LOW VOLUME ROADS WORKSHOP
Napier, New Zealand, July 2009

Low Cost Slope Stabilisation

Tim Hunt
Scott Wilson Thailand

REAAA© Driving Progress
ROAD ENGINEERING ASSOCIATION OF ASIA & AUSTRALASIA (NZ)

What do we mean by low cost?

- Optimum use of low-skilled labour
- Maximum use of locally available materials
- Logical approach to design
- Use of local road maintenance contractors

This will be illustrated by the work carried out under the SEACAP 21 project in Laos

SEACAP 21

What was the project trying to achieve?

The objectives were:

- **To use best-practice appropriate slope stabilisation methods using local materials and technologies**
- **To extend the present technologies to cover specific landslips**
- **To assist in the procurement and supervision of slope stabilisation trials**
- **To disseminate the results by means of workshops, manuals, specifications and training**

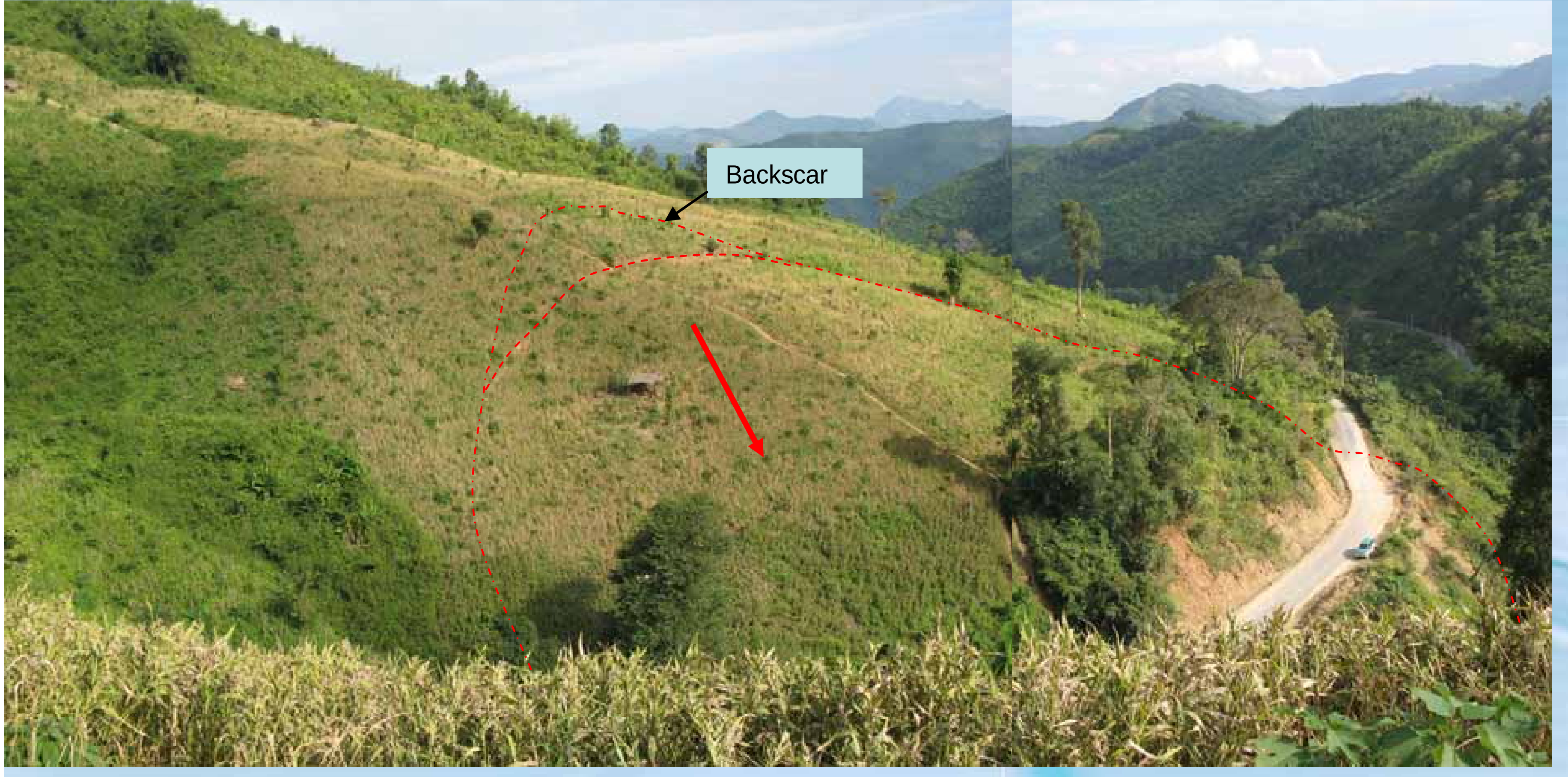
- Laos is about 90% the size of New Zealand
- Located between Thailand and Vietnam
- Population 6.3 million
- 75% hilly or mountainous
- 50% forested

- Project area about 250km north of Vientiane
- Mountainous terrain from 450m to 1450m elevation
- Annual rainfall in excess of 2000mm

Typical below-road failure

Typical above-road failure

Typical through-road failure



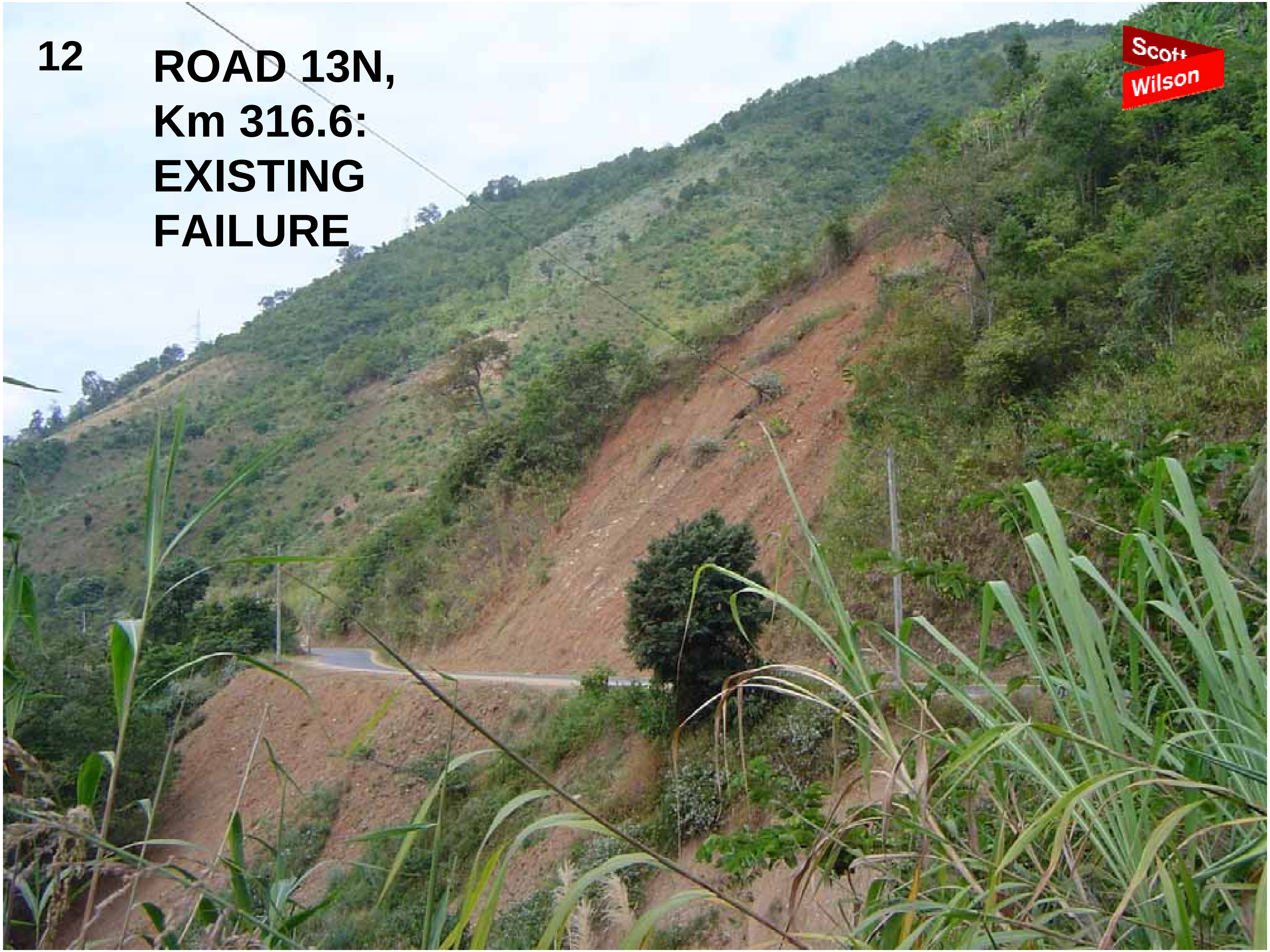
13 stabilisation sites eventually chosen comprising a mix of failure types.

