

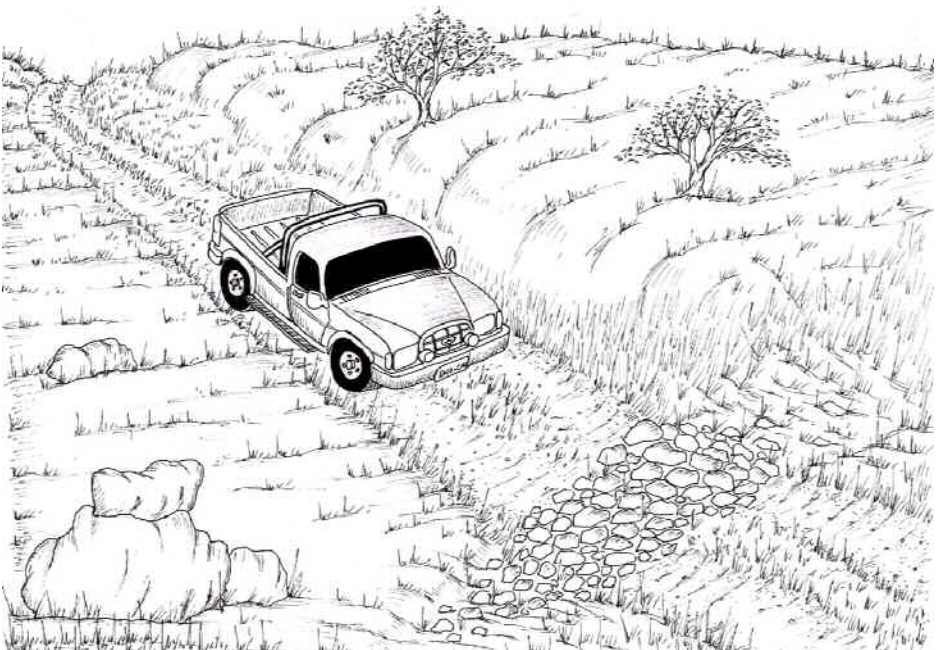
Spot Improvement

Manual

for

Basic Access

(This is an English translation of the Mozambican *Manual de Melhoramentos Localizados para Acesso Garantido* and is to be used as an internal document by the PMO-RALG, Tanzania.)



Spot Improvement
Manual
for
Basic Access

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Preface

Mozambique is a vast country with long distances between villages, towns and cities. It has a dispersed rural population and poor soils that are erodible or slippery during the rains and dusty during the dry season. In these conditions, the rehabilitation of roads to a high standard for all communities is a major challenge.

In this context, the National Road Administration, ANE, must take an important decision: do we construct a small number of roads to a high standard, that will allow people to travel comfortably and rapidly, or do we adopt an approach which will benefit more people, even though they may not be able to travel at higher speeds at all times? A few years ago this decision was being considered by many Road Authorities around the world.

ANE decided to adopt a policy of improving very low traffic tertiary, vicinal and unclassified roads using a spot Improvement approach. This implies that repairs are undertaken only at those sites that are impassable, difficult or dangerous for passing traffic and the sections which are not impassable, difficult or dangerous are not improved. Although the final result may not appear uniform, for example some parts will be of a high standard and others may be natural earth, the advantage of this approach lies in the savings that can be made. These savings can be used to improve more roads for the benefit of more communities, providing year round access for all, allowing rural economies to develop and reducing poverty.

A considerable number of managers, engineers and technicians will be involved in the promotion and implementation of this policy, particularly because the management of the categories of roads on which spot improvements are appropriate is to be gradually transferred to district authorities. As a result, it was necessary to write a Manual (the one you are now reading) which explains what spot improvements are and how they should be planned and designed.

This is the first time that a Spot Improvement Manual has been written in Mozambique. If you think that parts of the Manual could be improved, or if you have other ideas for spot improvements, please submit them to ANE for inclusion in the next revision of the Manual.

António Félix Mambo
Director of Regional Roads
June 2006

Acknowledgements

Following its decision to adopt a spot Improvement approach on very low traffic roads managed by district authorities, ANE commissioned TRL to produce this Manual. The production of the Manual was supported by the Department for International Development (DFID). The members of the TRL team, Rob Geddes and Simon Done, are extremely grateful for the opportunity that was given to them to help in the implementation of this approach. The authors would like to acknowledge the high level of support received from ANE during the project and the contributions of the engineers, technicians, contractors and government officials who participated in the regional seminars during which the early drafts of the Manual were discussed and refined.

This version of the Manual is an English translation of the original *Manual de Melhoramentos Localizados para Acesso Garantido* which was produced for the National Roads Administration (ANE) in Mozambique in June 2006. This version will be used by the PMO-RALG, Tanzania as an internal document only in the process of developing a similar manual for Tanzania. Permission for this was granted by ANE in a letter dated the 12th of March 2007.

June 2007

Glossary

Administrative Post Consultative Council	A community based organisation which facilitates communication between communities and the Administrative Post Government
Alignment	The line that the road or track follows on the ground
Allowance	Payment to labourers by the DA
ANE	Administração Nacional de Estradas / National Road Administration
Anthill	Soil whose condition is altered by ants and which becomes very slippery when wet
Asphalt road	Road with a bituminous surface
Basic Access	A level of service which is appropriate for some very low volume roads where the priority is to travel in safety and with confidence of arriving at one's destination
Clay	Soil with very small particle size (< 0.002 mm) which forms very hard lumps when dry and is slippery when wet
Community Committee	A committee which is formed by the community to organise itself and to identify and resolve its own problems
Contingency	An additional percentage to the estimated construction costs to cover costs which are necessary but unexpected
Contract package	A list of selected works which a contractor may contract to complete
Critical site	A site where Basic Access (as defined in this Manual) is not possible
Cross drainage structure	Structure such as a culvert or a drift that allows water to cross a road
DA	District Administration
District Consultative Council	A council which allows communication between the communities and the District Government
District Development Plan	A document that includes all the development plans of the District
District Technician	An engineer or technician who works within the DA
DPOPH	Provincial Directorate of Public Works and Housing
Drain	A ditch that removes water from a site
Drainage	The process by which water is removed from the road
Execution norm	A construction process which is described in official documents of a competent authority
Fill/embankment	A section of road whose level is raised by placing, spreading and compacting layers of soil
Formation	The structure of a road, including the cross section, the camber and the side drains
Full rehabilitation	Improvement along the full length of the road in order to allow vehicles to travel rapidly and comfortably
Grading	Improvement of a soil or gravel surface using a grader, for example a towed grader
Gravel	A type of soil which can produce a durable surface
Gravel road	Road with a surface of gravel
Improved surface	A surface which is made stronger and more resistant through the use of imported materials

Inclined track	A track with sufficient longitudinal gradient that water is able to flow
Inspector	Person who checks if the quality and quantities of an item of work are in accordance with the specifications
Key questions	A series of questions that can be used to assess each alternative in a list on the basis of defined criteria
Local Forum	An civil society institution that is established at an Administrative Post
Longitudinal	Direction along the alignment of a road
Mitre drain	A diagonal drain which carries water from a side drain onto the surrounding land
Mud	Soil which is weak and which deforms when wet
National Road	Primary and Secondary Road
National specification	The construction standard which conforms with official government documents
Natural earth road	Road with a surface of local soil
NGO	Non Governmental Organisation
Normal wear and tear	Normal reduction in quality or shape that is caused by the combined action of climate and traffic and that can be rectified with maintenance
Pair-wise comparison	The method by which each alternative in a list is compared with all the others in order to identify the highest priority
Periodic maintenance	Activities to rectify large defects, including gravelling
Potholes	Holes in the surface of the road which can damage vehicles and force them to travel more slowly
Primary resources	Resources which can be directly allocated to an item of work, such as cement
Primary Road	Road that connects provincial capitals, other cities, principal ports and principal border posts
Project Manager	Person who, for the purposes of this Manual, manages the construction of spot improvements on behalf of a community
Reference point	A point, such as a building or junction, that can be used to reference the distance along the road
Regional Road	Tertiary and Vicinal Road
Relief structure	Structure that carries water from a side drain across a road in order to reduce the volume of water in the drain
Retention	A percentage of the value of the contract which is retained by the Client until after the completion of the contractual defects liability and can be used by the Client to repair any defects
Road commission	A committee which is formed by a community in order to manage the construction of spot improvements
Rocky outcrop	Large rocks at the surface which can be removed only with great effort
Routine maintenance	Activities to rectify small defects, including grass cutting and pothole filling
Sand	Granular soil with a particle size between 0.06 and 2 mm, which is firm when wet and loose when dry

Scour check	A small barrier constructed in a side drain to reduce the speed of flow of water
Secondary resources	Resources which cannot be directly allocated to an item of work, such as general site transport
Secondary Road	Road that connects primary roads and provincial capitals with river and maritime ports, primary roads with centres of high economic importance, and primary roads with other border posts
Side access	Informal access from the road to a private property alongside the road
Side drain	A drain alongside the road
Slippery	A surface with a lack of traction, especially when wet
Spot improvement	Improvement of a road at a critical site in order to provide Basic Access, as defined in this manual
Standard speed	The vehicle speed which is used in the definition of Basic Access
Standard vehicle	The type of vehicle which is used in the definition of Basic Access
Surrounding land	The land on either side of the road
Tertiary Road	Road that connects secondary roads to other primary and secondary roads or district centres, or connects district centres with administrative posts, or with centres of high economic importance
Track	A road that has deteriorated and lost its formation or an informal route that was never constructed as a road
Unclassified Road	Roads and tracks that are not included in the national classification system
Unit costs	The cost of a unit of a resource such as an hour of labour or a cubic metre of sand
Vicinal Road	Road that connects tertiary roads and administrative posts with population centres
Water course	A channel where water normally passes such as a stream or a river
Work task	A system in which a standard quantity of work is allocated to each worker per day and which can be completed in about 6 hours

Chapter 1 Introduction

1.1 Spot Improvements

Management of the road network in Mozambique

The road network of Mozambique comprises two categories of road: National Roads and Regional Roads.

National Roads: Primary and Secondary roads that generally carry a high volume of traffic.

Regional Roads: Tertiary, Vicinal and Unclassified roads that generally carry very low volumes of traffic.

When a road is improved in Mozambique the following are generally provided along the entire length of the road: formation, drainage, a gravel or bituminous surface and cross drainage structures. After the works, vehicles can travel at higher speeds and in comfort. This level of improvement is called 'full rehabilitation' and is very expensive.

Most journeys on National Roads are long, and the traffic level is high. Therefore, when improvements are required, it is normally justifiable to 'fully rehabilitate' these roads, even when funds are limited.

However, full rehabilitation is not justifiable on some Regional Roads due to the large size of the road network and its corresponding high demand for funds. If a selected Regional Road is fully rehabilitated there may not be sufficient funds to rehabilitate other roads. As a result the communities served by these other roads will remain without even basic road access. They will have to walk wherever they need to go, including to health posts, schools and markets.

Therefore, how can Regional Roads be managed with limited funds?

The priorities of those who use Regional Roads

A high speed of travel is not normally the priority of the users of Regional Roads. Their priority is to travel safely, without encountering obstacles and without damaging their vehicles or cargo. They need to be confident that for the next few years they will be able to carry their farm products to the market or that they will be able to get to the hospital whenever they need to. Having this confidence is more important than travelling quickly for these road users. This level of service is called Basic Access.

Basic Access is achieved through the construction of spot improvements. Spot improvements include only the repair of critical sites along the road, where vehicles pass with difficulty, or where they cannot pass at all. The sections of the road that are not damaged, where vehicles already pass easily and safely, and that have a low probability of deteriorating in the near future, are not improved.

Costs of spot improvements

The cost of providing Basic Access is less than the cost of fully rehabilitating the same road. The cost of maintaining a road that provides only Basic Access is also less than the cost of maintaining a fully rehabilitated road. Therefore, if only spot improvements are constructed on Regional Roads, there will be spare funds that can be used to provide Basic Access on other roads. There will be fewer people who will have to walk in order to reach health posts, schools and markets.

Spot improvements and maintenance

Spot improvements are different to maintenance. Spot improvements are necessary to provide Basic Access after it has been lost, and generally are implemented by contractors on measured contracts. Maintenance is required before Basic Access is lost and is often carried out through level of service contracts. This Manual covers the design of spot improvements but does not cover the implementation of routine or periodic maintenance. However, spot improvements can be carried out at the same time as maintenance. Combining spot improvements and maintenance into a single contract is a viable method of improving and maintaining a road. After the construction of spot improvements it is necessary to maintain them.

Management of spot improvements

Spot improvements can be part of a continuous cycle of improvement of Regional Roads. After the critical sites along a road have been improved, it is often the case that the traffic level rises. This rise in traffic can cause the deterioration of other sites currently in good condition. If the condition of the road is monitored and the management procedures allow spot improvements to be carried out every year, for example by combining spot improvements and routine maintenance into a single contract, these new critical sites can be improved whenever necessary. Ideally, there should be funding available to carry out all required spot improvements every year. The spot improvement approach is a cost effective method for gradually improving an entire network according to the needs of the road users.

In order that spot improvements can benefit the communities along the road for many years, they must be constructed to high standards and meet national requirements. Funds must be available for their maintenance. If standards are low or maintenance funds are not available, the improvements will deteriorate and it will be necessary to reconstruct them after a short period of time.

In some areas, such as alongside rivers or in the mountains, the spot improvement approach may not be suitable. If it is found that more than 75% of the road does not currently provide Basic Access, it is recommended that full rehabilitation is considered for the road.

The design of spot improvements described in this Manual is ideally applicable for vicinal and unclassified roads, for which the DAs are responsible.

1.2 Main activities covered by the Manual

There is a large variety of activities that can be carried out as spot improvements. However, this Manual focuses on those activities which control the flow of water and repair erosion. There are three reasons for this:

- The traffic volumes on the majority of Regional Roads, particularly those that are the responsibility of the DAs, are very low. Therefore the deterioration due to rainfall and the flow of water is much greater than the deterioration caused by traffic.
- Flowing or standing water is the most common reason for loss of access.
- The cost of preventing erosion is generally much lower than the cost of repairing the damage caused by the same erosion in order to restore lost access.

If preventative measures are taken before erosion begins, Basic Access can be provided along many Regional Roads at very low cost.

1.3 Definitions

The Manual uses the definitions in Table 1.

Term	Definition
Basic Access	A road or a site provides Basic Access if all of the following aspects are true: • The standard vehicle can pass all year round, except for a period of up to 24 hours after rain when the road can be closed • The standard vehicle does not need to travel slower than the standard speed • The standard vehicle can pass without the driver, the passengers or other road users being at risk of injury • The standard vehicle can pass without damaging the road beyond normal wear and tear, even when it is raining • The standard vehicle can pass without being damaged and without damaging its cargo beyond normal wear and tear • It is unlikely that the condition of the road will deteriorate in the near future or even during the next rains
Critical site	This is a site that does not provide Basic Access in accordance with the above definition.
Spot improvement	This is the repair of a critical site in order to provide Basic Access in accordance with the above definition.

Table 1 Definitions

The standard vehicle is used in the identification of critical sites, but it does not define the standard of the improvement. All improvements are constructed in accordance with national specifications. The choice of standard vehicle depends on the use of the road and must be decided by the authority that is responsible for the road. For example, a standard vehicle for a tertiary road in an area of agricultural production could be a 3 tonne truck. A 2WD pick up or even a bicycle can be the standard vehicle for an unclassified road where heavy vehicles are not required.

The standard speed is also used in the identification of critical sites, but it is not used to define the speed at which a vehicle can travel along the rest of the road. The standard speed depends on the choice of standard vehicle and must be determined by the authority that is responsible for the road. For example, the standard speed could be 10 km/h for a 3 tonne truck but 20 km/h for a 2WD pick up.

1.4 The target group

This Manual was written to be used by the following organisations:

- DAS
- DPOPH
- ANE Provincial Delegation
- Municipal Councils
- Local contractors
- NGOs
- Community leaders
- Farmer Associations and other local community groups
- Transport Associations

It is expected that the DAs will be the main users of this Manual. Whenever an organisation that intends to use the Manual does not have sufficient technical capacity, they should ask for assistance and advice from ANE.

1.5 Areas covered and not covered by the Manual

The Manual provides the following:

- Guidance on planning and designing spot improvements on Regional Roads in Mozambique
- Technical information on spot improvement solutions
- Technical designs for the most common solutions
- Guidance on how to organise the construction of the spot improvements
- Training material appropriate for those who will be involved in the work and who have limited technical knowledge

The Manual does not provide the following:

- Technical designs for less common solutions
- Detailed guidance on carrying out the construction activities. For this guidance, the reader should refer to the book *Building Roads by Hand*, which can be obtained from ANE and which is described in more detail in Chapter 7
- Guidance on the planning and implementation of routine and periodic maintenance
- Information on low cost solutions which can provide temporary access, but which are unlikely to last more than a year

1.6 Which technology to use

Spot improvements can be implemented using equipment or labour. The user of this Manual must decide which method is most appropriate in his or her situation. Normally this decision is based on practical issues, such as access to machinery and the availability of labour.

1.7 The involvement of local communities

The communities alongside a road can be involved in various ways in the improvements to the road. Options vary from a high level of involvement and a very low level. Table 2 shows six different models of community involvement.

Model	Description
Self-help	The people plan and construct their own projects without external help
Active	The people work with others to plan and manage the project
Consultation	The people give their opinion on subjects related to the project
Contribution	The people contribute with labour, money and materials
Commercial contracting	The people are paid to work on the project or to provide materials
Passive	The people in the area are informed of what will happen

Table 2 Models of Community Involvement

A high level of community involvement during the planning, design and construction phases has the following advantages:

- There is a greater likelihood of the community understanding why only the critical sites will be improved
- There is a greater likelihood of the people assisting ANE or the DA to monitor the road condition after the improvements have been made, and to identify critical sites that appear as the traffic rises
- There is a greater likelihood of the community taking responsibility for maintenance of the road after its improvement
- There is a greater likelihood of the road providing Basic Access for an extended period of time.

Regional Roads can be improved using any of the models of community involvement described above. This Manual provides specific guidance for the two models normally used in Mozambique: self help and commercial contracting.

Self-help

A community or local organisation realises that the improvement of a road or track will improve the living conditions and opportunities for its members. The community or organisation proposes the improvement of the road to the DA through the system of local councils. However, the road is not accepted to be included in the District Development Plan. The community or organisation might be allowed to use the district tractor and trailer, but must plan, design and construct the improvements without funding or other direct assistance from the DA or ANE.

Commercial contracting

The DA identifies one or more road as being important to its District Development Plan. The DA asks ANE to survey the roads, programme the required works and contract a commercial contractor to complete the works. The contractor is encouraged to employ local people. If the DA has a District Technician, he or she can take on some of the responsibilities of ANE relating to the work.

1.8 Additional documents

Although this Manual contains the information required by the user to provide Basic Access on most Regional Roads, there are three documents that provide additional useful material. These are listed in Table 3.

Document	Details
Manual for the construction of bituminous surfaces using labour on low volume roads <i>(This is a TRL document in English)</i>	Low cost bituminous surfaces can be used to provide Basic Access in some circumstances. The Manual explains how to prepare the base of the road and how to design and construct a range of surfaces, using labour based methods.
Environmental Guide for the road sector <i>(This is an ANE document)</i>	This Guide explains how the environment can be affected by road improvements and which measures can be taken to reduce these impacts.
Building Roads by Hand <i>(This is an international document available in English and other languages)</i>	This Manual offers detailed guidance on the execution of construction activities.

Table 3 Useful additional documents

1.9 Using the Manual

The Chapters of this Manual guide the user through the necessary steps to provide Basic Access. The Chapters are described in Table 4 below.

Chapter	Description
1. Introduction	This Chapter explains the important concepts behind spot improvements and how to use the Manual.
2. Identification of Critical Sites	This Chapter provides a list of specific defects that can cause Basic Access to be lost and explains how to carry out a survey of the road to identify the sites that do not provide Basic Access.
3. Selection of Appropriate Solutions	This Chapter explains how to use the information from the road survey to select an appropriate solution from a list of options (see Chapter 8), design the solutions, show them on a strip map, and prepare Bills of Quantities.
4. Cost Estimate	This Chapter explains three methods that can be used to estimate the costs of the selected solutions, ranging from a detailed method appropriate for contractors preparing a proposal to a simple method appropriate for work being carried out by a community group on a self-help basis.
5. Cost Reduction	This Chapter explains four methods that can be used to reduce the cost of the construction works when funds are limited,
6. Implementation of Spot Improvements	This Chapter provides a summary of two models for the implementation of spot improvements that are commonly used in Mozambique, and explains how a road which has received spot improvements should be managed in subsequent years.
7. Training	This Chapter provides publicity and training material, including two posters (the posters are separate from the Manual), a set of completed survey forms and strip maps, and the programme for a 3 day training course.
8. Catalogues of Recommended Solutions	This Chapter provides information on the design of a wide variety of possible solutions, as listed in Chapter 3.

Table 4 Description of Chapters

1.10 Revision of the Manual

This Manual was produced in June 2006. A revision is planned for 2008. The revision will be based on the experience of the users of the Manual in the Provinces and the Districts. All users are therefore asked to send to ANE any comments, suggestions, recommendations or other information that might be useful to the proposed revision.

Chapter 2 Identification of Critical Sites

The first stage in the provision of Basic Access is the identification of critical sites during a survey of the road. This chapter explains how this is achieved.

2.1 Defects

It is necessary to construct a spot improvement at all critical sites which do not provide Basic Access, according to the definitions in Table 1, and that cannot be repaired by maintenance.

The definitions of Basic Access provide general criteria for identifying critical sites. However, it can be difficult to identify critical sites using only these general criteria. The descriptions of specific defects that are known to impede access can greatly assist with the identification of critical sites.

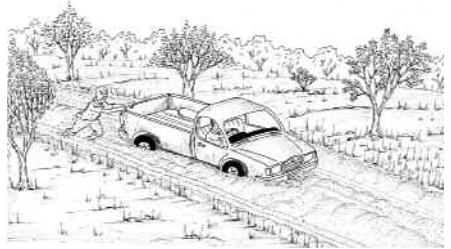
Table 5 provides this list of defects and descriptions, grouped according to where the defects are typically found.

If a defect is encountered that is similar to the description, it is unlikely that there is Basic Access on the road, and it is unlikely that the defect can be repaired by maintenance. The site is, therefore, critical and a spot improvement must be constructed.

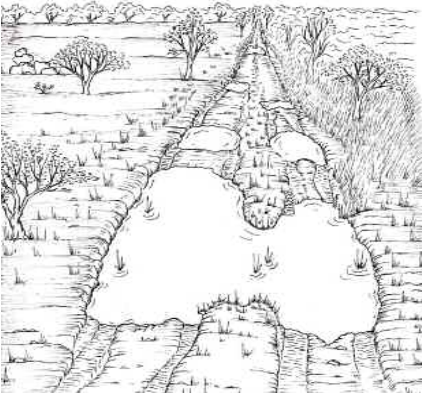
Table 5 also indicates which dimensions should be recorded, and if certain questions should be asked during the survey in order to allow the spot improvement to be properly designed and assessed for the quantity of work.



Erosion channels



Area of loose sand



Potholes



Muddy area

Figure 1 Illustration of some types of defects

Defect and Description	Dimensions and Questions
Inclined tracks with small erosion channels	
Inclined track with erosion channels less than 5 cm deep ¹	Length Gradient of track
Water courses	
Existing water course without an adequate structure (with or without water)	Width of water course when flowing Depth of water course when flowing Speed of water when flowing Length of drain/channel in poor condition
Existing structure severely damaged	Type of structure Size of damage
An embankment is narrow and vehicles pass within 50 cm of the edge	The volume of material that is required to widen the embankment or repair the damage
Soils, Surfaces and Alignment	
Longitudinal inclined erosion channels more than 5 cm deep	Length with erosion Gradient of the road/track Total volume of the channels Possibility of digging mitre drains on either side of the road/track to divert the water ²
The road/track has potholes	Length affected Total volume of the potholes
The road/track is low lying and floods during the rains	Does water flow along a track into the potholes? Distance to an area which is lower, to which the site can be drained
Muddy area which deforms when wet	If an interception drain is required, how long will it need to be? Depth of water when flooded
The surface is clayey and slippery There is dust which is dangerous and unhealthy	Length of section
Area of loose sand	Length of section
Roots on the surface damage bicycle tyres	Total length of visible roots Length of affected road/track

Conflict between motorised and non-motorised vehicles, poor visibility or vehicles approaching one another find it difficult to pass	Length of section Reason for conflict
Surface is anthill and slippery	Area of the road/track that is affected
Rocky outcrop at the surface	Length of section
The road/track has poor alignment, resulting in many critical sites	Length of alternative alignment
Drains and Slopes	
Water flows from the surrounding land and overflows from the side drain onto the road	Length of blocked drain Is it a side access that is blocking the side drain? If an interception drain is required, how long will it need to be? Is a cross drainage structure required?
Water flows in the side drain and overflows onto the road	Length of blocked drain Is it a side access that is blocking the side drain? Gradient of the side drain Is it possible to dig mitre drains to reduce the flow in the side drain? ² Is a relief structure required?
The depth of erosion in the side drain is more than 10 cm or the erosion is moving laterally towards the road	Length of erosion Total volume of erosion Gradient of the side drain Is it possible to dig mitre drains to reduce the flow in the side drain? ² Is a relief structure required?
Erosion on other slopes is deeper than 10 cm	Total volume of erosion Area of erosion

1. An inclined track with erosion channels less than 5 cm deep does not prevent Basic Access. However, erosion prevention is recommended for all tracks with sufficient gradient that water flows along the track, and all tracks where erosion is present, since it is probable that the erosion will increase over time. Prevention measures are generally inexpensive.

