



## Standard specifications for bio-engineering works

The standard specifications for bio-engineering works given in this chapter cover all of the techniques described in the *Site Handbook*. They are based on field experience and have been devised on the basis of standard contracting procedures for works. They follow the sequential numbers given in the Department of Roads' standard specifications (the sequence 2800 being assigned to bio-engineering). They are approved for use by the Department of Roads.

## 6.1 INTRODUCTION

The list below shows the full range of specifications given in the Department of Roads Standard Specifications and are approved for use by the Department of Roads.

### 2800 PROVISION OF SEED

- 2801 Grass seed collection
- 2802 Tree and shrub seed collection

### 2810 PROVISION OF PLANT CUTTINGS

- 2811 Provision of grass cuttings
- 2812 Provision of hardwood cuttings

### 2820 NURSERY CONSTRUCTION

- 2821 Nursery establishment
- 2822 Construction of nursery beds

### 2830 NURSERY OPERATION AND MANAGEMENT

- 2831 Nursery production of grass
- 2832 Nursery production of trees and shrubs in polypots
- 2833 Nursery production of hardwood plants by vegetative methods
- 2834 Extraction of plants from the nursery
- 2835 Compost and mulch production

### 2840 SLOPE PREPARATION FOR BIO-ENGINEERING

- 2841 Slope trimming
- 2842 Disposal of spoil
- 2843 Final cut slope preparation for grass planting and seeding
- 2844 Final preparation of fill and debris slopes for bio-engineering

### 2850 SITE PLANTING AND SOWING

- 2851 Sowing of grasses on site
- 2852 Direct seed sowing of shrubs and trees on site
- 2853 Site planting of grass slips and cuttings
- 2854 Site planting of shrubs and trees raised in polythene pots
- 2855 Site planting of hardwood cuttings
- 2856 Brush layering, palisades and fascines
- 2857 Use of fertiliser

### 2860 JUTE NETTING WORKS

- 2861 Supply of jute netting
- 2862 Placement of netting

### 2870 WIRE BOLSTER CYLINDERS

- 2871 Fabrication of bolster panels
- 2872 Placement of contour bolsters
- 2873 Placement of herringbone bolsters

### 2880 SITE PROTECTION

- 2881 Provision and role of site watchmen
- 2882 Fabrication of bamboo tree guards
- 2883 Placement of bamboo tree guards

### 2890 SITE AFTERCARE AND MAINTENANCE

These specifications can simply be copied directly from this book for use in contracts. They provide for changes to be specified 'by the Engineer' so that particular sites can be treated on an individual basis.

### 2800 PROVISION OF SEED

1. The Contractor shall provide or collect seeds of the required species in accordance with the requirements described hereafter, of the species and quantities required, as and when required. He shall supply all necessary expertise, resources and facilities to ensure that these requirements are met in full. It is essential that the seed is of a high quality as it forms the basis to the success of any bio-engineering programme.
2. The Engineer will give indications as to the expected amounts of seeds required and the time of availability. But it is the Contractor's responsibility to ensure that adequate quantities of seeds are obtained in a timely fashion.
3. The weights to be specified are for sun-dried seeds separated completely from fruiting bodies and other unwanted parts, and ready for storage and subsequent sowing. There is usually a large discrepancy between this weight and that of the freshly collected, untreated fruits.
4. Should the Contractor be unable to supply the specified seeds, the advice of the Engineer should be sought. It may be possible to substitute other species. Some commercial seed sources in Nepal and India are known to supply old or badly treated seeds. For this reason, seed should not be obtained commercially without the Engineer's written authority.

### 2801 GRASS SEED COLLECTION

1. The species of grass seeds to be collected will be determined by the Engineer. The

Contractor will be responsible for determining seed sources, though these may be specified by the Engineer's instructions. Seeds should normally be collected in or very close to Division of use or the project area.

2. If the Engineer does not specify the species, then the current approved list of bio-engineering plants, as determined by the Geo-Environment Unit of the Department of Roads should be referred to.
3. Seeds must be collected from as many individual plants as possible. With grasses, it is difficult to determine the best genetic material from the appearance of form; but it is generally sound practice to select from the largest and most vigorous plants.
4. The Contractor may under no circumstances damage or remove the roots of grass plants while collecting seed. The Contractor is responsible for safety measures and for making all necessary arrangements with landowners, farmers and the local District Forest Office, as applicable, before the collection of seeds.
5. Seeds may only be collected when fully ripe. Seeds collected early are not viable when planted and will cause a failure of the planting programme. The Contractor will be held liable if the germination rate of seeds is seriously lower than the normally expected percentage (as defined in publications issued by the Geo-Environmental Unit).
6. Immediately after collection, seeds must be separated from flower heads by the method normally used by farmers for other grasses. Once separated, the seeds must be sun-dried before storage.
7. Seeds must be stored in a cool, dry, ventilated building with adequate precautions taken against pests. Containers should be raised above the floor. They should not be kept in the same building as cement, or any chemicals, fuels or lubricants. Grass is best stored in bags made of hessian (jute) sheet. Seeds should be carefully inspected on a weekly basis to ensure that there is no deterioration or mould formation, or pest attack. Seeds can

only be stored successfully if they have been properly dried in the sun beforehand.

## **2802 TREE AND SHRUB SEED COLLECTION**

1. The species of tree and shrub seeds to be collected will be determined by the Engineer. The Contractor will be responsible for determining seed sources, though these may be specified by the Engineer's instructions. Seeds should normally be collected in or very close to the working area.
2. If the Engineer does not specify the species, then the current approved list of bio-engineering plants, as determined by the Geo-Environmental Unit of the Department of Roads should be referred to.
3. Seeds must be collected from as many healthy individual plants as possible. In any event, they must be collected from at least ten individual plants. The plants from which the seeds are collected must show vigorous growth and good form. Mis-shapen and stunted plants should not be considered.
4. The Contractor must under no circumstances damage plants while collecting seed. The Contractor is responsible for making all necessary arrangements with landowners, farmers and the local District Forest Office, as applicable, before the collection of seeds.
5. The collection of seeds from trees can be a dangerous business, placing the collectors at considerable personal risk. Specialist equipment and training is available in Nepal for this purpose. It is the Contractor's responsibility to ensure safe working conditions for his employees or subcontractors.
6. Seeds may only be collected when fully ripe. Seeds collected early are not viable when planted and will cause a failure of the planting programme. The Contractor will be held liable if the germination rate of seeds is seriously lower than the normally expected percentage.
7. Immediately after collection, seeds must be separated from fruit by the method normally used by farmers and foresters for this purpose; this depends on the individual species but may

be a time-consuming process for certain fruits. Once separated, the seeds must be sun-dried before storage.

8. Seeds must be stored in a cool, dry, ventilated building with adequate precautions taken against pests. Containers should be raised above the floor. They should not be kept in the same building as cement, or any chemicals, fuels or lubricants. If kept in sealed containers, the seeds should be carefully inspected on a weekly basis to ensure that there is no deterioration or mould formation. Seeds can only be stored successfully if they have been properly dried in the sun beforehand.

### 2810 PROVISION OF PLANT CUTTINGS

1. The species of plants to be collected for vegetative propagation will be determined by the

Engineer. The Contractor will be responsible for determining plant material sources, though these may be specified by the Engineer's instructions. Plants should normally be collected in or very close to the working area.

2. If the Engineer does not specify the species, then the current approved list of bio-engineering plants, as determined by the Geo-Environmental Unit of the Department of Roads should be referred to.

### 2811 PROVISION OF GRASS CUTTINGS

1. Cuttings of various types must be taken from grass species which are known to propagate easily by vegetative means.
2. Cuttings must be made from as many healthy individual plants as possible. The plants from

Local name	Botanical name	Best propagation	Details
Amliso	<i>Thysanolaena maxima</i>	Rhizome cuttings	Stem: 100 - 150 mm; rhizome: 50 - 80 mm
Babiyo	<i>Eulaliopsis binata</i>	Slip cuttings	Stem: 100 - 150 mm; root: 30 - 60 mm
Dhonde	<i>Neyraudia reynaudiana</i>	Stem/slip cuttings	Stem cuttings: 2 nodes plus 50 mm each side Slips: stem: 100 - 150 mm; root: 30 - 60 mm
Kans	<i>Saccharum spontaneum</i>	Slip cuttings	Stem: 100 - 150 mm; root: 30 - 60 mm
Katara khar	<i>Themeda species</i>	Slip cuttings	Stem: 100 - 150 mm; root: 30 - 60 mm
Khar	<i>Cymbopogon microtheca</i>	Slip cuttings	Stem: 100 - 150 mm; root: 30 - 60 mm
Khus	<i>Vetiveria lawsoni</i>	Slip cuttings	Stem: 100 - 150 mm; root: 30 - 60 mm
Napier	<i>Pennisetum purpureum</i>	Stem cuttings	Two nodes plus 50 mm each side
Narkat	<i>Arundo donax</i>	Stem/slip cuttings	Stem cuttings: 2 nodes plus 50 mm each side Slips: stem: 100 - 150 mm; root: 30 - 60 mm
Padang bans	<i>Himalayacalamus hookerianus</i>	Large slip cuttings	Stem: 750 - 1200 mm; root: 100 - 200 mm
Phurke	<i>Arundeuella nepalensis</i>	Slip cuttings	Stem: 100 - 150 mm; root: 30 - 60 mm
Sito	<i>Neyraudia arundinacea</i>	Slip cuttings	Stem: 100 - 150 mm; root: 30 - 60 mm
Tite nigalo	<i>Drepanostachyum intermedium</i>	Large slip cuttings	Stem: 750 - 1200 mm; root: 100 - 200 mm

which the cuttings are taken must show vigorous growth and good form. Grass clumps showing stunted growth should not be considered as sources.

