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The development of a bi-level geographic information systems (GIS) database model for informal settlement upgrading.

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ABSTRACT

Existing Urban GIS models are faced with several limitations. Firstly, these models tend to be single-scale in nature. They are usually designed to operate at either metropolitan- or at the local-level. Secondly, they are generally designed to cater only for the needs of the formal and environmental sectors of the city system. These models do not cater for the "gaps" of data that exist in digital cadastres throughout the world. In the developed countries, these gaps correspond to areas of physical decay or economic decline. In the developing countries, they correspond to informal settlement areas.

In this thesis, a new two-scale urban GIS database model, termed the "Bi-level model" is proposed. This model has been specifically designed to address these gaps in the digital cadastre. Furthermore, the model addresses the short-comings facing current informal settlement upgrading models by providing mechanisms for community participation, project management, creating linkages to formal and environmental sectoral models, and for co-ordinating initiatives at a global-level. The Bi-level model is comprised of a metropolitan-level and a series of local-level database components. These components are inter-linked through bi-directional database warehouse connections. While the model requires Internet-connectivity to achieve its full potential across a metropolitan region, it recognises the need for community participation-based methods at a local-level. Members of the community are actually involved in capturing and entering informal settlement data into the local-level database.

In addition to an extensive literature review, two preliminary case studies were carried out to acquire an appropriate background to the topic researched. The first was carried out on the Cape Town City Council GIS. In the second case study, the Visual Settlement Planning (ViSP) approach in Belo Horizonte was examined. The lessons learnt from these case studies and the literature review led to the development of the theoretical framework for the Bi-level model. The model was then applied to two case studies in the Cape Metropolitan Region (CMR). In the first case study, the model was applied to map and analyse the growth of informal settlements throughout the CMR. In second application, the model was used to develop a database for Integrated Catchment Management in the Lotus River catchment. The two case studies illustrate not only how the Bi-level model can be applied to the informal and environment sectors of the city system, but also how it can be applied across a range of modelling scales.

Internationally, the Bi-level model provides a significant contribution in terms of providing a mechanism for addressing some of the problems that have hindered the diffusion of GIS not only in the developing countries but also in European and in other developed countries. More specifically, it provides a generic model for inter-linking and co-ordinating the development of GIS databases for those areas of the city that are characterised by a lack of digital data.

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Glossary of Terms

AFTEN	Africa Technical Environment Division of the World Bank
AIT	Asian Institute of Technology
AM/FM	Automated Mapping / Facilities Management
AVSI	Associazione Volontari per il Servizio Internazionale / Voluntary Association for International Service
ALB	Automatisiertes Liegenschaftsbuch
ALK	Automatisiertes Liegenschaftskarte
APL	Application Programming Language
ARC	Agricultural Research Council
BDU	Urban Data Banks
BLA	Black Local Authority
BSU	Basic Spatial Unit
CAD 126	Cartografia e Servicos Informatizados para o Planejamento Urbano / Cartography and Computerised Systems for Urban Planning
CAD	Computer Aided Design
CARP	Computer Assisted Regional Planning
CBO	Community-based Organisation
CCC	Cape Town City Council
CEED	City Electrical Engineer's Department
CEMIG	Companhia Energetica de Minas Gerais / Minas Gerais Power Company
CiGIS	Community-Integrated GIS
CIS	Corporate Information System
CIS	Commonwealth Independent State (former USSR)
CMA	Cape Town Metropolitan Area

CMC	Cape Town Metropolitan Council
CMR	Cape Town Metropolitan Region
CNIG	National Centre for Geographic Information (Portugal)
CNIG	National Commission for Geographic Information (France)
CODESC	Instituto de Cooperacao e Desenvolvimento Social / Social Development Co-operation Institute
COPASA	Companhia de Saneamento de Minas Gerais / Minas Gerais Sanitation Company
CRISP	Computerised Rural Information Systems Project
CSIR	Council for Scientific and Industrial Research
DC	District Council
DEM	Digital Elevation Model
DIAGONAL	Diagonal Consultores Associados / Diagonal Associated Consultants
DIS	Directorate for Information Systems
DPI	Dots per inch
DTM	Digital Terrain Model
DWAF	Department of Water Affairs
DSS	Decision Support System
ED	Enumeration District
EIS	Environmental Information System
EISD	Environmental Information System Development
EHP	Environmental Health Project
ELM	East London Municipality
ENPAT	Environmental Potential Atlas (as developed by the Department of Environmental Affairs and Tourism)
ESRI	Environmental Systems Research Institute
GEMS	Global Environmental Monitoring System

GIS	Geographic Information System
GJTMC	Greater Johannesburg Transitional Metropolitan Council
GOAL	GIS Object Orientated Analysis Language
GPS	Global Positioning System
GRID	Global Resource Information Database
GUI	Graphical User Interface
ICIS	Integrated Catchment Information System
ICM	Integrated Catchment Management
IGMI	Italian Geographic Military Institute
IGN	National Geographic Institute
ILLUDAS	Illinois Urban Drainage Area Simulator
IS	Information Systems
iSLP	Serviced Land Project
IT	Information Technology
LA	Local Authority
LAE	Linkage Accessibility Environment
LAGUNYA	Langa, Guguletu and Nyanga
LIM	Land Information Management
LUPAM	Land use Planning and Mapping Project
MAI	Advanced Imager
MC	Metropolitan Council
MERKIS	MaBstaabsorientierte Einheitliche Raumbezügsbasis für Kommunale Informations-systeme
MGE	Microstation Graphic Environment
MGGA	Microstation Grid Analyst

MIS	Maintenance Information Systems
MIS	Municipal Information System
MLC	Metropolitan Local Council
MOMRA	Ministry of Municipal and Rural Affairs
MSDF	Metropolitan Spatial Development Framework
MWPW	Ministry of Works, Power and Water (Brahain)
NEAP	National Environmental Action Plan
NDH	National Department of Housing
NGO	Non-governmental Organisation
ODA	Overseas Development Administration
ODBC	Open Data Connectivity
PADCO	Planning and Development Incorporated Company (PTY) Ltd.
PA:WC	Provincial Administration of the Western Cape
PIOJ	Planning Institute of Jamaica
PMMG	Policia Militar do Estado de Minas Gerais / State of Minas Gerais Military Police
PRODABEL	Companhia de Processamento de Dados do Municipio de Belo Horizonte / Belo Horizonte Data Processing Company
PROFAVELA	Programa Municipal de Regularisacao de Favelas / Municipal Law for the Regularisation of Favelas
PROLAND	Proland decision Support system ("Proland" refers to the proactive management of settlement and infrastructure development.)
PUC	Pontificia Universidade Catolica / Pontifical Catholic University
RC	Regional Council
RDBMS	Relational Database Management System
RLA	Rapid Land Use Assessment methodology
SDE	Spatial Database Engine

SETAS	Secretaria de Estado do Trabalho e Acao Social / State Department of Labour and Social Welfare
S&LI	Survey and Land Information
SMC	Sociedade Mineira de Cultura / Society of the State of Minas Gerais for Culture
SSMS	Shelter Sector Monitoring System
TLC	Transitional Local Council
TMS	Technical Management Services
UCT	University of Cape Town
ULAIS	Urban Land Availability Information System
UNCHS	United Nations Centre for Human Settlements (Habitat)
UNDP	United Nations Development Programme
UNU/IIST	International Institute for Software Technology (IIST) of the United Nations University (UNU)
URBEL	Companhia Urbanizadora de Belo Horizonte / Belo Horizonte Urbanization Company
ViSP	Visual Settlement Planning
WRC	Water Research Commission
WEDC	Water, Engineering and Development Centre, Loughborough University Technology
WHO	World Health Organisation
WVU	West Virginia University

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

Over the last decade there has been a rapid spread of Geographic Information System (GIS) technology throughout the developed and developing countries of the world. This diffusion of GIS has been particularly widespread in local government throughout countries in Europe (Masser et al., 1996). Furthermore, Worrall (1997) indicates that the use of GIS for the spatial analysis, development, monitoring and evaluation of public policy by organisations has increased significantly in recent years. Some of the factors that have contributed to the greater acceptance of this technology include the availability of data, increased user-friendliness, reduced cost of ownership and seamless integration into the Windows environment (Computer Graphics, 1997). While the diffusion of GIS has occurred to a limited degree in developing countries it remains largely restricted to the developed countries. About 80 % of the GIS market was still situated within the developed countries by 1993 (Craglia, 1993). In addition to this, despite the rapid spread of this technology, there are still a number of problems that have hindered the diffusion of GIS in both the developed and developing countries. One of these is the lack of digital data for urban areas of physical decay and/or economic decline (Miellet, 1996: 181). These gaps in the digital cadastre have arisen in part as a result of the predominantly cadastral approach[1] that has been adopted in the implementation of GIS in both the developed and developing countries. In the developing countries these gaps in the digital cadastre correspond predominantly to informal settlement areas, ie. those areas of land which have been occupied illegally and in a random manner by the urban poor.

There is a need to address these "gaps" in the digital cadastre in both the developed and developing countries. However, the widespread development of informal settlement areas (UNCHS, 1996, Derek & Assoc., 1992)[2,3] and the poor living conditions (Environmental Health Project, 1996)[4] associated with these settlements indicate that there is an even greater urgency to address this problem in the specific context of informal settlements.

In comparison to countries in other areas of the world[5], Sub-Saharan Africa has the highest incidence of urban poverty (42%), the highest population without access to health services (30%) and safe water (40%), and the lowest life expectancy at birth (51.3 years) (World Bank, 1988a, 1990; UNDP, 1995). South Africa has the highest GDP in Africa, but it is not immune to these problems. Thus estimates of the urban housing shortage in the country lie between 2.3 and 3.4 million units (Kruger and Davies, 1994). Currently, 39 % of the urban housing is 'informal' (about 1.5 million units); 5.2 % of the households live in hostels and 13.5 % of the households live in squatter settlements (Government of South Africa, 1994). There is also a shortfall with respect to the provision of urban services: 25 % of urban households lack piped water, 48 % cannot access flush toilets, or ventilated pit latrines, and 46 % lack electricity services.

In view of the extent of the informal settlement "problem" in South Africa, in July of 1995, the Settlement Upgrading Programme of the UNCHS (Habitat), facilitated by the Water Research Commission (WRC) of South Africa, presented a seminar in Pretoria. The seminar was addressed to local authorities and research organisations active in GIS and focused on the ViSP (Visual Settlement Planning) approach to the upgrading of informal settlements. ViSP represented the GIS base of an integrated methodology for the upgrading of these settlements. It had been commissioned by the UNCHS and had subsequently been undergoing trials to test its appropriateness and viability in Nairobi, Kenya and in Belo Horizonte, Brazil. The results, particularly in the latter case, had been extremely successful, and the purpose of the Pretoria workshop was to demonstrate this success and to explore the potential for the application of the ViSP approach in South Africa.

As a consequence of the Pretoria workshop, the Urban Management Research Group[6] at UCT entered into a joint research effort between the Civil Engineering Department (UCT) and the Cape Town City Council (CCC), which was to be funded by the Water Research Commission (WRC). The current programme of the research group focuses on the development of upgrading methodologies for informal settlements which are based on a policy of minimal / optimal relocation (Abbott et al., 1997). Most of the research work presented in this thesis has been carried out utilising the GIS facilities, funding and research opportunities that have arisen out of the Urban Management Research Group's research programme.

1.2 EXTENT OF THE CURRENT LITERATURE

The literature associated with this research may be divided into three areas. The first deals with the use of GIS, the second with local literature on GIS-based informal settlement related research studies, and the third with the international literature on the application of GIS for informal settlement upgrading applications. The literature review revealed that both the second and third areas are quite severely limited.

With respect to the literature on local GIS-based informal settlement studies, the literature does not deal with issues such as the spatial dynamics of informal settlements. Very little, if any, work has been done on establishing the growth rates or densities of informal settlements in South Africa. Using the Cape Metropolitan Region (CMR) as an example, there have been some previous counting studies, but these do not provide a detailed mapping of the informal settlements, nor do they distinguish between freestanding shack areas and backyard shack bearing areas. Furthermore, while several authors agree that the current housing policies are inappropriate (Spiegel et al, 1994; Behrens, 1993), these arguments are usually based on references to theoretical issues or on ideological grounds. There has not been any strategic-level work on analysing the broader spatial implications of the current relocation policy.

In comparison to the literature available for GIS applications in developed countries, very little work has been published on GIS applications developed specifically for informal settlement upgrading in the developing countries (Yaakup et al., 1990; 1994, PADCO, 1993; 1994). Even less has been published on how local authority systems can be adapted to deal effectively with the data processing requirements of upgrading projects in low-income developing countries. Most of the literature discussing municipal GIS systems and the problems associated with the implementation of GIS within local authorities are based on case studies situated in Britain, other European countries and in the North America (Craglia, 1993). The reason for this bias in the research of municipal GIS systems towards case studies situated in developed countries is simply the fact that the majority of the existing municipal GIS systems lie within developed countries.

Finally, while the usefulness of GIS as a strategic management tool for a multitude of applications is widely acknowledged in the developed countries[7], the literature on strategic-level applications for informal settlement upgrading is practically non-existent. Very little work has been published on GIS-based informal settlement applications in South Africa, although the potential for the development of GIS-based upgrading applications is well recognized (Wulfsohn, 1995; Wium et. al., 1995). Where GIS has been applied in informal areas, it has been mainly used to monitor voter registration processes, as has been the case in Gauteng and Kwazulu-Natal (Global Information Systems, 1995; Scan, 1995).

1.3 RESEARCH HYPOTHESES

The hypotheses tested in this thesis relate to issues that have prevented the development of GIS-based informal settlement upgrading applications within the municipal environment. Discussed below are the definition of each hypothesis, the reasons for researching each hypothesis, and any significant secondary findings that arose as a result of exploring the hypotheses.

The first hypothesis deals firstly with the issue that the implementation of GIS within a developing country faces a different set of support mechanisms and system output requirements than a system situated within a developed country. Secondly, it states that these differences demand a modification of the urban GIS database model conventionally employed in developing countries. These models were originally designed to cater for the needs of formal settlements in developed countries in Europe and North America, which are characterized by the absence of informal settlements. While Craglia (1993) highlights the importance of the contribution of institutional and cultural factors to the development of GIS in two European countries (Britain and Italy), the differences between developed and low-income developing countries go far beyond differences in culture. A local authority attempting to implement a GIS system for informal settlement upgrading work in a developing country must seriously evaluate a series of problems that would never have to be considered by a similar authority in a developed country[8].

The literature review in part 1 of this thesis suggests that internationally, the cadastral approach does not cater for the needs of informal settlements in the developing countries nor for the needs of the areas of least economic growth in the developed countries. While the cadastral approach may be appropriate for the formal sectors of the city, where the dwelling units and population display a greater degree of stability, it appears to be less suitable for dealing with the generally more mobile informal settlement areas[9]. Locally, the results of a GIS user survey in the Cape Town City Council also suggest that the cadastral approach[10] has significantly hindered the development of applications for informal settlement upgrading. As a result of these findings, the first hypothesis has been formulated as follows:

H1:

Existing GIS implementation approaches in developing countries have led to the development of municipal GIS systems based on similar systems originally designed for developed countries. These systems have been designed to meet the needs of formal settlements within the city. They are not well suited to the informal settlement areas or to the urban areas of physical decay and / or economic decline.

Two highly significant factors arise out of the research supporting the first hypothesis. The first is the fact that the spatial planning requirements which are catered for by metropolitan planning GIS systems that does exist (see for example the PROLAND model described in section 4.4.5) need to be adapted to allow such systems to become more representative and more useful. The second is that the database structure for a GIS system in a metropolitan organisation in a developing country should be far more flexible in order to cater for informal settlement areas.

The second hypothesis deals with the issue that GIS can be used as a strategic-level tool for informal settlement upgrading. The reviews on local and international GIS-based informal settlement upgrading programs suggest that very few of these systems have been designed for strategic-level applications. In Gauteng, the municipal GIS has a strategic-level component. However, the system appears to be greatly under-utilized with respect to potential applicability for informal settlement upgrading. In Cape Town, the PROLAND system mentioned above has been developed to identify vacant land available for the implementation of the relocation upgrading policy in the CMR. No consideration is given to informal settlement development in this GIS database model.

A key problem facing informal settlement upgrading in Cape Town is the inadequacy of the current policies on informal settlement areas in the Cape Metropolitan Region (CMR). The current housing policy of the Provincial Administration of the Western Cape (PA:WC), which is being implemented through the integrated Serviced Land Project[11] (iSLP), has been criticized by several authors (Spiegel et al., 1994; Behrens, 1993). Despite the claim by PA:WC (1997) that a "minimum relocation"-based policy is being applied, it is clear that a predominantly relocation-based policy is being followed in the CMR[12]. This policy has also been criticized for being based exclusively on a quantified approach[13], for excluding a community participation-based approach[14], as well as data on social processes[15], physical and other constraints (Spiegel et al., 1994; Behrens, 1993)[16] and of following inappropriate layout planning standards (Behrens, 1993)[17, 18, 19]. Furthermore, Spiegel et al. (1994) argue that the extremely fluid nature of some of the households within informal settlement in the CMR undermines the current housing policy which is designed to deliver a specified number of houses within a given time period and financial budget[20].

The inappropriateness of the current policies suggests that there is a need for an effective policy reformulation tool. More generally, there is a need for a tool for the management of "gaps" in the digital cadastre, which correspond to the urban areas of physical decay and economic decline in the developed countries and to the informal settlements in the developing countries. The large number of strategic-level applications developed for infrastructure management in the developed countries suggests that a GIS-based tool can be designed to meet this need. Hence the second hypothesis has been formulated as follows:

H2:

There is a demand for the development of GIS-based strategic-level applications for informal settlement upgrading worldwide. This demand is particularly great in areas such as the CMR, where the upgrading policy is primarily one of relocation to new formal areas. It can be shown that GIS can play a key role in formulating and managing a strategy for informal settlement upgrading at the strategic metropolitan-level.

The third hypothesis calls for the development of a GIS database model for informal settlement upgrading which functions at two distinct levels. The literature review suggests that current GIS-based informal settlement upgrading systems developed by provincial government, as well as systems developed by consultancies, tend to function on only one spatial level. These systems are generally dedicated either to local-level or metropolitan-level applications. PROLAND is an example of a GIS system developed by provincial government (PA:WC, 1997) which operates only at the metropolitan-level. The literature suggests that in this system, only the needs of metropolitan spatial planners who have developed specific spatial frameworks, and the requirements of those imposing a relocation policy, have been met. At the other extreme, the results of a study of the a GIS-based informal settlement upgrading initiative in Belo Horizonte, the Alvorada Programme, suggests that in this case the GIS was designed for local-level applications only[21]. It is clear that whereas the metropolitan-level can assist in strategic-level planning, local interventions and the evaluation of in situ upgrading projects require the development of local-level databases. Taking these factors into consideration, the third hypothesis[22] has been formulated as follows:

H3:
The information processing tasks associated with informal settlement upgrading work involves localised detailed mapping, as well as broad based planning and management decisions. This necessitates that data processing be carried out at two levels, namely at the metropolitan level and at the informal settlement level. In order to meet this requirement a Bi-level approach must be followed for the development an informal settlement upgrading database.

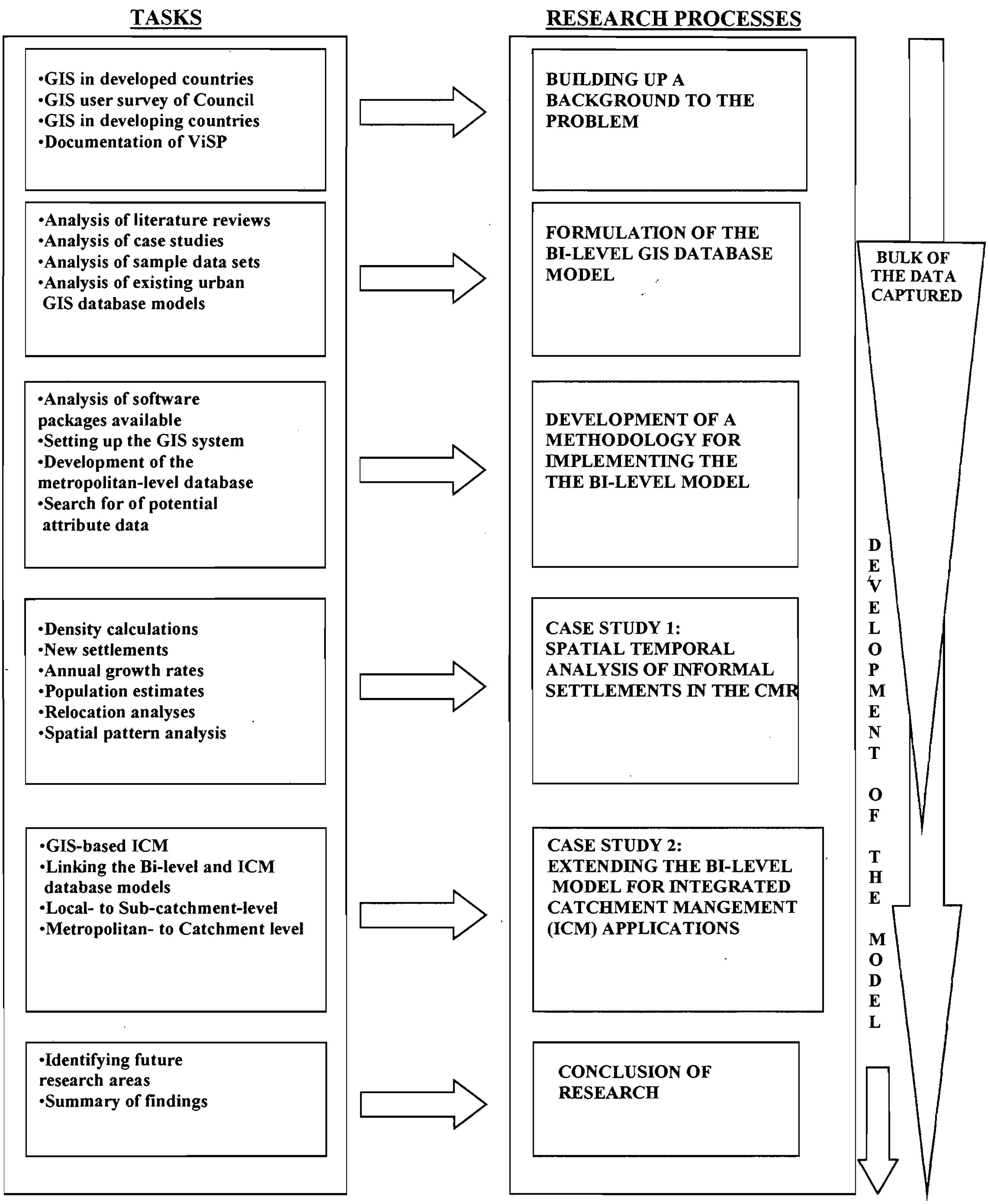
In general, the literature review suggests that a more flexible multi-scale approach is required in urban GIS modeling, in order to address the "gaps" in the digital cadastre. The concept of multi-scale systems has been applied for the development of applications in other fields of research. In particular, multi-scale systems have often been implemented for the modeling of ecological, geohydrological and other natural systems (Schaller, 1994). In the case of these "natural" GIS systems, the focus on system development lies on the solution of an environmental problem. The system developers have allowed the nature of the available data types to define the working level of the system. In adopting this approach both the high resolution continous data and low resolution data for strategic planning are incorporated within the same database. The literature review suggests that spatial planners intending to apply GIS for informal settlement upgrading should adopt a similar approach.

1.4 RESEARCH METHODOLOGY

The research methodology was defined in an evolutionary manner[23] as the understanding of the research problem improved during the research programme. The basic processes employed in the implementation of this methodology may be grouped into two types of processes. The first consists of processes carried out to build a background to the research topic. The second consists of processes carried out in the development, implementation and application of an urban GIS database model designed to address problems identified by the background. The sequence in which these stages occurred during the period of Feb 1996 to Feb 1998 and the tasks carried out during these processes are shown schematically in figure 1.1. Each of these task groups was essential for the development of the database and led to gradual development of the conceptual database model proposed in this thesis.

Broadly stated, the research has focussed on determining the manner in which centralized local authority GIS systems can play an effective role in the development of more logical informal settlement upgrading strategies in South Africa and in other middle to low-income developing countries of the world. A comprehensive background was developed for this research through a series of literature reviews and through two case studies. As starting point it was considered necessary first to review the use of GIS in local authorities in Europe where it has been in operation for many

Fig 1.1 The research methodology



years. This review suggested that these systems were faced with a series of problems that hindered the diffusion of GIS in Europe. In order to establish if similar problems were present in local authorities in South Africa, a GIS user survey was carried out in May 1996 in a number of the Engineering and Planning branches of the in the local municipal authority (Cape Town City Council, CCC). The result of the user survey, which represents the first case study, suggested that similar problems were faced in the Council. But it also revealed additional problems that did not appear to be present in developed countries. A review was then carried out to determine if these problems facing GIS were also present in other developing countries. A second case study was then carried out on what was at the time one of the world's leading GIS-based informal settlement upgrading initiative, namely the Visual Settlement Planning (ViSP) approach adopted in Belo Horizonte, Brazil.

An analysis of the background information suggested that all of the existing urban GIS database models for informal settlement upgrading are faced with a number of key conceptual limitations. An analysis of several GIS sample data sets collected from the two key GIS systems investigated in the case studies also revealed a series of practical limitations associated with the database structures. A new conceptual GIS database model for informal settlement upgrading was subsequently designed in such a way as to address the limitations facing existing models. This model was termed the "Bi-level model"[24]. The validity of this model was then tested through its implementation and application.

The first step carried out in implementing the Bi-level model required a suitable software platform to be selected. While the literature review provided an initial understanding of the software requirements of a system developed for informal settlement upgrading work, the rapid rate of change in computer technology necessitated a brief overview of the key GIS systems available in South Africa. This overview was essential for the system selection process and was subsequently extended and updated based on information collected at the international iKusasa CONSAS '97 conference held in Durban in late 1997.

Once the GIS system was set-up, the focus was placed on the development of the metropolitan-level database component of the Bi-level model. The bulk of the raw data capturing process involved the mapping of informal settlements in the Cape Metropolitan Region (CMR). For this exercise, 1: 20 000 (1996) ortho-rectified imagery acquired from the National Department of Housing (NDH) was georeferenced and used to map freestanding shacks by heads-up digitizing. The data formed the basis of the shack counting work conducted and has been summarized onto three maps, which provide the latest information on the spatial distribution of freestanding shack areas in the CMR. In addition to the raw data on informal settlement a number of other data sets were acquired from the Council and imported into the system. These data sets, which consisted of detailed cadastral data for formal settlements around Ikapa[25] and of a very limited amount of infrastructure data at a metropolitan-level, were acquired primarily to be able to place the newly acquired informal settlement data in the context of the formal city[26].

The applicability of the Bi-level model was then tested through two case studies. In the first case study, the Bi-level model was used in a series of basic spatial-temporal analyses of informal settlements in the CMR. The basic spatial analyses focused on the calculation of informal settlement areas and densities (dwelling units / hectare). Population estimates and growth rate estimates were also calculated. Qualitative spatial pattern analyses and density calculations (dwelling units/hectare) allowed two types of settlement classification schemes to be proposed for the CMR. Furthermore, two types of spatial temporal analyses were carried out. The first involved a comparison of the newly acquired data with previous studies (Van Zyl, 1995; Deware et al.,1991; MacroPlan, 1995)[27]. This comparison enabled the detection of a number of new informal settlements in the CMR. It also enabled the net growth or decline in the number of freestanding shacks experienced over a period of two years to be calculated for each informal settlement. The second case study involved a test of the feasibility of the potential sectoral model[28] linkage, which is proposed as a means of extending the applicability of the Bi-level model. For this test the results of a separate WRC funded project on the Lotus River catchment have been utilized[29].

The concluding work focussed on identifying future areas of research and on evaluating the potential for utilising satellite imagery for informal settlement upgrading applications. Other future applications for storm water runoff analysis and a quantitative cluster analysis informal settlement classification procedure were also considered.

1.5 EXTENT OF RESEARCH

The research carried out for this thesis covers a wide range of aspects. It follows that in some cases there has been very little previous work to draw upon[30]. In order to address this problem local government was approached with several requests for data were made to various local authorities in the Cape Metropolitan Region throughout 1997. However, no feedback of information was received throughout the duration of this thesis, despite intense efforts on the author's part. A number of difficulties exist with respect to acquiring informal settlement information from local authorities. These difficulties are listed below.

- The loss of information due to the restructuring of local government[31]
- A dispersion of records due to the redefinition of service provision areas[32]
- A lack of willingness on the part of local authorities to provide information[33,34,35]
- A lack of willingness by consultancies to provide information[36,37]

The general lack of data and information on several of the key areas researched led to the development of a thesis that is largely based on case-studies. In total four case studies were conducted. The first case study was carried out on the Cape Town City Council and helped to address the problem of acquiring information from local authorities mentioned above. The second case study was carried out on the ViSP approach employed in the Alvorada Programme (see chapter 5). Together with the literature review, the information acquired through these case studies led to the development of a new bi-level GIS model for informal settlement upgrading. The lack of GIS data for informal settlements in the CMR, further prompted the author to develop an informal settlement GIS database for the CMR based on this new model. A system was then developed in order to implement this model. Using this system two further case studies were carried out to test the applicability of the model. The results of these studies were then analyzed in the context of the literature available.

The adoption of a highly analytical GIS approach from the start of the project has been largely restricted by the lack of attribute information for informal settlements in the CMR. Other than the lack of a detailed attribute database at the metropolitan-level[38], two other restrictions face the analyses in the present study. The first is the lack of a backyard shack data for the imagery used to obtain the 1996 freestanding shack count data. The absence of this data prevents a complete comparison with a previous shack counting exercise conducted on 1994 aerial photography for the CMR (van Zyl, 1995). The second restriction lies in two key assumptions that required for quantifying the housing need[39].

The Bi-level model proposed in this thesis consists of a metropolitan-level database and a series of local-level databases. The development of a local-level database is a process that can take a long time and be very costly. The development of the cadastral vector database requires the acquisition of up to date helicopter photography for the settlement. Furthermore the development of the socio-economic database requires community support. The latter can only be obtained through community participation based methods and can take many months. In view of the time constraints facing the thesis, it was decided to focus on the development and application of the metropolitan-level database of the model. The development of a local-level database for New Rest became a reality in 1999 when the New Rest / Kanana Development Trust was established. Although this work was done after most of the research work for the thesis had already been completed, it has been useful to include some of the experiences of this work here.

1.6 STRUCTURE OF THE THESIS

The thesis consists of eleven chapters. Chapters 2 - 11 can be divided broadly into three sections. The first part is comprised of chapters 2 - 5, the second of chapters 6 - 8, and the third of chapters 9 to 11. The first part provides a background to the thesis, the second develops a new GIS model for informal settlement upgrading, while the third tests the applicability of this new model.

The first part comprises the introduction and framework, and provides a background to the local and international status of GIS applications developed for informal settlement upgrading work. This first part illustrates that there is a need both locally and internationally for the development of a GIS database model that is designed to facilitate the development of GIS applications for these areas that are generally omitted from the city's GIS database.

As a starting point in exploring the way that GIS is used, chapter 2 provides a background on its operation in Europe, where it has been utilized for many years. The European experience of GIS in local government highlights the factors that influence the diffusion of GIS, and on the problems facing GIS implementation approaches conventionally adopted throughout the world. It provides a brief overview GIS within nine European countries (Great Britain, Germany, Netherlands, Denmark, Greece, Italy, Portugal, Poland and France) with an emphasis on the institutional context, coverage, applications and diffusion of GIS in these countries[40]. This chapter provides a comparative background by which to gauge the status of GIS applications in developing countries in the first instance, and then specifically in Cape Town. Chapter 2 suggests that the cadastral approach has hindered the diffusion of GIS in Europe has led to the development of "gaps" in the digital cadastre for those urban areas of physical decay and economic decline.

Chapter 3 was written with the aim of establishing whether a municipal GIS in a developing country such as South Africa is faced with the identical and possibly additional problems to those encountered in local authorities in Europe. A key difference between the European case studies and South Africa is the presence of informal settlements in the latter. Thus a natural extension of the research carried out for this chapter was to establish whether the GIS applications created by local authorities in SA have developed to incorporate informal settlement areas. To address these issues it was first essential to overview the use of GIS in the largest local authority in Cape Town. This was achieved by carrying out a user survey of GIS in the Cape Town City Council (CCC). The survey had several aims. Firstly, it would give an indication of the main problems facing the implementation of GIS in the CCC. Secondly, it would illustrate whether GIS applications that included informal settlement areas were being developed by the CCC. Thirdly, the survey was essential for research into the potential application of a particular type of planning approach (ie. the Visual Settlement Planning (ViSP)) in Cape Town. Chapter 3 suggests that as in Europe, the cadastral approach in the Council has also led to the development of "gaps" in the digital cadastre. However, in the case of Cape Town these "gaps" appear to correspond predominantly with the informal settlement areas.

In chapter 4 the use of GIS in a number of developing countries is reviewed with three key aims. The first is to establish whether the problems encountered in the Council were unique to this system or whether these problems are shared by systems in other developing countries. The second is to determine the extent to which GIS applications have been developed for informal settlement upgrading in other developing countries. The third aim is to identify the requirements of a sustainable and effective GIS in a developing country. The chapter begins with an overview of informal settlement upgrading applications driven by two prominent international development agencies, namely the World Bank and the USAID (through the Planning and Development Corporation (PADCO)). A number of GIS are then considered firstly in the African context (South Africa, Kenya, Mauritius and Ghana) and secondly within the context of other non-African developing countries (India, Cambodia, Commonwealth Independent State and Middle East). In the former the emphasis is placed on GIS in South Africa.

All of the GIS-based development programmes reviewed in chapter 4 have one problematic criterion in common. They have all been designed for countries where the regularisation of land tenure in informal settlement areas remains an issue of major national debate. In chapter 5, one of the world's leading GIS-based approaches to informal settlement upgrading, the Visual Settlement Planning (ViSP) approach in Belo Horizonte (Brazil), is examined in detail. This approach forms the GIS-based component of a larger informal settlement upgrading initiative, the Alvorada Programme, and differs significantly from the GIS-based programmes in other developing countries. The development, feasibility and success of this approach is largely attributed to changes in the legislation on land ownership in informal settlement areas in Brazil. In 1983 the Municipal Law for the Regularization of Favelas (PROFAVELA - Programa Municipal de Regularisacao de Favelas) was passed in Brazil. This law placed Brazil as one of the first developing countries to recognize the favela (informal settlement) resident's rights to ownership of the land they occupied. The key principle embodied in the PROFAVELA Law is that the settlement structure of the favela be maintained. Thus the approach followed in the Alvorada Programme is one whereby the process of spatial restructuring is based on a detailed evaluation of the problems and potentials of each favela. This evaluation process is carried out through the development of a local-level GIS database for in-situ upgrading. Using this approach a General Plan (Plano Global)[41] has been developed for each favela considered in the Alvorada Programme. In chapter 5 a description and brief analysis of the Visual Settlement Planning (ViSP) approach arising out of a one-month study is presented.

The second part deals with the development of a GIS database model for informal settlement upgrading. It discusses the conceptual framework of a GIS database model, namely "The Bi-level model" which was developed to address the limitations faced by current GIS-based informal settlement upgrading initiatives. The definition of the conceptual framework of the model is followed by detailed discussions illustrating how the appropriate system and database components may be developed to implement the model.

Several issues that arise out of chapters 2 - 5 highlight the need for the development of a new urban GIS database model. The discussions in chapter 2 show that the diffusion of GIS in the developed European countries has been hampered significantly by problems associated with the cadastral approach. Amongst these problems are the slowness of the approach, data maintenance problems, the lack of applications development, data under-utilisation, technical problems and the lack of digital data. Identical problems and more severe organisational and technical problems are encountered in the Cape Town City Council (chapter 3) and on GIS systems in other developing countries (chapter 4).

The lack of digital data in particular remains a problematic issue in both the developed and developing countries. It is clear that there is a need for the development of a GIS database model that facilitates the development of GIS applications for areas that are generally excluded from the digital cadastre. In the case of the developing countries these areas correspond predominantly to informal settlement areas. While a number of GIS models have been designed specifically to address the lack of data in the informal settlement areas for upgrading applications, chapters 4 and 5 suggest that these models are faced with key limitations. These models appear to be generally characterised by the lack of mechanisms for community participation and for integrating the informal settlement with the formal settlement and environment. In addition, the literature suggests that these models are based on single-scale approaches and tend to function as distinctly isolated databases.

In chapter 6, the conceptual framework for the development of an informal settlement upgrading information GIS database model that addresses the problems identified in chapters 2 - 5 is developed. First, the scalar and non-scalar requirements that face the development of informal settlement upgrading applications is considered. This is followed by discussions on the theoretical weaknesses of the ViSP approach, other Urban GIS database models and structures, and local factors that affected the development of the model. The GIS database model proposed here, which has been termed "the Bi-level model", is then defined in terms of its framework, database components, software requirements and database linkages. The significance of the model and the manner in which it differs from other models is then discussed. The basic components that must be considered in the model to ensure that it can operate within the context of sustainable urban development are subsequently outlined. The means for extending the Bi-level model firstly for environmentally sustainable development and secondly for a global co-ordination of informal settlement upgrading projects are then discussed.

The true test for validating any conceptual model lies in whether the model can be easily developed and usefully applied. The first step in testing the validity of the Bi-level model lies in setting up an appropriate GIS system on which to build the model. In order to establish the most appropriate software configuration for implementing the model, it was considered necessary to review the capabilities of some of the key high-end and low-end GIS platforms available on the market at the present time. This is done in chapter 7 where the main GIS systems available in South Africa (Intergraph, Arc/Info, MapInfo, GenaMap, Idrisi, Atlas GIS, AutoCAD Map and Orthodraw) are evaluated in terms of the software requirements facing the model.

The second step towards testing the feasibility of the Bi-level model proposed in chapter 6 lies in utilizing a GIS system to build the database components of the model. In chapter 8 the development of the metropolitan- and local-level database components of the model is discussed in great detail. The chapter then focuses on a number of the technical issues associated with the implementation of the Bi-level model in the Cape Metropolitan Area[42]. These issues include the design and setting-up of the GIS system and the data capturing and data processing tasks involved in setting-up the database. In addition, the manner in which the model may be used as a tool for the diffusion of GIS data is also focused upon. In particular, the linkages between the metropolitan- and local-level databases and the feasibility of creating these linkages are discussed. Here the issue of the appropriate GIS software configuration is returned to as two of the more suitable GIS software configurations are suggested for the model. The discussion examines two ways in which the Bi-level model may be used to facilitate the diffusion of GIS data. These are firstly through the application of database linkages, and secondly, through the application of the local-level database. With respect to the latter, the manner in which the low-end GIS platform may be used for disseminating information to the community and for negotiating upgrading proposals is discussed.

The third part examines the utility of the Bi-level model developed in Part Two through the development of two case studies. In the first case study, the applicability of the metropolitan-level database developed in chapter 8 is examined. Van Zyl (1995) comments on the uncertainty and differing results of existing shack count studies and highlights the need of reliable data for planning and projection applications[43]. In chapter 9, the potential for utilizing the Bi-level model in order to address this need for reliable data is tested. This is done through a series of comparisons with previous data sets and through the calculation of several variables that may be used to characterize informal settlements in the Cape Metropolitan Region (CMR). The 1996 shack count data are used to obtain settlement densities, net growth rates and population estimates. The chapter then considers two potential indicators for prioritizing the upgrading process in the CMR. The first is a minimum relocation analysis tool based on the existing sub-settlement densities and on the proposed planning densities. The second is based on a qualitative informal settlement spatial pattern analysis.

In the second case study (chapter 10), the ease with which the applicability of the Bi-level model may be extended by applying linkages to potential sectoral database models[44] is tested. The components of a potential sectoral model which was recently developed by the author for Integrated (urban water) Catchment Management (ICM), are first briefly discussed. The manner in which the Bi-level model may be connected to this ICM sectoral model database is then discussed in detail. In testing the utility of this connection, the issue of "gaps" in the digital cadastre, suggested by chapters 2 - 5, is returned to. Recent research by the author on GIS-based ICM applications (Grobicki et al., in press) highlights that one of the key problems facing hydrological modeling at the sub-catchment–level is the lack of detailed cadastral data for informal settlements. This chapter examines whether the creation of linkages between the local-level informal settlement databases embodied within the Bi-level model and sub-catchment-level ICM databases can be instrumental in overcoming this problem.

The application-based case studies are followed by the final chapter (11), which summaries the conclusions of all the foregoing research chapters in parts 1 to 3. This chapter begins by discussing the validity of the hypotheses in the light of the research findings. This is followed by discussions on the feasibility of multi-scale approaches in other countries, the applicability of the Bi-level model and by a summary of the main findings of the thesis that are relevant to both local and international researchers. The thesis concludes with a final section (11.4) that identifies five areas for future research.

CHAPTER TWO: MUNICIPAL GIS SYSTEMS AND THE PROBLEMS FACING GIS IN EUROPEAN COUNTRIES

2.1 INTRODUCTION

A starting point in exploring the way that GIS is used is to look at its operation in a European context, where it has been operationalised for many years. The European experience of GIS in local government provides a background on the factors that influence the diffusion of GIS, and on the problems facing GIS implementation approaches conventionally adopted throughout the world. It was considered essential to develop such a background before the status of GIS in developing countries could be considered. The discussion is organized into three main sections. The first section provides a broad overview of a number of GIS characteristics within nine European countries. The focus of this overview lies on the institutional context, coverage, applications and diffusion of GIS. The second section focuses more closely on the last three issues on a country by country basis. This review has been derived from the following papers: Junius et al. (1996), Ciancarella et al. (1996), Arnaud et al. (1996), Kiib (1996), Assimakopoulos (1996), Miellet (1996), Bartnicka et al.(1996), Graafland (1996), Masser & Craglia (1996) and Masser & Campbell (1996). In the case of Britain, there is a brief discussion on implementation typologies[1] derived from Campbell et al. (1995) and Masser & Campbell (1996). The third section synthesizes the European experience on the basis of the key problems encountered and provides an analysis of the trends in the thinking which have controlled some of the more recent GIS developments in these countries. The discussion provides a comparative background by which to gauge the status of GIS applications in developing countries in the first instance, and then specifically in Cape Town.

2.2 OVERVIEW

The work by Masser & Craglia (1996) reviews the status of GIS in the Europe through eleven assessment criteria[2]. In this section, only the institutional context, digital data availability, applications and diffusion of GIS will be considered.

<u>Institutional context</u>
An inspection of the information in appendix 1 tables1-3 suggests that six types of institutional context may be recognized with respect to the diffusion of GIS in the local government[3]:

1. local government stability
2. decentralization of powers to local government
3. privatization of local government
4. political reform
5. proactive modernization, and
6. limited financial and manpower resources

These contexts have strongly influenced the diffusion of GIS in these countries. Thus the decentralization of powers to local government (Denmark, France) and privatization of local government tasks (Britain) have accelerated the diffusion of GIS, while proactive government measures to modernize local government (Portugal[4] and Poland), contracting of local IT functions to private sector (Greece) and the application of EC funding mechanisms (Greece, Portugal) appear to be less effective in diffusing GIS. Countries with stable local governments (Germany, Netherlands) have focussed largely on slow cadastral database approaches which has encouraged the development of parallel systems within local authorities. Countries faced with political reform (Italy and Poland) and limited financial and manpower resources (Greece) have experienced limited diffusion of GIS.

Digital data availability

Digital data is widely available in Britain, Germany, Denmark, and France. In Great Britain, the Ordinance Survey provides a comprehensive digital topographic data service (Masser & Craglia, 1996). The Service Level Agreement reached with local authorities has boosted the diffusion of GIS in Britain. In contrast, there is a lack of digital data facing Poland, and to a greater extent, facing Greece and Italy.

Main applications

In most cases, GIS used for automated cartography / digital mapping. In Greece, Poland and Germany, GIS is applied mainly for surveying and topographic / cadastral database management. It is used as mapping tool for local planning and management in Great Britain, strategic land use planning in Italy and Portugal, and topographic and thematic mapping in the Netherlands. Other applications include: environmental monitoring (Italy) and utility management (Denmark).

Extent of diffusion

The diffusion of GIS is almost universal in Great Britain and Germany, Denmark and the Netherlands and widespread in France. The availability of human and financial resources and of up to date digital data have facilitated diffusion of GIS in Britain. In contrast, diffusion in Italy has been limited to medium and large cities. Similarly few and highly localized occurrences of GIS are found in Portugal, Greece and Poland.

2.3 GIS EXPERIENCES IN THE EUROPEAN COUNTRIES

In this section a number of issues such as GIS implementation approaches, data coverage and applications are discussed to varying degrees for nine European countries. Particular emphasis is placed on the extent of diffusion in each country. In the case of some countries (eg. France, Germany and Poland), issues pertaining to multi-scale database models are highlighted. Here only a brief description of each country is given. Further details appear in tables 1 - 3 in appendix 1.

It is useful at this stage to clarify the definition of the term "multi-scale database model". Multi-scale techniques are implemented both in the display and in the capture of GIS data. In the former, data is typical captured on a single scale and displayed at various fixed scales. An example of this multi-scale viewing facility is the "view-by-scale" utility that has been incorporated as part of the legend properties dialogue box in GeoMedia[5]. This technology is typically used to simplify the viewing of large detailed urban cadastral databases in Europe. Another example of a multi-scale viewing facility is the pyramid format file structure developed locally. In this case, the technology has been designed to accelerate the viewing of large raster files created from digital ortho-photography. These techniques differ significantly from multi-scale data capturing methodologies. While the former involves a "scale-selective" display of a single-scaled database of homogenous detail, the latter involves a scale-selective data capturing process, which results in a multi-scaled database of inhomogenous detail. The multi-scale database models discussed in this thesis refer to the latter definition.

2.3.1 Great Britain

In terms of the extent of diffusion, Campbell & Masser (1996) found GIS to be almost universal in the counties and Scottish regions by 1993. It occurred in half of the metropolitan districts and in one sixth of the shire / Scottish districts. With respect to implementation, Campbell (1993) defines a threefold typology of system implementation in British local government. This typology includes a classically corporate, a theoretically / pragmatic corporate and a fiercely independent approach. None of these is ideal[6]. Another relevant issue with respect to the implementation of GIS is the distinction between single and multi-department[7] systems. The latter were particularly dominant in the Shire and Scottish districts and in the Metropolitan Districts. With respect to GIS applications, the planing and development departments were the most frequently cited departments while planning was the lead department in the majority of cases. The result of a survey of 404 departments involved in 195 GIS facilities in 1993 (Campbell et al., 1995: 71) is shown in appendix 1 table 4. Although the planning department is the lead department in most cases, operational and estate management applications are much more frequent than strategic planning applications (Masser & Craglia, 1996).

2.3.2 Germany

Junius et al (1996) indicates that GIS was almost a universal phenomenon in Germany by 1994. Between 70 to 80 cities had GIS and 10 had firm plans to acquire a GIS system.
In Germany, both surveying-based and scale-based GIS initiatives have been followed. Amongst the surveying-based GIS initiatives are the ALB/ALK digital cadastre and the official topographic-cartographic information system (ATKIS). The former is comprised of the automated cadastral register (ALB[8]), designed as a standard database management

system, and the automated cadastral map (ALK[9]). The ATKIS system was launched in the late 1980's. It covers all topographic maps from 1:25 000 to 1: 100 000. As with the ALB/ALK system, the ATKIS system is faced with a series of problems and is not expected to be completed before 2000. The problems with a cadastral approach can be drawn out of the ALB/ALK digital cadastre experience in Germany. These problems are discussed in a subsequent section below. With respect to scale-based initiatives, the MERKIS[10] system provides a primary example of such a system. The MERKIS system has been defined as - "a scale-oriented unified spatial reference system for local government information systems."(Junius et al.,1996: 70). In essence, this system was introduced in an attempt to reduce the growing number of parallel systems developing in local authorities in Germany. Some of the coverages in the MERKIS model include:

1. local base maps (city base maps 1:500 to 1:2500, cadastral maps, and German base maps 1:2500 to 1: 10 000)
2. land use plans
3. thematic maps, engineering and landscape projects and facility management maps
4. districting and location/allocation for public facilities planning maps
5. land use inventory maps

"The core principal of MERKIS is that all local government GIS in Germany are to be based on a unique spatial reference system. In each municipality, only one agency is to be responsible for the administration and updating of the spatial reference system." (Junius et al., 1996: 70).

2.3.3 Netherlands

Graafland (1996) indicates that the extent of diffusion in Netherlands was almost universal amongst municipalities above 50 000 inhabitants and in approximately 50 % of those above 20 000 inhabitants. Graafland (1996) describes a large scale mapping project called GBKN, which is managed by the central cadastre. The aim of the project has been to create a nation wide digital topographic map at a scale of 1:1000. However, the lack of large scale digital maps, as a result of the slow progress of the National Digital Cadaster programme, has significantly hindered the diffusion of GIS.

2.3.4 Denmark

Denmark has three administrative levels of government: central government, counties and municipalities. Kiib (1996) indicates that GIS has been used extensively in the Danish local government since the 1970's. Kiib (1996) indicates that over 80 % of all municipalities were using registered-based systems where georeferencing is present by 1993. By this period, GIS/AM/FM was almost universal in authorities with more than 50 000 inhabitants, and GIS was present in half of the counties. It thus not surprising that digital data is widely available. The GIS is primarily used for mapping and utility management.

2.3.5 Greece

This is the first of the European countries that are lesser developed in terms of GIS system development (see section 2.4). With respect to the diffusion of GIS, Assimakopoulos (1996) indicates that only about 10 % of all cities have GIS. The status of GIS developments in Greece has been severely inhibited by the overall lack of resources (Assimakopoulos, 1996). In particular, the availability of digital data is extremely limited. Roads and administrative boundaries data are available only at a scale of 1:1000000 for the whole country. Contour data (1:5000) is available for only a small number of areas. There is also a lack of skilled manpower resources.

2.3.6 Italy

Ciancarella et al (1996) indicates that by 1994 GIS was present in two thirds of the regions and in one third of the provinces in Italy. Another one third of the provinces had firm plans for acquiring a GIS. With respect to the medium to large cities, GIS was present only to a limited extent. Ciancarella et al (1996) discuss the political upheavals that have constrained the diffusion of GIS in Italy. The tendency towards decentralization following 1990 reform has seriously affected this diffusion. There has been a limited amount of digital data available as a result of the slow progress made by the national mapping agencies and the Cadastre in developing digital topographic data bases. Amongst the provinces the diffusion is more widespread. Most applications lie in the fields of automated mapping production and thematic mapping. It should be noted that there are no metropolitan area-wide GIS as yet in Italy (Ciancarella et al., 1996).

2.3.7 Portugal

By 1994 Arnaud et al. (1996) indicates that only twelve municipalities in Portugal had GIS, while a further 24 had AM / FM facilities. In addition there was only a limited amount of digital data available, while the length of experience with respect to GIS was minimal or non-existent in most municipalities. Intended applications were mainly related to planning as a result of recent legislation requiring the production of municipal master plans. Proactive government initiatives designed to modernize the Portuguese government were expected to change this situation. In particular the creation of the National Centre for Geographic Information (CNIG) and legislation requiring all municipalities to prepare municipal plans was expected to increase the amount of digital data available. Further more the government has taken the initiative to fund the computerized management of municipal master plans and the development of local nodes for the national GIS.

2.3.8 Poland

Overview

This discussion is particularly relevant to this study as significant work has been done in Poland[11] on formulating policies to enable the implementation of multi-scale GIS approaches. For the experiences of GIS in Poland two publications were focussed on. One publication, by Bartinicka et al. (1996), dealt with two potential GIS implementation models for Poland. The second publication dealt with a GIS implementation plan report for the City of Gdansk by PADCO.

Extent of diffusion

A report by the Planning and Development Collaborative International Incorporated Company (PADCO) on the City of Lodz GIS indicated that the diffusion of GIS was accelerated through the LIS Modernization Program in 1991 (PADCO, 1994d). This programme advocated that LIS modernization should be implemented at the regional level using existing (though updated) information as a system base / " obligatory module". Despite these changes, Bartnicka et al (1996) indicates that the diffusion of GIS was still very limited by about 1994. Only 30 to 40 systems existed amongst the small to medium sized towns (20 000 to 100 000 inhabitants). Furthermore there were few regional and / or sub-regional GIS by this stage.

The central and local database models

Bartnicka et al (1996) describe a local and a central model for the implementation of GIS within local authorities in Poland. In evaluating both models, the authors highlight the high financial, technical and organizational difficulties associated with the implementation of the central model. They conclude that the local model of implementation is more likely to succeed. Of the two models described by Bartnicka et al.(1996: 185), the central model ascribes to a cadastral based implementation approach. In the central model, the creation of any GIS data is assumed to be based in the Departments of Surveying and Geodesy. These departments are responsible for collecting spatial data on parcels, buildings and infrastructure "..at the largest scale (1:500, 1:1000)". Furthermore, various institutions (governmental, self-governmental, co-operative and private) can and in some cases will be obliged to provide the Surveying and Geodesy departments with information. In addition, the data can only be accessed by non-Surveying or non-Geodesy department users upon payment. There are a large number of problems envisaged for this system. These are discussed in the following section under the heading of Poland. In contrast to the pilot projects based on the central model, the pilot projects based on the local model have proved to be highly successful. In the case of Plock region, a GIS database which is now in constant use was constructed within eight weeks. The scale implemented was 1: 25000, the departments which initiated the system were the Planning and Environmental Protection departments. Other local-level pilot projects have achieved success in Szczecin, Swidnik and Sierpc.

Bartnicka et al (1996: 194) argue a number of reasons for implementing projects at a local-level. "The projects at a local-level:

1. are more realistic in scope as they reflect the needs perceived by practioners of local planning offices, utility companies etc;
2. are cheaper and faster to implement because information included into digital map layers are only those which are really needed;
3. are more likely to be successfully implemented in existing conditions (equipment availability, personnel qualifications and attitude);
4. allow for selection of appropriate software;
5. will be implemented only by an enthusiastic team with sound leadership (given the amount of problems to overcome);
6. allow for tailor-made training."

The work by PADCO in Poland (PADCO, 1994 c) focused on the development of a GIS / LIS Implementation Plan in order to achieve an integrated urban information system. The methodology was designed to assist the implementation of GIS/LIS at the local, regional and national levels. This plan provided a large number of system development recommendations[12]. In particular, a key strategy that emerged from the Gdansk project was the creation of public / private partnerships[13] to manage and support GIS/LIS development and operations (PADCO, 1994 c)[14]. The work by PADCO in Poland also provides examples of the problems typically associated with cadastral-based approaches to GIS. These together with the problems associated with a local-level implementation approach proposed by Bartnicka et al (1996) are discussed in section (2.4).

2.3.9 France

The discussion of GIS in France has been left to the end as it provides the best example of a country where a mutli-scale approach to GIS has accelerated the creation of applications for urban developers and planners. Miellet (1996) indicates that by 1996 two thirds of the cities with more than 100 000 population had GIS and that it is used widely in inter-communal agencies.

<u>Overview</u>

The discussion by Miellet (1996) provides an invaluable background into the state of GIS in France. In comparison to a series of other papers on European GIS, this paper suggests that the understanding of urban GIS and strategic management and planning applications has advanced the furthest in France. The paper gives a useful background to the concepts of appropriate scales for particular applications and the importance of decentralization in the diffusion of GIS. Specifically, the importance of selecting <u>an appropriate scale for a functional urban GIS</u> is highlighted by Miellet's work. It also illustrates that only the needs of local authorities (technical management) remains addressed in most cases. While the cadastral approach appears to have been maintained with a limited degree of success, it suffers from a multitude of problems (see section 2.4). Finally Miellet quotes two examples which are unique with respect to the French approach and its success. The first deals with a regional implementation of GIS for policy analysis. The second deals with a multi-level approach to urban GIS. In his concluding discussion, Miellet (1996) draws attention to the concept of linking a regional GIS to a concerted national GIS or "supranational" system[15].

Urban Data Banks (BDU)

Two revolutions greatly influenced the diffusion of GIS in France in the 1980's. The first related to technological developments[16]. The second related to the impact of the Decentralization Acts of 1982. While technological advancements continue in all parts of the world today, the impact of acts which focus on the decentralization of powers to local authorities on the diffusion of GIS cannot be overstated[17]. The decentralization of laws led to a diversity and multiplication in the number of project clients as well as to new needs (Wolf, 1993:14). In response to these needs, the Lengange Commission (National Commission for Geographic Information (CNIG)), recommended that a topographic land ownership plan be prepared which combined the cadastral approach with a topographic element. The two scale-plan (Plan Topo-Foncier) integrated a 1: 5000 scale plan for the whole of France and a 1: 2000 scale plan for areas deemed to be priority zones for structure planning (10 % of the national land surface area) (Miellet, 1996; Denegre, 1989). The results of a user survey illustrated that the 1:2000 scale of the is plan was too restrictive for detailed planning work (Miellet, 1996).

A third factor which has greatly influenced the diffusion of GIS in France is the availability of data. Miellet (1996: 166 - 167) discusses in detail the content of the various data sources available. The following discussion focuses on the scale of each of these data sources. The brief descriptions reveal that essentially a multi-scale approach is being followed at a national level. The following five reference databases are currently being developed in France (Miellet, 1996):

The IGN (National Geographic Institute)

1. The cartographic database (BDCarto)
2. The topographic database (BDTopo)
3. The Georoute database
4. The Digital Cadastral Plan (PCI) of the National Tax Office (DGI)

The BDCarto database[18] can be scaled between 1: 50 000 and 1: 250 000, while the BDTopo database[19] and the Georoute database[20] are used to produce 1: 25000 scale maps and local maps (1: 500 – 1: 2000) respectively. The PCI database covers the whole of France. In order to achieve the multi-scale database outlined above, the DGI has opted for a collaborative data capturing strategy. In addition, it has attempted to impose a series of strict data capture controls on local government organizations (Miellet, 1996)[21]. Miellet (1996) highlights the evolution in the application[22] of GIS that has resulted from the shift from a cadastral towards a multi-scale approach to GIS (Miellet, 1996:173): "In the space of a decade, the introduction of GIS into the urban arena has profoundly changed the vocation of the BDUs. The major implications of this have been mainly in the evolution of the scale of basic reference. The basic plan of the road network is no longer an obligatory development stage and the adopted scales are more often compatible with the work of urban developers and planners. This has had a significant bearing on the time required and the cost of data capture. The long lead-time required for data capture 20 years ago will become part of an unfortunate historical trial run."

2.4 PROBLEMS FACING IMPLMENTATION OF GIS IN EUROPE

The problems facing the cadastral approach may be discussed under the following headings:

1. the slowness of the approach
2. organizational problems
3. data maintenance
4. development of parallel systems
5. applications development
6. data under-utilization
7. digital data availability
8. technical problems

2.4.1 The slowness of the approach

The slowness of the approach has been noted in Germany, Netherlands, Italy and France. In Germany, Junius et al. (1996) describes in detail the slowness of the data capturing process associated with the cadastral approach. Digitization of cadastral maps began in the early 1980's in some local governments, whereas in others it has not commenced yet. The automated cadastral map (ALK) has been completed in only two municipalities and it is estimated that state-wide completion would take a further 20 years (Junius et al. 1996). The local governments have therefore been advised to confine the digitization to the built-up areas. The automated cadastral register (ALB) is in a similar status. The delay has resulted in an urgent need for sewerage system and other utility network base maps (eg. gas and electricity). In Netherlands, the cadastral-based project GBKN has been faced with the same problem of slow progress. Graafland (1996) states: "After many years of work, only a small part of the Netherlands has been mapped in a digital form." He claims that the project failed[23] because of the different interests of the participants (cadastre, utility companies, local government). In Italy, the diffusion of GIS has been severely restricted as a result of the slowness of the cadastral approach (Masser & Craglia, 1996). Ciancarella et al. (1996: 90) comments: "It must be appreciated however, that it will take many more years before all urban areas have digital cadastral maps available". In Italy, the mapping responsibilities in Italy are shared between the Italian Geographic Military Institute[24] (IGMI) and the Cadastre. Since 1986, the Cadastre (The Cadastral Administration of the Ministry of Finances) has been conducting a programme to update its maps and records and convert them into a digital format[25,26]. By 1993 only 27 % of the total 310 000 map sheets had been digitized. To date only a small number of Provinces have complete digital base maps including cadastral and topographical data (Ciancrella et al, 1996).

In France, the "Underground Cadastre" of the City of Lille (1:200) was based on a survey of the road network and information from subdivision plans. " As a result of choosing this very detailed scale, data capture for the 1800 km of roads took 15 years!" (Miellet, 1996: 170). The completion of the data capture for the land parcel management was envisaged to take 23 years (Miellet, 1996). One of the most successful systems was developed for the City of Marseille. Here the first topographic map at 1:200 was produced only 6 years after the system was introduced. A series of digital cadastres initiated in the 1970's for the cities of Paris, Lyon, St-Etienne, Bordeaux and Montbeliard were completed in the mid 1980's (again average of 15 years is suggested for the database completion). The PCI (Digitized Cadastre Plan) for the whole of France is envisaged to take another 30 years. Miellet (1996) summarizes that the problems encountered in the early cadastral-based BDU initiatives arised as a result of technological deficiancies and an underestimation of the time required to capture data that often did not exist or was incomplete (Miellet, 1996: 171).

2.4.2 Organizational problems

The problems associated with GIS in the European case studies were predominantly organizational in nature (Masser & Craglia, 1996). Organizational problems have been observed in Britain, Germany, Netherlands, Denmark, Greece, Italy, Portugal, Poland and France. In Britain, 27.2 % of problems were classed as organizational. The organizational problems included the poor quality of managerial structures for implementing GIS, followed by the shortage of skilled staff and the lack of encouragement from senior staff. "In several cases staff resistance also presented a significant problem." (Campbell and Masser, 1995). In Germany, the organizational problems relate more to the integration of the ALK/ALB system, which remains to be realized (Junius et al., 1996). Certain attribute fields of information which have values dependant upon inputs from departments situated external to the cadastral authorities remain empty[27]. In Netherlands, organizational problems have prevented the adoption of a series of "functional design" standards (GFOs) which have been developed by the association of Dutch municipalities (VGN) (Graafland, 1996: 199). These standards have been defined to standardize municipal information systems and to facilitate data exchanges. Very few municipalities have adopted the GFOs. The major problem preventing the application of the standards is the great differences in the size of the municipalities and in the number and the skills of the municipal staff.

In Greece, Assimakopoulos (1996) highlights the political and organizational issues as being the most problematic. He also notes an unwillingness of end-users to accept computer use as part of their jobs. In Italy, problems associated with organizational issues

S&LI and the City Electrical Engineer's Department (CEED). A high level Project Management Board was set up to oversee the process and a member of the Directorate for Information Systems (DIS) was employed by S&LI and the CEED to carry out the technical analysis. Although contracted by the two users, the DIS employee reported to the Project Board. Although the two users outlined above were chosen to pilot the GIS, it was recognised that one outcome would be the purchase of a single software package which would then be used by all future users. Hence it was considered important to take into account the potential needs of these other users when making the selection.

To this end, the Project Management Board conducted a user needs analysis within the Council. This could be described as a classical GIS analysis, in the sense that it followed a standard international format. Hence the survey sought to identify the potential uses that different branches and directorates within the council might have, and to rank these in priority order, initially within the branches and directorates and then across the council. This process was intended to provide the basis for planning and optimizing the resources that the Council would be committing to GIS, and to cost these resources. The result of the user needs analysis is discussed in detail by Milne (1995).

In setting priorities (Table 3.1 below), it was recognised that priority was to be given to the cadastre, in line with the choice of S&LI as the pilot user and also because this was considered to form the base GIS layer for all other users. However, it was also recognised that the rankings given to the applications at the time of the survey was likely to change as the core system was developed and expanded, and as the Council became more familiar with and appreciative of the benefits of using GIS tools. Hence the report stated that the priority list would "certainly be reviewed within 18 months of implementing the core system". This has not been done to date, possibly because the core system is not yet considered to be complete.

TABLE 3.1: LIST OF GIS PRIORITIES IDENTIFIED FOR THE CAPE TOWN CITY COUNCIL

1	Cadastral and topographical mapping
2	Property Creation
3	Leasing, acquisition and disposal of city land
4	Property transfer and registration
5	Street numbering
6	Land use
7	Plan approval
8	Building works
9	Zoning
10	Census
11	Water Distribution
12	Valuations

3.4 THE CURRENT GIS USER SURVEY

3.4.1 Objectives of the Current User Survey

The primary purpose of the survey was to gain a better understanding of how GIS might be used effectively as a tool to support the upgrading of informal settlements. The experience of Belo Horizonte (with which this research was linked) indicated that a successful GIS for informal settlements could operate with varying degrees of autonomy from a municipal GIS system. Whatever the degree of autonomy chosen, however, it was considered important to define the relationship between the municipal and the local settlement GIS systems, and for this relationship to be accepted by the local authority responsible for the upgrading process. Hence it is important to understand the municipal GIS system. The purpose of this user survey is to gain that broader understanding for the City of Cape Town.

Three broad objectives were defined for the user survey:

1. to document the current state of GIS development within the Cape Town City Council, with a focus on the Departments of Engineering and Planning;
2. to analyze the approach taken to the use and implementation of GIS within those departments; and
3. to explore the potential for GIS, from the perspective of the Council, in the development and upgrading of low-income informal settlements.

3.4.2 The methodology of the survey

Information for the survey was gathered primarily by personal interview. As series of individual interviews was during the period March - April 1996, conducted with representatives of the following branches and directorates of the City Council:

DEPARTMENT	BRANCH/DIRECTORATE
City Engineer	Drainage and Sewerage
	Roads
	Scientific Services
	Parks and Forests
	Cleansing and Water
City Planner	Survey and Land Information
	Town Planning
City Administrator	Information Services

3.4.3 The structure of the questionnaire

Unlike the majority of GIS user needs analysis surveys, which are aimed at establishing only the software and hardware system configuration, the objective of this survey was intended to look a actual use of GIS five years after the introduction of a corporate system. Hence, whilst the structure of the questionnaire took into account the experiences gained from other surveys associated with informal settlements CUSSP / PADCO (1996) and Wiggins and French (1991), it went beyond those surveys in the type of detail that it requested. This questionnaire sought to extract information from the individual branches/ directorates on four issues:

1. the depth of knowledge and understanding of GIS
2. current applications
3. views of potential applications
4. attitudes and exceptions with respect to the use of GIS in informal settlements.

The questionnaire was customised for each Branch or directorate interviewed (see Appendix 2). Information requested on the data used by the interviewee covered the following issues: data name, location, source, type, format, date, scale, accuracy, use, data sharing and data requirements. In order to establish areas of interest for the development of GIS applications, a series of customised potential application tables were constructed for the Engineering branches[7].

3.5 THE CORPORATE INFORMATION SYSTEM (CIS)

The human resources for the CIS are grouped together under the Directorate for Information Systems (DIS). DIS in turn has three project groups, financial, small computer systems, and property and persons group. This last one in turn has two components, GIS and the RDBMS. Each of these two sub-groups has its own project manager. The data itself is "owned" by the individual user who commissioned its collection.

Stavrides argues that a well established network currently exists within the city council, and that data sharing is occurring between branches connected to the present system (Stavridis, 1996). However, this is only applicable to spatial data linked to the Genamap GIS software or to alpha numeric data attached to the Oracle database. It appears that large amounts of data continue to be captured and generated by highly customised information packages throughout Council without the intent of ever incorporating these data into the present system. Furthermore, despite the emphasis placed on the development of an integrated Information Systems (IS) resources unit by the IS Strategy, expertise in the fields of data capture, application software development and use, data analysis, and system construction / installation (all of which constitute fundamental and inseparable components of any IS), remains divided between two branches, namely: the Survey and Land Information branch, and the Directorate of Information Services.

It is believed that the clear divide which exists between these two "powerful GIS" branches, each primarily concerned with maintaining the quality of the present system via their own field of expertise, has been at least partly responsible for the slow development of GIS within the City Council. It is not difficult to imagine, under these circumstances, that a branch of the council seeking advice will ponder for while upon the political repercussions of its action, before selecting which of the two GIS expert groups in Council to approach on a matter which goes beyond data sharing or system installation.

3.6 THE REVIEW OF BRANCH AND DIRECTORATE USE OF GIS WITHIN THE CAPE TOWN CITY COUNCIL

Below is a review of the results of the user survey in ten parts. The review covers the following topics: current applications, data capturing methods, current databases, data sharing, utilization of software, attitude to GIS, potential applications, views and perceptions, level of expertise and a synopsis of the problems which characterize the implementation of GIS in the CCC.

3.6.1 Current applications

There is a general lack of GIS applications throughout the City Council. The main reason given by a number of the engineering branches, which *are* actively involved in the implementation of GIS within the Council (Waterworks, Drainage and Sewerage and Roads), for the lack of current GIS applications is that the branch's database has yet to be to be populated. The Waterworks branch has addressed this problem by placing the capture of the base data as a priority over the development of applications. The Roads branch has more wisely opted for a parallel data capturing and applications development process. Typical applications employed by Metro Transport include determining the number of hotels per suburb for transportation planning. Transport analysis zones have been outlined through GIS for the inner city. Population data were extracted for the initial analysis. MapInfo has been used by Metro Transport. Other transport planning applications involve network analysis and the location of accident spots. The data used in these analyses were acquired from the Roads branch of the Engineering department. The road centre lines were used in the analyses.

3.6.2 Data capturing methods

The Survey and Land Information branch captures topographical and cadastral data using aerial photography and photogammetric techniques. Other data sources which are used to complement the SLI database include: the Surveyor General's Office, the Deeds Office and other local authorities. The information is captured using Microstation and then entered directly into the GenaMap GIS system. Most of the remaining branches interviewed initially generate paper or plastic sheet hard copy records of new base (/ "as built" / role) maps of areas under current development for inventory and inspection purposes. With the exception of the Water branch, the new data is not entered directly onto the GIS system. In the case of Town Planning, the maps are placed onto the system within a year. Within the Drainage and Sewerage branch, project maps are generally kept less frequently than base maps, and are created for new works and extensions. (e.g. Diep river canal). Storm water drains currently being mapped are recorded onto paper (i.e. data which is currently being captured for informal settlement areas is not being entered into GIS) Storm water and sewerage drains which have been captured by CAD are currently being recaptured for certain areas of Cape Town.

3.6.3 Current databases

Data dictionaries

The Survey and Land Information, Water, Drainage and Sewerage, and Town Planning branches were able to provide copies of their data dictionaries. The Roads branch produced the data capturing sheets currently being used to construct a GIS pavement management system. No data has been captured by: Scientific Services, Cleansing, Parks and Forests. There is also no evidence to suggest that these branches are even considering the construction of branch specific data dictionaries.

The Survey and Land Information branch holds the most comprehensive data dictionary in the Council to date. The database is structured into a series of master projects[8] the largest of which are the topographic and cadastral projects. Other master projects include: census, electricity, water, build, parks, roads, drain, metro, zone and meta. The Water branch indicated which data were being captured. The data types that are currently being captured onto the GIS system include water connection types, sources, and use. Other data types, which exist only a hardware format and which will be captured eventually onto the system, include leaks detected, water payments, water quality, consumption etc.

Data problems and maintenance issues

Most of the maintenance and record base maps for the serviced areas have not been documented or produced in hard copy format - let alone captured onto the GIS system. This is particularly the case for the Roads and Drainage and Sewerage branches. All of the engineering utility service branches interviewed lack base maps and records for the informal settlement areas. "Data types such as current levels of service, road maintenance history and costs etc., have not been captured as it should have been" (Roads). In contrast, the Scientific Services branch appeared to have well kept records for many years of time series data[9] (ie. water quality and air pollution).

3.6.4 Data sharing

A number of branches within the City Council claim to make use of the Survey and Land Information (SLI) cadastral and topographic database for reference purposes. These branches include: Waterworks, Drainage and Sewerage, Roads, Town Planning, Metropolitan Transport and Urban Studies. The Town planning branch also utilises various other data sets (bore hole data, population data, property owners and zoning data). The Metropolitan Transport branch has defined transport analysis zones for the inner parts of the city of Cape Town using the SLI database. The Urban Studies branch used GIS to analyse the results of the recent Census. Another data set which has been used by various departments is the Electricity Department's database[10].

The Cleansing, Scientific Services and Parks and Forests branches do not currently use the City Council's database. The Cleansing branch believes that the current system is not shared, due to the lack of accurate base data, and will probably remain so. In addition, the Cleansing branch believes that branch responsible for collecting and dispersing GIS data within the Council has adopted a policy of desegregating information, in a manner which strongly inhibits the data sharing capabilities of the system[11].

3.6.5 Utilization of software

Within the Council, various personal computer , mini computer and mainframe based software suites are used. The various branches which were interviewed can be grouped into GIS software users, non-GIS software users[12] and branches which do not use any software. As most of the branches, with the exception of S.L.I. and Metro Transport, are still in the initial phases of constructing a branch specific GIS system, most of the current analytical applications are performed on non-GIS software platforms. The Metropolitan Transportation branch utilises the MapInfo GIS software. S.L.I. utilises the Genamap system to capture and process cadastral, topographic, land use, census, property ownership, lease and development related data. The Cleansing and Scientific services branches are dominated by non-GIS software packages. Finally, neither GIS nor analytical software is currently being used by the Parks and Forests branch.

3.6.6 Attitude to GIS

The survey revealed the following four main user groups within the Council:

- A dominant technical mapping user group (ie. Survey and Land Information), which manages the municipal GIS database and is concerned primarily with the production of a highly accurate cadastre and the development of property-based management applications.

- A group of engineering-based user branches, which are focusing primarily on utility mapping for the development of operation- and maintenance-based applications (eg. pavement management system).
- A number of disenchanted user groups, in particular the planning and transportation groups, which have initiated separate, independent GIS systems.
- A number of potential user groups, which are resistant towards the implementation GIS (eg. Cleansing and Scientific Services). These groups fail to see how the system may be applied other than for automated mapping and data sharing and believe that GIS should be a user demand driven process completely.

3.6.7 Potential applications

All of the branches except the Cleansing and Scientific Services branches felt that additional applications could be incorporated by the present system. The potential applications of interest lie in the fields of routing, planning, design, overall management, budgeting, and maintenance of the existing infrastructural services. In particular, the Water branch wished to develop GIS system links between the maintenance, revenue and consumption databases. Several potential applications were also envisaged by the Parks and Forests branch[13].

3.6.8 User views and perceptions

There is a general consensus that the GIS facility is being under-utilised. This has been attributed mainly due to "a chronic lack of knowledge of GIS in the Board" (S&LI). Other reasons raised by S&LI. for this situation include a lack and suspicion of computers, and not sufficient support on new applications from top management. Most of the branches interviewed also felt that the Council's GIS software system is suitable to meet the different GIS requirements. However, the Cleansing branch held a very poor opinion of the quality of Council's current GIS database. The Directorate of Information Services (D.I.S.) pointed out the fragmentation in the current software type used throughout the Council. For example, at least four CAD packages are being applied (MapCAD, AutoCAD, Cadie and Genamap Cad). Town Planning indicated that the Genamap system is good in terms of the analytical capabilities, but that it lacks in its presentation capabilities.

3.6.9 Level of expertise

The survey indicated that there is a general lack of GIS expertise throughout the Council[14], while the limited amount of expertise which does exist is distributed between the SLI and Directorate of Information Services (DIS) user groups. This has resulted from the organizational structure and is acting as a brake on the wider development of GIS expertise within Council. GIS was seen as a specialist area, which should be retained firmly under the control of technical specialists. This is patently invalid as an assumption and untenable if an organisation wishes to develop a GIS "culture". It became obvious from the survey that all the GIS users require training in the use of

GIS. A great deal of rivalry exists amongst two expert user groups (SLI and DIS), and it is evident that control over spatial data is seen as a basis for power and control within the Council. The general lack of expertise and knowledge of GIS is reflected by: 1) an increasing demand for a user friendly system, 2) an inability of user groups to sustain initiated applications, 3) a general lack of staff support and 4) a widespread reluctance to explore the analytical capabilities of the GIS system.

3.6.10 Synopsis of problems

The following key problems were identified:

- an inappropriate data capturing strategy
- a lack of engineering-base data on the GIS system
- a lack of data integration and data sharing
- the under-utilization of the system
- the development of parallel GIS systems within the same organization
- the user unfriendly nature of the system
- a lack of infrastructural services based applications
- a lack of applications for informal settlement areas
- a general lack of knowledge and expertise with respect to GIS
- a highly focused distribution of the limited expertise which does exist
- an inability of the various user groups to sustain an initiated application
- a general lack of staff support at all levels in all branches
- the reluctance to recognize the potential capabilities of the GIS system
- an inappropriate implementation strategy
- the need to recognize different accuracy requirements of different user groups
- the lack of a well organized training program
- the lack of an easily accessible user support group

The problems associated with setting up a major GIS system are not limited to Cape Town. The role of GIS in local government is an issue of international debate as indicated in chapter 2. The large spatial component attached to decision-making at this level provides an obvious justification for using GIS. At the same time, however, the multiplicity of users, and the fragmented nature of decision-making, means that the implementation of GIS is fraught with difficulties. Internationally there are two experiences which are particularly relevant to South Africa. These are the United Kingdom and Brazil. The United Kingdom is useful because of the similarities in the two local government systems, with South Africa having adopted the British model of local government. Brazil, on the other hand, has strong similarities to South Africa developmentally, particularly in respect of urban development. The characteristics of GIS in these two countries are discussed in more detail in chapters two and five.

3.8 AN ANALYSIS OF THE GIS POLICY IN THE CITY COUNCIL

To a large degree the GIS of the Cape Town City Council is a product of its time, and reflects the views on best practice as they were perceived, in developed countries, in the late 1980s. The parallel with the United Kingdom has already been drawn. A similar situation exists in the United States. Typical of this thinking is "The Local Government Guide to Geographical Information Systems: Planning and Implementation", produced by the ICMA of the United States. This publication argued strongly that priority applications should drive the GIS, that GIS within an organization should have a 'champion' and that there should be a clear implementation plan. These basic 'rules' provided the basis City Council programme. The programme also followed the recommendation that the first application should be strategic.

The objective in choosing strategic applications to begin the GIS development process is the high profile that success gives the programme visibility, credibility and momentum. This is where the problems began in the City Council. First of all, a six-month lead project took four years, during which time no other major GIS development was possible. Secondly, there is the choice of the lead project itself. It is extremely doubtful whether the choice of cadastre building as the lead project would ever achieve the type of visibility and credibility which was required for the GIS, if it was to gain the type of support it needed to play the central role that was envisaged for it at the beginning. In order to explore this problem more deeply, it is necessary to look at two distinct facets of the City's approach. The first of these is linked to the nature of the organization, and deals with a number of organizational issues. The second facet deals with the relationship between data capture and application development.

3.8.1 Organizational Structure

Stavridiis (1996) indicates that the first step for developing organisations, which is to be followed in initially setting up a GIS, should to adopt a "Planning Approach". At the same time, he also recognises that long term solutions must be sought which will enable South Africa to shift from a developing to a developed country. Implicit in this is the recognition of the importance of distinguishing between three states, namely: where are we now, where do we want to go; and how are we going to get there? This was never really thought through, primarily because the first state was interpreted within a very narrow contextual framework.

In exploring the organisational structure developed for GIS, four issues emerge. The first of these relates to the acceptable level of technology. In this regard it is important to note that the International Institute for Software Technology (IIST) of the United Nations University (UNU) sees GIS as: "important also for the IT development of developing countries" (Bjorner, 1995). Further more, in the experience of UNU/IIST "Developing countries . . . are as able to catch up quickly, in fact to jump across several generations of software technologies, right into the most advanced today as any." Bjorner (1995). Thus the issue is clearly not one of software capacity within the organisation.

This leads to the second issue, which deals with the organisational structure itself. ICMA identify four options in the debate about where GIS should be situated: single were cited as most prominent (Masser & Craglia, 1996: 215)[28]. These problems included "lack of coordination, lack of skilled staff and a general lack of awareness[29]." The lack of coordination results in: extremely slow decision making, poor information flows with other agencies and changes in priority over time. In Portugal, the organizational problems that were identified included internal bureaucratic structures, human resource problems such as the lack of skilled staff and continuing technical support from vendors (Masser & Craglia, 1996). Additional problems included the lack of awareness of GIS and the lack of local champions. The organizational problems encountered in Poland in the Gdansk Surveyor General Office included issues such as the applied standards, management requirements, varying perceptions, staff compensation and analyses and financial planning and analyses. The organizational problems experienced in France, included " a desire to manage the totality of the process in-house with coordination or partnership with external organizations." A similar problem arose with respect to the RGU and PCI national projects, where the prospective users were not consulted. As result many of these projects were abandoned. Similar BDU projects in the 1980s continued to take 5 years[30].

2.4.3 Data maintenance

Data maintenance problems have been observed in Germany and in Italy. In Germany, there remains the lack of a mechanism by which the system can be kept up to date. Even in Germany, which has been characterized as a rather stable country in comparison to other developed European countries, land use changes very fast. "Updates are performed only on request, with the effect that the <u>land use information is notoriously out of date</u>."(Junius et al, 1996: 69). In addition there is the risk of inconsistencies in the updating of the ALB and ALK (Felletschin, 1993). Furthermore, the cadastral approach does not in practice allow the implementation of a mechanism for improving the accuracy of maps[31]. The result is that the maps always remain to be improved by a "later stage incremental surveying procedure" - which never gets applied.

2.4.4 Development of parallel systems

The delays associated with access to data as a result of the cadastral approach has encouraged local and regional government departments in Germany, Italy and Poland to set up their own GIS independently of other agencies. The problems associated with the development of parallel systems include: the duplication of data capture and storage, inconsistency of the spatial reference system and incompatibility of base map geometries (Junius et al., 1996). Similarly, in Italy regional authorities have developed systems to address the inadequacies of current national mapping programs[32]. Both the IGMI and Cadastre do not produce maps at scales of 1:5000 to 1:10000. The regional authorities are attempting to fill this gap for landuse and infrastructure planning. This has resulted in a greater variation[33] in scales, standards and level of currency for maps in this scale range (Ciancarella et al, 1996: 90; Bezoari & Selvini, 1992). In Poland, local authorities have acquired their own data often in partnership with private sector. In Greece, similar practices has led to a proliferation of private sector databases.

2.4.5 Applications development

In Germany, Greece, Poland and France it has been observed that the application of a cadastral approach tends to hinder the development of other applications within the same organisation. In Germany, where the diffusion of GIS has progressed the fastest in surveying, there is not a single city in which surveying is without GIS support. All other applications are far behind. All together, only 19% of all potential applications have been met in the large German cities (Junius et al.,1996). In Greece and Poland, surveying and topographic database management also represent the main applications. Similarly, in Italy, the top-down approach, which is often associated with the implementation of the cadastral-based systems, has inhibited the development of GIS applications. In a project initiated by the Ministry for the Development of Southern Italy, a series of ARC/INFO based GIS systems were to be provided with digital maps to a number of provinces free of charge. Only three of ten provinces accepted the offer. "The other seven refused because of a lack of awareness or skills or because they felt "bullied into it"." (Ciancarella et al., 1996: 100). While in France, there is a lack of planning applications and a lack of applications for areas of little or no economic growth[34] (Miellet, 1996: 181): "The full dimension of geographic information as a support to local planning action has to be understood by local government at the decision-making level. It is necessary to promote a geographic information culture that includes more than just the technical aspects of its manipulation." Further more, the manner in which the cadastral approach has hindered the development of other applications such as planning is illustrated in the following statement: " At the urban level, there is a concentration of localized data appropriate to the use of GIS, while the high profile technical management component of the work of city councils has allowed the early implementation of GIS. This has subsequently provoked the specialist developments that have sometimes been difficult to transform to the needs of applications directed at planning." (Miellet, 1996: 181).

2.4.6 Data under-utilization

The under-utilization of data has been observed in France. The cadastral approach implemented in the PCI has drawn criticisms from user-groups situated in France itself. Miellet (1996) highlights the concern that these databases will remain utilized for little other than the technical management of the information itself. Miellet (1996: 168) describes the controls on the local authority database development process as follows: "The setting up of the data models for the databases and their cataloging has taken into consideration the principal clients of these products, ie. the local authorities. When the specifications were defined, the agenda of local authorities in the field of geographic information was set by the technical services of those authorities. Thus the databases have been designed essentially to suite traditional data management applications."

2.4.7 Digital data availability

A lack of digital data exists in Greece, Italy, Portugal and Poland. The lack of data in Greece has already been pointed out in section 2.3. It is also important to note the lack of even paper-based previous record keeping in Greece. In Italy, the lack of digital topographical data forces local authorities and other GIS users to spend considerable financial and manpower resources in data capturing. In Portugal only 65 % of the country is covered by 10 000 scale orthophoto maps from the National Mapping Agency. Some digital data at 25000 scale from the Army Cartographic Services also exists. In Poland, only half of the country is covered in good quality cadastral information (Masser & Craglia, 1996).

2.4.8 Technical problems

Technical problems were encountered in Great Britain, Denmark, Greece, Portugal and Poland. In Great Britain, 29 % of the problems experienced were classed as technical. Hardware reliability, followed by lack of systems compatibility were the key technical problems. In Denmark, the results of a survey of 33 municipalities revealed that 33 % of the municipalities highlighted technical problems as the most serious group of problems, while data related and organizational problems came equal second (Kiib, 1996: 138). Small municipalities were found to be facing more severe technical problems, whereas the larger municipalities experienced more organizational problems. In Greece, there is a general lack of technical skills and software support.

2.4.9 Discussion

The European countries discussed in section 2.3 may be grouped into countries that are developed and countries that are lesser developed in terms of GIS systems development. The former group consists of countries that are characterized primarily by a universal diffusion of GIS. The latter group consists of countries that are characterized by a limited diffusion of GIS. Based on these criteria, the following countries may be placed into group of greater systems development: Great Britain, Germany, Netherlands, France and Denmark. Similarly, the following countries may be placed into the group of lesser systems development: Greece, Poland, Portugal and Italy. The problems facing the implementation of the cadastral approach groups. However, there are some problems that are either unique to or more dominant in the lesser developed countries. In addition to highlighting the weaknesses of the cadastral approach, the above discussion provides an indication as to why some of the European countries are more "developed" in terms of GIS systems development than others. Two key problems distinguish the lesser developed (in terms of GIS systems development) from the more developed European countries. The first relates to the availability of digital data. While the more developed countries are characterized by a widespread availability of digital data, it is often not available for large parts of the lesser developed countries. A second difference lies in the availability of technical skills. While GIS skills are easily available in the developed countries, very little or no skills exist in the lesser developed countries.

2.4.10 Problems facing the central and local database models

A number of problems are associated with both the central and local database models proposed by Bartnicka et al. (1996). It is clear that the central model suffers from a number of problems that have been experienced as a result of the cadastral approach. These include: the slowness of the process[35], organizational problems[36, 37] and technical problems[38]. Perhaps more important is the fact that the model fails to address the needs of many potential GIS users[39] (Bartnicka et al., 1996: 188). While a large number of these problems were not encountered in the local-level model implementation case studies, technical skills, attitudes and finance remained a problem[40]. A number of other problems which seemed more prominent or unique to the implementation of local-level projects[41] as identified by Bartnicka et al (1996: 194) were as follows:"

1. Even basic concepts are often misunderstood, for example differences between raster and vector data
2. The choice of software is often incidental, resulting in implementation problems.
3. The financial risk of wrong decisions is high.
4. This approach is characterized by mostly chaotic implementation of different and often accidentally chosen off-the-shelf GIS software by local governments.
5. Transfer of data between various units and up in the hierarchy may be difficult due to software compatibility."

2.5 ANALYSIS OF GIS IN THE EUROPEAN COUNTRIES CONSIDERED

<u>Trends in the thinking which has controlled GIS developments</u>

Four trends can be recognized in thinking which has controlled the evolution of the implementation of GIS in local authorities in Europe. These are trends are particularly evident in the GIS experiences in Germany and France and to a lesser degree in Italy, and area as follows:

1. A realization that a cadastral approach is both inefficient and problematic.
2. A realization that the slowness of the cadastral approach has resulted in a proliferation of data sources.
3. A realization that a multi-scale approach to GIS is required.
4. A decision to try to combat the proliferation of data sources by enforcing strict (and possibly unrealistic) data capture controls.

The European countries which have followed a cadastral approach have all experienced similar problems. These countries include Germany, Italy, Denmark, France, Poland, Netherlands and Greece. In the Netherlands, the "slow progress of large-scale mapping project based on Cadastre has led to local authorities acquiring their own digital mapping individually or in partnership with utility companies and private sector."(Masser & Craglia, 1996: 223). Slow progress has also taken place in Italy by the National Mapping Agency and Cadastre. This has led to the development of regional topographic databases and to a profusion of data sources. A similar proliferation of data produced by private sector databases has taken place in Greece, where surveying and topographic and topographic database management represent the main applications. In Poland, almost half of the country is covered in cadastral information. However, the quality of this data is questionable (see PADCO experiences in Lodz in chapter 4). In addition, slow progress of digital data conversion and organizational difficulties has again led to private sector partnerships. Similarly, in Germany local authorities collaborate with respect to the development of digital topographic databases (eg.ALK and MERKIS). In Denmark, municipalities co-manage the cadastral data with the Danish Survey and the Cadastre. In France, the Institute Geographic National, the Cadastre and the local authorities also collaborate on the development of the cadastral database.

The realization that a multi-scale approach is required is best shown by the developments in Germany and France. In Germany the trend towards scale-base initiatives is exemplified in the MERKIS[42] database design. This model is by definition "a scale-oriented unified spatial reference system for local government information systems."(Junius et al., 1996: 70). For the case of France a number of quotations have already been listed in section 2.3 above.

The strict data capture controls can be seen specifically in the France and Germany. Miellet (1996: 167) states: "Faced with the size of the task at hand, the DGI has sought to develop a number of partnerships by defining an operational framework for the development and the updating of cadastral records integrated in GIS and acquired by local government organizations. The principle is simple: digitization cannot be done without the agreement of the DGI which then obtains a magnetic copy of the record and remains the data manager with regards to information up-dating. Special conventions have been agreed with major network managers (the national telecommunications, electricity and gas utilities)."

In Germany, "the core principal of MERKIS is that all local government GIS in Germany are to be based on a unique spatial reference system. In each municipality, only one agency is to be responsible for the administration and updating of the spatial reference system." (Junius et al., 1996: 70). According to Junius et al (1996), the implementation of MERKIS requires major reorganization of local government administrations. This reorganization process has only commenced in eleven large cities in Germany. Further more, Junius et al. (1996) states: "It has been recognized that in most cases the traditional structure of local government is not adequate for the kind of information management envisaged by MERKIS." Some failures[43] of earlier GIS projects can be traced to the neglect of institutional constraints (Cummerwie, 1993). Junius et al. (1996: 72) indicate that an implementation of MERKIS requires: a modification of the existing organizational structures within local government. Furthermore he defines this modification as " a major intervention into a highly complex organizational system, in which responsibilities, interdependencies and procedures have evolved over a long time." The local authority case studies by Junius et al. (1996) illustrates that even in the country of origin, the scale recommendations of the model is followed by only 1 out of every three potential applications.

The needs addressed by the system

In addition to the problems already discussed, an implementation of the cadastral approach leads to a lack of applications for the areas of the least economic growth, and to a lack of applications within the least technologically advanced municipal authorities. The discussion in chapter 4 illustrates that in most developing countries it is not the needs of the informal settlement communities (which are usually situated in the areas of least economic growth) that are addressed by GIS systems. Instead, generally the needs of spatial planners, the needs of formal settlement communities, as well as the needs of the key areas of economic growth, that are addressed. A similar situation is true in the developed countries. In the case of France, Miellet (1996: 168) describes the controls on the local authority database development process as follows: " The second key problem deals with the restricted use of GIS in areas of least economic growth."

As already defined above, the BDU is essentially based on a cadastral approach. The following quotation further suggests that a local authority GIS implementation policy, which restricts itself to a purely cadastral based approach (which usually requires expensive GIS systems and technical expertise) hinders the implementation of GIS in the poorer / less technologically advanced departments of local authorities: "The pattern of evolution which is outlined is like that of the BDU with the progressive establishment of a dichtonomy between authorities that have the information tools for coherent management and planning for whom the digital data are captured and available and those who will remain at the margins of the diffusion of this advanced technology. " (Miellet et al, 1996: 179). In France, the problem of the restriction of GIS applications to the higher level of local authorities has been overcome for the regions which perceive GIS as a tool for planning and additionally as a tool to promote the image of the authority (Miellet, 1996).

CHAPTER 3: A USER SURVEY OF GIS IN THE CAPE TOWN CITY COUNCIL

3.1 INTRODUCTION

The review of GIS applications in local authorities in Europe (Chapter 2) illustrated that the cadastral approach is faced with a multitude of problems. This chapter was written with the aim of establishing whether a municipal GIS in a developing country such as South Africa is faced with the identical and possibly additional problems. A key difference between the European case studies and South Africa is the presence of informal settlements in the latter. Thus a natural extension of the research carried out for this chapter was to establish whether the GIS applications created by local authorities in SA have developed to incorporate informal settlement areas. To address these issues it was first essential to overview the use of GIS in the largest local authority in Cape Town. This was achieved by carrying out a user survey of GIS in the Cape Town City Council (CCC).

The survey had several aims. Firstly, it would give an indication of the main problems facing the implementation of GIS in the CCC. Secondly, it would illustrate whether GIS applications that included informal settlement areas were being developed by the CCC. Thirdly, the survey was essential for research into the potential application of a particular type of planning approach (ie. the Visual Settlement Planning[1] (ViSP)) in Cape Town. Fourthly, it would reveal other issues that need to be addressed to ensure that any other informal settlement upgrading GIS database model would be compatible with the local municipal environment. It is important to note that this when survey was carried out GIS was being implemented in the CCC through a single complex GIS system. This has since started to change[2] as smaller GIS systems have become more sophisticated and capable of deploying[3] and integrating[4] data amongst different systems.

This chapter is written in thirteen sections including this introduction. Sections two to nine comprise an overview of GIS in the CCC. Section two provides the background to both the current, as well as to an earlier GIS user survey managed by the Council (Milne, 1992). Section three discusses the establishment of GIS in the CCC. Section four describes the current user survey in terms of the objectives and methodology. Section five briefly describes the Corporate Information System (CIS) in the CCC. The sixth section presents the results of the survey while section seven discusses the development of GIS in the CCC. Section eight provides an analysis of the GIS policy in the CCC. Section nine identifies key issues that are linked to policy formulation. Section ten analyses several factors that have controlled the diffusion of GIS in SA in the context of the European experiences. Section eleven highlights the differences and similarities between the Council GIS and local authority GIS systems in Europe. Issue of the extent to which GIS applications have been developed for informal settlements is returned to in section twelve. The chapter ends with a section that summarizes the findings of the survey.

3.2 BACKGROUND

GIS is playing an increasingly important role in local government. Between 60 and 80 per cent of all decisions, which need to be taken by local authorities, have a spatial component (Martinez & Abbott, 1998). At the same time, there is also significant potential for the prevention of duplication through the sharing of a spatially linked database. In spite of these advantages, however, the practical application of GIS in a local authority context has not been particularly successful or effective, when measured against its potential. This is illustrated by research carried out in local authorities in the United Kingdom (Campbell, 1994) and in Europe (Masser & Craglia, 1996), and the results of the survey show that many of these problems are duplicated in South Africa.

In addition to the organisational issues, Martinez & Abbott (1998:9) highlight three additional factors that make the introduction of GIS in local government in South Africa even more complex. These are:

1. The shortage of technical capacity within local government[5].
2. Local authorities in South Africa have responsibility for the installation and maintenance of the full range of physical infrastructure services. The nature of these partnerships means that large local authorities are still require extensive graphical database management systems which cover the full range of utilities.
3. South African cities have to deal with increasing numbers of informal settlements. Little experience exists on the use and management of GIS for large numbers of dwellings which lack known, and stable, cadastral information.

In order to understand how these and other factors might influence the introduction of the ViSP approach in Cape Town, a GIS user survey was carried out in three different departments of the City Council. The user survey resulted in a comprehensive report (Martinez & Abbott, 1998). This chapter presents the key results of that survey.

3.3 ESTABLISHMENT OF A GIS SYSTEM WITHIN THE CAPE TOWN CITY COUNCIL

The importance of GIS had been recognised by Technical Management Services Branch (TMS) of the City Council in 1987, and was an important factor in the decision to merge TMS with the Surveys and Land Information Branch (S&LI) [6]. However, while the potential of GIS was pointed out to the external consultants carrying out a study of IT in the Council, they failed to recognise its full importance. As a result, the only recommendation that emerged in this regard was that there should be a further study of the potential for GIS within Council. Such a study was carried out, in-house (Milne, 1992). This study took one year and resulted in two recommendations. The first was that there should be a property and persons project to select a Related Data Base Management System (RDBMS), and the second was that the CADD system in S&LI should be replaced by a GIS system. At the same time, a further in-house study of data management suggested that ownership (or, more correctly, custodianship) of data should be devolved to individual "users" (i.e. branches and directorates), although it should be made available to all other users who needed that data for Council business. Two users were selected to pilot the change from CADD to GIS, namely department GIS; shared GIS dominated by a single department; multi-departmental GIS; and multi-agency GIS. Internationally, Wulfsohn (1995) states that the multi-agency (or corporate) model is favoured in local government because of its innate rationality and comprehensiveness. Antinucci et al (1991) provide the basic argument in support of this system, stating "it is viewed that the major benefit of the corporate or multi-agency model is the reduction of redundant activities among separate departments" (Antinucci et al, 1991:17). This is achieved by departments sharing resources; in particular, the most expensive resource: data[15].

Interestedly, although corporate GIS is espoused as the way to go in international literature (Wulfsohn, 1996:4) only about 15% of systems in British Local Government in 1993 were implemented in a classically corporate style (Campbell and Masser, 1995:82). The same study showed that about 50% of systems were implemented in a "fiercely independent" style, this being "the introduction and development of a GIS by a single department" (Campbell and Masser, 1995:82). The remainder of systems, categorized as "theoretically/ pragmatically corporate" which are groups of departments sharing resources, either by intention or the full corporate system not developing to fruition Campbell and Masser, 1995:82). It seems that departments are intuitively voting with their feet for a system that suits their needs and cultures (Wulfsohn, 1996:4).

The City Council chose a different route to any of those described above. The report of PE Consultants in the early 1990's recommended the centralizing of information but failed to include GIS within this definition. GIS was seen at the time as an application, the responsibility for which would lie with individual departments. The result has been that there is a lack of clarity over responsibility for GIS within the Council. Theoretically the Project Board was responsible for co-ordination, but this body does not function effectively. As a result there was, in practice, no clear responsibility. Equally, because the Board is so ineffective, there was no 'Corporate Client'. Each individual user was responsible for its own portion of GIS. In practice, this meant that the Survey and Land Information Directorate was the most powerful user. This was because it "owned" the cadastral and topographical layers which, under the present system of GIS development, form the base layers for all other users.

In theory, these other users are not contracted or bound to use the S&LI database. For example, they could obtain the cadastral data from the Surveyor General, who owns the only legally recognised cadastral information base. In practice, however, few branches even know this, and would be unlikely to take that route even if they were aware of it. The net result is that the Council effectively operates a 'shared GIS dominated by a single department' with this department being the Directorate of Survey and Land Information.

This may have appeared to be a rational choice at the time, given the strategic objectives described earlier. However, the reality is that the strategic objectives originally identified were themselves inappropriate. This in turn has led to serious problems of functionality. The use of partial data has been discouraged, limiting GIS initiatives in other branches or departments. Where other departments have wanted to establish major systems without waiting for a complete cadastre, they have felt it necessary to set up totally separate systems. Thus the Electricity Department runs what is effectively an independent, parallel system, albeit on Genamap. Metropolitan Transport, on the other hand, have moved completely out of the system and have set up their own GIS on ArcInfo.

The third issue linked to organization is the linkage and relationship between different types of computer software. The PE report failed to grasp the growing importance of GIS technology. As a result information technology was effectively divorced from GIS technology within the Council. Equally important, however, was the failure to recognize the need to create synergy between the GIS and the wider range of software design packages in use within the Council.

UNU/IIST argues strongly that an organisation should have internal data flow links between its individual branches, as well as interfaces to the external infrastructure or environment. Further more, UNU/IIST states that two distinct types of software need to be recognised:

1. software packages, "which support individual planning and operational aspects"; and
2. infrastructure software, "which support cross-function operations: information (i.e. data) interchange and the invocation of procedures in one package from other packages" (Bjorner, 1995).

These goals are achieved through a well-established three-step process which involves: domain analysis, requirements captures and software development. The domain analysis involves identifying characteristics of the environment in which the system is to operate. Criteria such as the nature of the problem to be tackled, the current technological support, staff availability (managers, operators and users), the market (clients), and the computing and communicating platforms. This process is conducted by a combination of software engineers and domain specialists. The processes of requirements capture and software development are further discussed by Bjorner (1995).

The need for achieving a high level of engineering model to GIS integration has also been highlighted previously by Wright (1993), as being essential to the development of engineering-based GIS applications. "From an engineering perspective, the technology of GIS is insufficient as a comprehensive methodology for spatial engineering analysis. While reliable data bases are certainly an important component of an engineering spatial decision support system, the integration of proven analytical modelling and analysis methodologies is also essential. Until we are able to achieve a high level of model to GIS integration, the benefits of GIS will remain limited to simple data manipulation and display functions." The lack of recognition of this issue, and its link to the failure of the GIS, can be traced back directly to the GIS management structure.
The fourth, and final, issue is that of training. Little, if any, thought was given to this issue. GIS was seen as a specialist area, which should be retained firmly under the control of technical specialists. This is patently invalid as an assumption and untenable if an organisation wishes to develop a GIS "culture". It became obvious from the

survey that all the GIS users require training in the use of GIS. In addition to a training which overviews the capabilities of the Council GIS system, there needs to be a greater inter-branch awareness of each branch's database structure, status and development. As an example of the urgent need for greater inter-branch GIS awareness, during the interview with the Roads branch, the strongest GIS supporter in the City Engineer's Department, the interviewee was referred to the Directorate of Information Services for the technical details of the questionnaire.

If GIS utilisation is to be improved, it is essential that the applications development process be driven from within the branch and that the analytical requirements of the various branch members be communicated to the applications developers within the Council. Ideally, of course, this means that applications should be developed by the users themselves. The members of a branch can only make maximum use of the GIS system at their disposal if they are aware of the system's capabilities and of the branch's database status. This need for the education of branch personnel in GIS may be inferred from the following statement by the Directorate of Information Services (DIS). "Hence the application of GIS is financially viable in the initial stages of the project, *and becomes nonviable as the responsibility for analysing and maintaining the data shifts to the individual engineering or other Council branches concerned.*" Clearly this suggests a need to develop the data maintenance and analysis skills within the personnel of the individual branches.

The general lack of training within the individual branches supports the general point made in the previous section about the narrow expertise base, which has resulted from the manner in which the GIS knowledge is securely "kept" by the branches which are experts in the field of GIS (i.e. DIS and SLI). Evidence of a strong internal 'rivalry' was clearly identified in the surveys, although this may not be evident from the interviews on record. This perception derived both from the attitude of those interviewed as well as from the numerous "off the record" comments. In fact, the GIS related tensions within the Council can best be described as "common knowledge", whilst simultaneously being kept completely "off the record". In asking the question "why the rivalry?", the conclusion has to be drawn that control over spatial data is seen as a basis for power and control within the Council. Such a situation extends far beyond the training issue. It is acting as a brake on the wider development of GIS expertise within Council and in so doing is limiting the development potential of the City.

The above discussion has focussed on four specific issue related to the organisation of the GIS. In more general terms, it is interesting to correlate the situation in Cape Town with general experience internationally. Wong et al. (1996) in the United States have outlined ten attitudes which can lead to the failure of a GIS project. Seven of these ten attitudes that apply, to a greater or lesser extent, to the Cape Town experience are as follows:

1. Waiting for the entire database to be developed before developing applications.
2. Once the needs have been determined, allowing no changes.

3. Implementing a user-unfriendly system.
4. Providing no user access or training.
5. Not bothering with management support.
6. Defining or designing the GIS project in a 'closet'.
7. Having false or unrealistic expectations.

The organizational structure chosen by the Council must carry a large share of the responsibility for these failings. However, they are also closely linked to a second characteristic of the Cape Town system, namely the approach adapted to the relationship between data capture and GIS application development.

3.8.2 The relationship between data capture and application development

In theory the whole thrust of the City Council's GIS development programme is applications driven (Milne, 1995). In practice, however, a very different approach emerges. From the list of 80 potential GIS applications reported by Milne (1995), 12 GIS priorities were established. Of these the first four required the construction of a cadastre. Because the group responsible for managing the GIS system were also responsible for all four of these priorities, this defined the future development of the GIS system and limited it to a data collection exercise.

This did not have to be the case, as the separate development of the Metropolitan GIS system indicates. What this approach reveals is a specific interpretation of GIS (that the professional surveyor) which fails to recognize the wide diversity and creativity of this developmental medium.

It has been known for a number of years that GIS applications exist on different levels. The ICMA defined three distinct levels: wide area planning (small data bases); locality analysis (more data and greater detail); and finally facilities management, tax mapping and engineering design. These distinctions are critical. There are a large number of GIS applications that do not depend upon a high-accuracy cadastral base for their implementation. In fact, Campbell (1994) specifically identified, among the four factors that enhance the chances of success in a GIS:

1. The development of simple applications producing information which is fundamental to the work of the potential users, and
2. User directed implementation, involving participation of all stakeholders in the project.

This lack of recognition of what may be termed low-accuracy GIS projects, has severely limited the expansion of GIS within the Council, and particularly within the Directorate of Planning. Even where a more detailed cadastral information base might be utilized, the existing system is too complex and cumbersome for widespread use. The degree of expertise, and ongoing level of use, which is required to utilize the system effectively precludes its use by the large majority of planners and engineers. This is becoming apparent from the slow, but steady increase in interest that is being shown in lower level GIS products such as MapInfo. The net result is that the Council's expensive and valuable asset, namely geographical or spatially referenced data, is under-utilized. In addition, the cadastre-based approach has led to a complete lack of the base data required by the non-technical mapping and surveying user groups. The engineering user groups in particular are faced with a lack of utility-related base data. This problem may be gradually overcome by several modifications to the present data capturing strategies[16].

3.9 KEY ISSUES LINKED TO POLICY REFORMULATION

The GIS system operated by the City of Cape Town is not capable of providing a widespread GIS system for City as it is currently structured, at least within the short to medium-term[17]. This section deals with the key areas needing to be addressed if the existing GIS system is to be made functional.

3.9.1 GIS hardware

The current GIS system is cumbersome and not in the least user friendly. In its present form it is poorly suited to the wider needs of the City. If the existing system is to be retained, then steps have to be taken to provide a more appropriate, and user friendly, interface, between this system and the users. In addition, there has to be greater recognition of the different needs of users. Because the Council GIS development system focussed solely on the 'doers'[18], the capacity to develop the GIS was severely restricted. This constraint was further compounded by the emphasis on the cadastre and the locating of the system in one specific department, which has limited even the 'doers' to a small group of less than ten people. The way round this problem is to utilise an interfacing system which will effectively manage the GIS system. A good example of this is the new Intergraph GeoMedia system. A second is that being developed by Autodesk for the Intranet. The existing GENAMAP system would remain, but would be used primarily for georeferencing of the existing database.

3.9.2 Organizational structure

The current organizational structure is inappropriate for the development of an effective GIS system. At present one user effectively controls the entire system. If the City is to move to an applications driven approach, then a distinction need to be drawn between the management of the GIS system and the users. The management of the GIS hardware needs to be separated from the cadastral base and the setting up, and ongoing maintenance, of the cadastre, should be moved to a user group. Then, within the different user groups, there needs to be an individual assessment of accuracy requirements which is linked to the specific application[19]. The changes proposed here are similar to those introduced by the Greater Johannesburg Metropolitan Council, which have resulted in a demonstrable expansion of GIS utilization.

3.9.3 Data sharing and integration

There are two issues that need to be considered with respect to data sharing and data integration in the CCC. Firstly, in contrast to the general trend towards systems and data integration, which characterises the system as a whole, there seems to be a general lack of awareness relating to the data capturing and processing activities within the different branches and directorates which utilise data of common interest. This is particularly evident amongst the Water[20], Drainage and Sewerage[21], and Scientific Services[22] branches. The importance of data capture management has been recognised in Germany in the form of a technical information sheet which lays out standard practices (Schubert, 1995). It is essential the various data capture initiatives within the CCC should adhere to a data capturing standard which will facilitate future data sharing activities, both internal and external to the Council.

Related to the potential for sharing data, is the issue of software integration. Software integration may be achieved by writing data format conversion scripts in a variety of Application Programming Languages (APLs)[23,24]. Alternatively, one may use a number of standard conversion drivers already exist for the larger software suites (e.g. Microstation, Oracle etc.). The first step is to establish whether the software's output format is compatible with the Oracle conversion driver. If this is not the case, the individual branch should seek to customise its software to write output in a format which is configured for Oracle as the database receptacle. This would be the most appropriate DBMS output format to select, as it is currently being utilised by S.L.I. and the remaining GIS users in Council. In addition, the data which has already been processed by customised software could be converted by an APL, or reprocessed by the recustomised in-house software. This will enable what has been referred to as "seamless integration" to be achieved.

There are three levels of integration which may be considered in terms of organisational data flow integration[25]. The first being at the inter-branch level, the second at the intra-branch level, and the third between an individual branch or a composite of branches and an external agency. It is believed that most of the municipal branches should strive for the first two levels - in other words, internal data flow integration should be the preliminary primary goal. Secondly, the third level or external data integration may be aimed for by branches dealing with crisis situations. In particular, the Drainage and Sewerage branch may find it useful to interact with Metro Transport for dealing with flooding problems. Metro Transport may already be applying the data integration procedures outlined above in co-operating with health care agencies in Cape Town.

3.9.4 Applications development

It is believed that the construction of a database within each branch[26] should be an application driven process. This will ensure that motivation will be retained throughout the data capture process, and will also reduce the amount of data redundancy in the resulting database. A better appreciation of exactly how the system will be applied should be sought early on in the data capturing process by the participating branches. It should be remembered that only a very small "real" data set for the area of interest is required to test an application. Alternatively, a true size municipal data set from another local authority, or possibly even a "pseudo data set" may be used in order to develop and test applications.

3.9.5 Level of expertise

Two recommendations arise from the level of expertise observed in the City Council. Firstly, there is a need for a well organised and integrated training programme, which encompasses all GIS users, which reflects their differing levels of need. The programme must be structured to build the internal technical and analytical capacities of individual user groups. The applications development process must be a *user driven* and *user maintainable* phenomenon for it to succeed. Clearly this suggests a need to develop the data maintenance and analysis skills within the personnel of the individual branches. Secondly, there is a need for easily accessible user support in various forms. This may be achieved by implementing: 1) a user support group which may be contacted telephonically or by e-mail, 2) access to on-line help manuals to enable users to learn how to use application programs, and 3) graphical user interfaces (GUI) for dominant user groups. The GUI option is not recommended as this option consumes a great deal of the system's processing time, and could thus slow the system down incredibly.

3.10 ANALYSIS OF GIS IN SA IN THE CONTEXT OF EUROPEAN EXPERIENCES

<u>Analysis of GIS in SA in context of European experiences</u>
In analyzing the implementation of GIS in SA in context of the European experiences, three issues require consideration. Firstly it is important to note that in contrast to the developed European countries which have undergone significant decentralization and privatization processes, South Africa is still in a process of socioeconomic and political reform. Secondly, that despite these differences, South African GIS initiatives are based on developed country systems, and as a consequence are faced with the cadastral approach problems facing developed countries, as well as with additional problems unique to informal settlement bearing developing countries. Thirdly, that the differences in the level of GIS diffusion and GIS experience between the developed European countries and South Africa, must be considered before simply attempting to adopt strict data capturing controls and data standards as recently defined in Germany and Netherlands.

The impact of decentralization processes on the diffusion of GIS in the European countries is referred to in numerous case studies (Masser et al., 1996). Miellet (1996) remarks on the impact of the 1982 Decentralization Acts as follows: " These Acts transferred responsibilities notably in town planning, in structure plan-making and infrastructure management to local government which as a result started looking for information technology solutions to assist its decision-making in these fields. It is clear that these major institutional changes are at the root of the rapid increase in demand for GIS at all levels of local government: urban authorities, departments, and regions."

How does the situation in South Africa compare to the institutional contexts defined for the European countries? The SA local authority institutional context may be characterized as one of great political instability and reform, limited financial and manpower resources, contracting of work to private sector, and recently a very limited amount of proactive modernization methods. Privatization of utilities and decentralization of powers to local government is only just beginning. South Africa differs significantly from the developed European countries in that utility companies still need to be developed. Some privatization has occurred - mainly electricity (ESKOM) and in some parts of the country water provision through the creation of Water Boards. Both are using GIS. The remaining utility services: drainage and sewerage, roads, cleansing lag behind. Another service privatized is the Metro (railways). Thus on the basis of the institutional context, one would expect the diffusion of GIS in local government in South Africa to lag behind the more modernised developed European countries such as England, Netherlands, Germany and Denmark.

This situation is clearly indicated by a recent survey on GIS in government organisations in South Africa (van Helden, 1999). The results of the survey showed that only 155 out of 694 government organisations (22,3 %) have adopted GIS technology and that only around 20 % have plans to start a GIS in the near future (van Helden 1999, p. 132). The highest level of GIS adoption is at the provincial level of government (42,5%), followed by the national (29 %) and local level (19 %). While the survey suggested that the diffusion of GIS at the metropolitan level in SA compares quite favourably with the UK and even with the rest of Western Europe, the same is not true for local government. Van Helden (1999, p. 133) clearly states that the diffusion of GIS in local government in South Africa lags behind the United Kingdom: " Taking the total figure in consideration we are behind the UK specially if we keep in mind that the UK figures are for 1993. By 1993 29 % of local governments in the United Kingdom already had GIS facilities and 37 % where planning to acquire GIS in the near future (Masser et al. 1999, p. 53)." With respect to the length of GIS experience, van Helden (1999) reveals that while the first GIS in SA were started during 1979, more than 87 % of all authorities had acquired GIS facilities since the beginning of 1990. This is similar to the situation in Europe where most local authorities purchased GIS since 1990 (Masser et al., 1996).

The multitude of problems facing the cadastral approach in the developed and developing countries have already been discussed. The trend towards collaborative data capturing approaches in the European countries has also been mentioned. This trend has been adopted to deal with the magnitude of the task of building national digital topographical and cadastral databases. It is clear that collaborative data capture ventures will play a significant role in maintaining the cadastral database building component of a multi-scale approach in the developed European countries. However, the potential for implementing such approaches in South Africa and in other developing countries is far more limited than in the developed countries. The main reason being that the decentralization and privatization processes have yet a very long way to go in South Africa. Nationally effective collaborative data capturing ventures require a high level of GIS diffusion and a widespread occurrence of GIS skills. The widespread occurrence of GIS in local authorities and in utility companies in South Africa has yet to take place. As a consequence, there are fewer potential partners available for creating such "special conventions".

The quotations listed above from Junius et al. (1996) on the problems facing the implementation of the MERKIS database model raises certain questions with respect to the applicability of such an approach in South Africa. One is tempted is ask questions such as: how effectively could the implementation of restrictive data capture measures be employed in South Africa? How would these potentially scale-based and accuracy based restrictions influence the development of GIS applications for informal settlement upgrading projects? Would it imply that the local authorities (and possibly other bodies) would be unable to contribute effectively to local informal settlement database initiatives? The lack of success in the maintenance of data standards in some of the world's countries leading the way in GIS developments (Germany and Netherlands) suggests that the implementation of highly restrictive data capturing controls in developing countries are doomed to fail.

In particular, there are two problems with meeting the MERKIS model requirements in South Africa. Firstly, the restructuring of local government in South Africa involves an ongoing process of the redefinition of responsibilities, interdependencies and procedures in local authorities. It is unlikely that the roles and responsibilities of local government will be clearly defined in a short period[27]. Secondly, it is highly unlikely that in a country such as SA., where major organizational modifications are already being made to retain some form political stability, " a major intervention into a highly complex organizational system" would be welcomed or even at all possible. Clearly the implementation of a MERKIS type model will remain unpractical for the vast majority of developing countries for many years to come. Yet the model illustrates an example of how a purely cadastral approach has led to the realization that a multi-scale approach to urban GIS modeling is required in even the most developed countries.

3.11 COMPARISONS OF THE CCC GIS WITH GIS SYSTEMS IN DEVELOPED EUROPEAN COUNTRIES

An initial consideration of the City Council GIS in the context of the European experiences reveals that the Council's GIS resembles the early purely cadastral GIS initiatives implemented in the developed European countries. As a consequence, the Council's system is faced with many of the problems which characterized they early cadastral based systems. Furthermore, although the Council's GIS implementation approach has been based on an approach defined for developed European countries, the Council's system is situated in a country faced with constraints similar to those facing developing European and other developing countries of the world.

Similarities

Many of the earlier GIS initiatives in the developed European countries were considered as failures. For example in France, Miellet et al. (1996: 168) comments: "A number of failures in the 1970s, linked to the implementation of systems for managing geographic information in local authorities, raised questions about cost-benefit analysis for digital information use." Similarly, Dupuy (1992: 37) comments: "French local authorities do not seek, with the exception of some rare examples, organizational revolution. Elected staff members have not been really aware of the information technology potential. Staff have been very slow to take up the information technology tool." It has already been shown that the City Council GIS is an underutilized and ineffective system.

There are several similarities between the Council's GIS and systems in local authorities in both the developed and developing countries. Masser and Campbell (1995) indicate that the majority of GIS systems in Great Britain, Germany, Portugal, Denmark, Greece, France and Poland were purchased since 1990. Thus GIS has been within the City Council for about the same length of time (since about 1987), if not longer than many of the local authorities in Europe. As in local authorities in Greece, Poland and Germany, GIS in the City Council is applied mainly for surveying and for topographic and cadastral database management. Other similarities include the dominance of the ArcInfo software. The European local authorities are dominated by Arc/Info software in Greece, Italy and Britain. In South Africa, ArcInfo dominates the metropolitan GIS systems. A number of the characteristics of the City Council's GIS resembles the characteristics of local authority systems situated specifically within the developing European countries. The institutional context facing the implementation of GIS in the Council resembles the institutional contexts facing local authorities in Italy, Poland and Greece. The extent of the diffusion of GIS in South Africa resembles the status in Italy, Portugal, Greece and Poland. The lack of digital data (for the informal settlement areas) facing the City Council resembles the lack of digital data facing local authorities in Poland, Greece and Italy.

Similar problems

A number of similarities can also be drawn from a comparison between the problems facing the Council GIS today and the problems associated with cadastral approaches in Germany, Italy and France. The problems associated with the implementation of a cadastral approach in the City Council and in local authorities in these countries include:

1. The slowness of the data capturing process associated with the cadastral approach.
2. Organizational issues including the lack of database integration.
3. The lack of a mechanism by which the system can be kept up to date.
4. The lack of a mechanism for improving the accuracy of maps.
5. The development of parallel systems and all of the problems associated with such developments. These associated problems include: duplication, inconsistency of the spatial reference system and incompatibility of base map geometries.
6. The lack of other applications within the same organization.

Problems associated with the cadastral approach in France specifically, which are present in the City Council GIS include:
1. Specifically the lack of planning applications.
2. The restricted use of GIS in areas of least economic growth.
3. The restricted use of GIS within the less technically advanced departments.
4. A total in-house management of projects. Prospective users were not consulted and as result many of these projects were abandoned.
5. A lack of awareness of GIS and a slow uptake of the technology.

Differences

A number of the institutional differences between South Africa and the European countries are discussed in chapter 4. Here only two additional comments will be made here before returning to the discussion on the problems facing the cadastral approach. Firstly, it is important to note that the lack of planning applications experienced in France and in the City Council is not typical of all developed European countries. In the City Council the lead department is clearly the Surveying and Land Information department followed by the Directorate of Information Services. In contrast, in many of the British local authorities, the leading department is planning. The second comment relates to differences arising from the different economic and technologic resources available to the CCC as opposed to the European countries. Firstly in Cape Town there are not as many locally developed GIS to choose from as in Europe. Products are generally developed overseas. This implies that in areas outside key CDB metropolitan centres (eg Johannesburg in SA), it is difficult to get software support. Secondly, associated with the lower level of GIS diffusion in South Africa is the lower potential for collaborative data capture ventures. This has already been discussed above.

Different problems

A number of problems facing the application of the cadastral approach in the City Council, were either absent or far less evident in the cadastral experiences in Germany, France and Italy. These problems were however typically encountered in cadastral approaches in the developing European countries such as Greece and Poland and included the following:

1. A lack of engineering base-data on the GIS system.
2. A lack of data integration and data sharing.
3. The user unfriendly nature of the system.
4. A lack of infrastructural services applications.
5. A lack of applications for informal settlement areas.
6. A highly focused distribution of the limited expertise which does exist.
7. A general lack of staff support at all levels in all branches.
8. A need to recognize different accuracy requirements of different user groups.
9. A lack of a well organized training program and an easily accessible user support.

3.12 THE ROLE OF GIS IN INFORMAL SETTLEMENTS IN CAPE TOWN

This section has purposely been placed after the discussion. The integration of Ikapa with Cape Town only took place at the local election, although several departments of the City Council had been working in Ikapa for a year or two before that. Hence Ikapa did not fall within the City's jurisdiction with respect to detailed management activities. Any gathering of geo-referenced data thus arose more from the difficulty of separating out spatially intertwined areas rather than from a conscious policy decision.

Once the decision was made to start collecting Ikapa data in 1995, a second difficulty arose. A large proportion of the dwellings in Ikapa is 'illegal' in terms of current legislation. These dwellings are predominantly of two types: those situated in informal settlement areas, and those in the yards of formally established sites. This makes it extremely difficult to develop a cadastre by the route followed in the former City Council area. Dwellings have been located spatially by digitizing from aerial photographs, but to a lesser accuracy than is the case for the rest of the cadastre. The result is that Ikapa does not fall comfortably within the existing data capture programme, and the Departments of the Council have had to adopt a different approach to GIS in that area. This section looks firstly at the current approach and then analyses this approach in the light of the findings developed in the previous section.

3.12.1 The current situation

The Survey and Land Information branch indicated that although historical data was available, very little is on the database, and certain parts of this data are being scanned. In terms of the entire Ikapa database, only 35 % have been captured at this stage (S.L.I.). The land use and property ownership information is currently being placed on to the UNIX system. The financial systems data (consumption and costs) were being captured at the time of the survey and was expected to be completed later in the year. Any remaining data is taken across in ASCII format from Windows to the UNIX system. The following aerial photographs are available: 1994 colour photographs at a scale of 1 in 10 000; 1995 black and white photographs at a scale of 1 in 3 000.

With regard to physical infrastructure, the situation when City Council officials examined the Ikapa records was bleak. The was negligible information, even on paper prints. The Drainage and Sewerage branch indicated that "approximately only 30 % of Ikapa is supplied with cleansing services. In the remaining areas, buckets are emptied out into the streets. The cleansing system requires a complete restructuring. Sewer and storm water drains exist, but have not been maintained and are no longer functional. The design capacities and layout of the drainage system must still be mapped. Essentially all of the services provided must be upgraded." As a result, the new Council let a series of contracts to Consultants to map the existing infrastructure. This mapping work is expected to be complete by the end of 1997. Currently this information is being collected using paper prints. At this stage no decision has been made on the speed of conversion of this information into a digital format.

On a more general level, none of the Engineering Department's branches have applied GIS to upgrade the infrastructure services provided to low-income / informal settlement areas in Cape Town. The Planning Department's Survey and Land Information branch (S.L.I.) has applied the GenaMap system to produce plans for the Vrygrond informal area and the Mitchell's Plain low-income area upgrading projects. The system has also been used by S.L.I. to identify areas of over crowding, unemployment, vacant land, high crime rates, and poor health and education. However this type of development work remains extremely limited.

3.12.2 GIS development of informal settlements

The approach to the use of GIS in informal settlements is extremely conventional, and is based upon the same data collection mentality that drives the GIS system in the rest of the City. The major problems facing the provision of services to Ikapa are seen to relate to the maintenance and construction of roads, sewers and storm water drains for the formal areas. It is perceived that there is a lack of sewer records and of management and health related services such as cleansing, sanitation and water provision. The infrastructure, which was planned 30 years ago, has not been maintained over the last 10 - 20 years and must be upgraded to meet the present demands. At this stage, informal settlements and backyard shacks are seen as problem areas to be dealt with under the 'Integrated Serviced Land Project (iSLP)'. Hence the major concern related with these dwellings is their impact on conventional services standards. With backyard shacks, for example, the occurrence of houses on top of sewers is seen as particularly problematic. In informal settlements, storm water flooding and fires present problems during the wet and dry seasons respectively. Accessibility is a key problem identified by the Cleansing branch. Roads are impassable and it is difficult to access gully grids. Illegal dumping is particularly problematic in the township outskirts. Stray dogs are also a problem.

A major blockage to the development of a useful and meaningful GIS system stems from the strong 'compartment' structure of the Council. There is negligible use made of different types of data. Thus one of the key issues inhibiting the application of the analytical capabilities of GIS is the extremely limited availability of socio-economic data for the informal settlement areas in Cape Town. The socio-economic data analyses conducted by the City Planner's department to date have studied relationships and trends purely between socio-economic variables (City Planner's Statistical and demographic Information, 1994). No studies which examine the relationships between the existing utilities infrastructure and socio-economic data on an analytically powerful platform have been conducted.

Demographic statistics for Langa, Gugulethu and Nyanga include: population (age by dwelling type), gender of household heads, education, monthly income, income earning activity, household size and persons per room. However, the raw data is of a very low resolution and has either been expressed as a percentage of a number of shacks surveyed per informal settlement area , or as a population number per housing type per informal settlement area. The current social research programmes are being conducted at the macro, regional, city and local levels, and as sectoral /special interest studies (de la Harp, pers. comm., 1996). All of these again represent sampled surveys.

It is interesting to compare this with the approach to data integration taken in Belo Horizonte, Brazil, where the GIS system provides the backbone to the upgrading strategy. There, the information acquired *(and required)* for informal settlement upgrading in Belo Horizonte has been collected at the domicile or dwelling unit level (A.V.S.I. pers. comm., 1996). Data types such as the number of people, interviewee details, dwelling construction material, level of each service provided, and so forth are collected on a *per dwelling unit* basis. It is believed that the 1996 Census will provide the required level of information, however it will be a long time before the results become available. Coupled with this lack of socio-economic data, this survey has illustrated that there is a general lack of base maps and maintenance records for all the utility services provided to Ikapa. Essentially, the type of information that would be really useful for detailed local informal settlement planning and engineering GIS-based projects simply does not exist at this point in time.

In conclusion, the approach to the use if GIS in the very low income and informal settlements of Cape Town presents in microcosm all the flaws and weaknesses of the City's current approach to GIS which were described in the previous section. It also highlights the sterility of that approach. While data on existing services can be mapped, and different branches see opportunities for GIS to be used to gather and store information (on the tree population of Ikapa for example), the existing GIS system is simply incapable of providing a GIS base for settlement upgrading. There are no mechanisms in the system to accommodate a Belo Horizonte type approach, for example. If GIS is to provide a basis for informal settlement upgrading in Cape Town, then this will have to be done using a completely new approach.

3.13 FINDINGS

The survey has shown that there is an urgent need to develop G.I.S.-based applications for upgrading the infrastructure services provided to informal settlement areas in Ikapa. It clearly illustrates that even the simplest analytical capabilities of GIS such as buffering, reclassification / registering, spatial query building etc., have not been used by the majority of the branches in Council. This is understandable for the low-income informal settlement areas - where there remains a lack of attribute data and a lack of base maps to capture. However, very little evidence exists of any analytical uses in the formal settlement areas where base maps, maintenance records and attribute data are available to a great extent. There is definitely a general lack of knowledge with respect to firstly, the analytical capabilities of a G.I.S. and secondly, the potential benefits of an integrated information system. There is little consensus amongst the branches interviewed in terms of the current extent of data sharing, and the degree to which the data sharing capacity of the system will be exploited in future[28]. There is however, a great deal of consensus on the under-utilisation of the system. It is doubtful as to whether the current problems should be simply ascribed to the "transitional stage" within Council that accompanied the recent political developments in South Africa.

CHAPTER FOUR: A REVIEW OF GIS APLICATIONS IN DEVELOPING COUNTRIES: GENERAL STATUS AND THE DEVELOPMENT OF APPLICATIONS FOR INFORMAL SETTLEMENT UPGRADING

4.1 INTRODUCTION

In chapter 2 it was shown a number of European countries that are lesser developed in terms of GIS systems development are characterised by a lack of digital data availability. The overview of the Cape Town Council GIS showed that GIS in Cape Town is characterised by the same problem. However in the latter case, the lack of digital data is a problem primarily in informal settlement areas. In this chapter the use of GIS in a number of developing countries was reviewed with two key aims. The first was to establish whether the problems encountered in the Council were unique to this system or whether these problems are shared by systems in other developing countries. The second was to determine the extent to which GIS applications have been developed for informal settlement upgrading in other developing countries. Taylor (1991) provides an excellent review of GIS in developing countries. Taylor's paper gives one a general outline of the problems facing developing countries at a national scale. His discussion highlights the need for placing the database design and development process of developing country GIS systems into the context of the problems facing these countries, instead of adopting existing systems which are designed to meet the needs of developed countries. He also highlights the need for having GIS projects driven by indigenous scientists as opposed to by foreign aid agencies and consultancies. Where Taylor's discussion remains lacking is in that he does not provide either a mechanism or a GIS model by which to achieve the goals he has outlined. He also tends to ignore the role of local authorities in the GIS development process. Yet the work by Masser et al. (1996) (see chapter 2) has clearly illustrated the importance of local authorities in the diffusion of GIS throughout Europe. In Taylor's work there is no reference to informal settlements per se, only "developing countries". Thus the specific urban settlement dynamics which distinguish formal and informal settlements are not discussed. The concepts of sustainability and sectoral models amongst a series of other issues are also not discussed. In addition, no attempt is made to embody the failings and successes of existing developing country GIS systems into a database model for the development of future databases within these countries. Nevertheless, Taylor (1991) remains a key paper in the literature on GIS in developing countries.

Chapter 4 aims to highlight the key problems facing the implementation of GIS in developing countries. A second objective is to identify the requirements of a sustainable and effective GIS in a developing country. Together these two factors provide an essential background for the database model developed in chapter 6. The chapter commences with a listing of criteria that have been used to analyse the various systems considered in this study. This is followed by an overview specifically of informal settlement upgrading applications driven by two prominent international development agencies. A number of GIS are then considered firstly in the African context, and secondly within the context of other non-African developing countries. In the former the emphasis is placed on GIS in South Africa. This is followed by a synopsis of the problems facing the implementation of GIS in these countries and by a number of comparative analyses. The status of GIS in the developing countries is first compared to the European countries (discussed in chapter 2). The chapter ends with a focus on South Africa again in the last section, which compares the Cape Town City Council system to other developing country systems and to the Gauteng Metropolitan Council system.

4.2 ISSUES CONSIDERED IN THE ANALYSIS OF GIS SYSTEMS OCCURING IN DEVELOPING COUNTRIES

The issues considered in the analysis of GIS systems occurring in developing countries may be grouped as follows:

1. data availability
2. political and bureaucratic
3. socio-economic
4. technical
5. implementation
6. system development
7. database design (structural)
8. database design (conceptual)

The selection of the criteria considered under each group of issues was determined by referring to previous studies (Masser & Craglia, 1996) and by focusing on those issues that would provide a useful background to the GIS database model proposed in chapter 6. The issue of data availability refers to the availability of both digital and hard copy data. The political and bureaucratic issues include the institutional context, government stability and government structure. The issues discussed under system development include the sustainability of GIS system, the main applications, initiators of system and the scales of photography used for mapping. The structural issues discussed under database design include the structure, content, the basic spatial unit employed and the level of application of the database. Whilst the conceptual issues discussed under database design include the GIS needs of addressed by the system, the requirements of database model and the GIS needs of informal settlement community. These issues are discussed to varying degrees under each of the countries The focus has been placed on describing:

- issues that have been problematic to the implementation of GIS, and
- issues pertaining to the structure and conceptual framework of GIS database models

With respect to the selection of the countries which have been considered, there is information available on South Africa. There are then other African countries which have been included, namely: Botswana, Kenya, Mauritius and Saudi Arabia. Finally there are a number of developing countries considered which lie outside Africa. These comprise: Malaysia, India, China, Cambodia, Russia and Brahain. The situation in Brazil, which is an important study area, is considered through a detailed case study of the ViSP approach to informal settlement upgrading in Belo Horizonte (Chapter 5) and has thus been excluded from this chapter.

In appendix 3 table 1 a detailed summary of the above listed and other[1] issues are presented for several GIS systems. The issues presented in this table provide useful background to other sections of the thesis[2]. In appendix 3 table 1 the details for four South African systems and four foreign systems are summarised. The former includes the Cape Town City Council, PROLAND, the transformation system developed by Napier (1994) and the Greater Johannesburg Transitional Metropolitan Council. The latter consists of four systems that were developed by PADCO for government departments in the Philippines, Poland and Jamaica. In the case of Poland two systems, one for the City of Gdansk and one for the City of Lodz are summarised. While the experience of GIS in Poland has been dealt with in chapter 2, case studies for all of the other countries mentioned here are discussed below.

While much has been written on the diffusion of GIS in Europe, very little literature exists on the extent of diffusion of GIS in developing countries[3]. However, it is safe to assume this diffusion has occurred to a similar or less widespread extent than in the lesser developed European countries[4]. With the exception of South Africa and the Philippines, this issue is not further discussed in this chapter. In South Africa, GIS is used widely at the national, provincial and metropolitan levels, and at the local level in the formal settlement areas. A recent mandate was issued by the Cabinet to the Reconstruction and Development Programme Ministry in the Office of the President to submit a proposal for the alignment of GIS for development planning at a national level in South Africa. Currently there is no structured relationship between a large number of GIS systems which have developed within the government. In the Philippines, the diffusion of GIS was accelerated by a mandate issued in 1994 which devolved the authority of approving land use maps prepared by cities from a national to local and provincial government levels. This led to the development of the PADCO-based GIS initiatives discussed below.

4.3 GIS-BASED UPGRADING PROGRAMS DRIVEN BY INTERNATIONAL DEVELOPMENT AGENCIES

Two key international organisations have been involved in the creation of LIS and GIS based development programmes. These two organisations are the World Bank and the Planning and Development Collaborative International Incorporated Company (PADCO), which is often funded by USAID or the Inter American Bank. The World Bank Mission reports (for 1991 and 1993/4) focuses on the implementation of spreadsheet based programmes for informal settlement upgrading. Although it is clear that a GIS based approach should be followed, these initial studies are briefly discussed as they provide the first examples of an information systems based approach to informal settlement upgrading based in South Africa. The work of PADCO provides a series of examples of GIS-based development programs in the Philippines, Jamaica and other areas.

4.3.1 Experiences of the World Bank

The primary goals of the World Bank 1991 Urban Sector Reconnaissance Mission to South Africa were to facilitate housing supply and ensure adequate infrastructure supply in the informal settlement areas surrounding Port Elizabeth, the Witwatersrand, Durban and Cape Town. The construction of a LIS was seen as essential in order to ensure the improvement of the services, and in order to allow low-income households to get closer to their place of employment. The key products of the approach were several zone maps illustrating informal and formal housing areas which were provided with no, partial or full infrastructure services, histogram plots of the area of vacant developable land as a function of distance from CDB and an attribute database for all the informal settlement area polygons mapped for each city. The source of the preliminary residential database was the 1985 Census. This database contains the following information for the census allotments: area, number of people, population density, projected population density projected population, present service level, percentage of squatters, income and land price. Other data types contained in the database include: incremental infrastructure costs (minimal to basic, to intermediate, to full), vacant land infrastructure costs (basic, intermediate, full), affordability and density of vacant land (affordable density, affordable plot size, number of people on vacant land, cumulative number of people on vacant land). The database utilizes tables on the cost of the supply of services and socio-economic data to determine the affordability of obtaining or upgrading the existing infrastructure services. The services considered include: water, sanitation, roads, storm water drainage and electricity.

Although the World Bank approach is claimed to rely entirely on spreadsheets and CAD software[5], the authors of the Mission Report recognise the. " a real Geographic Information System might be required in the future when the data and analysis requirements become more complex,.." (World Bank, 1991). More recently, the World Bank has collaborated with PADCO on a world wide research project on the application of SPOT satellite imagery and GIS for urban planning (PADCO, 1996 b). One of the issues that were addressed included the classification of informal areas. The World Bank Africa Technical Environment (AFTEN) Division has also contracted PADCO to develop a GIS-based Environmental Information System (EIS) for Africa (PADCO, 1996 b).

4.3.2 Experiences of the Planning and Development Collaborative International Incorporated Company (PADCO)

Overview

The Planning and Development Collaborative International Incorporated Company (PADCO) is a private sector consultancy based in the United States. It has produced GIS-based upgrading applications for a number of urban areas. Of them four were made available: Montego Bay, Jamaica, Honduras and the Philippines[6]. One of the key approaches developed by PADCO for informal settlement area database management is the concept of a point-based land information system (LIS). The work in Montego Bay focuses on the identification of different housing typologies and on the application of ARC/INFO overlay techniques for enumeration district and open land analyses, road and hydrology length per area based models and zone distance analyses (PADCO, 1993 a, 1993 b, 1993 c). The work in Jamaica has focused on the development of a Shelter Sector Monitoring System (SSMS) and has involved the identification of key short term and long term indicators. The work in the Philippines has focused on the implementation of a Rapid Land Use Assessment GIS based methodology. This included the production of a squatter analysis map which illustrated the of land use codes for low, medium and high density housing in Cebu, Davao, Lipa and Naga (1994 b). In this case the software which was applied included ARCVIEW 1. A number of reports were also provided on a LIS/GIS implementation plan developed by PADCO for the city of Gdansk in Poland (PADCO, 1994 c). This case study has been discussed in chapter 2.

PADCO has also been involved in informal settlement area GIS related work in a number of other locations in Eastern Europe (Ukraine), South East Asia (Cambodia, Indonesia), Asia (Pakistan, Nepal), Africa (Tunisia, South Africa) South America (Belize, El Salvador, Guyana, Honduras, Venezuela) and the United States (Washington). Detailed reports were not available for these areas from PADCO, however, each of these areas will be briefly mentioned here, based on the information synthesised in PADCO (1996 b).

Within the Ukraine PADCO is initiating a regional pilot land titling and registration system, with a view to extending it into a national system. In Cambodia, the Rapid Land Assessment (RLA) methodology (see below) is being applied for urban land use mapping. In Indonesia, a series of GIS projects are underway, which involve staff training (Land use Planning and Mapping Project, LUPAM), the development of an integrated land use database (Land Resource Evaluation and Planning Project, LREPP II), and the development of and land monitoring system for the BOBATEK area. In Pakistan PADCO has been involved in the Urban Development Project, the Urban Land Availability Information System (ULAIS), and in the Karachi Master Planning Process. The Urban Development Project focused on the extending the existing master plans for the provision of water, sanitation, drainage, electrification and street lighting, the preparation of preliminary engineering studies and cost estimates for area upgrading and development, transportation, solid waste collection and other services (PADCO, 1996 b). Unfortunately, the relevant reports remain confidential documents. In the ULAIS project, PADCO collaborated with a local engineering firm NESPAK to construct a 1:25 000 scale land use GIS database for eleven cities in Pakistan, in order to assist in the location of areas within the cities, which are available for sheltering low income groups. In the Karachi Master Planning Process, population growth, land use, infrastructure provision, investment and financial feasibility modelling has been conducted. In Nepal, PADCO has been involved in the production of: infrastructure maps for Janakpur, a design manual for GIS-based residential development for the Urban Development Project, customized menus for PC Arc/INFO using the Simple Macro Language (SML) utility for the International Centre for Integrated Mountain Development in Kathmandu, and the design of an integrated infrastructure-based application for policy level analysis.

In South Africa, PADCO has been involved in the preparation of a draft GIS implementation plan and community-based applications for East London Municipality (ELM) in the Eastern Cape. No reports were available at the time of this literature survey. The work in Tunisia focused on staff training and in the production of customised manuals. In South America, PADCO has worked on a number of projects, including: a Facility Mapping System Electric Utility Template for ArcCAD (Belize), a GIS user needs analysis for the Government of El Salvador, the design of an urban rehabilitation program for the Government of Guyana and in the development of a GIS implementation plan for an agronomy project in Caracas, Venezuela. In the United States, PADCO has collaborated with the Inter American Development Bank (IADB), the World Bank (see below), and other private companies (eg. Bisson Exploration Inc.). The work with the IADB involved the development of a multi-sectoral prototype GIS for the Project Analysis Department's (PRA) Environment Protection Division of the IADB. The system utilises PC-based vector and raster GIS software such as: PC ARC/INFO, ATLAS-GIS, MapInfo, Idrisi, Erdas, ArcCAD and ArcView. The work with Bisson Exploration Inc. involved the application of GIS for the exploration of Mega-watersheds in Ethiopia and Botswana.

A management assessment of the Department of the Surveyor General and The Office of the Registry of Deeds (Harare, Zimbabwe) land delivery information system was conducted by PADCO (1995). This study is not discussed here, but may be worthwhile referring to further information on some of the management issues that may hamper the implementation of a LIS in a third world country.

One of the issues identified as being key to the success of land information system (LIS) / GIS based upgrading programs is that there should be a certain degree of interaction between the database constructors and the private sector (PADCO, 1994 c). PADCO strongly suggests that the data collected should be sold to support network and database maintenance costs.

4.3.3 Experiences of PADCO in Jamaica

The work of PADCO in Jamaica focussed on the design and implementation of a Shelter Sector Monitoring System (SSMS) for the provision of serviced land and infrastructure to low-income communities in Jamaica. This process took place over two phases. The first phase was based on a spread sheet approach. The limitations of the resultant database forced a second GIS-based phase to be implemented. Here the characteristics and lessons learnt from both phases are briefly discussed.

The Shelter Sector Monitoring System (SSMS)

The aims of the first phase of the SSMS program[7] were to enable the Planning institute of Jamaica (PIOJ) to track the performance of the Jamaican shelter sector and to provide a resource base for housing sector agencies. PADCO was commissioned to: 1) design a short-term baseline 'system', 2) design a plan for longer term improvements to the 'system', 3) support the activities of a Shelter Data Analyst, 4) identify baseline indicators. To achieve these objectives, a spreadsheet-based database was designed with short term and long term indicators (Appendix 3 Table 2). These indicators were selected on the basis of: 1) the clarity of the indicator, 2) the availability of the data, 3) the reliance on "authority". In view of the very limited success of this system, and also due to the fact that it was quickly superseded by a GIS-based approach, the reader is referred to PADCO (1992) for further details on the exact definitions of the indicator categories. The database was designed with a view to meeting the needs of planning and development agencies. These agencies require reliable housing data on a regular basis. The spreadsheet software, Lotus 3.1, was viewed as the answer for a short-term system, primarily for its ease of use.

The indicators for the short-term system reflect the status of services provided at the national and metropolitan levels, for both urban and rural areas. The survey data are collected for several years to detect regional variations. Data collection at smaller geographic levels (parish and district) were intended to enable micro-patterns within the larger geographic areas to be detected. However, no publications of such work at a micro-scale were produced utilising the database designed for the first phase of the SSMS program. Within the context of the first phase SSMS (PADCO, 1992) GIS was viewed as important for the long-term system to enable data collection in the informal housing sector. No publications on the development or implementation of the long term system are available. Instead the development of the short term system was immediately succeeded by the second phase of the SSMS program - which was predominantly GIS-based. Two key recommendations were derived from the results of the first phase of the SSMS. Firstly, PADCO indicated that the PIOJ should envisage selling data to the private sector, such as the insurance sector and real estate agents, to recover costs of procuring data. Secondly, it was found that the median household income proved to be one of the most import data types to monitor. Details on how this value was calculated are discussed by PADCO (1992).

The experience of GIS-based development initiatives in Montego Bay

In the Montego Bay area, tourism has placed increased demands on the housing market. Despite the low population growth rate (2 %) this has had negative impacts on residential development. The aims of the second information system development work carried out by PADCO in Jamaica were to:

1. institute a GIS database
2. define a housing typology for the Montego Bay area, and
3. address deficiencies in the informal sector using the spatially referenced data.

The definition of a housing typology based on distinct residential developments was carried by interpreting aerial photos[8]. Unique housing types were assessed and aggregated into homogenous groups. The various housing types are shown in the figure 1 in appendix 3. Physical characteristics such as housing type, structure, form, topography and basic socio-economic characteristics were incorporated in the housing typology. For example, low-density villas are characterised by a higher household income than informal housing on steep slopes.

Tabular census data (1982-1989) was incorporated into the GIS-based physical housing analysis. Population and dwelling units data by Enumeration District (ED) were collected. The EDs were used as the basic spatial units and structural elements for the database and analyses. The ED boundary layer was combined with a housing typology to relate census information to each housing type. Note that polygons from the ED layer do not directly overlay the polygons or areas described by each housing typology (further details related to fuzzy matching is discussed in this report). The GIS database was implemented to produce statistical summaries and to spatially delineate specific areas based on criteria such as for the development of new housing areas. Other data layers which were incorporated into the system include: open areas, distance from roads, hydrology buffers, wetland buffers, proximity to urban area.

The combination of these data sets enabled a number of analyses to be performed. These included an enumeration district overlay analysis, an open land analysis and a zone distance analysis. In the enumeration district (ED) overlay analysis, housing areas and ED boundaries were overlain to assess which EDs fell in which housing type area. In addition, the fraction of each ED contained within the different housing areas was calculated. This was carried out to assess the socio-economic characteristics of each area that was identified within each housing typology. In the open land analysis ARC/INFO coverages of the roads, hydrology, slope, urban fence and proximity to existing housing were overlain. In addition, buffer zones were created for the open land (10 m - 20 m of existing roads) and hydrology / conservation areas (10 m, 20 m, 50 m, 250 m and 500 m buffers). In the zone distance analysis, the proportion and number of population and dwelling units at different distances from the city centre was calculated. For the calculation procedure a centre point in the city was selected and a series of 1-mile concentric circles drawn. The circle distance file was overlain by the housing file and both files were then used to re-calculate population and dwelling unit statistics. The summary statistics for each distance zone were compiled and shifts in housing patterns and population movement over time were studied.

The results of the analyses discussed above revealed how the housing areas and other land use type areas were changing. It was noted that 56 % of the most recently built houses had developed in the informal sector. In addition there had been a shift of various housing types into conservation areas. The study also identified a restricted zone of new housing development, which was radially distributed.

4.3.4 The experience of the Rapid Land Use Assessment (RLA) methodology in the Philippines

The Rapid Land Use Assessment (RLA) methodology is based on the use of the Russian KVR 1992 (2m spatial resolution) and SPOT Panchromatic / Multi-spectral Merge images (PADCO, 1994 a, 1994 b). The main products of the work carried out in the Philippines in the mid-90's were maps which compared the actual land use with the land use zoning maps for the above mentioned cities. A squatter analysis map was also produced for the City of Cebu. Other potential applications identified by PADCO included: voting analysis, land availability and suitability studies, road inventory and maintenance and tax mapping, health and population analyses, housing analyses, infrastructure and housing vulnerability, disaster mitigation, planning and risk assessment, project management applications (PADCO, 1994 a).

The RLA methodology utilises: high resolution satellite imagery, PC-based GIS (ARCVIEW 1), land use classification training, field surveys, manual image input and local knowledge. The RLA methodology enables the production of land use maps by classifying the imagery data into the following land use class groups: high density housing, medium density housing, low density housing, rural settlements, commercial, industrial, institutional, transportation, parks and recreation, utilities, agricultural-industrial, agriculture, forest, land under development, open land, water, quarries and mines, beach resorts and clouds. The image classification has been conducted on the basis of colour, texture, pattern, shape and size. The area and percentage are determined for each land use type for each city studied. The scale of the land use maps typically produced are 1:25000.

In the case of the Philippines RLA, comparative statistical analyses of the actual land use (eg agriculture) and zoning (eg. industrial) were conducted. The City of Cebu squatter analysis focuses on the thematic mapping of various shanties, residential areas and squatter associations. The classes which were defined for each housing density class group in Cebu were as follows: high density housing: high density, apartments buildings, high density shanties; medium density: medium-density sub-divisions/villages/compounds, bungalows, town homes/condos, shacks and low density: compounds/villages (PADCO, 1994 b). The low income squatter analysis involved the identification of squatter shanty areas and in analysing the location of these areas in relation to the economic activity, infrastructure, and valuable land in order to plan the effective relocation of the squatters. The city squatter associations were located spatially and information such as the number of members and address of the association were recorded. From the vacant city land mapped by the RLA approach, the available land was identified as having the following characteristics: a slope of < 5%, being well drained and within 8km of the city. The land suitability was also defined as a function of the width of the roads, quantity and quality of water and sewerage, telephone services and population density.

Relatively simple computer systems may be used to implement the RLA methodology. The computer system at Cebu utilises relatively small amount of memory space (16 MB RAM) and relies on tape back ups. The GIS software used include: ArcCAD 11.4 with ArcView. In Lipa the GIS software Idrisi version 4.1 (a grid-based modelling package) is employed (PADCO, 1994 a).

4.3.5 The experience of the Lots by dots™ approach in Honduras

In the point-based LIS (Lots by dots™) approach adopted by the Municipality of San Pedro Sula, Honduras, each property is represented by a point, to which attribute data are attached (PADCO, 1996 a). This differs from conventional approaches that tend to attach attribute data to polygon boundaries. The key attributes used to identify the property points include: property location, geographic co-ordinate, property identification number and cadastral number. Other attribute data monitored include: ownership data (name address), access to transportation networks, land cover, assessed value (land and structure), survey data (area, co-ordinate geometry, lot measurements), topography, climate, quality of soil, land use, zoning, permit data, scanned or related parcel survey. This results in a 90 % reduced data capturing time and a 50 % reduced data processing time. The main disadvantage of the approach is that one cannot conduct land geometry -based analyses during the development of the database. The GIS implementation process in this case involved the application of ArcCAD and ArcView software. The RLA methodology involved the use of satellite imagery and global positioning (GPS) systems. The resultant GIS was used to analyse urban growth modelling, land suitability and population modelling.

4.4 GIS IN SOUTH AFRICA

4.4.1 Introduction

Five GIS systems that are currently being implemented for informal settlement upgrading related work were analysed. These are: 1) the GIS system developed for Greater Johannesburg Transitional Metropolitan Council (GJTMC), 2) the Community-Integrated GIS (CiGIS) in the Mpumalanga Province, 3) the MEGASUB Housing and Electrification Program (HELP) database, 4) the metropolitan level, supply driven PROLAND systems, which meets the government's needs, and 5) the local-level database developed by the ODA for the analysis of housing plans.

The discussion of the GIS system developed for Greater Johannesburg Transitional Metropolitan Council (GJTMC) reveals that the failings[9] of the cadastral approach have been recognised in South Africa. It also indicates that municipalities are becoming more accepting with respect to more progressive and flexible GIS solutions.

It is evident from the needs analysis (Martinez & Abbott, 1996) that almost no GIS related work has been conducted by the local municipal authorities to assist the upgrading of informal settlement areas in Ikapa (see chapter 3). The main reason for this was the lack of attribute data and reliable infrastructural base maps. Some discussion of the use of GIS in South Africa has already been published by Wulfsohn (1995) and Wium et al. (1995). GIS systems have been applied in Guateng, and in Kwazulu-Natal to aid the data capturing and manipulation associated with the voting process (Global Information Systems, 1995; Scan, 1995). In the case of the Gauteng Community Elections, MapInfo was used. Wulfsohn (1995) questions the appropriateness of applying technologies which do not require an input by the community and supports the lots by dots approach followed by PADCO. He stresses the need to incorporate community participation in the planning and operation of the database and identifies risks and hazards as key areas on which the community may contribute information. Other characteristics of the LIS recommended by Wulfsohn (1995) are that it should be low-cost, simple and fast.

The discussion of local GIS systems designed for mass housing provision reveal that the current local systems are highly focused and cater either only for the metropolitan level or the local level. The PROLAND system described later has been designed to support the implementation of the current government relocation policy and the needs of metropolitan spatial planners. The needs of the community, the ability for assessing in situ upgrading possibilities, the compatibility of the PROLAND database with the present CCC GIS and a multitude of other issues have not been catered for in the design of this decision support system. Although the discussion by Napier (1994) deals specifically with a micro-level GIS application (ie. incorporating the phenomenon of low-income housing transformations into GIS), it highlights a number of valuable key issues that are generally applicable, and that should be kept in mind during the database design process.

The discussion by Wulfsohn (1995) supports two of the hypotheses stated in the thesis. Firstly, his work reveals that the focus is on collecting, physical geographic information and " although not explicitly stated, the urban information systems are directed to the formal sectors". He also states that the type of information strategy envisaged and the problems experienced are very similar to other countries. Thus Wulfsohn's work supports the first part of hypothesis 1: that a formal approach is applied in developing countries. Secondly, Wulfsohn argues that " it is important to emphasise changes in settlement dynamics at various scales and to integrate the informal sector in order to build up an effective, goal directed urban information system." Where this thesis contributes with respect to the first observation is by highlighting that it is the *cadastral component* of the conventionally applied GIS approach which is not suitable on its own for developing countries. In figure 2 in appendix 3 an extract of the cadastral database built by the City Council in 1996 is shown. For the majority of the informal settlement areas cadastral boundaries do not exist. Where cadastral boundaries do exist, the housing structures do not conform to these boundaries. The shacks often overlap two or three land parcels. In addition, there are often two shacks within a single land parcel. Such problems bring into question both the usefulness and the practicality of attaching the socio-economic data associated with families in these areas to parcel boundaries or parcel boundary centroids. Secondly, the thesis develops a database model which enables the informal settlement to be integrated into the city GIS. The need for such a model is clearly stated in the second quotation from Wulfsohn (1995). Thirdly the Bi-level approach proposed in chapter 7 enables the changes in settlement dynamics to be monitored at two scales at least - again in keeping with the need for a variable scale approach as observed by Wulfsohn (1995). The research by Wulfsohn (1995) focussed on identifying the application of GIS for growth management in South Africa. The issues he addressed included the growth management strategies under development or in use, tools applied for growth management applications, the implementation of GIS for the growth management and the requirements of a DSS for growth management.

4.4.2 National Level Systems

This discussion draws from a paper by Wulfsohn (1995), which reviews the growth and status of GIS applications in the various metropolitan local authorities in South Africa. The majority of local government offices which have acquired GIS have installed ARCINFO and GENAMAP GIS systems. Many of the GIS users within these institutions complain of the difficulty of using these systems and use simpler programs such as MAPINFO and ATLAS for metropolitan wide analyses. In addition to the problem of parallel systems, Wulfsohn (1995) highlights the lack of GIS skills in these metropolitan departments and the high cost of involving consultants in setting up these systems.

The Durban and Gauteng (Central Witwatersrand) Regional Services Council have addressed the issue of urban information systems through two publications: "An information system for the urban strategy department' and ' Proposal for the development of an information to support the integrated development framework process'. Both documents viewed by Wulfsohn and key concepts filtered from this reference. The Durban document focuses on the internal design and components of a strategic information system and on organisational and institutional issues important on setting up a new system. The Central Wits document focuses on identifying Potential Development Areas by a technical analysis of employment opportunities, vacant land, infrastructure and other physiographic variables. With respect to strategic level planning using GIS in Johannesburg, "...the main aim was to densify along major arterials, use existing infrastructure and resource capacities and integrate the urban environment (Whitehead, 1994)".

It is clear that the need for strategic level work has been identified in all the metropolitan centres (supports hypothesis three). However, the focus of this work lies mainly on the identification of vacant land. Secondly, all of the above approaches focus on addressing the housing problem from a metropolitan spatial planner's point of view only. The theoretical framework for these systems are typically developed in isolation of the concerns of the involved communities. The need for community participation in planning activities involving settlement relocation or upgrading has been highlighted by Abbott et al. (1997). Also little of any consideration has been given to the following important issues:

- integrating local and metropolitan level analyses process
- integrating strategic level systems developed by provincial government (PA:WC) and
- municipal systems developed by local government
- integrating these systems with data inputs originating from the community
- integrating the systems through a software interface that would expedite communication across all key organisations and levels of government involved in the upgrading process

The situation with respect to informal settlement GIS applications in Cape Town and Gauteng are looked at in detail in other sections. Here the status in Durban and Port Elizabeth is derived from Wulfsohn (1995). In Durban, many informal settlements are being mapped and surveyed. Other types of data collected include: land use (vacant land, potential activity corridors, employment areas), road and rail infrastructure, and the identification of opportunity areas. A basic needs database has also been compiled for settlements in the region. This report quantifies a human development index in each settlement. Durban has also used SPOT imagery to develop land use and conservation maps[10]. In Port Elizabeth, the approach is again one of identifying vacant land and determining suitability and phasing for urban expansion with regard to optimal utilisation of existing infrastructure and minimal expansion costs. Estimates of future land needs on the basis of population projections made by Mercer (1994).

4.4.3 The Gauteng Metropolitan System

The discussion below focuses on the implementation of GIS within the Greater Johannesburg Transitional Metropolitan Council (GJTMC). It outlines the development of the system, benefits, the organisational structure, and key aspects of the implementation process which have resulted in a more successful implementation of GIS than in the CCC. This discussion draws upon an interview carried out by Abbott (1997) on the head of the Gauteng Planning Directorate and from an analysis of a series of maps produced by the GJTMC. The criteria discussed earlier in this chapter have been used to distil and reorganise the information included from the interview.

The Gauteng GIS was initiated 1984 by the Statistical Services Branch and later taken over by the Planning branch in 1988. In 1992 the Land Information Department was established and GIS was incorporated as a branch. Thus the staff at Gauteng Municipality have been exposed to GIS for over a decade (14 years). The formation of the land information department was preceded by a corporate GIS facility that was based on the Siemens software. This was replaced by a system that was designed to cater for the needs of more of the departments, and would thus bring these departments "in line" in terms of the use of a common software platform. A new system called Maintence Information Systems (MIS) was established by a multi-disciplinary user group. This system was designed to cater for the needs of the Water, Waste, Electricity and Planning Departments. This system was developed separate from the cadastral from the outstart. Each group captures their data and the cadastral data is used as a base for all the departments. The Land Information Services thus has the responsibility of cadastral maintenance and project support. Both require GIS and database management support. The project support often requires simple data sets which are easier to create and up date. With respect to implementation, the success of this process has been gauged by the integration of GIS at the lowest level of the organisation. With respect to software selection, the head criticised vendors for selling highly sophisticated and complex systems which become unused. The system appears to have useful applications which extend beyond automated mapping tasks. In particular the system is used for query building.

One of the key issues to note is that the system was started as a land surveying utility and was therefore developed as a cadastral database from the start. This approach is now used in only 2.3 % of the projects (Floyd, 1997, pers. comm.). While the cadastral approach set a standard position of 300 mm closure level on a stand and 25 mm on built-up areas, the majority of the present projects work at a far lower accuracy. The future aim is to digitise within township co-ordinates (1-2 m accuracy). The main motivation for following a cadastral approach initially was that it was assumed that a high accuracy would enable the system to be used by the surveyors. In practice however, the GIS maps remained an unacceptable substitute for conventionally produced paper maps to the surveyors. According to the head of the Planning Directorate, by following a cadastral approach, one never reaches a finalisation of the data capturing process. The latest 1:2500 GIS map for Gauteng remained continually out of date. Currently, the data capturing is prioritized in terms of projects and there is little detailed cadastral data capturing taking place. Even this limited amount of activity on the cadastral approach is criticised.

By shifting away from a purely cadastral approach to GIS the developers of the GJTMC GIS have enabled a widespread development of applications throughout the council. In contrast to the Cape Town City Council which has no informal settlement upgrading applications on its database, the Gauteng municipality has recently turned its attention to developing such applications. The key initial application has involved a mapping of the informal settlements. Aerial photos and facilitators (consultants?) were used to build the system. The settlements have been prioritised in terms of need and a small data base of key criteria has been built. To date these criteria include: the distance to major transportation network and the soil conditions. The same methodology has been extended to the transitional areas. Other applications have included a vacant land analysis.

An inspection of informal settlement bearing map-outputs from the GJTMC GIS system revealed a number of key factors with respect to: 1) the approach adopted by this institution for informal settlement GIS work, 2) nomenclature problems associated with mapping informal settlements, 3) the problem with using political boundaries to define the basic spatial unit for a metropolitan system. Typical metropolitan level map production scales range from 1:75000 - 1:200000. Informal settlements are usually not registered with a formal town name. The result is a number of default settlement names determined by topographical features in the vicinity of the settlement. Examples of such settlement names in the Gauteng region include: 66 -66th Avenue, 149-12th Avenue, 149-20th Avenue, 2nd street etc.

The informal settlement map produced by the GJTMC (1996) Land Information Department illustrates provisional MSS Boundaries, basic infrastructure, major boundaries, roads and railways. The presence of "Old Municipal boundaries" and current "Metropolitan substructure boundaries" is typical of other developing country metropolitan centres. The multiplicity of boundaries is determined by the local government stability. In countries undergoing social and political reform, which is often the case for developing countries, transitional metropolitan councils are often encountered. This highlights the need for avoiding the implementation of systems which utilise politically determined zones as the basic spatial unit. An example of such a system already discussed is PROLAND, where information is aggregated with reference to local substructure boundaries.

An example of the nature of the local level informal settlement work being conducted at Gauteng was provided for the area encompassed in the Kliptown development framework (GJTMC). This map includes the following features: 1:20 year flood line, 1: 50 year flood line, marshes, dams, vleis, drainage channel, slopes, sinkholes and other land use types (formal, informal, public open space, retail). Parcel boundaries are not illustrated for over 95 % of the informal settlements in this region. Only one small area in the vicinity of Dhlamini (20/298) illustrates a number of linear features which may be related to land ownership rights. (The original map legend does not define the feature type.) The map illustrates that local level work focuses on risk analysis, namely flooding and sinkholes.

The above discussion on the Gauteng experience of municipal GIS serves to substantiate the first and the fourth hypotheses stated in this thesis. Firstly, it clearly illustrates that in one of the most advanced (with respect to the implementation of GIS) government metropolitan municipalities in South Africa, it has become realised that the conventional cadastral approach is not meeting their needs. Secondly, this experience illustrates the positive influence a multi-department driven approach can have to the system development and application processes. It is also clear that the responsibilities of the project and of the cadastral maintenance procedures must be treated separately.

4.4.4 Community-Integrated GIS (CiGIS) in the Mpumalanga Province

The "Community-Integrated GIS" (CiGIS) methodology currently being tested in Mpumalanga is based on a research project that was initiated by the West Virginia University (W.V.U.) (Weiner and Harris 1999). While the methodology is agency-driven, it is not top-down nor privileged toward traditional scientific knowledge (Weiner and Harris 1999, p.8). Instead the approach is comprised of a series of community participation based methods[11]. Furthermore, it places a strong emphasis on the use of multi-media[12] also (Weiner and Harris1999, pp. 8-9).

In addition to incorporating a traditional cadastral database (Weiner and Harris 1999, p12), the CiGIS database is built by collecting data on: 1) the historical geography of forced removals, 2) differential perspectives on land potential, 3) perspectives on socially appropriate and inappropriate land use, 4) politics and power relations that help shape natural resource access, ownership and use patterns and 5) areas where land reform should take place (Weiner and Harris 1999, pp.11-12). The socially differentiated local knowledge is compiled through participatory mental mapping exercises. Participant group views on the five issues are recorded on tracing paper overlaid on topographic map sheets and GIS map products. These mental mapping workshops typically include 5-8 people in which groups of men and women are interviewed separately. The mental mapping workshop is followed by a participatory land use planning exercise.

While the CiGIS methodology places an emphasis on community-participation and on the regional political ecology, it lacks a local-level database component. It has been designed to operate primarily at the sub-regional (1:100 000) and metropolitan (1:24 000) levels. This prevents the database from being used for local level analysis and implementation applications. It also seems to have been designed as a "stand alone" methodology. No mechanisms are suggested by Weiner and Harris (1999) for integrating this database with other databases.

4.4.5 The MEGASUB Housing and Electrification Program (HELP) database

Towards the end of 1997, ESKOM, the Department of Housing and MEGASUB NADIA (PTY) Ltd initiated the development of a database of informal settlement areas in South Africa. This database, which has been called the Housing and Electrification Program (HELP) data set, has been developed primarily for various planning (namely: integrated development, regional and town, infrastructure creation) and market research applications. The database was collected using aerial photography at the scales of 1:20 000, 1: 30 000 and 1: 50 000 and thus includes data at the metropolitan to sub-regional scales. The basic spatial unit[13] (see discussion in chapter 6) which has been used is the settlement density area. The settlement density data for these areas was calculated programmatically within the GIS environment. In addition to the density data, a variety of associated services and public service attribute data are attached to the settlement density area. Over 36 different attribute data types have been captured, with a particular emphasis on services data (water, sanitation, electrical infrastructure, public services and telephone network). To identify the settlement areas an X-Y co-ordinate code and several settlement names[14] are used.

To date, data has been collected for the North West, Northern Province, Eastern Cape, Free State, Kwa-Zulu-Natal and Mphumalanga areas. While the MEGASUB database provides an excellent framework for developing sub-regional level informal settlement upgrading strategies in these areas, it lacks mechanisms for incorporating data related to local-level and community participation processes. Furthermore, the database appears to have been designed to operate as an isolated standalone management tool.

4.4.6 The PROLAND system

Proland is based on Arcview3 and Excell. It does not have CAD or image processing capabilities. How does PROLAND measure against the criteria used to gauge the various systems analysed in this study? PROLAND does not have the multi-task capabilities required by the upgrading GIS systems used in the ViSP methodology. It appears to be a broad based planning system which meets the housing provision policy formulation needs of metropolitan-level spatial planners in local government. There is no local-level to the system. It is a system which meets the needs of a select few. The absence detailed socio-economic and physical attribute information, detailed topographical and cadastral vector data and low-altitude raster imagery imposes two restrictions on the application potential of the system. Firstly it would be very difficult to incorporate the program into the community participation process. This is a critical failing of the system as the current government policy again and again emphasises the need for upgrading approaches which include a community participation component. Secondly, the absence of local-level data does not support the data requirements of the implementation process. The absence of this data from the system prevents the system from being used to:

1. analyse the needs of a community as a whole
2. analyse these needs with reference to the existing local infrastructure
3. analyse these needs in parallel with the process of identifying potential sites for in situ upgrading.

The PROLAND system has been designed for a narrow set of needs. A large system is used to construct a database, which is then marketed as a finished, low-level GIS platform product. Analysis of the upgrading process is not regarded as an ongoing process on the high-level platform. The system does not meet the data requirements for community participation or for implementing the upgrading process at the local level. Another major weakness of the program is that it only deals with vacant or greenfield land. By excluding data on the land available through infilling and redevelopment (brownfield land), it is not possible to use the system to identify potential in-situ upgrading possibilities.

4.4.7 A GIS-based Housing Plan Analysis System

The system developed by Napier functions at the dwelling unit level and is thus an example of a local level GIS approach to informal settlement upgrading. It focuses on one aspect of the upgrading process: the development of a database for the analysis of house plans recording user-initiated extensions of government built, low cost housing (Napier, 1994)[15]. Two aspects of the discussion by Napier (1994) are particularly relevant to the present thesis. The first relates to the how the appropriate design of a database is defined by the nature of the available information. This issue has already been alluded to in the introduction The second aspect relates to the benefits and limitations of GIS for establishing informal settlement databases. The system utilises ARCINFO software. The discussion by Napier gives an excellent description of the basic spatial unit (BSU) concept and contributes to various sections of this thesis (see chapter 6).

4.4.8 Conclusions

The PROLAND metropolitan spatial planner driven approach needs to be modified to include a multitude of other factors facing informal settlement upgrading. As it stands, the PROLAND system is a highly focussed and isolated system. The same is true for the MEGASUB HELP database and CiGIS systems. The MEGASUB database lacks mechanism for incorporating local-level and community participation based data. While the CiGIS methodology places a strong emphasis community-participation but also lacks a local-level data capturing and processing mechanism. GIS-based approaches to urban modelling should be developed with an aim to integrating multiple sources and types of data and should cater for multi-purpose needs. Napier (1994) highlights the need to recognise that the appropriate database design is dependent on the nature of the available data. Indeed the third hypothesis of the present thesis, which demands a bi-level approach and the arguments against adopting a purely cadastral approach to municipal GIS in a developing country, are in keeping with this issue. Another issue which needs to be considered in the development of the database design for informal settlement upgrading applications, is that of focusing on the problem at hand rather than designing systems for future planning scenarios and for catering only for the current upgrading policy. For example, the PROLAND system caters only for relocation planning. The discussion on PROLAND revealed the narrow-minded and focused approach presently being adopted for informal settlement upgrading GIS applications in PA:WC. In the case of PROLAND, neither the nature of the problem nor of the information available have been considered in the database development process.

4.5 GIS IN OTHER AFRICAN COUNTRIES

A recent review was carried out by the United Nations (Fourie 1998) on the various types of cadastres and land information systems used in Africa. This review assessed the overall status and the extent of the development of these systems and their capacity to assist decision-makers. In this section a brief overview of this work is first presented. This is followed by discussions on the use of GIS in three African countries for which literature was available.

4.5.1 A brief overview of cadastral systems in Africa

The discussion by Fourie (1998) highlights some of the key problems facing cadastral systems in the African developing countries. It also identifies a series of requirements that should be met by future Land Information Management (LIM) systems in these countries. With respect to the requirements facing future LIM systems in the developing African countries, Fourie (1998) supports a multi-scale approach and the use of different types of "identifiers". In particular, the discussion highlights the need for treating the cadastral system as a subsystem[16] of the LIM system (Fourie 1998, p. 6). It proposes that these objectives be met through the development of a graphical national spatial framework termed "AFRICOVER" and stresses the importance of creating linkages from the graphical reference framework to the geometric framework and between the central and local levels (Fourie 1998, pp. 20-25).

With respect to the problems with the cadastral system, the review by Fourie (1998) indicates that cadastral and LIM systems in Africa are not providing land management decision-makers with sufficient information to make informed decisions. This is because of the lack of documentary evidence of title for up to 90 percent of the parcels in developing countries, the lack of LIS and GIS systems, and the incomplete coverage of the manual systems that do exist (Fourie 1998, p4). Furthermore, Fourie (1998, pp.4-6) discusses in detail some of the major problems with the cadastral systems in the African developing countries. In particular Fourie comments that the cadastral systems:

- are out of date, expensive to maintain and inefficient
- are slow in providing information to decision makers
- are centralized, and thereby prevents district and local decision makers from accessing data
- often lack data on informal settlements
- have information spread among several government departments making it difficult to access
- are isolated within the government surveying and mapping departments
- often lack clear land and/or information policies and/or the policies are outdated
- often have many parcels with "cloudy" and ambiguous information
- are faced a great shortage of urban mapping
- are difficult to link to other land information systems[17]

Furthermore Fourie (1998, p. 5) states that the: "..high standards of accuracy linked to legal accountability issues often make cadastral systems cumbersome and inflexible. This in turn slows down information creation processes, makes it difficult to form institutional alliances within government in the information field and increases costs. All this directly affects the amount of information available to decision makers, as well as its timing."

The discussion by Fourie (1998) is particularly relevant to this study as it suggests that the first and third hypotheses of the thesis may be true. With respect to the first hypothesis, Fourie (1998, p 4) states clearly that the cadastral systems in the African developing countries are a product of colonial histories of these countries and that they are not meeting the needs of the population in these countries[18]. While with respect to the third hypothesis, statements are made in the discussion that are clearly in support of a multi-scalar approach (ie. one of varying scales / accuracies)[19] to urban modeling that places the land office at the local level[20] (Fourie 1998, p 7,10). In particular, Fourie (1998, p. 9) states:" The LIM system should include the data sets being created at the centre by the macro, broad brush or initial planning exercises and surveys. It should also include the information created on the ground, as an outcome of the stakeholders negotiations. It should also manage the information flows between the centre and the local level, as these are critical to the success of such a participatory land use decisions and the knowledge sharing process."

The discussion by Fourie (1998) provides a valuable review of cadastral systems in Africa and identifies in a theoretical manner the requirements of a LIM for a developing country. However, it fails to clearly define a GIS database model framework designed to meet these requirements. Furthermore, the technical issues associated with the implementation of such a system are not dealt with in any detail. While the need for a multi-scale approach, which extends to the local level, and for inter-database linkages is recognized in the theoretical discussion, the AFRICOVER framework proposed by Fourie (1998) does not address these requirements. The discussion suggests that it operates primarily in an isolated manner and only at the sub-regional scale (1:250 000). Furthermore, while the AFRICOVER framework is briefly alluded to, no mention is made of the required software platform and a multitude of other issues.

4.5.2 Kenya

Two GIS initiatives are briefly discussed here for Kenya. These are the environmental applications driven by the United Nations and the health care applications driven by the University of Nottingham. Taylor (1991) has discussed the role of the United Nations in the development of GIS initiatives in Kenya. The United Nations Environmental Programme is partly based in Kenya and has thus driven the development of a grid based system (Global Resource Information Data Base , GRID) for environmental planning. Details of the UN Global Environmental Monitoring System (GEMS), of which GRID forms one part, is discussed by Taylor (1991: 74). The key software (Arc/Info) was provided as a donation from IBM and ESRI.

The GIS initiative developed by the University of Nottingham has been used to monitor and display the use of local health facilities in Kenya (Williams et al., 1997). The GIS has been used to highlight areas where local clinics are avoided, areas with low take-up rates for child immunisation and areas where patients are required to travel excessive distances to obtain appropriate health care services. In addition, the system has been used to provide a better representation of the areas influenced by each of the clinics. The discussion by Williams et al. (1997) provides a clear example of how the needed applications of a GIS system in a developing country differs from that of a developed country. Factors such as quality of health care service, equity of accessibility and efficiency are of concern. In addition, " the primary health care approach of 'health for all by the year 2000' now emphasises preventative medicine" is cited by Williams et al. (WHO/UNICEF, 1978). Accessibility remains a problem as appropriate road infrastructure remains lacking. "Over half of the people have to walk for over an hour to reach a clinic."(Williams et al.: 1997: 729). The need for such types of applications is practically absent from developed countries.

Arc/Info was implemented in the Meru District Kenya to analyse child immunisation, family planning, ante-natal and maternity care patients using clinics run by the Chogoria PCEA Hospital (a non-governmental organisation). Three spatial problems were investigated: 1) areas creating pressure on the hospital outpatients department, 2) areas not engaging effectively in child immunisations, 3) areas from which people travel long distances to obtaining child immunisations. The true patient "catchment areas " were mapped for each clinic. The key benefits utilising the GIS lay in the ability to apply overlays, and its ability to accelerate site selection analyses. Williams et al (1997) indicate that the primary utility of GIS in developing countries lies in the development land use and infrastructure facility planning applications.

The Kenyan application revealed the problems with the application of GIS at a local level as being more one of data quality related. Data existed since 1985 as Dbase files on the Chogoria Community Health Department Information System. " Nevertheless substantial data capture problems existed since although unique client numbers and address codes of villages are included, the 30 824 records of child immunisations in 1987 did not distinguish new patients, nor were the traditional 'ntura' or villages shown on the maps. Effective monitoring had been limited without map displays..." (Williams et al.1997: 729). The absence of the villages from maps can be partly ascribed to the manner in which the settlement populations are distributed. "Settlement is dispersed and people live on their farms, but they belong to a traditional village even though it has no administrative functions and its area is not shown on any maps." (Williams et al., 1997: 729)

A number of other quotations may be derived from Williams et al. (1997) which support the hypotheses of this thesis. Firstly a comments which supports the first hypothesis is: "the lack of suitable available maps and data in developing countries, however, frequently means that tasks which might be routine applications of GIS in developed countries, often become pioneering ventures when used in developing countries." (Williams et al.1997: 1) Secondly, the following comment supports the need for a Bi-level approach in developing countries (hypothesis 3): "The growing trend towards decentralisation of national development planning activities, to regional, sub-regional or local government bodies means that decision-making must be taken closer to the grassroots level. Planners therefore need to use more detailed techniques of spatial analysis." (Williams et al. 1997: 1). This comment highlights the need to develop local level planning databases. It also suggests the need for local level GIS capacity building. Further on in the discussion on health care in Kenya Williams comments: "Analyses now need to be based on the needs and usage of health services by small areas, and GIS is likely to play an increasing role in this work."(Williams et al. 1997: 278).

4.5.3 Mauritius

In the discussion on applications in Mauritius, Williams et al (1997) examine buffering and overlay applications for land use decisions, in particular sites for new housing and tourism development are selected. Arc/Info was utilised in the selection of a site for new urban development for high class housing and tourism facilities. The selection criteria were established on the basis of 1) the road network and communications, 2) water supply, 3) energy and power supply,4) agriculture and 5) natural wildlife and ecology. This structure and type of application is similar to that of PADCO in Montego Bay. (Which is not surprising as that particular case study represented another Arc/Info based tourism application.) The database which was applied consisted essentially of maps resulting from the buffering and overlay of vector coverages. These maps were structured into the following five layers within the database:

1. Road transport: Motorways, A-roads, B-roads
2. Rivers & Bore holes: Rivers, domestic, industrial irrigation
3. National Power Grid: powerlines accross the country
4. Land use: HG Agriculture, Marginal, Urban Water
5. Aquifer & Nature Reserve: Ravenala, Lowland, Coniferous forest

The work by Williams et al. (1997) illustrates a number of potential applications for SA. From the Mauritian study, site selection applications for the relocation programs such as the iSLP and tourism based applications are both relevant to SA. It is well known that the economy of Cape Town and other major metropolitan centres in SA thrive on tourism. The Kenyan study suggests the potential for medical applications. In addition to these potential areas for GIS applications, the there is also a need to identify the other areas for GIS initiatives in developing countries. In particular, there is a need to identify potential applications for local industries that contribute significantly to developing country economies. An example of this is the field of tourism in Mauritius (Williams et al). Williams et al. (1997) suggest that other potential applications for GIS in Mauritius lie in the fields of agriculture, in particular for sugar plantations: "Sugar takes up 90 % of the cultivable land, occupies over 28 % of the labour force, and accounts for over 75 % of foreign exchange earnings." (Williams et al., 1997: 2). The development of such an application would in essence be an example of a national or " regional economic risk" type application as opposed to a "physical local level risk" type application (landslides, flooding). ("The economy has been vulnerable to climatic conditions and the world price for sugar." Williams, 1997: 2). Thus question of appropriate applications for developing countries can begin to be formulated into a series of survival-related questions. These question include what applications are needed for:

1. the people to survive
2. the economy to survive
3. the environment to survive

Currently the majority of GIS applications address only the second and third items on the list. Agricultural based applications can be placed in the economy survival class. This question of:
" what needs are or should be addressed by a GIS in a developing country?" is discussed further in chapter 8.

4.5.4 Ghana

Larbi et al. (1997) discusses the methodology in creating a GIS for land management in Ghana. It has been designed for land ownership and tenure and environmental applications. It is essentially an environmental information system (Environmental Information System Development, EISD) , through which the National Environmental Action Plan (NEAP) of Ghana is being implemented. The land ownership component of the EISD aims at creating 1: 250 000 maps in digital and paper format for planning purposes. Three types of land ownership have been entered into the GIS : state land, vested land and customary land. (Customary land owners own 70 % of land in Ghana.) Data capture was based on available cadastral maps and verbal description of the boundaries. Other data entered into the database included: mineral and timber concessions data. The manner in which Arc/Info has been used to create the land ownership GIS in Ghana is discussed in further detail by Labri et al (1997).

The following comments from Larbi et al (1997) suggests that the system has been successfully implemented. "Apart from initial problems of mastering the software the development of the land ownership GIS can be described as successful. " "The greatest benefit of the exercise so far has been the fact that it has revealed the incomplete and incoherent nature of land ownership data in the country." (Larbi et al, 1997: 377). The GIS provides a basis for qualitative and quantitative analysis of land information. Although it does not have a legal status, it can be used to prevent violent clashes over land contribute generally to land management.

Again, as in many previous African GIS database developments funded by donors the emphasis lies on the environment. The system has been designed to address the needs of implementing the NEAP objectives, not the needs of the community in the informal settlement areas. The fact that the project is co-ordinated by the EPA ensures that the communities needs will fall second to that of the environment. The primary focus of GIS systems (formal, informal and environment) in developed and developing countries is discussed in chapter 8. Perhaps a different primary focus should have been selected for the Ghana GIS database. The fact that the system is funded by foreign donors raises a question of the sustainability of the system. Other key issues to note from this reference are the applicable scales and the problems associated with the cadastral approach which was adopted. Further criticisms relating to the utility of this database is that there is no transformation, no projection defined and no georeferencing (step 2, Figure 2: 376, Larbi). The manner in which then different data sources will be overlain remains questioned. Larbi comments in his conclusion that the linking up of relatively small scale maps created for the land ownership GIS to the large scale maps used for day to day land transactions (kept by Lands Commissions) remains to be addressed. Finally, despite the benefits of the system to land management (Larbi et al., 1997) the system still does not have a legal status.

4.6 GIS IN OTHER DEVELOPING COUNTRIES

4.6.1. India

The discussion by Taylor on the status of GIS in India highlights the key initiatives and problems encountered in the implementation of GIS. He focuses on national GIS initiatives and on an initiative driven by the Asian Institute of Technology (AIT). Both initiatives are discussed here in the context of the hypotheses dealt with in the thesis. The discussion on the first set of initiatives contributes to the hypothesis that local and metropolitan level (ie. a multi-scale or bi-level model approach) databases simultaneously and in a co-ordinated manner. The discussion on the AIT initiative highlights some of the requirements of local level GIS databases.

National GIS initiatives

In terms of the availability of imagery and communication networks, India appears to be advanced compared to other developing countries. The National Informatics Centre has developed a satellite-based communication system called NICNET, and utilises SPOT, Landsat and other remote sensing data extensively (Saxena, 1989). Part of these satellite-based initiatives is India's own satellite (IRS IA) launched in 1988. The national GIS system discussed by Taylor (1991) was developed as an answer to the "Government of India's overall plan for information management and its application to the development process" (Taylor, 1991: 77). The initiators of the system consisted of the Planning Commission of the Government of India, which selected several task forces to make recommendations for the development of the system. The software packages utilised in the creation of the national GIS databases include Arc/Info and GRIDS.

A key point made by Taylor (1991) the need for a multi-scale approach. Taylor suggests that macro and micro levels systems exist in India. At a macro-level, the Survey of India aims to build the Digital Cartographic Database. This database is to cover the country at two scales: two scales: 1: 250 000 and 1: 50 000. At a micro-level (district and below) it was recommended that a Natural Resources Database Management System should be developed as a Decision Support System for the planning and management of natural resources locally. Apparently, ten pilot district based centres have been established. District level applications have also been carried out in the Computerised Rural Information Systems Project (CRISP) through the National Informatics Centre. Indigenous GIS systems such as ISROVISON (Rao et al, 1989) and micro-based pilot projects at the rural district level were also noted by Taylor and others (Chappuis and Golbery 1984; Krishnayya, 1986). Although macro and micro application are present the implementation follows a predominantly "top down approach", with the development of local level databases occurring to a far more limited extent than regional or national databases.

Taylor highlights a number of problems facing the implementation of GIS in India which were previously identified by Dobson (1988). Some of these are technical in nature. Taylor highlights the following technical problems facing India: 1. cost of data capture, 2. quality of data, 3 rate of change, 4. database sizes. The rapid rate of change is a serious problem in terms of keeping the database up to date especially were the cities are growing at up to 7 % per annum (eg. Bangkok). However, these problems are minor in comparison to the political and bureaucratic barriers which exist. These include:1 security 2. the involvement of too many organisations in the data capture process, and 3. the community level does not receive any benefits from the "top-down" approach. With respect to the institutional problem of national security, the associated problems are as follows: 1. existing maps are classified documents, 2. maps must be certified by the Survey of India before they can be published, 3. maps on a scale of 1: 4000 000 or larger must be cleared by the Ministry of Defence before printing, 4. the publication of maps indicating incorrect external boundaries is a criminal offence. As a large part of India (40 - 60%) lies with the restricted or secret area category, it is not possible to map at scales greater than 1:250 000 for 40 - 60 % of the country. A second institutional problem highlighted by Taylor (1991) and Misra (1989) is the large number of organisations involved in the data collection and in formulating policies on land and water in India. Misra (1989: 224) illustrates the magnitude of the problem, cited by Taylor, 1991: "..a National Surveys Co-ordinating Committee, to resolve this problem...would have to have as full members no less than 15 organisations, 16 ministries, five training and research institutes, three professional bodies and four regional remote sensing organisations. To be effective, observers from 17 other organisations would be required."). The third institutional problem discussed by Taylor (1991) is that of ensuring that the results of the "top-down" model reach the community. Even though the need for this was recognised (Arur, Naryan and Goplalan, 1989), maps of 1: 50 000 and better remain unavailable for local level applications. Clearly this is unacceptable for local level work. (The Belo Horizonte case study revealed that maps of about 1: 300 to about 1: 75 are the required scales for local level work). Taylor continues: "These problems are not, of course, unique to developing nations, but in countries like India both population size and geographical extent compound the scale of the problem."(Taylor: 77). The sustainability and the needs addressed by the national system remain questionable. The funds for the Digital Cartographic Database were acquired from the UNDP. This again raises the question of how sustainable the system will be. Again the question arises who's needs has the system been designed for? - the government of course.

A number of quotations may be extracted from Taylor (1991) which support the need for a multi-scale approach (hypothesis 3). The need for extending mapping activities to local level applications has been noted in India by Arur et al (1989): "The Nation's planner's have already accepted the village panchayats as the basic unit for development activity in the country. It should be our aim to ensure that the products of Digital Cartography reach this ultimate unit for aid in planning and development '. Furthermore, Parthasaradhi and Kirshnanunni (1989: 321) comment: "The suggestion has been made that at least six different databases at various levels and scales will be required since ...no single level of database would meet all of the diverse requirements of planners for macro-, regional and micro-level planning for the management of resources. "

The applicability of first world technology in developing countries is brought under question by Singh (1989: 425; cited in Taylor, 1991: 79): "the modern techniques and the pace of their adoption should be devised so as to suit the specific conditions our country is facing. We cannot afford running in the mad race of developed countries for modernisation, ignoring our specific constraints and the need based requirements. It's high time that some introspection is done in this vital field...wider implementation of any technique should be embarked upon only after proven adaptability. The amount of indigenisation achieved has to be made a deciding factor for this purpose." The second component of Singh's comment highlights the need for exploring the implementation of local level databases and the need for examining the lower end GIS platforms available for this purpose. Taylor's final comments relating to the implementation of GIS in India reads as follows (Taylor, 1991: 79):

"Is a comprehensive centralised national GIS the best solution to the development challenges facing the Indian nation or is a more decentralised, micro-based 'bottom-up' approach based on systems for planners at the village level such as that suggested by AIT more appropriate? What is the best mix between 'top-down' and 'bottom-up' approaches? Is the importation of 'black box' technological solutions from Europe and North America more effective than the development of indigenous expertise? What level of indigenous expertise is required to gain 'socio-economic command' of this technology?"

These comments suggest that it is not the GIS technology but rather the approach followed in the implementation of the GIS technology that should be reviewed. The author agrees broadly with Taylor's views and argues that the methodology requires the implementation of a much more flexible approach to the implementation of GIS in developing countries. It is this "more flexible approach" that is incorporated into the proposed Bi-level model (chapter 6).

In answer to the first two questions, I would argue that a Bi-level approach, in which the development of the local level databases is co-ordinated by a macro-level database, is required. The "best mix" is dependant on each country, but in all cases it is possible to incorporate inputs from the community in the database building process, albeit through paper maps and questionnaires only, as opposed to a single low end computer platform per settlement or local authority (chapter 8). In response to the third question, again the answer lies in a "solution". There is no need to reinvent the technology when the funds required to do this could be better used in implementing existing technology locally, and in effect thereby achieve the objective of developing indigenous GIS expertise. Chapters six - eight clearly illustrates that the appropriate technology already exists. In response to the final question, I would argue that a variable level of expertise is required. The required expertise depends on which user group (community, national, provincial or local authority etc.) a user represents and on the type of query he or she wishes to conduct (see chapter 8 for more details).

The Asian Institute of Technology

The Asian Institute of Technology received funding from the United Nations to developed local level GIS-based initiatives in India. The Computer Assisted Regional Planning (CARP) approach developed by Yapa (1988, 1989) is decentralised and PC-based. The software used include: BASIC, AUTOCAD and DBASE. Only the simplest hard ware and software configuration was utilized. The hardware included: a 640 KB PC, a digitising tablet, a graphics monitor, and 10 MB memory. This system proved to be " in constant use as the basis for monitoring planning projects and carrying out routine work from district planning offices" (Yapa: 1989: 32-3). This approach focused on using local resources and on training the indigenous communities. Where the AIT approach is lacking is in that it does not recognise the need for a metropolitan level co-ordination of local databases. Consequently the local level platform configuration developed for CARP has resulted in a disjoint information system. For metropolitan level co-ordination of upgrading projects, the selected software must ensure connectivity between the local and metropolitan level databases (see chapter 6).

The discussion by Taylor on the CARP system gives an idea of the minimum software and hardware configuration requirements of local level databases. Essentially map drawing and database management capabilities are required at the local level according to Yapa (1988). Ten years have passed since the CARP configuration was suggested. Far better low level platform software packages are available for implementation at the local level.

4.6.2 Cambodia

As in the case of Kenya, Thmarpouk has a poor transportation infrastructure. There are few roads. The key road that does exist is a loose surface road and only the remains of a railway exist. A key problem in resettlement plans is to find available land. Other problems facing the application of the resettlement plans include land allocation conflicts upon the arrival of the new settlers. The Cambodian GIS initiative discussed here represents an example of a regional scale approach to policy analysis. It is also an example of a typical foreign research focussed initiative developed within a university environment (Agricultural University of Norway). (In this respect it is similar to the initiative developed by the University of Nottingham for Kenya.) The paper highlights some of the key problems facing settlements in Cambodia (lack of roads) and problems facing the development of GIS.

A regional GIS database was developed in Cambodia to assess the feasibility of a proposed repatriation plan[21] for Thmarkpouk (Strand, 1993). The system was applied to characterise settlements with respect to the proximity to other features and to integrate various information sources into a single database for statistical analysis and database management. The data required for the database was land use and land ownership. The bulk of the attribute data was in the form of land use descriptions. The database was designed for an area of 3092 km squared and covered 170 proposed new villages. The objective of the study was to evaluate the suitability of the resettlement proposal through a series of suitability analyses using cartographic overlays. To achieve this water availability and areas of possible land allocation conflicts were analysed. Water availability determines the agricultural suitability of areas for new development. Buffers were created along major water ways indicating the distance to water at distances of <500, 500 - 1000, 1000 - 2000, and > 2000 m. Areas of possible land allocation conflicts were also delineated by creating buffer zones around existing and proposed settlements.

A problem facing the development of GIS applications is that the "... actual extent of the settlements is not known: the villages are only marked by point locations. Land allocation around the villages must be estimated, and a reasonable best guess is to allocate a circular area around each village. According to the plan, a village should house 200 families. If each family is given 2 ha of land, 400 ha is needed for a village. A model village can be represented as a circle with 1130 m radius. Adding some area for roads and public facilities, a circular zone extending 1200 m out from the village centres was created. Similar zone were established around existing as well as around proposed villages.[22] Strand (1993) argues that the repatriation plan is based on a framework of new roads planned as straight lines between the district towns and that the proposed road network rather than the agricultural suitability seems to be the guiding criterion in locating the villages. He continues that soil differences have to be taken into account in the new settlement plan as they have different agricultural suitabilities. By applying a chi-squared frequency analysis test on the distribution of existing and proposed villages on different soil types, Strand (1993) illustrated that the repatriation plan failed to observe differences in soil suitability accounted for by the existing villages.

A second component of Strand's study involved the identification of alternative relocation areas defined by a rule-based analysis of land suitability. The results of this work are presented in a thematic map with the following classes: proposed settlement with available land, proposed settlement with possible soil deficit, proposed settlement with land suitable or unavailable and land available for relocating settlements. Strand's work illustrates the applicability of GIS to resettlement planning. Following the mapping of the villages and hydrology water availability and land allocation maps were created.

4.6.3 Commonwealth Independent State (CIS) (former USSR)

The following discussion derives from Koshkarev (1993). It gives an idea of GIS in a post-communist country. Koshkarev (1993) describes in detail the political, socio-economic and institutional environments in which GIS developments are occurring[23]. He highlights the major socio-econmic and political reform currently underway in the CIS. These economic reforms, privatisation of property and new legislation in the field of economy have favoured the establishment of GIS companies (Koshkarev, 1993).

GIS has been applied in Moscow, Kazan, Georgia, Baltic Republics, Moldavia, Western Siberia and in the Far East (Koshkarev et al., 1989; 1990). A number of institutions utilise GIS for thematic mapping and image processing[24]. Some GIS initiatives such as the electronic atlas of Tadjikistan (a socio-economic and environmental database) have been initiated by foreign funding (Badenkov & Koshkariov, 1990). In this case the system was planned by MAB UNESCO, the UN University and received funding from Sweden and the United States. In addition, the vast majority of the licences for the foreign software products listed below were donated by foreign funding agencies. The USSR has also been involved in the GRID GEMS UNEP programme by establishing a regional centre for the GRID global network in Moscow.

A survey of the PC-based software carried out in 1991 revealed the following software products as the most prominent foreign developed systems being used within the in the USSR: PC ARC/INFO (ESRI, Inc.), TerraSoft (Digital Resource Systems Ltd.), MapInfo (MapInfo Corp.), EPPL7 (Minnesota Land Planning Agency) and IDRISI (Clark University). With respect to the implementation of these systems, in 1991 all of the systems except EPPL7 (which is under-utilised) were still in an experimental phase. A number of systems have also been produced within the USSR. These include amongst others: the "Thematic Mapping System", the "MAG" package, "Relief-Processor" system, the "KAPRIZ" and "ECOKART" decision support tools, the "ATLANT"/"ARCHIMED" environmental simulation system. These systems have been designed for specialised applications, such as DEM processing, screen map design, and environmental simulations, and have been developed largely by universities within the CIS (Moscow State University and Kharkov University).

In addition to the environmental modelling applications two key hazard applications have been applied. In the first instance, GIS was used to evaluate the environmental consequences of the Spitak earthquake in Armenia (1988) (Borunov et. al., 1991). GIS was also used to monitor the ground water flow in the 45 km radius of the Cherynobyl NPP. A federal information system (GEOCON) for dealing with large natural and technogenic catastrophes is also planned. The reforms which have taken place will lead to the development of other non-enviornmental applications. Koshkarev (1993) envisages that the large-scale privatization of land property and the growth of unemployment due to reform will necessitate two key GIS initiatives. The first is a land information system for a real estate and ownership inventory, the second is a federal system for employment opportunities.

Koshkarev lists a large number of workshops, conferences and seminars (held during the period of 1983-1991) which dealt with the topic of problems facing the implementation of GIS in the USSR. Techinical problems include a shortage of modern hardware (eg. high-resolution monitors, min-computer based workstations), as these products were still on the COCOM list. One key problem is the lack of digital data. With respect to the availability data, until 1991 the CIS countries had no system of digital mapping. As a result, GIS developers were forced to carry out map digitization functions typically carried out by state surveys and topographic services such as the UK Ordnance Survey and the USGS. A second key problem is related to national security. Research furthering the development of GIS in the CIS has been greatly hindered by the national security measures imposed by the previous USSR. Koshkarev (1993: 39 indicates: " The gulf of secrecy that was evident until very recently limiting access to the detailed (large-scale) maps of the USSR and remotely sensed images has gravely damaged the geo-sciences by blocking normal research work. Another problem, possibly unique to the post-communist countries, is that of unreliability of information sources due to misinformation by the state. "Deliberate distortions of the state statistical records used for plotting large scale-maps on socio-economic themes has been equally harmful....The problem of unreliability of the Soviet cartographic sources (deliberate distortions nad 'blankspots') has been described ...and it is no secret that for a long time the instructions for the USSR cartographic service obliged it to use distorted base maps for small-scale thematic mapping." Koshkarev (1993: 39).

4.6.4 Bahrain

The development of LIS and GIS in Brahain has been driven by the increase in land values as a result of the wealth of oil in the region. The availability of digital data is restricted to digital topographic data which was a by product 1:1000 aerial mapping carried out in 1982. Bell et al.'s paper highlights two trends that were emerging in Brahain since 1993. First the trend towards UNIX and PC network platforms, secondly the trend towards electronic links between government departments. [25] Here the discussion focuses on a description of the cadastral database approach which has been adopted and on the problems which have been encountered.

The problems which faced the Survey Directorate established in 1978 and which hastened the development of the system discussed below included: duplicated land ownerships, unreliable master plans, amongst other issues discussed by Bell et al (1993)[26]. The Ministry of Works, Power and Water (MWPW) and the Survey Directorate had encountered similar problems and purchased parallel systems with a view to future networking. The resultant database structure is one in which each contributor places data onto a separate layer. The various contributors involved in the development of the database include: 1) the Survey Directorate (base grid, topographic and cadastral boundary), 2) Planning Directorate (planning information), 3) MWPW electricity cables, road reserves, water supply and sewerage), 4) Brahain Telecommunications (fibre-optic cables), 5)The Central Municipal Council (local authority applications), 6)The Land Registry (LRD) (registered land), and 7) the Central Statistics Organization (CSO) (resident registration numbers). Both Intergraph hardware and software components have been utilised in the design of the system.

The cadastral database was designed to accommodate the following accuracy constraints: 1) graphic surveys of 0.3 m accuracy, and 2) instrumental surveys of 0.05 m accuracy.(It is legally required to express survey dimensions to a repeatable accuracy of 0.1 m.) Other constraints related to the attribute content of the database are listed by Bell et al.(1993). A issue to note is that the database is composed of the following three layers:

- A "blue" layer which was captured from 1:1000 Cadastral Index maps. This layer has a relational accuracy of 3 - 10 m.
- A "green" layer captured from new graphic surveys. This layer had an accuracy of 0.3 m.
- A "red" layer which contained data captured from instrumental surveys. This layer had an accuracy of < 0.05 m.

In each case the more accurate layer was allowed to supersede the data of a less accurate layer.

Problems facing the implementation of this system include: mutual currency of data, compatibility of level of accuracy, the provision of forward planning information for areas reserved for specific land uses and security (Bell et al., 1993). An additional problem was that each parcel of land had four systems of reference. This necessitated the creation of a file to relate the elements of the various reference systems together with the owner's name into a database which would enable entry of any one to automatically identify others.
Once the database was largely initiated, two additional problems were encountered. Bell comments on the problem that there remains gaps in the red and green layers and that "the upgrading and inclusion of these parcels to an acceptable accuracy is one of the more difficult areas of current investigation"(1993:, 32). The second problem was encountered with the title deeds information when the red layer was initiated: "Older Title Deeds in the rural areas were normally defined by their dimensions along physical boundaries such as tracks, bands and irrigation channels. Rapid development frequently destroyed these land marks and the geometry of the original surveys was quite inadequate to pin the relative index into absolute position on the grid. Using groups of deeds bounded by established hard boundaries and detailed research interpreting old air photography, obsolete mapping and every other available source, the pattern of deeds in each cell was resurrected and co-ordinated to form a key contribution to the red layer."(1993: 32-33)

The key GIS initiative in Brahain has followed can best be termed a "variable accuracy" or "multi-layered" cadastral approach. Thus the Brahain system provides an example of a multi-scale system. However, it remains essentially a cadastral approach and differs from the model proposed in this study in a number of ways. Firstly, informal and formal settlement areas are not treated separately. Secondly, a metropolitan level database for strategic level planning is not incorporated into the system. Thirdly, the structure of the database and the location of the database is significantly different. Other aspects such as local level informal settlement upgrading, community participation and informal settlement community needs are not addressed by the system at all. In addition despite the more flexible nature of the Brahain Survey Directorate's cadastral approach, there remains the problems which have already been discussed above.

4.6.5 Middle East

The discussion of GIS in the Middle East is comprised of two parts. Th first deals with the development of Municipal Information System (MIS) GIS in Saudi Arabia. The second describes the recently developed Qatar Societal GIS system that has gained international recognition. widespread recognition. The discussion by Al-Ankary (1991) argues that the scarce financial and technical resources in developing countries require that a more flexible approach (than that for a developed country) must be adopted when creating a GIS database. He has interpreted this flexibility to mean that an incremental method involving several phases should be followed when establishing a GIS in the municipal sector. Al-Ankary (1993) utilises the Ministry of Municipal and Rural Affairs (MOMRA) Municipal Information System (MIS) as a case study to evaluate the appropriateness and effectiveness of an incremental implementation method. He argues that the approach can be effective, but also indicates that it has several " weakness and problems, such as the long period of implementation and a lack of co-ordination between different agencies and offices, (which) must be resolved to ensure ultimate success of such an approach." (Al-Ankary, 1991: 85). Here the discussion focuses on a description of this database and its problems.

The Municipal Information System (MIS)

The Municipal Information System (MIS) was designed to aid planning and resource allocation and distribution activities on a regional scale. Al-Ankary describes two alternative database design solutions which were considered for this purpose. These were:1) a comprehensive integrated information system and 2) an incremental system with independently established information sub-systems that can be integrated in a comprehensive system at a later stage. Several reasons were listed for avoiding the comprehensive integrated system approach. These problems face the development of a similar system in any developing country. They include (Al-Ankary, 1991: 38):

- The difficulties that face the collection of vast amounts of data which requires substantial financial and human resources beyond the capability of any single municipality.
- The large requirements for hardware and software, which again would be beyond the funds available.
- The lack of technical experience in the field of GIS could lead to critical mistakes on a project on such a large scale.

The second incremental approach has proven useful after the first two stages. The critical issue to note is that "there is no defined period for the completion of each stage and it is left to the availability of the resources required."(Al-Ankary, 1993: 38). The structure of the second approach involves three levels: a local municipal, a regional and a national level. The configuration of the computer system is discussed in detail by Al-Ankary. In brief the contents of each level can be described as follows:

- At the local level, which enables each municipality to store, retrieve and update information within the municipal boundary, as needed for daily use.
- At the regional level, which enables the Directorates of Municipal and Rural Affairs (regional branches of MOMRA) to monitor the performance of the municipalities and rural clusters and to evaluate the needs of cities and villages within each region

- At the national level, which enables the central departments of MOMRA to obtain information at all levels in order to ensure a regional balance of development and a better planning performance.

For the purposes of a discussion in chapter 11 it is useful to note the architecture of the computer infrastructure is proposed for implementing the above database levels. Al-Ankary (1993: 88-89) comments: "Regionally, a smaller sub-system will be located in the administrative centre of each district. Between 14 to 20 regional subsystems will be established in the final stages, and these will be connected to the central system.... Centrally, the ICC at MOMRA will house the major units of the system.....At the local (municipal) level, microcomputers (IBM compatible) are being used for storing and updating data. The microcomputers will be used as stand-alone stations for local purposes and as online terminals when they become integrated into the national network with possible communication between both the central and regional centres."

The Qatar Societal GIS system

Qatar is the first country to implement a comprehensive nation wide GIS and is recognised as having one of the finest GIS implementations in the world (CGIS, 1997). On the whole, this system is based on a multi-scale approach. The system relies on a high accuracy cadastral-based approach in the urban areas of Qatar and a lower accuracy mapping approach in the remaining areas of the country.

The National GIS Steering Committee in Qatar administers data dictionaries and database specifications. A primary task of the CGIS was the development of digital mapping specifications and standards for the production of Qatar's Digital Topographic Database. The CGIS and National GIS Steering Committee worked with each agency that has implemented GIS to create a volume set National GIS database and data dictionaries one for each of 16 government agencies. The digital topographic (DT) database consists of three components:

- Digital topographic (DT) Base Maps
- Digital elevation models (DEM)
- Ortho-imagery

The Digital topographic (DT) Base Maps consists of vector data maps for the urban areas at a scale of 1: 1000 These areas have been digitized from aerial photography at a scale of 1: 4000 - 1: 5000. The remaining areas have been captured at 1: 10 000 using 1: 30 000 aerial photography. Similarly the DEMs have been generated with a greater accuracy in the urban areas (correct to 10 cm) than in the rest of the country (correct to 1 m). The ortho-imagery is comprised of 10 cm pixels produced using 1:4000 scale aerial imagery for the urban areas. While ortho-imagery comprised of 1 m pixels has been developed from 1: 54000 scale aerial photography for the remaining areas. All sensitive areas have been obliterated to enable use of the data without imposing security risks.

All three components of the DT database can be viewed by the GISnet[27], which is a high speed network interconnecting many distributed GIS databases throughout Qatar. The data on the Qatar GIS is diffused further through GIS kiosks and through a series of software products that have arisen from the system. These software products are essentially a series of tools for automatic map production and for extracting or transforming co-ordinate data. Amongst them are the following packages: EPF (Electronic Place Finder), AmaPS (Automated Map Production System), INSTMAP, INSTAVIEW, MAPExpress, GEONAB, QTRANS, SPIDER and GPS Data Online.

The Qatar system is highly innovative in comparison to other international GIS initiatives. This is particularly the case in terms of the multi-scale nature of the database and in terms of the GIS diffusion mechanisms that have been employed. However, the system has been designed primarily as a cartographic tool and as a result is faced with certain limitations in terms of informal settlement upgrading applications. There are no mechanisms for community participation or for the co-ordination of informal settlement upgrading projects. Furthermore the detailed attribute and vector data are limited (plot numbers, street names, state names and municipality names) to formal areas of the city where the cadastral boundaries have been clearly laid down.

4.6.6 China

The experience China suggests that the government of this developing country is the furthest advanced in terms of its overall approach and thinking in the field of GIS. This case study reveals that in China: 1) the need for a multi-scale approach appreciated and 2) the government seems to be truely interested in addressing the GIS users needs. Unlike the situation in other developing countries where the national security restrictions imposed by the government have hindered the development of GIS (eg. CIS and India), the Chinese government has positively contributed to the diffusion of GIS by funding GIS research initiatives.

Developments in the field of GIS in China have been accelerated by the establishment of a Laboratory of Resource and Environment Information Systems by the Government of China. In other words, whereas the GIS developments in many other developing countries are funded by the donor community, in China such developments are funded by the government of China. In addition to this, the advanced state of the indigenously developed technical capabilities related to GIS (Taylor, 1991) assures the sustainability of GIS initiatives. China has a history of mapping, processing of remote sensing imagery and computer assisted cartography. It has been involved in the development of its own hardware and software, the launching of its own satellites and has sent indigenous specialists for overseas training. Taylor comments: "The country has the capability to assess and analyse imported hardware and software and to adapt that technology to its own situation"(Taylor, 1991: 80). This is a skill that every developing country needs to acquire. It is a skill which needs to replace foreign based GIS initiatives such as those driven by PADCO.

GIS is perceived by Chen as having socio-economic benefits. In addition, Chen comments that "the needs of the users are the basic considerations of the system. (Chen, 1987: 225). At the micro-level, PCs have been introduced into counties. Hardware and software produced in China is utilized for these county systems. Furthermore, Taylor (1991: 79) comments "The importance of comprehensive information for local level planning has been appreciated and the plan is to have a micro-based GIS in every county to aid in decision making.". However, Taylor cites only two areas where such systems were in operation (the Daxing and Fushui counties) (Li and Sun, 1986; Zhong and Zhong, 1987). Grid-based local urban systems (for Dukou and Tianjin) and river basin systems (for the Hwang Ho, Chanjian and Jinshajiang rivers) have also been developed for water management and flood-risk related applications. Provincial level (Jiangsu Province System) and national level systems (the China Tourism Resource Information System and the National Agricultural Information System) have also been developed (Sun et al, 1987; Yan et al, 1987; Zhang & Khou, 1987). Other GIS initiatives include the Population Atlas of China and the Economica Atlas of China Projects (Chinese Academy of Sciences, 1987).

It is clear from Taylor's and Chen's comments that a multi-scale philosophy has been adopted in the implementation of GIS in China. The development of county (local-level) systems is still in its initiation, but the following quotations suggest a national commitment to a multi-scale approach (Taylor, 1991: 79): "The national strategy is for a balance between local, regional, and national applications of GIS; careful thought is being given to techniques and procedures for data normalisation and standardisation. A unique coding methodology has been devised for county names and a database of administrative units of the county has been built.". Taylor. A grid-based system based on latitude and longitude, has been used to establish the first stage of a national database. Chen regards a duality in the form of national and regional GIS levels:

"....on the basis of an analysis of experience in other countries and the lessons that could be learned from them, it was realised that the needs for data sharing to permit national and macro-level decisions could hardly be met with dispersed and unconnected regional systems. On the other hand, a solely national system might be unable to function for may regional tasks because data were over-generalized. A dual system combining both national and regional components in a multi-level structure, with an emphasis on national control but without neglecting regional initiatives, seemed the most appropriate approach to developing a geographic information system for China."
(Chen: 1987: 224)

This comment reveals an understanding for the need for a multi-scale approach, however, it neglects to realise the importance of including the local level systems in this process.

4.6.7 Other countries

A recent study by Price (1998) discusses the implementation of GIS in three other countries that have not been dealt with in this work. His study discusses the Integrated Land Use System (ILUS)[28] in Singapore, the Batam Industrial Development Authority GIS (BIDA-GIS)[29] in Indonesia and the Integrated City Management System (FACIS)[30] in Malaysia. Price (1998: 10-1) uses these case studies to illustrate the problems associated with a "hard" system approach and of lack of awareness of, and insensitivity to, a different culture. Price (1998) discusses in detail national and corporate cultural issues that have influenced the GIS system development process in these countries. In this section, some of the problems that were encountered in the development of these systems are briefly summarised.

A key similarity between the ILUS and BIDA GIS is that both systems were developed using the Siemen's "Process Engineering" methodology (Price, 1998: 10-26). The unflexible nature of this methodology proved to be problematic as a result of communication problems[31]. The "Process Engineering" methodology also proved problematic in South Africa[32] (Price, 1998: 10-29). Both these experienced technical problems relating to hardware and software, as well as organisational problems. In the case of the ILUS system, the GIS software capabilities could not meet all of the users' needs. Hardware problems were also experienced because of the size of the system. As a result, the development of this system cost considerably more and took longer than was originally planned. With respect to the BIDA system, the only software problems encountered were defects (Price, 1998: p36). In addition, there were also disagreements between the system developer and client (BIDA). Further more, the result of a top-down system initiation process led to the development of a system that remains under-utilised[33] (Price, 1998: 10-40). Price (1998: 10-43) discusses in detail the reasons for the failure of the Batam project. These have been summarised here as follows:

- a lack of commitment by senior management in BIDA
- the developer's lack of understanding of Indonesian culture
- the commercial responsibilities of the development team
- poor communication between the developer and BIDA
- the opposition of the Head of IT in Jakarta
- project phases that were defined by financial rather than technical criteria

The implementation of the FACIS system proved less problematic as the developers of this system drew from the lessons learnt from the development of the ILUS and BIDA systems. Two key issues led to the greater success of this system. In contrast to the ILUS and BIDA systems, the FACIS system was implemented using a systems development approach that is more flexible than the "Process Engineering" methodology. In addition, the development of this system was placed entirely in the hands of a local company (Price, 1998: 10-44).

4.7 SYNOPSIS OF PROBLEMS FACING THE IMPLEMENTATION GIS IN DEVELOPING COUNTRIES

The problems identified in the various case studies that have been discussed in this chapter can be grouped into the following categories:

1. Data availability problems
2. Political and bureaucratic problems
3. Socio-economic problems
4. Technical problems
5. Implementation problems
6. Database design problems (structure)
7. Database design problems (conceptual issues)

Each of these categories is discussed in turn below.

<u>Data availability problems</u>

- The <u>lack of detailed digital topographical and cadastral data</u>. This refers to both the hard and softcopy formats of this type of information. Digital data availability with respect to such data sets is generally extremely poor. This is the case in Kenya and Cambodia where villages are very often not mapped. Where data does exist it tends to be out of date or problematic to import into other applications (eg. Kenya).
- The <u>lack of</u> acceptable quality <u>hard copy base maps</u>. Where records do exist for infrastructure, they are usually out of date. This is especially the case for sub-surface infrastructure networks (storm water drainage systems). Incomplete and incoherent land ownership data is also a problem in Ghana.
- In addition to the lack of base maps for engineering infrastructures, there is also often <u>a lack of land use maps</u>. In these cases the initial applications designated for development are often

forced towards land use mapping (eg. Philippines). A basic land use map is essential to the majority of GIS urban applications.

- Often the actual extent of settlements is not known, as the villages are only marked by point locations (eg. Cambodia).
- The lack of digital data in many developing countries places additional data capturing responsibilities on GIS developers. This has been the case in the CIS countries where there was no system of digital mapping until the 1990's. These additional responsibilities significantly hinder the development of GIS applications in these countries.

Political and bureaucratic problems

- National security restrictions have been problematic in India and in the CIS. In India these scale restrictions make it impossible for local level implementations to be initiated. As a large part of India (40 - 60%) lies with the restricted or secret area category, it is not possible to map at scales greater than 1:250 000 for 40 - 60 % of the country. In the CIS, national security restrictions limiting access to the detailed (large-scale) maps of the USSR and remotely sensed images has gravely damaged the geo-sciences by blocking normal research work.
- The post-communist countries have also been subjected to deliberate distortions of the state statistical records used for plotting large scale-maps on socio-economic themes. (eg. CIS)
- The resistance to giving GIS-based land management maps a legal status. This has been experienced in Ghana. The same is true in South Africa (Municipality of Gauteng).
- The relocation policy of the current government discourages local authorities from placing informal settlements onto the metropolitan GIS databases. These areas are not seen as permanent settlements and it therefore seems senseless to spend too much time or money mapping these areas.

Socio-economic problems

- The distribution of GIS skills is highly localized. The vast majority of the population are computer illiterate. GIS skills exist essentially in the form of visiting consultants such as PADCO and GDZ.
- There is a need for the indiginization of skills and resources for GIS initiatives. The bulk of GIS initiatives in Africa and Latin America have been developed by foreign organisations, only in Asia, particularly in China has there been any evidence of the indiginization of GIS (Taylor, 1991).
- There is a lack of financial resources to develop indigenous skills. Developing countries are faced with a series of socio-economic problems such as poor transportation and other infrastructure problems (eg. Kenya). In addition there are other problems such as land allocation conflicts associated with resettlement plans (eg. Cambodia). The dominance of such problems in these countries prevents local governments from using their limited financial resources to invest in computer-based upgrading methodologies.
- Rapid rate of change. (Bangkok, Cape Town, Johannesburg, Sao Paulo etc). The rapid rate of change associated with informal settlement areas discourages local authorities from mapping these areas into the "City database".
- Migratory patterns of informal settlement inhabitants. The phenomenon of "circulatory migration" in South Africa has already been referred to in chapter 1.
- Developing countries are very often characterised by a far higher degree of political instability than developed countries. Developing countries are typically in the process of local government

transformation. The result of widespread local government restructuring is often a dispersion of records and further delays in the upgrading process.

- Post-communist countries are characterised by a series of socio-economic reform processes. These processes hinder the implementation of GIS (which requires a relatively high degree of organisation stability) within local authorities in these countries.

Technical Problems

- Associated with the problem of lack of digital data is the problem of the cost of data capture.
- The quality of existing data is often a problem.
- GIS systems in India have been criticised for not being able to handle large database sizes.
- The level of computer-based information infrastructure is generally very poor. Access to INTERNET is restricted to large cities. The distribution of INTERNET access centres to areas of informal settlements is only starting in South Africa. In the majority of the developing countries it remains an issue for future consideration only.
- Techinical problems in the CIS and in other post-communist countries include a shortage of modern hardware (eg. high-resolution monitors, min-computer based workstations), as these products were still on the COCOM list.

Implementation problems

- The involvement of too many organisations in the data capture process. (India)
- The community level does not receive any benefits from the "top-down" approach.
- Systems donated by foreign countries are underutilized and remain in an experimental phase indefinitely, or simply collapse once the system developers have left the country. A large number of systems in the CIS, which were developed upon receiving funding or free software from Sweden and the United States remain underutilized. System developed by PADCO in the Philippines collapsed once the development agency stopped maintaining the system.
- Koshkarev lists a large number of workshops, conferences and seminars (held during the period of 1983-1991) which dealt with the topic of problems facing the implementation of GIS in the USSR.

Database design problems (structure)

- Systems created within local authorities and by development agencies tend to be designed in a single level manner. They are intended to address either local or metropolitan level issues only. Local examples are the PROLAND system, the Megasub HELP database (both at the metropolitan level) and the housing plan analysis system (at the micro-level). Foreign examples include the projects by PADCO in the Philippines and in Jamaica and the AFRICAGIS system in the African countries.
- Systems designed within local authorities tend to follow a cadastral approach. Local examples include the Gauteng Transitional Metropolitan Council (GTZMC) and the Cape Town City Council (chapter 3). Foreign example include the purely cadastral system developed by the Survey Directorate in Brahain. The problems associated with cadastral systems in the African developing countries have already been discussed in section 4.5.1.

Database design problems (conceptual)

- Systems tend to address the needs of spatial planners, surveyors, or development agencies and not the needs of the community. This is evident in the PADCO initiatives in Jamaica and in the Philippines, in the South African PROLAND and Megasub HELP databases and in the AFRICAGIS database.

- In some cases no consideration has been given to ensuring that different data sources can be integrated. For the Ghana land ownership database no projection or transformation was defined and no georeferencing was carried out. This approach negates one of the key advantages of a GIS-based approach.

4.8 GENERAL CONCLUSIONS ON THE IMPLEMENTATION OF GIS IN DEVELOPING COUNTRIES

This section is comprised comments arising from the discussion by Taylor (1991). These comments revolve around the following issues: appropriate technology for developing countries, the need for indiginization of GIS skills and appropriate data types for GIS applications in developing countries.

Often it is brought into question whether GIS technology is applicable in developing countries (Dangermond, 1988; Taylor, 1991) [34], [35],[36]. I argue that it is not the technology, but rather the "approach" as referred to by Taylor (1991) which should be brought under scrutiny. Taylor's conclusion recognises that a mixture of the "bottom-up" and "top-down" approaches is required in developing countries[37]. However, this realisation alone is insufficient to ensure the success of GIS initiatives in developing countries. The present author argues that while a flexible scale approach is required, there are certain aspects of such an approach which can be more rigorously defined in terms of a GIS implementation model to facilitate its implementation by developing countries on a world wide basis. A clarification of the potential working scales, database structures, hardware and software configurations, problems, applications, communication networks and other issues need to be considered. These issues are dealt with in chapters six to eleven of this study. The need to recognise that GIS must be seen in the context of development policies and approaches of government is also important [38], [39] (Taylor, 1991; Stefanovic et al, 1989).

There are two other issues dicussed by Taylor which have been referred to in this study. The first deals with the need for indigenized technologies. The second deals with appropriate data types (ie. raster versus vector). Taylor comments that the GIS systems must be introduced by indigenous scientists who understand both the technological and socio-economic context in which the systems are to operate[40]. In his conclusion on the future of GIS in developing countries, Taylor argues that there is a need for the technology to be "indigenized" and to be adapted for local needs. He also argues that approaches which depend on foreign donors, expatriate experts or foreign firms are least likely to succeed. The additional case studies considered in this thesis (in particular the PADCO studies) contribute to Taylor's arguments in this respect.

With respect to the second issue, he comments that countries too small to develop their own expertise should look to China rather than to the United Sates, Europe or Canada as a source for technology transfer, and continues that "China's pragmatic raster-based systems, utilizing remotely sensed data with databases of a manageable size may be more useful than "Cadillac vector-based systems" designed for North America or European realities ." (Taylor, 1991: 81). I would agree to some extent with the first part of these comments. However on the issue of raster based systems being more appropriate than vector based systems for developing countries I would disagree. Remote-sensing raster based systems may be appropriate for regional systems, but are totally inadequate for local level GIS initiatives. The present study highlights the need for local database development to assist in the implementation of informal settlement upgrading plans. The requirements of such local databases demand both raster and vector based data inputs.

4.9 DIFFERENCES BETWEEN GIS SYSTEMS IN DEVELOPING AND DEVELOPED COUNTRIES

A series of differences may be highlighted between the implementation in developed countries and developing countries. Some of these differences have already been highlighted in the preceding discussions.

4.9.1 Length of experience in GIS

The development of GIS in the developed countries has preceded similar developments in the developing countries by about twenty years. GIS was first developed in Canada in the 1960s and was based on mainframe technology. In the developing countries the initiation of GIS activities only commenced in the 1980s (Taylor, 1991: 73) and microcomputer technology has been principally employed (Edralin, 1990).

4.9.2 The developers of the GIS initiatives

Whereas the developed countries have GIS initiatives predominantly developed by local organisations, Taylor (1991) observed that GIS initiatives in the developing countries are generally funded or supported by international aid agencies and that many are pilot or research projects as opposed to operational systems. In addition, the systems are controlled by outsiders, not by indigenous scientists. Taylor cites a number of UN and ITC funded examples of GIS initiatives in developing countries. The UN has been responsible for the GRID system based in Nairobi and Geneva and for the Asian Institute of Technology (AIT) in Bangkok. Another foreign GIS developer for third world countries includes ITC. This agency has its own microcomputer-based GIS called ILWIS (Integrated Land and Water Management Information System). Taylor (1991: 75) continues later in his discussion: "Most of the systems being purchased at present are being obtained by government agencies and often the purchase is supported in part by ODA funds from a variety of donors. " Further more he quotes Sundaram (1987: 55), who demands a "socio-economic command of the development of science and technology" to prevent a continuation of the mismatching tasks performed by the GIS and the reality of the current application situation. Taylor (1991: 76) argues that it is necessary for indigenous scientists and decision makers to gain a greater understanding and control of GIS.

I would argue that even if these demands are met it does not ensure a successful implementation of GIS in a developing country. One need only to reconsider the City Council case study briefly. This is an example of a local GIS driven by South African GIS experts. Yet the system has not been very effective. Another local example already discussed in detail is PROLAND. This is an example of a system developed by South African scientists, yet it too has had no significant impact. An excellent knowledge of GIS amongst the decision makers and indigenous scientists is clearly not enough. In addition to a better GIS knowledge base, a willingness to develop innovative and appropriate GIS models is needed amongst the local GIS experts. Spatial models for developing countries need to recognize the complex dynamics of informal settlements, the potential for government policy analysis, the potential for developing spatially based multi-party communication networks incorporating all parties involved in the upgrading process, and above all such models need to focus on the informal settlement' communities' need, in addition to the needs of local and national government planners.

4.9.3 Socio-economic-political differences

These differences have already been discussed at length in the analysis of GIS in South Africa with respect to the European experiences. They can be grouped into socio-economic-political differences of resources and differences of reforms. The socio-economic resource differences include the far more limited financial, technological infrastructure and computer literate human resources which face the developing countries. The impact of the lack of such resources can not be underestimated. As Campbell (1996) points out, it is the availability of human and financial resources and of up to date digital data which has facilitated diffusion of GIS in Britain. The same is true for a number of other developed European countries such as Germany, Netherlands, France and Denmark. The socio-economic-political reform differences include a series of processes underway in the developing countries entering the post-communism and post-apartheid eras. Koshkarev (1993) has described some of these processes for the CIS. In South Africa and in other African developing countries such as Zimbabwe, these processes include the regularization of land tenure.

In addition to the greater resources available for the development of GIS initiatives, the developed countries have already undergone a large number of reforms. Masser et al. (1996) point out numerous European countries where changes in the legislation involving a decentralization of responsibilities to local authorities and, where proactive government initiatives involving the funding of GIS schemes in local government, have accelerated the diffusion of GIS. These countries include Great Britain, Germany, Denmark, Netherlands and France.

Several attempts have been made to accelerate the diffusion of GIS in a number of developing countries through legislative reforms (eg. Phillipines, Poland, South Africa) and through funding schemes (Greece and Portugal). Despite a number of land information system related mandates, many developing countries in the South have not yet experienced the accompanying legislative reforms which are required to make local level implementation of GIS for informal settlement upgrading a reality. The control that these processes can exert on the diffusion of GIS has been illustrated by several case studies. Thus two key socio-economic-political environmental factors which will continue to hinder the diffusion of GIS within many developing countries include the privatization of utility services and the lack of security of tenure in informal settlement areas. While the post-communist countries (and probably the post-apartheid countries as well) continue to recover from a history of repression and mis-information. The implication is that these developing countries have less reliable historic information to build their GIS databases than the developed countries.

4.9.4 GIS Needs

The needs facing the GIS systems of the developed and the developing countries are different in numerous ways. While engineering applications within the developed country local authorities are concerned with improving the quality of service provided, the GIS of many developing countries have yet to address the issue of providing even the most basic services. In addition to local level infrastructure upgrading applications, developing countries require systems to aid the registration and transfer of land ownership rights in countries undergoing a regularization of land tenure. Further more, while strategic level applications have been created for developed countries and for some of the formal areas of metropolitan regions within the developing countries, there remains a great need for strategic level applications focussed on informal settlement upgrading initiatives.

4.10 COMPARISONS BETWEEN THE CAPE TOWN CITY COUNCIL (CCC) GIS AND OTHER SYSTEMS

4.10.1 The CCC GIS and systems in other developing countries

In a previous discussion on the problems identified in the various developing countries studied, seven categories were applied to group the problems identified. The problems facing the Council's GIS are briefly considered here in the context of these categories.

Data availability problems

As with local authorities in Kenya, Cambodia and Ghana, the City Council is faced with a lack of: detailed digital topographical and cadastral data, acceptable quality hard copy engineering base maps. However, unlike the situation in the Philippines, there is no need for regional level land use maps. Further more unlike the situation in Cambodia, where villages are remain often only marked by point locations, the City Council has recently begun to collaborate the UCT to map informal settlements in the CMA. Finally, unlike local authorities situated in countries which have only recently acquired a national system of digital mapping (eg. CIS), the City Council has been able to access data for a large number of areas mapped by the Surveyor General. This has reduced the amount of additional data capturing responsibilities on GIS developers within the Council.

Political and bureaucratic problems

Unlike the situation in India and in the CIS, GIS within the Council has not been faced with severe national security restrictions. Whether or not deliberate distortions of the state's data occurred in South Africa during the Apartheid period (as occurred in the communist countries) lies beyond the scope of this thesis. Two other political / bureaucratic problems facing the Council which have already been discussed are the resistance to giving GIS-based land management maps a legal status (also experienced in Ghana) and relocation policy of the current government.

Socio-economic problems

The socio-economic problems facing the implementation of GIS in the City Council are similar to those encountered in the majority of the developing countries. These include:

1. the highly localized distribution of GIS skills
2. the need for the indiginization of skills and resources for GIS initiatives
3. the lack of financial resources to develop indigenous skills
4. the rapid rate of urbanization
5. the high degree of political instability
6. local government transformation processes which result in a dispersion of records.

In addition the other problems specific to informal settlement GIS applications for the CMA include the migratory patterns of informal settlement inhabitants already discussed.

Technical Problems

The technical problems facing the Council are not as severe as in the poorer developing countries. There is also no shortage of hardware or software as faces the CIS.

Implementation problems

GIS implementation problems are abundant within the Council and amongst the vast majority of local authorities within the developing countries. As in India, the Council's approach to GIS prevents any benefits from the system to be derived at the community level. Further more, as is the case with externally developed systems and GIS applications in CIS, applications initiated by external departments within the Council's engineering branches are unsustainable without continued external support and maintenance.

Database design problems (structure)
As with most GIS initiatives throughout the world, applications within the Council continue to follow a single level application philosophy. The key application in the Council follows the cadastral approach. Some of the problems facing this approach have already been outlined in the discussion on the cadastral approach followed by Survey Directorate in Brahain. In contrast to local authorities in China, India and in Saudi Arabia, the need for a multi-scale approach has yet to be acknowledged by the City Council and other local authorities in South Africa.

Database design problems (conceptual)
As with the GIS systems in Jamaica and the Philippines, the Council's GIS does not address the needs of the community. In the case of Jamaica and the Philippines, it is the needs of the planning and development agencies that area addressed. In the case of the Council, it is the needs of the Surveying and Land Information department that are addressed. Further more, was the case during the construction of the Ghana land ownership database, little attention is currently given to data sharing issues by the engineering branches within the Council.

4.10.2 The CCC GIS and the Greater Johannesburg Transitional Metropolitan Council (GJTMC) system

It is useful to briefly compare the development of GIS in the Greater Johannesburg Transitional Metropolitan Council (GJTMC) and the Cape Town City Council (CCC). These two Councils are faced with the similar socio-economic, political and other problems. In particular, they are both faced with the problem of informal settlements, and with the lack of cadastral data associated with these areas.

Similarities
The Greater Johannesburg Transitional Metropolitan Council (GJTMC) and the Cape Town City Council (CCC) GIS systems underwent similar developments in the initial phases of GIS implementation. In both cases the GIS was started as a land surveying utility and was therefore developed as a cadastral database from the start. As a consequence, there are strong similarities between the problems which initially faced the GJTMC system, and those that continue to face the CCC GIS. These problems include amongst others: 1) a continually out of date cadastre, 2) a lack of GIS applications throughout the organisation and an absence of GIS applications for informal settlement areas. Software compatibility has been a problem common for both organizations. A key problem which faced the GJTMC GIS system was the lack of interaction between MapInfo and the main system (Genamap)[41]. Similar problems were encountered with MapInfo users within the CCC GIS.

Differences
The key differences between the GJTMC and the CCC GIS arose during later developments which took place during the implementation process. These developments which occurred within the GJTMC included a change in the organizational structure for GIS implementation and a shift towards a more scale flexible, less cadastral approach to GIS. These differences in the management of the GIS may be partly due to recent changes in local government. Associated with the Gauteng

Upgrading Programme has been the regularization of land tenure in informal settlement areas. In contrast, the population residing in informal settlements within the Cape Town metropolitan area continues to be subjected to a relocation policy.

With respect to the organizational structure, at the GJTMC it has become clear that the responsibilities of the project and of the cadastral maintenance procedures must be treated separately. With respect to the second issue, the cadastral approach is now used in only 2.3 % of the projects in the GJTMC. While the cadastral approach set a standard position of 300 mm closure level on a stand and 25 mm on built-up areas, the majority of the present projects work at a far lower accuracy. The future aim is to digitize within township co-ordinates (1-2 m accuracy). Currently, the data capturing is prioritized in terms of projects and there is little detailed cadastral data capturing taking place. Even this limited amount of activity on the cadastral approach is criticized.

The development of the Cape Town City Council GIS has lagged behind the development of the GJTMC system in two ways. Within the CCC GIS remains under the control of a single department, namely the Survey and Land Information Department, and consequently a cadastral approach continues to be followed. Secondly, as a result of this lack of change, problems which no longer dominate the GJTMC system are still present in the CCC. By shifting away from a purely cadastral approach to GIS the developers of the GJTMC GIS have enabled 1) a widespread development of applications throughout the Council and 2) a development of applications for informal settlement areas.

CHAPTER FIVE: THE IMPLEMENTATION OF THE VISUAL SETTLEMENT PLANNING (ViSP) APPROACH TO INFORMAL SETTLEMENT UPGRADING IN BELO HORIZONTE

5.1 INTRODUCTION

In chapter 4, several key international and local GIS-based development programmes were reviewed. All of these programmes have one problematic criterion in common. They have all been designed for countries where the regularization of land tenure in informal settlement areas remains an issue of major national debate. The Belo Horizonte approach, and specifically the Alvorada Programme differs significantly in this respect from the programmes discussed previously. In 1983 the Municipal Law for the Regularization of Favelas (PROFAVELA - Programa Municipal de Regularisacao de Favelas) was passed in Brazil. This law placed Brazil as one of the first developing countries to recognize the favela (informal settlement) resident's rights to ownership of the land they occupied. The PROFAVELA law assigned the then 120 favelas in the municipality of Belo Horizonte to Special Zones of Social Interest. This enabled these areas to be exempted from the general planning and building regulations applying throughout the municipality and to be considered for in-situ upgrading through the development of spatial plans.

The key principle embodied in the PROFAVELA Law is that the settlement structure of the favela be maintained. Thus the approach followed in the Alvorada Programme is one whereby the process of spatial restructuring is based on a detailed evaluation of the problems and potentials of each favela. This evaluation process is carried out through the development of a local-level GIS database for in-situ upgrading. Using is approach a General Plan (Plano Global)[1] has been developed for each favela considered in the Alvorada Programme. The initial aim of adopting the concept of a General Plan was to enable these plans to determine a set of urban guidelines and lines of intervention necessary for the consolidation of settlements (AVSI, 1996). By 1994 General Plans had been drawn up in the Alvorada Programme for several regions involving about 5600 families. These regions included: Vila Sumare, Vila Tiradentes, Vila Sao Tomas, Conjunto Jardim Felicidade, Vista do Sol and Vila Marmiteiros.

This GIS-based component of the Alvorada Programme has been referred to as the ViSP (Visual Settlement Planning) approach to the upgrading of informal settlements. This chapter proposes to explore the ViSP approach in detail and to assess its strengths and weaknesses as a basis for spatial definitions and management of informal settlements. The work presented here constitutes a description and brief analysis of in Belo Horizonte arising out of a one-month study. The chapter begins with an overview of the evolution of the organizational structure of the Alvorada Programme. It then outlines the current hard and software system configurations and the data capture, processing and structuring methodologies adopted in the Visual Settlement Planning (ViSP) approach in Belo Horizonte. With the rapid advances taking place in computer technology, the characteristics of a computer system which best addresses the needs of an informal settlement upgrading GIS system has inevitably changed. However, the information presented here provides an indication of the basic hardware and software requirements for GIS-based local level informal settlement upgrading initiatives elsewhere. Other issues discussed in this section include the thematic maps produced by the ViSP approach, experiences of the ViSP approach in other areas and the key advantages of the approach.

5.2 EVOLUTION OF THE ORGANIZATIONAL STRUCTURE

In 1983 the pressure from civil society, in association with other issues led to the passing of the Municipal Law for the Regularization of Favelas (PROFAVELA - Programa Municipal de Regularisacao de Favelas), the first law in Brazil that recognized favela resident's rights to ownership of the land they occupied (Abbott et al., in press). The PROFAVELA Law applies to densely occupied favelas with economically needy populations, that existed up until the date of the aerial photography survey of 10 September 1981 (updated in 1996) (Abbott et al., in press: 45). These areas are assigned Special Sector 4 zoning (now referred to as ZEIS (Zonas Especias de Interesse Especial - Special Zones of Social Interest) 1 and 3), which recognizes, where possible, the characteristics of spontaneous occupation. They are therefore excluded from the general norms applying throughout the municipality. Instead, they are subject to specific norms issued by decree, together with the approved spatial plan. The areas are exempted from taxes and contributions for upgrading for a period of 5 years. Ownership of the plots may be directly transferred to occupants.

The Pastoral de Favelas developed a ten year target through which approximately ten favela legislations a year would reach the then 120 favelas in the municipality. However, implementation remained slow due to bureaucratic problems experienced by the municipality and due to a lack of experience in favela intervention. Two developments were significant in overcoming the implementation obstacles. Firstly, identifying a lack of technical capacity, the Catholic Church, through the Pastoral de Favelas, invited the Voluntary Association for International Service (AVSI - Associazione Voluntari per il Servizio Internazionale) to give technical support to the upgrading in Belo Horizonte. Secondly, the Union of Workers of the Periphery (UTP - Uniao de Trabalhadores de Periferia) supported by other organizations responded to the municipality's problem with bureaucratic procedures by proposing the creation of a separate public body specifically charged with the implementation of the PROFAVELA Law (de Azevedo, 1987: 134). This proposal was implemented through the creation of the Upgrading Company of Belo Horizonte (URBEL - Companhia Urbanizadora de Belo Horizonte) in 1985 out of the municipal mining and housing company FEROBEL. However, due to URBEL's low operating budget, AVSI's main partner in upgrading was the state of Minas Gerais. This situation changed in 1993 when the progressive Worker's Party (PT - Partido dos Trabalhadores) entered into power. As a result URBEL received more resources than in previous years and was now in a position to articulate an upgrading programme. This enabled AVSI to work in a closer relationship with URBEL. The AVSI-URBEL partnership led to the elaboration of the Alvorada Programme, a pilot project implementing the integrated upgrading methodology, and funded in part by the Italian government through AVSI and in part through municipal and state funding. This initiative was targeted at 6 favelas as a pilot intervention, pioneering the GIS supported approach and encompassing a significant shift from an engineering focus to recognizing the favela as an issue of urbanism (Abbott et al., in press). Though recognized as a successful approach, implementation of the Alvorada Programme has been extremely slow. A discussion of the methodology follows as well as an evaluation follows in the remaining sections of this chapter.

5.3 METHOD OF INVESTIGATION

5.3.1 Aims

The purpose of the survey of the Visual Settlement Planning Approach (ViSP) adopted in Belo Horizonte was to document the current GIS-based ViSP applications in the fields of urban management, planning, squatter-settlement upgrading and natural hazard alleviation in Belo Horizonte[2,3]. This included overviews of the following issues:

- monitoring, fast response and mapping applications
- technical and analytical capabilities of the software applied in the ViSP approach[4]
- the role of GIS in the community participation process
- analytical GIS applications for stormwater management and other applications in the squatter areas

5.3.2 Methodology

The methodology involved the following procedures:

- interviews of staff involved in the Alvorada Program,
- hands on experience of the software used at AVSI, and
- the analysis of maps[5], sample data sets[6] , reports[7], and other outputs[8]

A full listing of these data sets and documents appears in tables 1 and 2 in appendix 4. A week was spent becoming acquainted with the general aspects of the ViSP approach through the Alvorada Project. The various activities which were observed included: the data capturing and processing associated with socioeconomic, cadastral, topographic, infrastructure services and other data types, thematic mapping activities, legislative and planning activities and community participation procedures. These processes were observed in the context of one specific project namely the Villa of Nossa Senhora dos

Passos. The remaining period was spent becoming acquainted with the application of the following software packages AutoCAD, the Gheo software suite, MapInfo and other customized software packages.

The discussion on thematic mapping is derived from unpublished internal reports circulated within URBEL. The description of the Gheo software suite, which has been selected as the backbone for the information processing component of the methodology, has been distilled from the Italian documentation by CARTECH (1996) and from observations on the application of this software in the CAD 126 Computerized Cartography Laboratory in Belo Horizonte. The discussion on the database structure was written by inspecting the GHEO configuration files associated with the data files acquired from AVSI. Although the methodology is claimed to have been operational in B.H. for just over the period of two years (AVSI, 1996), many of the fundamental concepts which are the basis of the approach have been previously discussed by (Moura, 1993). In addition, the work by Moura et al. (1993), which was conducted on the Intergraph and Microstation software platforms, although no longer applied in Belo Horizonte, remains relevant, as we have selected the latest versions of these platforms for this project[9].

5.4 DEVELOPMENT OF THE VISP SYSTEM AND THE ALVORADA PROGRAMME

A strong partnership exists between URBEL and AVSI and together with other agents, these organizations have developed a methodology for intervention in the informal settlement areas. This partnership involves agreements for technical and financial cooperation the following three areas:

- The Alvorada Programme
- An information system applied to shanty town areas and,
- Global Plans for existing settlements

This section reviews the key aspects of the Alvorada Programme and describes the ViSP approach implemented in the construction of the information system.

5.4.1 The Alorada Programme

In Belo Horizonte, which has a total population of 2.5 million, more than 400 000 people live in 200 squatter settlements ("favelas") (AVSI, 1997). These areas are characterized by a high risk of flooding and landslides. The programme has been designed for the social-urbanistic and environmental recovery of degraded urban areas in the metropolitan region of the city of Belo Horizonte[10]. It has been implemented in several favelas. Amongst these are the Vila Nossa Senhora Aparecida, Vila Apolonia, Lixao, Vila

Marcola, Vila Senhor dos Passos and Vila Ventosa. In the Vila Nossa Senhora Aparecida, which contains 1300 families, 15 % of the area has a slope above 47 %. In addition to difficult access, the vila is faced with precarious sewerage, drainage and garbage collection. The Vila Marcola faces similar problems. In this case 50 % of the area has a slope of above 47 %. The Vila Apolonia (1100 families) is characterised by a low level of consolidation. The vila is disconnected both internally and with the surroundings, and is also faced with an absence of infrastructure and services. The Lixao settlement (411 families) is situated on a garbage dump and as such represents a settlement in a critical risk area. Gas emissions from the decaying garbage dump are a serious fire hazard. The Vila Senhor dos Passos is well connected to the surroundings but has a disconnected internal passageway. There is also a considerable demand for land regulation facing this favela. The Vila Ventosa has no accessibility for urban services and is also characterized by a precarious sewerage system.

5.4.2 The Visual Settlement Planning (ViSP) approach

Prior to the introduction of the ViSP approach in Belo Horizonte several years of collaborative research initiatives had already taken place in this field (Moura et al., 1993). During 1989 - 1992, AVSI together with the Pontifical Catholic University of Minas Gerais and the University of Bologna collaborated on the development of a computerized-based approach to informal settlement upgrading[11]. Computer science applications were developed in the CAD 126 Computerized Cartography Laboratory at the AVSI headquaters in Belo Horizonte. Moura et al (1993) discuss in detail the methodology and the thematic mapping scheme which resulted from these initiatives. At the time, the project had been limited by serious financial limitations which had prevented the full completion of a topographical survey and of specific census data collection. As a result the favela of Vila Nossa Senhora Aparecida was chosen as these data types had already been collected in the past for this area. The software which was used at the time was Microstation - Intergraph (version4.0)[12], dBase III, Dig-Road and Cartocad - TDV. The Visual Settlement Planning (ViSP) approach was initially developed by UNCHS (Habitat), in cooperation with the Technical Research Centre of Finland (VTT) as a GIS-based emergency relief tool for disaster relief. The present system is the product of years of international research and implementation. In particular, the development of the ViSP system has been influenced by previous GIS application experiences in Kenya and Italy.

5.4.3 The Role of GIS in the Alvorada Programme

A typical Alvorada Programme project consists of several phases and of a multitude of collaborative planning, surveying, social interactions and other processes. Such a project as for the Sr. Dos Passos favela can be broken down into four key phases. These are preliminary research (1), preliminary surveys, formulation of guidelines and urban plan (2), planning processes (3), and implementation processes involving the provision of infrastructure (4).

The components of each of these phases have been loosely translated from an Alvorada Programme flowchart for the Senor dos Passos upgrading project to produce table 3 in appendix 4. The first phase consists of a series of surveys and preliminary research projects. The second phase leads to the development of a preliminary urban plan. In the planning phase project diagnosis and urban plan are further developed. The definition of the parcel boundaries and the land registration processes are also included in this phase. The fourth phase involves the development of detailed construction plans and the implementation of these plans. Throughout all of the phases the social action group is intensively involved in negotiations with the affected communities. The GIS database developed for the ViSP approach is initiated subsequent to or during the second phase. The database is developed throughout the duration of the project and several application maps are extracted from the system to aid activities in the third and fourth phases. The GIS system has three registers (AVSI, 1997). These registers are designed for the analysis of the area and for its subsequent management and are as follows:

- A register for town planning-environmental ties
- A register of the occupants
- A land register

The register for town planning-environmental ties gathers information on provisions and land tenure characteristics, as well as hydromorphological and environmental risk characteristics. The register of the occupants consists of socioeconomic census or sample data of the area population. It contains data on family units including the following data types: name, sex, age, education, employment, housing conditions and degree of community organisation. The land register consists of data relevant to the use and ownership of the land. This includes information such as location, area, type of use, tenure and period of occupation. The development of the basic low accuracy cadastral database which results from the ViSP approach is complemented by data inputs from other organizations. The key organizations[13] which have contributed to the development of the Alvorada Programme GIS databases are listed in table 4 in appendix 4.

5.4.4 Steps in the ViSP approach

The sequence of steps employed in the ViSP approach in Belo Horizonte, with exception to the use of videography, is essentially identical to the sequence followed in Kenya (Table 5.1). The capture and use of video imagery has been implemented in Kenya only. Very little if any video imagery based work has been done in Belo Horizonte. In contrast to the Kenyan methodology that incorporates a video camera mounted to an aircraft, the methodology used in Belo Horizonte uses only a hand held 35 mm camera for photographs taken from a helicopter. Table 5 in appendix 4 lists further details on the hardware and software that was implemented in the ViSP approach in Kenya.

Table 5.1 Steps involved in the ViSP approach in Kenya (modified from: Nieminen 1995)

1. **Collection of existing map material of the target area**
2. **Preparations to take aerial videos, photos of the area**
3. **Flight over the area (aerial photos, slides, videos)**
4. **Processing of the material acquired from flights (film development, printing of paper copies)**
5. **Capture of video images onto the computer**
6. **Capture of slides and aerial photos into the computer**
7. **Geo-referencing of captured material (also use of GPS)**
8. **Geometrical correction of images, when applicable**
9. **Building of photo mosaics**
10. **Print-outs and "raw maps" for survey teams**
11. **Attribute data collection in the field**
12. **Preparation of GIS map base from picture/image material**
13. **Linking collected attribute data to GIS map-base**
14. **Statistical analysis, preparation of thematic maps**
15. **Visualization of picture material (add texts, symbols)**
16. **Preparation of plans, improvement options etc**
17. **Awareness campaigns using processed picture and image material**
18. **Implementation and follow up**

In Belo Horizonte, the GIS component of the ViSP approach focuses on the development of numerous local level databases. A separate database is developed for each informal settlement being upgraded. Thus the areas covered by the local level databases can typically range from 3.6 ha (Lixao) to about 24 ha (Vila Marcola). These databases area designed for detailed micro-scale work. The principle functionality of the database changes throughout the duration of the project. Initially it serves as a tool for drawing up the settlement diagnostics and preliminary urban plan. As the project develops and more detailed geotechnical, infrastructural services, socioeconomic, land ownership and topographical surveying data are entered into the database, other planning related applications become possible. The database is then used: in the land parceling process, to identify specific resettlement areas etc. In the final stages of the project, the database is used to guide the implementation process.

A number of differences exist between the techniques developed in Italy and those employed Belo Horizonte. In Belo Horizonte, GIS has been used primarily to guide local-level implementation projects. In Italy, other urban management applications have been developed by the University of Bologna and CAR-TECH. These applications involve more complex analyses of the data acquired in the ViSP project, and have been developed on additional software systems not used in Belo Horizonte (namely, Intergraph and Arc-Info software). In Belo Horizonte, a planning approach has been followed, involving substantial community interaction, and the focus has been on implementation. In contrast, in Italy the focus has been on research and analysis.

5.4.5 General Plan (Plano Global)

It is important to briefly consider the definition of the "Plano Global" which has been developed as part of the Alvorada approach as the implementation of this concept significantly influenced the further development of the ViSP system. The definition of the concept of a "General Plan" as used in the Alvorada Programme documentation is not clearly defined in terms of the cartographic elements that are typically included on such a plan. Two quotations from the AVSI (1996) documentation which bests describes the purpose of the General Plan are as follows:

1. " They are included as a base for reference within the context of a policy for progressive investment that proposes replacing a practice of timed intervention or unarticulated emergencies", and

2. " The General Plan may be regarded as a stage in the development of a planned process that will guide the evolution of the settlement that comes from knowledge of the site and of its peculiarities as a preliminary step and as inspiration for future transformations."

Yet another description of the concept of a General Plan can be quoted from AVSI (1998): "The general area plan is the defining instrument for town-planning and social alternatives, necessary to the integration of informal settlements in the urban context." An attempt was made to more clearly define the components of a typical general area plan by inspecting several area plans produced by the Belo Horizonte ViSP GIS system. The general plans are generally plotted out at a scale of 1:2000 and illustrate features such as natural drainage, convergence points, primary, secondary and local alleys etc.

5.5 HARDWARE AND SOFTWARE IMPLEMENTED

5.5.1 Discussion

The emphasis of the Alvorada Programme on the creation of General Plans for local-level informal settlement upgrading necessitated a number of changes to the ViSP technology that had been previously implemented in Kenya. The hardware configuration employed in the ViSP approach in Belo Horizonte is essentially analogous to the hardware configuration listed by Nieminen (1995) the ViSP system in Kenya (see table 4 in appendix 4). However, the software configuration however is significantly different and forms the bulk of this discussion. Already mentioned, the ViSP system configuration has evolved to a limited extent from the original system implemented in Kenya. The key difference lies in the software products used. The development of the system in Belo Horizonte has also drawn and continues to draw extensively from experiences in Italy[14]. In Kenya a simple system was designed based on existing and readily available technology. In Belo Horizonte, this configuration proved inadequate for the complexity of the upgrading methodology. While the focus of the system in Kenya had been on settlement mapping for emergency relief applications, the system in Belo Horizonte placed significant emphasis on the development and application of a detailed socio-economic and physical infrastructure database for informal settlement upgrading.

These new demands required changes in the method of acquiring aerial photography and in the software implemented. The Kenyan methodology relied on the use of an aircraft that offered a minimum flying height of 500 to 1000 m. In addition, the video camera was used to capture the imagery directly onto computer disks. The creation of the local-level databases in the Alvorada Programme however required higher resolution photography that could only be obtained from a low flying helicopter (300 to 500 m flying height). In addition, the digital data recording system used in Kenya (that had proved to be problematic in the long run) was replaced by a 35 mm hand-held camera and a negative scanner. In addition to these hardware changes, a major change was required to the ViSP methodology in terms of the software configuration. In particular the TNTMIPS[15] software was replaced as it resulted in georeferencing[16,17], design[18], plotting[19], data integration and image processing[20] problems.

In order to meet the new GIS requirements the developers of the Alvorada Programme GIS system merged the ViSP technology originally developed in Kenya with the ideas of the Pontifical Catholic University of Minas Gerais and the University of Bologna. Furthermore, the Italian software company CARTECH was taken onboard to develop new software, particularly in the area of coupled raster-vector data integration. Although this is now a common feature of all modern GIS systems, the approach was extremely innovative and advanced for its time. The outputs of these developments were a four-component interactive system comprising the following:

- the Gheo software suite
- AutoCAD 12/13 and tracer for AutoCAD,
- MapInfo Version 4.0
- a relational Data Base Management System

The technical features of the Gheo software suite are discussed in detail by CAR-TECH (1996)[21]. The software is integrated in a seamless manner with AutoCAD, which serves as the vector data capturing interface. The system requires a soft-engine graphics accelerator[22] and a relational database (Oracle, SQL or Quadbase). The individual components are discussed in greater detail below.

5.5.2 The Gheo Software Suite

The Gheo software suite represents a GIS system comprised of a fully integrated dual database. The dual database is composed of a graphic database , which contains all the geometric and topological information related to the entities represented on the map, and a descriptive database, which contains all the quantitative and descriptive data associated with the geographic data. The Gheo software suite consists of the following modules: Gheomake, Gheocheck, Gheobuild, Gheoload, Gheoraster and Gheo. The purpose of each of these modules is discussed below.

The Gheomake module is used to create the configuration files for the GIS database (see section 5.5.3). The Gheocheck module is used to verify that the geometry of the graphical elements is correct. It assists line work processing operations such as deleting duplicated lines, verifying lines which end on a vertex, deleting overshoots, undershoots, and zero length lines. As with most other line work processing macros, a tolerance level must be set to ensure suitable results upon program execution. The Gheobuild module is used to construct the topology of digitized files and to featurize the graphical database. The topology building process defines the relative spatial positions of adjacent elements in the graphical database. This process is required before geographically defined spatial queries can be defined. The Gheoload module represents a batch module for drawing data preprocessed by Gheobuild. It is essentially used to load compressed vector data.

The Gheoraster module is an image processing module which is used to load and unload raster images, georeference images, create mosaics, set dithering, resize images and insert calibration points. In conjunction with AutoCAD, the Gheoraster module can be used independently of the Gheo module (discussed below), for heads-up digitizing. The georeferencing functionality enables enables an image (eg. a scanned aerial photo or base map) to be reproduced in real coordinates, through a geometric transformation. Within the Gheoraster environment it is possible to create raster backdrops to vector data. Such representations place the vector data into context and are useful for serving as a communication tool.

The Gheo module has been designed as a simplified GIS user interface. It enables interactive editing, drawing, database management and consulting, by the site server and client users. Unlike the other modules listed above, it can be used as a standalone low-end platform GIS system linked to an SQL RDBMS. It generally far simpler to use than the Gheo suite, and more specifically, it enables thematic maps to be produced far more easily. However, compared to the Gheo suite, it has far fewer spatial analysis capabilities and no image processing capabilities.

In ViSP GIS laboratory in Belo Horizonte, the Gheo suite is employed and the key module used for the majority of the data capturing tasks is Gheoraster. The remaining modules of the suite are indispensable, but are used for far shorter and fewer data processing tasks.

5.5.3. Other software products used

In addition to the Gheo software suite, the following software products are used:

- AutoCAD 12/13, tracer for AutoCAD, and AutoLISP
- MapInfo Version 4.0
- a Relational Data Base Management System (RDBMS)

The AutoCAD software is the principle digitizing and design tool used in the methodology. Tracer for AutoCAD12 is used to digitize raster images of contour maps or building plans. It is a semi-automatic data conversion tool used to convert map raster images to vector drawings. It is particularly useful for dealing with maps shown on tracing paper. The AutoLISP software is used to automate procedures carried out in Gheoraster. The MapInfo software is good for presentation purposes (see chapter 6 for further details). It is used for data visualization, elementary data analyses (thematic mapping) and presentation, rather than for data capture. The RDBMS SQL software is used in Belo Horizonte. Other RDBMS software packages that can be linked to the Gheo suite include: Oracle, Ingres, Informix and Quadbase.

5.5.4 Database structure issues

The database is composed of graphic and alphanumeric data. The graphic database is organised in terms of geotypes. A geotype represents a determined category of graphic objects, such as a road or highway. An infinite number of sub-levels may be generated per geotype category. For each geotype, the graphic element representation (polyline, polygon, point, text), the type of line, thickness, color etc., is usually specified. Attached to each geotype is an alphanumeric attribute table. Relational linkages are created between the different geotype attribute tables when the need arises for creating queries which depend on the attribute data associated with two or more geotypes.

The structure of the database is determined by the contents of the configuration files. In these files, the settings of parameters which are fundamental to the execution of the GHEO programs are listed. The configuration files are used to define the relations between the graphic database and the alphanumeric attributes. It is possible to state the directories of the graphic and alphanumeric databases and the customized characteristics per object, outside the database, and to visualize the recalls in AutoCAD. The associated configuration files may be created by almost any editor or through the GEOMAKE module. Configuration files may also be used to customize the execution and accelerate the run-time of the application GHEO programs.

5.6 THE DATA CAPTURING PROCESS

5.6.1 Types of data captured

Vector data

The vector database is comprised of area-based, polyline -based, text-based and line-based layers. Attribute data are linked to area centroids in the case of the area-based layers, and attached to placed points in the case of the possible layer types. The vector data is organised into 95 levels approximately, and may be grouped into categories relating to planning, the physical environment, annotation, boundaries, complementary elements, physical elements, single point elements etc (see table 5.2). Each geotype is placed on its own layer and is characterized by a unique set of display attributes. Associated with each geotype are fields of attribute data which may be represented in one or more alphanumeric data tables (eg the edificio level has links to the edificio and domi-sec attribute tables).

Raster data

The methodology employed to capture the imagery data for mapping in Belo Horizonte involves the use of helicopter photography. A normal hand held 35 mm camera is used to obtain the photographs as the helicopter hovers over the point of interest. The key advantage of this approach is that a much lower flying height (and consequently a much higher resolution) can be obtained than if an aircraft is used to take the photography. The negatives of the photos are subsequently scanned and georeferenced using the image processing software. The accuracy of the pictures on the flight altitude, vegetation canopy of the area, weather conditions, and on the equipment used for taking the imagery. This approach has been criticized for involving the non-conventional use of a helicopter. However, the low altitudes obtainable by using a helicopter enable maps at a scale of 1:250 to be created on a regular basis. The method has been specifically designed to enable individual plot boundaries to be defined. Often, because of the high density of housing structures in the informal settlement areas, different plots will fall under one roof. In other words a single roof may cover one or more domiciles. The 1:250 resolution, enables very subtle differences in roof texture to be distinguished.

Attribute data

The socioeconomic data captured is entered into an attribute table extracted from the cadstral and infrastructure attribute data tables (see complete set of original tables below). The socioeconomic data types lie in the following categories: identification, planning, construction materials, infrastructure, domestic animals, gender by age, interview data and other survey related data. Table 5.3 provides a full listing of the data types translated from a DBF table definition file (DOMICI.DBF, see table 6 in appendix 4) and from the socioeconomic, physical-environmental research questionnaire constructed by the Companhia Urbanizadora de Belo Horizonte (URBEL). A number of the fields are repeated for further details. These complementary columns have been created for the following fields: equivalent use of lot, management of occupation of benefactor, interviewee details: family position, civil status, occupational status, other sources of rent, alternative proof of length of time of occupation, other permanent residents, building material, sewerage, type of water provision, water treatment, garbage disposal, other animals bred and quantity, and other vindications / institutes/ councilors.

Table 5.2 Groups of vector data layers according to the GHEO.CFG configuration file of 7-3-1995. Levels which are comprised of polylines (p) or lines (l) are indicated.

CADASTER/ PLANNING **nucleus** **block** **lot** **lot area** **dead end street** **square**	**SERVICES** **stand pipe (chafariz) (l)** **telephone (l)** **post (l)** **kerb line (l)**	**BOUNDARIES** **Munincipal limit** **GLEBAS divisions** **Public participation division** **lot divisions** **limit of administrative region** **SE4 polygon** **Fence**	**COMPLEMENTARY ELEMENTS** **manhole cover** **poles** **garbage depo**
TERRAIN RELATED / PHYSICAL ELEMENTS **declivity** **contours** **primary contours (p)** **secondary contours (p)** **ravines (p)** **tallus (p)**	**TRANSPORTATION / ROAD STRUCTURE** **road ways** **Pedestrian ways** **Tracks** **Bridges** **Stairs** **footpath**	**SERVICE DOMAIN** **COPASA** **CEMIG** **RFFSA** **DEMETRO** **DNER_DER** **Special transport ways** **Water courses**	**SINGLE POINT ELEMENTS** **drainage waste/source** **sewerage waste/source**
BUILDING **Residencial** **Commercial** **Services** **collective use** **industrial** **mixed** **vacant** **other**	**OTHER INFRASTRUCTURAL ELEMENTS** **Sewerage (p)** **water (p)** **surface drainage (p)** **subsurface drainage (p)** **electric energy (p)**	**REGIONS** **Regions**	**SINGLE AREA ELEMENTS** **Dump** **Vegetation** **gathering point** **open area** **invaded area** **undivided area** **renovation area** **risk area**
URBAN EQUIPMENT AREA **leisure area** **sports area** **park**	**WATER SERVICES** **water network** **derived from network** **water valve** **water use** **private**	**HYRDOLOGY** **Permanent course (p)** **Intermediatecourse (p)**	**TEXT** **road name** **house number** **cadastral stamp** **lot number** **lot dimensions** **coordinates** **contour**

A field is allocated to each type of building material constituting the walls- irrespective of whether there is one type of material (brick) which represents 100 % of the walls in nearly all cases. The same is true for the roof materials and the numbers of different animals present. In addition, for each roof material a field is dedicated for the state of conservationof that material - again irrespective of whether that material is present or not. Similarly, 12 default fields are created for the age/gender data - irrespective of the age and gender distribution characteristics of the favela. The result of this type of data population strategy is a large number of empty fields, which inhibits reading the files. The various options available for classifying the infrastructural data are discussed in the thematization section below. The interviewee details category is repeated as many times as the number of interviewees addressed. The tables which were inspected revealed an average of three repetitions of this set of data fields. A number of indexing fields are also repeated for each table. These include: region, module, nucleus code, number of cadastral stamp.

Table 5.3 Types of attribute data captured for the ViSP approach.

CATEGORY	ATTRIBUTE DATA FIELDS
IDENTIFICATION	**Region, modality, code of nucleus**
PLANNING	**Sector, block, lot, number of domicile, cadastral stamp, ideal fraction, provisional address, definitive address , equivalent use of lot, area occupied, management of occupation of benefactor, property holder of the benefactor, time of occupation: years, months, proof of length of time of occupation, property of other permanent residents, total number of witnesses, name of witness number 1, address of witness number 1, number of other permanent residents, address of other permanent resident, number of rooms, number of persons in domicile**
CONSTRUCTION MATERIALS	**Percentages of material constituting walls (bricks, mud bricks, wood / canvas / tin, other) state of conservation of material constituting walls (bricks, mud bricks, wood / canvas / tin, other), percentage of material constituting roof (ceramic tiles, masonary, fiberglass, metallic tiles, other), state of conservation of roof material, observations on construction materials**
INFRASTRUCTURE	**Sewerage, light, type of water provision, water treatment, garbage disposal**
ANIMALS	**Quanitity of animals (pigs, goats, horses, chickens, domestic, other)**
GENDER & AGE	**Number of males and number of females in the following age groups: 0-6, 7-12, 13-18, 19-30, 31-50, > 50 years old**
INTERVIEWEE	**Interviewee: name, gender, age, nationality, family position , civil status, civil situation, profession, observation of profession, occupational status, rent, sources of other rents, value of other rent, schooling, capable of signing, document number, institutions participated by interviewee**
SURVEY / COMMUNITY PARTICIPATION	**Vindications of improvements requested by residents, institutions assisting community, councilors, liderance reference no.1/no.2, necessity of nucleus: no.1, no.2 and no.3.**
OTHER	**Current minimum salary, researcher, date, field officer, revisor, date of revision, observations of researcher, observations of technician**

5.6.2 Data capturing techniques employed

Vector data

Two types of vector data are captured, namely topographic and cadastral data. The topographic data is captured in the field using land surveying equipment. This equipment consists of an electronic theodolite, a distance meter and a data collection instrument. The topographic map represents the basemap and is produced in an AutoCAD environment. The developers of the ViSP GIS system in Belo Horizonte confirmed that Microstation provides data capturing tools and other functionalities superior to AutoCAD, however, they selected the latter software for two reasons. Firstly, there is a greater availability of skilled AutoCAD users in Belo Horizonte and secondly, the suppliers of the AutoCAD software offered a better software support deal.

The architecture of the database has been designed to meet the needs of both cartographic and GIS thematic mapping applications. In order to meet the cartographic requirements the vector outputs on a map must appear as simplified and realistic as possible. For example, adjacent houses utilizing the same wall must appear to do so in the output. On the other hand, the thematic mapping requirements necessitate that each house be represented by a closed polygon. For this reason adjacent houses are individual digitized as separate polylines and subsequently closed to form polygons. The line work matching is carried out using the "zoom-in" and "stretch" facilities of the software.

Image files which are digitized using AutoCAD version 13 may be imported into AutoCAD version 12 for vectorization. The vectorization procedure commences by loading two overlapping georeferenced image files (eg. 16-339 and 17-339, where the first no. refers to the photo number and the second to the flight number). The colors of the both images are subsequently normalized /smoothed to range over 250 color types. This is because AutoCAD can only recognize 250 colors. Each type of element has a predefined level. Once the digitizing environment has been setup, the vector level to be edited or created is subsequently activated and the vector data capturing process can begin.

Raster data

The image processing techniques employed in the ViSP approach can be grouped into the following set of steps: 1) initial georeferencing, 2) image calibration, 3) mosaicing and 4) clipping. Prior to the initial georeferencing process, the raster data is converted from TGA format to TIF format, and subsequently to the Gheo GDE format. The Gheoraster software suite is used to georeference scanned aerial photographs on the computer screen. Subsequent to this, several points which have had x and y co-ordinates measured in the field are individually selected on the GDE image. The Universal Transverse Mercator co-ordinate system (UTM) is generally used in this process. Once the co-ordinate data has been edited, it is used to generate a surface of vector-based triangles by which the image may be georeferenced. These are triangles that have vertices which extend beyond the boundary of the original image, and which will be used to link the image to an adjacent image. The software corrects the point by interpolating its new position on the image using the least squares method. During the georeferencing process, the photo may or may not be corrected for elevation. This depends on whether elevation data is available or not. For the case where elevation data is not available, an elevation based triangular irregular network cannot be created. The number of control points selected for each image depends on the quality of the image, the area covered by the image, the flying height, and on the heterogeneity of the ground at that location. For an area of 800 meters squared, 11 points are indicated on the 35 mm color photo print, and is the basis for georeferencing the image on the basis of location co-ordinates. It should be noted that triangular network generated during the georeferencing procedure is based only on location and not elevation data. This triangular irregular network (TIN) model is referred to as a locational TIN model. The georeferencing procedure enables the exact locations of points which have not been measured in the field, but which constitute the image, to be located via the triangular network model.

The first step in the image calibration procedure involves the production of a list of calculated co-ordinates in order to identify error points characterized by poor correlation values. Two methods can subsequently be applied to correct any error points. Firstly, an incorrect point can be shifted by trial and error in the four N / S / E / W directions and the changes in the error sizes observed. This can be repeated with more defined correction orientations. Alternatively, measured points on an adjacent photo can be selected as the vertices of the triangles near the error point.

The mosiacing process essentially involves a collation of all the georeferenced images for an area. Unlike the TNTMIPS (5.0) software, the mosaicing capabilities of Gheoraster enable multiple georeferenced images to be viewed simultaneously and to be easily plotted. The mosaicing process requires that consecutive images display an average overlap of about 30 %. Without this overlap, the construction of the mosaic is impeded by edge distortions on the imagery. Once a mosaic has been created, the overlapping imagery is clipped. This procedure enables the file size to be reduced significantly. It also improves the continuity of adjacent images. The clipping process carried out by constructing a polyline around the selected portion of the photography which is to be retained.

Locational TIN models have been constructed for the northern, eastern, and southern-most extreme parts of the Ventosa favela). Currently there is no on-line mechanism for monitoring the various data capturing projects which are on the go simultaneously. Several areas of interest have simply been "colored-in" on an out of date base map.

Attribute data

The attribute data entered onto the system is initially collected using a well-structured field questionnaire. This questionnaire has been developed by URBEL and captures urban planning, infrastructure, legislation and socioeconomic data (see table 7 in appendix 4). A CLIPPER software program was written by Galvao (1995) to aid the conversion of the hardcopy information into a computer format. This program the only socioeconomic data capture program employed, and is still being developed. The attribute data component of the ViSP GIS database is composed predominantly of only domicile related attribute data. A limited amount of infrastructure data indicating the level of services provided also appears. This is to be supplemented by detailed infrastructure and geological intervention data. These data capturing components of the CLIPPER program discussed above have yet to be written.

Linkage of the vector and attribute databases

The linkage of the vector and attribute databases is a complex process involving the use of several customized routines (see table 8 in appendix 4). In the first instance, a program is run to label the polygons. This program is firstly used to construct linkages ("ligacoes") between the polylines / polygons on the basemap and an ID table. Each block of the vectorized file is coded by three basic indices: 1) favela, 2) villa and 3) lot. Each polyline / polygon has a label associated with it. Once polygon linkages have been constructed several Gheo line work cleaning and topology building routines must be run. The GEOCHECK routine[23] is run to check for polygons which are not closed. The GEOBUILD and GEOCLEAN commands are subsequently used to close these polygons and to create topology. An ASCII file is then created which can be read by Gheo. The GHEOLOAD command can subsequently be used to read this file. The ASCII file is then imported into the MapInfo program, and a relational link or join is subsequently constructed between the ASCII file and the attribute code table.

5.7 STRUCTURE OF THE DATABASE

The complete database is essentially comprised of three types of data entities: 1) the cadastral and infrastructure vector data levels, 2) the cadastral and infrastructure alphanumeric data tables and 3) the socioeconomic alphanumeric data tables. The cadastral and infrastructure database forms the set of base maps to which the results of the physical and socioeconomic researches are attached. An examination of the following configuration files, associated with the data provided by AVSI (1996): GBUILD.CFG, GLOAD.CFG and GHEO.CFG, has been used to identify the structure of the current database.

The alphanumeric database follows a dBaseIII file format and an ORACLE database is used for relational database management. Previously, lots were used for the organisation of the attribute data. Currently, the domicile geotype is the feature which largely controls the data organisation. The attribute tables which are used on a regular basis are typically comprised of 121 (Senhor dos Passos) to 164 (Ventosa) fields of data. The number of fields is largely dependent on the comprehensiveness of the socio-econmic and physical survey, and often appears to be too many in most cases. A group of 15 fields relates to each person interviewed within a domicile. This group of fields is repeated within the database as many times as the number of people interviewed. Another source of data redundancy lies in the repetition of a large number of identification fields (municpal area, munimincipal code, favela, favela code, nucleus, nucleus code..etc), which is repeated for each table. Most of these fields are never used in the final thematic map production phase - so why waste processing time dragging these data through each stage of the process? In fact, the only fields of interest are the mapid / link field(s) and the fields which contain the relevant attribute data. New tables are created by constructing spatial queries and relational joins between tables as the need arises. These techniques are often applied to consider relationships such as between the fields of domicile and infrastructural data. For example, in the case of evaluating water provision, the following tables (field/field..) are constructed through spatial queries: (water network / building), (water network code/buidling/water conduit), (water network code / water valve/water conduit), (water network/water use / cadastral stamp).

An inspection of the GLOAD.CFG configuration file illustrates that the alphanumeric database is comprised of 21 original tables. New tables are derived from these data by the construction of spatial queries and through the application of relational joins (see above). In table 9 in appendix 4, the attributes associated with the table of each featurized geotype, derived from the GBUILD.CFG configuration file of 7-3-1995, are listed. The abbreviations listed in part A of the table below are derived from the orginal cfg file listing. The abbreviations in part B of the table were defined to facilitate the representation of table 10 in appendix 4. Where the original text could not be translated, the original terminology has been retained.

5.8 APPLICATIONS OF THE DATABASE

5.8.1 Thematic mapping

Types of thematic maps

The cartographic outputs that are currently produced for the Alvorada project may be loosely classified into maps for urban analysis, area planning, and integrated programme maps. The urban analysis maps illustrate features such as the areas of lots and health services used at scales ranging from 1: 500 to 1:1000. The concept of General Plans, which illustrate the diagnostics and upgrading proposals for a single informal settlement, also falls into the area planning category. The integrated programme category contains maps integrating various data types for planning purposes. For example, cadastral stamp numbers and other text layers are superimposed on the cadastral vector map, which in turn may be superimposed on the color raster image used for digitizing. Other maps produced include:

1. Detailed CAD-type plans at scale of 1:75. Contours are typically superimposed on the cadastral and detailed planning maps, and is particular relevance to the favelas in B.H. as a result of the rough terrain..

2. Thematic maps represent single variables related the prevalent housing types in terms of the location and the nature of the habitation (ie. situated in: resettlement, insalubrious or risk areas, or areas with a slope exceeding 47 %), and other variables such as the distribution of the population distribution classes.
3. Thematic maps which synthesize multiple variables related to the infrastructural services into categories such as: good, medium, bad, medium-good, medium bad, other etc. (The ranking schemes applied are further discussed below.)
4. Thematic maps which synthesize multiple variables related to the housing materials and state of conservation into categories such as: good, medium, bad, medium-good, medium bad, other etc.

Standard guidelines adopted for the production of thematic maps

A series of standard data category representation guidelines have been developed for the production of the thematic maps. The following section outlines exactly what features have been selected for thematisation and what data range categories have been selected to represent the data visually. Table 5.4 which lists the standard guidelines adopted for the production of thematic maps in the ViSP approach has been drawn up by investigating the socioeconomic and physical environment research questionnaire and a large number of thematic maps produced in Belo Horizonte.

Land ownership

The land ownership data consists of lot area information and data relating to the domicile. The lots areas are subdivided into classes according to the regularization strategy adopted. The minimum sized lots received the greatest attention. For reference the value of the lots defined for the nucleus were also represented even though the strategy does not imply the regulation of this judicial figure. Finally, the legal values were also considered to regularize the maximum area. The values selected for the area range limits (ie. 80 and 125 m^2) are linked to the number of inhabitants in the area. The main area type categories and the ranges considered for the area and domicile data are shown in Table 5.5 .

Infrastructure

The infrastructural and sanitary conditions data is represented firstly on a per service basis and secondly as a map which synthesizes all the infrastructural services information for a location. Each level of service option has been graded on a point scale. The values associated with each level of service are listed in Table 5.5. The ratings listed in brackets are often interchanged with 3 = good, 2 = medium, 1 = medium / bad, bad =0.

Socioeconomic

The socioeconomic data consists of data specific to the inhabitants of each domicile within the settlement, and of data relating community participation issues. With respect to the community participation data, categories exist for indicating the communication channels through which the dwellers specifically vindicate improvements in the community (eg. dwellers association) and categories for other community groups dwellers may simply interact with.

Table 5.4 Standard guidelines adopted for the production of thematic maps in the ViSP approach in Belo Horizonte

Planning

1. Management of property: owner (1), undocumented owner (2), rented (3), shared (4), other (5)
2. Land use of lot (single- or multi-family residential/ commercial/services/collective services / industrial / mixed / open or vacant lot / others)
3. Type of occupation (own with documents/own without documents/shared/rented)
4. Acquisition time (up to 5 years/from 5 to 10 years/from 10 to 20 years/more than 20 years)
5. Number of levels comprising the dwelling (1/2/3/>3)
6. Risk (none/risk present)
7. Number of domiciles on the lot (0/1/2-3/4-5/>5)
8. Ideal fraction (present or yes = 1 / absent or no = 2)

Interviewee details

9. Family position : head of family (1), husband/ wife/companion/ (2), son/daughter (3), parent (4), lives alone (5), aggregated (6), others (7)

Land ownership

10. Area of lots (m^2): (0-40, 40-80, 80-125, 125-300, >300)
11. Ownership of lots: PROFAVELA municipal areas / USUCAPIÃO private areas / State land

Health services

12. State hospital / polyclininc / convention clinic / other

Domicile

13. Time of occupation (up to 5 years, 5-10 years, 10 - 20 years, > 20 years)
14. Number of rooms in total (1 - 3, 4 - 6, 7 - 10, > 10)

Infrastructure

15. Sewerage: linked to the official COPASA network (3), linked to the non-official network (2), linked to the pluvial gallery (2), ditch or pit (2), mixed / others (1), lacking-open air (0)
16. Sanitation: individual internal (1), individual external (2), collective (3), lacking (4)
17. Light: CEMIG network (2), clandestine (1), lacking (0)Water: COPASA network / hydrometer (3), clandestine (2), others / mixed (1), lacking (0)
18. Water treatment: water box with lid (3), uncovered water box (2), direct from network and not stored (1), drum (0), others/mixed (0)
19. Garbage disposal: treated for collection (2), garbage deposit container, litter bin, incinerated (1), discarded onto: kerbs of public roads, water ways, dumps, others/mixed (0)

Socio-ecomonic data

20. Number of occupants in the domicile (0-1, 2-5, 6-9, $\geq$ 10)
21. Income per capita: (Minimum salary per person) = [total domicile income]/[number of people in the domicile]): (0 - 0.3, 0.3 - 0.6, 0.6 -1, 1 -2, >2)
22. Density: Number of habitations per m^2 (0-29.6, 21.6-43.2, 43.2-69.5, 69.5-135, >135)
23. Community associations used to vindicate improvements: eg. dwellers association, known politicians
24. Other community participation groups: eg. dwellers association, religious groups, councilors

Construction materials and state of dwelling

25. Construction material: brick (4), earth (3), wood/canvas/tin (2), other (1).
26. The state of conservation of the construction material: (good=1/regular=0.5/bad=0.1)
27. Cover: ceramic tiles: = 5, mud =4, amianto tiles = 3, metallic tiles = 2, other = 1.
28. The state of the cover: bad (0-3), medium (3-4), good (4-5).

Construction materials

Each type of wall building material is allocated a certain point value on a scale. The state of the buildings is subsequently evaluated by the multiplying the material value the wall by the percentage which that material constitutes the dwelling. This is then termed to represent the partial value of the building. Where a dwelling is composed of various materials, a total of the various partial values would be calculated. Thus in the case of a building which is composed of 80% brick and 20% earth, a summed partial value of 3.8 would be calculated. Following this, the equivalent values are multiplied by the respective values indicating the state of conservation of the material (good=1/regular=0.5/bad=0.1) to arrive at a reference value. For example, a if the earth wall component of a dwelling comprises 20 % of that dwelling (partial value=0.6), and has a regular state of conservation, then a reference value of 0.3 is calculated for that component of the dwelling. Again the various reference values are summed per dwelling for the case of multiple construction materials. In this manner the maximum wall value attainable is 4. The following categories are then defined to represent the summed reference values: 0-2 (bad, 2-3 (medium), 3-4 (good). The second component of evaluating the nature of the dwellings relates to an evaluation of the cover material. In this case the following rating scale is applied: ceramic tiles = 5, mud =4, amianto tiles = 3, metallic tiles = 2, and other = 1. The maximum roof value obtainable is 5. The state of the cover is rated into bad (0-3), medium (3-4), good (4-5).

Synthesis maps

Two types of synthesis maps are produced in Belo Horizonte as part of the ViSP methodlogy. These are 1) an urban infrastructure synthesis map and 2) a building evaluation synthesis map. The urban infrastructure synthesis thematic map is created by adding the values of the various services provided. A maximum value of eight is attainable. The sum total of the service levels provided is subsequently reduced to one of the following categories bad (1-5), medium (6) and good (7-8). The synthesis map of the building evaluation is obtained in terms of the wall material, incidence of the materials, and the state of conservation of the materials. To obtain a synthesis map of the building conditions the following table and rating scale are applied:

Table 5.5 Matrix used to create a building evaluation synthesis map

	WALLS			
R		BP (4)	MP (3)	RP (2)
O	BC (5)	BBC (9)	MPBC (8)	RPBC (7)
O	MC (4)	BPMC (8)	MPMC (7)	RPMC (6)
F	RC (3)	BPRC (7)	MPRC (6)	RPRC (5)

Good	=	BP + BC (9)
Medium to good	=	BP + MC or BC + MP (8)
Medium	=	MP + MC or BP + RC or RP + BC (7)
Medium to bad	=	MP + RC or RP + MC (6)
Bad	=	RP + RC (5)

Moura et al. (1993) describe several other synthesis maps which were not viewed during the 1996 visit to the AVSI CAD 126 computer laboratory, but which have most certainly influenced the development of the present thematic mapping process employed in Belo Horizonte. These maps included: 1) an urban infrastructure and health synthesis map, 2) an urban landscape synthesis map, 3) a land occupation restrictions synthesis map and 4) a final diagnosis map.

The urban infrastructures and health synthesis map is the result of the maps on the pavement type, water network, sewage system, electric power and refuse disposal. The standards which have been applied are listed in table 11 in appendix 4. The application of these standards enable the level of urban infrastructure rated as good (Gi), medium (Mi)and low (Li). Similarly the health conditions controlled by the level of infrastructure are rated as good (Gh), medium (Mh)and low (Lh). Linking the classifications, the street-based urban infrastructures and health map is obtained according to the result of the combined standards (see table 12 in appendix 4). The construction of the urban landscape synthesis map is discussed in detail by Moura et al. (1993: 174 -175). This map essentially represents a synthesis of the equipped areas, functional zoning and land use maps. Elements which have been included on this map are as follows:

- Points of sale
- Public services points
- Operating and potential equipped areas
- Low-level residential areas
- Medium and medium-low residential areas

The land occupation restrictions map results from the slope, basic geological and land occupation restrictions map. Further details on this map type are discussed by Moura et al. (1993). The final diagnosis map is the result of the sum of the urban infrastructure and health, urban landscape and land occupation restrictions synthesis maps. The main aim of this map is to illustrate the area's general profile. The following elements are represented:

- Occupation restrictions
- Low and medium-low standard buildings
- (used or potentially useable) equipped area
- a poorly served area, in terms of shops, services, urban infrastructures and health
- a poorly served area, in terms of shops and services supply
- a poorly served area, in terms of urban infrastructures and health

The sequence of the map production process and the manner in which the various maps are combined to produced the synthesis maps and the final diagnosis maps is illustrated in figure 5.1.

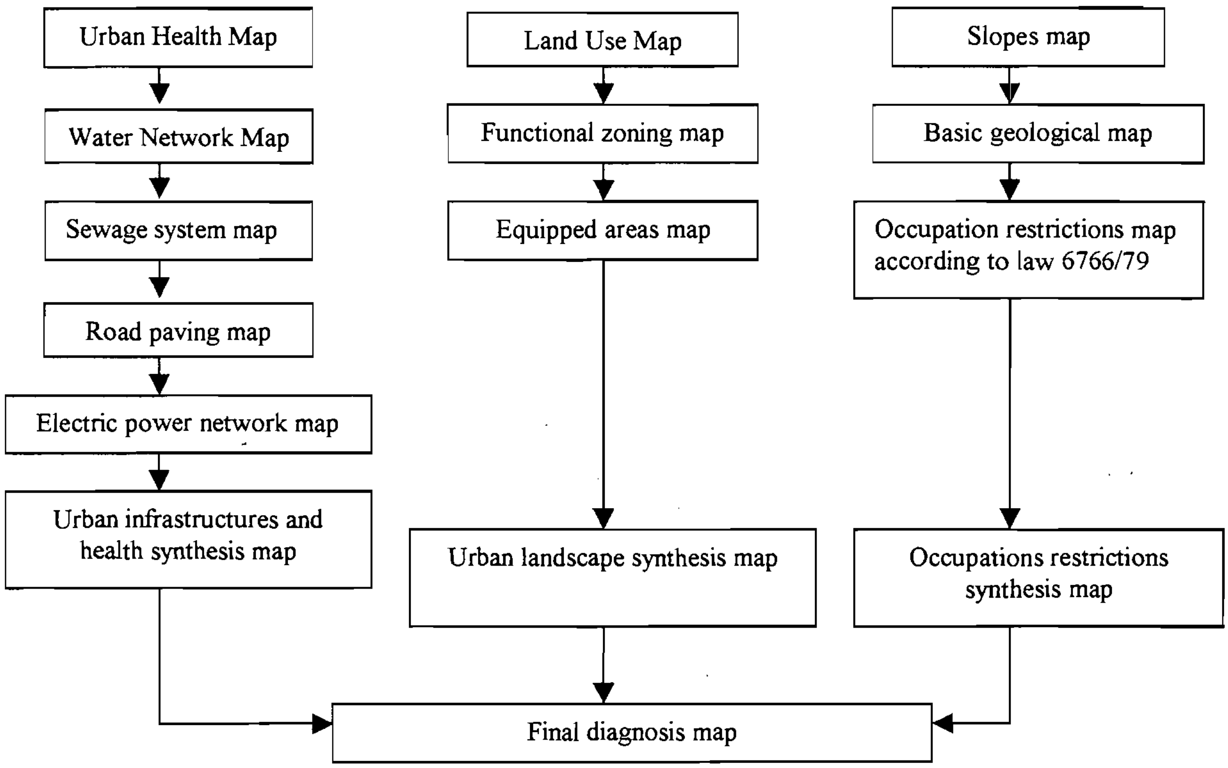


Figure 5.1 Process employed in the production of a final diagnosis map (source: Moura et al. 1992: 173)

Relocation maps

The relocation map represents another type of thematic map which arises during the settlement diagnosis process. On this map the following categories are illustrated:

1. relocations for the widening and opening of the roadways
2. relocations as a result of poor living environment and health risks
3. relocations as a result of physical risks (eg. land slides, fires)
4. relocations for the opening of areas for resettlement

5.8.2 Other outputs

Other outputs produced by the GIS system implemented in the ViSP approach include General Plans, combined raster-vector outputs, detailed planning maps and final diagnosis reports. The concept of General Plans (Plano Global) has already been discussed in section 5.4. The types of information illustrated on the general planning maps are shown in table 13 in appendix 4. With respect to the combined raster-vector outputs, cadastral and topographic vector data layers are often plotted against the corresponding colour orthophotos for illustrative purposes. For the final stages of planning projects, the street affected is mapped in detail, with all the cadastral and topographic data captured at a high resolution (plot and dwelling dimensions and so forth). All the hazard areas and the URBEL/AVSI upgrading proposals are illustrated. This appears as a pull-out map at the beginning of the report. The remainder of the report consists of a photograph, an architectural planning map, all the socioeconomic data, and the characterization / upgrading proposal for each dwelling along the street.

5.9 ANALYSIS OF THE VISP APPROACH

The Brazilian case study has highlighted several issues regarding the requirements of a GIS-based approach to local level informal settlement upgrading work including the software requirements and the database structure and content requirements. The conclusions which can be drawn from the Brazilian experience regarding the first issue will be discussed here. The second issue is discussed in chapter 8. In addition, the research has enabled several differences between Cape Town and Belo Horizonte to be identified, which necessitate modifications to the ViSP approach if it is to be applied in South Africa.

5.9.1 Software requirements for local level informal settlement upgrading work

The examination of the various software components of the ViSP approach in Belo Horizonte enabled a series of key software requirements to be identified for local level informal settlement upgrading work. The requirements can be considered in the context of the following criteria which are often used to described GIS systems:

1. The analytical capability
2. Ease of use
3. Data capturing tools
4. Line work processing utilities
5. Image processing utilities
6. Thematic mapping utilities
7. Potential for customization
8. Alphanumeric and graphical database interface
9. Layout and plotting tools

These issues are considered in detail in chapter 7. Here only the essential requirements of some of these criteria are discussed very briefly.

With respect to the analytical capability, the Brazilian experience has shown that only the most basic spatial analysis tools are required. Most of the "analysis" in the ViSP process involves the production of thematic maps. With respect to data capturing tools, the system must be capable of heads-up digitizing. Furthermore, since most of the vector data is captured off of raster images, the system needs to have image processing utilities for georeferencing scanned images. Other requirements of the system are that it must be user friendly, there needs to be a RDBMS, it should be easy to customize the system to, and finally, one should easily be able to modify map layouts.

5.9.2 Advantages of the ViSP approach

The key advantages of the ViSP methodology which have ensured the sustainability and success of the upgrading projects carried out as part of the Alvorada programme to date may be summarized as follows (AVSI, 1997):

1. The collaborative nature of the approach
2. The integration of actions
3. The continuity of the recovery process
4. The use of appropriate methods
5. The direct participation of the community
6. The "non-cadastral" nature of the approach
7. The rapid nature of the methodology

The collaborative nature of the approach is evident in the large number of actors involved in the process. The presence of NGOs ensures a good co-operation between different parties and encourages the use of less bureaucratic management systems. The collaborative nature of the approach ensures a more effective utilization of human and financial resources. With respect to the development of the database, it ensures that time is saved during the data capture process. It also provides an effective medium for communication between all of the key role players that drive or are affected by the upgrading process.

The integration of actions within the urban, land, social and economic environments has granted the ViSP projects a high likelihood of sustainability. This integration of actions is reflected in the multi-faceted nature of the GIS database. The multi-disciplinary nature of the database facilitates the development of a wide range of applications. The continuity of the recovery process has given an incentive for financial and social sustainability and for human resources development. The use of appropriate methods is clearly evident in the selection of software and data sources. The software selection reflects a balance between the advanced image processing capabilities of the high end GIS platform (Gheo software) required for detailed land use mapping, and the less powerful attribute data analysis capabilities of the low end platform (MapInfo) required for thematic mapping. In addition, the key source of imagery data is aerial photography as opposed to video photography. The direct participation of the community is used to monitor of the transformation process.

This aspect of community participation is one of the key factors distinguishing the ViSP approach from upgrading initiatives in other developing countries. The discussions in chapters 2- 4 clearly illustrated how the vast majority of these systems are not designed to meet the needs of the community. In contrast, this overview has clearly shown that the ViSP methodology is designed specifically to meet the needs of community. The two key areas of community needs which are addressed by the approach are: the regularization of land tenure and the identification of high risk areas. The fact that the methodology does not depend on the creation of a detailed cadastral database - ie. of high accuracies (0.5 - 0.3 m) as developed by many municipal land surveying departments - implies that GIS applications can be created more rapidly than through approaches relying on cadastral-based GIS systems.

5.9.3 Problems associated with the ViSP approach

There are a number of theoretical and technical weaknesses associated with the ViSP approach. These are discussed in detail in chapters 6 and 7. Here only a brief mention of these problems is made. Some of the key problems identified were as follows:

1. Redundancies in the database structure and content
2. A disregard for the importance of elevation data and for the software requirements for dealing with such data.
3. The predominantly single-level nature of the approach (ie. only local-level databases are developed)
4. Implementation of inappropriate software and under-utilization of software products
5. Limitations of the software with respect to their widespread application and access to software support
6. Limitations of the software with respect to the local integration of multiple data sources
7. Limitations of the software with respect to the multiple analytical requirements of an informal settlement upgrading system residing within an municipal environment
8. Limitations of the hardware and software with respect to the data capturing and storage facilities
9. Limitations of the software with respect to ease of use

With respect to the treatment of elevation data, the georeferencing procedure used in Belo Horizonte does not include a correction for height variations on a regular basis. In fact, there is no surface modeling software available on the Belo Horizonte ViSP GIS system.

The need for extending the capabilities of the GIS system employed in the upgrading methodology for dealing with elevation data was already recognized in the work by Moura (1993)[24]. With respect to the single-level nature of the database, it is important to note that the GIS databases built through the ViSP approach have been designed for local-level applications only. There is only one vector layer of metropolitan information in the whole program (AVSI, 1996). On this representation, the settlements have represented thematically according to the population density (in people per domicile) is indicated. Other than for this single macro-scale representation, no further development of a metropolitan level database for Belo Horizonte has been planned.

5.9.4 Applying the Belo Horizonte approach to Cape Town

There are several key differences between Belo Horizonte and Cape Town that would strongly influence the adoption of the ViSP methodology for upgrading informal settlements in Cape Town. These differences may be grouped into the following issues:

- Differences in housing policies
- Differences in the existence of appropriate organizational structures
- Differences in the potential for collaborations
- Differences in the physical and socioeconomic characteristics of informal settlements

One of the key differences facing the implementation of the ViSP approach or any other GIS-based informal settlement upgrading approach in Cape Town is the current housing policy. In Belo Horizonte, " policies for action have begun to change and the original trend towards eviction and removal has been replaced by alternatives towards consolidation and urban integration of these areas" (AVSI, 1996). The basis for the development of upgrading programmes such as the Alvorada Programme was the approval in 1993 of the PROFAVELA Law (AVSI, 1997). This law led to the development of the concept of "special social interest zones" (SE4), which became the precondition for land tenure regularization and access to urban services. In contrast, while the Guateng Upgrading Programme has been established in Johannesburg, the inhabitants of informal settlements in Cape Town continue to be faced with a policy of relocation.

A second key difference lies in the existence of appropriate organizational structures for implementing these new policies. The present local government in Belo Horizonte created the Municipal Housing System and several new organizations to develop and implement the Municipal Housing Policy. These organizations include: the Belo Horizonte Urbanization Company (URBEL), the Housing Municipal Council (CMH) and the Popular Housing Municipal Fund (FMHP). The creation of such organizational structures in Cape Town will only occur once changes in the local housing policy and legislation similar to those in Belo Horizonte have taken place.

The differences in terms of potentials for collaboration refer to the different levels of privatization in Belo Horizonte and Cape Town. Privatization has occurred to a greater extent in Belo Horizonte. Private utility companies exist for most of the previously state owned services (eg. COPAS, TELEBRAS, CEMIG etc.). Many of these utility companies are advanced with respect to their GIS facilities and as such can play a significant role in a collaborative data capture process. In South Africa this shift towards privatization is still occurring and the GIS capabilities of these newly emerging companies has yet to undergo a significant amount of development.

The differences in the physical and socioeconomic characteristics of informal settlements may in turn be grouped into the following key issues:

- Differences in the spatial distribution and location of informal settlements[25]
- Differences in the risks and problems facing informal settlements[26]
- Differences in the construction materials employed in informal settlements[27, 28]
- Differences in settlement dynamics
- Differences in political and racial issues[29, 30]

CHAPTER SIX: THE DEVELOPMENT OF THE BI-LEVEL MODEL

6.1 INTRODUCTION

The discussions in chapter 2 have shown that the diffusion of GIS in the developed European countries has been hampered significantly by problems associated with the cadastral approach. Amongst these problems are the slowness of the approach, data maintenance problems, the lack of applications development, data under-utilisation, technical problems and the lack of digital data. Identical problems, together with other, more severe organisational and technical problems were encountered in the Cape Town City Council (chapter 3) and on GIS systems in other developing countries (chapter 4).

The lack of digital data in particular remains a problematic issue in both the developed and developing countries. It is clear that there is a need for the development of a GIS database model that facilitates the development of GIS applications for areas that are generally excluded from the digital cadastre. In the case of the developing countries these areas correspond predominantly to informal settlement areas. While a number of GIS models have been designed specifically to address the lack of data in the informal settlement areas for upgrading applications, the previous chapters have shown these models are faced with key limitations. Thus they are generally characterised by the lack of mechanisms for community participation and for integrating the informal settlement within the formal settlement and environment. In addition these models are based on single-scale approaches and tend to function as distinctly isolated databases.

In this chapter, the conceptual framework for the development of an informal settlement upgrading information GIS database model, that addresses the problems mentioned above is developed. The first two sections focus on the scalar and non-scalar requirements facing the development of informal settlement upgrading applications. This is followed by discussions on the theoretical weaknesses of the ViSP approach, other Urban GIS database models and structures and local factors that affected the development of the model. A new bi-level model is then defined in terms of the framework of the model's database structure, the database components, software requirements, database linkages and differences from other models. The chapter concludes by illustrating two ways in which the Bi-level model may be adapted in order to extend its applicability. The first adaptation enables the model to incorporate the concept of environmental sustainability. The second adaptation enables the model to be extended for a global co-ordination of informal settlement upgrading projects.

The Bi-level model was initially developed specifically for informal settlement upgrading applications. As it evolved, however, it has demonstrated wider applicability. Thus in retrospect, it presents a database management tool of much greater significance. Hence the model is applicable not only in the developing countries with informal settlements, but also more generally in any country that is faced with gaps in the digital cadastre.

6.2 SCALAR ISSUES

This discussion focuses on two aspects of scale selection. The first deals with the scale of imagery selected for mapping informal settlements. The second defines and discusses factors influencing the selection of the basic spatial unit (BSU) employed in the GIS database structure.

6.2.1 Selection of mapping scales

The scale of photography available for selection varies from country to country. However, the case studies considered in this thesis reveal that there are three[1] types of imagery that are commonly utilised for informal settlement mapping applications. These are: 1) satellite imagery, 2) aerial imagery and 3) helicopter imagery. The imagery available through each of these three data acquisition mechanisms is available for certain scales and the applicability of each is ultimately constrained by the ground resolution required by the end user's application. Satellite imagery is typically available at the following scales: 1: 50 000, 1: 25 000 and 1: 100 000. Aerial photography is commonly utilised for urban GIS applications and is available in the following scales: 1: 10 000, 1: 3000 and 1: 2000 in many of the developing countries in the world. The scales of helicopter imagery typically used for local level informal settlement work in Belo Horizonte range from 1:500 to 1:300 (see chapter 5).

The use of satellite imagery is generally restricted to strategic level applications for resource management in rural areas. It has been successfully applied for developing land use classification schemes (PADCO, 1994 a, 1994 b) and for coarse informal settlement area-based spatial temporal analyses (Ferreira, 1997). However, the ground resolution available on satellite images prevents a multitude of both strategic level and local level applications. While the use of satellite imagery may be suitable for land resource management applications, it cannot meet the ground resolution required for metropolitan-wide informal settlement upgrading plan analyses. For such analyses individual shack locations must be resolvable on the imagery. Furthermore, satellite imagery cannot be used for the local level informal settlement upgrading applications. Such applications require the mapping of shack outlines.

With respect to aerial imagery, although all three aerial photography scales can be applied for mapping informal settlements, the poorer the resolution the greater will be the technological demand on the image processing aspect of the methodology[2]. Furthermore, the lower the resolution of the aerial photography, the more memory intensive and time consuming the mapping exercise will become. The problem is reduced through the use of 1: 2000 and 1: 3000 imagery. However, these scales are faced with the problem of being far less available in most developing countries. Unlike satellite and aerial imagery, the use of helicopter imagery, at a scale of about 1: 300, can facilitate a large number of local-level informal settlement upgrading applications.

6.2.2 Selection of the basic spatial unit

Several authors have discussed the issues affecting the selection of a basic spatial unit (BSU) (Napier, 1994 ; Flowerdew and Green, 1994; Visvalingam, 1991; Martin, 1991). Visvalingam (1991: 12) defines it in the following way: "Basic spatial units are the smallest spatial units for which information is collected and / or made available". Flowerdew and Green (1994) discuss the BSU from the point of view of trying to establish a common standard for data collection and presentation to facilitate data interchangeability. The selection of the BSU will be influenced by the level of spatial accuracy required by the system users - be it for detailed spatial planning or for aggregating data at a regional level. Even at the regional level there remains the choice of administrative (eg.sub-structure areas), functional (infrastructure service areas), naturally defined (catchment areas) and other region types. In selecting potential BSUs for Urban GIS databases, Martin (1991) discusses three approaches: the individual-level approach, the area-based aggregation approach and the modelled distribution approach[3]. Visvalingam (1991: 14) draws the distinction between BSUs that correspond to observable phenomena and those that correspond to artificial or imposed zones such as political wards or measurement units. Napier points out that the greater linkage of a BSU to reality, the greater the likelihood that it can be employed for other functional applications. The concept of the basic spatial unit is shown schematically in figure 6.1. In this diagram a number of potential basic spatial units for informal settlement upgrading GIS applications are shown. These include: a dwelling unit polygon, a room centroid, a settlement centroid, a sub-settlement centroid, a parcel centroid and a shack centroid.

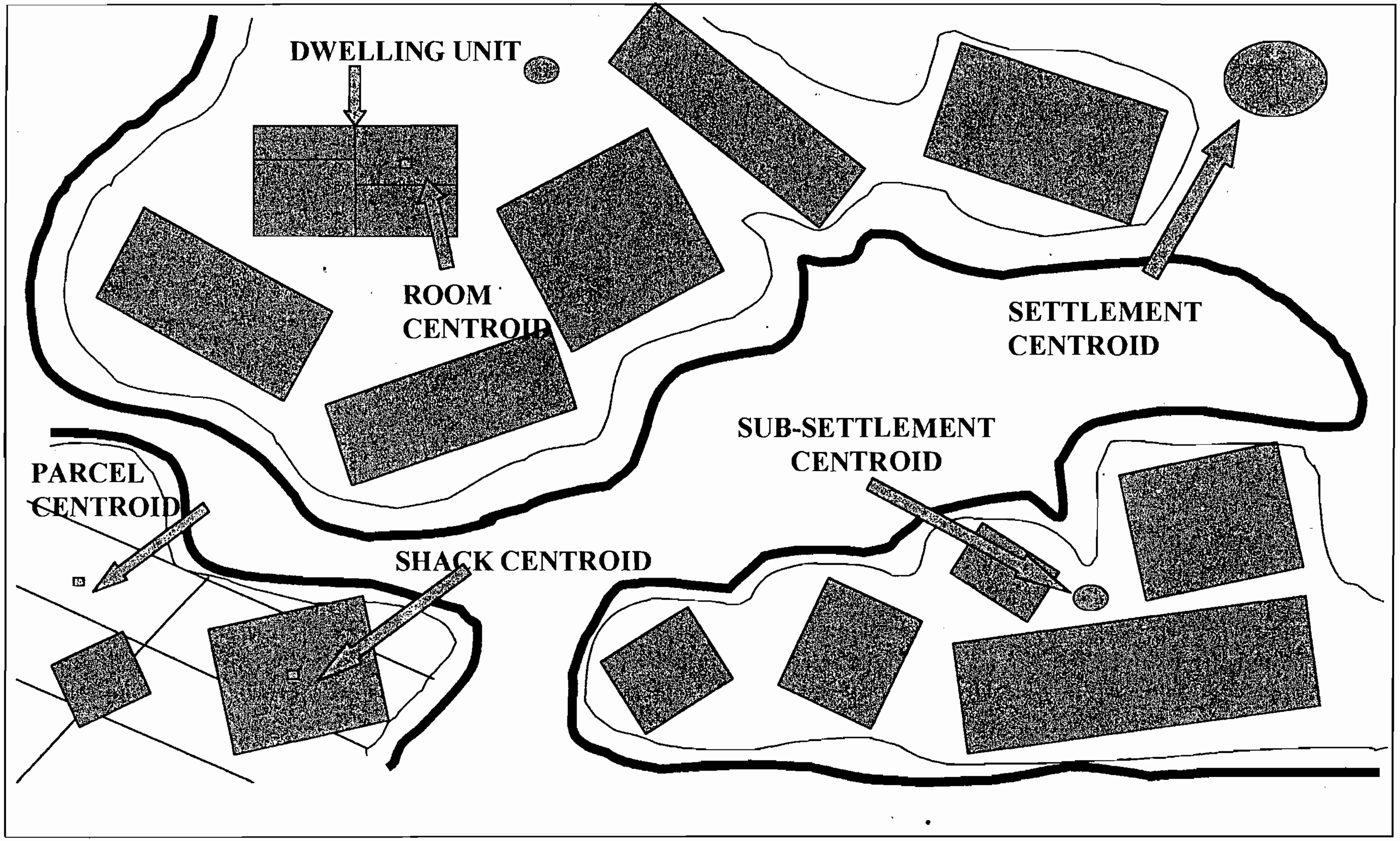


Figure 6.1 Some potential basic spatial units for an informal settlement GIS database. The basic spatial units shown here include: a dwelling unit polygon, a room centroid, a settlement centroid, a sub-settlement centroid a parcel centroid and a shack centroid.

6.2.3 Needs facing strategic-level applications

Several authors have argued that very little use is made of GIS for strategic-level planning in developing countries (Nijkamp and DeJong , 1987; Taylor, 1991; Edralin, 1990). A number of GIS systems were reviewed by Nijkamp and DeJong (1987). These included amongst other systems: SALADIN (West Java), MAP (Kenya), USEMAP (Sri Lanka), ITC Image Processing Lab GIS (Columbia) and the Comprehensive Resource Inventory and Evaluation System (CRIES) (Central America and Carribean countries). Most of the applications were found to be experimental and none of the systems was a fully integral part of the ongoing planning process (Taylor, 1991: 75.). Furthermore, Nijkamp and DeJong (1987: 103)state that " coherent and integrated spatial planning is rare, and systematic use of information in computerised systems is uncommon. In the few cases registered, the GIS has usually a limited domain and is implemented and maintained in the framework of a development project led by expatriate experts." The review by Edralin (1990) revealed that the design and use of GIS for developing country applications remained unresolved and that although the potential of GIS was accepted, it remained practically unused as a support mechanism in planning.

The situation in South Africa is slightly better. A number of strategic-level planning applications developed by metropolitan and provincial government authorities in South Africa have been described by Wulfsohne (1995) (see chapter 4). However, the focus of these applications lies mainly on the identification of vacant land (eg. PROLAND). Further more, these applications address the housing problem from a metropolitan spatial planner's point of view only. The theoretical framework for these systems are typically developed in isolation of the concerns of the involved communities. The need for community participation in planning activities involving settlement relocation or upgrading has been highlighted by various authors (Abbott et al, 1997). There has also been no consideration given to how the strategic-level systems developed by metropolitan and provincial authorities can be integrated:

1. with municipal GIS systems developed by local government,
2. with data inputs originating from the community, and
3. through a software interface that would expedite communication across all key organisations and levels of government involved in the upgrading process

6.2.4 The need for multi-level approaches

The need for multi-level GIS approaches in developing countries has already been highlighted in chapter 4. The need for a two-scale analysis approach to informal settlement upgrading has been identified by non-GIS researchers both internationally and in South Africa (see below). This illustrates that the nature of the informal settlement upgrading "problem" demands that even at purely a conceptual level, a two-level approach must be adopted - irrespective of the analysis tools applied.

From the international viewpoint, a recent discussion by Banjerjee (1997) supports the need for a two-level approach to informal settlement work. He states that the answer lies " in a multi-pronged measure, both short and long term, encompassing macro-planning, and micro-planning." In detail he describes the components of the micro-planning[4] and macro-planning measures[5] required (Banjerjee, 1997: 30)[6]. Durand-Lasserve (1997) discusses the changes occurring in the redefinition of public land use policies. He argues that these changes suggest that "intervention must address all dimensions of irregularity at once, in order to achieve the progressive integration of illegal settlements in the city." This quotation has two implications of relevance to the present study. First it highlights the need for a GIS approach which encompasses the regional and local levels of analysis. The term "dimensions" can be interpreted either as all the "scales" for both local and metropolitan, or as all the "facets" or "aspects". Even if the second meaning is taken then one must agree that intervention and upgrading requires local informal settlement data. At the same time the fact that informal settlement growth is definitely a regional phenomenon, implies that both the local and regional levels are required to encompass all the "dimensions" of informal settlements. Secondly, the quotation refers to a "progressive integration" of illegal settlements in the city. This integration process requires that both the formal and informal infrastructure networks can be resolved. This in turn implies that a micro-scale component is essential to the GIS database.

The need for multi-level GIS approaches for informal settlement upgrading in South Africa can be observed in the work of several authors local (Spiegel et al. 1996; Wood; 1980; Behrens, 1993). From a planning perspective, Spiegel et al (1996: 13) cites Wood (1980) as follows: " an adequate explanation of population movement patterns demands integration of both 'macro' and 'micro' determinants", and continues: "... the experiences of domestic unit formation and change that we document are products of significant macro-historical processes....". These quotes clearly indicate the necessity for applying spatial analysis tools that function on at least two levels. Behrens (1993) also highlights the need for a tool enabling the coordination of the upgrading work at a metropolitan level[7].

Coupled with the factors highlighted by Spiegel et. al. (1996) which support a macro-based approach in the study of population dynamics in the Cape Town Metropolitan Region (CMR), is the fact that the policy formulators associated with the latest restructuring of the local government would greatly benefit from a macro-level informal settlement database. Using Cape Town as an example, this would be true whether the seven new sub-structures will each be responsible for upgrading informal settlement areas within their boundaries, or whether the responsibility will be shared between the central and local sub-structures. If the central authority has to share this responsibility with the local authorities then an adoption of a two-level approach would greatly facilitate its planning and resource co-ordination activities with respect to its upgrading responsibilities towards the six local substructures.

There is also a general recognition that there is a need for to view the upgrading of a local settlement within the broader context of the city's existing infrastructure networks. One of the recommendations in the iSLP guidelines document (Derek & Assoc., 1993: 11) reads as follows: "Circulation systems in new townships should be designed to take into account surrounding metropolitan-scale traffic flows." One of the key advantages of a two-level approach is that it facilitates the integration of local and metropolitan data levels for this broader type of contextual network analysis.

6.3 NON-SCALAR ISSUES

Some of the key non-scalar issues associated with the development of GIS databases for informal settlement upgrading include the GIS needs, the database structure and the content of the database. Here only a brief mention of the GIS needs is made. Many developing countries throughout the world have the following three key GIS application needs[8] (Axes et al., 1997):

1. the need for generating or updating of a digital cadastre,
2. the need for generating a LIS for supporting the land registration and land titling processes, and
3. the need for incorporating information derived from the community into the spatial planning process.

A discussion by Zungu (1997) highlights the second and third issues listed above. For an informal settlement in Kwa-zulu Natal, Zungu (1997) identified two issues that must be addressed after regularisation of land tenure. Firstly, the information which will help to establish housing types affordable to the community needs to be entered into a GIS[9]. Secondly, an information system that will accelerate the registering, transferring and land allocation processes needs to be created. Furthermore, Zungu (1997) continues that such a system needs to be able to incorporate inputs from community-based organisations (CBC's) and other parties. A call for a system which integrates inputs from all levels and types of organisations involved in the upgrading process is embodied in statements such as:" The formation of partnerships needs to be accommodated in the local land management framework. This framework is to incorporate sound planning principles, the long term needs of SGO's, the requirements of finance houses, the needs of local authorities in relation to service provision and making it possible for individuals to upgrade their land rights."(Zungu, 1997: 3). The need for incorporating information derived from the community into the spatial planning process can also be seen in the following comment: "The main issue of concern is that of affordability levels of the urban poor. However, this requires strong community participation or involvement during the formalisation of tenure." The non-scalar issues discussed here only further highlight the need for a multi-scale approach.

6.4 EXISTING URBAN GIS MODELS

Several GIS approaches applied in urban GIS modelling have already been discussed in detail in chapters 2 - 5. In this section, the key aspects of these models are considered in terms of the database structure and content. The data base structure is discussed from the point of view of the basic spatial units employed in the model. The content refers to the types of attribute information attached to the BSU elements. The strengths and weaknesses of each of these aspects of the models and the practicality of employing these models for the multi-purpose requirements of an informal settlement upgrading GIS are also discussed.

6.4.1 Developing countries

A schematic summary of a number of the models employed in South Africa is illustrated in figure 6.2. Essentially the South African models analysed thus far all fall into Shalaby's Urban GIS model group. Within this general group, the models can be classed into:

1. Metropolitan-level Systems (eg. PROLAND and ENPAT)
2. Municipal or Cadastral Systems (eg. CCC and GTZMC), and
3. Local-level Systems (eg. ViSP, Urban Modeller, Napier's model)

The models depicted in figure 6.2 all have the disadvantage that they have been designed to operate at a single level. The metropolitan- and municipal-level systems have been designed to cater for the needs of spatial planners and not the needs of the community. This is evident from the absence of informal settlements in the metropolitan- and municipal -level databases. While the local-level systems cater for the community's needs, there is no metropolitan-level component to the database. The result is that these models are often implemented in an uncoordinated and sporadic manner. Not shown in figure 6.2 is the visual urban simulation model discussed by Goosen (1997)[10]. This model caters specifically for the architectural needs facing planers and designers in expensive formal settlement areas.

A number of Urban GIS models designed for informal settlement applications in other developing countries have already been described in chapter 4. Three of the key models developed by PADCO (discussed in detail in chapter 4) are:

1. the Lots by Dots™ model
2. the Rapid Land Use Assessment (RLA) model, and
3. a housing typology-based model

In each case a different basic spatial unit (BSU) has been employed. The first model utilises a single point feature as the BSU to represent each property. This point represents an identifier and a geographic locator. In the second model a land use classification zone is used as the BSU. While in the third model, the BSU corresponds to a housing typology zone.

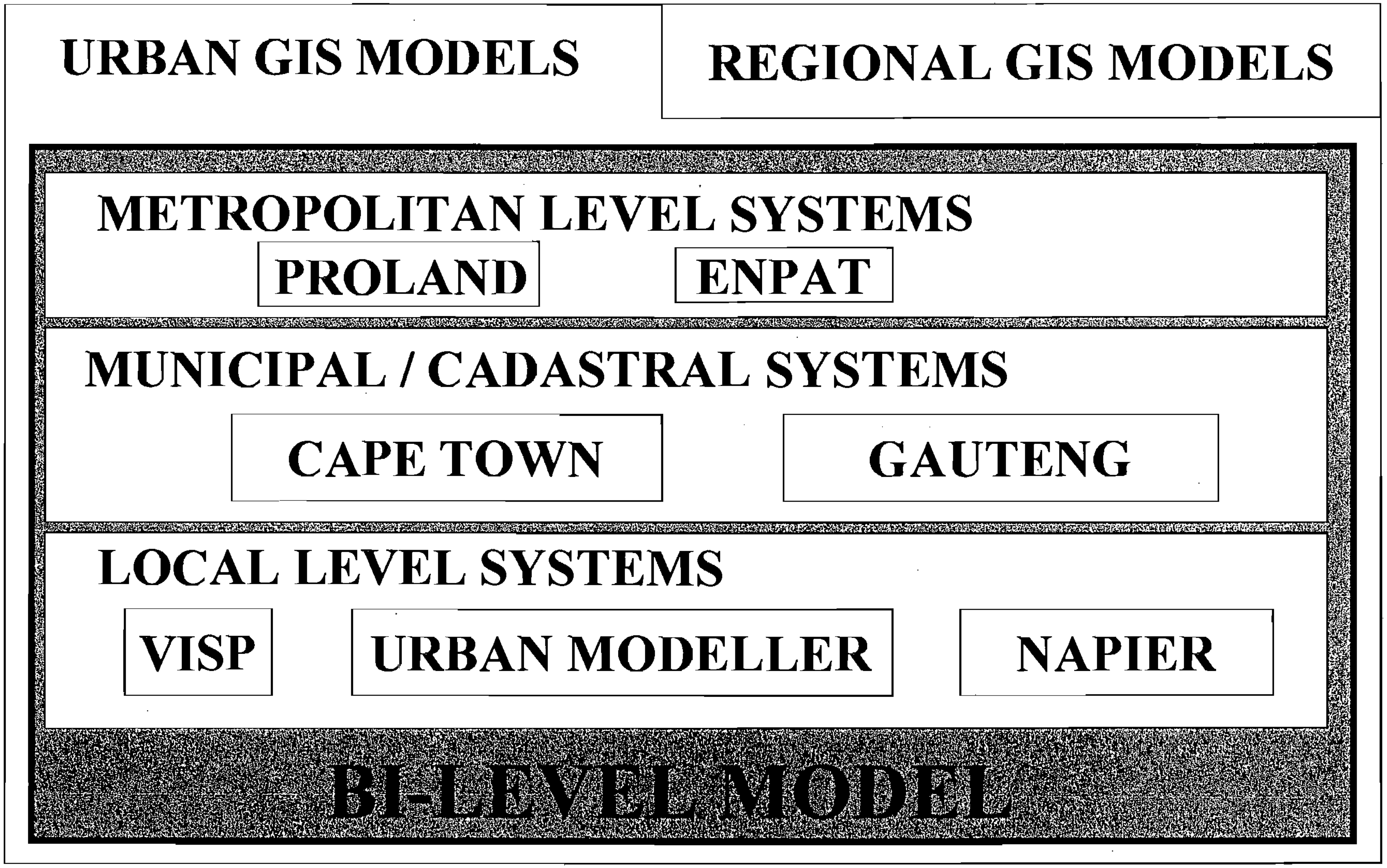


Figure 6.2 The vast majority of urban GIS models are designed for single-level applications. In contrast, the Bi-level model functions at two levels at least (ie. the metropolitan- and local-levels). Detailed municipal or cadastral databases (usually available only for formal settlement areas) can be accommodated in the model through sectoral model linkages.

There are a large number of advantages for employing a point-based BSU model[11]. However, the disadvantages of the model become apparent when one attempts to extend its application to aid implementation and planning processes taking place at the local-level. Firstly, with respect to community participation a polygon-based representation of a dwelling is more readily associated with the structure than a point. This becomes important when one is considering the use of maps in community participation processes. Secondly, a Lots by Dots™ approach prevents any local planning and design exercises requiring the outline of the dwellings. At a local-level, such an approach is really only valid for a counting exercise. A point per dwelling unit representation is sufficient if the database is aiming to cater for metropolitan-based spatial planning. However, the practicality of attaching of the attribute data discussed in chapter 4 for each of the points becomes unmanageable[12] for metropolitan-level applications.

The zone-based BSU models listed above are quick to implement but are faced with the same problems as the metropolitan-based models shown in figure 6.2. In RLA and housing typology models, neither the location, nor the outline of individual dwelling units are retained. As a result these models can only be applied at the metropolitan-level and can only cater for the needs of spatial planners.

6.4.2 Developed countries

The trend towards multi-scale GIS databases in Europe has been highlighted in chapter 2 [13]. This trend is particularly evident in the MERKIS model developed in Germany and in the Urban Data Banks model in France. The mapping scales employed in these models range from 1:500 to 1:10 000. These models have been developed to address the needs of formal settlements in developed countries. While the concept of a multi-scale approach can be incorporated into the framework of an informal settlement upgrading GIS database model, the MERKIS and Urban Data Bank models themselves are not directly applicable to developing countries such as South Africa. The principal focus of these models lies in integrating all local government GIS in a country[14, 15]. It may be plausible to seek such ideals in developed countries that have decades of GIS experience and an exceptional availability of digital data. However, the requirements facing the implementation of these models seem to be unrealistic goals for developing countries[16]. Cummerwie (1993) has shown that the failures of some of the earlier GIS projects in Europe can be traced to the neglect of institutional constraints. It is thus essential to briefly consider these requirements in the light of the institutional constraints facing the implementation of such models in local authorities in South Africa.

Junius et al. (1996: 72) states that "it has been recognised that in most cases the traditional structure of local government is not adequate for the kind of information management envisaged by MERKIS." Furthermore, he continues that an implementation of MERKIS requires a modification of the existing organisational structures within local government and defines this modification as "a major intervention into a highly complex organisational system, in which responsibilities, interdependencies and procedures have evolved over a long time." The local authority case studies by Junius et al. (1996) illustrates that even in the country of origin, the scale recommendations of the model have been followed by only one out of every three potential applications.

There are two problems with meeting these model requirements in South Africa. Firstly, the restructuring of local government in South Africa involves an ongoing process of the redefinition of responsibilities, interdependencies and procedures in local authorities. It is unlikely that the roles and responsibilities of local government will be clearly defined in a short period[17]. Secondly, it is highly unlikely that in a country such as South Africa, where major organisational modifications are already being made to retain some form political stability, " a major intervention into a highly complex organisational system" (Junius et al.,1996: 72) would be welcomed or even at all possible. Clearly the implementation of a MERKIS type model will remain impractical for the vast majority of developing countries for many years to come. Yet the model illustrates an example of how a purely cadastral approach has led to the realisation that a multi-scale approach to urban GIS modelling is required in even the most developed countries.

6.5 GENERAL DISCUSSION ON THE KEY ELEMENTS OF URBAN GIS MODELS

The Urban GIS models created for developed and developing countries differ in terms of the required level of accuracy. The poor developing countries, characterised by a low degree of urbanisation, tend to have lower GIS accuracy level requirements than the highly urbanised developed countries (see figure 6.3). Similarly, the viability of the cadastral approach differs according to the degree of urbanisation. In this case, the lower degrees of: settlement stability, accuracy and complexity of applications required in developing countries, make the cadastral approach less viable for these countries than for the developed countries.

Two key factors controlling the design of an Urban GIS model are primary sectors to be addressed by the model and the order in which these sectors are prioritised. This will not only determine the order in which different types of information can be made available, but may also set constraints on subsequent types of analyses[18]. There are essentially two primary sectors within the urban environment in a developed country city system: the natural environment and the formal settlements. In a developing country city system, the informal settlements present a third primary sector. The potential orders of prioritisation of each of these three primary sectors in Urban GIS

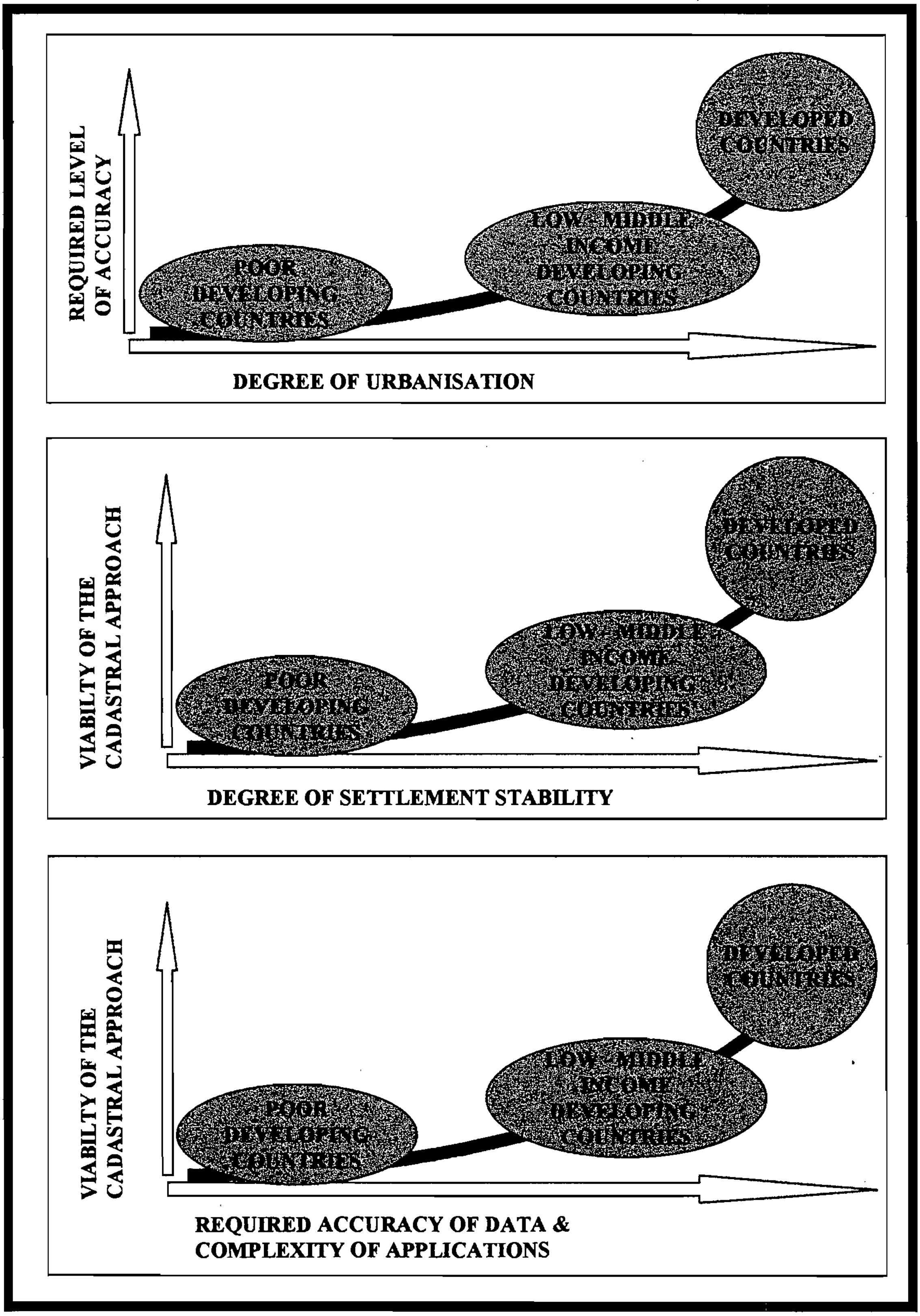


Fig 6.3 Required levels of GIS accuracy in developed and developing countries.

models for developed and developing country cities is shown in figure 6.4. While the informal settlement sector is omitted from developed country models, it holds the position of greatest need in developing countries. However, current models for developing countries tend to ignore the informal sector and address the needs of the formal sector only. An alternative solution lies in placing an equal emphasis on the formal and informal sectors. In the developed countries only two Urban GIS model scenarios exist. The first places the environment in the position of greatest need. The second places the formal sector in the position of greatest need.

6.6 LOCAL FACTORS INFLUENCING THE DEVELOPMENT OF THE MODEL

Two key local factors strongly demanded that a metropolitan-level be incorporated into the design of a GIS database for informal settlement upgrading in the Cape Metropolitan Region (CMR). These factors were firstly the dynamic nature of informal settlements in the CMR, and secondly the status of informal settlement upgrading policies in the CMR. In the first instance, a metropolitan-level is useful to track the rapid growth of informal settlements in the CMR. Secondly, it can be used to evaluate and optimize the relocation policy being implemented on a metropolitan-wide basis by the provincial or metropolitan government. Furthermore, while it is recognized that informal settlement upgrading demands local-level databases, the absence of a number of the preconditions required by the ViSP approach demanded that the development of the metropolitan-level of the database precede any local-level database initiatives.

6.7 THE BI-LEVEL MODEL

6.7.1 Introduction

The Bi-level model is a GIS database design which has been developed to enable GIS to be used for informal settlement upgrading applications by municipal organisations and other key role players involved in the upgrading process. The model consists of a series of inter-linked GIS databases. It provides the framework for linking a multitude of local-level informal settlement upgrading databases and can also be interfaced with existing municipal cadastral databases. This in turn enables informal settlements to be analysed in the context of the existing formal settlement urban infrastructure.

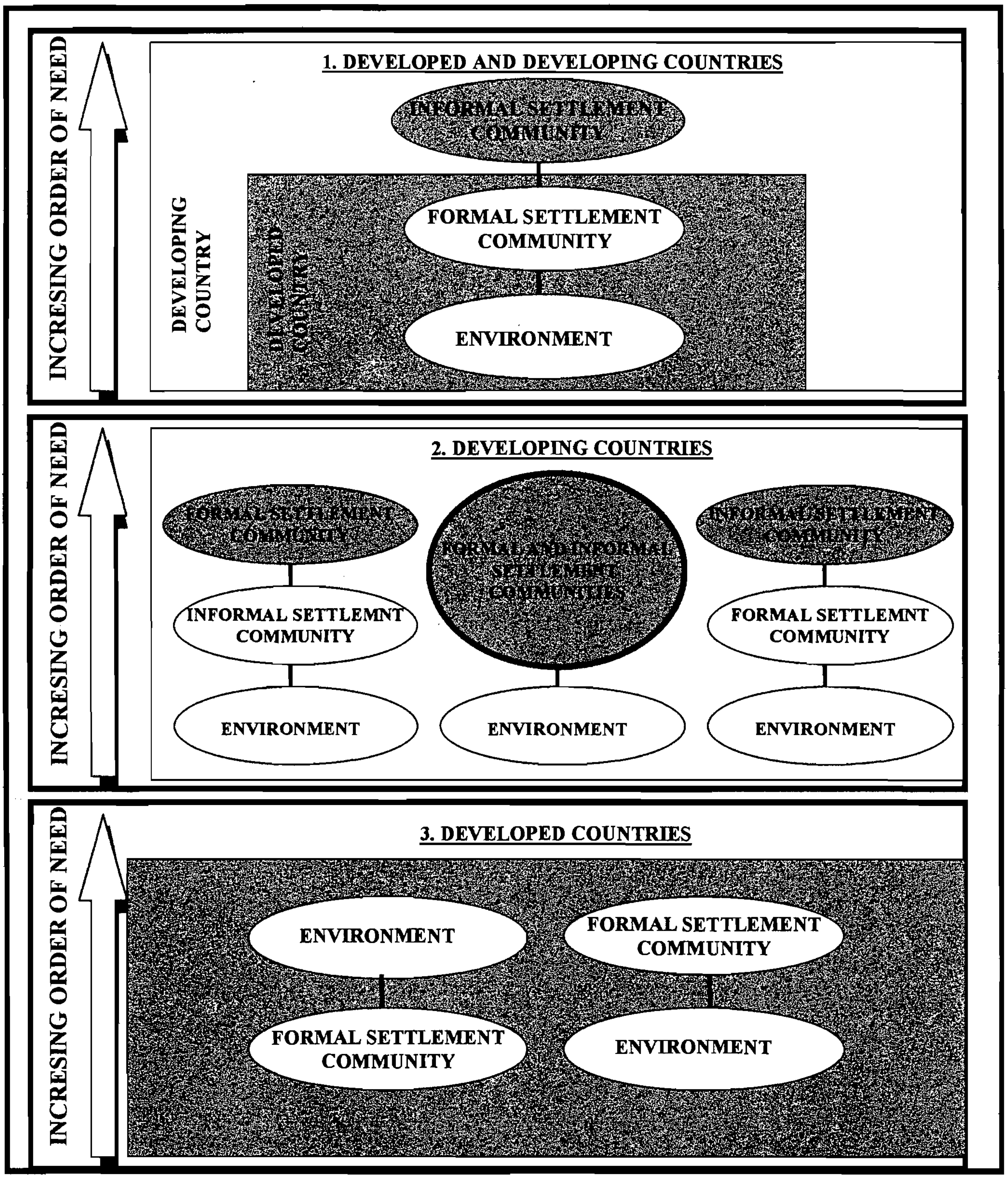


Figure 6.4 Schematic illustrations indicating the manner in which the three primary sectors of urban GIS models (the environment, formal and informal settlements) may be prioritized.

One of the most important aspects of the Bi-level model is that it requires the recognition that the basic spatial unit of an urban GIS in a developing country must be multiple in nature in order to address the needs of both the formal and informal settlement sectors. Metropolitan centres of developing countries typically display a greater degree of heterogeneity in comparison to those of the developed countries. This is due to the presence of informal settlements scattered within and around the urban fabric of the formal cities in developing countries. The Bi-level model is based on the principal that in order to make a municipal GIS database functional for the development of both the formal and informal settlement area applications, the structure of the database must reflect and cater for this lack of homogeneity that exists within developing country cities. The accuracy of the model must be flexible enough to make it functional in all parts of the city. The Bi-level model thus encourages the use of a variable basic spatial unit (BSU).

In defining the model it is essential to consider the nature of the databases that are linked to it as well as the nature of the linkages that are used to build the model. It is also necessary to briefly consider the software configuration required as the implementation of the model necessitates specific data distribution capabilities. The linkages form an integral part of the model as they control the development and the functioning of the Bi-level model. These linkages may be defined both in terms of the characteristics of the databases that are linked and in terms of the accessibility these databases. In the following sections the framework, database components, software requirements and database linkages that comprise the Bi-level model are discussed.

6.7.2 The framework of the model

The key features of the Bi-level model are shown in figure 6.5. At the centre of the Bi-level model is a metropolitan-level database. Attached to this basic reference framework are a series of local-level databases. All of the databases are constructed using identical project system parameters and are thus perfectly compatible. Furthermore, these parameters are selected to ensure compatibility with local authority GIS and other government systems. The Bi-level model itself resides within a Universal Reference Framework, which is essentially the set of all the information systems databases on earth. Many specialised information systems feed into the universal reference framework. In this case, the Bi-level model represents a system specialised for informal settlement upgrading applications. Within the Universal Reference Framework, there are a number of databases that can serve as useful extensions to the Bi-level model. These may be termed as potential sectoral models to the Bi-level model.

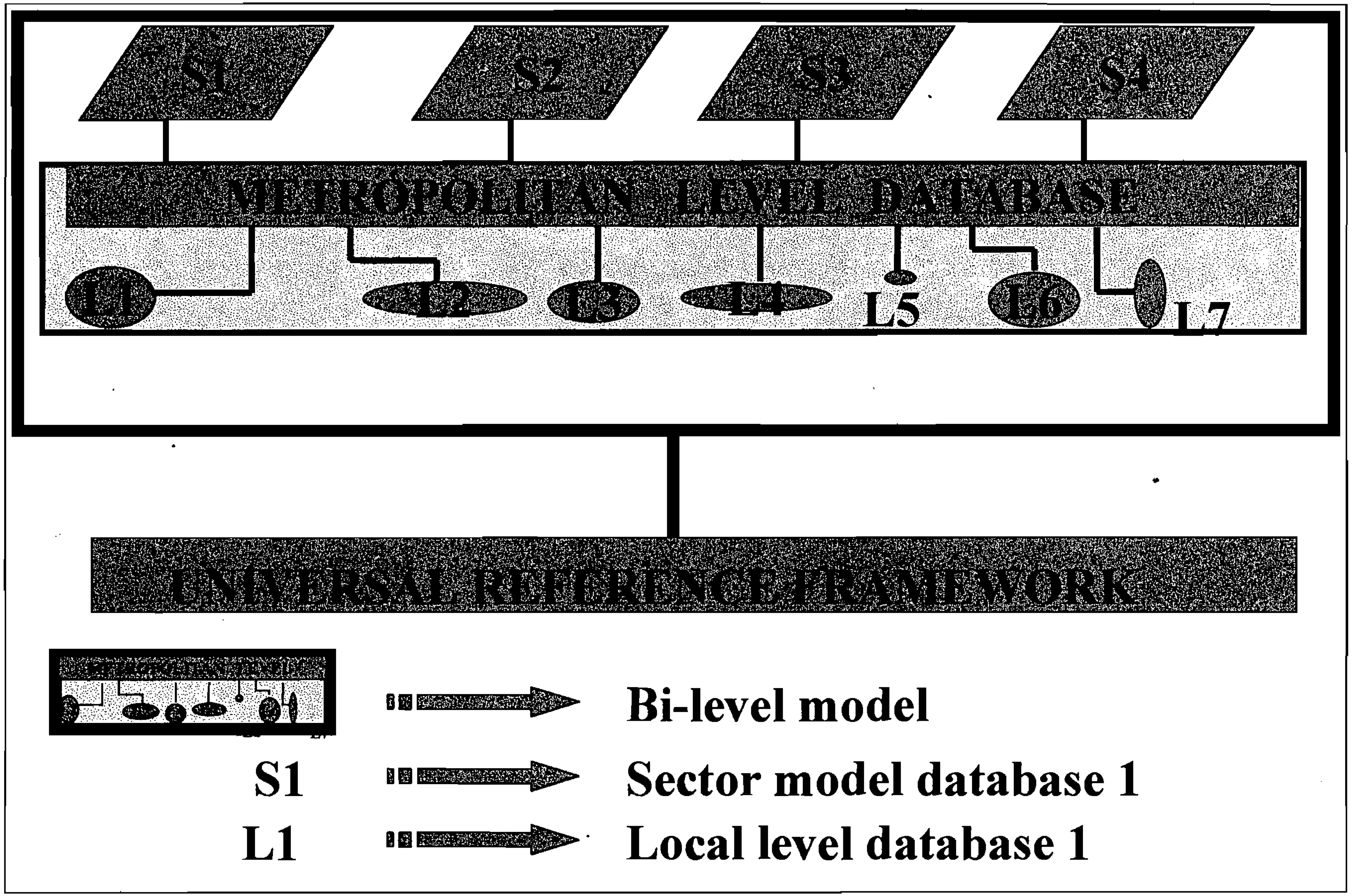


Figure 6.5 A schematic illustration of the Bi-level model. The metropolitan-level, local-level and linkages to sectoral models are highlighted here.

6.7.3 The database components of the model

The metropolitan-level database

The metropolitan-level database consists of a combination of raster, vector and attribute data types. The raster data is comprised of ortho-rectified aerial photography images at a scale of 1: 10 000 to 1: 20 000 or better. These images have been scanned to have a pixel resolution of approximately 1 - 2 m. The images cover all of the informal settlement bearing areas in the metropolitan area and are used as a backdrop for digitising the vector data. Due to the large file size of each image, the bulk of the raster data is kept on CDs. Only extracts of the imagery that correspond to the informal settlement areas are retained on the system. The vector data itself is comprised of shack points, settlement and sub-settlement area boundaries and centroids. The basic spatial unit implemented in the metropolitan-level database is the sub-settlement centroid. This basic spatial unit was selected as it facilitates the calculation of sub-settlement densities. The basic attribute data attached to the sub-settlement centroid consists of information such as the settlement name, sub-settlement density and area. Other types of data that can be added to the attribute database as it is developed are the levels of service for each infrastructure type and information on physical risks. The metropolitan-level database is further discussed and illustrated in great detail in chapter 8.

The local-level database

Again each local-level database is comprised of a combination of raster, vector and attribute data. The raster data consists of low-altitude helicopter photography at a scale of 1:200 to 1: 300. These images are georeferenced using the ortho-rectified imagery in the metropolitan-level database[19]. Unlike the imagery used to develop the metropolitan-level of the database, the local-level images are scanned in at a much lower resolution (200 dpi) and are used to create a mosaic for the settlement of interest. This mosaic is sufficiently small (typically about 50 MB) to be kept on the system and is used as a backdrop to digitise the vector data associated with the local-level database. The mosaic is used to create a basic digital cadastre and to capture the existing infrastructure for the settlement. The features that are captured include shacks, shack centroids, toilets, stand pipes, tracks and streams. The basic spatial unit implemented at the local-level is the shack polygon. The shack centroid represents an alternative option for the basic spatial unit at this level. However, the latter option requires the creation of an additional join in the thematic mapping process, as in practise the creation of visually meaningful thematic maps necessitates that the data be linked to the shack polygons. Once a basic digital cadastre has been developed it is checked through on the ground confirmation. This vector database is then populated with detailed socio-economic data on the settlement.

The types of attribute data that are attached to the shack polygon provide information on the dwelling, shack owner, the spouse and children of the shack owner and other residents of the shack. The attribute data exists as separate tables and are linked through a series common identification numbers in order to save space. The data associated with the dwelling includes information on the number of occupants, flooding, infrastructure services etc. The shack owner data includes information on income, employment, education, age, the tenure type etc. These data sets are entered onto the system by the community using a specially developed user-interface. Some examples of potential local-level databases for the CMR are shown in figures 6.6.

Sectoral models

The concept of "sectoral models" was originally coined by May et al. (1997). Sectoral models are in essence models that have been developed to model sub-systems within the city. In the context of the current work, the potential sectoral models essentially represent a selection of databases from the Universal Reference Framework that can be used to extend the application of the Bi-level model. In the case of the Bi-level model developed for informal settlement upgrading one of the key potential sectoral models is the local authority cadastral database. The types of data that can be accessed through the linkage to a cadastral database include parcel boundaries, servitude areas, topographic data and other types of information for the formal settlements surrounding the informal settlement. Examples of potential sectoral models (indicated by S1, S2...etc.) for the CMR are shown in figure 6.7.

6.7.4 The software requirements of the model

There are a number of specific requirements facing the software configuration that is used to implement the Bi-level model. These requirements include specific data distribution, database linkage and ease of use capabilities. The implementation of the Bi-level model requires a single high-end GIS software platform coupled with a series of low-end GIS platforms. Essentially the metropolitan-level of the model resides on the high-end platform. Local-level databases may be linked directly to this main system via the intranet or may reside on remote desktop platforms and be linked via the Internet. The reason for adopting an Internet-based GIS software platform is to make the GIS data accessible to a wider audience and to thereby increase productivity. Furthermore, the low-end GIS platform must enable multiple data warehouses to be accessed and support a bi-directional linkage to the RDBMS. Through the construction of database linkages, the low-end platform should enable the most current data to be accessed and enable the data to be shared in a secure, read-only environment. Finally, the low-end platform should be easy to use.

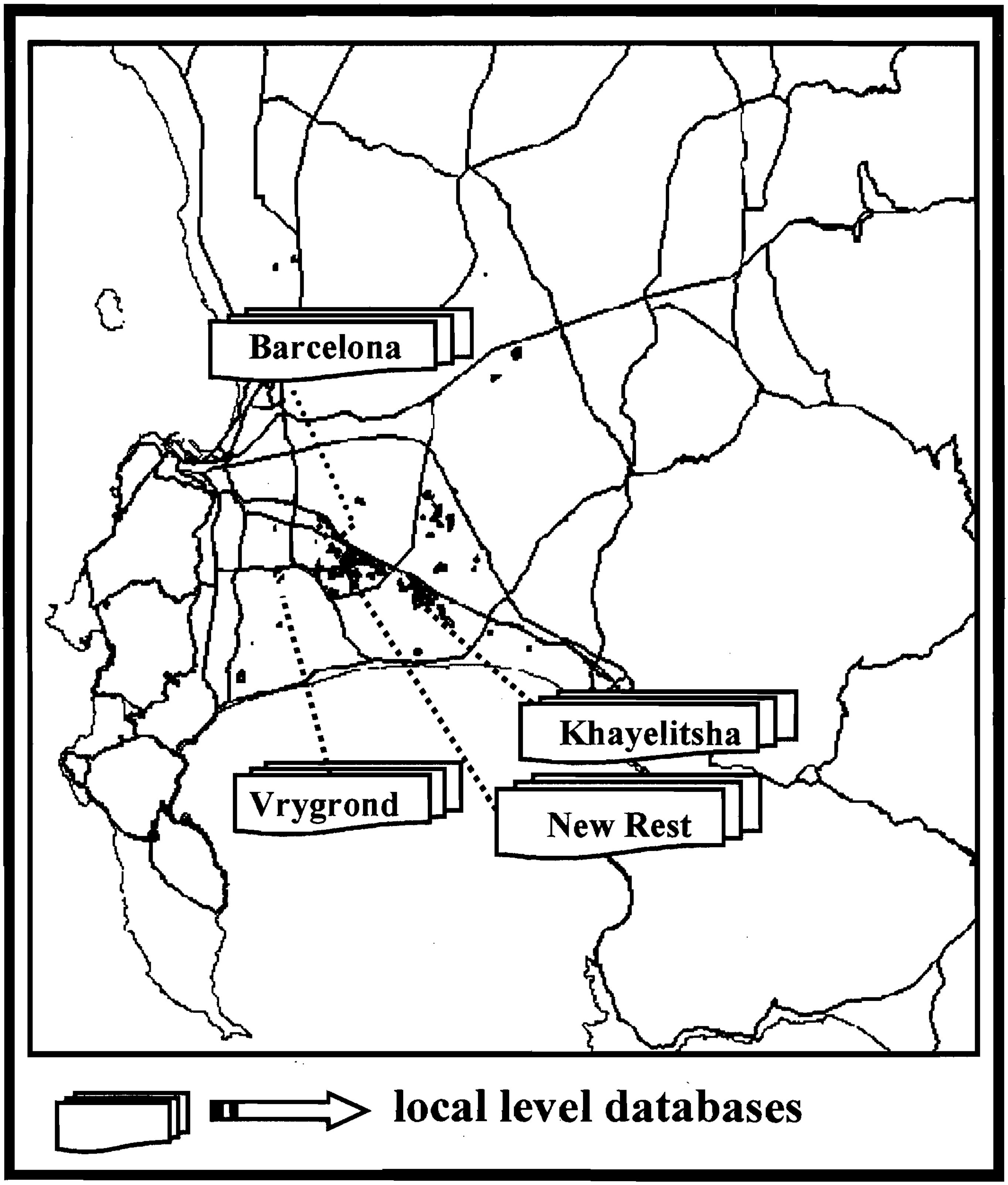


Figure 6.6 Examples of some potential local-level databases shown against one of the vector layers in the metropolitan-level database for the Cape Town Metropolitan Region.

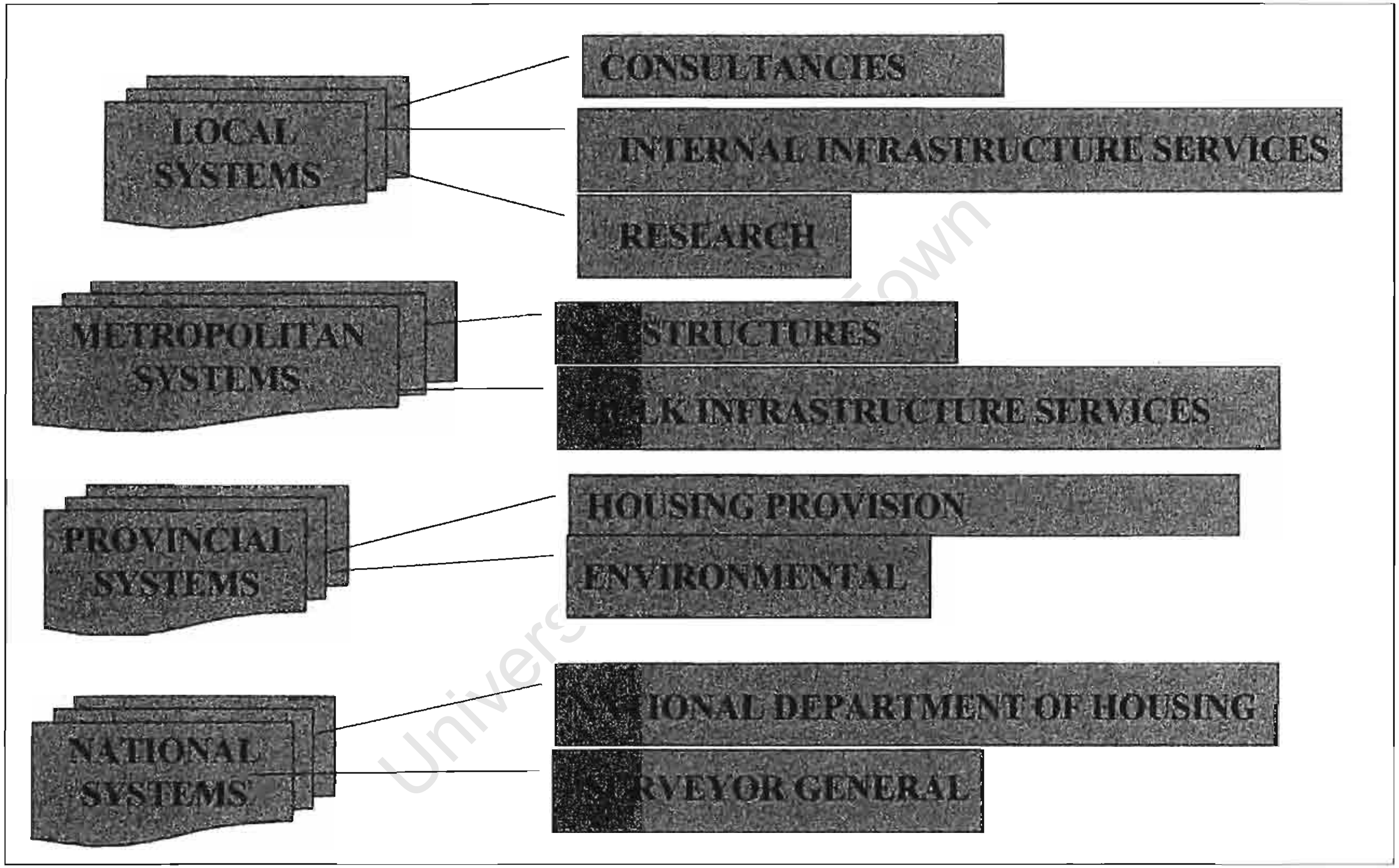


Figure 6.7 A schematic illustration of potential sources of sectoral models for the Bi-level model .

6.7.5 The linkages in the model

Three types of database linkages form part of the Bi-level model. These are the:

- metropolitan-level to local-level database linkages
- metropolitan-level to sectoral model database linkages, and
- local-level to sectoral model database linkages

The first two of these are shown in figure 6.5. These linkage types are defined on the basis of the content of the databases linked. In addressing the issue of implementation of the Bi-level model, it is more useful to define the linkages in terms of the location and the type of software in which the databases reside. In view of these criteria linkage between the main metropolitan-level and local-level databases may be broken down into a further three types dictated by the GIS capabilities of the local authorities or other local organisations involved in the development of the local-level databases. These connections can be described simply as linkages between the metropolitan-level project on the main system and local-level databases on:

- the main system intranet
- remote client machines with significant data capturing and processing facilities
- remote client machines with very limited data capturing and processing facilities

In the case of the first linkage type, there is no computer facility situated locally (ie. at the informal settlement). Data may only be available to the community by visiting the computer facilities of adjacent informal settlements or from a visiting social worker carrying a laptop. In the case of the second linkage type, the developers of the local database are actively involved in the data capturing process. In the case of the third linkage type, the local-level database for an informal settlement is largely constructed on the main system and accessed by local client PCs utilising a standard low-end GIS platform. Other software may be used in the settlement. The key difference between the third and the first linkage type is that the data is accessed and possibly complemented by the local computer facilities.

For both the second and third types of linkages pre-processed data outputs from the main system may be utilised by the local systems in such manner as to accelerate the data capturing process. These outputs could include warped maps and images for the second group of database developers. In the case of the third linkage type, a basic GIS vector database template would enable the local staff to attach the attribute data. Thus the developers of the main system must not only create and update the metropolitan-level of the informal settlement database, but should also act a support service for the settlements faced with very limited computing facilities. Detailed infrastructure data should reside on the local databases. Furthermore, attribute can be captured on existing desktop software products, such as Excell or Access, within the local-level areas by the local authorities and subsequently imported onto the standard low-end GIS platform.

Further characteristics of these linkages are discussed in detail in chapter 8. It is more important here to note that these basic linkage types can be created through the low-end GIS platform database connection utility. Using the concept of a database connection these linkages can be redefined in a manner that reflects the varying degrees of accessibility of each database. The linkages can be seen to extend across four intranet- / Internet-based linkage accessibility environments. These are: the Corporate Intranet and three types of Internet environments that may characterised by containing local sites:

- based on a standard low-end GIS platform
- based on other GIS platforms supported by the standard low-end GIS platform
- based on all other types of software

Based on the software requirements listed in chapter 7 a standard low-end GIS platform may be defined to implement the model. The standard low-end GIS platform selected must be capable of supporting direct connections to databases on other machines situated on the same platform and to databases on the more common high-end GIS software systems such as: Arc/Info, Intergraph MGE, and Oracle (Spatial Data Option). The Corporate Intranet and the first type of Internet environment linkage can be easily constructed using such in-built database connection facilities. Databases in the second Internet linkage environment are less accessible in terms of interfacing than sites on the first Internet-level, as a direct database connection cannot be established. Instead the application of specialised conversion or server utility programs is required to create an interface to the data sets. These databases may reside on less common GIS software environments such as MapInfo, REGIS or on CAD software. The nature of a linkage to a local-level informal settlement database site may shift from a type 2 to a type 1 connection as further software is created to enable the standard platform to support these packages. The third Internet environment linkage type contains the majority of the remaining databases in the Universal Reference Framework.

The second Internet environment linkage type enables a large number of potential sectoral models to be linked to the Bi-level model database. Systems that can be accessed using this linkage type include those developed by government institutions such as: the Agriculture Research Council, the Department of Water Affairs, municipal GIS systems and the Council for Scientific and Industrial Research. Many of these systems are currently based on ArcInfo and can be accessed through the Internet by creating a database connection from the standard low-end platform.

6.8 SIGNIFICANCE OF THE MODEL

In order to fully realise the significance of the Bi-level model it is essential to review briefly the problems facing the Urban GIS models considered thus far. These can be grouped into problems facing Urban GIS models in general and those facing informal settlement upgrading initiatives specifically.

6.8.1 Problems facing Urban GIS models

The discussions in chapter 2 have shown that the diffusion of GIS in the developed European countries has been hampered significantly by problems associated with the cadastral approach. Amongst these problems are the slowness of the approach, data maintenance problems, the lack of applications development, data under-utilisation, technical problems and the lack of digital data (section 2.4). Identical problems were encountered in the Cape Town City Council (chapter 3). In this case, however, the lack of digital data corresponded predominantly with the informal settlement areas (section 3.6.10). In addition to a series of common problems the discussions in chapters 2 and 4 revealed the validity and the general need for multi-scale approaches to GIS.

In terms of informal settlement upgrading GIS applications specifically, the cadastral approach is faced with the critical problem that for the majority of the informal settlement areas cadastral boundaries do not exist. Where cadastral boundaries do exist, the housing structures do not conform to these boundaries. The shacks often overlap two or three land parcels. There are also often two shacks within a single land parcel. In addition there is a constant movements of the shacks themselves. Such problems bring into question both the usefulness and the practicality of attaching the socio-economic data associated with families in these areas to parcel boundaries or parcel boundary centroids (see figure 2 in appendix 3).

Current informal settlement upgrading and low-cost housing development GIS database models such as the PADCO, ViSP, Urban Modeller, PROLAND and other initiatives are characterised by the lack of:

- a mechanism for community participation
- a multi-scale approach
- a mechanism for project management
- linkages to the formal sector
- linkages to the environmental sector
- a mechanism for co-ordinating initiatives at a global-level

Current urban GIS models tend to focus either on the metropolitan-level (eg. PROLAND) or on the local-level (eg. Urban Modeller, ViSP) only. As a result, the metropolitan-level models suffer from a lack of a mechanism for community participation, while local-level models suffer from a lack of a mechanism for project co-ordination and management. Furthermore, local-level models tend to ignore the environment and the formal settlement surrounding the informal settlement of interest. While treating the informal settlement as an isolated pocket within the city has the advantage of simplifying the modelling process, such an approach is unsuitable on its own. A mechanism must be incorporated into the model for facilitating linkages to databases modelling the formal and environmental sectors. Such linkages are required to ensure environmental sustainability and to encourage planning initiatives designed to integrate the informal and formal settlement areas of the city.

6.8.2 General Urban GIS modeling problems addressed by the Bi-level model

Internationally, the Bi-level model provides a significant contribution in terms of providing a mechanism for addressing some of the problems that have hindered the diffusion of GIS not only in the developing countries but also in European and in other developed countries. More specifically, it provides a generic model for inter-linking and co-ordinating the development of GIS databases for those areas of the city that are characterised by a lack of digital data. While the "black box" approach to informal settlement upgrading facilitates the implementation process, it also results in a series of disjointed local-level databases. This problem circumvented from the out start in the Bi-level model. Furthermore, the Bi-level model represents a generic tool that can be applied more widely than to just informal settlement areas. Figure 6.5 is important in this regard as it illustrates the generic nature of the model. While the model was initially devised as a tool for managing local-level informal settlement upgrading databases, it can be applied to manage the development of any type of local-level database created to compensate for gaps in the digital cadastre.

One of the technical problems that has particularly hindered the diffusion of GIS in both the developed and developing countries is the complexity of the high-end GIS software platform that is required to implement the cadastral approach. These high-end GIS systems are typically cumbersome and not user-friendly. While such high-end platforms cater for the needs of those developing a cadastral database ("Doers") (see chapter 7), such systems are poorly suited to the needs of the vast majority of potential GIS users ("Users")[20]. The Bi-level model addresses this problem by placing a strong emphasis on the fact that a coupled software system is required. The metropolitan-level database is created and maintained on a high-level GIS platform. However, the local-level databases are intended specifically to reside on a series of low-end GIS platforms characterised by a user-friendly interface and only the key GIS analysis tools (such as basic polygon and linear analyses). Furthermore it should be noted that the Internet-based GIS platforms were designed specifically for the diffusion of information to a wider audience. In this way the Bi-level model is designed to encourage the diffusion of GIS amongst the majority of its potential user groups. In addition to the key software requirements listed in chapter 7, the standard low-end GIS platform can be selected so that:

- a proprietary language is not required for customisation
- multi-media support is provided, and
- the viewer software is freely available on the Internet

These additional requirements may be used to further facilitate the diffusion of the GIS data comprising the Bi-level model database.

The problems associated with the slowness of the cadastral approach are circumvented in the Bi-level model, as the development of the metropolitan- and local-level databases can commence before a detailed digital cadastre for the city has been completed. Two other problems addressed by the Bi-level model are that of data maintenance and data under-utilisation. The problem of data maintenance is reduced to some extent as the nature of the database linkages ensures that the latest version of the database can be viewed each time it is accessed by a connection. The problem of data under-utilisation is also addressed as the linkages between the three different database types (metropolitan, local and sectoral) facilitate the transfer and sharing of data between the different GIS user groups. Furthermore while the cadastral approach has been known to hinder the development of planning and other non-surveying-based applications in municipal organisations, the Bi-level model specifically encourages the development of such applications for those areas of the city that are normally neglected from the GIS.

6.8.3 Informal settlement-specific problems addressed by the Bi-level model

<u>A dwelling-unit based approach</u>
The Bi-level model circumvents the primary problem facing the implementation of the cadastral approach in informal settlement areas by proposing an alternative basic spatial unit. While the cadastral approach relies on a parcel polygon or parcel centroid basic spatial unit, the Bi-level model relies on the use of a shack polygon or shack centroid basic spatial unit at the local-level. The model is thus not constrained by the absence of parcel boundary or political boundary definitions (such as the sub-structure boundaries employed in the PROLAND model) which may alter with time.

<u>A mechanism for community participation</u>
The Bi-level model provides a mechanism for community participation in the upgrading process in two ways. Firstly the community is directly involved in the development of the local-level database. As in the case of the ViSP approach in Belo Horizonte, each community member fills in a detailed socio-economic questionnaire. This information is captured by community members into the attribute database through a user-friendly input interface. Secondly, the local-level database provides a platform for negotiation between the community, local authority, development agencies, consultancies and other role players. Using the standard low-end GIS

platform one can construct a local-level negotiation database for each infrastructure type in the settlement. A number of workspaces can then be created for illustrating:

- upgrading proposals by local authorities
- upgrading proposals by consultancies
- upgrading proposals by the community
- problem areas detected by the community

By developing such an information infrastructure, the community leaders may be kept informed of the latest local authorities development plans, and of all the upgrading possibilities available from different consultancies. In turn, the local authorities could be kept up to date on the community's views and on the various consultancy options. This negotiation-based approach can be used to reduce the degree to which the engineering-based job market is monopolised by certain consultancies. Furthermore, it inspires a more collaborative planning approach towards upgrading an informal settlement. The community feels that it is inputting into the planning process as opposed to simply adding to the development of a database.

<u>A mechanism for data diffusion</u>

The Bi-level model provides a mechanism for GIS data diffusion amongst all the key role players involved in informal settlement upgrading projects. It caters for the diffusion of information amongst two types of audiences. The first represents audiences who have access to a well developed information infrastructure. This group contains national, provincial, metropolitan and to a lesser extent local government audiences (figure 6.8). These user groups can have access to the system via the Internet. The second group holds potential user groups within the local-level without access to Internet facilities. This group consists of certain local authorities, consultancies, NGO's and communities. In the absence of Internet facilities, the information requirements of the second group are catered for largely by community participation. This takes the form of detailed social-economic surveys and community workshops. Thus a key aspect of the model is that it caters for technical and non-technical information input and feedback mechanisms. Where possible, Internet kiosks near to the settlement may also be utilised. In addition to illustrating extracts from a Bi-level informal settlement upgrading database, the local-level GIS platform can be used to disseminate other types of information that are of interest to a community member, such as:

- the upgrading plans for a settlement
- the sites available in the relocation area
- the infrastructure in the area surrounding the relocation area

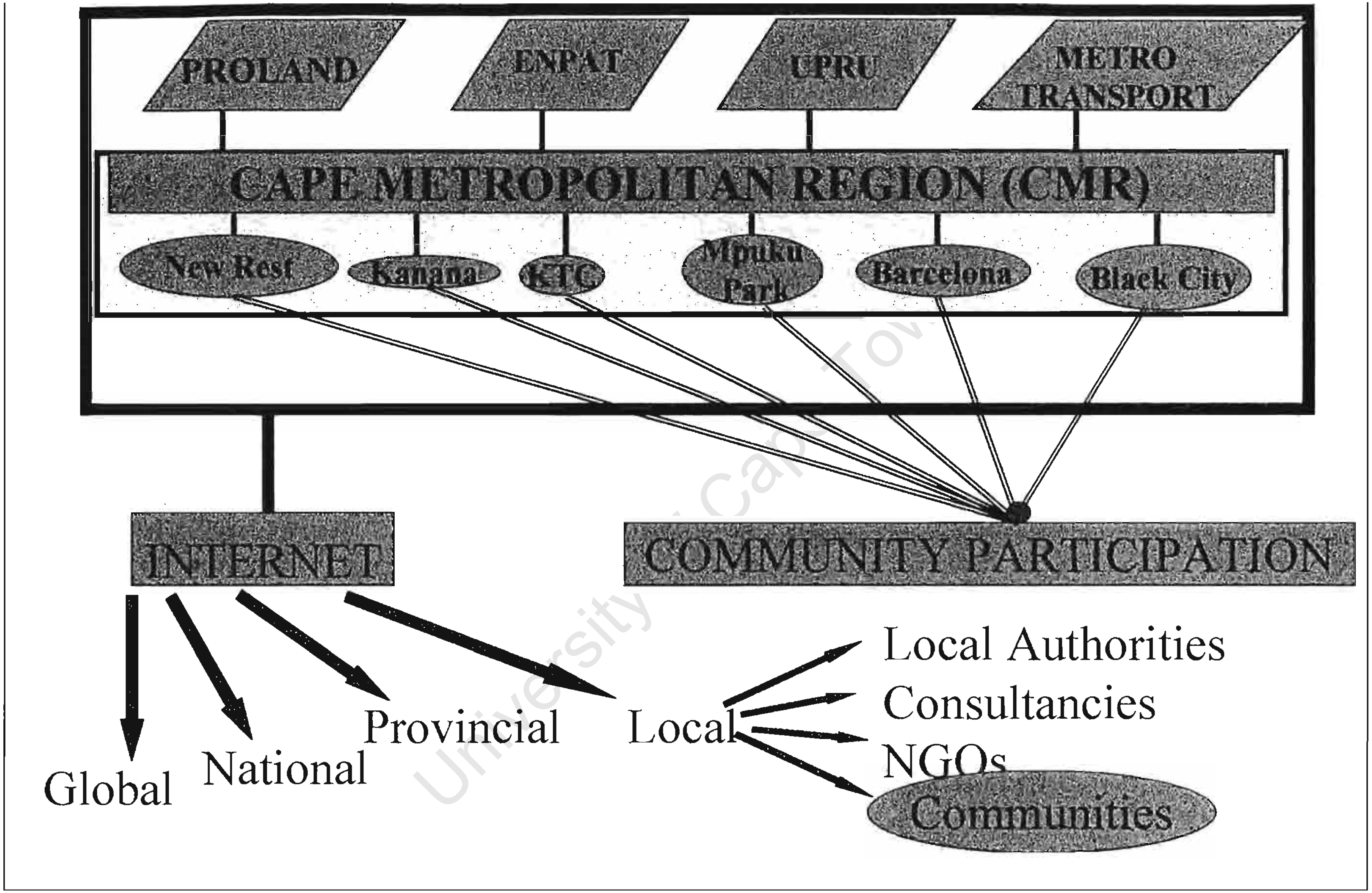


Figure 6.8 Examples of potential local-level and sectoral model databases for the CMR. Also shown are the potential Internet- and community participation- based audiences.

A multi-scale approach

The Bi-level model has been designed specifically to address the international need for a multi-scale informal settlement upgrading GIS database model. Unlike other Urban GIS models, the Bi-level model operates on both the metropolitan- and local-levels (figure 6.2). Furthermore the model can be extended to incorporate information which has been captured at any scale between or beyond (eg. regional) these two key levels by applying a sectoral linkage. The multi-scale approach enables the needs of the community to be considered in parallel with the needs of planners. On the one hand, the metropolitan-level provides metropolitan spatial planners with the information required for the evaluation and implementation of local government policies. On the other hand, local-level databases provide a means of incorporating inputs derived from the community into the planning process.

A mechanism for project management

As a result of the multi-scale approach, the model may be used not only for local-level informal settlement upgrading project management work, but also for the management of multiple upgrading projects at a metropolitan-level. The basic attribute data that comprises the metropolitan-level database (such as the settlement density, level of infrastructure, annual growth rate) may be used to:

- prioritise the upgrading sequence of several settlements
- monitor the progress of current upgrading projects
- optimise the allocation of local government resources for informal settlement upgrading

Linkages to the formal settlements and the environment

The Bi-level model has been designed to enable the informal settlement to be analysed in the context of the surrounding formal city and the environment. By applying a sectoral linkage it is possible to view an informal settlement database in the context of the surrounding formal city cadastral database. This database linkage can be useful when trying to create linkages between the infrastructure networks in the formal and informal settlement areas. Similarly, a sectoral linkage may be used to view the settlement in the context of an environmental database. This database linkage may be used to ensure that any proposed upgrading initiative is environmentally sustainable

A mechanism for co-ordinating initiatives at a global-level

The Bi-level model may be easily extended to enable a global co-ordination of informal settlement upgrading programs. Two levels can be envisaged for a global extension of the model: a global-level and metropolitan-level. The basic spatial unit employed at the global-level would be the centroids of the informal settlement-bearing metropolitan areas in the world. While the basic spatial unit at the metropolitan-level would be the centroid of each informal settlement in a metropolitan area.

6.9 COMPARISON OF THE BI-LEVEL MODEL WITH OTHER URBAN GIS MODELS

6.9.1 Comparisons with local authority GIS models in S.A.

The problems associated with the cadastre-based approach implemented in the Cape Town City Council have already been discussed in chapter 3 [21, 22]. A second South African local authority that has been considered briefly in this thesis is the Gauteng Transitional Metropolitan Council (GTZMC) (see section 4.4.4). The Bi-level model may be compared with three approaches that have been followed or proposed for the GTZMC. The first is the conventional cadastral approach, which has already been compared with the Bi-level model. The second is the land parcel-based system proposed by Shalaby and Whitehead (unpublished). In this system the land parcel is the basic spatial unit. In addition to sharing the problems faced by the conventional cadastral approach, such as the length of time required to set up the database, the model suffers from a number of other limitations. Firstly, it requires security of tenure and the definition of parcel boundaries in the informal settlement areas. For this reason alone, it cannot be applied to areas such as Cape Town where a relocation policy is still being implemented. Secondly, the Entity Relationship Model (ER Model) proposed for the system focuses solely on the planning data required for the registration and transfer of title deeds processes. There is no room in the ER model for a community participation component.

The third approach the Bi-level can be compared to is a metropolitan-level approach being followed in the GTZMC. The result of an interview by Huchzermeyer (18/12/96) indicated that this database was being used to co-ordinate the upgrading process at a metropolitan level. Furthermore, it was indicated that a settlement database is attached to each informal settlement. While the results of this interview suggest that a two-level approach is under implementation in GTZMC, nothing has been published concerning this system. Further more, the lack of information provided on the basic spatial units employed, the content and structure of the individual informal settlement databases and a multitude of other issues prevent this approach from being compared with the Bi-level model.

Finally, a brief look is taken here at a GIS database recently proposed for the Khayelitsha Local Authority (City of Tygerberg, 1998). The database model proposed for the Khayelitsha Administration essentially follows a cadastral approach. Although an informal settlement area basic spatial unit (similar to the metropolitan-level informal settlement BSU used in the Bi-level model), is employed in the database, no significant attribute data has been attached to these areas[23, 24]. Further more, there is no intention to extend the database for local level informal settlement upgrading work. This system has been designed to provide data management tools for Coastal Services District (CSD) officials. It does not address the needs of the informal settlement communities in Khayelitsha.

6.9.2 Comparisons with the ViSP approach

The Bi-level model has drawn a great deal from the ViSP approach in Belo Horizonte in terms of the design of the local-level database. In fact, the local-level sample data sets acquired from the Alvorada Programme provide the initial local-level database template for the Bi-level model. Yet the ViSP approach is faced with some significant preconditions. Furthermore, despite the excellent internal structures of the local-level database, there is no structure for inter-linking the individual databases. As pointed out in chapter 5, the ViSP approach requires several preconditions before it can be implemented. In summary these are:

- the existence of an institutional framework to co-ordinate the various activities associated within an upgrading project
- the existence of an organisation which focuses on social-work and on the capture of detailed socio-economic survey data
- a permanency of the relevant informal settlement[25]

The Bi-level model caters for the lack of a number of these preconditions facing the development of informal settlement applications in Cape Town. Whereas the ViSP approach focuses specifically on the local-level[26], the Bi-level model functions at both the local- and metropolitan-level. This metropolitan-level of the database can be used to co-ordinate the upgrading process in a strategic manner. This issue has yet to be addressed in Belo Horizonte. Furthermore, the metropolitan-level of the database enables regions characterized by non-permanent informal settlements to be monitored.

6.9.3 Comparisons with the PROLAND model

There are numerous key differences between the PROLAND system and the Bi-level model. The PROLAND model is a single-level model catering for the needs of planners. It is a metropolitan-level model designed to aid planning associated with the relocation process. The model takes into account the ideals of the spatial planning frameworks such as the MSDF and the vacant land identified by the Provincial Administration: Western Cape (PAWC). However, there is no mechanism for inputting information from the local communities be affected by the relocation process.

In contrast to the PROLAND model, the two-level nature of the Bi-level model enables both the in-situ upgrading and relocation upgrading possibilities to be evaluated in parallel. Further more the local-level databases in the Bi-level model have been incorporated specifically to ensure that the community has a means of inputting information into the planning process. There is also a significant difference in the role of the high- and low-end GIS platforms employed in both models[27]. Further more, there is a distinct difference in the BSUs employed in both models. In the case of the PROLAND model information is aggregated with reference to local substructure boundaries. In contrast, the Bi-level model employs informal settlement centroids as the metropolitan-level BSU.

6.9.4 Comparisons with models employed by PADCO

The Bi-level model differs from the various models developed by PADCO primarily in terms of the BSUs, the number of levels employed and the needs addressed by the system. In the Lots by Dots™ model developed by PADCO, points are used at the local-level to represent lots and attribute data are attached to these points. In the Bi-level model, points are used in two manners at the metropolitan-level. Firstly, they are used to represent shacks to which no attribute data are attached. Secondly, points are also used to represent settlement centroids, to which settlement attribute data are attached. The other two models developed by PADCO that have been discussed previously (the Rapid Land Use Assessment and the Housing Typology models) are restricted to the metropolitan-level and employ zone-type BSUs (ie. land use zones and housing type zones). In contrast, the Bi-level model operates at two levels. Furthermore, it emphasizes the need for dwelling unit points, followed by dwelling unit polygons at an appropriate time. The only model developed by PADCO that addresses the needs of the community is the Lots by Dots™ model that may be used to assist in the land registration and title deeds transfer process. The remaining two models developed by PADCO address the needs of city planners and development agencies as opposed to the community's needs.

6.9.5 Comparisons with multi-level models employed in Europe

The key difference between the multi-scale database models under development in Europe (MERKIS, Plan Topo-Foncier and Urban Data Bank) and the Bi-level model lies in the principle focus or functionality of the model. The principle aim of the European models lies in a nation-wide integration of all local authority GIS databases. In contrast the principle aim of the Bi-level model lies integrating the data sources of associated metropolitan-level and local-level databases. The primary goal of the Bi-level model is not a nation-wide integration of all local authority GIS databases (which would decades), but rather to provide a realistically obtainable mechanism for accelerating the informal settlement upgrading process in the metropolitan centres of South Africa and other developing countries. A further difference between the two-scale Plan Topo-Foncier approach, initially proposed for France, and the Bi-level model lies in the scales employed in the database design. The Plan Topo-Foncier incorporated: a 1: 5000 scale plan for the whole of France and a 1: 2000 scale plan for areas deemed to be priority zones for structure planning (10 % of the national land surface area) (Miellet, 1996; Denegre, 1989). These two scales employed in the Plan Topo-Foncier model were far coarser than the scales used in the Bi-level model (ie. 1:10 000 and between 1:200 to 1:500).

6.9.6 Comparisons in the light of three primary sectors of a city system

In section 6.5 the three primary sectors of a city system (ie. the formal, informal and environment sectors) were defined. This concept of primary sectors can be used to compare the key urban GIS models that have been considered in this study. The order in which each of the primary sectors is ranked in the Urban GIS model determines the nature of the resultant database. The resultant systems may cater purely for the needs of a single primary sector or for a combination of sectors (see figure 6.9). The ENPAT model is example of a model that caters purely for environmental needs. The local authority cadastral GIS systems employed in Cape Town and previously in Gauteng cater purely for the formal settlement area needs. On the other hand models such as the transformation database designed by Napier (1994), the ViSP model and Urban Modeller focus purely on the informal settlement area needs. With respect to models designed to cater for the needs of two primary sectors, the PROLAND model can be considered to cater for the formal city and environmental needs. This model focuses on an eradication of the informal settlements by relocation and places a greater priority on the application of the MSDF concepts than on evaluating in situ upgrading possibilities. The Quantifiable City model caters primarily for the formal city and environmental needs. While the latest developments in the GTZMC are beginning to cater for the needs of both the formal and informal settlement.

Urban GIS models designed for informal settlement housing and relocation programmes such as the PROLAND model focus on the implementation of upgrading policies rather than on attempting to address the informal settlement housing problem in the best manner possible. Unless more open minded and unbiased approaches are adopted in the development of Urban GIS models, alternative policies and solutions cannot be evaluated.

The Bi-level model has been designed to focus on the informal settlements at the metropolitan-and local-levels. Information on the main infrastructure networks for the entire metropolitan area, including the formal settlement areas, also appear in the metropolitan-level. Detailed data on the formal areas surrounding informal settlements and models to ensure environmental sustainability can be attached to the Bi-level model as sectoral models.

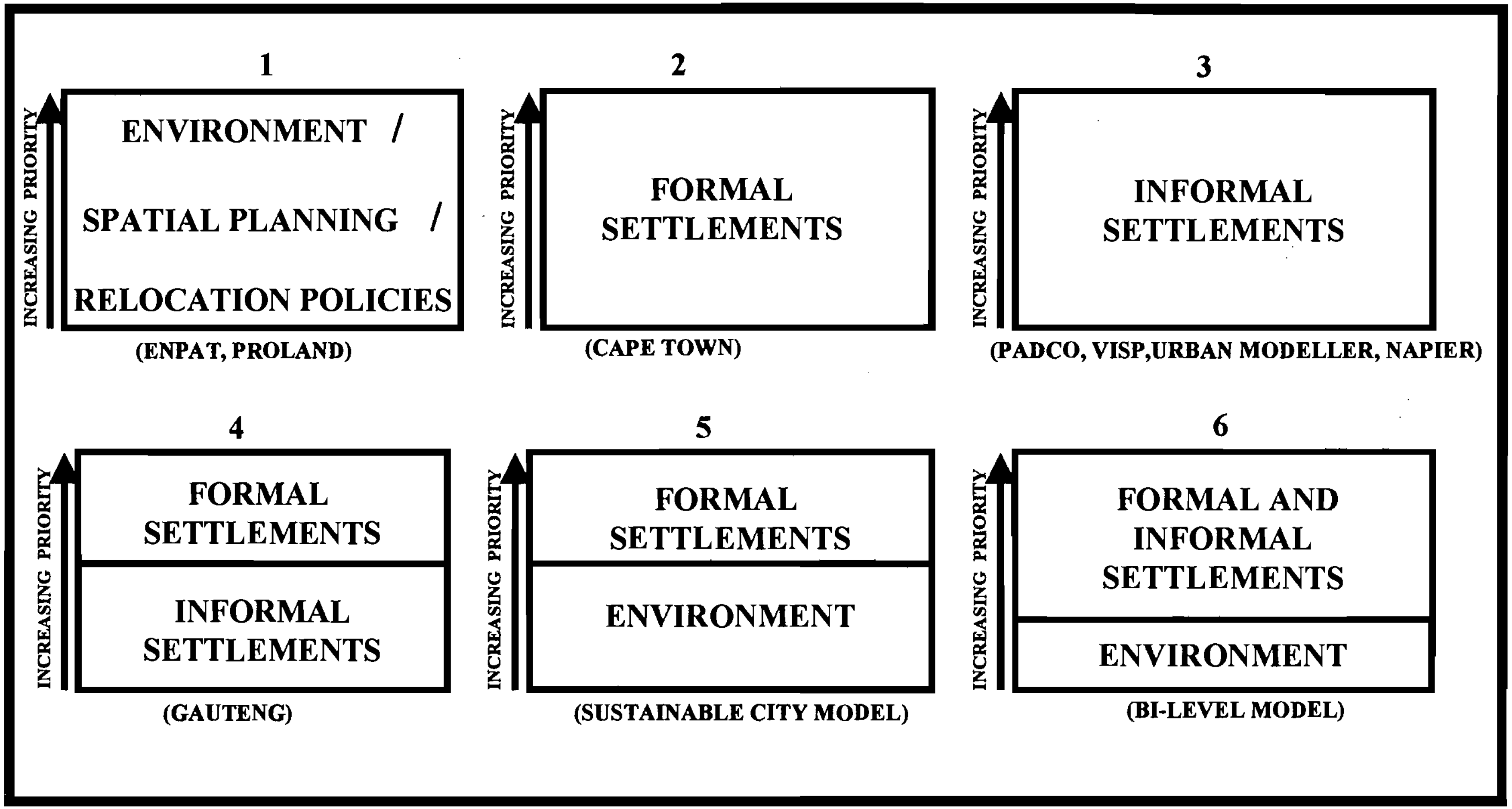


Figure 6.9 Controls on the development of urban GIS models. The key elements addressed by various urban GIS models are shown.

6.10 EXTENDING THE BI-LEVEL MODEL FOR SUSTAINABILITY

6.10.1 The Quantifiable City model

One manner in which the model may be extended is to include linkages with other local specialised databases. For this purpose it is particularly useful to examine the conceptual framework developed by May et al. (1997) for a sustainable city GIS database. This discussion defines the concept of a "sectoral model", which is useful when considering the extension of the Bi-level model. A number of definitions exist for the concept of sustainable development[28]. The Quantifiable City model developed by May et al. (1997) has been based on the City of Leeds. May et al. (1997) presents a methodology for the development of sustainability indicators (figure 6.10).

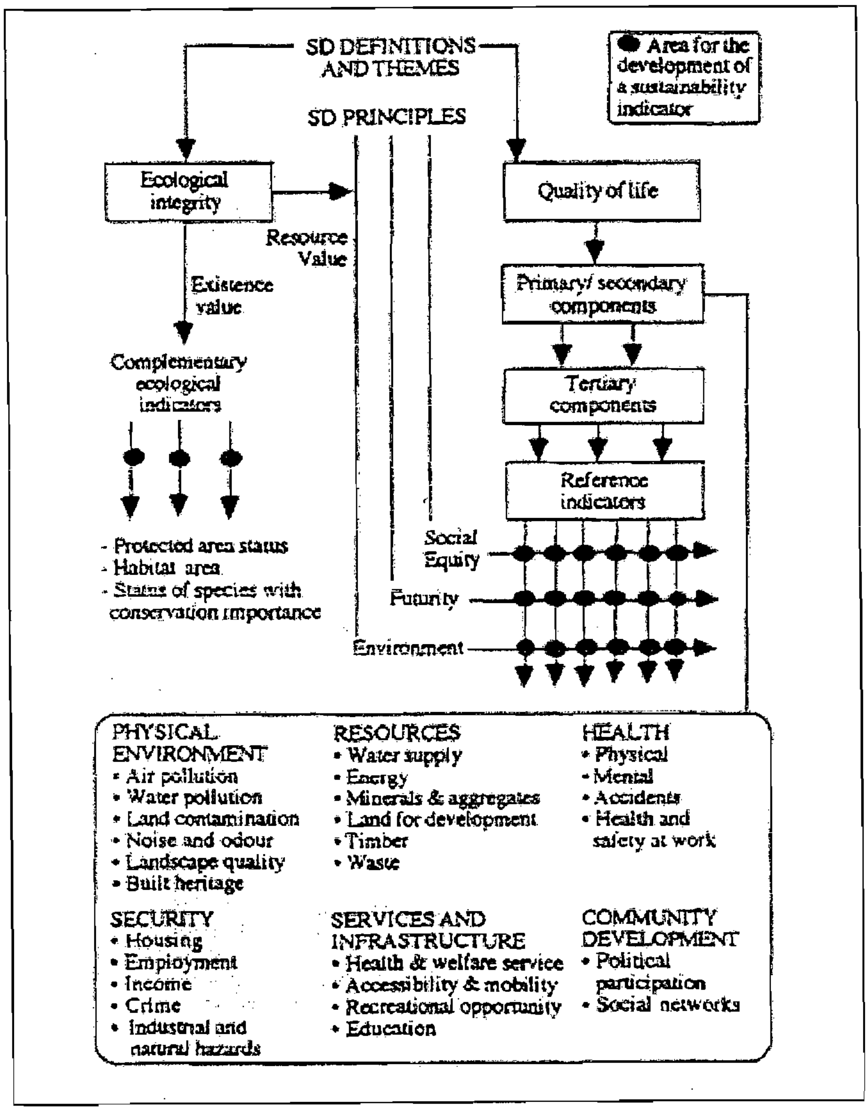


Figure 6.10 The development of sustainability indicators for the Quantifiable City model. (Source: May et al., 1997)

Four groups of sustainability indicators were defined. These are complementary ecological factors, social equity, futurity and environment. The indicators were developed to measure the quality of life and ecological integrity. Primary, secondary and tertiary components of quality of life were subsequently identified by applying a hierarchical disaggregation procedure to information collected by a literature review. The six primary components identified included: health, physical environment, natural resources, goods and services, community development, personal development and security. Reference indicators were then identified for sixty-four of the most significant secondary and / or tertiary components (May et al., 1997). Further more, May et al. (1997) outline a strategy for developing a sustainable city system model[29]. A conceptual model[30] is subsequently utilised to identify sectoral models[31] catering for the model components.

The Quantifiable City model then seeks to integrate numerous sector models in a common framework so that the potential is developed to quantify sustainability indicators relevant to a wide range of urban processes and management options. May et al (1997) give an example of how a sector model may be linked into the Quantifiable City model[32]. In the Quantifiable City model, the city system is regarded as a complex network of inter-linked subsystems. For each sector of activity within the city, one or more subsystems may be modelled. Examples of activity sectors in a city include: land use, transport, air pollution, public health, water quality, ecological community, water resources, recreational capacity and sewage generation. May et al. (1997) recognised the need for linking these sectoral models to obtain a holistic city model. The concept of model sector links is shown in figure 6.11.

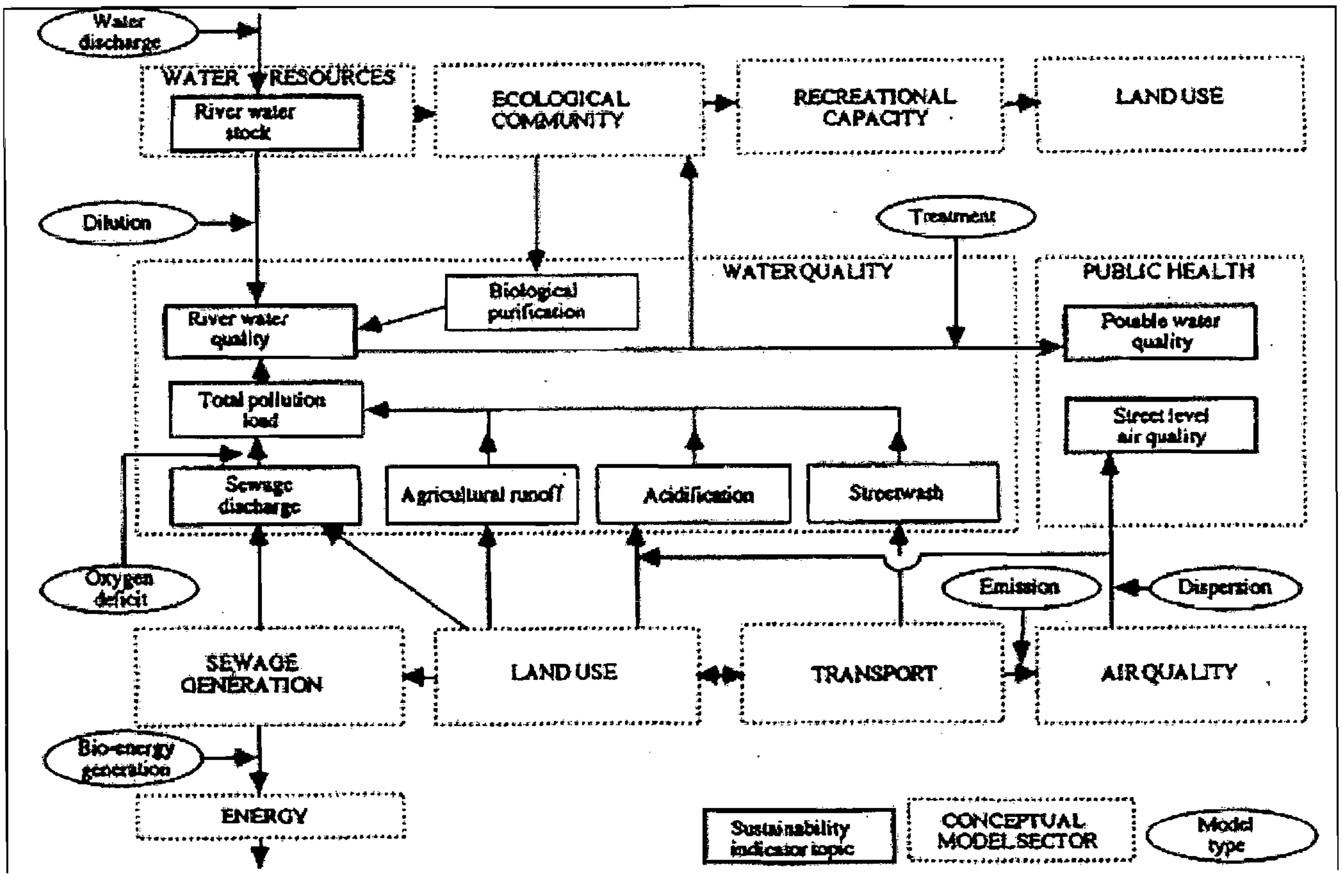


Figure 6.11 Conceptual model sector links: water quality types (source: May et al, 1997: Figure: 2)

6.10.2 Problems facing the implementation of Quantifiable City model

There are two key factors inhibiting the implementation of the Quantifiable City model in Cape Town. Firstly, the model has been developed to meets the needs of a formal city (Leeds) in a developed country. Secondly, there is a general lack of potential sectoral models being implemented locally.

With respect to the first issue, the fact that the Quantifiable City model has been designed for a city in a developed country characterised by an evolved "GIS diffusion environment". Britain is characterised by 1) an almost universal diffusion of GIS in local government, 2) a high digital data availability, and 3) a focus on the application of GIS for planning and management in local government. As illustrated in chapters 2 - 4, some of the European countries and all of the developing countries are characterised by less evolved GIS diffusion environments. Certainly in the case of South Africa, GIS is still not a "universal phenomenon in local government" and there is very little digital data for informal settlement areas. Further more, the needs of the community in a formal country city differ greatly from the needs informal settlement communities. In addition, the municipal LIS departments follow a strictly cadastral approach to the implementation of GIS. This has hindered the development of local planning and management applications. The lack of such local applications implies that a large gap of potential sector models for the development of a sustainable city model for Cape Town exits. Finally, the existing potential sector models have been developed to meet the needs of upgrading policies that have evolved from a previous apartheid based regime. This raises the question as to the usefulness and the appropriateness of incorporating such models into a sustainable city model for Cape Town.

In view of these differences, the methodology proposed for the development of sustainability indicators for the Quantifiable City model (figure 6.10) must be re-evaluated to be applied in a developing country. More emphasis must be placed on the principal of social equity. The issue of social equity is not as critical in the model for the developed countries as in developing countries that have had extended histories of political oppression and continue to hold huge social inequities. Secondly, the manner in which the six primary components have been defined and illustrated suggests that equal emphasis should be placed on all six components. While an equal emphasis may be appropriate in a developed country Quantifiable City model, it is certainly inappropriate in the vast majority of developing countries. In order to address the needs of informal settlement communities an application of the Quantifiable City model to a developing country city needs to focus far more on the development of sustainability indicators for the security, services and infrastructure and community development primary components of the model.

6.10.3 Potential local sectoral models for sustainability

Each of the Urban GIS models considered in section 6.4 function as distinctly separate entities. Yet each contains information that could complement analyses in other Urban GIS databases. In essence the architecture of these models reflects a need for a greater integration of specialised local sectoral models. The need for greater integration extends beyond the need to integrate these distinctly separate databases which reside in different institutions. The local authority GIS systems examined in this thesis has shown the need for a greater degree of internal database integration within individual municipal environments. May et al. (1997) also identified this need for integration[33]. One mechanism for achieving this integration is by creating links between different sectoral models as discussed by May et al. (1997). While the applicability of the Quantifiable City model as defined by May et al. (1997) to a developing country city remains questionable, the importance of incorporating the concept of sectoral model linkages into Urban GIS models should be recognized. A number of potential sectoral models for the Bi-level model are shown in figure 6.7. Several sources of sectoral models may be considered. These include:

1. models recommended by national government agencies,
2. models from commercial consultancies, and
3. models from the academic community.

In implementing the sectoral linkage process, the first step involves a collection of basic information about the potential sectoral models. Information such the model's name, author, owner, purpose, input and output variables, spatial and temporal scale, platform, operating system, programming language and availability need to be collected (May et al., 1997). In this section only the names of a few potential sector models have been listed.

The concept of integrating multiple subsystem models by creating linkages between different sectoral models is valuable to all types of Urban GIS models. The following discussion focuses on identifying potential sectoral models that may be linked to the Bi-level model. In this adaptation of the Quantifiable City model, the problem facing the majority of the city's population (the informal settlement community) is placed at the core of the information system. The focus lies on the identification of potential sectoral model linkages that can improve the quality of life of the informal settlement communities. Far more emphasis is placed on identifying sectoral models that can contribute information on the secondary and tertiary components of the following primary component groups: security, services and infrastructure and community development. The remaining primary components: the physical environment, resources and health may be catered for by lower resolution sectoral models. Some of the secondary components comprising these primary components include:

- Physical environment: water pollution, water supply
- Resources: vacant Land and water resources.
- Health: physical, mental, accidents

The need for water pollution and water supply sectoral models is particularly relevant to informal settlements in the Cape Metropolitan Region (CMR). In Cape Town, the Lotus River catchment (see chapter 10) provides a prime example of how storm water runoff from informal settlements can worsen the conditions in a river already suffering from water pollution as a result of agricultural activities (Grobicki et al., in press). With respect to water supply, several studies by local engineering consultancies and the Department of Water Affairs have illustrated that there is a growing need to implement alternative water resource management strategies for the Cape Town Metropolitan region (DWAF, 1994; DWAF, 1992a, DWAF, 1992b). The results of the Western Cape System Analysis (DWAF, 1994) illustrated the urgent need to shift from a "water supply management" strategy towards a "water demand management and conservation" strategy in the CMR. To enable this transition to take place an effective information system that incorporates information on water use in the region will have to be constructed. These water uses include: agricultural water use, urban water use and the recycling / re-use of effluent. Clearly urban water use incorporates the informal and formal sectors of the city. The growing need for an urban water resource management system illustrates the potential for creating a link between the Bi-level model to a water resource management sectoral model.

In comparison to Leeds, few potential sectoral models exist in Cape Town. A number of models identified with the Cape Town Metropolitan Area (CMA) are listed in Table 6.1 below [34]. A number of these models were identified from the results of the user survey discussed in Martinez & Abbott (1998). The advantage of considering sectoral models being implemented in the City Council is that the creation of links to these models would ensure the continued compatibility of the Bi-level model with the local authority systems[35]. Further more two other potential sectoral models which can be incorporated to include environmental and integrated catchment management considerations in the modelling process are the ENPAT[36] and ICIS[37]. Another potential sectoral model for CMA in the future is an information system developed specifically for stream-lining land transfer and registration the processes.

Table 6.1 Potential sectoral models for the Bi-level model identified within the Cape Town Metropolitan Area.

<u>POTENTIAL SECTORAL MODELS USED WITHIN THE CITY COUNCIL</u>

EPA AIR POLLUTION MODEL **(Scientific Services Branch)**
PAVEMENT MANAGEMENT SYSTEM **(Roads Branch)**
ROADSHOW **(Cleansing Branch)**
SATURN **(Transport Branch)**
STORMWATER **(Drainage and Sewerage Branch)**
TRANSIT **(Transport Branch)**

<u>OTHER POTENTIAL SECTORAL MODELS USED IN THE CMA</u>

HOUSEHOLD AFFORDABILITY MODELS (URPRU)
PROLAND (PAWC)
ENVIRONMENTAL POTENTIAL ATLASES (ENPAT)
INTEGRATED CATCHMENT INFORMATION SYSTEM (ICIS)

6.11 A GLOBAL EXTENSION OF THE BI-LEVEL MODEL

A second way in which the Bi-level model may be extended is to include linkages with other metropolitan-level informal settlement upgrading databases. In essence, this refers to a "global extension" of the Bi-level model concept. Miellet (1996) draws attention to the concept of linking a regional GIS to a concerted national GIS or "supranational" system. In this section the possibility of extending the metropolitan-level database of the Bi-level model into a tool for planning informal settlement upgrading projects at a global-level is briefly explored. Such a tool would be useful for international planning and development organisations such as United Nations UNCHS (Habitat), USAID, PADCO, World Bank and GDTZ. It could provide a basis for optimising and monitoring global policies that affect the urban poor throughout the world.

Two levels can be envisaged for a global extension of the Bi-level model: a global-level and a metropolitan-level. At the global-level it is envisaged that only the centroids of the informal settlement-bearing metropolitan areas in the world would be represented. The types of attribute information that could be attached to the metropolitan area centroids include the average informal settlement density, average growth rate, death rate etc. At the metropolitan-level, the boundaries or centroids to each settlement in a metropolitan area could be represented. The information on this level could be identical to or simplified from metropolitan-level of the Bi-level model in the metropolitan-level of the Bi-level model discussed in section 6.7.3. There is also the option of treating the detailed metropolitan-level databases as sectoral models to the global extension of the Bi-level model. A schematic illustration of a global extension of the Bi-level model is shown in figure 6.12.

While the resolution of current readily available satellite imagery is unsuited to the development of local-level databases (see section 11.4.3), this imagery can be used to implement the global-level database described here. The work by Ferreira (1997) suggests that satellite imagery can be used for developing or updating the metropolitan-level database at regular intervals. The main difference that would result if satellite imagery is used instead of the ortho-photography (as has been done in this project) is that the information on the location of individual shacks would not be recorded. While the results of using satellite imagery may or may not be suitable for metropolitan-level work, it is most probably suitable for the needs of the "Global-level" GIS database model for informal settlement upgrading proposed here.

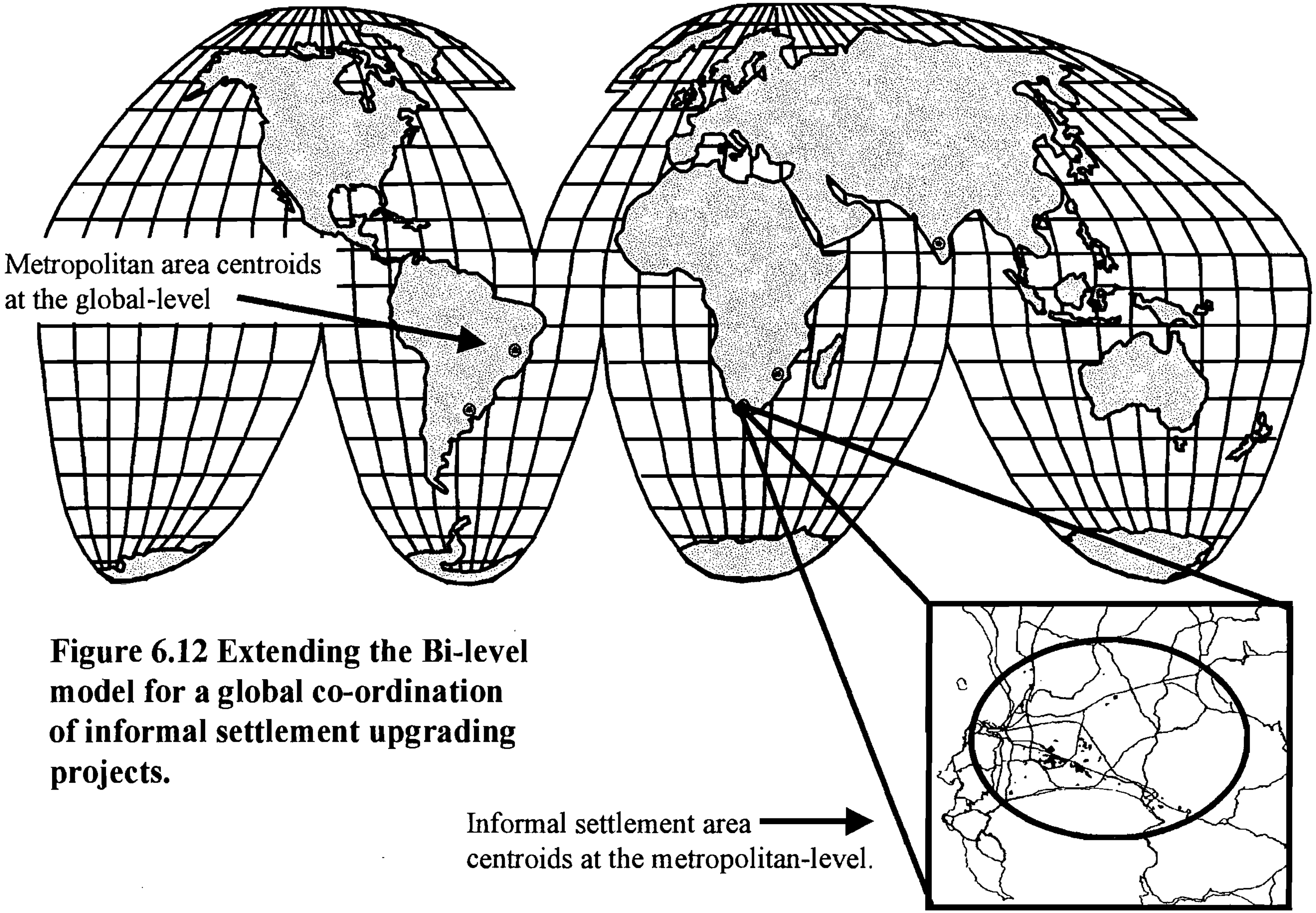


Figure 6.12 Extending the Bi-level model for a global co-ordination of informal settlement upgrading projects.

CHAPTER SEVEN: THE DEVELOPMENT OF THE SYSTEM

7.1 INTRODUCTION

The only way to test the validity of the Bi-level database model proposed in chapter 6 is to develop a system on which the database model can be implemented and applied. Chapter 7 deals with the first part of this test procedure. It deals with issues that relate to the selection of an appropriate software platform on which to implement the Bi-level model. GIS is based on the use of software applications that are in turn, subject to the process of rapid technological development and change. Part of this process has been a recent trend towards the simplification of GIS systems. Much of the change has occurred over the period of this thesis, which means that the technology used here has been constantly modified. The thesis needs to recognize these changes. This is done first by a brief discussion on the trend towards system simplification. From there, there are three sets of issues that are considered. The first set of issues deal with the needs / demands facing GIS systems in developing countries. Evolving from this, is the second set of issues that deals with some of the lessons learnt from the implementation of the ViSP approach in Belo Horizonte. These lessons are then used to inform the discussion on the requirements of the system. The third set of issues relates to the main software systems available in South Africa. These systems are then evaluated in terms of their strengths and weaknesses. In particular factors such as the cost, software support, technical capabilities, use within local government institutions, Internet connectivity and the ease of use were evaluated. Arising from these discussions is the construction of the Urban Management GIS system at the University of Cape Town. The chapter concludes with a section that sums up the benefits of the Cape Town system over the system used in the ViSP approach in Belo Horizonte.

7.2 RECENT CHANGES IN THE SOFTWARE DEVELOPMENT

Up until very recently, many organizations such as the Cape Town City Council have opted for systems that cater have catered for a minority of users. Extensive experience of GIS utilization within many different organizations by Intergraph, a major supplier of GIS systems, led to the following conclusion. "For most organizations, departments, and individuals, the initial scope of their project was *not to share* data but *to manage* the assets that they owned" (Intergraph 1997:2). At the time that the City Council purchased its system the large GIS suppliers targeted their product at the owners and maintainers of data, a group which Intergraph refers to collectively as he 'doers'. But this is a very small group. The people who should ultimately provide geographical solutions fall into different categories, which Intergraph defines as either 'users' or 'viewers'. Here the term user has a more specific meaning than that used previously. This specific meaning will be used only for this one section, in order to develop the concept developed by Intergraph. These three groups, i.e. doers, user and viewers, have widely different needs in respect of GIS, which may be illustrated in the following way:

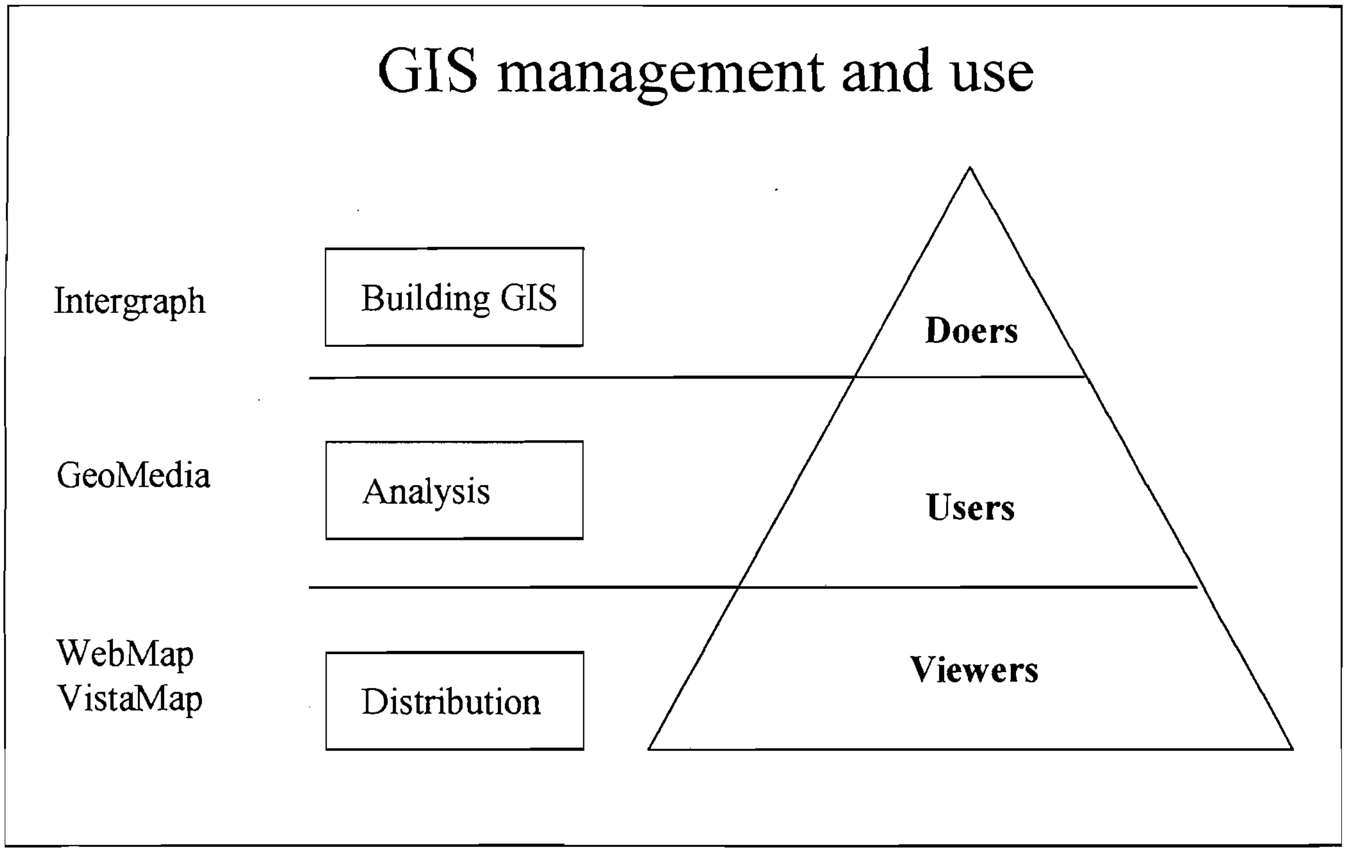


Figure 7.1 The needs of the three key different GIS user groups within a corporate environment (Source: Intergraph, 1997: 2).

In order to meet the demands of all three user groups in a more equitable manner, many software suppliers have started to create products directed at the "Users" and "Viewers" groups. A good example of this is the new Intergraph GeoMedia system. A second is that being developed by Autodesk for the Intranet. It seems likely that this trend towards system simplification will have a significant impact on the diffusion of GIS as it encourages the use of GIS amongst a much larger user group.

7.3 REQUIREMENTS GIS SYSTEMS IN A LOCAL MUNCIPALITY

It is essential at this stage to consider briefly the requirements facing GIS in a local authority. There are two reasons for this. Firstly, in order to facilitate some of the sectoral model linkages to the Bi-level model (see sections 6.7. - 6.8) it is essential that the system selected for the implementation of the model be compatible with local municipal systems. Secondly, the following discussion illustrates the critical importance of taking the issues discussed in section 7.2 into account when designing a system.

Milne (1994) gives an idea of the software requirements facing a large local municipal system, namely the Cape Town City Council[1]. In a section entitled "Critical factors in selecting a GIS" (Milne, 1994, 4-5) identifies the requirements which were theoretically used to select a GIS system for the City Council. Some of the key functional requirements identified were that the system should have[2], [3]:

1. a GIS/CAD interface or facilities provided
2. query station implementation with access to data across network
3. an interface to a stereo-plotter, via CAD or GIS
4. topology
5. a RDBMS interface
6. customization capabilities (Menu appearance, programming macros)
7. CAD capabilities (3D, data input mechanisms, range of disciplines)
8. data exchange capabilities (File exchange)
9. a database with continous coverage and a variety of data types in the GIS
10. a facility for dealing with contours and spot heights
11. GIS network support
12. a Digital Terrain Model
13. a facility to convert existing data
14. OSI compliancy

The requirements listed by Milne (1994) provide a typical example of the capabilities of a system that has been designed to cater for the needs of the "Doers" described in section 7.2. Despite a great deal of preplanning involved in the approach followed by Milne (1994), the user survey of the Cape Town City Council (see chapter 3) indicated that the resultant system remained grossly underutilized. At the time of the survey, the Council's GIS system was cumbersome, not in the least user friendly and was poorly suited to the wider needs of the City (Martinez & Abbott, 1998). Furthermore the survey indicated that if the existing system was to be retained, then steps would have to be taken to provide a more appropriate, and user friendly, interface, between this system and the users. In addition, there needed to be a greater recognition of the different needs of users. Because the Council's GIS was developed with a focus solely on the 'doers', the capacities of the "users" and "viewers" were severely restricted. This constraint was further compounded by the emphasis on the cadastre and the locating of the system in one specific department, which has limited even the 'doers' to a small group of less than ten people. Furthermore, the survey indicated that the way round this problem is to utilize an interfacing system that will effectively manage the GIS system. The existing GENAMAP system would remain, but would be used primarily for georeferencing of the existing database.

7.4 LESSONS LEARNT FROM BELO HORIZONTE

It is clear from section 7.2 that the broader potential use of the system, represented by the "Users" and "Viewers", must be remembered when designing a system configuration for the Bi-level model. Having established this first principle, the next step in the system design process is to consider the software requirements for informal settlement upgrading work as suggested from the literature survey and more particularly from the ViSP experience discussed in chapter 5.

The Belo Horizonte experience has been invaluable to this project as it provided the first set of guidelines for identifying the requirements of a GIS system for informal settlement upgrading. However, these requirements evolved not only due to the changes in software as outlined in section 7.2, but also as a result of the experiences derived from implementing the Bi-level model. The experiences associated with the development of a methodology for implementing the Bi-level model are discussed in detail in chapter 8. It is useful at this stage however to review some of the technical problems facing the ViSP approach, before considering the requirements of a GIS system for informal settlement upgrading in section 7.4. The following section examines the technical limitations of the GIS component of the ViSP approach employed in Belo Horizonte and Kenya. The judgements on the limitations of the ViSP system are based on the requirements envisaged for a system designed to enable the implementation of the Bi-level model (discussed in chapter 6) in the Cape Metropolitan Region (CMR). These limitations include:

- redundancies in the database structure and content
- inappropriate software and software under-utilization
- software support problems
- data integration limitations
- limited analytical capabilities
- files size restrictions
- lack of ease of use

7.4.1 Redundancies in the database structure and content

There is a great deal of redundancy in the attribute data base component of the ViSP approach. This redundancy manifests itself in two ways. Firstly there is a redundancy in the database content in terms of the data types captured. A number of the variables captured via the detailed socioeconomic research are entered directly into the system but have never been utilized since the initiation of the project. These variables include data such as a detailed gender and age data and information on the animals kept in the informal settlements. Secondly, the database structure has a large number of redundant columns. Of the approximately 155 columns typically included in the Alvorada Programme ViSP databases (see chapter 5), between 30 and 60 columns have no data values for the majority of the records in the database. The apparent excess in variable columns arises from structuring the database in a manner to allow information on up to 3 interviewees to be associated with each dwelling unit. In most cases only one person is interviewed per dwelling unit. Considering that up to thirty variables are captured per interviewee, this results in a redundancy of 30 - 60 variable columns per record. This type of redundancy hinders data processing tasks depending on the database structure. Tasks such as viewing the data are slowed down as one must unnecessarily scroll through a series of empty columns. A second set tasks which is hampered by bad database management practices is data conversion[4].

It is clear that an extremely large attribute database is very difficult to view and manage. Given that the informal settlement upgrading database should either reside in a municipal environment or be easily compatible with local municipal systems, a more streamlined and efficient database structure is required. This issue of better database management becomes extremely important when one is aiming for approaches to achieve a sustainable integration of national, metropolitan and local data sources in the future.

7.4.2 Inappropriate software and software under-utilization

There is also a redundancy in terms of software packages recommended for the ViSP approach. The TNT-MIPS product in particular, which was listed in the initial ViSP software requirements document, was found to be unused in implementation of ViSP in the Alvorada Programme. In fact, the technicians at AVSI listed the use of TNT-MIPS as being one of the major factors contributing to the failure of the ViSP approach in Kenya. Another software product originally listed as part of the ViSP GIS software configuration was Atlas GIS. This product was also not utilized at all in Belo Horizonte. Further more, the products implemented in the ViSP approach in Belo Horizonte, namely the Gheo suite and the MapInfo software, are grossly underutilized with respect to their functional capabilities.

7.4.3 Software support problems

The main software product utilized in the ViSP approach in Belo Horizonte, Gheo, is manufactured by an Italian-based software supplier. This posses serious problems with respect to the practical implementation of this product in countries outside Europe. Firstly, the menus on the Gheo interface as well as the Gheo manuals and on-line documentation are also only available in Italian. Needless to say such a language restriction could never allow this product to be implemented directly in South Africa or in the vast majority of other developing countries in the world. Clearly and English and possibly other language interfaces are required. The second problem which arises with implementing a product supplied by a foreign country is the difficulty associated with obtaining direct support from the supplier[5].

7.4.4 Data integration problems

One of the key aspects of the Bi-level approach is that it should encourage an integration of multiple data sources - in particular, the software should encourage the integration of large and small local authority systems. The investigation of the Belo Horizonte ViSP system illustrated that the output of the Gheo system has successfully been integrated with MapInfo via a locally developed macro. Thus if one momentarily ignores the language barrier highlighted above, the system could be potentially compatible with local-level MapInfo systems. The second issue to consider then is how compatible the Gheo system is with the high-end platform local authority systems? Customized translation programs can be written to ensure compatibility. This is a long and costly process however. A more critical problem with respect to compatibility, is that the Gheo system lacks the extensive Internet-based GIS capabilities required for the Bi-level model.

7.4.5 Limited analytical capabilities

The analytical capabilities of the Gheo software suite are limited with respect to its potential for creating engineering analysis applications. The suite does not contain a component for dealing with elevation data or digital terrain modeling applications. This limitation seems acceptable for the ViSP approach in Belo Horizonte, which does not utilize elevation data[6]. However, it does not allow the full requirements of a large municipal system as outlined by Milne (1994) (section 6.2 above) to be met.

7.4.6 File size restrictions

The ViSP system faces a series of technical problems hindering the implementation of the Bi-level model proposed in chapter 7. The configuration of the ViSP system has been designed to cater specifically for data capture from low altitude helicopter photography. This has resulted in a less flexible data input mechanism inhibiting its application for data capture from other types of imagery.

The tape drive and floppy disk drive requirements as outlined in the original ViSP GIS system configuration are out of date. Most data transfers require disks, .zip cartridges or CDs. Municipal vector data files are typically 50 MB or more in size and necessitate the use of 100 MB zip cartridges. Aerial imagery can range from 22 MB to about 400 MB or more in size. However, only a limited amount of memory is available for image processing tasks on the ViSP GIS system. The limited memory available implies that only a small number of images can be loaded onto the system at any given time. While this may be acceptable for the case where only low altitude helicopter images need to be processed, the lack of memory storage space would prevent loading high resolution aerial photography images on such a system. The experience with aerial photography image processing has shown that very large amounts of memory space are required (see chapter 8)[7].

7.4.7 Lack of ease of use

This brief discussion on the lack of ease of use brings the reader back to the issues raised in section 7.2. In addition to the essentially inaccessible on-line documentation and software support facing the implementation of the Gheo software within South Africa, the interface of the Gheo software product presents further problems. More than a year after the author's initial visit to AVSI GIS laboratory in Belo Horizonte, the software suppliers were still in the process of experimenting with the production of a windows-NT based version of Gheo. Until then all the key capabilities of the software were activated via complex command line key-ins[8], in a manner similar to the UNIX workstation Arc/Info environment. The need to memorize a large number of specialized command sequences is far from user friendly when compared to the software products which are utilize Windows based icons and dialogue boxes.

7.5 REQUIREMENTS FACING GIS SYSTEMS FOR INFORMAL SETTLEMENT UPGRADING

7.5.1 Software requirements

The research indicates that the software selected to facilitate data processing for informal settlement upgrading work in developing countries must meet a series of requirements. These requirements are considered here in the context of three areas that have been researched in this thesis. The first and second areas have already been discussed. They refer firstly to the lessons learnt from the Belo Horizonte experience (section 7.4), and secondly, to the software requirements that have been defined for the implementation of the Bi-level model (section 6.7.4). In addition, the discussion also draws from lessons learnt during the development of a methodology for implementing the Bi-level model (see section 8.4). The software requirements discussed here may be grouped into criteria relating to broad-based issues and to technical aspects of the system. The broad-based issues will remain the same for a long period of time and are generic requirements. The technical requirements should be updated as the capabilities of software products continue to improve with the rapid and on-going developments in computer technology.

In terms of the broad-based issues, there are three basic requirements that the system software must meet. The first requirement is that the software must cater for the data processing needs of the local-level informal settlement upgrading projects. Secondly it must cater for the needs of a higher-level system designed to manage the development of a number of local-level systems. Thirdly it must cater for implementation within the municipal environment. The first and second requirements can only be catered for by the implementation of a two-tier system as indicated in section 6.7.3. In other words, a high-end platform coupled with a series of low-end GIS platforms must be used. In order to facilitate the widespread development of local-level databases, the low-end platform should be easy to use, low in cost, and compatible with existing municipal systems. The need for the software to be able to function within a municipal environment is two-fold. Firstly, as seen from the Belo Horizonte experience, the municipality can play a key role in the upgrading process. Secondly, as seen from Masser et. al (1996), the municipality can also play a key role in the diffusion of GIS throughout a country.

The technical software requirements facing the system, are summarized here. Essentially, the system needs to[9]:

- be easily customized
- be fully integrated
- have CAD capabilities
- have analytical capabilities
- have internet capabilities
- facilitate rapid data capturing
- facilitate image processing tasks
- facilitate rapid and appropriate outputs
- interface with other software

7.5.2 Hardware requirements

The hardware requirements may be considered in terms of the following issues:

- data storage capacities
- output facilities
- display facilities
- input / data capture facilities

With respect to the data storage capacities, the system must be capable of transferring and processing large amounts of data. The sizes of vector files acquired from the City Council and more specifically of the imagery files used to map informal settlements revealed the need to be able to cope with huge files (up to 250 MB). For this reason it is essential to have at least a CD drive. Additional facilities which can be used to extend the capacity of the system include: an external drive and a zip-drive. The output facilities must be capable of producing large color plots for community participation. This can be catered for by an A0 inkjet plotter needed. The display facilities must cater for extensive image processing. To facilitate the georeferencing and other image processing tasks, it is preferable to use large monitors (eg.20 inch). With respect to the data capture facilities, previously, digitizing tablets (A4 to A0) played a key role in data capturing activities in upgrading programs. The current trend in data capturing techniques is towards heads-up digitizing. This requires that the hardware configuration enable the scanning of maps, negatives, diapositives and contact prints at a range of resolutions[10].

7.6 FURTHER CLARIFICATION OF THE REQUIRED SOFTWARE CRITERIA

Sections 7.2 to 7.5.1 provided a background on how the software requirements facing the selection of a GIS system for the implementation of the Bi-level model evolved. As section 7.2 indicated many changes and developments had occurred in the available GIS technology since the design of the system implemented in the ViSP methodology. It was thus necessary to review the capabilities of GIS systems available in South Africa before a system could be selected for the implementation of the Bi-level model. Before considering a number of alternative systems, it is essential first to briefly define each of the criteria that have been applied in the system evaluation process in section 7.7 and 7.9. The criteria[11] used in the evaluation procedure were as follows:

1. analytical capability
2. ease of use
3. data capturing facilities
4. image processing capabilities
5. layout / output facilities
6. compatibility with other systems
7. customization capability
8. relational database management system (RDBMS) interface
9. Internet compatibility
10. system integration
11. approximate cost

7.6.1 Analytical capability

The ViSP approach in Belo Horizonte indicates that at least a number of simple spatial analysis tools are required for informal settlement upgrading applications. These include thematic mapping, spatial queries, buffering and vector overlays. Whether or not digital terrain and other surface modeling software should be used in upgrading projects remains a debatable issue (Moura et al., 1993)[12].

7.6.2 Ease of use

The use of a software package is facilitated by features such as:

1. the presence of dialogue boxes[13] and "wizards" designed to facilitate both routine and potentially complex operations
2. access to tool boxes for carrying out CAD-based operations
3. access to a range of applications via one application interface (ie. seamless integration), and
4. access to on-line help in a universally recognized language.

Packages that are difficult to use are characterized by features such as:

1. command line-based input mechanisms
2. the absence of icon-based and menu-driven user interfaces
3. the inability to capture and edit data captured in an interactive / real-time manner
4. the inability to view the results of graphics processing operations (such as featurizing and centroid-placing) in an interactive manner, and
5. the need to run distinctly separate and specialised applications for even the simplest set of inter-related processes.

Such features are often typical of the UNIX-based workstation software systems such as Arc/Info, which are difficult to use.

7.6.3 Data capturing facilities

With respect to the data capturing process, the need to be able to view vector data as it captured (in real time) is also critical[14]. In addition, CAD capabilities are required for initial engineering and urban planning designs and for the later detailed planning designs used during the implementation and construction phase. Some systems (eg. Intergraph) include specialised in-built macros designed to aid the data capturing and editing processes. Heads-up digitizing and auto-vectorization tools are amongst some of these tools available for streamlining the data capturing process.

7.6.4 Image processing capabilities

The image processing capabilities should enable images to be georeferenced, clipped and mosaiced. The image processing capabilities varies a great deal from one GIS system to another. Some packages have none (Atlas GIS), others enable basic registering facilities (MapInfo), while at the top of software range, high-level GIS platforms usually include specialised image processing modules (Arc/Info and Intergraph). Stand alone image processing packages dedicated to viewing ortho-rectified imagery, with little or no other GIS functionalities are also available (Orthodraw).

7.6.5 Layout / output facilities

The layout / output facilities have to be such that thematic maps and raster-vector based plots can be produced rapidly and easily. Some packages have excellent in-built layout facilities (eg. MapInfo). Others require the use of a separate software program (eg. Imagineer).

7.6.6 Compatibility with other systems

The need for the system to be compatible with local municipal systems has already been discussed. At the time that the various packages were being evaluated, the City Council's GIS and RDBMS software were GenaMap and Oracle respectively. It was thus preferable to select a system that would be compatible with these systems. In addition, if data conversions had to be required, they should be easy and quick and should preserve topological structures.

7.6.7 Customization capability

The system should be should be easily customizable and should preferably require non-propriety languages for the customization process. The need for easy customization is particularly relevant to overcoming potential language barriers when considering potential local level implementations of the system. South Africa and other developing countries are characterized by a multitude of indigenous languages. Consequently, the system should facilitate the development of GUI's in indigenous languages[15].

7.6.8 Relational database management system (RDBMS) interface

In addition to the graphical database, an alphanumeric database is required to store the socioeconomic and other attribute data associated with the graphical elements. A standalone package such MapInfo, with its own alphanumeric database can be used to deal with single settlement databases. However, if the system is to be compatible with local municipal systems a relational database management system (RDBMS) interface is required[16]. To ensure compatibility with the City Council RDBMS, a GIS-based upgrading system for Cape Town would require an Oracle RDBMS interface.

7.6.9 Internet compatibility

The reason for requiring Internet capabilities is to enable the implementation of the Bi-level model proposed in chapter 7. For this purpose, the highest quality Internet capabilities should be sought after. These capabilities should enable a seamless integration of data from multiple warehouses[17], conduct on-the-fly projection transformations and enable basic GIS analysis capabilities. If possible a two-way data exchange capability[18] between the server and client databases should also be sought after.

7.6.10 System integration

The need for seamless integration between the individual modules and supporting software packages comprising a high-end GIS platform has already been stated. For example, one should not have to exit the image processing module to use the CAD or spatial analysis facilities of the system.

7.6.11 Cost

Information on costs of available software products fluctuates a great deal. For the purposes of this evaluation, the information on costs has been simplified into two categories: high cost and low cost software products.

7.7 THE KEY GIS SYSTEMS AVAILABLE IN SOUTH AFRICA

7.7.1 Introduction

It is clear that there is a vast range of GIS products and CAD products, which are often used in conjunction with GIS products, available on the international market. These include amongst others ESRI, Intergraph, Microstation, Autodesk World, Dangraf, GEOCAD, Comp. V. / System 9, Small World, Apic, Axis, Alper Records, G-GP, SICAD and ALK-GIAP (Masser et al., 1996). In this section, the focus is placed on the key GIS systems that were available on the South African market at the time that a system was being selected for the implementation of the Bi-level model are discussed. More specifically, the capabilities of a number of high-end and low-end GIS software platforms are briefly described in the context of the criteria defined in sections 7.6 and 6.3. In some cases the descriptions for the high-end platforms (eg. Arc/Info) tend to be much longer than for the low-end platforms (eg. Atlas GIS). This is because the high-end platforms tend to be comprised of a range of software modules, where as the low-end platforms are usually comprised of standalone software products.

The discussion is based on a background acquired from courses, extensive hands-on experience and from the IKUSAS CONSAS 97 conference[19]. Courses were attended on Arc/Info[20], ArcView, Atlas GIS, Intergraph[21]. Extensive hands-on experience was obtained for Arc/Info, AutoCad[22], Intergraph's MGE system (desktop version) [23, 24], Microstation and MapInfo (Version 4)[25]. Other software systems examined in less detail include: the Genamap system (City Council) Orthodraw (AOC) and AutoCad Map[26]. The sample data sets collected in Brazil was analyzed using MapInfo, Arc/Info and ArcView. The data on Ikapa collected from the Cape Town City Council was used to examine the hydrological modeling and cluster analysis capabilities of Arc/Info. Where possible, examples of the application of each software package for informal settlement upgrading work have been listed, and the key GIS packages used within municipal environments have also been indicated.

As indicated in sections 7.1 and 7.2, the software tools available for GIS are under constant change and development. The following descriptions reflect the experiences of the author up until the middle of 1997. It is probable that many developments have occurred since then. Nevertheless, the discussion reflects the capabilities of the software systems that were available at the time the system was being selected. While the discussion maybe out of date in the context of the very latest software developments, it highlights the software capabilities required for informal settlement upgrading applications. It also provides a necessary background for understanding why a specific high-end coupled with a low-end GIS platform software configuration (discussed in section 8.6) has been selected for the Urban Management GIS system at UCT.

7.7.2 ESRI GIS products

Arc/Info

The Arc/Info Workstation Version software was considered for several reasons, the main reason being that it is one of the world's most widely used GIS systems[27]. Hands-on experience on the UCT Arc/Info system indicated that this system has excellent analysis capabilities[28]. The analysis modules include: Spatial Analyst[29], Network, Tin, Grid, Cogo, GIS-T, RouteSmart[30, 31]Conflate[32] and ArcStorm. However, the system is generally difficult to use as it is based on a UNIX workstation environment and relies on the user being acquainted with a large number of special key-in command lines[33,] There is a dedicated suite of products for image processing[34]. With respect to output and layout facilities, the ArcPress[35] facility may be used. The system is compatible through MapObjects interlopability and ArcView. Translation products such as the MapInfo products Shapelink and Arclink also exist. The MapObjects module can also be used to customize the system[36]. With respect to an RDBMS facility, a recently developed module called a Spatial Database Engine (SDE)[37] assists the database management and access tasks[38]. In terms of system integration, this system is less integrated than Intergraph in terms of shifting from one application module to other. With respect to approximate cost, the Arc/Info system represents a high-end GIS platform with a high cost (> R 150 000).

ArcView

The most recently developed desktop ArcView[39] products were not available for hands-on experience. It is thus difficult to gauge the capabilities and ease of use of these products. At the time when this review was initially written, ArcView was essentially a viewing platform for data captured in Arc/Info. It therefore had limited data capturing and image processing facilities. It did not have CAD drawing capabilities. Recent developments have extended the capabilities of this software. For example there has been the development of the CAD drawing reader and CAD theme builder extensions[40]. The compatibility of the ArcView system with other GIS software can also be improved by using the Data Automation Kit (a dedicated translation module). ArcView can be customized through Avenue or by using Visual Basic[41]. With respect to Internet capabilities, the ArcView Internet Map server[42] has a wizard facilitating a user to publish data on the Internet[43]. The approximate cost of ArcView, which represents a low-end GIS platform, lies way below R50 000.

The widespread use of Arc/Info and ArcView has already been mentioned. In the field of informal settlement upgrading it has been applied in Kuala Lumpur (Malaysia) (Yaakup et al., 1990, 1994). Other types of applications such as a land register and environmental applications are also found in the developing countries Ghana (Larbi et al, 1997) and the CIS (Koshkarev, 1991). With respect to applications in local government, Arc/Info is applied in South Africa (Gauteng Municipality), Greece, France, Great Britain and Italy[44].

7.7.3 Atlas GIS

Atlas GIS initially was initially developed as a business focused desktop mapping package. The patent to this software was subsequently bought by ESRI in 1996. The package offers little other than extensive presentation capabilities. These capabilities include: basic map designing and output, visualization of spatial data, spatial analysis, and the management and query of attribute and spatial data (ITS, UCT, 1995). The spatial analysis capabilities are limited to only the simplest kinds of analysis such as: buffering and data aggregation.

7.7.4 Orthodraw

This product is locally produced in South Africa by a surveying and land information services consultancy (AOC Holdings, Cape Town). It has been designed specifically for viewing aerial photography imagery. For this task alone it is extremely well suited. The pyramid format files utilized enable one to zoom-in and -out of the image in a very rapid manner. One limitation resulting from utilizing this file structure is that one can only view a reduced number of zoom-levels in comparison to when utilizing other imagery file formats. The file size of an image saved in pyramid format is also much larger than that of the -TIFF format file of the same image. It has essentially no analytical capabilities, only the very basic of data capturing facilities (ie no CAD capabilities), no RDBMS interface, no Internet capability, and very little if any customization tools and output facilities. It can essentially only be integrated directly with MapInfo . Some advantages include: its ease of use and low cost compared to its equivalent high platform image processing software products.

7.7.5 MapInfo

As a standalone product, MapInfo 4 is rather limited with respect to its analysis[45], image processing[46] and data capturing capabilities. Some of these limitations can be addressed by utilizing other specially developed modules (such as Vertical Mapper[47], TrendMap, TerraAlign, ClusterPlus[48] and MASTER RASTER[49]) in conjunction with MapInfo. One of the reasons frequently used for including MapInfo into a system based on a high-end GIS platform is that the product enables the layout of a map to be rapidly and easily created for plotting. High-end GIS systems are excellent in many respects, but tend to be extremely cumbersome when it comes to plotting-out a simple map or creating a thematic map[50,51]. In terms of compatibility, MapInfo also fares well when compared to the high-end platform[52, 53]. With respect to customization, the software can only be customized using the MapBasic package. The RDBMS functionality of MapInfo can be extended through the MapInfo SpatialWare module[54]. The MapXtreme module enables organizations to place maps on the Internet or Intranet (MapInfo Corporation, 1997b)[55]. The system shows a far lower degree of integration in comparison to typical high-end platforms[56]. Despite the large number of limitations MapInfo remains a very powerful low-end platform products providing similar and less powerful tools. The ease of use of this low-end GIS platform has resulted in its widespread use in local governments throughout Europe (eg. Britain). Locally, in the Cape Town City Council, many of the non-specialist GIS branches are developing systems on this platform in parallel to the Council's main system - simply because it is far easier to use. It is used widely in local authorities many developed countries in Europe including Great Britain, Germany and Finland (MapInfo Corporation, 1997a, c). It is also used in numerous developing countries such as the CIS (Koshkarev, 1991), Botswana (Nkambwe, 1991), Zaire (MapInfo Corporation,1997a) and Poland.

7.7.6 GenaMap

The main GIS system in the Council at the time of the survey was GenaMap (see chapter 3). In view of the fact that the Bi-level model emphasizes that the selected system should be compatible with existing municipal systems (section 6.7), it was considered essential to consider GenaMap as a potential high-end platform. This GIS system has limited analysis[57], image processing[58], compatibility[59], CAD[60], and Internet[61] capabilities and is also not user friendly[62]. Other than these limitations, the software appears to have adequate output, RDBMS[63] and macro programming facilities[64], and is well integrated with respect to its own modules. This GIS system is used widely in Australia and globally for military applications (Genanews, 1994). In South Africa, only two of the local authorities have utilized GenaMap, namely the Cape Town City Council (CCC)[65] and the Greater Johannesburg Transitional Metropolitan Council (GJTMC). Both of these authorities have shifted to an Arc/Info - ArcView system more recently.

7.7.7 AutoCAD Map

This recently developed software is easy to use, highly compatible[66], and has good layout[67], RDBMS[68] and data capturing[69] facilities. However, it is very limited in terms of its analysis[70] and image processing[71], customization[72] and Internet[73] facilities. With respect to system integration, AutoCAD Map offers a seamless integration with several software systems[74]. This software is cheap relative to the high-end platforms and offers more value for money in comparison to other standalone low-end GIS platforms. In view of its low cost, it is becoming popular amongst local authorities in South Africa and in Europe[75].

7.7.8 Intergraph GIS products

Unlike the discussion on the ESRI GIS products (section 7.7.2), here only the high-end platform of the Intergraph software suite is considered. The low-end platform, GeoMedia, is discussed in detail in section 8.6.1. In comparison to other high-end platforms, this system excellent analysis[76], image processing[77], data capturing[78] and output[79] capabilities[80]. It is also easy to use[81], has excellent RDBMS facilities[82] and extremely well integrated. With respect to compatibility, the Intergraph system has been an "open GIS" for far longer than the majority of other high-end GIS systems on the market[83]. In comparison to all of the other high-end platforms considered, Intergraph displays the greatest level of seamless integration[84]. With respect to Internet capabilities, this system outshines all of the other GIS products available on the market to date (see the discussion on the Geomedia[85] product in section 8.6). With respect to cost, Intergraph is one of the more expensive high-end platforms[86]. However, it should be noted that only a small number of modules are required for carrying out the types of applications discussed in this thesis (see section 6.7). Further more, the viewer software for Intergraph's Internet-based GIS low-end platform, GeoMedia Viewer[87], is freely available. The excellent qualities of this product have encouraged its widespread use in many developed countries in North America and Europe[88], as well as in many developing countries[89].

7.7.9 Idrisi

Idrisi[90] is essentially a specialised raster based image processing system produced by the Graduate School of Geography at Clark University. Its strength lies in its excellent image analysis and processing capabilities. With respect to its ease of use, it compares to that of a high-end platform system without the network associated problems resulting from the RIS-RDBMS linkage. In comparison to other systems it is limited in terms of its data capture capabilities[91], compatibility[92], RDBMS facilities[93], Internet facilities[94], system integration[95] and is relatively expensive in view of its limitations. The first version of Idrisi has been implemented in the (CIS) (Koshkarev, 1991) and to a great extent in Africa for environmental applications. In South Africa, one difficulty facing the use of this package remains the lack of local software support. There is no Idrisi software supplier in South Africa. As a result technical problems can only be addressed by e-mails and through a limited personal user contacts.

7.7.10 Other commonly used systems

The following GIS software systems are utilized in local authorities in Denmark (in decreasing order of importance): Microstation / MGE, AutoCAD + point, Dangraf, GEOCad, MapInfo, ArcInfo, Comp. V. / System 9 (Kiib, 1996: 134). An additional 6 % of the GIS software in the municipalities is accounted for by other packages. In a number of the developed countries which have Arc/Info as the dominant GIS in local government, a number of secondary packages are also used. In France Arc/Info shares the GIS market with Apic - a French package (Miellet, 1996). In Great Britain, Axis, Alper Records and G-GP are the dominant secondary software products (Campbell & Masser, 1996). Germany has the SICAD and ALK-GIAP software systems, the latter of which is free to German local authorities. In the CIS a large number of old and highly specialised packages are often. These include: Terrasoft and EPPL7 (Koshkarev, 1991).

7.8 THE SOFTWARE SELECTION PROCESS

The software selection process can be broken down into two "sub-processes". The first is a process of addressing the needs of the users of the system. The second involves addressing the needs of the application of the system. In the selection of the software for the UCT GIS Research section (a university research facility) the primary focus has been on the addressing the needs of the application of the system. A number of additional issues must be considered if the software is to be implemented within a local authority.

An analysis of the manner in which the software was selected for the Cape Town City Council GIS system raises some questions with respect to the most appropriate system selection method. In the case of the City Council, the GIS evaluation team was made up of representatives from ISU, SLI and Electricity only. In addition to only the GIS specialists departments having representation in the evaluation team, only managers were invited to be involved in the process. The following quote from Milne (1991: 7) describes the process further: "A Project Board session was organised for each vendor. The vendors...were all invited to a benchmark and they were scored on their technical suitability with tests that were conducted by the evaluation team. The developer and supplier of the products were also evaluated...". Two factors are clear from this quote. Firstly, that the non-GIS specialist departments, which represented the vast majority of the engineering, planning and other branches of the Council at the time, were not involved in the evaluation procedure to any significant degree. Secondly, that the actual users of the system, the vast majority of which have non-managerial positions, were excluded from the process entirely. It is hardly surprising, that the system has failed to be implemented to any degree in these departments even six to seven years after its initial implementation. One conclusion one can derive from the Council experience is that the needs of these two groups, the end-user and the non-specialist departments, must be somehow incorporated into the system selection process[96]. The potential role of low-end GIS viewing platforms in addressing this issues has already been discussed in section 7.2.

7.9 EVALUATION OF GIS SYSTEMS TO IMPLEMENT THE BI-LEVEL MODEL

7.9.1 Introduction

In order to implement the Bi-level model outlined in chapter 6, a combined high- and low-end GIS software platform configuration is required. This section evaluates the potential for incorporating each of the GIS systems considered in section 7.7 into such a configuration.

7.9.2 Evaluation of GIS systems for implementing the Bi-level model

ESRI

As indicated in section 7.7 the ESRI product range offers both a high-end and a low-end platform option. With respect to the former, the Arc/Info system did not appear to be efficient when compared to the other high-end platform software options. This inefficiency related to: 1) its lack of ease of use, 2) awkward data capturing facilities, 3) limited image processing facilities, 4) extremely limited output facilities, 5) poor compatibility with other systems, 6) the lack of an Internet functionality and 7) the poor degree of system integration. With respect to the potential low-end platform option, ArcView was found to be inferior to some of the other software packages. Unlike the case for other software options such as GeoMedia, a propriety language developed by ESRI is required to customize the Internet interface of ArcView. Furthermore, although ESRI has shifted the development of the Arc/Info - ArcView system towards a modular architecture and towards "open GIS", these developments have lagged a number of years behind similar developments in the Intergraph range.

Atlas GIS

This package was viewed too limiting even to serve as the low-end platform component of a GIS system for informal settlement upgrading. These limitations included: the absence of CAD design capabilities, non-existent image processing capabilities, extremely limited analysis capabilities and limited compatibility with other software systems. The Atlas GIS software was previously listed as part of the ViSP GIS software requirements (see chapter 5). However, the experience in Brazil and Kenya showed that the tasks initially allocated to be carried out on this product would be more effectively conducted on other software in the system.

Orthodraw

Orthodraw was created essentially to address the image processing limitations of MapInfo. The redraw rate is one of the greater time delays in the data acquisition process when high-end platform systems are used[97]. The rapid image viewing capability offered by Orthodraw is excellent and if used in conjunction with MapInfo, the software may suite the needs of a local-level system. It could be used for viewing preprocessed images and maps and for building a local-level attribute database. However, the limited capabilities of both these packages require a high-end system for image processing, data capturing and design applications.

MapInfo

The excellent compatibility of MapInfo with other common key systems (Intergraph, Arc/Info, AutoCAD etc.), its ease of use, its rapid map creating facility and relative low cost as a stand alone product are key factors that favor the application of this software as one of the potential low end-platforms. Several factors place Geomedia as a better option for the low-end viewer platform. Firstly, MapInfo requires a propriety language to customize the MapInfo Internet interface. In contrast, Geomedia can be programmed via a range of non-propriety languages. Further more the Internet capabilities of Geomedia are far superior to that of MapInfo.

GenaMap

The GenaMap system offers only poor data capturing and design facilities. A clear illustration of this lies in the fact that the photogrammetry laboratory of SLI in the City Council, which has GenaMap as the main GIS system, continue to use a combination of Intergraph equipment (Intervue workstations) and Microstation for the capture of detailed topographical and cadastral data from aerial photography.

AutoCAD

The strengths of this software lie in its CAD-base, excellent compatibility with other software, its data capture facilities and customizability. In comparison to the high-end GIS software platforms, AutoCAD Map has limited analytical, image processing, data capturing and Internet-based GIS functionalities. The Internet capabilities provided by Autodesk MapGuide does not enable a bidirectional link to an Internet-based GIS database as in the case of GeoMedia.

MGE Intergraph

The Microstation Graphical Environment (MGE) of the Intergraph System (Intertech) encompasses all of the data capturing and analysis requirements of a settlement upgrading programme in a highly integrated and flexible manner. This software represents the potential high-end platform of a national, metropolitan or large local level municipal system. To enable implementation of GIS in small local level authorities the application of this main system has to be coupled with simpler, local-level satellite systems. Two low-end platforms are available for facilitating the implementation of GIS at a local level: MapInfo and GeoMedia. Although MapInfo is not an Intertech product, the MGE software has in-built translators to facilitate the exchange of data between these two systems. GeoMedia, which is an Intertech product, is fully compatible with a number of systems and has the added benefit of being a "universal GIS". (See sections 6.3. and 8.7.2.)

Idrisi

While the Idrisi system was never intended to be an all-purpose GIS system, it seems unlikely that it could cater for either of the platforms required in the two-tier system. The software is simply too specialized to serve either as one of the high- or low- end platform components of the proposed required coupled software configuration (see section 6.7). Firstly, although it is possible to carry out attribute and spatial database management operations, there does not appear to be any relational interface system software modules available[98]. A second problem facing the applicability of this product within a municipal environment is that it does not cater for non-image processing needs of the user group[99].

7.9.3 Conclusions of the evaluation process

In this section only the main conclusions with respect to the high-end platform of the coupled software configuration for implementing the Bi-level model are drawn. When the software was selected for this project (1996), the differences between the various software products were more marked. Within the period of two years these differences reduced tremendously as new modules were generated for carrying out similar tools initially pioneered by the leading GIS developers. The Intergraph system was therefore chosen as the most suitable for this application for the following reasons.

1. Its lead in terms of GIS developments[100].
2. Its lead in terms of its Internet capabilities.
3. The best in-built system integration facilities upon purchase.
4. The best data capturing tools.
5. The best ease of use combined with access to analytical tools, in comparison to other high-end platforms.
6. The special financial and technical support provided to academic research institutions.

Despite recent development in the various software product ranges, Intergraph maintains the lead in terms of its Internet capabilities. The latest ArcView (Version 3.0) has the ArcView Internet Map Server and MapObjects Internet Map Server extensions, which enable maps to be published on the Internet. Other key software products such as MapInfo have similar products. However, it is only the Intergraph Geomedia product which has: 1) a two-way communication functionality on the Internet, 2) direct access to the actual database, 3) on-the-fly transformation correction facilities and a multitude of other exclusive GIS Internet capabilities (see chapter 8). With respect to system integration, amongst all of the high-end platform candidates, Intergraph provides the best in-built system integration facilities upon purchase[101]. The data capturing tools and easy access to powerful analytical tools have already been discussed. The last issue, relating to the special financial and technical support provided by Intertech to academic research institutions has also proved to be a deciding factor for system selection in other universities[102].

7.10 LOCAL FACTORS INFLUENCING THE SELECTION OF GIS SOFTWARE

The local factors which have influenced the selection of the system for the UCT Urban Management GIS facility are as follows:

- local physical risks
- GIS systems in local authorities in Cape Town
- GIS systems in other government institutions in Cape Town

- rapid growth of settlements in Cape Town
- local status of informal settlement upgrading
- local system recognition and software support
- local market pressures
- local language

7.10.1 Local physical risks

In Cape Town, informal settlements are faced primarily with flooding problems. The primary local physical risk thus necessitated a system facilitating the development of stormwater drainage applications. For this purpose, the potential for adding on sewer system design and surface modeling modules was sought after.

7.10.2 GIS systems in local authorities in Cape Town

The need for the selected GIS system to be compatible with local authority software systems has already been highlighted. The need for compatibility is essential as the Council represents a major source of raw background data (eg. parcel boundary data) which may be used to place informal settlement data into a metropolitan urban context. Further more, the Council represents a major potential client for processed informal settlement data. The selected system thus had to be compatible with the City Council's GenaMap and Oracle software suites. Software products used to lesser extent in the Council included MapInfo (in Planning) and Microstation (in Surveying).

7.10.3 GIS systems in other government institutions in Cape Town

Other government systems considered included the Department of Water Affairs, Department of Agriculture system and the Council for Scientific and Industrial Research (CSIR). All of these and a number of other government systems in South Africa employ Arc/Info[103]. In order to facilitate the development of sector model linkages (see chapter 7) involving these systems, it was necessary to ensure that the system would be compatible with the Arc/Info system.

7.10.4 Rapid growth of settlements in Cape Town

The dynamic nature of informal settlements in Cape Town necessitated a system capable of 1) rapid data capturing techniques and 2) processing aerial photography. If possible specialised macros should be built into the software to enhance the data capturing processes. The data capturing process should be such that: 1) one can see the data being digitized, 2) cleaning routines should also be automated and visual 3) heads-up digitizing and automatic vectorization should also be possible. The rapid growth of informal

7.10.8 Local language

The selected software had to be based in English. In other words, the documentation, on-line help and user interface all had to written in English. Further more, the software had to have the capacity to be easily customized using non-propriety programming languages. This was required to facilitate the development of user interfaces based on native languages such as Xhosa, Zulu, Afrikaans etc.

In summary, a consideration of the local factors revealed that in comparison to the ViSP GIS system, greater GIS capabilities would be required for the development of a GIS informal settlement upgrading database for Cape Town. These capabilities included amongst others: a greater analytical capability, enhanced data capturing facilities, a facility for systems integration via the Internet and a greater ease of use.

7.11 SOFTWARE SELECTION FOR THE CAPE TOWN SYSTEM

The first software components of UCT Urban Management GIS system (obtained in June 1996) are listed in table 7.1. By December 1996 the system had been extended to include a multitude of other packages including: modules from the Intergraph Modular Graphical Environment (MGE) system, Microstation (Version 05.00.95), Oracle Version 7.2 Workgroup Server and Adobe Photoshop. The MGE suite consists of a series of modules, which may be grouped into core, desktop GIS, analysis, planning, mapping, image processing and data capture modules (table 7.2). Only a selected few of these modules are absolutely essential. Other modules can be acquired later as the need arises[105]. This section outlines the basic components of the Intergraph MGE suite and highlights the modules most useful for the work in this thesis. The software configuration discussed below gives a guideline to the most cost effective and useful MGE software-based system required for informal settlement upgrading applications.

The current software configuration of the UCT Urban GIS system may be grouped into the following four layers:

1. A primary layer composed of "operating platform" software
2. A secondary layer of core MGE modules
3. A tertiary layer of data capturing and processing modules, and
4. A quaternary layer for Internet-based GIS

Table 7.1 The first components of the Urban Management GIS system

Software components:

MS Windows NT 3.51
Microsoft Mouse V2.0A (OEM)
Ms Office Professional Windows 1995

Hardware components:

Flexi P54G, ISA/PCI-2, 256 K cache, No RAM, Base Unit
Pentium P54C-133 Processor
H/Drive W/Digital 2.1GB IDE
Diamond Stealth 64V PCI, 2MB
VDU - SAMPO SVGA-NI 20 ', .28 pitch
VRAM 2-4 MB Upgrade for Stealth64 Card
RAM 72-pin EISA SIMM 32M X 36 - 07, Full Parity (X 2)
Keyboard, 101 key enhanced ports
Including 2 serial parallel ports
ET 200T Combo NIC
CD16/8X CD-ROM

The primary layer includes software components such as the Windows NT operating system, a CAD package (Microstation '95), a relational database management system (Oracle Workgroup Server Version 7) and a relational interface system (RIS 05.03). Together these software components comprise the basic software configuration upon which the MGE software suite resides[106]. The secondary layer contains the core MGE modules essential for project initiation and administration, and for the most basic map analysis tasks. These MGE modules include Basic Administrator, Basic Nucleus and Base Mapper. The tertiary layer holds the most useful and powerful software for the analysis, capture and output of data[107]. It consists essentially of mapping and image processing modules. In particular the following modules were used most frequently for this project: Basic Imager, Advanced Imager and Projection Manager. In addition to these modules a large number of Microstation Development Language (MDL) applications (APPS) are available. Of these MDLAPPS, the following proved to be most useful: I/GeoVec, IRASB and IRASC. The fourth layer consists of software designed to: integrate data processed on the high-end MGE system with other GIS systems, convert the MGE database into an Internet-based GIS and to act as a simplified user-interface. The Geomedia package, which is discussed in detail in section 8.6.1, may be used for these three objectives. To convert the Geomedia Geoworkspace maps into high quality maps publishable on the Internet, the Imagineer Techincal software module may be used.

A large number of the potential tertiary level modules have been omitted from the system. The entire desktop module range was omitted[108]. A number of the analysis and planning modules have also been omitted from the system. These include Segment Manager, Voxel Analyst, Modeler, Image Analyst and Parcel Manager modules. Modules which are on the system, but which remain under-utilized include Analyst, Grid Analyst, Terrain Analyst and Network Analyst, Image Viewer and Image translator. Most of the project outputs required to date have not demanded the application of these modules[109]. The Map Finisher MGE module has also been under-utilized. Currently, all of data which to be plotted is imported into Geomedia and plotted using the Imagineer Technical package[110]. A schematic diagram of the MGE software configuration (modified from Intergraph Corporation: 1995c) is shown in figure 7.2. The UCT Urban Management GIS system contains all of these components with the exception of the Internet-based GIS Viewing Seat software.

Table 7.2 The various software modules available in the Intergraph Modular Graphical Environment (MGE) software suite.

MODULE / APPLICATION GROUP	ASSOCIATED MGE MODULES
CORE MODULES	Basic Nucleus
	Administrator
	Mapper
DESKTOP APPLICATIONS	VistaMap
	MapOff
	GisOff
	CivilOff
	MuncOff
	MgePC2
ANALYSIS APPLICATIONS	Analyst
	Grid Analyst
	Segment Manager
	Voxel Analyst
	Terrain Analyst
	Network Analyst
	Modeler
PLANNING APPLICATIONS	Parcel Manager
	Parcel Vec
MAPPING APPLICATIONS	Map Finisher
	Projection Manager
IMAGE PROCESSING APPLICATIONS	Basic Imager
	Advanced Imager
	Image Viewer
	Image Translator
DATA CAPTURE APPLICATIONS	I/GeoVec
	MPTiger
	MDLG
	Ascii Loader
SERVER MODULES	RisOrads
	RisMsfds
	RisInfds

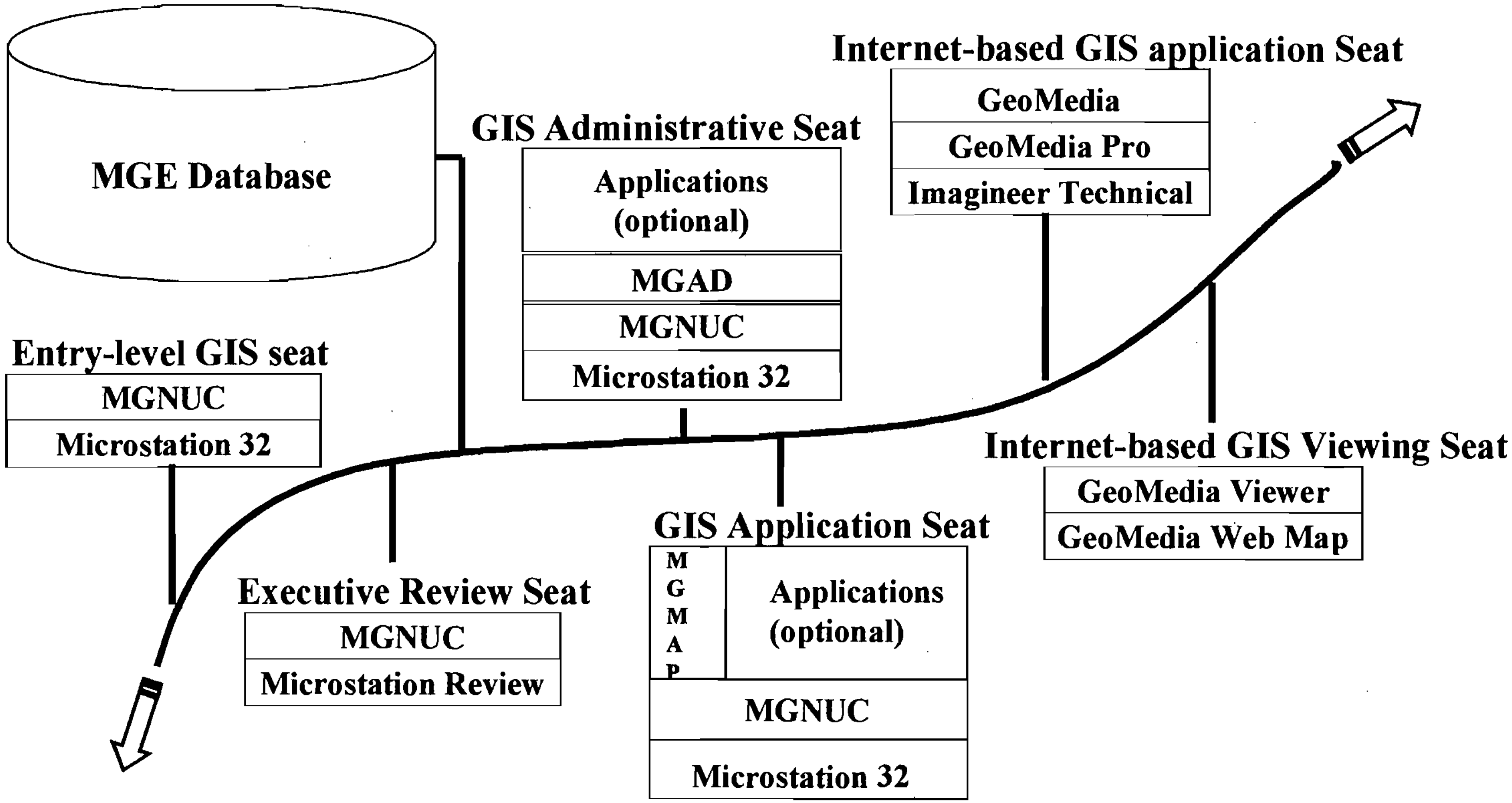


Figure 7.2 Schematic diagram of the MGE software configuration. (Modified from Intergraph Corporation: 1995c) The UCT Urban Management GIS system contains all of the above components with the exception of the Internet-based GIS Viewing Seat software.

The main problems experienced in the implementation of the system were associated with 1) the lack of regular and cheaply available MGE support in Cape Town[111], 2) setting up the initial network configuration and 3) setting up the linkage between MGE and the RDBMS[112]. As a result, a further six months followed after the system selection process before a system was established and functional

7.12 HARDWARE SELECTION FOR THE CAPE TOWN SYSTEM

The first hardware and software components to be included in the Urban Management GIS system are shown in table 7.1. The total value of this configuration was valued at R22 519 at the time of purchase (June 1996). By December1996, the system had been expanded to include a HP A0 350 C Design Ink Jet Plotter, an A3 UMAX color scanner and a 20-inch Intergraph TD color monitor. In 1997 an additional Pentium machine and a file server were added to the system. Other key hardware additions to the system during 1997 - 1998 included: a 5 GB external drive, a zip-drive and a CD-writer. The start of 1999 has seen the arrival of a Cannon Bubble Jet Printer. The current hardware configuration is shown schematically in figure 7.3.

7.13 TECHNICAL ADVANTAGES OF THE UCT SYSTEM OVER THE ViSP SYSTEM

Both approaches have a low-end platform. In terms of the layout, thematic mapping and ease of use these packages are equivalent. The Urban Management GIS system supercedes the Belo Horizonte ViSP system in terms of its excellent:

- Internet-based GIS tools
- data capturing facilities
- data storage capacities
- ease of use
- analytical capabilities, and
- integrated nature of the system

Unlike the Belo Horizonte GIS system, which has essentially no Internet-based GIS facility, the UCT system has access to excellent Internet-based GIS tools. These tools are present in the low-end viewer platform of the system (Geomedia). With respect to data capturing, the Microstation software provides similar to superior capabilities in comparison to the AutoCAD software used in Belo Horizonte. Further more, special macros (eg. I/GeoVec, IRASB and IRASC) present on the UCT system may be used to speed up the digitizing process. The greater data storage capacities of the UCT system gives the user more flexibility in terms of image processing tasks. With respect to ease of use, in contrast to Gheo, Arc/Info, ArcView and other software packages, all of the modules in the MGE suite utilize the same user-interface design. This facilitates the system

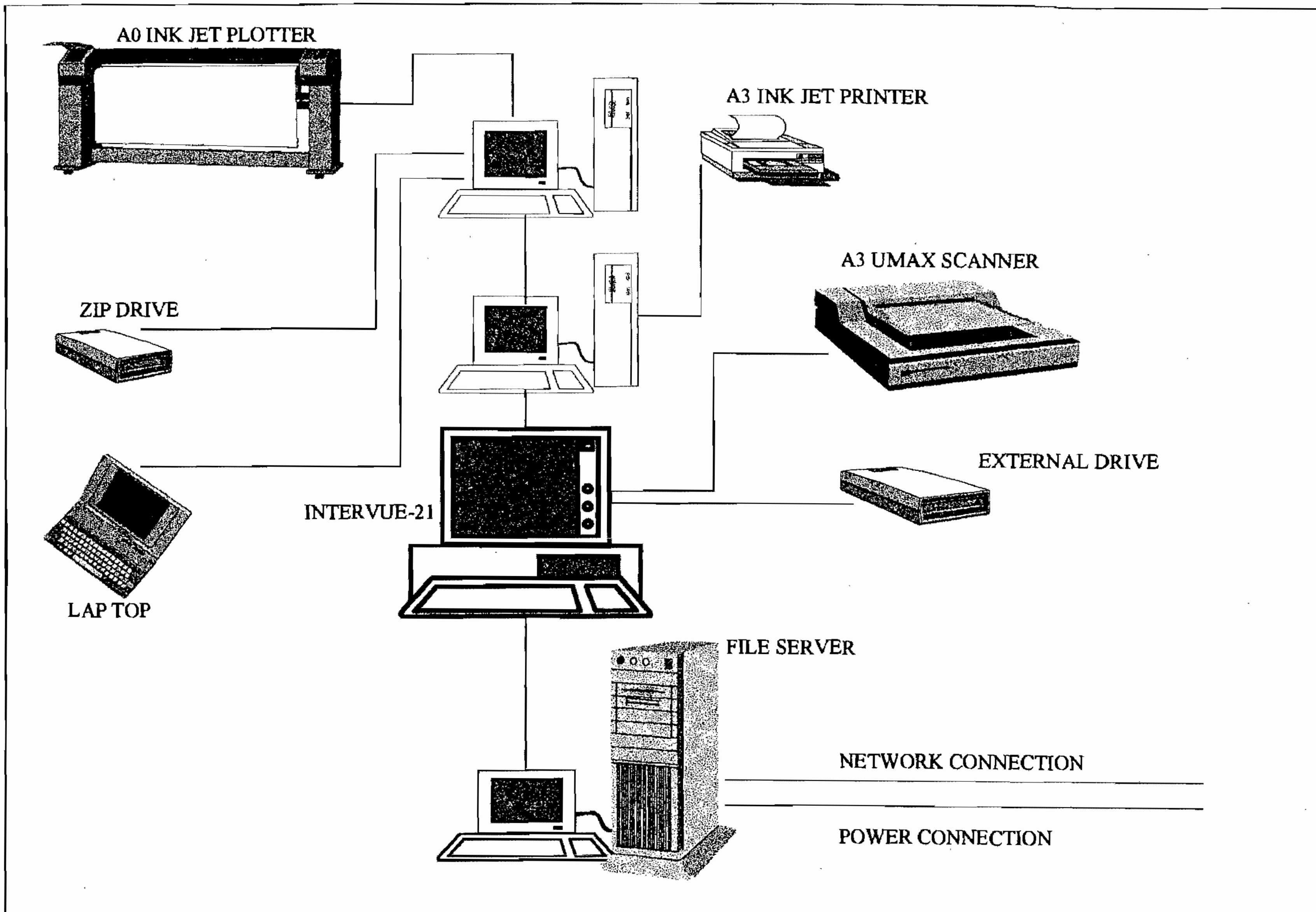


Fig 7.3 Hardware configuration of the UCT Urban Management GIS system (15/2/99).

learning process. In addition, unlike the Intergraph system has English-based on-line documentation and help facilities. The dialogue boxes in MGE are also far more user friendly than the command line prompts and complex key in sequences one must apply in the Gheo software. In terms of the engineering and other analysis capabilities the UCT system MGE software holds a far greater range of specialised analysis modules to chose from. This greater range offers a greater degree of flexibility for future system development initiatives. Finally, the UCT system is far more integrated in sense that all modules can be easily accessed via an applications pop-down menu in Microstation. On the Gheo system, one frequently has to exit the program and change the operating system to utilize certain software modules.

CHAPTER 8: THE DEVELOPMENT OF A METHODOLOGY FOR TESTING THE BI-LEVEL MODEL

8.1 INTRODUCTION

In chapter 7 a number for prerequisites for implementing the Bi-level model were dealt with. Essentially the software requirements facing the model and several potential GIS systems that met these requirements were discussed. In particular chapter 7 highlighted need to use a high-end platform coupled with a low-end GIS platform to facilitate the diffusion of the data collected for the implementation of the Bi-level model.

The second step towards testing the feasibility of the Bi-level model proposed in chapter 6 lies in utilising a GIS system to build the database components of the model. In this chapter the development of the metropolitan- and local-level database components is discussed in great detail. Firstly a brief overview of the phases of the implementation process and some organisational issues is provided. The chapter then focuses on a number of the technical issues associated with the implementation of the Bi-level model in the Cape Metropolitan Area[1]. These issues include the design and setting-up of the GIS system and the data capturing and data processing tasks involved in setting-up the database. Furthermore, the manner in which the model may be used as a tool for the diffusion of GIS data is also focused upon. In particular, the linkages between the metropolitan- and local-level databases and the feasibility of creating these linkages are discussed. Here the issue of the appropriate standard low-end GIS platform is returned to as two of the more suitable GIS software configurations are suggested for the model. The discussion illustrates two ways in which the Bi-level model facilitates the diffusion of GIS data. Firstly through the application of database linkages, and secondly through the application of the local-level database. With respect to the latter, the manner in which the low-end GIS platform may be used for disseminating information to the community and for negotiating upgrading proposals is discussed.

Although both the metropolitan and local-level databases are discussed here, due to time limitations a focus was placed on the development of the metropolitan-level database[2]. Furthermore, it is important to note that the ViSP methodology employed in Belo Horizonte (see chapter 5) has contributed significantly to the development of the methodology for implementing the local-level database component of the Bi-level model discussed in section 8.5. The Belo Horizonte experience has formed the backbone of the local-level methodology described here. Yet this methodology is in itself being evolved as a result of lessons that are being learnt from a current real-life local-level upgrading project, initiated by the New Rest / Kanana Development Trust, in Cape Town.

8.2 IMPLEMENTATION OF THE BI-LEVEL MODEL

Chapter 6 showed how the implementation of the Bi-level model could be broken down into at least three phases. These involved the development of the metropolitan-level, the development of the local-level databases, and the creation of linkages to sectoral models. A fourth phase, which would actually precede the implementation of the model in real life, involves a "location analysis". This analysis comprises an investigation of the local upgrading policies, housing typologies, previous socio-economic and mapping studies, and other criteria characterising informal settlements in the metropolitan area considered for the implementation of the model. The existence of any data available for informal settlements in the area should be noted and, if possible collated. The information collected in this phase provides a basis for building on existing databases. It provides the background for creating a GIS that can be integrated with existing local systems and helps to avoid duplication in the data capturing process. It is also useful to begin identifying potential sectoral models. In the context of this thesis, the location analysis of the Cape Town Metropolitan Region has essentially been covered in chapters 1, 3 and 4.

The second phase, which follows the location analysis (phase 1), focuses on the development of a metropolitan-level informal settlement database for the area. For this the latest aerial photography of the scale most suitable for identifying and mapping the smallest basic spatial unit of the database must be acquired. Once the boundaries of all the settlements have been mapped at a metropolitan-level, the third phase which involves the development of local-level informal settlement databases may begin. The discussion by Stavriidis (1996: 4) suggests that the implementation of the high- and low-level resolution data capturing strategies should take place in a consecutive fashion[3]. In the implementation of the Bi-level model, the initial work should commence on the metropolitan-level. Once a basic framework has been set-up and a pilot area has been identified for analysis, the work on the local-level may also be commenced. The research indicates that the key point is that both levels can be developed in parallel. The development of the metropolitan-level database is essentially seen to be open-ended. Data is continually added to the centroids of the informal settlement areas as it becomes available. Subsequent databases are added to the local-level as new areas are identified for analysis.

The development of the local-level databases involves the acquisition of low-altitude helicopter imagery. Initially one or two local-level databases can be developed as attribute data starts being attached to the metropolitan-level of the database. Once the vector database has been created for a local-level database, attribute data collected by detailed socio-economic surveys can be attached to the dwelling units. Once both the metropolitan-level and local-level of the database are functional, the vector database framework and database linkages for more complex types of analyses can start to be investigated.

The fourth phase of the implementation process involves the creation of linkages to available sectoral models. The final aim of the implementation process is an informal settlement GIS which can be used by all the levels and branches of a local authority for informal settlement planning and upgrading.

These four phases are shown schematically in figure 8.1. It is important to note that the development of the two database levels and the linkages to sectoral models is an ongoing process.

Furthermore, the linkages in the Bi-level model (see section 6.7), which have been incorporated into the model as a means of enhancing the diffusion and transfer of GIS data, necessitates that the implementation process recognises other potential users and contributors to the database. In addition to following a phased implementation approach, it is essential to ensure that the database is built in a manner that caters for information flows to and from all of the potential organisations involved in an upgrading project. This can be achieved by making the database-building process a collaborative process involving the collation of any existing relevant data from multiple data sources[4]. In this project several sources of data were utilised to build the metropolitan-level of the database. In essence, the initial database-building concept was to allow the format of the existing local government data to control the preliminary development of the database. This ensured that the model was forced to take into account the limitations facing real local municipal GIS databases. Further more, it ensured that the GIS would be compatible with the municipal GIS system and prevented duplication in the data capturing process.

The degree to which local organisations are willing to collaborate on the development of a metropolitan informal settlement upgrading database varies. For this thesis, a number of local government organisations such as the Cape Town Metropolitan Council and the National Department of Housing were found to be extremely supportive. In contrast, several consultancies and the Provincial Administration of the Western Cape (PA:WC) were found to be extremely unsupportive.

8.3 SETTING-UP THE GIS SYSTEM

As indicated in chapter 7 the first step in testing the Bi-level model requires the setting-up of a GIS system on which to implement the model. In sections 7.11 and 7.12 the software and hardware configurations selected for the UCT GIS system were described. In this section some of the key issues on how the UCT system was set-up are discussed. Firstly it is important to note, while the implementation of a GIS usually takes a number of years[5]. The Urban Management GIS system was installed in June 1996 and was functional by December 1996. The core applications were developed during the second year of the project[6]. In the third year of the project, the system was recognised by local government as a useful upgrading tool and it is currently being implemented for policy analysis and informal settlement upgrading work.

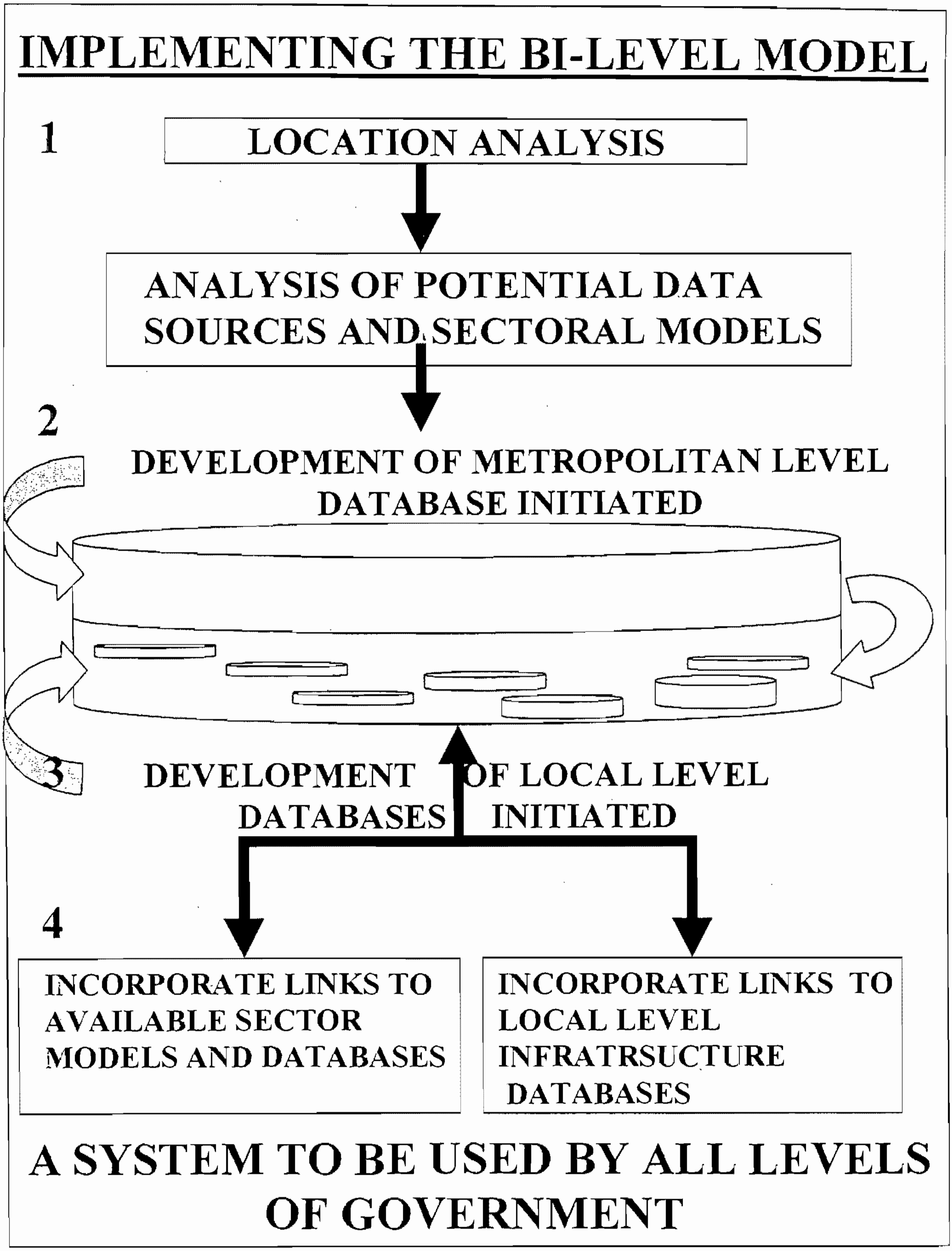


Figure 8.1 The four stages involved in implementing the Bi-level model.

The process of setting-up the GIS system once the hardware and software components are in place can be broken into the following main steps:

1. setting-up a formal filing structure
2. creation of a database
3. generation of a project
4. establishment of a communication link between the project and the database

In the early stages of this project, not much thought was given to designing an appropriate filing structure. More recently, the importance of establishing a formal filing structure has become increasingly important with the growth of the number of projects on the system[7] (Douglas, in progress). The filing structure employed currently on the system is shown in figure 8.2. Essentially, a number of shared drives have been created. The file types currently being generated for metropolitan-level and local-level informal settlement upgrading projects are as follows: MGE project files, other Microstation design files used for reference, Geomedia Geoworkspace files, Geomedia Warehouse files, TIFF imagery files, georeferenced TIFF imagery files, Imagineer Drawings, extracts of the imagery as well as snapshots and bitmaps of the imagery. Images are stored on the external drive and on CDs. Initially the actual MGE projects resided in the PRJ directory of the RDBMS client machines. This required that at least 200 MB was available on the temporary directory of each PC carrying one or more MGE projects. With the current system set-up, each project can be accessed from various machines and by more than one user at any time.

A:	3 1/2 floppy disk
C:	local disk
D:	local disk
E:	local disk
F:	CD ROM disk
N:	scans
O:	MGE projects
R:	CAD files
T:	ACCESS warehouses
U:	Geoimages
V:	GeoMedia geoworkspaces
W:	Imagineer drawings
X:	screen captures
Z:	general files

Figure 8.2 The file structure employed on the current Urban Management GIS system.

The creation of the database is performed on the Oracle Workgroup server (Version 7) relational database management system. For the metropolitan-level database created in this project, a database with a user name of Metro was created and allocated 20 MB of database memory[8]. Once a database alias had been created, a Tablespace was created for the GIS project. To this Tablespace, additional database files of 20 MB each were added throughout the course of the project as required. Subsequent to the creation of a database, the actual project initiation process may begin. This involves a series of criteria that must be specified using various MGE Project Administrator tools. The MGE Project Planner (Document No.: DJA05101K) provides a good outline to the workflow for this process. The generation of a project in MGE essentially involves the following the creation of the: schema, project, project schema, categories, features, attribute tables and a seed file[9]. For the metropolitan-level database created here, a schema and MGE project, called CAPETOWN and INFORMAL respectively, were generated.

Two groups of categories were initially created for the project. The first was designed to enable detailed cadastral vector data acquired from the City Council to be imported into MGE. The second group consisted of a single category designed specifically for the metropolitan-level database. The data categories that were set up to import the City Council data included: cadastre, electricity, storm water, structures, topography, transport, recreation and water. The manner in which City Council vector data was reorganised into these categories is shown in Table 8.1.

Table 8.1 Definition of data categories for importing cadastral data acquired from the City Council

CADASTRE:	**parcel boundary**
ELECTRICITY:	**electricity box, substation, electricity pole, pylon**
STORMWATER:	**canal, dam, manhole, sluice, pipe, bollar**
STRUCTURES:	**building, shack canopy, construction, factory, fence, private swimming pool, public swimming pool, flats, house, out building, steps, platform, wall, public, ruin, religious buildings, school, patio**
TOPOGRAPHY:	**spot height, embankment, marsh, river**
TRANSPORT:	**access way, bridge, foot path, express way, national road, train platform, railway, road, track, ramp, gravel road**
RECREATION:	**sports field**
WATER:	**hydrant, watertank**

The application of this group of categories was superseded by the category defined for the INFORMAL project. This occurred as the nature of the research shifted from operating solely at a local-level to applying the bi-level model. This second project environment, INFORMAL, was created for the development of a database containing data to estimate the number of freestanding shacks and shack densities in the informal settlements in the Cape Town Metropolitan area. One category (COUNTS) was created to cater for all the data associated with the shack counting exercise conducted at a metropolitan-level. Three key features were created within this category. These were the shack (point), the informal settlement (area) and the informal settlement centroid (point).

One of the critical steps in the project set-up process involves the creation of a seed file that contains all of the co-ordinate information for the project. The seed file represents an empty design file with the appropriate co-ordinate system information. This information is modified via the Co-ordinate System Manager module. For the INFORMAL metropolitan-level MGE project, a Transverse Mercator (Gauss Conform) projection with a longitude of origin value of 19:00:00.0000 d:m:s was applied. The false easting, false northing and latitude of origin values were set to 0. The ellipsoid used for the projection employed in the MGE project is based on the "Modified" Clarke 1880 spheroid (Milford, 1997) (see appendix 5 table 1). Once the database and project creation tasks were completed and the relational interfacing software (RIS05.4) had been loaded onto the client machine, the communication link between the server and the client machine was established using the RIS Schema Manager. The initial process of getting the client and server machine to communicate proved to be very time consuming due to the lack of local expertise on this matter at the time[10].

8.4 DEVELOPMENT OF THE METROPOLITAN-LEVEL DATABASE

8.4.1 Conversion of existing vector data

GenaMap to Arc/Info

Two types of conversions were carried out on cadastral vector data acquired from the Cape Town City Council's GIS database (see table 2 in appendix 5). The first conversion of data, from GenaMap to ArcInfo, was carried out in the initial phases of the project when the possibility of utilising the UCT GIS facility was being considered[11]. The conversion process proved to be extremely awkward and time consuming. The experience showed that GenaMap is not compatible with the majority of GIS systems[12]. As a last resort, the data was imported data into Arc/Info by applying the GenaMap DXF export utility and the ArcInfo DXFARC command[13]. The application of this conversion process into DXF format resulted in a loss of the symbology[14] information. Furthermore, by running the DXFINFO Arc command, a listing of the exported data file structures was obtained (appendix 5 table 3). An inspection of this listing illustrated several problems with this import method and with the original data provided[15]. Having obtained the data into an ArcInfo environment, the next step was to convert it into shape files for viewing in ArcView[16]. This inspection revealed another problem that arose possibly as a result of the data conversion process. Essentially, an inconsistency in the alignment of the vector data was observed. In some cases, adjacent buildings overlap. There are also discontinuities in the building and road vectors (see figure 8.3). It is difficult to say whether these inconsistencies are purely the result of the data conversions or whether they were present in the original database.

MapInfo to MGE

As a result of the problems initially experienced with the GenaMap to ArcInfo conversion, subsequent cadastral data sets were acquired from the City Council in MapInfo format[17]. The cadastral data was initially viewed in MapInfo and subsequently imported into the MGE system[18]. Once an initial understanding of the table structure of the MIF data was obtained within MapInfo, the MapInfo to MGE conversion could be carried out. In this data conversion process a parameter file was constructed to place the information onto different levels. The parameter file was written to select the vectors on the basis of the ID column value in the MapInfo table and to assign distinct feature definitions to each of the different types of vectors.

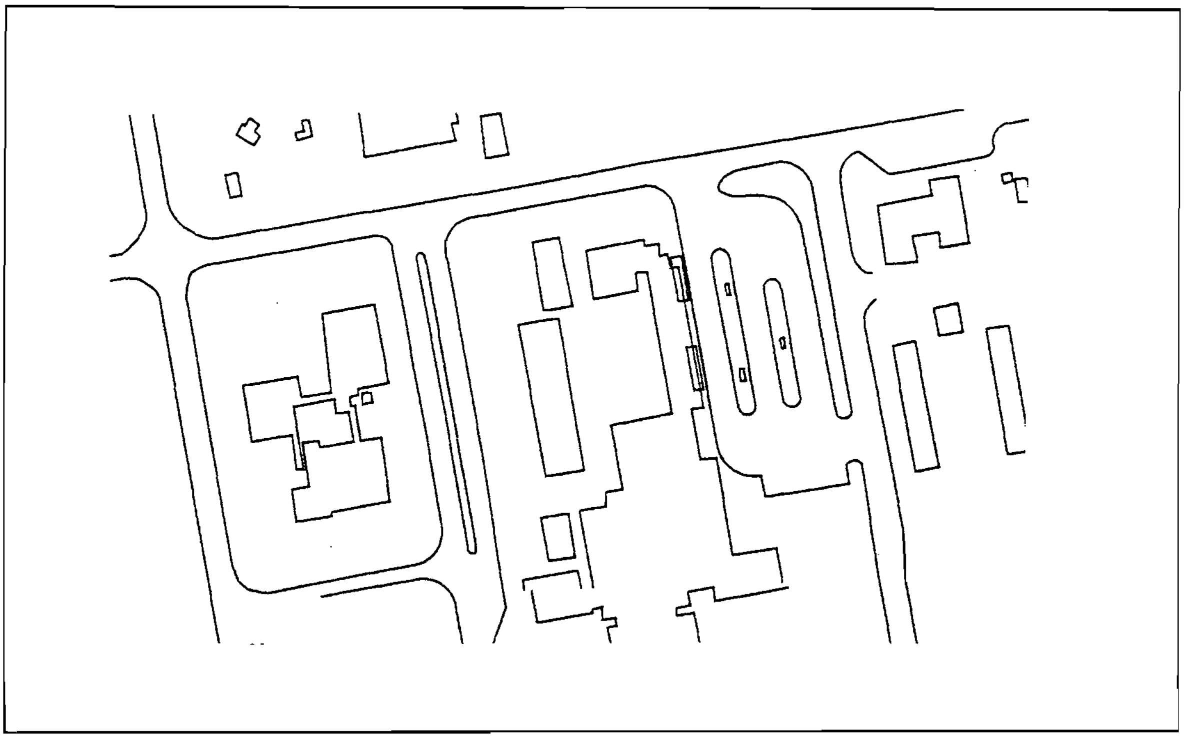


Figure 8.3 An illustration of data mismatches possibly resulting from the GenaMap to Dxf to ArcInfo data conversion process.

In addition to the cadastral data set for the main informal settlement bearing area of Cape Town, a second data set showing the key infrastructure networks at the metropolitan-level was obtained from the Council (see appendix 5 table 4). This data was also imported using the MapInfo Translator tool. Another vector data set acquired from the City Council, but which was not converted was the spot-height data for Ikapa[19]. The initial investigations on which conversion sequence should be applied revealed two factors very clearly. Firstly that the GenaMap to ArcInfo to ArcView conversion sequence would require a great deal of data conversion time and that the results of the conversion process would not necessarily be acceptable as a result of mismatches and other vector data inconsistencies. Secondly the investigations showed that the GenaMap to MapInfo to MGE conversion sequence was both more efficient and accurate in terms of the required data conversion process.

8.4.2 Capture of new data

The process of capturing new data can be broken down into three steps. These are the capture of raster data, image processing and the capture of vector data. This section focuses on the capture of the raster and vector data. The image processing which precedes the vector data capturing process is discussed in section 8.4.3. The capture of the raster data can be broken down into two further processes. These are the selection of the imagery and selection of the scanning resolution.

Selection of imagery
The selection of the imagery to be used is dependent on a number of issues. For the purposes of shack counting it was found that satellite imagery was in appropriate as the individual shacks could not be distinguished. Within the context of the Bi-level model proposed in Chapter seven, aerial photography may be applied for the development of the metropolitan-level of the database. Once local-level databases have been identified for development, the helicopter photography may be acquired for these areas. Thus a combination of aerial and helicopter photography is recommended with the acquisition of helicopter photography being carried out in a highly selected basis. In this section the various imagery sources considered for the development of the metropolitan-level of the database are discussed. The treatment of the helicopter imagery is discussed in section 8.5.

Initially, the possibility of acquiring new aerial photography images for the Ikapa area was considered. However, the total cost involved suggested that this approach would be too costly[20]. Instead it was decided to use the existing imagery which had been made available by the National Department of Housing (NDH). At the time of image selection for this project the following imagery represented the most recent available sets of aerial photography available from the National Department of Housing. These were the 1:20 000 (December 1995), 1:30 000 (December 1993) and 1:30 000 (December 1991) sets of photography. Two other sets of imagery captured by the City Council were also considered for the project[21]. These were the 1: 3 000 B/W Contract 135/95 Nyanga / Guguletu (6/11/95) and the 1: 10 000 Cape Metropolitan Area 18/12/94 (13 photos).

The 1:20 000 December 1995 imagery from the NDH was selected for this project as it provided the most recent set of imagery covering the whole metropolitan area. Prior to the scanning process, all of the contact prints for this flight were inspected at the Surveyor General by a research colleague[22]. All of the images which contained back yard and or free standing shack areas within the metropolitan area boundary, defined on a 1997 1:325 000 scale map by the Cape Metropolitan Council, were selected. From over a hundred photos covering the whole metropolitan area only 43 were selected. A table of images bearing informal settlements in the metropolitan area (appendix 5 table 5) was used to select the images containing free standing shack areas[23].

Selection of scanning resolutions
The selection of the scanning resolution also depends on several issues. The variation in image quality with increasing scanning resolution for the three key imagery types (helicopter, aerial and satellite) is shown in figure 8.4. The key issue is the image resolution required for the specific mapping exercise at hand. In the case of a shack counting exercise it is essential to be able to distinguish individual shacks easily. Two other key factors that will determine the appropriate scanning resolution are the

availability of the imagery (see above) and of memory storage space on the system. A range of scanning resolutions was applied for the different sources of raster imagery used in this project. The 1:20 000 December 1995 imagery was scanned by Surveys and Mapping at 72 dots per inch (dpi) using a specialised high resolution scanner. Other sources of imagery including: contact prints, paper map copies, diapositives and negatives were scanned using an in-house A3 UMAX (Mirage D-16L med) scanner and the Adobe Photoshop 3.0 software.

Before the 1: 20 000 imagery was scanned by Surveys and Mapping, the most suitable scanning resolution (using the A3 scanner) and image file size for the UCT GIS Research centre system was determined by trial and error. For each scanning resolution setting, it was noted how far one can zoom-in on the resulting image before individual shacks become unrecognisable or too difficult to map. For the aerial photography, the best results using the A3 scanner were achieved with a tif file size of about 300 MB for each image. The Surveys and Mapping was requested to select the maximum scanning resolution that would enable at least two images to be saved per CD and still enable shacks to be clearly defined. Scanning by Surveys and Mapping took eight hours per image for complete ortho-rectification. The result was files sizes in the order of 297.7 MB. On the whole, the scans enabled shacks to be easily identified. More recent work on a related project has shown that in the case of helicopter imagery, the choice of scanning resolution is less critical as the initial imagery is already of a high resolution. In practice, 200 dpi has been found to be sufficient for the treatment of the helicopter imagery.

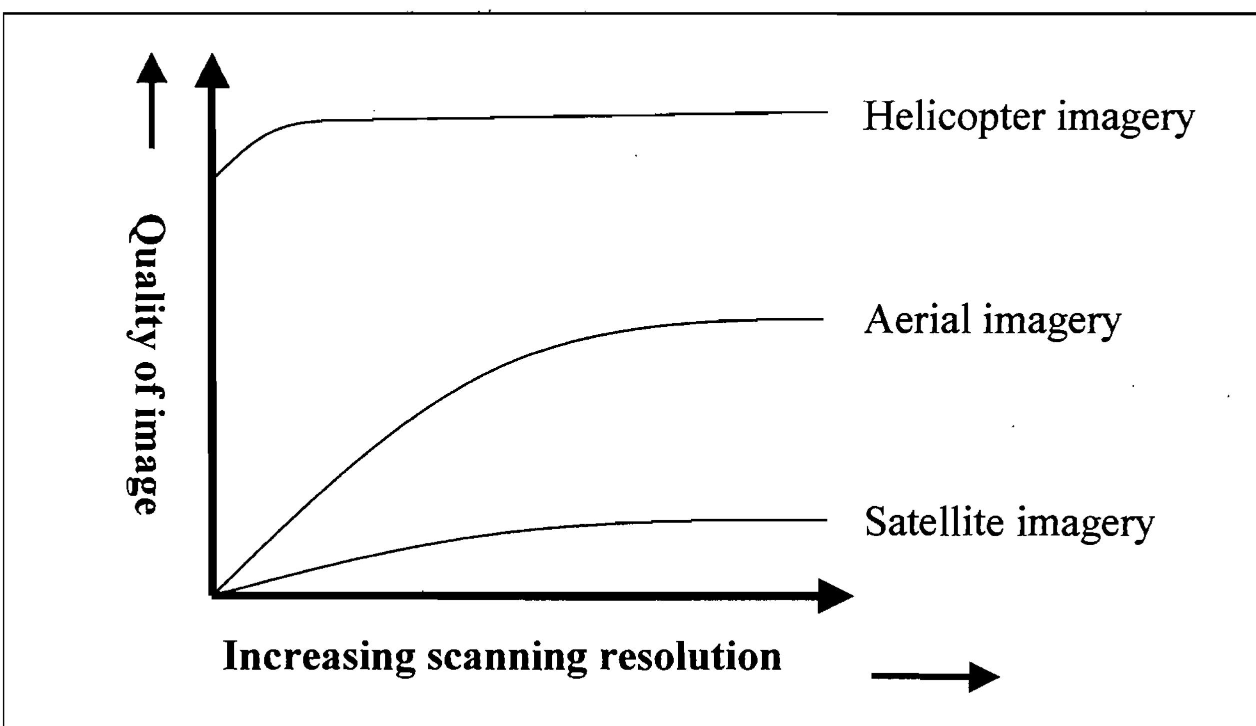


Figure 8.4 A schematic illustration of the variation in the scanning resolution required for different types of imagery.

Capture of vector data

The capture of vector data for the creation of the metropolitan-level database consisted of capturing the shack locations and settlement boundaries. Initially the possibility of carrying-out an automatic digitisation process by applying image classification-based techniques was considered (see below). This approach proved too time consuming. Instead it was decided to digitise the required features by following a simple heads-up digitising approach.

Evaluating a classification-based data capture approach
An experiment to test the feasibility of carrying out the counting procedure by applying classification methods was conducted using the MGE Advanced Imager (MAI) module. A training set was defined by drawing polygons around selected shacks. Different training set samples were selected on the basis of varying roof colour[24]. Essentially, the result of the process was a number of "blobs" representing numerous conglomerations of shacks within the settlement and sub-settlement areas on the classified image .The results may have been better if a larger number of classes were defined[25]. However, the practicality of applying this approach was questioned as the shack roofs showed a great variation in colour in each image and within single informal area sub-settlements. In addition, the colours of similar and in many cases the same feature varied from image to image. To create similar cross-image colour ranges would have required manipulating the contrast-brightness ratio and other image parameters. Several characteristics of the imagery would have made the digitising of the shacks by an automated image classification procedure unpractical[26].

Capture of shack locations
The descriptions on the table of images bearing informal settlements in the metropolitan region were used initially to locate the informal settlements on the images. Other items which were used to guide the mapping process were:

- a map produced by the Survey and Land Information Branch which showed informal settlements recognised by the City Council
- an ortho-photograph from the Surveyor General, and
- the maps in a previous population study Van Zyl (1995)

A template was designed to assist in the data capturing process. Essentially, the template consisted of an 8 x 8 grid defined such that the grid size corresponded to the optimum zoom level for recognising shacks (figure 8.5). This proved to be a significantly useful data capturing tool as one of the greatest time consuming components of the data capturing process involved the time taken to zoom-in and -out of the imagery. This is not surprising as each of the initial images were over 239 MB in size. The problem was compounded by the fact that the overview facility in MGE, designed to speed up the image redraw rate, was not functional on the system. The grid was used to systematically annotate areas were backyard shacks occurred (for aiding later data capture) and areas were no shacks were present. Shack points were placed subsequently by zooming into the remaining grid cells. The vector data was captured following the design file template scheme outlined here. In this manner a series of separate design files were created - one for each image.

Capture of settlement boundaries

Initially clusters of shack points were used to place sub-settlement boundaries. The minimum sub-settlement size was set at a grouping of four shacks. Such a low setting was used as this value essentially represents the detection limit for newly emerging settlements in the mapping process. Subsequent to this, adjacent sub-settlements were used to delineate settlement boundaries.

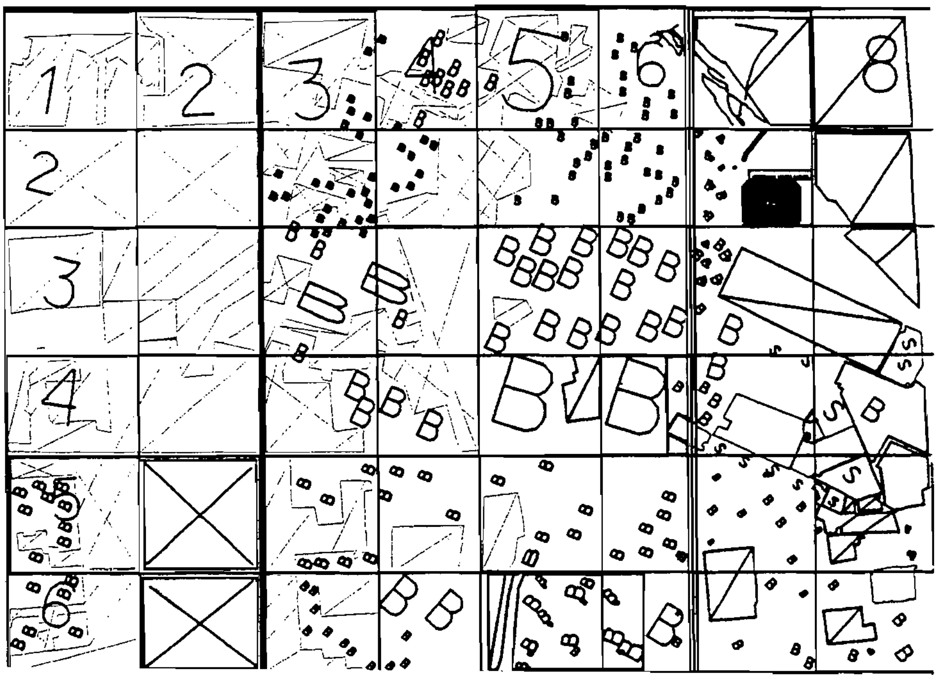


Figure 8.5 The template created within Microstation for aiding the vector data capture process.

8.4.3 Graphics data processing

Image processing

The image processing required for building the metropolitan-level and local-level databases involves essentially four procedures to varying degrees[27]. These are positioning, resampling, mosaicing and the creation of image extracts. In order to construct the metropolitan-level database, the 1996 NDH imagery, which had been supplied in an ortho-rectified format, was moved into position. The raster data provided by Surveys and Mapping was acquired in a GEOTIFF format. For each aerial photograph a TIFF image and an associated GEO text file was provided. This GEO text file describes the projection and co-ordinate data for the imagery and enables the imagery to be correctly positioned in the MGE universal space. The metropolitan-level images were positioned initially by an image to map warping facility[28] and subsequently by applying a modified affine transformation[29] procedure. The transformation-based approach was found have three key advantages over the warping-based technique. Firstly it may be used to save storage space. Secondly, the result of process is exactly replicable[30], and thirdly, it is far more rapid.

Seven of the warped images were saved at the same resolution as provided. These images overlay parts of Ikapa and Khayelitsha, the main informal settlement bearing area of the Cape Metropolitan Area. The remaining images were resampled[31] and saved only as affined images. The resampling was carried out immediately after each image had been counted. The initial pixel size averaged 0.5 mu (microstation units) (eg. image 99410011 had a pixel size of 0.500871). In order to reduce the file size, the images were resampled with a pixel size of 5 X 5 mu using the Advanced Imager Affine transformation facility. This resulted in a file size of 2 MB for each image. These affined images proved to be useful backdrops to the metropolitan-level vector data (see figures 8.6 to 8.9)[32].

Mosaicing

While the mosaicing functionality can be applied at any level in a GIS database, it was found to be less applicable in the development of the metropolitan-level of the database in this project. The mosaicing function is generally applied to remove the overlap between adjacent images. The ultimate aims of applying this tool include: 1) a reduction in the total file size of the imagery covering an area and 2) the removal of unsightly overlaps from a collage of images. In the case of the metropolitan-level database constructed here, only a few images covering the metropolitan area were selected (ie. specifically the images which covered informal settlement areas). Further more, only a handful of these images overlap. Given the disparate distribution of the metropolitan-level raster data (see figure 8.6), it made little sense to create a mosaic.

Creation of extracts

The original high resolution imagery used in the vector data capture process is difficult to work with[33]. The problems associated with using the high resolution imagery can be reduced by creating extracts from the imagery. This is essential for publishing the results analyses based on the metropolitan-level of the database. An extract can be created for each settlement and can be used as an image backdrop to the vector data for that settlement.

Vector data processing

The graphics processing involved once the vector data has been captured is comprised of four steps. These are the merging of design files, line-work cleaning, featurizing, and the placement of centroids.

Merging of design files

The merging process may be used to copy graphic elements situated in a number of design files to a single destination file. In addition to enabling associated data to be collated into a single file, the merging process automatically results in a reduction in the total file size[34]. Each of the design files created for the metropolitan-level database averaged 1.7 MB in size. Considering that the software supplier

Figure8.6 The thirty-four georeferenced images which were used to map the freestanding shacks in the Cape Metropolitan Region (CMR). The vector data here represents catchment boundaries in the region. The orthorectified images taken at the end of 1996 were provided by the Chief Directorate of Surveys and Land Information.

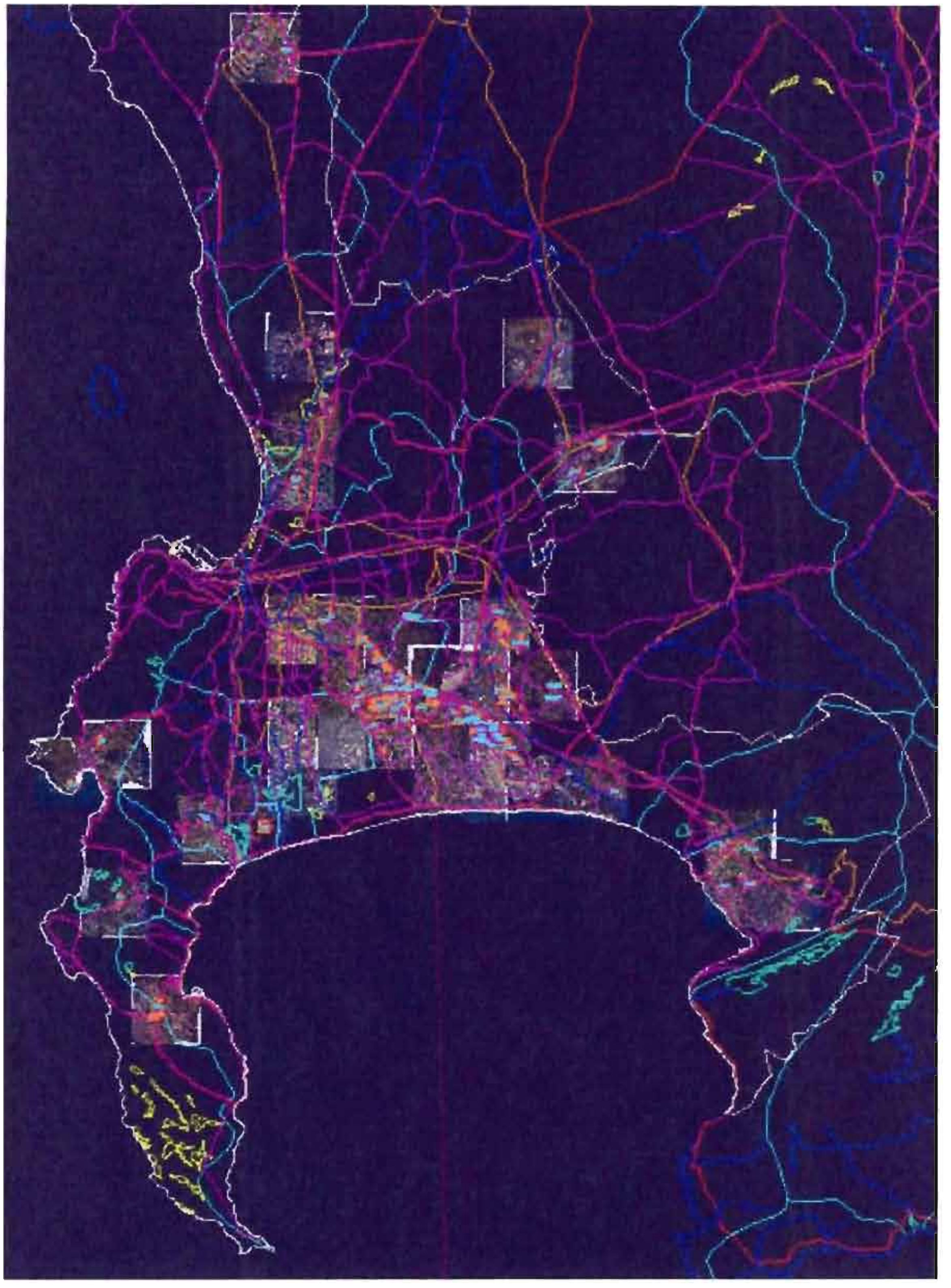


Figure 8.7 The georeferenced images placed against a base map illustrating a greater amount of vector data at the metropolitan-level. The additional data shown here includes the roads and railways data. The latest informal settlement vector data appears as the blue and cyan patches.

Figure 8.8 A zoomed view of the Table Bay area in the Cape Town Metropolitan Region. The street vectors (white) for the formal settlement areas of the city are available are displayed. This type of information that can be useful for placing local-level informal settlement databases into the context of the formal city.

Figure 8.9 Detailed vector data for Ikapa acquired from the CMC and the new shack counts data placed against an affined version of the imagery used to capture the new data. The detailed vector data for Ikapa includes all the topographical and cadastral data originally captured by the Survey and Land Information Branch of the CMC (such as parcels, formal housing, hostels, etc.). This is another example of already existing data that can be used for placing local-level informal settlement databases into the context of the formal city.

recommended that the merging functionality should not be implemented on more than about 20 MB of files at a time, the various design files were successively merged in two stages. During each stage of the merging process, all of the files to be merged were referenced, fenced and merged into a new file. In the first instance four sets of files were merged[35]. The four design files created in this manner were then in turn merged. The final file size was 3,249 KB. The Projection Manager module FENCE FILE facility was used to retain the projection information during the merging process.

Line-work cleaning and featurising

Part of the graphics processing involves the application of line-work cleaning routines. Once the vector data had been captured, the MRFCLEAN MDLAPP was applied on the informal settlement boundaries to ensure that the boundaries represented clean line string based boundaries. A tolerance level of 0.5 m was employed in this procedure. The boundaries were subsequently converted into complex shapes and each of the graphic elements were featurized using the FEATURE MAKER tool in the BASE MAPPER module.

Placing centroids

Once the data had been featurized, centroids were placed inside the informal settlement sub-area boundaries using the CENTROID PLACER tool available in BASE MAPPER. In many cases, several sub-areas were mapped for a single settlement. Many of these sub-areas in turn contained open land. These "holes" of open land were also mapped. Centroids were subsequently placed for all the mapped areas and then deleted for the open land areas. Considering that 43 images had been used in the mapping process and that about 50 settlements had been mapped by van Zyl (1995), it was estimated that the total number of settlements should lie at above 50. Initially, 189 centroids were placed when the CENTROID PLACER tool was applied. This indicated that in total, 189 sub-areas[36] had been mapped.

8.4.4 Attribute data processing

The attribute data capturing process for this project was restricted to only the basic data required for the metropolitan-level. Essentially, only area, shack counting and density calculations were performed. In addition to the standard MSLINK and MAPID columns created during the featurization process, the following attribute coulmns were created and attached to each informal settlement area centroid: the settlement name[37], area (hectares), density (dwelling units per hectare), perimeter (m) and shack count. In figure 8.10 an example of the attribute data types attached to a settlement centroid for the Barcelona informal settlement are shown.

Settlement area

Once the centroids to the informal settlement boundaries had been placed, the AREA LOADER tool in BASE MAPPER was applied to calculate the areas of the informal settlement sub-areas. The application of the AREA LOADER tool involves the

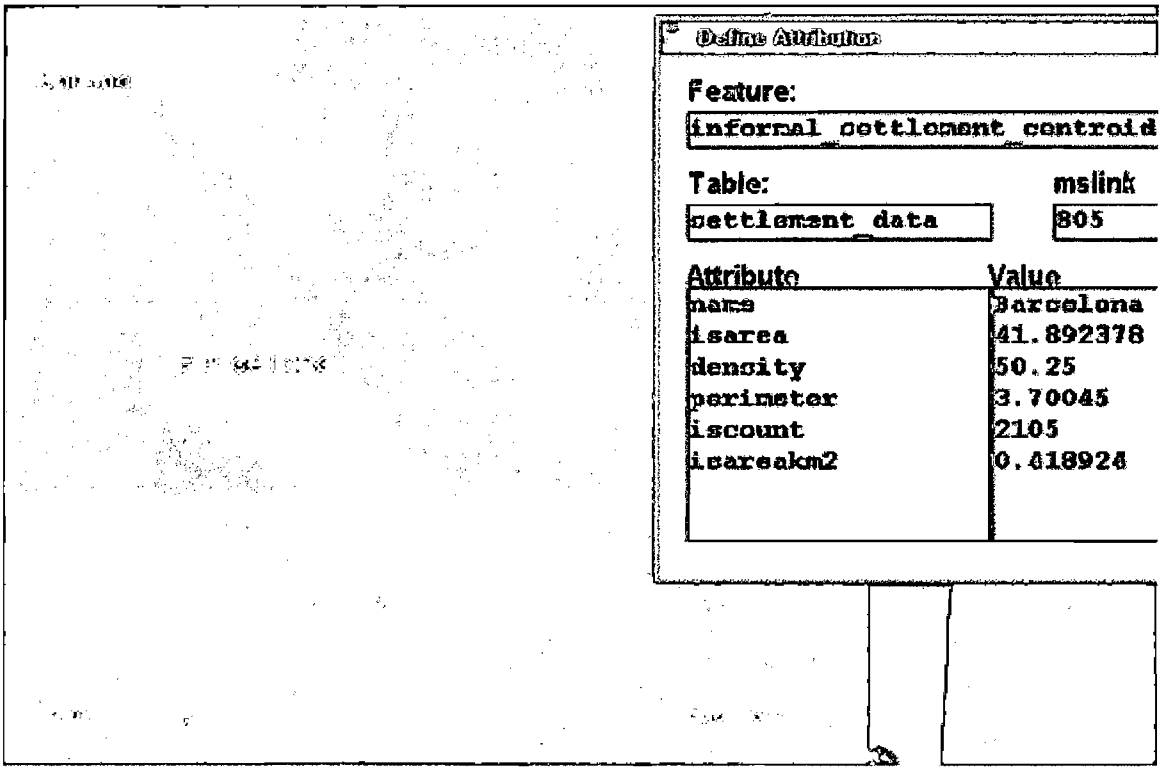


Figure 8.10 A zoomed view of the Ikapa area. The shack data captured in this work (red points) have been used to delineate informal settlement area boundaries. Attached to each area centroid, are attribute data such as the informal settlement name, area, perimeter, number of shacks and the density of shacks.

selection of the boundary and centroid of the areas to be calculated. A universal list file (ULF) is created which selects only the levels with these features for the process. By deleting the centroids to the open space areas digitized within the informal sub-settlement boundaries, one can run the AREA LOADER process in such a fashion so as to exclude the empty space (ie. non-shack bearing areas) within the free standing shack areas. The result of running AREA LOADER process was that six duplicate centroids were detected and 151 sub-settlement areas were calculated. Figure 8.11 further illustrates the manner in which the areas were calculated.

Settlement density and perimeter

A hard copy of the records in the metropolitan-level database was obtained via the RIS interactive utility (0.5.03.01.25) by using the following spatial query language (SQL) command: " select * from settlement_data where isarea > 0". Using the area data listed on this plot, the settlement density (dwelling units per hectare) was calculated for each settlement sub-area using a hand-held calculator and entered into the system. The perimeter values (m) were automatically generated as a result of running the AREA LOADER process.

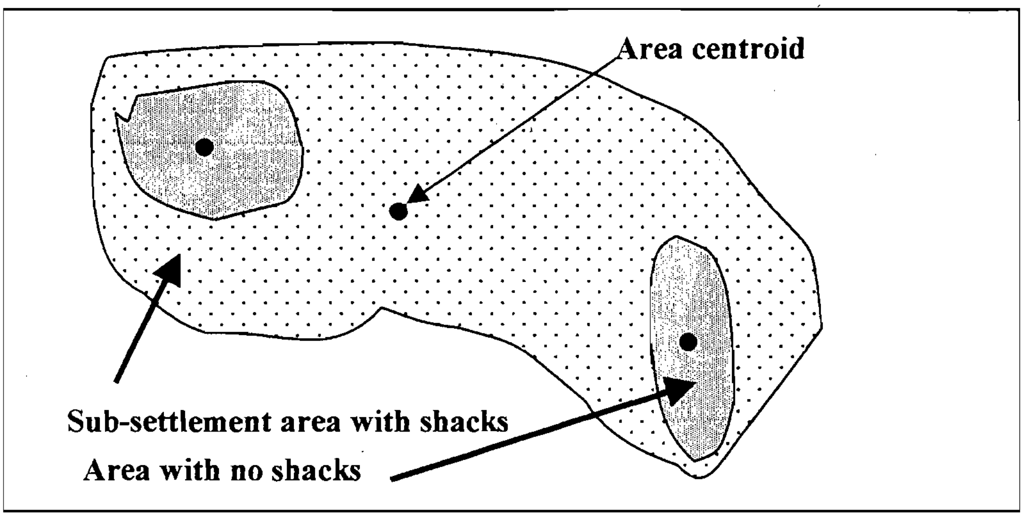


Figure 8.11 Centroids were placed in the shack-bearing and non-shack-bearing areas of large sub-settlement areas. The centroids to the non-shack-bearing areas were deleted prior to the area calculation procedure. This enabled only the areas for the shack-bearing parts of the sub-settlement to be calculated.

Settlement shack count

The counting procedure relied essentially on the utilities available within Microstation 95 for manipulating the contents of levels and element characteristics. The process involved fencing the shacks associated with one sub-settlement area of interest and applying the MODIFY ELEMENT tool to shift these shack features to an empty level. The DISPLAY USE utility was then used to determine the number of features shifted on to the new level. These shacks were then replaced in the original level and the process repeated with other sub-informal settlement areas. Two problems are associated with the counting process. The first is related to the capture of the shack vector data. Problems with capturing vector data for shacks arise when trees cover shacks and when toilets are digitised as shacks. An additional problem is that the number of households may be greater than one per dwelling unit.

8.4.5 Preliminary use of the database

Once all the graphics, image attribute processing tasks had been completed for the metropolitan-level it was possible to use this database as a communication tool during discussions with key local authority and community individuals. The database provided a means of creating presentations designed specifically to track down data, potential collaborations and future funding. The merged design file containing all the informal settlements was used to reference the affined images covering the mapped informal settlement areas, thereby providing a strong visual representation highlighting the key informal settlement areas in the Cape Town Metropolitan Area (see figures 8.6 to 8.10). Slides were created by taking screen captures of views in the MGE environment. The screen captures were subsequently edited in Adobe Photoshop and imported into Microsoft Power Point. Where plots of the high resolution imagery were required, the imagery was resaved in Adobe Photoshop as a 256 colour indexed file. This resulted in a much smaller file (averaging 99 MB). The data collected in the creation of the metropolitan-level of the database was used primarily to carry out a spatial temporal analysis of informal settlements in the Cape Town Metropolitan Region (CMR) (see chapter 9). A series of maps showing the distribution of informal settlement areas in the metropolitan region were also produced. These maps covered the CMR, key informal settlement bearing area in the CMR (Ikapa), and Khayelitsha (see maps 1 to 3 in appendix 5).

8.5 DEVELOPMENT OF THE LOCAL-LEVEL DATABASE

Due to time limitations data was only captured and processed for the metropolitan-level of the database used in this project. More recently, work on the development of a local-level database for informal settlement upgrading has been carried for a different research project. While the focus of the latter project falls outside the scope of the present thesis, it is useful to include some of the issues pertaining to the development of a local-level database here. Furthermore, it must be noted that the ViSP approach in Belo Horizonte has contributed significantly to the development of the methodology for implementing the local-level database component of the Bi-level model. The experiences detailed in chapter 5 have served as guidelines for all the facets of the data capturing, data processing and the preliminary use of the data described here.

8.5.1 Data capture

<u>Selection of settlement</u>
A key issue that must be considered prior to the initiation of the local-level database development process is the selection of which settlements to capture at the local-level. This process is essentially demand driven. In the application of the Bi-level model, the metropolitan-level of the model can be used to assist in this selection process. However, community support remains the primary factor when selecting a settlement. In the case of the current informal settlement upgrading project being carried out by the Urban Management Research Group, a large number of potential settlements were initially approached through the SANCO organisation. From these, the settlement that showed the greatest community support (New Rest) was selected for the development of a local-level database[38].

<u>Acquisition of imagery</u>
While the acquisition of helicopter imagery for the development a local-level database was not carried out as part of this project, subsequent work in a related project has required the acquisition of such imagery. This work together with the Belo Horizonte application of ViSP has shown that a helicopter flying height of 200 to 300 m is most appropriate for developing local-level databases. Furthermore, the flight plan should be structured to enable overlaps of between 60 % and 90 % for adjacent photographs[39]. The helicopter survey was organised with the Aviation Business Centre. The flight plan was constructed on a plot of an image of New Rest extracted form 1996 (1:20 000) aerial imagery (see figure 8.12). Eight strips were flown across the width of the settlement along a north to south direction. The flying altitude was set to 200 m and ten frames were taken along each strip to ensure a minimum overlap

of 60 % along the direction of flight. The image footprint was thus set to 200 X 200 m. The first strip was flown along the railway line adjacent to New Rest. Subsequent strips were flown from along the N2 towards the south. To maintain a constant direction of flight, houses in the formal settlement area to the north of New Rest and other fixed points to the south of the informal settlement were selected before the flight. An additional ninth strip was flown along the length of the settlement for interest. The total flying time was 55 minutes. A large fraction of this time was spent on landing the helicopter on two occasions in order to change the film.

Capture of vector data

The vector data captured for the New Rest local-level database includes the following features: shack polygon outlines, major roads and footpaths. In addition, the following data types were acquired from the Surveyor General in a DXF file format: servitude areas and erf boundaries.

Capture of attribute data

With respect to the attribute data should be captured, the Belo Horizonte case study provides a first draft attribute database template. The attribute database for the New Rest local-level database has been structured in such a manner as to keep the social, economic and infrastructure data collected during the field surveys in different Geomedia database Warehouses. These warehouses have been named as follows: dpsnrimp, dpenrimp and dpinrimp (where dp stands for design project, nr stands for New Rest, imp stands for implementation and s, e and i stand for social, economic and infrastructure respectively. In figure 8.13, the structure, content and links of the attribute tables containing the social data are shown. The database has been structured in this manner to conserve space

8.5.2 Raster data processing

Image-to-image warping

The helicopter imagery captured for New Rest was positioned in space by using an image- to-image warping procedure. The 1996 NDH raster image containing New Rest was initially positioned in space using the affine transformation procedure discussed above. From the 110 photographs captured during the helicopter flight, 21 overlapping photographs were selected to represent the entire settlement. An extract corresponding to each image was the created from the 1996 image. Using each 1999 image an its corresponding extract, approximately 15 identical points were identified and annotated in a design file. These annotations were used to facilitate recognizing corresponding control- and input- points during the warping process.

Figure 8.12 Flight plan constructed on 1996 aerial photography. The direction of flight is shown.

<u>Mosaicing</u>

Subsequent to the warping process, a mosaic of all the images was created. In the first instance, adjacent images were resampled to have identical x and y pixel size dimensions (0.3 mu). In practice it was found that if this was not carried out, an error message indicating that the images required an identical scale resulted during the mosaicing process. Secondly, during the mosaicing process the "zero" value pixels were ignored. This resulted in a removal of black lines on overlapping images created by zero-valued image edge pixels.

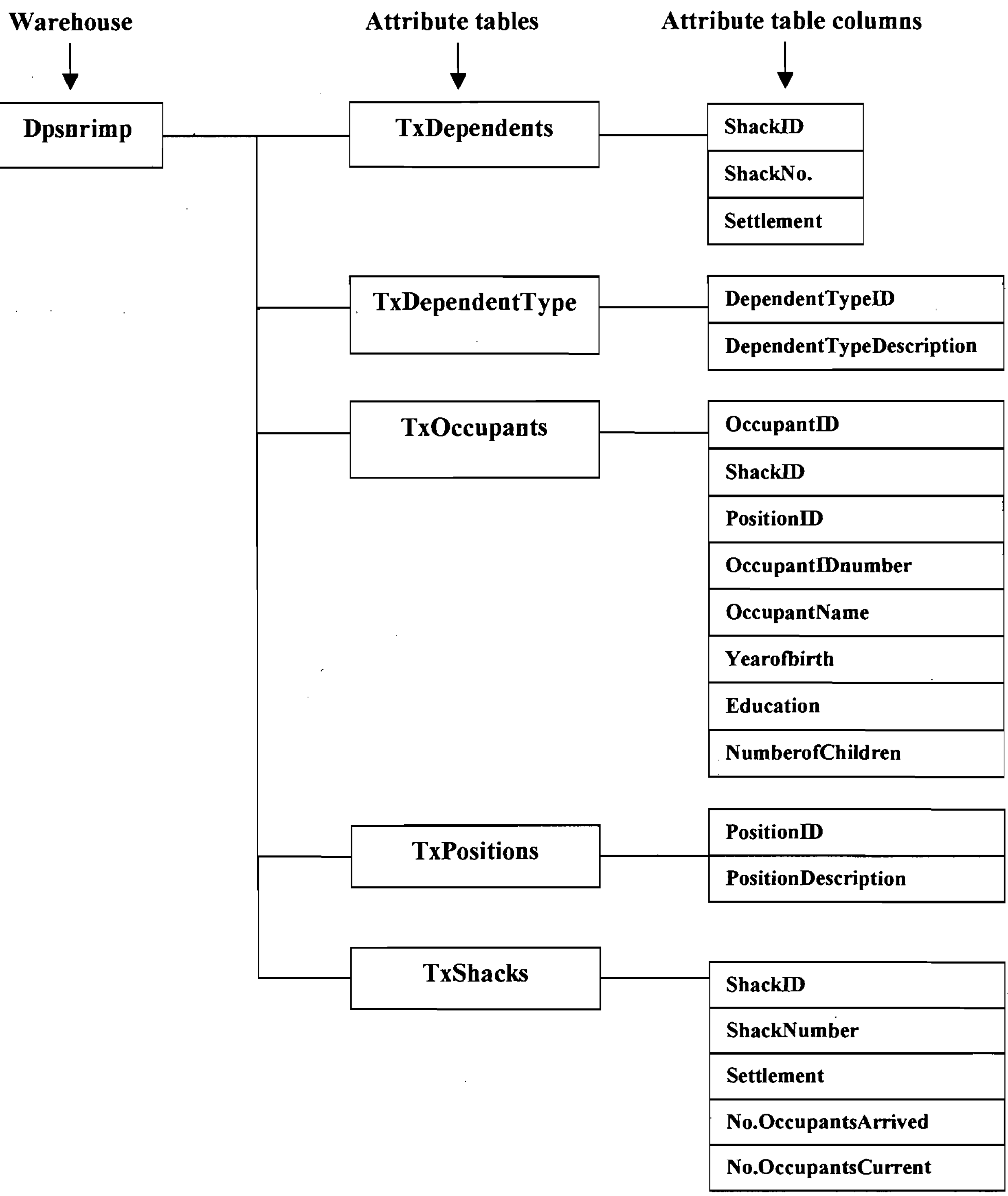
8.5.3 Attribute data processing

Thus far no attribute data processing has been carried out. However, it is envisaged that the attribute data will be used to create a series of query-based thematic maps. These maps will be based on the social data and on the planning data.

8.5.4 Preliminary use of the database

The preliminary use of the local-level database created for the New Rest upgrading project has been to provide plots for community participation. In order to create the maximum size plots, the settlement image[40] was rotated within Adobe Photoshop so that the maximum length dimension corresponds to the vertical.

Fig 8.13 The structure, contents and linkages of attribute data tables associated with the social database constructed for New Rest.



8.6 INTERFACING THE DATABASE WITH OTHER LOCAL-LEVEL SYSTEMS

This discussion deals with the software system configuration and the database locations and linkages requirements envisaged for interfacing the metropolitan- and local-level databases. The reason for adopting an Internet-based GIS software product is to make the GIS data more widely available and to thereby increase productivity. Chapter 10 illustrates how GIS can be implemented as an effective communication tool amongst policy makers associated with the upgrading process. This section illustrates how access to the same data can be extended to a wider audience by the appropriate selection of the low-end platform software required for the implementation of the Bi-level model. It essentially provides a GIS-based communication tool - not only for single enterprise-based decisions, but also for decisions based on regionally and nationally dispersed policy makers, consultancies, housing agencies, funders, politicians etc.

8.6.1 Potential system configurations

A number of potential system software configurations are shown in figure 8.14. Essentially the metropolitan-level of the model resides on the high-end platform. Local-level databases may be linked directly to this main system via the intranet or may reside on remote desktop platforms and be linked via the Internet. The most suitable software packages for the high- and to a lesser degree the low-level platform options have been discussed in chapter 6. With respect to the low-end platform options, a new software product which has recently been introduced in South Africa and which can be used to interface the main system with local systems is GeoMedia (Computer Graphics, 1997). This software facilitates spatial and attribute queries, offers the application of buffering tools and an open software development environment on a desktop GIS platform. More importantly, it allows GIS data from many sources to be integrated simultaneously without translating data. Certain packages such as Geomedia (Intertech) enable two-way communication processes between a client database and a remote GIS database.

Advantages of GeoMedia

The following discussion has been extracted from a number of Intergraph information brochures on the GeoMedia software. It focuses on the key features of this software and highlights the potential role of this product in the implementation of the Bi-level model. In essence, this software represents the best low-end platform for the system configuration discussed above. The Intergraph GeoMedia Web Map product enables GIS data to be made available over intranets and the Internet. For this reason it has often been referred as the "Universal Geographic Client" by the manufactures. One of the key advantages of implementing a Web-based GIS software package is that it enables GIS data to be distributed in an inexpensive manner through standard Web browsers such as Microsoft Internet Explorer and Netscape Navigator. It thus enables the GIS data to be made more readily accessible. The GeoMedia software holds a number of key advantages[41] over other Web mapping GIS applications that are available.

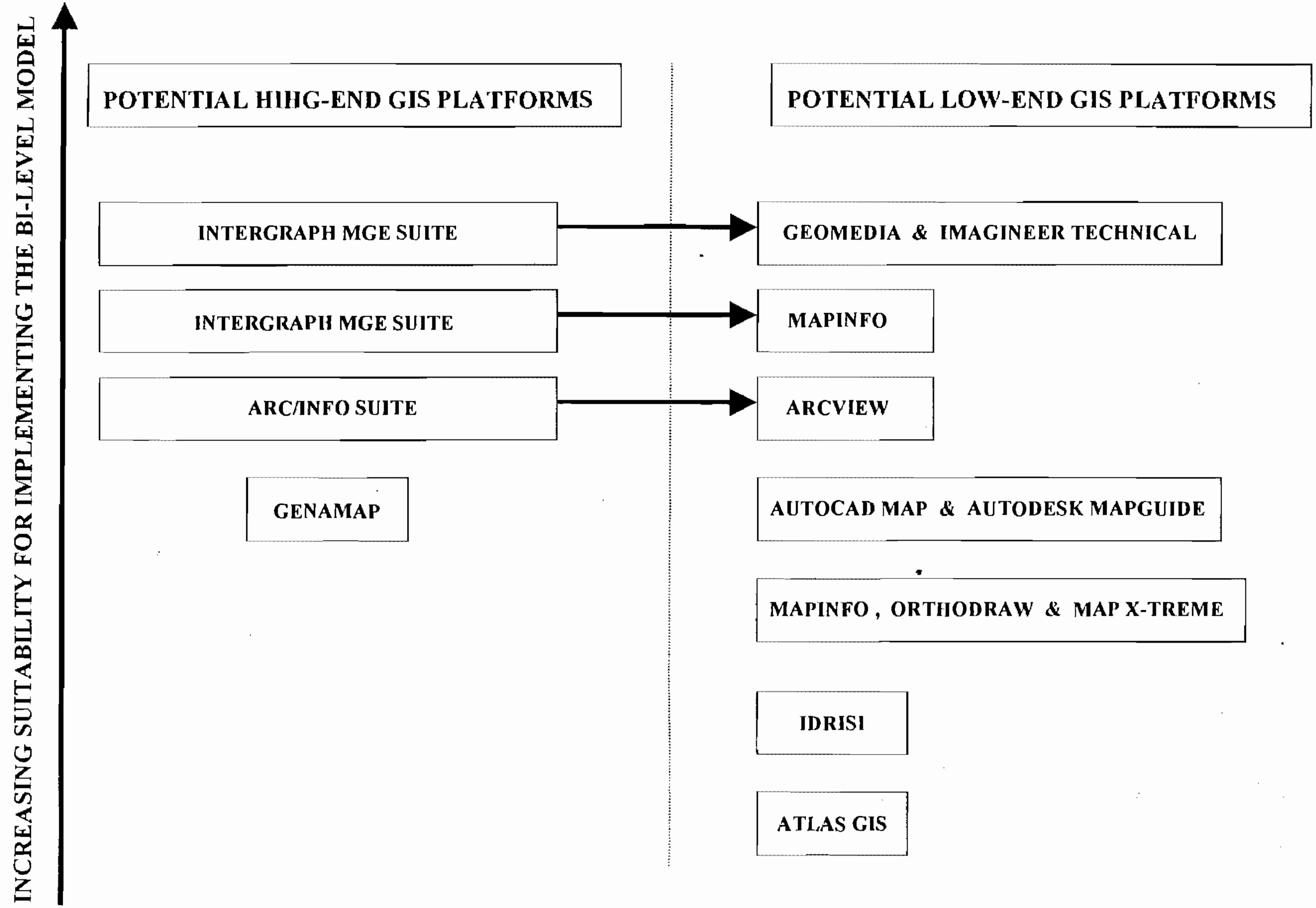


Figure 8.14. Potential high-end and low-end GIS platform combinations for the implementation of the Bi-level Model.

Unlike most other Web GIS application software packages available on the market, GeoMedia enables the most current data available in related databases to be accessed about queried features - ie. the "smart vector maps" are updated each time geographical information is updated on the server. The ActiveCGM[42, 43]open data format implemented in GeoMedia enables users to extract and interact with live data. In addition, the vector-based maps can contain hyperlinks on individual features within the map. The software is relatively easy to use as it requires little or no programming skill. It has been designed for non-specialist applications. The only computer skills required of this software are the ability to Windows and the Web. Furthermore, it represents an open GIS solution as it uses no proprietary languages or data formats. It reads both FRAMME (Facilitates Rule-based Application Model Management Environment systems) and MGE data without translation and can be customised using standard development tools (eg. Java, ActiveX, Pwersoft's Powerbuilder, Microsoft Excel, Visual Basic and Visual C++). It enables GIS data to be shared in a secure, read-only environment that protects the data. It provides multi-media support enabling raster images, video and audio to be linked to the GIS.

A key advantage of the software is that it enables multiple data warehouses to be accessed simultaneously[44]. Unlike any other GIS Web mapping software GeoMedia enables multiple GIS data sources to be accessed, served, merged and aligned - all on a single desktop platform. Many types of data warehouses can be accessed as it supports Open Data Connectivity (ODBC). Multiple connections to various databases can be constructed easily via a wizard within a single session. In addition, it performs an automatic projection transformation to register the data to a common reference system. The ability to support multiple data type connections means that GeoMedia can integrate MGE, FRAMME, ARC/INFO and Microstation data in a single environment. Within one window, several disparate data types can be viewed or used as input into a spatial query. Geographical data from CAD drawings, GIS files, attribute databases and raster images can be integrated. Geomedia also supports a bi-directional linkage to Oracle's Spatial Data Option[45, 46]. This compatibility enables a widespread access to spatial and attribute data. Given that the local municipal system's RDBMS is Oracle this represents an additional advantage in terms of ensuring compatibility between the various local systems. