Structures 19 to 22 lie between ~18m and ~32m from the R46 road edge. Crash barriers along the road prevent access from the R46 to these structures. Instead, towers will be accessed from an existing track off the R46 near structure 23 and via newly constructed access roads along the servitude. Figure 4-9 indicates towers 21 and 22 proximity to the road edge.

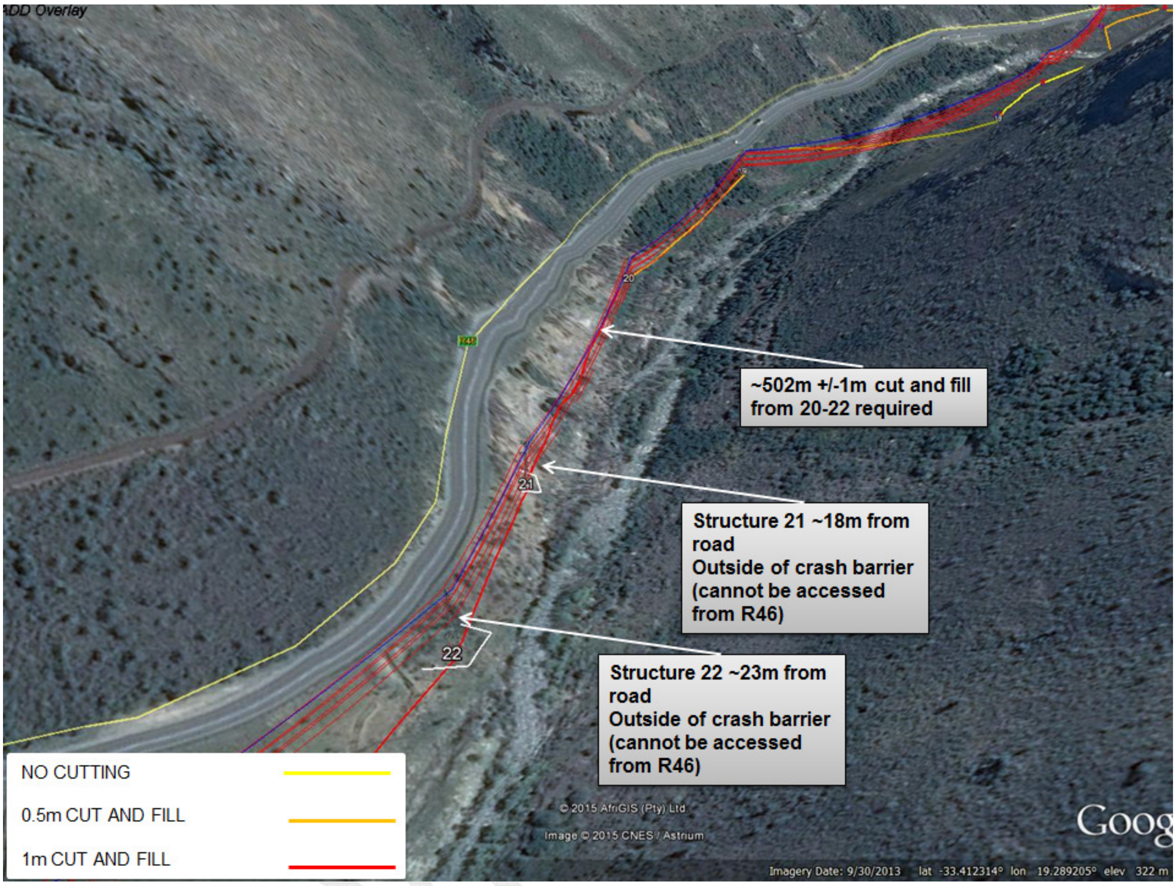


Figure 4-9: Example of towers in close proximity to the road edge

Towers 24 to 31 will be accessed via a new access road starting from the existing road between structure 32 and 31. See Figure 4-11. A substantial amount of cut and fill will be required to access structures positioned between these two structures. Towers here are located where steep side slope exist and tower footing protection is a further requirement at most tower positions.

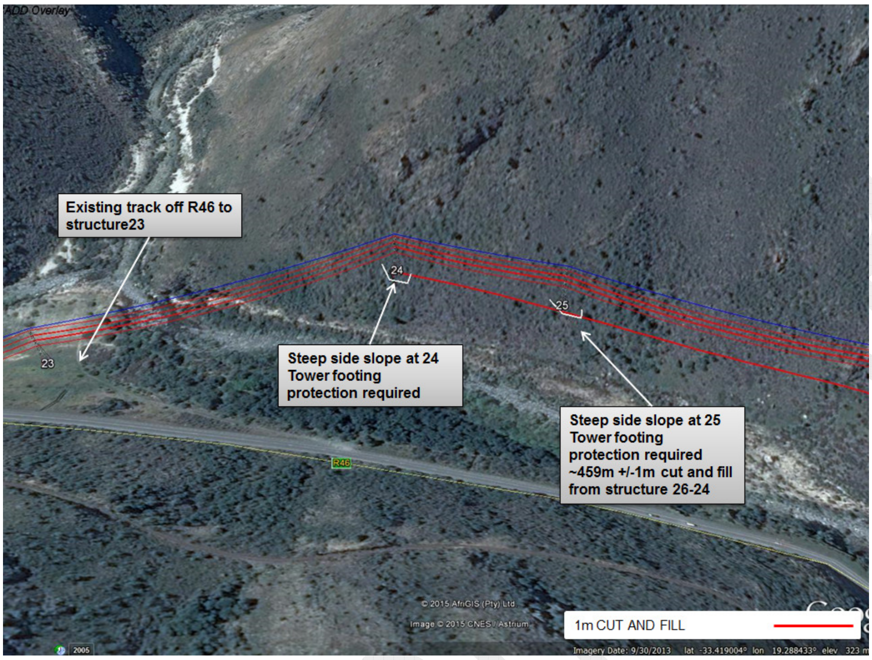


Figure 4-10: Cut and fill required to access towers 24 and 25

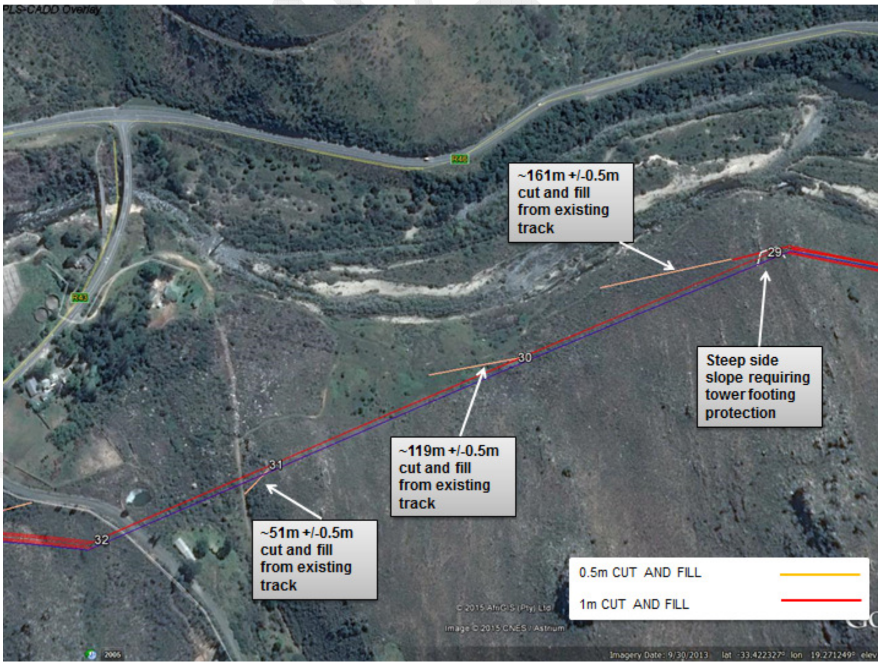


Figure 4-11: New access created off existing road near tower 32

Where existing farm or jeep tracks are available, cut and fill access creation off these dirt roads has been specified to tower positions. This is relevant for towers 30 to 39 on this route.

Lastly, as this route does not traverse as many farms as the mountain pass route, a fewer gates have been specified.

