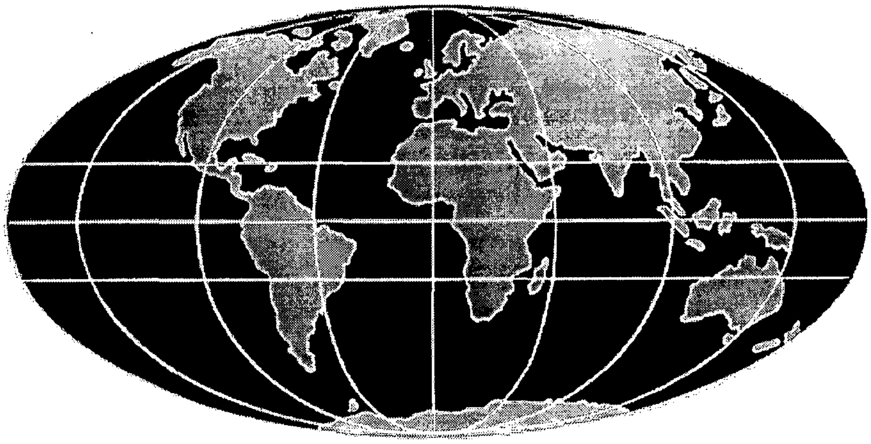
TRANSPORT RESEARCH LABORATORY

DFID Department For International Development

# TITLE: Development and Implementation of a Construction Material Information System

by: M E Woodbridge, J R Cook and B Moestofa



Transport Research Laboratory
Crowthorne
Berkshire RG45 6AU
United Kingdom

PA3449/99

PA3449/99 WOODBRIDGE, M E, J R COOK and B MOESTOFA (1999). **Development and implementation of a construction material information system.** *Seventh International Conference on Low-Volume Roads, Baton Rouge, Louisiana, USA. 23 - 26 May 1999*

# Development and Implementation of a Construction Material Information System

M. E. WOODBRIDGE, J. R. COOK, AND B. MOESTOFA

The exploitation of aggregates and soils for highway construction has a considerable impact on the economy and the environment and it is important that utilization of these materials is cost-effective. Obtaining and maintaining good records is costly and requires professional expertise. With modern computer technology it is possible to store information systematically and compactly. If quarry information is available in one central locality, better planning of road construction and maintenance and better management of materials resources can be realized. The research undertaken to create a materials information system in Indonesia is described. A pilot system was designed and tested in the province of West Java and comprehensive data collected from about 800 quarry sites. The Indonesian Directorate General of Highways, encouraged by the results of the pilot study, decided to introduce the system to all 27 provinces of Indonesia. Training courses were held to teach good practice and were successful because of improvements in the quality and quantity of data provided, but there is still scope to improve the utilization of the system by potential users. With accurate data the system is an improvement on the status quo. The system is simple to use, can be updated when necessary, and provides the basic information required by highway engineers. It is transferable to other countries in transition with minimal alteration. The data can be used in conjunction with terrain classification and Geographic Information Systems packages (such as MapInfo) to indicate potential new material sources.

In the West, aggregate consumption currently averages about 5 tonnes per person per year. In developing countries the figure is less, possibly between 1 and 2 tonnes per person. For Indonesia, with an estimated population of 200 million, an annual aggregate consumption thus is substantial. The location, exploitation, and movement of large tonnages of stone has a considerable impact on the economy and environment.

Construction aggregates are of low value and most of their cost to the consumer is for transport from the source to the point of use. Aggregate prices in the United Kingdom average around £6 per tonne, and haulage is of the order of £0.1 per tonne per km. It thus is advisable to locate quarries as close as possible to the construction site, but this is not always feasible and depends on geological conditions. Before commencing any construction project, surveys are carried out to locate raw materials. A review of the records generally is undertaken before embarking on field surveys but such records often are dispersed, out of date, or of uncertain reliability. Records kept by quarrying companies often are commercial secrets. Obtaining good records is costly because it requires professional expertise.

It is possible to store such information systematically and compactly in desktop PCs. The information can be analyzed according to specific needs and the results can be produced and distributed effectively. Spreadsheet or database software systems can be used but databases are more efficient at storing and manipulating large amounts of data. Centralization of these data facilitates cost-effective planning of road construction and maintenance and enables better management of existing natural resources.

