SMALL IRRIGATION PROGRAMME, PHASE II

GUIDELINES

ON

BIO-ENGINEERING PRACTICES

FOR

SLOPE STABILISATION

AND

EROSION CONTROL WORKS

PROGRAMME MANAGEMENT AND
IMPLEMENTATION SUPPORT CONSULTANT

BIRATNAGAR

OCTOBER 2021

TABLE OF CONTENTS

1. SUMMARY

Construction and rehabilitation of irrigation infrastructure in mountainous and hilly areas has various types and degrees of environmental challenges. Environmental damages and problems are categorized as physical, biological, social, cultural and sometimes archaeological categories. Environmental damages include problems of landslides, slope failures, soil erosion, spoil disposal, quarrying, deforestation and sedimentation. Environmental damages can be rehabilitated, restored, stabilized or minimized by adopting bio-engineering measures. Hence, in the case of SIP, bio-engineering is a means of environmental mitigation (*nature-based solution*) to minimize negative impacts of irrigation infrastructure construction or rehabilitation and maintenance. On the other hand, bio-engineering stabilizes slopes and protects the irrigation infrastructure.

This guideline provides the information required to design, plan and implement the bio-engineering work for slope stabilization and erosion control. It also covers the establishment of bio-engineering nurseries and maintenance of bio-engineering site. This guideline covers the following main topics:

- What is bio-engineering?
- What does it do and where and when should it be used?
- Engineering functions of bio-engineering system
- Bio-engineering techniques for slope stabilization and erosion control
- Site assessment procedures
- Selection of bio-engineering techniques for slope stabilization and erosion control work
- Selection and propagation of plants for bio-engineering
- Maintenance activities
- Safety procedures for bio-engineering work sites
- Bio-engineering works rate analysis norms
- Standard specification for bio-engineering works
- Lists of plant species for bio-engineering

2. INTRODUCTION

2.1. WHAT IS BIO-ENGINEERING?

Bio-engineering is the use of living plants for engineering purposes, to reduce shallow-seated instability and erosion on slope. Plants are generally used in combination with small-scale civil engineering structures. Bio-engineering represents an additional set of tools for engineers to stabilize landslides, minimize the erosion and rehabilitate the degraded slopes. Incorporating the use of bio-engineering measures usually offers a more effective solution to the slope instability and erosion problems.

Fig 1: Example of bio-engineering work

2.2. WHAT DOES BIO-ENGINEERING DO?

Bio-engineering systems have the same functions as those of civil engineering systems. They are effective at depth of up to 500 mm below the surface.

Bio-engineering systems are parallel with civil engineering systems in the way that engineering functions performed are common to both. There are differences in the strength and flexibility of the materials and consequently in the factors of safety which can be attained. Also, vegetation is dynamic rather than inert. It takes some time for the materials to gain their maximum strength but they tend to become stronger over the time.

2.3. ENGINEERING FUCTIONS OF BIO- ENGINEERING SYSTEM

Function	Civil engineering system	Vegetative system
Catch	Check dams Catch walls Coir netting	Contour lines (grass lines, brush layer) Live check dam Shrubs and bamboo (many stems)
Armour	Revetment walls Stone pitching	Mixed plant storeys giving complete cover, Grass carpet (dense, fibrous roots)
Reinforce	Reinforce earth Soil nailing	Densely-rooting grasses, shrubs, and trees Most vegetation structures
Anchor	Rock anchors by bolting	Deeply-rooting trees and shrubs (long string roots)
Support	Retaining walls Prop walls	Large trees and bamboos (deep and dense root system)
Drain	Surface drains French drains	Down slope and diagonal vegetation lines Angle fascines

Further, there are other benefits of bio-engineering system that are not supplied by civil engineering systems:

- Environmental restoration and improvement: a cover of vegetation encourages other plants and animals to live on the slope
- Limiting the lateral extent of instability: the rooting system of trees can interrupt the shear plane and stop it from spreading further in the current phase of active instability

- Plants provide useful products such as fruits, fodder, fire wood and timber

2.4. WHERE CAN BIO-ENGINEERING BE USED?

Bio-engineering techniques for stabilizing slopes should be used on:

- All areas of bare soil on embankment and cut-face slopes;
- Wherever there is a risk of gullying;
- All slopes where there is a risk of shallow slumps or planar slips;
- Any slope segment in which civil engineering structures are planned or have been built and the surface remains bare;
- Any area that has failed and needs to be restored, other than rock slopes;
- Any area such as tipping and quarry sites or camp compounds that requires rehabilitation.

As with all engineering works, it is important that the techniques selected are correct for the site to be treated and that the work is carried out with all due care and attention.

2.5. WHEN IS BIO-ENGINEERING DONE?

Bio-engineering works are planned in the same way as other works, following the annual pattern of planning, budget estimation and submission of detailed site assessment, estimation and implementation. However, some differences exist: the timing to establish and maintain bio-engineering nurseries, for example, is controlled by seasons (***See Annual Calendar of Bio-engineering work, Chapter 5.2***).

2.6. INTEGRATION OF CIVIL ENGINEERING AND VEGETATIVE STRUCTURES

Stabilising a slope can be done, using

- civil engineering work, on its own;
- vegetative engineering work alone;
- a combination of the two.

This guideline is prepared with the underlying assumption that a combination of both normally offers the most optimum solution to the variety of instability problems affecting a site. Engineers and technicians need to understand the principles governing the relationship between vegetative engineering systems and civil engineering systems.

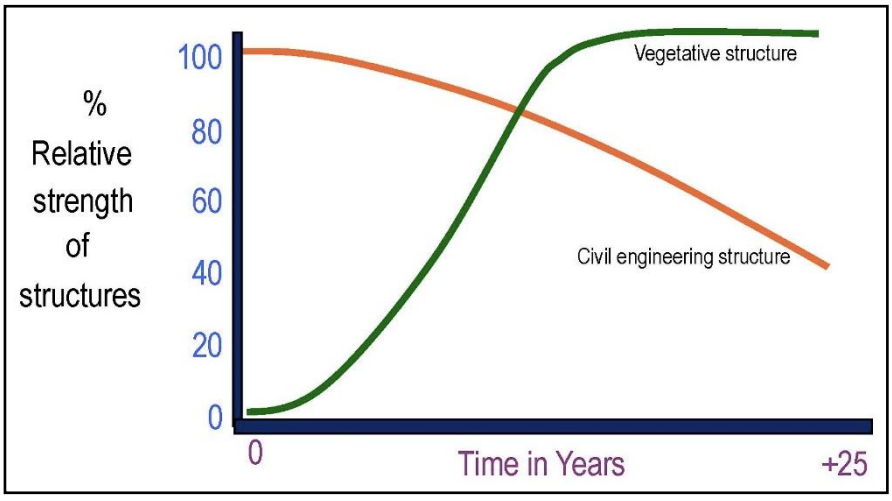


Fig 2: Relative strength of works over time

The strength of a structure at various stages of its life can be related to its maximum strength. Figure 2 shows the difference between bio-engineering and civil engineering structures: vegetative structure takes a few years to reach maximum strength.

Over time the relative strength of civil engineering structures decreases, while that of plant structures increases. Note that these graphs relate to the performance of each type of structure separately and they do not compare the actual strength of civil engineering structures with the strength of vegetative engineering structures.

An example on a micro scale is shown in Figure 3. Coir net and grass can both be used to perform a catching function. In the beginning, fine soil retaining capacity of the coir net is very high and each small square behaves as mini check-dam. With time, the coir decays which weakens the net and consequently its' soil retaining capacity decreases. Eventually the net will fail to carry out any retaining function at all. In contrast, grass slips are not immediately very effective, but their capacity to retain soil increases as the plants grow and their root and shoot systems develop.

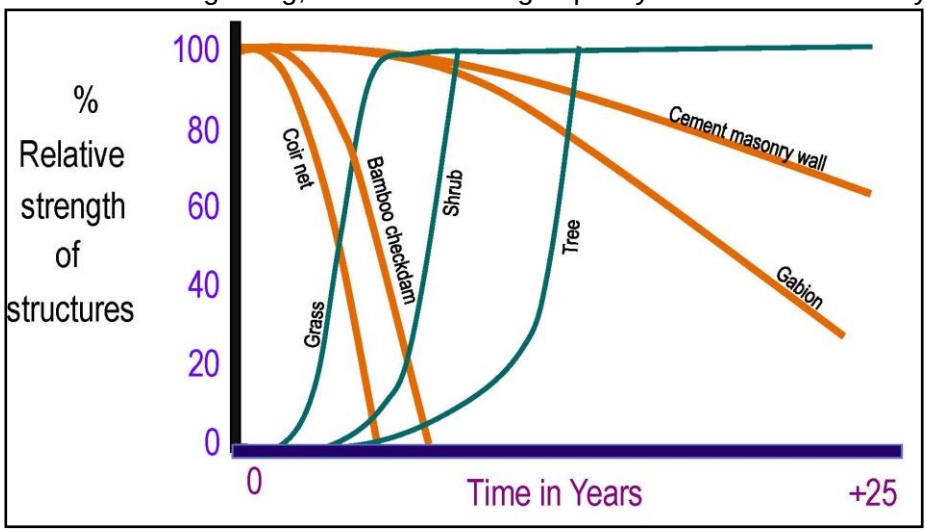


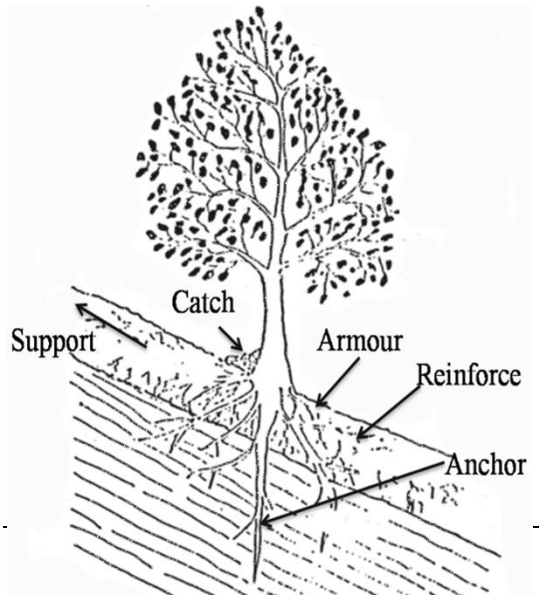
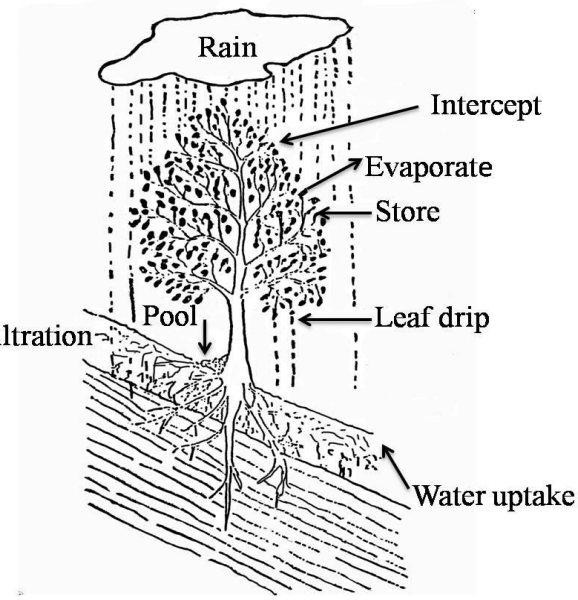
Fig 3: Relative strength of different types of vegetative works

When grass is fully grown, it remains at about 100 percent relative strength. As the relative strength of the coir net declines, the relative strength of the grass increases. The soil retaining function of the coir net is handed over to the grass (*See Figure 3*).

Relationships between the functions of civil and vegetative engineering structures are:

- Structure protects plant;
- Plant protects structure;
- Plant enhances performance of structure;
- Plant replaces structure.

2.7. MECHANICAL AND HYDROLOGICAL FUNCTIONS OF PLANT ON SLOPE

Mechanical effects	Hydrological Effects
	

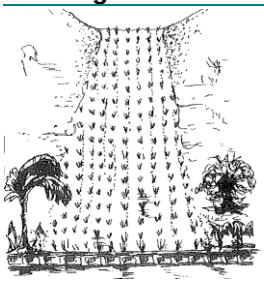
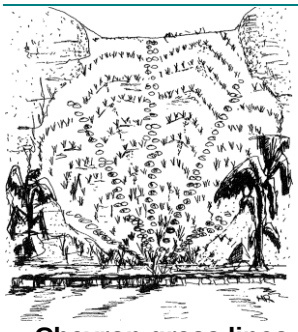
3. BIO-ENGINEERING TECHNIQUES FOR SLOPE STABILIZATION

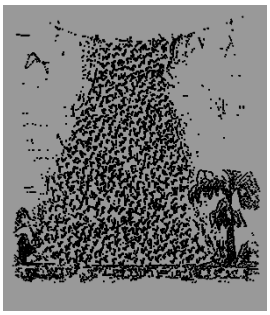
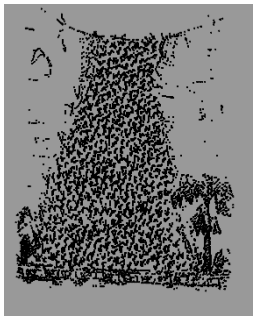
There are numerous techniques of bio-engineering, and variations on those techniques. Although many systems have been introduced and tested, only those listed below have been found to be consistently successful.

