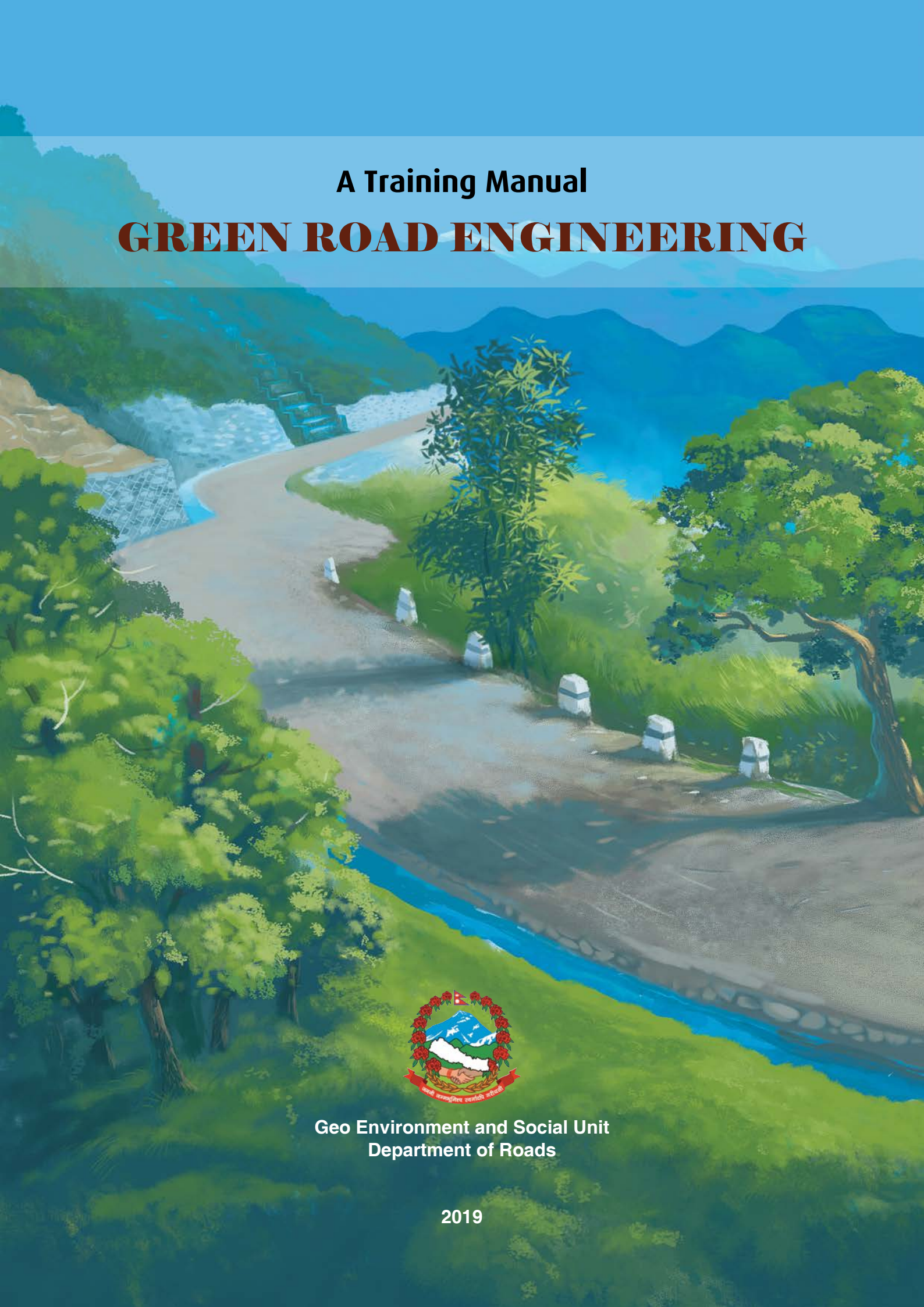
A Training Manual

GREEN ROAD ENGINEERING



Geo Environment and Social Unit
Department of Roads

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Several notorious landslides have been reported due to haphazard road construction, especially in hilly areas due to increased trend of sub-standard village road construction. With priority of local government to expand hilly roads for better accessibility to markets, healthcare and educational opportunities; demand driven non-engineered roads are on the rise. Such sub-standard roads often create landslides by undercutting slopes thereby increasing divergent infiltration that results in debris fall during heavy rainfall.

With massive investment in capital expenditure, infrastructure development, mainly roads, are on the rise at local levels. Technicians and elected representatives working at the local levels need to have the knowledge on the need for Green Road construction approaches for sustainable use of Natural Resources with no or very little impact on the natural ecosystem.

This training manual will be supportive for forthcoming trainings on Green Road Construction approaches to intensify the engineering knowledge embedded with technicians (Engineers) and local representatives who are engaged in planning, construction and monitoring of local roads.

Department of Roads has collaborated with WWF Nepal and USAID's Hariyo Ban Program to mainstream environmental aspects on various projects that are being planned and are under construction across Nepal. We appreciate this opportunity to collaborate and believe that this Manual will be useful to improve the quality of local roads.

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Table of Contents

Acronyms and Abbreviations

ADB	Asian Development Bank
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DoR	Department of Roads
IUCN	International Union for Conservation of Nature
CP	Compensatory Plantation
EIA	Environmental Impact Assessment
EMAP	Environmental Management Action Plan
EPA	Environment Protection Act
EPR	Environment Protection Rule
ESF	Environmental and Social Framework
ESMF	Environmental and Social Management Framework
GESU	Geo Environment and Social Unit
GRE	Green Road Engineering
IEE	Initial Environmental Examination
JICA	The Japan International Cooperation Agency
MoFE	Ministry of Forest and Environment
MoPIT	Ministry of Physical Infrastructure and Transport
NEPAP	Nepal Environmental Policy and Action Plan
NPWC	National Parks and Wildlife Conservation Act
Ppt	Power Point Presentations
RAP	Resettlement Action Plan
SD	Scoping Document
SDGS	Sustainable Development Goals
SWCA	Soil and Watershed Conservation Act
TOR	Terms of References
WB	World Bank
WWF	World Wide Fund for Nature

Preface

To improve connectivity and generate growth opportunities, development of road network is a high priority of Government of Nepal. With federal restructuring; local and provincial governments have also set high precedence on the development of road network within their jurisdiction. With road network being top priority at all levels, the quality and standards of construction are sometimes over looked which in turn has intensified environment issues. Unplanned roads contribute to un-stabilized earth surface which results in debris flow and landslides. Roads development along side river valleys create increment in river sediment impacting on hydro projects and is also a hinderance to wildlife movement. Roads often enhance water infiltration issues down stream and also induces flash floods.

Geo Environment and Social Unit (GESU), Department of Roads have been focusing on the need of green strategies to improve the construction standards of rural roads through its various publications. While efforts are constantly made from various forums like capacity building trainings, through publications, etc.; reaching out to all local level implementors of rural roads remains a challenge.

This publication of "Green Road Engineering Training Manual" is an effort to help continue train local level technicians who are direct implementors of rural road projects and at the same-time, capacitating non-technical participants who are in charge of monitoring rural roads at local levels.

Training Intentions and Target Recipients

This training on "Green Road Engineering" delivers the science behind stabilizing rural roads and intends to improve the current sub-standard roads construction practices seen at local levels. Its primary target participant are from technical and non-technical background at local level government agencies.

The minimum criteria to be incorporated as a technical participant is that he/she should have basic background information and knowledge on Civil Engineering applications. While non-technical participant should have information and capacity to understand and the requirements of a proper functional rural roads.

The Technical and Non-technical participants involvement in learning about this manual is as follows:

Technical participants: Technicians involved in planning, designing and executing roads at local levels. They will be engaged from Day 1 to Day 5.

Non-Technical participants: Elected Representatives, Administrative staffs who are involved in monitoring of rural roads. Day 5 is mainly dedicated for these participants.

Before the Training

1. Learning Needs

Basic information of prior knowledge about road engineering, bio-engineering, environmental aspects of roads, Environmental Impact Assessment (EIA), Initial Environmental Examination (IEE), Green Road Engineering (GRE) approaches are expected from participants. The specific needs and challenges of the participant at working areas also needs to be assessed and this will be done through learning need questionnaires (Annex 1).

2. Curriculum and Learning Activities

Based on the training needs analysis, Curriculum (Schedule) of the training must be prepared (Annex 2) with concrete learning objectives. Based on the curriculum, trainer will select the specific modules for the training and prepare the audio-video presentation, power point presentation, poster presentation accordingly.

3. Training Materials

3.1 Inhouse Training Materials	3.2 Training Materials for Field
▪ Power Point Presentations (Ppt)	▪ Checklists
▪ Meta Cards	▪ Pencils and Markers
▪ Flip Charts	▪ Ball Pen & Notebook
▪ Pencils and Markers	▪ Digital Camera
▪ Notebook	▪ Global Positioning System (GPS)
▪ Color Photographs of Case Studies	▪ Geological Hammer
▪ Case Study Reports	
▪ Related Reports (if Available)	

DAY I

During the Training

Session One: Opening and Welcome

Time: 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Welcome the participants and officially open the training	▪ The training facilitator will call chief guest and guests in the dash and introduce the chairmanship.	▪ Objectives of the Training
▪ Introduce the objectives and methodologies of the training	▪ A Brief introduction of participants	▪ Value of Green Road Engineering
▪ Explain the objectives of Green Road Engineering	▪ Welcome Remarks by organizer	▪ Environmental Aspects and Importance
	▪ Power point presentation about objectives of the training	▪ Legal Requirements and Interventions
	▪ Remarks by guests & Chief Guest	
	▪ Closing of Opening Session by Chairman	

Session Two: An Overview of Bioengineering

Time: 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Concept of Bioengineering	▪ Brainstorming and Open Forum	▪ Engineering Functions of Vegetations (Catch, Support, Armour, Reinforced, Anchor, Drain)
▪ Advantages, Limitations and Cost effectiveness of Bioengineering	▪ Discussion on Bioengineering (10 Minutes)	▪ Mechanical and Hydrological Functions
▪ Use of local available materials & local human resources	▪ PowerPoint Presentation *(Ppt-I)* on Overview of Bioengineering (40 Minutes)	▪ Relative Strength, Handover Principle & Cost Effectiveness of Bioengineering
▪ Ecofriendly approach to road construction	▪ Queries and Solutions (10 Minutes)	▪ Selection of Suitable Plant Species
▪ Effectiveness of Bioengineering (Case studies: pictures before and after implementation)	▪ Rapporteur	

Green Road Engineering:

Green Road Engineering is basically a concept of implementing green approaches to stabilize slopes which promotes better functionality of roads by preventing debris flow, proper management of sub-surface water and eventually decreasing sedimentation load on rivers. The use of simple technology, local resources, participatory approach from planning to implementation stage and environmental consideration are relevant to Green Road Engineering concept.

The roads that are planned or build now should be functional for a sustained time frame at all weather conditions with basic repair and maintenance. This concept of Green Road Engineering introduces basic concepts to stabilize rural roads to make them functional for a considerable time span. Basically, the concept of Geology, Bioengineering, engineering functions, water crossing structures are mainly covered by this concept.

Ppt-I: Overview of Bioengineering

What is Bio-Engineering

- Bio-engineering is "the use of living plants for engineering purposes" for stabilization of slopes
- Bio-engineering offers the engineer a new set of tools but does not normally replace the use of civil engineering structures;
- Bio- Engineering system work by fulfilling the Engineering functions required for the protection and stabilization of slopes

Engineering Functions of Vegetations

Catch Function	Eroding Material falls down the slope as result of gravity alone or with the aid of water. The stem of vegetation performs this function
Requirement	Strong numerous and flexible stems, ability to recover from damage
Examples in Nepal	Micro scale: Clumping grasses in contour grass lines. Larger scales shrubs with many stems; large bamboos
Civil Engineering Equivalent	Catch walls
Combination of Both	Catch wall with bamboos above

Armour Function	Armour the slope against surface erosion from both runoff and rain splash, to be effective, this requires a continuous cover of low vegetation
Requirement	Dense surface cover of vegetation, Low canopy small leaves
Examples in Nepal	Grass lines or a complete grass carpet of clumping or spreading grasses
Civil Engineering Equivalent	Revetment
Combination of Both	Vegetation-stone pitching

Reinforce Function	Reinforce soil by providing a network of roots that increases soil's resistance to shear. The degree of effective reinforcement depends on the form of roots and the nature of soil.
Requirement	Plants with extensive roots with many bifurcations. Many strong fibrous roots
Examples in Nepal	Densely rooting clumping grasses planted in lines; some shrubs and trees.
Civil Engineering Equivalent	Reinforced earth
Combination of Both	Jute netting with planted grass

Anchor Function	Anchor the surface material by extending roots through potential failure planes into firmer strata below, if the potential failure is deeper than 0.5 m this is achieved only by large woody plants with big vertical roots (tap roots)
Requirement	Plants with deep roots. strong long vertical oriented roots
Examples in Nepal	Deeply rooted shrubs and trees
Civil Engineering Equivalent	Soil anchor
Combination of Both	Combination of anchors and trees

Support Function	Support soil mass by buttressing and anchoring. Large heavy vegetation, such as tree at the base of slope or micro scale grass clumps of grass can buttress small amounts of soil above them
Requirement	extensive, deep and wide spreading root system, many strong fibrous roots.
Examples in Nepal	Large Clumping bamboos, most trees
Civil Engineering Equivalent	Retaining walls
Combination of Both	Retaining walls with bamboo crib walls

Drain Function	Drain excess water from slope. The planting configuration of vegetation can enhance drainage, avoiding saturation and slumping of materials. Vegetation can also help to reduce pore water pressure within the slope by extracting water from roots
Requirement	Plants small enough to be planted in closely -packed lines. Ability to resist scour. Highleaf area to enhance transpiration
Examples in Nepal	Down slope and diagonal vegetation lines, particularly those using clumping grasses. Most shrubs and trees
Civil Engineering Equivalent	Surface, subsurface drain
Combination of Both	French drain and angled grass lines

Mechanical Functions of Vegetations

Mechanical Mechanisms	Effects
1. Stems and trunks trap materials that are moving down the slope (catch)	Good
2. Roots bind soil particles to the surface and reduce their erodibility (armour)	Good
3. Roots penetrating through the soil cause it to resist deformation (reinforce)	Good
4. Woody roots may open the rock joints due to thickening as they grow (wedge)	Bad
5. The root cylinder of trees supports the slope above by buttressing and arching	Good
6. Tap root or other vertical roots penetrate the firmer stratum below and pin down the overlying materials (anchor)	Good
7. Vegetation exposed to wind transmits dynamic forces into the slope (disturb)	Bad

