


AFCAP Project Phase 4

Back Analysis of Previous Low Volume Rural Roads in Mozambique

DRAFT PROJECT INCEPTION REPORT

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Transport Research Laboratory

DRAFT PROJECT REPORT

Analysis of Performance of Previous Low Volume Rural Roads in Mozambique

Inception Report

Prepared for: Project Record: **AFCAP/MOZ/001/G**

Inception Report

Client: **AFCAP**

Mozambican National Roads Administration (ANE)

This Draft Report has been prepared for AFCAP and ANE for the sole purpose of Project Report Review.

The views expressed are those of the author(s) and not necessarily those of AFCAP or ANE.

	Name	Date Approved
Project Manager	Kenneth Mukura	
Technical Referee	John Rolt	

Contents

Tables

Figures

1 Introduction

The Mozambican National Roads Administration (ANE) has embarked on a Regional Roads Investment Programme (RRIP). The programme is being supported by the Swedish International Development Agency (ASDI), which is providing the funding for construction works, including site supervision, and by the UK's Department for International Development (DFID) through its African Community Access Programme (AFCAP)[1], which is providing technical assistance for research, application of innovative solutions, development of guidelines, communication, and mainstreaming.

TRL has been commissioned by Crown Agents to carry out Phase 4 of the AFCAP programme in Mozambique to undertake a back analysis of previously constructed low volume roads (LVRs) and monitor their historic and current performance.

2 Objectives of the Rural Roads Investment Programme (RRIP)

The objective of ANE's RRIP is to bring important unpaved low-volume roads to an improved standard to maximise interconnectivity and all-weather passability on the network, and reduce longer term maintenance costs. The concept of the programme is based on the "targeted interventions" (spot improvement) approach, and the intention is to apply a range of road construction technologies suitable for the varying conditions found in the country. This includes areas in the coastal zone where materials suitable for the construction of low traffic roads by traditional means cannot be found within a reasonable haul distance. Stand-alone "pilot" projects are being carried out in all ten provinces of Mozambique.

The overall programme is being managed by the ANE Directorate of Maintenance (DIMAN) in Maputo. The individual projects are being administered by the provincial delegations of ANE (DPANE), with technical support from DIMAN. The design of the works and site supervision is being carried out by DPANE and their provincial consultants.

The current programme involves both demonstrations of relatively well-understood methods in Mozambique which are covered by regional or international design standards, but which may require local modifications, and innovative solutions that are best described as research. There are many sections of road that have been built in Mozambique in the past where low cost techniques have been applied. For example, the use of emulsion stabilised sand for road bases has been the subject of experimentation in Mozambique over several years. However, there has been no systematic monitoring of these sections of road and therefore no scientific evaluation of their performance in relation to the designs, materials, traffic level, environmental conditions or quality of construction. The latter, for example, plays a significant role in the deterioration of roads and is always a factor that must be evaluated, especially when new methods are being introduced that contractors are not familiar with. Therefore there is a risk of the contractors not complying with appropriate standards and specifications.

Furthermore, appropriate maintenance regimes are required for roads built using non-conventional materials and sealed with low cost surfacing. In order to be effective, the maintenance regime should be linked to the designs, materials, the environment and the traffic. The Africa Community Access Programme (AFCAP) has agreed to assist ANE with the back-analysis of the performance of a number of sections that were built in the last two decades prior to the current programme. This will involve detailed research on their construction, pavement design as built, materials, age, environment, traffic data and performance.

Results from the assessment of the performance of a sample of relatively old sections of road combined with an assessment of the performance of some of the new sections to date will provide important information for developing guidelines for the selection of the most suitable solutions for many of the road building problems encountered in Mozambique.

The project will make a significant contribution to the suite of specifications and work norms which are being development by TRL under the RRIP/AFCAP project. It will harmonise the on-going preparation of work norms and guidelines with the results of the back analysis of the performance of the older road sections.

3 Report Objectives

This report covers the inception of this phase of the overall project. This phase is entitled, *'Analysis of Performance of Previous Low Volume Rural Roads in Mozambique'.* The results of this analysis will provide additional research data to feed into the current development of specifications, work norms and guidelines for the provision of low volume surfaced roads (LVSRs) in Mozambique.

The objectives will be achieved through four main activities:

- Preliminary activities, including site visits and desk study of historical projects.
- Field investigations involving measurements of the current condition of the roads and collection of samples for testing in the laboratory.
- Laboratory testing of materials.
- Analysis of test results and reporting.

4 Project Organisation

4.1 Project Team

Phase 4 of the project utilises some of the arrangements that were put in place for Phases 1 to 3. The structure of the team and responsibilities has changed from Phase 1 as shown in Table 4-1.

Table 4-1 Local team structure

Position	Role
Maintenance Director	Directing the research, liaising at higher levels in ANE and between ANE and TRL. Providing guidance and advice to the project in line with the RRIP objectives.
Head of Maintenance Dept.	Managing execution and evaluation of the project.
ANE Project Coordinator	Coordination of project activities at National Level, supervision of works. Collaboration with TRL Team in relation to the management of the project. Participating in the actual fieldwork and data management
Director of Projects	Responsible for preparing and coordinating the laboratory testing programme in collaboration with TRL and Maintenance Director.
Provincial Delegacaos	These will contribute to the project with local experience, field surveys, recording and collation of data, participating in data analysis in collaboration

• Maputo Province: • Inhambane Province: • Zambezia Province: • Nampula Province: • Cabo Delgado Province: • Niassa Province:	with TRL Team within each province as follows: Marracuene-Ferroviario and Boane-Limbombos Road Pambara-Rio Save Road Rio Zambezi-Nocoadala and Quelimane-Namacurra Roads Nametil-Angoche Road Oasse-Mocemboa da Praia Road Mainamba-Metangula and Mandimba-Lichinga Road
Provincial Consultants and Contractors	Through the respective Provincial Delegados, responsible for assisting in providing as-built and maintenance information and taking part in reconnaissance and detailed surveys.
Other Third Parties	Responsible for providing relevant data, e.g. rainfall data from the Met Office.

The team is headed by the Director of Maintenance who oversees the project and is the centre of liaison at higher levels. The Head of Maintenance manages the execution of the project while the day to day running of the project lies with the ANE Project Coordinator, Rubina Normahomed The AFCAP coordinator is assisted by the Provincial Delgados covering the respective Provinces where the projects are located. In addition, the Provincial consultants and contractors, through the Provincial Delegados, assist in providing as built and maintenance information as well as participating in reconnaissance and detailed surveys.

5 Project Scope

The main aim of the overall project is to produce recommendations for specifications and work norms for low volume roads in Mozambique. These will be based on the results of the trials and demonstrations constructed during the previous 3 phases of projects. However, these trials are relatively new and therefore their long term behaviour will not be validated.

The scope of the work to be carried out under this project (Phase 4) is designed to supplement the results obtained in Phases 1 to 3 with long term performance data from sections of road that were built many years ago using similar techniques but whose performance has never been evaluated. This endeavour will increase the volume of data and will make the analysis statistically more reliable.

The project includes the following tasks

a) Training of local personnel through involvement in all aspects of the project, i.e.
   i) Setting up of research projects
   ii) Fields surveys and investigations
   iii) Data collection and collation
   iv) Analysis and presentation of results
   v) Developing specifications
b) The selection and investigation of road sections for use in the study. It was initially intended, in accordance with the Terms of Reference, that 5 roads be selected in 5 provinces. Selection of the road sections will depend on:
   i) The level or extent of deterioration
   ii) The pavement structure
   iii) The materials used
   iv) The level of traffic
   v) Previous maintenance carried out

Following initial reconnaissance (reviewing 9 roads in 6 provinces), a total of 7 roads have been selected in 6 provinces, comprising a total of 20 road sections. These are described in detail in Section 7 of this report, and also summarised in Table 9-1.

The condition and performance of the roads will be investigated. Most of them are categorised as low volume roads.

The pavement construction types to be covered by the study included the following:

A) Surfacings
   i) Double surface dressing (DSD)
   ii) Otta seals
   iii) Sand seals and other surface treatments
B) Road bases
   iv) Emulsion treated bases (ETB)
   v) Untreated sand bases
   vi) Unconventional bases such as laterites and calcretes

vii) Hot sand asphalt

5.1 Preliminary Activities

The Consultant carried out the following tasks during the Inception Phase:

1) A desk study of the selected projects in consultation with the client and agreement on the selection criteria and the initial list of roads to be included in the research. Outputs of the desk study including traffic data, construction reports and rainfall data can be found in Section 6.
2) Field visits to finalise the selection of roads and to identify sites for detailed investigations. Section 7 contains information about each of the roads surveyed during reconnaissance visits.
3) Development of a field investigation and laboratory testing programme for each site. In tandem with this task, ANE's provincial laboratories were assessed in terms of personnel and appropriate serviceable equipment. A summary of this assessment is in Section 6.2.4 and in Appendix A.
4) From the sites studied, five sites were selected that form a representative list to be investigated during the detailed phase of the project. Section 8 provides recommendations for the roads and study sections.
5) For the sites selected, investigation procedures and an implementation programme were established. Section 9 comprises a programme of work for the detailed investigations.
6) The road classification and information on the historical and current traffic loading on each selected road were obtained. This information is available in Section 6.
7) Information on external factors, such as cyclones and rainfall which may have influenced deterioration was obtained. This information is available in Section 6 and Appendix B and C.
8) Construction records were obtained from the ANE headquarters and provincial offices for some of the roads (Section 6.2.1).
9) Maintenance records from the ANE headquarters and provincial offices were obtained.

5.2 Field Investigations

These investigations will form part of the detailed phase of the project and will include:

i) Visual condition assessments
ii) Drainage evaluation
iii) Rut depth measurements
iv) Deflection tests to measure the in-situ elastic properties (i.e. the pavements' load spreading properties)
v) Dynamic Cone Penetrometer (DCP) tests to determine the in-situ layer strengths and thicknesses
vi) Extraction of cores of the surfacing for testing

vii) Test pits to obtain in-situ dry density and moisture contents of the pavement layers and samples of the materials for laboratory testing of properties that cannot be obtained from non-destructive testing on site

5.3 Materials Testing

The consultant will conduct a range of laboratory tests, including but not limited to the following:

i) In situ moisture content.

ii) Classification: grading (particle size distribution), Atterberg limits, linear shrinkage.

iii) Compaction: maximum dry density (MDD), optimum moisture content (OMC).

iv) Strength: CBR (at soaked, OMC and 0.75.OMC).

v) Bituminous surfacing: binder content, aggregate characteristics, properties of the bitumen aggregate mix, if appropriate.

5.4 Analysis and Documentation

This will comprise:

i) Collation of raw data ready for pavement analysis.

ii) Analysis of data.

iii) Development of performance trends.

iv) Input of data to the Highway Development and Management Model (HDM-4). The data will be used to calibrate the road deterioration models contained in HDM-4 to represent road deterioration of low volume roads in Mozambique.

v) Use of HDM-4 to predict future performance of the test sections.

vi) Draft conclusions and recommendations.

vii) Proposal of specifications for low volume roads to be incorporated in the manual that will be developed under Phase 2 and Phase 3 of the RRIP/AFCAP Project.

5.5 Reporting

The following reports will be submitted to the client:

i) An Inception Report covering the preparatory and preliminary works

ii) Brief monthly progress reports describing activities carried out during the month, a summary of test results obtained, and initial findings and recommendations.

iii) A Final Report describing all the works undertaken on the project, including the data collected, its analysis and the results obtained.

The Final Report will include conclusions drawn from the work and will provide recommendations on aspects to be adopted and incorporated in the guides and work norms (*normas de execução*) for a range of pavement designs and surfacings for low volume rural roads in Mozambique. These guides will be used by ANE engineers and their consultants tasked with the management of low volume rural roads.

In accordance with the Terms of Reference, the reports will be submitted in English. Translation of these documents from English to Portuguese will, if necessary, be organised separately.

5.6 Transfer of Knowledge

The transfer of knowledge to ANE staff is a key component of this assignment, and therefore ANE staff will participate in all stages of the project. This will contribute to capacity building within ANE and ensure continuity of the project beyond the implementation stage. A one-day workshop will be held in Maputo to disseminate findings of the project to ANE engineers, selected experts in the field and other stakeholders.

6 Progress

TRL commenced work upon signing the contract in July 2012. The inception of the project included the following stages:

i) Project start up meetings with DFID, Crown Agents and ANE
ii) Deployment of staff to Mozambique
iii) Selection of candidate roads in consultation with ANE
iv) Collection of as-built and maintenance records for the project roads
v) Collection of climatic data from the Meteorological Office
vi) Reconnaissance surveys of the projects
vii) Preparation of the Inception Report
viii) Ongoing consultation with ANE via meetings and reports
ix) Full time participation of key ANE personnel at all stages of the project

The Technical Proposal describes the methodology that will be used to conduct detailed surveys on the test sections. At this inception phase, a total of 9 roads in 6 provinces underwent reconnaissance so that the choice of final sections for detailed study would not be restricted.

6.1 Selection of Candidate Roads

The selection of candidate roads was carried out at a strategic level and focussed on roads that had been constructed using non-standard procedures. The selected roads varied in terms of age, construction type, current condition and geographical location. The names of the candidate roads are given in the following section.

6.2 Data Collection

One of the primary tasks carried out during the inception phase of this project was the collection of relevant data from ANE and other third parties for use in the understanding of the construction, maintenance and performance of the selected roads and sites. The sourcing of data from ANE was coordinated by DIMAN, although some direct contact was also made with the respective directorates and provincial delegations to expedite the process. It was not possible to collect all the required information at the time of submitting this report. The data that were sourced and collected is presented below.

