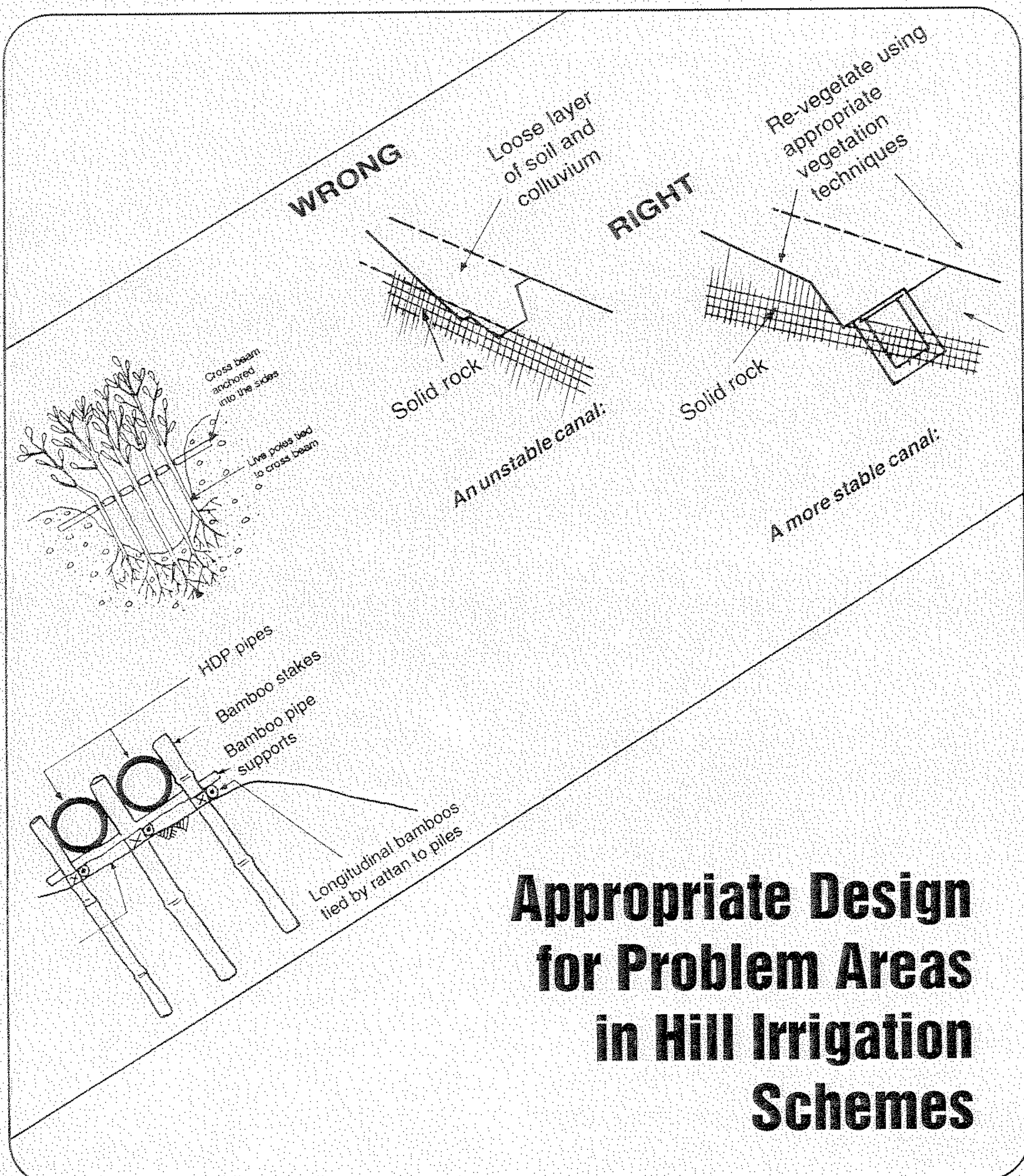
Poverty Alleviation Through Employment Generation in Irrigation Works Programmes

APPROPRIATE DESIGN OF SMALL-SCALE HILL IRRIGATION STRUCTURES



Appropriate Design for Problem Areas in Hill Irrigation Schemes

NEPAL SPECIAL PUBLIC WORKS PROGRAMME
MANUAL NO. 2

Module No 6

APPROPRIATE DESIGN FOR PROBLEM AREAS IN HILL IRRIGATION SCHEMES

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Problem Areas for Irrigation Canals in the Hills

- slopes prone to landslides,
- active landslides,
- seepage zones,
- slopes suffering serious soil erosion.

Irrigation Canals and Slopes Prone to Landslides

There are three practical problems which the irrigation engineer needs to address when faced with constructing irrigation canals across unstable slopes:

- the identification of potential landslide areas;
- protection of slopes through appropriate measures;
- choice of appropriate canal sections which will not aggravate the problem.

Irrigation Canals and Landslides

There are two practical problems the irrigation engineer needs to address when faced with landslide crossings:

- stabilising any landsliding that has already taken place or is on-going;
- choice of appropriate measures to convey irrigation water across the landslide zone.

Irrigation Canals and Seepage Areas

Seepage is often associated with unstable slopes and landslides.

Even on stable slopes high seepage rates, especially during the monsoon season, can cause the following problems along canal alignments:

- excess spring-water flowing from slopes above the canal leading to overtopping and possible gullying;
- upward groundwater pressure from below the canal causing damage to any impervious lining.

Irrigation Canals and Soil Erosion

The are two practical problems the irrigation engineer needs to address when faced with constructing irrigation canals across degraded slopes:

- seriousness and type of soil erosion, i.e. rainsplash, overland flow, rilling, gullying, etc;
- soil conservation and slope protection through appropriate measures;
- choice of appropriate canal sections which will not aggravate the problem.

Unstable Slopes and Landslides

Mountain Zone Classification

Mountain zone classification is used to identify potential and actual landslide areas in irrigation systems.

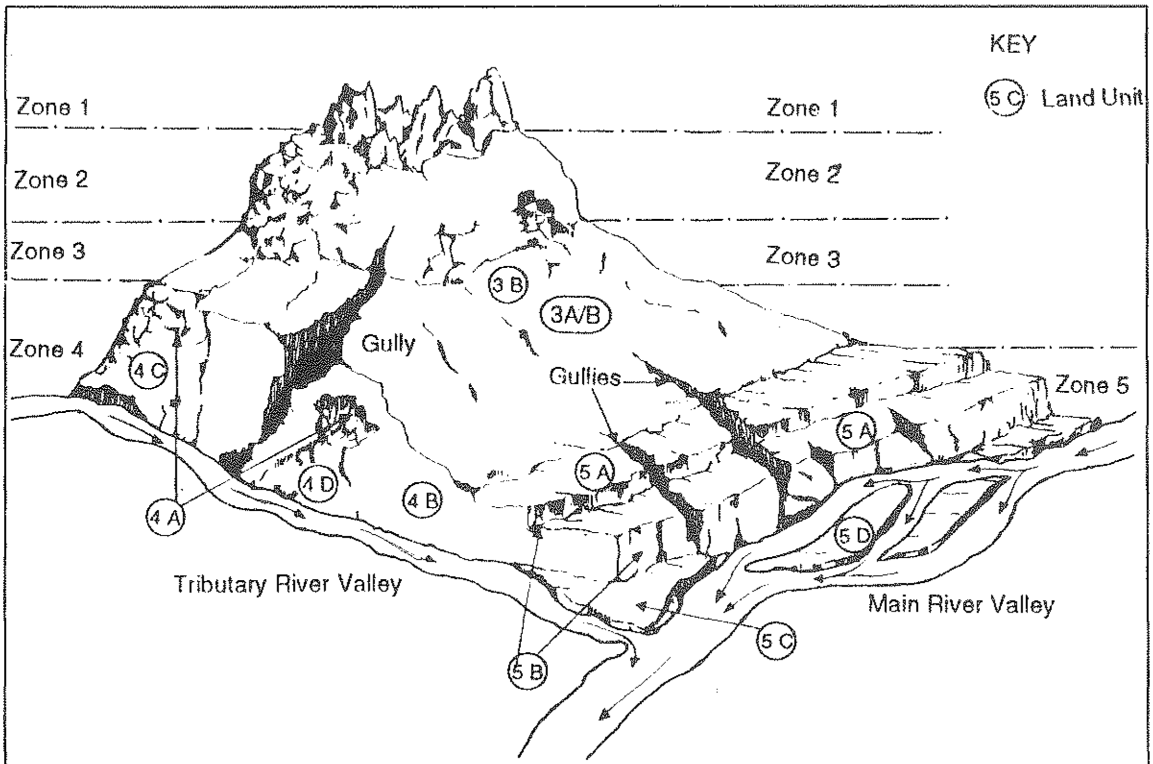
It is difficult for even a trained person to identify and accurately predict exactly when and where a landslide will occur. Landslides, with the exception of soil creep, occur suddenly and without any warning.

At best, through the appropriate choice of slope protection, engineering design and construction methodology, the risk and rate of landsliding along a canal alignment can be reduced. A scientific basis for making the correct choice of protection, design and construction measures is the geotechnical technique of terrain hazard classification.

Under this technique, the Himalayan terrain is classified into five mountain zones - **Mountain Zone Classification.** Each of the five zones are differentiated into several typical **land units** based on criteria of slope stability/instability. By identifying a given piece of land with a defined land unit its slope behaviour can be reasonably predicted. Therefore, by identifying the different mountain land units along a proposed irrigation canal alignment it is possible for the irrigation engineer to prepare appropriate slope protection measures, landslide stabilisation techniques and engineering designs to reduce the risk of landslides.

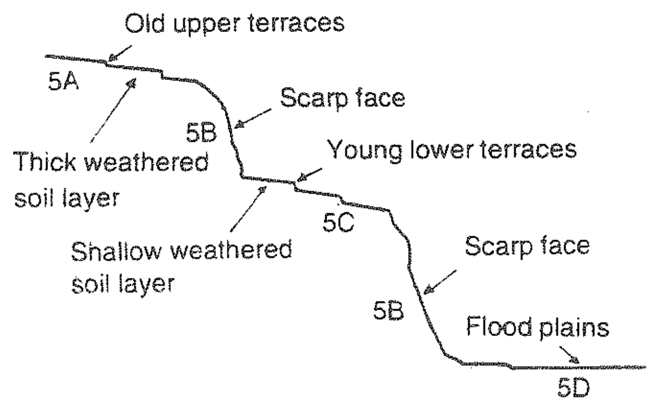
Figure 6.1 shows the five zones and lists the physical characteristics of the three zones typical of small scale hill irrigation systems in Nepal. Generally, canals will be more stable in Zone 3 and less stable in Zone 4 as far as landslide activity is concerned. In Zone 5, soil erosion protection becomes an important consideration. In summary, land units 3A/B, 4B/C/D and 5B are most prone to serious landsliding.

Figure 6.1
Physical Characteristics of Mountain Zones 3, 4 and 5, with Special Reference to Stability



See page 5 for stability characteristics of mountain zones 3, 4 and 5

Figure 6.2
Land Units in Mountain Zone 5



Mountain Zone 3 land is characterised by:

Shallow slopes (generally less than 35 degrees) that are relatively stable with few active landslides.
The top soil profile may consist of:
a) in situ weathered soil layers up to three metres thick, or;
b) consolidated landslide debris.
The main problem in this area is:
Rapid surface erosion once the vegetation is removed: leading to landslips which can block canals or damage canal segments.
Unprotected fresh slopes formed in this land unit can erode rapidly causing the canal to choke. Therefore, the new design must emphasise the re-use of the fertile top soil to re-establish the vegetation quickly.

Mountain Zone 4 land is characterised by:

Steep slopes (generally more than 45 degrees) that are highly unstable with active landslides and active gully erosion.
The top surface profile of mountain zone 4 may consist of bare rock slopes with shallow loose debris or active colluvium (landslide debris).
Typical surface profiles of the different land units are as below:
Land unit 4A: Very steep bare rock slope.
Land unit 4B: Steep slope; bed-rock at shallow depth; thin layer of weathered rock.
Land unit 4C: Landslide debris; fairly thick layer of unconsolidated weathered material; still active.
Land unit 4D: Landslide debris now stable; but landslide easily triggered.
The main problems in these land units are:
4A: Fissured rock; rock dip planes sloping at unsuitable angles for easy canal constuction.
4B: Mantle of unstable weathered rock; canals must be founded on solid base for stability.
4C/D: Weathered rock and colluvium easily triggered into motion by inappropriate designs and construction methods.