This paper describes the research undertaken to create a materials information system in Indonesia. The research was funded by the International Bank for Reconstruction and Development (IBRD) and the Department for International Development (DFID). After the success of the development work the Indonesian Department of Public Works supported countrywide surveys carried out by the provincial engineering offices. The development work was carried out by the Transport Research Laboratory (TRL) of the United Kingdom, which collaborated with a sister organization in Indonesia, the Institute of Road Engineering (IRE). They subsequently supervised the provincial data collection.

M. E. Woodbridge, Transport Research Laboratory, Old Wokingham Road, Crowthorne, United Kingdom. J. R. Cook, Consulting Geologist, 14 River View Gardens, Strawberry Hill, Middlesex, United Kingdom TW1 4RT. B. Moestofa, Institute of Road Engineering, Jalan Raya Timur, Ujungberung, Bandung, Indonesia.

## BACKGROUND

Indonesia is divided into 27 provinces, including the capital Jakarta, spread over a vast area of land and sea far exceeding that of the United States. It is a country with an estimated population of 200 million, with diverse ethnic groups and languages, although there is an official language spoken throughout the archipelago. Central government is located in Jakarta, a city of 12 million people on the comparatively small island of Java, which has 7 percent of the land area of Indonesia supporting 60 percent of the total population. Official policy is to encourage emigration to the eastern provinces, which are relatively underpopulated. There is thus a program for the construction of many new or upgraded roads in the eastern provinces. Apart from this, however, there is a need to maintain and, from time to time, rehabilitate the existing road network and provide the resources for an expanding motorway system to alleviate traffic congestion on Java.

Indonesia is a very large and populous country spread over a large number of islands at different stages in infrastructural development. The region is influenced by three major plate tectonic units and a diverse geological history, hence a wide variation in construction material resources (*1*). Islands such as Java have abundant resources of volcanic extrusive materials and, as yet, little problem with aggregate supply, but the sedimentary regions of Kalimantan have little hard rock or available alluvial gravels.

The Indonesian government has recognized for some time the value of a working materials information system, to assist both the central planning department and the provincial engineering offices. Quarrying activities are haphazard and most are unrecorded: also, although regulations exist they often are not enforced. By contrast, in the developed world quarrying operations are now carefully regulated. Quarry output is controlled, reserves are measured, and future development programs are required by law. Safety regulations are strictly enforced. In this way, usage trends and the effects of environmental impact can be known in advance, and planning is facilitated.

## OBJECTIVES

The overall objective was to determine the distribution, quality, and quantity of construction materials in Indonesia. However, for a project of this scope there were different objectives for each participating organization (Table 1).

These different objectives influenced the database design. For the provincial engineers a simple spreadsheet probably would be adequate but for central planning and research a more complex database was required: all needs had to be embraced for the project to be sustainable.

## PROJECT DESIGN

There have been four phases of development of the materials information system in Indonesia, summarized in Table 2.

The concept of the construction material information system (CMIS) arose out of pilot studies undertaken in West Java province (*2*). An inventory methodology was developed containing a database of existing aggregate sources (*3*). Expansion of this trial to a national scale was carried out in phase 3 when data from existing aggregate source records were collected. A major problem was the low reliability of these data, necessitating the development of a ranking system of accuracy in the database files. Data accuracy was ranked according to location, environment, and material. By the end of phase 3 it was realized that extensive fieldwork and laboratory testing would be required to expand the database nationally to a worthwhile size, and that this work would be most effectively carried out by staff from the provincial offices.

The first three phases involved the initial decisions regarding the data to be collected and the software system required to process the data. A database system was selected because the potential amount of data was very large. Three database file systems were worked out: a simple one for entering reconnaissance or existing data for inferred resources or reserves, with approximately 60 data fields in two database files; a more complex one for field assessment containing nearly 500 fields in 20 database files for indicated resources or reserves; and a third system containing detailed pit and borehole information for measured resources or reserves. All systems were linked via common fields so that the data could be selected from several database files if necessary according to the specific enquiry. Data collection procedures were designed to facilitate the input of large amounts of numerical and descriptive data into a commercial database package. This package (Foxpro) complied with the following specifications:

- It could handle large amounts of data in .dbf format and permitted data selection for reporting.
- It had devices whereby data entry and integrity were not compromised by the user.
- A straightforward data query and retrieval system was available.
- Data could be amended simply.
- Reports could be prepared via the system's own facility or downloaded to another program.