Phase 1

- Those sites requiring mainly bio-engineering measures to prevent further instability. This comprised 3 sites, the work carried out just prior to and during the onset of the 2007 wet season.

Phase 2

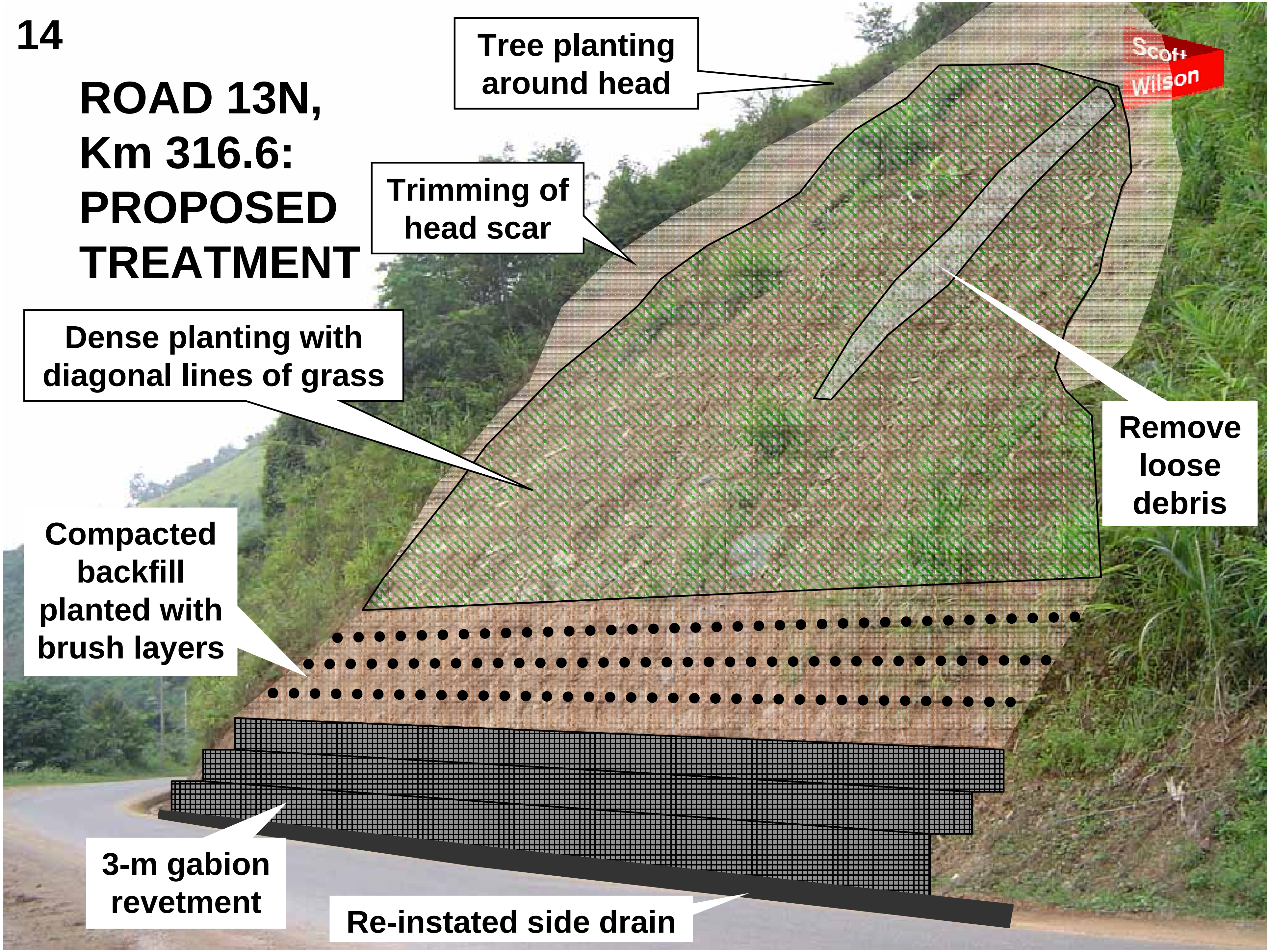
- Those sites requiring mainly geotechnical measures to prevent further instability. This comprised 10 sites, the work carried out mainly during the 2007/08 dry season.


12
ROAD 13N,
Km 316.6:
EXISTING
FAILURE
Scott Wilson


13
ROAD 13N, Km 316.6: LANDSCAPE APPRAISAL
Shifting cultivation on slope above failure may have affected slope hydrology
Scott Wilson
Slope composed of fragmented phyllite and residual soil, transported and mixed to make a weak colluvial mass
Spring water emerging on slope to SE of failure
Road benched into steep lower section of a long convex slope
Steep planar debris slide averaging 50°
Slope below road destabilised by large volume of debris tipped in emergencies

14

ROAD 13N, Km 316.6: PROPOSED TREATMENT



Phase 1 Construction

Km
242.6

Phase 2 Construction

Earthworks and Structures
- Construction Issues

- Safety
- Spoil disposal
- Wall foundations
- Masonry walls
- Gabion walls
- Backfill
- Others