3.1. BIO-ENGINEERING TECHNIQUES FOR SLOPE STABILIZATION

Grass Planting Systems	
Planted grass line	Grass slips are planted in lines on a slope. The lines can be either on the contour (horizontal), down slope (vertical), diagonal or chevron; all four give specific advantages in different locations.
Grass seeding	Grass seed is spread over a surface to give complete surface armouring. It is often covered with mulch to aid establishment.
Sodding/Turfing	A surface is covered with sods of turf brought from elsewhere. This gives complete and instant surface armouring.
Large Plant Systems	
Shrub and tree planting	Seedlings of shrubs and trees are planted at intervals throughout a site. This is only feasible on less steep slopes. They grow to reinforce, catch, anchor support to the slope.
Shrub and tree seeding	The seeds of shrubs and trees are inserted into cracks on steep, rocky slopes. They can also be broadcast over a site. They grow to reinforce and anchor the slope.
Large bamboo planting	Large clumping bamboos are planted on a site. The clumps provide reinforcement and support to the slope.
Vegetation Structures	
Brush layering	Woody or hardwood cuttings are laid in trenches across a slope, usually following the contour. These form strong barrier to prevent the development of rills and trap materials moving down the slope and reinforce the slope as they grow.
Palisades	Woody or hardwood cuttings are planted in line across a slope, usually following the contour. These form a barrier and trap material moving down the slope and reinforce the slope as they grow.
Live check-dams	Woody or hardwood cutting are built to form a live check-dam. They reinforce gullies and trap material moving downwards.
Fascines	Bundles of live branches are laid in trenches across a slope, usually following the contour. Once grown, these form a strong barrier to prevent the development of rills and trap material moving down the slope.
Related Small Physical Measures	
Wire bolster	These usually take the form of a gabion tube 30 cm in diameter. They are laid into trenches across the slope usually following the contour. These form strong barrier to prevent the development of rills and support to top 30 cm of debris.
Sub-soil drain	Sub-soil drains are usually installed in the slope to remove ground water quickly and efficiently up to safe location. It protects the slope from liquefaction and debris slide up to the depth of 2 meters.
Jute/Coir netting	A network of woven jute or coir netting placed on the slope. It protects the surface and improves the slope surface for plants and acts as a mulch.

3.2. COMPARISON OF GRASS PLANTING SYSTEMS

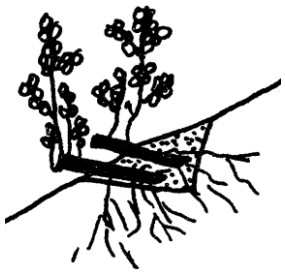
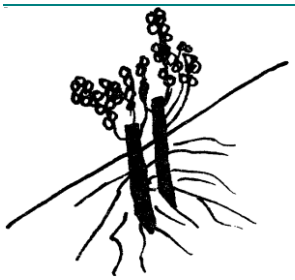
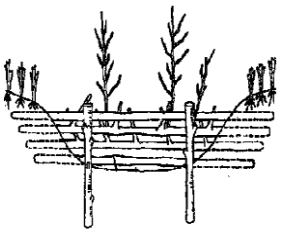
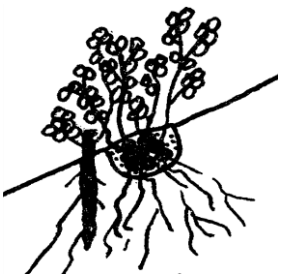
Configuration	Critical slope	Normal spacing	Advantages	Limitations
 **Horizontal/contour grass lines**	Planting of grass slips in geometric lines across the slope or along the contour. Slopes ≤ 65°	Plants at 100 mm centres within rows. Row spacing: Slope <30°: 700 -100 mm Slope 30-45°: 500 mm Slope >45°: 300 mm	Traps material moving down slope. Holds runoff on highly impermeable materials	Can increase the infiltration rate on slope and liquefy the porous materials.
 **Downslope/vertical grass lines**	Planting grass slips in geometric lines down the slope or towards drainage lines. Slopes ≤ 65°	Plants at 100 mm centres within rows. Row spacing: Slope 30-45°: 500 mm Slope >45°: 300 mm	Maximizes surface drainage while protecting against erosion. Minimizes infiltration	On very impermeable materials, runoff can be damaging. Planted grass can suffer from drought.
 **Diagonal grass lines**	Planting grass slips in geometric lines diagonally across the slope usually at 45° to the contour. Slopes ≤ 65°	Plants at 100 mm centres within rows. Row spacing: Slope 30-45°: 500 mm Slope >45°: 300 mm	Appears to combine the features of both horizontal and vertical planting in majority of sites.	Where specific advantages of horizontal and vertical planting patterns are critical, diagonal planting should not be used.
 **Chevron grass lines**	Planting grass slips in lines towards drainage lines at 45° to the contour. Slopes ≤ 65°	Plants at 100 mm centres within rows. Row spacing: Slope 30-45°: 500 mm Slope >45°: 300 mm	Enhances surface drainage and minimises infiltration.	Cumulative surface water needs to provide safe discharge.

Configuration	Critical slope	Normal spacing	Advantages	Limitations
 **Grass seeding**	Grass seeds spread evenly over the surface and usually covered with mulch. Slopes ≤ 65°	Most species require a seeding rate of 35 grams/m². Mulch, if applied should be at a 0.05 m³ mulch/m²	Can be used to create an even cover over all surfaces.	None of the structural advantages of grass slip planting. Plants take longer to develop from seeds than from slips.
 **Sodding/Turfing**	Turf cut from elsewhere is placed on the surface and pegged if necessary. Slope ≤35°	Requires an equal area of turf cut for the surface to be treated. Pegging should be at 250 mm centres on slope >15°	Instant surface cover	Relatively costly. Creates equal bare areas at the source of the turf. There is discontinuity between the turf and the under-lying material.

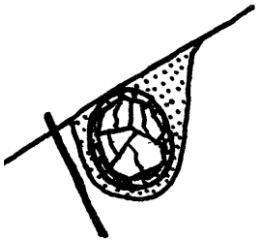
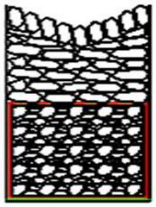
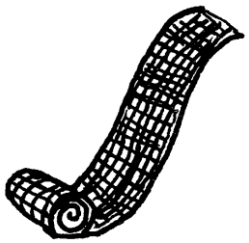
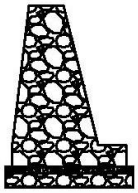
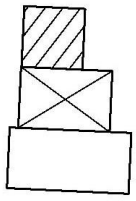
3.3. COMPARISON OF LARGE PLANT SYSTEMS

Configuration	Critical slope	Normal spacing	Advantages	Limitations
 **Shrub and tree planting**	Seedlings of shrubs and trees are planted on a geometric pattern. Slope ≤ 35° Slope 35-45° with care	Plants spaced at 2000 mm centres in off-set rows. Rows 2000 mm apart.	Establishes plantation of larger plants effectively which contributes to the reinforcement, support and anchoring of the slope.	Seedlings take about 5 years to contribute significantly to slope strengthening. Care and protection required in first three years.
 **Direct sowing shrub and tree seed**	Direct sowing of shrub and tree seeds on any slopes. Direct seeding: Slopes 35-80° Broadcasting: Slopes ≤ 50°	Direct sow at 50 to 100 mm centres, as conditions dictate. Broadcasting rate depends on seed weight.	Establishes a cover of larger plants on any slope however rocky. These provide good reinforcement and anchorage.	Seedlings take about 5 years to contribute significantly to slope strengthening. Protection required in early years.
 **Bamboo planting**	Large clumping bamboos are planted, usually near the base slopes. Slope ≤ 35°	Individual plants spaced at 2000-3000 mm intervals in a single row or in off-set rows. Rows 2000 mm part.	Establishes a very strong line of plants which provide the best reinforcement, trapping and support at the base of a slope.	Bamboos take about 5 years to contribute significantly to slope strengthening. Protection required in early years. Not in hot and dry sites.

3.4. COMPARISON OF VEGETATION STRUCTURES

Configuration	Critical slope	Normal spacing	Advantages	Limitations
 **Brush layering**	Lines of woody cuttings lay in trenches. The tops protrude above the surface. Slope ≤ 45°	Cuttings laid in row at spacing of 50 mm centre (*i.e.,* 21 cuttings/running meters). Row/Layer spacing: Slope <30°: 2000-4000 mm Slope 30-45° 1500-2000 mm	A strong and low-cost barrier to trap material and reinforce the slope; especially useful on debris slopes however loose.	Construction gives rise to considerable level of disturbance to the slope.
 **Palisade**	Lines of woody cuttings inserted in the ground. The tops protrude above the surface. Slope ≤ 60°	Cuttings planted in row at spacing of 50 mm centre (*i.e.,* 21 cuttings/running meters). Row/Layer spacing: Slope <30°: 2000-4000 mm Slope 30-45° 1500-2000 mm	Provides strong and low-cost barrier to trap material and reinforce the soil, with minimum disturbance to the slope.	Not as strong and effective as brush layering
 **Live checkdam**	Flexible checkdam made from a variety of woody cuttings Gully slope ≤ 45°	Spacing depends on gully condition. But they should normally be at 2000 mm to 4000 mm centres.	An effective low-cost structure to reduce erosion in smaller gullies. Can also be used in between masonry check dams.	Large and very active gullies require stronger measures than can be provided by vegetation.
 **Fascine**	Bundles of live woody cuttings are laid in trenches just below the surface. Slope ≤ 45°	Cutting planted @4 running meter of cutting per running meter. Fascines spacing: Slope <30° 3000 mm Slope 30-45° 2000 mm	A strong and low-cost barrier to trap material and support and reinforce the slope, useful on a wide variety of sites.	Construction gives rise to disturbance to the slope.

3.5. COMPARISON OF RELATED CIVIL ENGINEERING STRUCTURES

Configuration	Critical slope	Normal spacing	Advantages	Limitations
 **Wire bolster**	A 300 mm diameter gabion tube, laid in a trench, with the top flush with surface. Slope ≤ 45°	Spacing depends on site condition. Normal spacing: Slope <35°: 4000 mm Slope 35-45°: 2000 mm	Strong and long-lasting method of supporting and reinforcing a slope surface and preventing gully development on slope.	Construction gives rise to disturbance to the slope and relatively expensive.
 **Sub-soil drain**	500 mm wide and 1000 to 1500 mm trench fill with filter materials. Slope ≤ 45°	Spacing depends on site condition. Normal spacing: Main drain: 10 meters apart. Herringbone drain: 5 meters apart.	Very effective to remove ground water quickly and efficiently from slope.	Construction gives rise to disturbance to the slope and relatively expensive.
 **Jute or Coir netting**	Temporary surface cover to aid grass establishment on very steep slopes. Slope ≥ 50°	Complete cover of standard netting with 40 x 40 mm mesh of 5 to 8 mm yarn. Anchoring pegs at 500 to 1000 mm centres.	Very effective aid to the establishment of a permanent grass cover on hard, dry materials on steep cut slope.	As it forms mulch, it raises the moisture content of soil if the material has poor internal drainage which can lead to liquefaction.
 **Stone soling/Rip-rap on rill**	Slope ≤ 45° with rill erosion. Size of the rill and ridge depends on site condition.	Spacing depends on site condition.	Very effective to provide safe drainage of surface water from the slope	Construction causes disturbance on the slope.
 **Cement masonry retaining wall/chechdam**	Retaining wall: Up to 40° slope at the base of slope. In some cases, it may be erected at middle of slope, instead of at toe. Check-dam: In gully.	-	Retaining wall: retains the slope by supporting slope. Check-dam: protects gully floor and catch the debris moving through gully.	Construction causes disturbance on the slope.
 **Gabion retaining wall/checheckdam**	Retaining wall: Up to 40° slope at the base of slope. In some cases, it may be erected at middle of slope. Check-dam: In gully.	-	Retaining wall: retains the slope by supporting slope. Check-dam: protects gully floor and catch the debris moving through gully.	Construction causes disturbance on the slope.

4. SELECTION OF BIO-ENGINEERING TECHNIQUES

Where slope tends to be long and steep, and the climatic variables are poorly understood, it is necessary to make broad assumptions on the factors relating to slope stability. Attaining a desired factor of safety may not be economically feasible.

With such wide variety of materials and sites, choosing stabilization techniques is a complicated process. There are many variables, most of which cannot be practically measured in the field. Therefore, it is not possible to set quantitative limits on many of the parameters. This section gives a practical analysis to reach an optimum course of action.

Bio-engineering serves two distinct roles:

I. Providing *additional techniques for stabilising shallow failures and controlling erosion*; and
II. *Enhancing civil engineering structures* by protecting them and maximising their effectiveness.

In both roles, bio-engineering techniques must be carefully integrated with civil engineering structures.

Every slope has a different type of erosion and failure processes and often there will be more than one processes affecting each part of a slope. Freshly cut or just failed slopes are usually subject to erosion and all slopes need to be covered, and thus be stabilised immediately. Erosion and failure processes must be identified before remedial work can be started. Example of the most common problems are given in the table below:

Description	Depth	Mechanism	Function required
Top soil erosion, gradually wearing off.	Top 0.1 metre.	Sheet and surface erosion	Armour
Removal of soil by running water with formation of shallow channels that can be smoothed out completely by normal tillage.	<0.5 metre channel.	Rill erosion	Catch Armour
A channel with steep sides caused by erosion and cut in unconsolidated materials by concentrated but intermittent flow of water usually during and immediately following heavy rains.	>0.5 metre channel	Gully erosion	Catch Armour Reinforce
Mass slope failure on a shallow slip plane parallel to the surface. This is the most common type of landslide, slip or debris fall. The plane of failure is usually visible but may not be straight, depending on site conditions. It may occur on any scale.	Frequently 0.5 metres or less below surface or along a local discontinuity	Translational landslide or debris slide	Reinforce Catch Anchor Drain
Mass slope failure on a deep, curved slip plane. Many small, deep landslides are the result of this process. Large areas of subsidence may also be due to these.	>1.5 metres deep.	Rotational landslide	Support Reinforce Anchor Drain
Slumping or flow where material is poorly drained or has low cohesion between particles and liquefaction is reached. These sometimes look similar to planar slides, but are due to flow rather than sliding. The resulting debris normally has a rounded profile.	Frequently 0.5 metres or less below surface.	Slumping or flow of material when very wet.	Drain Reinforce

Description	Depth	Mechanism	Function required
Collapse due to failure of the supporting material. This usually takes the form of a rock fall where a weaker band of material has eroded to undermine a harder band below.	0.5 to 2 metres in road cuts; deeper in natural cliffs.	Debris fall or collapse.	Reinforce Support

4.1. STEP 1: SITE ASSESSMENT PROCEDURE

There are assessment procedures to determine the remedial treatment of sites. Each site has a different type of erosion and failure processes, which must be carefully examined and identified for effective solution before remedial work is started. This procedure will help to map an unstable site and determine the remedial treatment of site. The procedure is given in logical order to obtain an important feature of site. The column on the right suggests the action to be taken.