Mountain Zone 5 land is characterised by:

Old upper terraces with thick weathered soil layers - in unit 5A.
Younger lower terraces with shallow weathered soil layers - in unit 5C.
Flood plains of gravel, cobbles with no soil cover - in unit 5D, and scarp faces between terraces consisting of loosely cemented gravel, cobbles and weathered rock in unit 5B.
The main problems in the different land units are:
5A and 5C: High permeability and erodibility if surface soil cover is penetrated for construction of canals.
5B: High instability and active landslides.
5D: High risk of flooding.

Land Units 3A and 3B

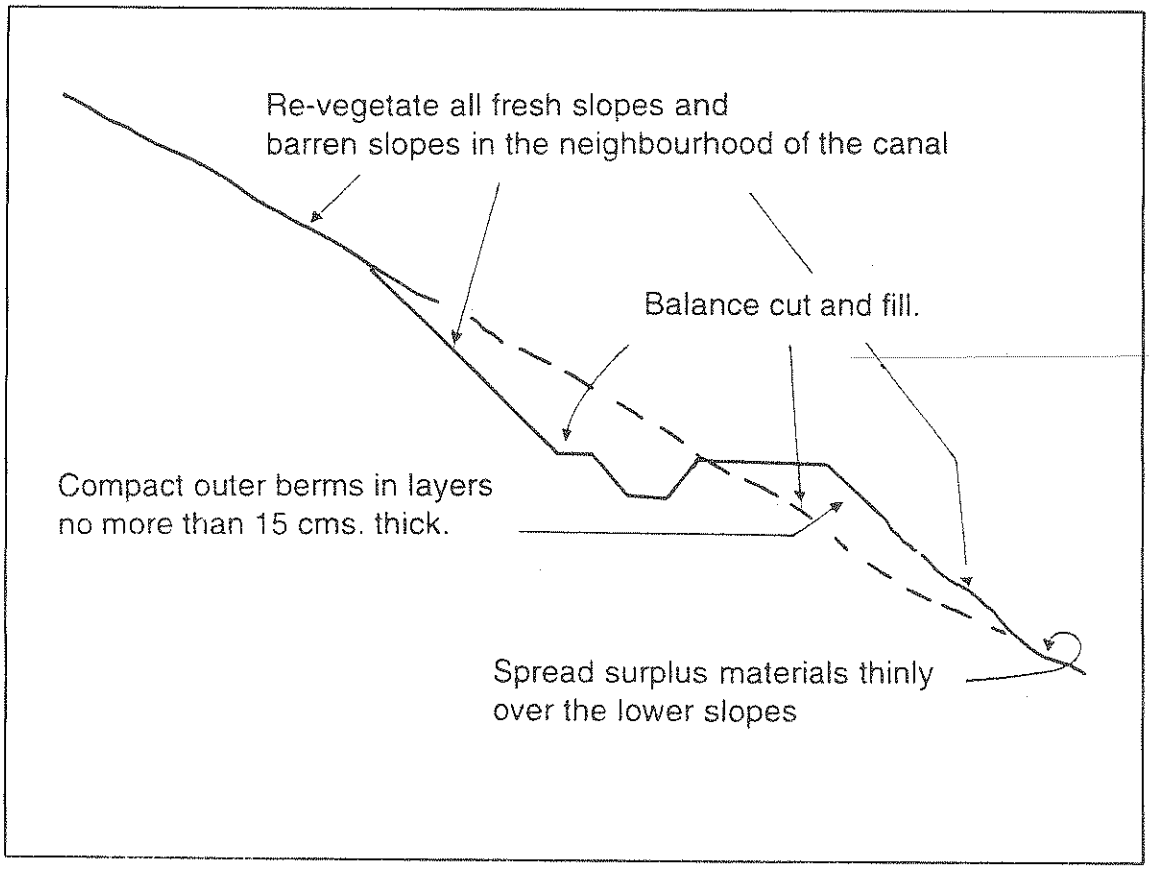
Recommended Inert and Bio-Engineering Measures for Land Units 3A/B

Land units 3A/B are generally covered with a shallow layer (of up to 3 metres) of in situ weathered soil. Some areas may have deep layers of weathered soil.

Surface erosion is high.

Canals in these land units must have balanced cut and fill sections to avoid too much excavation and exposure of erodible layers, see Figure 6.3.

Figure 6.3
Preventing Exposure of Erodible Layers of Soil by using Balanced Cut and Fill Canal Sections in Land Units 3A and 3B



Shallow landslides or landslips above and below the canal alignment are likely to occur in this land unit. When adequate berms are not provided above the canal alignment, as in Figure 6.4, even shallow landslides and landslips can block canals causing overtopping leading to erosion of downhill slopes.

Timely bio-engineering measures such as those recommended below can reduce the risk of landslides and landslips.

Vegetative techniques *

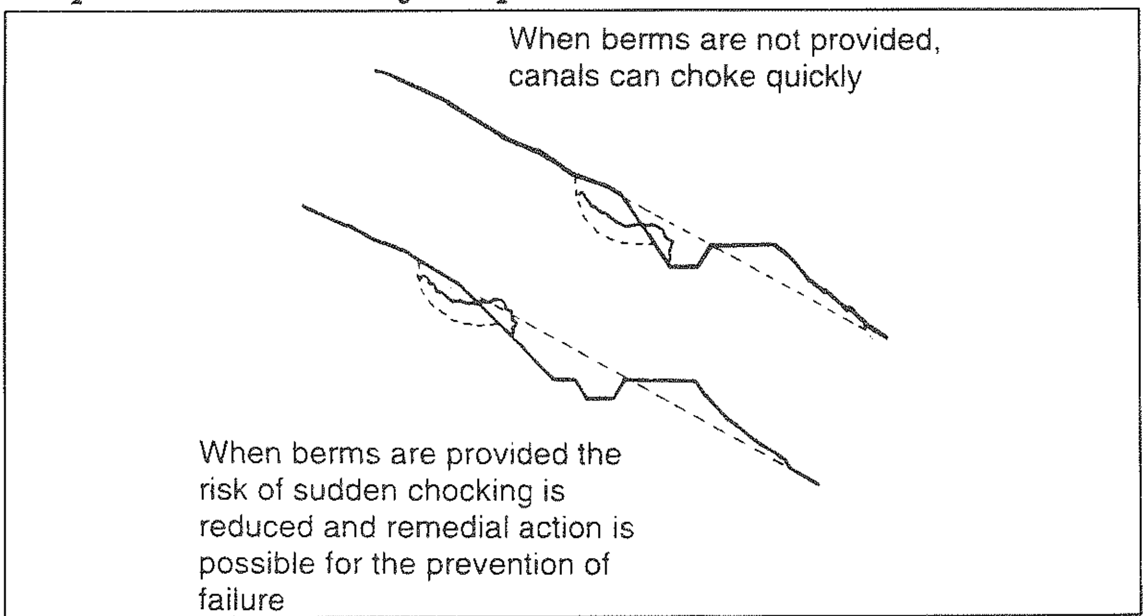
for spoil/new fill areas:

- brush layering, or
- brush matting, or
- live stacking with seeding, or
- live stacking with grass and shrub plantation.

for new cut areas:

- grass and shrub plantation, or
- jute netting with seeding, or
- jute netting with grass and shrub plantation, or sodding.

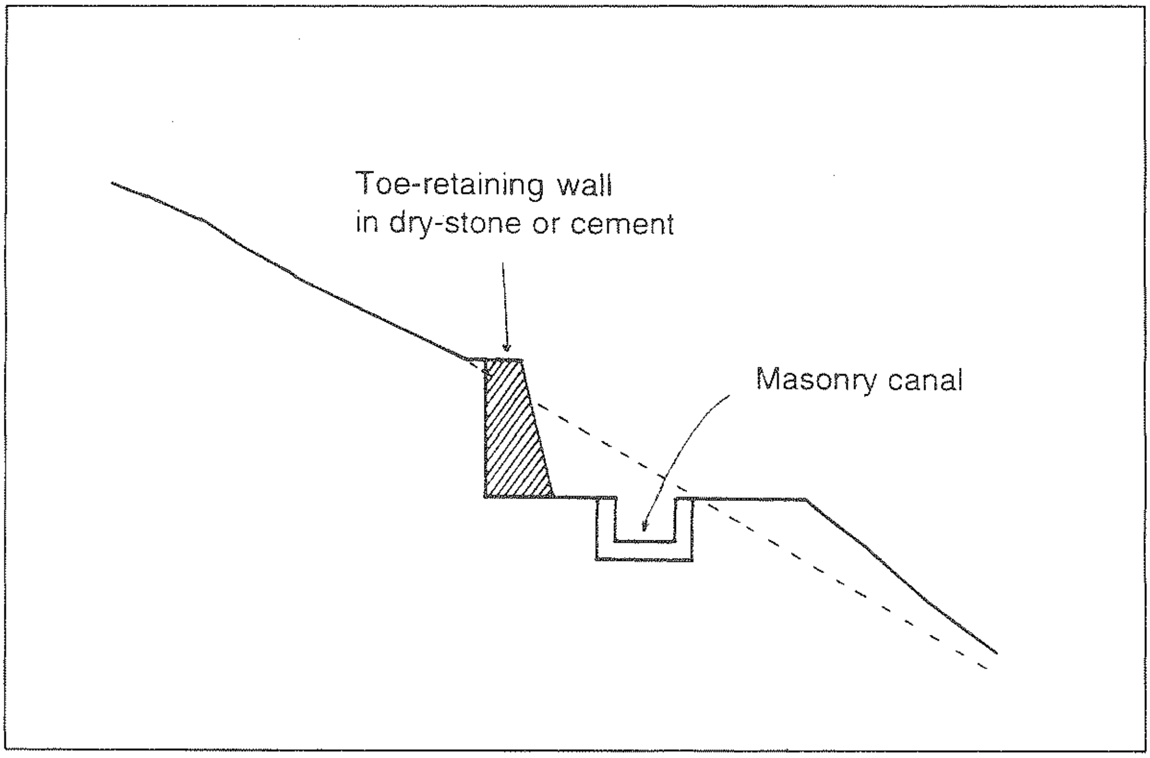
Figure 6.4
Preventing Failure due to Choking of Canals by Providing Adequate Berms and Safe Slopes



* see pages 33-37 for examples of vegetation techniques

In areas where landslips have occurred or are imminent, inert engineering measures must include toe-retaining walls and possibly covered canal sections, see Figure 6.5. The inert engineering measures must be well supplemented with bio-engineering measures prescribed for the prevention of landslips.

Figure 6.5
Use of Toe-Retaining Wall for Prevention of Minor Landslips



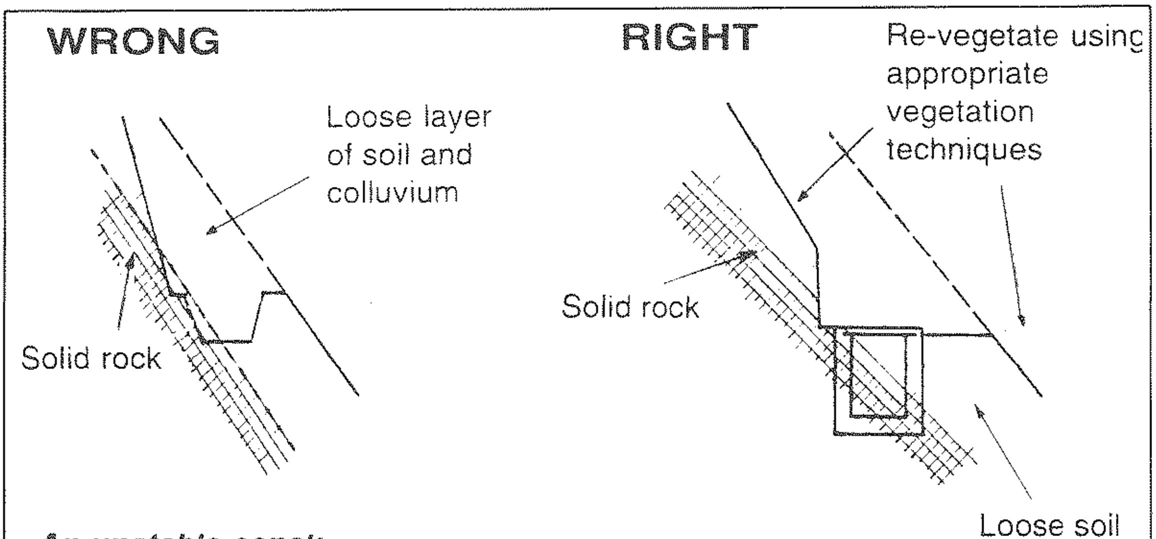
Land Unit 4B

Recommended Inert and Bio-Engineering Measures for Land Unit 4B

Land unit 4B is characterised by a thin mantle of weathered rock lying on top of sounder rock. This layer may be less than 3 metres deep.