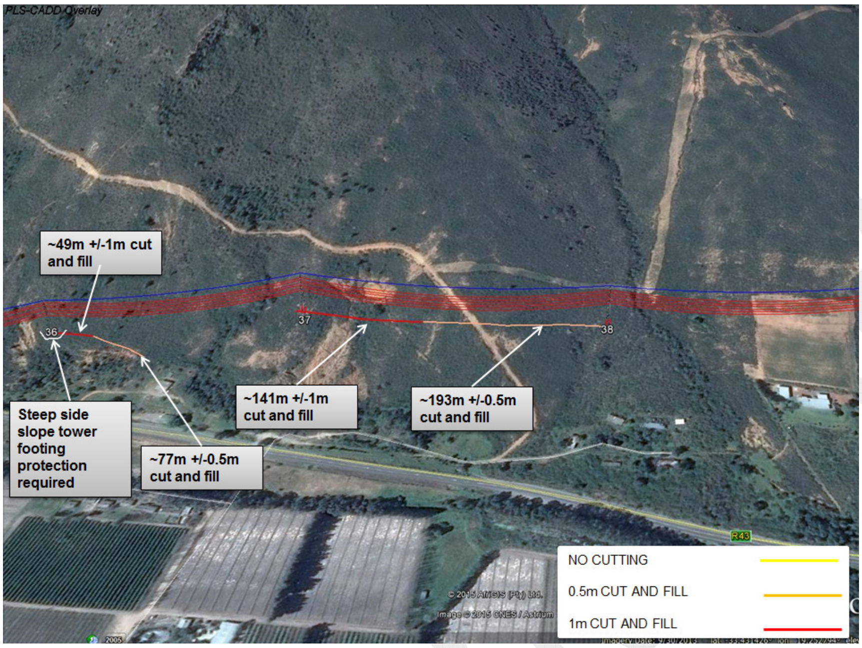


Figure 4-12: Example of cut and fill off existing dirt road for access

5 Conclusion

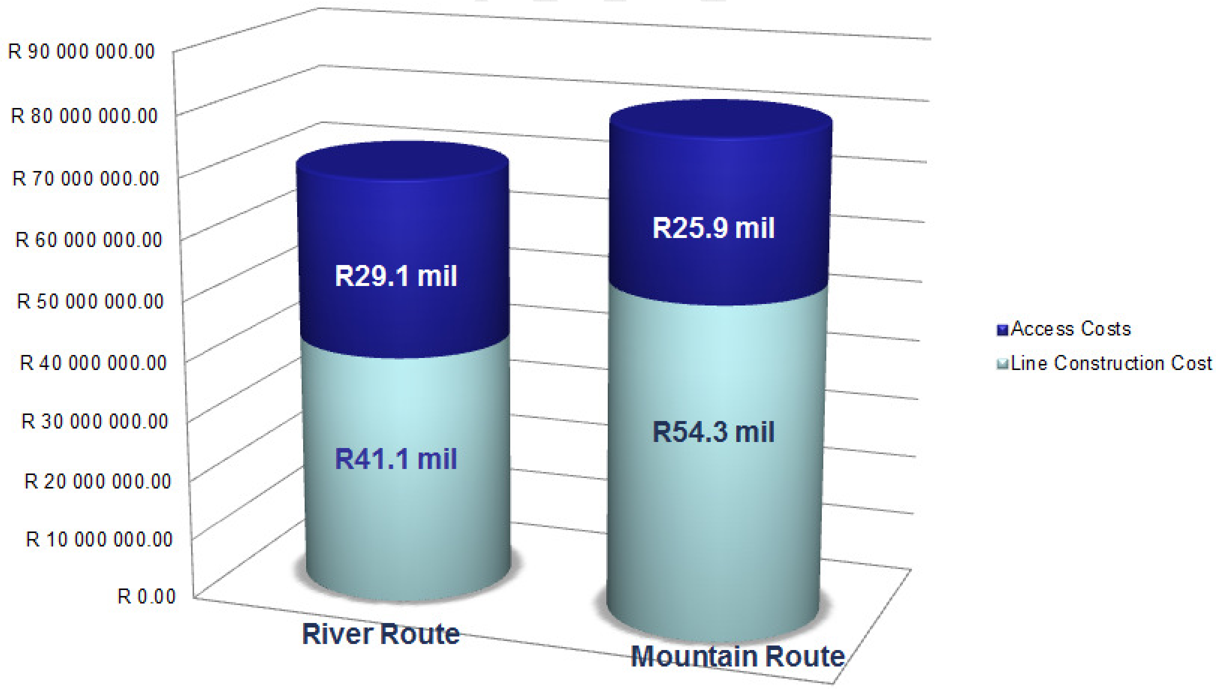
Based on the analysis both routes are feasible but do offer unique considerations for each option.

The number of towers required for each line is almost identical. The mountain route however, requires several more 247 strain structures, as long spans and heavy weight spans need to be supported. In addition, a number of tall structures with maximum leg extensions are required to manage side slope as the line traverses the mountain. The towers and associated foundations are heavier , which can be seen in the almost R 13 million capital cost increase when compared to the river route costing.

The river route is shorter and requires shorter structures than the mountain pass route. However, the practicality of building in the river route corridor is of concern.

The time of year of construction is crucial, as river crossings may pose more of a challenge during rainy months. In addition, traffic control, congestion and safety concerns related to building in close proximity to both road and rail is a large factor to consider. The relevant permits and authorisation for this as well as water use licences for the placement of structures within/in close proximity to flood line areas and water buffer zones will be required.

The overall estimated cost comparison for both route options is given in the graph below.



6 Reference Standards

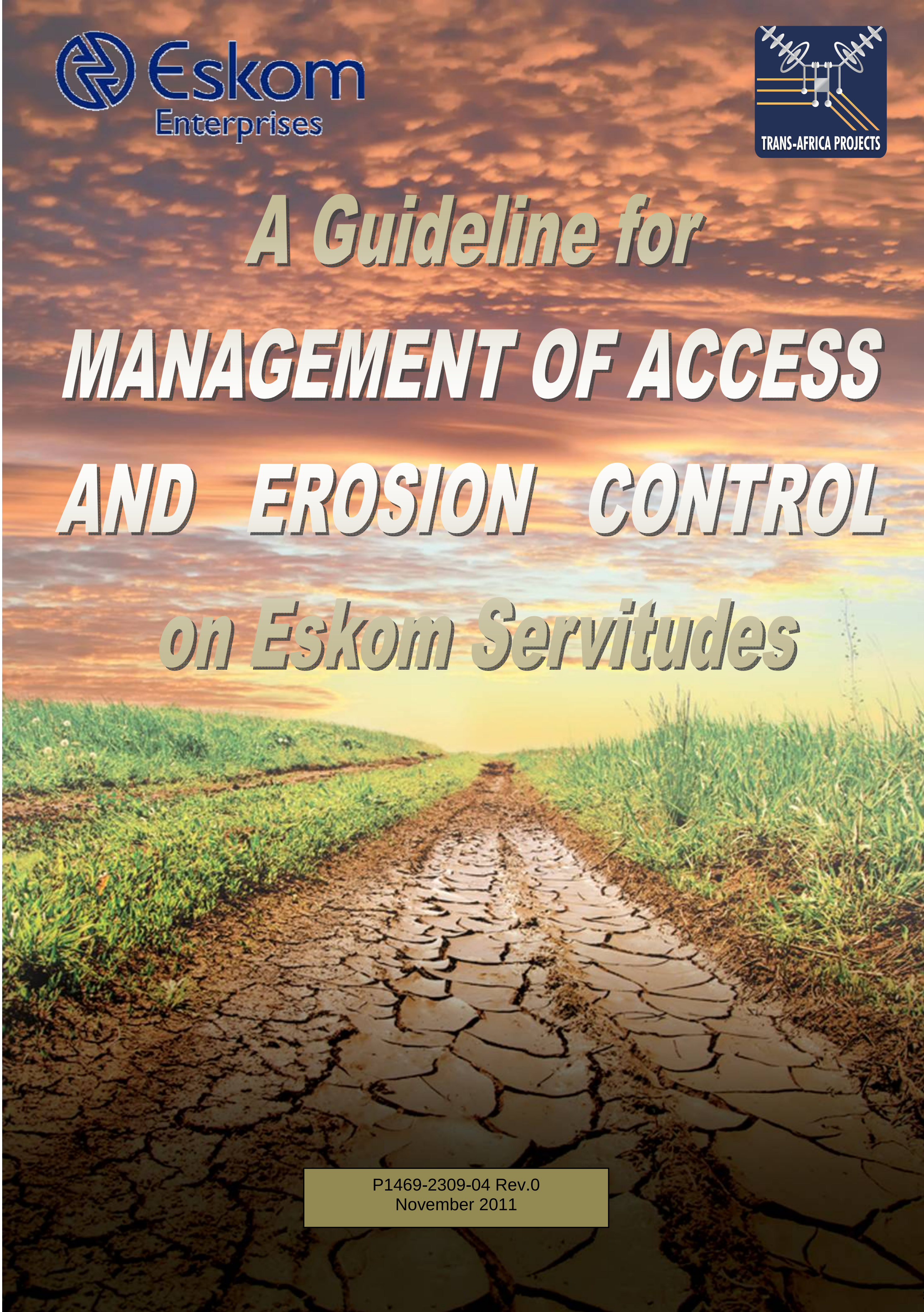
Standard number	Revision No	Title
P1469-2309-04	0	A Guideline for Management of Access and Erosion Control on Eskom Servitudes

7 References

(1) TAPGREOL Rev. 1 ACCESS AND GROUND EROSION PROTECTION DURING OVERHEAD LINE CONSTRUCTION

(2) By Mr W. Mashiloane, SOIL CONSERVATION PROJECTS IN RURAL COMMUNITIES, http://www.dfac.mil.za/

APPENDIX A: EROSION CONTROL GUIDELINE



A Guideline for MANAGEMENT OF ACCESS AND EROSION CONTROL on Eskom Servitudes

Eskom Enterprises

TRANS-AFRICA PROJECTS

P1469-2309-04 Rev.0
November 2011

A Guideline for MANAGEMENT OF ACCESS AND EROSION CONTROL on Eskom Servitudes

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P1469-2309-04	0	30 November 2011

Table of Contents

1 INTRODUCTION

South Africa falls within the relatively little known "Third Major Soil Region" of the world. This implies that soil patterns are completely different from those of the developed countries at the high latitudes in the northern hemisphere and also different from the deep, highly weathered soils of the humid tropics. Most of our soil has been classified as "very degraded" (see soil degradation map of the world - Figure 1). South Africa is also dominated by very shallow soils due to hard rock parent materials. Low, inefficient rainfall seriously limits soil formation. All this contributes to the fact that most South African soils are extremely vulnerable to various forms of degradation and have low recovery potential, thus small mistakes in land use planning and land management can be devastating with little chance of recovery.

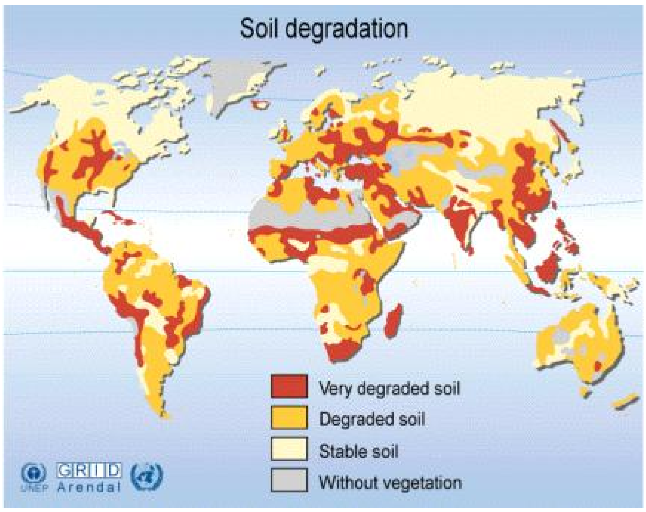

Figure 1: The GLASOD estimate of global land degradation: note that this includes all forms of soil degradation, not just erosion. From UNEP-GRID [29]

Within the Eskom servitude environment the results of soil degradation is very real and active. Not all soil erosion is caused by Eskom's intervention of building power lines, but the initial building of access routes during construction of these power lines as well as post construction activities along the line and the lack of maintaining access routes or patrol roads, is of major concern.

During the construction phase of a power line, the impact of vegetation clearing and the formation of roads for larger vehicles probably has the most profound effect on soil structure, resulting in potential for erosion. This eventually impedes inspection and maintenance as servitude access roads become degraded. Alternative routes are then created which increases the potential for further erosion.