6.2.1 As-Built Data

It was not possible to collect all the as-built data for the respective projects. The information that was available at the time of writing the report is summarised below:

PROVINCE	Project	Available Information	Date
MAPUTO	Marracuenne-Ferroviario	Progress Report No. 1- Labour Based Section	July 2005
		Progress Report No. 1- Equipment Based Section	July 2005
		Tender Document- Labour Based Section	October 2003
		Tender Document- Equipment Based Section	October 2003
MAPUTO	Boane-Limbombos-Goba	No Information received to date	
INHAMBANE	Pambara-Rio Save	Limited Information Mix design charts	
ZAMBEZIA	Rio Zambezi-Nicoadala	No Information received to date	
	Quelimane-Namacurra		
NAMPULA	Nametil-Angoche	Project completion Report- Vol.1 and 2	June 2007
CABO DELGADO	Oasse-Mocemboa da Praia	No Information	
NIASSA	Maniamba-Metangula	Final Report	2008
NIASSA	Mandimba-Lichinga	Works Completion Report	2008

6.2.2 Maintenance Records

Maintenance records were still unavailable from DIMAN and the provinces at the time of producing this report. The information collected will be used in the detailed phase of the study.

Information obtained during preliminary enquiries suggests that only routine maintenance that includes pothole patching, grass cutting and drain clearing was carried out (excluding crack sealing). No periodic maintenance such as reseals was carried out and neither was any rehabilitation executed on any of the candidate roads. More information will be provided in due course and may be incorporated in the progress report for the month of October.

6.2.3 Deflection Data

ANE carried out a nationwide deflection testing exercise on all sealed roads in 2010. The survey was designed to determine pavement strengths for the different sections of road for planning purposes. These data were sought from ANE for the assessment of the sections that will be earmarked for research. The data and information will be used in a number of ways:

1. The pavement deflection data will be used to determine uniform sections in terms of pavement stiffness. Pavement stiffness has a direct influence on performance and this will be an important parameter in the development of specifications for low volume roads.
2. The pavement stiffness values from the deflection data will be used with the DCP test data to determine the adequacy of the pavement structures for the traffic.

The deflection data has been supplied by ANE from the FWD measurements. However, the data is not appropriate for use in the project because the tests were carried out at 10km intervals, which is too wide. Some of the selected sections are 5km long or less. This means that, by chance, there could be only one test result in the whole segment of road selected for investigation under this project. Consequently, further deflection tests will need to be carried out as part of the planned field surveys. There are two options available:

1. There exists a Benkleman Beam at ANE and this could be used to carry out the deflection tests. This test is more laborious and slow but feasible. This test requires a hired lorry to provide the wheel loading.
2. There is a PRIMA at TRL UK which can be shipped to Mozambique and is used to determine pavement stiffness though it does not give data that is as elaborate as that provided by the FWD.

6.2.4 Laboratory capacities to carry out surveys and testing

Inquiries were made into the capability of ANE, in terms of equipment and personnel, to carry out field investigations and laboratory testing. Standard questionnaires were distributed to the provincial laboratories through the project co-ordinator. The responses received showed that the laboratories generally had the equipment and personnel to carry out soil and aggregate testing. However, all the laboratories did not have the capacity to carry out the following:

- Triaxial tests because it is not a commonly used test method to assess the strength or suitability of material for pavements in Mozambique.
- Bitumen tests.
- In situ density tests using nuclear density devices due to the non-availability of equipment.

In addition to the above, the following observations were also made:

- The laboratory in Niassa has only one member of staff. This falls short of the staff complement required to carry out both field investigations and laboratory testing.
- The equipment in some of the laboratories needs calibration. This requires some of the equipment to be shipped to South Africa and then back into the country again, because the calibration equipment is bulky and cannot be undertaken in situ.
- Some of the laboratory staff are involved in on-going projects within the respective provinces. This leaves them with limited availability to participate in this project.

The capacity of the ANE laboratories to carry out the tests is summarised in Appendix A.

6.2.5 Traffic Data

Traffic data were obtained from the client for all the roads except the unclassified Marracuene-Ferruviario road. There was limited time to review the data at the inception stage and hence the data will be used during the detailed investigation phase of the project. The summary Annual Average Daily Traffic (AADT) data are contained in Table 6-1.

Data on traffic loading in terms of equivalent standard axle (ESAs) is not available but efforts will be made to carry out snapshot axle load surveys during the detailed field surveys. It is possible to use a portable weighbridge or weigh pad for this purpose. Weighbridges have been identified at some sites on the trunk roads and axle load data can be extracted during detailed investigations. On minor roads, portable weigh pads will be used. This information is important in that the traffic could consist of a large number of light vehicles which have very low damaging factors on the pavement thus the AADT by itself does not give the full picture of the traffic loading.

In the case that it is not possible to measure axle loads, information will be sought from ANE on standard values of loading for different categories of vehicles.

6.2.6 Rainfall Data

Rainfall data were obtained from the Meteorological Office. The data were for the stations that were identified as being closest to the respective projects. The data consisted of annual rainfall, maximum rainfall for each month and details of any unusual or severe conditions that prevailed, such as floods. All the data were collected for the period 2006 to 2012.

Mozambique is experiencing climate change with the recurrence of adverse weather including tropical storms and cyclones which hit the coastal and some inland areas several times a year. A summary of the major cyclones was obtained from the Meteorological Department and is given in Table 6-1 and Appendix B.

The information on precipitation during adverse weather was also procured from the Meteorological Department. This is the maximum annual daily rainfall in mm shown in Table 6-1 and Appendix C. This shows the magnitude and intensity of rainfall which has had significant influence on the performance of the roads. During the rainy season of 2012, flood damage reached US$18 million.

Table 6-1 Key data for candidate roads

Province	Road No.	Road Name	Length (km)	Year of Construction	Contractor	Consultant	Type of Surface	Type of Base	Design/ Construction documents	Maintenance records	Traffic (2011 AADT)	Annual Average Rainfall (mm) (1996-2011)	
													Station
MAPUTO	Unclassified	Marracuene - Ferroviario	2	2005	CETA	Africon	Sand Seal	Emulsion Treated Sand Base	Method statement/ specifications	No Information		806	Marracuene
MAPUTO	R400	Boane-Pequeno Limbombos-Goba	3	No Information			Double Surface Dressing	Crushed rock/cement treated base	No Information	No Information	1,197	No Information	
INHAMBANE	N1	Pambarra - Rio Save	13	2009	CETA	Stange	Hot Sand Asphalt	Patched Double Surface Dressing on cement treated base	Design Charts	No Information	538	532	Vilanculos
ZAMBEZIA	N1	Nicoadala - Rio Zambezi	1.8				Hot Sand Asphalt	Crushed stone	No Information	No Information	512 (Rio Zambezi) 548 (Rio Luala) 864 (Nocoadala)	894	Caia
ZAMBEZIA	N10,N11	Quelimane - Namacurra	5.2				Hot Sand Asphalt	Macadam	No Information	No Information	1975 (Quelimane) 1185 (Namacurra)	1,288	Quelimane
NAMPULA	N104	Nametil - Angoche	7.2	2007	CETA/CMC JV	Black & Veatch	Sand cover on Otta Seal	Laterite	Completion Report	No Information	229	1,089	Nametil
CABO DELGADO	N380	Oasse - Mocimboa da Praia	3.1	2001	OPCE/MOTA	CPG/CPP	Sand Seal	Emulsion Treated Sand Base	No Information	No Information	218	1,279	Mocimboa da Praia
NIASSA	N13	Lichinga - Mandimba	13	2005	CMC Africa Austral	ANE	Otta Seal	Natural Gravel	Completion Report	No Information	290 (Lichinga) 80 (Mandimba)	1,279	Lichinga
NIASSA	N361	Maniamba - Metangula	12	2008	CMC Africa Austral	ANE	Otta Seal	Natural Gravel	Project Progress Report	No Information	55	1,279	Lichinga

Traffic data obtained from the 2011 ANE Traffic Data Report

6.3 Selection of Sub Sections

The criteria that were adopted at the beginning of the project in order to select the sub sections for each road were:

- Classification of road
- Traffic
- Age of road
- Construction type
- Availability of construction and maintenance records
- Current pavement condition
- Most importantly, the local knowledge and expertise of the ANE staff were also decisive in the identification of the candidate roads.

7 Details of the Road Sections

7.1 General

A reconnaissance survey was undertaken to identify a range of study sections in the six provinces. A map of Mozambique and the locations of the road sections is included in Appendix D.

The detailed characteristics of the road sections are presented below. This is based on the as-built and maintenance data (if available) that were collected, together with the observations and assessments that were carried out as part of the reconnaissance survey. For the purposes of referencing the road sections, a datum was selected and marked with paint, and the GPS locations were recorded. The chainages of each section were marked from this datum.

7.2 Classification of Road Condition

The classification of the road condition was based on the visual observation relating to the following road characteristics in

Table 7-1:

- Ride quality
- Extent of potholes
- Extent of cracking
- Rutting.

Table 7-1 Road condition criteria

Road Condition	Riding Quality	Surface Condition	Potholes	Cracks	Base
Good	Good	No surfacing loss	None	Minor, localised, sealed	Intact, not visible through the surfacing;
Fair	Slight Discomfort	Surfacing loss noticeable	5 %	Minor but extensive (reflective, on wheel paths, edge of carriageway)	Not visible, through the surfacing but visible on edge drops

Poor	Significant Discomfort	Surfacing loss extensive	5%-10%	Major and extensive (reflective, on wheel paths, edge of carriageway)	Visible through the surfacing and edge drops
Very Poor	Severe Discomfort	Complete surfacing loss/traffic avoiding running lane, requires reconstruction	>10%	Ravelling and Disintegration	Disintegration; traffic avoiding running lane, requires reconstruction

7.3 Maputo

7.3.1 Marracuene – Ferroviario Road (Unclassified)

This is an unclassified road in Maputo province that offers an alternative route to the N1 to Maputo City and Marracuenne. The road is about 27km long and was constructed in 2005 using sand seal on an emulsion-stabilised sand base.

Four study sections were identified on this road, having a combined length of 2km. They were constructed in the year 2005. There are no maintenance or traffic data available for this road. However, site observations show that it is heavily trafficked by light to medium trucks which mainly serve as public transport. The alignment is generally flat and straight. The sections are generally in poor condition, and are characterised by several potholes and cracks. The finished road level is generally below ground level, and appears to be poorly drained along the entire project extent.

Details of the study sections are given in Table 7-2 and typical views of the sections are given in Figure 7-1.

Table 7-2 Properties of study sections

PROVINCE	Maputo
Road Name	Marracuene-Ferruviario Road
Road Length	27 km

Emulsion treated base ETB DATUM: Marracuene

Section	Start Chainage	End Chainage	Section Length (km)	Surfacing Type	Base Materials	Visual Condition (Good, Fair, Poor)	Longitudinal Section Geometry (Flat, Slope, Rolling)	Cross-sectional Geometry (Trough, Crest, Flat)	Sub-surface drainage (Good, Fair, Poor)	Other Remarks
1	Km: 0+000	0+300	0.3	Sand seal	ETB	Poor	Flat	Trough	Good	Road level below natural ground level
2	Km: 0+300	0+900	0.6	Sand seal	ETB	Fair	Flat	Trough	Good	Road level below natural ground level
3	Km: 2+800	3+000	0.2	Sand seal	ETB	Poor	Flat	Trough	Good	Road level below natural ground level
4	3+800	4+100	0.3	Sand seal	ETB	Poor	Flat	Trough	Good	Road level below natural ground level

The surface condition of Section 1 is poor with several potholes and surface loss. Section 2 is better than Section 1 but most traffic tends to drive on the sandy side of the road which is smoother.

Section 3 is identical in condition to Section 1. The surface has several potholes and depressions by the side of the surfaced portion where water ponds.

Section 4 has deeper and wider potholes and traffic generally avoids using the road section and rather uses the side of the road. It is in very poor condition.

Section 1

Section 2

Section 3

Section 4

Figure 7-1 Typical Sections of the Marracuenne – Ferroviario Road

Although this road was built in 2005, it is already showing signs of significant structural and surfacing failure. The causes of the failure will be investigated during the detailed phase of this study. This could be attributed to some of the following:

1. Under design of the pavement
2. Non-compliance with the method statement during construction
3. Drainage induced failure associated with the road level being below ground level
4. Seasonal moisture variations/repeated wetting and drying.

7.3.2 Boane – Limbobos – Goba Road (R400)

This road connects Boane, which is approximately 40km south-west of Maputo along the N2, to the Limbobos dam and on further south-west towards the town of Goba at the Mozambique-Swaziland border. The total length of the road is about 45km. Information on the age, construction and maintenance of this road was not available at the time of preparing this report.

The study sections identified during the reconnaissance survey have a combined length of about 3km, and are representative of the condition and materials of the road.

There are two different pavement constructions on the road. From Boane to Rio Umbuluzi the road comprises a double surface dressing on a stone macadam base, and from Rio Umbuluzi to the Limbombos dam it comprises a double surface dressing on a cement-stabilised sand base. The two sections are separated by a bridge (currently collapsed) over the river. The general terrain is undulating and mostly straight. Most of the road is still in good condition and functioning well but sections exist that are visually in fair or poor condition. The road crosses swamps in some locations.

Details of the study sections are summarised in Table 7-3 and views of the study sections are given in Figure 7-2.

Table 7-3 Properties of study sections

PROVINCE	Maputo
Road Name	Boane-Limbombos-Goba
Road Length	45 km

Double surface dressing DSD DATUM: Boane

Cement treated base CTSB

Section	Start Chainage	End Chainage	Section Length (km)	Surfacing Type	Base Materials	Visual Condition (Good, Fair, Poor)	Longitudinal Section Geometry (Flat, Slope, Rolling)	Cross-sectional Geometry (Trough, Crest, Flat)	Sub-surface drainage (Good, Fair, Poor)	Other Remarks
1	Km: 0+000	0+300	0.3	Double Surface Dressing	Crushed Rock	Good	Flat	Crest	Good	No side drains exist but kerbs exist
2	Km: 0+300	0+800	0.5	Double Surface Dressing	Crushed Rock	Poor	Slope	Flat	Good	Potholes, Cracks and Patching
3	Km: 4+700	5+100	0.4	Double Surface Dressing	CTSB	Good	Flat	Flat	Good	
4	Km: 5+400	5+700	0.3	Double Surface Dressing	CTSB	Fair	Flat	Flat	Good	Cracks all over but minor potholing
5	Km: 7+700	7+960	0.3	Double Surface Dressing	CTSB	Good	Slope	Crest	Poor	Minor Rutting
6	Km: 7+960	8+600	0.64	Double Surface Dressing	CTSB	Poor	Flat	Crest	Poor	Rutting, Cracking and Potholes

Section 1 and 2 were constructed with a crushed stone Macadam base. Section 1 is in good condition despite being predominantly flat and without side drains. Section 2 is visually in poor condition with several potholes and cracks. The geometry of this section alternates between flat and sloping. Sections 3 to 6 were built with a cement treated sand base (CTSB). Section 3 is flat and the visual condition is good. Section 4 is in fair condition with several crocodile cracks and minor potholing. Section 5 is sloping and is located in a swamp. The visual condition is good with minor rutting. Section 6 is located in a swamp but, unlike Section 5, the condition is poor with significant rutting, cracking and potholing.

Section 1

Section 2

Section 3

Section 4

Section 5

Section 6

Figure 7-2 Typical Sections of the Boane – Limbombos – Goba Road

7.4 Inhambane

7.4.1 Pambarra – Rio Save Road (N1)

This road starts at the Pambarra junction at the turn-off to Vilanculos and continues up to the Rio Save. It is a segment of about 121km on the main trunk road N1. The construction consists of hot sand asphalt (HSA) surfacing laid on patched double surface dressing which was laid on a cement treated base and sub-base.

There are 15 study sections, with a combined length of 13km, which were built in 2009 as a maintenance treatment for portions of the road that were highly distressed; the original dressing had developed several deep potholes at these locations.

Most of the sections are flat terrain, although a few sections have horizontal curves, most of which are built on embankments. Visually, all the sections are in good condition with only very minor cracks, no potholes and no ruts.

The sections built on embankments do not have any visible evidence of surface drainage. However sub-surface drainage may be a problem in areas where the embankments were built in swamps.

Details of the study sections are given in Table 7-4 and typical views of the sections are given in Figure 7-3.

Table 7-4 Properties of study sections

PROVINCE	INHAMBANE
Road Name	Pambara - Rio Save (1)
Road Length	121 km

Double surface dressing DSD

Cement treated base CTB

DATUM: Vilanculos Junction

Section	Start Chainage	End Chainage	Section Length (km)	Surfacing Type	Base Materials	Visual Condition (Good, Fair, Poor)	Longitudinal Section Geometry (Flat, Slope, Rolling)	Cross-sectional Geometry (Trough, Crest, Flat)	Sub-surface drain (Good, Fair, Poor)	Other Remarks
1	Km: 17+900	19+200	1.3	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	
2	Km: 22+200	23+700	1.5	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	7m wide, minor pitting, pronounced edge drop
3	Km: 48+600	49+600	1	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	Mix seems stiffer than S1 and S2
4	Km: 50+000	50+200	0.2	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	Junction to Inhasorro, DSD Scraped off first
5	Km: 50+400	50+600	0.2	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	Junction to Inhasorro, DSD Scraped off first
6	Km: 57+900	58+500	0.6	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	
7	Km: 69+300	69+600	0.3	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	
8	Km: 69+800	69+900	0.1	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	

PROVINCE	INHAMBANE
Road Name	Pambara - Rio Save (2)
Road Length	121 km

Double Surface Dressing DSD

Cement Treated Base CTB

DATUM: Vilanculos Junction

Section	Start Chainage	End Chainage	Section Length (km)	Surfacing Type	Base Materials	Visual Condition (Good, Fair, Poor)	Longitudinal Section Geometry (Flat, Slope, Rolling)	Cross-sectional Geometry (Trough, Crest, Flat)	Sub-surface drainage (Good, Fair, Poor)	Other Remarks
9	Km: 70+200	70+800	0.6	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	Curve
10	Km: 74+900	75+600	0.7	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	
11	Km: 76+100	76+900	0.8	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	
12	Km: 93+900	94+600	0.7	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	Low lying but elevated prone to flooding
13	Km: 104+000	105+600	1.6	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	Curve, low lying + straight
14	Km: 106+500	108+000	1.5	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	Straight then more elevated curve
15	Km: 110+500	112+400	1.9	Hot Sand Asphalt	Patched DSD on CTB	Good	Flat	Crest	Good	Curve straight
SAND BORROW PIT	Km: 43+600		0							On RHS towards Rio Save

The sections have very similar characteristics but with minor differences. There is some minor pitting in Section 1; the mix on Section 3 looks leaner; Section 12 is low lying; and there are curves on Sections 13, 14 and 15.

Section 3


Section 7


Section 12


Section 13

Figure 7-3 Typical Sections of the Pambarra – Rio Save Road

7.5 Zambezia

7.5.1 Rio Zambezi – Nicoadala Road (N1)

This road connects Rio Zambezi to the junction at Nicoadala. The road is about 150km long and passes through mainly undulating terrain.

There are 6 sections of hot sand asphalt (HSA) surfacing that were identified as potential candidates for the detailed study. The total length of these sections is 1.75km. These sections were built as a maintenance treatment for spots on the road that had developed significant distress. There are no data available on the age of the road, although it is described as 'very old' by ANE. The pavement structure consists of hot sand asphalt on patched asphalt on cement treated base and sub-base.

Some of the sections lie in swampy low-lying land and others are on a hill crest with no visible sub-surface drainage problems.

Visually the condition of the sections varies between good, fair and poor with significant rutting and cracking noticed in the poor sections.

Details of the study sections are given in

Table 7-5 and typical views of the sections are given in Figure 7-4.

Table 7-5 Properties of study sections

PROVINCE	ZAMBEZIA
Road Name	Rio Zambezi - Nicoadala
Road Length (	

Double surface dressing DSD

Cement treated base CTB

DATUM Rio Zambezi

Section	Start Chainage	End Chainage	Section Length (km)	Surfacing Type	Base Materials	Visual Condition (Good, Fair, Poor)	Longitudinal Section Geometry (Flat, Slope, Rolling)	Cross-sectional Geometry (Trough, Crest, Flat)	Sub-surface drainage (Good, Fair, Poor)	Other Remarks
1	Km: 42+700	42+810	0.113	Hot Sand Asphalt	Patched on CTB after milling DSD	Good	Slight Slope	Crest	Good	
2	Km: 48+200	48+300	0.064	Hot Sand Asphalt	Patched on CTB after milling DSD	Good	Slight Slope	Flat	Good	No Sealed Shoulders
3	Km: 105+000	105+170	0.17	Hot Sand Asphalt	Patched on CTB after milling DSD	Good	Slope approaching low lying	Flat	LHS Swampy with rice growing	High embankment
4	Km: 105+500	105+600	0.09	Hot Sand Asphalt	Patched on CTB after milling DSD	Good	Flat	Trough/Cut	Good	
5	Km: 140+700	141+900	1.2	Hot Sand Asphalt	Patched on CTB after milling DSD	Fair	Flat	Crest	Good	Low lying land, though well drained. Some cracks and 5 potholes
6	Km: 155+000	155+200	0.2	Hot Sand Asphalt	Patched on CTB after milling DSD	Poor	Flat	Crest	Good	Crocodile cracks, rutting and flow.

Sections 1 and 2 are on a longitudinal slope. They show no significant defects and appear to be in good condition despite there being no sealed shoulders. Section 3 is also on a longitudinal slope but, unlike Sections 1 and 2, is in a swampy location with some of the side drains waterlogged. Despite this it appears to be in good condition. Section 4 is flat and lies at the bottom of the slope. It also appears to be in good condition. Section 5 is similar to Section 4 but the visual condition can be described as fair showing cracking and minor potholing. Section 6 is also flat but it shows significant cracking and rutting.

Section 3

Section 5

Section 6

Figure 7-4 Typical Sections of the Rio Zambezi – Nicoadala Road

7.5.2 Quelimane – Namacurra Road (N10)

This road is part of the trunk road N10. It connects the city of Quelimane to the junction at Nicoadala. The road is about 30km long and passes through mainly level but low-lying terrain characterised by swamps. The construction consists of four sections of hot sand asphalt (HSA) surfacing that was applied as a maintenance alternative to the conventional asphalt concrete strengthening overlay. The HSA overlay was applied on a pavement originally comprising a double surface dressing (DSD) overlying a crushed stone base, natural gravel sub-base and embankment fill in that order. The average height of the embankment is 2m and is waterlogged on most of the sections. Five study sections with a total length of 5.2km were surveyed.

Visually the sections all appear to be in good condition with only minor differences in surface appearance between them.

Details of the study sections are given in Table 7-6 and typical views of the sections are given in Figure 7-5.

Table 7-6 Properties of study sections

PROVINCE	ZAMBEZIA
Road Name	Quelimane - Namacurra
Road Length	

DATUM Quelimane

Section	Start Chainage	End Chainage	Section Length (km)	Surfacing Type	Base Materials	Visual Condition (Good, Fair, Poor)	Longitudinal Section Geometry (Flat, Slope, Rolling)	Cross-sectional Geometry (Trough, Crest, Flat)	Sub-surface drainage (Good, Fair, Poor)	Other Remarks
1	Km: 6+000	7+400	1.4	Hot Sand Asphalt	Macadam	Good	Flat	Crest	Embankment in Swamp	
2	Km: 7+400	8+600	1.2	Hot Sand Asphalt	Macadam	Good	Flat	Crest	Embankment in Swamp	Visible difference in Mix
3	Km:1 6+900	18+000	1.1	Hot Sand Asphalt	Macadam	Good	Flat	Crest	Embankment in Swamp	Extra layer of HSA on surfaced shoulders
4	Km: 21+300	21+900	0.6	Hot Sand Asphalt	Macadam	Good	Flat	Crest	Embankment in Swamp	
5	Km: 26+500	27+400	0.9	Hot Sand Asphalt	Macadam	Good	Flat	Crest	Embankment in Swamp	Minor deformations on inside of curve as bridge is approached
6*	0+000									In Quelimane City
7*	61+000									Sub-base borrow pit on theLHS towards Rio Zambezi
8*	51+000									Sand from Rio Licuari on LHS towards Rio Zambezi

* Borrow pit sites

Section 1

Figure 7-5 Typical sections of the Quelimane – Namacurra Road

7.6 Nampula

7.6.1 Nametil-Angoche Road (N104)

This road links the provincial city of Nampula to the port city of Angoche. It was built as part of the Rural Roads Rehabilitation Programme in 2007. The entire road consists of alternating paved and unpaved sections, approximately 63km in length. However, the reconnaissance survey was limited to the paved sections

The construction of the paved sections consisted of a single Otta seal with a sand cover seal surfacing on a cement stabilised base overlying a lateritic and granular sub-base.

Concrete lined side drains were also constructed at locations that are at risk of erosion by runoff. Improvements to drainage also included the re-excavation of silted mitre drains and the construction of new ones.

As part of the rehabilitation, three trial sections of variable lengths were constructed as follows:

1. Ch 14+800-14+900 (100m) single Otta seal with no sand cover seal on a natural base material
2. Ch 27+400-27+500: Two sections of prime at different consistencies on a gravel wearing course (to determine the effects of the prime in increasing the durability of the surfacing). However, this trial section lies within the unpaved section of the road and therefore does not form part of the study sections.

Five study sections, with a combined length of 7.2km were identified. The study sections lie on terrain that ranges from flat to rolling. They do not show any visible signs of failure apart from isolated sections, most of which are at the interfaces of the paved and unpaved sections. The road generally lies above the natural ground level and is in good condition.

Details of the study sections are given in Table 7-7 and typical views of the sections are given in Figure 7-6.

Table 7-7 Properties of study sections

PROVINCE	Nampula
Road Name	Nametil-Angoche
Road Length	63 km

Cement treated base CTB DATUM Nametil

Section	Start Chainage	End Chainage	Section Length (km)	Surfacing Type	Base Materials	Visual Condition (Good, Fair, Poor)	Longitudinal Section Geometry (Flat, Slope, Rolling)	Cross-sectional Geometry (Trough, Crest, Flat)	Sub-surface drainage (Good, Fair, Poor)	Other Remarks
1	0+000	2+500	2.5	Otta seal	CTB	Good	Rolling	Crest	Good	N/A
2	3+600	3+800	0.2	Otta seal	CTB	Good	Rolling	Flat	Good	N/A
3	4+000	5+000	1	Otta seal	CTB	Good	Rolling	Flat	Good	N/A
4	9+000	10+500	1.5	Otta seal	CTB	Good	Rolling	Flat	Good	N/A
5	11+700	13+700	2	Otta seal	CTB	Good	Rolling	Flat	Good	N/A

Section 1

Section 2

Section 3

Section 4

Figure 7-6 Typical sections of the Nametil-Angoche road

7.7 Cabo Delgado

7.7.1 Oasse-Mocimboa da Praia Road (N380)

This road connects Pemba to Mocimboa da Praia via Sunate on the N1 and Macomia. The road is approximately 43km long. The longitudinal alignment ranges from flat to rolling, whilst the cross sections range from full cutting, partial cutting/filling to full embankment.

The road was constructed in 2001 using an emulsion treated sand base (ETB) overlaid by a sand seal surfacing. However, more details of the as-built and maintenance information for this road were not available at the time of producing this report.

Eight study sections with a combined length of 3.1km were identified. Visually, the road condition ranges from good to very poor. The sections in good condition are located where the road level generally lies above ground level. Sections in poor condition are at locations where the road level lies below the ground level and where the road lies within partial or full cutting. Typical defects observed on the study sections include rutting on the wheel paths, cracking, potholes and surface stripping and disintegration.

Details of the study sections are given in Table 7-8 and typical views of the sections are given in Figure 7-7.

Table 7-8 Properties of study sections

PROVINCE	Cabo Delgado
Road Name	Oasse-Mocimboa da Praia
Road Length	43 km

Emulsiont treated base ETB DATUM Oasse

Section	Start Chainage	End Chainage	Section Length (km)	Surfacing Type	Base Materials	Visual Condition (Good, Fair, Poor)	Longitudinal Section Geometry (Flat, Slope, Rolling)	Cross-sectional Geometry (Trough, Crest, Flat)	Sub-surface drainage (Good, Fair, Poor)	Other Remarks
1	Km: 0+000	0+300	0.3	Sand Seal	ETB	Fair	Flat	Crest	Good	Block cracks-(shrinkage) unsurfaced shoulders Road level above ground level
2	Km: 0+300	0+900	0.6	Sand Seal	ETB	Poor	Flat	Flat	Good	Potholes (1.5x0.5m) Transverse cracks Stripping Road level below ground level
3	2+000	2+500	0.5	Sand Seal	ETB	Poor	Slope	Flat	Good	Potholes Rutting on Mocimboa bound wheel track Road level at ground level
4	2+800	3+100	0.3	Sand Seal	ETB	Good	Slope	Flat	Good	
5	20+800	21+300	0.5	Sand Seal	ETB	Very Poor	Rolling	Crest	Poor	Road level below ground level
6	22+100	22+500	0.4	Sand Seal	ETB	Good	Slope	Crest	Poor	Road level above ground level
7	22+500	22+800	0.3	Sand Seal	ETB	Poor	Flat	Crest	Poor	Potholes Cracks Surface Disintegration Failure mainly on Mocemboa bound lane where water ponds in cutting Road level below ground level Cut and fill cross section
8	22+800	23+000	0.2	Sand Seal	ETB	Poor	Low lying	Crest	Poor	Rutting, Cracking and Potholes Road level above ground level

Sections 1 and 2 are on flat terrain, the road lies above ground level and appears well drained. Section 1 is in a fair condition and most of the visible defects are block cracks.

Section 2 is in poor condition as characterised by the stripping of the surfacing, transverse cracks and severe potholing (typically 1.4m by 0.5m), which are mainly concentrated in the Oasse-bound lane.

Section 3 is on a sloping alignment and the road level is generally below ground level. The condition of this section is poor and is characterised by block cracking, potholes and rutting, which is mainly localised in the outer wheel path of the Mocimboa-bound lane.

Section 4 is on a longitudinal slope. The road level is above ground level and it is in good condition. Section 5 is in rolling terrain and the cross section is in part cut and part fill. The condition of the section is very poor, most evident in the cutting on the Mocimboa-bound side of the carriageway where the road lies below the natural ground level. There is no evidence of sub-surface drainage. The typical depth of edge drops is 300mm.

Section 6 is on a longitudinal slope and the road is above ground level. The section is in good condition and the visible defects are block cracks that are localised approximately 1m on either side of the edge of the pavement.

Section 7 is on flat terrain, with most of the road lying below ground level. The section is in poor condition and is characterised by cracking, surface disintegration and potholes. These defects are localised in the Mocimboa da Praia-bound lane. There is no evidence of sub-surface drainage.

Section 8 lies within a low-lying part of the road. However, the road level is elevated approximately 1.5 metres above ground level. The section is in a fair condition. Visible defects are edge drops and cracks, which are localised within 1m of the edges of the pavement.

Section 1 and 2

Section 2

Section 4

Section 5

Figure 7-7 Typical sections of the Oasse-Mocimboa da Praia road

7.8 Niassa

7.8.1 Maniamba-Metangula Road (N361)

This road connects Lichinga, the provincial capital, to the town of Metangula on the shores of Lake Niassa. The total length of the road is approximately 30km. The terrain varies from rolling to mountainous.

The road construction comprises an Otta seal with a sand cover seal on a natural base and sub-base.

Although the construction of the road is the same, there are two distinct sections, each approximately 14km long. The differences between the distinct sections are the age and general condition of the pavement

The recently constructed section was constructed in 2008 and consists of the 14km section between Metangula and halfway to Maniamba. It contains sub-sections that are variable in terms of terrain and pavement condition. The terrain ranges from flat to mountainous, whilst the pavement condition ranges from good to very poor.

The older section lies in terrain that ranges from low to mountainous. Information on its construction and maintenance are not available but further enquiries are being made.

There are nine study sections, with a combined length of 14.2km which are located within both the earlier and more recently constructed sections.

Details of the study sections are given in Table 7-9 and typical views of the sections are given in Figure 7-8.

Table 7-9 Properties of study sections

PROVINCE	Niassa
Road Name	Maniamba-Metangula
Road Length	30 km

DATUM: Metangula

Section	Start Chainage	End Chainage	Section Length (km)	Surfacing Type	Base Materials	Visual Condition (Good, Fair, Poor)	Longitudinal Section Geometry (Flat, Slope, Rolling)	Cross-sectional Geometry (Trough, Crest, Flat)	Sub-surface drainage (Good, Fair, Poor)	Other Remarks
1	0+000	2+500	2.5	Otta seal	Natural Gravel	Good	Flat	Flat	Good	Road is in urban area Programme for paving all drains in urban area ongoing Accumulation of sand in Lichinga bound lane-possibly due to runoff
2	2+500	2+600	0.1	Otta seal	Natural Gravel	Poor	Flat	Flat	Good	Potholes Cracking Access to petrol station
3	3+600	3+800	0.2	Otta seal	Natural Gravel	Poor	Slope	Flat	Good	Potholes Rutting Road level at ground level
4	4+000	5+000	1	Otta seal	Natural Gravel	Good	Slope	Flat	Good	
5	0+000	0+200	0.2	Otta seal	Natural Gravel	Fair	Rolling	Crest	Poor	Road level below ground level
6	0+200	4+100	3.9	Otta seal	Natural Gravel	Very Poor	Slope	Crest	Poor	Road level above ground level
7	4+100	6+900	2.8	Otta seal	Natural Gravel	Poor	Flat	Crest	Poor	Potholes Cracks Surface Disintegration
8	9+000	10+500	1.5	Otta seal	Natural Gravel	Fair	Low lying	Crest	Poor	Rutting, Cracking and Potholes Road level above ground level
9	11+700	13+700	2	Otta seal	Natural Gravel	Good	Low lying	Crest	Poor	Rutting, Cracking and Potholes Road level above ground level

Section 1 is 2.5km long and lies wholly within the urban area of Metangula. The longitudinal alignment is straight and the vertical alignment is generally flat. There are a number of culverts that collect water from the mountainous (Maniamba/Lichinga-bound) side of the carriageway and this water is discharged to the land which is adjacent to the Metangula-bound side of the road.

The study section is in good condition and is characterised by the following:

- Sand on carriageway on the mountainous side of the road cross section. It is not clear whether this sand accumulation is a result of runoff overtopping.
- Paved drains on the upstream side of the watercourses/low-lying areas. The programme of paving the side drains is on-going.

Section 2 is 0.1km long and is located approximately 2.5 km from Metangula. The road lies below natural ground level, and there are signs of poor pavement condition and deterioration characterised by potholes, patching, runoff overtopping and severe cracking and patching.

Section 3 is 0.2km and is located within the mountainous area that the road traverses. The study section is in a poor condition and is characterised by severe cracks and potholes. There is no visual evidence of sub-surface drainage.

Section 4 is 1km long and is in the mountainous area. It is well drained and there is no evidence of any structural or surfacing defects. The study section is in good condition.

Section 5 is 0.2km long and lies within low lying and mountainous terrain. It is in a fair condition and is characterised by crocodile cracking and surface stripping.

Section 6 is 3.9km long and lies within terrain that ranges from flat, low lying to mountainous. The study section is in a very poor condition and is characterised by stripping, disintegration, potholes and complete surfacing disintegration in some areas. The road along this section generally lies in areas where there are deep cuts due to the mountainous terrain. The side drains are not paved and there is no evidence of sub-surface drainage. The absence of sub-surface drainage may have contributed in part to the poor pavement condition. Some localised maintenance work is being carried out on some of the areas with the most severe pavement failures. The work includes pothole repair, drainage improvement and partial to full pavement reconstruction.

Section 7 is 2.8km long and lies in flat terrain. The road level lies above ground level throughout. This study section is in good condition.

Section 8 is 1.5km long and lies within rolling/undulating and low-lying terrain. It is in a fair condition and is characterised by marginal rutting within the wheel paths, cracking and minor potholes.

Section 9 is 2km long and lies within rolling/undulating and low-lying terrain. It is in good condition and is characterised by minor rutting, cracking and potholes.

Section 1

Section 2

Section 6

Section 6

Figure 7-8 Typical Sections of the Maniamba-Metangula road

7.8.2 Lichinga-Mandimba Road (N13)

This road connects Lichinga, the provincial capital, to Mandimba, and serves as the strategic route that connects Mandimba to the Malawi border. The terrain is winding and mountainous. The total length of the road is 148km. The road was constructed in 2007 as part of the short term interventions to minimise gravel loss on roads that were built under the 2005 emergency works programme. The construction comprises an Otta seal with a sand cover seal on a natural base and sub-base.

There are 10 study sections, with a combined length of 15km which form the surfaced sections that were built in 2007 as part of the short term interventions. The condition of the study sections range from good to very poor.

Details of the study sections are given in Table 7-10 and typical views of the sections are given in Figure 7-9.

Table 7-10 Characteristics of study sections

PROVINCE	Niassa
Road Name	Lichinga Mandimba
Road Length	148 km

DATUM: Mandimba

Section	Start Chainage	End Chainage	Section Length (km)	Surfacing Type	Base Materials	Visual Condition (Good, Fair, Poor)	Longitudinal Section Geometry (Flat, Slope, Rolling)	Cross-sectional Geometry (Trough, Crest, Flat)	Sub-surface drainage (Good, Fair, Poor)	Other Remarks
1	0+000	0+900	0.9	Otta seal	Natural Gravel	Very Poor	Flat	Flat	Good	Potholes mainly on centre line Cracking and patching Edge drops Road level below ground level
2	0+900	2+700	1.8	Otta seal	Natural Gravel	Good	Rolling	Flat	Good	Crocodile cracks on Mandimba bound lane Road level above ground level
3	2+700	3+800	0.2	Otta seal	Natural Gravel	Fair	Flat	Flat	Good	Potholes Rutting Road level at ground level
4	3+800	4+900	1.1	Otta seal	Natural Gravel	Fair	Slope	Flat	Good	Cracking Patching
	9+500	10+800	1.3	Otta seal	Natural Gravel	Poor	Rolling	Crest	Poor	Road level below ground level
6	10+800	11+000	3.9	Otta seal	Natural Gravel	Poor	Rolling	Crest	Poor	Road level above ground level
7	11+000	13+300	2.3	Otta seal	Natural Gravel	Poor	Rolling	Crest	Poor	Potholes on centre line of carriageway
8	81+600	83+900	2.3	Otta seal	Natural Gravel	Fair	Mountainous	Crest	Poor	Cracks, patches and potholes
9	83+900	84+100	0.2	Otta seal	Natural Gravel	Fair	Flat	Crest	Poor	Cracks, patches and potholes
10	87+200	88+200	1	Otta seal	Natural Gravel	Good	Low lying/sag	Crest	Poor	Cracks, patches and potholes

Section 1 is 0.9km long and lies within the urban area of Mandimba. It is in a very poor condition characterised by edge drops, cracking, patching and potholes, the latter being localised within the middle of the carriageway. The road level lies below the ground level.

Section 2 is 1.8km long and is in a good condition. The road lies above ground level and there are some crocodile cracks on the Mandimba bound lane.

Section 1

Section 2

Section 8

Section 9

Figure 7-9 Typical sections of the Lichinga-Mandimba road

8 Recommendations

As described earlier in this report, nine candidate roads with representative ages, construction types, and conditions were selected for the reconnaissance survey. Study sections for each road were identified and details of the conditions were presented. The information is summarised in Table 8-1.

Table 8-1 Summary of road characteristics

No	Road Name	Surfacing	Base	General Condition
1	Marracuene-Ferruviario	Sand seal	Emulsion Treated Base	Poor
2	Boane-Libombos	Double Surface Dressing	Granular and cement treated	Good to Poor
3	Pambara-Rio Save	Hot sand asphalt	Cement stabilised	Good
4	Rio Zambezi-Nicoadala	Hot sand asphalt	Cement stabilised	Good to Poor
5	Quelimane-Namacurra	Hot sand asphalt	Macadam	Good
6	Nametil-Angoche	Sand cover on Otta seal	Cement-stabilised	Good
7	Oasse-Mocimboa da Praia	Sand Seal	Emulsion Treated Base	Fair to Poor
8	Maniamba-Metangula	Sand cover on Otta seal	Natural gravel	Good to Poor
9	Mandimba-Lichinga	Sand cover on Otta seal	Natural gravel	Good to Poor

In order to maximise the possible range of construction types in the detailed investigation phase of the project, to avoid unnecessary repetition, and to manage the project within the resources available, it is recommended that the following 7 roads, comprising 20 study sections be studied during the detailed phase (Table 8-2).

These roads were selected because they represent a broad range of surfacing type, condition, rainfall, traffic volume and age, and the 2 roads excluded from the sample (Marracuene - Ferruviario and Maniamba – Metangula) were found to have characteristics and construction types that were duplicated by other sections.

Table 8-2 Recommended roads and study sections

No	Road Name	Age (yrs)	Surfacing	Base	General Condition	Inclusion in Detailed Investigation	Justification for Inclusion/Exclusion	No. of Sections
1	Marracuene-Ferruviario	7	Sand seal	Emulsion treated base	Poor	Exclude	Highly deteriorated and beyond analysis	N/A
2	Boane-Limbombos	No information	Double surface dressing	Granular	Good to Poor	Include	Only section with double Surface Dressing on Macadam base	2
			Double surface dressing	Cement stabilised	Good to Poor	Include	Only section with double Surface Dressing on cement treated sand base	4
3	Pambara-Rio Save	3	Hot sand asphalt	Cement stabilised	Good	Include	Sections generally in good condition throughout	1
4	Rio Zambezi-Nicoadala	No information	Hot sand asphalt	Cement stabilised	Good to Poor	Include	Sections showing more varied range of pavement condition compared to Pambara-Rio Save	3
5	Quelimane-Namacurra	No information	Hot sand asphalt	Crushed stone	Good	Include	Sections showing more varied range of pavement condition compared to Pambara-Rio Save	1
6	Nametil-Angoche	5	Sand cover on Otta seal	Cement stabilised	Good	Include	Only section with Otta seal on cement treated base	3
7	Oasse-Mocimboa da Praia	11	Sand Seal	Emulsion treated base	Fair to Poor	Include	Sections similar to Marracuene-Ferruviario and suitable for analysis	3
8	Maniamba-Metangula	4	Sand cover on Otta seal	Natural gravel	Good to Poor	Exclude	Section similar to Mandimba-Lichinga	N/A
9	Mandimba-Lichinga	5	Sand cover on Otta seal	Natural gravel	Good to Poor	Include	Section similar to Maniamba-Metangula but more varied in terms of terrain and road condition	3

9 Programme for Detailed Investigations

In accordance with the Terms of Reference, the following activities will be carried out during the detailed investigation stages of each road:

9.1 Field Investigations

1. Visual condition assessments to measure and record the extent of cracking, patching, surface stripping and bleeding
2. Drainage evaluation to assess whether adequate surface and sub-surface drainage has been provided for and/or is functioning
3. Rut depth and roughness measurements using the Bump Integrator
4. Deflection tests to measure in-situ stiffness of the pavements – it has not been verified whether deflection data are available in ANE. If available and deemed to be sufficient, then deflection surveys will not be necessary.
5. DCP tests to determine the in-situ strength and layer thicknesses
6. Trial or test pit excavation to determine the profile of the pavement, to obtain in-situ dry density and moisture contents of the pavement layers and samples of the materials for laboratory testing of properties that cannot be obtained from non-destructive testing on site .
7. Extraction of cores of the surfacing for testing

9.2 Materials Testing

Classification: grading, Atterberg limits, linear shrinkage,

1. Compaction: MDD, OMC
2. In situ moisture content
3. Strength: CBR (soaked, OMC, 0.75 OMC)
4. Bituminous surfacing: binder content, aggregate characteristics.

Materials testing is critical to the successful completion of the project. It is important for the main stakeholders of the project to ensure that reliable results are obtained at this stage. Of particular concern is the testing of the bitumen. The assessment of the bitumen is expected to yield results which will influence the development of specifications for low volume roads. To this effect it is important to determine a number of parameters.

Bitumen becomes brittle with age, resulting in cracking and the ingress of water to the lower pavement layers causing a greatly increased rate of road deterioration. Although this cannot be prevented, the length of time that it takes for the bitumen to deteriorate to a critical level is vital for the overall performance of the road. Premature failure of surfacings is common nowadays and the causes could be the quality of the bitumen that is being supplied, flaws in the construction process or inappropriate surfacing choice or design which result in the too rapid alteration of the bitumen. Thus measuring the properties of both new and old bitumen is an essential component of the study.

Aging of fresh bitumen will help to determine how the bitumen change over time and this may reveal some deficiencies in performance in typical tropical environments

Ductility used to be a major test in the determination of bitumen quality and this has been eliminated over time and substituted with viscosity tests, which is an indirect test. Poor ductility in the binder leads to premature cracking of the surfacing such that crack initiation would take a much shorter period. Ductility tests will be carried out in this project in addition to the penetration and viscosity tests.

The plan is to carry out bitumen tests at TRL's laboratory in the UK using specialised equipment and expertise in the test procedures. The materials testing will be carried out in Mozambique and others in Zimbabwe Central Roads Laboratory.

The transportation of materials from the sites to the local laboratories will be the responsibility of ANE. Also materials testing in ANE laboratories will also be the responsibility of ANE with technical assistance rendered by TRL.

The capacity of the ANE provincial and headquarters and LEM to carry out the materials testing has been presented in Chapter 6 of this report.

9.3 Analysis and Documentation

A detailed technical review of existing data will be undertaken to establish its utility in carrying out the back analysis of the study sections. There is a possibility that some of the as-built and maintenance records may not be available for some of the study sections (for instance Boane-Limbombos-Goba, Oasse-Mocimboa da Praia and Rio Zambezi-Nicoadala). In such situations, the back analysis will be based solely on the results of the field investigations, laboratory testing, and local knowledge of ANE staff. This information will be complemented and compared with the HDM-4 deterioration models generated for the respective study sections.

The HDM-4 model will be used to generate deterioration models based on different scenarios of traffic loading, pavement type, environmental factors and maintenance regimes. The actual condition and performance of the study sections, evaluated using data collected from field surveys and laboratory testing, will be compared with the HDM-4 output, thereby making it possible to evaluate the performance trends of the study sections with respect to traffic, pavement type, material specifications and maintenance regimes.

The pavement deflection surveys data that were collected in 2011 was at 10km intervals and more strategic in its nature since the exercise was conducted to carry out a network level assessment. It is therefore very limited in its use for carrying out the back analysis, which requires data to be collected at shorter intervals.

Figure 9-1 on the next page shows the Activity Schedule, whilst

Table 9-1 shows a list of the bitumen, deflection and other associated tests that are required to fully assess the performance of the pavements and their material characteristics.

Figure 9-1 Activity Schedule

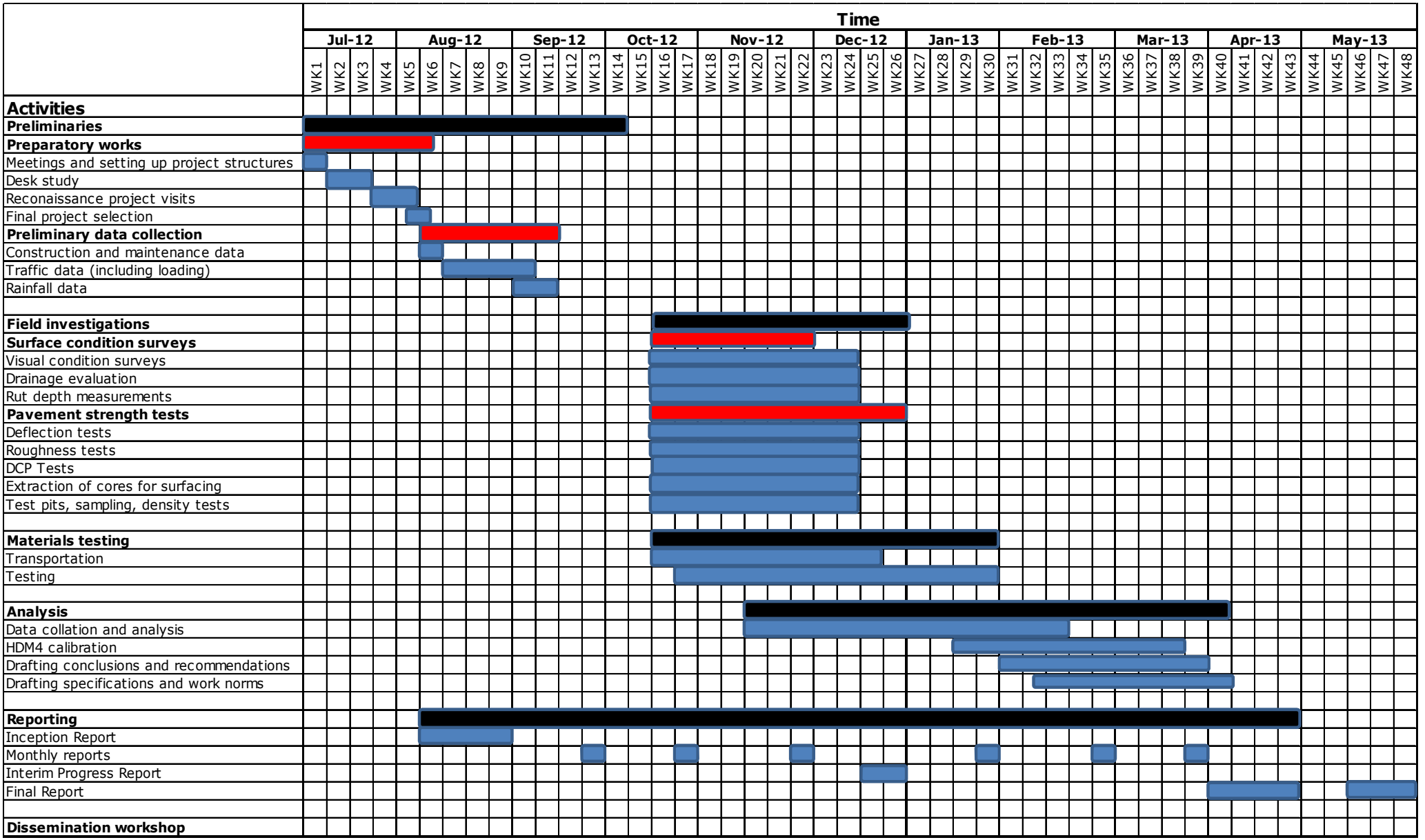

Table 9-1 Materials required to assess performance

Item		Test Method	Estimated no. of samples	Remarks
	Soil and Pavement Materials Tests			2 test pits for Pambarra-Rio Save and 1 pit per section for all other study sections
1	Plastic Limit	BS 1377-2	63	3 samples/pit (base, subbase and subgrade)
2	Liquid Limit	BS 1377-2	63	3 samples/pit (base, subbase and subgrade)
3	Shrinkage Limit	BS 1377-2	63	3 samples/pit (base, subbase and subgrade)
4	Dry Sieve Analysis (All BS Sieves from 50mm down to 75μm(No.200))	BS EN 933-1	42	2 samples/pit (base, subbase and subgrade)
5	Wet Sieve Analysis (All BS Sieves from 50mm down to 75μm(No.200))	BS 1377-7	42	2 samples/pit (base, subbase and subgrade)
6	Moisture Content Determination (Oven drying 105-110°C)	BS 1377-7	63	3 samples/pit (base, subbase and subgrade)
7	Maximum Dry Density Determination (MDD)	BS 1377-7	42	2 samples/pit (base, subbase and subgrade)
8	California Bearing Ratio (CBR)	EN 13286-47	63	3 samples/pit (base, subbase and subgrade)
9	Triaxial Tests	BS 1377-8	21	1 samples/pit (base, subbase and subgrade)
10	In Situ Density by Sand Replacement Method	BS EN 12390	42	2 samples/pit (base, subbase and subgrade)
	Aggregate and Surfacing Materials Tests		9	3 samples for each road (Boanne-Limbombos, Nametil-Angoche and Lichinga Mandimba)
11	Aggregate Crushing Value (ACV) - Dry Test	BS EN 1097-2	9	3 samples for each road (Boanne-Limbombos, Nametil-Angoche and Lichinga Mandimba)
12	Aggregate Crushing Value (ACV) - Wet Test	BS EN 1097-2	9	3 samples for each road (Boanne-Limbombos, Nametil-Angoche and Lichinga Mandimba)

13	10% Fines Aggregate Crushing Test (10%FACT) - Dry Test	BS EN 1097-2	9	3 samples for each road (Boanne-Limbombos, Nametil-Angoche and Lichinga Mandimba)
14	10% Fines Aggregate Crushing Test (10%FACT) - Wet Test	BS EN 1097-2	9	3 samples for each road (Boanne-Limbombos, Nametil-Angoche and Lichinga Mandimba)
15	Aggregate Impact Value (AIV) - Dry	BS EN 1097-2	9	3 samples for each road (Boanne-Limbombos, Nametil-Angoche and Lichinga Mandimba)
16	Aggregate Impact Value (AIV) - Wet	BS EN 1097-2	9	3 samples for each road (Boanne-Limbombos, Nametil-Angoche and Lichinga Mandimba)
17	Water Absorption	BS EN 13755	9	3 samples for each road (Boanne-Limbombos, Nametil-Angoche and Lichinga Mandimba)
18	Flakiness Index Test	BS EN 933-3	9	3 samples for each road (Boanne-Limbombos, Nametil-Angoche and Lichinga Mandimba)
	Bitumen Tests			
19	Bitumen Extraction Test (Composition)	EN 12697-1	30	For 6 roads and 5 sections per road, 1 sample per section.
20	Bitumen Recovery	EN 12697-3	12	For 6 roads two samples recovered for the tests below. That is 12 samples.
21	Rolling Thin Film Oven Test (RTFOT)	EN 12607-1	18	Ageing 3 samples for each of 2 cut-backs, 2 pengrades and 2 emulsions
22	Softening Point Test	EN 12697-1	10	Samples recovered from 2 above plus 2 samples of emulsion and 2 samples of penetration
23	Penetration Test	EN 1426	10	Samples recovered from 2 above plus 2 samples of emulsion and 2 samples of penetration
24	Standard Viscosity Test (STV)	EN 1427	4	2 samples of cut-back and 2 samples of prime.
25	Ductility Tests	EN 13589	18	Fresh samples of 2 cut-backs, 2 pengrades and 2 emulsions and repeated on un-aged samples and repeated on 6 recovered samples
26	Analytical Test Method: Composition	BS598-102	8	Samples of 2 cut-backs, 2 pengrades and 2 emulsions and 2 primes.

10 References

1. TRL (2006). Engineering Standards and Life Cycle Costing for Low-Volume Labour Based and Unpaved Roads – Mozambique Country Component: Final Report. Crowthorne: TRL Limited

2. Mukura, K. (2006). Guideline for Quality Assurance Procedures for Road Works. Crowthorne: TRL Limited

3. Overby, C. (1999). A Guide to the Use of Otta Seals. Oslo: Directorate of Public Roads, Road Technology Department International Division

4. ANE (2007). Normas de Execucao (Work Norms). Maputo: National Roads Administration

5. Ministry of Transport and Energy, Department of Roads, Part P Materials Specifications Manual

6. Ministry of Transport and Energy, Department of Roads, Part F Construction Manual

7. TRL (2006). SADC Guideline: Low Volume Sealed Roads. Southern Africa Development Community (SADC)

Appendix A - Assessment of laboratory capacity

Province Cabo Delgado
Number of staff 4

Tests	Equipment Available to perform?	Staff Available to perform?	Remarks
Soil and Pavement Materials Tests			
Plastic Limit	Yes	Yes	
Liquid Limit	Yes	Yes	
Shrinkage Limit	Yes	Yes	
Dry Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	Yes	
Wet Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	Yes	
Moisture Content Determination (Oven drying 105-110°C)	Yes	Yes	
Maximum Dry Density Determination (MDD)	Yes	Yes	
California Bearing Ratio (CBR)	Yes	Yes	
Triaxial Tests	No	No	
In Situ Density by Sand Replacement Method	Yes	Yes	
In Situ Density by Nuclear Gauge	No	Yes	
Aggregate and Surfacing Materials Tests			
Aggregate Crushing Value (ACV) - Dry Test	Yes	Yes	Machine needs calibration
Aggregate Crushing Value (ACV) - Wet Test	Yes	Yes	
10% Fines Aggregate Crushing Test (10%FACT) -	Yes	Yes	
10% Fines Aggregate Crushing Test (10%FACT) -	Yes	Yes	
Aggregate Impact Value (AIV) - Dry	Yes	Yes	
Aggregate Impact Value (AIV) - Wet	Yes	Yes	
Los Angeles Abrasion Value (LAV)	No	No	
Water Absorption	Yes	Yes	
Flakiness Index Test	Yes	Yes	
Bitumen Tests			
Bitumen Affinity	No	No	
Softening Point Test	No	No	
Penetration Test	No	No	
Distillation (Composition Tests)	No	No	
Ductility Tests	No	No	

Province Inhambane
Number of staff 4

Tests	Equipment Available to perform?	Staff Available to perform?	Remarks
Soil and Pavement Materials Tests			
Plastic Limit	Yes	Yes	
Liquid Limit	Yes	Yes	
Shrinkage Limit	Yes	Yes	
Dry Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	Yes	
Wet Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	Yes	
Moisture Content Determination (Oven drying 105-110°C)	Yes	Yes	
Maximum Dry Density Determination (MDD)	Yes	Yes	
California Bearing Ratio (CBR)	Yes	Yes	
Triaxial Tests	No	No	
In Situ Density by Sand Replacement Method	Yes	Yes	
In Situ Density by Nuclear Gauge	No	Yes	Equipment for ongoing project use only
Aggregate and Surfacing Materials Tests			
Aggregate Crushing Value (ACV) - Dry Test	Yes	Yes	
Aggregate Crushing Value (ACV) - Wet Test	Yes	Yes	
10% Fines Aggregate Crushing Test (10%FACT) - Dry	Yes	Yes	
10% Fines Aggregate Crushing Test (10%FACT) - Wet	Yes	Yes	
Aggregate Impact Value (AIV) - Dry	Yes	Yes	
Aggregate Impact Value (AIV) - Wet	Yes	Yes	
Los Angeles Abrasion Value (LAV)	No	No	
Water Absorption	Yes	Yes	
Flakiness Index Test	Yes	Yes	
Bitumen Tests			
Bitumen Affinity	No	No	
Softening Point Test	No	No	
Penetration Test	No	No	
Distillation (Composition Tests)	No	No	
Ductility Tests	No	No	

Province Maputo

Number of staff 3

Tests	Equipment Available to perform?	Staff Available to perform?	Remarks
Soil and Pavement Materials Tests			
Plastic Limit	Yes	Yes	
Liquid Limit	Yes	Yes	
Shrinkage Limit	Yes	Yes	
Dry Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	Yes	
Wet Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	Yes	
Moisture Content Determination (Oven drying 105-110°C)	Yes	Yes	
Maximum Dry Density Determination (MDD)	Yes	Yes	
California Bearing Ratio (CBR)	Yes	Yes	
Triaxial Tests	No	No	
In Situ Density by Sand Replacement Method	No	Yes	
Aggregate and Surfacing Materials Tests			
Aggregate Crushing Value (ACV) - Dry Test	Yes	Yes	
Aggregate Crushing Value (ACV) - Wet Test	Yes	Yes	
10% Fines Aggregate Crushing Test (10%FACT) -	Yes	Yes	
10% Fines Aggregate Crushing Test (10%FACT) -	Yes	Yes	
Aggregate Impact Value (AIV) - Dry	Yes	Yes	
Aggregate Impact Value (AIV) - Wet	Yes	Yes	
Los Angeles Abrasion Value (LAV)	No	No	
Water Absorption	Yes	Yes	
Flakiness Index Test	Yes	Yes	
Bitumen Tests			
Bitumen Affinity	No	No	
Softening Point Test	No	No	
Penetration Test	No	No	
Distillation (Composition Tests)	No	No	
Ductility Tests	No	No	

Province Nampula
Number of staff 3

Tests	Equipment Available to perform?	Staff Available to perform?	Remarks
Soil and Pavement Materials Tests			
Plastic Limit	Yes	Yes	
Liquid Limit	Yes	Yes	
Shrinkage Limit	Yes	Yes	
Dry Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	Yes	
Wet Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	Yes	
Moisture Content Determination (Oven drying 105-110°C)	Yes	Yes	
Maximum Dry Density Determination (MDD)	Yes	Yes	
California Bearing Ratio (CBR)	Yes	Yes	
Triaxial Tests	No	No	
In Situ Density by Sand Replacement Method	Yes	Yes	
Aggregate and Surfacing Materials Tests			
Aggregate Crushing Value (ACV) - Dry Test	Yes	Yes	
Aggregate Crushing Value (ACV) - Wet Test	Yes	Yes	
10% Fines Aggregate Crushing Test (10%FACT) - Dry Test	Yes	Yes	
10% Fines Aggregate Crushing Test (10%FACT) - Wet Test	Yes	Yes	
Aggregate Impact Value (AIV) - Dry	Yes	Yes	
Aggregate Impact Value (AIV) - Wet	Yes	Yes	
Los Angeles Abrasion Value (LAV)	No	No	
Water Absorption	Yes	Yes	
Flakiness Index Test	Yes	Yes	
Bitumen Tests			
Bitumen Affinity	No	No	
Softening Point Test	No	No	
Penetration Test	No	No	
Distillation (Composition Tests)	No	No	
Ductility Tests	No	No	

Province Niassa
Number of staff 1

Tests	Equipment Available to perform?	Staff Available to perform?	Remarks
Soil and Pavement Materials Tests			Only 1 laboratory staff available for the whole province
Plastic Limit	Yes	No	
Liquid Limit	Yes	No	
Shrinkage Limit	Yes	No	
Dry Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	No	
Wet Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	No	
Moisture Content Determination (Oven drying 105-110°C)	Yes	No	
Maximum Dry Density Determination (MDD)	Yes	No	
California Bearing Ratio (CBR)	No	No	Machine needs calibration
Triaxial Tests	No	No	
In Situ Density by Sand Replacement Method	Yes	No	
In Situ Density by Nuclear Gauge	Yes	No	3 machines available
Aggregate and Surfacing Materials Tests			Machine broken down
Aggregate Crushing Value (ACV) - Dry Test	No	No	
Aggregate Crushing Value (ACV) - Wet Test	No	No	
10% Fines Aggregate Crushing Test (10%FACT) - Dry Test	No	No	
10% Fines Aggregate Crushing Test (10%FACT) - Wet Test	No	No	
Aggregate Impact Value (AIV) - Dry	No	No	
Aggregate Impact Value (AIV) - Wet	No	No	
Los Angeles Abrasion Value (LAV)	No	No	
Water Absorption	No	No	
Flakiness Index Test	No	No	
Bitumen Tests			
Bitumen Affinity	No	No	
Softening Point Test	No	No	
Penetration Test	No	No	
Distillation (Composition Tests)	No	No	
Ductility Tests	No	No	

Province Zambezia
Number of staff 3

Tests	Equipment Available to perform?	Staff Available to perform?	Remarks
Soil and Pavement Materials Tests			
Plastic Limit	Yes	Yes	
Liquid Limit	Yes	Yes	
Shrinkage Limit	Yes	Yes	
Dry Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	Yes	
Wet Sieve Analysis (All BS Sieves from 50mm down to 75µm(No.200))	Yes	Yes	
Moisture Content Determination (Oven drying 105-110°C)	Yes	Yes	
Maximum Dry Density Determination (MDD)	Yes	Yes	
California Bearing Ratio (CBR)	Yes	Yes	
Triaxial Tests	No	No	
In Situ Density by Sand Replacement Method	Yes		
In Situ Density by Nuclear Gauge	No		Troxler not working
Aggregate and Surfacing Materials Tests			
Aggregate Crushing Value (ACV) - Dry Test	Yes	Yes	
Aggregate Crushing Value (ACV) - Wet Test	Yes	Yes	
10% Fines Aggregate Crushing Test (10%FACT) - Dry Test	Yes	Yes	
10% Fines Aggregate Crushing Test (10%FACT) - Wet Test	Yes	Yes	
Aggregate Impact Value (AIV) - Dry	No		
Aggregate Impact Value (AIV) - Wet	No		
Los Angeles Abrasion Value (LAV)	No		
Water Absorption	Yes		
Flakiness Index Test	Yes		
Bitumen Tests			
Bitumen Affinity	No		
Softening Point Test	No		
Penetration Test	No		
Distillation (Composition Tests)	No		
Ductility Tests	No		

	Capacity of ANE and LEM laboratories to carry out materials testing **Additional Tests**					
Item	**Bitumen Tests**	**Test Method**	**Estimated number of samples to be tested**	**Does ANE have Equipment and personel to do the test** **Yes/No**	**If NO, does the National Laboratory have capacity to carry out** **Yes/No**	**Remarks**
1	Bitumen Extraction Test (Composition)	EN 12697-1	30	NO	NO	For 6 roads and 5 sections per road, 1 sample per section.
2	Bitumen Recovery	EN 12697-3	12	NO	NO	For 6 roads two samples recovered for the tests below. That is 12 samples.
3	Rolling Thin Film Oven Test (RTFOT)	EN 12607-1	18	NO	NO	Ageing 3 samples for each of 2 cut-backs, 2 pengrades and 2 emulsions
4	Softening Point Test	EN 12697-1	10	NO	NO	Samples recovered from 2 above plus 2 samples of emulsion and 2 samples of penetration
5	Penetration Test	EN 1426	10	NO	YES	Samples recovered from 2 above plus 2 samples of emulsion and 2 samples of penetration
6	Standard Viscosity Test (STV)	EN 1427	4	NO	NO	2 samples of cut-back and 2 samples of prime.
7	Distillation (Composition Tests)	EN 1431	4	NO	NO	2 samples of cut-back and 2 samples of prime.
8	Ductility Tests	EN 13589	18	NO	NO	From aged samples of 2 cut-backs, 2 pengrades and 2 emulsions and repeated on un-aged samples and repeated on 6 recovered samples
9	DSR Method: Complex Shear Modulus and Phase Angle	EN 14770	18	NO	NO	From aged samples of 2 cut-backs, 2 pengrades and 2 emulsions and repeated on un-aged samples and repeated on 6 recovered samples
10	Analytical Test Method: Composition	BS598-102	8	NO	NO	samples of 2 cut-backs, 2 pengrades and 2 emulsions and 2 primes.
11	Storage stability of modified bitumen	EN 13399	6	NO	NO	For 2 emulsion samples and 2 cutbacks and 2 pengrades

	Capacity of ANE and LEM laboratories to carry out materials testing **Additional Tests**					
Item	**Bitumen Tests**	**Test Method**	**Estimated number of samples to be tested**	**Does ANE have Equipment and personel to do the test** **Yes/No**	**If NO, does the National Laboratory have capacity to carry out** **Yes/No**	**Remarks**
	Soil and Pavement Materials Tests					
	Triaxial Tests (U100 quick undrained or multistage)	BS 1377 Part 7	18	NO	NO	12 base material samples from 6 roads and 6 samples from 6 borrow pits
	Aggregate and Surfacing Materials Tests					
	Polished Stone Value (PSV)	EN 1097-8	6	NO	NO	6 surface agregate samples from 6 roads.
	Petrography (Mineralogy)	EN 932-3	12	NO	NO	6 Surface agregate samples from 6 roads and six base samples from 6 roads
	In-Situ Tests					

Appendix B – Cyclones Data

Nome de Tempesta de	Duração	Intensidade	Classificação	Local Afectado
Astride	23/12/99 – 03/01/00	95km/h (60mph) 985 hPa (mbar)	Tempestade Tropical Severa Categoria I	Mongincual
Leon-Eline	07/02-22/02/00	185km/h (115mph) 930 hPa (mbar)	Ciclone Tropical Intenso Categoria IV	Maputo e Gaza
Hudah	24/03-08/04/00	220km/h (140mph) 905 hPa (mbar)	Ciclone Tropical Categoria IV	Zambézia e Nampula
Dera	05/03-12/03/01	140km/h (85mph) 960 hPa (mbar)	Ciclone Tropical Categoria II	Zambézia e Nampula
Cyprien	30/12/01-03/01/02	100km/h (65mph) 980 hPa (mbar)	Tempestade Tropical Severa	Costa de Sofala e Zambezia
Atang	04-12/11/2002	55km/h (35mph) 998 hPa (mbar)	Tempestade Tropical	Costa de Cabo Delgado
Delfina	30/12/02-05/01/03	90km/h (55mph) 984 hPa (mbar)	Tempestade Tropical Severa	Nampula e Norte da Zambézia
Japhet	25/2-06/03/2003	112km/h (70mph)	Ciclone Tropical Intenso Categoria IV	Inhambane, Manica e sul de Sofala
Cela	05-21/12/2003	120km/h (75mph) 975 hPa (mbar)	Ciclone Tropical Categoria I	Canal de Moçambique
Elita	26/01-12/02/2004	120km/h (75mph) 970 hPa (mbar)	Ciclone Tropical Categoria I	Canal de Moçambique

Gafilo	01/03-01/03/2004	230km/h (145mph) 895 hPa (mbar)	Ciclone Tropical Muito Intenso Categoria V	Costa de Inhambane e Sofala
Ernest	16/01-25/01/05	165km/h (105mph) 950 hPa (mbar)	Ciclone Tropical Intenso Categoria III	Costa de Sofala e Zambezia
Boloetse	20/01/05-06/02/06	155km/h (100mph) 950 hPa (mbar)	Ciclone Tropical Intenso Categoria III	Zambezia
Anita	26/11/05-04/12/06	83km/h (52mph) 996 hPa (mbar)	Tempestade Tropical Moderada	Canal de Moçambique
Favio	11/02-23/02/2007	222km/h (138mph) 925 hPa (mbar)	Ciclone Tropical Intenso Categoria IV	Inhambane e Vilanculos
Jaya	26/03-08/04/07	222km/h (138mph) 935 hPa (mbar)	Ciclone Tropical Intenso Categoria III	Costa norte de Moçambique
Elnus	29/12/07-05/01/08	65km/h (40mph) 995 hPa (mbar)	Tempestade Tropical Moderada	Canal de Moçambique
Jokwe	02/03-16/03/2008	195km/h (120mph) 940 hPa (mbar)	Ciclone Tropical Intenso Categoria III	Nampula e Zambézia
Fanel	18/01-23/01/09	185km/h (115mph) 927 hPa (mbar)	Ciclone Tropical Intenso Categoria III	Canal de Moçambique
Izilda	24/03-27/03/09	200km/h (175mph) 978 hPa (mbar)	Tempestade Tropical Severa Categoria I	Canal de Moçambique
Joel	26/05-29/05/10	111km/h (69mph) 996 hPa (mbar)	Depressao Tropical	Canal de Moçambique

Appendix C – Rainfall Data

Estação: Marracuene Período: 1997 - 2011

Elemento: Precipitação total mensal (das 9 as 9 horas em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1996	192.3	232.3	228.2	37.9	7.3	6.3	154.8	0.0	7.5	110.7	90.3	39.9
1997	219.4	326.5	40.8	27.6	28.2	0.6	84.0	42.3	26.5	90.3	176.2	40.3
1998	156.5	62.5	52.0	83.9	24.3	19.3	1.4	5.8	7.1	34.5	205.8	90.8
1999	277.7	273.1	154.2	115.5	39.7	20.3	12.0	17.0	65.9	39.4	138.0	38.0
2000	193.0	490.0	335.1	102.2	23.0	33.2	35.0	0.5	18.2	40.5	202.6	95.9
2001	35.2	258.6	104.1	93.7	0.0	20.5	22.8	1.2	5.0	43.0	199.4	208.1
2002	156.2	16.2	44.2	5.0	0.0	11.7	76.0	2.5	6.5	82.9	35.5	76.2
2003	25.5	80.7	133.9	31.7	17.6	123.7	12.2	0.0	44.5	22.0	5.1	34.5
2004	158.2	177.0	238.4	67.0	7.2	14.5	33.2	8.3	17.5	89.7	76.1	85.6
2005	136.6	70.9	118.0	45.5	60.5	2.5	7.5	0.0	3.7	12.0	134.5	115.7
2006	24.2	29.3	22.0	6.3	31.7	20.5	0.0	0.0	--	10.7	68.4	--
2007	148.0	157.1	333.5	35.5	21.3	7.5	22.3	30.9	2.0	146.7	22.3	99.0
2008	91.4	39.0	82.4	51.1	8.0	0.0	5.5	7.0	18.5	195.0	--	36.8
2009	47.0	44.5	48.0	17.5	43.1	0.0	0.0	26.0	0.0	5.5	14.3	162.2
2010	231.0	39.6	26.5	70.3	33.7	22.5	3.5	19.0	0.0	0.0	4.9	33.5
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Estação:Umbeluzi

Elemento: Precipitação total mensal (das 9 as 9 horas em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1997	73.6	109.0	64.0	55.7	7.5	25.6	137.0	0.3	0.0	81.8	8.3	93.5
1998	217.0	81.0	22.6	50.4	5.0	15.0	0.0	12.5	2.0	74.5	63.5	113.8
1999	53.5	89.3	99.2	53.1	3.8	32.2	11.5	82.1	89.1	58.5	80.1	21.5
2000	531.2	114.3	8.5	60.7	6.0	42.2	0.0	19.1	23.1	16.9	50.2	72.6
2001	112.6	204.2	23.2	31.8	9.4	0.0	14.5	6.6	4.3	19.6	316.4	158.2
2002	65.5	17.5	17.0	2.5	0.0	0.0	15.4	9.2	30.8	45.3	14.1	47.6
2003	5.8	74.2	28.6	2.0	9.1	57.6	5.2	0.0	28.8	6.6	17.9	20.2
2004	189.7	75.0	89.0	36.0	8.9	2.9	76.0	18.0	1.7	42.2	108.7	56.6
2005	162.2	48.9	111.2	35.8	9.2	1.1	1.2	7.2	23.1	8.6	34.1	16.9
2006	98.3	97.5	163.7	22.7	1.5	3.6	8.3	18.8	11.6	43.0	104.4	118.7
2007	24.2	64.8	43.0	118.0	0.0	5.1	7.9	0.0	13.3	39.7	51.7	210.3
2008	77.0	31.0	85.2	48.7	15.2	14.2	0.0	0.0	15.2	0.5	0.0	23.6
2009	129.9	72.4	76.3	5.4	1.7	28.5	13.7	8.3	14.6	0.0	26.2	94.3
2010	32.8	125.2	100.7	22.0	25.2	14.2	0.6	8.5		118.5	129.9	246.6
2011	121.2	32.0	62.5	12.5	0.0	0.0	0.0	25.0	0.0	60.9	120.7	135.8
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Estação: Vilanculos

Elemento: Precipitação total mensal (das 9 as 9 horas em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1997	290.1	72.0	87.5	43.2	16.0	12.1	63.9	1.6	24.8	113.2	127.9	12.4
1998	263.2	54.7	158.2	57.3	24.6	0.9	10.3	32.6	23.0	51.1	94.0	327.2
1999	396.0	914.5	180.7	20.5	40.1	42.8	24.9	14.7	0.2	11.8	49.1	108.3
2000	51.9	546.9	361.7	100.9	57.1	39.6	62.3	24.4	5.2	2.5	101.1	236.0
2001	90.5	545.4	370.8	88.0	24.3	43.1	21.5	3.6	4.2	8.5	122.5	224.2
2002	11.9	9.1	84.3	28.6	2.4	33.7	70.8	17.6	18.7	46.3	73.4	5.3
2003	41.6	38.5	221.5	26.4	16.5	199.7	4.6	1.2	23.3	70.9	42.3	2.4
2004	62.6	72.9	191.3	65.4	29.8	20.0	5.6	0.7	5.3	106.6	9.8	121.2
2005	50.7	44.1	86.1	13.3	27.2	8.4	18.9	0.7	19.7	3.0	25.4	482.0
2006	65.1	139.9	447.1	82.2	39.4	83.2	5.8	8.8	0.0	0.0	3.7	42.8
2007	241.4	193.4	217.7	76.8	7.5	51.9	11.0	3.2	1.3	4.0	95.7	129.4
2008	121.2	64.9	122.0	14.8	88.0	281.0	9.7	2.7	6.7	0.6	12.3	277.3
2009	253.0	168.6	117.7	48.5	50.2	25.5	31.8	8.0	6.1	6.5	165.3	31.4
2010	137.7	162.0	128.0	153.4	31.3	16.8	75.3	4.7	0.0	0.8	37.4	96.5
2011	208.4	15.3	10.0	124.8	19.0	50.3	31.6	0.2	1.2	26.8	20.9	35.5
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Estação: Caia

Elemento: Precipitação total mensal (das 9 as 9 horas, em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1997	105.6	66.6	109.3	184.9	83.8	11.4	8.9	42.2	34.2	43.1	215.1	120.2
1998	282	38.6	124.1	46.4	70.5	21.2	0.0	2.5	1	0.0	6.5	176
1999	270.6	217.4	48.7	46.5	10	17.3	35.4	49.2	77.8	25	47.3	166.8
2000	142.7	47.2	11.8	41.6	51.1	4.8	0.0	12.2	49.2	36.6	225.1	284.8
2001	103.2	82.1	33.8	50.0	12.5	21.2	20.6	7.0	3.7	23.6	91.8	92.8
2002	252.2	116.3	102.0	174.0	51.7	53.6	58.6	2.6	1.4	2.9	31.4	256.4
2003	89.7	177.7	211.3	134.0	71.7	63.6	62.5	13.4	21.1	15.0	66.8	104.4
2004	87.7	164.9	84.3	27.1	8.9	49.5	27.7	4.8	0.0	18.1	62.4	63.1
2005	175.2	373.9	247.3	118.1	68.3	32.5	8.6	0.0	5.2	5.8	43.8	253.2
2006	248.6	91.1	117.5	19.4	0.0	29	54.5	24.7	8.5	18.5	66	81.5
2007	333.1	307.9	185.3	61.3	9.2	43.7	42.0	0.0	0.0	69	0.0	118.2
2008	202.8	86.7	167.7	22.8	2.5	29.5	25.1	14.3	0.2	63.8	8.9	155.9
2009	96.9	189	441.3	138.3	34.4	29	68	5.3	14.1	0.0	57.7	300.5
2010	78.3	183.6	59.6	42.9	50.4	12.5	23.0	10.0	0.0	0.6	112.3	109.2
2011	50.0	21.8	54.5	18.6	7.1	18.4	25.4	8.9	2.5	13.3	45.7	57.7
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Estação: Quelimane

Elemento: Precipitação total mensal (das 9 as 9 horas, em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1997	156.5	576.0	117.9	94.6	34.8	2.4	91.7	17.5	40.7	32.3	116.9	213.7
1998	463.8	267.6	155.3	53.2	26.4	20.6	54.0	106.5	11.4	67.0	71.0	114.8
1999	294.4	212.0	185.1	365.6	43.0	37.5	112.3	8.3	5.1	21.4	59.7	122.8
2000	436.6	170.7	--	261.5	126.9	63.2	169.1	25.7	13.9	18.0	96.0	209.3
2001	600.8	316.8	395.2	54.0	118.5	1.7	55.7	18.4	5.1	1.0	6.7	139.4
2002	220.1	253.1	172.4	16.3	18.6	78.7	6.0	36.4	18.5	41.2	10.7	63.4
2003	387.3	256.0	326.7	67.9	38.8	94.2	50.9	14.6	12.6	0.3	35.0	143.7
2004	166.6	189.9	101.7	156.1	155.2	137.9	34.3	9.5	42.1	4.7	59.5	129.1
2005	145.3	205.1	300.7	53.6	62.9	34.0	29.3	2.3	20.4	2.9	1.6	264.0
2006	165.1	81.7	193.0	132.7	103.2	62.7	7.8	1.0	34.5	14.7	92.2	139.4
2007	639.5	150.8	211.9	161.1	77.6	24.3	58.6	12.1	0.0	3.6	195.2	262.5
2008	249.1	144.9	170.0	27.2	39.4	33.0	18.6	34.6	5.3	0.3	2.6	140.7
2009	109.1	209.5	241.4	111.2	32.7	5.9	67.5	26.0	1.9	14.5	18.3	145.0
2010	85.9	174.2	105.4	88.6	44.5	118.5	70.8	17.5	0.8	1.5	32.6	219.6
2011	174.3	296.3	247.8	237.9	48.3	12.8	107.9	48.6	9.9	26.5	32.3	97.3
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Estação: Namacurra

Elemento: Precipitação total mensal (das 9 às 9h, em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1995	419.0	349.2	155.5	75.6	11.3	15.8	49.5	6.2	21.2	59.4	102.9	125.4
1996	139.0	276.0	201.5	118.1	78.0	38.9	18.8	0.0	15.0	87.9	286.3	281.3
1997	179.5	210.0	80.0	100.0	78.0	33.5	8.0	0.0	0.0	13.3	287.0	234.0
1998	101.6	252.2	369.4	115.4	49.3	34.3	53.1	--	25.0	5.5	28.4	106.4
1999	153.2	193.6	70.1	75.4	48.5	18.5	46.0	44.3	0.0	28.6	23.4	93.2
2000	153.2	193.6	70.1	75.4	48.5	18.5	46.0	44.3	0.0	28.6	23.4	93.2
2001	199.5	94.5	176.6	170.5	84.0	180.0	38.5	10.0	21.1	33.0	95.5	252.0
2002	206.0	251.0	299.5	224.0	65.0	87.0	118.5	52.4	10.0	0.0	310.3	129.4
2003	253.5	220.1	281.0	276.4	86.4	66.1	85.5	5.2	0.0	70.7	90.3	327.9
2004	178.5	467.7	489.0	121.6	41.8	99.9	79.2	28.4	25.8	35.8	149.7	514.3
2005	172.3	75.5	134.3	31.3	58.9	190.9	46.8	9.8	2.8	0.0	189.5	--
2006	96.7	67.3	--	25.1	28.4	170.6	11.5	8.0	0.0	55.0	47.9	111.1
2007	493.7	201.9	334.8	94.2	27.7	38.9	60.0	47.6	2.3	67.9	18.2	125.6
2008	99.7	237.2	57.6	25.9	6.6	22.7	42.4	14.3	0.0	7.2	0.0	28.1
2009	136.4	67.8	50.6	43.4	36.5	25.7	28.3	0.0	3.0	7.1	79.0	--
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Estação: Morrumbala

Elemento: Precipitação total mensal (das 9 às 9h, em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1995	60.6	24.6	19.0	21.5	30.6	12.8	0.0	7.6	3.7	26.4	43.1	45.2
1996	61.2	32.3	39.3	74.1	25.5	24.3	8.9	5.6	2.3	22.9	25.8	73.5
1997	27.7	130.6	28.8	52.4	20.4	10.8	24.4	10.0	23.6	9.4	57.8	58.7
1998	40.6	97.6	21.7	32.3	8.6	14.6	9.4	4.8	0.5	70.6	60.8	20.8
1999	27.8	65.8	30.8	28.6	4.6	16.6	6.8	9.8	0.0	28.6	51.3	101.7
2000	167.5	270.5	129.7	69.9	20.5	8.6	20.8	10.8	2.3	1.2	42.2	48.0
2001	68.4	60.2	111.7	28.8	32.5	14.2	8.6	--	0.0	4.6	15.6	58.4
2002	100.6	70.2	48.2	12.8	0.0	12.2	22.4	24.8	4.7	50.3	38.2	48.8
2003	70.2	78.6	98.8	22.4	11.2	34.2	28.2	8.4	56.2	12.0	78.2	40.6
2004	60.3	69.8	50.5	4.0	10.8	26.8	37.1	4.5	0.8	29.5	66.5	386.4
2005	132.7	133.6	188.2	32.4	0.0	7.0	37.0	0.0	9.2	27.0	63.6	129.7
2006	166.4	157.1	188.9	75.3	25.8	19.9	42.3	42.5	36.0	47.2	83.7	199.9
2007	622.6	65.6	420.5	38.9	9.2	0.0	36.6	30.4	3.6	22.5	71.0	263.9
2008	191.1	487.9	151.7	59.5	27.8	27.2	20.2	0.9	--	41.6	90.5	118.8
2009	306.3	132.8	71.4	37.1	38.1	3.8	53.4	58.3	6.9	0.0	25.9	268.8
2010	175.7	245.4	101.5	132.3	29.8	30.2	47.8	9.7	45.1	91.9	38.9	372.7
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Estação: Angoche

Elemento: Precipitação total mensal (das 9 às 9h, em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1996	194.7	245.0	639.7	34.3	16.1	79.6	14.5	14.3	0.4	17.9	2.4	237.9
1997	258.0	317.3	122.7	172.8	59.3	9.2	26.8	4.9	1.5	12.5	12.3	364.8
1998	221.2	248.6	120.3	52.4	1.8	5.4	54.4	36.1	0.2	0.1	2.4	20.7
1999	160.4	145.1	94.0	175.1	10.5	29.6	35.2	15.6	9.2	0.7	8.2	105.8
2000	270.9	351.5	28.4	122.3	24.6	21.5	3.3	45.3	22.6	4.6	153.4	316.8
2001	227.6	137.4	261.8	110.1	16.7	11.3	20.0	12.7	0.7	14.1	32.0	104.1
2002	228.9	168.7	296.5	110.1	33.0	97.7	52.3	32.9	11.4	2.8	10.9	188.1
2003	394.8	170.1	132.4	21.2	0.5	36.6	30.3	2.4	0.3	0.0	15.8	69.9
2004	327.9	217.0	215.1	216.6	16.0	47.0	24.6	9.4	0.2	3.4	23.6	67.4
2005	302.8	63.8	4.6	70.2	21.9	68.6	47.4	0.0	2.7	48.3	3.6	84.2
2006	65.3	104.5	100.2	179.2	1.1	27.7	17.4	0.8	0.9	0.2	37.1	79.3
2007	310.2	189.8	90.8	194.9	79.4	21.1	18.3	5.1	0.7	37.7	1.3	108.3
2008	89.2	234.1	59.4	16.7	19.9	27.3	8.7	18.5	41.1	0.5	11.2	51
2009	149.2	375.6	291.7	159.9	47.4	41.9	52.2	19.0	57.4	2.1	83.0	73.2
2010	235.6	194.0	120.3	26.0	25.5	75.0	44.7	33.1	0.0	7.4	--	54.8
2011	348.9	147.1	81.7	38.3	73.6	115.8	--	40.6	0.0	2.9	97.4	51.3
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Estação: Nametil

Elemento: Precipitação total mensal (das 9 as 9 horas, em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1991	375.4	236.6	321.7	79.2	18.8	26.1	20.3	3.8	0.7	47.1	173.2	161.5
1992	178.6	278.9	71.8	122.4	21.9	13.3	6.5	8.1	38.3	123.7	86.2	229.2
1993	274.3	34.4	51.6	98.9	13.5	19.2	30.4	3.7	0.3	16.9	73.2	246.2
1994	165.6	365.7	236.7	38.1	53.1	74.6	47.8	4.7	10.4	3.2	59.3	174.1
1995	245.4	215.2	61.5	129.7	5.7	27.7	3.3	6.4	0.0	59.7	30.8	257.7
1996	70.1	226.3	185.8	164.2	19.4	43.4	2.6	9.3	3.1	35.2	15.3	230.9
1997	276.2	63.3	62.5	46.3	7.6	4.7	11.8	6.5	32.4	38.5	96.1	145.1
1998	117.7	265.3	189.5	157.7	1.7	20.9	9.1	0.0	4.7	34.4	56.2	374.9
1999	70.4	241.0	166.7	123.7	10.5	32.9	32.9	2.7	5.0	0.0	122.7	148.7
2000	103.6	101.2	215.8	124.6	12.2	19.2	12.9	23.0	1.0	13.0	12.2	239.0
2001	50.8	198.5	119.1	85.0	9.6	31.9	28.0	0.3	3.5	66.0	22.1	228.1
2002	353.4	201.3	154.3	77.3	13.3	6.0	31.2	23.5	2.7	42.1	128.0	156.7
2003	313.9	165.0	102.3	59.5	13.1	11.1	30.0	17.4	3.0	0.4	0.0	117.7
2004	206.8	301.4	216.8	63.5	23.0	8.9	20.8	8.3	0.0	0.0	160.5	271.6
2005	200.8	143.4	192.7	369.5	12.4	--	23.8	29.6	69.0	130.6	97.4	279.5
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Estação: Lichinga

Elemento: Precipitação total mensal (das 9 as 9 horas em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1995	246.4	223.9	--	28.9	23.0	0.0	0.7	0.0	0.0	0.0	12.4	--
1996	221.8	220.0	257.6	86.6	67.6	1.1	0.2	0.0	188.4	5.2	0.7	146.6
1997	224.2	129.3	65.1	166.2	106.2	0.0	1.9	0.0	0.0	67.8	112.4	399.8
1998	286.5	61.5	156.5	71.9	4.8	0.0	0.0	0.0	0.0	81.4	9.5	70.1
1999	370.6	291.4	558.0	94.5	30.9	15.3	0.5	6.6	0.2	6.2	110.1	94.4
2000	375.2	201.3	245.7	32.8	0.0	1.7	3.7	0.0	0.0	13.4	219.7	219.6
2001	183.0	247.2	359.8	39.9	12.5	0.0	0.0	1.4	0.0	24.7	5.2	217.5
2002	550.1	371.2	153.3	73.4	2.0	3.8	0.0	0.5	2.8	1.4	64.4	215.3
2003	402.2	266.8	351.3	30.6	0.0	0.0	4.5	1.3	0.0	0.0	113.4	249.3
2004	254.6	175.8	124.2	126.1	7.0	3.8	2.1	1.9	1.4	36.1	74.8	328.5
2005	269.9	123.6	160.5	93.4	70.1	11.7	7.9	1.5	11.9	7.6	12.4	327.7
2006	257.4	221.7	318.2	49.1	15.8	0.2	0.4	0.2	0.0	33.3	279.7	101.1
2007	129.3	155.5	111.3	17.8	6.0	0.8	3.3	0.0	0.0	53.0	9.5	355.9
2008	425.2	195.5	97.2	31.4	28.1	5.3	0.2	8.2	0.0	32.1	166.0	279.5
2009	363.8	323.0	192.3	70.3	2.7	0.2	1.6	0.1	0.0	24.9	122.5	218.5
2010	162.3	241.2	263.8	126.2	20.0	8.0	22.8	6.2	0.3	1.0	11.8	37.8
2011	192.3	65.8	275.1	34.5	2.6	0.0	0.0	0.0	0.0	17.0	62.0	108.2
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Estação: Mocimboa da Praia

Elemento: Precipitação total mensal (das 9 as 9 horas em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1996	186.9	251.7	109.9	39.7	249.5	10.3	10.4	--	0.0	55.5	1.1	20.8
1997	75.6	150.9	--	140.9	60.6	96.9	33.6	5.3	0.0	34.6	73.4	276.2
1998	470.6	207.9	122.8	255.4	42.0	13.9	0.3	16.4	19.5	8.4	6.8	35.5
1999	147.6	194.8	187.1	186.1	48.2	29.0	72.8	45.0	--	--	36.0	185.8
2000	26.3	140.7	344.2	31.2	43.3	72.5	54.4	27.1	--	10.7	135.3	205.7
2001	185.9	144.4	162.0	185.9	30.5	6.0	0.0	0.0	0.0	24.5	0.0	138.0
2002	145.4	72.8	174.8	236.5	11.9	0.0	3.4	9.1	38.3	2.3	60.9	118.6
2003	165.2	210.3	301.5	70.3	10.6	4.5	8.0	11.0	0.0	0.0	0.0	171.9
2004	234.5	396.2	115.4	269.1	21.9	--	0.0	2.1	2.0	16.3	76.0	300.9
2005	109.9	--	110.4	76.6	95.8	13.9	3.6	28.8	5.4	7.2	3.0	13.7
2006	122.9	175.1	263.3	158.6	129.5	9.8	19.3	23.1	7.6	3.4	58.9	130.9
2007	83.5	22.5	119.6	146.4	8.4	8.6	10.8	25.5	48.8	50.9	8.6	66.5
2008	129.9	154.7	140.9	176.4	5.6	13.9	5.3	0.0	11.2	169.4	42.1	91.1
2009	75.0	2158.5	161.5	139.2	46.8	6.0	18.3	1.3	5.7	11.7	4.7	123.1
2010	181.5	117.9	292.5	227.4	18.5	14.4	19.7	20.4	0.0	0.0	11.8	83.1
2011	185.9	144.4	173.6	72.6	7.5	10.3	10.4	14.1	7.8	49.2	3.2	153.9
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Estação: Mueda

Elemento: Precipitação total mensal (das 9 as 9 horas em mm)

ANO	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1997	116.3	160.6	146.0	52.3	18.6	9.8	0.2	1.8	4.4	10.0	70.5	136.0
1998	209.3	281.5	369.0	185.3	46.9	8.8	38.6	5.9	4.9	10.7	128.4	363.6
1999	64.8	260.2	225.7	176.9	11.4	13.2	0.4	2.6	0.3	15.6	26.1	44.9
2000	355.9	208.2	196.9	149.3	7.6	2.6	8.3	14.8	0.4	7.9	48.4	216.7
2001	179.0	329.3	118.4	214.2	10.2	12.0	16.2	0.0	3.5	1.2	0.2	176.8
2002	201.2	172.7	96.6	175.1	34.4	38.8	1.7	0.0	0.3	1.6	165.0	84.3
2003	136.7	157.4	187.4	220.0	33.3	4.5	1.7	0.2	3.2	0.3	53.6	201.9
2004	81.5	150.2	229.3	115.3	12.5	0.2	0.3	0.0	1.9	6.4	30.8	--
2005	77.9	108.5	52.0	38.2	7.3	2.5	0.0	5.0	4.2	0.0	17.6	111.2
2006	96.2	100.7	374.5	53.1	15.8	0.0	0.0	3.4	0.0	0.0	1.1	232.0
2007	406.0	137.5	95.3	94.6	0.0	0.0	0.0	0.0	20.3	4.9	11.4	205.8
2008	255.7	445.7	146.3	56.3	2.9	4.2	0.5	0.0	0.0	5.3	35.1	100.1
2009	88.2	156.4	165.9	95.6	31.5	0.5	0.9	13.9	0.2	4.1	149.2	194.0
2010	141.3	510.1	159.5	291.0	77.7	5.5	0.0	7.5	4.1	0.0	35.3	111.1
2011	101.5	373.8	302.6	203.3	111.4	19.1	0.0	0.0	6.0	--	--	--
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Appendix D – Map of Study Roads