Hydrological Effects of Vegetation

Hydrological Mechanisms	Effects
1. Leaves intercepts raindrops before they hit the ground (armour)	Good
2. Water evaporates from leaf surfaces	Good
3. Water is stored in the canopy and stems	Good
4. Large or localized water droplets fall from leaves	Bad
5. Surface run-off is checked by stems and grass leaves (armour)	Good
6. Stems and roots increase the roughness of ground surface and the permeability of the soil (armour)	Good/Bad
7. Roots extract moisture from soil which is then released to atmosphere through transpiration	Good

Session Three: **Slope Stability and Water Management** **Time:** 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Concept of Slope Stability and Water Management	▪ Brainstorming and Open Forum Discussion on Bioengineering (10 Minutes)	▪ Factors Influencing Slope Stability, Techniques of Slope Stability
▪ Civil Engineering Works for Water Management	▪ PowerPoint Presentation *(Ppt-II)* on Overview of Slope Stability and Water Management (40 Minutes)	▪ Ground Condition, Cut Slope and Treatment
▪ Construction of Bolsters, Sub-Soil Drains, Coir or Jute Netting, Drop Structures	▪ Queries and Solutions (10 Minutes)	▪ Failures and Weathering
▪ Understanding Hydrological Analysis and Flood Trace on Rivers and Fields	▪ Rapporteur by Facilitator	▪ Purpose of Water Management and Water Management Issues & Problems
▪ Effective Slope Stability and Water Management (Case studies: pictures before and after implementation)		▪ Types of Water Management Techniques: Surface and Subsurface Drains

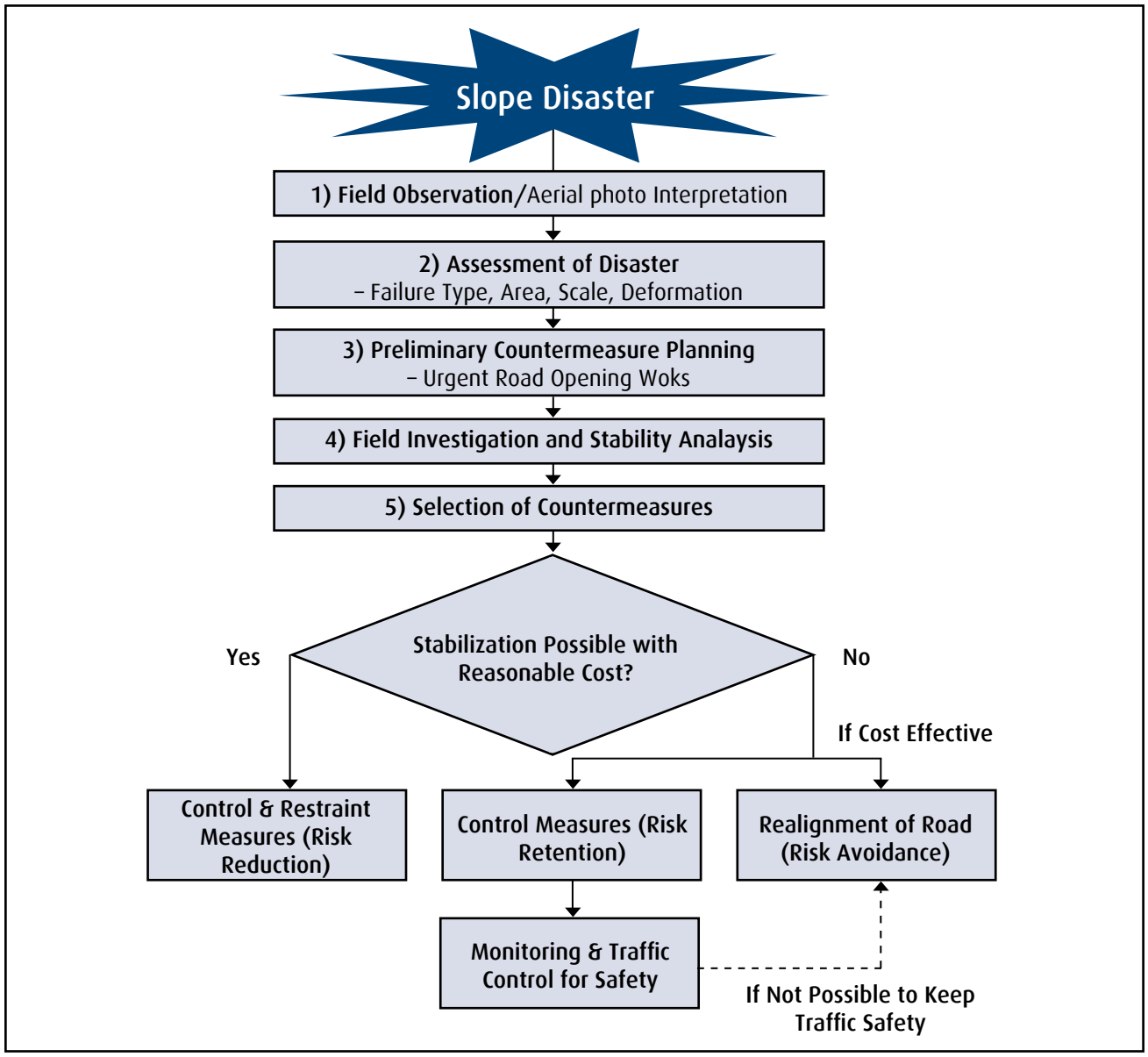
Session Four: Environmental Safeguard Policies **Time:** 60 Minutes

Learning Objectives	Methods	Resources
▪ Concept of Environmental Safeguard	▪ Brainstorming and Open Forum Discussion on Bioengineering (10 Minutes)	▪ Nepal Environmental Policy and Action Plan, NEPAP, Environment Protection Act, EPA, Environment Protection Rule, EPR, Forest Act/ Rule, Forest Sector Policy, National Parks and Wildlife Conservation Act/Rules, Soil and Watershed Conservation Act/Rules, CITES Act, राष्ट्रिय प्राथमिकताप्राप्त योजनाको लागि राष्ट्रिय वनक्षेत्र प्रयोग गर्ने सम्बन्धी कार्यविधी, Environmental and Social Management Framework (ESMF)
▪ National Environmental Safeguards Laws	▪ PowerPoint Presentation*(Ppt-III)* on Environmental Safeguard Policies (40 Minutes)	▪ Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), The International Union for Conservation of Nature (IUCN) Red List, Ramsar Convention (The Convention on Wetlands of International Importance),Convention Concerning the Protection of the World Cultural and Natural Heritage, Convention on Biological Diversity (CBD)
▪ International Environmental Conventions and Protocols	▪ Queries and Solutions (10 Minutes)	▪ Asian Development Bank Environment Safeguard Policy, World Bank Environmental and Social Framework (ESF), The Japan International Cooperation Agency (JICA) Environmental Policy
▪ National Environmental Safeguard practices	▪ Rapporteur	
▪ International Environmental Safeguard Practices		
▪ Adoption of National and International Commitments in National Scenario (Case studies)		

Ppt-II: Slope Stability and Water Management

Factors Influencing Slope Stability

- Lithology: Soil and rock types
- Slope Inclination
- Degree of Factorization in rock mass
- Weathering
- Ground Water
- Surface Water
- Earthquake
- Human induced disasters

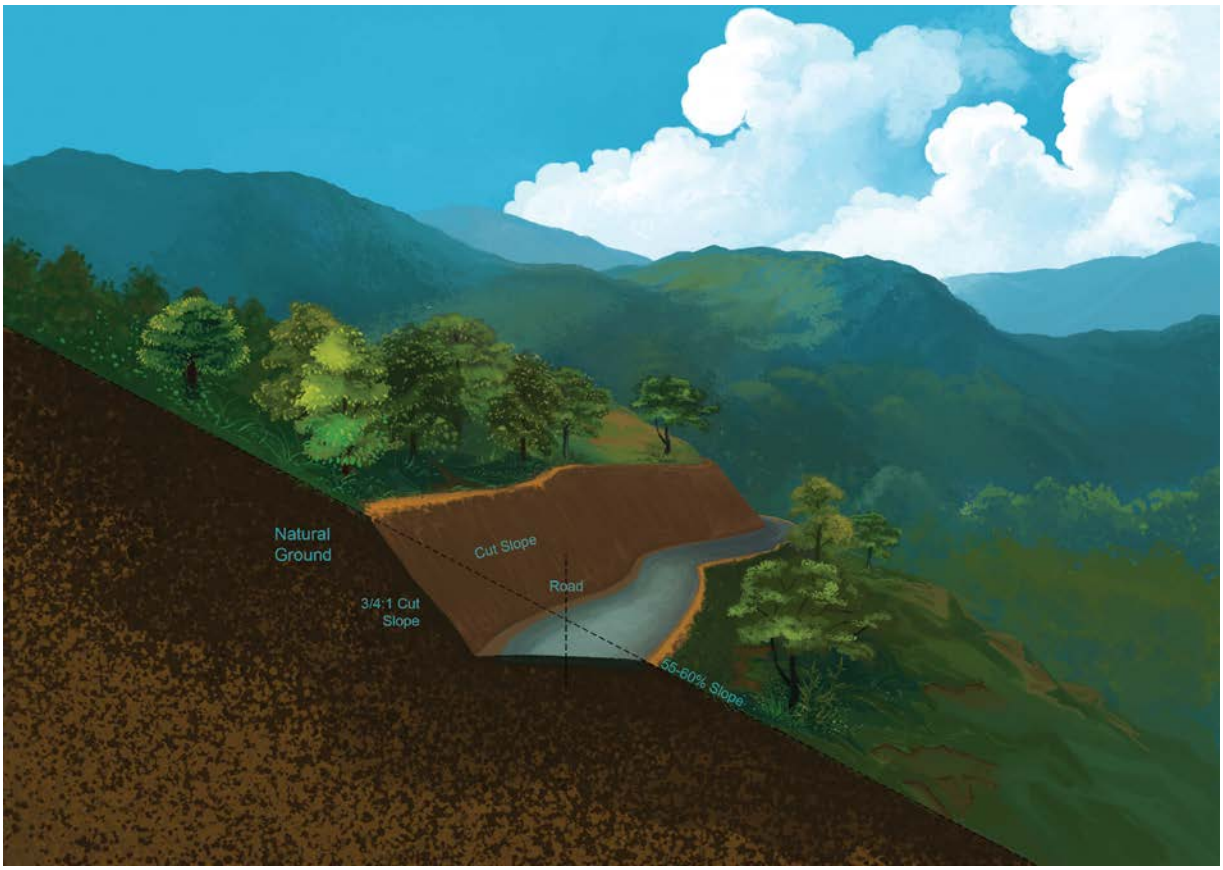


Source: Guide to Road slope Protection work.

Option for road slope stabilization	Water management
▪ Earthwork	▪ Safe management of water flow to fulfill the objective.
▪ Bio engineering	▪ Water management is the single and most important factor in the design / Maintenance of infrastructure in hilly/mountainous areas.
▪ Slope work	▪ Infrastructure, such as roads, involve design of surface drain, sub-surface drain, drainage crossing, and erosion control measures.
▪ Water Management	▪ More than 80 % of total rainfall occurs in rainy season
▪ Anchor work	▪ Exists high to low altitude in moderate length and have high gradient
▪ Wall and Resisting Work	▪ Young and fragile geology
▪ Pile work	▪ High yearly sediment yields Water is a principal enemy of roads
▪ Alternative works	▪ Needs careful assessment
	▪ Difficult and challenges for urban roads

Cut slope construction option

A. Balanced cut and fill



B. Full Bench construction

C. Small cut and Retaining wall

Note: Alternatives B and C require an off- site disposal area for the excavated material. Some excavated granular material may be placed into the mechanically stabilized Earth retaining wall in alternative C.

Ppt-III: Environmental Safeguard Policies

- National Laws: Nepal Environmental Policy and Action Plan, NEPAP, Environment Protection Act, EPA, Environment Protection Rule, EPR, Forest Act/Rule, Forest Sector Policy, National Parks and Wildlife Conservation Act/Rules, Soil and Watershed Conservation Act/Rules, CITES Act, राष्ट्रिय प्राथमिकताप्राप्त योजनाको लागि राष्ट्रिय वनक्षेत्र प्रयोग गर्ने सम्बन्धी कार्यबिधी, Environmental and Social Management Framework (ESMF)
- International Environmental Laws: Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), The International Union for Conservation of Nature (IUCN) Red List, Ramsar Convention (The Convention on Wetlands of International Importance), Convention Concerning the Protection of the World Cultural and Natural Heritage, Convention on Biological Diversity (CBD)
- Donor's Environmental Laws: Asian Development Bank Environment Safeguard Policy, World Bank Environmental and Social Framework (ESF), The Japan International Cooperation Agency (JICA) Environmental Policy

Slope Stability and Water Management at Krishna Bhir (Prithivi Highway)

Earthen Side Drain for Water Management

Cascade at Krishna Bhir (Prithivi Highway)

Session Five: Water Movement and Related Hazard; River/Stream Bank Management in Watershed **Time:** 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Concept of Water Movement and Related Hazard; River Training Works	▪ Brainstorming and Open Forum Discussion on Bioengineering (10 Minutes)	▪ Water Management Illustration, Issues, Problems and Purposes
▪ Methods of River Training Works: Channel Improvement, Retards, Revetments, Retaining structures, River Bank Protection	▪ PowerPoint Presentation *(Ppt-IV)* on Water Movement and Related Hazard; River/Stream Bank Management in Watershed (40 Minutes)	▪ Types of drainage structures
▪ Case Studies of River Bank Management	▪ Queries and Solutions (10 Minutes)	▪ Cross drainage structures
	▪ Rapporteur	▪ Surface and sub surface drains
		▪ Erosion Protection Works, Debris Removal Works, Repair of Culverts and Drains
		▪ Design examples

Session Six: Causes and Mechanisms of Slope Failures **Time:** 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Concept of Slope Failure Mechanism	▪ Brainstorming and Open Forum Discussion on Bioengineering (10 Minutes)	▪ Causes and Types of Slope Failure
▪ Classification of Landslides	▪ PowerPoint Presentation on *(Ppt-V)* Causes and Mechanisms of Slope Failures (40 Minutes)	▪ Failure Mechanism
▪ Slope Stability Analysis	▪ Queries and Solutions (10 Minutes)	▪ Components of Unstable Slopes
▪ Typical causes of Landslides: Effective Stress & Pore pressure, shear strength	▪ Rapporteur	▪ Factors Influencing Slope Stability
▪ Properties of Ground Water		▪ Slope Stability Planning and Measures
▪ Shape of Potential Failure Masses		
▪ Case Studies of Slope Failure		

Ppt-IV: Water Movement and Related Hazard; River/Stream Bank Management in Watershed

Water Management

- Safe management of water flow to fulfill the objective.
- Water management is single and the most important factor in design / Maintenance of infrastructures in mountainous areas.
- Infrastructures, such as roads, involve design of surface drain, sub-surface drain, drainage crossing, and erosion control measures.
- More than 80 % of total rainfall occurs in rainy season
- Exists high to low altitude in moderate length and have high gradient
- Young and fragile geology
- High yearly sediment yields Water is a principal enemy of roads
- Needs careful assessment
- Difficult and challenges for urban roads

Purpose of Water Management

- To protect the slopes from erosion
- To protect shallow depth instabilities due to surface water
- To reduce pore pressure
- Drain off water
  - Safely and
  - As quick as possible

Types of Drainage Structures

- Based on function Road related Drainage structure are classified as
  - Surface drain
    - Surface drain
    - Catch drain
    - Cross Drain
    - Slab Culvert
    - Box culvert
    - Arch Culvert
    - Pipe Culvert
  - Sub surface drainage
  - French drain

Types of Surface Drain

1. Surface drain
2. Sub surface drain
3. Lined drain
4. Unlined drain
5. Roadside drain
6. Off road drain
7. Open drain
8. Covered drain

Based on geometry

1. V shaped drain
2. Trapezoidal drain
3. Flat bed drain
4. Saucer or Tick drain
5. Buried drain
6. Masonrydrain
7. Precast concrete drain

Culverts

- A culvert helps move water under a road or driveway to a stream, lake, or detention basin
- Culverts can be classified (such as any span under 6 m), based on shape, material used and flow pattern.

Water Management Related Problems

Side drain

- Side drains are sized by ad hoc selection of standard drawings and without hydraulics calculation
- Under capacity side drains result in the weakening of pavement layers, / erosion of berms and side slopes
- Unlined side drain/ frequent blockage causes scour
- Long side drains (in excess of 100m) in high rainfall areas may interruption to flow by debris and landslide materials
- Lack of protection below the outlet of the side drains at the switchbacks enhance gullying and massive failures
- Side drains alone are not enough in case of the sub-surface water table is above the road
- Landslides
- Absence of subsurface may be cause of landslide
- surface / sub surface drain is suitable to stabilize slope.

Drain Repair

- Is there crack at invert and side of drain?
- Is mortar/ tipkar of invert and side is in exact position or any loose stone?
- Is there boulder packing works has done during routine maintenance?
- Condition of side drain cover is ok or any missing?
- Is there any settlement of precast concrete drain?
- Is the cross section of earthen drain intact or any problem of scour occurs?
- Either road neighbor has fill up drain/ use for irrigation purpose and create any problem or not?
- Is there too much damage which cannot be covered in scope of recurrent maintenance or not?

Culvert Repair

- Are there additional cracks after last inspection?
- Is there Rusting on steel pipes and culvert pipes?
- Is there any temporary repair at invert and side of culvert?
- Is there any settlement of culvert and scour at inlet/ outlet?
- Condition of scupper which has been constructed to drain water?
- Condition of headwall and catch pit?
- Is there exposed reinforcement on damage concrete cover?
- Is there any obstacle to culvert by the road neighbors?
- List of damage which is beyond the scope of recurrent maintenance?

Steps for Drain Design

The most widely used equation for uniform flow is Manning Equation:

$$Q=VxA=\frac{1}{n}R^{\frac{2}{3}}\sqrt{S}\ x\ A$$

Where,

- V - Velocity, m/sec,
- n - Manning's Roughness coefficient
- R - hydraulic radius, m, (A/P)
- A - Wetted cross-sectional area of flow, in m^2
- S - Slope of the channel m/m

Manning Coefficient for Open Channels

Bed Type	n
Earthen, clean, recently completed	0.016 - 0.018
Earthen with short grass and weeds	0.022 - 0.027
Gravel soil, clean, uniform	0.022 - 0.025
Earthen fairly uniform sides, clean cobble bottom	0.030 - 0.040
Concrete formed no finish	0.013 - 0.017
Concretebottom, dressed stone sides	0.015 –0.017
Cement rubble masonry	0.030 - 0.025
Brick	0.014 - 0.017
Mountain stream, no vegetation in channel, steep banks, trees and brush along bank submerged at high stage	
Bottom of gravel, cobbles, few boulders	0.04-0.05
Bottom of cobbles, with large boulders	0.05-0.07

Safe Velocity of Flow

Typical safe velocities for different materials

Bed Material	Safe velocity (m/s)
Loose clay or line sand	up to 0.5
Coarse sand	0.5- 1.0
Fine sandy or stiff clay	1.0- 1.5
Coarse gravel, rocky soil	1.5 -2.5
Boulders, rock	2.5 - 5.0

Example of Design

Given

- Design a section of trapezoidal side drain assuming following parameters?
- Average runoff coefficient = 0.371
- Rainfall intensity 125mm/ hr
- Length of side drain = 250m
- Average width of land drained to side drain = 300m
- Gradient of road in considered section = 5 %
- Manning's roughness coefficient = 0.02
- Bottom width of side drain = 0.3m side slope of side drain 1 vertical: 1.5 horizontal

Design Suitable Drain??

Solution

Drainage area (A_d) = 300 X 250 = 75000 m^2

Rain fall intensity (i) = 125/3600 = 0.0347 mm/sec

run off Q = C I A_d

= 0.371 X 0.0347 X 75000/1000 =0.9655m^3 /sec

Q = A. V

$0.9655 = (d + 1.5 d^2) (1/0.02) \{(d+1.5d^2)/ 3.6 d\}^{0.6667} (0.05)^{0.5}$

solving d= 0.34 m11:2711:27

Provide 40 cm deep trapezoidal section side drain.

Ppt-V: Causes and Mechanisms of Slope Failures

Causes of Slope Failure

- Weathering
- High monsoon precipitation (surface and ground water)
- Rapid melting snow or ice
- Strong earthquakes
- Deforestation and overgrazing
- Poor construction technique and lack of maintenance of irrigation canals
- Inappropriate land use pattern

Failure Mechanism

- Erosion
  - Sheet erosion
  - Reel and gully erosion
  - Piping
- Slide, within soil or along soil rock interface
  - Any mass movement of soil or debris down slope
  - May be translational rotational or flow
  - A very common mechanism in Nepal
- Plane failure in rock
  - Plane failure
  - Wedge failure
  - Toppling
- Disintegration
  - Tensile failure of soft rock or consolidated soil
- Differential weathering
  - A very common mechanism in Nepal

Factors Influencing Slope Stability

1. Lithology: Soil and rock types
2. Slope Inclination
3. Degree of Fracturization in rock mass
4. Weathering
5. Ground Water
6. Surface Water
7. Earthquake
8. Human Factors

Causes and Mechanism of Failure

Type of Material	Cause of Failure	Mechanism of Failure
Debris	Surface water/ Ground water	Erosion /Shear failure
Soft Rock	Weathering	Plane or shear failure or disintegration
Hard Rock	Weathering	Plane Failure
Alternative Hard Rock and Soft Rock	Weathering	Differential weathering plus plane failure

Water Related Problems in Highways of Nepal

Debris flow in Dharan-Dhankuta Road, 1989

Erosion in Bhalubang-Kohalpur Sector, 1993

DAY II

Session One: Design Aspects of Small-Scale Civil Engineering & Water Management Structures **Time:** 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Concept of Small-Scale Civil Engineering and Water Management Structures	▪ Brainstorming and Open Forum Discussion on Bioengineering (10 Minutes)	▪ Retaining walls: toe wall, slope wall, breast wall etc., Revetment walls, Prop walls/dentition, Check dams, Stone Pitching, Gabion wire bolsters, Jute netting, Wire netting, Surface drains, Sub-surface drains, Cascades.
▪ Types of Small-Scale Structures adopted in Nepal	▪ PowerPoint Presentation *(Ppt-VI)*on Design Aspects of Small-Scale Civil Engineering & Water Management Structures (40 Minutes)	
▪ Methods and Cost for Constructing Small-Scale Structures	▪ Queries and Solutions (10 Minutes)	
▪ Effectiveness of Small-scale Structures for Water Management and Slope Stability	▪ Rapporteur	

Session Two: Environmental Assessment in Road Sector **Time:** 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Concept of Environmental Assessment	▪ Brainstorming and Open Forum Discussion on Bioengineering (10 Minutes)	▪ Terms of References (ToR), Scoping Document (SD), Deed of Inquiry, Thresholds and Criteria of IEE/EIA,
▪ Legal Process and Current Practices of Environmental Impact Assessment (EIA) and Initial Environmental Examination (IEE) in Nepal	▪ PowerPoint Presentation *(Ppt-VII)*on Environmental Assessment in Road Sector (40 Minutes)	▪ Environmental Components,
▪ Environmental Management Action Plan (EMAP), Environmental Standards, Environmental Audit	▪ Queries and Solutions (10 Minutes)	▪ Compensatory Plantation, Resettlement Action Plan (RAP), Land Use and Land Acquisition, Ancillary Facilities,
▪ Case Studies of EIA, IEE, EMAP & Environmental Audit	▪ Rapporteur	▪ Management and Monitoring Plan, Environmental Audit

Gabion Wall

Wire Netting

Masonry Revetment

Jute Netting

Ppt-VI: Design Aspects of Small-Scale Civil Engineering & Water Management Structures

Main Small Civil Engineering Infrastructures Commonly Used in Nepal

- Retaining walls:
  - Toe wall
  - Slope wall
  - Breast wall etc.
- Revetment walls
- Prop walls/dentition
- Check dams
- Gabion wire bolsters
- Jute netting
- Wire netting
- Surface drains
- Sub-surface drains
- Cascades

Jute Netting (Unbituminized)

Application	Cheap, sandy soil, harsh slopes, 45 - 60º for standard mesh (40x40)mm 30 - 45º for wide mesh (150x450)mm
Position:	Top and Mid slope
Life span	1 season
Site requirement	Smooth plane slope, Homogeneous materials
Limitations	Not on fine plastic soils or poorly drained soil with high rates of slumping; Not on debris slope; Cannot be used in rilling soil;

Jute Netting (Bituminized)

Application:	Cheap, sandy soil, harsh slopes, 45 - 60º for standard mesh (40x40)mm 30 - 45º for wide mesh (150x450)mm
Position:	Top and Mid slope
Life span	5+ years
Site requirement	Smooth plane slope,Homogeneous materials
Limitation	Not on fine plastic soils or poorly drained soil with high rates of slumping; Not on debris slope; Cannot be used in rolling soil;

Check Dams

Application:	Small gullies <40° slope
Position:	Gullies Mid & down slope
Life span	25 years +
Site requirement	Good foundation Need to be well keyed
Limitation	

Stone Pitching

Application:	Erodible soil slopesup to 35 degrees; Site with heavy seepage areas like flood plain areas; Gully floors between check dams; Scour protection by rivers
Position:	River banks Gully base & floor
Life span	25 years +
Site requirement	
Limitation	Damaged by debris & swift water

Revetments

Application:	Debris >50° slope Cut slopes>50° slope Spoil at angle of repose
Position:	Usually at toe
Life span	25 years +
Site requirement	Stable cut slope which would otherwise destabilize by the seepage
Limitation	Gives only protection and not support

Prop/Dentition Walls

Application:	To support overhanging rock To check differential weathering of alternate beds of soft and hard rocks
Position:	at mid slope
Life span	25 years +
Site requirement	Stable foundation bed Hard bed not too fractured
Limitation	Do not offer total support to overhanging rock mass; Only checks erosion/weathering of softer bands of alternating rocks

Wire Bolster Cylinders

Application:	On long slopes between 35 to 50° to prevent scour or gullying
Position:	at mid slope
Life span	25 years +
Site requirement	Well drained material for contour bolsters Poorly drained material for herring bone bolsters
Limitation	Can be undermined

Retaining Walls

Application:	To support hill side slope or slope segments from the valley side
Position:	at mid and lower slope
Life span	25 years +
Site requirement	Any slope having slope instability problems with slip plane at >50 cm
Limitation	

Wire Netting

Application:	Hard rock slope
Position:	Up and Mid slope
Life span	20+ years
Site requirement	
Limitation	Expensive Difficult to install Not on soft rock

Wattle Fence

Application:	Cheap, easy to install
Position:	Top and Mid slope
Life span	1-2 seasons
Site requirement	Stakes can be driven
Limitation	Weak, Undermining

Wire Fences

Application:	>30-degree slope
Position:	Mid slope
Life span	10 to 20 years
Site requirement	Stakes can be driven
Limitation	Expensive Small amounts retained

Slope Cover

Application:	Permeable slope Any slope
Position:	Gullies Mid & down slope
Life span	25 years +
Site requirement	Stakes can be driven
Limitation	Good foundation Need to be well keyed

Surface Drains

Application:	On slope surface
Position:	
Life span	Depends on type of surface drains provided
Site requirement	Any site <35° Gabion or concrete drains can be used on slopes up to 45°, cascade drains can be used in slopes >45°
Limitation	

Sub-Surface Drain

Application:	On slopes having shallow water table
Position:	
Life span	Depends on type of surface drains provided
Site requirement	Any site <35°
Limitation	Slopes dominated by boulders

Ppt VII: Environmental Assessment in Road Sector

Environmental Impact Assessment (EIA)

- "EIA is systematic, reproducible and interdisciplinary evaluation of potential effects of the proposed actions and its practical alternatives on Physical, Biological, Cultural and Socio-Economical attributes of a particular geographical area" (USEPA 1993)
- "Environmental Impact Assessment" means a report on detailed study and evaluation to be prepared to ascertain as to whether, in implementing a proposal, the proposal does have significant adverse impacts on the environment or not, whether such impacts could be avoided or mitigated by any means or not (EPA, 1997)
- "Initial Environmental Examination" means a report on analytical study or evaluation to be prepared to ascertain as to whether, in implementing a proposal, the proposal does have significant adverse impacts on the environment or not, whether such impacts could be avoided or mitigated by any means or not (EPA, 1997).

Historical Development

United Nations Conference on Human Environment,1972 (5-16 June) (Called Stockholm's Convention)
P1- Man has the fundamental right to freedom, equality and adequate conditions of life, in an environment of a quality that permits a life of dignity and well-being, and he bears a solemn responsibility to protect and improve the environment for present and future generations. (up to P-26)

Convention on Environmental Impact Assessment in a Transboundary Context,1991 (Espoo, Finland), Entry into force: 10 Sep,1997) (45 parties including USA, Canada)

"Environmental impact assessment" means a national procedure for evaluating the likely impact of a proposed activity on the environment;

Environmental impact assessments as required by this Convention shall, as a minimum requirement, be undertaken at the project level of the proposed activity. To the extent appropriate, the Parties shall endeavour to apply the principles of environmental impact assessment to policies, plans and programmes. (art 7.)

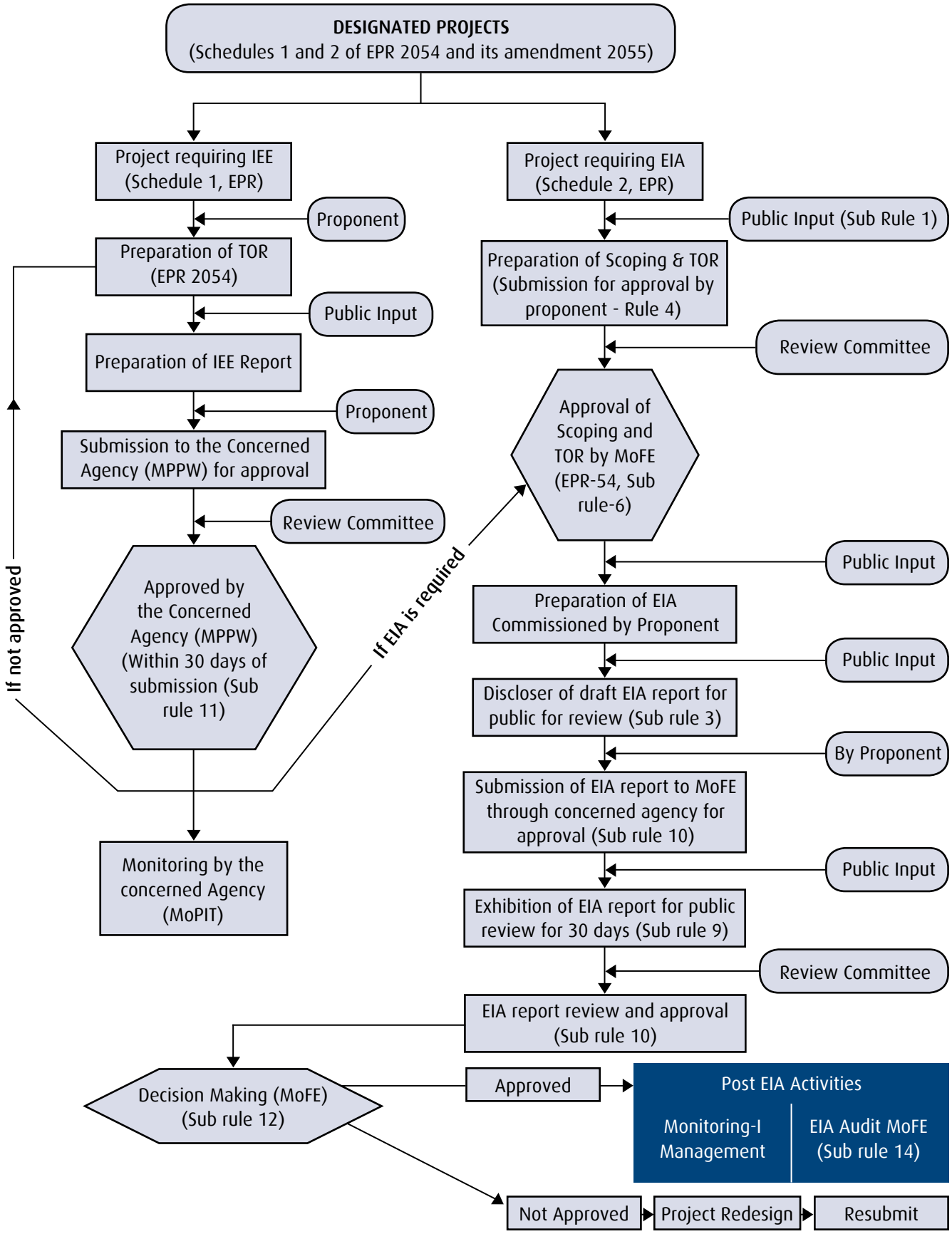
United Nation Conference on Economic Development-1992

Environmental Impact Assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a component national authority (Rio Declaration Principle 17)

Nepal's Milestones
National Environmental Impact Assessment Guideline, 1993
Environment Protection Act, 1997
Environment Protection Rules, 1997
Screening Criteria in Nepal
Schedule-1 of EPR-Shall Conduct IEE
Schedule-2 of EPR-Shall Conduct EIA

Process of Environment Assessment in Nepal

Figure 2.2: **Steps to Conduct an IEE or EIA Study**



Gaps and Opportunities in Environmental Assessment in Nepal

- Intrusion of EA in Project Cycle
- Consulting firms
- Available Human Resources in Market
- Human Resources
- Data
- Implementation & Monitoring
- Time Taken for Approval
- Co-ordination (Inter ministerial, Intra officials-divisions, with consultancies)

Session Three: Design Aspects of Soil Bioengineering Structures **Time:** 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Concept of Design Aspects of Bioengineering	▪ Brainstorming and Open Forum Discussion on Bioengineering (10 Minutes)	▪ Selection of Optimal Techniques, General Assessment Methods and Initial Treatment
▪ Methods & Techniques of Soil Bioengineering for Site Stabilization	▪ PowerPoint Presentation *(Ppt-VIII)* on Design Aspects of Soil Bioengineering Structures (40 Minutes)	▪ Detail Assessment of Site and Knowledge Assessment of Engineering Functions Required
▪ Alternatives for Civil Structures	▪ Queries and Solutions (10 Minutes)	▪ Cost Effectiveness and Handover Principles
▪ Plant Species selection for Bioengineering	▪ Rapporteur	▪ Plant Species Selection for Various Aspects

Session Four: Environmental Aspects for the Project Planning and Execution **Time:** 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Concept of Environmental Aspect for Project Planning and Execution	▪ Brainstorming and Open Forum Discussion on Bioengineering (10 Minutes)	▪ National and International Landmark Decisions
▪ Project Cycle and Environmental Interventions	▪ PowerPoint Presentation *(Ppt-IX)* onEnvironmental Aspects for the Project Planning and Execution(40 Minutes)	▪ National Governing Guidelines/ Manuals/Directives
▪ Strategic planning and Decision Making	▪ Queries and Solutions (10 Minutes)	▪ Project Life Cycle and Integration of Environmental Concept
▪ Physical & Cultural, Biological, Socio-Economic, Chemical Aspects	▪ Rapporteur	▪ Strategic Environment Assessment and Project Level Environmental Assessment
		▪ Sustainable Development and Goals

Ppt-VIII: Design Aspects of Soil Bioengineering Structures

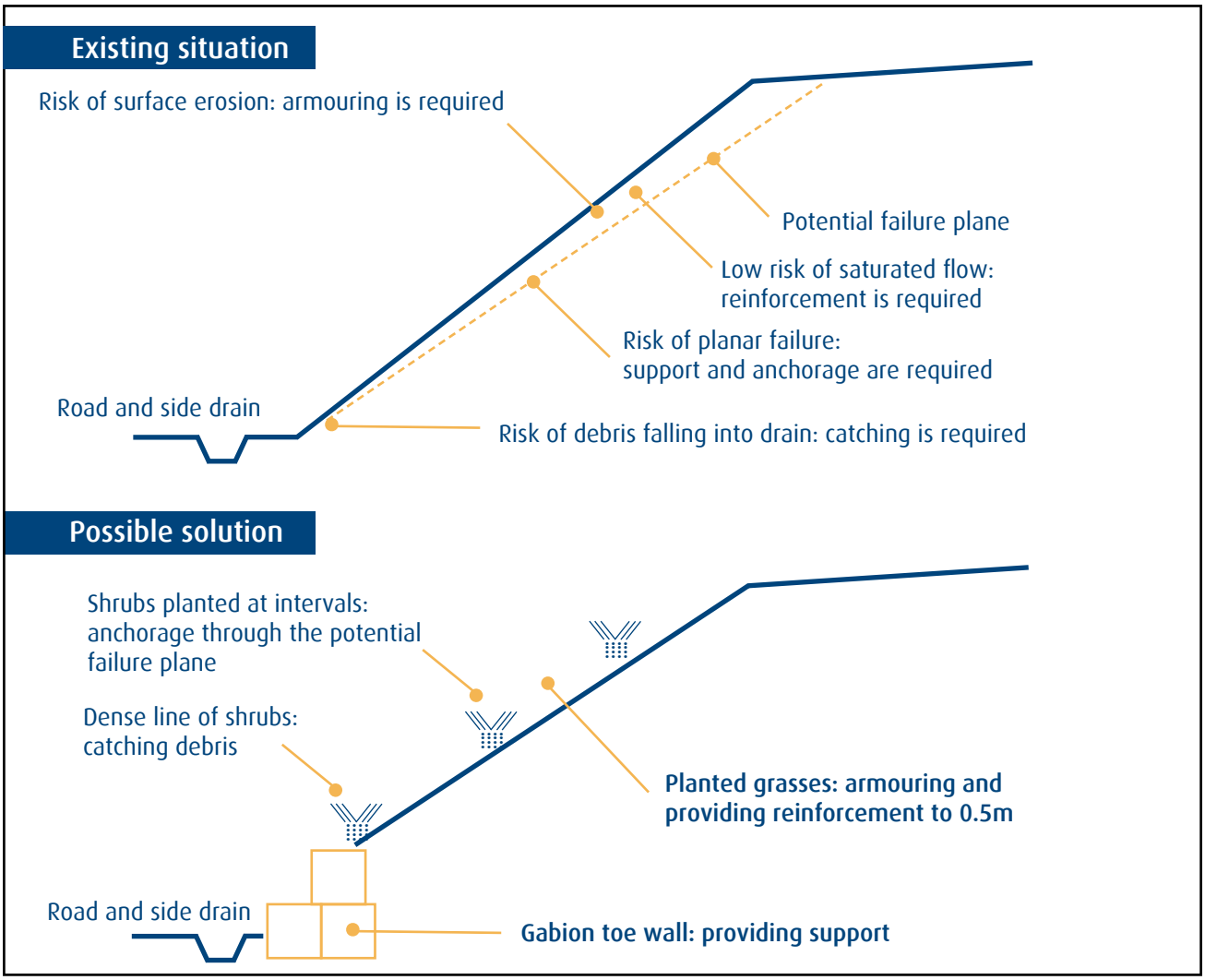
Integration of Vegetations with Civil Structures

- Bio-engineering in combination with civil structures has proved to be a very cost-effective solutions to a range of slope instability problems;
- Integration to serve either complimentary functions or same functions.

Bio-Engineering Alternatives for Civil Engineering Structures

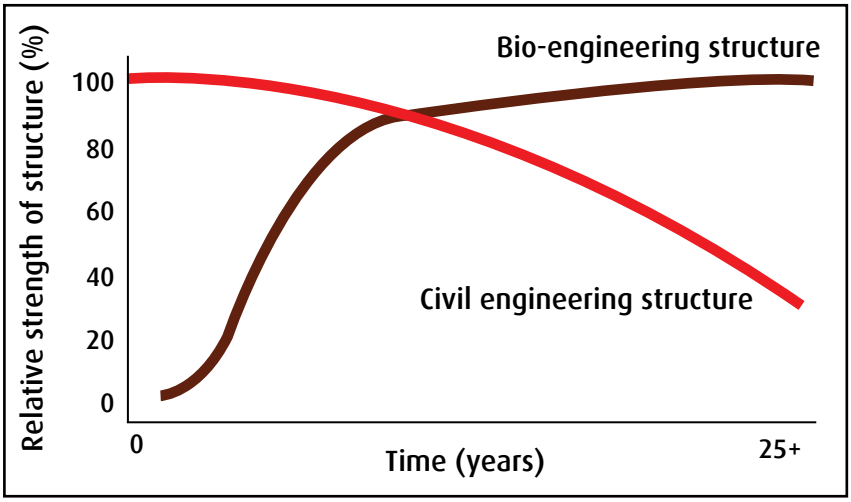
Engineering function	Civil Engineering system	Bio-Engineering system
Catch	Catch wall, Catch Fence	Shrubs, Bamboo stems
Armour	Revetment, Surface Rendering	Grass Carpet (Dense, Fibrous roots)
Reinforcement	Reinforced Earth, Soil Nailing	Densely rooted grass and Trees
Anchor	Rock Anchor	Deeply rooted Shrubs and Tree (Long and Strong roots)
Support	Retaining, Toe, Breast wall	Shrubs, Large Trees (Deep dense root systems forming a soil cylinder)
Drain	Surface and Sub-Surface Drain	Bamboo, large leaf plants, Brush layering, fascines

Integration with Civil Structures:



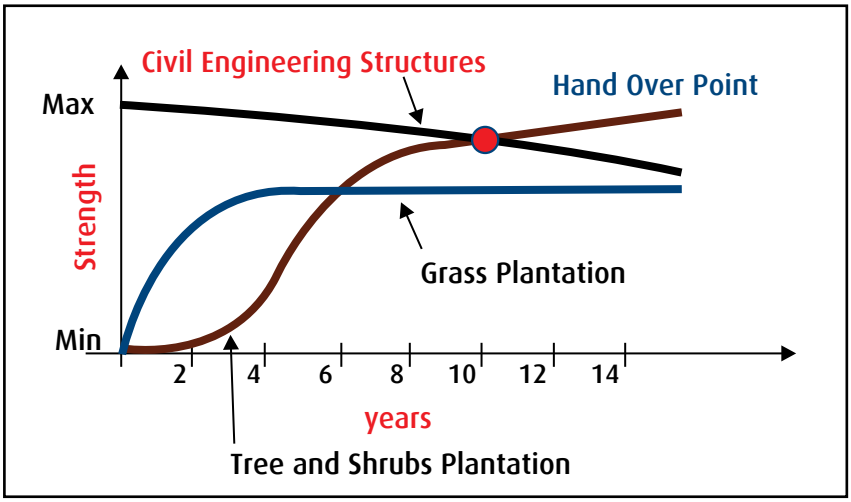
Source: Reference Manual-Roadside Bioengineering

Relative Strength of Structures with Time:



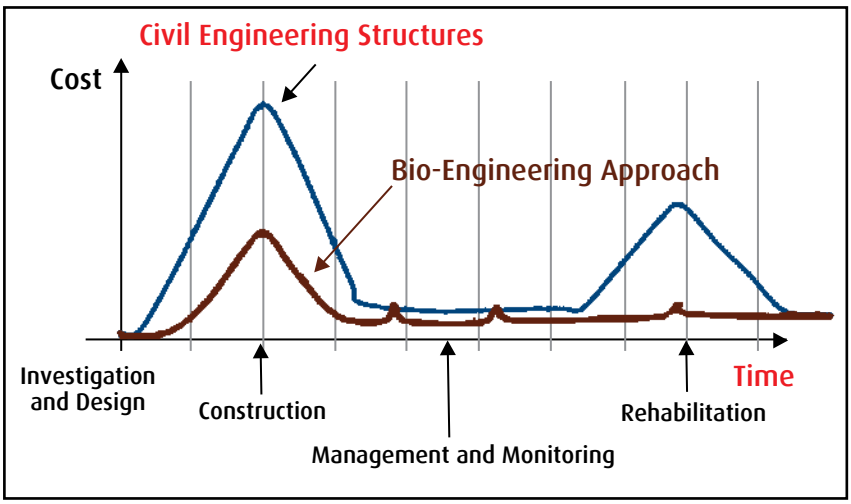
Source: Reference Manual-Roadside Bioengineering

Hand Over Principle



Source: Reference Manual-Roadside Bioengineering

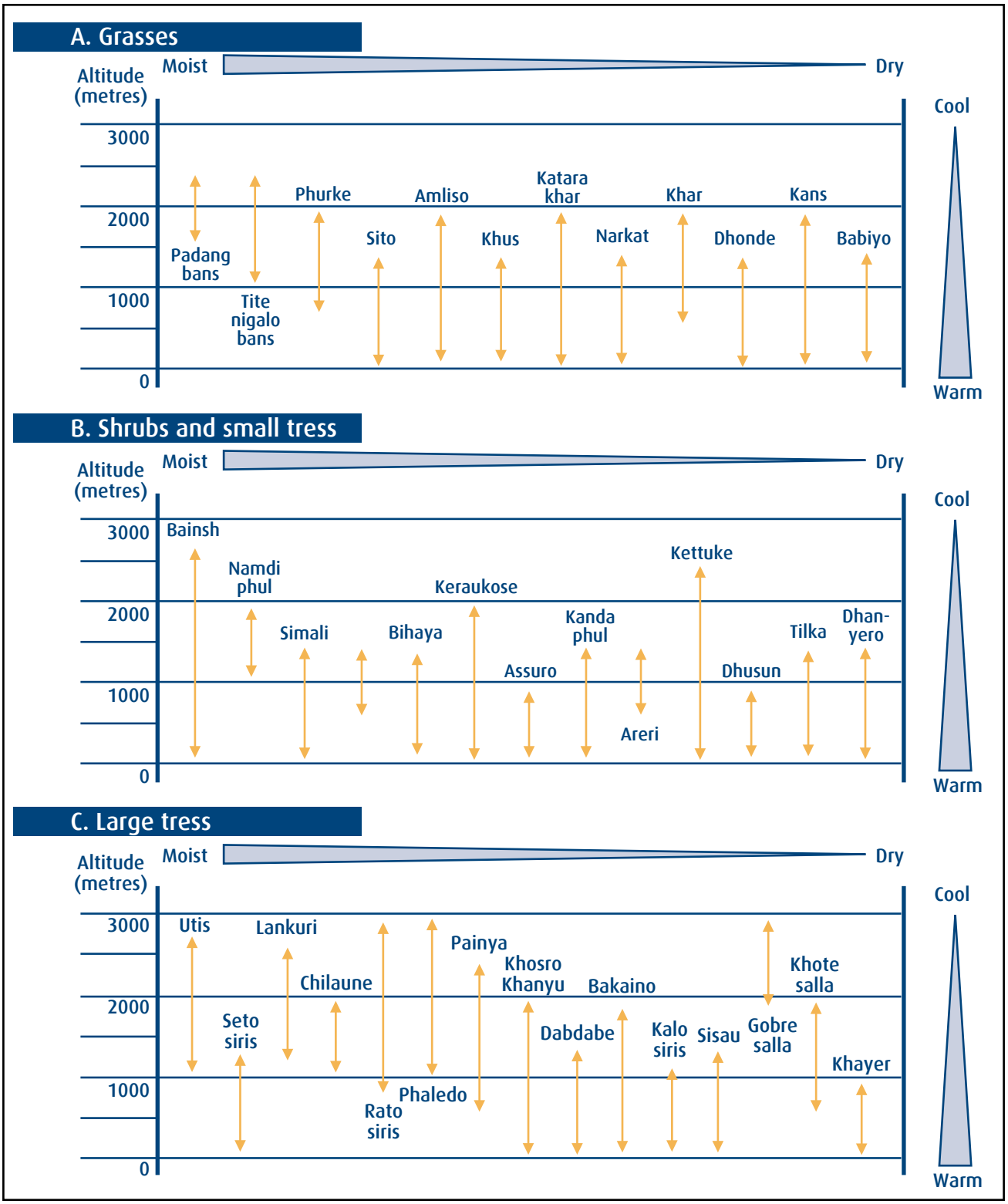
Hand Over Principle



Source: Reference Manual-Roadside Bioengineering

Selection of Plant Species depends on:

- Method of propagation;
- Biological and social considerations;
- Establishment, vigour and persistence;
- Site suitability;
- Potential value to local farmers;
- Availability

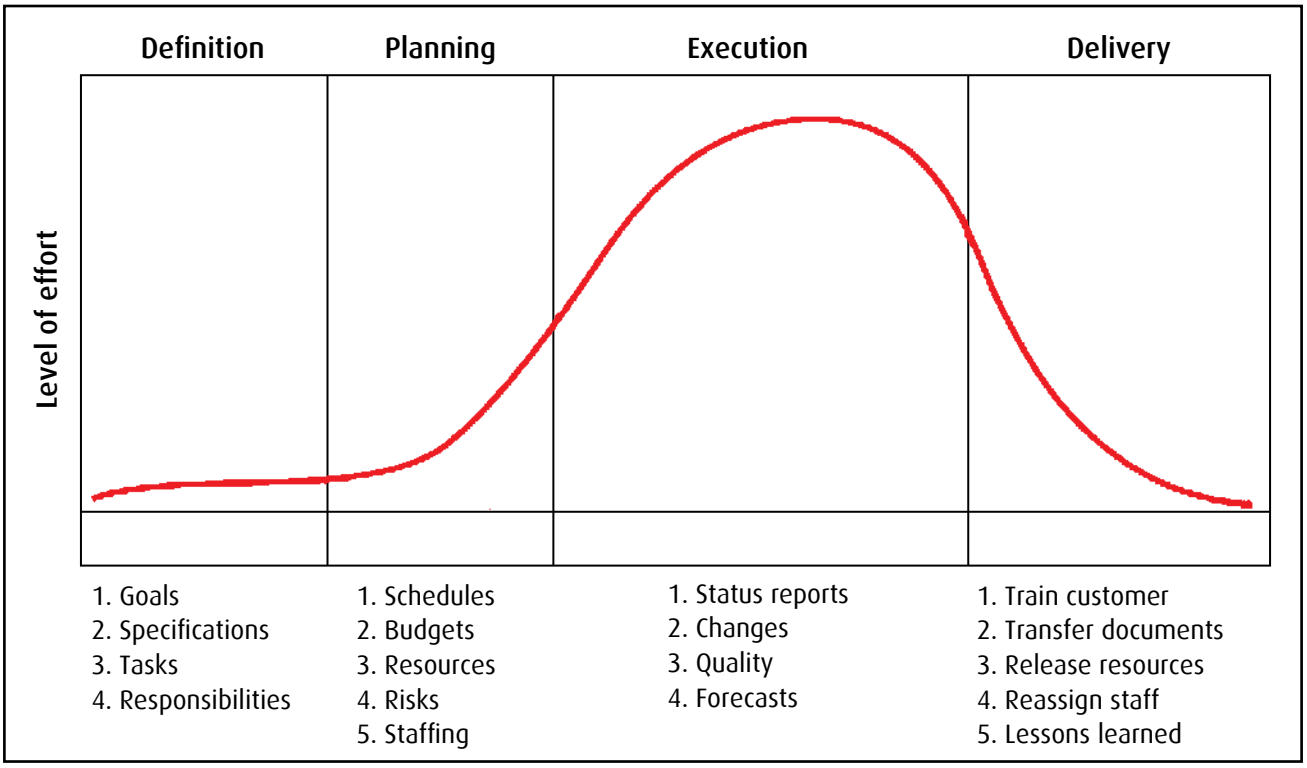


Source: Roadside Bio-Engineering; Reference Manual

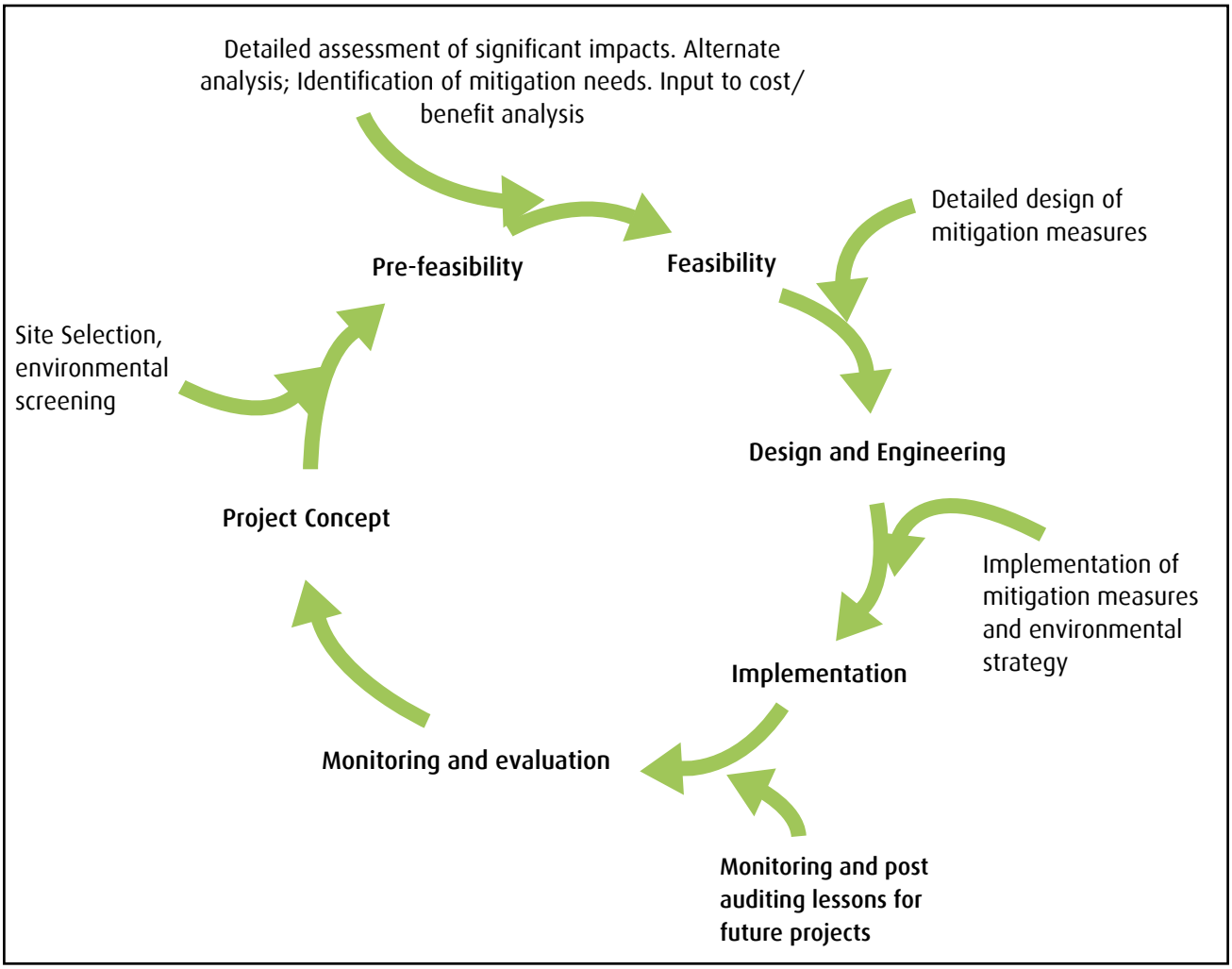
Ppt IX: Environmental Aspects for the Project Planning and Execution

Project Life Cycle

- Defining Project
- Planning Project
  - Strategic Environmental Assessment (SEA)
    - Plan, Policies and Programs
  - Environmental Impact Assessment (EIA)
  - Initial Environmental Assessment (IEE)
    - Physical, Biological, Socio-economic and cultural Aspects, Impacts Identification, Predictions and evaluations
    - Environmental Management Plan, Monitoring Plan, Environmental Costs, Roles and Responsibilities etc.
  - Environmental Management Plan (EMP)
    - Activities, Responsibility, Supervision, Time of delivery, Deadlines, Costs etc.
  - Executing Project
    - Environmental Management Plan
    - Environmental Monitoring
  - Delivering Project
    - Environmental Audit

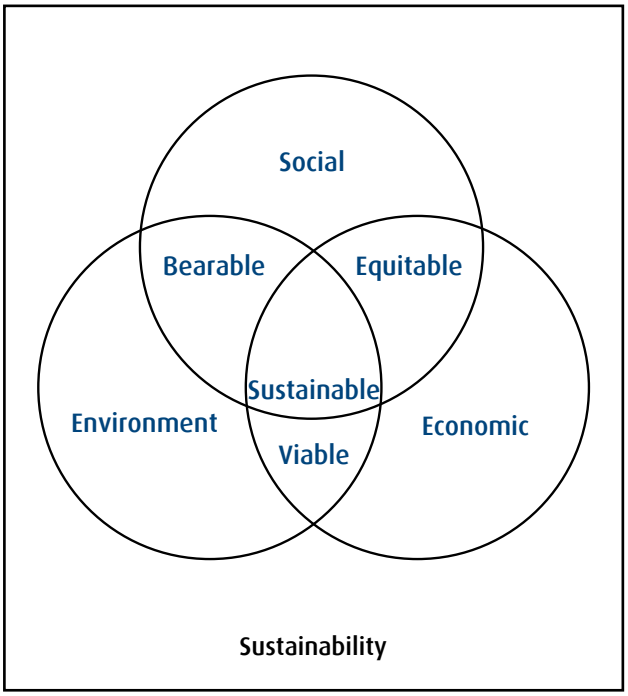


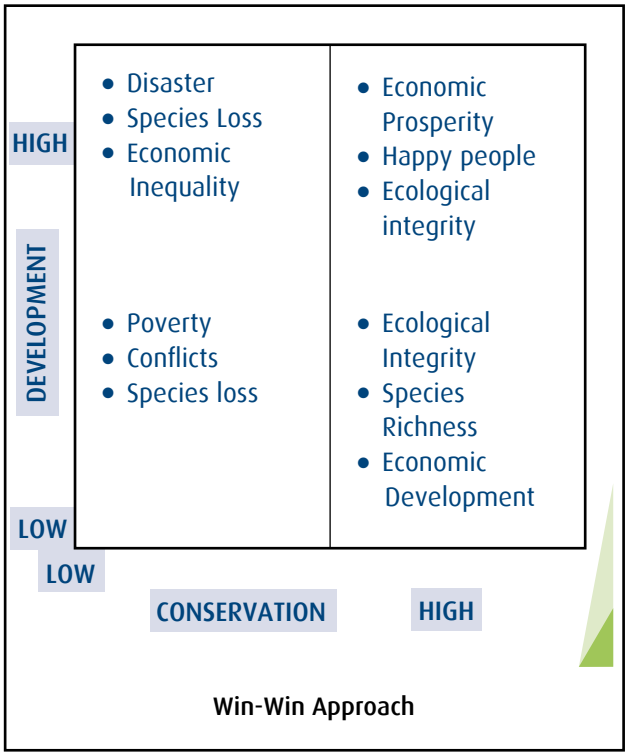
Integration of Environmental Aspects in Project Cycle



Source: Environmental and Social Management Framework 2013

Sustainability and Win-Win Approach





Session Five: Green Road Monitoring **Time:** 60 Minutes

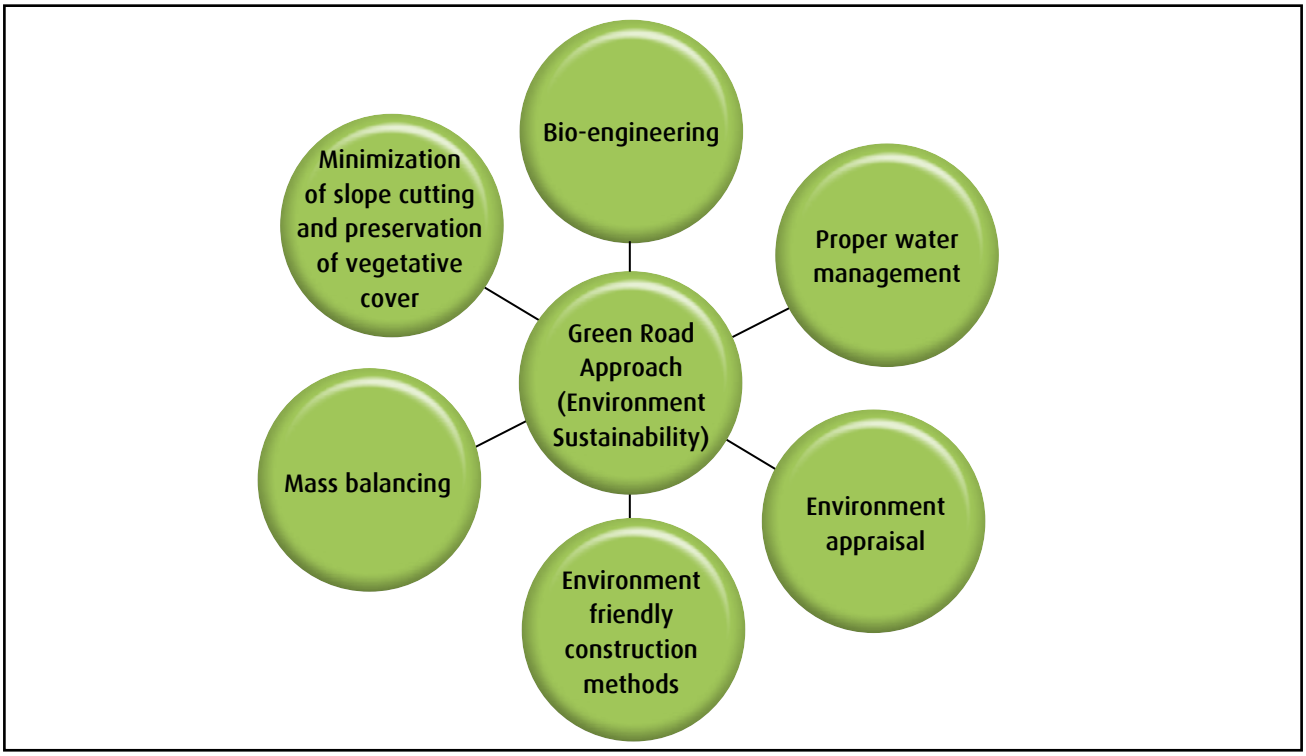
Learning Objectives	Methods	Expected Outcome
▪ Concept of Environmental Monitoring of Roads	▪ Brainstorming and Open Forum Discussion on Bioengineering (10 Minutes)	▪ Legal Aspects of Environmental Monitoring
▪ Strategies and Techniques of Monitoring	▪ PowerPoint Presentation *(Ppt-X)*on Green Road Monitoring (40 Minutes)	▪ Monitoring Planning and Monitoring Indicators
▪ Preparation of Checklists for Green Road Monitoring	▪ Queries and Solutions (10 Minutes)	▪ Monitoring Agencies and Responsibilities
▪ Identification and Documentation of Monitoring Indicators	▪ Rapporteur	▪ Monitoring Checklists
▪ Monitoring Agencies and Responsibilities		

Session Six: Wildlife Friendly Linear Infrastructures **Time:** 60 Minutes

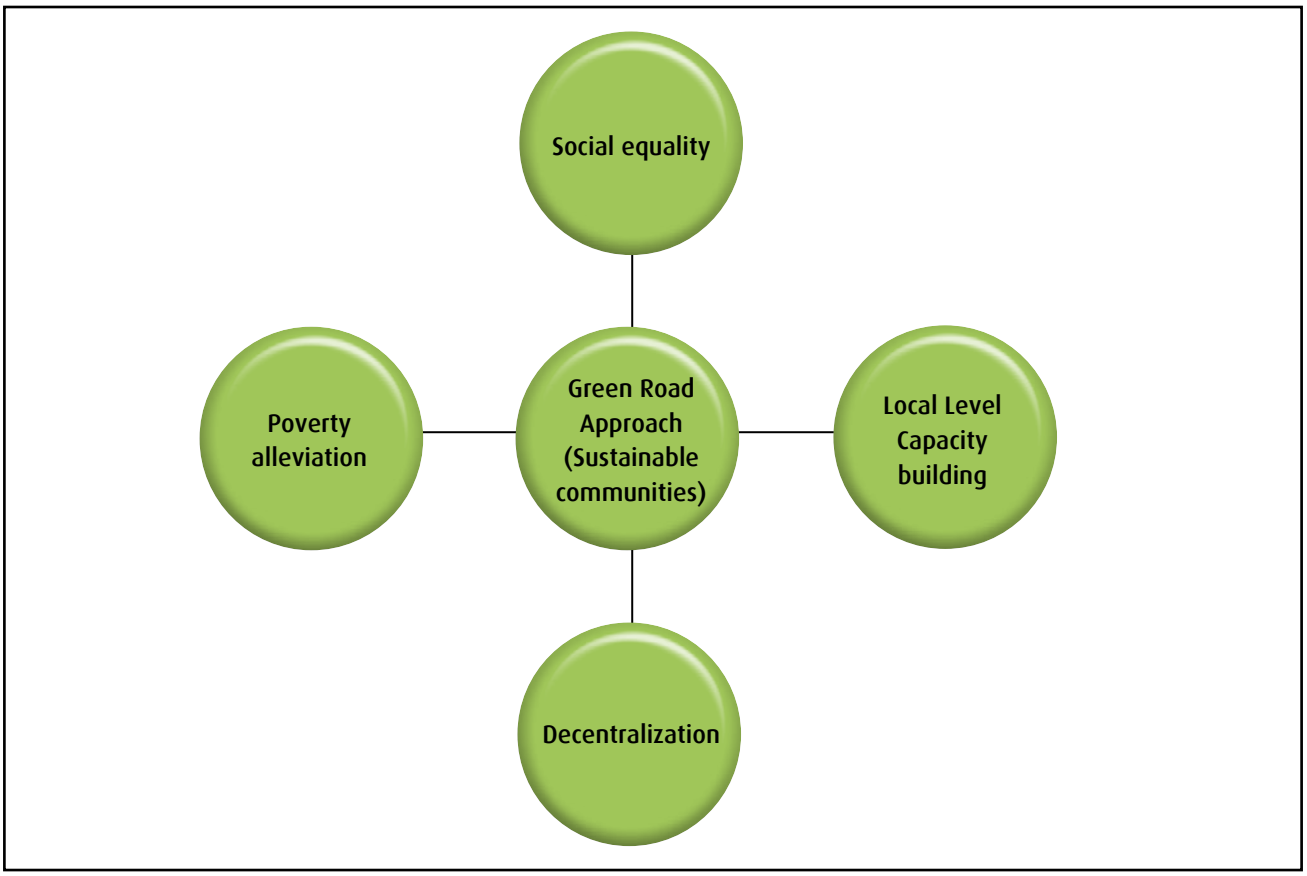
Learning Objectives	Methods	Expected Outcome
▪ Concept & Types of Wildlife Friendly Infrastructures	▪ Brainstorming and Open Forum Discussion on Bioengineering (10 Minutes)	▪ Linear Infrastructures in Nepal
▪ Wildlife Friendly Infrastructures in Practices: National & International	▪ PowerPoint Presentation *(Ppt-XI)*on Wildlife Friendly Linear Infrastructures (40 Minutes)-	▪ Impacts of Linear Infrastructures and their Mitigating Strategies
	▪ Queries and Solutions (10 Minutes)	▪ Wildlife Friendly Liner Infrastructures in Nepal and sustainability
	▪ Rapporteur	

Ppt-X: Green Road Monitoring

Concept of Green Roads and Sustainable approach



Green Road Approach for Sustainable Communities



Components of Monitoring

- Physical: Bio-Engineering works, Air, Water and Noise Pollution, Ancillary Facilities, Land Acquisition, Quarry sites, Public Utilities etc.
- Biological: Forest Land Acquisition, Trees to be felled down, Protected species, Compensatory Plantation, Carbon emission etc
- Socioeconomics and Cultural: Cultural Sites, Land Acquisition, Employment generation, GESI, Private Structure Damages etc

Environmental Standards in Nepal

- Ambient Air Quality Standards
- Noise Quality Standards
- Drinking water Quality
- Standards for DG Sets
- Lead in Paints
- Plastic Bags Standards

Sample of Monitoring Plan Executed in Approved Documents (EIA/IEE)

Parameters	Verifiable Indicators	Verification Methods	Location	Schedule	Responsible Agency	
					Implementation	Monitoring
Slope stability						
Bio-engineering of Disturbed Slopes						
Disposal of Spoils and construction Wastes						

Monitoring Checklist Sample

क्र.सं	विवरण	छ वा छैन	कैफियत
क	निर्माण चरणका कार्य		
१	जानकारी बोर्ड		
२	सडकको एलाइनमेन्ट डिजाइन अनुसार		
३	कटिगं स्लोप साइटको माटो अनुरुप		
४	काटेको माटो तोके अनुसार		
५	पानी व्यबस्थापनको लागी नालीको साइज उपयुक्त		
६	सडकको स्लोप		
७	पेभमेन्टको मोटाइ, लम्बाइ, चौडाइ		
८	गीटीको साइज		

Ppt-XI: Wildlife Friendly Linear Infrastructures

Basics of Linear Infrastructures

Those infrastructures which have a definite width, but the length extends for an unconfined limit refers to linear infrastructures. These structures follow a line and are elongated for a considerable length.

Types of Linear Infrastructures

- Roadways
- Railways
- Irrigation canals
- Transmission Lines
- Tunnels

Impacts of Linear Infrastructures

- Deforestation / Forest Loss
- Barrier Effect
- Human Wildlife interaction
- Road Traffic Mortality
- Pollution
- Habitat Fragmentation
- Drowning Effects
- Electrocuting
- Flyways / Birds' Migratory route issues

Mitigation Strategy

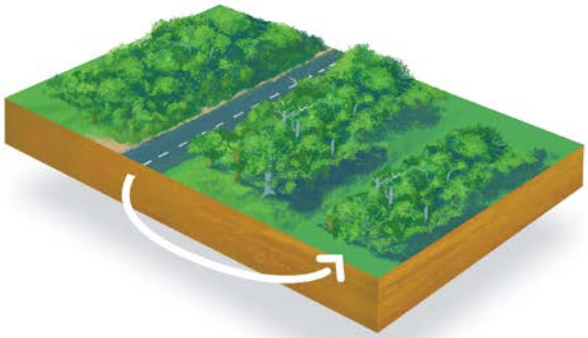
- Avoid
- Minimize/Mitigate
- Compensate

Fragmentation

Avoidance

Minimization by use of overpass/underpass

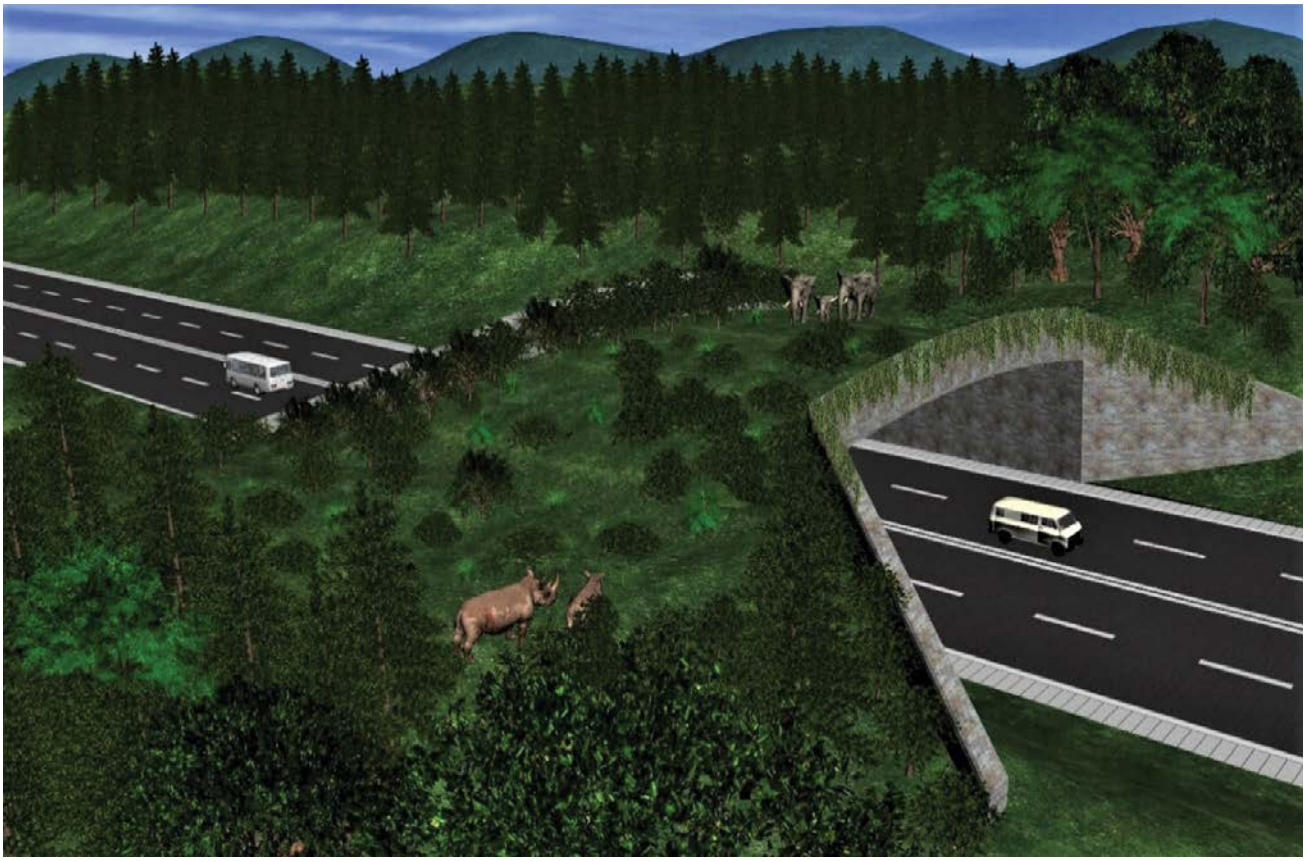
Compensation by replacement of habitat nearby



Mitigation structures

Basics of Linear Infrastructures

- Overpass



- Underpass

- A typical jumpout

- Canopy bridge

DAY III

Session One: Practical Field Training and Observations in Selected Road Section **Time:** 4 hours

Learning Objectives	Methods	Expected Outcome
▪ Bio-Engineering Techniques	▪ Facilitator will divide participants into four groups	▪ Types of Adopted Bioengineering Methods for Slope Stability
▪ Slope Stabilization Techniques	▪ Each group will have all materials	▪ Cost of Implementation and Adoption
▪ Road Safety Measures	▪ Traverse Survey, Observation, Inspection, Discussions with Stakeholders, Photo/Videography will be adopted	▪ Road Safety Measures adopted
▪ Implementation of EMAP		▪ Environment Friendly Infrastructures adopted
▪ Environment Friendly Infrastructures: Animal Underpass, Overpass, Canopy Bridges, Guided Fences		

DAY IV

Session One: Group Presentation (Field Works) of Participants — **Time:** 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Field Visit Objectives	▪ Presentation of Each Four Groups (10 Minutes Each)	▪ Learned about various techniques of Slopes stabilization
	▪ Discussion with Trainer (20 Minutes)	
	▪ Rapporteur	

Session Two: National Policy on Environmental Protection and Conservation — **Time:** 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Concept of Natural Resources Management	▪ Brainstorming and Open Forum Discussion on Bioengineering (10 Minutes)	▪ Empowerment of Environmental Scopes in Government of Nepal (Local, State and Federal Level)
▪ National and International schemes of Natural Resources Management	▪ PowerPoint Presentation*(Ppt-XII)* on National Policy on Environmental Protection and Conservation (40 Minutes)	▪ Environmental Issues in Various Sectors
▪ Process and Practices of National and International Natural Resources Management	▪ Queries and Solutions (10 Minutes)	▪ Biodiversity in Nepal and their Protection Strategies
	▪ Rapporteur	▪ National and International Instruments in Environmental Conservation
		▪ Sustainable Development

Session Three: Closing of the Program — **Time:** 60 Minutes

Learning Objectives	Methods	Expected Outcome
▪ Welcome the participants and Guests for Closing of Program	▪ The training facilitator will call the chief guest and guest in the dash and introduce the chairmanship.	▪ Closing of the Program
▪ Lesson Learn	▪ Two Participants Representatives Will Summarize the Lesson Learnt	
	▪ Summarizing the Training by Rapporteur	
	▪ Remarks by guests & Chief Guest	
	▪ Certificates and Token of Love Distribution	
	▪ Closing of Session by Chairman	

Ppt-XII: National Policy on Environmental Protection and Conservation

Environmental Rights as per Constitution of Nepal

- Rights of Federal Government
- Rights of State Government
- Rights of Local Government
- Common Rights (Federal, State & Local Level)

Natural Resources

- Forests, Fauna & Flora, Forest Products and Biodiversity
- Water Resources
- Land and Productivity
- Mines and Minerals
- Alternative Energy
- Landscapes

Protected Areas in Nepal

- National Parks
- Wildlife Reserves
- Conservation Areas
- Hunting Reserve

Biodiversity Status of Nepal

Landscape Level Conservation Status in Nepal

- Kailash Landscape (KL)
- Terai Arc Landscape (TAL)
- Chitwan-Annapurna Landscape (CHAL)
- Scared Himalaya Landscape (SHL)
- Kanchenjunga Landscape (KCL)

National Laws Governing Biodiversity Conservation

- Constitution of Nepal
- Environment Protection Act, 1997
- Environment Protection Rules, 1997

International Conventions Governing Biodiversity Conservation

- Convention of International Trade in Endangered Species of Wild Fauna and Flora, (CITES) 1975
- Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat, 1975
- Convention on Biological Diversity (CBD), 1992

Post Training Evaluation: After the completion of training session, Pre-test questions (Annex 1) will again be distributed and the level of knowledge acquired by the participants will be assessed through comparison of the results during pretest. Training Facilitator will collect all the pre-test and post test forms and will evaluate accordingly.

DAY V

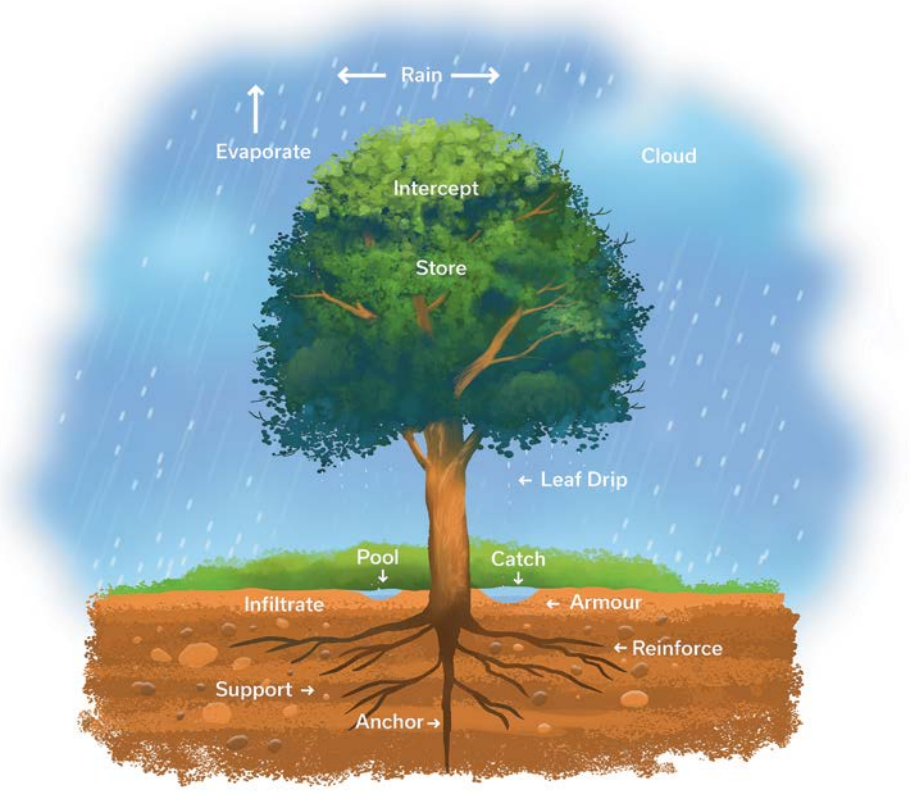
Integrating Non-technical Participants

Capacitating Non-technical Participants

The fifth day of the training is targeted towards non-technical participants, however, engagement of technical and non-technical participants helps build a common understanding in assessing rural roads to uplift their standards.

On this day, participants are capacitated by describing various governmental policies on environment protection and infrastructure development. The road development scenario is described to share information on overall road development in Nepal and impacts on natural well being due to sub-standard rural roads.

Overall rural roads development strategies, current practices in local levels are discussed with examples of local context are described and strategies to improvise them are explained. The participants are explained with examples of schematic pictures related to road development and ways to mitigate impacts of sub-standard rural roads.

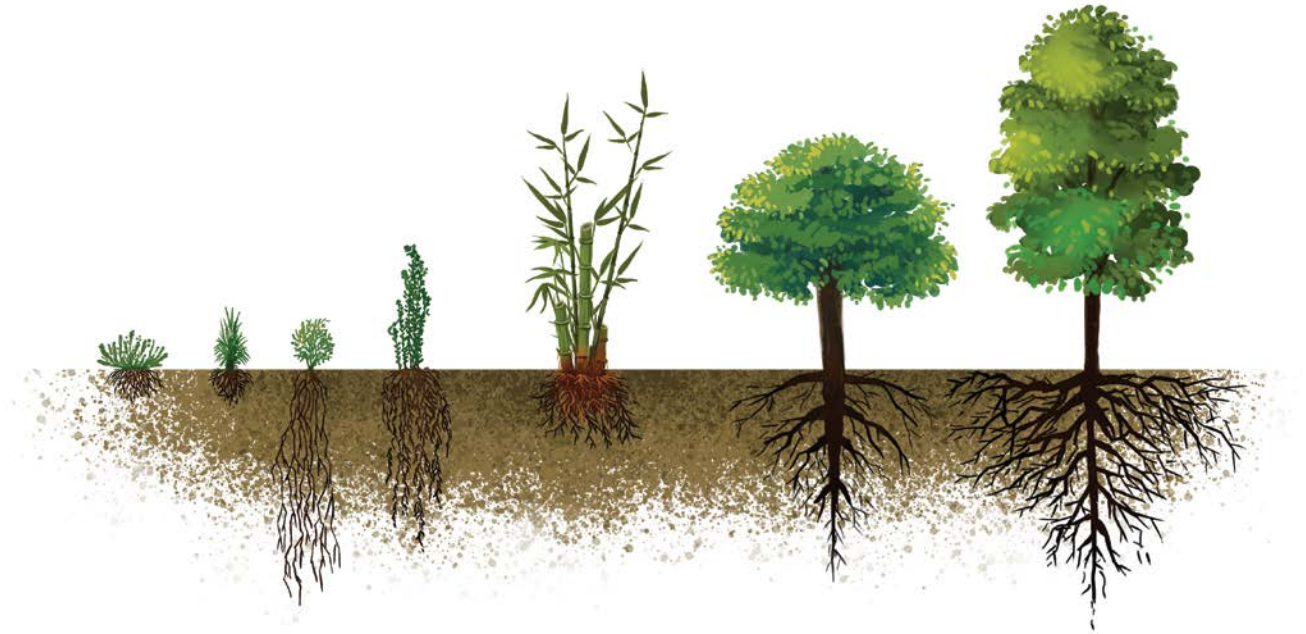


Picture: Hydrological & Mechanical function of a Trees

Description: A tree catches rain fall which intercepts through its leaves and helps to bind the earth beneath by enhancing the anchorage function. Water infiltrates through the earthen surface and helps support vegetation growth further.

Picture: Message - Don't mix two things together: Road and Water.

Description: Water flow through the road deteriorate the road condition by potholes and ditch creation which promotes degradation of base material of the road. Proper drainage and water diversion are must to protect roads.

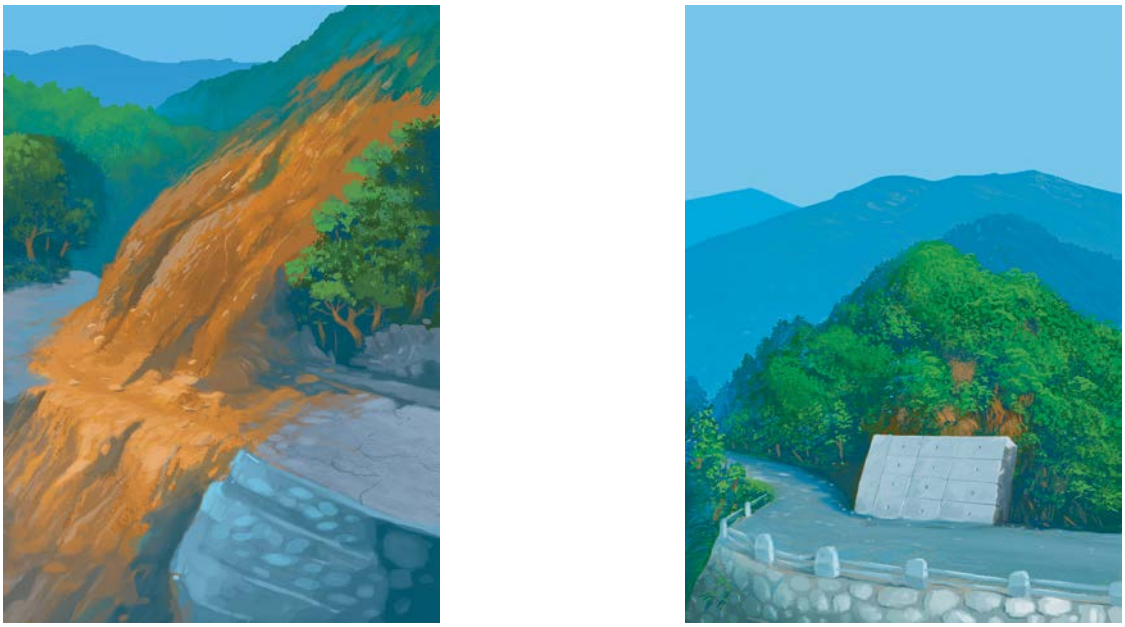


Picture: Root types and anchorage function

Description: Use of various bio engineering plants depend upon altitude, location, availability of moisture, north/south slope etc. The right use of plants as bioengineering material stabilizes the earth surface. There are plants which have soft fibrous roots which are required for earthen surfaces while others have hard roots which should be avoided at rocky terrain. Proper use of proper plants at required locations help support soil stabilization.