Eskom servitude roads run through private land, conservation areas, environmentally sensitive areas and inaccessible areas (eg. mountains and marshes). Where servitude roads are well maintained, they will typically be used by both Eskom and the landowner. However, the converse has often undermined landowner relationships and even attempts to restrict Eskom's right to access.

Lastly, failure to control erosion has often jeopardised the stability of tower foundations, as confirmed in on-going erosion rehabilitation and other tower foundation stabilization programs.

2 OVERVIEW

2.1 Scope

The objective of this guideline is to assist soil conservation rehabilitation through a generic procedure to identify, manage and outline the processes to address soil erosion within the Eskom servitude. Erosion risks applicable to the towers will also be discussed.

The scope will apply to Eskom servitude roads and power line structures within the business units which are subjected to soil erosion. This guideline was formulated for Transmission Servitudes, however the principles may be equally applicable to Distribution lines.

This guideline will address soil erosion caused by water flow specifically and not any other forms of erosion i.e. wind erosion.

Although this document is aimed at the management of existing servitudes after construction, the systems prescribed may well be relevant during the construction phase of the overhead line. It is often the temporary nature of servitude accesses created during construction and the resultant erosion that translate in increased cost to Eskom during the operation of the overhead line.

In the light of responsibilities outlined in the following section, the lines and servitudes manager who accepts newly constructed lines may well require that appropriate erosion control measures are in place at the time of handover, and the contents of this guideline thus have relevance as a basis for handover inspections.

2.2 Responsibilities

Eskom has a legal obligation to prevent its operations from causing soil erosion. This is supported by a variety of legislation, including (but not limited to): The Conservation of Agricultural Resources Act of 1983, the National Environmental Management Act of 1998 the Soil Conservation Act of 1969, the Conservation of Agricultural Resources Act of 1983 and the Environment Conservation Act of 1989, the National Water Act (Act 36 of 1998).

At the operational level, the responsibility to manage soil erosion within the Eskom servitude vests with the Lines and Servitude Manager of the specific region, who would typically delegate the investigation and maintenance of the servitude to the relevant project managers and supervisors.

3 NORMATIVE REFERENCES

During construction, existing processes and procedures within the Eskom Environmental Management System and approved Operation Environmental Management Plan must be acknowledged and followed outside of this guideline.

Design specifications for structures mentioned in Section 6 will have to be formulated and executed in accordance with the requirements of the specific site, although virtually all structures do have basic construction standards to be effective.

The following publications should be read when designing these structures:

TRMSCAAC1 Rev 3 – Eskom Specification - Transmission Line Towers and Line Construction

SANS 1200 DK - Gabions and Pitching

SANS 1200 DM - Earthworks (roads, subgrade)

EIC/385 - Eskom Specifications, Environmental Impact Control

ESKPVAAZ1 - Eskom Specification, Environmental Impact Management Program

TST41-213 Eskom Transmission Procedure, Environmental Aspects and Management

The above list should not be regarded as exhaustive and further normative references may be required by Eskom.

4 DEFINITIONS

Access route:

A route or road within the servitude or a road leading to a servitude or power line. Access roads may also be jointly used by the Landowner.

Berm:

A built area constructed across in a road to divert water flow off roads in sloping terrain.

Cellular Confinement Systems:

Rigid, thick-walled geocell systems to facilitate stream crossings

Diversion Channel:

A recessed area constructed across in a road to divert water flow off roads in sloping terrain, typically used in steeper accesses where berms are not suitable.

Gabion:

A block shaped stone structure contained in a wired mesh basket, typically used as a retaining wall or weir.

Geocell system:

A mattress of expanded open cells, typically constructed of welded plastic strips, and filled with seeded soil, gravel, graded stone, or concrete.

Geotextile:

A knitted or woven geofabric polymer material, which is designed to allow the passage of water and fine particles, while retaining larger soil particles.

Reno Mattress:

A stone structure contained in a wired mesh basket, typically flatter and wider than gabion baskets, typically used to protect against water erosion at the foot of a weir, or as a drift crossing over small streams.

Servitude:

The area under a power line used by Eskom to conduct line patrols and maintenance activities. Under a servitude agreement, Eskom do not own the land but have the right of access for the purpose of maintenance.

Rip-rap:

Rock that is laid against a slope as erosion protection, commonly against a geofabric layer.

Stone Pitching:

Rock that is laid against the slope and set into place with mortar to produce a hard wearing impervious surface.

Silt fence:

A structure ideal for smaller eroded areas allowing a maximum of 500mm of soil can be built up.

Weir:

A structure that slows down the flow of water, creating a pond and encourages the building up of sediment encouraging vegetation to grow.

5 GENERAL PRINCIPLES

The basic general principle of managing soil erosion is to identify the source formation of the soil erosion in advance, and to react as soon as possible according to the measures that are needed for that particular problem. A blanket solution cannot be applied and must be specific to the problem.

Soil erosion is controlled and reversed effectively by the following methods:

- Diverting water away from sensitive areas (roads and tower sites) by means of berms, channels and drains
- Facilitating the growth of natural vegetation, by protection of topsoil and silt, by retaining systems, and seeding
- Reducing the speed of run-off by dissipating energy or diverting water flow along gentler slopes, for eg by the construction of stepped water-courses

The methods suggested in this guideline have been selected based on established control methods that offer medium to long term protection with low maintenance.

5.1 Unsuitable Soil Erosion Control Methods

A number of soil erosion methods and structures that have been suggested by official bodies (for example the Department of Agriculture) may not be suitable for Eskom, since these methods are aimed at the prevention and control of erosion by landowners. Such structures may be temporary, low cost structures and / or require frequent maintenance or utilise unsuitable material. These erosion structures include:

- Use of vehicle tyres, insulator strings or other waste material (Figure 2)
- Use of biodegradable material, including braches or straw bales

Figure 2: Use of waste material in erosion structures is not recommended [32]

In addition, incorrect construction or incorrect application of erosion control systems may also constitute unsuitable methods. For example, unprotected pipes over a stream crossing will present an impassable obstacle if the approaches are washed away.

There are a multitude of erosion control systems and products which have been considered, but not included in this guide. These include eco-logs, erosion blankets, turf reinforcement mats, soil reclamation rolls (SRR), seeded coir mats and various interlocking block systems. These systems may provide sufficient erosion protection, however, have not been included due to cost, and negative experience in application. For example, gabion baskets are generally preferred over interlocking block retaining walls, as gabions are able to re-settle into voids without failing.

5.2 Assessment of Execution of Erosion Controls

After an erosion concern has been highlighted by Eskom, an assessment is typically conducted, in order to quantify the extent of -, and to remedy the problem. The scope for an assessment and execution should include the following outputs:

A: Investigation Stage:

- Extent of erosion
- Underlying causes
- Suggested appropriate erosion control systems
- Estimated project budget

B: Execution Stage:

- Contract Documentation
    - Contract Data
    - Bill of Quantities
    - Works Information
    - Site Information
- Detail designs,
- Supporting specifications

The scope will address specific soil erosion prevention structures. These structures are of such a nature that it can be utilized almost in any situation. Dimensions and specific designs will need to be developed according to the actual terrain conditions.

6 SOIL EROSION STRUCTURES

6.1 Access Roads

Servitude access roads are typically designed for very low and infrequent traffic volumes, and therefore conventional road design and construction techniques do not apply, as the associated cost would be prohibitive.

At commissioning and handover stage the custodian of the line should insist on a reasonable access to the line where practical, based on the following principles.

6.1.1 Basic Access Philosophy During Construction

Conventional road construction, involving the laying of sub-bases and wearing courses is avoided as far as practicable. The following, progressively more expensive guidelines will apply in traversing progressively more difficult terrain:

1. The preferred access route will follow a "least impact" course along the line within the servitude boundary.
2. As per TRMSCAAC1 Rev.3, maximum use of existing roads and tracks should be made, as far as practicable, and the condition of private roads recorded prior to use by the Contractor's Environmental officer.
3. Where this is not possible due to potential erosion risks, environmental concerns, or landowner restrictions, access to each tower or series of towers should follow a "least impact" course from the closest practical location.
4. All such roads should be aligned as far as possible to avoid the need for any "cut or fill" to the existing ground level.
5. Where the least impact route traverses terrain with a side slope of more than 8.5^o (0,45m over 3m or 1:6.5) road construction requiring cut & fill may be undertaken. This guideline may be adjusted where it can be demonstrated that a potentially unsafe access route or increased erosion could result.
6. Where it is not deemed practical or desirable to construct any roads, access by a suitable footpath can be made to ensure safe passage on foot. Preferably, vehicular access to within 200m to such "inaccessible" tower sites should be made to allow concrete to be pumped to site. In such cases, maximum use of hand excavation and erection can be pursued.
7. Where the above methods are not possible, helicopter assisted construction techniques could be considered. This is the least favoured construction access option from a cost perspective.

Where roads requiring cut or fill have been constructed, these should not be closed after construction, unless precluded by environmental, erosion or landowner restrictions. Rehabilitation and fortification of erosion protection on such roads must be completed at the completion of construction.

The installation requirements for berms may be relaxed during the construction period to facilitate easier access to tower positions, provided that a moderate erosion potential has been verified by the Environmental officer.

Roads should be planned according to principles of water runoff and should ideally be positioned on a watershed or ridge, and along contours. The overall slope of a road should not exceed 7% and may over short distances be increased but should never exceed 18%. Sensitive soils may cause a change in route.

As per TRMSCAAC1 Rev.3, all access routes are to be flagged to enable visitors and suppliers to reach specific tower locations on the accepted access route.

The following structures are mainly suggested to prevent general erosion conditions within the servitude

6.1.2 Water Diversion Berms - Positioning and Construction:

Description:

A berm serves as a structure to divert water away from the road surface and reduces the speed and erosion potential of surface run-off. It is built perpendicular to, or diagonally across the road. Berms are constructed with compacted, imported or local soil (depending availability), and consist of approximately 2m³ of soil.

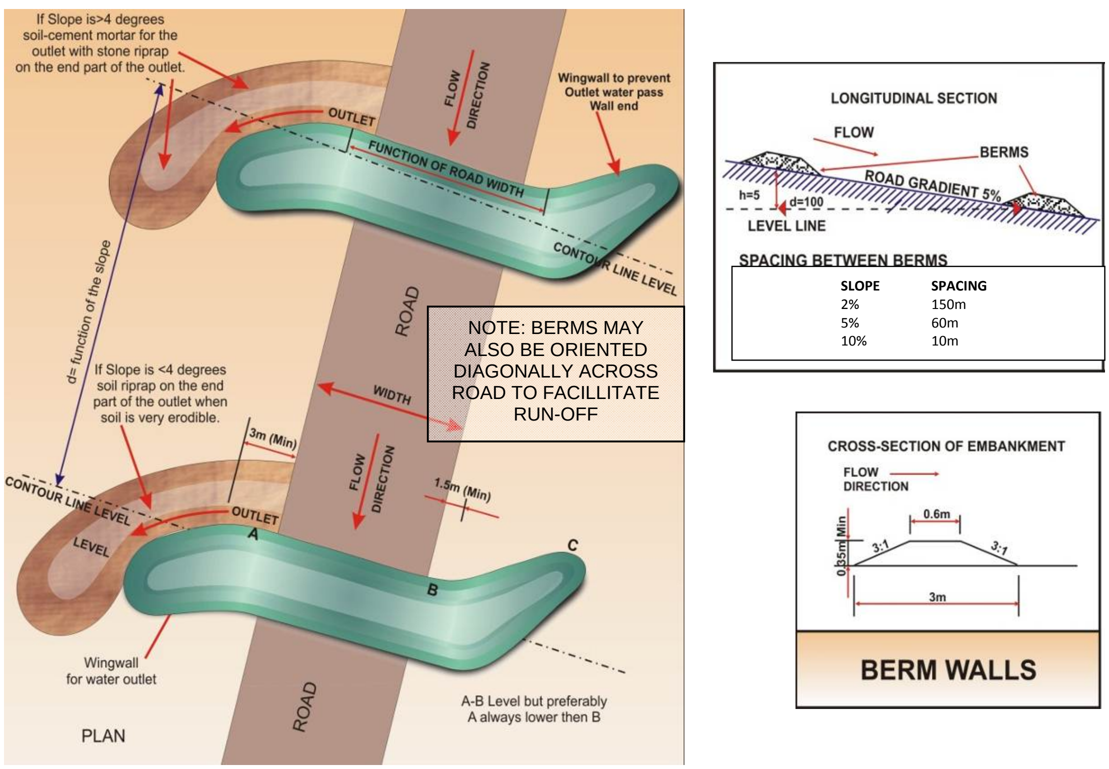

Figure 3: Water diversion berm [17]

Application:

Berms are to be constructed with the primary purpose of preventing erosion of access roads, however the profile of the berm is to be shaped with due consideration to the resulting ride quality of the access track.

The contractor may elect to delay the construction of berms to the end of the contract in areas where a moderate erosion potential exists, provided that erosion developing along the access road during the construction activities shall be rehabilitated promptly, and that existing drainage systems shall not be blocked or altered in any way by construction activity.

A lower average berm spacing is suggested by this specification: Berms spacing (in meters) = 300m / Slope of the road (%). See Figure 3*.

In very flat areas with a low erosion potential, this implies that berms may not be required at all. The inclusion of erosion control measures and berm spacing may be adjusted as directed by the Employer's environmental officer.

Relevant notes:

In steeper sloping areas (typically where a 2 wheel drive vehicle requires diff lock), the berm may be stabilised and compacted with 1:8 cement soil mixture. For stabilisation to be effective, it is imperative to mix and moisten the stabilised soil before compacting the berm with a mechanical hand operated compacting roller. Failure to effect proper stabilisation as per the preceding method will result in the gradual disintegration of the berm. The use of diversion channels is however preferred over stabilised berms in steep access roads, due to the probability that stabilisation is commonly not executed properly.

6.1.3 Diversion Channels

Description:

Diversion channels are constructed with the main purpose to assist with the drainage of water away from the road surface in steeply sloping terrain, and are preferred over berms on steep roads, as they facilitate ride quality and result in more durable erosion control.

They may be constructed using stone pitching where natural material is available (Figure 4) or from 25 MPa concrete (Figure 5).

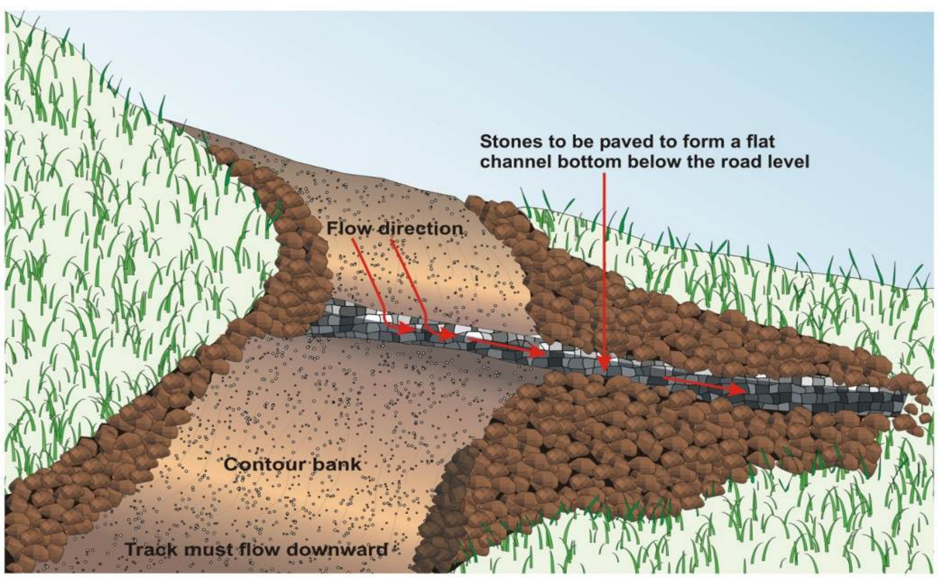

Figure 4: Diversion channel constructed with stone pitching, and flowing into rip-rap [17]

* Note that the suggested berm spacing here is in contradiction to TRMSCAAC1 Rev.3, which requires berms to be spaced at 10 to 50m. It is felt that this requirement is not appropriate in flat areas with a low erosion potential.

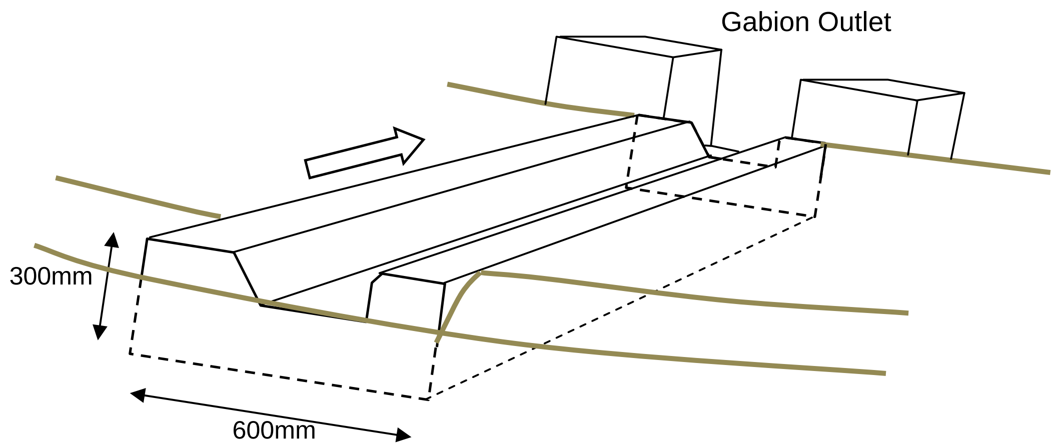

Figure 5: Concrete diversion channel with Gabion Outlet [17]

Application

This application is mainly for sloping terrain to divert storm water at various intervals on a down slope away from the road surface.

Relevant notes

The gradient of the road will predict the amount of outlet channels that will be required. Spacing is to be as per Figure 3.

6.1.4 Outlet Drains

Description:

A concrete, gabion, or stone pitched structure built to allow storm water to flow away from the road surface, without causing erosion of the road fill material or outflow area. (See Figure 6.)

The most common form of outlet would be a gabion basket structure.

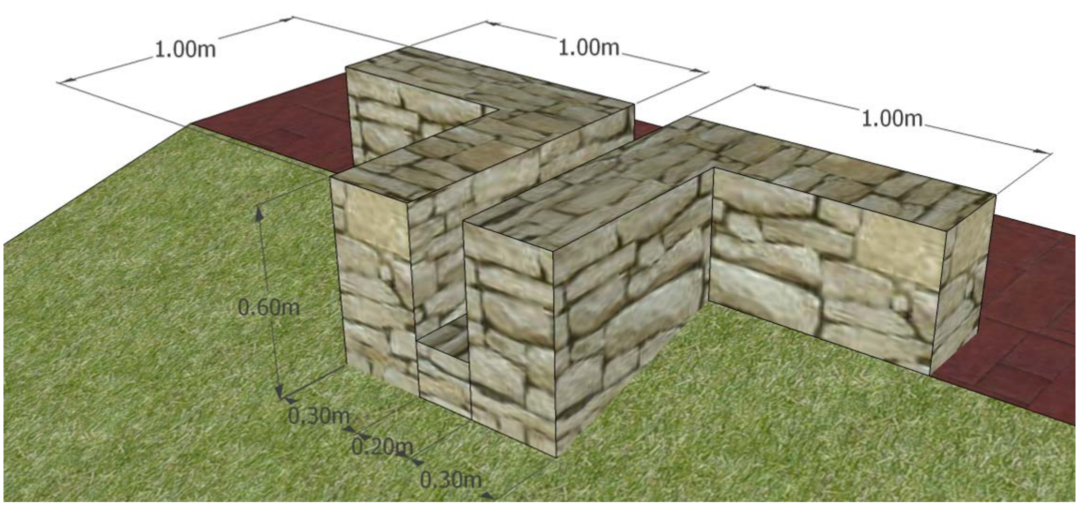

Figure 6: Gabion outlet drain [17]

Application:

Where there is a risk that water run-off from berms or channels in sloping roads could erode the fill material or outlet area, it is preferable to construct a protected outlet area with stone rip – rap. However, in steeper terrains, a gabion outlet drain may be specified, based on the erosion potential at the outlet.

Outlet drains will refer to positions where the road forms a dip, water then accumulates and floods the road surface causing the water to flow out at the shoulder of the road (or lowest point on road shoulder) causing eroding of the road shoulder.

Relevant notes:

These drains consist of 600mm high, 1m long and 600mm wide gabion walls with a reno mattress outlet. The gabions are set 300mm deep at the road surface. Measurements may be adjusted by the supervisor depending on the road condition. The downstream outlet channel may need to be extended or lined, depending on the slope.

6.1.5 Construction of new roads in sloping terrain

Description:

This process describes the construction of a road in a sloping terrain and emphasises the need for a cross fall towards the up slope side of the route. This prevents the erosion of less hardwearing fill material.

A diversion channel is then used to drain storm water at specific points where the water can be diverted away from the road.

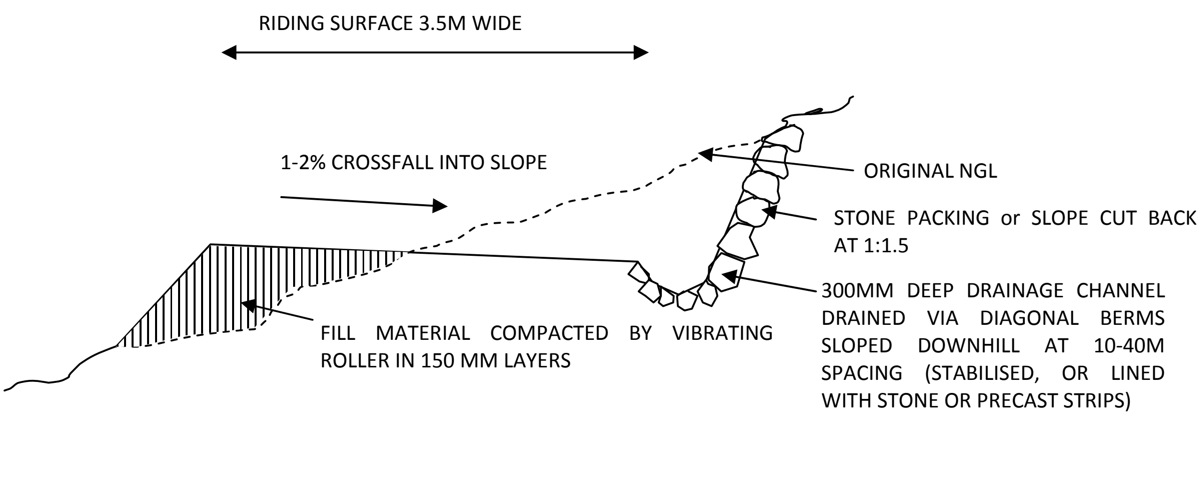

Figure 7: Sloping of road and construction of drainage channel [17]

Application:

This application is required for sloping terrain where cut and fill is required to access steep terrain.

Relevant notes:

The maximum riding surface width for newly constructed roads is 3.5m, provided that road widening may be required to enable passing of vehicles at appropriate intervals.
The cross fall slope of roads requiring cut to fill shall be 1-2%, against the natural ground slope to avoid erosion of filled material. Fill material must be compacted by vibrating roller in 150 mm layers.

Runoff is drained via a 300mm deep channel (See Figure 7) and directed off the riding surface at regular intervals via diagonal berms or channels sloped downhill at 10-40m spacing (lined with stone or concrete strips).

6.1.6 Concrete Strip Roads

Description:

A two track concreted surface with water diversion gutters for steep slippery surfaces, used mainly in mountainous areas. (See Figure 8.)

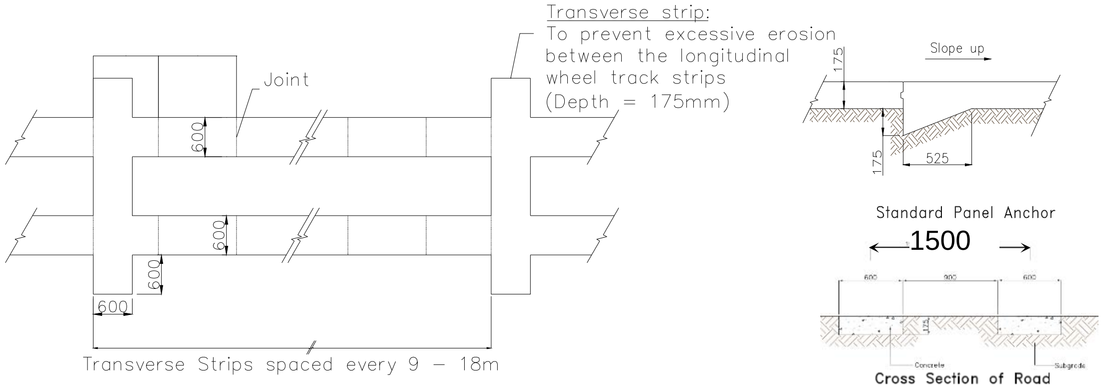

Figure 8: Concrete strip road [17].

Application:

The utilization of concrete strip roads as wheel tracks, are proposed for slippery, steep, lose sand or gravel surfaces. The construction of concrete strip roads is justified where its construction makes access possible with a 2 wheel drive LDV.

Relevant notes:

Strip roads are constructed on the steep sections of the access road only. Concrete strips will be cast 600mm wide and 900mm apart, centre to centre. Minimum thickness of the concrete will be 175mm.

Grooved joints are used where the strips are placed in a continuous operation in lengths considerably greater than 1.5m. Keyed joints are to be used in the so called alternate-panel method of construction, i.e. the first, third and fifth panels, etc. are placed on the first day, and the in-fill second, fourth and sixth panels on the second day, etc. Where continuous placing with grooved joints is interrupted for more than an hour, a keyed joint is required. Each strip must be divided into panels by transverse grooved or keyed joints. For very steep slopes it is preferable to use keyed joints.

The water content of the concrete must be reduced to prevent the concrete from flowing downhill during compaction. The target slump for strip road concrete is 60mm.

Panel anchor blocks must be incorporated in the construction of the concrete strips at bottom end of the slope

6.1.7 Precast Block Strip Roads

Description:

A structure mainly used in mountainous areas for steep sloped roads manufactured from concrete interlocking blocks attached to each other with wire that will ensure that the structure stays intact.

Various Proprietary systems are available,, such as Armorflex[†] or G8 EarthLOCK[‡] or Concrete Strip roads may be considered as equivalent structures.

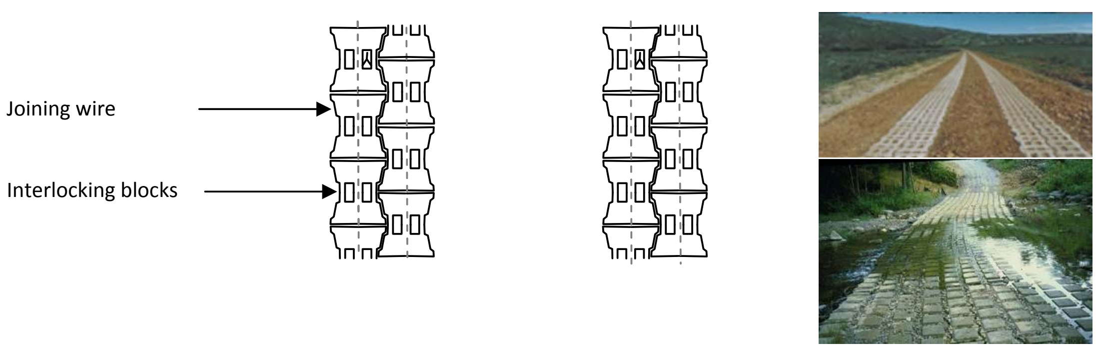

Figure 9: Precast units and completed roads [17] [19]

Application:

The precast type interlocking systems are recommended for steep sloped roads of up to 1:16 gradient, and may be used where concrete batching for strip roads is not practical. Precast roads covering the full road width as shown above may also be suitable for stream crossings.

Relevant notes:

Shorter lengths of road with a longitudinal slope of up to 1:16 may be constructed with precast blocks joined by wire. The blocks may be pinned to the subgrade with steel Y-standards at 5m intervals.

[†] Armorflex is a trade name of Technicrete, a Murray and Roberts company. Alternative products to Armorflex exist in the marketplace.
[‡] G8 EarthLOCK is manufactured by GreenLock under licence of Neat Contech

6.2 Water Crossings

Basic Philosophy:

Current legislation requires that permits are obtained in order to cross streams or where the stream banks or bed could be affected by the works. The construction of permanent stream crossings will only be undertaken where no alternative access to a tower position is possible, and only once appropriate permitting requirements have been met.

The construction of temporary accesses for the purposes of construction is subject to the Employer's environmental representative and environmental restrictions.

If access is across running water, precautions should be taken not to impede the natural flow of water.

The flood plains and banks of rivers and water courses upstream and downstream of crossings are environmentally sensitive areas which need to be protected from erosion.

6.2.1 Cutting through embankments

Description:

The correct method that should be followed when cutting through small water crossings or dry river beds is illustrated in Figure 10 below. The relevant permits are to be obtained prior to work commencing.

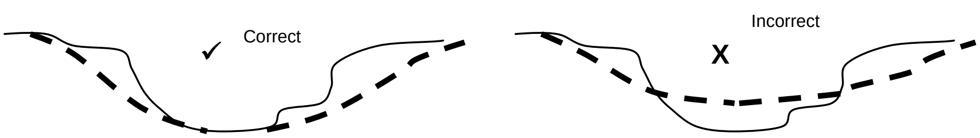

Figure 10: Correct and incorrect way of cutting through embankments [17].

Application:

Methods to cut through river banks or deep erosion ditches are needed to ensure access along the servitude in such a way that no further damage is done to the embankments of the river, stream or erosion gully.

Note that an alternative to the above method is to build up the stream bed in eroded areas, as indicated in Figure 17, but in such systems, sufficient protection is provided to retain soil and the use of rip-rap or graded stone is required to prevent the formation of marshy of muddy conditions at the crossing point.

Relevant notes:

When cutting through the embankments of watercourses and small rivers, the road cuttings should likewise be protected to prevent erosion from spreading in the direction of the servitude road.

No soil should be pushed into the watercourse, as this will impede the natural flow of water. Rather, the banks of the watercourse should be cut as illustrated in Figure 10. Watercourse crossings should be designed and maintained to withstand a 1 in 20 year flood.

6.2.2 Cellular Confinement Systems (CCS)

Description:

This system allows for temporary crossings through dry river beds, soft soils or Marsh land. It consists of a rigid walled geocell layer filled with subgrade material or graded stone. (See

Figure 11.)