Safety

Traffic

Workforce

Removal of spoil

Failure plane

DCP testing

Mortared masonry construction

Rounded stone

Angular stone 1

Angular stone 2

Dressed stone

Backfill density testing

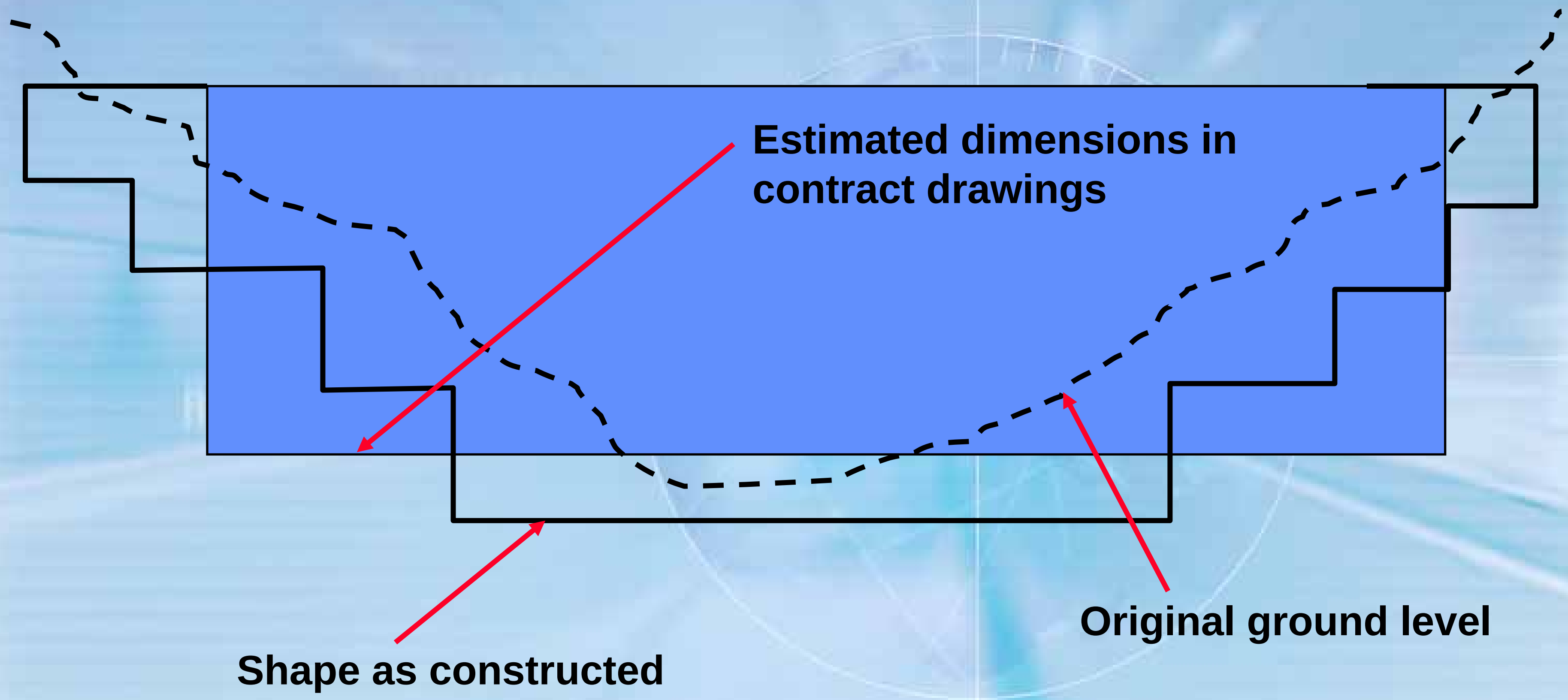
Compaction using pedestrian roller

Access track construction

Stage construction

Incomplete walling

Retaining wall - front elevation



Slope Maintenance Site Handbook

Slope Maintenance Manual

Slope Maintenance Site Handbook

ສາທາລະນະລັດ ປະຊາທິປະໄຕ ປະຊາຊົນລາວ

ສັນຕິພາບ ເອກະລາດ ປະຊາທິປະໄຕ ເອກະພາບ ວັດທະນະຖາວອນ

ປື້ມຄູ່ມືປະຈຳສະໜາມ
ການບຳລຸງຮັກສາຕະຝັ່ງ

SLOPE MAINTENANCE SITE HANDBOOK

ກະຊວງໂຍທາທິການແລະຂົນສົ່ງ

ກັນຍາ 2008

Scott Wilson

Slope Maintenance Site Handbook

- Written for site staff: technicians, supervisors etc
- English and Lao language
- A5 size, 70 pages, illustrated mainly with photographs
- Structured around the MPWT's MACs
- Definition of Maintenance for Slopes
- Routine Maintenance of Slopes
- Emergency Maintenance of Slopes
- Rehabilitation and Improvement

Routine Site Inspection

1.2 Routine Site inspections

Why is it necessary to carry out routine site inspections?

There are comparatively few occasions when a large-scale failure of a slope or wall occurs without some early warning. In most cases (except for minor slips), there are usually warning signs.

What should I look out for?

Check the reasons why the drainage system is damaged or cracked. Do the cracks in the roadside drain extend across the road? Is the damage being caused by differential movements? Are the roadside drains being blocked regularly in a particular location? Is the slope above/below moving?

Cracking in roadside drain and road surface caused by large scale slope movements

Cracking in the shoulder caused by fill slope movements below the road

Check the retaining walls and slopes above and below the road on foot. Are they in good condition? Are movements taking place? Are there any worrying signs of undue erosion or ravelling occurring?

What if the situation looks serious?

Report it to your supervising engineer. As best as you can, fill in a Landslide or Wall Report (see Section 5).

2.2 Erosion

What should be done if erosion is occurring?

Erosion taking place below the road is usually due to a concentrated flow of water from the road finding its way onto an erodible slope or gully. This often happens when the roadside drains have been blocked, or where the surface water is able to run down the lower side of the road. In these cases the blockage should be cleared, or a temporary earth bund constructed on the edge of the road to prevent the water from running down the slope. The problem also often occurs at the lower end of road supporting retaining walls. Eventually, the temporary earth bund should be replaced with a concrete upstand or kerb, to make sure that the water flow is redirected to a suitable location where it will not cause further erosion.

Severe shoulder erosion at the end of a retaining wall caused by road surface run-off.

Erosion also commonly takes place in streams and gullies above and particularly below the road. In this case it might be necessary to construct a check dam or non-erodible lining, for example out of gabion or mortared masonry.

If the erosion is occurring above the road, then the source of the water needs to be determined. If it is the result of human activity, for example rice irrigation, housing etc, then the appropriate village authorities should be notified. If it is the result of natural causes, then bio-engineering techniques may solve the problem (see Section 4.4).

2.5 Vegetation management

Why is it necessary to manage vegetation?
The roadside slopes are mainly covered in vegetation. This helps to control erosion on soil slopes. However, the plants grow rapidly and need to be controlled regularly to stop them from extending out into the road. They become dangerous to traffic when they hide pedestrians, cause vehicles to be driven in the middle of the road or reduce drivers' sight lines

How should vegetation be controlled?
Plants should be cut back several times a year, according to need. Smaller plants can be cut with a machete. Plants must never be pulled or dug out by roots, and must never be burnt.

Where should the material that has been cut be placed?
Ensure that the cut plant material is placed in locations where it won't be washed into the drainage system during heavy rain; for example on a flat area on the opposite side of the road. The removed material should be left in tidy piles but not burnt.

Vegetation is being cut on the lower cut slope to improve drivers' sight lines. Once the cutting is finished, the material will be removed from the drain and piled on the other side of the road.

What else needs to be done?

Ask the labourers to look out for any damage or cracks in the ground and point these out to you. This may be an indication of instability, especially on the lower side of the road. Any such damage or cracks will need to be repaired under Rehabilitation or Emergency Maintenance. Make sure that the labourers do not light fires to burn vegetation, especially at the end of the day.

Emergency Maintenance

3.3 Temporary drainage measures

Why are temporary drainage measures required?

If the failure is located below the road, immediate steps should be taken to prevent water from the road surface or drainage system from entering the crest of the failure and creating further instability. It may be necessary to dig catchpit bypass channels to prevent roadside drainage water from entering a culvert. The upstream roadside drain may need to be blocked and water directed across the road away from the failure by an earth bund to a more suitable temporary discharge point.

If the failure is located above the road with debris blocking the roadside drain, then immediate measures should be taken to prevent the water from crossing the road and discharging at random down the valley slope.

A temporary drain dug in debris that has fallen from above the road.

Emergency work following the collapse of a culvert on a national highway.

Rehabilitation and Improvement

4.2 Construction of new walls

What are the main types of walls?

There are three main types of wall constructed in Laos: masonry, gabion and reinforced concrete. Masonry walls can be composite or fully mortared.

Mortared masonry wall

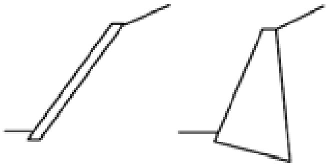
Composite masonry wall

Gabion wall

Reinforced concrete wall

Retaining walls may be constructed below or above the road. They retain the ground behind them. Revetments may also be constructed above the road.

From the road, Revetments and Retaining Walls can both look the same. The difference is that Revetments are very thin (usually only 300mm thick) and only prevent erosion and shallow sliding from occurring at the base of the slope. They are not very strong, and they do not act as retaining structures.



Revetment Wall *Retaining Wall*

Bio-engineering

What is bio-engineering? Bio-engineering is the use of plants to undertake light engineering tasks. Certain types of plants can be used to control erosion and shallow landslides. Often it is used in association with small-scale structures.

When should bio-engineering techniques be used?

Bio-engineering techniques should normally be used to control erosion or stabilise or prevent shallow slope movements where the depth to the sliding surface is up to 0.5 m and to protect slopes against erosion. If the depth to the sliding surface is greater than 0.5 m, then bio-engineering techniques should only be carried out in conjunction with other slope stabilisation techniques described in section 4.3.