SITE ASSESSMENT PROCEDURE STAGES		ACTION
Stage 1	**Observe the site** ▪ Look at the general locality and situation of the site; ▪ Location of slide: Location above the canal, below the canal.	Observe and note
2	**Examine erosion and failure process** ▪ Surface erosion, such as sheet, rill and gully; ▪ Planar sliding, on a shallow slip plane parallel to the surface (translational landslide); ▪ Shear failure, on a deep, curved slip plane (rotational landslide); ▪ Slumping of material when very wet, low particle cohesion; ▪ Falling of debris due to failure of the supporting material. ▪ Debris flow following intensive rain storms.	Describe
3	**Examine causes of failure** ▪ Surface water causes sheet, rill and gully erosion; ▪ Ground water causes slumping, piping, translational and rotational slide; ▪ Undercutting causes translational and rotational slide; ▪ Weathering causes plane, wedge failure and toppling; ▪ Addition of weight causes slumping, debris flow.	Describe
4	**Examine depth of failure** ▪ Less than 25 mm; ▪ 25-100 mm; ▪ 100-250 mm; ▪ 250-1000 mm; ▪ More than 1000 mm.	Describe
5	**Examine the material formation of slope** ▪ Debris (Alluvium or colluviums); ▪ Soft rock; ▪ Hard rock; ▪ Alternating hard and soft rocks. All of these could be present on one landslide. The drawing should show where they are.	Describe and draw

SITE ASSESSMENT PROCEDURE STAGES		ACTION
6	**Examine the rock orientation, weathering grade and degree of fracture** Visit each rock outcrop. Measure any relevant rock planes; observe how the planes relate to the slope and failure planes. Make sure that the rock observed are true outcrops and not simply large boulders partly buried on the slope. Check the weathering grade and degree of fracture of rock. Note following: ▪ Bedding of the rock; ▪ Degree of weathering of the rock; ▪ Degree of fracture of the rock.	Measure and describe
7	**Draw plan and profile of site** ▪ Draw a plan of site with the help of a clino-compass or freehand sketch; ▪ Measure and record slope length and breadth; ▪ Draw slope profile and measure and record slope length and angle. Completed drawing should be well illustrated and labelled to let another person recognize which zones are present and where: ▪ Crack zone; ▪ Scar or failure zone; ▪ Transportation zone; ▪ Deposition zone.	Draw, measure and note
8	**Divide the slope into the segment** After the main failure of site, there may be different types of erosion on slope due to the material formation of slope, water movement behaviours on slope and steepness of slope. Thus, carefully divide the site into the segments on the basis of material formation of slope, slope angle and water movement behaviour on slope.	Draw and describe
9	**Examine the causes and mechanism of failure of <u>each</u> segment** ▪ Surface water causes sheet, rill and gully erosion; ▪ Ground water causes slumping, piping, translational and rotational slide; ▪ Undercutting causes translational and rotational slide; ▪ Weathering causes plane, wedge failure and toppling; ▪ Addition of weight causes slumping, debris flow.	Describe
10	**Examine material drainage of site or site moisture** ▪ **Drainage** – Well or good drain; – Poor drain. ▪ **Moisture** – Wet: permanently damp sites; – Moist: sites that are reasonably well shaded or moist for some other reason; – Dry: generally dry sties; – Very dry: sites that are very dry which are usually quite hot as well.	Describe Describe

SITE ASSESSMENT PROCEDURE STAGES		ACTION
11	**Examine the history of slide** – Has not moved within the last 5 years; – Has moved this year for the first time; – Has moved within the last 5 years but not this year; – Moves every year by initial mechanism - diminishing; – Moves every year by initial mechanism - constant or getting worse.	Describe
12	**Examine the life progression of slide** Assess the likely evaluation of the slide from its current condition into the future. Possibilities are as follow: – Stable slope formed, or will stabilise naturally; – Further movement expected, by less serious mechanism (post-slide adjustment); – Repeated movement expected, by initial mechanism or another equally serious one.	Describe
13	**Determine required engineering functions to stabilize the site** ▪ Catch; ▪ Armour; ▪ Reinforce; ▪ Anchor; ▪ Support; ▪ Drain.	Describe
14	**Look for the altitude and aspect of the site**	Note
15	**Look for annual rainfall of site or region**	Note
16	**Look for land use pattern** – Barren land, dry cultivation, wet cultivation, community forest, national forest, private forest or grazing land.	Describe
17	**Existing structures if any**	Draw and describe
18	**Surrounding vegetation** – Trees; – Shrubs; – Grasses.	Note

Once there is enough information of site from a straightforward site investigation, decisions can be taken.

4.2. STEP 2: ASSESSING THE REQUIREMENT OF CIVIL ENGINEERING TREATMENTS

At this stage, standard civil engineering structures (retaining, breast, revetment, prop, check-dam, surface and sub-surface drainage) should be considered. The series of questions in the table below helps to simplify the process of assessing the requirements for major civil engineering treatments;

Question	If answer is "YES"
Is the slope segment or the whole site subject to a deep-seated (>1 meter depth) shear (rotational) failure?	Use retaining walls to support the toe. Alternatively, it may be possible to remove weight from higher up on the slope by heavy trimming.
Is the slope segment very long (greater than 30 meters), steep and in danger of a mass failure below the surface?	If suitable foundations are available, use retaining walls to break the slope into smaller, more stable length. Some other kind of physical scour check should be used, such as wire bolster cylinder.
Is the foot of the slope undermined, threatening upper segments or the whole slope above?	Use revetment, toe or prop walls as per the necessity of site.
Is there a distinct overhang or are there large boulders poorly supported by a soft eroding band?	Use prop or dentition to support the overhanging.
Does the slope segment have a rough surface, or is it covered in loose debris; or is it a fractured rocky slope or does it have any very steep or overhanging sections, however small?	Trim the slope as far as possible to attain a smooth, clean surface with straight profile in cross-section.
Is there seepage, a spring or groundwater on the site or a danger of mass slumping after heavy rain?	Use sub-surface drains for safe drainage of water from slope.
Is the slope made up of poorly drained material, with high clay content?	Use surface drains for safe drainage of water.
Is the site a major gully, subject to occasional erosive torrents of water?	Use check dams to reduce the scouring effect.

4.3. STEP 3: SELECT THE BIO-ENGINEERING TECHNIQUES

Once the civil engineering structures are decided, any deeper-seated problems will have been addressed by civil engineering measures, such as retaining walls, check dams and drainage system. This step gives details of bio-engineering and other related techniques for protecting the surface, stabilizing the upper 500 mm and improving surface drainage; and for enhancing and protecting large civil engineering structures. These are required as part of the whole stabilization package; bio-engineering must be fully integrated with any civil engineering structures.

The flowchart below suggests appropriate techniques for different slope segments. It is assumed that these are combined with appropriate civil engineering structures where necessary to enhance slope stability. Many factors determine the optimum technique or combination of techniques but only the most important have been included here.

SELECTION OF BIO-ENGINEERING TECHNIQUES

Start → Slope Angle	→ Slope Length	→ Material Drainage	→ Site Moisture	→ Previous/ Potential Problems	→ Functions Required	Technique(S)
> 45°	> 15 meters	Good	Damp	Erosion, slumping	Armour, reinforce, drain	▪ Diagonal grass lines
			Dry	Erosion	Armour, reinforce	▪ Contour grass lines
		Poor	Damp	Slumping, erosion	Drain, armour, reinforce	▪ Rill and ridge formation and stone pitching on rills, chevron grass lines,
			Dry	Erosion, slumping	Armour, reinforce, drain	▪ Diagonal grass lines
	< 15 meters	Good	Any	Erosion	Armour, reinforce	▪ Diagonal grass lines or ▪ Jute/coir netting and randomly planted grass
		Poor	Damp	Slumping, erosion	Drain, armour, reinforce	▪ Down slope grass lines or ▪ Diagonal grass lines or ▪ Rill and ridge formation and stone pitching on rills, chevron grass lines,
			Dry	Erosion, slumping	Armour, reinforce, drain	▪ Jute/coir netting and randomly planted grass or ▪ Contour grass lines or ▪ Diagonal grass lines
30°-45°	> 15 meters	Good	Any	Erosion	Armour, reinforce, catch	▪ Horizontal bolster cylinders and shrub planting ▪ Diagonal/Contour grass lines and vegetated stone pitched rills or ▪ Site grass seeding, mulch and wide mesh jute/coir netting.

SELECTION OF BIO-ENGINEERING TECHNIQUES

Start Slope Angle	Slope Length	Material Drainage	Site Moisture	Previous/ Potential Problems	Functions Required	Technique(S)
30°-45°		Poor	Any	Slumping, erosion	Drain, armour, reinforce	▪ Herringbone sub-soil drain and diagonal grass lines, shrub planting or ▪ Herringbone sub-soil drain and shrub planting grass seeding, mulch
	< 15 meters	Good	Any	Erosion	Armour, reinforce, catch	▪ Brush layer of hardwood cuttings or ▪ Contour grass lines or ▪ Contour fascines or ▪ Palisade of hardwood cuttings ▪ Grass seeding and cover with mulch.
		Poor	Any	Slumping, erosion	Drain, armour, reinforce	▪ Herringbone sub-soil drain and diagonal grass lines, brush layer, or shrub planting and grass seeding and cover with mulch or ▪ Herringbone fascines and shrub planting and grass planting or seeding with mulch
<30°	Any	Good	Any	Erosion	Armour, catch	▪ Site seeding of grass and shrub/tree planting or ▪ Shrub/tree planting
		Poor	Any	Slumping, erosion	Drain, armour, catch	▪ Herringbone sub-soil drain, diagonal grass lines and shrub/tree planting or ▪ Herringbone sub-soil drain, shrub/tree planting and grass seeding with mulch
	< 15 meters	Any		Erosion	Armour, catch	▪ Sodding and shrub/tree planting

SELECTION OF BIO-ENGINEERING TECHNIQUES

Start → Slope Angle	→ Slope Length	→ Material Drainage	→ Site Moisture	→ Previous/ Potential Problems	→ Functions Required	Technique(S)
	Base of any slope			Planar sliding or shear failure	Support, anchor, catch	▪ Large bamboo planting or ▪ Large tree planting
Gullies ≤45°	**Any gully**			Erosion	Catch, armour, reinforce	▪ Large bamboo planting or ▪ Live check dam or ▪ Vegetated stone pitching
Special conditions						
>30°	Any	Any rocky material		Debris fall	Reinforce, anchor	▪ Site seeding of shrubs/small trees
Any loose sand		Good	Any	Erosion	Armour	▪ Jute/coir netting and randomly planted grass
Any red soil		Poor	Any	Erosion, slumping	Armour, drain	▪ Rill and ridge formation and stone pitching on rills, diagonal/chevron grass lines, shrubs/trees planting

5. PLANT SELECTION AND PRODUCTION

5.1. PLANT SELECTION

It is important to select the right species of plant for use in each bio-engineering technique. While selecting plant species, there are four factors to consider: technique, function, propagation method, and site suitability.

5.1.1. Technique and function, and propagation method

Through the previous assessment of site, techniques and functions required for each slope segment has been determined and now the plants needed should be identified. The most appropriate category of plant and its method of propagation depends on the selected techniques. These factors are summarised in the table below.

Technique	Functions	Plant Category	Propagation Methods
Planted grass lines in all configurations	Armour, catch and reinforce	Grasses	Slip/rhizome/stem cutting
Site seeding with grass	Armour, catch and reinforce	Grass	Seeds
Sodding/Turfing	Armour	Small grasses	Small sward grasses
Brush layer, palisade, live check dam, fascine	Catch, reinforce	Shrubs and small trees	Hardwood cuttings
Shrubs/small tree planting	Reinforce, catch	Shrub/small tree	Seeds
Site seeding with shrubs/small trees	Reinforce, catch, anchor	Shrub/small tree	Seeds
Large tree planting	Support, anchor, reinforce	Large tree	seeds
Large bamboo planting	Support, catch, reinforce	Large bamboo	Rhizome cuttings
Small bamboo planting	Catch, reinforce	Small bamboo	Rhizome cuttings

5.1.2. Site Suitability

Whatever the function and propagation method required of plants by the bio-engineering technique, the plants selected must be able to grow in the site being treated. The suitability of each species to their growing in the site is affected by temperature which is related to altitude and moisture (wet, moist, dry and very dry) that should be considered while selecting plant species.

5.1.3. Selection

Plant species should be selected according to technique, category, propagation method and site conditions using the table in **Annex A**. However, this is not limited.

5.2. ANNUAL CALENDAR OF BIO-ENGINEERING WORKS

FISCAL YEAR	FIRST YEAR												2ND YEAR	
Months	SRAWAN	BHADRA	ASWIN	KARTIK	MANGSIR	POUSH	MAGH	FALGUN	CHAITRA	BAISAKH	JESTHA	ASHAD	SRAWAN	BHADRA
Activity	AUG.	SEP.	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Make initial work plan of year														
Prioritise the works														
Assess the site														
Determine and design civil engineering works														
Choose the right vegetative structures														
Select the species to use and quantify plant needs														
Finalise priority against available budget														
Arrange implementation and prepare documents														
Prepare for plant propagation														
Make necessary site arrangements														
Prepare the site for work														
Implement the civil engineering works and slope preparation														
Implement the vegetative works											±			
Maintain the works														

± *Depending on monsoon rain*

5.3. PLANT PRODUCTION IN NURSERY

Bio-engineering programmes require a large number of healthy plants of the right species in different forms within a short span of time. In most cases, it is necessary to raise plants in nurseries in order to have adequate high-quality stock.

The function of a plant nursery is:

- to supply enough plants of the right species;
- to have plants in good, healthy condition, in the right form required for planting;
- to have plants at the right time;
- to have plants at a reasonable cost.

In certain cases, it is possible to obtain grass and hardwood cuttings from river beds without causing damage.

Main Methods of Plant Production in Bio-engineering Nurseries

Plant Category	Planted in the Nursery as	Planted on Site as
Grass	Cutting (slips/rhizomes/stem) Seeds ‘	Cutting (slips/rhizomes/stem) Seeds
Shrubs and trees	Seeds Cuttings	Seedlings Cuttings Seeds
Bamboo	Single node cuttings	Rooted single node cutting Rhizome

5.4. NURSERY BED CONSTRUCTION DETAILS FOR PLANT PROPAGATION

5.4.1 Grass slip beds

Grass slips are very strong and resistant; hence, it does not require much care during the construction of beds for grass slip multiplication as for most other nursery plants. However, the soil should be fertile and either a loam or sandy loam in texture. Following procedure should be used for making the beds:

1) Cultivate the original ground throughout the area and heap the soil into mounds to form beds. Mark out the beds using line string and shape the mounds. Cut pathways between the beds and heap the soil on the beds, so they are well drained.
2) If the soil has a high clay content, add sand to make it into a loam or sandy loam soil.
3) If the soil is not very fertile, lay 15 cm of forest soil and washed sand, in a 3:1 ratio, on top of the bed.
4) Once the bed is shaped off, it should be no more than 30 cm high and no more than 100-120 cm wide at the top.

5.4.2 Grass seedling beds

Grass seedlings produced in the nursery are raised in 25 cm high beds made as follows:

1) Compact and flatten the original ground, leaving a slight camber to facilitate drainage.
2) Lay 5 cm of washed gravel on the compacted ground.
3) Follow this by 5 cm of compost and forest soil mixed in a 1:1 ratio.

4) Finally lay 15 cm of forest soil and washed sand, in a 3:1 ratio, and flatten the bed off. The bed should be no more than 120 cm wide at the top.

5.4.3 Beds for sowing tree and shrub seeds

These need to be made most carefully, as the seeds are often very small and young seedlings can be extremely tender. Seed sowing beds should be a minimum of 15 cm high and 100 cm wide. Make the bed up with the following layers from bottom to top:

1) 5 cm of washed gravel to facilitate drainage;
2) 5 cm of un-sieved forest soil;
3) 5 cm of a 1:3 mix of sieved forest soil and washed medium fine sand;
4) 1 - 3 cm layer of washed sieved and sterilised sand.

Cover the bed using a shade made from bamboo slats and plastic sheeting. It should be between 80 and 100 cm high. Surround the bed with an edging of bricks, bamboo or stone.

5.4.4 Standout beds for poly-pots

Standout beds are prepared for plants that are raised in poly-pots. Make the beds 100 cm wide and as long as it is convenient. Build a frame 15 cm high made of bricks, stone or bamboo to support and protect the seedlings. Compact the original ground well and place a 5 cm thick layer of gravel on the soil to facilitate drainage. Place shades made from bamboo slatted covers that can easily be rolled up 100 - 120 cm above the beds.

5.4.5 Beds for bare root seedlings and stumps

Some species of tree are raised as bare root seedlings or stumps because they grow more quickly, develop better rooting systems after planting, are easier and cheaper to transport to site and are cheaper to raise than containerised seedlings. They require different forms of management and care which must be provided if this type of production is to be successful.

Prepare beds as follows:

1) Compact the original ground, leaving a slight camber to allow for drainage; if available, bamboo sheaths placed on the ground are useful to prevent roots growing into the original ground.
2) Place 2 - 5 cm of washed gravel as a drainage layer.
3) Prepare a mixture of forest soil, fine compost (or *gobar*) and sand in a 2:1:1 ratio and put a 20 cm thick layer on top of the gravel.
4) Place a 1:1 ratio of sieved soil and washed fine sand in a 20 cm thick layer on top.
5) After the seed has been broadcast, sprinkle on sand to the same thickness as the seed being sown.

After the seed is sown, cover the bed with hessian jute until the seed germinates. Erect bamboo shades 100 to 120 cm high with a bamboo slatted cover that can be rolled on or off. Gradually remove the shade over several weeks, exposing the plants to increasing amount of sun each day.

5.4.6 Beds for stool cuttings

Stool cuttings are made by growing seedlings, cutting off the top and roots and planting them. This is used with species such as *sisau*, *kimbu*, poplar and *rudrakshya*. It produces vigorous plants. Beds are generally prepared as follows:

1) Dig the soil to a depth of 30 cm; add a *doko* of compost for every 5 m² of bed to the soil and mixed it in well.

2) Mix forest soil and fine compost (or *gobar*) in a 2:1 ratio and place a layer 20 cm thick on top of the original dug material.

3) Add a mix of 1:1 ratio of sieved soil and washed fine sand in a 10 cm layer on top.

4) Use bamboo shades 100-120 cm high with a bamboo slatted rollable cover over the bed in the first weeks after planting the cuttings. Place the cuttings at 50 cm centres. Weed thoroughly and occasionally give a handful of compost to encourage growth. Take the first cuttings after the second monsoon growth.

5.4.7 Beds for bamboo culm cuttings

Bamboo culms must be kept very wet, therefore bunds and complete shade with hessian jute are important. Beds are prepared as follows:

1) Dig the original ground to a depth of 50 cm and lay 2 - 3 cm of gravel in the base. Mix the soil with forest soil in a ratio depending on the quality of the original soil.

2) Lay 10 cm of un-sieved forest soil on top of this.

3) Follow this by 20 cm of sieved forest soil on the top.

4) Bund the edges of the bed to help retain water.

5.5. CALCULATION OF NURSERY SIZE

The amount of land required depends upon the number of plants to be produced, the time they will spend in the nursery and the density at which they will stand in the beds as well as on the slope and quality of the site.

Before starting the calculation of area needed, it is useful to list the various components of the nursery that are required:

- seed beds (for bio-engineering nursery usually a total bed area 10 m²);
- grass beds (main grass plant growing area);
- standout beds (main shrubs/trees growing area);
- paths, working area, soil storage, compost bay;
- hut for tools and seed store.

The calculation for nursery size is based on the main plant growing area required. For example, a nursery is needed for following average annual production:

- 500,000 grass slips; and
- 18,000 shrubs/trees plants in 4” x 7” poly-pots

In this hypothetical example, the grasses and half of the shrubs/trees need less than one year but other half of the shrubs/trees in poly-pots require between one and two years in the nursery.

i) For 500,000 grass slips

Bed space is required for (500,000 / 5) = 100,000 slips to grow into slumps which will give a multiplication by five times when the plants are taken to site. The stand at 100 per m².

Space required = 100,000 / 100 =1,000 m²

ii) For 18,000 polypots of 4” x 7” size

Space is required for 22,500 (18,000 + 25%), with allowance for losses and culling. They stand at 128 nos. per m² when spaced out.

Space required = 22,500 / 128 = 176 m²

But half of these plants require twice as much space because they will be in the nursery for more than 12 months:

Space required = 176 + 176 / 2 = 264 m²

Total space required = 1000 + 264 = 1264 m²

This must be multiplied by 1.5 for an un-terraced nursery or by 3 for a terraced nursery, to allow space for all components of nursery. An un-terraced nursery would therefore need 1896 m² for the main plant growing area, and a terraced nursery 3792 m². In addition, space will be needed for seed bed for shrubs/trees (total bed area 10 m²).

6. MAINTENANCE OF BIO-ENGINEERING SITES

Bio-engineering sites must be maintained as any other irrigation structures. There are some particular needs of maintenance for bio-engineering sites, i.e., maintenance of vegetation. The reasons of the maintenance of vegetation are to derive the maximum benefits in terms of bio-engineering contribution, productivity and appearance. The maintenance tasks for vegetation are listed in the table below according to the intervention frequency. Civil engineering structures of bio-engineering sites must also be maintained according to normal practice of irrigation canal maintenance work.

Bio-engineering Maintenance Activities

Category	Description
A. Routine	
Protection of sites	Control of the use of sites by people and animals which might cause unacceptable damage to the vegetation.
Weeding	Removal of unwanted vegetation which is competing with the growth of desired plants.
Mulching	Mulch is made by cutting the stems and leaves of unwanted plants. It is placed around the seedlings to keep soil cool and moist thereby enhancing growth.
Grass cutting	Grasses are cut on an annual basis to encourage vigorous growth and development of new shoots.
B. Periodic	
Thinning and pruning of trees and shrubs	Thinning means removing selected trees and shrubs to decrease the density of plants. Pruning is the removal of lower branches. Both open out the canopy and allow ground cover plants to grow better.
Repair of vegetative structures	The repair of any form of bio-engineering treatment, mainly brush layer, fascines, live check dams, palisade and turfing.
Vegetation enrichment	Planting more grasses, trees, shrubs within a site area or in gaps within existing vegetation.
Removal of trees and shrubs	The removal of any unwanted large trees and shrubs from a site.

6.1. ROUTINE MAINTENANCE ACTIVITIES OF BIO-ENGINEERING

6.1.1. Protection of bio-engineering site

Why protection	People may cut grasses, shrubs or trees too much, or at the wrong time of the year which can stunt the growth and prevent plants from fulfilling their functions. If plants are cut before the seeds fall, there will be less natural regeneration, especially from grasses. However, at certain times, local people can be very helpful; this is especially the case if they will carry out the site protection themselves.

	Animals may eat small plants, prevent growth of shrubs and trees by browsing through them and damage the slope with their hooves. Animals are very difficult to control if they are allowed on to a site.
When to protect	▪ when plants are very small and vulnerable (usually in the first one or two years after planting); ▪ whenever there is a risk of significant damage by the local people or their animals.
How to protect slopes	Planted sites can be protected in one of three main ways: ▪ A watcher can be employed to watch the site. If this is done, s/he could also do mulching and other works, rather than just to walk around watching the site. This would need encouragement from the responsible person/s or agencies. ▪ Protection with fencing after planting can be made compulsory. ▪ An arrangement can be made with local people to protect the area. This is often the most long-lasting, but is also the hardest task to achieve. It can be done only if there is a clear incentive for the people involved, such as providing large quantities of fodder from the site. Whatever system is used, it is very important that both the areas to be protected and the duties to be performed are clearly defined. The concerned organization/authority must ensure that the people doing the protection really understand what is expected of them. Box below gives an example of duties that a site watcher is expected to perform.

Duties of Watchers to Protect Planted Sites or Areas

Site watchers should be active in a range of duties, including:

1. Watching all sites and ensuring that no domestic or wild animals graze the areas;
2. Explaining to local people the importance of protecting the areas; asking them to graze animals and to cut fodder and firewood well away from the site, and enforcing this as necessary;
3. Tending the plants and mulching the site carefully to promote and improve growth;
4. Cutting weeds in the adjoining canal reserve and forest areas to make mulch for the plants on the site;
5. Alerting the responsible person of any untoward events, such as damage to any of the site structures, blocking of canal, etc;
6. Helping to replace and enrich the bio-engineering planting during the rains;
7. At other times, carrying out minor repairs of up to 0.25 m^3 to physical structures on the slopes.

The watcher should be given the best possible support from the concerned organization/authority. Local watchers are often the most effective in reducing damage. This seems to be partly because they personally know everyone who uses the area.

6.1.2. Mulching

What is mulching	Mulching is the positioning of dead vegetation around seedlings to keep the soil cool and moist. Mulch is usually made by cutting up the stems and leaves of plants.
Why do mulching	Mulching is required in dry sites to improve the growth of plants less than three years old. By keeping the soil cool and moist, mulching increases the rate of growth. Plants grow quickly and their roots help to strengthen the slope. Where grass seeding has been done, mulching also protects delicate new grass plants from both scorch by hot sun and damage by rain splash.
When to mulch	Mulching is most needed when there is too much sun and too little water. This means any time during the dry season and early rains (i.e., from December to June), depending on the site. On dry sites, all new shrub and tree seedlings should be mulched directly after planting.
How to mulch	Mulch can be made from the stems and leaves of any plants. Collected material should be chopped: the maximum size is 150 mm. It can be stored until required, if necessary. If possible, mulch should be made from annual and perennial herbs, such as *Eupatorium adenophorum*. The greenery should be collected when there is most material available. This is most often in July and August. However, requirements always have to be assessed specifically and local sources should be checked. Straw and thatch grasses can also be used. Mulching grass seeded areas: Spread the mulch over the grass seeds in a layer approximately 40 mm thick (i.e., using 4 m^3 per 100 m^2 of slope surface). Mulching individual plants: Spread the mulch around the plant being treated in a layer 50 mm to 100 mm thick. A circle of radius 150 mm should be left next to the plant itself. Outside this, the mulch should form a circle of about 750 mm radius.
Which materials and tools should be used	Most mulching operations will require: ▪ a sickle for cutting the plants; ▪ a heavy knife for chopping the weeds into small pieces; ▪ a basket for transporting the mulch

6.1.3. Grass cutting

Why cut grasses	Cutting grasses encourages them to remain vigorous and to put out new shoots. It also allows better inspection of slopes and provides useful products.

When should grasses be cut	Grasses are cut once a year, after the seeds have fallen. This means that cutting must not take place before the beginning of *Magh* for most species. Grasses should be cut on all accessible bio-engineering sites. If the grass is used as fodder, it may be cut earlier. Grass cutting can take place any time during *Magh* and *Falgun*. If the grasses impede canal at other times, they should be cut immediately.
How should grasses be cut	Cut grasses about 150 mm above the ground, using a sickle. Care must be taken not to pull out the roots of the grass clump. Also, other plants must not be damaged; special care must be taken of small shrub and tree seedlings.
What are products from grass cutting	Any cut grass can be used for mulching the plants on the site. If not, it can be used for thatching, fodder, fibres, brooms or other uses, according to the species. For this, cutting time might vary to get good quality products. Care must be taken for the disposal of products grown on canal reserve land. Products from other land should normally be given to the land owner or community group responsible for the land.
Which materials and tools should be used	Most grass cutting operations will only require a sickle.

6.1.4. Watering

Why do watering	Watering can help enormously to improve the growth of plants on harsh sites during the later dry season (*Chaitra* to *Jestha*). If watering is done, mulching is normally done as well.
When should you water	Watering is done only in these situations: ▪ on all bamboos planted in dry sites; ▪ on critical sites, where good plant cover must be established before the start of the monsoon rains; or ▪ when water is easily available on site, such as from a nearby river or a spring; or ▪ when a dry period occurs soon after planting in early monsoon, and resources allow; or ▪ where a site watcher has no other duties and water is available close to the site. Watering is done on days without rain, normally during May to November, either in the morning or evening. It should not be done during the middle of the day when it is sunny as too much water would evaporate).
How to water	Water must be applied slowly and should be allowed to infiltrate, preferably using a sprinkler. It must not run off. If necessary, the ground can be lightly cultivated to increase infiltration. For shrub and tree seedlings, water can be poured into a small trench just up the slope. Watering rates: ▪ grass plants: 0.25 litres per plant per day;

	▪ shrub and tree seedlings: 5 litres per plant per day; ▪ bamboo plants: 10 litres per plant per day.
Which materials and tools should be used	If possible, water should be brought by pipe. Otherwise, it can be carried in buckets or watering cans.