Figure 11: Temporary dry river bed or march crossing [30,31]

Application:

Where sandy river beds, moderately marshy or soft soil areas are to be crossed which cannot support construction vehicles, a temporary crossing surface may be constructed.

This system will allow higher axle loads to be supported efficiently with a thin layer of subgrade. It is however not suited to areas with flowing water.

6.2.3 Drift Water Course Crossings

Description:

A crossing structure built with a reno mattress to will allow access through water streams and small shallow rivers. (See Figure 12.)

Application:

This structure will allow access through shallow watercourses or river beds.

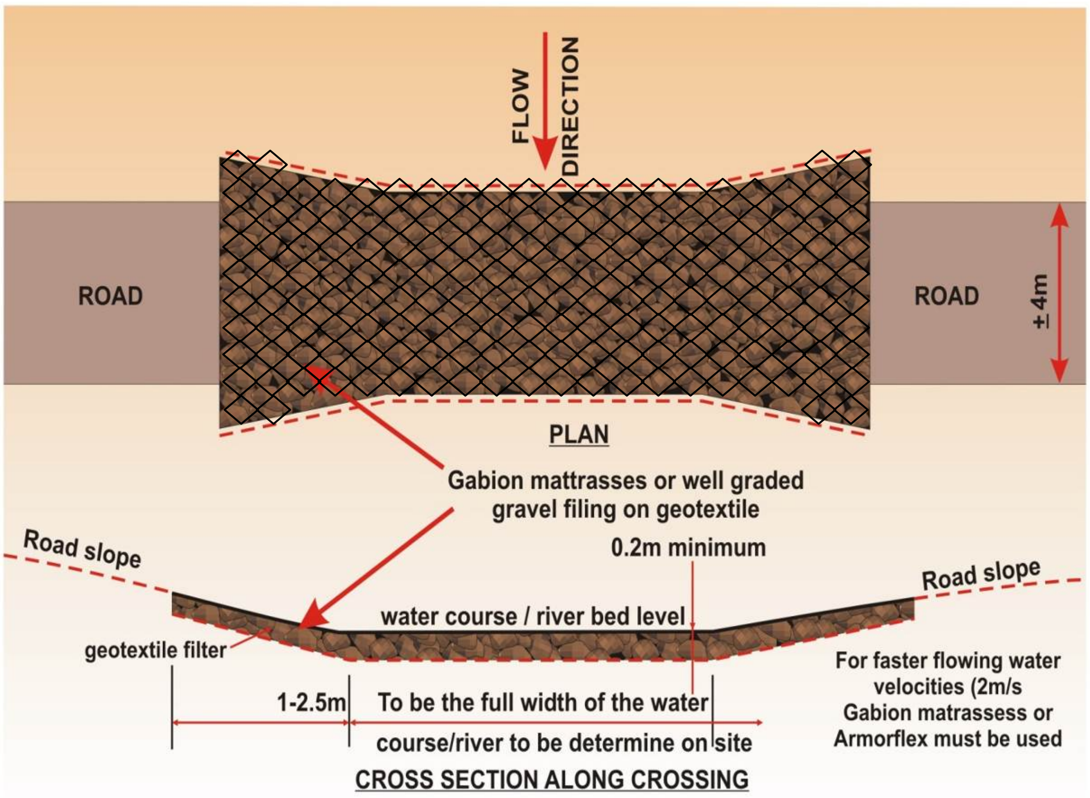

Figure 12: Reno Mattress drift crossing [17]

Figure 13: Reno Mattress drift crossing with concrete strips [32]

Relevant notes:

This structure is not suitable for perennial streams. The Construction of drifts must take cognisance of relevant permit requirements and must be aligned with stream bottoms as shown in Figure 10. Experience has shown that failure to execute this will result in the tilting or breakup of the drift.

Lining or filling the mattress with concrete strips corresponding with the vehicle tracks results in a more durable drift crossing as it protects the wire mesh from abrasion with every vehicle passage. (See Figure 13.)

Note that the use of metal in any structure exposed to extended periods of wetting will require additional corrosion protection. For this reason it is imperative to use gabion basket wire of suitable grade and galvanising.

Drifts may be constructed on Reno mattresses, as shown in Figure 12. For moderate traffic volumes, “Armorflex” type paving (illustrated in Figure 9) should be used. For faster flowing water velocities (>2m/s), low level bridge crossings are more suitable.

6.2.4 Concrete Filled Geocells

Description:

A concreted geocell system (also known as “Hyson Cells”) is a mat comprising square, hollow cells fabricated from thin plastic film. The mat may be equipped with integral laced rigging. Geocells are be filled with concrete to form an interlocking "cell slab" cast in situ. The hollow cell matrix acts as vast formwork. The formwork is sacrificial and is left embedded in the concrete to serve as jointing.

The "cell slab" may be likened to perfectly laid block paving with rounded keyway jointing.

However this flexible "cell slab" paving is not laid block by block but rather, it is laid in bulk by pouring ready-mix concrete into the Geocells formwork. (See Figure 14 and Figure 15.)

Figure 14: Geocells used with concrete (Hyson Cells [22])

Figure 15: Geocells used as an approach to a low level pipe crossing[13]

Application:

Geocells may be used to create a light duty road surface on stream crossing approaches, or where no natural rocky material is available. It may be more applicable during the construction phase of the line, when there is a supply of ready – mix concrete.

6.2.5 Low Level Bridge or Culvert Crossing (Pipes With Concrete Slabs)

Description:

This structure is constructed with a combination of stone, mortar, storm water pipes and gabion baskets. (See Figure 16.)

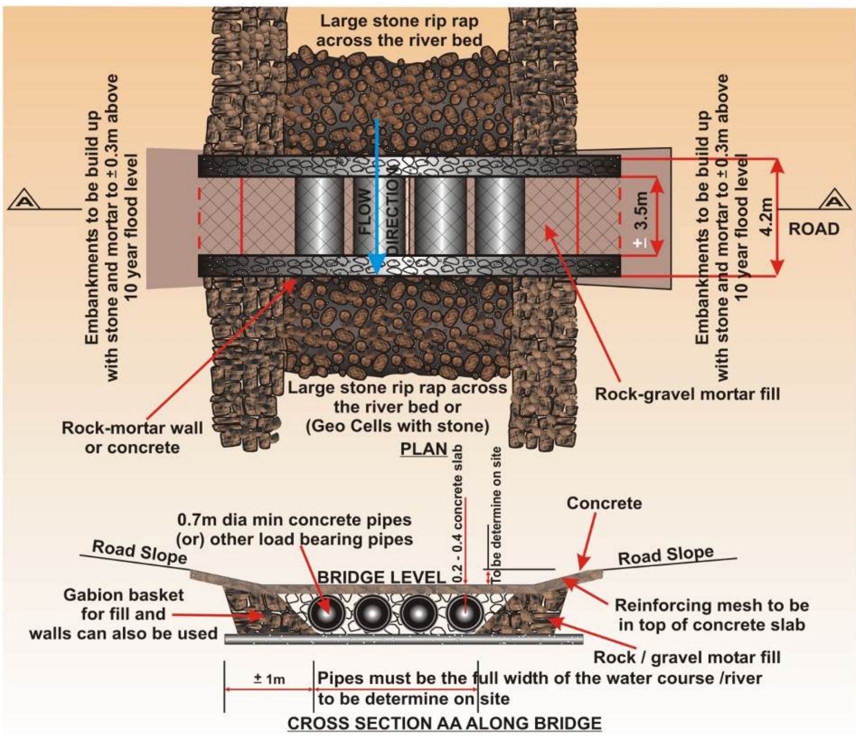

Figure 16: Low level bridge[13]

Application:

An involved construction process that will allow access through rivers with low and higher water flow volumes.

Relevant notes:

Low level bridge or culvert crossings should be constructed and maintained bearing in mind the following:

- The combined diameters of the pipes in the bed stream should be equal to the width of the water course, that is, the distance from one embankment to the opposite embankment, and have a diameter of approximately the depth of the 1 in 5 to10 year flood level.
- The pipes should be laid with a cross-fall of 2 to 5 % on a 150mm+ thick concrete blinding layer. They should be built-in at the ends with rock mortar walls (or gabions) and an in-between fill of rock or gravel mortar should be used. The rock mortar walls and fill should extend well into the embankments (1to 2 m).

- For higher water flow volumes and velocities, the top layer over the pipes should be a reinforced concrete slab of ± 350mm thick.
- Embankments should be built up with stone and mortar (or cells with gravel and mortar or other means for example, gabions etc.) to about ± 0.3 m above the 5-year flood levels.

The riverbed should be protected for about ±1 m upstream and ± 2 to 3 m down-stream with mortar stone rip rap or Hyson cells with stone. Refer

- Figure 16 for the design layout.
- Note that such crossings may fail during flooding if debris has been allowed to accumulate in the pipes, and periodic inspection and maintenance is therefore required.

6.2.6 Stabilization of Drainage Drifts

Description:

A system that will prevent erosion developing into the road surface where the road crosses an erosion ditch. (See Figure 17) Such structures typically consist of a gabion / retaining wall that and a rip rap.

Application:

To stabilize a natural drainage flow over a road, preventing the down strream section to erode back into the road. It is applicable to shallow gully crossings.

Relevant notes:

This structure is mainly for erosion ditches where the road crosses the gully, and where the building up of soil is desirable to maintain the road level.