This shallow layer can be easily triggered into a sliding motion by inappropriate design and construction of the canal. For stability, the base of the canal must be founded on solid rock. Over-excavation in this land unit can trigger landslides, hence narrow rectangular canal sections are preferred, see Figure 6.6.

Figure 6.6
Correct and Incorrect Design and Construction of Canal Sections in Land Unit 4B



An unstable canal: because a larger part of the canal's base is on loose soil.

A more stable canal: because a larger part of the canal's base is on firm soil; less earth excavation because the canal section is narrow; adequate re-vegetation

For more stability upslope and/or downslope, toe-retaining walls/revetments may need to be built adjacent to the canal.

Because the area is highly unstable timely bio-engineering measures such as those recommended below must be taken to prevent the occurrence of landslides.

Vegetative techniques*

for newly cut slopes in soil:

- brush layering, or
- live stacking with grass and shrub plantation, or
- jute netting with grass seeding, or
- jute netting with grass and shrub plantation, or sodding.

for eroded or natural slopes:

- live stacking with pioneer plantation, or vegetated dry masonry walls.

In areas where slides have occurred or are imminent, all loose material must be removed to expose the firm layer below, and the canal built on this firm layer. Appropriate vegetative measures from the list prescribed above must also be taken to prevent the future occurrence of landslides.

* see pages 33-37 for examples of vegetation techniques

Land Units 4C and 4D

Causes of Instability

Land units 4C/D are characterised by actively degrading and highly unstable soil layers.

Any disturbance to the slope will result in further landslides.

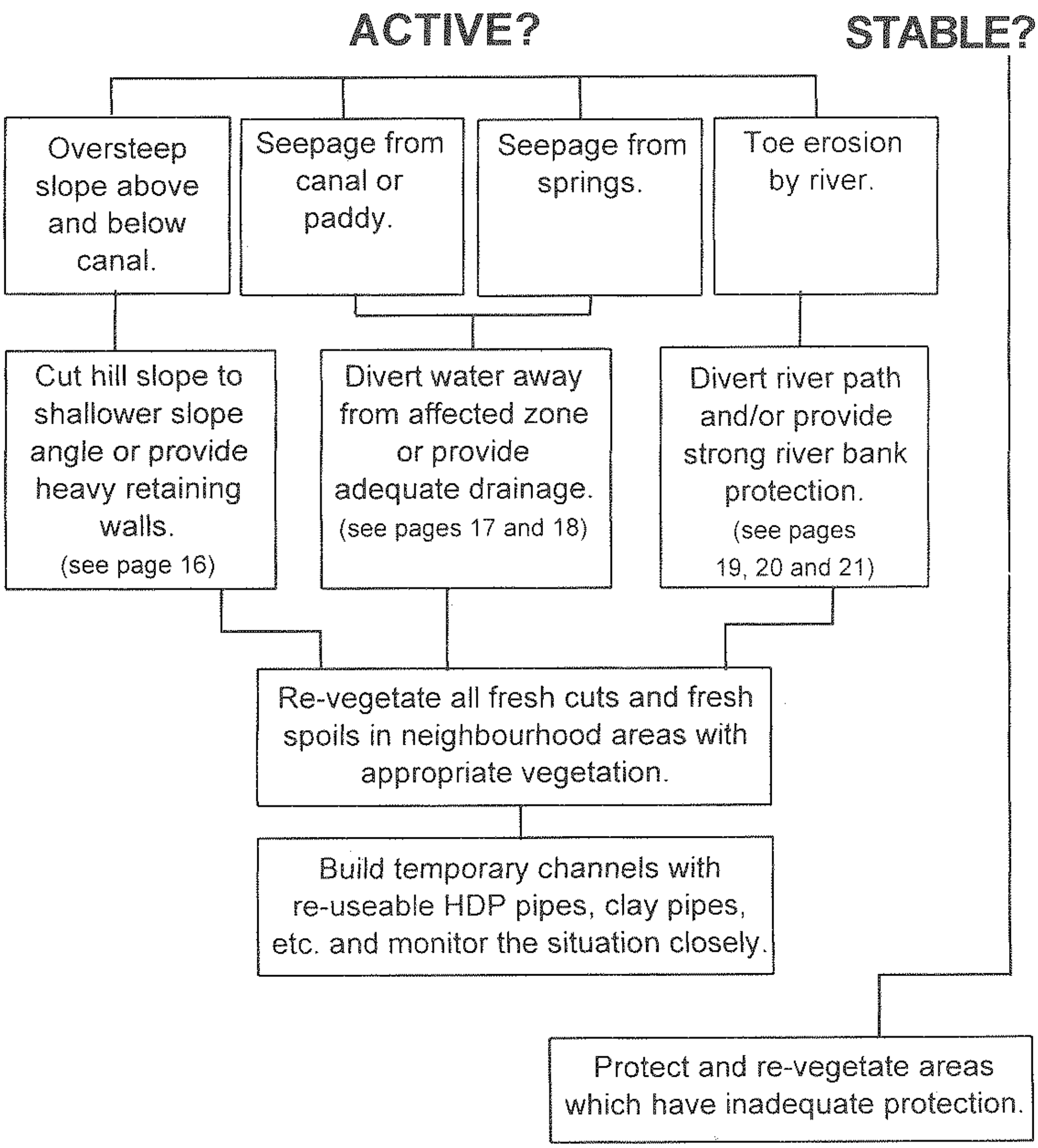
Bio-engineering treatment of areas in land units 4C and 4D will depend on the particular factor/s which are causing instability.

The main causes of instability in these land units are:

- oversteep slopes,
- excessive seepage, and
- continuous toe erosion.

The flow diagram in Figure 6.7 describes how problems arising from the above factors can be solved.

Figure 6.7
Main Causes of Instability in Land Units 4C/D and Methods for Dealing with such Instability Problems



Adapted from Environmental Protection Manual, ILO/HMGN, 1992

Recommended Inert and Bio-Engineering Measures for Land Unit 4C/D

Engineering measures for reducing the risk of slope failure in this land unit will depend on the particular factor/s which are causing instability.

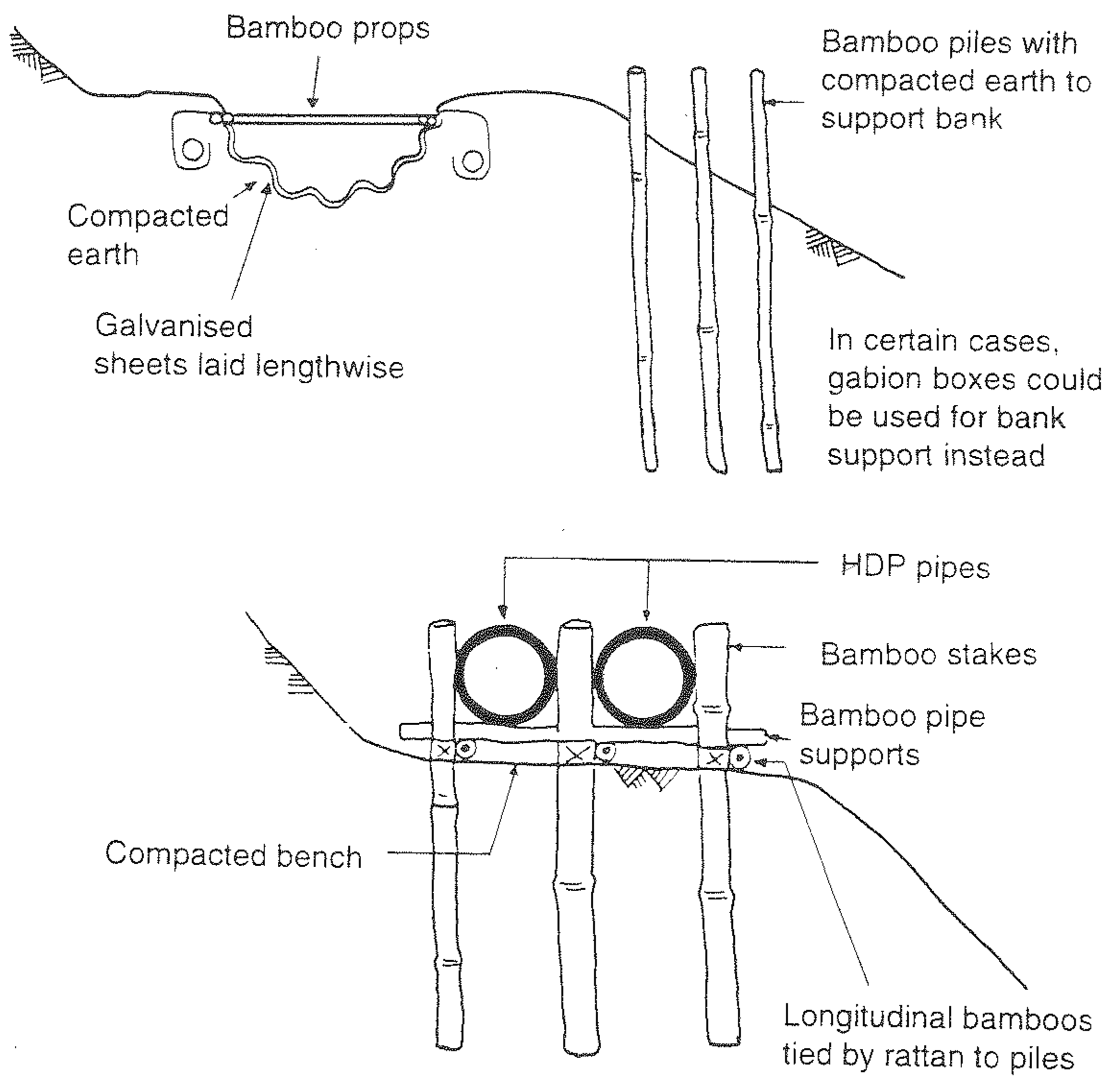
These measures are:

- temporary channels,
- toe-retaining walls,
- drains,
- river bank revetments, and
- spurs.

Temporary Channels

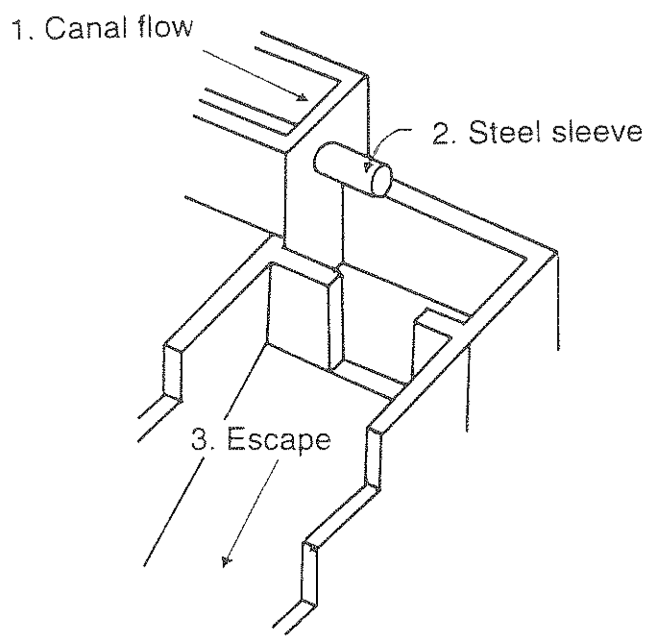
Because the hill slopes of land units 4C/D are highly unstable, due to one or more of the reasons shown in Figure 6.7, temporary channels need to be built in these areas. These channel sections need to be small and leakproof because leakage of canal water in this zone can trigger landslides. Temporary and impermeable HDP pipe, corrugated iron sheet, hollowed-out oil drums or slate channels are recommended in this area, see Figure 6.8.