To minimize the databank size use was made of coded options under general headings of source location and size; product type, rate of production, and price; and environmental factors relating to land use, quarry restraints, and quarrying impact (*4*).

When the local engineering staff of the provincial offices began their work in the fourth phase, it was realized that the initial systems developed for the IRE geologists and engineers were too complex for the provincial engineers and needed streamlining. Additionally, the standard of computing facilities in the provincial offices varied widely. A modified data collection form was designed and the software system amended. Training courses were given to the local staff in all aspects of the work, including the laboratory engineering testing of the samples, and periodic vetting of the performance of the provincial teams subsequently was carried out. It was essential to underline the importance of obtaining good-quality data for the system (*5*).

## RESULTS

### Field Form and Fieldwork

The field data collection form, agreed with IRE engineering staff, is presented in Figure 1. It provides basic data for sources of raw materials, whether they are unconsolidated materials from rivers, soil/surface weathered rock, or crushed hard rock from quarries. The form is easy to understand by nongeologists and is divided into categories, each with several items. If the item consists of a series of options, the list of options is displayed on the field sheet.

**TABLE 1 Project Objectives for Participating Organization**

| Organization | Objectives |
|---|---|
| Indonesian Dept of Transport | Obtain data on the location, properties and cost of road materials; identify shortages |
| IRE | Develop the technical capability of staff; develop the methodology to collect & process materials data, develop expertise to locate new material sources |
| TRL/DfID | Develop methodologies transferable to other developing countries |
| IBRD | Obtain better information for assessment of road management schemes |

**TABLE 2 Development Phases of Construction Materials Information System**

| Development Phase | Description | Dates |
|---|---|---|
| 1 Background Research | Review of existing systems in light of Indonesian needs. Identification of key data. | 1988, TRL TRL/IRE |
| 2 System Setup | Design of field data collection forms, database file systems and output systems. Trial in one province (West Java) | 1988/9, IBRD/DfID TRL/IRE |
| 3 System Development | National survey of available provincial data and incorporation into database file systems | 1991/3, IBRD/DfID TRL/IRE |
| 4 System Implementation | Field data collection, laboratory testing, design of streamlined database file system and data input by provincial engineering offices | 1995/7, IBRD/DfID/Indonesian Dept of Public Works TRL/IRE/provinces |

The data are arranged on the field sheet in the order that an investigator might collect them. Thus, the investigator would seek information concerning the location of the deposit first, followed by the general environment or setting of the deposit, followed by details concerning the material itself, and so on. Laboratory results would have to be entered later.

Concerning the field work, a training course to explain and demonstrate the basic principles is essential, especially if the personnel involved are not trained geologists. Topics of special importance in the Indonesian surveys were as follows:

- Determination of the strategy and tactics of a regional survey: which quarries to survey and in what order?
- Determination of quarry location; most provincial engineers in Indonesia found this difficult and maps are difficult to obtain. The purchase of a Geographic Positioning System, a hand-held apparatus relatively inexpensive to buy and maintain (about $1,000 when new for a modest model), easy to use, and sufficiently accurate for the purpose was recommended. Accurate map coordinates are indispensable so that the quarry can be relocated for subsequent detailed work and for spatial presentation of the data in Geographic Information Systems packages such as MapInfo.
- The collection of representative samples from a deposit. This is not a simple task, but the implications are profound.
- The standardization of laboratory testing in different laboratories.

### Computer Work

The following describes the software system developed for provincial use in the fourth phase of development.

The field and laboratory data is inputted into a PC by using an adapted version of a database program (Foxpro 2.6 for Windows). Every province was provided with a copy of the software, suitable for 386-DX computers or better, having a minimum of 8 Mbyte RAM and running on Windows 3.1 or 3.11. Most provinces had computers of this standard but a DOS version was provided for those that did not. The software is contained on three standard diskettes and is easy to install. On opening the program, the user is presented with a series of three screens similar in appearance to the field data collection form (Figure 1). New data can be entered or existing data browsed or amended. The software package has an advantage over the standard Foxpro software in that the number and type of data field titles cannot be altered. It also has the capability to produce a standard report, which is a printout of the data shown on the screen.

Although this may be suitable for the individual provinces, a more flexible system may be preferred for the central office or for research purposes. This can be produced in a standard manner from the database software coupled to a specialist software report writing package such as Report Writer, version 6.5 for Windows; alternatively, and this may be more attractive for many users, the data may be downloaded to a spreadsheet program for further processing.

In Indonesia each province sends a copy of its completed data diskette to IRE at the end of each year. These data are added to the master database. Inquiries from the Department of Transport are addressed through this database.

## PROGRESS

The Indonesian Department of Transport commenced its own data collection in the 1994/5 fiscal year. The project was intended to run 5 years with a total investment of about $500,000 per year. Until the fourth phase started in August 1995 there had been no assessment of performance of the provincial survey teams. Training courses were held in June and July 1996, and Table 3 gives an indication of the improvement in performance as judged by several factors. These factors were the quality of the written report and number of deposits assessed, the results of random field checking of selected provincial teams, the assessment of their computer skills, and condition of the computers and the condition of the laboratories.

## POTENTIAL USES OF MATERIAL INFORMATION

Potential uses for the materials information system are as a data source for the following:

- For government planning, consultant, contractor;
- To make resources maps of a region;

**INDONESIAN INSTITUTE OF ROAD ENGINEERING**

JL. RAYA TIMUR 264, PO Box No. 2 UJUNGBERUNG - BANDUNG 40294 - INDONESIA.

**CONSTRUCTION MATERIALS INVENTORY: FIELD FORM**

**LOCATION**

1 Location No
2 Province
3 District
4 Subdistrict
5 Desa — 6 Village
7 River
8 Road from — 10 Road No
9 Road to — 11 Road Status (1. National, 2. Provincial, 3. District, 4. Village)
12 Kms from (8)
13 Road Condition (1. Asphalt, 2. Gravel, 3. Earth)
14 Access road distance — 15 Access road condition (1. Asphalt, 2. Gravel, 3. Earth)
16 Coordinates E / N
17 Ownership (1. Private, 2. Concession) — 18 Operating status (1. Fully operational, 2. Partially operational, 3. Not operational, 4. Under development)
19Operating method (1. Manual, 2. Mobile plant) — 20 Utilities available (1. No utilities, 2. Electric power, 3. Water, 4. Water & electricity)

**ENVIRONMENT**

1 Geomorphology (1. River, 2. Coastal, 3. Valley side, 4. Hill, 5. Mountain, 6. Plain) — 2 Land Use (0. None, 1. Housing, 2. Industrial, 3. Plantation, 4. Agriculture, 5. Forestry, 6. Mining, 7. Other)
3 Environmt. Impact (0. None, 1. Village, 2. Industrial, 3. Plantation, 4. Agriculture, 5. Forestry, 6. River, 7. Tourism) — 4 Quarry Restraints (0. None, 1. Housing/buildings, 2. Flooding, 3. Environmental impact, 4. Physical)

**FIGURE 1 Construction material inventory system: field data entry form.**
*(continued on next page)*

- In conjunction with terrain maps, to identify new sources of materials; and
- To make land zoning maps.

The existence of a databank would be most useful in regions where aggregates are scarce. A pressing example of this is in Central Kalimantan province (Figure 2), where major infrastructural schemes have been proposed to facilitate access to new rice-growing areas to close the widening gap between consumption and supply of this staple in Indonesia. Currently aggregates are imported from Sulawesi at great cost but there are local sources that presumably would be far cheaper to exploit. A well-researched CMIS would provide information for the compilation of guides on the availability of suitable materials.

Another example is provided by Bali, a province of Indonesia, which has conflicting pressures caused by the need to reconcile its population's needs with tourism. Currently, all construction materials used are alluvial gravels and sands. Sources of hard rock aggregate, more suitable for some uses such as unbound roadbases, need to be identified. Figure 3 shows the conflicting nature of all these activities on the land space available on Bali and indicates the advantages of compiling a zoning map of the area.

A liaison was proposed between the central Indonesian map-making authority (Bakosurtanal) and the CMIS. The former has

**QUARRY MATERIAL DATA**

**1 Physical State** 1. 2.
1. Loose
2. Massive
3. 'Compact'

**2 Material Type** 1. 2.
1. Sand & Gravel
2. Rock
3. Conglomerate/Breccia
4. Soil

**3 Material definition** 1. 2.
1 Alluvium, Terrace deposit
2. Andesite, Granite, Diorite, Metamorphic
3 Conglomerate, Breccia
4. Limestone, sandstone, shale

**4 Reserve estimate, $m^3$** 1. 2.
1. < 10.000
2. 10.000-25.000
3. 25.000-50.000
4. 50.000-100.000
5. 100.000-250.000
6. 250.000-500.000
7. 500.000-1.000.000
8. 1.000.000-2.500.000
9. > 2.500.000

**5 Field estimate of size percentages (*for alluvium/terrace*)**
(>200mm) Boulder 1. 2.
(76-200mm) Cobble 1. 2.
(2-76mm) Gravel 1. 2.
(0.06-2mm) Sand 1. 2.
(<0.06mm) Fines 1. 2.

**6 Overburden Type** 1. 2.
1. None
2. Loose
3. Mixed loose & hard
4. Compact

**7 Overburden Thickness** 1. 2.
1. < 1m
2. 1 - 2m
3. 2 - 4m
4. > 4m

**8 Material Use** 1. 2.
1. Surface dressing
2. Asphalt aggregate
3. Roadbase
4. Subbase
5. Concrete aggregate
6. Fill
7. Housing & others

**QUARRY PRODUCT DATA**

**1 Type** 1. 2. 3. 4.

**2 Size, Max & Min (mm)** 1. 2. 3. 4.

**3 Production rate ($m^3$/minggu)** 1. 2. 3. 4.

**4 Price (Rp/$m^3$)** 1. 2. 3. 4.

FIGURE 1 (*continued*) (*continued on next page*)

responsibility to prepare national resource inventories. There is an obvious mutual advantage of coupling the CMIS on the one hand and digitized map-making on the other. All potential uses would benefit by the incorporation of software systems linking text and numerical data with spatial data. Geographic Information Systems software, such as MapInfo, can perform this capability.

The use of the Bakosurtanal Land System maps has been a major factor in the derivation of terrain-resource correlations (*6*). This work was carried out for all Indonesia and would provide a basis by which to progress to more detailed correlations. The CMIS would be a useful source of data to complement this work.

The CMIS laboratory data contains much information on aggregate properties. It contributes significant background information to research testing programs involving the problems associated, for instance, with the use of aggregates of variable quality and the development of testing procedures more closely allied with the in-service performance of aggregates.

The development of quarries and pits can have a detrimental effect on the environment. The current CMIS records qualitative information indicating general areas of concern. It would be possible to extend this into more systematic recording of measurable factors such as noise, dust, and water pollution.

## CONCLUSIONS

The location, exploitation, and movement of construction materials is an undertaking requiring considerable effort and having a significant

**SAMPLE DESCRIPTION AND LABORATORY TESTS REQUIRED**

**1 Material Type** 1. 2.

1. Loose
2. Massive
3. Compact

**2 Sample derivation** 1. 2.

1. Test pit
2. Borehole
3. Surface
4. Side section
5. Hand

**3 Sample Size (kg)** 1. 2.

**4 Laboratory Tests required**

| | | | |
|---|---|---|---|
| Water Absorption | | Elongation | |
| Specific Gravity (bulk) | | Flakiness | |
| Specific Gravity (ssd) | | Stripping | |
| Specific Gravity (app) | | Sulphate Soundness | |
| Los Angeles Abrasion | | Atterberg Limits | |
| 10% Fines (dry) | | Compaction | |
| 10% Fines (soaked) | | Grading | |
| Impact Value (dry) | | CBR | |
| Impact Value (soaked) | | Swell | |
| Polished Stone Value | | Organic Content | |

**REMARKS**

**1 Photo Nos**

**2 Survey team**

**3 Survey date**

**Notes**

**FIGURE 1** *(continued)* *(continued on next page)*

effect on the economy and the environment. Maintaining and making available accurate computerized records of these materials is a worthwhile task and facilitates project planning.

The development of a computer database system in Indonesia to store and process quarry records is described. Key elements of the system are that it should be straightforward and easy to operate and available to a large number of users. An integrated training scheme covering all aspects of the data collection and processing is essential.

The CMIS is transferable to other countries in transition with minimal alteration to its data collecting procedures and file structures.

There are a number of potential uses of the CMIS in resource planning, appropriate utilization of construction materials, and support for further research.

The system can be made more user-friendly by combining maps and the numerical data via Geographic Information Systems software packages.

## ACKNOWLEDGMENTS

Colleagues at TRL were involved in the early planning stages of the project. Coworkers at IRE in Bandung have always provided indispensable support. In the later stages of the project the assistance of the Central Office of Research and Development of the Public Works Department of Indonesia (Balitbang) was invaluable in conducting the provincial surveys.

**LABORATORY TEST RESULTS**

| | |
|---|---|
| **Date** | |

| **AGGREGATE TEST RESULTS** | **SAMPLE 1** | **SAMPLE 2** |
|---|---|---|
| Water Absorption, % | | |
| Specific Gravity (dry), % | | |
| Specific Gravity (sat sur dry), % | | |
| Specific Gravity (apparent), % | | |
| Los Angeles Abrasion, % | | |
| 10% Fines Value (dry), kN | | |
| 10% Fines Value (soaked), kN | | |
| Impact Value (dry), % | | |
| Impact Value (soaked), % | | |
| Elongation, % | | |
| Stripping, % | | |
| Flakiness, % | | |
| Sulphate Soundness, % | | |
| Polished Stone Value, % | | |

**SOIL TEST RESULTS**

| COMPACTION | **SAMPLE 1** | **SAMPLE 2** |
|---|---|---|
| Compaction type | | |
| Maximum dry density, kg/cc | | |
| Optimum moisture content, % | | |
| CBR at Optimum moisture content, % | | |
| CBR (at OMC) after 4 days soaking, % | | |
| Swell, % | | |
| Organic Content, % | | |

| ATTERBERG LIMITS | **SAMPLE 1** | **SAMPLE 2** |
|---|---|---|
| Liquid Limit (LL) | | |
| Plastic Limit (PL) | | |
| Plasticity Index (PI=LL-PL) | | |

| **GRADING** | **SAMPLE 1** | **SAMPLE 2** |
|---|---|---|
| Passing 2.5" sieve | | |
| Passing 1.5" sieve | | |
| Passing 3/4" sieve | | |
| Passing 3/8" sieve | | |
| Passing No 4 sieve | | |
| Passing No 8 sieve | | |
| Passing No 16 sieve | | |
| Passing No 30 sieve | | |
| Passing No 50 sieve | | |
| Passing No 100 sieve | | |
| Passing No 200 sieve | | |

**FIGURE 1** *(continued)*

**TABLE 3 Indonesia: Evaluation of Provincial Survey Teams' Performance in Materials Information Project**

| | 1994/5 (25 provinces) | | | | | 1995/6 (26 provinces) | | | | | 1996/7 (26 provinces) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total no of deposits assessed | 423 | | | | | 459 | | | | | 617 | | | | |
| Performance Rating* | 1 | 2 | 3 | 4 | 0 | 1 | 2 | 3 | 4 | 0 | 1 | 2 | 3 | 4 | 0 |
| Number in category | 3 | 9 | 9 | 1 | 3 | 4 | 14 | 6 | 1 | 1 | 17 | 7 | 2 | 0 | 0 |

*Performance Rating: 1, Good; 2, Acceptable; 3, Requires some improvement; 4, Requires much improvement; 0, No report supplied.