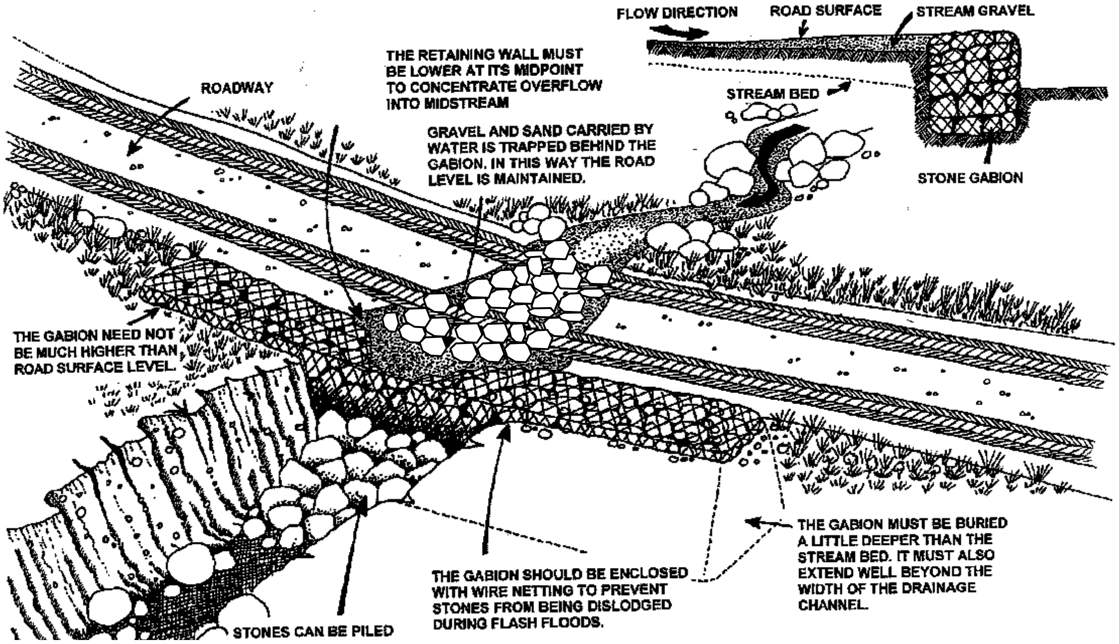

Figure 17: Stabilizing of drifts on downstream side [19]

6.2.7 Closure of Roads for Erosion Control

Description:

The closure of roads involves the reinstatement of natural side – slope, or the placement of fill material at the entrance to roads intended for closure.

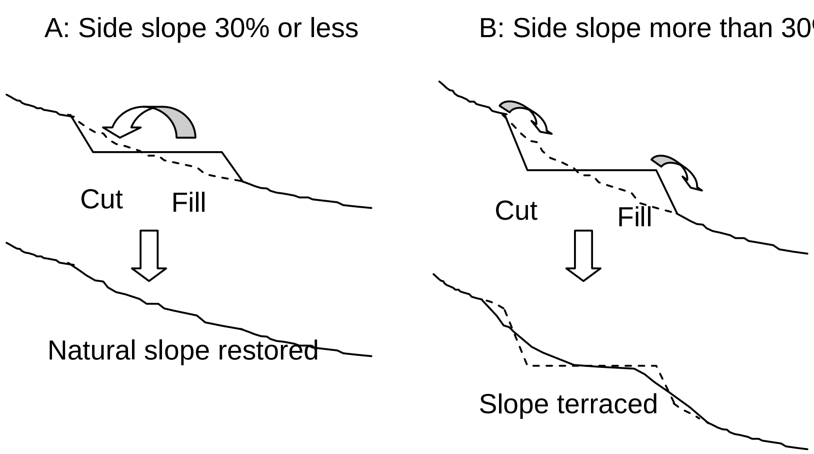

Figure 18: Slope reinstatement for road closure [17].

Application:

This process will be applicable where access or servitude roads have to be closed due to alternative roads that has been built or on request of the landowner, or where multiple accesses have been created to the same area.

While the utility should attempt to maintain access to all tower sites on the servitude, there are also situations where road closures will be required. These locations are usually in environmentally sensitive sites or mountainous areas and should be flagged for closure in the EMP.

Relevant notes:

In areas of 30 % slope and less, the fill of the road should be placed back into the roadway, to restore the natural ground slope as indicated in Figure 18. Here it is important to use equipment that does not work outside of the road it is closing. (For example a Tractor Loader Back-actor may be used and should operate from the cut portion of the road, working backwards and closing the road as it retreats.)

On steeper slopes (greater than 30 % slope), the equipment should break the road shoulder down, so that the slope nearly approximates to the original slope of the ground. The cut banks should be pushed down into the road, and a terraced side slope should be re-established with an erosion control system and re-vegetated.

6.3 Tower Foundation Protection and General Erosion Prevention Structures

Basic Philosophy:

The protection of the tower structures on any line is probably as important as protection of access route to the line.

Erosion close to the tower position and perhaps not within the servitude or servitude road must also be addressed since it can encroach onto the tower. The formation of erosion close to the tower might not have been noticed during the construction stage but environmental changes and commercial activities close to the tower is real and needs to be monitored on a regular basis.

Tower erosion rehabilitation methods may require heavier systems and engineers should adopt conservative solutions for the protection of structures.

6.3.1 Water diversion channels

Description:

Water diversion channels are lined or unlined channels to divert water around tower structures. Generally, channels in slopes of 4% or more should be lined, but cognisance of the natural erodability of the soil needs to be considered.

Application:

In flat terrain, towers in depressions may be subjected to seasonal sheet flooding, as shown in Figure 20. In such cases, water can be intercepted and diverted around the tower.

In cases where existing structures are close to existing streams, the course of streams may be diverted along new alignments away from the structure (see figure 19).

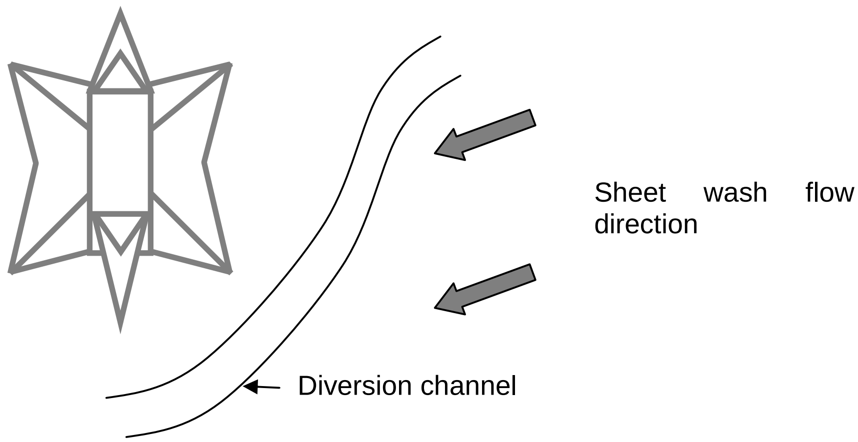

Figure 19: Placement of diversion channel to intercept sheet-wash

Figure 20: Erosion of general tower area in flat terrain

Relevant notes:

The diversion of existing watercourses must be planned and agreed to by the landowner, and environmental specialists should be consulted to ensure that impacts are acceptable and that the appropriate permit requirements are being met.

6.3.2 Hydroseeding

Hydroseeding is a fast, and cost effective method of encouraging accelerated growth of natural vegetation over large areas. It entails a process of combining seed, mulch, fertilizer, tackifiers (chemicals facilitating adhesion), and optional soil amendments with water to mix in a tank to form thick slurry. This slurry is applied with pressure via hose onto the soil to create the ideal environment for seed germination and turf development. Vegetation establishes quickly providing a uniform cover for erosion control.

Figure 21: Application of hydroseeding[23]

Application:

Eskom has not employed this method extensively, but it may have application in areas where large areas of sensitive (erodible) soil surround the tower area.

It may not be suitable in dry regions that cannot sustain the growth of grass. A seed mix compatible with the bioregion needs to be specified on a project by project basis. Suitable ground cover types include Synodon dactylon, Vetiver grass, Hedera helix (English Ivy) etc. Local specialists should be referred to in order to obtain the most appropriate seed mix for the bioregion.

6.3.3 Gabion Walls

Description:

Gabions are the most common form of erosion protection on overhead lines. A gabion block consists of a stones encased in a heavy duty wire-net (double twist hexagonal woven mesh or welded wire mesh). Various sizes of gabion blocks are stacked to form retaining wall systems, outlets and and weirs. (See Figure 22.)

Gabions are generally rectangular blocks, however sack gabions or cylindrical shapes may also be specified. Reno mattresses are flat gabions often used in combination of gabion baskets.

Gabion Walls are generally analysed as gravity retaining walls. Dimensions will need to be calculated according to the slope gradient, erosion risk and composition of the soil.

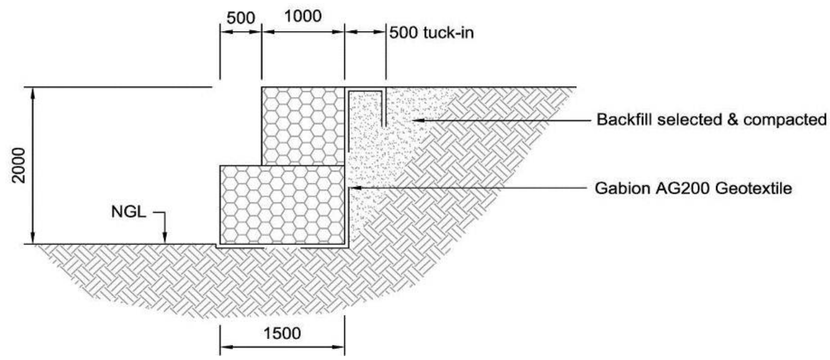

Figure 22: Basic outlay of a gabion wall [17]

Figure 23: Sack Gabion weirs [32]

Application:

Gabions have a wide variety of application. They may be used as tower protection structures, as weirs, drift crossings, weirs, or general retaining systems to allow the reclamation of eroded areas.

Figure 24: Before and after image of extensive gabion and reno mattress protection[5]

Figure 25: Gabion wall protecting tower leg and pole foundations [17], [28]

Relevant notes:

Soils or up slope embankments which are subjected to dynamic or static loading must be stabilised to ensure equilibrium of the surrounding environment. When soils is confined or loaded, distributing forces are set up that may give rise to sliding, overturning and bearing failures.

Gabion structures can also be used as retaining walls to protect the service road in sloped areas against caving of the soil.

To counteract these effects slope reinforcements may be required. The specifications as referred to in **SANS 1200DK** should be taken in consideration when building Gabion Mattress Retaining Walls.

Stone filling can be rock from the surrounding environment, primary crusher run, or obtained from an approved source as indicated by the *Employer* or *Technical Specification* related to the specific project.
Backfill material behind structures and below structures to be compacted to a minimum of 98% MOD AASHTO. Typically a G200 geotextile will be used at all mesh / soil interfaces

No single gabion cage should be longer than 4m.

6.3.4 Stone pitching

Description:

Stone pitching is similar to rip-rap (rock that is laid against the slope), but is set into place with mortar to produce a hard wearing impervious surface.

Application:

Stone pitching has already been suggested for use in drainage channels as illustrated in Figure 4. It may also be used for a variety of applications, namely tower protection (Figure 26) and as protection on embankments or outlet drains. Stone pitching may be suitable where natural stone is available. It is also considered more aesthetically acceptable than using interlocking precast units.