Figure 6.8
Temporary Channels in Land Units 4C/D Using Corrugated Iron Sheets and HDP Pipes



The temporary channels should include designed break structures which control spill-water when the pipes move downslope with subsequent landslides. Spill-water should pour over solid rock or boulders or down natural drainage lines and not over the landslide zone. Figure 6.9 shows a break structure for use with HDP pipes.

Figure 6.9
Break Structure and Chute to Carry Water Away from Landslide in Times of Landsliding



1. Earth canal converges into a box section.
2. HDP pipe with single clamp, clamped lightly so that HDP pipe will pull off at times of sliding.
3. Canal water escapes down the chute and is diverted away from the landslide area.

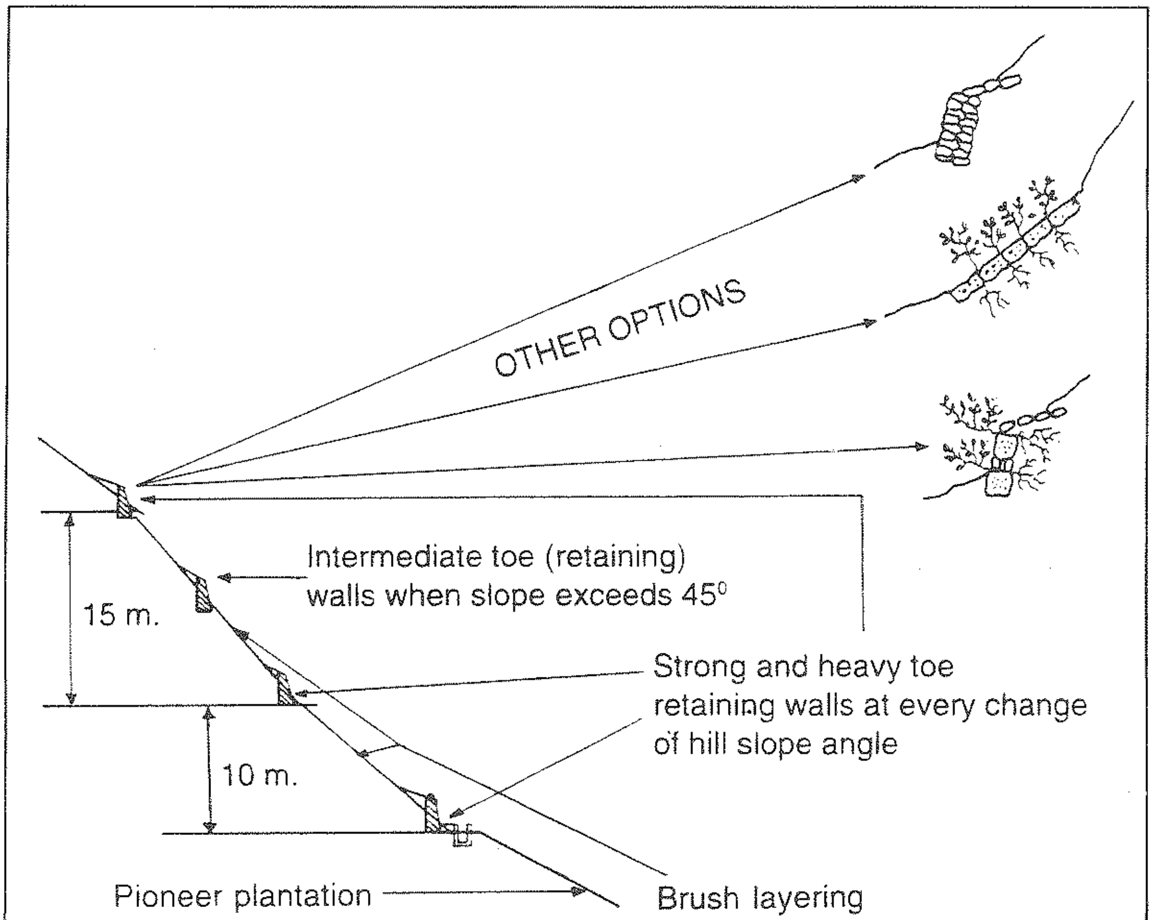
In areas where landslide has occurred or is imminent, all loose material must be cleared, platforms for temporary canals cut and structures as described above must be constructed. Bio-engineering measures must be relied upon for lasting solutions.

Toe-Retaining Walls

When existing slopes cannot be trimmed to shallower slope angles, because it would involve large excavations or loss of valuable land, then a series of toe-retaining walls need to be provided to stabilise the slopes. See Figure 6.10.

Adequate pioneer plantations must also be provided in this area to increase the stability of the slope.

Figure 6.10
Using Toe-Retaining Walls to Stabilise Oversteep Slopes When Trimming to Shallower Slope Angles is Not Possible in Land Unit 4D



See pages 33-37 and the Manual on Environmental Protection Measures, ILO/HMGN, 1992 for more details of vegetative techniques.

Drains

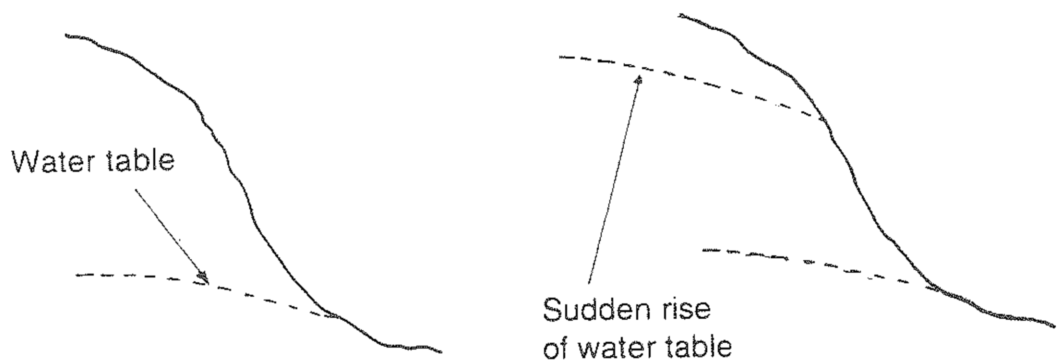
A rapid rise in the water table of a hill slope in land unit 4C/D can induce landslides by weakening the soil strength. See Figure 6.11.

The risk of landslides due to the rapid build-up of the water table inside a hill slope in land units 4C/D can be minimised by providing adequate drainage.

Sub-surface drainage through deep holes drilled on the face of the hill slopes are ideal, but may be difficult to provide in remote hill areas.

Alternatively, surface drains and complementary vegetative measures can be provided on such areas.

Figure 6.11
Effect of a Rapid Rise in the Water Table on the Stability of a Hill Slope



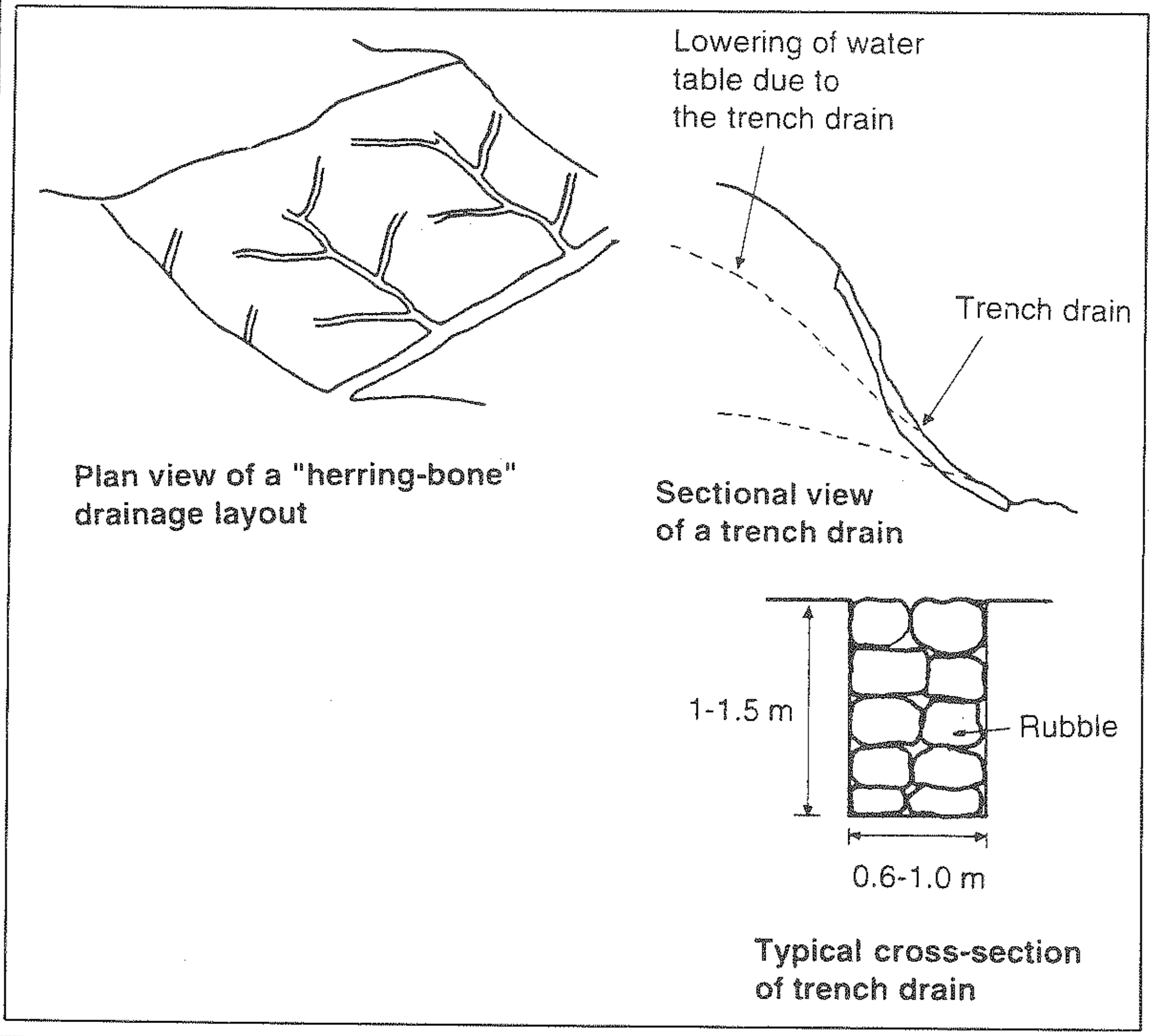
In the dry season the water table is low: The individual soil particles are not lubricated with water: hence there is a GREATER shear strength between soil particles to prevent landslides/landslips.

After heavy rains the water table rises rapidly, if adequate drainage is not present in the hill slope. The individual soil particles are now lubricated by the presence of a thick film of water around them. The "dry state" shear strength is REDUCED, resulting in landslides/landslips.

Surface rubble drains in "trench" and "herring-bone" layout, as shown in Figure 6.12, can prevent the rapid build-up of the water table. These drains should be used in combination with appropriate vegetative techniques such as:

- grass and shrub plantation, or
- bush layering, or
- live stacking.

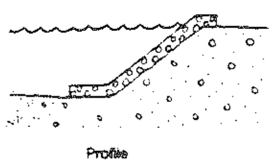
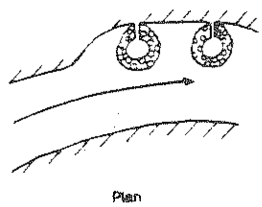
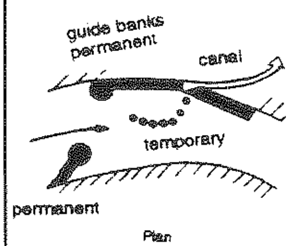
Figure 6.12
Trench and Herring-Bone Drains for Stabilising Slopes with Inadequate Drainage



River Bank Protection Works

The bottom slopes of land unit 4C/D which are in contact with river flows can be subject to river bank erosion. Depending on the need, the severity of the situation, the nature of the soil and the steepness of the river bank, river bank protection measures listed in Figure 6.13 can be adopted.