2. Record the length of mitre drains which is required to a point at which water can be discharged. If it is not possible to dig mitre drains, it may be necessary to construct a relief structure.

Table 5 Defects and Dimensions

2.2 Survey

The survey is carried out using a Critical Site Survey Form. The Form records the critical sites, their locations and the information which will be required when the solutions are being designed and the costs are being estimated. The Form is found in Figure 2 and should be photocopied and expanded before being used. In Section 7.3 an example of a completed Form can be found.

The survey team should include:

- 1 or 2 members of ANE staff
- 1 or 2 members of DA staff, ideally including the District Technician
- Someone who knows the route well and its condition throughout the entire year. It is recommended that a member of each community along the route joins the team when the survey passes through their area.

The survey should be carried out in the following manner:

1. Identify the start of the road and divide the road into 100 metre sections. The start of the road can be identified using a reference point such as a junction or a village centre. The road can be divided into sections either by fixing distance posts every 100 metres along the road before beginning the survey, or by using a vehicle with an accurate trip-meter following the survey teams.
2. During the survey three aspects should be recorded in the bottom part of the Form.
 - The location of a reference point such as a junction, a clearly visible building or a large water course at least every 3 km so that at a later date the start point and the critical sites can be identified after the distance posts have been removed.
 - Alternatives which can save costs, such as local sources of materials or route realignments. These alternatives are described in Section 5.1.
 - Any useful additional information which may arise in conversations with local people. This can also be obtained before or after the survey.
3. Complete the reference information at the top of the first Form.
4. Record '0+000' under 'From' on the first row and walk to the first 100 metre mark, observing and discussing with other members of the team the condition of the section and any critical sites.
5. Record the type of the section as 'T', 'ER', 'GR' or 'S' under 'Type', respectively for Track, Earth Road, Gravel Road and Sealed.
6. Record the approximate width of the surface used by traffic under 'Width'.
7. Referring to the definitions in Table 1, and repeated in the lower part of the Form, record the level of Basic Access with a cross in one of the four following columns.
8. Make a cross in the next column if the section is an inclined track with erosion channels more than 5 cm but less than 10 cm deep. This information is recorded separately because it is recommended that erosion prevention measures are constructed on these tracks, even if the track currently provides Basic Access.
9. If the section provides Basic Access for the entire year, no further details are required in this row. The team may, however, wish to record information that would allow any change in condition to be monitored.

10. If the section does not provide Basic Access for the entire year, each critical site (including the inclined track with erosion channels less than 5 cm deep) is recorded separately with a cross under the description of the defect. The chainage of the defect is recorded as accurately as it is possible to measure on foot. The dimensions as indicated in Table 5 and possible solutions are also recorded.
11. If more than one critical site is found within one section, a separate row should be used for each critical site.
12. Record '0+100' under 'To' of the final row used to record critical sites in the first 100 metre section. However, if there are several consecutive sections that provide year round Basic Access, only one row needs to be used for 200, 300 or more metres.
13. Continue to the next 100 metre section, and return to step 4 above.
14. Continue to the end of the road or track. Although each Form has ten rows, it can cover more than 1 km if there are several consecutive sections in the same condition, or less than 1 km if some sections have two or more critical sites.

Figure 2 Critical Site Survey Form

[illegible]

Chapter 3 Selection of Appropriate Solutions

The second stage in the provision of Basic Access is the selection of the most appropriate solution for each critical site. This Chapter explains how this is done.

3.1 Solutions

It is necessary to select the most appropriate solution for each site. Tables 6 and 7 relate each defect from Table 5 to the solutions that can provide Basic Access in each case. The final column gives the Code that can be used to locate full details of each solution in Chapter 8.

A series of solutions is suggested for most defects. In some cases these solutions are alternatives; in others they work in combination. For example, Basic Access can be provided in loose sand either by realigning the road around the area or by constructing a road formation and then an improved surface. Given the wide variety of conditions that can be found in Mozambique, it is not possible to provide, in a single table, the exact solution for each defect that may be found. For this reason Tables 6 and 7 provide recommendations rather than instructions. The user of the Manual should read the details of each solution and seek help, if available, in order to make the most appropriate selection.

An important decision that the user of this Manual must take regarding the choice of spot improvement is whether a track should remain as an unformed track or be improved to an engineered road. The decision depends on factors such as the severity of the defect, the capacity of the organisation to carry out the improvement, the funding available, the traffic volume and the likelihood of rapid increase in traffic, rainfall and the risk of erosion, and the type of local soil. This Manual cannot make this decision for the user, but recommends that if it is likely that an improved track will last for less than 5 years before it suffers further damage, it would be better to improve it now to an engineered road. There are six defects in Table 6 which are affected by this decision.



Track



Road

Do not overlook the sections where 'Inclined track with erosion channels less than 5 cm deep' was recorded on the Form. Wherever this was recorded, diversion humps should be provided.

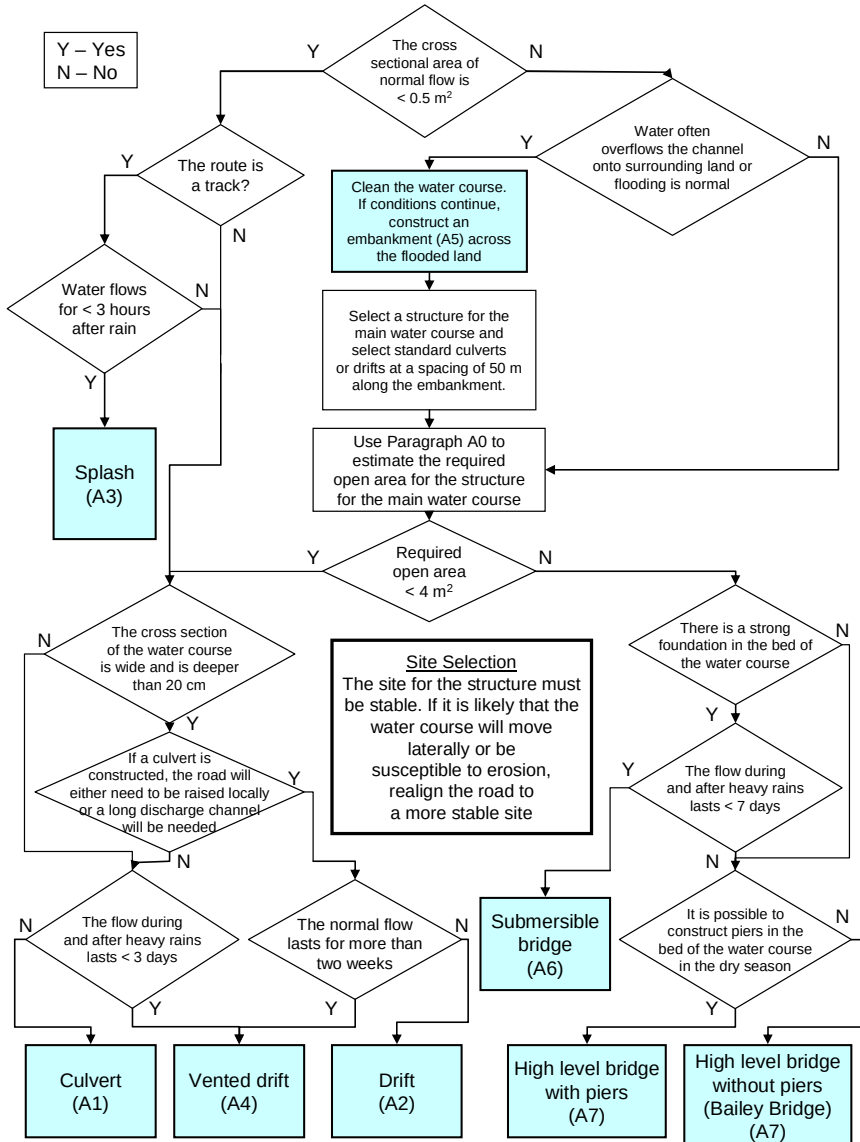
After the selection of solutions, the details in Chapter 8 should be used to design the works in order to meet the requirements of the site.

Defect and Description		Recommended Solutions	Code
Inclined tracks with small erosion channels			
Inclined track with erosion channels less than 5 cm deep		Repair the erosion	B2
		Diversion humps	B3
C r i t i c a l S i t e s	Water courses		
	Existing water course without an adequate structure (with or without water)	Construct a cross drainage structure Drain	Sec. A * B15
	Existing structure severely damaged	Repair the structure or construct a new structure	Sec. A *
	An embankment is narrow and vehicles pass within 50 cm of the edge	Widen the embankment	A5
	Soils, Surfaces and Alignment		
	Longitudinal inclined erosion channels more than 5 cm deep	Track	
		Repair the erosion	B2
		Diversion humps	B3
		Track with gravel	C2
		Realignment	B22
	The road/track has potholes The road/track is low lying and floods during the rains Muddy area which deforms when wet	Road	
		Repair the erosion	B2
		Formation	B9
		Mitre drains	B11
		Improved surface	C3-7
		Realignment	B22
		Track	
		Pothole filling	B7
		Diversion humps	B3
		Interception drain	B14
		Drain	B15
		Realignment	B22
	The surface is clayey and slippery There is dust which is dangerous and unhealthy	Road	
		Pothole filling	B7
		Embankment/fill	B8
		Formation	B9
		Improved surface	C3-7
		Realignment	B22
		Drain	B15
	The surface is clayey and slippery	Track	
		Improved surface	C1-2
	There is dust which is dangerous and unhealthy	Road	
		Formation	B9
		Improved surface	C3-7

C r i t i c a l S i t e s	Area of loose sand	Track	
		Track with gravel	C2
		Road	
	Roots on the surface damage bicycle tyres	Formation	B9
		Improved surface	C3-7
		Realignment	B22
		Track	
		Remove the roots	B5
		Road	
	Conflict between motorised and non-motorised vehicles, poor visibility or vehicles approaching one another find it difficult to pass	Remove the roots	B5
		Embank/fill	B8
		Formation	B9
		Track	
		Grass cutting	B19
		Bush clearing	B20
		Stumping	B21
		Road	
		Separate track	B6
		Widen the formation	B9
S i t e s	Surface is anthill and slippery	Removal of anthill	B4
	Rocky outcrop at the surface	Road on rock	B10
		Improved surface	C3-7
		Realignment	B22
	The road/track has poor alignment, resulting in many critical sites	Realignment	B22
	Drains and Slopes		
	Water flows from the surrounding land and overflows from the side drain onto the road	Clear the side drain	B16
		Improve the side access	B17
		Interception drain	B14
		Construct a cross drainage structure	Sec. A *
	Water flows in the side drain and overflows onto the road	Clear the side drain	B16
		Improve the side access	B17
		Mitre drains	B11
		Construct a relief structure	A1, 2, 3 *
	The depth of erosion in the side drain is more than 10 cm or the erosion is moving laterally towards the road	Repair the erosion	B2
		Mitre drains	B11
		Scour checks	B12
		Construct a relief structure	A1, 2, 3 *
		Drain lining	B13
	Erosion on other slopes is deeper than 10 cm	Repair the erosion	B2
		Bio-engineering	B18

* In Mozambique seven types of cross drainage structure are normally used. Each one suits a different situation and location. Figure 3 below can be used to select the structure which is most appropriate for a particular site.

Table 6 Defects and Recommended Solutions



More information on each structure can be found in Section A of Chapter 8. The design and construction of all structures requires skill and experience. Individuals and groups that do not have this skill and experience should not attempt to construct them.

Figure 3 Recommended cross drainage structures

3.2 Spot improvement strip map

After the appropriate solutions have been selected for each site, they should be shown on a Spot Improvement Strip Map. The Strip Map allows the solutions to be specified. The Strip Map can form part of the contract documentation if the works are to be constructed under contract. The Strip Map is shown in Figure 4 and should be photocopied and expanded before being used. In Section 7.3 an example of a completed Strip Map can be found.

The Strip Map is completed in the following manner.

1. Complete the reference information at the top of the first Strip Map.
2. Write '0+000' next to 'From' in the first column.
3. Next to 'Reference Points' write the details and chainage of whatever reference points were recorded during the survey in the first 100 metre section. These points can be used to locate the critical sites after the removal of the distance posts.
4. Record all the required solutions in the first 100 metres, grouped in the same manner as in Tables 5 and 6 and on the Survey Form: inclined tracks; water courses; soils, surfaces and alignment; and drains and slopes. For each solution it is necessary to record in the three cells the chainage of the critical site, the Code of the solution, and any relevant quantities or measurements of the solution.
5. The quantities are necessary for estimating the costs. If the solution is complex, such as a culvert, it may be necessary to provide more information on a separate sheet.
6. If in a 100 metre section more than one solution in the same group is required, another column should be used, listing again the chainage, the Code and the relevant quantities.
7. Write '0+100' next to 'To' in the final column which is used to record the solutions for the first section of 100 metres.
8. If no solutions are required in a 100 metre section, the same column can be used for the next section. If no solutions are required in a series of sections, the same column may be used for 200, 300 or more metres.
9. Continue with the solutions in the following 100 metre section, returning to step 2 above.
10. Continue until all solutions have been recorded. Although each Strip Map has ten columns, it can cover more than 1 km if solutions are not needed in several consecutive sections, or less than 1 km if more than one solution of the same group is needed in some sections.
11. Any necessary additional information can be recorded in the row at the bottom of the Strip Map next to 'Notes'.

Figure 4 Spot Improvement Strip Map

District	Road	Start	End	Surveyor	Date
		From (km)			
		To (km)			
		Reference Points			
		Chainage (km)			
Inclined tracks with erosion channels < 5 cm		Code			
		Quantities			
	Chainage (km)				
Water courses		Code			
		Quantities			
	Chainage (km)				
Soils, Surfaces and Alignment		Code			
		Quantities			
	Chainage (km)				
Drains and Slopes		Code			
		Quantities			
	Notes				

3.3 Bill of Quantities

If the works are constructed under a contract, it is necessary to list the selected solutions in the form of a Bill of Quantities (BoQ). A BoQ lists the quantities of each required work item and is used by a contractor to submit a price when tendering for a contract. A BoQ also lists some additional items that a contractor is expected to provide, such as insurance for those who are employed on the site, and the construction and removal of the site camp. The BoQ is used by the client to manage the payments to the contractor after the work starts. An example BoQ can be found in Section 4.1.

The works can be divided into contract packages. The size and price of the contract packages should match the capacity of the contractors who are available to carry out the works. In this case a Strip Map and a BoQ are prepared for each contract package.

Chapter 4 Cost Estimate

The third stage in the provision of Basic Access is the estimate of the construction costs of the selected solutions. This Chapter explains how this is done.

There are three methods for estimating construction costs. These are explained in the three following sections.

The estimate of construction costs allows the required works to be assessed against the available funds and allows a comparison to be made between different solutions.

Before organising the construction of spot improvements, the authority responsible for the road should ensure that it has sufficient funds available, not just for the construction, but also for the maintenance of the improvements in the long term.

4.1 Estimate using unit rates

This method is more accurate than the other methods but takes longer and requires more experience and knowledge of the construction process. It is appropriate for those contractors tendering for a contract and for ANE staff who have to assess proposals.

The method is based on a careful estimate of the required resources to complete the works and on the unit rate of each resource (which must be obtained locally). The contractors must ensure that the unit rates used in a proposal will be accurate during the contract period. Material costs may, for example, vary over time and from place to place.

This method is the same as the method used to estimate costs in a full rehabilitation contract, although in spot improvement contracts it is important to consider the additional transport costs between isolated work sites. In addition to this, since the overall cost per kilometre is low, costs such as site management and the construction and operation of the site camp normally constitute a higher proportion of the total costs.

Primary resources: materials, labour and equipment

These are the resources that can be directly attributed to an item of work. These include the weight of cement, the volume of stones and the number of labourer-days necessary to construct a culvert. These primary resources are given for each item of work in Chapter 8. The quantities must be multiplied by the unit cost of each item. The unit costs should take into account the level of utilisation. For example, if it takes an hour to transport the labourers to their work site, and if this time is paid, this non-productive time must be attributed to the cost of the work activity.

Secondary resources: materials, labour and equipment

These are the resources which cannot be directly attributed to a work item. They include the general supply of fuel to the site, hand tools and the tractors used for transporting labourers, materials and equipment from the camp to the work sites. They also include the cost of skilled workers such as masons, who have long term contracts and who must be paid even if they don't have work on a particular day. Secondary resource costs also include the cost of a tractor which is hired for the long term but which can only be used for (say) 3 hours on a given day. The objective is to ensure that all the costs which are required to complete the works are covered in the cost estimate. Contractors sometimes assume that secondary resources are a fixed percentage of the primary resources, but this percentage can vary depending upon the type of the work.

Transport

These are the costs of transport of materials and equipment from their source to the site camp.

Profit

All contractors must make profit in order to remain in business. Given that profit increases the tendered price of a contract, the contractors must strike a balance between the profit that they wish to make and the likelihood of increasing the price such that they do not win the contract. Profit normally varies between 5% and 15% of the total costs.

Indirect company costs / overheads

All companies carry costs that cannot be included in a specific contract. These include office operation costs, administration costs and financing costs due to borrowing money in order to buy materials and equipment and pay salaries before payment is received for the completion of work in the first month of the contract. Overheads normally vary between 30% and 60% of total the contract cost.

Risk

On many contracts there is a risk of not being able to comply with the work programme, for example due to heavy rains or the loss of access to the site. Therefore it is normal for contractors to add costs of around 2 to 10% of the total costs, depending on the contractor's assessment of risk.

Tables 7 a-f show how the costs of a culvert, a drift, a diversion hump, fill/embankment, clearing a side drain and a stabilised track can be estimated. The quantities of each resource are taken from Chapter 8. It can be seen, for example, that the total cost of a culvert is much greater than the cost of only the primary resources.

Resource	Unit	Quantity	Unit cost (example)	Total
Primary resources				
Cement	50 kg	21	190.000	3.990.000
Sand	m ³	3	0	0
Concrete stone	m ³	4	800.000	3.200.000
Masonry	m ³	4	500.000	2.000.000
Steel	kg	42	50.000	2.100.000
Labourers	person-day	20	60.000	1.200.000
Gang leaders	person-day	2	100.000	200.000
Masons	person-day	3	100.000	300.000
Tractor	equip-day	2	1.200.000	2.400.000
Trailer	equip-day	2	300.000	600.000
Water pump	equip-day	10	50.000	500.000
Water tank	equip-day	10	300.000	3.000.000
Cement mixer	equip-day	10	300.000	3.000.000
Roller	equip-day	0	620.000	0
Secondary resources				
Fuel	Litre	140	30.000	4.200.000
Tools	Each	2	250.000	500.000
Transport of materials	Journey	1	500.000	500.000
			Total	27.690.000

* It is assumed that the sand is supplied free of charge by the community or that the contractor obtained the sand for free

Table 7a Estimate of the cost of a single culvert of 0.5 m²

Resource	Unit	Quantity	Unit cost (example)	Total
Primary resources				
Cement	50 kg	2.5	190.000	475.000
Sand	m ³	0.3	0	0
Concrete stone	m ³	0.6	800.000	480.000
Masonry	m ³	0.6	500.000	300.000
Steel	kg	10	50.000	500.000
Labourers	person-day	10	60.000	600.000
Gang leaders	person-day	1	100.000	100.000
Masons	person-day	0.5	100.000	50.000
Tractor	equip-day	0.2	1.200.000	240.000
Trailer	equip-day	0.2	300.000	60.000
Water pump	equip-day	1	100.000	100.000
Water tank	equip-day	1	300.000	300.000
Cement mixer	equip-day	1	300.000	300.000
Roller	equip-day	0	620.000	0
Secondary resources				
Fuel	Litre	8.4	30.000	252.000
Tools	Each	1	250.000	250.000
Transport of materials	Journey	0.2	500.000	100.000
			Total	4.107.000

* It is assumed that the sand is supplied free of charge by the community or that the contractor obtained the sand for free

Table 7b Estimate of the cost of a drift per metre length

Resource	Unit	Quantity	Unit cost (example)	Total
Primary resources				
Cement	50 kg	0	190.000	0
Sand	m ³	0	0	0
Concrete stone	m ³	0	800.000	0
Masonry	m ³	0	500.000	0
Steel	kg	0	50.000	0
Labourers	person-day	30	60.000	1.800.000
Gang leaders	person-day	3	100.000	300.000
Masons	person-day	0	100.000	0
Tractor	equip-day	0	1.200.000	0
Trailer	equip-day	0	300.000	0
Water pump	equip-day	3	50.000	150.000
Water tank	equip-day	3	300.000	900.000
Cement mixer	equip-day	0	300.000	0
Roller	equip-day	3	620.000	1.860.000
Secondary resources				
Fuel	Litre	30	30.000	900.000
Tools	Each	1	250.000	250.000
Transport of materials	Journey	0.2	500.000	100.000
			Total	6.260.000

* It is assumed that the sand is supplied free of charge by the community or that the contractor obtained the sand for free

Table 7c Estimate of the cost of a diversion hump

Resource	Unit	Quantity	Unit cost (example)	Total
Primary resources				
Cement	50 kg	0	190.000	0
Soil	m ³	10	0	0
Concrete stone	m ³	0	800.000	0
Masonry	m ³	0	500.000	0
Steel	kg	0	50.000	0
Labourers	person-day	10	60.000	600.000
Gang leaders	person-day	1	100.000	100.000
Masons	person-day	0	100.000	0
Tractor	equip-day	0.5	1.200.000	600.000
Trailer	equip-day	0.5	300.000	150.000
Water pump	equip-day	0.5	50.000	25.000
Water tank	equip-day	0.5	300.000	150.000
Cement mixer	equip-day	0	300.000	0
Roller	equip-day	0.5	620.000	310.000
Secondary resources				
Fuel	Litre	15	30.000	450.000
Tools	Each	1	250.000	250.000
Transport of materials	Journey	0.1	500.000	50.000
			Total	2.685.000

Table 7d Estimate of the cost of fill/embankment per 10 m³

Resource	Unit	Quantity	Unit cost (example)	Total
Primary resources				
Cement	50 kg	0	190.000	0
Sand	m ³	0	0	0
Concrete stone	m ³	0	800.000	0
Masonry	m ³	0	500.000	0
Steel	kg	0	50.000	0
Labourers	person-day	5	60.000	300.000
Gang leaders	person-day	0.5	100.000	50.000
Masons	person-day	0	100.000	0
Tractor	equip-day	0	1.200.000	0
Trailer	equip-day	0	300.000	0
Water pump	equip-day	0	50.000	0
Water tank	equip-day	0	300.000	0
Cement mixer	equip-day	0	300.000	0
Roller	equip-day	0	620.000	0
Secondary resources				
Fuel	Litre	0	30.000	0
Tools	Each	1	250.000	250.000
Transport of materials	Journey	0.2	500.000	100.000
			Total	700.000

* It is assumed that the sand is supplied free of charge by the community or that the contractor obtained the sand for free

Table 7e Estimate of the cost of clearing a side drain of 100 m

Resource	Unit	Quantity	Unit cost (example)	Total
Primary resources				
Cement	50 kg	0	190.000	0
Sand	m ³	8	0	0
Concrete stone	m ³	0	800.000	0
Masonry	m ³	0	500.000	0
Steel	kg	0	50.000	0
Labourers	person-day	10	60.000	600.000
Gang leaders	person-day	2	100.000	200.000
Masons	person-day	0	100.000	0
Tractor	equip-day	1	1.200.000	1.200.000
Trailer	equip-day	1	300.000	300.000
Water pump	equip-day	0	50.000	0
Water tank	equip-day	0	300.000	0
Cement mixer	equip-day	0	300.000	0
Roller	equip-day	0	620.000	0
Secondary resources				
Fuel	Litre	20	30.000	600.000
Tools	Each	1	250.000	250.000
Transport of materials	Journey	0.2	500.000	100.000
			Total	3.250.000

* It is assumed that the sand is supplied free of charge by the community or that the contractor obtained the sand for free

Table 7f Estimate of the cost of a stabilised track of 100 m

Table 8 shows how a BoQ is produced for the total costs of improvements along an 800 metre length of road, where the work will take 2 months. The work items in Table 8 are the same as those in the example Survey Form and Strip Map in Section 7.3. The unit costs used in the Table are given only for the purpose of the example. In practice the actual costs should be used.

Insurances

Contractors should pay insurance so that if any person employed on the site is injured, they can receive compensation. This item is often left separate on the BoQ so that the client can check that the workers on the project and the public are properly protected.

Construction of the camp

A camp must be constructed before the start of the works and, in most cases, removed at the end. Camps include offices, accommodation, first aid facilities, workshops and storerooms. This item is often left separate on the BoQ so that the client can easily check that sufficient funds are provided for the provision of a camp that is of good quality and suitable for those who will live there and use its facilities.

Operation of camp facilities

Many activities take place within the site camp. These include administration, equipment maintenance, storage of tools and materials, first aid, cleaning and cooking. This requires administrators, mechanics, storekeepers, nurses, cleaners and cooks to be paid and office materials, spare parts, food and other items to be bought.

