigation Plans incorporating NbS

Annex 6: Guidance Document on Use of Nature-based Solutions for Site-specific Landslide Risk Mitigation

Annex 7: Task C Report: Stakeholder Consultation, Knowledge Sharing and Capacity Strengthening

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