3. Apart from the clumps which are dug up to make cuttings, the Contractor must under no circumstances damage other plants. The Contractor is responsible for making all necessary arrangements with landowners, farmers and the local District Forest Office, as applicable, before the excavation of plants to make cuttings.
4. The type of cuttings to be made depends on the species and should be as shown in the table below. If the species used is not listed here, then the latest technical information provided by the Geo-Environmental Unit should be consulted. If the species is still not covered, then stem and root slip cuttings should be used.
5. Where roots are required for the cuttings, grass clumps should carefully dug up. They must not be pulled hard, as this can damage the material. They must be separated carefully by hand, using a sharp khukuri or razor blade when necessary. There must be no tearing of the plant fabric.
6. Stem cuttings must be made using sharp secateurs. The top cut should be made at right-angles to the stem and the bottom cut should be made at 45° to the stem: this is to show the orientation of planting.
7. Once cuttings have been made, they must be wrapped in wet hessian jute immediately. At all times, cuttings are to be kept moist and as cool as possible, and should be wrapped in wet hessian between all operations such as digging out of the ground, splitting out, trimming and planting. Under any circumstances, all cuttings must be planted the same day that they are made.

## 2812 PROVISION OF HARDWOOD CUTTINGS

1. Hardwood cuttings must be taken from shrubs and trees of species which are known to propagate easily by vegetative means.

2. Cuttings must be made from as many healthy individual plants as possible. The plants from which the cuttings are taken must show vigorous growth and good form. Mis-shapen and stunted plants should not be considered as sources.
3. The species from which hardwood cuttings are to be made for bio-engineering works normally includes assuro (*Adhatoda vasica*), bainsh (*Salix tetrasperma*), kanda phul (*Lantana camara*), namdi phul (*Colquhounia coccinea*), saruwa or bihaya (*Ipomoea fistulosa*) and simali (*Vitex negundo*)
4. Apart from the branches from which cuttings are taken, the Contractor must under no circumstances damage plants while taking cuttings. The Contractor is responsible for taking safety precautions and for making all necessary arrangements with landowners, farmers and the local District Forest Office, as applicable, before the making of hardwood cuttings. In no event is more than 60 percent of the aerial parts of a single plant to be removed in the making of cuttings.
5. Hardwood cuttings must be made from stems which are between 6 and 18 months old. Materials outside this range are not normally vigorous or strong enough to survive as cuttings. The Contractor may be held liable if the success rate of cuttings is seriously lower than the normally expected percentage.
6. Hardwood cuttings must be made using sharp secateurs or a sharp saw. The top cut should be made at right-angles to the stem and the bottom cut should be made at 45° to the stem: this is to show the orientation of planting. Under no circumstances must there be any damage to the bark of the cutting.
7. Hardwood cuttings are normally 20 to 40 mm in diameter and of the following lengths: 300 to 500 mm for palisades, vegetated stone-pitched walls and for pegging jute netting; 450 to 600 mm for brush layers; and a minimum of 1000 mm for fascines. For live check dams, all cuttings are to be 2000 mm in length; the cuttings for cross pieces should be 20 to 50 mm in diameter and the truncheon cuttings for the vertical elements should be

30 to 80 mm in diameter: truncheon cuttings are made from the species listed in paragraph 8 below. This size should not be exceeded for the majority of species unless specified by the Engineer.

8. A number of species can be propagated using large truncheon cuttings. In this category fall chuletro (*Brassaiopsis hainla*), dabdabe (*Garuga pinnata*), kavro (*Ficus lacor*), phaledo (*Erythrina* species) and *Gliricidia sepium*. Hardwood cuttings for these species should be in the range of 1500 to 2500 mm in length and 30 to 80 mm in diameter unless otherwise specified.
9. Once cuttings have been made, they must be wrapped in wet hessian jute immediately. At all times, cuttings are to be kept moist and as cool as possible, and should be wrapped in wet hessian between all operations such as taking from the parent plant, trimming and planting. Under any circumstances, all cuttings must be planted the same day that they are made.

## 2820 NURSERY CONSTRUCTION

1. The Contractor shall provide nurseries to contribute stocks of grasses, shrubs and trees for planting operations as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required by the Engineer. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.
2. The establishment and effective operation of plant nurseries is a skilled business requiring experienced and trained staff. These specifications alone do not provide all the information needed to set up and run nurseries. The Contractor should seek the advice of specialist agencies and should refer to the large number of reference books available on the subject..
3. The purpose of a nursery is to supply good quality, healthy plants of the correct type and species, at the precise time they are required, and at a reasonable cost.

## 2821 NURSERY ESTABLISHMENT

1. The Contractor shall provide nursery facilities adequate to supply all of the stock required for planting operations. Alternatively, he may procure planting stock from elsewhere at the time of site planting, providing it is of a standard acceptable to the Engineer and as described hereunder.
2. In selecting a site for a nursery, the Contractor must fulfil the following requirements.
  - (i) Nurseries must be as close as possible to all sites to be planted. They must be at the same altitude as, and in an identical climatic area to, the sites to be planted.
  - (ii) Wherever possible, nurseries must be established on land owned by the Department of Roads if it is available and biophysically suitable. If it is not, other land of His Majesty's Government should be used if it is available.
  - (iii) Nurseries should have a reliable and adequate supply of water which remains constant throughout the later part of the dry season.
  - (iv) Nurseries should have all weather vehicular access.
  - (v) Nurseries should have a perimeter of stock proof fencing, effective against all domestic animals.
  - (vi) Nurseries should have a weather- and pest-proof office cum seed store and proper storage facilities for seed. Seed must be kept cool, dry and in sealed containers, as specified in clauses 2801 and 2802.
  - (vii) All nurseries should be provided with at least two above-ground compost bays, built of stone, brick or timber. These will be used on an alternate basis to ensure a continual supply of compost.
  - (viii) Where a nursery is established on a slope exceeding 2°, the ground must be levelled by terracing before beds are constructed.

- (ix) A constant staff of qualified and experienced people must be provided.
- (x) There must be adequate space in each nursery location for all operations to be performed in the cycle of work. In particular, all plants need to be spaced out periodically as they grow and there must be adequate bed area to accommodate them.

## 2822 CONSTRUCTION OF NURSERY BEDS

1. Nursery beds must be made in a different way according to their purpose. The Contractor must ensure that there are adequate beds available for all the operations to be undertaken in the nursery.
2. There must be paths around all beds to ensure the best possible access for operations such as weeding and watering.
3. The table below summarises the construction details of the four main bed types, which are described in full in paragraphs 4 to 7.
4. Soil beds should be constructed to hold grass seeds, grasses being propagated by vegetative means and tree stool cuttings. These can be of any practical length but must be flat and of one metre in width. They should rise to a height of 250 mm above the surrounding ground. They are made up as follows: 50 mm of washed gravel is placed above the ground; then 50 mm of 1:1 mix of sieved soil and compost; and the bed is topped with 150 mm of 3:1 mix of sieved fertile, loamy forest top-

soil and washed sand. All sieving should be done with a mesh size of 2 mm or smaller. One square metre of such a bed will contain 100 grass slips spaced at 100 mm centres within rows at 100 mm centres and will produce at least 300 slips for planting out, depending on the particular species, and the soil and climate of the nursery.

5. Seed beds must be made very carefully for germinating small seeds of shrubs and trees. These can be of any practical length but must be flat and of one metre in width. They should rise to a height of 170 mm above the surrounding ground. They are made up as follows: 50 mm of washed gravel is placed above the ground; then 50 mm of unsieved forest soil; 50 mm of 1:3 mix of sieved forest soil and washed sand; and the bed is topped with 20 mm of washed, sieved and sterilised sand. All sieving should be done with a mesh size of 1 mm or smaller.
6. Standout beds should be constructed to hold seedlings in polythene pots. These can be of any practical length but must be flat and of one metre width. Bed floors should be above surrounding ground level and they should have a 50 mm layer of gravel placed above compacted ground. They should have a surround, preferably made from flat stones or bricks. One square metre of standout bed will contain an average of 115 filled pots of the size specified (100 × 180 mm) when spaced out.
7. Beds for the propagation of bamboo culm cuttings should be made specially. These can be

Bed type	Beds for grass seeds, grass slips and tree stool cuttings	Seed beds for tree seedlings	Stand out beds for polypots seedling	Beds for the propagation of bamboo culm cuttings
Bed size	1000 mm wide × 250 mm high	1000 mm wide × 170 mm high	1000 mm wide × 150 mm high	1000 mm wide × 300 mm high
Details of construction	50 mm of washed gravel placed above the ground; then 50 mm of 1:1 mix of sieved soil and compost; and topped with 150 mm of 3:1 mix of sieved forest topsoil and washed sand.	50 mm of washed gravel placed above the ground; then 50 mm of unsieved forest soil; 50 mm of 1:3 mix of sieved forest soil and washed sand; and topped with 20 mm of washed, sieved and sterilised sand.	50 mm layer of gravel placed above compacted ground. A flat stone or brick surround.	Ground below the bed is dug to a depth of 300 mm. Bed is made with 100 mm of unsieved soil (lower) and 200 mm of sieved soil (upper). A bund 100 mm high is formed around the edge.

of any practical length but must be flat and of one metre width. They should rise to a height of 300 mm above the surrounding ground. They are made up as follows: the ground below the bed is dug to a depth of 300 mm; the bed itself is then made with 100 mm of unsieved soil on the original surface, and 200 mm of sieved soil above this. All soil sieving should be done with a mesh size of 2 mm or smaller. Finally, a bund 100 mm high is formed around the edge.

8. Shades must be constructed over the beds and kept in position over delicate seedlings during hours of intense sunlight, according to need. Shades should be 750 to 1000 mm above the soil or the top of filled pots, and angled so as to be effective for as much of the day as possible (*i.e.* with the lower side to the south). Bamboo strips laced together with coir (coconut fibre) string are particularly suitable in most cases; but over tree and shrub seed beds, thatched shades with a polythene lining must be used.

### **2830 NURSERY OPERATION AND MANAGEMENT**

1. The contractor must operate the nursery according to a high standard. The nursery is to be staffed well tended at all times. It must be maintained in a clean, tidy and efficient manner at all times. Plants must always be healthy and vigorous.
2. Due to the nature of bio-engineering works, nurseries will normally be operated and managed by small local contractors with a range of agricultural skills. Nurseries may also be operated and managed by direct employees of the Division Road Office.
3. Plants must be kept properly weeded at all times.
4. Watering, as required for good plant growth, must be carried out regularly in the cool of the evening between sunset and dusk. The Contractor must ensure that the soil in all beds is kept moist but not saturated at all times. Beds must be kept moist even when empty, so that the soil is kept in good condition.

5. The timing of many nursery operations is of the utmost importance. Activities such as seed sowing and the taking of cuttings must be carried out within the critical few weeks when they will yield the desired results. Most other operations, such as spacing out, root pruning and watering, must also be carried out in a timely manner. The contractor is responsible to keep works to the strict schedule required and under no circumstances to permit delays.