Figure 26: Stone pitching used as protection of wood pole [27, 26]

6.3.5 Weir structures

Description:

A structure normally used to allow the build on of soil in an erosion gully by slowing down the speed of water flow and allowing settlement of sediment. A weir can be constructed of concrete, gabions, or interlocking blocks specifically designed for use in flowing water (eg. "Waterloffel" blocks). The preferred structure type is a gabion weir, as outlined in Section 5.1.

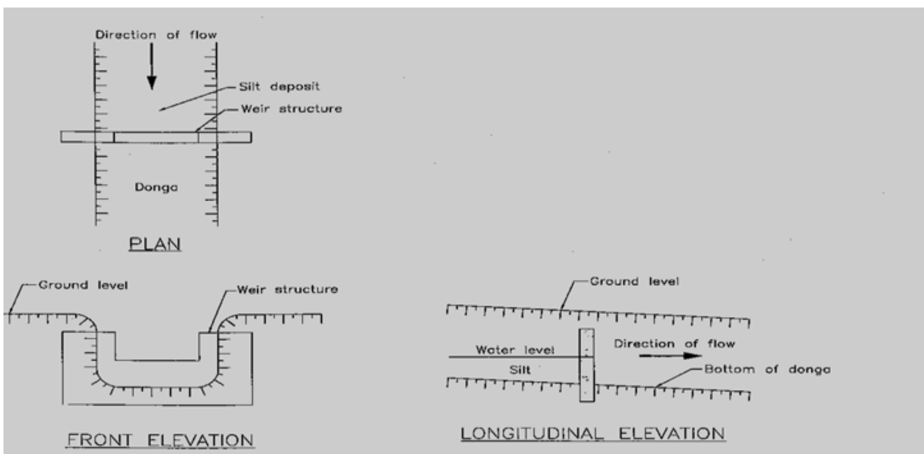

Figure 27: Outline of a Weir structure [25]

Application:

To enhance the reclamation of soil on erosion gullies and where damage to the servitude access would result.

Relevant notes:

It is important that weirs are keyed sufficiently into the sidewalls and base of the gully, and that the spill level lies below the natural ground level (See Figure 27). Failure to observe this will result in scouring around the structure and eventual failure.

6.3.6 Silt Screens

Description:

Silt screens or silt fences are constructed from UV resistant netting that are installed inside the erosion ditch or erected across the affected area to prevent erosion and to assist with the build-up of soil, in the same way as weirs.

The structure is built perpendicular across the affected area and key walls are constructed to stabilise the structure. (See Figure 28 and Figure 29)

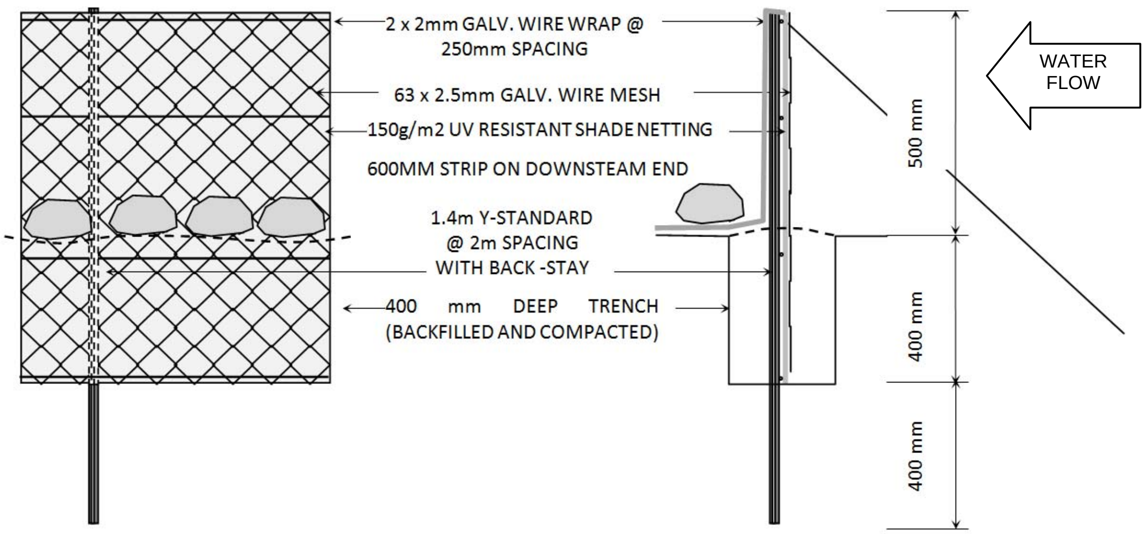

Figure 28: Silt screen using galvanized wire [17]

Figure 29: Silt screen application [32]

Application:

This method is recommended for small catchment areas where the maximum overflow water height does not exceed 200mm. The maximum spillway height from the bottom of the ditch must not be higher than 500mm and a total freeboard of 500mm is recommended.

Relevant notes:

Silt screens operate by intercepting, ponding and filtering sediment – laden run-off by reducing the flow velocity.

The silt-screen is much more cost effective than a gabion mattress, but can fail if used for deeper erosion gullies.

Experience with geofabric in these systems has led to premature failure due to the clogging of pores and the build-up of hydrostatic pressure in flooding. For this reason, UV resistant shade netting is used which is not prone to clogging.

7 MAINTENANCE OF EROSION SYSTEMS

Although the solutions selected in this guideline have relatively low maintenance requirements where properly constructed, there are some potential problems that may occur and can result in failure of the system.

7.1 Inspections

Installed systems need to be inspected at moderate intervals, typically every 2-4 years (depending on rainfall and erosion potential), to determine whether rainfall has damaged or impacted on the efficiency of solutions. For this reason, inspections should preferably take place after the rainy season.

The two most common problems experienced in erosion systems are silting and scouring. When these factors are identified early they are easy to remedy, however unattended problems may lead to complete re-construction of an erosion system.

7.2 Silting

Unwanted silting refers to the build-up of sediment in structures required to channel water away from sensitive areas. When this happens, water overflows causing erosion around and under soil erosion mitigation structures, leading to subsidence and eventual failure.

Silting needs to be remedied by simply cleaning out the sediment, and placing it in areas where it will not re-enter the system.

7.3 Tunnelling and scouring around structures

Tunnelling and scouring occurs where water erodes and undermines structures (See **Figure 30**). It is evidenced by voids on the upstream side of retaining structures and subsidence or cracking of the soil erosion structure.

Figure 30: Subsidence of Gabion Structures following flooding [9]

This can be remedied by replacement of soil with rock fill material to prevent further scouring, replacement of rusted gabion baskets, and geofabric, or the lifting, compaction and replacement of the gabion system in severe cases.

Remedial measures should be undertaken with due consideration to the root causes of the original subsidence and the installation of additional measures to prevent re-occurrence.

8 REFERENCES

[1] Cement & Concrete Institute, Concrete Strip Roads For The Farm, http://www.cnci.org.za/

[2] B. Huntley; C. Sunter and R. Siegfried, South African Environments into the 21st Century –. Human, Rousseau & Tafelberg, Cape Town 1990

[3] Veld Rehabilitation Management Guidelines (Conservation Management Services for the Ostrich Industry Biodiversity Management Project)

[4] Professor M.C. Laker, The extent of Soil Erosion - Dave Favis-Mortlock, KwaZulu Dept. Nature Conservation

[5] Vosloo, H. - Soil Erosion Guideline – Eskom (Reference 41-337)

[6] Barricades and Small Structures for the prevention of Soil Erosion – ARC-Institute for Agricultural Engineering (Agricultural Research Council)

[7] Garland, Hoffman & Tood, Soil Degradation, UKZN, http://intranet.ukzn.ac.za/geog/

[8] Department of Agriculture website, Soil conservation structures, http://www.elsenburg.com/info/els/074/074e.html

[9] Eskom Publication, The fundamentals and practice of Overhead line Maintenance, Power series vol.2, 2002

[10] Matthee, J F and Van Schalkwyk, C J, A Primer on soil conservation - Department of Agriculture publication- 2001

[11] Eskom Specification, Environmental Impact Control (EIC/385) , Eskom-Transmission , March 1985

[12] Eskom Specification, Environmental Impact Management Program (ESKPVAAZ1), Eskom-Transmission , Jan 2000

[13] Eskom Specification, Transmission Line Towers and Line Construction (TRMSCAAC1 rev.3) , Eskom-Transmission , March 2001

[14] Eskom Publication, The fundamentals and practice of Overhead line Maintenance, Power series vol.2, 2002

[15] Determination of longitudinal grades on rural roads, Polus, et. al., Israel Institute of technology, 1995

[16] Eskom Transmission Guideline -Soil Erosion Guideline, 41-337, 2010

[17] TAPGREOL Rev. 1 ACCESS AND GROUND EROSION PROTECTION DURING OVERHEAD LINE CONSTRUCTION

[18] By Mr W. Mashiloane, SOIL CONSERVATION PROJECTS IN RURAL COMMUNITIES, http://www.dfac.mil.za/

[19] R. A. Lohnes, LOW WATER STREAM CROSSINGS:DESIGN AND CONSTRUCTION RECOMMENDATIONS, Center for Transportation Research and Education, Iowa State University

[20] Land Rehabilitation Systems - Gabions and mattress construction specifications, www.lrs.co.za

[21] Land Rehabilitation Systems -Mild tensile steel wire gabion and mattress product specification, www.lrs.co.za

[22] Hyson Cells, Hyson Cells compared to industrial block paving, www.hysoncells.co.za/

[23] Hydromulch Website: http://www.hydromulch.co.za/Hydroseeding.html

[24] Maccaferri Southern Africa – Revetment Walls, www.maccaferri.co.za/

[25] Van Heerden, J. – Photographs and Participation in Erosion Audits, 2011

[26] Builder Bill Website, Graphical construction Glossary, http://www.builderbill-diy-help.com/stone-pitching.html

[27] Eskom Publication, The Planning Design & construction of Overhead Power Lines, Power series vol.1, 2005

[28] Trans-Africa projects: Eskom Karoo Transmission CLN erosion report

[29] UNEP – GIRD, Environmental Knowledge for Change, Website http://maps.grida.no/go/graphic/degraded-soils

[30] GEofix Website, http://www.geofix-int.com/productos_ing.php

[31] Erosion Control Network website, http://www.erosioncontrolnetwork.com/cellular-confinement/cellular-confinement.aspx

[32] Van Heerden, J. Various photographs kindly supplied by Mr. van Heerden