6.2. PERIODIC MAINTENANCE ACTIVITIES OF BIO-ENGINEERING

6.2.1. Pruning and Thinning of Shrubs and Trees

What are pruning and thinning	Pruning is shortening the long branches of a tree or large shrub. Thinning means removing selected shrubs or trees to decrease the density of plants. In practice, this usually means removing about half the number of trees on the site. There are three forms of thinning: 1. pollarding: a tree is cut 2 to 3 metres above the ground and new shoots grow up; 2. coppicing: a tree is felled and new shoots come from the stump; 3. selection thinning: a tree is felled and the stump is allowed to die.
Why do pruning and thinning	To increase the light penetrating through the canopy. This will improve the plants growing on the ground underneath, especially shrubs and grasses, and reduce surface erosion.
When to prune and thin	When a plantation is dense and shrubs or trees have crowns that are touching. This may be about every five years, but every site should be inspected annually. Shrubs and trees are best pruned during winter (*Poush* to *Falgun*) when disturbance is least likely to hinder the growth of the remaining plants.
How to prune and thin	Start by **pruning**. First shorten the bottom branches, up to half the total height of the shrub or tree. Cut branches cleanly and without causing damage. Cut the branches nearest the ground first and move upwards. Use sharp tools to cut branches. Where the branch is more than 50 mm in diameter, make a small cut underneath the branch first. The bark should never be torn: this can damage the plant badly. Now ask this question: Has the canopy been opened enough just by pruning, so that there is now enough light penetrating to allow grasses to grow under the trees? - If “yes”, then the operation is complete. - If “no”, then **thin** the trees. **Thinning** is carried out by following this procedure:

	▪ Inspect the site carefully and decide which trees should be kept and which should be removed. ▪ Choose to keep vigorous, healthy trees that will continue to grow well if they are given more space. ▪ As you choose the trees to be felled, select them in this order: 1. All dead, dying or seriously damaged trees. 2. Trees of bad shape and large crown. 3. Next, select trees to leave a variety of sizes and ages. ▪ Mark with paint or slash with a big knife the trees that should be felled. ▪ Fell the marked trees. ▪ Thin a site according to its requirements, to achieve 50 to 67% open space and only 33 to 50% canopy.
What are products from pruning and thinning	Firewood is the main product from pruning operations. But very little firewood will be produced from plants that have been regularly pruned for several years. A range of sizes of poles will be produced from thinning, suitable for many uses (building, fences, etc.). However, much of the cut material will be suitable only for firewood if plants are not straight, or if they are an unsuitable species for timber. Care must be taken for the disposal of products grown on community reserve land. Products from other land should normally be given to the land owner or community group responsible for the land.
Which materials and tools should be used	▪ Most pruning operations require a large knife, secateurs or small saw. ▪ Most thinning operations require a saw or axe. ▪ Paint for marking trees that will be thinned or pruned. ▪ Use very sharp tools; working with blunt tools can damage trees.

6.2.2. Repair of Vegetation Structures

What is the repair of vegetation structures	The repair of any form of bio-engineering treatment: mainly palisades, fascines and brush layering, re-planting of seedlings and re-turfing. This should be done as and when required.
Why repair vegetation structures	To maintain the effectiveness of the treatments and to ensure that they become stronger over time.
When should vegetation structures be repaired	Sites with bio-engineering construction should be checked regularly. This should normally be once every six months or less. Repairs should be programmed as part of the regular maintenance work plan. Repairs to living structures should be done during the monsoon.

How to repair vegetation structures	Engage a person/s or a group of persons to repair bio-engineering sites. The minimum amount of disturbance should be made to the site. The work to be done depends on the particular bio-engineering treatment and the type of damage. A suitable site watcher can undertake very small repairs; otherwise, they will need to be done by the maintenance team.
Which materials and tools should be used	These are normally the same as for the original construction of the structure being repaired. The materials and tools required are given in the appropriate rate analysis norms.

6.2.3. Vegetation Enrichment

What is vegetation enrichment	Vegetation enrichment means planting more grasses, shrubs or trees within the site area where the planted plants did not survive. It can also involve the planting of shrubs and trees to replace those removed for certain reasons.
Why enrich vegetation	▪ To establish more plants in places where there are gaps. ▪ To introduce or change the species composition on a site; for example, to increase the range of species or to move away from a single species by planting seedlings of other species.
When to enrich vegetation	▪ Whenever there are gaps in the vegetation in which erosion might start. ▪ When it is necessary to change the mixture of species. This might be to support the natural succession from pioneer to climax community species. ▪ When the other remaining vegetation is not adequate to protect the slope. ▪ Actual enrichment planting should be done during the monsoon rains.
How to enrich vegetation	Carefully select plants that are desired on the site and that should grow well, and raise them in the nursery. Plant only in gaps, not under a dense forest canopy. Spread the planting over several years and concentrate on successful establishment in a small area each year, if the total area available for planting is large. Vegetation enrichment is best combined with other operations that increase the amount of light penetrating the canopy (such as thinning and pruning). In this case, enrichment should be concentrated in gaps or open areas in the canopy.
Which materials and tools should be used	These are normally the same as for the original planting of the vegetation being enriched. The materials and tools required are given in the appropriate rate analysis norms.

6.2.4. Removal of Unwanted Trees and Shrubs

Why remove unwanted trees and Shrubs	A tree may be removed for any of the following reasons: ▪ The tree is dead and may fall down. ▪ The tree is surcharging a steep slope, or is too big and unstable for the slope on which it is growing. ▪ The tree needs to be cut as part of a thinning programme. This will allow light to penetrate and help the understorey grow. ▪ The tree needs to be cut to allow coppice shoots to come from the stump. ▪ The tree needs to be cut if it is disturbing canal.
When should unwanted trees and shrubs be removed	Whenever a problem occurs, a tree needs to be removed. If possible, shrubs and trees are best removed during the dry season when the disturbance is least likely to hinder the growth of the remaining plants.
How to remove unwanted trees and shrubs	Organise group of persons to fell the tree or shrub and dispose of the produce suitably. Large trees should be felled so that they do not damage young trees and shrubs unduly. If a tree with a very large crown has to be felled, it should be pruned first to remove the branches. It should also be felled across the slope to avoid excessive damage.
Which materials and tools should be used	Most removal operations require the same tools as for thinning. These are: a saw, or an axe, and paint for marking trees to be cut. All tools used should be very sharp. So as to avoid damage to trees with blunt tools.

7. SAFETY CODE OF PRACTICE FOR WORKING ON SLOPES

Slopes in hilly areas are dangerous by nature. Along with the obvious danger of falling off steep slopes, there are dangers of falling debris or tools hitting other workers and of the slope itself giving way. Always follow the proper safety rules.

Some Safety Precautions to Maintain while Working on Slopes

1. These precautions are designed to promote the safety of all persons whilst working on slopes at sites where people are at risk of falling from a distance of more than 2 meters.
2. No person should work unaccompanied unless they are on a very gentle slope (less than 30° slope). All personnel should leave the slope to take refreshments, meals etc.
3. During site works, all fragile slopes should be clearly marked off and people be informed of the dangers.
4. All access equipment, ropes and tackle should be inspected and adequately be in a sound condition.
5. Where persons could fall over the edge of a slope, temporary guard rails or ropes should be installed where practical. All persons exposed to a risk of falling should be provided with a secure and well anchored safety line. Such a rope should be of sufficient strength to provide them with the safe arrest in the event of a fall.
6. Care should be taken to prevent tools and loose objects falling from the slope. Loose articles should be raised or lowered in a safe manner. They should not be carried up or down the ladders, unless in the case of small items, which may be carried in a suitable shoulder bag.
7. Extreme care should be exercised on slopes during adverse weather conditions (wind, rain, fog and darkness as it can create its own hazards in addition to the hazards inherent in the slope work) and site conditions should be properly assessed before allowing access to the slope. Only when absolutely necessary, people should go on to slopes in heavy rain or during the hours of darkness. In such cases, no person should go on to the slope unaccompanied.
8. Any scaffolding that is used should be composed of good quality materials. Bamboos should be freshly cut of strong and flexible nature. Scaffolding should be correctly erected by competent persons and of appropriate capacity.
9. Ladders should be in good condition and adequate for the job. Ladders should extend one meter beyond the landing point and must be on a firm base, correctly pitched and lashed as soon as is possible. Unlashed ladders should be footed.
10. If there is any potential hazard to people below where the slope work is taking place, adequate temporary warning notices, barriers and a look out person should be employed. Where appropriate, standard traffic warning and control measures should be taken.
11. Appropriate protective clothing should be worn including, where necessary, protective helmets and boots with steel toe caps and slip resistant soles.

REFERENCES

Howell, J.H. 1999, Roadside Bio-engineering,

Eastern Region Road Maintenance Project. 1993, Bio-engineering for Road Protection in Nepal: techniques used on the Jogbani-Basantapur Road, Nepal.

ITECO. 1990, Handbook for Bio-engineering Methods in Gully and Landslide Stabilisation Works. Lamosangu-Jiri Road, Charnawati Rehabilitation Programme Phase III, ITECO/SDC/HMGN, Affoltern.

Shankar Rai. 2009, Bio-engineering for Slope Stabilisation in Rural Road Construction in Nepal, District Roads Support Programme, ITECO Engineering/SDC, Nepal.

ANNEX A: LIST OF PLANT SPECIES

1. GRASS FOR BIO-ENGINEERING (Includes small legumes)

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Amliso	Thysanolaena maxima	√	Large clumping	Terai-2000m	Varied	Rhizome cuttings	Grazing risk
Babiyo	Eulaliopsis binata	√	Medium-sized clumping	Terai-1500m	Hot and dry	Slip cuttings/seeds	Grazing risk
Banso ghas	Eragrostis tenella		Large spreading	500-1800m	Varied	Slip cuttings/seeds	Grazing risk
Buffalo grass	Cenchrus ciliaria		Medium-sized spreading (exotic)	500-1800m	Varied	Slip cuttings	Grazing risk
Clover	Trifolium species		Small spreading legume (exotic)	Terai-2000m	Moist	Slip cuttings/seeds	Grazing risk
Dangre khar	Cybopogon pendulus		Large clumping	Terai-1200m	Varied	Seeds	
Desmodium	Desmodium distortum		Spreading legume (exotic)	Terai-1800m	Varied	Stem/slip cuttings	Grazing risk
Desmodium greenleaf	Desmodium intortum		Spreading legume (exotic)	Terai-1200m	Varied and dry	Stem/slip cuttings	Grazing risk
Dhonde	Neyraudia reynaudiana	√	Large clumping	Terai-1500m	Hot and dry	Slip cuttings/seeds	Non palatable
Dubo	Cynodon doctylon		Small creeping	Terai-1800m	Varied	Stem cuttings	
Dhungre	Unknown		Large clumping	1500-2500m	Damp or shady	Slip cuttings	
Dhus	Unknown		Large clumping	1500-2500m	Varied dry to moist	Slip/stem cuttings	

1. GRASS FOR BIO-ENGINEERING (Includes small legumes) .... contd.

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Jaughans	Unknown		Large spreading	1600-3000m	Varied	Slip cuttings/ seeds	
Kagati ghans	Cymbopogon citratus		Large clumping	Terai-1500m	Varied	Slip cuttings/seeds	
Kans	Saccharum spontaneum	√	Large clumping and spreading	Terai-2000m	Hot, dry to moist	Slip cuttings	Non palatable
Katra khar	Themeda species	√	Large clumping	Terai-2000m	Varied	Slip cuttings/seed	
Khar	Cymbopogon microtheca	√	Medium-large clumping	500-2000m	Hot and dry, Varied	Slip cuttings/seeds	
Khus	Vetiver zizanioides	√	Medium-large clumping	Terai-1500m	Varied	Slip cuttings	
Kikiyu (Thulo dubo)	Pinnisetum clandestinum		Small creeping (exotic)	Terai-1800m	Varied	Stem/slip cuttings	
Kudzu	Pueraria lobata		Spreading legume (exotic)	500-1500m	Varied	Stem/slip cuttings	
Molasses	Melinis minutiflora		Medium-large spreading (exotic)	Terai-1800m	Varied to dry	Slip cuttings/seeds	
Musekharuki	Unknown		Small spreading	Terai-2500m	Varied	Slip cuttings	
Napier	Pennisetum purpureum		Large semi clumping (exotic)	Terai-1750m	Varied; needs fertile soil	Stem cuttings	Grazing risk
Narkat	Arundo clonax	√	Large clumping and spreading	Terai-1500m	Hot and dry; Varied	Stem/slip cuttings	

1. GRASS FOR BIO-ENGINEERING (Includes small legumes) .... contd.

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
NB21	P. purpureum typhoides		Spreading (exotic)	Terai-1750m	Varied	Stem cuttings	Grazing risk
Padang bans	Himalayacalamus hookerianus	√	Large clumping (small stature bamboo)	1500-2500m	Moist	Large rhizome cuttings	Grazing risk
Phurke	Arunduella nepalensis	√	Medium-sized clumping	700-2000m	Varied; stony	Slip cuttings/seeds	
Rato kans	Frianthus rufipilus		Medium-sized clumping	900-2200m	Varied	Slip cuttings/seeds	
Salimo khar	Chysopogon gryllus		Medium-sized clumping	800-2000m	Varied	Slip cuttings/seeds	
Seteria	Seteria anceps		Medium-large spreading (exotic)	500-2500m	Varied to dry	Slip cuttings/seeds	Grazing risk
Sito	Neyraudia arundinacea	√	Large clumping	Terai-1500m	Varied	Slip cuttings/seeds	Non palatable
Stylo	Stylosanthes guianensis		Spreading legume (exotic)	500-1500m	Varied	Stem/slip cutting	Grazing risk
Thulo kharuki	Unknown		Medium-large clumping	600-2000m	Varied	Slip cuttings/seeds	
Tite nigalo bans	Drepanostachyum intermedium	√	Large clumping (small stature bamboo)	1000-2500m	Varied	Rhizome cuttings	Grazing risk

2. SHRUBS/SMALL TREES FOR BIO-ENGINEERING

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Aak	Calatropha giganteum		Small shrub, large fleshy leaves	Terai-1000m	Hot and dry; harsh	Seeds	
Ainselu	Rubus ellipticus		Thorny shrub up 2 m high	1000-2500m	Varied	Seeds/root cuttings	
Alainchi	Elettraria cardomomum		Herb	1000-2500m	Moist	Seeds	
Amala	Phyllanthus emblica		Small tree	Terai-1500m	Hot and dry harsh	Seeds	
Amba/Ambak	Psidium guajava		Small tree up to 5 m	Terai-2000m	Varied and dry	Seeds	
Aparajita	Clitoria ternatea		Climbing shrub (exotic)	Terai-1500m	Varied	Seeds	
Areri	Acacia penata	√	Small thorny tree up to 5m high	500-1500m	Hot and dry harsh	Seeds	
Argeli	Unknown		Shrub up to 3 m	1500-2500m	Varied dry to moist	Hardwood cuttings	
Arile kanda	Caesalpinia decapetala		Thorny climber (exotic)	Terai-1500m	Varied	Seeds	
Asuro	Adhatoda vasica	√	Shrub up to 3 m high	Terai-1000m	varied	Hardwood cuttings	
Bains	Unknown not salix		Shrub up to 5 m high	1300-2000m	Varied	Hardwood cuttings	
Baramasephul	Bougainvillea spectabilis		Thorny climber (exotic)	Terai-1500m	Varied	Hardwood cuttings	
Ban chutro	Berberis aristata		Thorny shrub up to 2 m high	1500-3000m	Varied	Seeds	

2. SHRUBS/SMALL TREES FOR BIO-ENGINEERING .... contd.

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Ban silam	Elsholtzia blanda		Shrub	Terai-1500m	Varied		
Bayer	Zizyphus mauritiana		Thorny shrub up to 5 m high	Terai-1200m	Hot and dry harsh	seeds	
Bhimsenpati	Buddleja asiatica		Shrub up to 4 m high	600-1800m	Hot and dry harsh	seeds	
Bhui katahar	Ananas comosus		Thorny herb up to 1 m high	Terai-1600m	Hot and dry harsh	Stem cuttings	
Bhujetro	Butea minor	√	Shrub up to 4 m high	500-1500m	Hot and dry harsh	Seeds	
Bilaune	Maesa chisia		Shrub	Terai-2000m	Varied		
Bokshi ghans	Mimosa rubicaulis		Shrub up to 3 m high	500-1700m	Varied	Hardwood cutting/seeds	
Chiya	Camellia sinensis		Shrub up to 4 m high	Terai-2000m	Varied and moist	Hardwood cuttings	
Chutro	Berberis asiatica		Thorny shrub up to 2 m high	1000-2500m	Varied and dry	Seeds	
Coffee	Coffea arabica		Shrub up to 2 m high	Terai-2000m	Varied	Seeds	
Dhanyero	Woodfordia fruticosa	√	Shrub up to 3 m high	Terai-1500m	Hot and dry harsh	Seeds	
Dhusun	Celebrookea oppositifolla	√	Shrub up to 3 m high	Terai-1000m	Hot and dry harsh	Seeds	
Gahate	Desmodium sepcies		Shrub up to 4 m high	400-1500m	Varied	Seeds	
Ghangaru	Pyracantha crenulata		Shrub up to 2 m high	1500-2500m	Varied		

2. SHRUBS/SMALL TREES FOR BIO-ENGINEERING .... contd.

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Ghurmiso	Leucosceptrum canum		Small tree up to 8 m high	1000-2500m	Varied	Hardwood cuttings/seeds	
Imili	Rumex hastatus		Herb up to 1 m high	600-2000m	Hot and dry harsh	Seeds	
Kanda phul	Lantana camara		Shrub up to 2 m high	Terai-1750m	Hot and dry harsh	Hardwood cuttings	
Ketuke	Agave americana		Large cactus	Terai-2400m	Hot and dry	Root suckers	
Keraukose	Indigofera atroturpurea	√	Shrub up to 5 m high	Terai-2000m	Hot and dry	Seeds	
Khirro	Sepium insegne		Small tree	800-1500m	Varied and dry	Hardwood cuttings/seeds	
Kimbu	Morus alba		Small tree	Terai-2000m	Varied and dry	Hardwood cuttings	
Kunyelo	Trema orientalis		Small tree	Terai-1500m	Stony and dry	Hardwood cuttings/seeds	
Lalupate	Poinsettia pulcherrima		Shrub up to 5 m high	Terai-1500m	Varied	Hardwood cuttings/seeds	
Namdi phul	Colquhounia coccinea	√	Shrub up to 3 m high	1000-2000m	Varied	Hardwood cuttings	
Nil kanda	Duranta repens		Thorny shrub	Terai-1500m	Varied and dry	Hardwood cuttings/seeds	
Pate siuli	Opuntia ficus indica		Large thorny cactus	Terai-1800m	Varied and dry	Stem cuttings	
Rahar	Cajanus cajan		Shrub up to 4 m high	Terai-1500m	Varied and dry	Seeds	

2. SHRUBS/SMALL TREES FOR BIO-ENGINEERING .... contd.

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Rato chulsi	Osbeckia stellata		Shrub	Terai-1500m	Varied		
Saruwa/ Bihaya	Ipomoea fistulosa	√	Shrub	Terai-1500m	Varied sunny site; stands water logging	Hardwood cuttings	
Sajiwan/Kadam	Jatropha curcas		Shrub up to 4 m high	Terai-1000m	Varied	Hardwood cuttings/seeds	
Simali	Vitex negundo	√	Small tree up to 6 m high	Terai-1750m	Hot and dry; varied	Hardwood cuttings	
Sisal	Agava sisalana		Cactus	Terai-1000m	Hot and dry; varied		
Sihundi	Euphorbia royleana		Shrub	900-1800m	Varied		
Tara phul	Helianthus tuberosus		Spreading herb	800-1500m	Varied	Root cuttings	
Thakal	Phoenix humilis		Small stature palm tree	Terai-1000m	Hot and dry; needs shade	Seeds	
Tilka	Wendlandia puberula	√	Small tree	Terai-1500m	Hot and dry; harsh	Seeds	

Rec. √ = tested and recommended

3. TREES FOR BIO-ENGINEERING

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Acacia	Acacia auriculiformis		Non thorny small tree (exotic)	Terai-1000m	Hot and dry; harsh	Seeds	
Amp/Aap	Mangifera indica		Medium size fruit tree	Terai-1200m	Hot and dry	Seeds/Grafting	
Ashare phul	Lagerstroemia parviflora		Medium to large tree	Terai-1200m	Varied to dry	Seeds	
Babul/Kikar	Acacia nilotica		Medium size thorny tree (exotic)	Terai-1000m	Hot and dry; harsh	Seeds	
Badahar	Artocarpus lakoocha		Medium to large deciduous tree	Terai-1300m	Varied and moist	Seeds	
Bakeno	Melia azedarach	√	Medium to large deciduous tree	Terai-1800m	Hot and dry; harsh	Seeds	
Bange kath	Populus ciliata		Large deciduous tree	2000-3000m	Dry to moist	Hardwood cuttings	
Banghi	Anogeissus latifolius		Large deciduous tree	Terai-1700m	Hot and dry	Seeds	
Birendra phul	Jacaranda mimisifolia		Medium size deciduous ornamental tree (exotic)	Terai-1600m	Varied to dry	Seeds	
Champ	Michelia champaca		Large deciduous tree	500-1500m	Varied to moist	Seeds	
Chilaune	Schima wallichii	√	Large evergreen tree	900-2000m	Varied; dry to moist	Seeds	
Chiuri	Aesandra butyracea		Large tree	Terai-1700m	Varied	Seeds	

Rec. √ = tested and recommended

3. TREES FOR BIO-ENGINEERING .... contd.

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Chuletro	Brassaiopsis hainla		Small tree	800-2000m	Varied	Seeds	
Dabdabe	Garuga pinnata	√	Large deciduous tree	Terai-1300m	Varied and dry	Seeds/Hardwood cuttings	
Dar/Githi	Boehmeria rugulosa		Small to medium tree	300-`1300m	Varied	Seeds/Hardwood cuttings	
Deshi katus	Castanea sativa		Large tree (exotic)	1000-2000m	Varied	Seeds	
Dhalne katus	Castanopsis indica		Large tree	900-2900m	Varied	Seeds	
Dhupi salla	Cryptomeria japonica		Large evergreen tree (exotic)	1200-2500m	Varied but not hot or dry	Seeds	
Dodhilo	Ficus neriifolia		Deciduous fodder tree	900-2200m	Varied	Seeds	
Gobre salla	Pinus wallichiana	√	Large tree	1800-3000m	Dry; varied	Seeds	
Gliricidia	Gliricidia sepium		Small leguminous tree	Trai-500m	Hot not too dry; free draining	Seeds/Hardwood cuttings	
Gogan	Saurauia nepaulensis		Medium-sized fodder tree	750-2100m	Varied	Seeds	
Golainchi/Goila	Plumeria acuminata		Ornamental tree	500-1500m	Varied and dry	Seeds	
Gulmohar	Delonix regia		Medium-sized ornamental tree	Terai-1000m	Varied and dry	Seeds	

Rec. √ = tested and recommended

3. TREES FOR BIO-ENGINEERING .... contd.

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Ipil Ipil	Leucaena species		Small fodder tree	Terai-1500m	Varied and dry	Seeds	
Jamun	Syzygium cumini		Medium-sized evergreen tree	Terai-1600m	Moist	Seeds	
Kadam	Anthocephalus chinensis		Large deciduous tree	Terai-1000m	Varied and moist	Seeds	
Kagati	Citrus aurantifolia		Small fruit tree	500-1500m	Varied	Hardwood cuttings	
Kaju	Anacardium occidentale		Small nut tree	Terai-1600m	Varied		
Kalki phul	Callistemon citrinus		Small ornamental tree	Terai-1800m	Varied	Seeds/Hardwood cuttings	
Kalo siris	Albizia lebbeck	√	Medium-sized deciduous tree	Terai-1200m	Hot and dry; harsh	Seeds	
Kangiyo	Gravillea robusta		Large tree	Terai-1600m	Varied	Seeds	
Kapur	Cinnamomum camphora		Evergreen tree	Terai-2000m	Moist	Seeds	
Kavro	Ficus locar		Large tree	Terai-1600m	Varied	Hardwood cuttings	
Khanyu (Khasre)	Ficus semicordata	√	Fodder tree	Terai-2000m	Hot and dry; varied	Seeds	
Khari	Celtis australis		Medium-sized deciduous tree	700-2400m	Varied	Seeds	
Khasru	Quercus semecarpifolia		Large tree	1700-3800m	Varied	Seeds	

3. TREES FOR BIO-ENGINEERING .... contd.

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Khayer	Acacia catechu	√	Large thorny tree	Terai-1000m	Hot and dry; harsh	Seeds	
Koiralo	Bauhinia Variegata		Medium-sized fodder tree	Terai-1900m	Varied and dry	Seeds/polypots	
Kutmero	Litsea monopetala		Medium-sized evergreen fodder tree	Terai-1600m	Varied to stony and dry	Seeds/polypots	
Lahare pipal	Populus euramerica		Large deciduous varieties (exotics)	Terai-1700m	Moist	Hardwood cutting	
Lankuri	Fraxinus floribunda	√	Large deciduous tree	1200-2700m	Varied; best in moist site	Seeds/polypots	
Lapsi	Choerospondias axillaris		Medium to large deciduous tree	950-1900m	Varied and dry	Seeds/polypots	
Macadamia	Macadamia tetraphylla		Exotic nut tree	Terai-1600m	Hot and dry; harsh	Seeds/polypots	
Mashala	Eucalyptus camaldulensis		Large tree with thin crown	Terai-1800m	Hot and dry; harsh	Seeds/polypots	Best eucalypt in Nepal stifles nearby plants
Mayal/mel	Pyrus pashia		Small tree, often spiny	1500-2500m	Varied	Seeds/hardwood cutting	Spreading superficial roots; roots sucker
Musure katus	Castanopsis tribuloides		Large deciduous tree	500-2300m	Varied and dry	Seeds/polypots	Most widespread of all *katus*

3. TREES FOR BIO-ENGINEERING .... contd.

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Nebharo	Ficus auriculata		Medium-sized fodder tree	Terai-2000m	Varied and dry	Seeds/hardwood cutting	High gazing risk
Nim	Azadirachta indica		Large evergreen tree	Terai-900m	Hot and dry	Seeds/polypots	
Okhar	Juglans regia		Medium-sized nut tree	1200-2800m	Varied and moist	Seeds/polypots	
Painyu	Prunus cerasoides	√	Medium-sized flowering tree	500-2400m	Varied and dry; stony	Seeds/polypots	
Patle katus	Castanopsis hystrix		Large evergreen tree	1000-2500m	Varied	Seeds/polypots	
Phalant	Quercus lamellosa		Large forest tree	1600-2800m	Moist sites preferred	Seeds/polypots	Best in area of higher rainfall
Phaledo	Erythrina species	√	Three fodders species	900-3000m	Varied	Seeds/hardwood cutting up to 2 m	Long cuttings are very successful
Rajbriksha/amaltas	Cassia fistula		Medium-sized ornamental tree	Treai-1400m	Varied and dry	Seeds/polypots	Popular ornaments
Rani(khote) salla	Pinus roxburghii	√	Large coniferous tree	500-1950m	Hot and dry; varied	Seeds/polypots	Not on moist sites; use only exceptionally
Rato sirsi	Albizia julibrissin	√	Medium-sized deciduous tree	800-3000m	Varied and moist	Seeds/polypots	Fast growing in damp
Ritha	Sapindus mukorossi		Large tree	700-2000m	Varied	Seeds/polypots	

Rec. √ = tested and recommended

3. TREES FOR BIO-ENGINEERING .... contd.

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Sahijan/shobhanjan	Moringa oleifera		Small ornaments	Terai-1000m	Hot and dry; varied	Hardwood cutting up to 2 m	
Sal	Shorea robusta		Large forest tree	Terai-1000m	Varied; dry to moist	Seeds/polypots	
Saur	Betula alnoides		Small tree	1200-3000m	Varied to moist	Seeds/polypots	Natural coloniser
Seto siris	Albizia procera	√	Medium-sized deciduous tree	Terai-1350m	Moist	Seeds/polypots	Sensitive to grass competition
Sisau	Dalbergia sissoo	√	Large boarleaved tree	Terai-1400m	Varied	Seeds/polypots/stump cutting	Needs reasonable soil
Suntala	Citrus chyracarpa		Small fruit tree	500-1500m	Varied	Hardwood cutting	
Tanki	Bauhinia purpurea		Medium-sized deciduous tree	Terai-1600m	Varied and dry	Seeds/polypots	High gazing risk
Tendu	Diospyros malabarcia		Medium-sized everygreen forest	Terai-1500m	Moist site and good soil	Seeds/polypots	High gazing risk
Tooni	Toona ciliate		Large deciduous tree	Terai-1700m	Moist sites and good soil	Seeds/polypots	
Uttis	Alnus nepalensis	√	Large broadleaved tree	900-2700m	Varied and moist	Seeds/polypots	

Rec. √ = tested and recommended

4. LARGE CLUMPING BAMBOO FOR BIO-ENGINEERING

(Species used or recommended for bio-engineering throughout Nepal)

Local name	Botanical name	Rec.	Character	Altitude	Sites	Best propagation	Comments
Choya/tama bans	Dendrocalamus hamiltonii		Thin culm, heavy branching	300-2000m	Moist	Culm cutting	
Dhanu bans	Bambusa balcooa		Thin culm, heavy branching	Terai-1600m	Varied	Culm cutting	
Kalo bans	Dendrocalamus hookeri		Heavy branching, brown hair	1200-2500m	Varied	Culm cutting	
Mal bans	Bambusa nutans		Strong, straight culms	Terai-1500m	Dry/varied	Traditional method	Subspecies cupulata
Nibha/ghopi/lyas bans	Ampelocalamus patellaris		Smaller, blueish culms	1200-2000m	Varied	Traditional method	
Tharu bans	Bambusa nutans		Strong, straight culms	Terai-1500m	Varied	Traditional method	Subspecies nutans

Rec. √ = tested and recommended

5. PLANTS WHICH SHOULD NOT BE USED FOR BIO-ENGINEERING

Local name	Botanical name	Reason for not using as a bio-engineering species
Smaller plants		
Banmara	Eupatorium adenopherum	Very shallow rooting; stifles other plants; has become a damaging weed (colonizer)
Tite pati	Artemesia vulgans	Very shallow rooting; stifles other plants; has become a damaging weed (colonizer)
Annual grasses	Various	Too short-lived
Trees		
Cassia (exotic)	Cassia siamea	Causes undue grass competition; creates heavy shade when canopy closes; competes heavily with other species
Ipil Ipil	Leucaena leucocephala	Growth has been severely hampered by attacks of the insect Psyllid.
Patula *salla*	Pinus patula	Frequently suffers from either drought or nutritional problems in Nepal hill plantation.
Teak	Tectona grandis	This tree tends to suppress all undergrowth and is known to give rise to conditions allowing extensive erosion below its canopy.