Site management

These are the overall costs of managing the site, including the supervisors and the foremen. These are supervision costs that are not included in the unit costs of individual work items.

Contingency

It is not possible to predict all the costs that will occur on a construction site. Sometimes works are required in addition to those that were included in the BoQ. The client must pay for these works. Therefore it is common to add 10% to the total cost estimate as a contingency. The contingency is used only when additional work is required. It is not a bonus for the contractor after the work is finished. The additional costs that arise because the contractor is working inefficiently must be paid by the contractor.

Taxes

Commercial organisations must include IVA (tax) in their invoices. This tax is normally included as the final item in a BoQ.

When contractors submit a BoQ as part of a proposal, they often increase the price of those activities for which they think that the quantities are going to increase beyond the estimate in the BoQ (for example if more defects are identified and the contractor is instructed to carry out more work) and reduce the price of other items in order to increase the likelihood of profit. Contractors also often increase the price of items that will be carried out at the start of the contract and reduce the price of other items. This is done in order to increase the contractor's income at the start of the contract, and reduce the amount of interest paid on any loans.

Code	Item	Unit	Quantity	Unit cost (example)	Total
Preliminaries					
1.1	Insurance	Month	3	1.000.000	3.000.000
1.2	Camp				
1.2.1	Construction of the camp	Unit	1	2.000.000	2.000.000
1.2.2	Removal of the camp	Unit	1	500.000	500.000
1.3	Operation of the camp facilities: administrator, mechanic, storeroom, nurse, cleaner	Month	3	7.500.000	22.500.000
1.4	Site management				
1.4.1	Supervisor	Pers-month	3	9.000.000	27.000.000
1.4.2	Foreman	Pers-month	3	3.750.000	11.250.000
A. Cross drainage structures					
A1	Culvert 0.5 m ²	Aperture	1	27.690.000	27.690.000
A1	Culvert 0.5 m ²	Aperture	2	27.690.000	55.380.000
A2	Single drift	Metres	10	4.107.000	41.070.000
A2	Single drift	Metres	12	4.107.000	49.284.000
B. Tracks, Roads and Drains					
B3	Diversion humps	Unit	5*	6.260.000	31.300.000
B8	Fill/embankment	10 m ³	28	2.685.000	75.180.000
B16	Clear side drain	100 metres	0.2	700.000	140.000
C. Improved surfaces					
C1	Stabilised track	100 metres	0.7	3.250.000	2.275.000
				Sub-total	348.569.000
				Profit (10%), Overhead (40%) and Risk (5%)	191.712.950
				Sub-total	540.281.950
				Contingency (10%)	54.028.195
				Sub-total	594.310.145
				Tax (17%)	101.032.725
				Total	695.342.870

* The spacing of the humps, and therefore the total number, depends on the gradient of the track

Table 8 BoQ for a road of 800 m

4.2 Estimate using required quantities

This method is appropriate when part of the detailed design is carried out after the start of the work, or when the works are carried out by a community group on a self-help basis.

The method is based on an overall estimate of the work, supervision, materials and equipment that will be required to construct the selected solutions. The quantities of material for each type of solution are given in Chapter 8. An engineer, technician or other individual with practical site experience is normally able to estimate the other contributions such as tools and equipment which are required to complete the works. Table 9 gives an example of all the resources that can be required for spot improvements along the same 800 metres of road that was used for Table 8. The unit costs used in Table 9 are given only as example. In practice the actual costs prevailing in local markets should be used.

Code	Item	Unit	Quantity	Unit cost (example)	Total
1.0 Preliminaries					
1.1	Insurance	Month	3	1.000.000	3.000.000
2.0 Labour					
2.1	Labourer	Pers-day	810	60.000	48.600.000
2.2	Gang leader	Pers-day	80	100.000	8.000.000
2.3	Mason	Pers-day	20	100.000	2.000.000
2.4	Supervisor	Pers-month	3	9.000.000	27.000.000
2.5	Foreman	Pers-month	3	3.750.000	11.250.000
2.6	Administrator	Pers-month	3	3.750.000	11.250.000
2.7	Mechanic	Pers-month	3	1.500.000	4.500.000
2.8	Driver	Pers-month	6	1.500.000	9.000.000
2.9	Storekeeper	Pers-month	3	1.500.000	4.500.000
2.10	Nurse	Pers-month	3	1.500.000	4.500.000
2.11	Cleaner	Pers-month	6	750.000	4.500.000
3.0 Materials					
3.1	Cement	50 kg	118	190.000	22.420.000
3.2	Sand/soil	m3	300	0	0
3.3	Concrete stone	m3	25	800.000	20.000.000
3.4	Masonry	m3	25	500.000	12.500.000
3.5	Steel	kg	346	50.000	17.300.000
4.0 Tools and equipment					
4.1	Tools	Unit	1	15.000.000	15.000.000
4.2	Tractor	Month	3	9.600.000	28.800.000
4.3	Trailer	Month	3	2.550.000	7.650.000
4.4	Water pump	Month	3	1.700.000	5.100.000
4.5	Water tank	Month	6	3.900.000	23.400.000
4.6	Cement mixer	Month	3	5.100.000	15.300.000
4.7	7T truck	Day	7	1.000.000	7.000.000
4.8	Fuel	Litre	1200	30.000	36.000.000
				Sub-total	348.570.000
				Profit (10%), Overhead (40%) and Risk (5%)	191.713.500
				Sub-total	540.283.500
				Contingency (10%)	54.028.350
				Sub-total	594.311.850
				Tax (17%)	101.033.015
				Total	695.344.865

Table 9 Estimate of the required quantities for 800 m of road

4.3 Estimate using the costs of similar solutions

This method is based on a comparison between the selected spot improvements and other similar improvements that have already been constructed in the area. This method is less exact than the two previous methods but is quicker and needs less detailed experience of the construction process. It is appropriate for a road authority that wishes to obtain approximate costs for planned works. It is not appropriate for a contractor bidding for a contract.

In order to compare the actual requirements with the costs of similar projects, the following questions should be considered.

- Is the size of the improvements similar? Larger solutions cost more.
- Do the solutions use the same materials? Different materials have different costs.
- Are the improvements constructed using the same methods and using the same labour and equipment? Different methods have different costs.
- Do the same contributions by local parties or overheads apply in each case? If in one case the transport costs are free, the total cost would be lower.
- When was the similar improvement constructed? Normally costs increase over time.
- Was the similar improvement constructed nearby? Costs often vary from one place to another.
- Are both improvements part of a programme of work of similar overall size? A single improvement will probably cost more than an improvement that is part of a large programme of work.
- Is the distance from site to the nearest town similar in both cases? Costs are often greater in more isolated locations.
- What types of agreement were made for the construction? The cost of works constructed in a commercial contract will probably differ from the cost of works carried out by a community on a self-help basis.

If the proposed spot improvements are very similar to the works that are to be used for comparison, the costs will probably also be very similar. Any difference in the work, however, will probably result in different costs. It is for the user of this Manual to decide how the differences will affect the overall costs.

Chapter 5 Cost reduction

Chapter 2, 3 and 4 described how to identify critical sites, how to select the appropriate solutions, and how to estimate their costs.

In some cases, there is less money available than the total cost of the selected solutions for the roads in the current programme. It may be necessary, therefore, to reduce the costs. There are four ways to reduce costs.

5.1 Construct more cheaply

The following options can be considered to reduce construction costs:

1. Can the cost of labour be reduced? An allowance agreed locally and paid directly by the DA can be less than the national minimum wage. This option is appropriate only if the local community will benefit directly from the improved road.
2. Can the local communities contribute materials? Some communities can contribute concrete stone, gravel, water and other construction materials. This option is also appropriate only if the contributors will benefit directly from the improved road.
3. Is it possible to implement the spot improvements through a system of self-help (as described in Section 6.1)? This option can be more economical than implementation by a contractor (described in Section 6.2).
4. Can local materials be used as alternatives to materials imported from outside the area? This option should only be used if the local materials are of similar quality to the specified materials.
5. Can the improvements be constructed using a cheaper design? For example, scour checks can be constructed using sticks, stones, bamboo or other materials, depending on what is available, and culvert or bridge walls can be constructed using sacks containing a mixture of sand and cement if stones are not available. Short bridge decks can be constructed using timber if cement or stone is not available. These options should be used only if the result will be of similar quality to the original design.
6. Is it possible to construct alternative but equivalent structures more cheaply? Drifts and submersible bridges are often cheaper than culverts and high level bridges, although they may cause the road to be closed for a few hours or days after rain.
7. Is it possible to construct cheaper surfaces for cross drainage structures? There are alternative surfaces that can be as durable and resistant to erosion as concrete. For example the surface of a drift can be made with flat stones instead of concrete.
8. Will a different alignment result in fewer spot improvements or in cheaper improvements? The decision to realign a road depends on the terrain, the soil types and other factors related to the new alignment.
9. Whatever method is used, on no account should the quality of the work, such as the gravel or the level of compaction, be reduced.

These options and their implications should be carefully assessed by ANE, the DA, the road users and the local community. If options to construct more cheaply are accepted, the total cost of the programme should be re-estimated, using the revised designs.

5.2 Prioritise roads

The cost of a proposed programme of road improvements can be reduced if only the high priority roads are selected.

At the District level, the Development Plans normally include projects from many different sectors, such as roads, water supply, education, agriculture, markets and public health. The plans often include two or more roads. The responsibility for the selection and prioritisation of these projects has been decentralised from the Provincial Government to the Districts. The Districts receive proposals from a series of Local Forums, Community Committees and Consultative Councils at District and Administrative Post level. These institutions use a range of methods to prioritise their projects, including pair-wise comparison, discussions and participatory assessments based on a series of key questions and on the funding available.

At the Provincial level, procedures are available that ANE can use to assess and prioritise road projects, often including in Development Plans those roads which are eligible for funding from the Road Fund. The prioritisation procedures typically use criteria such as the road class, the population served by the road, and the costs of the improvements.

Whichever prioritisation method or procedure is used, the highest priority road is selected first and funds are allocated to it. If funds remain, the second priority road is selected. This process continues until all the available funds have been allocated.

All of the spot improvements identified on the selected roads should be constructed. The roads which were not selected can be included later when there are more funds available.

5.3 Prioritise critical sites

This method identifies the high priority critical sites along each road. The high priority critical sites are improved using the available funds. The lower priority critical sites are improved when more funds are available.

High priority critical sites are identified by altering the definition of Basic Access. For example:

- The acceptable period of closure of a road at a water course after rain can be extended to 3 days. If the traffic level is very low or if there is an alternative route that is not closed, the acceptable period of closure can be extended to a week. This may result in small seasonal water courses remaining unimproved, thus reducing the costs.
- The period when Basic Access applies can be reduced from year round to during the dry season only. This may result in small seasonal water courses and sections of slippery road remaining unimproved.
- The standard vehicle can be changed, for example, from a 3 tonne truck to a 4 wheel drive pick up. This may result in narrower tracks or in some slippery slopes remaining unimproved.

- The standard speed can be reduced. This may result in sections of road which are rough but stable remaining unimproved.

Any reduction in the level of service must be discussed and agreed with all parties. The reduction must still ensure that Basic Access is provided to the majority of users, in accordance with the revised definition.

Some aspects of the definition of Basic Access cannot be changed. The following sites must always be given high priority.

- Sites where the driver, the passengers or other road users are at risk of injury.
- Sites where there is a high probability that a standard vehicle will damage the road beyond normal wear and tear as it passes.
- Sites where there is a high probability that the conditions will deteriorate during the next rains.

5.4 Reduce the road length

Some roads and tracks provide access from a main road or the centre of a community to an area of agricultural production. The importance of the road or track may reduce along its length, with very few people travelling to the far end. Costs can be reduced by reducing the length to be improved.

To use this method, divide the road or track into short lengths between reference points such as water courses or villages. Estimate the costs of the spot improvements required on each section. Allocate funds equal to the estimated costs for the first section. If funds remain, these are available for the second section. The process continues until the allocated funds are equal to the available funds. The sections which receive funds are improved. The remaining sections can be improved when more funds become available.

Chapter 6 Implementation of Spot Improvements

Chapters 2 to 5 explain how critical sites are identified and how appropriate solutions are selected and designed within the available budget.

This Chapter provides a summary of the implementation process, from the identification of the problem through design and construction, to operation and evaluation. It also indicates the parties which are responsible for each phase.

The Chapter has two sections, which cover the two models for the implementation of spot improvements which are normally used in Mozambique. These two models were introduced in Section 1.7.

- Self-help – improvements of a road or track by a community or local organisation without funding or direct assistance from the District or Province.
- Commercial contracting – improvement of a road or track by ANE or the DA and by a contractor using formal contracting procedures

Other implementation models also exist, such as a local organisation in partnership with the DA.

A final section in this Chapter describes how a road which provides Basic Access should be managed in the future.

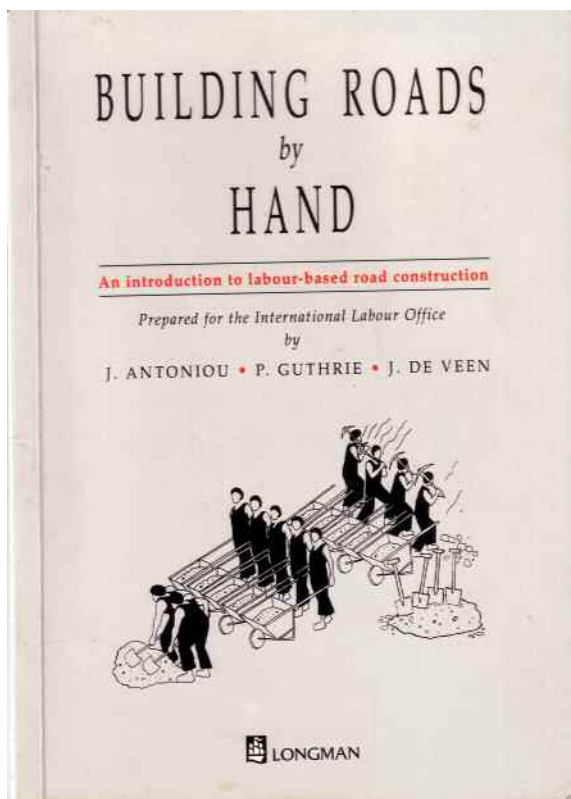
This Chapter does not provide:

- Official procedures and forms used by ANE or DAs when evaluating works contracts.
- Management and organisation of the works (management of the resources, organisation of the works, technical procedures, determination of daily work tasks, the organisation of labour, etc.)

If guidance on site management and organisation is required, it is recommended that the book *Building Roads by Hand* is referred to. This book can be obtained from ANE. Guidance on the construction of roads using labour-based methods can be found in the following chapters:

Chapters

- 1 Basic skills
- 2 Surveying and setting out
- 3 Clearing
- 4 Earthworks
- 5 Drainage
- 6 Gravelling
- 7 Planning
- 8 Reports and control
- 9 Stores
- 10 Starting and organising
- 11 References



6.1 Implementation through 'self-help'

Table 10 shows the phases which should be followed if spot improvements are to be implemented by self-help by a community or local organisation.

Phase	Description
Identification of the problem ↓	A local resident identifies the need for the improvement of an unclassified road or track. If other community members agree with the idea, it is passed on to the decentralised structure of Local Forums, Community Committees and Consultative Councils at District and Administrative Post level. Each body discusses the proposals that they receive using the methods described in Section 5.2, and pass those proposals that they consider to be priority up through the different structures until they reach the DA for possible inclusion in the District Development Plan. At some point in the process the idea is rejected and the community is informed that there are not enough funds, although the DA may have a tractor and trailer available for use. Apart from this, the DA cannot provide any more assistance.
Feasibility study ↓	The community forms a road commission that assesses the funds which are available for the project. The funds can come from individual contributions, an NGO, taxes from agricultural vehicles which use the road, market taxes etc. The commission assesses what non-financial contributions are available from the community. These can include labour and materials such as concrete stone and gravel. The level of the contributions may depend upon whether or not the contributors will be the sole users of the road and whether or not local leaders support the work. The commission appoints a project manager who has some experience in road construction. The project manager makes a survey of the road or track and identifies the critical sites (Ch.2), selects the appropriate solutions (Ch.3) and estimates the costs (Ch.4). It is not necessary to include profit, overheads, risk or tax in the cost estimate. If necessary, reduce the costs (Ch.5) and prepare a final set of solutions.
Design ↓	The project manager produces the final designs for the solutions (Ch.8). The final designs are shown in a Spot Improvement Strip Map. The commission can ask for assistance from ANE or the District Technician during the design and construction phases.

Construction	The commission identifies workers from the community and agrees the working arrangements and rates of pay. The possibility of paying an allowance which is less than the national minimum wage should be considered, with the authorisation of the DA. The workers should be paid using a task based system, in which a standard daily task, requiring about 6 hours of work, is allocated to each worker.
↓	The project manager trains the workers in the necessary site activities and obtains the necessary materials and tools. Some materials and tools can be obtained free of charge from members of the community. The project manager is responsible for organising the works. The project manager also acts as supervisor, ensuring that the works are carried out to a high standard. All ongoing activities should be located as close together as possible. The maximum distance between sites depends on the availability of transport for the project manager.
Operation ↓	Some workers are appointed to continue to work after construction ends in order to maintain the road. The commission must arrange for additional funds for the maintenance.
Monitoring and evaluation	The commission should continue to function after construction ends in order to monitor the following aspects: • Does the road provide Basic Access according to the definitions? • Were the final costs similar to the estimated costs? • Are the spot improvements acceptable to the local people and the road users? • Is the road being well maintained? • Are traffic levels increasing? • Are more critical sites appearing as the traffic levels increase? The replies to these questions will indicate if the spot improvements were well implemented and if further spot improvements should be planned.

Table 10 Implementation process for ‘self-help’

6.2 Implementation through ‘commercial contracting’

Table 11 shows the phases which must be followed if spot improvements are to be implemented by ANE and a contractor.

Phase	Description
Identification of the problem ↓	The need for an unclassified road or track to be improved may be identified either by a local resident, who passes the suggestion through the decentralised structure of Community Commissions, Local Forums and Consultative Councils, or by a member of the DA. The road is assessed in the context of the development objectives of the District. If the road is considered to be sufficiently important, it is included in the District Development Plan. The DA decides to implement the project themselves, or contacts ANE in order to include the road or track in the ANE annual work programme. Alternatively, ANE identifies a tertiary or vicinal road as being in need of improvement and of high priority using criteria such as those described in Section 5.2.
Feasibility study ↓	The DA or ANE surveys the road or track and identifies the critical sites (Ch.2), selects the appropriate solutions (Ch.3) and estimates the costs (Ch.4). The DA or ANE prepares a work programme and BoQ and receives a budget from the local administration or the Road Fund. If necessary, the costs are reduced (Ch.5) and a final work programme is prepared.
Design ↓	The DA or ANE produces the final designs for the solutions in the final work programme (Ch.8) and makes a more accurate estimate of the costs. The work programme is divided into contract packages, whose likely cost and size corresponds with the capacity of the contractors available to carry out the work. The cost of each contract package is estimated. A Spot Improvement Strip Map and a BoQ are prepared for each contract package.
Procurement and negotiation ↓	The DA or ANE prepares the tender documents, using standard forms, and invites contractors with adequate qualifications to bid for the contract packages. The DA or ANE assesses the proposals on technical and financial grounds. The DA or ANE offers the contract to the preferred bidder.

Construction	The contract starts when the contractor agrees the construction programme with the DA or ANE, recruits and trains the local workers, builds site camps and finds sources of materials. Work then begins on the spot improvements. The DA/ANE inspectors either live in the site camps or visit the sites regularly in order to check that all works follow the agreed construction programme and comply with the contractual specifications. ↓ Every month, the completed works are measured and the payments are calculated using the agreed rates. The contractor is paid within the period stipulated in the contract. When all spot improvements in the contract package are completed, the entire works are measured and the final payment is made. The management of the construction of spot improvements at isolated sites is often more difficult than a full rehabilitation contract. The contractors must plan the activities so that the workers and equipment are used as efficiently as possible. The following suggestions can improve efficiency. • Ensure that all resources are available at the site so that each activity can proceed at a constant rate until complete. Avoid delays due to a lack of materials. • Complete all works within a distance of 5 km from the site camp before moving the camp to another location.
Operation	Works contracts normally include a maintenance period of six months or a year after the work is complete. The client retains a percentage of the payment to the contractor ('retention') during this period. After the maintenance period, there is an inspection and if there are no defects the retention is paid to the contractor. ↓ After the maintenance period the road should be placed under routine maintenance. This should include maintenance of unimproved sections.
Monitoring and evaluation	The DA and ANE should monitor the road after the end of construction and assess the follow aspects: • Does the road provide Basic Access according to the definitions? • Were the final costs similar to the estimated costs? • Are the spot improvements acceptable to the local people and the road users? • Is the road being well maintained? • Are traffic levels increasing? • Are more critical sites appearing as the traffic levels increase? • Do neighbouring communities express interest in having spot improvements on their roads? The replies to these questions will indicate if the spot improvements were well implemented. They will also inform the DA/ANE whether or not more spot improvements should be planned on the road as part of a continuous cycle of network improvement.

Table 11 Implementation process for 'commercial contracting'

6.3 The long term maintenance of Basic Access

When a road is fully rehabilitated, it is necessary to allocate maintenance funds to it and ensure that the necessary maintenance is carried out.

When a road is improved with spot improvements, the provision of Basic Access can cause traffic levels to increase. This can cause more critical sites to occur and the need to carry out more spot improvements. After several years, a road which passes through an area of growing economic activity can appear to be almost completely rehabilitated, while a road which passes through an area with less activity can remain as a series of spot improvements along an unimproved track.

The long term management of Basic Access has the following characteristics.

- The regular monitoring of road condition and the identification of new critical sites is important. The local communities can help this monitoring and therefore should be in close contact with the authority which is responsible for the road.
- The maintenance of the road should start as soon as possible after the provision of Basic Access. The combination of maintenance with additional spot improvements in a single contract can be more practical than having separate contracts for these activities on the same road. After construction the spot improvement works should be maintained.
- The maintenance of a road on which spot improvements were constructed includes carrying out some activities along the improved sections and different activities along the unimproved sections. It may be necessary, for example, to grade a section of gravel and clear the drains, while along a section of unimproved track, only grass cutting may be required.
- It is possible that local communities can carry out some maintenance activities such as grass cutting and drain clearing.
- If maintenance and additional spot improvements are not carried out, Basic Access may be lost in a short period of time. The communities, the local government and other parties will lose confidence in the approach and the investment will be lost.
- The spot improvement approach is a practical means of gradually improving an entire network in accordance with the needs of the road users.

Chapter 7 Training

This Chapter provides a set of training and publicity material.

7.1 Posters

This Manual includes two posters. The first contains photographs that explain the benefits of Basic Access to communities and should be displayed in a public place. The second shows many defects that are found on Regional Roads, suggests appropriate solutions and should be displayed in the office of the ANE Provincial Delegation or the DA.

7.2 Presentation

The CD, included within the back cover of the Manual, contains a presentation that gives an introduction to spot improvements and an overview of the Manual. It can be used by various users, including technicians and engineering students. The presentation allows an instructor to discuss each concept and respond to questions before manually proceeding to the next slide.

7.3 Completed Survey Forms and Strip Maps

The Manual includes several forms that can be used to identify critical sites and to select the spot improvements. Figures 5 and 6 show a Survey Form and a Strip Map, completed with the same information, which can be used during training and instruction. The CD also contains blank and completed forms.

7.4 Training course

Since the spot improvement concepts are new to many engineers and technicians in Mozambique, it is recommended that all those who will be using this Manual should attend a training course. Tables 12a-c provide a suggested programme for a training course. The training course should be delivered by an engineer who has been trained and who is familiar with the Manual. Experience in planning, designing and constructing spot improvements is an advantage. The training course is also useful for ANE and DA officials who are involved in the funding of spot improvements, and for contractors who will construct the improvements. It is noted that the timing of the training programme is approximate. The course should be given to no more than 20 trainees at a time, and should be given in a room where participants sit facing one another rather than all in rows facing forward.

Before the start of the course the instructor should, with assistance from local ANE officials, identify a nearby road about 3-4 km long that is appropriate for spot improvements and install distance pegs every 100 metres. This section of road is used for the on-site training exercise.