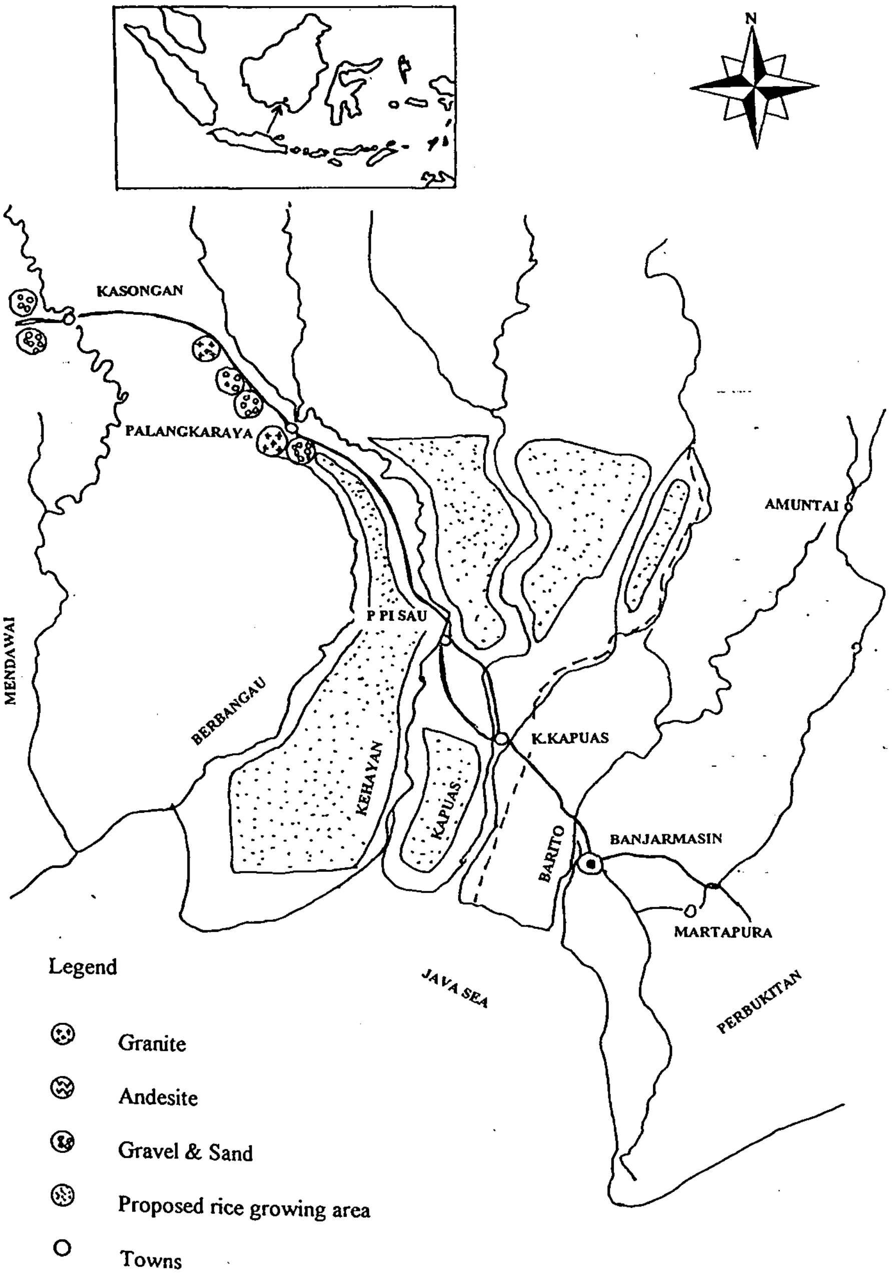



**FIGURE 2 Aggregates resource map for Central Kalimantan province.**

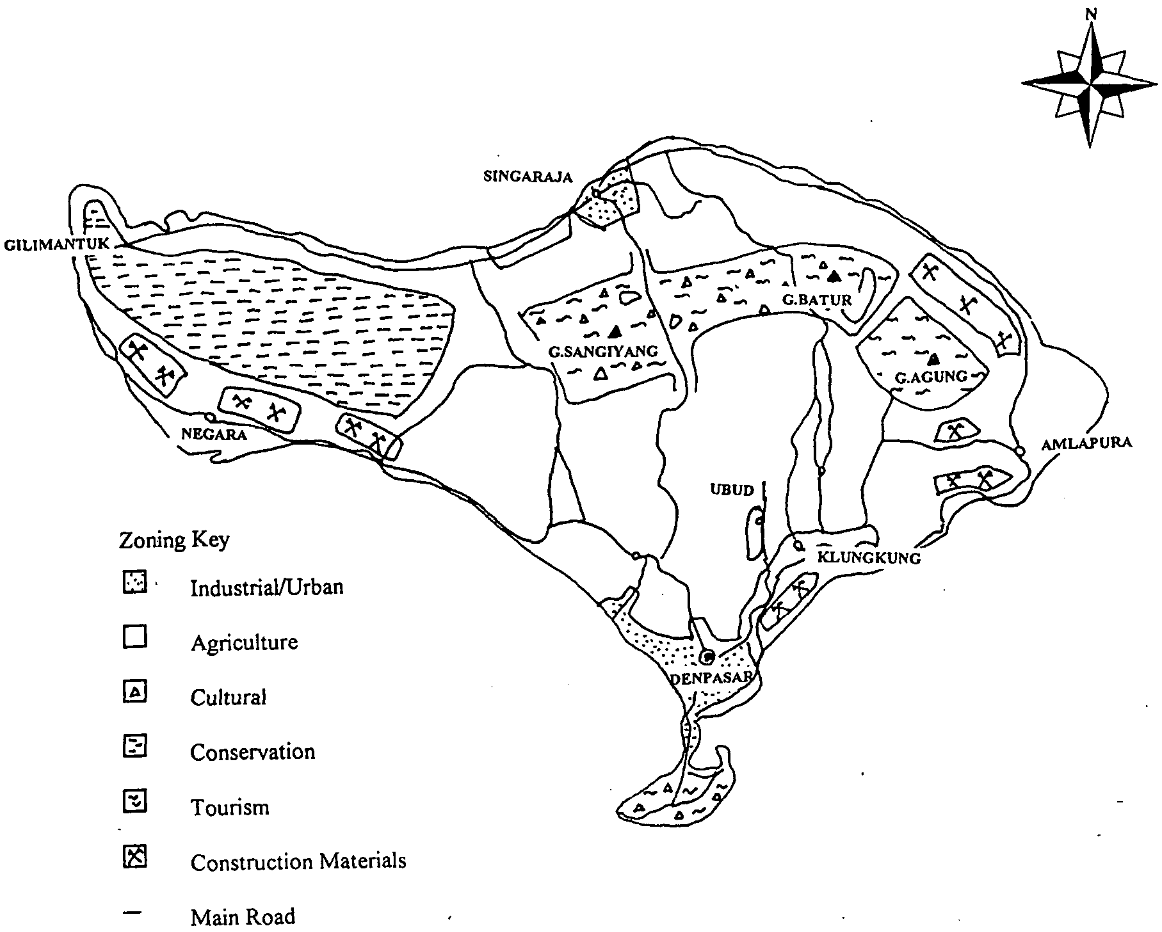



**FIGURE 3 Proposed land zoning for Bali province.**

## REFERENCES

1. Sukamto, K., and M. M. Pubo-Hadiwijoyo. *Encyclopaedia of European and Asian Regional Geology.* Chapman-Hall, 1997, pp. 376–384.
2. Cook, J. R., and B. Moestopha. *A Road Materials Inventory for West Java and Part of South Sumatra.* IRE Research Report 11.072. PT. 89. Institute of Road Engineering, Bandung, Indonesia, 1989.
3. Cook, J. R., P. J. Beaven, and B. Moestopha. The Design and Use of a Road Materials Inventory. *Proc., 6th Road Engineering Association of Asia & Australia,* Kuala Lumpur, Malaysia, 1990.
4. TRL. *The Formation and Management of a National Road Materials Inventory. IBRD Technical Assistance and Research Programme.* Institute of Road Engineering, Bandung, Indonesia, 1993.
5. TRL. *The Indonesian Construction Materials Information System (ICMIS).* Project Report PR/OSC/613/97. IBRD Road Research and Development Programme, 1997.
6. RePPProT. *The Land Resources of Indonesia: A National Overview.* Land Resources Department ODA, Indonesia, 1990.