Note. Species such as *salla* (pines) and *masala* (eucalyptus) should only be used in mixtures with other plants, where they constitute no more than 50% of the plants. In this capacity they have distinct advantages but single stands tend to stifle surface plant cover. A mixture of *rani salla* and *chilaune*, for example can be particularly effective in a number of ways.

ANNEX B: STANDARDS SPECIFICATIONS FOR BIO-ENGINEERING WORKS

TECHNICAL SPECIFICATIONS		
ITEM 18-1 DoLIDAR		**PROVISION OF SEED**
	18-1.1	General
	18-1.2	Grass Seed Collection
	18.-1.3	Tree and Shrub Seed Collection
ITEM 18-2 DoLIDAR		**PROVISION OF PLANT CUTTINGS**
	18-2.1	General
	18-2.2	Provision of Grass Cuttings
	18-2.3	Provision of Hardwood Cuttings
ITEM 18-3 DoLIDAR		**NURSERY CONSTRUCTION**
	18-3.1	General
	18-3.2	Nursery Establishment
	18-3.3	Construction of Nursery Beds
ITEM 18-4 DoLIDAR		**NURSERY OPERATION AND MANAGEMENT**
	18-4.1	General
	18-4.2	Nursery Production of Grass
	18-4.3	Nursery Production of Trees and Shrubs in Poly-pots
	18-4.4	Nursery Production of Hardwood Plants by Vegetative Methods
	18-4.5	Extraction of Plants from the Nursery
	18-4.6	Compost and Mulch Production
ITEM 18-5 DoLIDAR		**FINAL SLOPE PREPARATION FOR BIO-ENGINEERING**
	18-5.1	General
	18-5.2	Cut Slope Preparation for Grass Planting
	18-5.3	Final Preparation of Fill Slopes for Bio-engineering
ITEM 18-6 DoLIDAR		**SITE PLANTING AND SOWING**
	18-6.1	General
	18-6.2	Sowing of Grasses on Site
	18-6.3	Direct Seed Sowing of Shrubs and Trees on Site

	18-6.4	Site Planting of Grass Slips and Cuttings
	18-6.5	Site Planting of Shrubs and Trees Raised in Poly-pots
	18-6.6	Site Planting of Hardwood Cuttings
	18-6.7	Brush layering, Palisades and Fascines
	18-6.8	Use of Fertiliser
ITEM 18-7 DoLIDAR		**JUTE NETTING WORK**
	18-7.1	General
	18-7.2	Supply of Jute Netting
	18-7.3	Placement of Jute Netting
ITEM 18-8 DoLIDAR		**GABION WIRE BOLSTER**
	18-8.1	General
	18-8.2	Fabrication of Bolster Panels
	18-8.3	Placement of Contour Bolster
	18-8.4	Placement of Herringbone Bolster
ITEM 18-9 DoLIDAR		**SITE PROTECTION**
	18-9.1	General
	18-9.2	Provision and Role of Site Watchperson
	18-9.3	Fabrication of Bamboo Tree Guard
	18-9.4	Placement of Bamboo Tree Guard
ITEM 18-10 DoLIDAR		**SITE AFTERCARE AND MAINTENANCE**

BIO-ENGINEERING WORKS NORMS RATE ANALYSIS NORMS												
S.No.	**Respective Clause of Specifications**	**WORK DESCRIPTION**	**UNIT**	**RESOURCES**								
				LABOUR			**CONSTRUCTION MATERIALS**			**TOOLS AND EQUIPMENT**		
				LEVEL	**UNIT**	**QUANTITY**	**TYPE**	**UNIT**	**QUANTITY**	**TYPE**	**UNIT**	**QUANTITY**
61 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Collection and preparation of seeds** a) Collection of grass seeds from sources within 1 km. of the road, including separating seed for storage and drying seed in the sun.	Kg.	Unskilled	Nos.	1.50	Sealed bag	Nos.	1.00	*Khukuri*	-	3% of labour cost
		b) Collection of large shrub seeds (e.g., *bhujetro*) from sources within 1 km. of the road including seed preparation for storage after drying.	Kg.	Unskilled	Nos.	0.45	Sealed bag	Nos.	1.00	*Khukuri*	-	3% of labour cost
		c) Collection of medium-sized shrub seeds (e.g., *keraukose*) from sources within 1 km. of the road including seed preparation for storage after drying.	Kg.	Unskilled	Nos.	0.75	Sealed bag	Nos.	1.00	*Nanglo*	-	3% of labour cost
		d) Collection of medium-sized shrub and tree seeds (e.g., *areri*, *khayer*, *gopre* and *rani salla*, *sisau*) from sources within 1 km. of the road including seed preparation for storage after drying.	Kg.	Unskilled	Nos.	0.95	Sealed bag	Nos.	1.00	*Nanglo*	-	3% of labour cost

BIO-ENGINEERING WORKS NORMS RATE ANALYSIS NORMS												
S.No.	**Respective Clause of Specifications**	**WORK DESCRIPTION**	**UNIT**	**RESOURCES**								
				LABOUR			**CONSTRUCTION MATERIALS**			**TOOLS AND EQUIPMENT**		
				LEVEL	**UNIT**	**QUANTITY**	**TYPE**	**UNIT**	**QUANTITY**	**TYPE**	**UNIT**	**QUANTITY**
		e) Collection of small shrub and tree seeds (e.g., *dhanyero*, *dhusun tilka uttis*) from sources within 1 km. of the road including seed preparation for storage after drying.	Kg.	Unskilled	Nos.	2.50	Sealed bag	Nos.	1.00	*Nanglo*	-	3% of labour cost
62 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Collection of grass and hardwood cuttings for vegetative propagation** a) Collection of grass clumps (e.g., *amliso*, *kans*, *khar*) from sources within 1 km. of the road to make slips for multiplication in the nursery.	1000 slips	Unskilled	Nos.	1.50	Hessian jute	m²	5.00	*Pick axe* *Khukuri*	-	3% of labour cost
		b) Collection of cuttings of small bamboos (e.g., *padand bans*, *tite nigalo*, *bans*) suitable for traditional planting from sources within 1 km of the road. The cutting minimum 10 cm of rooted rhizome and 90 cm of culm.	1000 nos.	Unskilled	Nos.	3.00	Hessian jute	m²	10.00	*Kodalo* *Khukuri*	-	3% of labour cost
		c) Collection of hardwood cuttings (e.g., *asuro bains, kanda phul, namdi phul*, *sarowa*, *simali*) from sources within 1 km. of the road. Material minimum 30	1000 nos.	Unskilled	Nos.	0.85	Hessian jute	m²	5.00	*Khukuri*	- -	3% of labour cost

BIO-ENGINEERING WORKS NORMS
RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		cm in length and 2 cm in diameter.										
63 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**1. Nursery operation and management** **(Bed preparation)** a) Construction seed beds for tree and shrub seedlings, including materials for beds and shades. Bed is 1 m wide x 17 cm high and made up of: 5 cm of washed gravel, 5 cm of unsieved forest soil, 5 cm of 1:3 mix of sieved forest soil and washed sand, 2 cm of washed, sieved and sterilized sand. (Add 5% to the number of bricks to allow for normal wastage)	5 m²	Skilled Unskilled	Nos. nos.	1.50 2.00	Bamboo Polythene sheet Bricks Gravel Unsieved soil Line string Binding wire	no m² nos m³ m³ m kg	9.00 9.00 96.00 0.25 0.10 13.00 1.50	*Khukuri* Shovel Pick Axe Screen mesh	- - - - -	3% of labour cost
		b) Construction of standout beds for the tree seedlings in polypots, including materials for the beds and shades. Bed is 100 cm wide x 15 cm high with a 5 cm layer of gravel placed above the compacted ground. (Add 5% to the number of bricks to allow for normal wastage).	5 m²	Unskilled	Nos.	6.00	Bamboo Bricks Line sting Binding wire Gravel	nos nos m kg m³	15.00 96.00 13.00 3.00 0.25	*Khukuri* Shovel Pick axe	- - - -	3% of labour cost

BIO-ENGINEERING WORKS NORMS

RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		c) Construction of beds for grass seeds, grass slips (vegetative propagation) and tree stool cuttings, including materials. Bed is 100 cm wide x 25 cm high and made up of: 5 cm of washed gravel placed above the ground, 5 cm of 1:1 mix of sieved soil and compost and topped with 15 cm of 3:1 mix of sieved forest topsoil washed sand	5 m²	Skilled Unskilled	Nos. Nos.	1.00 1.50	Gravel Forest soil Compost Sand Hessian jute	m³ m³ m³ m³ m	0.25 1.46 0.38 0.46 10.00	Shovel Pick axe	- - - -	3% of labour cost
		d) Construction of beds for propagation of bamboo culm cuttings. Bed is 100 cm wide x 30 cm high. The ground below the bed is dug to a depth of 30 cm. and bed is made with 10 cm un-sieved soil and 20 cm sieved soil. A bund 10 cm high is formed around the edge.	5 m²	Unskilled	Nos.	2.00	Forest soil Compost Bamboo poles Hessian jute	m³ m³ m³ m	1.46 0.38 6.00 25.00	Shovel Pick axe Knife Log saw	- - - -	3% of labour cost

BIO-ENGINEERING WORKS NORMS

RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
64 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Nursery operation and management** **(Seeds sowing, transplanting and planting hardwood cuttings)** a) Tree seed sowing @ 10 grammes per m² (medium-sized seed) or 2 grammes per m² (fine seeds) into seed beds including pre-sowing seed treatment.	5 m²	Unskilled	Nos.	0.04	seed	kg	0.050	Bowl		3% of labour cost
		b) Preparing potting mix and filling polypots including all materials for container seedlings [Note. 1 kg of 200-gauge polypots (4" x 7" laid flat) = 464 bags, 200-gauge black polythene is preferred.]	1000 nos	Unskilled	Nos.	10.00	Polypots Sand Soil compost	Nos. m³ m³ m³	1050.00 0.46 0,70 0.23	Sieve mesh shovel		3% of labour cost
		c) Direct sowing of tree seeds into polypots including seed treatment, by sowing one seed in half the pots and two seeds in the other half.	1000 nos	Unskilled	Nos.	0.62	Seed	Nos.	1500.00			3% of labour cost
		d) Pricking out young seedlings and transplanting into polypots	100 nos.	Unskilled	Nos.	0.18	-	-	-	Tray Wooden peg		3% of labour cost

BIO-ENGINEERING WORKS NORMS

RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		e) Pricking out young seedlings and transplanting into beds	1000 nos	Unskilled	Nos.	0.12				Tray Wooden peg		3% of labour cost
		f) Transplanting grass into beds from clumps. Slips are planted at 10 cm centres in rows 25 cm apart.	m²	Unskilled	Nos.	0.12	Hessian jute	m²	0.30	*Khukuri* Shovel		3% of labour cost
		g) Planting of hardwood cuttings of minimum 30 cm length to 20 cm depth into prepared beds, cuttings spaced at 5 cm centres within the rows with 20 cm between rows.	1000 nos.	Unskilled	Nos.	0.60	Hardwood cuttings	Nos.	1000.00	*Khukuri*		3% of labour cost
65 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Preparation of raised materials for extraction from the nursery** a) Grass culm cutting production from nursery stock single or double node (e.g., napier).	1000 nos.	Unskilled	Nos.	0.70	Hessian jute	m²	2.70	*Khukuri*		3% of labour cost
		b) Uprooting and preparing grass slips ready for site planting from nursery seedlings.	1000 nos.	Unskilled	Nos.	0.63	Hessian jute	m²	1.35	Fork Pick axe *Khukuri*		3% of labour cost

BIO-ENGINEERING WORKS NORMS
RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		c) Uprooting and preparing grass slips ready for site planting from nursery grass clumps raised from slips by vegetative propagation.	1000 nos	Unskilled	Nos.	0.33	Hessian jute	m^2	4.20	Shovel *Khukuri*		3% of labour cost
66 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Compost and mulch production** a) Mulch production by collection and cutting of weeds and other vegetation such as *tite pati*, *banmara* etc. within 1 km of the road and stacking along roadside.	m^3	Unskilled	Nos.	1.20				*Hansia Doko*		3% of labour cost
		b) Compost production by collection and cutting of weeds and other vegetation such as *tite pati*, *banmara* etc. within 1 km of the road including fine cutting and filling compost pit.	m^3	Unskilled	Nos.	1.20				*Khukuri Doko*		3% of labour cost
		c) Turning compost once per month.	m^3	Unskilled	Nos.	0.10				Shovel		3% of labour cost
67 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Direct seeding on site** a) Broadcasting grass seeds on slope <40° seeding rate 25 gram per m^2.	100 m^2	Unskilled	Nos.	0.17	Seed	kg	2.50	-	-	-