Figure 6.13
Types of River Bank Protection Works

TYPE	REVETMENT	SPURS	GUIDE BANKS
LAYOUT			
DEFINITION	Artificial surfacing of banks and bed	Elongated projection from bank to deflect current and bed load	Irrigation headworks
MAIN PURPOSE	Reduce river bank erosion	Improve river bank protection	Guide flow to irrigation intake
COMMENTS	Material usually stone (riprap), concrete panels or gabion baskets	Two types: Permeable and impermeable	Similar design to spurs

Revetments

Bank revetments using bamboo piles, bamboo straps and sandbags are appropriate for rivers with mild slopes and sandy beds suitable for driving in bamboo piles.

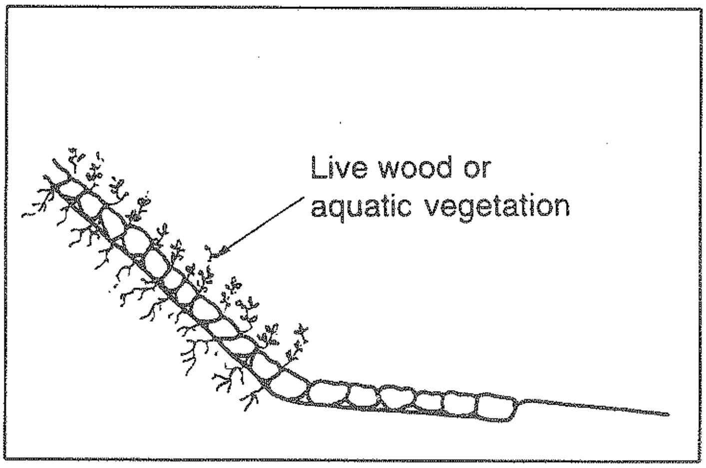
Bank revetments using rip-rap are more suitable when the bank slopes are not steeper than 40 degrees. Heavy stones and adequate aprons projecting into the river bed should be provided for effectiveness. Live wood and aquatic weeds can be planted in the joints between the stones placed on the slopes to bind the structure together thereby turning discrete blocks into a well-anchored mass.

Gabion bank revetments are appropriate on steeper bank slopes. Live wood and aquatic vegetation, as described above, will consolidate the gabion masonry into a well-anchored and solid mass more effective against river currents.

The plant species used with river bank protection works must be able to tolerate periodic flooding and waterlogging.

Photograph 6A
Sandbag Revetment Behind Rows of Bamboo Piles Protecting River Bank from Further Erosion

Figure 6.14
Dry-Stone Revetment Reinforced by Live Wood and Aquatic Vegetation



Spurs

Spurs are used to deflect the main flow path of a river away from an eroding bank or to align the approach flow upstream towards an infrastructure such as an intake.

Care should be taken to ensure that spurs do not deflect the main flow too much and cause scouring and erosion of valuable land on the opposite river bank.

Photograph 6B
Gabion Revetment with Short Bar Spurs to Protect Valuable Land

Simple Design Guidelines for Spurs

- Spurs should be built in groups: at least three spurs per group.
- Spurs within a spur field should be spaced at a distance approximately 2 to 3 times spur length.
- The spur nose should be protected against scour by stones/gabions.
- Spurs should generally be perpendicular to the river bank or pointed upstream.
- The upstream face of the spur must have a longer apron than the downstream face.
- The spur should be constructed with an apron which launches when the adjacent river bed is eroded.

For more design details of spurs refer to the Erosion and Sedimentation Manual by HMG Nepal, WECS of the MWR, 1987.

Land Unit 5B

Recommended Inert and Bio-Engineering Measures for Land Unit 5B

Land unit 5B consists of terrace scarp faces which are often sub-vertical and actively degrading, usually as sudden slumps forming cones of loose debris. The land is highly unstable and active with landslides. Whenever possible it is best to avoid constructing canals in this zone.

However, when construction is required, gabion revetment walls combined with vegetative measures can reduce the risk of landslides.

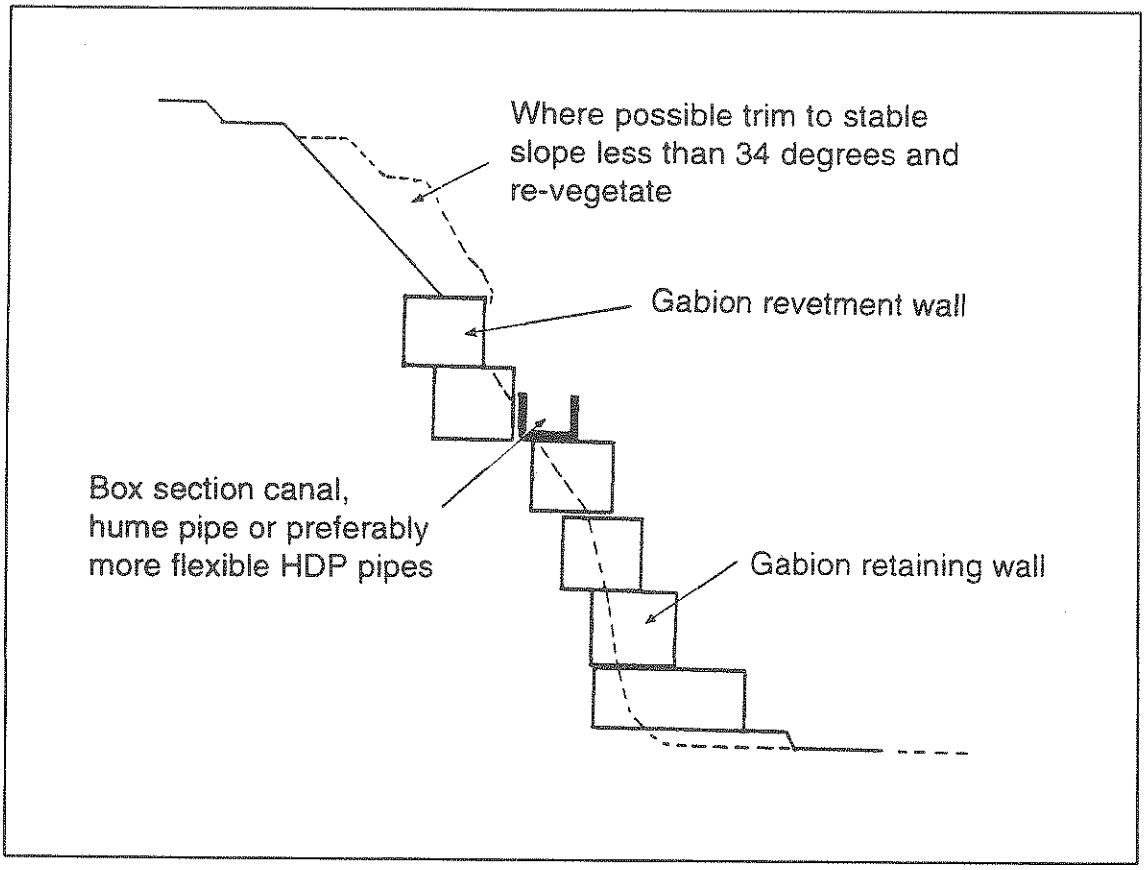
Trimming back is generally not possible, so gabion retaining walls should be used as support for the steeper scarp faces (see Figure 6.15). For scarp faces downslope of the irrigation channel that are not disturbed, both slope and canal should be protected with a gabion revetment wall. The scarp faces are highly permeable and erodible, hence no seepage from the canal must be allowed to cause soil erosion or slumping.

Appropriate vegetative techniques such as grass seeding, or grass and shrub plantation can help to reinforce the bare faces of this land unit. Likewise, vegetative gabions reinforce the retaining revetment walls.

If the landslide has already occurred or is imminent, all loose soil material must be cleared, a new embankment rebuilt with well-compacted layers of soil behind gabion revetments, and temporary channels constructed using HDP pipes.

All new cut and fill slopes must be re-vegetated with grass seeding, or grass and shrub plantation.

Figure 6.15
Recommended Design Using Gabion Walls and Leak Proof Channel Section for Scarp Face in Land Unit 5B



High Seepage Zones

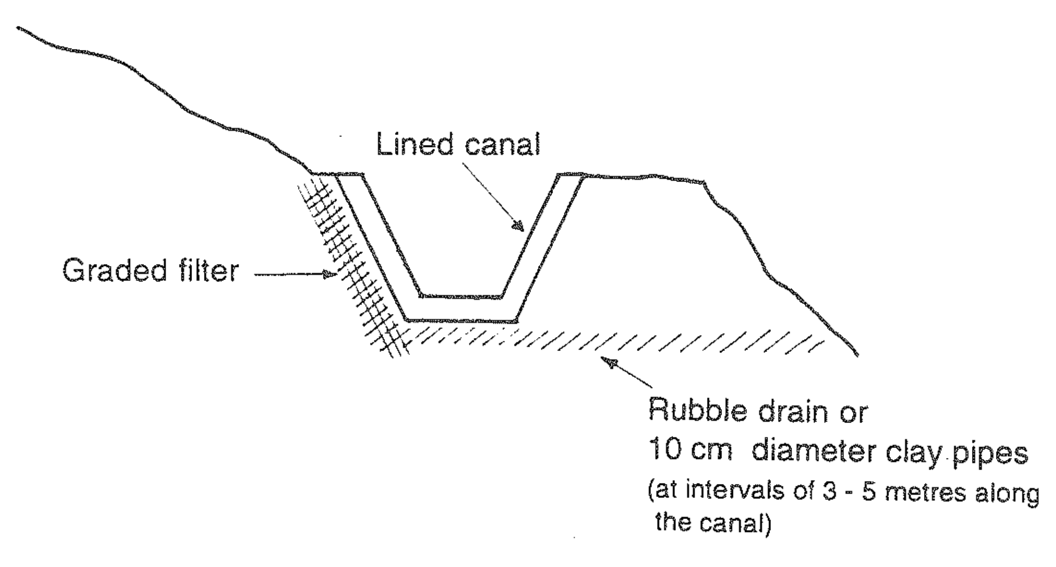
Irrigation Canals and Seepages (High Ground Water) Areas

Hillslopes with high water tables are potential problem areas because, when re-charged with groundwater during heavy rainfall, large quantities of seepage water can quickly enter open canals built on such locations.

Canals in this area often need to be lined because the ground is porous. When long stretches of canal are lined, the upward pressure exerted by the groundwater can produce cracks in the lining material.

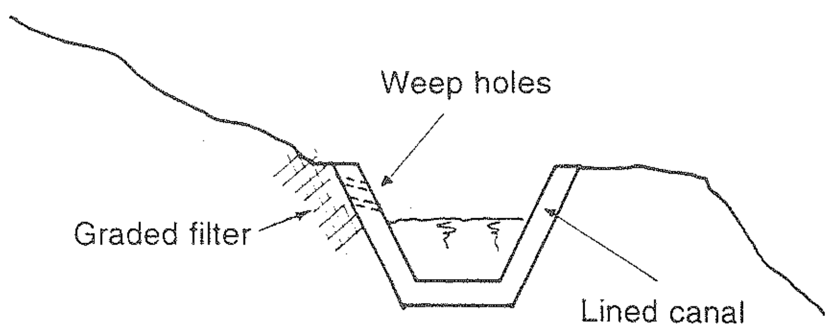
Therefore, the groundwater pressure needs to be released at regular intervals along the canal. Drains under the canal, as shown in Figure 6.16, need to be built in order to prevent the build-up of pressure on the canal from below.

Figure 6.16
Graded Filters and Drains for Preventing Build-up of Ground Water Pressure on Lined Canals



Another alternative is to provide weep holes in the canal walls to release uplift pressures. In porous areas, these weep holes will have to lie above the normal water depth in the canal to prevent the canal water from leaking into the soil below. See Figure 6.17.

Figure 6.17
Weep Holes for Preventing Build-up of Ground Water Pressure on Lined Canals



Soil Erosion

Irrigation Canals and Major Soil Erosion Zones

Erosion of a hill slope can affect a canal built across it in several ways, depending on the type and severity of erosion across the canal alignment.

Rain-Splash and Overland Flow Erosion

Erosion begins when the vegetation cover on a hill slope is broken or removed. Rain drops falling on the bare soil loosen the individual particles of the soil, and the overland flow that occurs after intense rainfall erodes the soil particles and transfers them downslope. Open irrigation canals lying below such hill slopes can quickly choke with sedimentary material made up of washed down soil and debris. The solution in these areas lies in the quick re-vegetation of the affected hill slope above the canal with appropriate species. Similar measures are recommended for the bare spoil areas downslope of the canal. Grass seeding and/or grass (eg: vetiver varieties)/shrub contour plantation, see Figure 6.18, and/or jute netting will be adequate for such areas. Until the grass and shrubs have taken root and proved effective, the canal must be regularly desilted to prevent it becoming choked and overtopping causing erosion on downhill slopes.

Rill Erosion

When erosion of the hill slope above and below the canal line has advanced to a stage where rills have begun to form, suitable vegetative techniques will be required to prevent further concentration of flow and soil transport. Suitable control measures include reshaping/trimming works in combination with:

- bush layering; or
- brush matting; or
- live stacking with seeding; or
- live stacking with grass/shrub plantation.

(See pages 33 - 37 for details.)

Gully Erosion

Gullies are relatively permanent steep-sided water courses which experience temporary flows during rainstorms. Gullies are almost always associated with accelerated erosion and therefore with landscape instability caused by too much water brought about by deforestation. Like landslides, gullies should be treated with respect.

Gentle gullies can be treated effectively using branch layering or vegetated palliside construction, see Figure 6.19 showing the principles and construction methods employed for preventing regressive erosion in gullies.

When deep gullies have already formed, a combination of the inert and bio-engineering methods shown in Figure 6.20 must be employed.

These will generally include inert structures such as weirs and checkdams using dry-stone and/or gabions.

Figure 6.18
Grass Seeding and Contour Grassing for the Control of Rainsplash and Overland Flow Erosion

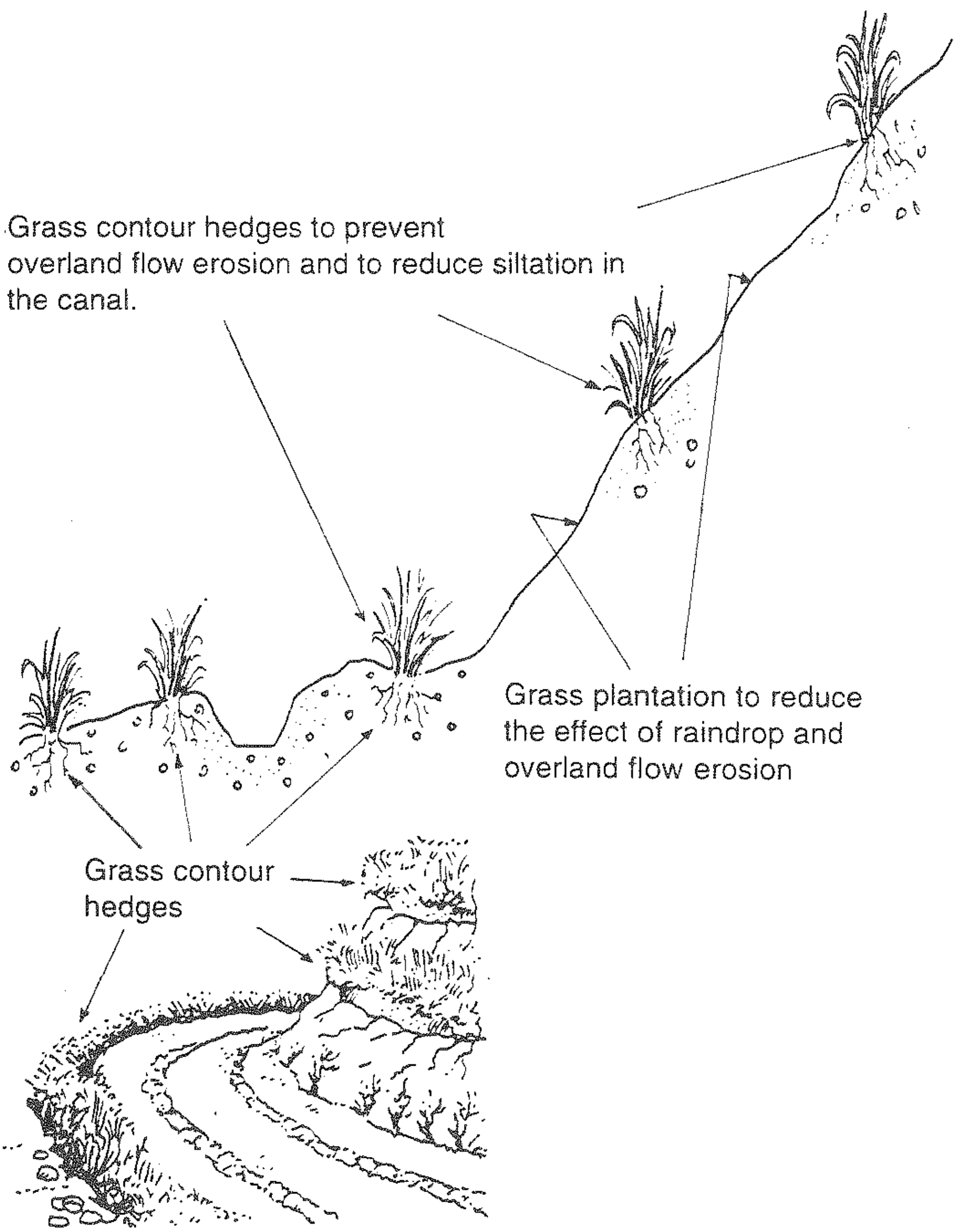
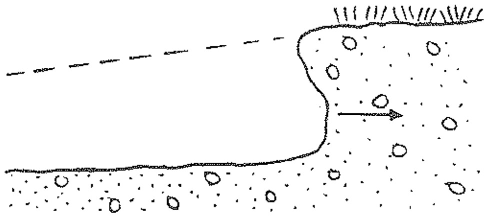


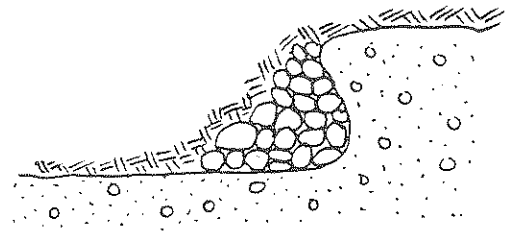
Figure 6.19
Principles and Construction Methods for the Control of Regressive Erosion of Gully Heads

Principle

This preventative measure is intended to arrest regressive erosion and block the advance of the gully, preventing it from progessing any further uphill.



The gully makes its way uphill by undercutting the bank, causing it to cave in

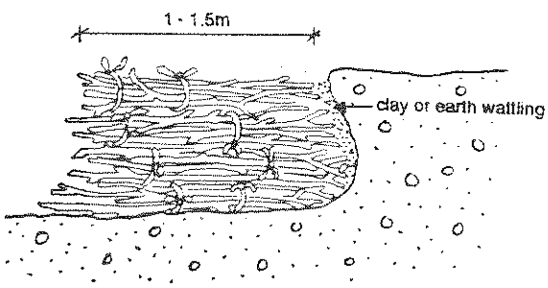


By creating a barrier of unerodable material, the gully is prevented from eating its way further uphill

Conditions This measure in only suitable for use in the first stages of erosion

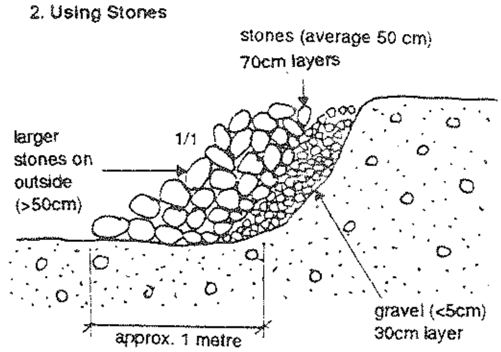
Construction

1. Using Branches



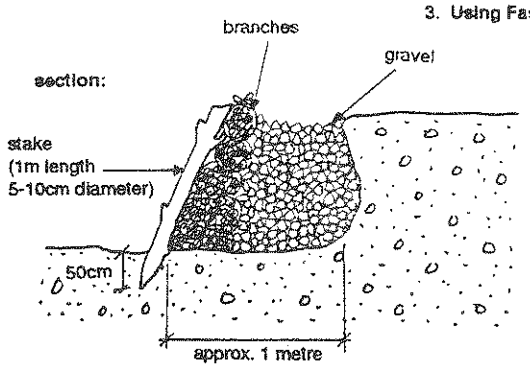
- tie the branches into bundles
- pack bundles into head of gully
- fill in any spaces between the earth and the bundles with clay or wattling made up of earth mixed with straw and twigs.

2. Using Stones



3. Using Fascines and Gravel

section:



plan:

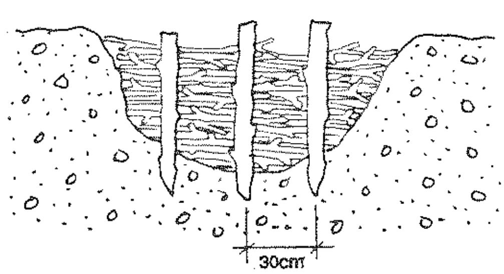


Figure 6.20
Inert and Vegetative Engineering Solutions for Deep Gullies

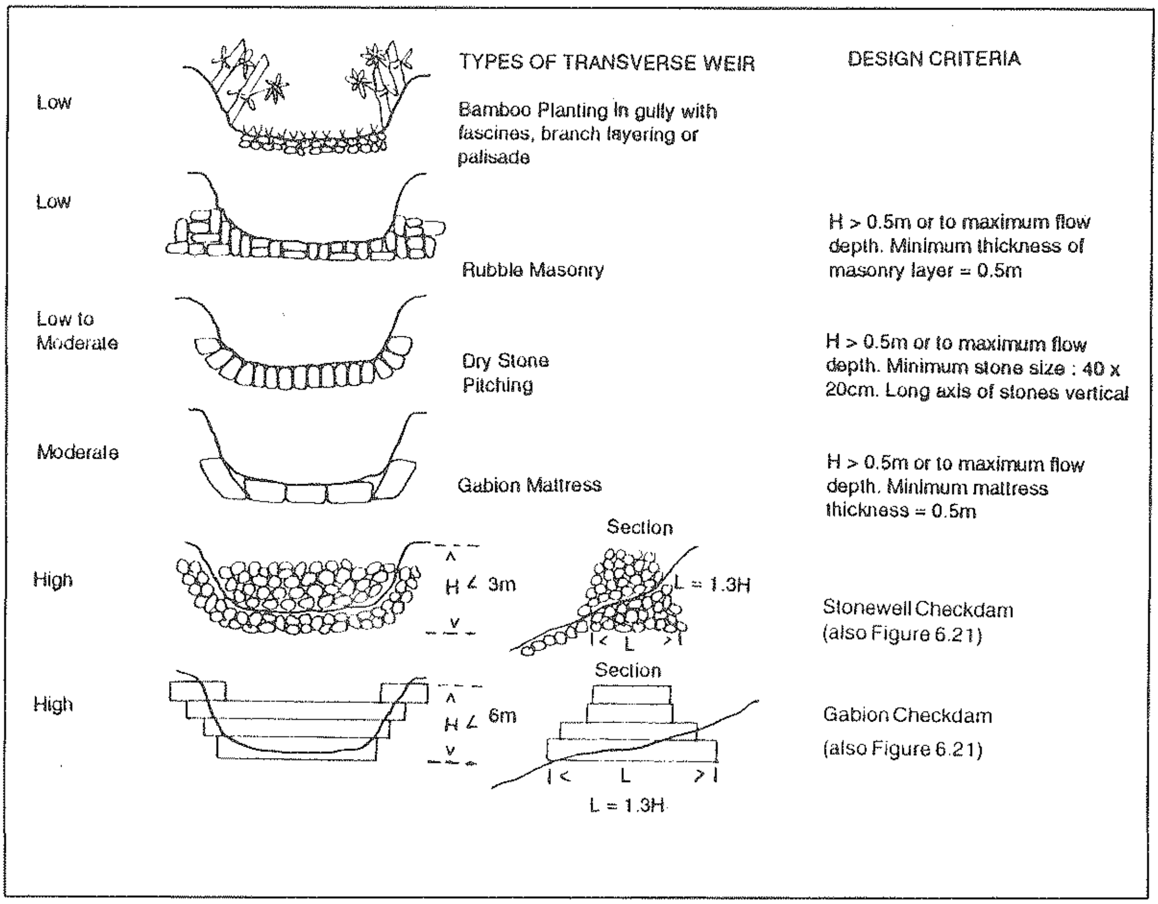


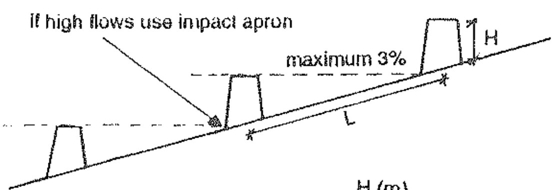
Figure 6.21
Simple Design Guidelines for Checkdams

DIMENSION AND SPACING OF CHECKDAMS

Purpose:
- Decrease gradient gully
- Reduce velocity of flow

But:

Remember checkdams will increase soil erosion further downstream: as the surface water flow strives for equilibruim local increases in velocity will lead to eddying and turbulence



$$L(m) = \frac{H\ (m)}{\text{Gradient of Gully}}$$

e.g. if gradient = 1/25 and the engineer wishes to use 1m high checkdams

$$\text{Spacing } (L) = \frac{1}{1/25} = 25 \text{ metres}$$

Recommended Canal Sections for Areas of Gully Erosion

In areas of shallow gullies the canal will generally consist of covered sections with adequate structural support. See Figure 6.22.