What are the best bio-engineering techniques?

The table below summarises the best available techniques.

Location	Technique	Advantages	Disadvantages
Cut slope in soil Road edge or shoulder in soil	Grass planting in lines, using rooted slips.	Rapid and complete surface cover.	Requires a soil slope without too many stones. Slow to establish on hard cut slopes.
Cut slope in mixed soil and rock	Direct seeding of shrubs and trees in crevices.	The best way to establish vegetation on rocky slopes.	Slow to provide a coverage good enough to resist erosion.
Fill slopes and backfill above walls	Brush layers using woody cuttings from trees or shrubs.	Instant physical barrier that interrupts runoff. Stronger than grass. Often successful on stony debris.	Can only be installed on slopes of 1V:1.25H or less, on unconsolidated materials.
Large and less stable fill slopes	Truncheon cuttings (big woody cuttings from trees).	Relatively strong plant material on slopes that are still unstable; withstands damage from moving debris.	Takes a long time to establish a complete cover. Needs a lot of planting material.
Gullies or seasonal stream channels	Live check dams using woody cuttings of trees.	Low cost, flexible structures to reduce erosion where water flow is concentrated.	Not as strong as check dams of gabion or masonry. Require careful supervision.
Other bare areas	Tree planting using potted seedlings from a nursery.	Allows a long term forest mix of trees to be restored.	Takes a long time to establish a complete cover. Seedlings are vulnerable to grazing for a few years.

What are the materials for these techniques?

Grass slips are small sections of a grass plant, made by splitting up a large clump. The stems are cut down to a height of 100 to 200 mm and the roots cut back to 40 to 80 mm. There should be 2 or 3 stems per slip.

Woody cuttings are taken from the branches of certain types of small trees. They are cut to be between 450 and 600 mm long, and the diameter should be between 20 and 40 mm in diameter. Shoots and leaves are trimmed off. For live check dams, cuttings are needed that are 2 metres in length.

Truncheon cuttings are made from the branches of large trees. They should be about 2 metres in length and 50 to 80 mm in diameter.

It is very important that plant materials for bio-engineering are kept cool and damp when they are being moved and prepared.

Which species of plants should be used?

The table below lists the plants that have been shown to be successful for bio-engineering work in Laos.

Species for grass slips	Species for woody cuttings	Species for direct seeding
Nyar khaem, dok khaem (broom grass) Nyar kha Nyar phaek Nyar khaem lao (2 different species) Nyar phaek, fek hom (vetiver)	Mak koh (chestnut) Korbai leuam(chestnut) Posa (paper mulberry) Mak nhiao ("diesel nut") Peuak meuak, toutiang Khee nok, khee hen, ngen (simali) Mai mook Thorng	Khileckdong Koun Khathin Tiou dam Pohou Hookatai Phak nao Som poi Phak thon

Almost any type of tree can be brought from a nursery as a potted seedling.

How is grass planting done?

Grass slips are planted in lines across the slope. The best results usually come from lines that are at 45° to the maximum slope. Start from the top and work downwards.

Mark out the lines on the slope and then plant the grass slips to the original depth and gently firm the soil back around them.

How is brush layering done?

Mark out horizontal lines every 2 metres down the slope. Start from the bottom and work upwards. Dig shallow trenches along the lines, 350 to 450 mm wide.

Lay the cuttings across the trenches with the bottom inwards and 80 to 100 mm of the top protruding from the slope. The cuttings should be 50 mm apart. Place a small amount of soil over the cuttings and then lay another line of cuttings. Replace all the soil and firm it down gently.

How are truncheon cuttings planted?

Use a crowbar to make a vertical hole that is about 20 mm wider than the cutting and at least 1 metre deep. Place the cutting in the hole and gently fill around it with loose soil. Truncheon cuttings are usually planted 1 metre apart on deep debris slopes.

Truncheon cuttings after one season of growth.

Finishing works

What finishing works are necessary?

Check all construction and bio-engineering details. Make sure that they have been completed as instructed. If necessary, instruct repairs.

Finally, the site should be inspected during or immediately after a period of heavy rain to see if the run-off is going where it is intended and without any erosion, and if not, to carry out any additional works to ensure that it does.

Before and after treatment

Road 13 North, km 316.
A revetment wall and various types of bio-engineering works were used to protect the slope.

Slope Maintenance Manual

ສາທາລະນະລັດ ປະຊາທິປະໄຕ ປະຊາຊົນລາວ
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ຄູ່ມືການສ້ອມແປງຕະຝັ່ງເຈື່ອນ

ກະຊວງໂຍທາທິການ ແລະ ຂົນສົ່ງ

ກັນຍາ 2008

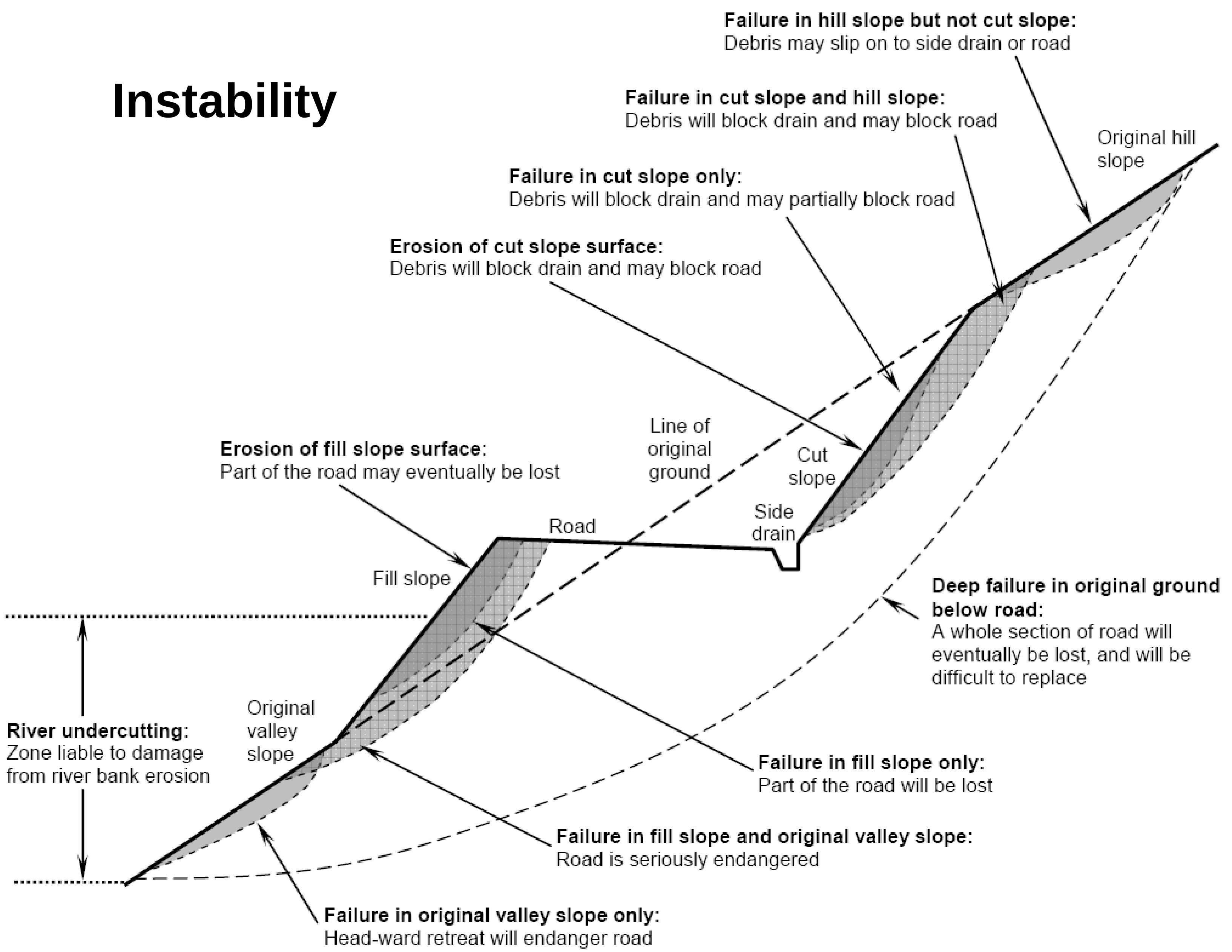
Slope Maintenance Manual

- Written for road management professionals: engineers.
- English and Lao language versions.
- A4 size, 108 pages, illustrated with drawings & photographs.
- Covers all relevant aspects of site inspection, design and construction.