Picture: A road surface being hit by debris flow.

Description: Two failure types have been shown here. Left failure type is rotational- Translational slide while the right is Debris flow.

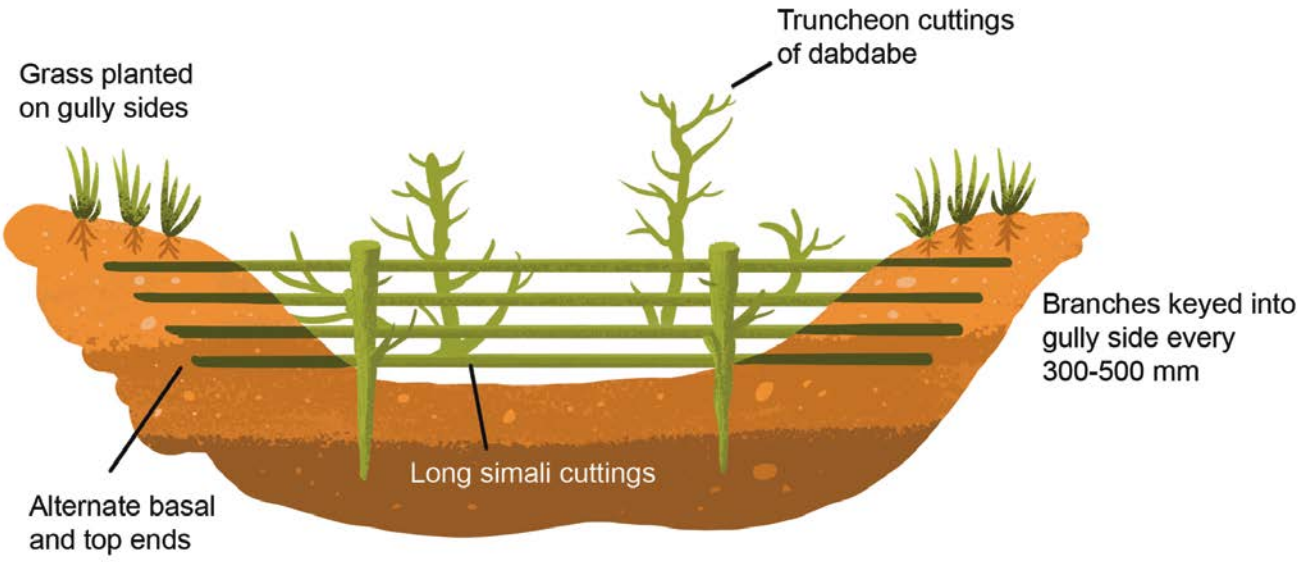


Picture: Failure of earth mass (left), recovery of landslide by engineering approach (right)

Description: Proper management of landslide zones could lead to a stabilized surface. A mixed bio-engineering approach is required to stabilize weak surfaces.

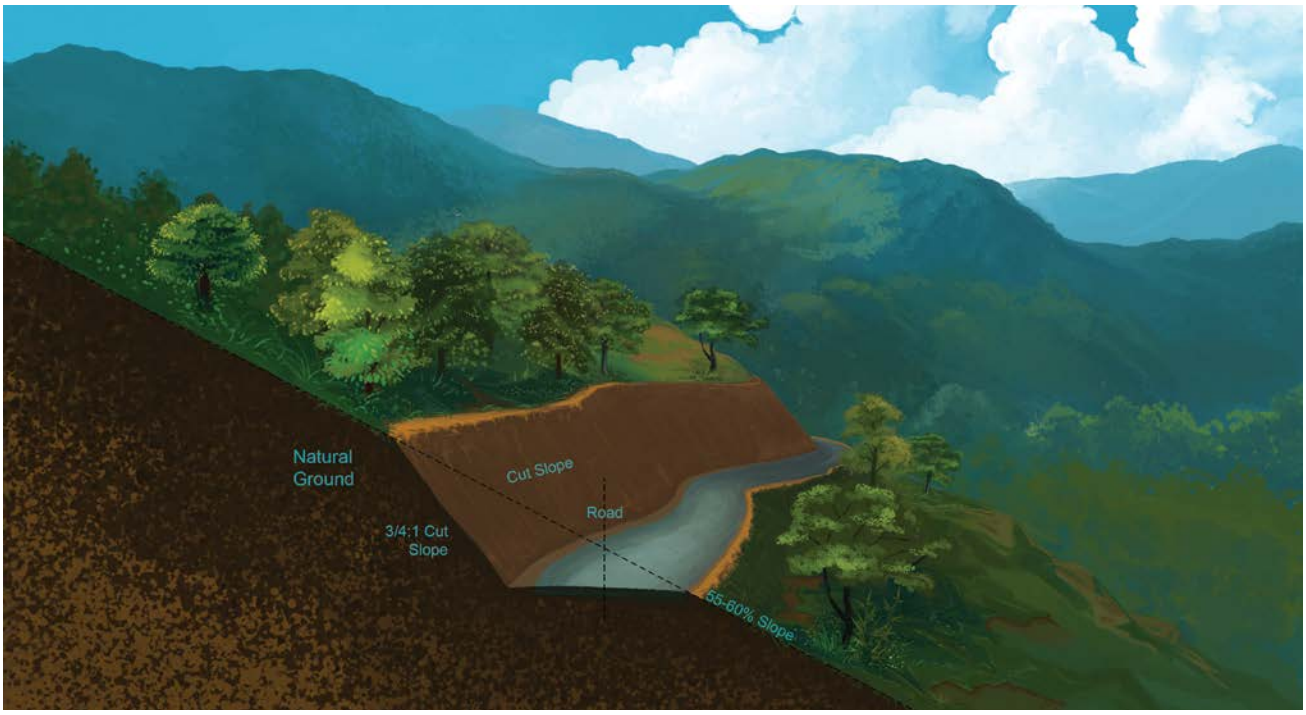
Picture: Low cost earth stabilizing wall

Description: A mixed use of stone masonry/dry stone and bamboo crib walls can stabilize debris flow. Bamboo crib wall enhances environment to support greenery which stabilizes earth surface.



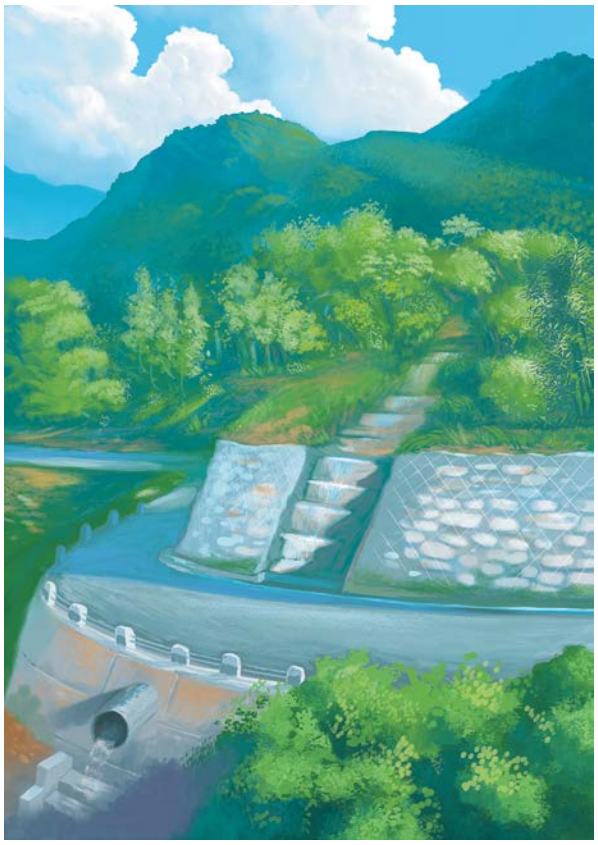
Picture: Live check dam

Description: A bamboo crib wall helps produce shoots which enhances earth grip and supports anchorage of loose soil mass.



Picture: A typical example of balanced cut and fill for road construction

Description: It is ideal to have a balanced cut and fill while constructing a road section as it is cost efficient and do not promote debris fall. However, cut and fill quantity depends upon geography of the terrain.



Picture: Use of bio-engineering techniques and proper water drainage system

Description: A fragile earth mass with excessive water availability can be managed properly by applying bio-engineering techniques of soil stabilization combined with proper management of surface water.

Picture: Outlet of water crossing structure

Description: At locations where water abundance is high, proper water crossing structure is a must. However, the outlet of such structures should be well secured with strong gabion boxes and/or RCC structures depending on the velocity of water flow to prevent scouring. Improper management of water crossing structures could lead to failure of such structures and impact the functionality of road at high flood times. Water crossing structures do as well serve as small animals crossing structure.

Picture: Trash rack for culvets to prevent clogging

Description: Water bodies carry various items including log, stone, gravel and other materials along with it. Wise use of barriers can easily help support anti clogging of water crossing structures.

Picture: Use of bridge for wildlife crossing

Description: River corridors are often used by wildlife. Bridges should leave out river corridors to make it favorable for wildlife movement.

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Annex-1: Pre-test (Bio-engineering in Road sector)

1. Distinguish between on- road maintenance and off-road maintenance.

2. Bio-engineering is effective for rotational failures.
   a. True b. False

3. Differential weathering is extensively seen in
   a. Mid-Siwalik rock formation b. Lower Himalayan formation c. Higher Himalayan rock formation

4. Number of distinct zones in landslides are:
   a. 2 b. 3 c. 4 d. 5

5. Brush layering and Fascines are used for controlling rill and gulley erosion.
   a. True b. False

6. Bio-engineering: the use of living vegetation, either alone or in conjunction with civil engineering

   a. True b. False

7. For the wise use of resources, we have to compare cost of
   a. COST OF RISK REDUCTION after repair / maintenance
   b. COST OF RISK REDUCTION after repair / maintenance, ROAD USER DELAY COST,
   c. COST OF RISK REDUCTION after repair / maintenance, ROAD USER DELAY COST SOCIAL and COST OF CLOSURE,
   d. COST OF RISK REDUCTION after repair / maintenance, ROAD USER DELAY COST SOCIAL COST OF CLOSURE and ROAD REPAIR COST

8. One possible option over short stretches to deal instability is Design a narrower road width to avoid excessive slope cutting
   a. True b. False

9. Maximum safe height for dry masonry is
   a. 2 m b. 4 m c. 6 m

10. Bio-engineering systems work in the same way as civil engineering systems and have the same functions. They are effective at depths of up to --------- mm below the surface
    a. 0.5 m b. 1 m c. 2 m

Annex-2: Detail Schedule

Session	Brief Content	Methods	Resource Person	Time
Day I				
Registration/Breakfast 8:30-9:30				
Opening Session		Welcome and Opening Remarks		9:30-10:30
Session I	An overview of soil bioengineering	Presentation		10:30-11:30
Session II	Slope stability and water management	Presentation of conceptual inputs & discussions on topic		11:30-12:30
Lunch Break (12:30-01:30)				
Session III	Environmental Safeguard Policies	Presentation of conceptual inputs & discussions on topic		01:30-2:30
Session IV	Water movement and related hazard; River/stream bank management in watershed	Presentation of conceptual inputs & discussions ontopic		2:30-3:30
Tea Break (3:30-4:00)				
Session V	Causes and mechanisms of slope failures	Presentation of conceptual inputs & discussions on topic		4:00-5:00
Session Closure				

Day II				
Session	Brief Content	Methods	Resource Person	Time
Breakfast(08:30-9:30)				
Session I	Environmental Assessment in Road Sector	Presentation of conceptual inputs & discussions on topic		09:30-10:30
Session II	Design aspects of Soil bioengineering structures	Presentation of conceptual inputs & discussions on topic		10:30-11:30
Lunch Break (11:30-12:30)				
Session III	Environmental Aspects for the project planning and execution	Presentation of conceptual inputs & discussions on topic		12:30-1:30
Session IV	Design aspects of small-scale civil engineering & water management structures	Presentation of conceptual inputs & discussions on topic		1:30-2:30
Tea Break (2:30-3:00)				
Session V	Wildlife Friendly Linear Infrastructures	Presentation of conceptual inputs & discussions on topic		3:00-4:00
Session VI	Monitoring Green Roads	Presentation of conceptual inputs & discussions on topic		4:00-5:00
Session Closure				

Day III (Field Assessment in Selected Road Section)				
Session	**Brief Content**	**Methods**	**Resource Person**	**Time**
Breakfast (08:00-09:00) Travel to Field Site				
Session I	Site observation at Selected Road Section	Road Traverse, Visual observation and recording, Photography/ Videography, Discussions		09:00-17:00
Lunch at Field (13:00-14:00)				

Day IV Sensitization to Elected Representatives, Local Consultants and Contractors				
Session	**Brief Content**	**Methods**	**Resource Person**	**Time**
Breakfast(08:30-09:30)				
Session I	Brief Presentation of Field Visits by Participants	PowerPoint Presentation of the Field Visit by Participants in a Selected Road Section		09:30-10:30
Session II	Sensitization to National policy on Environmental protection and conservation	Presentation of conceptual inputs & discussions on techniques		10:30-11:300
Session III	Closing, Certificate and Token of Love Distribution			11:30-12:30
Lunch and Closing (12:30 -)				

Hariyo Ban Program