When deep gullies threaten the stability of the slopes, HDP pipe canal sections with adequate structural support are recommended. See Figure 6.23.

Figure 6.22
Recommended Canal Sections Across Hill Slopes with Gentle Gullies

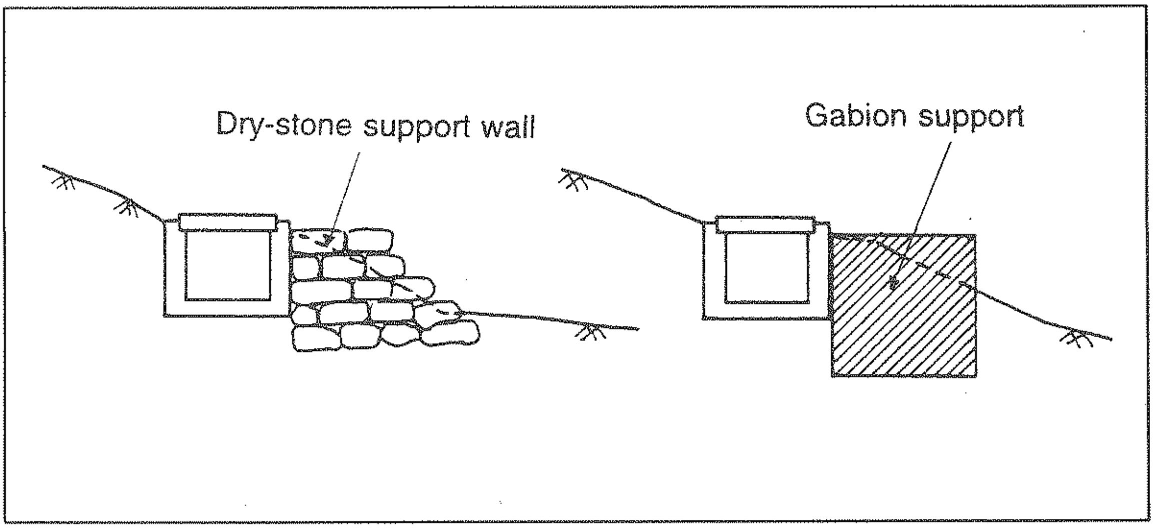
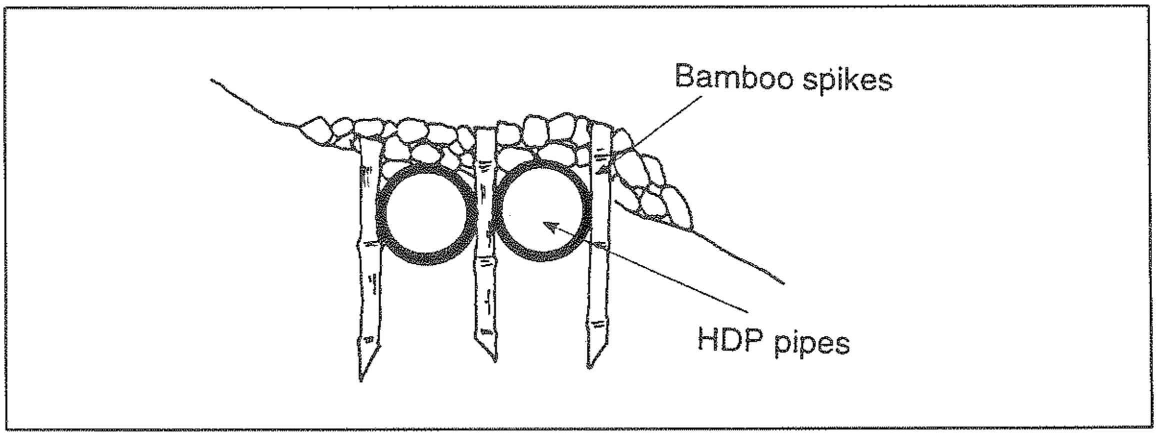


Figure 6.23
Recommended Canal Section Across Hill Slopes with Deep Gullies



The Uses and Limitations of Vegetative Slope Stability and Soil Conservation Measures

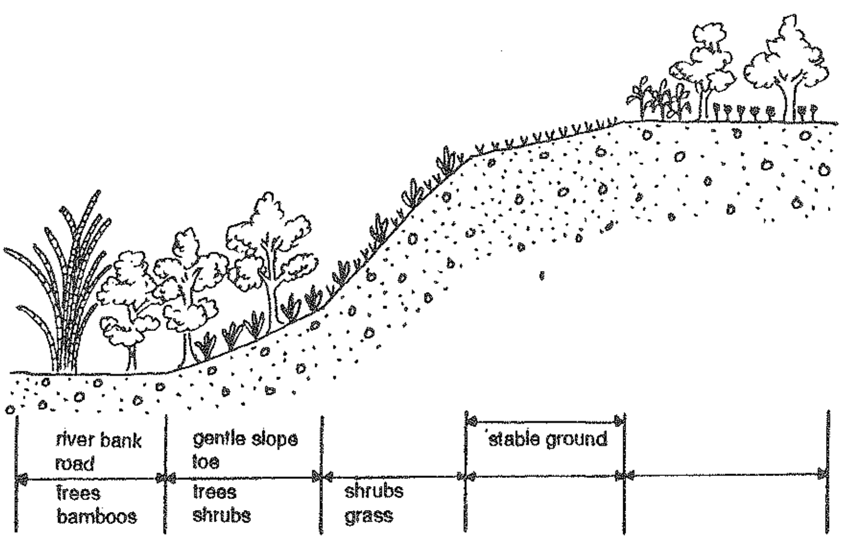
Tree, bush, shrub and grass species used for slope stabilisation or soil conservation measures must be carefully selected to suit the soil, climate, altitude, slope angle and orientation of the area with relation to sunlight. The wrong plant in the wrong place can destabilise the area instead of stabilising it.

For example, trees on steep, unstable slopes can, as a result of wind forces, destabilise the slope and lead to further landsliding. Trees on the toeslopes can add more counterweight to the soil mass and prevent landslides.

Figure 6.24 gives a general guideline for the correct selection and location of vegetative plantation techniques.

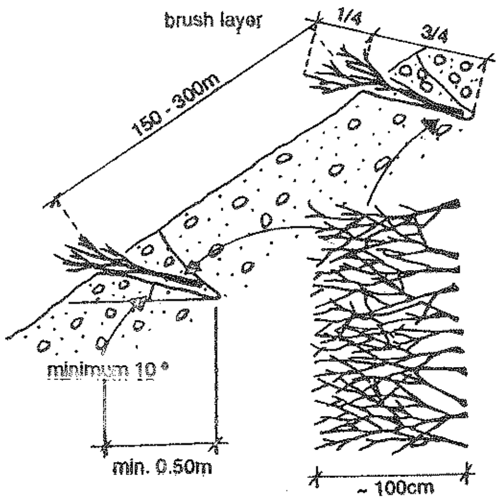
Tree, bush, shrub and grass species are subject to strength and time constraints before they can become fully effective and, depending on the situation, may need to be combined with inert engineering measures.

Figure 6.24
Correct Selection and Location of Vegetative Species



Name:
Brush Layer

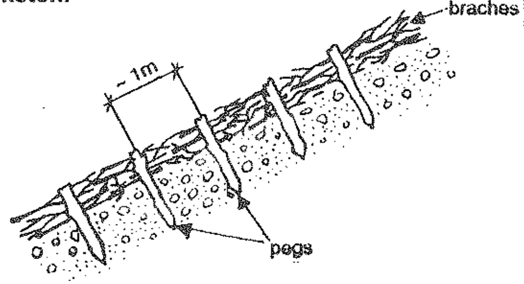
Sketch:



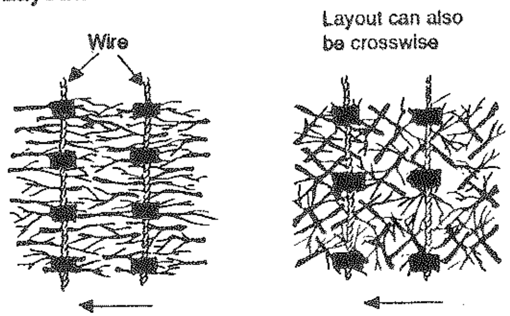
Construction Period:
During dormant season
Just before monsoon
(Jesth)

Name:
Brush Matting

Sketch:



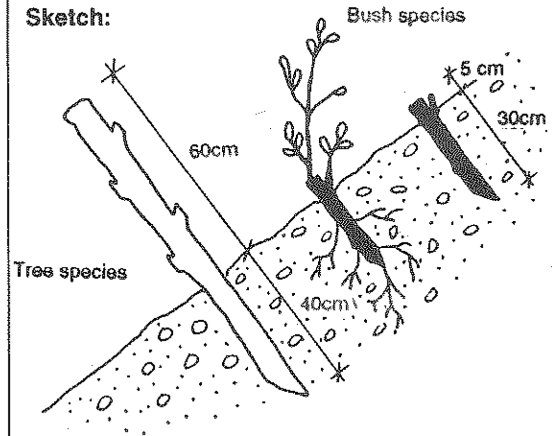
Layout:

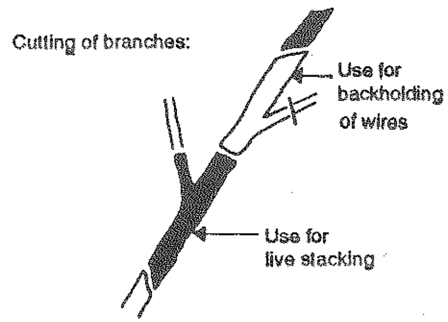


Construction Period:
During dormant season
Brush matting: before start of monsoon (Jesth)
Cutting of Branches: 2 weeks before, with storage of branches in moist, shady place

Name:
Live Stacking

Sketch:

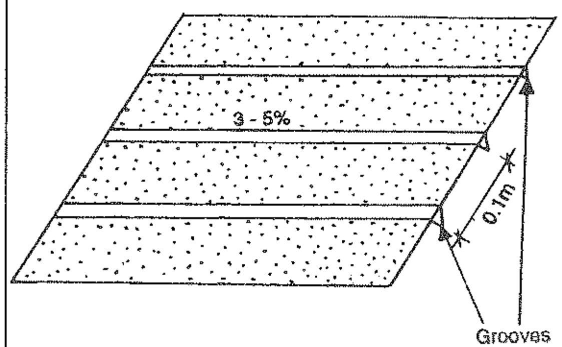




Construction Period:
During dormant season
Tree species: Falgun, Chaitra
Keep cuttings in moist place for two weeks
Bush species: Before start of monsoon (Jesth)