Figure 5 Example of a completed Critical Site Survey Form

[illegible]

Figure 6 Example of a completed Spot Improvement Strip Map

District

Road

Start

End

Surveyor

Date

	From (km)	0+000	0+100	0+200	0+300	0+500	0+600	0+700	
	To (km)	0+100	0+200	0+300	0+500	0+600		0+800	
Inclined tracks with erosion channels < 5 cm	Reference Points	Church 0+080				Junction w/ track 0+540			
	Chainage (km)			0+200 - 0+300		0+500 - 0+600			
	Code			B3		B3			
	Quantities			100 metres		100 metres			
Water courses	Chainage (km)		0+135	0+250			0+620	0+660	
	Code		A1	A2			A1	A2	
	Quantities		A = 0.5 m ²	L = 10 m			A = 1.0 m ²	L = 12 m	
Soils, Surfaces and Alignment	Chainage (km)			0+220 - 0+290			0+610 - 0+680		
	Code			C1-2			B8		
	Quantities			70 metres			350 m ³		
Drains and Slopes	Chainage (km)							0+725 - 0+745	
	Code							B16	
	Quantities							20 metres	
Notes		The community leader said that the population can provide sand free of charge							

Session	Duration	Details and Notes
Day 1		
Opening	15 minutes	Welcome to the participants by an appropriate person Welcome by the trainer
Introduction	15 minutes	Presentation of all participants Summary of the programme by the trainer
Presentation of the CD	45 minutes	The trainer gives additional details to those in the presentation
Exercise 1 Working in groups	30 minutes	Participants are divided into groups of 4-5 such that all members of a group are familiar with the same roads. Each group selects an actual road which could benefit from spot improvements and answers the following questions: 1. What is the name and number of the road? 2. How is it classified? 3. How long is the road? 4. Who are the main users of the road? 5. What type of vehicles use the road? 6. What is the actual condition of the road? 7. What are the problems that restrict access along the road? 8. What solutions do you suggest to resolve these problems? Paper and pens are given to each group so that they can write their answers.
Morning break	15 minutes	
Exercise 1 Presentations	60 minutes	Each group presents their responses for 5-10 minutes. Other participants can ask questions. The trainer asks questions to see if the groups have understood the concepts in the CD presentation.
Manuals	10 minutes	A Manual is given to each participant.
Reading	20 minutes	Participants have an opportunity to read the Manual.
Lunch	60 minutes	
Discussion Chapters 1, 2 & 3	120 minutes	The trainer explains the main aspects of Chapters 1, 2 and 3 *. All concerns and questions should be discussed.
Afternoon break	15 minutes	
Discussion Chapters 4, 5 & 6	90 minutes	The trainer explains the main aspects of Chapters 4, 5 and 6 *. All concerns and questions should be discussed.
Exercise 2 Preparation for the site visit	15 minutes	Participants are divided into groups of 4-5, each member ideally being from a different Province, District or organisation. The trainer explains how the exercise will be carried out. The trainer explains the survey procedure and how the Survey Forms and Strip Maps should be completed. Survey Forms are distributed.

* The main aspects of each Chapter are given in Table 13.

Table 12a Training course programme – First day

Session	Duration	Details and Notes
Day 2		
Travel to site	15 minutes	
Exercise 2 Surveys	180 minutes	The trainer gives instruction to each group in turn. The groups start their surveys one in front of the other, ideally with a separation of 100 metres. Each group surveys the entire route of the selected road. The members of the group should complete the Survey Form in turn, allowing each member to participate.
Return from site	15 minutes	
Lunch	60 minutes	
Exercise 2 Strip Maps	105 minutes	Each group analyses their survey, selects the appropriate solutions and completes the Strip Map with their solutions. Strip Maps are distributed.
Afternoon break	15 minutes	
Exercise 2 Presentation	90 minutes	Each group presents the solutions that they selected for 10-15 minutes. If possible, their Survey Forms and Strip Maps are projected onto a screen during their presentations. The other participants can then ask questions. The trainer asks questions to see if the Survey Forms and Strip Maps were correctly completed and if reasonable choices were made for the solutions.

Table 12b Training course programme – Second day

Session	Duration	Details and Notes
Day 3		
Exercise 3 Preparation	15 minutes	Participants sit in their groups. The trainer gives information relating to the costs and recommends to each group which method in Chapter 4 they should use.
Exercise 3 Costs	90 minutes	Each group estimates the cost of their spot improvements using the information given and the method recommended.
Morning break	15 minutes	
Exercise 3 Presentation	60 minutes	Each group presents the costs of their selected solutions for 5-10 minutes. The other participants can then ask questions. The trainer asks questions to see if the group correctly estimated the costs.
Exercise 4 Preparation	15 minutes	The trainer gives each group an envelope containing a sheet of paper. The paper has the funds available for the group. In all cases, the available funds are around 50% of the costs estimated by the group. The trainer asks each group to decide which works they will choose to use the available funds, using any of the methods in Chapter 5.
Lunch	60 minutes	
Exercise 4 Cost reduction	45 minutes	Each group decides which works they will carry out.
Exercise 4 Presentation	75 minutes	Each group presents their revised list of solutions and other relevant information for 10-15 minutes in order to explain how they will reduce their costs to the level of the available funds.
Afternoon break	15 minutes	
Discussion	45 minutes	The trainer summarises the Manual and how each group carried out the three phases of the exercise. The trainer then gives the participants the opportunity to ask questions on any aspect of the Manual.
Summary	30 minutes	Each participant is asked in turn for two or three comments on the Manual, along the following lines: • What they learned • How they will change the way in which they work • Suggestions to improve the Manual • Any other comments
Closing	15 minutes	The trainer thanks all participants for their involvement and the course is officially closed.

Table 12c Training course programme – Third day

Chapter	Main aspects to be stressed during training
1	• Mozambique has much rural poverty but funds are limited. It is fair for funds to be spread as widely as possible. • Spot improvements allow rural economies to develop. In order to help these economies over a long period of time, the improvements must be of good quality. • The priority of users of Regional Roads is to be confident that they will arrive (safely) at their destination. The time that the journey takes is less important. • The contractual combination of maintenance and spot improvements is an effective way of providing Basic Access. • The prevention of erosion before it starts helps to provide Basic Access at low cost. • The choice of the standard vehicle depends upon the use of the road and must be made by the authority responsible for the road.
2	• In order for spot improvements to be effective and to reduce rural poverty, the spot improvements must be constructed only at the sites where, in accordance with the definitions, Basic Access is not present. Other sites should not be improved.
3	• The user of the Manual should carefully choose from the list of recommended solutions. Some solutions should be constructed in combination, others are alternatives. • The required size of a cross drainage structure should be calculated using the instructions in Chapter 8. • Spot improvements should always be of good quality.
4	• The three methods for calculating costs are different in terms of required information, level of accuracy and ease of use. • Each method should be used only when indicated. • The quality of construction should never be allowed to drop.
5	• The reduction of costs should not result in a loss of spot improvement quality or in a loss of confidence in spot improvements by local communities and road users.
6	• The Manual explains what to do, not how to do it. • <i>Building Roads by Hand</i> is a useful reference. • Even when using self-help, it is better to organise a site as if it were a commercial operation with a project manager and careful supervision. • It is essential that long term management of spot improvements is planned, funded and carried out.

Table 13 Main aspects of each Chapter

Chapter 8 Catalogue of Recommended Solutions

After the most appropriate solutions have been selected for each critical site, it is necessary to design each solution to meet the demands of the site. This Chapter explains how this is achieved.

The Chapter gives information on the design and the cost estimation of all the solutions listed in Table 6, in Figure 3 and repeated in Table 14 below.

All solutions should comply with national specifications in terms of materials, execution and quality.

All cost estimates are for roads with Type C cross section, as shown in Paragraph B9.

Solution	Code
Section A – Cross drainage structures	
Estimate of the size of a structure	A0
Culvert	A1
Drift	A2
Splash	A3
Vented drift	A4
Embanked crossing	A5
Submersible bridge	A6
High level bridge	A7
Section B – Tracks, Roads and Drains	
Prevention of erosion	B1
Repair of erosion	B2
Diversion humps	B3
Removal of anthill	B4
Removal of roots	B5
Separate track	B6
Pothole filling	B7
Fill/embankment	B8
Formation	B9
Road on rock	B10
Mitre drains	B11
Scour checks	B12
Drain lining	B13
Interception drain	B14
Drain	B15
Clear the side drain	B16
Improve the side access	B17
Bio-engineering	B18
Grass cutting	B19
Bush clearing	B20
Stumping	B21
Realignment	B22
Section C – Improved surfaces	
Stabilised track	C1
Gravelled track	C2
Gravelled road	C3
Bituminous seal	C4
Sand seal	C4-1
Grit seal	C4-2
Otto seal	C4-3
Chip seal	C4-4
<i>Geo Cells</i>	C5
Sand Treated with Emulsion (STE)	C6
Mechanically stabilised clay	C7

Table 14 Contents of the Catalogue

Section A – Cross drainage structures

The most common reason for a loss of Basic Access is the absence of a cross drainage structure or a damaged cross drainage structure.

Where there is no structure, it is necessary to design and construct one. The most important part of the design is the estimate of the required size of the structure. Paragraph A0 describes two methods that can be used to estimate this size. Paragraphs A1-7 then give additional information on the design of the seven most commonly used structures in Mozambique. Figure 3 in Chapter 3 can be used to select the most appropriate structure for a particular site.

The other important subject to be considered during the design is the suitability of the site. The following questions should be asked.

- Is the crossing site on a curve in the water course? If so, the water course may move outwards and damage the structure. If the road crosses the water course at an angle of 90°, construction will be cheaper and will have a reduced risk of erosion and damage.
- Are there signs of erosion or sedimentation? If so, it is probable that these will get worse and damage or block the structure
- Is the water course in strong material? If so, there is less risk of erosion and undercutting.
- Is the water course straight at the point of crossing? If so, construction of the structure will be cheaper.
- Does the water course flood the surrounding land? If so, an embankment will also be needed across the area.
- Are there strong soils or rocks on both sides of the water course? If so, the structure will be able to support the weight of vehicles passing on the road.
- Is the water course in a deep valley? If so, the approaches can be very steep and at risk of erosion and a loss of Basic Access.

After considering these questions, the user of this Manual may decide that it is cheaper to realign the road to a more suitable site.

When a structure is damaged, it is necessary to carefully repair all the defects, and, if necessary, reconstruct parts of the structure. It is necessary to record the type of structure and the extent of the damage in order to be able to estimate the repair costs. Detailed guidance on carrying out the repair works is beyond the scope of this Manual. However, given that many structures become damaged when the structure overtops, it is recommended that the size of all damaged structures is checked using the methods in Paragraph A0 and that the size is increased if the size is found to be too small. In all cases, if a structure is severely damaged, it should be reconstructed.

Small cross drainage structures can be used away from water courses to allow water to cross a road from a side drain where the volume of flow is too high. These are called relief structures. Structures should not be constructed if the individual or the group does not have adequate technical skill and experience.

A0. Estimate of the size of a structure

The most important step in the design of a cross drainage structure is the estimate of the required structure size. Below are methods that can be used to make this estimate.

Cross drainage structures must accommodate the normal flow in the water course during heavy rain. It is not necessary to design the structure for the highest possible water flow because this can result in a very expensive design. Therefore the flow should be calculated such that the structure overtops during exceptional floods, with a return period of about 15 years.

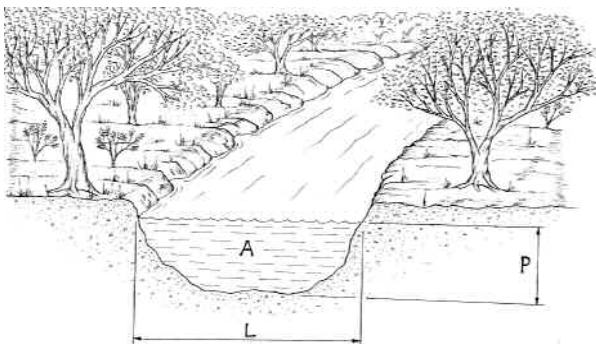
When structures are to be designed for minor roads, the two following methods can be used to estimate the flow in a water course.

1. Observational method

This method is suitable for large water courses with well defined channels. By visiting the site, the maximum level that the water is likely to reach once every 15 years can be estimated. The following sources of information can be used.

- A. Local residents normally know how high water can reach during high floods.
- B. Erosion on the channel sides and debris hanging from tree branches can indicate the maximum water level.
- C. For permanent water courses, assume that the channel is full when in flood.

After determining the maximum water level, calculate the cross sectional area of the water course up to this level. For a U-shaped channel, the cross sectional area is given by:



$$A = \frac{3 \times L \times P}{4}$$

A = the cross sectional area, in square metres

L = the width, in metres, of the surface of the water when in flood

P = the depth, in metres, of the water at its deepest point when in flood

The open area of the structure does not need to be equal to the cross sectional area of the water course in flood. The open area depends on the water speed. Use Table 15 to calculate the necessary open area. To determine the water speed during flood, throw a piece of paper into water and record the time that the paper takes to travel 20 metres along the water course. In the absence of flood, ie during the dry season, assume that the speed is 1 m/s.

Velocity of water in flood	Open area of the structure = X % of the cross sectional area of the water course
High speed (≈ 2 m/s or more)	90
Low speed (≈ 1 m/s)	50
Very low speed	20
Too slow to measure, for example a swamp	5

Table 15 Required open area for a cross drainage structure (1)

2. Rational method

For smaller water courses, it is often difficult to define the channel in which the maximum flow will be estimated. In this case, the required open area of the structure can be calculated from the maximum volume of water which is likely to flow during heavy rains. The volume of water depends on the area of land (the 'catchment') on which the rain falls and eventually flows through the structure, the nature of the terrain and the type of soil and vegetation in the area.

Use Table 16 to calculate the value of C. If a parameter is unknown, use the medium value.

Land	C1	Soil	C2	Vegetation	C3
Very flat	0.10	Sandy	0.15	Dense	0.25
Undulating (medium)	0.14	Medium	0.21	Medium	0.35
Mountainous	0.20	> 30% rocks or paved	0.30	None/light	0.50

$C = C1 + C2 + C3$

Table 16 Calculating C for a water catchment

Estimate the area of the catchment, using a topographic map. These maps are available at DINAGECA or the provincial administration. ANE officials can help to locate the site of the structure and calculate its catchment area on the map.

Use Table 17 to calculate the required cross sectional area for the structure using C and the catchment area. If the catchment area is flat and swampy and remains wet for more than a day after rain, the required open area can be halved.

C	Catchment area (ha) ¹	Required open area (m²) ^{2,3}
0.50	< 5	0.3
	5-10	0.5
	10-20	0.8
	20-50	1.6
	50-100	2.5
	100-250	4.7
	250-500	7.4
0.50 - 0.75	< 5	0.5
	5-10	0.8
	10-20	1.2
	20-50	2.3
	50-100	3.6
	100-250	6.8
	250-500	10.6
0.75 - 1.00	< 5	0.6
	5-10	1.0
	10-20	1.7
	20-50	3.0
	50-100	5.0
	100-250	9.0
	250-500	14.9

1. This method should not be used for catchments greater than 500 ha. ANE should be consulted for larger catchments.

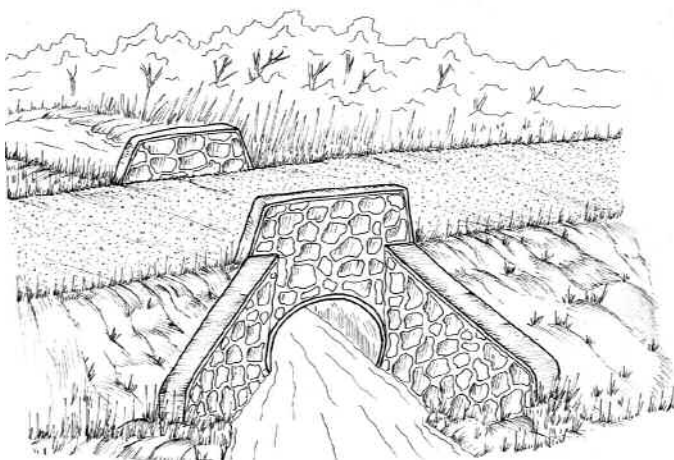
2. This method assumes that a structure will overtop, on average, once every 15 years.

3. Some structures, such as culverts, have a minimum practical size in order to allow maintenance, which may be greater than the figure specified in this Table.

Table 17 Required open area for a cross drainage structure (1)

A1. Culvert

A culvert consists of an inlet, one or more apertures and an outlet. Culverts carry water under the road. Normally they are constructed in narrow water courses but they can have many apertures in order to cross wide and shallow water courses.



Culverts also can be used away from water courses, to allow water to cross a road from a side drain where the volume of flow is too high. This type of culvert is called a relief culvert and should be located at the point where the high volume of water starts to cause erosion or the drain to overtop. Relief culverts should be used only when solutions such as drain clearing and opening a mitre drain are not possible.

Culverts can be constructed in various ways, depending on the materials and the available skills. Inlet and outlet structures are normally constructed with wet masonry. The barrel of the culvert can be constructed in various ways. Options include:

- Walls constructed in wet masonry with a slab of reinforced concrete. This type can have a height up to 1.5 metres and a width up to 2 metres
- Arch constructed in wet masonry, using a variety of temporary supports
- Concrete tubes, constructed alongside the site using a collapsible mould
- A metal arch or tube

Culverts can be constructed using sacks filled with a mixture of sand and cement in areas where it is difficult to obtain stones or rocks.

Culverts should be designed to allow the normal flow in the water course during heavy rain, overtopping only during exceptional rains with a return period of 15 years. Therefore the

most important aspect of culvert design is the open area through which the water flows. The required open area is calculated using the methods described in Paragraph A0.

The minimum recommended size of a culvert opening is a tube of diameter 600 mm. This diameter allows a worker to enter the tube during maintenance to remove obstructions. A greater open area can be obtained by using larger tubes, more tubes or different types of aperture. Larger apertures are more efficient in material usage but can require a deeper channel or more fill to carry the road over the culvert. The use of large diameter tubes can require special equipment to transport and lift them into place.

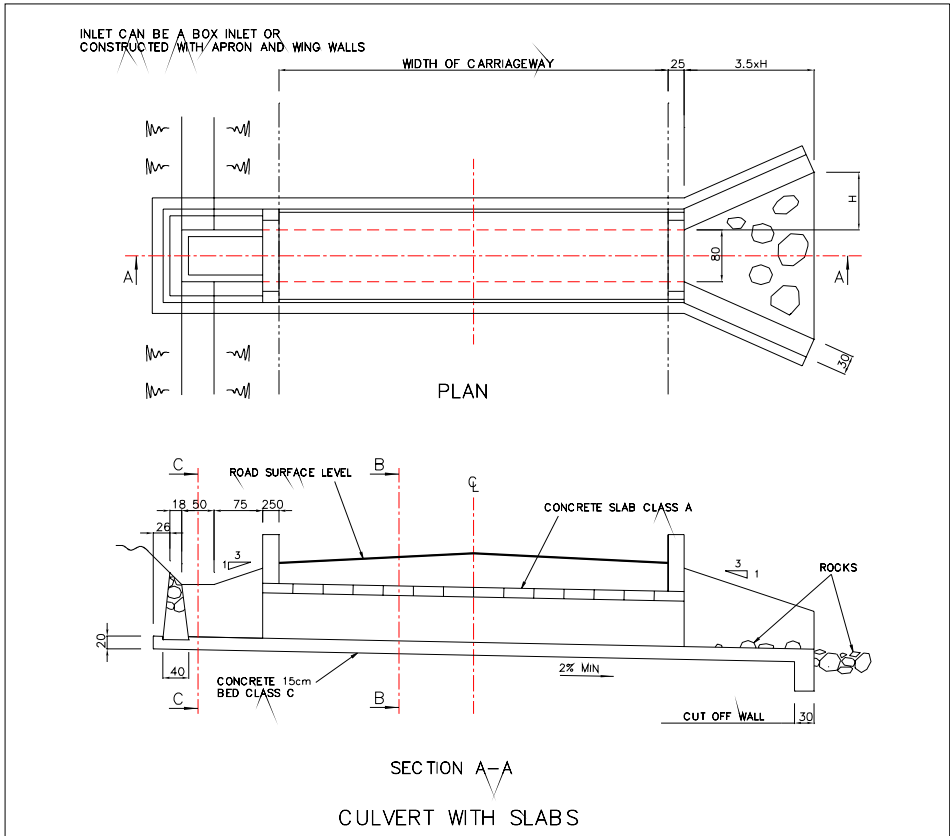
The invert of the culvert must be at the same level as the bed of the outlet channel. However, it is possible to lower the invert of the culvert and the bed of the outlet channel by 30 cm if the latter is no more than 20 metres. If the construction of the culvert needs the road to be raised locally in order to provide sufficient cover between the road and the top of the culvert, it is recommended that a drift is constructed, rather than a culvert, in order to prevent humps in the road.

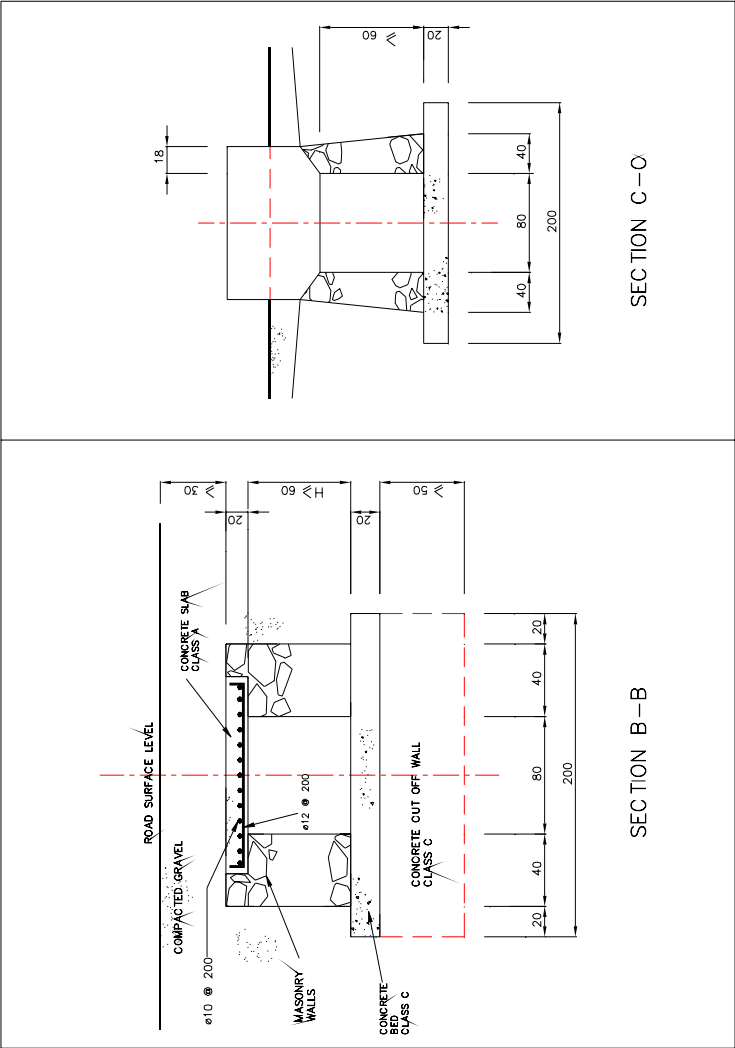
When culverts are located on earth roads, it is recommended that a layer of gravel or other improved surface is placed over the culvert and for 20 metres on either side.