### **2831 NURSERY PRODUCTION OF GRASS**

1. Grass will be propagated in nurseries either by seeding in carefully prepared beds or by vegetative propagation.
2. Where grass seeding is required in the nursery, finely sieved fertile soil mixed with clean sand to a texture of sandy loam must be placed in beds before the seeds are sown. Seeds will be covered with a sheet of hessian jute until they have germinated, when it will be carefully removed. Watering of fresh seedlings will be by a fine spray and *not* by the rose of a watering can.
3. Grasses to be propagated by vegetative methods will be of the species instructed. The Contractor should obtain adequate quantities of the plant material required, but under no circumstances is he to cause serious depletion of grass stocks in any steep or erosion-prone area.
4. Vegetative propagation will normally be by rhizome cuttings. With this method, the grass is treated in exactly the same way as a bamboo being propagated by the traditional Nepalese farmer's technique. A clump is carefully dug up and brought to the nursery, being kept cool and damp at all times. Stems are cut above the first or second node above the ground: this usually gives a length of 100 to 200 mm. The clump is separated carefully, with the minimum of damage to the rhizomes and fine roots. Slips should be separated out which keep a length of stem and about 50 mm of the rhizome. Each slip should have some buds on the rhizome, but in some grasses these can be difficult to see.

The slips should be planted with the soil surface at the same level as it was originally, in rows at 200 mm centres; slips should be at 200 mm centres within the rows. A sheet of hessian jute should be placed over the tops of the cuttings. When the new shoots are about 50 mm long, it can be removed.

5. Every two to three months, all grasses should be lifted from the beds, split carefully and replanted. It is normal that, once split out, three times the previous bed area is required. This is a standard practice to bulk up the supply of planting stock without having to degrade the natural vegetation cover in the region of the nursery.

#### 2832 NURSERY PRODUCTION OF TREES AND SHRUBS IN POLYPOTS

1. Trees and shrubs will be seeded either in seed beds or directly in polythene pots ('polypots'). Finely sieved fertile soil mixed with clean sand to a texture of sandy loam must be placed in well shaded beds for seeding. Watering of fresh seedlings will be by a fine spray, and *not* by the rose of a watering can.
2. All plants must be grown on in pots of dimensions 100 × 180 mm (4 × 7 inches) or greater when laid flat. The pots should be of black, 200 gauge polythene. They must have adequate drainage holes at the bottom and be filled with fertile forest topsoil mixed with clean sand to a texture of sandy loam.
3. Roots protruding from the bottom of pots must be pruned with a razor blade on a regular basis which will not exceed weekly and may need to be more frequent. Protruding roots should never be allowed to become more than 25 mm in length.
4. When polypot seedlings begin to compete with each other for light, they should be re-spaced as required. This would typically mean doubling the bed space occupied by the plants.
5. To be acceptable for planting on site, trees and shrubs must be healthy, vigorous and showing no signs of damage, wilt, irregular growth, fungal or pest attack, or nutrient disorder.

They must be at least 300 mm in height above soil surface level and of good form. The roots must be in good condition and there should be no signs of disturbance to the soil in the polythene pot, even after transport to site.

#### 2833 NURSERY PRODUCTION OF HARDWOOD PLANTS BY VEGETATIVE METHODS

1. Trees and shrubs which can be propagated by vegetative methods may be specified by the Engineer. The Contractor should produce these by the appropriate method, as required.
2. All cuttings and stools must be made as specified in clause 2812 and planted in fertile soil beds of the type specified in clause 2822.
3. Cuttings must be planted 300 mm apart in holes slightly larger than their diameter. They must be placed at such a depth that only one bud remains above the soil surface (*i.e.* about 30 mm of the cutting).
4. When plants compete with each other for light, they should be cut back as necessary.
5. To be acceptable for planting on site, trees and shrubs produced in this way must be healthy, vigorous and showing no signs of damage, wilt, irregular growth, fungal or pest attack, or nutrient disorders. They must be at least 500 mm in height above soil surface level and of good form.

#### 2834 EXTRACTION OF PLANTS FROM THE NURSERY

1. The Contractor is responsible for extracting plants from nursery beds and preparing them ready for transport. They should be extracted from the beds only on the morning that they are required for planting on site.
2. Plants must be hardened off, starting at least two weeks before they are to be taken out of the nursery. This process requires a gradual reduction in the amount of watering and shading. The aim is to prepare them for transfer to a much more hostile location.

3. The night before the plants are to be lifted, they should be thoroughly watered. This is to make the soil softer and ease the business of extracting the roots.
4. Plants growing in soil beds should be carefully lifted from the soil. There must be no pulling of stems or roots, but they must be dug out and extracted with no strain on any part of the plant.
5. Plants from soil beds must be wrapped in wet hessian jute. Hardwood plants should have a ball of soil around the roots. Grass clumps can have most of the soil shaken or washed off.
6. Polypot seedlings should be lifted and stacked neatly in metal or wooden trays. They must always be lifted by the pot and *never* by the stem or leaves.
7. All plants are to be kept moist, in a cool, shady place, until they are loaded for transport to site. In the vehicle, they must not be stacked high. For transport on rough roads, they must be packed in carefully so that they do not fall over or roll around. The vehicle must be shaded.

#### 2835 COMPOST AND MULCH PRODUCTION

1. The Contractor is to produce compost and mulch for nursery or site operations. It is to be produced in a timely manner, in the quantities required. Compost is normally required to sustain the long term fertility of nursery beds. Mulch may also be used in the nursery, but is normally produced to enhance site planting works, particularly the direct seeding of grass.
  2. Compost and mulch should be made from annual and perennial weeds of poor rooting characteristics, such as ban mara (*Eupatorium adenophorum*) and tite pate (*Artemisia vulgaris*). The greenery should be collected when there is most material available but before it forms seeds. This is most often in Shrawan and Bhadra.
  3. Collected material should be chopped finely and stored in a mound, compost bay or pit.
- The maximum size for chopped compost is 50 mm; the maximum size for chopped mulch is 150 mm.
4. Both compost and mulch should be kept moist but not waterlogged and in an aerated condition. They should be completely turned once a month on a regular schedule. Compost can have cow manure mixed in to assist the process of decomposition.
  5. Neither compost nor mulch should be applied until they are fully rotted. By this time they should be black and the parts of individual plants should be indistinguishable. Early application can lead to a nutrient loss in the soil if microbes extract nitrogen to decompose the added organic material.

#### 2840 SLOPE PREPARATION FOR BIO-ENGINEERING

1. The Contractor shall prepare slopes for planting operations as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.
2. In the course of all slope preparation works, it is essential that no damage is done to existing vegetation unless the Engineer's instruction specifically requires certain plants to be removed.
3. The timing of many bio-engineering operations is of the utmost importance. Activities such as planting and seed sowing must be carried out within the critical few weeks when they will yield the desired results. All other operations must be carried out in a timely manner to permit this to happen. The contractor is responsible to keep works to the strict schedule required and under no circumstances to permit delays.

#### 2841 SLOPE TRIMMING

1. Slope trimming is the main activity where debris masses and inherently unstable slope sections are removed, and the slope made sufficiently sound for civil and bio-engineering

works. The Contractor must first check that all prior construction work has been completed and that the site is clear of equipment. It is the Contractor's responsibility to ensure that there is safe access to the site. On very steep slopes, new paths must be made, and ropes or ladders provided as necessary. All site staff and labourers must be issued with safety helmets and protective footwear.

2. The Engineer will issue an instruction for the details of trimming required on each site. If this has not already been issued it is the Contractor's responsibility to request it from the Engineer and agree the details before work is commenced. Possibilities for slope trimming are as follows: minor trimming required only on part of site; keeping rill or gully pattern in plan section; trimming to a new designed plan section; new retaining wall to be backfilled; others, as determined by the individual site.
3. A trimming survey must first be carried out. Pegs and lines must be placed as necessary to show the workers how much material to trim. Notches must be cut through the mass to be trimmed to give the final cut lines.
4. When trimming a site, work must be started from the top of the slope segment. The slope is trimmed in steps from the top, using the steps as ledges for the workers to stand on during trimming.
5. If backfilling is required behind a retaining structure below, the trimmed material must be compacted at intervals as the operation proceeds. This will require halting the trimming, redistributing and compacting the debris as backfill. Compaction is carried out in level layers approximately 100 – 150 mm thick, laid back into the slope at about 5°. If possible, water should be added while compacting the material.
6. When the main trim has been completed, the workers should return to the top of the slope and work down again, carrying out the final trim. This should give a clean, smooth surface, good enough for vegetation to be planted on.

7. The final trim line should then be checked to ensure that it is straight and accurate throughout the site. If protrusions or indentations remain, they must be removed or filled with compacted material. Once the profile has been satisfactorily obtained, all debris must be removed from the site to an approved tipping area and the site left in a tidy condition.

#### 2842 DISPOSAL OF SPOIL

1. In mountainous areas, the disposal of spoil can lead to many problems of erosion and slope instability. The Contractor must follow the Engineer's instructions in disposing of surplus spoil in approved locations.
2. Where a landfill site is created, maximum use must be made of terraces, level ground and spurs. If spoil tipping has to be done on steep slopes, it is essential to select areas formed in resistant bedrock. Tipping should result in no more than the removal of vegetation and shallow soil, with negligible slope incision thereafter. Bitumen drum disposal chutes can be used to convey the spoil down a short slope to a safe site below.
3. During tipping, the Contractor must build many small spoil benches, rather than a few large ones, to avoid slope overloading. A drainage blanket must be installed beneath a spoil bench where there is any indication of a spring seepage at or near the spoil site. Spoil benches must be compacted during tipping. While benches cannot be compacted in the formal sense, they can be constructed in definite lifts, normally not more than 0.5 m thick, with the top surface of each lift approximately horizontal. This will allow machines involved in spreading the spoil to track the surface and provide some degree of compaction.
4. Where spoil benches are constructed on agricultural land, the Contractor must form the tip into a benched profile so that it can eventually be returned to agricultural production. In the meantime, the risers between levels must be protected against erosion by applying vegetation or constructing dry stone walls.

5. Where the top surface of the bench is large, runoff must be reduced by providing regular shallow interceptor drains. The slope of these drains should be constant as far as is practicable and should not be so steep as to induce erosion.
6. On completion, the Contractor is to leave spoil benches in their required shape and plant them with grasses, shrubs and trees to encourage maximum stability and resistance to erosion.
7. Where the tipping of spoil has been permitted on steep slopes above major rivers, the spoil should be completely removed from the slope and thrown into the river. The original ground should be restored with a full cover of vegetation.
8. Under no circumstances are the following permitted: tipping of spoil into stream channels other than major rivers, as the increased sediment load will lead to scour and siltation downstream; tipping of spoil on to slopes where road alignments, housing areas or farmland downslope might be affected; use of areas of past or active instability and erosion as tip sites, unless they are at least 50 metres from the road; the discharge of runoff over the loose front edge of a tip bench during or after construction; tipping of spoil in front of road retaining walls, where impeded drainage could soften the wall foundation.

#### 2843 FINAL CUT SLOPE PREPARATION FOR GRASS PLANTING AND SEEDING

1. The objective of final cut slope preparation is to produce a surface adequately prepared for grass planting or grass seeding. Grass lines are used to provide a strong surface cover but need a well prepared surface in which to be planted; if grass is to be an effective form of slope protection, it must be allowed to establish properly on a slope which does not subject it to undue stress from erosion and mass movement in its initial stages.
2. The Contractor must ensure that the slope under instruction is trimmed to a straight angle, according to the Engineer's specifica-

tion. Cut slopes to be planted with grass will normally be instructed as 3 vertical:2 horizontal, but this may be varied at the Engineer's discretion. In any event, a straight profile must be obtained. Concavities must be filled with well compacted material or, in some cases, with dry stone dentition. Convexities must be removed and it is essential that the general profile does not have a shape giving over-steep segments.

3. All loose material must be removed from the slope and tipped elsewhere in an approved location, as per the requirements of standard specification 2842.

#### 2844 FINAL PREPARATION OF FILL AND DEBRIS SLOPES FOR BIO-ENGINEERING

1. The objective of the final preparation of fill slopes and slopes comprising unconsolidated landslide debris is to produce a surface adequately prepared for shrub or tree planting or grass sowing, or a combination of these. Vegetation is used to provide a strong surface cover but needs a well prepared surface in which to be planted: if it is to be an effective form of slope protection, it must be allowed to establish properly on a slope which does not subject it to undue stress in its initial stages.
2. The Contractor must ensure that the slope under instruction is trimmed to a straight angle, according to standard specification 2841. In any event, a straight profile must be obtained. All masses of loose debris, especially where it has previously been tipped at the head of the slope, must be removed. Concavities must be filled with well compacted material or, in some cases, with dry stone dentition. Convexities must also be removed and it is essential that the general profile does not have a shape giving over-steep segments.

#### 2850 SITE PLANTING AND SOWING

1. The Contractor shall plant or sow grasses, shrubs and trees as required by the Engineer. This shall be done according to the specifications described hereunder, as and when

required. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.

2. Due to the nature of bio-engineering works, they will normally be undertaken by small local contractors with a range of agricultural skills. Any bio-engineering site activity may also be managed by direct employees of the Division Road Office.
3. It is the Contractor's responsibility to ensure that all planting stock, whether provided from a nursery under a separate contract or through a separate instruction, is of high quality and is vigorous enough to grow on the site to be planted.
4. All seeds and other planting stock must be of species indigenous to Nepal unless otherwise specified. All species must be covered in the current approved lists of species produced from time to time by the Geo-Environmental Unit of the Department of Roads. They must be appropriate for the precise site conditions in which they are to be planted and the Contractor must ensure that they apply to the specific altitude and other environmental characteristics of the site in question.
5. The timing of many bio-engineering operations is of the utmost importance. Activities such as planting and seed sowing must be carried out within the critical few weeks when they will yield the desired results. All other operations must be carried out in a timely manner to permit this to happen. The contractor is responsible to keep works to the strict schedule required and under no circumstances to permit delays.

#### 2851 SOWING OF GRASSES ON SITE

1. The sowing of grasses is intended to create a strengthened slope surface which is resistant to erosion. The Contractor is required to carry out the sowing of grass seeds according to the Engineer's specific instructions.
2. It is assumed that the site will already have been prepared for seed sowing, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that

the condition of the site is good enough for the successful establishment of grasses.

3. The Contractor is required to supervise all field operations very closely. The sowing of grass seeds is a delicate business and should be approached in the same way as for agricultural crops. The Contractor should employ experienced agricultural labourers for this work.
4. Seed will have been collected and stored under a separate instruction well before the time of sowing. However, it is the Contractor's responsibility to check that it has been carefully stored and remains fully viable.
5. Immediately before sowing, the ground surface should be lightly scarified to ease early root penetration. Seeds should then be laid thinly over the surface. Under no circumstances should they be broadcast, because the lightness of perennial grass seeds and the steepness of the slopes to be treated give a poor cover using such a technique. The Contractor is responsible for ensuring that the correct quantities of seeds are used, while giving a good, even cover.
6. A cover of 25 grammes of grass seed per square metre of surface should be achieved unless otherwise specified.
7. After sowing, a mulch of prepared and dried cut herbs should be laid over the whole seeded area in a thin layer. If the mulch is too thick it will prevent light from getting to the seed and will inhibit germination. Herbs suitable for this and locally available in large quantities are:  
tite pate (*Artemisia vulgaris*);  
tapre (*Cassia* species);  
ban mara (*Eupatorium adenophorum*).  
However, freshly cut herbs should not be used because of the danger of resprouting and weeding.
8. If specified, the mulch should be secured with jute netting of mesh size 300 × 500 mm and the netting fixed in place using suitable live pegs or hardwood cuttings (e.g. simali, *Vitex negundo*) at one metre centres.

2852 DIRECT SEED SOWING OF SHRUBS  
AND TREES ON SITE

1. The direct sowing of shrubs and trees is intended to create a strengthened slope surface which is resistant to erosion, and anchorage of unstable surface layers. The technique is particularly effective where very stony materials preclude the use of other planting techniques or where the site will be badly affected by disturbance during the planting of polytop seedlings, or where the site is still unstable and does not warrant the costs involved in planting but would benefit from relatively cheap seeding. The Contractor is required to carry out the sowing of shrub and tree seeds according to the Engineer's specific instructions.
2. It is assumed that the site will already have been prepared for seed sowing, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of shrubs and trees.
3. The Contractor is required to supervise all field operations very closely. The sowing of any seeds is a delicate business and should be approached in the same way as for agricultural crops. The Contractor should employ experienced agricultural labourers for this work.
4. Seed will have been collected and stored under a separate instruction well before the time of sowing. However, it is the Contractor's responsibility to check that it has been carefully stored and remains fully viable.
5. Sowing should start at the top of the slope and the labourers should work downwards. Care must be taken not to disturb areas already seeded.
6. To sow the seeds, a small hole should be made in the slope. The tool used to do this depends on the size of the seed. For some seeds, a piece of gabion wire is adequate; for others, a piece of mild steel with a flattened end is required. The hole should be in the best soil available but if there is little real soil, then a crevice

between two stones is acceptable. Two seeds should be placed in each hole and a covering of soil or whatever fines are available should be placed over them. This covering should never exceed 10 mm and should preferably be about 5 mm; it should never be less than this. Seeds should be placed at 50 to 100 mm centres, as ground conditions dictate.

7. In some cases the seed can be broadcast starting at the top of the site and working down slope as evenly as possible so that the whole site is lightly covered. This is used where the site is still active and only warrants minimum expenditure, or where the site is naturally rough, providing plenty of niches in which the seed can catch. Quantities of seed depend on the type of seed involved but are generally half that of the quantities used in the nursery. With utis (*Alnus nepalensis*) seed it should be at a rate of 1 gramme of seed per square metre.

2853 SITE PLANTING OF GRASS SLIPS  
AND CUTTINGS

1. The planting of grass slips and cuttings is intended to create a strengthened slope surface which is resistant to erosion. The Contractor is required to carry out the planting of grass seedlings or rooted cuttings, according to the Engineer's specific instructions. The configuration of planting will be determined according to individual site conditions. It will be either random, contoured or downslope.
2. It is assumed that the site will already have been prepared for planting, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of grasses, and accords with the specifications given in clauses 2840, and 2841 or 2842.
3. Using appropriate tools (such as tape measures and spirit levels), planting lines must be marked out with string as required. Unless specified differently by the Engineer, the row spacing to be marked out is as shown in the table below.

4. The Contractor is required to supervise all field operations very closely. The planting of grass slips is a delicate business and should be approached in the same way as the transplanting of millet seedlings. The Contractor should employ experienced agricultural labourers for this work.
5. The plants supplied to the Contractor should be prepared for planting by the Contractor as given below. The Contractor is to transport them from the nursery wrapped in hessian jute. At all times, plants are to be kept moist and as cool as possible, and should be wrapped in wet hessian between all operations such as extraction from the bed, pruning and planting. Under any circumstances, all plants supplied must be planted the same day that they are lifted from the nursery.
6. Grass slips or cuttings should be carefully separated from the clumps to give the maximum viable planting material. Any roots in excess of 25 mm should be cut off using a sharp khukuri or razor blade. Shoots and stems should be lopped off 100 mm above ground level.
7. Planting should be started at the top of the slope and under no circumstances should new plants be walked on or otherwise disturbed. Using a small bar (usually made of mild steel and with a flattened end), a hole should be made that is just big enough for the roots. The slip or cutting is inserted; care must be taken that the roots are not tangled or bent back to the surface. Soil is then replaced around the roots and firmed with the fingers. The spacing of plants within rows should be

100 mm unless otherwise specified.

8. If the soil is dry and there is no rain within 16 to 24 hours of planting, the site should be watered carefully with a fine spray. The Contractor will be required to water for the first two weeks after planting in the event of inadequate rainfall.
9. In certain circumstances it may not be possible to provide grass plants from a nursery. In this case the Engineer will specify the species and expected source of grass plants. It is important to minimise disruption to neighbouring land, in the event that species are collected from areas surrounding the road. It is the Contractor's responsibility to collect the stock required from a wide area and not to give rise to any soil erosion through the excessive removal of plants in one locality.

#### 2854 SITE PLANTING OF SHRUBS AND TREES RAISED IN POLYTHENE POTS

1. The planting of trees and shrubs is intended to replace or restore something of the natural vegetation on the slope to be treated. The Contractor is required to carry out the planting of seedlings to the Engineer's specific instructions.
2. It is assumed that the site will already have been prepared for planting, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of delicate young plants.

PLANTING CONFIGURATION	SLOPE ANGLE	ROW SPACING
Random lines	Slope less than 30 degrees	1000 mm centres
	Slope 30 to 45 degrees	500 mm centres
	Slope more than 45 degrees	250 mm centres
Contour lines	Slope less than 30 degrees	1000 mm centres
	Slope 30 to 45 degrees	500 mm centres
	Slope more than 45 degrees	250 mm centres
Diagonal lines	All slopes	500 mm centres
Downslope lines	All slopes	500 mm centres

3. The spacing of plants will be determined according to individual site conditions. However, it will normally be at one metre centres unless otherwise specified.
4. The Contractor is required to supervise all field operations very closely. The planting of trees and shrubs is a delicate business and should be approached in the same way as the planting of horticultural seedlings. The Contractor should employ experienced agricultural or forestry labourers for this work.
5. The plants supplied to the Contractor will normally be from a nursery as arranged by separate instructions, and will be ready for planting. They should be at least 300 mm in height above the soil surface and hardened off in the normal way. The Contractor is to collect the plants from the nursery and transport them to site with all due care. The plants will normally be supplied in polythene pots, which should not be removed until the moment of planting. Plants are to be lifted by the pots, *never* by the stem or leaves. At all times they are to be kept as cool as possible. The Contractor is responsible for ensuring that the soil around the roots does not dry out. Under any circumstances, all plants supplied must be planted within three days of removal from the nursery.
6. Planting should be started at the top of the slope and under no circumstances should new plants be walked on or otherwise disturbed.
7. A planting pit wide and deep enough for the main root to be buried in without bending it and wide enough for all the roots and surrounding soil ball should be made at the time of planting. Some compost if available should be mixed with the soil from the slit prior to backfilling around the roots. The polythene pot must be removed from the seedling by cutting it away with a razor blade. The plant should then be carefully placed into the hole, the compost and soil packed in, and all surrounding soil firmed up, taking care not to cause any damage to the plant or its roots. The surface over and around the pit should then be mulched using any appropriate, locally available material, such as manure,

compost, dead leaves or cut herbage. The use of freshly cut ban mara (*Eupatorium adenophorum*) and tite p te (*Artemisia vulgaris*) should be avoided, since it can resprout from the buds after being cut.

8. The Engineer may specify bigger seedlings for specific areas, such as those to be used intensively for amenity purposes. These will normally have been growing in a nursery for at least a year and should have well developed roots as well as aerial parts. They will be provided either as bare root stock with a substantial root ball, or in pots of a minimum of 100 × 180 mm laid flat dimensions. When these larger seedlings are planted, the pits will be of 300 mm diameter and 300 mm depth. In addition, well-rotted compost will be mixed with the soil backfill in a ratio of at least one part compost to ten parts soil.

#### 2855 SITE PLANTING OF HARDWOOD CUTTINGS

1. Certain trees and shrubs can be planted on site by means of hardwood cuttings. Where these are specified, the Contractor is required to carry out the planting of cuttings as required in the Engineer's instructions.
2. It is assumed that the site will already have been prepared for planting, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of delicate young plants.
3. The spacing of hardwood cuttings will be determined according to individual site conditions. However, it will normally be at 500 mm centres unless otherwise specified.
4. The Contractor is required to supervise all field operations very closely. The planting of tree and shrub cuttings is a delicate business and should be approached in the same way as the planting of horticultural cuttings (*e.g.* those of tea). The Contractor should employ experienced agricultural or forestry labourers for this work.
5. The cuttings are normally to be made as per

standard specification 2812 or will be supplied to the Contractor by separate instructions, and will be ready for planting. The Contractor is to collect the cuttings from the nursery and transport them from the nursery wrapped in hessian jute. At all times, cuttings are to be kept moist and as cool as possible, and should be wrapped in wet hessian between all operations such as cutting from the parent plant, trimming and planting. Under any circumstances, all plants supplied must be planted the same day that they are lifted from the nursery.

6. Planting should be started at the top of the slope and under no circumstances should new plants be walked on or otherwise disturbed. Using a small bar (usually made of mild steel and with a flattened end), a hole should be made that is just big enough for the cutting. The cutting is inserted and the soil is replaced around it and firmed with the fingers. The cutting should be inserted to a depth such that two-thirds to three-quarters of it is buried.
7. If the soil is dry and there is no rain within 16 to 24 hours of planting, the site should be watered carefully with a fine spray. The Contractor will be required to water for the first two weeks after planting in the event of inadequate rainfall.
8. Where rooted cuttings have been supplied from a nursery, they must be planted in such a way that the roots are not damaged or badly bunched in the planting hole; the hole must be big enough to take the roots so that they are properly spaced out all around the plant.
9. The Engineer may specify bigger cuttings for specific areas, using large truncheon cuttings. In this category fall chuletro (*Brassaiopsis hainla*), dabdabe (*Garuga pinnata*), kavro (*Ficus lacor*), phaledo (*Erythrina* species) and *Gliricidia sepium*. Cuttings of these species should be planted at 1000 mm centres. A large crowbar should be used to make the planting hole, but otherwise the technique is as described above for smaller cuttings. Under no circumstances should these cuttings be hammered into the ground.

## 2856 BRUSH LAYERING, PALISADES AND FASCINES

1. Under certain conditions, the Contractor will be required to construct vegetation structures using hardwood cuttings. Where these are specified, the Contractor is required to carry out the necessary preparation and planting works as required in the Engineer's instructions.
2. It is assumed that the site will already have been prepared for planting, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that the condition of the site is good enough for the successful establishment of delicate young plants.
3. The cuttings supplied to the Contractor may be from a nursery as arranged by separate instructions, and will be ready for planting. They should be at least 400 mm long for brush layering, 600 mm long for palisades and 1000 mm in length for fascines. The Contractor is to collect the cuttings from the nursery and transport them from the nursery wrapped in hessian jute. At all times, cuttings are to be kept moist and as cool as possible, and should be wrapped in wet hessian between all operations such as cutting from the parent plant, trimming and planting. Under any circumstances, all plants supplied must be planted the same day that they are lifted from the nursery.
4. If the instruction to the Contractor includes the provision of cuttings, then the Engineer will specify the species and expected sources, and the Contractor must then obtain the cuttings required. This will be done in the manner described in clause 2812 except that the size of cuttings will be of a minimum length of 600 mm for brush layering on landslide debris, 450 mm for brush layering on road embankments, 600 mm for palisades and 1000 mm for fascines, and minimum diameters of 30 mm for brush layering, 40 mm for palisades and 50 mm for fascines.
5. Cuttings of the following species, if specified, should be a minimum of 2000 mm in length: chuletro (*Brassaiopsis hainla*), dabdabe

(*Garuga pinnata*), kavro (*Ficus lacor*), phaledo (*Erythrina* species) and *Gliricidia sepium*.

6. The Contractor is required to supervise all field operations very closely. The planting of tree and shrub cuttings is a delicate business and should be approached in the same way as the planting of horticultural cuttings (e.g. those of tea). The Contractor should employ experienced agricultural or forestry labourers for this work.
7. Planting should always be started at the top of the slope and under no circumstances should new plants be walked on or otherwise disturbed.
8. Brush layering should be constructed as given below, unless specified differently.
  - (i) Starting at the bottom of the area to be treated, and using appropriate measuring equipment, exact lines should be marked out. From 1 metre above the bottom of the slope, a precise contour line should be marked out every 1 metre up the slope.
  - (ii) Starting at the bottom, terraces approximately 450 mm wide on landslide debris or 350 mm on road embankments should be excavated along the lines.
  - (iii) Cuttings should then be placed into each trench at 50 mm centres, the correct way up and angled so that they are at right-angles to the maximum slope angle. All cuttings should be inserted to a depth such that two-thirds to three-quarters of their length is buried.
  - (iv) The trench should then be partially backfilled and another line of cuttings placed along the trench at 50 mm centres and 100 mm behind the first line, and with the individual cuttings offset to coincide with the gaps between the cuttings in the first line. This results in cuttings at 25 mm centres in each brush layer (i.e. 40 cuttings per running metre). The trench is then completely backfilled and gently compacted. Any loose or excess material is cleared down the slope before the next line is planted.
9. Palisades should be constructed as given below, unless specified differently.
  - (i) Starting at the top of the area to be treated, and using appropriate measuring equipment, exact lines should be marked out. From 1 metre below the top of the slope, a precise contour line should be marked out every 1 metre down the slope.
  - (ii) Starting at one end and using a small bar (usually made of mild steel and with a flattened end), a hole should be made that is just big enough for the first cutting. The cutting is inserted and the soil is replaced around it and firmed with the fingers. The cutting must be the correct way up and angled so that it is vertical. The cutting should be inserted to a depth such that two-thirds to three-quarters of it is buried.
  - (iii) This process should be repeated along the entire line, with a series of cuttings placed at 50 mm centres.
  - (iv) If a double line is specified, then a second line of cuttings must be placed in the same way, 100 mm behind the first and with the individual cuttings offset to coincide with the gaps between the cuttings in the first line.
  - (v) The soil around the single or double line is then completely backfilled into any remaining gaps and gently compacted. Any loose or excess material is cleared down the slope before the next line is planted.
10. In some cases it will be specified that cuttings should be placed in a criss-cross fashion. Where this is to be done, one layer of cuttings is laid in the trench at 30° to one side of the line of maximum fall of slope. A second layer of cuttings is laid on top of this, at 30° to the other side of the line of maximum fall of slope. Backfilling and compaction are then completed.

10. Fascines are bundles of hardwood cuttings laid horizontally in trenches, and parallel to the line of the trench. The bundles are thereby completely buried. Fascines should be constructed as given below, unless specified differently.

- (i) Starting at the bottom of the area to be treated, and using appropriate measuring equipment, exact lines should be marked out. From 1 metre above the bottom of the slope, a precise contour line should be marked out every 1 metre up the slope.
- (ii) Starting at the bottom, trenches approximately 200 mm in depth should be excavated along the lines.
- (iii) Cuttings should then be laid along each trench, so that they lie horizontally along the trench. There should normally be eight cuttings together, although where material is short a minimum of four cuttings is permissible. They must be overlapped so that no two ends coincide. The cuttings must then be tied using jute or coir (coconut fibre) string at 500 mm intervals to form a bundle. As the fascine is created, it thereby forms a continuous bundle right across the slope.
- (iv) The trench should then be backfilled and gently compacted. The top of the fascine should be 50 to 100 mm below the surface. Any loose or excess material is cleared down the slope before the next line is planted.

11. The Engineer may specify that orientations other than along the contour of the slope are used. In this event, the Contractor must alter the laying out of lines accordingly and meet the precise angle required.

12. If the soil is dry and there is no rain within 16 to 24 hours of planting, the site should be watered carefully with a fine spray. The Contractor will be required to water for the first two weeks after planting in the event of inadequate rainfall.

#### 2857 USE OF FERTILISER

1. Under certain circumstances, the use of chemical fertilisers may be specified in place of farmyard manure or mulching. Unless otherwise specified, the rates given below should be used.
2. Levels of fertiliser application vary according to soil type and nutritional content. However, if nutritional data are not available, the following figures can be used as a rough guide:  
 Nitrogen: 10 g/m<sup>2</sup>;  
 Phosphorus: 5 g/m<sup>2</sup>;  
 Potassium: 4 g/m<sup>2</sup>.  
 The table below lists the chemical composition and percentage of the major plant nutrient elements in the chemical fertilisers commonly available in Nepal.

#### 2860 JUTE NETTING WORKS

1. The Contractor shall provide and install jute netting as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.
2. The Engineer may instruct that jute netting applications be used in conjunction with other techniques, particularly the sowing or planting of grasses. In this event, the netting should be applied before the plants are introduced. When planting, the labourers must take care only to hold or stand on the pegs and not to disturb the netting except when carefully placing grass seed underneath on the soil surface.

COMMERCIAL NAME	CHEMICAL FORMULA	PERCENTAGE N	P	K
Sulphate of ammonia	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	21	0	0
Urea	CO(NH <sub>2</sub> ) <sub>2</sub>	46	0	0
Triple superphosphate	CaH(PO <sub>4</sub> ) <sub>3</sub>	0	21	0
Muriate of potash	KCl	0	0	49
Complexol	Unknown	20	9	0
Diammonium phosphate	(NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub>	18	20	0

2861 SUPPLY OF JUTE NETTING

1. The Contractor will manufacture or obtain a supply of jute netting to the Engineer's specification.

2. The detailed specifications for *standard* jute netting are as follows. 'Standard' jute netting is used for placing on bare slopes and is normally planted with grasses. [Note: warp ends are the length-ways threads and weft strands are the cross-ways threads]

(i) Material: High quality tosa (special grained), 100% natural jute fibre from the latest harvest, properly treated and dried.

(ii) Yarn: Handspun 5 to 8 mm.

(iii) Strip size: minimum 1.0 × 10.0 metres; maximum 1.5 × 11.5 metres.

(iv) Warp ends: 27 ends per 1000 mm.

(v) Weft strands: 20 to 24 strands per 1000 mm.

(vi) Mesh size: 40 mm square mesh holes.

(vii) Weight: 0.8 to 1.2 kg per square metre.

3. The detailed specifications for *wide mesh* jute netting are as follows. 'Wide mesh' jute netting is used for holding mulch on to slopes which have been sown with grass seed. [Note: warp ends are the length-ways threads and weft strands are the cross-ways threads]

(i) Material: High quality tosa (special grained), 100% natural jute fibre from the latest harvest, properly treated and dried.

(ii) Yarn: Handspun 3 to 5 mm.

(iii) Strip size: minimum 1.0 × 10.0 metres; maximum 1.5 × 11.5 metres.

(iv) Warp ends: 7 ends per 1000 mm.

(v) Weft strands: 3 strands per 1000 mm.

(vi) Mesh size: 150 × 500 mm rectangular mesh.

(vii) Weight: 0.2 kg per square metre.

2862 PLACEMENT OF NETTING

1. The Engineer will normally instruct the placement of standard jute netting on slopes in excess of 40°. It is therefore a difficult task to place the netting in an effective manner which fulfils the Engineer's purpose. Carelessly placed netting is often useless and can actually be detrimental to the slope surface.

2. It is assumed that the site will already have been prepared for the application of jute netting, under a separate instruction; but it is nevertheless the responsibility of the Contractor to ensure that the condition of the site is good enough for the optimum effect to be attained. In any event, a smooth profile must be obtained. All loose debris must be removed. Concavities must be filled with well compacted material or, in some cases, with dry stone dentition. Convexities must also be removed and it is essential that the general profile does not have a shape giving over-steep segments.

3. Starting at one end of the site to be treated, a roll of netting should be pegged 300 mm above the slope to be covered.

4. The netting should be rolled slowly down the slope. Hardwood cuttings, ideally of simali (*Vitex negundo*) or pegs (usually made from split bamboo culms) should be hammered through the netting at centres of 500 to 1000 mm; they should protrude about 80 mm. Labourers must stand on these cuttings or pegs and not hang on to the netting.

5. This process should be repeated until the entire slope surface is covered. The strips are then laced together with lengths of the same jute yarn, to form a continuous net. The lacing must form joins every 250 mm or less.
6. The tension of the netting must now be reduced so that it hugs the slope surface precisely. This is done by pulling up about 200 mm at the bottom of the netting and hooking it on to the pegs a little higher up. This process is repeated up and across the slope until the netting rests snugly against the surface and is nowhere tight or pulled away from the surface in minor concavities.
7. The netting should then be pegged at 1000 mm centres with staples of 10 mm reinforcing bar at least 100 mm wide and 300 mm long, firmly hammered into the slope face. Additional staples should be used to hold netting closely against the face of concave slope segments.
8. Finally, the bottom of the netting is trimmed to give a tidy finish.
9. In the case of wide mesh jute netting, it will only be specified for use on slopes which have already been treated with grass seed and mulch. These will usually be less than 45° and are therefore easier to work on. However, the process of placing the netting is similar to that for standard netting.
10. Wide mesh netting should be pegged securely at the top and rolled slowly down the slope. Hardwood cuttings, ideally of simali (*Vitex negundo*) or pegs (usually made from split bamboo culms) should be hammered through the netting at centres of 1000 mm; they should protrude about 80 mm. Labourers must stand on these cuttings or pegs and not hang on to the netting. This process should be repeated until the entire slope surface is covered. The strips are then laced together with lengths of the same jute yarn, to form a continuous net. The lacing must form joins every 500 mm or less.
11. The tension of the netting must now be reduced so that it hugs the slope surface precisely and holds the mulch firmly against the

surface throughout the area covered. The netting should then be pegged at 1000 mm centres with staples of 10 mm reinforcing bar at least 100 mm wide and 300 mm long, firmly hammered into the slope face. Additional staples should be used to hold netting closely against the face of concave slope segments. Finally, the bottom of the netting is trimmed to give a tidy finish.

## 2870 WIRE BOLSTER CYLINDERS

1. The Contractor shall provide and install wire bolster cylinders as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary expertise, resources and facilities to ensure that these requirements are met.

## 2871 FABRICATION OF BOLSTER PANELS

1. Bolster panels will be either 5 × 1 metres or 5 × 2 metres in size, according to the type of bolster to be used. They will be woven with an hexagonal mesh in the same way as normal gabion panels. For the panel frame, 10 swg galvanised wire should be used; for the mesh, 12 swg is adequate. Wire should preferably have a high grade zinc coating. Failing this, a medium grade zinc coating is acceptable.
2. Weaving should start from one of the long sides. A total of 83 coils of wire should be spaced evenly along the 5 metre length. This gives a mesh width of about 60 mm. Each weave should have three twists, as for normal hexagonal mesh. If done reasonably tightly, this gives a length of about 80 mm to each mesh link. In any event, the mesh length should not exceed 90 mm. The mesh should be turned on to the larger frame wire at least one and a half turns and made fully secure.

## 2872 PLACEMENT OF CONTOUR BOLSTERS

1. A contour bolster treatment gives a series of stone-filled wire tubes of 300 mm diameter, laid in trenches cut across the slope. The tops of all the tubes should be flush with the surface of the slope in which they are placed. The purpose is to check scour of the slope surface

by preventing the development of rills and gullies.

2. The site to be treated should be given final preparation immediately before bolster installation. All small protrusions and depressions must be obliterated by cutting, or by infilling and compaction.
3. Starting at the base of the area to be treated, and using appropriate measuring equipment, exact lines should be marked out. From 2 metres above the base of the slope, a precise contour line should be marked out every 2 metres up the slope.
4. Starting at the bottom, trenches with circular base should be dug along the lines, adequate to take the final 300 mm diameter tubes.
5. Bolster panels should then be laid along the trenches and shaped to fit neatly into the base of the trenches, as well as into any curves formed as a result of the slope contours; each panel should be securely joined to the next panel, to form a continuous bolster tube.
6. The panels should be packed with stones, closed over and the edges wired together. All stones must be bigger than the mesh size. The same care should be taken as when filling a conventional gabion basket, and stones must be carefully placed to give good structural integrity.
7. The ends of the bolsters should be closed over and wired together. The trenches around all the bolsters should then be filled and compacted with material left from the excavations.
8. Once all of the lines are in place, all surplus debris should be cleaned off the slope. Mild steel bars of at least 10 mm diameter should then be driven into the slope through the lower sides of the contour bolsters. These should be at least every 2 metres along the lines. Bars should be 2 metres in length on slopes composed of soft materials, but at the Engineer's discretion, on slopes comprising hard rocky materials, bars of 1 metre length will be adequate. All bars must be driven

home until the tops protrude no more than 25 mm above the slope surface.

## 2873 PLACEMENT OF HERRINGBONE BOLSTERS

1. A herringbone bolster network is in essence a system of wire tubes of between 300 mm to 1200 mm in diameter depending on the amount of water flowing through the site, laid in trenches cut into the slope. A main bolster runs straight down the slope (the spine) with others running into it at an angle of 30 to 50 degrees to the fall of the slope (the herringbones or branches) depending on slope angle and terrain morphology. The tops of all the tubes should be flush with the surface of the slope in which they are placed or inlaid to allow boulder pitching to be laid over the top. The purpose is both to check scour of the slope surface by preventing the development of rills and gullies, and to drain the surface material in a similar way to a french drain. The diagonal components should be at 2 to 5 metre centres if measured straight down the slope.
2. The site to be treated should be given final preparation immediately before bolster installation. All small protrusions and depressions must be obliterated by cutting, or by infilling and compaction.
3. Starting at the base of the area to be treated, and using appropriate measuring equipment, exact lines should be marked out: every 7.1 metres across the slope, a line should run straight up to the top of the slope (these form the main bolster spines). From the base of the line, and every 3 metres above this, other lines of 5 metres length should be marked at 45 degrees to the main line (these will form the herringbones).
4. Starting at the bottom, trenches with circular base should be dug along the lines, adequate to take the final 300 mm diameter tubes, or 600 mm diameter tubes if larger (5 × 2 metre) panels are specified.
5. If it is specified that an impermeable lining should be used, then 20 gauge black polythene sheeting must be laid along the bot-

- toms of the trenches and the bolsters constructed on top of this.
6. Bolster panels should then be laid along the trenches and shaped to fit neatly into the base of the trenches, as well as into any curves formed as a result of the slope contours; the panels of the herringbones should be securely joined to the panels of the main bolster.
  7. The panels should be gradually closed together and secured, working up from the bottom of the slope, while stones are passed in from above to fill them. The stones should be randomly packed so as to allow free drainage, and all stones must be bigger than the mesh size. The same care should be taken as when filling a conventional gabion basket, and stones must be carefully placed to give good structural integrity.
  8. The upper ends of the herringbones should be closed over and wired together; they should touch the ends of the next herringbones but should not be secured to each other. The trenches around all the bolsters should then be filled and compacted with material left from the excavations.
  9. Once all of the lines are in place, all surplus debris should be cleaned off the slope. Mild steel bars of at least 10 mm diameter should then be driven into the slope through the sides of the main spine bolsters and the lower sides of the herringbone bolsters. These should be at least every 2 metres along the lines. Bars should be 2 metres in length on slopes composed of soft materials, but at the Engineer's discretion, on slopes comprising hard rocky materials, bars of 1 metre length will be adequate. All bars must be driven home until the tops protrude no more than 25 mm above the slope surface.
2. Because of the long time required for plants to become robust, the period of maintenance by the contractor will normally be for twelve months. However, in the case of small contracts, a period of only six months may be specified.

#### 2881 PROVISION AND ROLE OF SITE WARDENS

1. The Contractor is required to provide an adequate number of site wardens to fulfil the specified requirements. The function of a warden is broader than that of a watchman, chowkidar or heralu. It involves a number of routine maintenance operations.
2. Wardens must be mature and reliable characters who need little supervision for the adequate fulfilment of their duties. They must be active and physically fit. Old people who are losing their strength should not normally be employed. They must be experienced agricultural workers familiar with caring for plants. They must be prepared to remain on site through all hours of daylight and through all adverse weather conditions. They must eat their meals on site and at no time leave the site untended for any reason whatsoever.
3. The role of the warden is primarily to tend the plants. He or she must take the initiative in weeding, mulching, replanting failed plants, pruning and protecting plants against all pests. This is an active role requiring individuals with considerable energy and initiative. The warden must work constantly to maintain and improve the site and its bio-engineering plants.
4. The warden is also required to protect plants on the site from damage by local people, domestic and wild animals. In doing this he or she should use a friendly approach to the people as far as possible. The Contractor must educate the warden fully in the reasons for the job, so that he or she can explain to others the importance of safeguarding plants on the site. Wardens should be effective communicators with others since they also fulfil an inevitable function as the ambassador between the Department of Roads and local road neighbours.

#### 2880 SITE PROTECTION

1. The Contractor is to protect a planted site for the period specified. Protection is to include the prevention of damage to all manner of site works and plants by local people and domestic or wild animals. It also includes an active role in tending the plants and improving their growth, as specified below.

## 2882 FABRICATION OF BAMBOO TREE GUARDS

1. The Contractor shall provide bamboo tree guards as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary supervision, resources and facilities to ensure that these requirements are met.
2. The bamboo strips used to make bamboo tree guards are to be made from mal bans (*Bambusa nutans* subsp *cupulata*) whilst the uprights are to be made from tharu or dhanu bans (*Bambusa nutans* subsp *nutans* or *Bambusa balcooa*). Bamboo tree guards shall be a minimum of 450 mm in diameter by 1300 mm in height so that they are able to provide sufficient protection from grazing and from the elements for the first 18 months after planting the seedling.
3. The guard is made by cutting five bamboo posts which are a minimum of 50 mm wide by 10 mm thick and at least 1600 mm long. The posts should be cut so that they have a strong spear-like point at the bottom that can be driven into the ground when placing out on site. The bamboo poles used to make the uprights should be a minimum of 3 years old.
4. Bamboo strips, a minimum of 5 mm thick and 50 mm wide are cut from poles that are at least 2 years old. The bamboo used must be split so that the outer wall remains intact. Only lengths with the outer wall intact are to be used. The split bamboo should be the length of the whole bamboo pole that it is cut from, or as long as possible. The split bamboo must be woven in and out of the bamboo uprights and pulled tight, so that it is firm and strong. The end of each of the strips must be woven back into the basket and tied with binding wire to keep it in place. End pieces must not be left sticking out and unbound, because they quickly get broken and the basket starts to unravel from this point. The split bamboo should be woven round the poles so that when they are tightly pressed down there are no gaps in the guard.

## 2883 PLACEMENT OF BAMBOO TREE GUARDS

1. Tree guards are to be installed on site at the time of planting, no later than the second week of July, and must be placed carefully around the planted seedlings.
2. The tree guards should be placed over the seedling immediately after planting. The upright posts must be firmly driven at least 200 mm into the ground so that the guard is able to resist bashing and rubbing from cows, buffalo, goats and people. The woven slats should be pushed down firmly from the bottom upwards so that they touch one another and are free from large gaps.
3. Tree guards alone are not adequate protection for small plants. The Contractor must provide a site watchman in addition, for the time specified, to maintain the tree guards and ensure that local people respect them, and generally fulfil all the requirements of clause 2881.

## 2890 SITE AFTERCARE AND MAINTENANCE

1. The Contractor shall maintain planted bio-engineering sites as required by the Engineer. This shall be done according to the specifications described hereunder, as and when required. The Contractor shall supply all necessary expertise and resources to ensure that these requirements are met.
2. The Contractor shall carry out weeding as required throughout the site. All annual weeds and other unwanted plants shall be cut just above the ground and the aerial parts will be used to make compost or mulch. Weeds must not be pulled out by the roots since this disturbs the ground surface.
3. Weeding should be carried out throughout the growing season. It must be undertaken with particular diligence at the end of the monsoon, so that there is the minimum amount of competition during the subsequent dry season.

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4. The Contractor shall carry out mulching as required throughout the site. All plants required under the bio-engineering specifications will be mulched using material prepared as specified in clause 2835, or the aerial parts of weeds cut on the site or brought from elsewhere for the purpose. The desired plants should be kept mulched at all times but special care must be taken in the spring, when the soil moisture deficit is at its greatest.
  5. The Contractor shall replace failed, damaged, diseased and very weak plants, using fresh, healthy plants of the same species, at the correct time of year for planting. This replanting operation will normally be carried out during the monsoon in the year following the first planting works. Vegetation structures will be enriched by the planting of additional cuttings or seedlings, as instructed by the Engineer. Failed seeding areas will be reseeded at the appropriate time of year.
  6. In replanting and enrichment works, the Engineer may specify the use of different species. This will be done where failures or poor performance of plants may be attributed to poor stock or an incorrect initial choice of species.
  7. All bio-engineering sites must be maintained so that there are at least the following two storeys of vegetation. In certain locations, however, there may be a number of additional vegetation storeys.
    - (i) A dense ground cover of healthy grass plants, in the configuration specified at the time of planting.
    - (ii) An open canopy of shrubs or trees with a deeper rooting network.
  8. In general it is necessary to keep the upper canopy thinned in order to maintain the lower ground cover. Most grasses require high light intensities and become degraded if subjected to excessive shade from the overstorey. It is therefore the Contractor's responsibility to thin the canopy as necessary to permit adequate levels of light to penetrate for the optimum growth of the grass understorey.
  9. All thinning and pruning operations are to be undertaken in accordance with the guidelines issued by the Geo-Environmental Unit. Since these are skilled silvicultural operations, the Contractor must take appropriate professional advice and employ suitably skilled personnel.
  10. All products from thinning and pruning operations are to be disposed of in accordance with the regulations of His Majesty's Government. The Contractor should follow the instructions of the Engineer in this regard.
  11. Other maintenance operations are to be undertaken by the Contractor according to the instructions of the Engineer.

# Bio-engineering case studies

## **JOGBANI-DHARAN ROAD, km 33+840**

### **Brief site history**

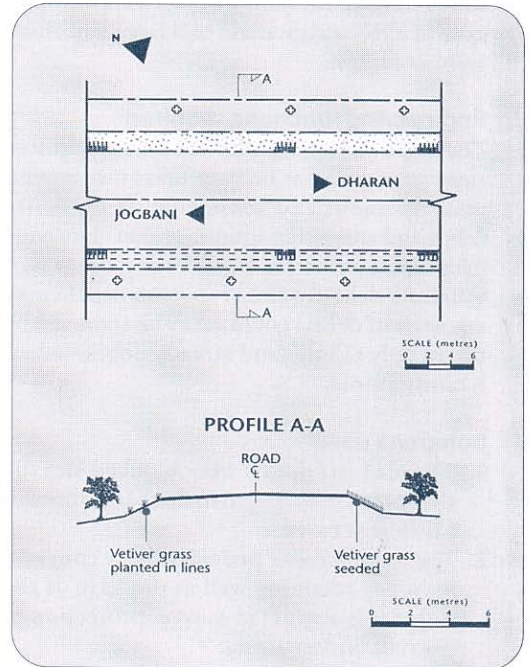
This section of road was rehabilitated in 1991/92. At the same time, the embankment was raised slightly and the road pavement widened to occupy the entire top of the embankment.

### **Engineering functions required**

The shoulders of the embankment were unconsolidated and needed armouring. Considerable amounts of water runs off the pavement in heavy rain.

### **Solutions used**

1. Grasses were used to armour the shoulders. They were planted on one side and seeded on the other, mainly for comparison. The lines planted on the eastern side grew faster, but adequate armouring was provided by both methods. The species used was khus (*Vetiveria lawsoni*).
2. Ornamental shade trees were planted at intervals on the ground between the embankment and the original borrow pits.



## DHARAN-DHANKUTA ROAD, km 5+700

### Brief site history

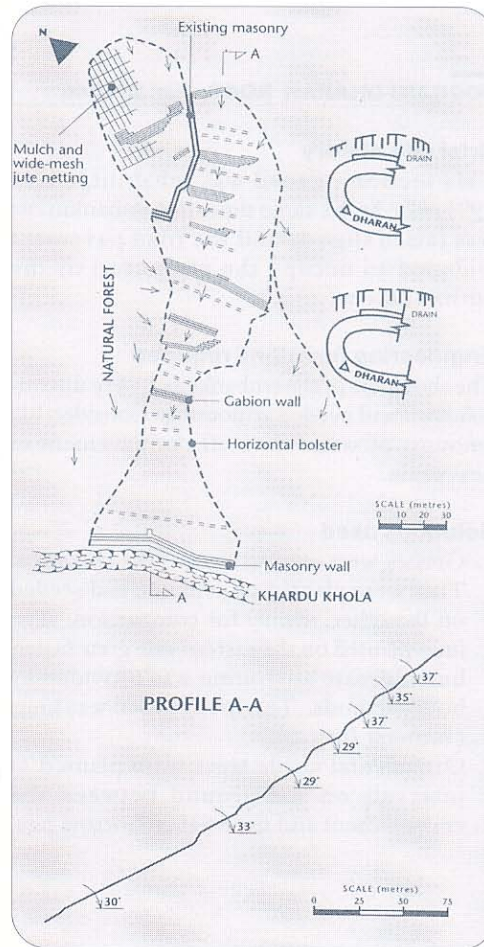
A complicated failure occurred in a gully to the west of a hairpin stack on the steep Mahabharat ascent above Dharan. A long masonry cascade, which drained the hairpins, failed catastrophically in 1988 and give rise to a large landslide-gully complex.

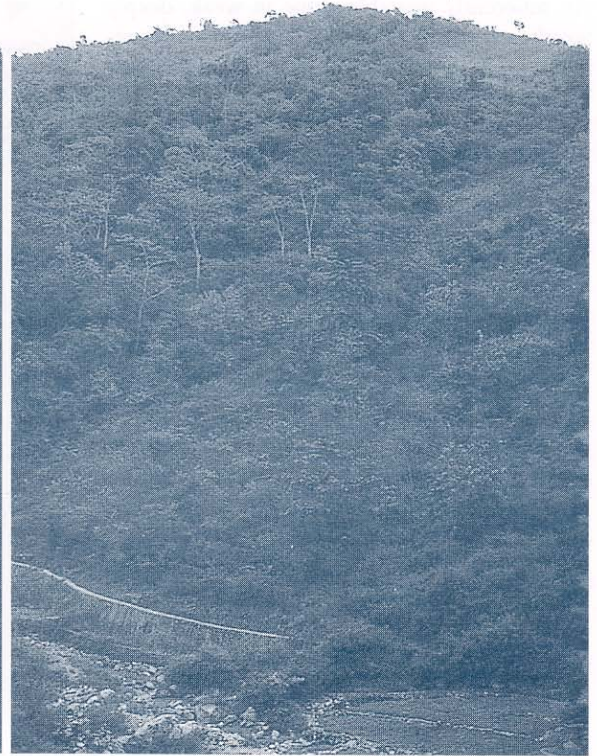
### Engineering functions required

The slope remaining after the failure required support to prevent further mass movement, reinforcement and anchoring of the loose debris, and armouring against erosion. Drainage needs were removed by diverting the water. Catching debris was not important, as small amounts of debris could easily be removed by the steeply falling (and already debris-laden) Khardu khola.

### Solutions used

1. The lead-off drains were blocked and the side drains re-arranged to discharge through a different cascade.
2. Toe support was provided by a concrete masonry retaining wall at the base of the slope; this also acted as river protection to prevent undercutting.
3. The slope was broken into smaller segments through the construction of seven major gabion check dams: each of these also served a support function, since they were designed as retaining walls for the slope segments above.
4. All walls were backfilled with compacted spoil. Excess spoil was removed to a safe tipping area.
5. Armouring and shallow reinforcement were provided by gabion wire bolsters, which were installed at 2-metre centres on all fill and loose debris areas.
6. Additional support was provided by planting bamboos above the toe wall. The species used was tharu bans (*Bambusa nutans*).
7. Tree seedlings were planted at 1 metre centres between the gabion wire bolsters on all fill and loose debris areas. The species used were khanyu (*Ficus semicordata*), various siris species (*Albizia* species) and tanki (*Bauhinia purpurea*). These were to provide reinforcement and anchoring.
8. Slips of the grass siso (*Neyraudia arundinacea*) were planted on particularly critical sections of the middle slope, to provide more armouring and reinforcement.
9. The upper section, which consisted of the failure head scar, was seeded with the grasses phurke (*Arundella nepalensis*) and siso (*Neyraudia arundinacea*); the seeds were covered in mulch, which was in turn held in place with wide mesh jute netting. This provided complete armouring (and later, reinforcement as well).
10. The upper section was also seeded with bhujetro (*Butea minor*) to provide anchoring of the remaining loose debris.





The masonry cascade that drained this hairpin failed catastrophically in 1988 and produced a large landslide cum gully complex (left). A series of gabion check dams, which also had a retaining function, were constructed to break the site into smaller segments. The bio-engineering package included bamboos planted above the toe wall to increase support. Planted seedlings of khanyu, tanki and siris grew to reinforce and anchor fill and loose debris areas. Sito slips armoured and reinforced the most critical areas. The head scar was seeded with phurke and sito, mulched and held in place by jute netting. This provided complete armouring. Bhujetro anchored remaining loose debris. The slope is now well protected by a combination of civil and bio-engineering works(right)

## DHANKUTA-HILE ROAD, km 4+700

### Brief site history

An inherently unstable slope in weak, deeply weathered gneiss was disturbed by road construction. Gradual subsidence was noticed following construction. During upgrading in 1990, the worsening mountain-side failure required complete rehabilitation. At the same time, it was decided to attempt stabilisation of the steep valley side slope to reduce distortion of the new metalled road surface and prevent a possible catastrophic failure.

### Engineering functions required

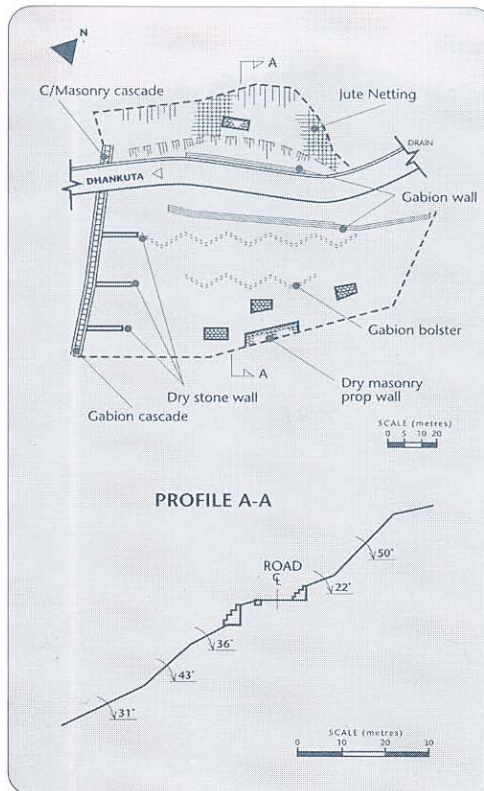
Valley side. Ideally, major toe support was required, but foundations were poor and the estimated cost was prohibitive. Support to the road itself was therefore planned, with extensive drainage, reinforcement and anchorage of the slope. Armouring of the weak, erodible, gneiss-derived soil was also essential.

Mountain side. Toe support was required to support the remaining debris mass. Otherwise mainly armouring was required, with some reinforcement of the debris above the support wall.

### Solutions used

#### Valley side

1. The road itself was supported by a gabion retaining wall at the top of the valley side slope. The other measures were therefore critical in stabilising a slope which was already subsiding and now additionally surcharged.
2. The slope was re-graded following the construction of the gabion wall, and concavities were filled with dry masonry to provide local support. On the steeper southern flank, the slope was broken into shorter segments using 3-metre high dry masonry support walls.
3. Drainage was provided through a range of measures. Herringbone gabion woe bolsters were installed. The existing cascade was improved. Fascines of simali (*Vitex negundo*) were laid in subsoil drains.
4. Armouring and shallow reinforcement were achieved by sowing phurke (*Arundnella nepalensis*) throughout the slope.
5. Deeper reinforcement and anchorage were provided by planting seedlings of utis (*Alnus nepalensis*), nebharo (*Ficus auriculata*) and other trees.



#### Mountain side

1. Toe support was provided by a gabion breast wall. A concavity in the head slope was filled with dry masonry to provide local support. Additional support was provided by planting large bamboos (bans or *Bambusa* species) to the south of the breast wall.
2. The head slope was trimmed and armoured with standard jute netting and slips of kans (*Saccharum spontaneum*).
3. The shrubs areri (*Acacia pennata*) and kerakose (*Indigofera atroturpurea*) were planted to reinforce the debris above the gabion wall.
4. Trees were planted around the head of the scar to provide products for local farmers.



This section of the Dhankuta-Hile road failed some years after construction (top, left). The likelihood of poor foundations ruled out the provision of major toe support, which could otherwise have been provided. Phurke was sown to armour the slope and provide some reinforcement. Seedlings of utis and nebharo were planted to offer deeper reinforcement and anchorage (top, right). Toe support was provided by a gabion breast wall and, later, supplemented by a plantation of large bamboos (above).

## Baglung loop, December 1994



## Baglung loop, September 1997

Rehabilitation called for the construction of toe walls to support actively unstable sections of the slope, and the rebuilding of drains. Bio-engineering measures included checking further erosion by planting dense line of grass and seeding the largest areas of coarse debris with grasses, shrubs and trees. Babiyo, a clump grass that prefers harsh, dry sites, was planted to bind the finer soil between rock fragments.