Name:
Seeding (grass, herbs, trees)

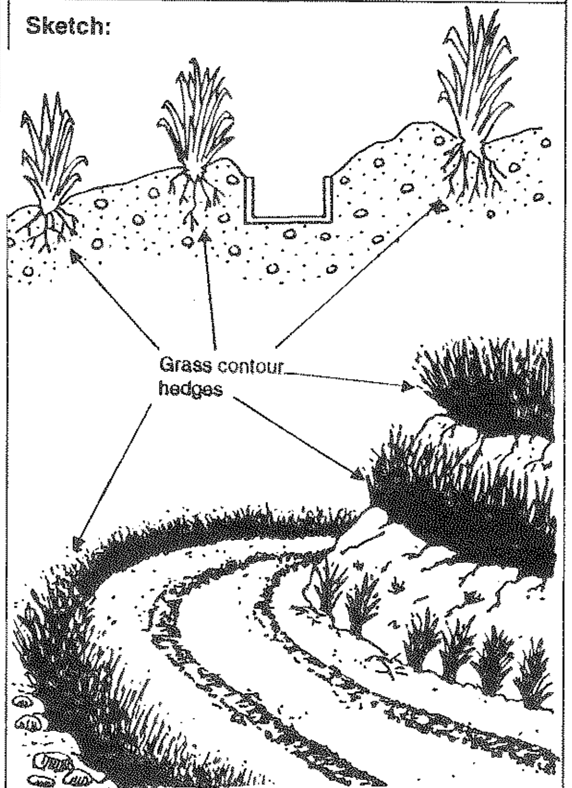
Sketch:



Construction Period:
During vegetation period
Falgun - Jesth
or end of monsoon (Bhadra)

Name:
Grass/Shrub Plantation

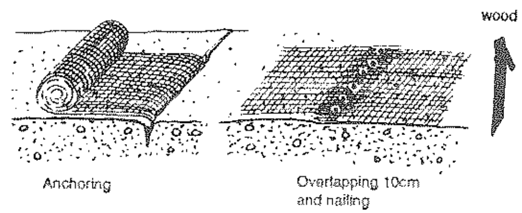
Sketch:



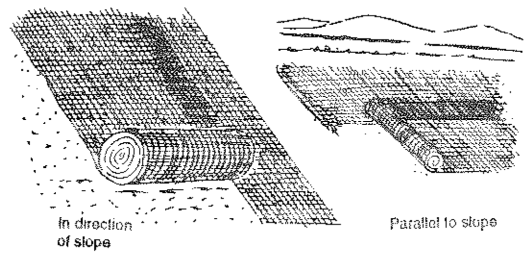
Construction Period:
Any time when water is available

Name:
Jute Netting

Sketch:



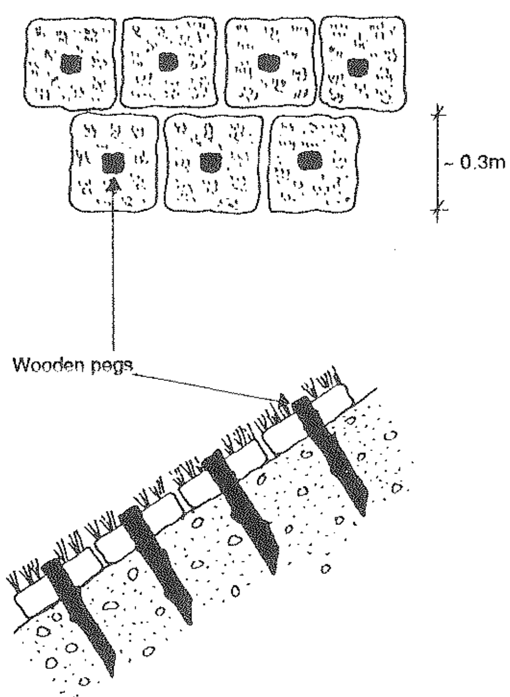
Layout:



Construction Period:
In combination with grass seeding,
Falgun - Jesth
In combination with live stacking,
Falgun, Chaitra

Name:
Sodding

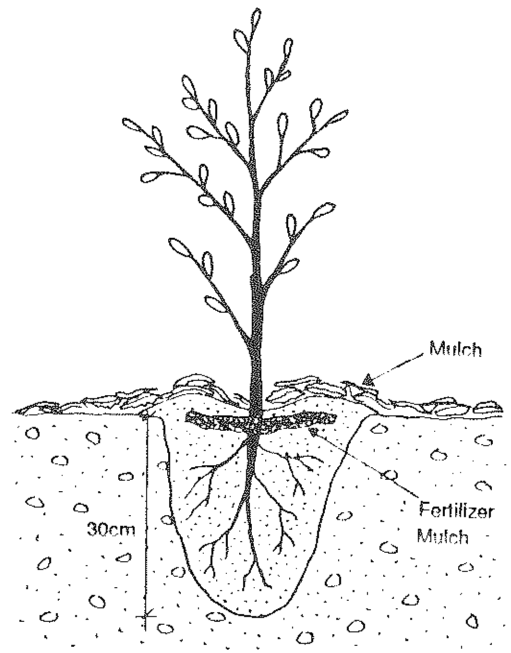
Sketch:



Construction Period:
Any time if water is available

Name:
Pioneer Plantation

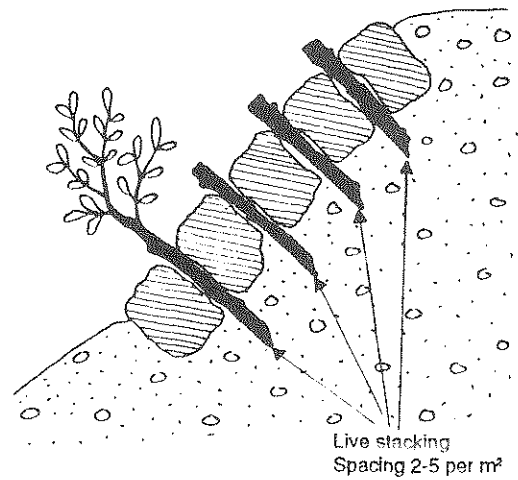
Sketch:



Construction period:
At beginning of vegetation period
(Asar - Shrawan)

Name:
Vegetated Dry Masonry Wall/Rip Rap

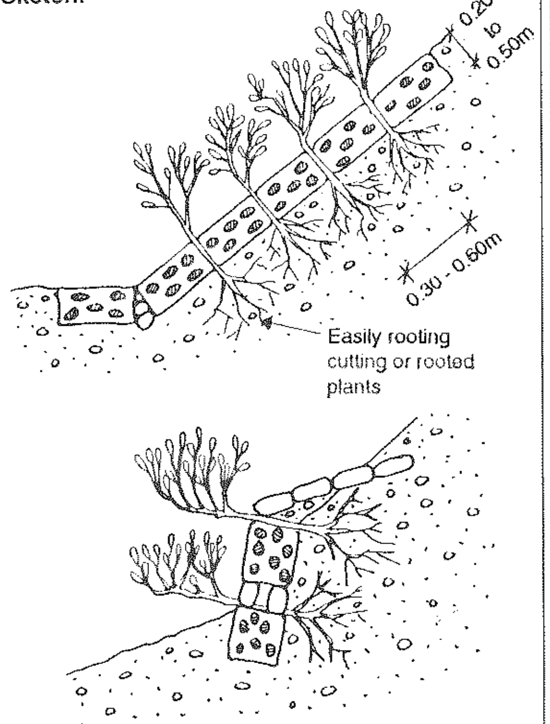
Sketch:



Construction Period:
During dormant season
Just before Monsoon (Baisakh, Jesth)

Name:
Vegetated Gabion

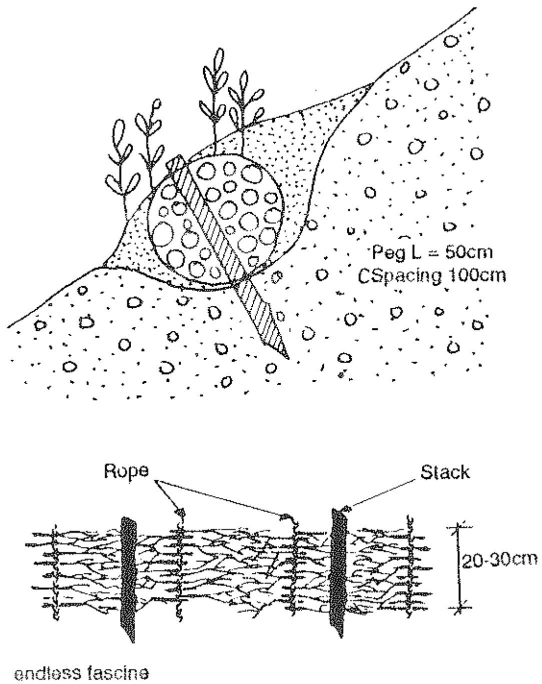
Sketch:



Construction Period:
During dormant season
Just before Monsoon (Baisakh, Jesth)

Name:
Brush Wattles (Slope Fascines)

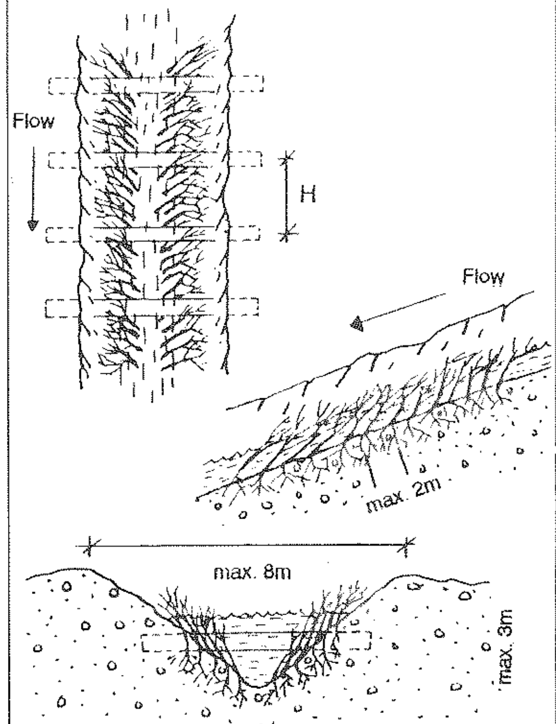
Sketch:



Construction Period:
During dormant season
Just before Monsoon (Jesth)

Name:
Branch Layering of Gullies (living)

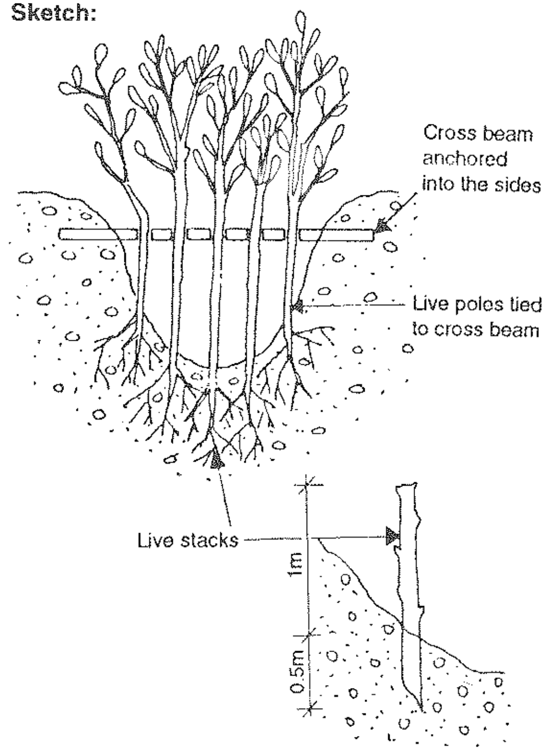
Sketch:



Construction Period:
During dormant season
- in wet gullies just before monsoon
- in dry gullies (Jesth)

Name:
Vegetated Palisade Construction

Sketch:



Construction Period:
During dormant season if gully is wet.
Just before monsoon if gully is dry
(Baisakh, Jestha)