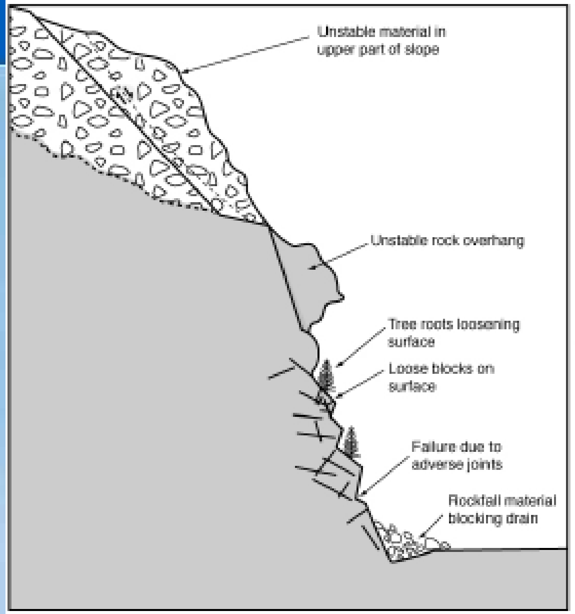
Technical Specifications

- Complete technical specifications for slope stabilisation and protection.
- English and Lao language versions.
- Based on international experience and best practices.
- Tested through SEACAP 21 trials and modified accordingly.

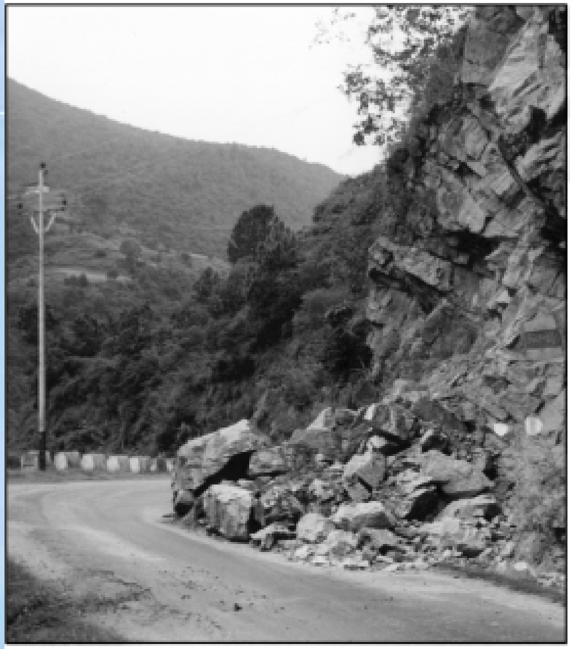
Instability



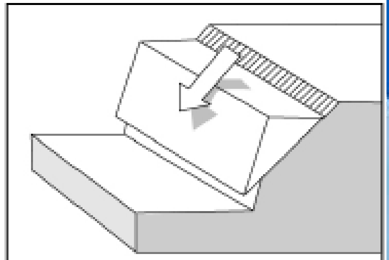
Diagnosis of rock slope instability



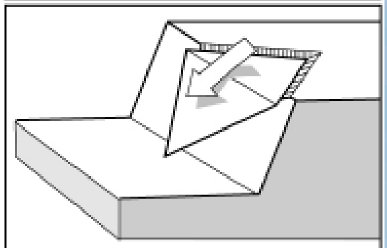
Rock slopes: typical maintenance problems
(right) Rock slopes: failure mechanisms



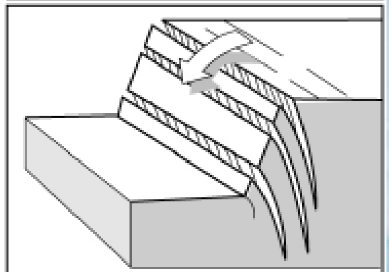
Rock slope toppling failure



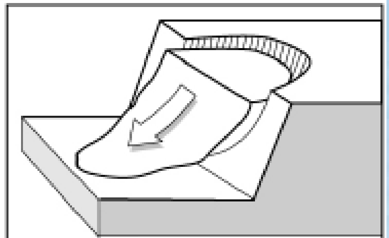
Planar failure in rock in which a discontinuity "daylights" the slope face



Wedge failure on two intersecting discontinuities with a line of intersection which "daylights" the slope

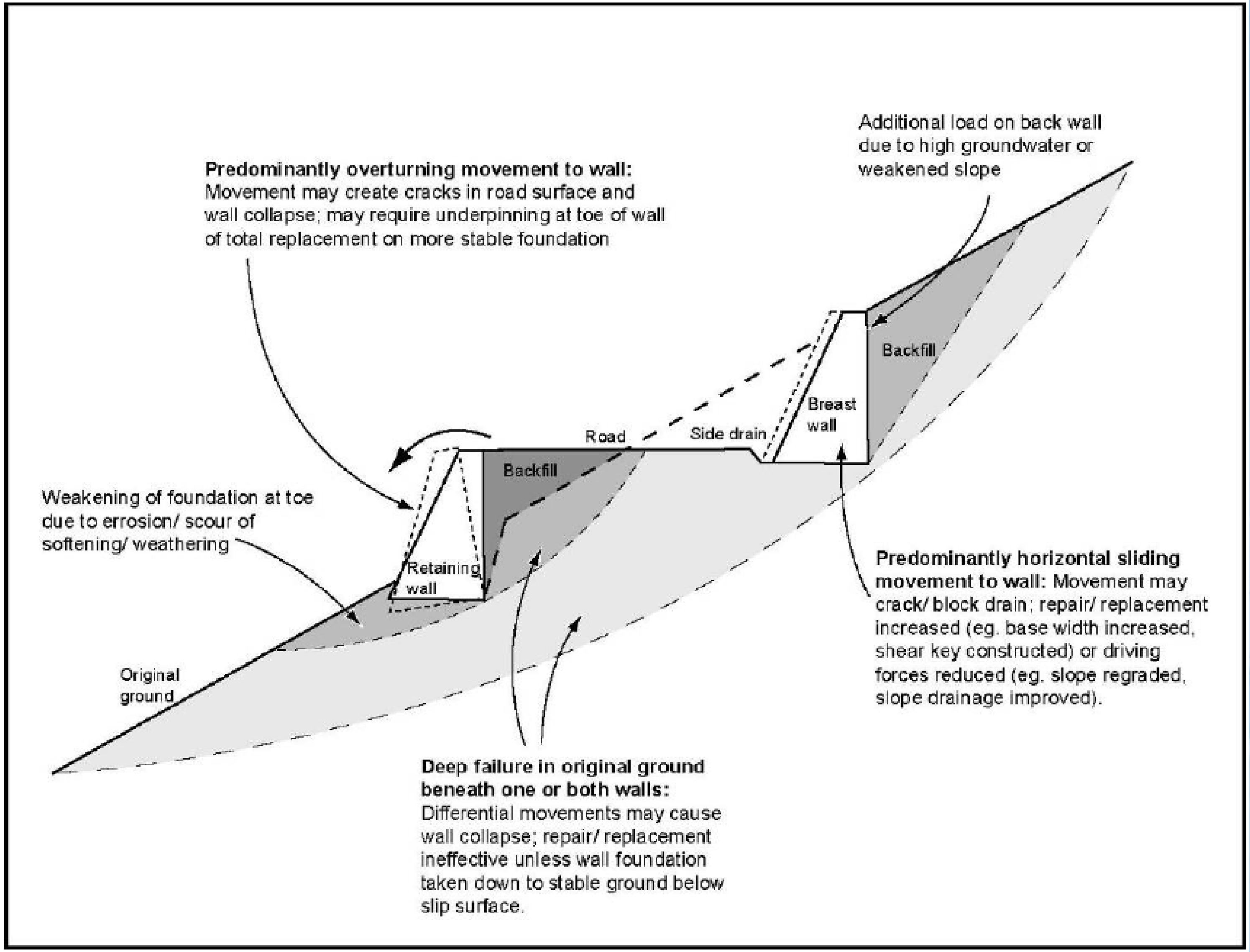


Toppling failure in hard rock with slabs or columns defined by discontinuities that dip steeply into the slope



