DFID Department For International Development

# COLLABORATIVE RESEARCH PROGRAMME ON HIGHWAY ENGINEERING MATERIALS IN THE SADC REGION

*Volume 4*

## *Establishment of Information Systems for Managing Road Construction Material Resources in Southern Africa*

**Transport Research Laboratory, Crowthorne, Berkshire, United Kingdom**

# Establishment of Information Systems for Managing Road Construction Material Resources in Southern Africa

**by C S Gourley and P A K Greening**

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# Establishment of Information Systems for Managing Road Construction Material Resources in Southern Africa


## by C S Gourley and P A K Greening




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# ESTABLISHMENT OF INFORMATION SYSTEMS FOR MANAGING ROAD CONSTUCTION MATERIAL RESOURCES IN SOUTHERN AFRICA

## Contents

## ABBREVIATIONS

| | |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| ASTM | American Society for Testing and Materials |
| CAS | Central African Standards |
| CRL | Central Roads Laboratory |
| CBR | California Bearing Ratio |
| DFID | Department for International Development |
| DMR | Departmental Materials Reports |
| GIS | Geographical Information System |
| HDM | Highway Design Manual |
| Ic | Coarseness Index |
| If | Fineness Index |
| Ip | Plasticity Index |
| MoTE | Ministry of Transport and Energy |
| RDB | Road Data Bank |
| SADC | Southern African Development Community |
| SATCC | Southern African Transport and Communications Commission |
| SIDA | Swedish International Development Agency |
| TRL | Transport Research Laboratory |

# Executive Summary


## Aims

The project objective was to create a system in which data on the location and use of road building materials could be held and accessed centrally by computer. The scope of the work involved the following main tasks:

- Establish a database of road building materials to provide a user-friendly system for the recording, organising, storage and retrieval of information
- Recommend methods for updating and sustaining the database
- Evaluate the potential of linking the database to a geographical information system (GIS)
- Assess the value of the database
- Investigate the possibility of using the database to predict the occurrence of new sources of material
- Identify the scope for a regional strategy for materials inventories.

## Work Undertaken

The type, quality and volume of data available were assessed for each of the countries involved in the project. This assessment indicated that the most cost-effective utilisation of project resources would be to focus on Zimbabwe and Malawi, where significant amounts of materials information were readily available. Different development procedures were adopted in each country in consultation with potential users.

Rigorous data management procedures incorporating good laboratory management practices and quality assurance procedures, were identified as an important prerequisite to setting up a materials inventory in order to ensure reliable data and sustainability of the database.

Materials database systems were designed for use in Zimbabwe and Malawi based on the nature of the information available and the manner in which it was originally stored. The sophistication of the systems implemented was partly a function of the available level of computer literacy.

Appropriate computer training has been provided to database staff and large amounts of data have been accessed and entered onto the databases utilising specially designed procedures.

## Achievements

Materials inventories have been developed and established in Zimbabwe and Malawi in which data on the location and use of road building materials is now held centrally by computer and accessed by users. The computerised systems enable materials information to be recorded, stored, organised and retrieved.

The information has been stored in related files (.dbf format) that are readily transferable between software packages and potentially compatible with further Information Technology developments.

Requirements for information and queries on various aspects of road making materials can now be directed to staff responsible for the materials inventories who can interrogate the systems to generate reports on behalf of users.

The materials inventories can be linked to other data through a GIS to provide a means of mapping, predicting and managing engineering resources. This has been demonstrated in a pilot trial.

The cost of collecting the data stored on the systems has been estimated. Materials inventories provide a means of getting added value from this investment by providing information for new development projects more cheaply through reducing survey and other costs.

Information from the materials inventory can now be used in conjunction with digitised topographic, geological, climatic and soils maps to predict where materials with required engineering characteristics are likely to occur.

## Recommendations

Rigorous data management procedures incorporating good laboratory management practices and quality assurance procedures are an important prerequisite to sustaining a materials inventory.

Although the basic structures of the materials inventories are in place, these inventories need to be continually updated, upgraded, and maintained. This requires the on-going provision of adequate financial resources.

Sections I and II of the original geotechnical data bank in Zimbabwe should be brought back into routine use. Two additional registers in the materials inventory are needed to achieve this.

A regional strategy, perhaps co-ordinated by SATCC, could be adopted to develop centralised materials inventories for the benefit of other countries in the region. Detailed implementation would depend on the available computer literacy, but this need not rule out the development of paper based systems as a first step.

The soil and materials classification and design CBR prediction procedures developed in Zimbabwe have potential for adoption outside the country. Additional research is required to determine how best to approach this. It is unlikely that data of the type and quantity available in Zimbabwe will be found elsewhere in the region, other than in South Africa. However, it is likely that the region could benefit by sharing and adopting many of the Central Roads Laboratory procedures and practices for the storage and retrieval of data.

The approach of using climatic area, parent materials type and simple soil classification procedures to predict the engineering characteristics of soils could probably be implemented in other countries in the region and elsewhere.

# 1. Introduction

## 1.1 Background

In the period between 1988 and 1991, TRL held discussions with government departments in countries of the Southern African Development Community (SADC) to identify subject areas which would benefit from research and technology development. The outcome of these discussions led to a programme of research on highway engineering materials in the SADC region funded by the Department for International Development (DFID) and the Swedish International Development Authority (SIDA). A two-man TRL team was established in Zimbabwe to work in collaboration with government departments in the region, other regional organisations, academic institutions and consulting engineers.

## 1.2 Objectives

The overall aim of the programme was to promote the economic and environmental use of natural gravels for roadbases in low-volume road construction and maintenance. This particular project focused on the availability of information on road building materials and the management of this information. The project objective was to create a system in which data on the location and use of road building materials could be held and accessed centrally by computer.

The scope of the work involved the following main tasks:

- Establish a database of road building materials to provide a user-friendly system for the recording, organising, storage and retrieval of information
- Recommend methods for updating and sustaining the database
- Evaluate the potential of linking the database to a geographical information system (GIS)
- Assess the value of the database
- Investigate the possibility of using the database to predict the occurrence of new sources of material
- Identify the scope for a regional strategy for establishing materials inventories

## 1.3 Regional emphasis

The programme had a regional focus. One of the main reasons for this was to enable national engineering organisations, both in government and the private sector, to benefit from the results of research conducted outside national borders. In the past, there had been a reticence to do this. Where good information on materials exists in a particular country, these data can often have application in neighbouring countries where similar conditions of geology, terrain, and climate exist. The project was therefore undertaken in collaboration the Southern African Transport Co-ordinating Commission (SATCC) so as to try and achieve a greater awareness of the research findings and increase the opportunities for technology transfer. This enabled SADC countries not directly involved in the programme to have an opportunity to comment on the project objectives and research methodology. It also provided greater opportunities for dissemination of the results of the research to representatives of the SADC countries at SATCC meetings, regional conferences and workshops.

There were also technical benefits by operating regionally. Collaboration with different road authorities enabled the project team to achieve a better appreciation of some of the existing practices and traditional methods, many of which are not widely known, even within the region. These methods are often based on long practical local experience but, because they have not had the benefit of modern research methods, they have not always been given wider consideration. It was considered very important that those techniques with proven track records should be identified and highlighted in the project. By operating in different countries, it was possible to extend the range of working practices, procedures and environments, to identify the user needs, and to tailor the recommendations to different institutional capacity. This approach extended the conditions to which the results of the research can be applied.

Although regional application was not a project objective, the importance of sharing and using the available information, data and knowledge should be an achievable future aim for the region.

## 1.4 General approach

The main activities in the project related to the development of a computer-based inventory to store existing data on road building materials. This could then be used to provide readily accessible engineering materials information early in project planning, site investigations and resource surveys.

It was clear at the project outset that extensive data existed in Zimbabwe, and that this represented a valuable local and regional resource. Some of the data management methods, classification procedures and innovative data handling techniques could also have much wider application in the region. The first priority was to capture these data and this task determined the early focus of the project. There was a need to enter these data into a database before interrogation procedures could be used in a meaningful way. Transfer of the data from paper files to the computer database was a major task, which involved a team of four people compiling and entering data over a three-year period. The large amount of data and the absence of a viable GIS in the Roads Department changed the scope of the project to some extent.

There was less information available in Malawi compared with Zimbabwe. The data in Malawi was contained mainly in documents reporting materials investigations carried out by the Ministry of Works or by private consultants. In Malawi two staff were employed part-time on data entry over a two year period. There was less information available in either Botswana or Zambia, so the project was based in Malawi and Zimbabwe.

## 1.5 Content of report

Chapters 2 and 3 discuss information in terms of the type of data required for road building purposes, the way that it is collected and stored, and the requirements of a computerised materials inventory. The development of the materials inventories implemented in Zimbabwe and Malawi are described in Chapters 4 and 5, respectively. An appendix lists the contents of the inventories in each case. Chapter 6 describes how the databases can be interrogated to obtain information stored in the inventories, and an appendix gives detailed examples of how this can be done. Issues concerning how the inventories need to be managed in a sustainable manner are discussed in Chapter 7, and this recognises the high value of the information currently stored, which is quantified in Chapter 8. Proposals for future development of the inventories are given in Chapter 9 and, finally, Chapter 10 draws conclusions from the work that has been undertaken.

# 2. Information and data

## 2.1 Information needs

The planning, design, construction and maintenance of projects in an effective and economic manner depend on reliable information being available to the engineer in an easily recognisable and accessible format, at an appropriate level of accuracy. Highway engineering projects present particular information problems because they can cover long distances across different terrain, geology and soils. Compiling and maintaining an inventory of material sources and properties is one way of making information available. Storing this information on microcomputer database provides a rapid, reliable and effective method of sorting, retrieving and presenting relevant information. Computer technology is now an accepted tool in a number of the materials laboratories in the region. It can be used to increase organisational capacity, ease high work loads and increase productivity.

A very large volume of data is collected during the construction, maintenance, rehabilitation or reconstruction of roads. These data are normally held centrally by the ministry or road department testing laboratory, who are responsible for the collection of data on the preliminary materials design and other aspects of road projects. Subsequent surveys are often carried out separately by contractors, whilst consultants compile the data on the as-built project.

The need for the storing of materials information in an organised way is well understood in the region. However, accessing historical records stored in paper files is a slow and laborious exercise. Potential users of this information have little incentive to search through records of this nature, and there is little interest in storing data in this way if it is unlikely to be used in the future.

The restructuring of many roads departments in the region has resulted in staff changes. Consideration is being given to privatising government organisations, including materials laboratories where many of the data are currently stored. In these circumstances, it is likely that archived information will be lost or destroyed. This emphasises the need to protect the substantial investment in collecting and storing of existing materials data in the region. Computer databases provide an effective method of storing data in a way that their availability for future use is reasonably assured.

The materials used in road construction and maintenance materials are an important and expensive resource. Furthermore, these resources are not limitless and are mostly non-renewable. Therefore, they need to be managed correctly. Proper management is only possible if the quality, volume and location of these road-building materials are known. Lack of access to historical data means that materials investigations often need to be repeated which incurs unnecessary cost. As such, the storage and use of existing data is very cost-effective.

## 2.2 Stages of data collection and storage

Materials engineers and technicians spend a great deal of time prospecting, mapping, sampling and testing materials. This work provides a source of information and data that are used by the planners and engineers in their decision-making processes. A conventional materials prospecting operation for either paved or unpaved roads includes the location of borrow materials and investigation of alignment soils. It is undertaken in a number of stages:

1. Planning or site investigation
2. Laboratory design
3. Construction
4. Data reporting and filing

Data are collected to ensure that the materials used in the road project meet the quality standards required by the specifications. They also provide an as-built record for the road.

*Planning or site investigation*
This stage usually involves collection of data on:

- Pit nomenclature and road project (unique reference)
- Location of borrow areas (geographic reference)
- Land ownership, current use and compensation arrangements
- Accessibility and haul distances
- Type of materials (over-burden and seam)
- Thickness and volumes of deposits
- Proposed use of the material
- Alignment soils and terrain characteristics
- Site investigation testing for structures and quarries
- Collection and labelling of samples for testing
- Location reference and date

*Laboratory design*
The design or approval testing stage involves characterisation of samples collected at the planning stage by:

- Location, description and type
- Index or classification testing (eg plasticity, grading etc.)
- Compaction testing
- Strength testing of compacted materials (eg unconfined compressive strength (UCS), soaked CBR, Texas triaxial)
- Particle strength testing
- Approval for use or rejection

*Construction*
This stage includes laboratory and site tests carried to approve quality of materials used in the work, including:

- Location by chainage (unique reference)
- Construction date
- Construction layer and material source
- Compaction characteristics (eg density and moisture condition)
- Index or classification check tests
- Treatment details (eg percentage of stabiliser added)

- Thickness
- Approval/rejection statements

*Data reporting and filing*
This stage involves the filing of planning, testing and as-built records by:

- Collection, sorting and filing of paper copies of information
- Compilation of summary reports
- Storage of this information
- Re-use or reference to the data at some later date

## 2.3 Data volumes

An example of the volume of work carried out and the amount of data collected by a typical materials laboratory in the region is given in Table 2-1. This summarises some of the activities of the Materials Planning Unit at the Central Roads Laboratory (CRL) in Zimbabwe over recent years.

**Table 2-1 Summary of activities of a typical materials laboratory in the region**

| Activity | 1993 | 1994 | 1995 | 1996 | Total |
|---|---|---|---|---|---|
| Soil survey (km of road) | 248 | 158 | 175 | 24 | 605 |
| Gravel location ($m^3$ x 1 000) | 711 | 522 | 973 | 103 | 2 309 |
| Concrete aggregate location ( $m^3$ x 1 000) | 6.5 | 11.5 | 47.3 | 4.9 | 70.2 |
| Bridge site investigations (number of sites) | 12 | 17 | 5 | 1 | 35 |

Each of these activities is supported by the collection of samples, transporting of materials, test preparations, testing and reporting of data. Table 2-2 illustrates the associated activities of the Soils Section at CRL in terms of the type and number of tests carried out. These tables illustrate the high output of work carried out by central materials laboratories in the region, and emphasise the need to introduce computer based materials inventory technology to assist with the storage, manipulation and presentation of these data.

**Table 2-2 Example of the quantity of testing carried out by a typical materials laboratory in the region**

| Test type | 1993 | 1994 | 1995 | 1996 | Total |
|---|---|---|---|---|---|
| Classification tests (alignment soils and borrows) | 1 231 | 2 734 | 1 095 | 768 | 5 828 |
| Subgrade design CBR (alignment soils) | 313 | 414 | 339 | 122 | 1 188 |
| Activity | 540 | 113 | 130 | 65 | 848 |
| Texas triaxial (base and sub-base) | 707 | 560 | 515 | 583 | 2 365 |

# 3. Requirements for the computerised materials inventory

## 3.1 User and institutional issues

The identification of the end users, their needs and requirements forms an integral part of the development process, and the commitment available at local level to support the system will underpin its success.

It is also important to appreciate that a materials inventory is not just a computerised data storage system. The data are derived principally from field and laboratory testing, thus raising issues of quality assurance and laboratory management. Also, management procedures and the availability of suitably trained staff need to be in place to enable the system to be updated, managed, maintained and used properly. Good laboratory management practice, and staff training and supervision, are essential elements to running an effective efficient materials laboratory. For example, the degree of staff training, equipment maintenance, calibration and sample handling will effect the quality, reliability and usefulness of the test results on which subsequent engineering decisions will be made. These issues are important if the data stored in a materials inventory are to be reliable, so are fundamental to the planning, design and operation of a materials inventory which is to be sustainable.

Meetings with senior materials staff and testing officers were held to establish user requirements, current laboratory practices, and information on the type, volume and quality of data available.