Primary resources for a single opening culvert with slabs
(for each aperture with an open area of 0.5 m²)

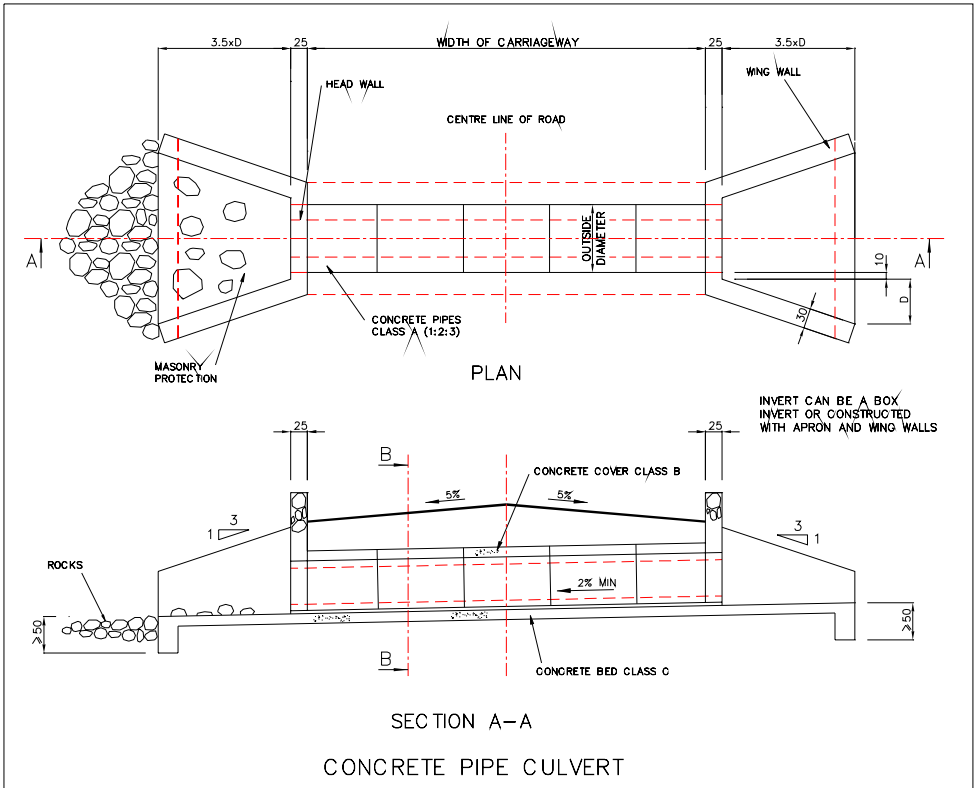
Resource	Unit	Quantity
Cement	50 kg	21
Sand	m ³	3
Concrete stone	m ³	4
Masonry	m ³	4
Steel	kg	42
Labourers	Pers-day	20
Gang leader	Pers-day	2
Masons	Pers-day	3
Tractor	Equip-day	2
Trailer	Equip-day	2
Water pump	Equip-day	10
Water tank	Equip-day	10
Cement mixer	Equip-day	10

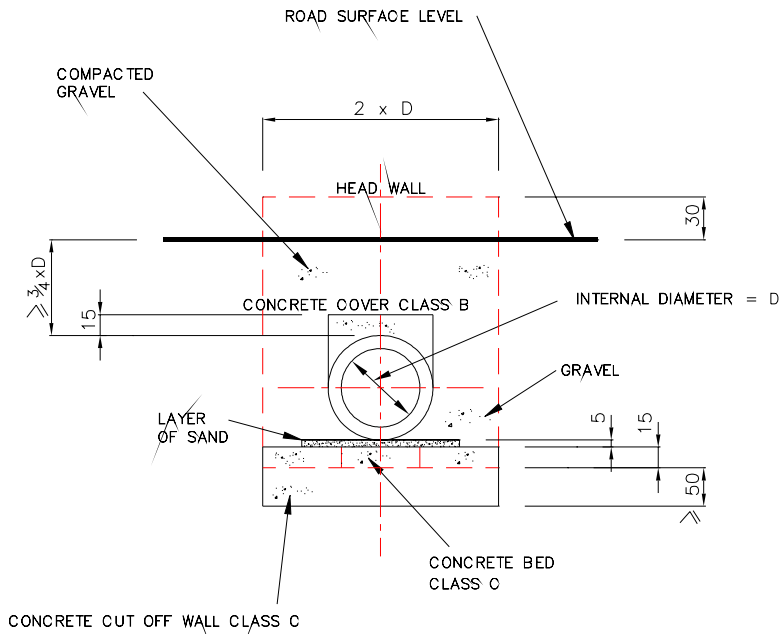
Culvert with slabs





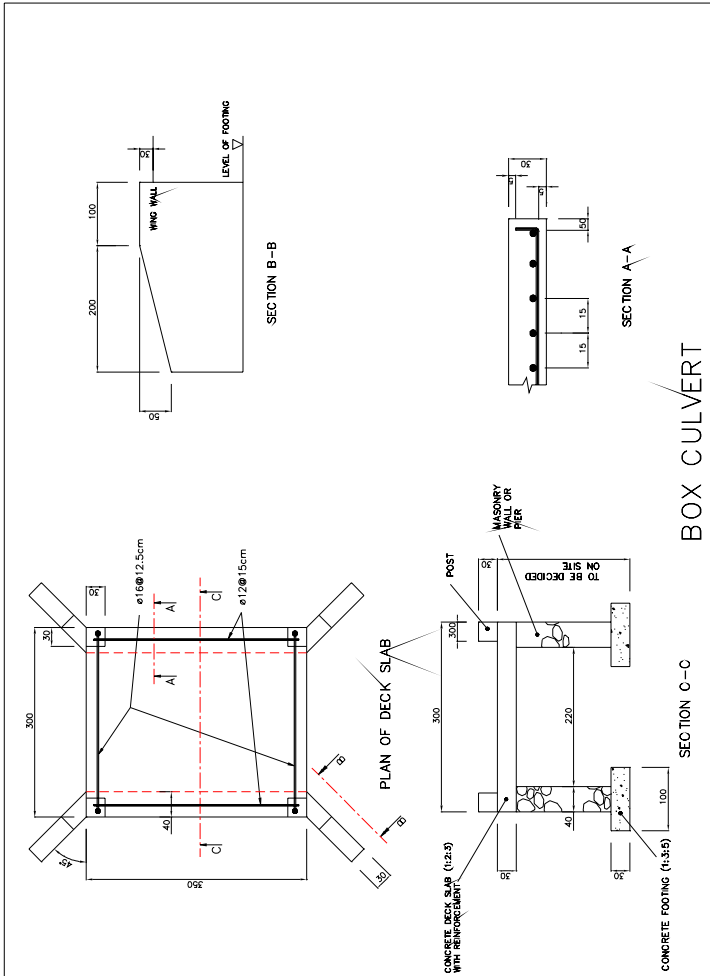
Concrete pipe culvert





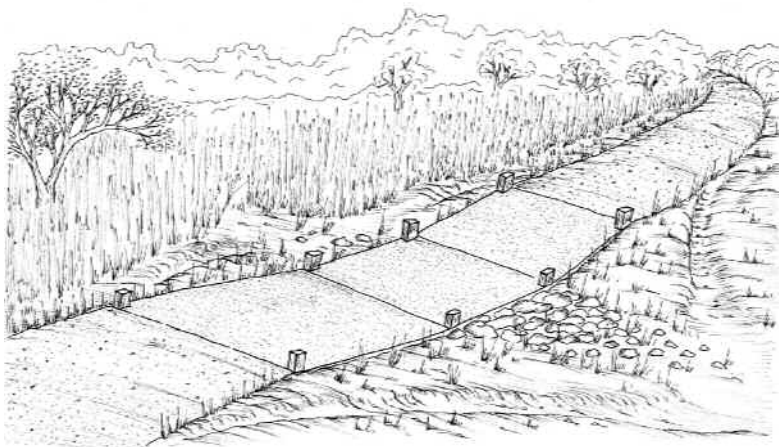
SECTION B-B

Box culvert



A2. Drift

A drift consists of a flat slab and two inclined approach ramps, over which water and vehicles pass. The drift carries water over the road.



Drifts are suitable for shallow water courses with a gentle gradient and at sites where raising the road over the culvert would require the transport of large quantities of earth. Drifts are normally constructed on water courses that flow only during the rains. They can also be used on permanent water courses where the normal flow is small, where the water speed is low, and normal depth is less than 20 cm. Drifts can also be used to reduce the flow in a side drain, in the same manner to a relief culvert. Posts are fixed to indicate the edges of a drift and the water level when it is flowing. It is also possible to construct blocks along the sides of the drift to help pedestrians to pass when water is flowing. Stones are placed in the water course to prevent erosion downstream and upstream of the drift.

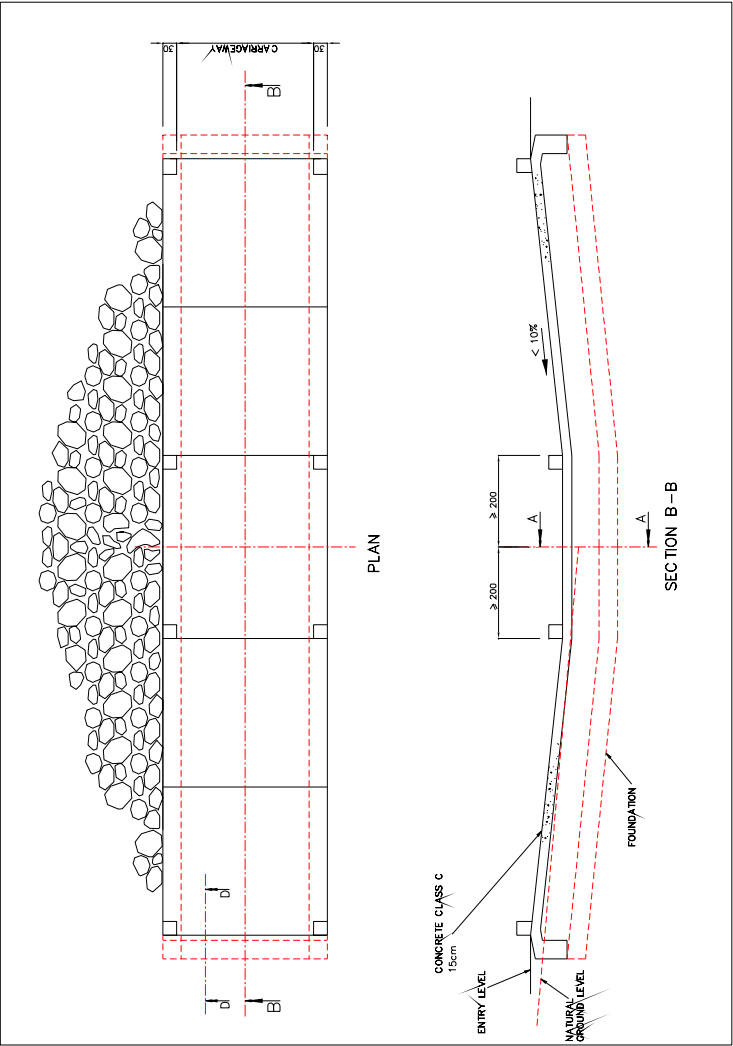
Drifts should be constructed with a shape as close as possible to the shape of the existing water course. The slab should be at the same level as the bed of the water course. The extent of the drift is normally calculated using the Observational method described in Paragraph A0. Drifts should cover the entire width of the water course when water is flowing. It is also possible to estimate the length and depth of the drift through the Rational method, providing the required open area between the approach ramps up to the level of the ends of the ramps. The ramps should extend at least 1 metre beyond the required high point. The cost of a drift is normally estimated per metre length.

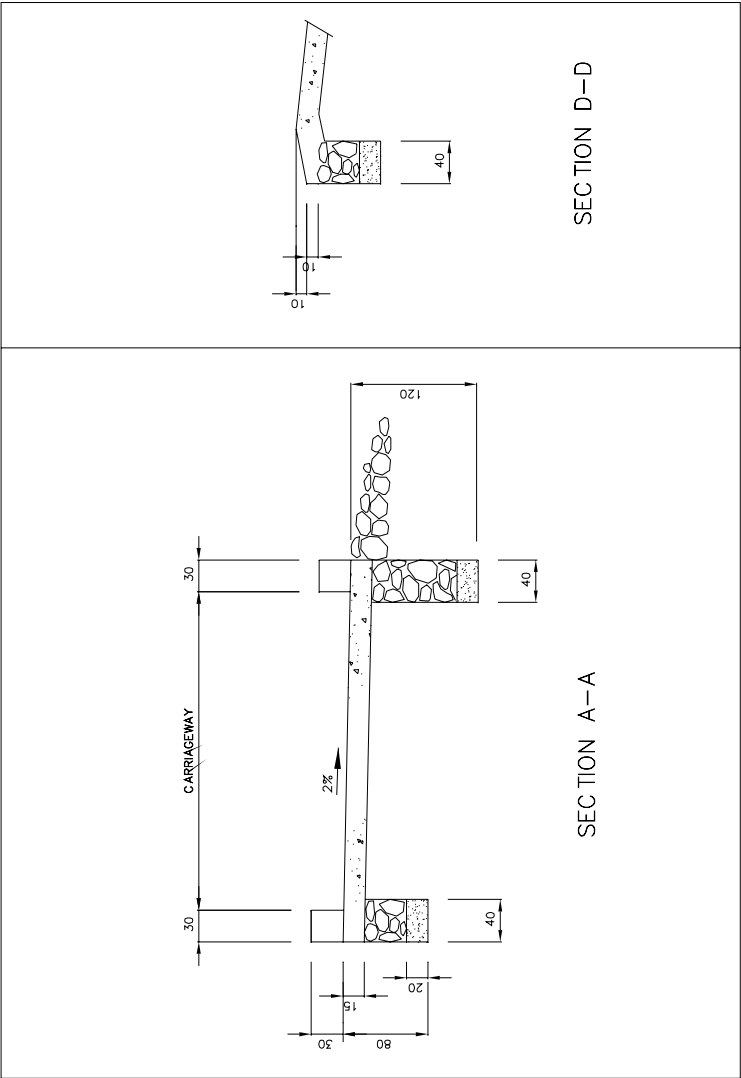
The slab and the ramps should be durable and non-erodible. They can be made from hand placed stone or concrete. When concrete is used, it should be reinforced with steel mesh. Construction joints should be provided so that each slab is no more than 5 metres long.

Vehicles that pass through a drift can drop water on the road for a distance of around 50 metres from the drift. This can make the road surface slippery or suffer from erosion, especially if the road is steeper than 5% and if the water flows over the drift for more than 2 days after rain. In this case, the road should be gravelled or provided with an improved surface for 50 metres in each direction.

Primary resources for a drift (per metre length)

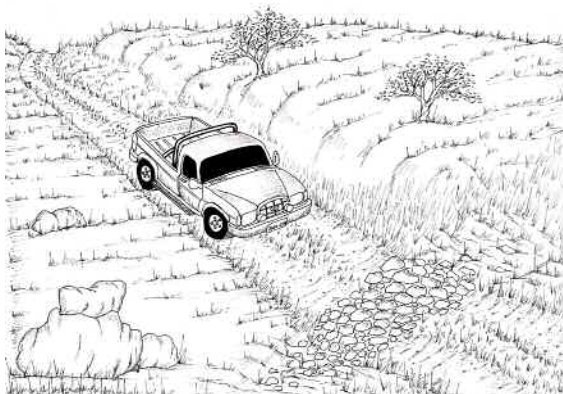
Resource	Unit	Quantity
Cement	50 kg	2.5
Sand	m ³	0.3
Concrete stone	m ³	0.6
Masonry	m ³	0.6
Steel	kg	10
Labourers	Pers-day	10
Gang leader	Pers-day	1
Masons	Pers-day	0.5
Tractor	Equip-day	0.2
Trailer	Equip-day	0.2
Water pump	Equip-day	1
Water tank	Equip-day	1
Cement mixer	Equip-day	1
Roller	Equip-day	0





A3. Splash

A splash is a type of low cost drift. It consists of a shallow channel which is protected against erosion and which passes across a track. Splashes are recommended for low water volumes.



The surface of the channel is protected by a material which is low cost and non-erodible, such as a layer of flat stones. Most low cost surfaces are porous and should not be used if the water flows for more than 3 hours after rain. A splash is suitable for intermittent water courses across tracks.

When the water course is flowing, all the water should pass between the edges of the splash in order to not damage the surface of the track. Normally the maximum length (in the direction of the road) of a splash is 5 metres.

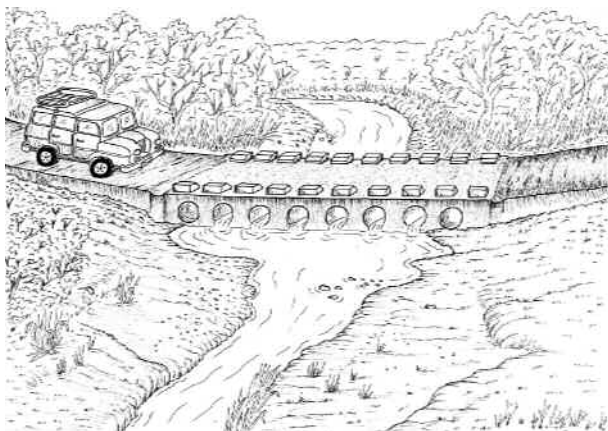
Splashes can also be used to reduce the flow in a side drain, in the same manner as a relief culvert.

Primary resources for a splash (each)

Resource	Unit	Quantity
Stones	m ³	3
Labourers	Pers-day	10
Gang leader	Pers-day	1

A4. Vented drift

A vented drift is a combination of a culvert and a drift. It has apertures for the normal water flow. During heavy rains water can also flow over the slab and the two approach ramps that are constructed over the apertures.



Vented drifts are suitable for carrying roads across water courses which have a base flow for most of the year and which have large flows for less than 3 days after heavy rains.

Vented drifts can be designed using the Observational method described in Paragraph A0. The apertures must allow normal flows to pass. The apertures and the area above the apertures to a depth of 20 cm must allow the water to flow during heavy rains.

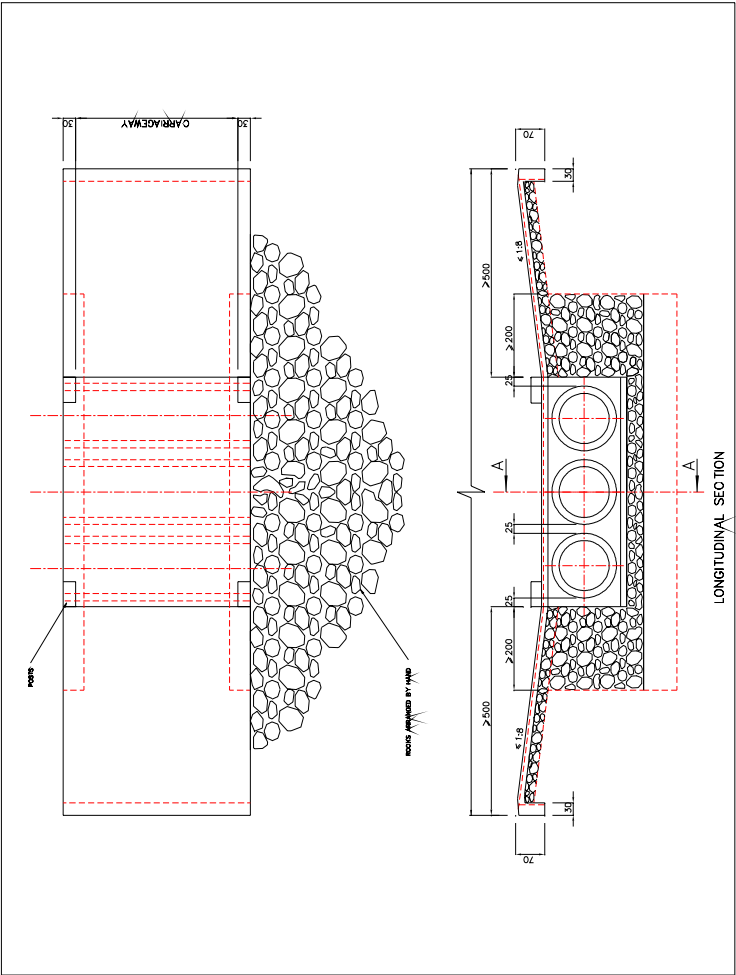
Each ramp should extend, at a gradient no more than 10%, at least 1 metre beyond the highest water level observed during heavy rain. The size of the apertures should be obtained by observing the flow under normal conditions (but not during the dry season).

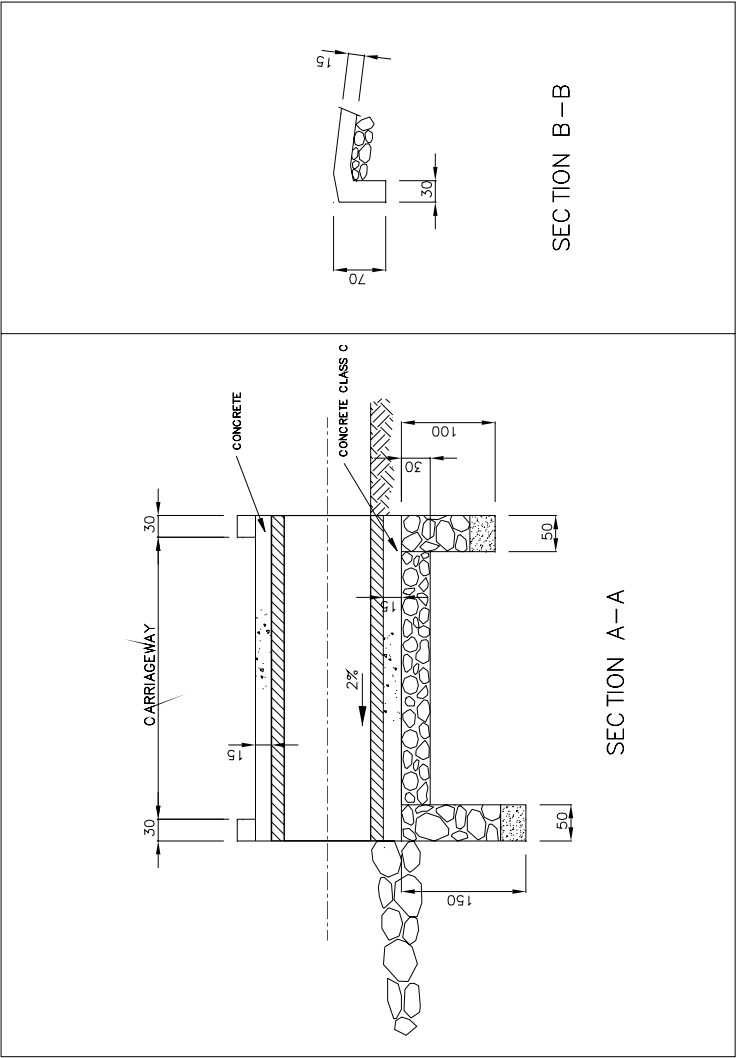
Vented drifts can also be designed using the Rational method, with the required open area equal to the area of the apertures plus the area above the slab up to a level at a point 1 metre before the end of the ramps.

The invert of the apertures should be at the same level as the outlet channel. Posts are fixed to indicate the edges of the structure and the water level so that vehicles can pass when water is flowing over the slab. It is also possible to construct blocks along the sides of the vented drift to help pedestrians to pass when water is flowing. Gravel or an improved surface should be placed on the road for 50 metres in each direction.

Primary resources for a vented drift (per aperture and per metre of approach ramp)

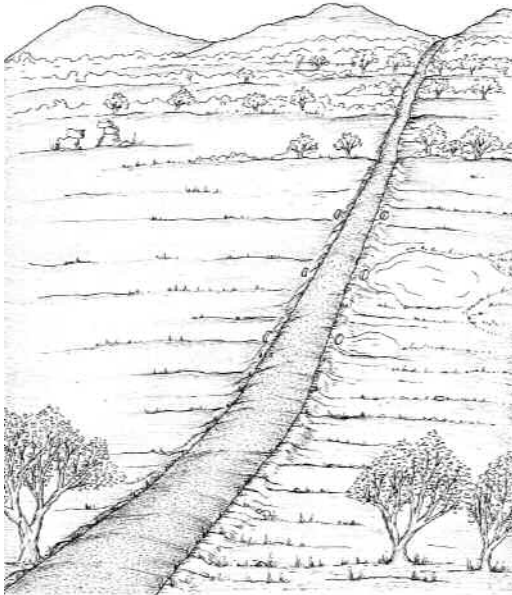
Resource	Unit	Quantity (per aperture)	Quantity (per metre of ramp)
Cement	50 kg	21	2.5
Sand	m ³	3	0.3
Concrete stone	m ³	4	0.6
Masonry	m ³	3	0.6
Steel	kg	42	10
Labourers	Pers-day	20	10
Gang leader	Pers-day	2	1
Mason	Pers-day	3	0.5
Tractor	Equip-day	2	0.2
Trailer	Equip-day	2	0.2
Water tank	Equip-day	10	1
Cement mixer	Equip-day	10	1





A5. Embanked crossing

An embanked crossing is a length of raised road which crosses a wide and shallow water course, an area where a water course floods during the rains or a flat area with poor drainage. An embanked crossing has a length of embankment and one or more cross drainage structures.



Embankments can normally be constructed with soils that are found near to the road. The soil that is used should form a strong and stable layer when compacted. Top soil and loose sand should be avoided.

The road surface on the embankment must remain dry all year round. Therefore the height of the embankment depends on the water level in the area. The top of the embankment should be at least 50 cm above the highest water level. In flat areas with poor drainage, it can be sufficient to construct an embankment only 50 cm high. The soil in the embankment should be spread in layers 10-15 cm thick and well compacted. The surface should be formed to give a camber. An improved surface should be provided, such as gravel (C3) or Geo-Cells (C5), in order to support the weight of the vehicles that pass along the road and to protect the surface of the road against erosion. Grass should be planted or allowed to grow on the sides of the embankment in order to protect the sides against erosion.

An embanked crossing normally needs structures to allow the water to flow. The required size of the apertures can be calculated using the Observational or Rational method described in Paragraph A0. Structures should be constructed along the embankment at intervals of no more than 50 metres. The deepest part of the crossing should have the largest structure.

Some embanked crossings, for instance across an area where a water course floods over the land, are constructed with a short length of the embankment at a lower level. The short lengths of embankment act as a drift and can prevent large pieces of debris from blocking the openings in the embankment when the water course is flooding. The low lengths of embankment should be protected against erosion when the water flows over them.

Primary resources for an embanked crossing
(per 10 m³ of material and without the cost of the necessary structures)

Resource	Unit	Quantity
Soil	m ³	10
Labourers	Pers-day	10
Gang leader	Pers-day	1
Tractor	Equip-day	0.5
Trailer	Equip-day	0.5
Water pump	Equip-day	0.5
Water tank	Equip-day	0.5
Roller	Equip-day	0.5

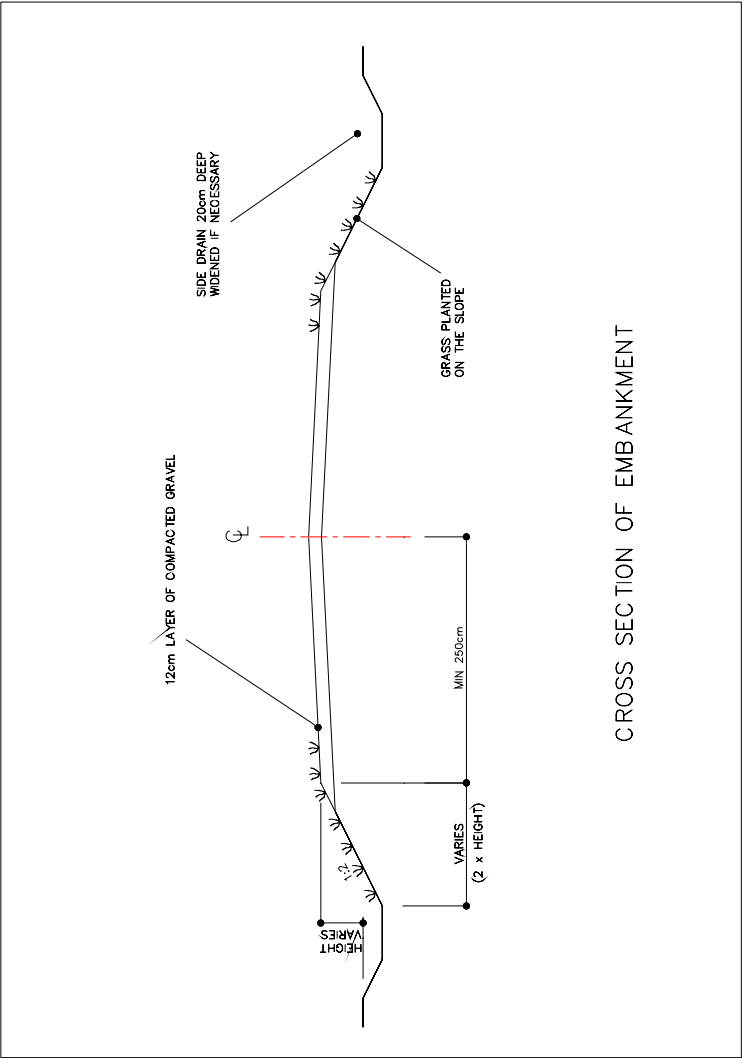
Over time, erosion and other factors can make the embankment narrow, requiring vehicles to pass dangerously close to the edge (i.e. within 50 cm).

The embankment must be widened in the following manner:

1. Decide if the embankment needs to be widened on one or both sides
2. Wait until the site is as dry as possible
3. Remove vegetation and loose soil from the side of the embankment to 1 metre beyond the base
4. Cut steps in the embankment slope. Each step should have a horizontal surface at least 50 cm wide and should be cut into stable, well compacted soil.
5. Place and compact suitable material in layers 15 cm thick to the required width of the embankment
6. Shape the slope and protect it with suitable vegetation
7. Reform the road to its original width, with an improved surface such as gravel (C3) or Geo-Cells (C5)

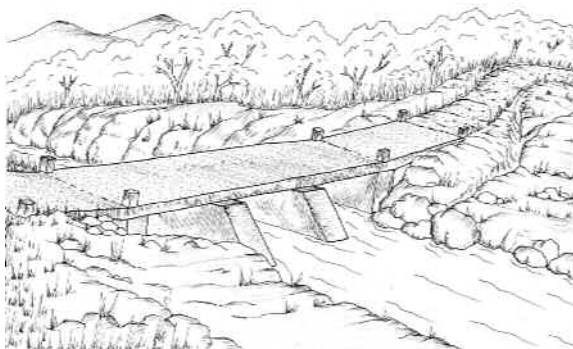
Primary resources for widening an embankment (per 10 m³ of material)

Resource	Unit	Quantity
Soil	m ³	10
Labourers	Pers-day	15
Gang leader	Pers-day	1
Tractor	Equip-day	1
Trailer	Equip-day	1
Roller	Equip-day	1
Water tank	Equip-day	1



A6. Submersible bridge

A submersible bridge is a vented drift with large apertures. It has apertures for the normal water flow. During heavy rains the water can also pass over the deck and the two approach ramps that are constructed over the apertures.



Submersible bridges allow roads to cross water courses which have large flows for most of the year and very large flows lasting for up to a week during and after heavy rains.

Posts are fixed to indicate the width of the structure and the level of the water so that vehicles can pass when water is flowing over the deck.

Submersible bridges should be designed using the Observational method described in Paragraph A0. The apertures must allow the normal flow of water to pass. The apertures and the area above the apertures up to a depth of 20 cm must be sufficient to allow the water to flow during heavy rains.

Each approach ramp should extend at least 2 metres beyond the highest water level observed during heavy rains. The level of the deck should be sufficiently high to allow the normal flow of water but must also be as low as possible to ensure that the structure is stable.

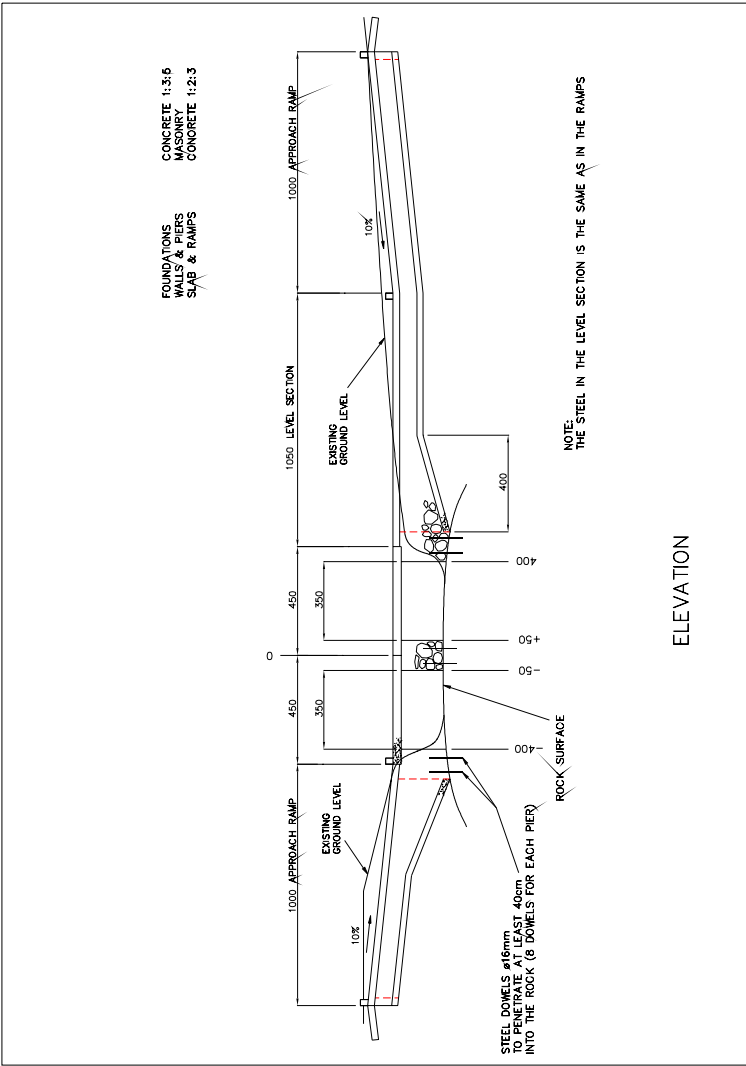
It is preferable that all the pillars are seated on a rock foundation. If the bridge is fixed on a rock foundation with steel dowels, it can be up to 2.5 metres high. If the bridge is not fixed with steel dowels, it can be up to 1.5 metres high.

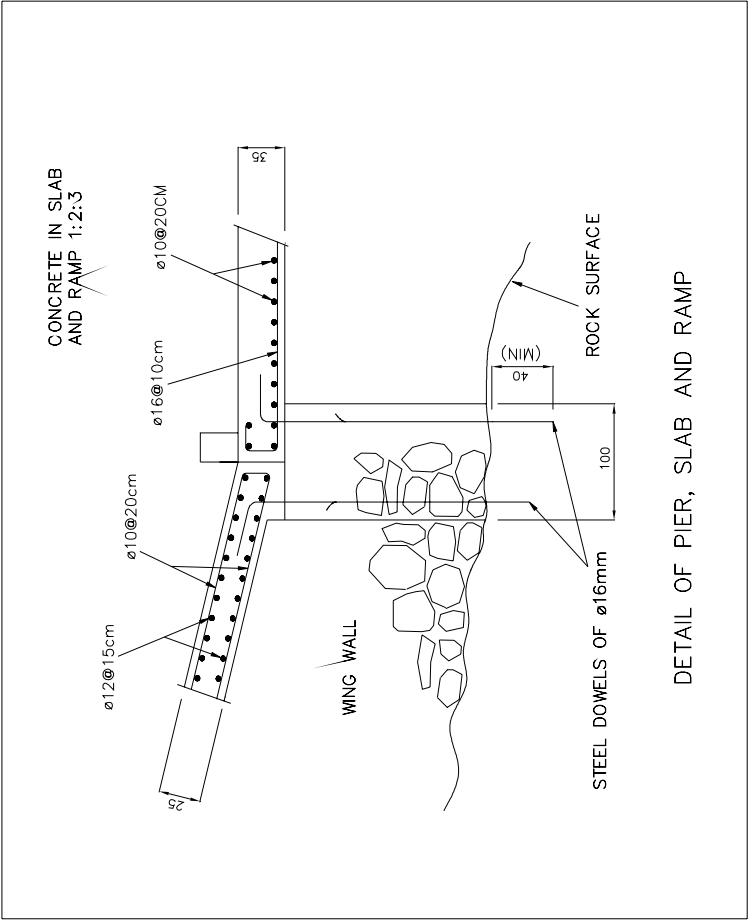
If it is not possible to provide sufficient open area with a submersible bridge of 1.5 or 2.5 metres height, it is necessary to construct a high level bridge (A7).

The design of submersible bridges should be approved by ANE before construction. ANE should inspect the structure every year and check that maintenance and repairs are being carried out as required.

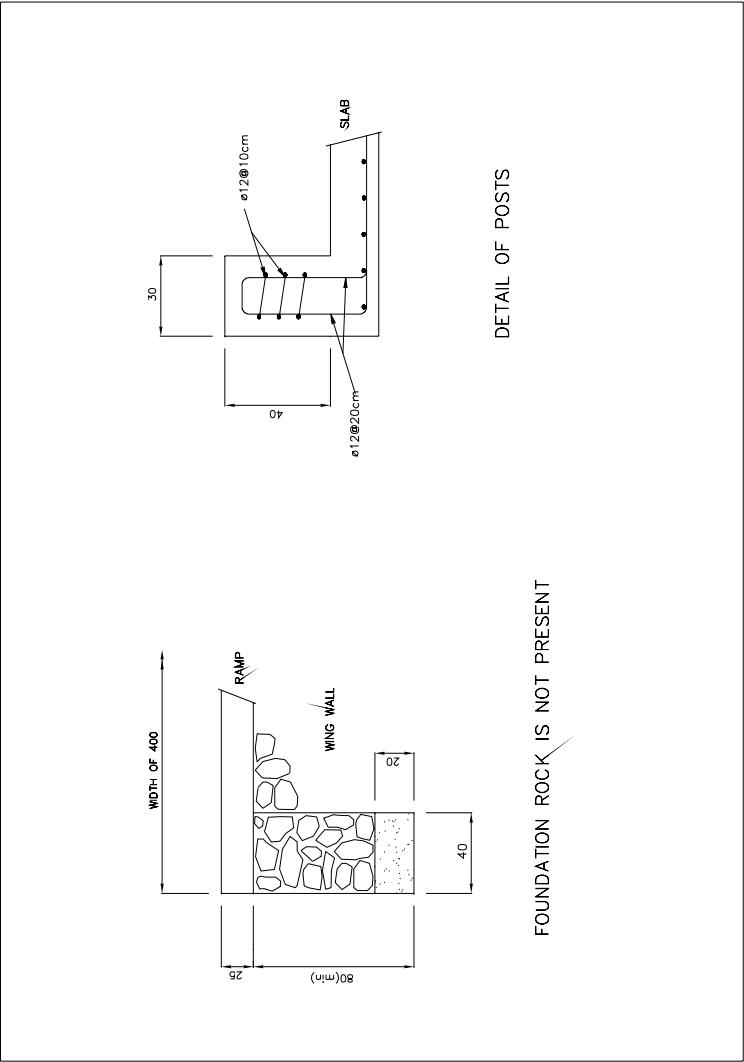
Primary resources for a submersible ridge
(per aperture of 2 x 5 metres and per metre of approach ramp)

Resource	Unit	Quantity (per aperture)	Quantity (per metre of ramp)
Cement	50 kg	88	2.5
Sand	m ³	9	0.3
Concrete stone	m ³	12	0.6
Masonry	m ³	16	0.6
Steel	kg	1,200	10
Labourers	Pers-day	60	10
Gang leader	Pers-day	10	1
Masons	Pers-day	20	0.5
Tractor	Equip-day	10	0.2
Trailer	Equip-day	10	0.2
Water tank	Equip-day	10	1
Cement mixer	Equip-day	10	1



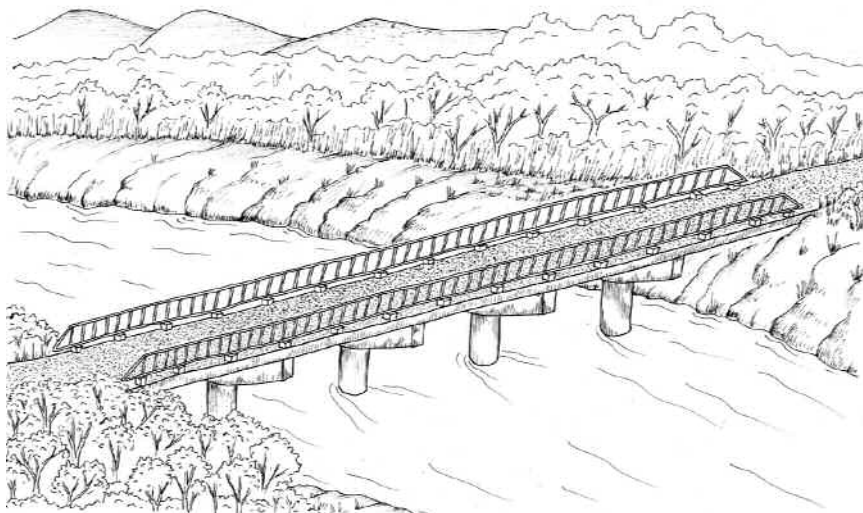


DETAIL OF PIER, SLAB AND RAMP



A7. High level bridge

A high level bridge allows a road to cross a wide or deep water course without the water passing over the top of the deck, even during heavy rain. The design of high level bridges is beyond the scope of this Manual. ANE should be contacted for assistance if the road crosses this type of water course. Metal bridges are often used at this type of site in Mozambique.



Section B – Tracks, Roads and Drains

This Section provides guidance on the design of a variety of spot improvements that can be used to provide Basic Access along tracks and roads. Some of the spot improvements are to the carriageway on which the vehicles travel; others are to the drainage system, given that flowing or standing water is often the reason for a site becoming critical. For this reason the Section begins with general guidance on the prevention of erosion.

B1. Prevention of erosion

Although this paragraph does not offer a specific solution to an identified defect, it contains general guidance on the prevention of erosion and should be read before carrying out any spot improvements.

Erosion is a key problem in Mozambique. Erosion has the following impacts.

- Top soil is lost and soil fertility is reduced
- Drains and water courses can become blocked with sediment
- Drains overtop and water runs along the surface of the road
- Erosion damages the surface of the road or track, causing a loss of Basic Access
- Erosion reduces the level of the road or track, thus attracting more water from the surrounding land and causing more erosion and weakening of the surface

The damage caused by erosion, although small at first, can increase rapidly. The prevention of erosion is much cheaper than the repair of damage caused by erosion. When access is important and funds are limited, it is particularly important to prevent erosion before it occurs and also to carry out prevention measures immediately after any erosion damage has been repaired.

The main cause of erosion is the water that accumulates and then flows towards a road or track. Inclined roads and tracks are especially vulnerable to erosion. Erosion can therefore be prevented by stopping water from flowing to the road and by stopping water from accumulating on the road.

Erosion damage caused by water flowing can be prevented in the following ways.

- If the water is flowing onto the road from the surrounding land, dig an interception drain (B14) to intercept and divert the water onto the surrounding land or into a water course.
- If the water is flowing along an inclined track, construct diversion humps (B3) to divert the water from the track onto the surrounding land. However, if the track is steep, it might be necessary to improve the track to a road (B9) and provide an improved surface (Section C).
- If the water is flowing along an inclined road, reconstruct the formation to a camber of 5% in order to shed the water into the side drains. It might also be necessary to provide an improved surface (Section C) if the surface is weak or the road is steep.
- If the water is causing erosion in the side drain or is making it overtop, reduce the volume of water by constructing mitre drains (B11) to divert the water onto the surrounding land, or relief culverts to carry the water to the opposite side of the road. Reduce the water speed by constructing scour checks (B12) in the side drain.
- If the water is flowing from a side drain towards the road surface, check that the side drains are clear (B16).
- Areas of bare soil are vulnerable to erosion. All surfaces, including the side slopes of an embankment, should be protected using bio-engineering techniques (B18).
- Provide drains only where they are necessary to collect water from the road or from the surrounding land. When a road passes across side-long ground, do not provide drains on the downhill side.

The prevention of erosion is the most important consideration in the design and construction of spot improvements.

B2. Repair of erosion

Erosion can often cause Basic Access to be lost, whether the water is flowing along the surface of the road or track, or it is flowing in the side drain and moves laterally towards the road. The first requirement is to improve the drainage system to prevent erosion. Various ways of achieving this are described in Paragraph B1.

After the drainage has been improved, the erosion can be repaired. The eroded area should be cleared down to firm material. Soil should then be placed in layers 10-15 cm, watered and compacted.

Primary resources for the repair of erosion (per m³ of erosion)

Resource	Unit	Quantity
Labourers	Pers-day	1
Gang leader	Pers-day	0.1
Roller	Equip-day	0.1
Water tank	Equip-day	0.1

B3. Diversion humps

The level of a track is often slightly lower than the level of the surrounding land. When it rains, water accumulates on the surface of the track. Since a track does not have any camber, this water is not shed onto the surrounding land. If the track is on a longitudinal gradient, this water will flow along the track and in most cases will erode the surface. Towards the end of a long slope, large quantities of water can accumulate and cause major damage.

In order to prevent this erosion occurring, it is necessary to ensure that the water does not accumulate and that it does not flow along the surface. One low cost solution is to construct diversion humps along the inclined track. A diversion hump is a ridge constructed diagonally across the surface of the track that diverts water to the side of the track, together with a mitre drain that carries the water from there onto the surrounding land.



It is recommended that diversion humps are constructed on all tracks that are sufficiently inclined that it is possible for water to flow longitudinally and cause erosion on the surface.

By removing water from the surface of a track, diversion humps can prevent the accumulation of water that causes large potholes to form at the low points on the track.

Diversion humps should be constructed at a spacing according to Table 18, although this can be reduced if longitudinal erosion continues to occur. In order to estimate the gradient of the track, look horizontally to a point on the surface of the track and then divide your own height by the distance to the observed point and multiply by 100.

Gradient of track (%)	Spacing of diversion humps (m)	
	Clay	Sand
< 2	100	50
2-4	60	30
4-6	40	*
6-8	25	*
> 8	*	*

* The track should be improved to a road

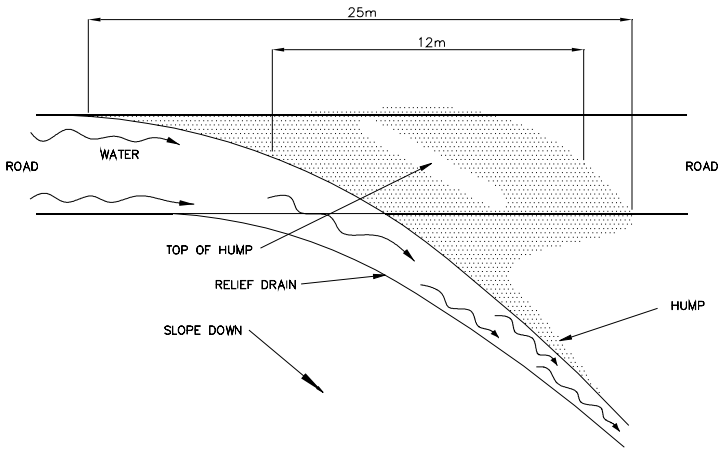
Table 18 Spacing of diversion humps

If the diversion humps do not stabilise a track against erosion, it may be necessary to realign the track or to improve the track to a road with an improved surface.

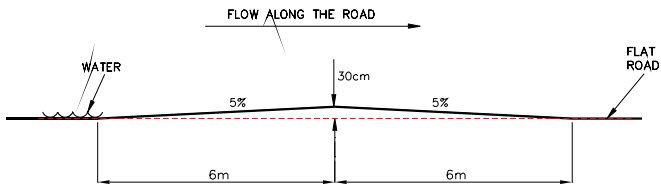
Primary resources for a diversion hump with a mitre drain of 10 metres

Resource	Unit	Quantity
Labourers	Pers-day	30
Gang leader	Pers-day	3
Water pump	Equip-day	3
Water tank	Equip-day	3
Roller	Equip-day	3

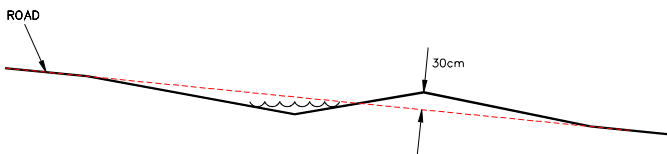
DRAINAGE HUMPH



PLAN



SECTION – FLAT ROAD



SECTION – INCLINED ROAD

B4. Removal of anthill

Anthills can occur along the line of a road or track. They can cause a series of problems such as:

- Blocked drains and diversion of water onto the road surface
- Slippery surface which is dangerous and which can prevent access



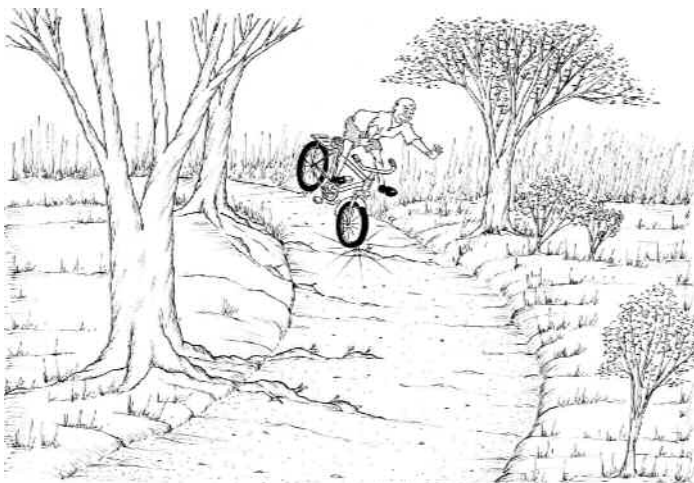
When these problems arise, it is necessary to remove the anthill and restore the shape of the road or track. This is achieved by digging the anthill to a depth of 15 cm across its entire area, then refilling with soil to the original level, watering and compacting. If available, measures should be taken to kill the anthill so that it does not regrow in the road or track.

Primary resources for the removal of anthill (per m³)

Resource	Unit	Quantity
Labourers	Pers-day	2
Gang leader	Pers-day	0.2
Roller	Equip-day	0.2
Water tank	Equip-day	0.2

B5. Removal of roots

Roots protruding from the surface of a track or road can damage bicycle tyres and injure cyclists. They can also damage the tyres of motorised vehicles. The removal of these roots is a low cost solution which can greatly benefit road users.



Dig around the roots and cut them to a depth of 15 cm below the surface. Fill the hole with strong material, water and compact.

Primary resources for the removal of roots (per square metre of removed material)

Resource	Unit	Quantity
Labourers	Pers-day	1
Gang leader	Pers-day	0.2
Roller	Equip-day	0.2
Water tank	Equip-day	0.2

B6. Separate track

On most Regional Roads in Mozambique, the volume of traffic is low and vehicles and other road users rarely come into conflict. However, conflict can occur between road users in the following situations:

- The road is narrow and vehicles cannot easily pass one another
- Visibility is limited due to poor alignment or high vegetation growing along the sides of the road
- There are many pedestrians and non-motorised vehicles that are vulnerable when in conflict with motorised traffic

If these problems arise on a track, it is necessary to cut vegetation on both sides in order to improve visibility and allow vehicles to pass in safety (B19, B20 & B21).

If these problems arise on a section of road, it may be necessary to widen the road, although this can be expensive. One cheaper solution is to construct a new track alongside the road for pedestrians and non-motorised traffic. This process involves the determination of an appropriate alignment, grass cutting (B19), bush clearing (B20), stumping (B21), levelling the soil surface and, where necessary, constructing a drainage system including diversion humps (B3) and drains (B15).



Primary resources for the construction of a separate track (per kilometre)

Resource	Unit	Quantity
Labourers	Pers-day	250
Gang leader	Pers-day	25

B7. Pothole filling

Potholes are a common reason for a loss of Basic Access in flat terrain. These occur in low areas where water accumulates and weakens the soil. When vehicles pass through these areas, they displace the weak soil, gradually creating a wide and deep pothole.

In order to provide Basic Access and ensure that it lasts for the following years, it is first necessary to improve the drainage to reduce the amount of water that accumulates in the low area. This is done by constructing diversion humps (B3) on the track, mitre drains (B11), interception drains (B14) to intercept water flowing over the surrounding land, and other drains (B15) where it is possible to drain the water away from the area. If these measures do not succeed, it may be necessary to form a road (B9) and construct an improved surface (Section C) across the area where the potholes form. It may also be necessary to raise the level of the road using an embankment (B8).

After the drainage has been improved, the original shape of the road or track can be restored. This is done in the following way. The pothole should be cleared of water and loose or soft soil down to strong material. Good soil should be placed in layers of 10-15 cm thick, watered and compacted

If the above solutions are too expensive, it may be preferable to realign the track or road around the flat area (B22).

Primary resources for pothole filling (per m³ of pothole)

Resource	Unit	Quantity
Labourers	Pers-day	1
Gang leader	Pers-day	0.1
Roller	Equip-day	0.1
Water tank	Equip-day	0.1

B8. Fill/embankment

There are several situations where it is necessary to raise the level of a road in order to provide Basic Access.

- There are large potholes due to the accumulation of water on the road
- There are large roots on the surface which are difficult to cut
- The soil is muddy and deforms when wet
- The route is low lying and floods during the rains

Embankments are described in Paragraph A5, where they are used with cross drainage structures to cross a wide and shallow water course, an area where a water course floods during the rains, or a flat area with poor drainage.

Information can be found in Paragraph A5 for the design, repair and cost estimation of embankments.

B9. Formation

In many situations it is necessary to form a road in order to provide Basic Access, including the following:

- Upgrade a track to a road
- The surface is prone to erosion
- The soil is loose sand
- The surface is slippery
- The soil is muddy and deforms when wet
- The route is low lying and floods during the rains
- A road has to be realigned to avoid a series of critical sites

The construction of road formation requires the area to be first cleared of vegetation and of top soil. Road formation consists of a raised surface with a camber of around 5% in order to ensure that water is shed from the surface, side drains, scour checks (B12) and mitre drains (B11).



In sites where the soil used to construct the formation is weak and erodible or deteriorates under traffic, it is necessary to provide an improved surface (Section C).

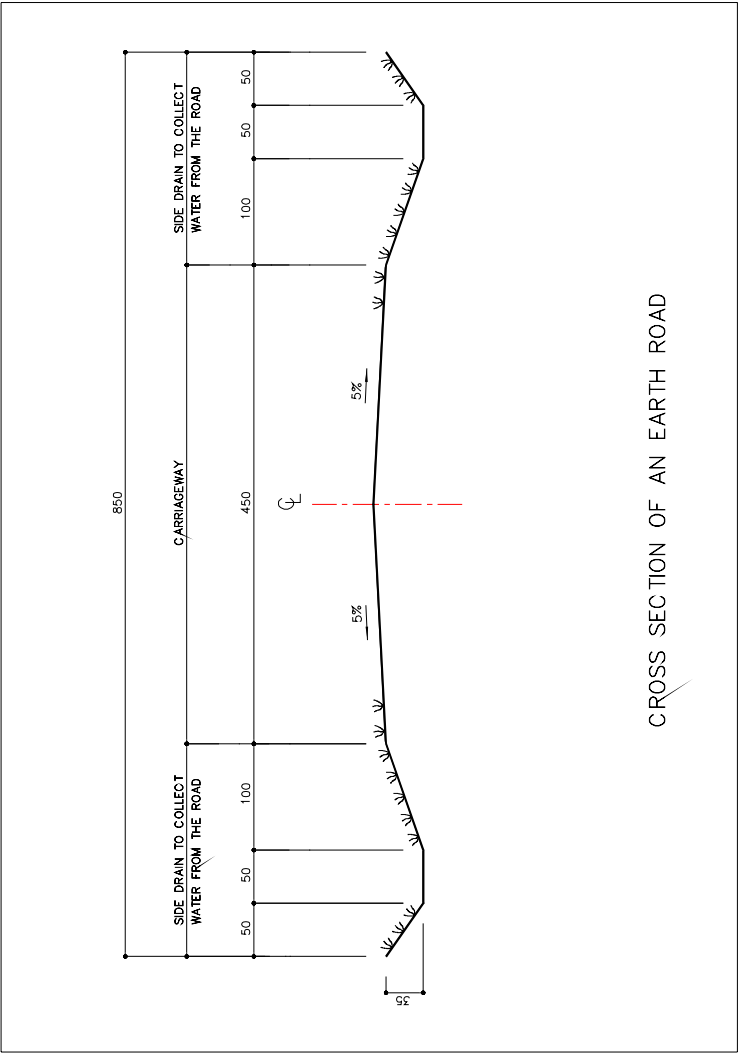
Primary resources for formation (per kilometre)

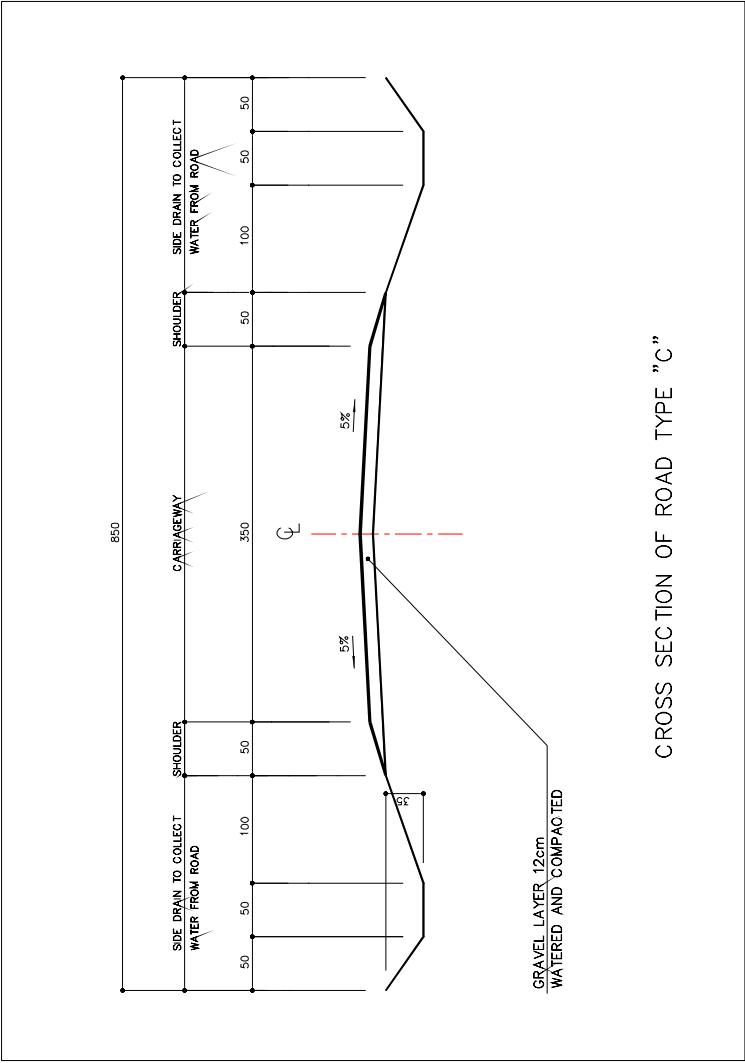
Resource	Unit	Quantity
Labourers	Pers-day	2,000
Gang leader	Pers-month	2
Tractor	Equip-month	0.5
Trailer	Equip-month	0.5
Roller	Equip-month	0.5
Water tank	Equip-month	0.5

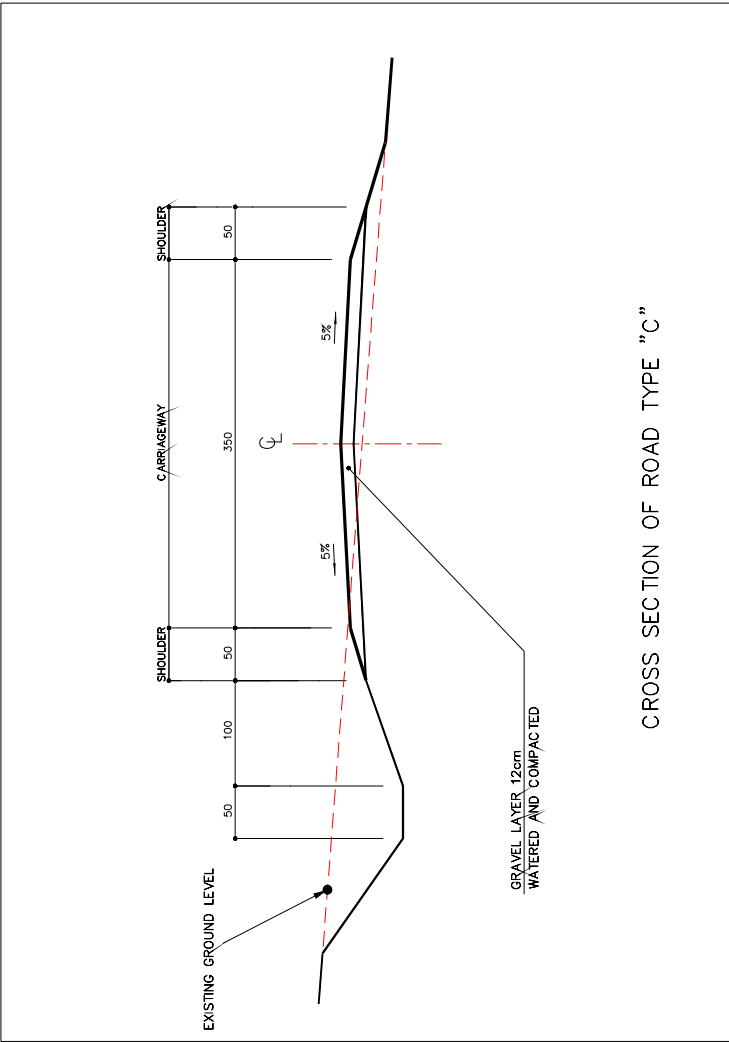
In some situations, a road may be too narrow for the traffic, especially when there are many non-motorised vehicles and pedestrians. If the affected length is less than 100 metres, the cheapest solution may be to widen the formation. This requires a side drain to be diverted and the surface to be widened.

Primary resources for widening the formation by 1 metre (per 100 metres)

Resource	Unit	Quantity
Labourers	Pers-day	100
Gang leader	Pers-day	10
Tractor	Equip-day	10
Trailer	Equip-day	10
Roller	Equip-day	10
Water tank	Equip-day	10



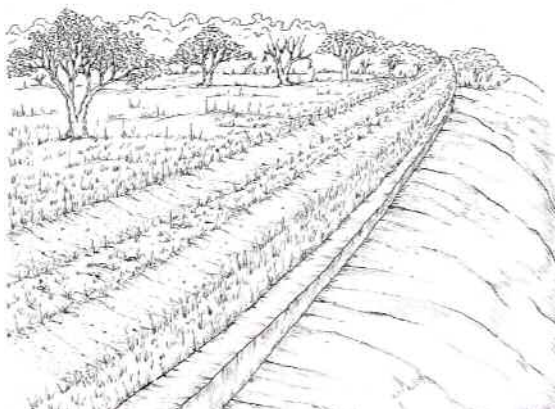




B10. Road on rock

Sometimes the track or road must cross a rocky surface. In some cases the rocky surface is smooth and the track or road provides Basic Access. However, in some cases the rocky surface is rough and does not provide Basic Access because vehicles can be damaged or must travel at very low speed.

The first solution is to remove the rock. If the rock is broken or weak, it can be easily removed in small pieces. If the rock is of less than 0.5 metre diameter, it can be removed by hand or buried under the track or the road. However, if the rock is extensive (rocky outcrop), the best solution is to construct the road over the rock.



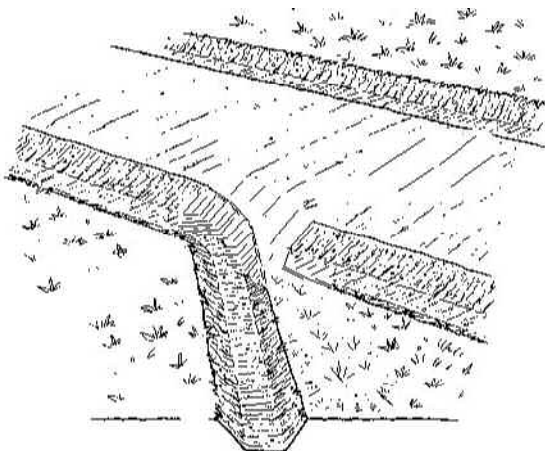
Construct a wall about 15 cm high along each side of the road. Good soil should be placed in layers 10-15 cm thick between the walls, watered and compacted. The walls contain the soil and prevent its erosion or displacement.

Primary resources for a road on rock (per 100 metres)

Resource	Unit	Quantity
Cement	50 kg	3
Sand	m ³	0.6
Masonry	m ³	3
Labourers	Pers-day	220
Gang leader	Pers-day	10
Mason	Pers-day	4
Tractor	Equip-day	4
Trailer	Equip-day	4
Roller	Equip-day	1
Water tank	Equip-day	1

B11. Mitre drains

Side drains overtop or erode if the volume of water is high. If the drain overtops, water can damage the surface of the road. Whenever the road is inclined and if the gradient of the terrain permits it, a mitre drain should be provided. A mitre drain diverts water away from the road.



A mitre drain should turn away from the side drain at an angle of 45° . The side drain should be blocked where the mitre drain starts to ensure that all the water in the side drain enters the mitre drain. The mitre drain should have a gradient of around 2% that reduces to 0% at the exit so that the water leaves at very low speed. The base of the mitre drain should be at least 0.5 metres wide and the sides should have a maximum slope of 45° . The excavated soil should be spread far from the mitre drain so that it is not washed back into the same drain when it rains. Allow grass to grow on the sides of the drain to prevent erosion.

Mitre drains should be provided at a spacing according to Table 19, although this can be reduced if overtopping or erosion becomes critical. To estimate the gradient, look horizontally to a point on the surface of the road and then divide your own height by the distance to the observed point and multiply by 100.

Gradient of side drain (%)	Spacing of mitre drains (m)
< 2	100
2-5	60
5-8	40
8-10	20
> 10	10

Table 19 Spacing of mitre drains

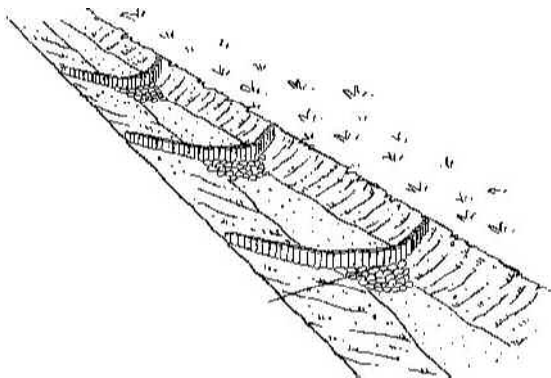
If the volume of water is large and it is not possible to provide mitre drains due to the gradient of the land, it might be necessary to construct a relief structure (Section A) in order to carry the water to the other side of the road.

Primary resources for a mitre drain (per 100 metres)

Resource	Unit	Quantity
Labourers	Pers-day	20
Gang leader	Pers-day	2

B12. Scour checks

Scour checks reduce the speed of water in the side drain, resulting in less erosion. In general they can be made from local materials, including timber, bamboo and stones. Rigid scour checks should not be made from concrete or wet masonry in loose soils.



It is important that the top of the scour check has the correct shape so that water is directed along the centre of the side drain. If not, water will tend to pass around the side of the scour check and erode the side of the road.

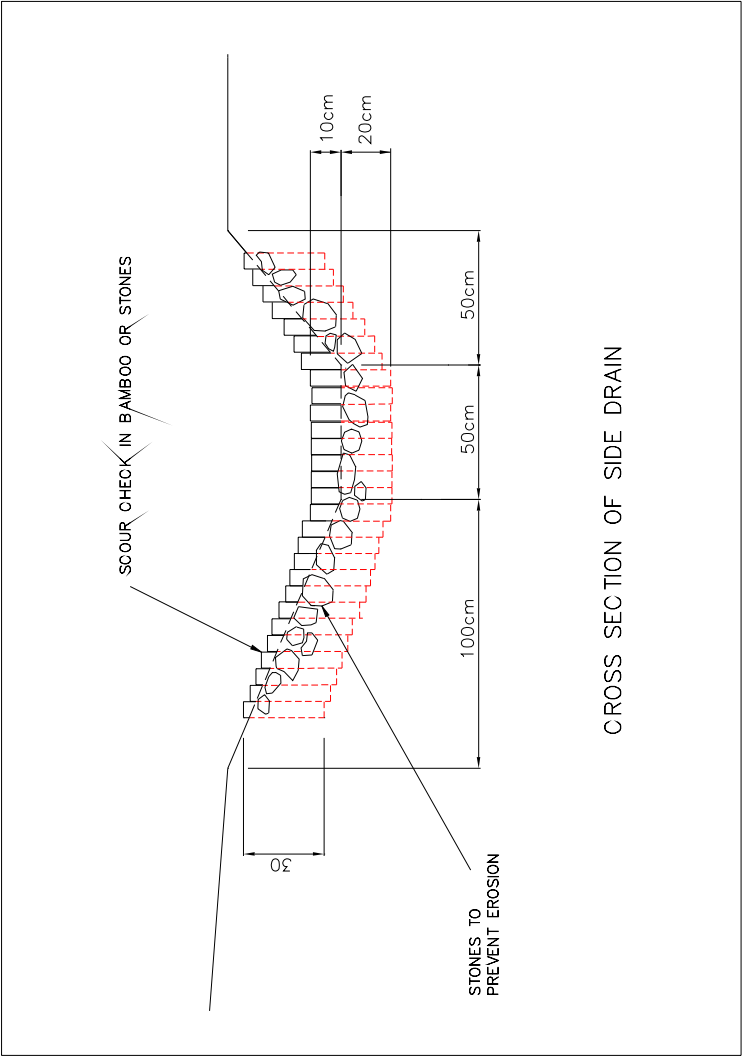
Scour checks should be provided at a sufficient spacing to keep the water below that which will cause erosion. The spacing depends upon the type of soil and the gradient of the side drain. Table 20 should be used as an initial guide. However, if erosion continues to occur or if the soil is very erodible, the spacing should be reduced and if the soil is resistant to erosion to spacing can be increased. To estimate the gradient, look horizontally to a point on the surface of the track and then divide your own height by the distance to the observed point and multiply by 100. Mitre drains should also be dug at sites where erosion is a problem.

Gradient of side drain (%)	Spacing of scour checks (m)
< 2	Not necessary
2-5	15
5-8	8
8-10	5
> 10	3

Table 20 Spacing of scour checks

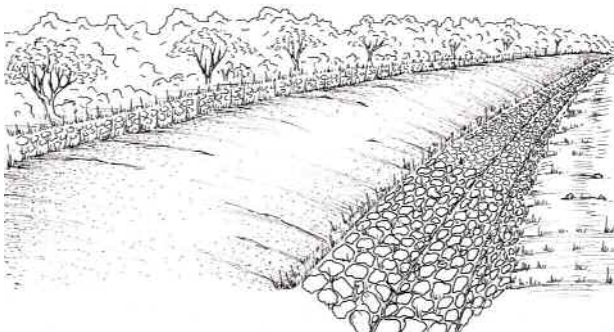
Primary resources for scour checks (each)

Resource	Unit	Quantity
Labourers	Pers-day	0.5
Gang leader	Pers-day	0.1



B13. Drain lining

The sides and the base of the side drains can be protected against erosion by lining the drain with a material which is resistant to erosion. This can include dry stone pitching, masonry, bricks, etc.



At sites where drain lining is provided, it is important to ensure that the water running off the road can enter the side drain unimpeded by the edge of the drain. If the flow of water into the side drain is blocked, the water will tend to erode the soil between the road and the side drain, eventually undermining the side drain.

Drain linings are most successful on roads with a non-erodible surface.

Primary resources for lining a drain with masonry (per m²)

Resource	Unit	Quantity
Cement	50 kg	0.22
Sand	m ³	0.04
Masonry	m ³	0.16
Labourers	Pers-day	1.0
Mason	Pers-day	0.2

B14. Interception drain

The drainage system of a road or track is designed to remove water that falls on the surface of the road or track and to prevent water flowing across the ground from reaching the road or track. An interception drain is part of the drainage system. Its objective is to intercept the water before it reaches the road and divert it, either onto the surrounding land or into a water course.

Interception drains should have a gradient around 2%, but if the drain ends on land instead of in a water course, the gradient should be reduced to 0% so that the water emerges at low speed. The base of the interception drain should be at least 0.5 metres wide and the sides should have a maximum slope of 45°. The excavated soil should be spread far away from the drain so that it is not washed back into the drain when it rains. Allow grass to grow on the sides of the drain to prevent erosion.

Primary resources for an interception drain (per 100 metres)

Resource	Unit	Quantity
Labourers	Pers-day	20
Gang leader	Pers-day	2

B15. Drain

A drain is a simple ditch which is excavated to remove water from a site. A drain can be required as an outlet from a cross drainage structure or to remove water from a low area where there are potholes or where the land floods when it rains.

A drain should be excavated from the site to a place where the gradient of the ground allows the water to flow away. The drain should be as short as possible and should have a gradient of around 2%, reducing to 0% at the end so that the water emerges at low speed. The base of the drain should be at least 0.5 metres wide but if the drain follows a water course, it should have the same width as the water course. The sides of the drain should have a maximum slope of 45°. The excavated soil should be spread far from the drain so that it will not be washed back into the drain when it rains. Allow grass to grow on the sides of the drain to prevent erosion.

In some sites it is not possible to dig a drain that will remove the water. In this case, other solutions are necessary, such as the construction of an embankment to raise the level of the road above the level of the water.

Primary resources for a drain (per 100 metres)

Resource	Unit	Quantity
Labourers	Pers-day	20
Gang leader	Pers-day	2

B16. Clear the side drain

At sites where a side drain has become blocked, its original shape and depth should be reformed, as shown on the standard road cross section. Use a wooden template to ensure that the correct shape and depth is achieved. The soil cleared from the side drain should be spread far from the drain so that it is not washed back into the drain when it rains. Allow grass to grow on the sides of the side drain to prevent erosion but the vegetation in the base of the side drain should be removed.

The cause of the blockage should be eliminated so that the side drain does not become blocked again. Generally the reason that side drains get blocked is the excessive accumulation of soil coming either from beyond the road or from erosion of the road surface. This can be prevented by:

- Construct a side access structure (B17)
- Before the water containing the soil enters the side drain, divert it away from the road using an interception drain (B14)
- Prevent erosion with bio-engineering (B18)
- Provide an improved surface (Section C) to prevent erosion of the road surface

Primary resources for clearing a side drain (per 100 metres)

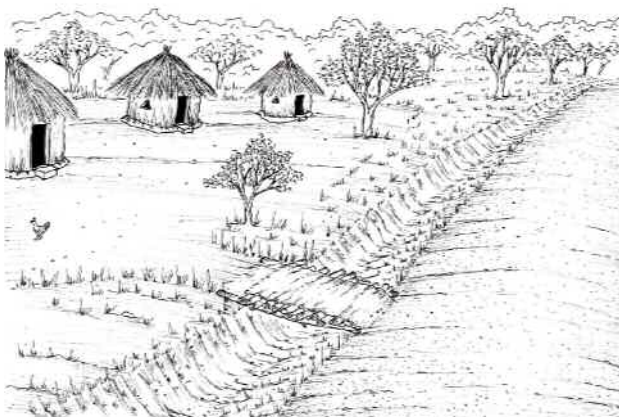
Resource	Unit	Quantity
Labourers	Pers-day	5
Gang leader	Pers-day	0.5

B17. Improve the side access

Side drains can become blocked with soil that is washed onto the road by water from a side access. Sometimes people living alongside the road fill the side drain with soil in order to provide access to their property from the road. The blockage makes the side drain overtop and the water cross or flow along the road. This results in erosion.

To prevent this happening:

- Clear the side drain (B16)
- Construct an interception drain (B14) that will divert the water away from the road and towards a culvert
- Construct a side access structure
- Instruct the local residents about the improvement and about maintenance of their own private accesses



Side access structures are normally constructed by local residents, using their own materials. If there are available funds, the structures can be constructed in concrete or in masonry according to standard culvert designs (normally aprons and wing walls are not required). Otherwise local materials can be used, such as timber.

Primary resources for a side access structure (in timber) for pedestrians (each)

Resource	Unit	Quantity
Labourers	Pers-day	2
Timber poles (Length: 250 cm Dia: 10 cm)	Each	12
Timber poles (Length: 120 cm Dia: 5 cm)	Each	40

B18. Bio-engineering

Bio-engineering includes the use of grass and other types of vegetation to protect slopes, embankments and other structures against erosion and other types of failure. The leaves of the vegetation reduce the impact of the rain on a soil surface, the stems slow down water flowing over the surface and the roots strengthen the slope and prevent land slips. Bio-engineering measures are normally needed at sites where a slope has become eroded or where construction work has removed the protective vegetation. It is necessary to choose vegetation types that are known to grow well locally in the in situ soil, and to not die back during the dry season.

There are a large number of bio-engineering techniques. Many of these techniques are described in the *Environmental Guide* which is mentioned in Section 1.8 and which can be obtained from ANE. This document should be used where possible. However, if this is not possible, the following four techniques will provide a reasonable level of protection.

Vegetation on a slope

This method protects gentle slopes which are prone to erosion. Spread top soil over the surface. Distribute seeds over the surface or plant small grass plants into the topsoil. The grass can be planted either evenly or in horizontal rows which can help to reduce run off. Alternatively, cut turf squares from a grassed area, place them on the slope and water them regularly. To help with this, grass plants can be grown in a nursery. Small shrubs can be planted on slopes more than 5 metres long.

Stone pitching with vegetation

This method protects slopes against erosion. Select stones about 10 cm thick. Spread a thin layer of top soil over the surface, followed by a single layer of closely packed stones. Plant grass in any gaps between stones so that their roots reach into the top soil. This method can also be used for lining a side drain.

Live scour checks

This method protects an erosion channel from further deterioration. Clear all loose material from the base and sides of the channel. Construct a scour check using live sticks and other vegetation. Combine horizontal and vertical sticks to make the wall of the scour check with gaps no larger than 5 mm. The wall should be lower in the middle than at the edges. All sticks should be embedded in the soil by 30-50 cm. The horizontal sticks should be placed in alternating directions. Construct the live scour checks with a spacing of 2-3 metres if the erosion occurs over a long distance.

Bundles of vegetation

This method can be used if grass is not sufficient to prevent erosion. Select a type of plant that will grow shoots where the bark is removed from a woody stick. Strip the bark in rings at a spacing of 30-50 cm and prepare bundles of these sticks. Cut horizontal trenches across the slopes, place the bundles in the trenches and cover with soil. The bundles will form thick barriers across the slope.

In all these cases, the vegetation must be watered in the early stages so that the plants can become established and continue to grow. Growth should be monitored during the following years so that the user can learn which method and which types of plant are the most effective in their area.

B19. Grass cutting

It may be necessary to clear an area of vegetation in the following circumstances:

- A track is to be widened to improve visibility and to allow other road users to travel and pass other vehicles more safely
- To provide access when vegetation has become extremely thick
- A new track is to be constructed to separate the vulnerable road users from the motorised vehicles
- A track or a road is to be realigned to avoid a series of critical sites
- Pedestrians find it difficult to walk through sites with thick vegetation
- A drain is blocked with vegetation and water is flowing onto the surface of the road



The required activity depends on the type of vegetation to be cleared. Grass cutting involves the cutting of grass and light vegetation to a height of 10 cm. It does not involve removal of the roots, since they reinforce the soil and help it resist erosion. Other clearing activities are the total removal of woody bushes (Bush clearing – B20) and the total removal of trees (Stumping – B21).

For a track it is recommended that a 3 metre width is cleared on either side of the track and for a road it is recommended that a 2 metre width is cleared beyond each side drain.

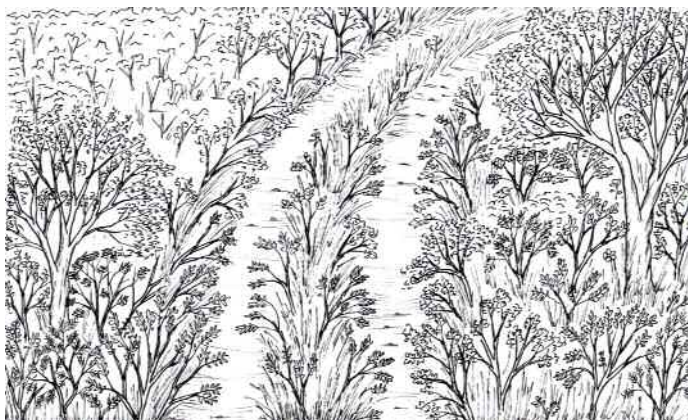
Primary resources for grass cutting (per 100 m²)

Resource	Unit	Quantity
Labourers	Pers-day	1
Gang leader	Pers-day	0.1

B20. Bush clearing

It may be necessary to clear an area of vegetation in the following circumstances:

- A track is to be widened to improve visibility and to allow other road users to travel and pass other vehicles more safely
- To provide access when vegetation has become extremely thick
- A new track is to be constructed to separate the vulnerable road users from the motorised vehicles
- A track or a road is to be realigned to avoid a series of critical sites
- Pedestrians find it difficult to walk through sites with thick vegetation
- A drain is blocked with vegetation and water is flowing onto the surface of the road



The required activity depends on the type of vegetation to be cleared. Bush clearing involves the total removal of vegetation with woody trunks up to a diameter of 30 cm. Where the roots are on the road they should be completely removed since they can regrow and damage vehicle tyres. Other clearing activities are the cutting of grass and light vegetation (Grass cutting – B19) and the total removal of trees (Stumping – B21).

For a track it is recommended that a 3 metre width is cleared on either side of the track and for a road it is recommended that a 2 metre width is cleared beyond each side drain.

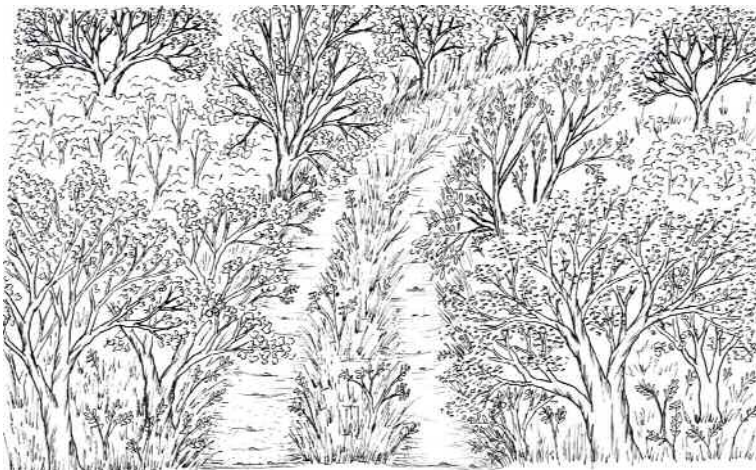
Primary resources for clearing (per 100 m²)

Resource	Unit	Quantity
Labourers	Pers-day	5
Gang leader	Pers-day	0.5

B21. Stumping

It may be necessary to carry out stumping in the following circumstances:

- A track is to be widened to improve visibility and to allow other road users to travel and pass other vehicles more safely
- To provide Basic Access when trees have grown into the line of the road
- A new track is to be constructed to separate the vulnerable road users from the motorised vehicles
- A track or a road is to be realigned to avoid a series of critical sites



The activity depends on the type of trees to be removed. Stumping involves the removal of trees with a main trunk diameter of more than 30 cm. The stump must be totally removed since it can regrow and damage vehicle tyres. Other clearing activities are the cutting of grass and light vegetation (Grass cutting – B19) and the total removal of woody bushes (Bush clearing – B20).

For a track it is recommended that a 3 metre width is cleared on either side of the track and for a road it is recommended that a 2 metre width is cleared beyond each side drain.

Primary resources for stumping trees (each)

Resource	Unit	Quantity (dia 30-70 cm)	Quantity (dia over 70 cm)
Labourers	Pers-day	5	10
Gang leader	Pers-day	0.5	1

B22. Realignment

At some sites it may be very difficult or expensive to construct the appropriate solution. Examples of these sites are:

- A muddy area
- A very steep hill in erodible soil
- A length of road that floods very deep during the rains
- An area with severe erosion
- A long length of loose sand
- A rocky area

Realignment should be considered in order to avoid the difficult or expensive site. The road can, for example, be realigned to a site where a shorter and lower embankment will be sufficient or follow an alignment around the critical site.

Guidelines for realignment are:

- Where possible the road should follow a line between rainfall catchments where it will not be crossed by water courses
- Where it is necessary to cross a water course, it is often better to relocate the site of the structure further downstream where the water course is better defined

A low road can be realigned alongside the original alignment, thereby raising the level of the road and using the original alignment as a large side drain. This side drain should then be protected against erosion with scour checks (B12) and the use of bio-engineering techniques (B18).

Section C – Improved surfaces

This Section provides guidance on a series of methods of providing Basic Access by improving the surface on which the vehicles travel. Although roads and tracks can often be improved by constructing a formation or improving the drainage, when the soil on the road surface gets wet and becomes weak or slippery, or when erosion occurs due to water flowing on the surface, it is necessary to improve the surface.

Two methods for improving the surface of a track when the traffic volume is very low are given here. The remaining methods are suitable for roads. Each method is suitable in different circumstances. Table 21 gives the criteria to select the most appropriate surface. Since all improved surfaces should be constructed on a prepared base, the Table also recommends which type of base should be used.

Conditions	Traffic (vehicles per day)	Base *	Surface
Track	Very low	Stabilised track Gravelled track	
Good materials naturally available	Less than 50	Gravel	
	Less than 50 (steep slope)	Gravel	Single Otta seal Grit seal Double Sand seal
	50-100	Gravel	Single Otta seal Single Chip seal Grit seal
	More than 100	Gravel	Double Otta seal Double Chip seal
Good materials not naturally available	Less than 30	Sand Treated with Emulsion (STE) <i>Geo Cells</i>	Single Otta seal Grit seal Double Sand seal
	30-100	Sand Treated with Emulsion (STE) <i>Geo Cells</i>	Single Otta seal Single Chip seal Grit seal
	More than 100	Chemically stabilised soil	Double Otta seal Double Chip seal

* The techniques for base construction are not described in this Manual. Guidance on their design should be obtained from ANE.

Table 21 Criteria to select the improved surface

C1. Stabilised track

This improved surface is a low cost solution for a track that has a surface of slippery clay.

Coarse sand is obtained locally and spread over the track in a layer 2 cm thick when the surface is wet. The vehicles that use the track gradually press the sand into the clay. It is necessary to monitor the surface for the first months, especially when it is wet. If the surface continues to be slippery it may be necessary to spread the sand which remains loose onto the areas with no loose sand, or to spread another 2 cm layer of new sand.

This solution should be combined with other activities to prevent water coming onto the surface. These can include diversion humps (B3) if the track is inclined, and drains (B15) if it is possible to drain water away from the site.

Primary resources for a stabilised track (per 100 metres and with a source of sand within 2 kilometres)

Resource	Unit	Quantity
Sand	m ³	8
Labourers	Pers-day	10
Gang leader	Pers-day	2
Tractor	Equip-day	1
Trailer	Equip-day	1

C2. Gravelled track

This improved surface is a low cost solution for a track prone to erosion, where the track passes through loose sand or has a surface of slippery clay. This solution is not suitable in an area of mud that deforms when wet.

A layer of gravel is placed on the surface of the track. The gravel should have a minimum thickness of 10 cm and extend 50 cm beyond each wheel track. The gravel should be watered and then compacted using a heavy roller or a truck.

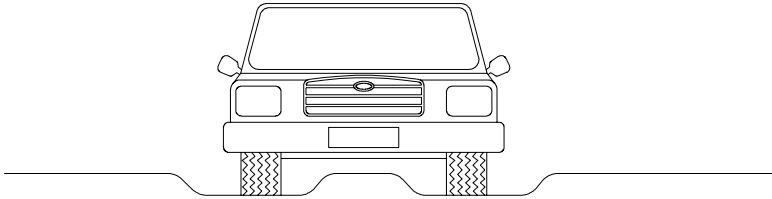
It is important that the gravel is of good quality. The user should refer to Paragraph C3 for guidance on the assessment of gravel quality.

Erosion channels and other damage to the surface of the track should be repaired before the gravel is placed.

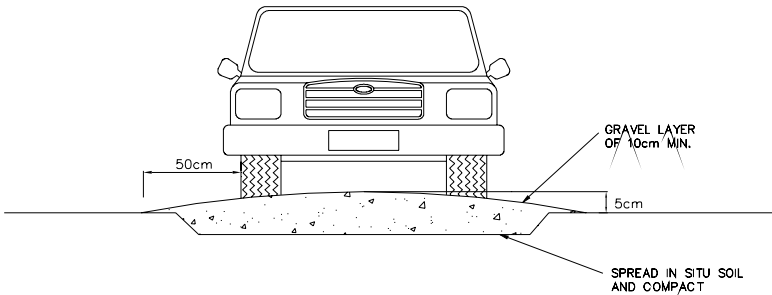
When this solution is used to prevent erosion or to reduce slipperiness, it should be combined with other activities to prevent water coming onto the surface. These can include diversion humps (B3) if the track is inclined, and drains (B15) if it is possible to drain water away from the site.

Primary resources for a gravelled track (per 100 metres and with a gravel pit within 2 kilometres)

Resource	Unit	Quantity
Gravel	m ³	42
Labourers	Pers-day	80
Gang leader	Pers-day	8
Tractor	Equip-day	4
Trailer	Equip-day	4
Roller	Equip-day	1
Water tank	Equip-day	1



BEFORE



AFTER

C3. Gravelled road

A gravel surface is the most common improved road surface in Mozambique. A layer of granular material, normally extracted locally, is placed and compacted on the road surface in order to improve the strength, traction and erosion resistance of the *in situ* soil. The gravel is placed on the formation with a camber of around 5% in order to ensure that rainfall is shed from the surface.

Gravel surfaces are appropriate for roads with less than 50 vehicles per day. The lifespan of a gravel surface can be prolonged if the camber is maintained and if potholes in the surface are repaired soon after they appear.

The thickness of the gravel layer depends on the level of traffic and the terrain. If there are more than 20 vehicles per day or if the gradient is more than 4%, a layer of 15 cm is recommended. If not, a layer of 12 cm is sufficient.

Primary resources for gravelling (per 100 metres with a thickness of 12 cm and with a gravel pit within 2 kilometres)

Resource	Unit	Quantity
Gravel	m ³	54
Labourers	Pers-day	100
Gang leader	Pers-day	10
Tractor	Equip-day	5
Trailer	Equip-day	5
Roller	Equip-day	1
Water tank	Equip-day	1

Digging, hauling, spreading, watering and compacting gravel is an expensive operation, even if the gravel pit is close to the site. A good quality gravel surface can last more than ten years before needing to be regravelled, but poor quality gravel can last less than 2 years. It is better to spend more money now to find good quality gravel than to use poor quality gravel that will last for only a short time.

Good gravel has two important characteristics. The first is the grading. The gravel should have a mixture of small and large particles. These particles form a dense matrix that is strong and stable under traffic. The second characteristic is plasticity. There should be a certain quantity of clay in the gravel. This helps to stick the particles together so that the matrix remains strong even when dry.

Gravel tests

It is necessary to test a sample of gravel before opening a gravel pit in order to ensure that it is of good quality. Two tests that can be used to test gravel are described below. Test B should only be used if the equipment required for Test A is not available.

To obtain a sample of gravel, remove all the soil on the surface until clean gravel is visible. Take a sample of gravel and keep it in a clean and dry bag or other container. For all the tests described here, a sample of 1 kilogramme is sufficient. Samples should be taken from the gravel pit every 20 metres or so. The limits of the good gravel should be marked clearly on the ground so that poor quality gravel is not used on the road.

Test A. Detailed gravel test

This test compares the grading and the plasticity of the gravel with the national specifications. Carry out a sieve analysis and determine the Grading Coefficient.

Grading Coefficient =

$$[(\% \text{ passing } 26.5 \text{ mm sieve} - \% \text{ passing } 2 \text{ mm sieve}) \times (\% \text{ passing } 4.75 \text{ mm sieve})] / 100$$

Sieve the gravel with a 0.425 mm sieve and carry out a linear shrinkage test. Determine the Shrinkage Product.

Shrinkage Product =

$$\text{Linear Shrinkage} \times \% \text{ passing } 0.425 \text{ mm sieve}$$

For each sample, mark a point on the chart in Figure 7. The gravel should be used only if the point is within area E1 or E2.

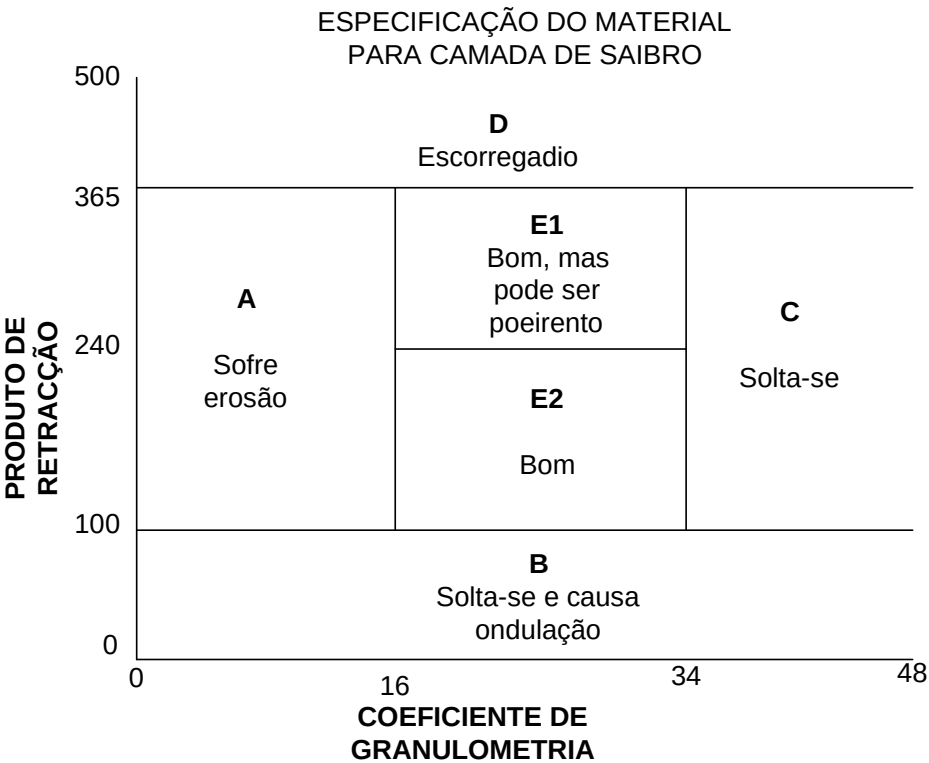


Figure 7 Chart for detailed gravel test

Key:
Saibro – Gravel
Produto de Retracção – Shrinkage Product
Coeficiente de Granulometria – Grading Coefficient
A – Erodes
B – Ravels and corrugates
C – Ravels
D – Slippery
E1 – Good but can be dusty
E2 – Good

Test B. Simple gravel test

There are two simple gravel tests. The first compares the gravel grading with a simplified specification. The second visually assesses its plasticity.

Test B1: Settlement test

Obtain a cylindrical glass jar at least 30 cm tall and with a diameter of at least 10 cm. Half fill it with soil. Then fill the jar with water up to three quarters full. Add a small spoonfull of salt. Shake the jar well until all the contents are mixed. Place the jar on a flat surface and wait until all the soil has settled and the water is clear. This can take up to 3 hours. The soil will settle in layers with the large particles at the bottom and the small ones at the top. It should be possible to identify three main layers: a coarse layer (stones), a sand layer and a fine layer. The coarse layer contains particles larger than 2 mm. The sand layer contains particles smaller than 2 mm but which are visible to the naked eye. The fine layer contains particles that are too small to be seen by the naked eye.

Measure the height of the coarse layer. Call this height C. Measure the height of the sand layer. Call this height S. Measure the height of the fine layer. Call this height F. Finally measure the total height of all the layers. Call this height T. Calculate the following.

The soil passes the test if all three following conditions apply.

Layer	Calculate	Limits (%)
Coarse	$\frac{C \times 100}{T}$	50-70
Sand	$\frac{S \times 100}{T}$	20-40
Fine	$\frac{F \times 100}{T}$	10-20

If the soil contains some very large particles, it is possible that it will not settle in separate layers and it will therefore be difficult to calculate the percentages. In this case it is necessary to make a visual assessment of the percentages and check that they are more or less within the given limits.

Test B2: Drying test

After the settlement test leave the soil in the jar until it is almost dry. Remove a sample of the fine material from the top of the jar and place it in a small open box. Leave the soil to dry completely. If it breaks into hard pieces, the material is clay and the soil passes the test. If it turns into powder when touched, the material is silt and does not pass the test.

C4. Bituminous seal

A gravel surface can be inadequate on some sections of road for the following reasons:

- The traffic level is high and the road needs frequent maintenance, including regravelling
- The road is on a steep slope and the gravel wears away or cannot provide sufficient traction
- The road passes through an area where people live and the dust caused by passing vehicles is a problem
- Sources of gravel are scarce, making regravelling expensive
- There is insufficient capacity to maintain a gravel road

In these circumstances the surface of the road can be improved by applying a bituminous seal. The seal has a surface which is impermeable and resistant to erosion which prevents water wearing it away or weakening the pavement layer below. The seal also provides a higher level of friction which improves traction for vehicles and prevents dust.

The seal should be applied onto a strong road base, constructed from either crushed stone or natural gravel. The road base should be supported by sufficiently strong soils (subgrade), normally the in situ soil.

In Mozambique the following four seals are commonly used. The design (which depends on factors such as the type of stone and bitumen), the cost estimate, the construction and other details of the seals are described in the *Manual for the Construction of Bituminous Surfaces using Labour on Low Volume Roads*, which can be obtained from ANE.

C4-1. Sand seal

A sand seal consists of:

- A prime coat
- A layer of bitumen
- A layer of sand with grading from 0 to 2 mm

The sand is rolled into the bitumen using a pneumatic tyred roller or a loaded truck.

The sand seal is appropriate for roads with very low traffic (less than 30 vehicles per day). The sand seal may last for only 2 years but the application of a second sand seal after 3 months can extend the service life up to 4-5 years. The sand seal can also be applied onto other bituminous seals in order to extend their service life.

C4-2. Grit seal

A grit seal consists of:

- A prime coat
- A layer of bitumen
- A layer of stone with grading from 0 to 6 mm

The grit is rolled into the bitumen using a pneumatic tyred roller or a loaded truck.

The grit seal is appropriate for roads with low and medium traffic (less than 100 vehicles per day) and can give a service life of 5-6 years.

C4-3. Otta seal

An Otta seal consists of:

- A prime coat
- A layer of bitumen
- A layer of gravel with grading from 0 to 16 mm or crushed stone

The gravel or stone is rolled into the bitumen using a pneumatic tyred roller or a loaded truck. It is necessary to roll until the bitumen moves up through the material.

The single Otta seal is appropriate for roads with medium traffic (up to 100 vehicles per day) and can give a service life of 5-6 years. A second Otta seal can be added for higher traffic levels and can extend the service life. A sand seal can also be added to a single Otta seal in order to extend the service life.

C4-4. Chip seal

A chip seal consists of:

- A prime coat
- A layer of bitumen
- A first layer of single sized stones from a crusher
- A layer of bitumen (optional)
- A second layer of single sized stones (optional)

Each layer of stones is rolled into the bitumen using a pneumatic tyred roller or a loaded truck.

A single chip seal normally has one layer of 10 mm stones. This is expected to provide a service life of 10 years on roads with traffic up to 100 vehicles per day. A single chip seal can also be used to reseal a bituminous surface in order to extend the service life.

A double chip seal normally has one layer of 13 mm stones and one layer of 6 mm stones. A double chip seal is expected to provide a service life of 10 years on roads with traffic higher than 100 vehicles per day.

C5. Geo Cells

Improved surfaces can provide a durable surface if the soil suffers from erosion or from a lack of traction. *Geo Cells* can also improve a weak surface such as loose sand or mud.

Geo Cells comprise a grid of plastic strips stretched across the surface of the road which is then filled with a cement-sand mix. The cement-sand hardens and creates a pavement of interlocking blocks. These blocks form a road base which is flexible but also stable. The block pavement can be sealed with a bituminous seal to improve its durability.



Geo Cells can be installed without the need of specialised equipment, apart from a light pedestrian roller. They are appropriate in remote areas where there are few labourers with technical skills. The plastic grid must be transported to the site but cement is available in almost all parts of Mozambique.

A thickness of 75 mm is normally sufficient on loose sand.

Primary resources for the construction of *Geo Cells*
(per 100 x 4.5 m with a thickness of 75 mm)

Resource	Unit	Quantity
Sand	m ³	42
Cement 8%	50 kg	61
Hyson Cells 300/210x0075	m ²	500
Labourers	Pers-day	200
Gang leader	Pers-day	16
Tractor	Equip-day	4
Trailer	Equip-day	4
Roller	Equip-day	4
Water tank	Equip-day	4
Cement mixer	Equip-day	4

C6. Sand Treated with Emulsion (STE)

Bitumen emulsion is mixed into a road surface of loose sand to a depth (normally) of 75 mm, shaped and compacted. When the mixture dries, it hardens and forms a stable base layer. The base should be sealed with a bituminous seal to provide traction for vehicles and to improve its durability.

STE is suitable for sandy areas where there is no natural gravel or stone for the construction of a road base. The disadvantages of STE are:

- The transport to site of bitumen emulsion, which contains a high proportion of water, can be expensive.
- Specialised equipment is required to mix the emulsion and the sand on the road surface.

Guidance on the design, cost estimate and construction of STE can be obtained from ANE.

C7. Mechanically stabilised clay

In some areas of Mozambique, especially the flood plains of rivers, the only available materials for road construction are river clay and sand. The clay can be formed into an embankment in order to raise the road above the flood level and when dry it is sufficiently strong to carry heavy vehicles. However, when wet the material becomes weak and slippery.

In order to provide a durable surface which is able to support traffic in all weathers, the clay can be stabilised by mixing sand into the surface. The proportion of sand varies according to the characteristics of the clay and the sand. The ideal proportion can be found by testing in a laboratory. Alternatively, trial sections can be constructed using 20%, 30% and 40% of sand and monitored during a rainy season to determine the optimal solution.

The stabilised surface is constructed in the following way:

1. Spread the desired layer of sand on top of the clay
2. Use an agricultural rotavator or a large plough to mix the sand to the required depth in the clay (normally 150 mm)
3. Compact the surface using a roller

Primary resources for mechanically stabilising clay (per 100 m³)

Resource	Unit	Quantity
Sand	m ³	2
Labourers	Pers-day	2.5
Gang leader	Pers-day	0.25
Tractor	Equip-day	0.25
Trailer	Equip-day	0.25
Agricultural rotavator	Equip-day	0.25