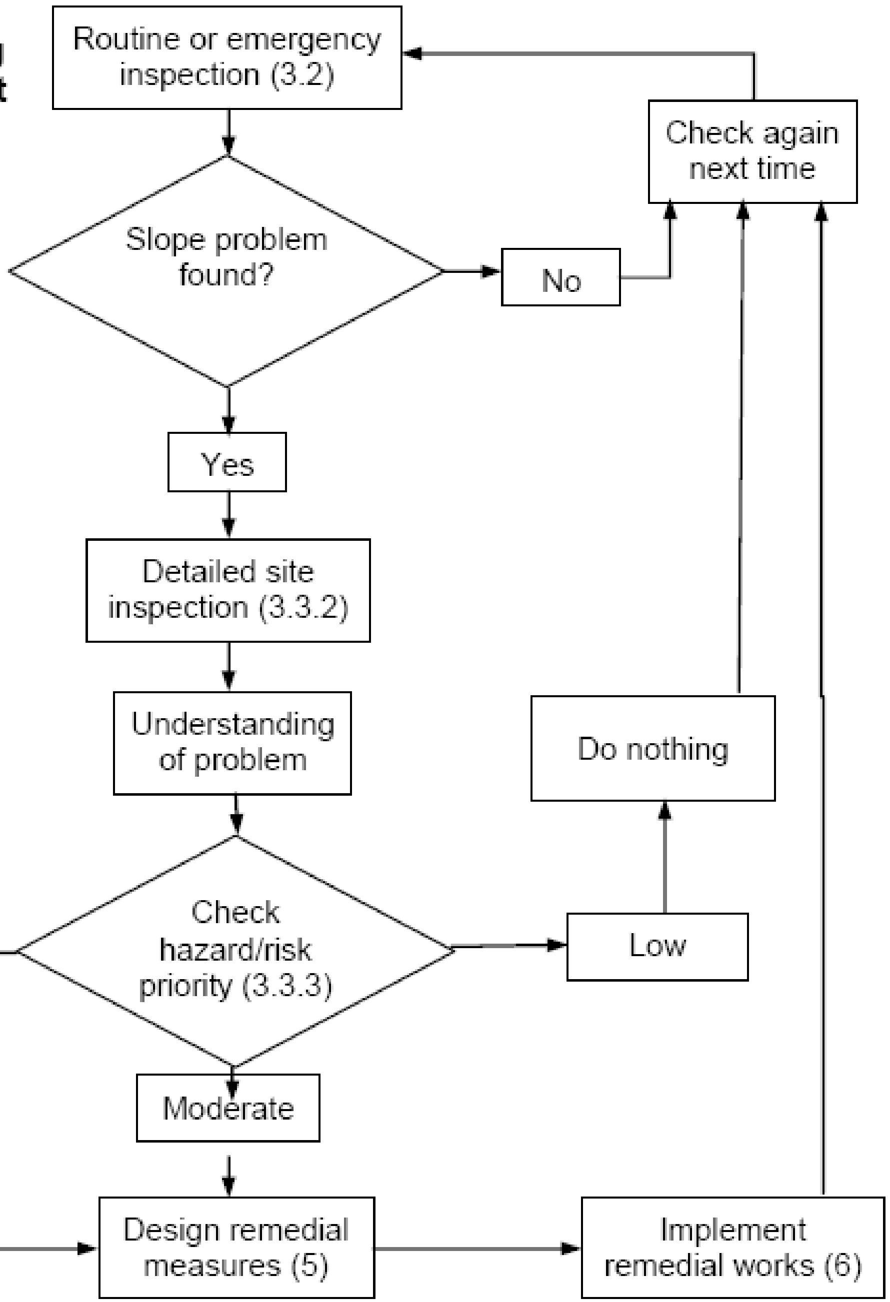
Circular failure in overburden soil, waste rock or heavily fractured rock with no identifiable structural pattern

Instability in walls



Site Assessment

Figure 3-1: Decision-making process for site assessment and problem diagnosis



Prioritisation by hazard and risk

Actual or expected consequences	Risk ranking 1	2	3	4	5
Road completely lost (or road subsidence greater than 1m) or occupied buildings damaged or destroyed	✓				
Road partially lost		✓			
Road completely blocked		✓			
Road subsidence less that 1 metre		✓			
Road partially blocked			✓		
Productive agricultural or forest land lost or destroyed				✓	
Walls damaged or slope drainage blocked or damaged				✓	
Roadside drainage damaged or blocked					✓
Continued erosion without destroying vegetation cover					✓

Ranking and priority

1. Top priority, emergency measures required immediately; buildings may need to be evacuated.
2. High priority; realignment may be necessary.
3. Moderate priority, but some temporary remedial measures are required immediately, such as slip debris clearance, emergency road signing etc.
4. Low priority, but some actions are required quickly, such as slip debris clearance.
5. Least priority, but should be tackled as soon as possible under routine maintenance.

Hazard ranking	Soil/highly weathered rock or colluvial slope		Rock slope, fresh to moderately weathered		Wall
	Height (m)	Angle (deg)	Height (m)	Angle (deg)	Height (m)
High	> 15	> 35	> 12	> 70	> 8
Moderate	5-15	25-35	7-12	50-70	3-8
Low	< 5	< 25	< 7	< 50	< 3

Notes: For slopes, use height or angle to derive highest category
Table based on average conditions