BIO-ENGINEERING WORKS NORMS

RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		b) Broadcasting grass seeds on slope <40° including cover with long mulch seeding rate 25 gram per m².	100 m²	Unskilled	Nos.	0.17	Seed Mulch	Kg m³	2.50 5.00	- -	- -	- -
		c) Broadcasting grass seeds on slopes <40-45°, including cover with long mulch and jute or coir netting of mesh size 300 mm x 500 mm. seeding @ 25 gram per m². Operation includes pegging with suitable live pegs or hardwood cuttings @ 1 m spacing.	100 m²	Unskilled	Nos.	6.25	Seed Mulch Jute net Live pegs	Kg m³ m² nos	2.50 5.00 105.00 128.00	*Khukuri* Mallet Wooden hammer		3% of labour cost
		d) Sowing shrub and tree seeds on all slopes, at 25 cm intervals, including digging planting holes to 5 cm depth and cove with soil. Two seeds per planting hole.	100 m²	Unskilled	Nos.	1.00	Seed	Kg	Depend on species	MS rod of 50 cm length	-	3% of labour cost

BIO-ENGINEERING WORKS NORMS

RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
68 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Planting grass cuttings on site** a) Planting single node culm cutting of grass (e.g., napier) on fill slopes < 45° embankment slope in plain area. Approx length 15-20 cm including digging planting holes 10-15 cm depth using metal rod or hardwood peg.	100 nos.	Unskilled	nos.	0.20	Grass cutting Hessian jute	nos. m²	100.00 0.27	MS rod or wooden peg of 50 cm length		3% of labour cost
		b) Planting single node culm cutting of grass (e.g., napier) on hard cut slopes < 45°. Approx length 15-20 cm including digging planting holes 10-15 cm depth using metal rod or hardwood peg.	100 nos.	Unskilled	nos.	0.35	Grass cutting Hessian jute	nos. m²	100.00 0.27	MS rod or wooden peg of 50 cm length		3% of labour cost
		c) Planting single node culm cutting of grass (e.g., napier) on hard cut slopes > 45°. Approx length 15-20 cm including digging planting holes 10-15 cm depth using metal rod or hardwood peg.	100 nos.	Unskilled	nos.	0.50	Grass cutting Hessian jute	nos. m²	100.00 0.27	MS rod or wooden peg of 50 cm length		3% of labour cost

BIO-ENGINEERING WORKS NORMS

RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		d) Planting rooted grass slips on embankment slopes in plain area at 10 cm spacing within the row. The first row is 0.75 m from the edge of the pavement and subsequent rows are spaced at 1 m intervals down the embankment.	m	Unskilled	nos.	0.02	Grass slips Hessian jute Line string	nos. m² m	11.00 0.14 1.00	MS rod or wooden peg of 50 cm length		3% of labour cost
		e) Planting grass slips on slopes <45° including preparation of slips on site. Operation includes digging planting holes to a max of 5 cm depth with metal rod or hardwood peg depending on nature of soil. The planting drills should be spaced 10 cm apart.	m²	Unskilled	nos.	0.20	Grass slips Hessian jute	nos. m²	100.00 0.27	MS rod or wooden peg of 50 cm length *Khukuri*		3% of labour cost
		f) Planting grass slips on slopes 45-60° including preparation of slips on site. Operation includes digging planting holes to a max of 5 cm depth with metal rod or hardwood peg depending on nature of soil. The planting drills should be spaced 10 cm apart.	m²	Unskilled	nos.	0.30	Grass slips Hessian jute	nos. m²	100.00 0.27	MS rod or wooden peg of 50 cm length *Khukuri*		3% of labour cost

BIO-ENGINEERING WORKS NORMS RATE ANALYSIS NORMS													
S.No.	**Respective Clause of Specifications**	**WORK DESCRIPTION**	**UNIT**	**RESOURCES**									
				LABOUR			**CONSTRUCTION MATERIALS**			**TOOLS AND EQUIPMENT**			
				LEVEL	**UNIT**	**QUANTITY**	**TYPE**	**UNIT**	**QUANTITY**	**TYPE**	**UNIT**	**QUANTITY**
		g) Planting grass slips on slopes >60° including preparation of slips on site. Operation includes digging planting holes to a max of 5 cm depth with metal rod or hardwood peg depending on nature of soil. The planting drills should be spaced 10 cm apart.	m^2	Unskilled	nos.	0.40	Grass slips Hessian jute	nos. m^2	100.00 0.27	MS rod or wooden peg of 50 cm length *Khukuri*		3% of labour cost
69 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Planting shrub and tree seedlings and cuttings on site** a) Planting containerized tree and shrub seedlings, including pitting, transplanting, composting, and placing tree guards on the toe of embankment slopes in plain areas not less than 8 meters from the road centre line. Pit size 30 cm diameter x 30 cm depth. Compost volume ¼ of the volume of the pit, mix with original soil.	10 nos.	Unskilled	nos.	0.25	Container seedling Compost Tree guard Green mulch	nos. m^3 nos. m^3	10.00 0.05 10.00 0.04	*Khukuri* MS rod planting bar Mallet Wooden hammer) *Doko*		3% of labour cost

BIO-ENGINEERING WORKS NORMS

RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		b) Planting containerized tree and shrub seedlings, including pitting, transplanting, composting, and mulching on slope < 30°. Pit size 30 cm diameter x 30 cm depth. Mix compost with soil and backfill into pit to ¼ of pit volume.	10 nos.	Unskilled	nos.	0.33	Container seedling Compost Green mulch	nos. m^3 m^3	10.00 0.05 0.04	*Khukuri* MS rod planting bar *Doko*		3% of labour cost
		c) Planting containerized tree and shrub seedlings, including pitting, transplanting, composting, and mulching on slope 30-45°. Pit size 30 cm diameter x 30 cm depth. Mix compost with soil and backfill into pit to ¼ of pit volume.	10 nos.	Unskilled	nos.	0.40	Container seedling Compost Green mulch	nos. m^3 m^3	10.00 0.05 0.04	*Khukuri* MS rod planting bar *Doko*		3% of labour cost
		d) Planting rooted tree stump cuttings and bare root seedlings, including pitting, transplanting, composting and mulching on slopes < 30°. Pit size 10 cm diameter x 20 cm depth. Compost volume ¼ 0f volume of the pit mixed with original soil.	10 nos.	Unskilled	nos.	0.17	Seedling Compost Green mulch	nos. m^3 m^3	10.00 0.03 0.04	*Khukuri* MS rod planting bar		3% of labour cost

BIO-ENGINEERING WORKS NORMS
RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		e) Planting rooted tree stump cuttings and bare root seedlings, including pitting, transplanting, composting and mulching on slopes < 30-45°. Pit size 10 cm diameter x 20 cm depth. Compost volume ¼ 0f volume of the pit mixed with original soil.	10 nos.	Unskilled	nos.	0.25	Seedling Compost Green mulch	nos. m^3 m^3	10.00 0.03 0.04	*Khukuri* MS rod planting bar		3% of labour cost
		f) Planting rooted tree stump cuttings and bare root seedlings, including pitting, transplanting, composting and mulching on slopes >45°. Pit size 10 cm diameter x 20 cm depth. Compost volume ¼ 0f volume of the pit mixed with original soil.	10 nos.	Unskilled	nos.	0.33	Seedling Compost Green mulch	nos. m^3 m^3	10.00 0.03 0.04	*Khukuri* MS rod planting bar		3% of labour cost
70 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Vegetative palisde construction, brush layering and fascines** a) Collection of hardwood cuttings for planting material (e.g., *asuro*, *namdi phul*, *simali*) from sources within 1 km of the road. Material to be approx 1m in length and minimum 5 cm in diameter.	1000 nos.	Unskilled	nos.	0.0.85	Adequate supply of bushes			*Khukuri*		3 % of labour cost

BIO-ENGINEERING WORKS NORMS
RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		b) Preparation and planting of live pegs of selected species (e.g., *asuro*, *namdi phul*, *simali*) of minimum 1 m length to 0.5 m depth into hard ground. Pegs spaced at 5 cm centres within rows, with 5-20 cm between rows and interwoven with vegetation.	m	Unskilled	nos.	0.17	Live pegs	nos.	20.00	Crow bar		3 % of labour cost
		c) Preparation and planting of live pegs of selected species (e.g., *asuro*, *namdi phul*, *simali*) of minimum 1 m length to 0.5 m into soft debris. Pegs spaced at 5 cm centres within rows, with 5-20 cm between rows and interwoven with vegetation.	m	Unskilled	nos.	0.12	Live pegs	Nos.	20.00	Crow bar		3 % ofl abour cost
		d) Site preparation for fascine laying; earth works in excavation of trench to 20 cm depth.	m	Unskilled	Nos.	0.06				Pick axe Shovel		3 % of labour cost

BIO-ENGINEERING WORKS NORMS RATE ANALYSIS NORMS												
S.No.	**Respective Clause of Specifications**	**WORK DESCRIPTION**	**UNIT**	**RESOURCES**								
				LABOUR			**CONSTRUCTION MATERIALS**			**TOOLS AND EQUIPMENT**		
				LEVEL	**UNIT**	**QUANTITY**	**TYPE**	**UNIT**	**QUANTITY**	**TYPE**	**UNIT**	**QUANTITY**
		e) Laying of live fascines using live hardwood cuttings of selected species (e.g., *asuro*, *namdi phul*, *simali*) of minimum 1 m length placed in bundles to give 4 running meters of cuttings per meter of fascine, including backfilling of trench and careful compaction.	m	Unskilled	nos	0.17	Hardwood cuttings of at least 1 meter in length.	rm	4.00	*Khukuri* Pick axe Shovel		3 % of labour cost
71 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Jute netting works** a) Standard jute netting for bare slopes and under planting with slips. Spinning row jute from 100% jute fibre into yarn and weaving the yarn into netting. Hand spun yarn 5 to 8 mm in diameter, width of net 1.20 meters, warp strands 27 nos per 100cm, weft strands 20-24 nos per 100 cm mesh size 30-40 mm square and 1.25 kg/m weight at 1.20 m widths**. (Note** A tosro is the weaving shuttle normally made from a split large bamboo culm**)**	m^2	Skilled	nos	0.36	Row jute	Kg.	1.25	*Khukuri* Bamboo Weaving frame		3% of labour cost

BIO-ENGINEERING WORKS NORMS
RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		b) Wide mesh jute netting for holding mulch on slopes. Spinning row jute from 100% jute fibre into yarn and weaving the yarn into netting. Hand spun yarn 3 to 5 mm diameter 1.20 m side and 11.2o m long. Mesh size 150 x 500 mm rectangular mesh and 0.25 kg/m at 1.20 m width. **(Note** A tosro is the weaving shuttle normally made from a split large bamboo culm**)**	m²	Skilled	nos	0.15	Row jute	Kg.	0.26	*Khukuri* Bamboo Weaving frame		3% of labour cost
		c) Placing 30-40 mm square mesh jute and coir netting on bare slopes (for later under planting with grass slips), including pegging with live hardwood cuttings or split bamboo pegs and loosening tension so that the net hugs the slope throughout.	m²	Unskilled	nos	0.15	Woven Jute net Hardwood or split bamboo peg	m² nos	1.00 5.00	Wooden hammer		3% of labour cost

BIO-ENGINEERING WORKS NORMS

RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		d) Placing 150 x 500 mm mesh jute netting to hold mulch on slopes, including application of mulch and pegging with live hardwood cuttings or split bamboo pegs and loosening tension so that the net hugs the slope throughout.	m^2	Unskilled	nos	0.10	Jute or coir net Hardwood or split bamboo peg mulch	m^2 nos m^3	1.00 5.00 0.05	Wooden hammer		3% of labour cost
72 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Fabrication of gabion bolster cylinders** a) Site preparation for 30 cm diameter bolster; earth works in excavation of trench.	m	Unskilled	nos	0.085				Pick axe Shovel		3% of labour cost
		b) Site preparation for 60 cm diameter bolster; earth works in excavation of trench.	m	Unskilled	nos	0.36				Pick axe Shovel		3% of labour cost
		c) Manufacture of gabion bolster panels 70 x 100 mm hexagonal mesh wire construction (10 SWG frame and 12 SWG mesh).	m^2	Skilled	nos	0.10	GI wire	Kg.	2.00	Gabion frame and tools		3% of labour cost

BIO-ENGINEERING WORKS NORMS

RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		d) Construction of 30 cm bolster cylinder; placing, stretching wire mesh, filling with boulders, closing and backfilling.	m	Unskilled	no	0.375	Boulder	m^3	0.09	Gabion tools *Doko*		3% of labour cost
		e) Construction of 60 cm bolster cylinder; placing, stretching wire mesh, filling with boulders, closing and backfilling.	m	Unskilled	no	0.75	Boulder	m^3	0.36	Gabion tools Doko		3% of labour cost
		f) Construction of 30 cm bolster cylinder; placing, stretching wire mesh over 20 gauge black polythene sheeting, filling with boulders, closing and backfilling.	m	Unskilled	no	0.375	Black Polythene Boulder	m^2 m^3	0.40 0.09	Gabion tools *Doko*		3% of labour cost
		g) Construction of 60 cm bolster cylinder; placing, stretching wire mesh over 20 gauge black polythene sheeting, filling with boulders, closing and backfilling.	m	Unskilled	no	0.75	Black Polythene Boulder	m^2 m^3	0.80 0.36	Gabion tools *Doko*		3% of labour cost
		h) Anchoring bolster; 12mm diameter MS re-bar cut into 2 m lengths for anchorage and placed at 1 m intervals.	nos	Unskilled	no	0.05	MS rod	m	2.00	Sledge hammer		3% of labour cost

BIO-ENGINEERING WORKS NORMS

RATE ANALYSIS NORMS

S.No.	Respective Clause of Specifications	WORK DESCRIPTION	UNIT	RESOURCES								
				LABOUR			CONSTRUCTION MATERIALS			TOOLS AND EQUIPMENT		
				LEVEL	UNIT	QUANTITY	TYPE	UNIT	QUANTITY	TYPE	UNIT	QUANTITY
		i) Laying of terram paper (geo-textile)	m²	Unskilled	nos	0.05	Geo-textile	m²	1.15	*Khukuri*		3% of labour cost
73 DoLIDAR	Refer to "Bio-engineering Information" of Dept. of Roads	**Bamboo tree guards** a) Weaving bamboo tree guards using bamboo poles as uprights; 1.60 m in height and weaving split bamboo with the outer wall intact around the posts. Dimensions of the guard are 0.60 m diameter x 1.30 m high.	nos	Unskilled	nos	0.25	Bamboo	nos	2.20	*Khukuri*		3% of labour cost