## 3.2 Laboratory management practice

Information was sought in the following areas:

- Laboratory organisation
- Provision of services
- Type of work undertaken
- Organisation of the work
- Organisation and recording of the data
- Standards and operational procedures
- Budgets, costs and staffing
- Quality control procedures
- Training
- Data storage procedures

Although the work carried out in the laboratories is generally similar in all countries, differences in management practices were identified in the following areas:

- Quality, standards and operating procedures
- Organisation, staffing and management
- Maintenance, checking and calibration of equipment and instruments
- Laboratory planning and operation

- Collection, handling, preparation and storage of samples
- Test equipment and measuring instruments
- Understanding and application of test procedures
- Operation of site laboratories and field investigations
- Data collection, control and reporting
- Level of staff training
- Provision of information services

A number of different test standards are in use in the region. These include Central African Standards (CAS), American AASHTO and ASTM standards, British Standards, South African Standards, and various mixtures of all these standards. Results derived from local procedures therefore need to be treated with care if they were to be applied in other countries or compared with test results elsewhere.

Some government laboratories are operating with old equipment, and funding for maintenance and upgrading of equipment is scarce. This is likely to have impacts on the ability to control testing quality and on the reliability of test results. The introduction of effective laboratory procedures and adequate funding are essential if quality standards are to remain high, and are prerequisites to the establishment of sustainable materials inventories.

## 3.3 Data sources

It was apparent the materials laboratories in both Malawi and Zimbabwe held good data, which was regarded as an investment. However, an assessment of the paper files recording the data suggested that separate materials inventories would need to be developed to meet the different practices adopted in the two countries.

In Malawi, data from materials investigations for road works have been kept in an organised series of Departmental Materials Reports (DMR series) since 1982. One of the first activities in Malawi was to source and collate these reports and establish a library of information within the Materials Branch. Approximately two hundred of these reports have been issued covering materials investigations for roads, buildings, bridge sites. These reports would be the sole source of information input to the materials inventory.

In Malawi, there is little in-house capability to construct roads and external contractors and consultants are normally used. In many cases, the files containing the materials data relating to construction projects are retained by the individual contractors and consultants, and copies of these files are often not passed to the Ministry. Where the Ministry does have copies, these are often widely dispersed and difficult to locate. In addition, contractors and consultants use different methods of presenting information in summary reports, and this makes it very difficult to establish a consistent data capture procedure that is user friendly. The fact that a number of reports could not be located underlines the importance of capturing these data on computer and protecting them for future use.

A typical DMR report on materials investigations includes information on:

- Geology and topography
- Climate and vegetation

- Alignment soil survey (soil description, sampling, Atterberg limits, grading, compaction, and CBR testing)
- Gravel pit survey (location, description, sampling, Atterberg limits, grading, compaction, and CBR testing)
- Rock sources for quarries
- Other relevant information

Zimbabwe has extremely good and very well organised historical information on its road construction materials. Materials test data and other information relating to the road construction process are stored at the CRL Records Office after being checked and verified by senior materials testing officers. The key test record sheets providing data summaries for the materials inventory were:

- *CL19: Gravel pit forms*
  containing information on location, material type, quantities, haul route and costing, pit plan, details of trial holes, indicator and grading tests, and summaries of Texas triaxial results for gravel pits

- *CL16: Field check sheet*
  containing as-built information and data on chainage, pavement design, laboratory and on-site compaction, sources, and the amount and type of stabiliser

- *CL7: Triaxial summary sheet (pit/stockpile)*
  describing of pit and stockpiled materials, approved use, and Texas triaxial and other engineering test results

- *CL2: Soils-gravels summary sheet*
  containing information on location, description, classification and CBR testing of alignment soils

- *Field log book*
  containing site information on alignment soils and terrain characteristics

The volume of data held in Zimbabwe is extremely large, with dedicated buildings and cabinets to the store the data, which remains in very good condition. Comparatively, much less information was accessible in Malawi. One of the reasons that the volumes of data available are so different is because of the way that road construction works are conducted in the different countries. In Zimbabwe, most road construction is carried out in-house and only in rare cases are external contractors and consultants employed. Thus, all information relating to the design, construction and maintenance of roads originates from and is held by the Ministry.

## 3.4 Development framework

The design and implementation of the materials inventories in Zimbabwe and Malawi followed a similar logical sequence of steps. The first step was to establish:

- Stakeholder and user needs and expectations
- Information type and availability

- Management structure and local technical capacity
- Initial data capture mechanisms and monitoring of operational procedures
- Staff requirements and training needs
- Computer training programmes
- Acquisition of hardware and software

Some staff training was carried out early in the project. Technical staff in Malawi and Zimbabwe attended computerised spreadsheet and database familiarisation courses, using the Lotus 1-2-3 and Microsoft FoxPro software packages. A two-week refresher course on laboratory testing was organised for technicians from Zimbabwe, Zambia, Malawi and Botswana.

The second stage of development comprised:

- Design of modular components of the system in a suitable format (such as data entry screens or simple spreadsheet)
- Development of the system components within the agreed framework (system can be stand-alone or part of larger information system)
- Prototype testing
- Bulk data entry
- Advanced computer training (database queries and reporting)
- Establishment of the system within the existing management framework
- Identification of system support and maintenance needs

In developing a system to meet the needs identified, the target solution might range from a complex integrated system to a simple database or spreadsheet. Any approach must satisfy the basic requirements of a materials inventory. The complexity of the systems developed in Malawi and Zimbabwe was different. This reflected the level of computer literacy and expertise, information availability, and the expectations of the end users. Each of the systems were developed to be:

- Sustainable, with budgets and trained staff available in the longer term
- Flexible to changes in user needs, hardware or software
- A recognised part of the materials laboratory management structure

# 4. Development of the materials inventory for Zimbabwe

## 4.1 Historical background

A geotechnical data bank has been in use in the Department of Roads for the last 25 years. The main reasons for its original development were to:

- Reduce operations to a minimum by indicating those areas where construction materials are known to exist, and by supplying the necessary information to identify these areas on the ground
- Assure uniformity of grouping and classification throughout the Ministry, (ie enabling everybody to 'speak the same language' in terms of materials)
- Supply information on the load bearing values of sub-soils
- Provide a means for training and instructing new staff

In its original format, described by Holden (1971), the geotechnical data bank consisted of four sections:

I Air photo interpretation
II Construction materials, identification and location
III Construction materials, mechanical properties
IV Sub-soil investigation data (this referred to information from layers below the normal hand excavated trial pits)

In recent years, the use of air photo interpretation has been discontinued, largely because of the loss of skilled staff from the department, and the main emphasis has been on recording and using information from Sections III and IV. Section III information has been incorporated within the materials inventory. However, the quality and relevance of the data held in Sections I and II is such that they still have application and, ideally, should be brought back into the materials planning procedures at CRL. Box 4-1 and Box 4-2 show examples of the data held within Sections I and II of the data bank. The existence of these data was not discovered until the final stages of the project, so they were not initially incorporated into the materials inventory. However, this is now being addressed by the Roads Department who are continuing with the task of updating and extending the materials inventory.

It is evident that the data recorded have considerable value for use in future engineering projects, both in Zimbabwe and elsewhere in the region. The data also have potential for application by district level engineers in low cost or labour based construction projects where there is little materials information, and where there is limited funding for prospecting.

*Box 4-1* Example of data held in Section I of the geotechnical data bank

*Geoclimatic Province:*
N<2 Eastern Highlands

*Parent material group:*
Sandstone

*Type:*
Sandstone, Arkose

*Characteristics*
Sedimentary rocks consisting of various sizes of angular to rounded grains from 2mm down. Usually cemented and fairly well consolidated. Minerals generally quartz. When broken, fracture goes around single grains. The massive fine variety is dark grey with scattered shale bands. The medium to coarse varieties are ochre and cream coloured and are sugary in texture.

*Landform*
Highly dissected, slightly tilted plateau; with only plateau remnants, with escarpments. Often step-like appearance. In lower terrain, also somewhat rounded and range like hills with gentle slopes.

*Drainage pattern*
Radial off isolated and rounded hills. Almost parallel off elongated plateau remnants. Bigger streams angular, with partly controlled drainage due to faulting. The steep, short watercourses have a typical (often arrow shaped) rather coarse herringbone pattern.

*Erosional form*
Strong V-shaped gullies.

*Vegetation*
On the top of the plateau, only scattered remnants of trees. On the gentle slopes, light to medium dense vegetation (trees). Gullies heavily wooded. Thick grass cover.

*Air photo pattern*
Top of plateau, almost flat terrain, very smooth to velvety due to thick grass cover. Slopes and lower terrain coarse to very coarse due to widely spaced trees.

*Photo toner/$R_i$*
NW (9) to LG (7). More heavily wooded areas MG (5).

*Photo tone colour:*

*Additional remarks:*
Quartzitic sandstones in the southern Eastern Highlands is in places inter-bedded with shale bands. Old shelf deposit.

***Box 4-2 Example of data held in Section II of the geotechnical data bank***

*Geoclimatic province:*
Limpopo-Sabi Depression

*Area:*
Chisumbanje-Lower Sabi

*Parent material type:*
Basalt (N>5)

*Local landform:*
Flat terrain with depressions

*Surface materials:*
On higher ground rock bars and outcrops with either black or brown basaltic soils. Topsoil often silty, especially towards Sabi, caused by down wash from higher ground. Black basaltic soil in depressions greater than one metre deep.

*Sub-soil:*
On higher ground solid rock or disintegrated rock. In depressions, black basaltic soils, greater than one metre deep.

*Agricultural classification:*
Moderately deep to deep, dark self-churning clays. Clay fractions mainly montmorillonite. Dark brown to black soils.

*Soil profile:*
BK 0845-3375 a-b
BK 1835-2345 c
BK 1315-3805 d-f

*Construction materials*
- Calcretes (show up as lighter patches); found in pans or slight depressions
- Disintegrating basalts may be used for sub-base in this area and are possibly suitable for lime stabilised bases; basalts are usually found in small rises or ledges
- Basalts provide good wearing course gravels, due to the continual disintegration, which produces fines. Only harder basalts are suitable for base; these may have to be crushed, in addition to stabilisation treatment
- Disintegrated basalt contains to a large extent montmorillonite in its clay fraction; when N>5, the basalt can be used for subgrade, sub-base and wearing course gravel

## 4.2 Classification of road construction materials

Zimbabwe has been divided into seven geoclimatic provinces, which roughly match the countries geomorphic provinces. Each of these is characterised by a Weinert (1980) 'N' factor. A map showing the provinces is included within Part E of the Ministry Design Manual, and a reduced copy is reproduced in Figure 4-1. The geoclimatic provinces (N-factor areas) are listed in Table 4-1.

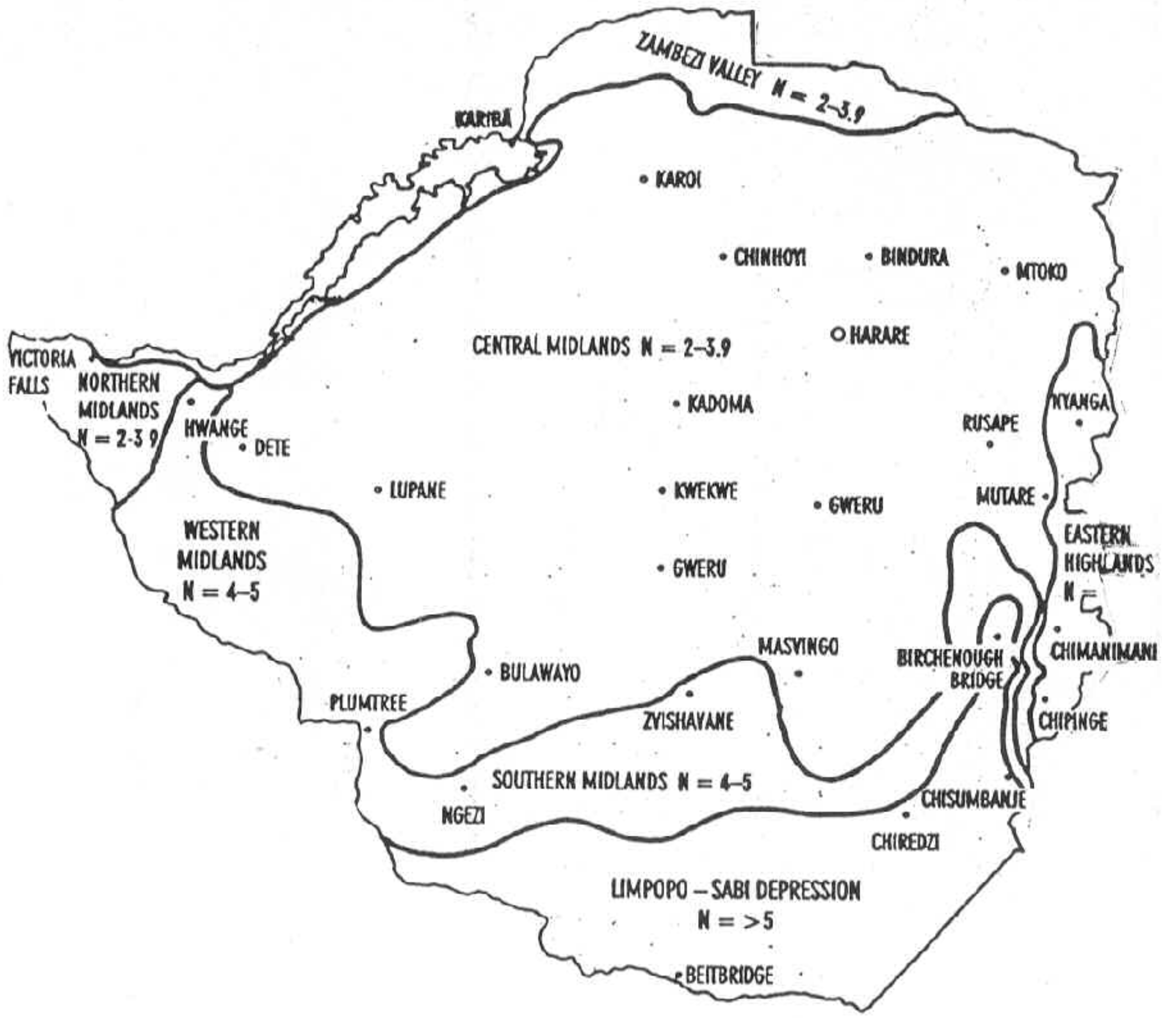



**Figure 4-1 Geoclimatic provinces in Zimbabwe**

**Table 4-1 Geoclimatic provinces in Zimbabwe**

| Geoclimatic Province | | N-factor |
|---|---|---|
| 1 | Eastern Highlands | <2.0 |
| 2a | Central Midlands | 2.0-3.9 |
| 2b | Northern Midlands | |
| 2c | Zambezi Valley | |
| 3a | Southern Midlands | 4-5 |
| 3b | Western Midlands | |
| 4 | Limpopo-Sabi Depression | >5.0 |

Nineteen different parent material groups have been identified within these geoclimatic zones in Zimbabwe. These have been sub-divided further to give the fifty types defined in Table 4-2. The road building materials are grouped using a standard Ministry classification procedure, which is based on index, tests, geology and climate. The group symbols, set out in Table 4-3, are used for plasticity (Ip), fineness index (If) and coarseness index (Ic) data ranges. The coarseness index is the percentage of material greater than 2.36mm, whilst the fineness index is the percentage of materials less than 75lm in size. Group classifications can then be assigned to the soils based on these properties. These are then expanded to provide a full classification by adding the symbols for climatic zone and geology, as shown in the example in Table 4-4. For example, where the group range [Ip/If/Ic] is [0-5/11-20/c], the group symbol become 0315c. The geoclimatic N value and parent material type are then added to fully classify the material, eg 2 Gr 0315c. The classification process applies to stabilised and unstabilised granular base materials, subgrades, improved subgrades, fill and road bed materials.

**Table 4-2 List of parent material groups**

| Parent material group | Type | Symbol |
|---|---|---|
| Granite | Granite | Gr |
| | Syenite | Sy |
| | Aplite | Ap |
| | Pegmatite | Pe |
| | Granite Porphyry | GrPo |
| Gabbro | Gabbro | Ga |
| | Pyroxenite | Py |
| | Norite | No |
| | Epidiorite | Ep |
| | Diorite | Di |
| Dolerite | Dolerite | Do |
| | Basalt | Bk |
| Serpentine | Serpentinite (all varieties) | Se |
| Gneiss | Gneiss (Ortho-Gneiss) | Gn |
| | Gneiss Granite | GnGr |
| | Para-Gneiss | Gn |
| Felsite | Felsite & Felsite Schist | Fl & FlSc |
| | Rhyolite | Rh |
| | Andesite | An |
| Greenstone | Greenstone & Greenstone Schist | Gsc |
| | Amphibolite, or | Am |
| | Hornblende Schist | Hsc |
| | Dolerite Schist | Dsc |
| | Porphyritic Schist | Psc |
| Schist | Phyllite | Pl |
| | Mica Schist | Msc |
| | Actinolite Schist | Asc |
| | Talc Schist | Tsc |
| Metallic schist | Banded Ironstone | Bi |
| | Jasper | Ja |
| Shale | Mudstone | Mu |
| | Shale | Sh |
| | Slate | Sl |

/continued

**Table 4-2 List of parent material groups (continued)**

| Parent material group | Type | Symbol |
|---|---|---|
| Limestone | Limestone<br>Dolomite<br>Marble | Ls<br>Dm<br>Ma |
| Sandstone | Sandstone<br>Arkose | Sa<br>Ar |
| Conglomerate | Conglomerate<br>Grits<br>Breccia | Cy<br>Gt<br>Br |
| Chalcedony | Chalcedony }<br>Chert }<br>Opal } | Ch |
| Quartz | Quartz (Crystalline)<br>Quartzite | Q<br>Qu |
| Alluvium | Loose, river laid material | Al |
| Sand | Sand (river)<br>Sand (aeolian)<br>Pebbles | Rs<br>As<br>-- |
| Clay | Black Cotton Soil | BCS |
| Pedogenic | Silcrete<br>Calcrete<br>Laterite<br>Ferricrete | St<br>Ct<br>L<br>FC |

**Table 4-3 Zimbabwe schedule of grouping for soil classification**

| Plasticity (Ip) | | Fineness (If) | | Coarseness (Ic) | |
|---|---|---|---|---|---|
| Ranges (%) | Group symbol | Ranges (%) | Group symbol | Ranges (%) | Group symbol |
| 0- 5 | 03 | 0-10 | 05 | 0-10 | a |
| 6-10 | 08 | 11-20 | 15 | 11-20 | b |
| 11-15 | 13 | 21-30 | 25 | 21-30 | c |
| 16-20 | 18 | 31-40 | 35 | 31-40 | d |
| 21-25 | 23 | 41-50 | 45 | 41-50 | e |
| 25-30 | 28 | 50-70 | 60 | 51+ | f |
| 31-35 | 33 | 70-80 | 75 | | |
| 36-40 | 38 | 80+ | 80 | | |
| 41-45 | 43 | | | | |
| 45+ | 45 | | | | |

**Table 4-4 Examples of groupings from indicator test results**

| Indicator results | | | Group range | | |
|---|---|---|---|---|---|
| Ip | If | Ic | Ip | If | Ic |
| NP | 16 | c | 0- 5 | 11-20 | c |
| 6 | 21 | d | 6-10 | 21-30 | d |
| 3 | 12 | c | 0- 5 | 11-20 | c |
| 18 | 32 | d | 16-20 | 31-40 | d |
| 19 | 27 | c | 16-20 | 21-30 | c |
| 8 | 19 | d | 6-10 | 11-20 | d |

*Notes:*
NP Non-plastic
Results are from same parent material type

## 4.3 Application of the classification

During the road reconnaissance survey, a centre-line soil survey is also carried out. Information on the soil classification in terms of Atterberg limits and grading is collected, together with information on soaked CBR, chainage, drainage and water table. In 1978, the historical records of these data were used to develop a method for the prediction of the subgrade soaked CBR for road design. The theory behind the development of this procedure is that soils falling within the same classification will attain similar strength values in terms of the soaked CBR if tested under the same conditions. Using statistical distributions of these data, decile, quartile, median and mean values of the strengths were computed and the predicted CBR values used for preliminary pavement design purposes. The selection of median, quartile or decile CBR values used depends on the design traffic group. These are median values for the traffic category of less than 50 000 cumulative equivalent standard axles (esa), quartile values for 50,000 to one million esa, and decile values for greater than one million esa.

Box 4-3 shows an example of the type of information held in Section III of the geotechnical data bank for a granitic soil. Knowing the basic classification [plasticity index (Ip), fineness (If) and coarseness (Ic)], together with the parent rock type and geoclimatic area, the relevant page or index card in the directory can be consulted and an estimation obtained of the engineering properties. These are given in terms of maximum dry density (average and range), optimum moisture content (average and range) and soaked CBR (decile, median and quartile).

This method of predicting CBR has been used very successfully in Zimbabwe for over 20 years. The method reduces the total amount of soils testing required, although it still requires confirmation and check tests. This provides an excellent example of how well organised historical materials data can be used to achieve substantial cost and time savings on the initial reconnaissance and design phases of road projects.

***Box 4-3 Example of data held in Section III of the geotechnical data bank***

*N-factor:* 2.0 - 3.9

*Geological origin:* Granite

Ic a to b

| Design data | | | Predictions | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | CBR (%) | | |
| Ip | Classification | If (%) | Density (Kg/m$^3$) | Wo (%) | Lower Decile | Lower Quartile | Median |
| 0-5 | 0305 | 0-10 | 1790-2000 | 7-10 | 46 | 49 | 52 |
| | 0315 | 11-20 | 1720-2080 | 7-15 | 24 | 33 | 43 |
| | 0325 | 21-30 | 1790-2090 | 6-14 | 21 | 29 | 39 |
| | 0335 | 31-40 | 1810-1960 | 9-14 | 18 | 21 | 26 |
| | 0345 | 41-50 | 1760-1860 | 13-15 | | | 15 |
| 6-10 | 0815 | 11-20 | 1840-2070 | 8-13 | 20 | 30 | 42 |
| | 0825 | 21-30 | 1830-2080 | 8-15 | 13 | 20 | 27 |
| | 0835 | 31-40 | 1850-2040 | 8-14 | 14 | 16 | 18 |
| | 0845 | 41-50 | 1730-1890 | 11-15 | 10 | 11 | 13 |
| | 0860 | 51-70 | 1680-2020 | 9-15 | | | 8 |
| 11-15 | 1315 | 11-20 | 1890-2050 | 10-13 | 17 | 24 | 32 |
| | 1325 | 21-30 | 1730-2100 | 8-17 | 9 | 13 | 18 |
| | 1335 | 31-40 | 1560-2130 | 10-23 | 9 | 11 | 14 |
| | 1345 | 41-50 | 1700-2000 | 9-17 | 6 | 8 | 10 |
| | 1360 | 51-70 | 1730-1770 | 16 | | | 5 |
| 16-20 | 1815 | 11-20 | 1920-2010 | 10-13 | | | 8 |
| | 1825 | 21-30 | 1900-2030 | 10-14 | 6 | 10 | 14 |
| | 1835 | 31-40 | 1740-2050 | 9-16 | 4 | 7 | 11 |
| | 1845 | 41-50 | 1710-1920 | 11-17 | 8 | 9 | 10 |
| | 1860 | 51-70 | 1620-1820 | 15-24 | 5 | 7 | 10 |

*Notes:*
Wo Optimum moisture content
Ip Plasticity index
If Fineness index

## 4.4 The Zimbabwe road data bank

The Department of Roads has, in recent years, developed a computerised road data bank (RDB). The system is used to store, update and retrieve key road related data items for Zimbabwe. The Ministry of Transport and Energy (MoTE) has derived a formal administrative procedure for adding, updating and validating data to the RDB. It is accessible to road administration departments and other users who need to obtain summary information. The structure of the RDB is illustrated in Figure 4-2 and contains nine basic information units, the contents of which are given below:

- *Basic data*
  contains information about the road network including route number, total length, maintenance units and the codes used in the remainder of the RDB [RDB 0-9]

- *Administration*
  contains information on road function, type and maintenance responsibility [RDB 10-19]

- *Traffic*
  contains information on traffic count stations and traffic count statistics [RDB 20-29]

- *Design and construction*
  contains the pavement design standard, structural design, design life, design speeds and pavement types [RDB 30-39]

- *Surface data*
  contains all the necessary surface condition information for bituminous and gravel roads [RDB 40-49]

- *Structures*
  contains information on structures such as culverts, drifts, grids along the road [RDB 50-59]

- *Geometry*
  contains horizontal and vertical alignment and the road cross-section details for the road [RDB 60-69]

- *Bridges*
  contains information on bridges including identity, name, chainage, structural details, hydrological information, maintenance details and accident history [RDB 70-79]

- *Materials*
  contains information on the road construction materials used [RDB 80-89] (not established at project inception)

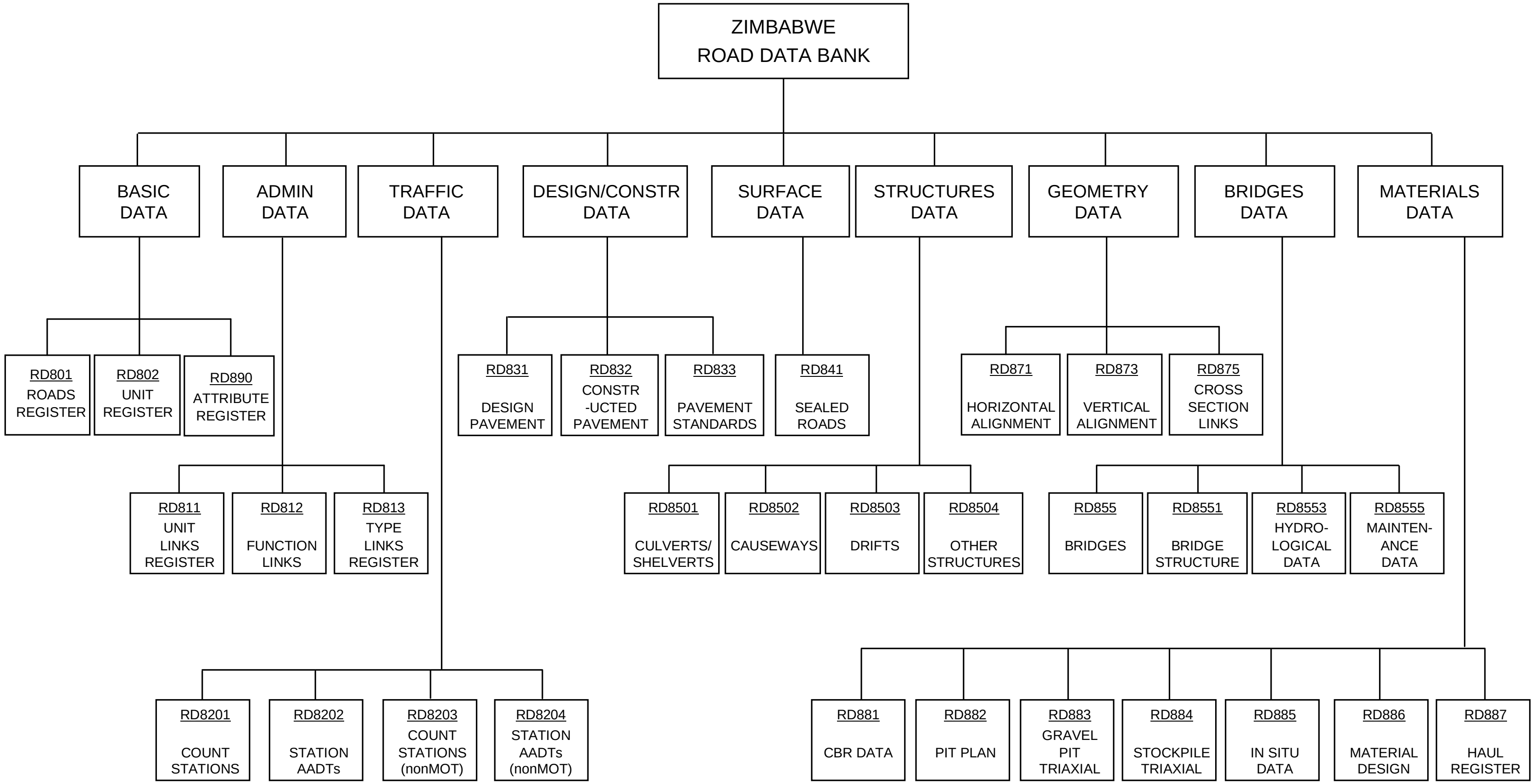



**Figure 4-2 Structure of the Zimbabwe road data bank**

The RDB software has been developed in Microsoft FoxPro using in-house staff from the Computer Branch, and a competent system has resulted. All of the data within the database are linked by unique identifiers, such as ‘road number’, and/or ‘chainage-from to chainage-to’. All data relevant to an information set are contained within a series of registers (files), each of which can be interrogated using identifiers such as ‘road number’ and ‘chainage’. Data in the different information sets can also be cross-referenced to give a variety of outputs. The data bank was distributed to the provinces in December 1993. They now have the responsibility to update certain registers and copy that information to the computer section within MoTE for validation and centralisation. The data are not available to reports until the validation procedure is complete.

At the time of the project inception, the materials register of the RDB had not been developed. It was therefore agreed with the Roads Department that the TRL project team and the CRL staff would work together with the Department’s Computer Branch on the development of the materials inventory. In this way, the development could satisfy both the project objectives and the needs of the RDB materials register. Thus reference to the Zimbabwe materials inventory in this report, by implication, means the information sets of the RDB.

## 4.5 Structure of the Zimbabwe materials inventory

The structure of the Materials Inventory needed to reflect the nature of the materials data collected in the Department and the end user requirements. It was therefore developed through a series of meetings with stakeholders in CRL, Computer Branch and end users in various branches within the Department. The agreed format and content of the materials inventory comprised eight registers (or database files), as shown in Box 4-4.

The original Section III of the geotechnical data bank, from which the design CBR is determined, was completely revised and updated during the project. In its original form, the statistical data were based on soil tests carried out up to 1978. All of the original data were located, combined with the subsequent soil test information up to 1996, and used to recompute the statistics from the larger updated data sets. The design CBRs (decile, quartile, median and mean values) for approximately 3,250 soils, with different soil group classifications, are now available. The design values derived from these larger data sets have improved statistical significance.

The contents of each of the registers, field names and field descriptions are given in Appendix A. An example of each of the registers is given in Appendix B.

**Box 4-4 Database registers in the Zimbabwe materials inventory**

*RDB 81: CBR data register*
contains data on the soaked CBR (California bearing ratio) for a range of different soil types found in Zimbabwe

*RDB 82: Pit plan register*
contains data on pit planning, such as pit identification number, location, area, and quantities of materials

*RDB 83: Pit triaxial register*
contains data on the index properties and Texas triaxial test data for samples taken during the pit proving trials

*RDB 84: Stockpile triaxial register*
contains data on the index properties and Texas triaxial test data for samples taken after the material has been stockpiled

*RDB 85: In situ register*
contains data on the centre-line soils to one metre depth

*RDB 86: Materials design register*
contains data on the road design, such as, subgrade design class, roadbase triaxial class and thickness, and recommended treatment

*RDB 87: Construction register*
contains data on the base materials used in the road, chainages, pit number and any modifications such as stabilisation of the materials

*RDB 88: Fill/subgrade register*
contains data on subgrade and fill materials from in situ or borrow pit investigations

*RDB 89: Wearing course register*
contains data on the wearing course from site investigations

The data items and their data types, which describe the materials test data, were set up as FoxPro data tables. Appropriate key field identifiers were chosen to link these tables to the main RDB. For the materials registers, the key fields or unique identifiers are road number (Road_No), chainage (From, To) and pit number (Pit_No). The Computer Branch developed a series of data entry screens to facilitate data input, editing and querying. The data entry screens display the data labels, which are fully explanatory, on a blue background, and users cannot change these. The data variables are displayed on a black background where data is entered or edited. A typical data entry screen is shown in Figure 4-3. The user interface displays a menu bar at the bottom of the screen. As the user moves across the menu bar, a brief explanation of the function of the option is displayed. The menu bar comprises the fields shown in Box 4-5.

Road Data Bank Data Maintenance RDB82

-RDB82- Pit Plan Register

| Pit-No | Road-No | Peg-H | Condition | Reserv-Area | Cairn-Area | N-Area |
|---|---|---|---|---|---|---|
| GECY/13 | 138 | 57.32 | MAIZE FIELD | 0.68 | 0.41 | 2-3.9 |

| Owner | Notif-Date | Haul-Dist | Grid-Ref |
|---|---|---|---|
| MR MATIZWA KAZINGIZI | 02/08/89 | 0.60 | 016299 |

| Map-No | Ovb-type | Seam-type | Sub-Soil | Obv-Thick |
|---|---|---|---|---|
| 1631C3 | GRS | L | L | 572 |

| Seam-thick | Std-Dev | Grv-Qty | Basic-Use | Treatment | New-State |
|---|---|---|---|---|---|
| 521 | 172 | 1400 | B2 | 3%CT | BASE1 |

Access-Infor: UNDEFINED

New-Owner: NONE

Remarks: B2(0.1M)NAT B1(0.1M)+3%CT

| Val-Date | Act-Date | Act-Date |
|---|---|---|
| 13/12/95 | 0 | 13/12/95 |

Ret/Beg/End/Nxt/Prv/Skp/Mod/Add/Cpy/Del/Lst/Filt/Tally/+/-/Help/Quit

Retrieve a record by its fields

**Figure 4-3 Example of data entry screen for Pit Plan register of materials data bank**

***Box 4-5 Contents of menu bar***

| | |
|---|---|
| *Ret* | Retrieves a record |
| *Beg* | Go to the first record in the register |
| *End* | Go to the last record |
| *Next* | Go to the next record |
| *Prev* | Go to the previous record |
| *Skip* | Go forward/backward by a number of records. When selected, an entry block appears at the end of the entry/edit menu bar. The number of records to be skipped can then be entered. |
| *Mod* | Allows the user to edit the current record |
| *Add* | Add a record to the database. When selected, all fields are cleared, with the exception of the VAL_DATE and ACT_DATE. |
| *Copy* | Duplicates the current record. This is used for adding records when the major part of the data is the same as that of another record. |
| *Del* | Deletes the record displayed. When this is selected, confirmation will be required before execution of the command. |
| *Lst* | Display records beginning from current record. The records are displayed in a browse window. The escape button is pressed to exit from this window. When the escape command is executed the record highlighted will be retrieved. |
| *Filt* | Allows the user to view the database according to their own needs |
| *Tally* | Counts the number of records in the register |
| *Quit* | Terminates the program |

## 4.6 Data capture

The database is structured in same way as the paper records have been organised at CRL. The materials registers were designed to use a single data record form for all of the information relevant to a particular register. Data capture comprised the following steps:

1. The original test data sheets were examined and summarised to identify the data required for the register
2. These data were then transferred to a data summary sheet, set up with a similar format to the data entry screens
3. The data were checked as they were transferred to the data entry sheet and rechecked after entry into the computer

The data collation, extraction to data entry sheet, and data entry into the computer were carried out by four full-time data entry clerks over a three-year period. Three desktop computers were used initially, but this was reduced to one when the bulk of the historical data had been entered.

Data entry continued until the end of the project. Table 4-5 shows the size of the materials inventory in Zimbabwe and the sources of data at the end of the project. CRL staff continued data entry for the design, construction registers and fill registers after completion of the project. Over 65 000 records were completed during the project, comprising over 2.25 million individual data items.

**Table 4-5 Records held for each register in Zimbabwe**

| Register no | Name | Data source | No of records | Total data entries |
|---|---|---|---|---|
| RDB 81 | CBR | CL 2 | 3 246 | 58 428 |
| RDB 82 | Pit plan | CL 19 | 3 658 | 103 264 |
| RDB 83 | Pit triaxial | CL 19 & CL7 | 4 208 | 159 904 |
| RDB 84 | Stockpile triaxial | CL 19 & CL7 | 3 232 | 122 816 |
| RDB 85 | In situ soils | Field survey books | 48 680 | 1 411 720 |
| RDB 86 | Materials design | CL 16 | 5 169 | 82 704 |
| RDB 87 | Construction | CL 16 | 9 402 | 291 462 |
| RDB 88 | Fill | | 0 | 0 |
| RDB 89 | Wearing course | CL 19(w) | 588 | 17 640 |

*Note:* Situation at March 1997

On average, it takes about 5 minutes to enter each record containing 25 to 30 fields. It is possible for one clerk to enter about 70 records per day, or approximately 15 400 records per year. The time taken just to enter data in Zimbabwe is equivalent to about five staff-years of work, and this is a factor that needs to be considered when planning other materials inventories.

# 5. Development of the materials inventory for Malawi

## 5.1 Structure of the Malawi materials inventory

The Departmental Materials Reports (DMR), produced by the Roads Department on soil and gravel pit investigations, provided the data source for the Malawi materials inventory. Computers were not used for routine data handling or reporting at the laboratory, so a programme of training courses were held to introduce project staff to basic computer skills and data handling. The Ministry had no computer department to support the development of the materials inventory, although some experienced staff were able to give intermittent support to the project team when required. A local specialist computer company was engaged assist with software development.

It was agreed with the senior staff at the Materials Branch that the format and contents of the materials inventory should follow the DMR format. Establishment of the inventory involved initial transfer of data from field survey and laboratory forms to Lotus spreadsheets. The registers developed for the Malawi materials inventory are listed in Box 5-1.

***Box 5-1 Database registers in the Malawi materials inventory***

*MALPLAN*
contains the general DMR information, including the hard copy report reference number, road name, road number, province, and the month and year of DMR publication

*MALSOILS*
contains information on the alignment soils, including on road name, chainage, sample number and depth, and description

*MALSOILT*
contains the laboratory soil test data for the alignment soils, including road name, number, chainage, sample number and depth (up to one metre), grading, plasticity, compaction characteristics and strength

*MALPITS*
contains the laboratory soil test data for gravel pits and quarries soils including road name, number, chainage, sample number and depth, grading, plasticity, compaction characteristics and strength

The contents of each of the registers, field names and field descriptions are given in Appendix A. An example of each of the registers is given in Appendix B.

Initially, spreadsheets were used for data entry, but as staff became more experienced and confident with computer technology, the completed spreadsheets were converted to database files for use in FoxPro. The link fields established made use of the road or pit name (Road_name; Pit_name), road or pit number (Road_No; Pit_No), and chainage (Chain_age) as the unique identifiers. Data entry was then continued through the standard FoxPro package.

## 5.2 Data capture

The data capture process was simpler than that used in Zimbabwe, as data entry followed the exact format of the summary tables in the DMR reports. These reports generally held information for all four registers. Data entry was carried out by two of the Roads Department materials technicians, part time over a period of two and a half years. The materials inventory is held on a dedicated desktop computer. Data entry continued until the end of the project. Table 5-2 shows the size of the Malawi Materials Inventory on completion of the project. Over 4300 records were completed comprising some 116000 individual data entries. Data entry has continued since the completion of the project.

**Table 5-1 Records held for each register in Malawi**

| Register name | No of records | Total data entries |
|---|---:|---:|
| MALPLAN | 44 | 265 |
| MASOILS | 1 344 | 8 000 |
| MALSOILT | 1 185 | 35 500 |
| MALPITS | 1 741 | 71 500 |
| *Note:* Situation at March 1997 | | |

# 6. Database queries and interrogation

Use of a computerised database offers several advantages. Data can be:

- Accessed easily
- Interrogated and edited so that data are added, modified or deleted, according to the needs of the user
- Manipulated by sorting, querying, filtering, and indexing
- Related to different databases with the same key fields (eg pit number or road number and chainage)
- Used to produce reports which are designed and produced according to the users' or customers' specifications

A key advantage of the database is that it can be interrogated to find single or multiple records that match criteria set by the user. Some examples are:

- Finding the geographical location, engineering properties, or land owner information relating to a particular pit or group of pits on a particular road, group of roads or province
- Finding gravels or soils with certain classification properties, and predicting the range of triaxial strengths for similar materials where the triaxial strength is unknown
- Finding the design for a particular road between certain chainages
- Determining the as-built structure or age of a particular section of road, for example if a pavement evaluation is being carried out
- Finding the design CBR for a new or old construction
- Evaluating quantities of resources still available from new or partially utilised pits for maintenance operations
- Determining the properties of in situ soils along a stretch of road

These and many other queries can be answered quickly using the appropriate register, or related fields between registers, and the data can be generated readily as reports.

The materials inventories in both countries are held in FoxPro databases, and querying and data manipulation follow standard FoxPro procedures. It is also possible to move the data between programs (eg database to spreadsheet or to a word processing package) if other computations, graphical presentations or reporting procedures are required. The Materials Inventory in Zimbabwe is maintained by Computer Branch, who can assist CRL with the generation of more difficult queries or reports.

Examples of database queries are given in Appendix C.

# 7. Management of materials inventories

Materials inventories are dynamic and need to be updated continually to be effective. A key issue in the development of materials inventories is the management and sustainability of the system. Key considerations for the management of the system include the following:

- Recognition by senior management and financial co-ordinators that the system exists, is a useful resource, and requires support from the department
- Identification of key user groups within and outside the roads department
- The need for a dedicated team of staff, including a materials inventory manager
- Adequately trained staff
- System managers should hold regular liaison meetings with end users and prospective users
- Recognition of the need for updating continually with new information, including the need for routines to be established for on-going selection and capture of new information
- Existing information should be checked and verified
- Procedures need to be in place to generate reports and queries for users
- Security systems need to be established; information needs to be virus checked and backed up regularly
- The use and management of passwords to increase security
- Recognition of the importance and implementation of quality control procedures at every stage
- Recognition of adequate financial and manpower resources to sustain and maintain the system, including upgrading of hardware and software

## 8. Value of materials inventories

Costs associated with the planning, sampling and testing activities involved in forming the materials inventories were obtained in Zimbabwe and Malawi. The in-house costs, including manpower and transport, of surveying a gravel pit to provide the necessary planning information for a wearing course gravel, roadbase or sub-base material were estimated for Zimbabwe to be about US\$0.33/$m^3$ (1997 prices). These costs include the cost of mobilising the survey teams, sampling, testing and reporting the data. Similarly the cost of carrying out a centre-line soils survey at every 80 metres would be in the order of US\$435/km. The cost of the information required to complete a field check sheet (CL16) would be around US\$560/km.

The estimated replacement cost of the information held in the materials inventories is given in Box 8-1: in Zimbabwe, this over US\$8 million; in Malawi, this estimated to be of the order of US\$200,000. Note that these costs are based on government accounting practices, and are unlikely to include full costs of depreciation, overheads, and the like. As such, they are likely to underestimate the value of the data in the inventory by a considerable amount.

**Table 8-1 Cost of data held in the Zimbabwe materials inventory**

| Register | No of records in register | Cost per record (US$) | Total cost (US$ x 1000) |
|---|---|---|---|
| RDB 81 | 3 246 | 40 | 130 |
| RDB 82 | 3 688 | 1 300 | 4 790 |
| RDB 83 | 4 208 | 90 | 380 |
| RDB 84 | 3 232 | 90 | 290 |
| RDB 85 | 48 680 | 35 | 1 700 |
| RDB 86 | 5 169 | 5 | 26 |
| RDB 87 | 9 402 | 90 | 850 |
| RDB 89 | 588 | 200 | 120 |
| Total replacement cost | | | 8 280 |

Large programmes of road rehabilitation are being planned in both Malawi and Zimbabwe. As the workload in this area increases, data in the materials inventories will become particularly valuable.

Consideration is being given to the commercialisation/privatisation of government testing laboratories. This means that, in the future, they will need to engage in income generating projects. The data in the materials inventories are a marketable resource, which could provide income by providing information on:

- Existing alignment soils
- Materials used
- Characteristics and typical location of the gravels available in the area
- Potential for existing borrow area extensions
- Previous design standard used and as-built condition

The information and data could be made available by interrogating the materials inventory with users paying for the service. User accessing information in the inventory could make large cost savings through reducing the amount of surveying and testing needed. The revenues generated could be used to support, maintain and develop the system. Potential users are not just limited to road engineers. The data could be of use to other areas of civil engineering, building and water development, and this should be recognised when marketing the system.

# 9. Future development

## 9.1 Institutional arrangements

The materials inventories that have been developed have the potential for expansion into much larger and more powerful systems. At the moment, it is important to put the management structures and other support systems in place, so that the inventories are sustainable in their current form. As staff become more familiar and proficient with the systems, expansion and development can be considered.

## 9.2 Additional data

In Zimbabwe, data are still being entered into RDB86 (Design) and RDB87 (Construction). Work has yet to start on data entry for RDB88 (Fill/subgrade), and this is planned to commence once RDB86 and RDB87 have been completed. Further data have also been entered into the Malawi materials inventory since project completion, and this has doubled the size of the database.

In both Malawi and Zimbabwe, staff in the provinces have been contacted and requested to provide any missing data or additional information appropriate to the materials inventories.

## 9.3 Additional registers

As other users of the system are identified and additional needs become apparent, new fields and registers can be added. Both systems developed in the project have this capability. The materials inventory in Zimbabwe Roads Department has recently been evaluated by end users in the Planning, Design, CRL and Computer Branch, and a number of amendments and new registers have been proposed.

The pit plan data register [RDB82], in the Zimbabwe materials inventory, holds information on the land ownership, area of pit, and notification dates for designation of the borrow area. This register can be updated to incorporate data on de-reservation, rehabilitation and compensation. This information would be very useful to the Planning Branch in the Departmental Headquarters. Planning Branch have indicated the need to determine the status of land acquisition arrangements, compensation payments and to track progress of claims. Such a system could be used to control fraudulent claims.

The information held on the pit plan register [RDB82] could also be used to determine the cost schedule for hauling materials, or to revise the haul schedule. More data items, or a related database table, could be added to store the unit cost of construction. These data could then be made available to the pavement design and planning sections.

The following additional information sets were highlighted as being of importance:

*Quarry and aggregate*
This would contain data on the location of quarries, and the engineering characteristics of materials produced for crushed stone base, concrete and bituminous surfacing aggregates.

*Concrete control for structures*
Important and expensive components of any road constructions are the bridges and other concrete structures. CRL in Zimbabwe routinely collect as-built data for these structures. This includes mix design, cement quality testing, aggregate testing, strength testing on concrete and steel, and impurities determination. These data would provide a complimentary as-built data source to a bridge management system or the bridges block of the RDB.

*Site investigations for structures*
Between 1993 and 1994, CRL carried out some 25 site investigations for bridges. These investigations involved logging the engineering characteristics of superficial and hard rock ground profiles close to the structure through digging trial pits and drilling, respectively. Tests modelling the in situ strengths of these materials were then carried out. The ground proof information and data obtained in this way is also of interest to the geological survey, the mining industry and water engineers. Similar information is available in some of the DMRs in Malawi.

*Ad hoc materials*
Other materials information on the characteristics and location of waste materials, such as mine waste, colliery spoil and furnace slags, could also be incorporated into the inventory.

*Pavement evaluation register*
This would contain data collected on the in situ strength of pavements from field surveys. These might include summarised dynamic cone penetrometer readings, deflection data from the falling weight deflectometer, deformation information from rut depth measurements, visual appraisal and surface condition information, the results of roughness surveys, such as those carried out using a bump integrator, and the like. These data could be used in conjunction with traffic data, which is held on the main RDB, to assist with planning future rehabilitation strategies, setting priorities, and generating local calibration factors for deterioration relationships, such as those in the HDM model.

## 9.4 Additional user groups

Considerable investment is currently taking place in the construction and maintenance of low volume access roads and tracks, often using labour based methods. District engineers working on these projects have little access to materials data or the funding necessary to carry out expensive materials investigation surveys. The materials inventory could provide valuable information to assist with this without needing to conduct full-scale materials surveys. By carrying out the fairly simple classification tests on site, a reliable estimate of the bearing capacity of the in situ soils can made using RDB81.

## 9.5 The materials inventory as a prospecting tool

The materials inventory in Zimbabwe has the potential to assist with the location of new gravel deposits, which are becoming increasing difficult to find in many parts of the country. The historical data already on the inventory also provide a useful guide to the expected properties of new deposits, if these are located in the same or a similar area.

However, the predictive potential of the system will only be realised fully when the materials inventory is used in conjunction with terrain data which exists in Zimbabwe. This information was described in Section 4.1. The use of a geographic information system (GIS) in conjunction with the materials inventory could provide a powerful tool for targeting prospective areas for detailed investigation. The pit database tables record the pit locations as grid references. Use of a GIS would enable materials data be displayed spatially on maps, from which interpolations into unknown areas can be made.

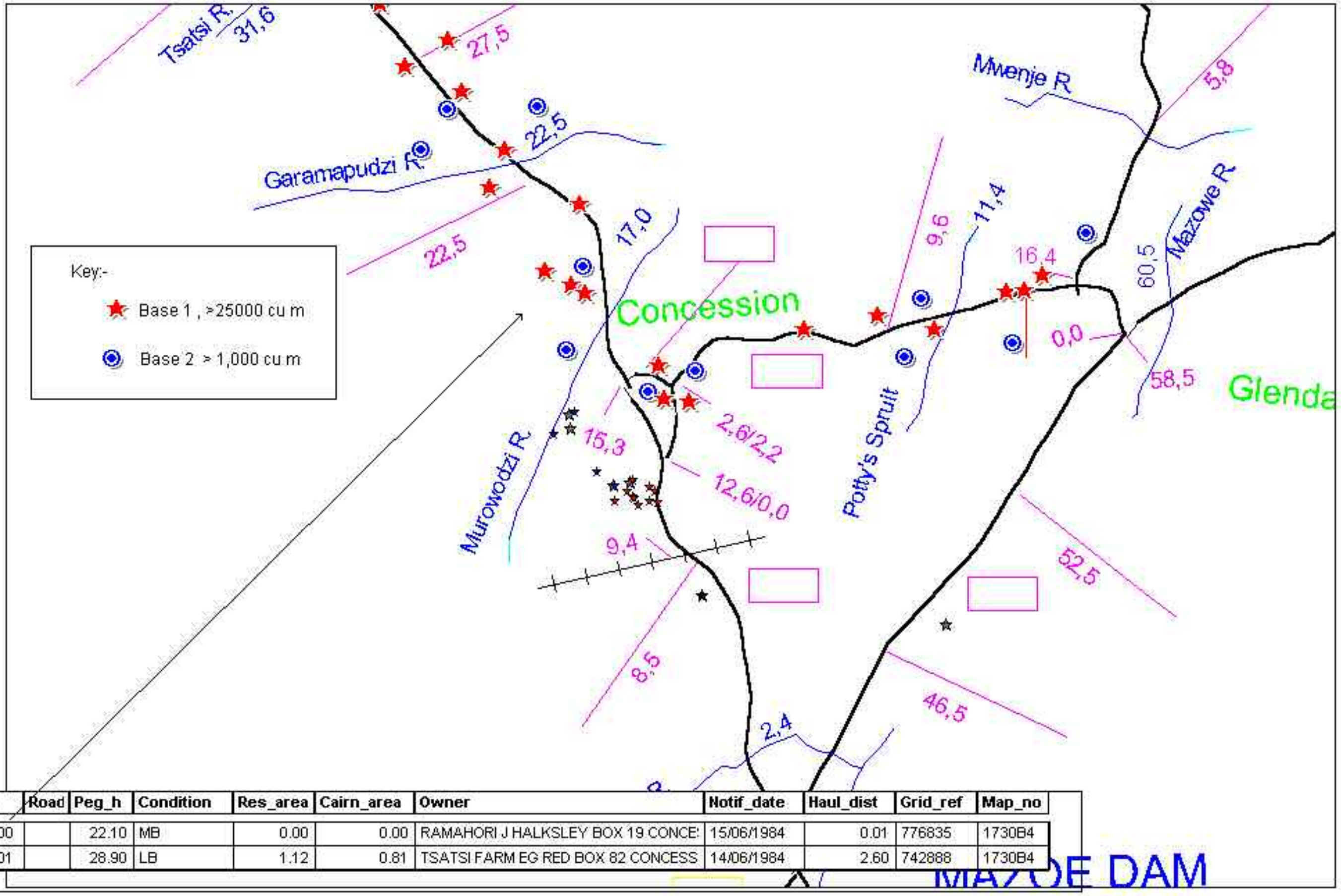
The soil survey information in RDB85, design information in RDB86 and the construction data in RDB87 and RDB88 are spatially referenced by chainage. Geographic co-ordinates corresponding to chainage would need to be recorded, perhaps using a global positioning system (GPS), so that chainage-related data could be mapped. The soils information, which is logged every 80 metres along the network, could also be mapped according to its classification and, when used in combination with the climatic and geological data, an engineering soils map showing design CBR could be produced.

Digitised topographic, geological, climatic and soils maps can be used in combination with the known materials and terrain information from the materials inventory to determine conditions where materials, exhibiting certain engineering characteristics, have been found previously. Once these conditions are known, other areas where similar conditions exist can be identified and mapped.

A simple pilot investigation to demonstrate the potential of such an approach was carried out during the project. Some of the geographic data were converted to a geographic co-ordinate system and overlaid on a portion of the digitised road map of Zimbabwe using the MapInfo GIS package. The result is shown in Figure 9-1. Use of such a system enables data held in the pit record on the map to be displayed by simply clicking the mouse pointer on the relevant borrow pit marker.

Management of non-renewable resources, such as gravels, is becoming an increasingly important issue for roads departments in the region. Materials inventories provide a method to track use and hold data on quantities and quality of future available resources. They provide a means whereby management decisions on their use can be made.

The data held in the materials inventories, if developed further as outlined above, could be used to assist materials prospecting and engineering soil characterisation in neighbouring countries where less materials, terrain and other engineering information is available. A number of countries in the region have expressed a desire to evaluate and pilot test the potential of using this approach, in addition to developing many of the materials data management procedures already used in Zimbabwe.




| Pit_no | Road | Peg_h | Condition | Res_area | Cairn_area | Owner | Notif_date | Haul_dist | Grid_ref | Map_no |
|---|---|---|---|---|---|---|---|---|---|---|
| CNMI-700 | | 22.10 | MB | 0.00 | 0.00 | RAMAHORI J HALKSLEY BOX 19 CONCE: | 15/06/1984 | 0.01 | 776835 | 1730B4 |
| CNMI-701 | | 28.90 | LB | 1.12 | 0.81 | TSATSI FARM EG RED BOX 82 CONCESS | 14/06/1984 | 2.60 | 742888 | 1730B4 |

| Std_dev | Gr_quant | Basic_use | Treatment | New_state | Access_inf | Remark | Val_date | Status | Act_date |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 2,000 | WC | | B1 | UN | UNSUITABLE WC IP TOO HIGH | 16/07/1996 | 0 | 16/07/1996 |
| 53 | 4,900 | WC | | B1 | PR-FRD | SUITABLE FOR USE AS WC | 16/07/1996 | 0 | 16/07/1996 |

**Figure 9-1 Example map showing borrow pit location and background information**

A system established in this way also has the potential for use in development planning, including land for housing, dams, reservoirs and other engineering structures, where construction materials are required and soils need to be characterised. Swell data, for example, can provide a relatively simple method of generating soil geohazard information when mapped geographically. Another user of the data could include the geological survey, where the soils information and data could be used to strengthen geological boundary extrapolations which would be useful in mineral prospecting. The soils and profile data also have application to agriculturists, land use planners and environmental specialists. The Ministry of Lands and Water Development (Research and Specialist Services) who are building a database of agricultural soils has already expressed interest in the materials inventory.

# 10. Conclusions

## 10.1 Establishment of a computerised materials inventory

1) Materials inventories have been developed and established in Zimbabwe and Malawi in which data on the location and use of road building materials can be held centrally by computer and accessed by users. The computerised systems enable materials information to be recorded, organised, stored and retrieved.

2) The type, quality and volume of data available were different in each of the countries. Different development procedures were adopted in each case in consultation with potential users.

3) The sophistication of the systems implemented was partly a function of the available level of computer literacy. Some computer training was provided.

4) Requirements for information and queries on various aspects of road making materials can now be directed to staff responsible for the materials inventories who can interrogate the systems to generate reports on behalf of users.

## 10.2 Updating and sustaining the database

5) Although the basic structures of the materials inventories are in place, these inventories need to be continually updated, upgraded, and maintained. This requires the on-going provision of adequate financial resources.

6) Good laboratory management practices, including quality assurance procedures, were identified as an important prerequisite to setting up a materials inventory. This requires good laboratory management and staff training to ensure reliable data and sustainability of the database.

7) Sections I and II of the original geotechnical data bank in Zimbabwe should be brought back into routine use. Two additional registers in the materials inventory are needed to achieve this.

## 10.3 Link between the database and a GIS

8) The materials inventories can be linked to other data through a GIS to provide a means of mapping, predicting and managing engineering resources. This was demonstrated in a pilot trial.

## 10.4 Value

9) The value of the data stored on the systems has been estimated. Materials inventories provide a means of protecting this investment. Such investment has benefits by providing

information for new development projects more cheaply through reducing survey and other costs.

### 10.5 Prediction of new sources of material

10) Information from the materials inventory can be used in conjunction with digitised topographic, geological, climatic and soils maps to predict where materials exhibiting certain engineering characteristics are likely to occur.

### 10.6 Regional strategy

11) A regional strategy, perhaps co-ordinated by SATCC, could be adopted to develop centralised materials inventories for the benefit of other countries in the region. Detailed implementation would depend on the available computer literacy, but this need not rule out the development of paper based systems as a first step.

12) The soil and materials classification and design CBR prediction procedures developed in Zimbabwe have potential for adoption outside the country. Additional research is required to determine how best to approach this. It is unlikely that data of the type and quantity available in Zimbabwe will be found elsewhere in the region, other than in South Africa. However, it is likely that the region could benefit by sharing and adopting many of the CRL procedures and practices for the storage and retrieval of data.

13) The approach of using climatic area, parent materials type and simple soil classification procedures to predict the engineering characteristics of soils could probably be implemented in other countries in the region. The benefits of using the system in this way also has application to other sectors and disciplines.

## 11. References

Holden, A, 1971. The establishment of a data bank for geotechnical information at the Ministry of Roads and Road Traffic. *Rhodesian Engineer, Paper No 125*, November, 1-5.

Weinert, H H, 1980. The natural road construction materials of Southern Africa. Pretoria: Academica.

## 12. Acknowledgements

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# Appendix A: List of registers and contents

## A1 Zimbabwe materials inventory

### RDB82.DBF PIT PLAN REGISTER

This register contains general planning information for gravel (base and wearing course) pits. The source of the data is the corresponding CL19 or CL19w.

| FIELD | DESCRIPTION |
|---|---|
| PIT_NO | pit number |
| ROAD | road number |
| PEG_H | haul to km peg on the road |
| CONDITION | condition of the land at the time of erecting the prospecting notice |
| RES_AREA | approximate area of reservation (in hectares) |
| CAIRN_AREA | area to be worked (delimited by beacons) |
| OWNER | name and postal address of the owner or agent |
| NOTIF_DATE | date the owner is informed of prospecting |
| HAUL_DIST | total haul distance from the pit to the peg (in km) |
| GRID_REF | grid reference of the pit on 1:50000 map |
| MAP_NO | number of the appropriate 1:50000 map used |
| OVB_TYPE | geological material type of the overburden |
| SEAM_TYPE | geological material type of the seam which will be used |
| SUB_SOIL | geological material type of the sub-soil |
| OVER_BURD | thickness of the overburden (mm) |
| SEAM | reduced thickness of the seam (mm) |
| STD_DEV | seam thickness reduction (mm) |
| GR_QUANT | volume of material extractable (m3) |
| BASIC_USE | approved use of the un-modified material |
| TREATMENT | percent and type of modification or stabilising agent |
| NEW_STATE | approved use of the modified material |
| ACCESS_INF | type of route available to the pit |
| REMARK | approval information given by or for the chief material engineer |
| VAL_DATE | date the validation status was given |
| STATUS | validation status of the record |
| ACT_DATE | actual date of entry of the record |

## RB83.DBF PIT TRIAXIAL REGISTER

This register contains testing information and data for gravel (base) pits obtained at the prospecting stage of the investigation. The source of the data is the corresponding CL19.

| **FIELD** | **DESCRIPTION** |
|---|---|
| PIT_NO | pit number |
| SAMP_CLASS | material classification for the sample |
| STOCK_QTY | estimated quantity of material ($m^3$) |
| GEO_ORIGIN | geological origin of the material |
| TREATMENT | condition (natural or modified) that the sample tested |
| LIQ_LIMIT | liquid limit of the material |
| PLAST_LIMIT | plastic limit of the material |
| PLAST_INDEX | plasticity index of the material |
| COURS_INDE | coarseness index of the material |
| FINENESS | percent passing a 0.075mm sieve |
| FINE_INDEX | fineness index of the material |
| PLAST_PROD | plasticity product of the material |
| REJECT_IND | reject index of the material |
| MAX_DENSIT | maximum dry density of the material for the compactive effort (COMP_EFFOT) used |
| OMC_CONT | optimum moisture content for the maximum dry density of the material at the compactive effort (COMP_EFFOT) used |
| MC_TEST | moisture content of the sample after capillarity and testing |
| MASS_CAPIL | surcharge applied to the sample (kg) |
| DAYS_CAPIL | days in capillarity |
| COMP_EFFORT | the compactive effort used to obtain the optimum moisture content and maximum dry density of the material |
| COHESION | cohesion measured in the sample at zero normal stress |
| TRIA_CLASS | triaxial class strength number |
| UCS_STRESS | unconfined compressive strength of the material |
| SURF_TEXT | surface texture of the material |
| PART_SHAPE | particle shape of the material |
| ORGAN_CONT | estimated organic content of the material |
| MICA_CONT | estimated mica content of the material |
| BASIC_USE | approved use of the un-modified material |
| NEW_STATE | approved use of the modified material |
| G_M | grading modulus of the material |
| IP_RANGE | range of plasticity index for the material |
| AASHTO_CL | AASHTO classification for the material |
| APPROVAL | approved use of the material given by or for the chief material engineer |
| VAL_DATE | date the validation status was given |
| STATUS | validation status of the record |
| ACT_DATE | actual date of entry of the record |

## RDB84.DBF STOCKPILE TRIAXIAL REGISTER

This register contains testing information and data for gravel (base) pits obtained from samples taken from the stockpiles at the pit. The source of the data is the corresponding CL19.

| FIELD | DESCRIPTION |
|---|---|
| PIT_NO | pit number |
| SAMP_CLASS | material classification for the sample |
| STOCK_QTY | estimated quantity of material ($m^3$) |
| GEO_ORIGIN | geological origin of the material |
| TREATMENT | condition (natural or modified) that the sample tested |
| LIQ_LIMIT | liquid limit of the material |
| PLAST_LIMIT | plastic limit of the material |
| PLAST_INDEX | plasticity index of the material |
| COURS_INDE | coarseness index of the material |
| FINENESS | percent passing a 0.075mm sieve |
| FINE_INDEX | fineness index of the material |
| PLAST_PROD | plasticity product of the material |
| REJECT_IND | reject index of the material |
| MAX DENSIT | maximum dry density of the material for the compactive effort (COMP_EFFOT) used |
| OMC_CONT | optimum moisture content for the maximum dry density of the material at the compactive effort (COMP_EFFOT) used |
| MC_TEST | moisture content of the sample after capillarity and testing |
| MASS_CAPIL | surcharge applied to the sample (kg) |
| DAYS_CAPIL | days in capillarity |
| COMP_EFFORT | compactive effort used to obtain the optimum moisture content and maximum dry density of the material |
| COHESION | cohesion measured in the sample at zero normal stress |
| TRIA_CLASS | triaxial class strength number |
| UCS_STRESS | unconfined compressive strength of the material |
| SURF_TEXT | surface texture of the material |
| PART_SHAPE | particle shape of the material |
| ORGAN_CONT | estimated organic content of the material |
| MICA_CONT | estimated mica content of the material |
| BASIC_USE | the approved use of the un-modified material |
| NEW_STATE | approved use of the modified material |
| G_M | grading modulus of the material |
| IP_RANGE | range of plasticity index for the material |
| AASHTO_CL | AASHTO classification for the material |
| APPROVAL | approved use of the material given by or for the chief material engineer |
| VAL_DATE | date the validation status was given |
| STATUS | validation status of the record |
| ACT_DATE | actual date of entry of the record |

## RDB85.DBF IN SITU REGISTER

This register contains information collected from in situ surveys carried out along the road alignment. The source of the data is the in situ materials survey field notebook.

| FIELD | DESCRIPTION |
|---|---|
| ROAD | road number |
| FROM | chainage where the data applies from |
| TO | chainage where the data applies to |
| LAY1_DEPTH | start depth of the first soil layer |
| LAY1_GEO | parent geology of the first soil layer |
| LAY1_IP | plasticity index of the first soil layer |
| LAY1_IF | fineness index of the first soil layer |
| LAY1_IC | coarseness index of the first soil layer |
| LAY2_DEPTH | start depth of the second soil layer |
| LAY2_GEO | parent geology of the second soil layer |
| LAY2_IP | plasticity index of the second soil layer |
| LAY2_IF | fineness index of the second soil layer |
| LAY2_IC | coarseness index of the second soil layer |
| LAY3_DEPTH | start depth of the third soil layer |
| LAY3_GEO | parent geology of the third soil layer |
| LAY3_IP | plasticity index of the third soil layer |
| LAY3_IF | fineness index of the third soil layer |
| LAY3_IC | coarseness index of the third soil layer |
| LAY4_DEPTH | start depth of the fourth soil layer |
| LAY4_GEO | parent geology of the fourth soil layer |
| LAY4_IP | plasticity index of the fourth soil layer |
| LAY4_IF | fineness index of the fourth soil layer |
| LAY4_IC | coarseness index of the fourth soil layer |
| FEATURE | details of any natural or man-made features within or adjacent to the road servitude |
| NAT_DRAIN | natural drainage adjacent to the road line |
| N_AREA | Weinert climatic area |
| VAL_DATE | date the validation status was given |
| STATUS | validation status of the record |
| ACT_DATE | actual date of entry of the record |

## RDB86.DBF DESIGN REGISTER

This register contains the design data for the road. The source of the data is either the CL 16 field check sheet or the completion drawing.

| FIELD | DESCRIPTION |
|---|---|
| ROAD | road number |
| FROM | chainage where the data applies from |
| TO | chainage where the data applies to |
| DESIGN_STD | design traffic standard for the road |
| BASE1_THICK | design thickness of base one |
| BAS1_CLASS | design Texas triaxial class of base one |
| BASE2_THICK | design thickness of base two |
| BAS2_CLASS | design Texas triaxial class of base two |
| BASE3_THICK | design thickness of base three |
| BAS3_CLASS | design Texas triaxial class of base three |
| BASE4_THICK | design thickness of base four |
| BAS4_CLASS | design Texas triaxial class of base four |
| SUB_GRADE | design subgrade CBR class |
| VAL_DATE | date the validation status was given |
| STATUS | validation status of the record |
| ACT_DATE | actual date of entry of the record |

## RDB87.DBF CONSTRUCTION REGISTER

This register contains as-constructed testing information and data for all layers placed on the road. The source of the data is the CL 16 field check sheet.

| FIELD | DESCRIPTION |
|---|---|
| ROAD | road number |
| FROM | chainage where the data applies from |
| TO | chainage where the data applies to |
| CONS_DATE | date of construction |
| LAYER | layer for which the data is applicable |
| THICKNESS | design thickness |
| MDD | Mod.AASHTO maximum dry density of the material |
| MFD | mean field density |
| OMC | optimum moisture content at the Mod.AASHTO maximum dry density |
| MCC | field moisture content at compaction |
| STABILISER | type of stabiliser used |
| PERC_SPEC | percent of stabiliser specified |
| PERC_ADDED | percent of stabiliser actually used |
| DEPTH | mean layer thickness (mm) |
| SUB_GRAD | design class of the subgrade |
| REMARK | comments and approval information of the RE |
| PIT_NO | pit number for the material |
| PIT_NO2 | pit number if a second pit has been used |
| PIT_GEOL | pit 1 parent geology |
| MINPIT_IP | minimum plasticity index |
| MAXPIT_IP | maximum plasticity index |
| MINPIT_IC | minimum coarseness index |
| MAXPIT_IC | maximum coarseness index |
| MINPIT_IF | minimum fineness index |
| MAXPIT_IF | maximum fineness index |
| SITE_GEOL | parent geology of the materials used on the road |
| SITE_IP | plasticity index of the material used on the road |
| SITE_IC | coarseness index of the material used on the road |
| SITE_IF | fineness index of the material used on the road |
| VAL_DATE | date the validation status was given |
| STATUS | validation status of the record |
| ACT_DATE | actual date of entry of the record |

## RDB88.DBF FILL/SUBGRADE REGISTER

This register contains testing information and data for subgrade and fill materials obtained from in situ or borrow investigations. The source of the data is the CL 2 summary sheet.

| **FIELD** | **DESCRIPTION** |
|---|---|
| ROAD | road number |
| PIT_NO | pit number |
| GRP_CLASS | group classification |
| IND_CLASS | individual classification |
| I_R | reject index |
| MICA_CONT | estimated mica content |
| DESCRIP | description of the material |
| GEO_ORIGIN | parent geology of the material |
| SURF_TEXT | surface texture of the aggregate |
| AGRE_HARD | hardness of the aggregate |
| AGRE_SHAPE | shape of the aggregate |
| TEST_TYPE | test type (group or individual) |
| TEST_STD | compactive effort used to obtain the optimum moisture content and maximum dry density of the material |
| STABILISER | type and percent of stabiliser used |
| MAX_DENSIT | maximum dry density of the material for the compactive effort (TEST_STD) used |
| OMC_CONT | optimum moisture content for the maximum dry density of the material at the compactive effort (TEST_STD) used |
| SCBR | design soaked CBR value |
| EXPANSION | percent expansion on testing |
| PLAST_PROD | plasticity product |
| REMARK | approval information and other relevant remarks |
| VAL_DATE | date the validation status was given |
| STATUS | validation status of the record |
| ACT_DATE | actual date of entry of the record |

## RDB89.DBF WEARING COURSE REGISTER

This register contains testing information and data for wearing course gravels obtained at the prospecting stage of the investigation. The source of the data is the corresponding CL19w.

| FIELD | DESCRIPTION |
|---|---|
| PIT_NO | pit number |
| PI_MAX | maximum plasticity index |
| PI_MIN | minimum plasticity index |
| PI_MEAN | mean plasticity index |
| IR_MAX | maximum reject index |
| IR_MIN | minimum reject index |
| IR_MEAN | mean reject index |
| IF_MAX | maximum fineness index |
| IF_MIN | minimum fineness index |
| IF_MEAN | mean fineness index |
| IC_MAX | maximum coarseness index |
| IC_MIN | minimum coarseness index |
| IC_MEAN | mean coarseness index |
| MAX_200 | maximum percent passing the 2.0mm sieve |
| MIN_200 | minimum percent passing the 2.0mm sieve |
| MEAN_200 | mean percent passing the 2.0mm sieve |
| MAX_425 | maximum percent passing the 0.425mm sieve |
| MIN_425 | minimum percent passing the 0.425mm sieve |
| MEAN_425 | mean percent passing the 0.425mm sieve |
| GRAD_MOD | grading modulus (mean) |
| MICA_CONT | estimated mica content |
| ORG_CONT | estimated organic content |
| GEO_ORIGIN | parent geology of the material |
| AGRE_SHAPE | estimated aggregate shape |
| AGRE_NAT | nature of the aggregate |
| REMARK | approval and remarks made by or for the chief material technician |
| VAL_DATE | date the validation status was given |
| STATUS | validation status of the record |
| ACT_DATE | actual date of entry of the record |

## A2 Malawi materials inventory

### MALPLAN: SOURCE OF DMRs

| FIELD | DESCRIPTION |
|---|---|
| REPORT_NO | relevant DMR report number |
| ROAD_NAME | name of the road (from-to) |
| ROAD_NO | route identification number |
| PRO_VINCE | province responsible for the road |
| MONTH | month of publication of the DMR |
| YEAR | year of publication of the DMR |

### MALSOILS: SOILS DESCRIPTION ALONG THE ROAD ALIGNMENT

| FIELD | DESCRIPTION |
|---|---|
| REPORT_NO | route identification number |
| ROAD_NAME | name of the road (from-to) |
| CHAIN_AGE | chainage of the test pit |
| SAMPLE_NO | sample number |
| DEPTH_M | depth of the layers in the soil profile in metres |
| DES_CRIPTION | engineering description of the soil |

## MALSOILT: ENGINEERING TEST DATA FROM SAMPLES

| FIELD | DESCRIPTION |
|---|---|
| REPORT_NO | route identification number |
| ROAD_NAME | name of the road (from-to) |
| ROAD_NO | route identification number |
| CHAIN_AGE | chainage of the test pit |
| SAMPLE_NO | sample number |
| DEPTH_M | depth of the layers in the soil profile in metres |
| P_375 | percent passing the 37.5mm sieve |
| P_265 | percent passing the 26.5mm sieve |
| P_19 | percent passing the 19.0mm sieve |
| P_132 | percent passing the 13.2mm sieve |
| P_95 | percent passing the 9.5mm sieve |
| P_475 | percent passing the 4.75mm sieve |
| P_236 | percent passing the 2.36mm sieve |
| P_600 | percent passing the 0.6mm sieve |
| P_425 | percent passing the 0.425mm sieve |
| P_300 | percent passing the 0.3mm sieve |
| P_150 | percent passing the 0.15mm sieve |
| P_075 | percent passing the 0.075mm sieve |
| W_L | liquid limit |
| W_P | plastic limit |
| CLASS | AASHTO classification |
| BSH_MDD | British Standard Heavy Maximum Dry Density |
| BSH_OMC | British Standard Optimum Moisture Content |
| CBR_93 | soaked CBR at 93% British Standard Heavy Maximum Dry Density |
| CBR_95 | soaked CBR at 95% British Standard Heavy Maximum Dry Density |
| CBR_98 | soaked CBR at 93% British Standard Heavy Maximum Dry Density |
| S_WELL | percent swell recorded in the CBR test |
| S_HRINKAGE | shrinkage |
| R_EMARKS | reserved for any special comments |

## MALPITS: PLANNING INFORMATION AND ENGINEERING TEST DATA FOR GRAVEL PITS AND QUARRIES

| FIELD | DESCRIPTION |
|---|---|
| REPORT_NO | route identification number |
| ROAD_NAME | name of the road (from-to) |
| ROAD_NO | route identification number |
| PIT_NO | number of the gravel pit |
| PIT_NAME | name of the gravel pit |
| PIT_GEOL1 | parent geology of the gravel |
| PIT_GEOL2 | additional parent geology if applicable |
| Q_UANTITY | estimated quantity of gravel/rock available |
| SAMPLE_NO | sample number |
| P_375 | percent passing the 37.5mm sieve |
| P_265 | percent passing the 26.5mm sieve |
| P_19 | percent passing the 19.0mm sieve |
| P_132 | percent passing the 13.2mm sieve |
| P_95 | percent passing the 9.5mm sieve |
| P_475 | percent passing the 4.75mm sieve |
| P_236 | percent passing the 2.36mm sieve |
| P_600 | percent passing the 0.6mm sieve |
| P_425 | percent passing the 0.425mm sieve |
| P_300 | percent passing the 0.3mm sieve |
| P_150 | percent passing the 0.15mm sieve |
| P_075 | percent passing the 0.075mm sieve |
| W_L | liquid limit |
| W_P | plastic limit |
| CLASS | AASHTO classification |
| BSH_MDD | British Standard Heavy Maximum Dry Density |
| BSH_OMC | British Standard Optimum Moisture Content |
| UCBR_95 | unsoaked CBR at 95% British Standard Heavy Maximum Dry Density |
| UCBR_98 | unsoaked CBR at 98% British Standard Heavy Maximum Dry Density |
| SCBR_95 | soaked CBR at 95% British Standard Heavy Maximum Dry Density |
| SCBR_98 | soaked CBR at 98% British Standard Heavy Maximum Dry Density |
| S_WELL | percent swell recorded in the CBR test |
| S_HRINKAGE | shrinkage |
| R_EMARKS | reserved for any special comments |
| DEPTH_OB | depth of overburden in metres |
| DEPTH_GRAV | depth of gravel in metres |
| GRID_ZONE | map reference sector |
| EAST_ING | easting reference |
| NORTH_ING | northing reference |
| A_CV | Aggregate Crushing Value |
| E_I | Elongation Index |
| F_I | Flakiness Index |

# Appendix B: Examples of records in registers

## B1 Zimbabwe materials inventory

**RDB82.DBF PIT PLAN REGISTER**

| **FIELD** | **DESCRIPTION** |
|---|---|
| PIT_NO | LNGU-022 |
| ROAD | 470 |
| PEG_H | 38.0 |
| CONDITION | LB |
| RES_AREA | 3.38 |
| CAIRN_AREA | 1.63 |
| OWNER | Mr Chimwande |
| NOTIF_DATE | 13/11/87 |
| HAUL_DIST | 0.8 |
| GRID_REF | 119850 |
| MAP_NO | 2031A1 |
| OVB_TYPE | GRS |
| SEAM_TYPE | L-Q |
| SUB_SOIL | FI-Q |
| OVER_BURD | 466 |
| SEAM | 437 |
| STD_DEV | 166 |
| GR_QUANT | 4700 |
| BASIC_USE | B1 |
| TREATMENT | NIL |
| NEW_STATE | B1 |
| ACCESS_INF | BT |
| REMARK | Approved as use for Base 1 (0.1M) Nat |
| VAL_DATE | 15/12/95 |
| STATUS | 0 |
| ACT_DATE | 15/12/95 |

## RB83.DBF PIT TRIAXIAL REGISTER

| FIELD | DESCRIPTION |
|---|---|
| PIT_NO | LNGU-022 |
| SAMP_CLASS | NP-E-14 |
| STOCK_QTY | 470 |
| GEO_ORIGIN | L-Q |
| TREATMENT | NAT |
| LIQ_LIMIT | NP |
| PLAST_LIMIT | NP |
| PLAST_INDEX | NP |
| COURS_INDE | 50 |
| FINENESS | 30 |
| FINE_INDEX | 14 |
| PLAST_PROD | |
| REJECT_IND | 0 |
| MAX_DENSIT | 2090 |
| OMC_CONT | 8.0 |
| MC_TEST | 9.0 |
| MASS_CAPIL | 6 |
| DAYS_CAPIL | 10 |
| COMP_EFFORT | TEXAS |
| COHESION | 20 |
| TRIA_CLASS | 3.0 |
| UCS_STRESS | 153 |
| SURF_TEXT | GRA-ROU-HC |
| PART_SHAPE | IRR |
| ORGAN_CONT | LOW |
| MICA_CONT | NIL |
| BASIC_USE | B1 |
| NEW_STATE | |
| G_M | 2.20 |
| IP_RANGE | NP-SP |
| AASHTO_CL | |
| APPROVAL | B1 (0.1M) NAT |
| VAL_DATE | 01/12/96 |
| STATUS | 0 |
| ACT_DATE | 01/12/96 |

## RDB84.DBF STOCKPILE TRIAXIAL REGISTER

| FIELD | DESCRIPTION | |
|---|---|---|
| PIT_NO | LNGU-022 | LNGU-022 |
| SAMP_CLASS | 6-E-16 | 6-E-16 |
| STOCK_QTY | 1700 | 1700 |
| GEO_ORIGIN | L-Q | L-Q |
| TREATMENT | NAT | 1%CMT |
| LIQ_LIMIT | 18 | 14 |
| PLAST_LIMIT | 12 | 5 |
| PLAST_INDEX | 6 | NP |
| COURS_INDE | 49 | 49 |
| FINENESS | 30 | 30 |
| FINE_INDEX | 16 | 16 |
| PLAST_PROD | 96 | |
| REJECT_IND | | |
| MAX DENSIT | 2090 | |
| OMC_CONT | 7 | |
| MC_TEST | 6 | 9 |
| MASS_CAPIL | 6 | 2 |
| DAYS_CAPIL | 10 | 7 |
| COMP_EFFORT | TEXAS | TEXAS |
| COHESION | 12 | 30 |
| TRIA_CLASS | 3.0 | 1.2 |
| UCS_STRESS | 121 | 512 |
| SURF_TEXT | GRA-ROU-HC | GRA-ROU-HC |
| PART_SHAPE | IRR | IRR |
| ORGAN_CONT | LOW | LOW |
| MICA_CONT | NIL | NIL |
| BASIC_USE | B1 | B1 |
| NEW_STATE | | |
| G_M | 2.20 | 2.20 |
| IP_RANGE | NP-SP | NP |
| AASHTO_CL | | |
| APPROVAL | B1 (0.1M) NATB1 | (0.1M) NAT |
| VAL_DATE | 02/06/96 | 02/06/96 |
| STATUS | 0 | 0 |
| ACT_DATE | 02/06/96 | 02/06/96 |

## RDB85.DBF IN SITU REGISTER

| FIELD | DESCRIPTION |
|---|---|
| ROAD | 940 |
| FROM | 12.28 |
| TO | 12.36 |
| LAY1_DEPTH | 10 |
| LAY1_GEO | Q |
| LAY1_IP | 8 |
| LAY1_IF | 25 |
| LAY1_IC | C |
| LAY2_DEPTH | 20 |
| LAY2_GEO | GR |
| LAY2_IP | 8 |
| LAY2_IF | 25 |
| LAY2_IC | A |
| LAY3_DEPTH | 60 |
| LAY3_GEO | GR |
| LAY3_IP | 8 |
| LAY3_IF | 15 |
| LAY3_IC | F |
| LAY4_DEPTH | 20 |
| LAY4_GEO | GR |
| LAY4_IP | 8 |
| LAY4_IF | 25 |
| LAY4_IC | A |
| FEATURE | AH |
| NAT_DRAIN | G |
| N_AREA | 2-3.9 |
| VAL_DATE | 08/09/96 |
| STATUS | 0 |
| ACT_DATE | 08/09/96 |

## RDB86.DBF DESIGN REGISTER

| FIELD | DESCRIPTION |
|---|---|
| ROAD | 940 |
| FROM | 12.38 |
| TO | 13.16 |
| DESIGN_STD | 0.3 |
| BASE1_THICK | 120 |
| BAS1_CLASS | 2.8 |
| BASE2_THICK | 120 |
| BAS2_CLASS | 3.6 |
| BASE3_THICK | 150 |
| BAS3_CLASS | 3.9 |
| BASE4_THICK | |
| BAS4_CLASS | |
| SUB_GRADE | SG9 |
| VAL_DATE | 13/03/97 |
| STATUS | 0 |
| ACT_DATE | 13/03/97 |

## RDB87.DBF CONSTRUCTION REGISTER

| FIELD | DESCRIPTION | | |
|---|---|---|---|
| ROAD | 410 | 410 | 410 |
| FROM | 49.82 | 49.84 | 49.80 |
| TO | 50.08 | 50.12 | 51.14 |
| CONS_DATE | 25/10/86 | 30/11/86 | 14/03/87 |
| LAYER | SG | B2 | B1 |
| THICKNESS | 150 | 133 | 133 |
| MDD | 2080 | 2098 | 2044 |
| MFD | 2024 | 2037 | 2070 |
| OMC | 9.5 | 8.5 | 9.5 |
| MCC | 93.3 | 61.7 | 75.1 |
| STABILISER | NIL | NIL | CMT PC15 |
| PERC_SPEC | | | 2.0 |
| PERC_ADDED | | | 2.0 |
| DEPTH | | | 133 |
| SUB_GRAD | SG9 | SG9 | SG9 |
| REMARK | | | |
| PIT_NO | IN SITU | CISR/31 | CISR/23 |
| PIT_NO2 | | | |
| PIT_GEOL | GN | GN | GN |
| MINPIT_IP | 11 | NP | NP |
| MAXPIT_IP | 15 | 10 | NP |
| MINPIT_IC | 11 | 34 | 43 |
| MAXPIT_IC | 20 | 62 | 65 |
| MINPIT_IF | 21 | 9 | 11 |
| MAXPIT_IF | 30 | 22 | 15 |
| SITE_GEOL | GN | GN | GN |
| SITE_IP | 6 | 4 | NP |
| SITE_IC | 26 | 44 | 48 |
| SITE_IF | 24 | 15 | 16 |
| VAL_DATE | 16/08/97 | 15/08/97 | 14/08/97 |
| STATUS | 0 | 0 | 0 |
| ACT_DATE | 16/08/97 | 16/08/97 | 16/08/97 |

## RDB89.DBF WEARING COURSE REGISTER

| FIELD | DESCRIPTION |
|---|---|
| PIT_NO | HEMA-705 |
| PI_MAX | 16 |
| PI_MIN | 13 |
| PI_MEAN | 15 |
| IR_MAX | 0 |
| IR_MIN | 0 |
| IR_MEAN | 0 |
| IF_MAX | 22 |
| IF_MIN | 16 |
| IF_MEAN | 19 |
| IC_MAX | 80 |
| IC_MIN | 22 |
| IC_MEAN | 34 |
| MAX_200 | 74 |
| MIN_200 | 67 |
| MEAN_200 | 71 |
| MAX_425 | 34 |
| MIN_425 | 28 |
| MEAN_425 | 31 |
| GRAD_MOD | 18 |
| MICA_CONT | NIL |
| ORG_CONT | LOW |
| GEO_ORIGIN | DGR |
| AGRE_SHAPE | GRA |
| AGRE_NAT | SOFT |
| REMARK | |
| VAL_DATE | 10/12/96 |
| STATUS | 0 |
| ACT_DATE | 10/12/96 |

## B2 Malawi materials inventory

### MALPLAN.DBF.

| FIELD | DESCRIPTION |
|---|---|
| REPORT_NO | DMR139 |
| ROAD_NAME | LIMBE-THYOLO-MULOZA |
| ROAD_NO | M2 |
| PRO_VINCE | SOUTHERN |
| MONTH | FEBRUARY |
| YEAR | 1990 |

### MALSOILS.DBF

| FIELD | DESCRIPTION |
|---|---|
| REPORT_NO | DMR139 |
| ROAD_NAME | LIMBE-THYOLO-MULOZA |
| CHAIN_AGE | 10.0 |
| SAMPLE_NO | 11 |
| DEPTH_M | 2.0 |
| DES_CRIPTION | BROWN SANDY-SILT |

## MALSOILT.DBF

| FIELD | DESCRIPTION |
|---|---|
| REPORT_NO | DMR139 |
| ROAD_NAME | LIMBE-THYOLO-MULOZA |
| ROAD_NO | M2 |
| CHAIN_AGE | 10.0 |
| SAMPLE_NO | 11 |
| DEPTH_M | 2.0 |
| P_375 | |
| P_265 | |
| P_19 | |
| P_132 | |
| P_95 | 100 |
| P_475 | 99 |
| P_236 | 98 |
| P_600 | 75 |
| P_425 | 65 |
| P_300 | 55 |
| P_150 | 43 |
| P_075 | 37 |
| W_L | NP |
| W_P | NP |
| CLASS | A4(0) |
| BSH_MDD | 1820 |
| BSH_OMC | 15.2 |
| CBR_93 | 15 |
| CBR_95 | 17 |
| CBR_98 | 19 |
| S_WELL | 0.1 |
| S_HRINKAGE | |
| R_EMARKS | |

## MALPITS.DBF

| FIELD | DESCRIPTION |
|---|---|
| REPORT_NO | DMR139 |
| ROAD_NAME | LIMBE-THYOLO-MULOZA |
| ROAD_NO | M2 |
| PIT_NO | 9 |
| PIT_NAME | MUHURA |
| PIT_GEOL1 | LATERITE |
| PIT_GEOL2 | |
| Q_UANTITY | 9000 |
| SAMPLE_NO | MIXED |
| P_375 | |
| P_265 | 100 |
| P_19 | 95 |
| P_132 | 88 |
| P_95 | 77 |
| P_475 | 55 |
| P_236 | 40 |
| P_600 | 30 |
| P_425 | 28 |
| P_300 | 26 |
| P_150 | 22 |
| P_075 | 20 |
| W_L | 32 |
| W_P | 17 |
| CLASS | A2-6(1) |
| BSH_MDD | 2026 |
| BSH_OMC | 9.2 |
| UCBR_95 | |
| UCBR_98 | |
| SCBR_95 | 36 |
| SCBR_98 | 42 |
| S_WELL | |
| S_HRINKAGE | |
| R_EMARKS | |
| DEPTH_OB | 0.1 |
| DEPTH_GRAV | 0.6 |
| GRID_ZONE | 36LYT |
| EAST_ING | 432 |
| NORTH_ING | 272 |
| A_CV | |
| E_I | |
| F_I | |

# Appendix C: Database queries

## C1 Selecting the materials inventory database

In the FoxPro command window, or by running a FoxPro command .PRG program, set the default directory to where the database tables are stored. For example:

```
SET DEFAULT TO C:\EARTH\AFRICA\ZIMBABWE
```

## C2 Example 1

*Finding the geographical location, engineering properties, or land owner information relating to a particular pit or group of pits on a particular road , group of roads or province.*
Queries are set up in a format such as the following:

```
SELECT road, pit_no, map_no, grid_ref, owner FROM rdb82.DBF WHERE road = "843"
```

By default, the query outputs to a temporary read-only table named ‘query.dbf’, which becomes the active work area. Because it is an active work area, if the user requires a printout of the results, or wants to save a file for word processing, then the following should be typed:

```
LIST ALL TO PRINT
or
LIST ALL TO road843.TXT
```

or, to save the query results for further processing:

```
SELECT road, pit_no, map_no, grid_ref, owner FROM RDB82.DBF WHERE road = "843"
INTO TABLE road843
```

which will create a table named road843.DBF

Note that sorting on a key field may not sort the output into an order which is immediately obvious. For example:

```
SELECT road, pit_no, map_no, grid_ref, owner FROM rdbB82.DBF WHERE road = "843"
ORDER BY pit_no
```

| ROAD | PIT_NO | MAP_NO | GRID_REF | OWNER |
|---|---|---|---|---|
| 843 | KENI-700 | 1829C4 | 567023 | ARDA SESOMBI RANCHES BOX 718 KWEKWE |
| 843 | KENI-701 | 1829C4 | 494023 | SESOMBI(NYONI)RESETTLEMENT SCHEME.RESETTLEMENT OFF |
| 843 | KENI-702 | 1829C4 | 484024 | SESOMBI RESETTLEMENT SCHEME,RESETTLEMENT OFFICER.B |
| 843 | KENI-703 | 1829C4 | 461031 | SESOMBI RESETTLEMENT SCHEME,RESETTLEMENT OFFICER,B |
| 843 | KENI-704 | 1929A2 | 373978 | MR J MUNJANJA Z.R.P SILOBELA,BOX 8010 KWEKWE |
| 843 | KENI-705 | 1829C3 | 345003 | MR M MALALISA,HLANGANISA WARD.FATIMA SCHOOL P BAG |
| 843 | KENI-706 | 1829C3 | 175003 | MR K SAYI.KANDA SCHOOL,P BAG 291 KWEKWE |
| 843 | KENI-708 | 1929A1 | 149945 | M.M MALALISA HLANGANISA WARD,FATIMA SCHOOL,P BAG 8 |
| 843 | KENI-709 | 1929A1 | 139953 | M.M MALALISA HLANGANISA WARD,FATIMA SCHOOL P BAG 8 |
| 843 | KENI-710 | 1928B2 | 083941 | M.M MALALISA HLANGANISA WARD.FATIMA SCHOOL P BAG 8 |
| 843 | KENI-711 | 1829C3 | 342002 | MR J MUNJANJA.SILOBELA Z.R.P P.O BOX 8010 KWEKWE |
| 843 | KENI-712 | 1829C4 | 558984 | MR JA BRONKHOST SOUTHCUM FARM P.O BOX 1281 GWERU |
| 843 | KENI700A | 1829C4 | 555993 | MR JA BRONICHOST. P.O BOX 1281 GWERU |
| 843 | KENI701A | 1829C4 | 559988 | MR JA BRONKHOST,SOUTHCUM FARM,P.O BOX 1281 GWERU |
| 843 | KENI707A | 1921A1 | 156947 | M.M MALALISA HLANGANISA WARD.FATIMA SCHOOL P BAG 8 |
| 843 | KENI707B | 1929A1 | 163939 | M.M MALALISA,HLANGANISA WARD,FATIMA SCHOOL P BAG 8 |

This example shows that care should be taken when constructing key fields.

The GROUP BY clause can be used to summarise information. For example, to derive a summary list of roads featured in the PIT PLAN register, and a count of the number of pit records for each:

```
SELECT road, COUNT(road) FROM RDB82.DBF GROUP BY road
```

| ROAD | CNT |
|---|---|
| 112 | 1 |
| 113 | 5 |
| 131 | 75 |
| 134 | 1 |
| 137 | 26 |
| 138 | 170 |
| 142 | 4 |
| 144 | 6 |
| 157 | 19 |
| 167 | 32 |
| 169 | 118 |
| 183 | 11 |
| 191 | 5 |
| 196 | 35 |
| 202 | 5 |
| 214 | 47 |
| 230 | 15 |
| 234 | 6 |
| 239 | 8 |
| 247 | 3 |
| 249 | 12 |
| 259 | 1 |
| 261 | 3 |
| 264 | 41 |
| 268 | 9 |
| 269 | 1 |
| 277 | 16 |
| 278 | 7 |

*etc*

## C3 Example 2

*Finding gravels or soils with certain classification properties and predicting the range of triaxial strengths for similar materials where the triaxial strength is unknown, perhaps when considering extending a borrow pit.*

```
SELECT pit_no, stock_qty, ip_range, MIN(ic), MAX(ic), MIN(if), MAX(if), MIN(ttc), MAX(ttc)
FROM rdb83 WHERE "LNGU" $ pit_no AND "NAT" $ treatment
```

The operator '$' is used to find occurrences of a text string contained within a longer text string, and is useful for finding approximate matches.

| PIT_NO | SAMP_CLASS | STOCK_QTY | GEO_ORIGIN | TREATMENT | LIQ_LIMIT | PLAST_LIM | PLAST_INDE | COURS_INDE | FINENESS | FINE_INDEX | PLAST_PROD | REJECT_IND | OMC_CONT | MC_TEST | MASS_CAPIL | DAYS_CAPIL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LNGU-014 | 5-E-11 | 1200 | L-Q | NAT | 21 | 16 | 5 | 50 | 25 | 11 | 55 | 2130 | 7 | 7 | 6 | 10 |
| LNGU-018 | NP-F-11 | 1700 | L | NAT | 0 | 0 | 0 | 52 | 29 | 11 | 11 | 2060 | 7 | 7 | 6 | 10 |
| LNGU-019 | 6-E-12 | 1800 | L-Q | NAT | 20 | 14 | 6 | 47 | 25 | 12 | 72 | 2090 | 6 | 7 | 6 | 10 |
| LNGU-017 | NP-E-12 | 2100 | L | NAT | 0 | 0 | 0 | 42 | 32 | 12 | 12 | 1980 | 10 | 10 | 6 | 10 |
| LNGU-020 | NP-F-9 | 2200 | L-Q | NAT | 0 | 0 | 0 | 58 | 25 | 9 | 9 | 2140 | 6 | 7 | 6 | 10 |
| LNGU-024 | NP-E-16 | 2300 | L-Q | NAT | 22 | 16 | 6 | 49 | 31 | 16 | 96 | 2050 | 8 | 7 | 6 | 10 |
| LNGU-020 | 4-F-15 | 2300 | L-Q | NAT | 21 | 18 | 4 | 56 | 30 | 15 | 60 | 2140 | 7 | 6 | 6 | 10 |
| LNGU-013 | 4-E-13 | 2700 | Q-L | NAT | 18 | 14 | 4 | 45 | 28 | 13 | 52 | 2090 | 7 | 7 | 6 | 10 |
| LNGU-011 | NP-F-14 | 2900 | L-Q | NAT | 0 | 0 | 0 | 56 | 30 | 14 | 14 | 2090 | 8 | 8 | 6 | 10 |
| LNGU-025 | 4-F-10 | 3000 | L-Q | NAT | 19 | 15 | 4 | 56 | 25 | 10 | 40 | 2060 | 7 | 8 | 6 | 10 |
| LNGU-008 | 5-C-17 | 3000 | L | NAT | 16 | 11 | 5 | 29 | 34 | 17 | 85 | 2200 | 7 | 6 | 6 | 10 |
| LNGU-010 | NP-E-10 | 3000 | L | NAT | 0 | 0 | 0 | 48 | 27 | 10 | 10 | 2130 | 7 | 9 | 6 | 10 |
| LNGU-016 | NP-E-10 | 3200 | L | NAT | 0 | 0 | 0 | 43 | 30 | 10 | 10 | 2050 | 9 | 9 | 6 | 10 |
| LNGU-005 | 8-E-15 | 3800 | L | NAT | 19 | 11 | 8 | 48 | 28 | 15 | 120 | 2230 | 6 | 6 | 6 | 10 |
| LNGU-023 | NP-E-14 | 4000 | L-DGR-Q | NAT | 0 | 0 | 0 | 45 | 31 | 14 | 14 | 2060 | 7 | 6 | 6 | 10 |
| LNGU-002 | SP-F-8 | 4100 | L-Q | NAT | 0 | 0 | 0 | 60 | 24 | 8 | 9 | 2100 | 7 | 8 | 6 | 10 |
| LNGU-022 | NP-E-14 | 4700 | L-Q | NAT | 0 | 0 | 0 | 50 | 30 | 14 | 14 | 2090 | 8 | 9 | 6 | 10 |
| LNGU-001 | 5-F-9 | 5800 | L | NAT | 17 | 12 | 5 | 53 | 25 | 9 | 45 | 2060 | 8 | 9 | 6 | 10 |
| LNGU-007 | NP-F-10 | 6200 | L-Q | NAT | 0 | 0 | 0 | 51 | 22 | 10 | 10 | 2220 | 5 | 6 | 6 | 10 |
| LNGU-009 | 7-E-16 | 7400 | L-Q-DGR | NAT | 22 | 15 | 7 | 44 | 33 | 16 | 112 | 2260 | 7 | 7 | 6 | 10 |
| LNGU-004 | 5-E-19 | 13000 | Q | NAT | 18 | 13 | 5 | 44 | 31 | 19 | 95 | 2120 | 7 | 7 | 6 | 10 |
| LNGU-003 | 8-E-25 | 19200 | Q | NAT | 22 | 14 | 8 | 46 | 37 | 25 | 200 | 2230 | 7 | 6 | 6 | 10 |

## C4 Example 3

*Finding the road design for a particular road between a certain chainage.*
Using the Materials Design Register, compare:

```
SELECT * FROM rdb86 WHERE "169" $ rdb86.road AND ( rdb86.from >= 35.00
AND rdb86.to <= 38.00  ) ORDER BY rdb86.chfrom
with
SELECT * FROM rdb86 WHERE "169" $ rdb86.road AND
( rdb86.from <= 38.00 AND rdb86.to >= 35.00  ) ORDER BY rdb86.chfrom
```

The latter will select road sections which pass through chainage points 35 and 38 as well as those in between them. Note : when recording data on return carriageways, it is sometimes the practice for the ‘from’ chainage to be greater than the ‘to’ chainage.

| ROAD | CHFROM | CHTO | DESIGN_STI | BASE1_THIC | BAS1_CLASS | BASE2_THIC | BAS2_CLASS | BASE3_THIC | BAS3_CLASS | BASE4_THIC | BAS4_CLASS | SUB_GRADE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 169 | 35.40 | 35.92 | 0.1 | 150 | 3.0 | 0 | | 0 | | 0 | | SG9 |
| 169 | 35.48 | 36.24 | 0.1 | 150 | 3.0 | 0 | | 0 | | 0 | | SG9 |
| 169 | 36.14 | 36.30 | 0.1 | 150 | 3.0 | 0 | | 0 | | 0 | | SG9 |
| 169 | 36.28 | 36.92 | 0.1 | 150 | 3.0 | 0 | | 0 | | 0 | | SG9 |
| 169 | 36.40 | 36.56 | 0.1 | 150 | 3.0 | 0 | | 0 | | 0 | | SG9 |
| 169 | 36.60 | 37.02 | 0.1 | 150 | 3.0 | 0 | | 0 | | 0 | | SG9 |
| 169 | 36.92 | 37.12 | 0.1 | 150 | 3.0 | 0 | | 0 | | 0 | | SG9 |
| 169 | 37.12 | 37.48 | 0.1 | 150 | 3.0 | 0 | | 0 | | 0 | | SG9 |
| 169 | 37.48 | 38.00 | 0.1 | 150 | 3.0 | 0 | | 0 | | 0 | | SG9 |

| ROAD | CHFROM | CHTO | DESIGN_STI | BASE1_THIC | BAS1_CLASS | BASE2_THIC | BAS2_CLASS | BASE3_THIC | BAS3_CLASS | BASE4_THIC | BAS4_CLASS | SUB_GRADE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 169 | 34.6 | 35.4 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |
| 169 | 34.64 | 35.08 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |
| 169 | 35.4 | 35.92 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |
| 169 | 35.48 | 36.24 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |
| 169 | 36.14 | 36.3 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |
| 169 | 36.28 | 36.92 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |
| 169 | 36.4 | 36.56 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |
| 169 | 36.6 | 37.02 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |
| 169 | 36.92 | 37.12 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |
| 169 | 37.12 | 37.48 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |
| 169 | 37.48 | 38 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |
| 169 | 37.96 | 38.92 | 0.1 | 150 | 3 | 0 | | 0 | | 0 | | SG9 |

## C5 Example 4

*Determining the as built structure or age of a particular section of road, for example if a pavement evaluation is being carried out.*
As above but using the Construction register:

```
SELECT * FROM rdb86 WHERE "169" $ rdb86.road AND ( rdb86.from <= 38.00
AND rdb86.to >= 35.00  ) ORDER BY rdb86.chfrom
```

| ROAD | CHFROM | CHTO | CONSTRUCT | LAYER | THICK | MDD | MFD | OMC | MCC | STABILISER |
|---|---|---|---|---|---|---|---|---|---|---|
| 169 | 34.86 | 35.08 | 9/2/1989 | BASE 1 | 169 | 2100 | 2098 | 7 | 91 | PBFC |
| 169 | 37.12 | 37.28 | 11/26/89 | BASE 1 | 143 | 2140 | 2140 | 7 | 94.3 | RSC |
| 169 | 37.28 | 37.48 | 11/26/89 | BASE 1 | 160 | 2120 | 2090 | 8 | 76.9 | RSC |
| 169 | 37.48 | 37.75 | 12/28/89 | BASE 1 | 158 | 2140 | 2091 | 7 | 86.2 | RSC |
| 169 | 37.75 | 38 | 12/28/89 | BASE 1 | 172 | 2090 | 2120 | 8 | 85.6 | RSC |
| 169 | 38 | 38.19 | 3/18/90 | BASE 1 | 151 | 2130 | 2066 | 9 | 74.2 | RSC |

## C6 Example 5

*Finding the design CBR for a new or old construction.*
For road 457, given a soil with class Gn0315c N2-3.9, what are the design median CBR, lower quartile CBR and lowest decile CBR and how many tests  were they based on:

```
SELECT med_cbr, lrqle_cbr, lrdec_cbr, no_tests FROM rdb81 WHERE ( "2-3.9" $ n_area )
AND  ( "GN" $ geol_orig ) ;
                AND   ( i_p     = 3     ) AND  ( i_f  = 15 )   ;
                AND   ( "C" $ i_c )
```

| MED_CBR | LRQLE_CBR | LRDEC_CBR | NO_TESTS |
|---|---|---|---|
| 45 | 30 | 20 | 8 |

## C7 Example 6

*Evaluating quantities of resources still available from new or partially utilized pits for maintenance operations.*
Conceptually, Road 169 is not yet built, but borrow pit planning is completed; what is availability of material of Base 1 quality, Base 2 quality, Wearing Course:

```
SELECT seam_type, basic_use, SUM(gr_quant) FROM RDB82
        WHERE road = “169”
        AND (SUBSTR(seam_type,1,1)=“Q” OR SUBSTR(seam_type,1,1)=“L”
        OR SUBSTR(seam_type,1,2)=“GR”
        AND (basic_use=“B1” OR basic_use=“B2” OR basic_use=“WC”
        GROUP BY basic_use, seam_type ;
        ORDER BY basic_use, seam_type
```

| SEAM_TYPE | BASIC_USE | SUM_GR_QUA |
|---|---|---|
| Q | B1 | 3600 |
| Q-DGR | B1 | 7700 |
| Q-L | B1 | 9000 |
| GRS | B2 | 4300 |
| L | B2 | 17900 |
| L-Q | B2 | 3400 |
| Q | B2 | 97700 |
| Q-DGR | B2 | 31600 |
| Q-L | B2 | 63151 |
| Q-L-DGR | B2 | 1000 |
| Q | WC | 10900 |
| Q-DGR | WC | 1900 |

## C8 Example 7

*Determining the properties of in situ soils along a stretch of road.*

Information is required for all borrow pits on Road 952 to determine the sum of gravel quantities for seam types Q_3600, L_15000 and Gr_12000. Queries of the following form are used:

```
SELECT * FROM rdb85 WHERE
```

When setting up queries as outlined above, simple queries such as the following can be used to help guide the user ascertain the range of values that will be found for a given data item:

```
SELECT no_tests, count(no_tests) FROM rdb81 GROUP BY no_tests ORDER BY no_tests
```

| NO_TESTS | CNT |
|---|---|
| 0 | 1 |
| 1 | 2165 |
| 2 | 370 |
| 3 | 168 |
| 4 | 101 |
| 5 | 78 |
| 6 | 51 |
| 7 | 50 |
| 8 | 29 |
| 9 | 16 |
| 10 | 12 |
| 11 | 13 |
| 12 | 7 |
| 13 | 9 |
| 14 | 8 |
| 15 | 4 |
| 16 | 6 |
| 17 | 3 |
| 18 | 3 |
| 19 | 7 |
| 20 | 3 |
| 21 | 2 |
| 22 | 4 |
| 23 | 1 |
| 24 | 3 |
| 25 | 2 |
| 26 | 1 |
| 27 | 3 |
| 28 | 1 |
| 30 | 3 |
| 31 | 1 |
| 32 | 1 |
| 35 | 4 |
| 37 | 1 |
| 40 | 2 |
| 42 | 1 |
| 43 | 4 |
| 46 | 2 |
| 50 | 1 |
| 52 | 1 |
| 53 | 1 |
| 54 | 1 |
| 63 | 1 |
| 65 | 1 |
| 84 | 1 |
| 99 | 1 |
| 107 | 1 |
| 227 | 1 |
| 303 | 1 |

SELECT i_p FROM rdb81 GROUP BY i_p

| GR | I_P |
|---|---|
| GT | 3 |
| IS | 8 |
| KS | 12 |
| L | 13 |
| LS | 16 |
| M | 18 |
| MS | 23 |
| MT | 25 |
| MU | 28 |
| MW | 33 |
| NO | 38 |
| PI | 43 |
| PL | 45 |
| PO | 48 |
| PY | |
| Q | |
| RS | |
| SA | |
| SC | |
| SE | |
| SH | |
| SI | |
| TO | |
| TS | |

SELECT i_f FROM rdb81 GROUP BY i_f

| I_F |
| --- |
| 5 |
| 15 |
| 18 |
| 25 |
| 35 |
| 40 |
| 45 |
| 60 |
| 70 |
| 75 |
| 80 |

SELECT i_c FROM rdb81 GROUP BY i_c

| I_C |
| --- |
| A |
| B |
| C |
| D |
| E |
| F |

SELECT geol_orig FROM rdb81 GROUP BY geol_orig

GEOL_OR
- AL
- AN
- AP
- AR
- AS
- BCS
- BI
- BK
- BS
- CT
- DG
- DM
- DO
- FC
- FL
- GN
- GR
- GT
- IS
- KS
- L
- LS
- M
- MS
- MT
- MU
- MW
- NO
- PI
- PL
- PO
- PY
- Q
- RS
- SA
- SC
- SE
- SH
- SI
- TO
- TS

SELECT n_area FROM rdb81 GROUP BY n_area

| N_AREA |
|---|
| 2-3.9 |
| 4-5 |
| 5+ |
| <2 |