Determination of treatment

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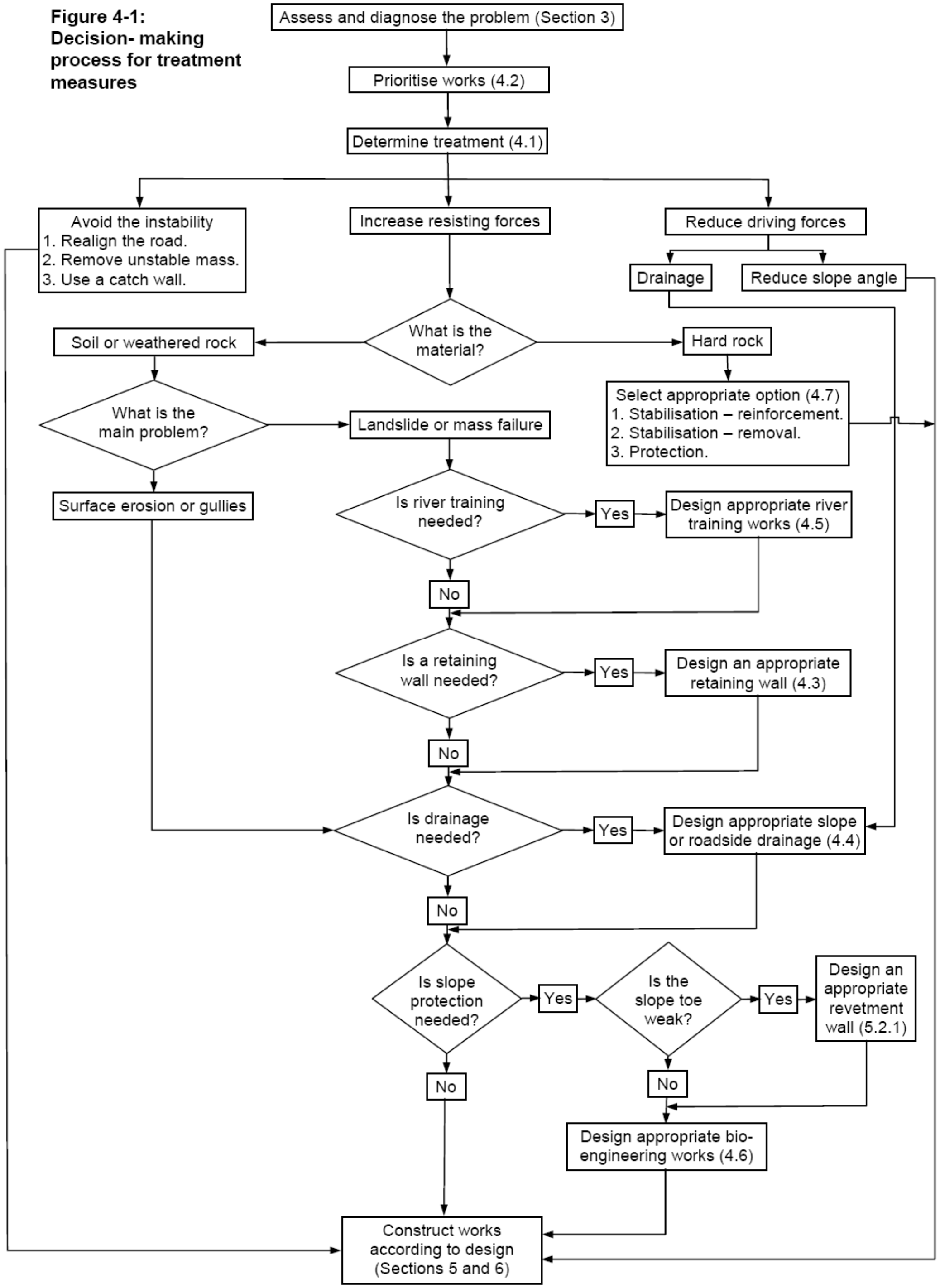
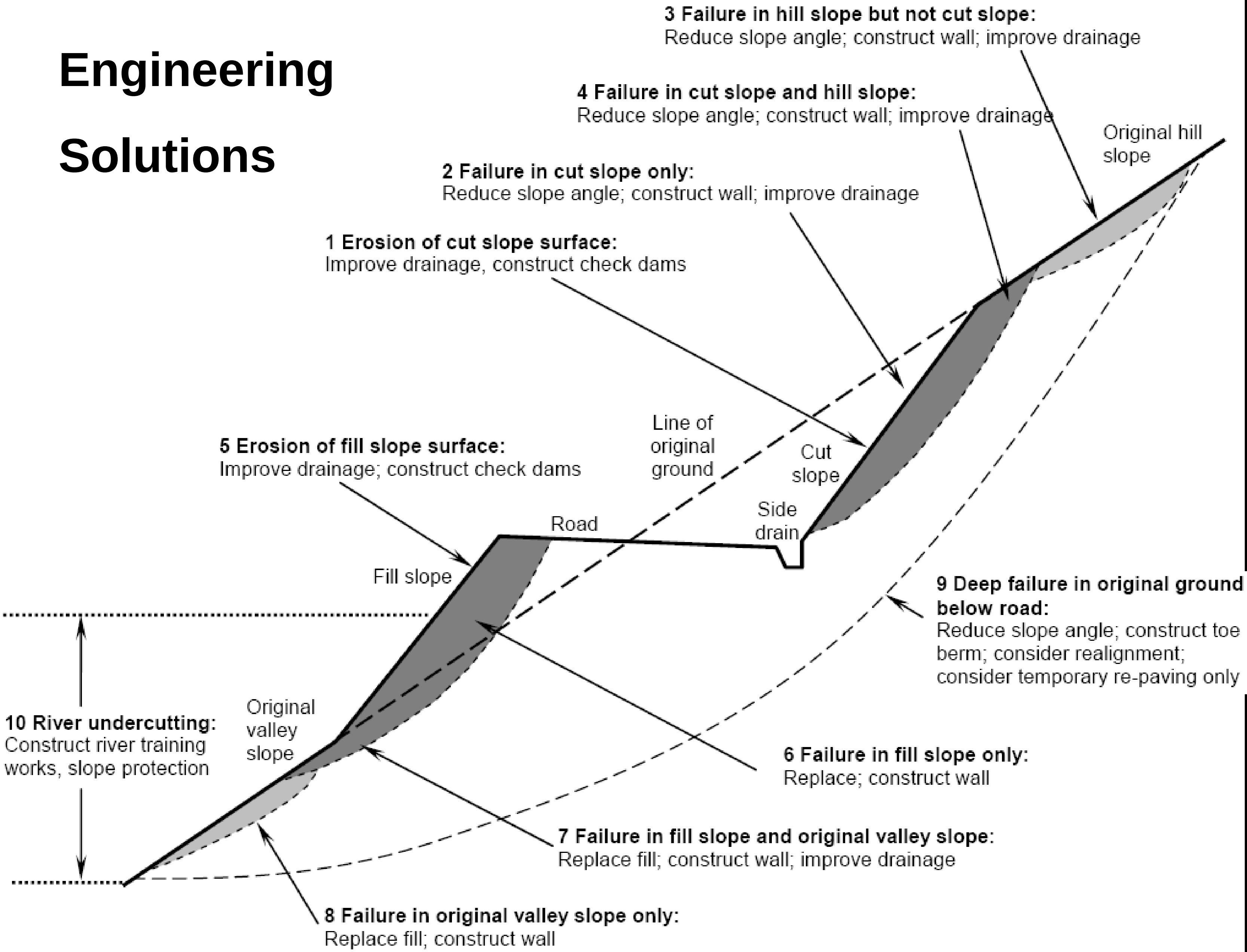


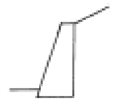
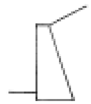
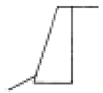
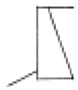
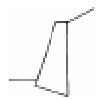
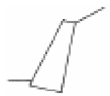
Figure 4-1: Decision- making process for treatment measures

Engineering Solutions



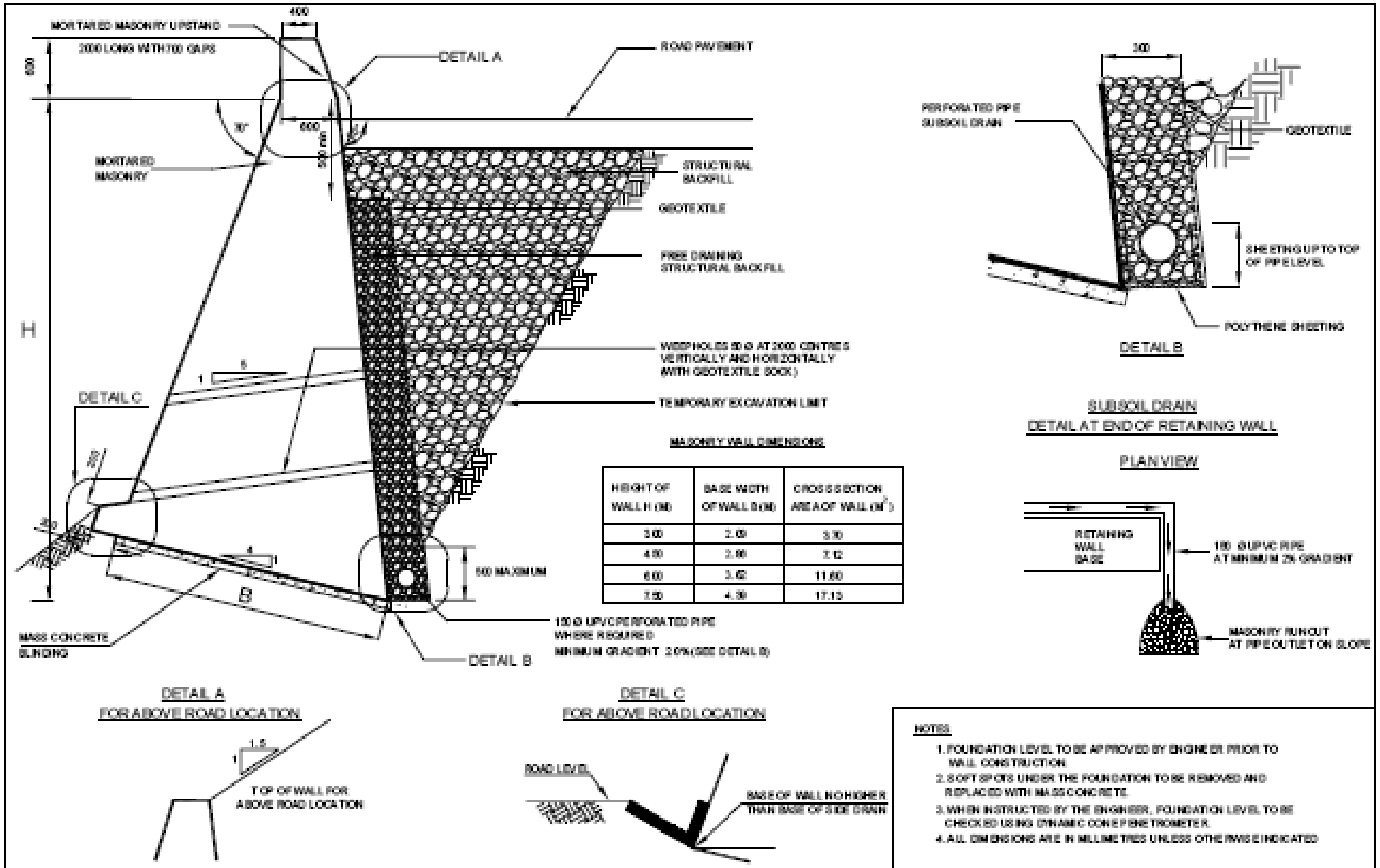
Designs are discussed for:

- Walls
  - Composite masonry
  - Mortared masonry
  - Gabion
  - Other types
- Revetments
- Catch walls
- Bio-engineering

Shape and location	Advantages	Disadvantages
	Lower toe pressure, greater resistance to overturning	Greater wall height for a fixed retained slope angle
	Smaller wall height for fixed retained slope angle	Lower resistance to overturning, higher toe pressure
	Lower toe pressure, greater resistance to overturning	Greater wall height for fixed height of retained soil
	Smaller wall height for fixed height of retained soil	Higher toe pressure, greater extent of excavation into road – more disruption to traffic
	Greater resistance to sliding	Shape not suitable for gabion construction, increased volume of excavation, positive drainage required at heel to prevent ponding and foundation softening.
	Greater resistance to sliding and overturning, ground bearing pressures evened out	Tilted shape more difficult to construct in gabion, increased volume of excavation, compaction behind wall more difficult, positive drainage required at heel to prevent ponding and foundation softening

Example: gravity wall design options

Typical details: Masonry Retaining Wall



HEIGHT OF WALL H (M)	BASE WIDTH OF WALL B (M)	CROSS SECTION AREA OF WALL (M^2)
3.00	2.09	3.70
4.00	2.88	7.12
6.00	3.62	11.60
7.50	4.30	17.13

NOTES

1. FOUNDATION LEVEL TO BE APPROVED BY ENGINEER PRIOR TO WALL CONSTRUCTION.
2. SOFT SPOTS UNDER THE FOUNDATION TO BE REMOVED AND REPLACED WITH MASS CONCRETE.
3. WHEN INSTRUCTED BY THE ENGINEER, FOUNDATION LEVEL TO BE CHECKED USING DYNAMIC CONE PENETROMETER.
4. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE INDICATED

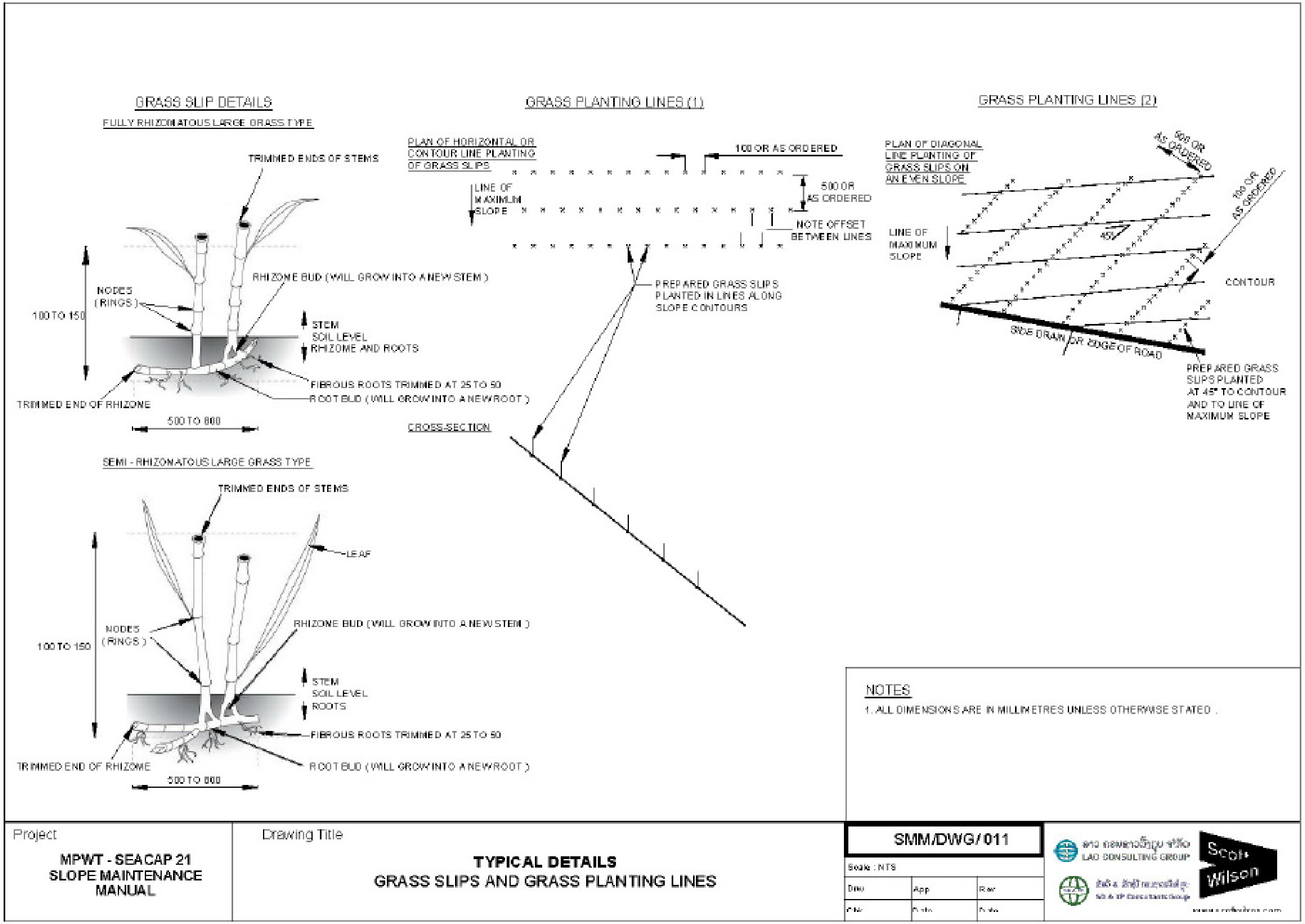
Project: MPWT - SEACAP 21 SLOPE MAINTENANCE MANUAL

Drawing Title: TYPICAL DETAILS MORTARED MASONRY RETAINING WALL

SMM/DWG/ 001

Scale : NTS

Typical details: Grass Planting




ບູລະນະຮັກສາທາງຫຼວງແມ່ນຮັກຊາດ
Love your Nation, Maintain the Roads

Further Information

The following dissemination forums support Low Traffic Volume Rural Roads (LVRR) knowledge in the REAAA region:

gTKP **global Transport Knowledge Partnership:**

www.gtkp.com

SEACAP **Southeast Asia Community Access Partnership**:
www.seacap-info.org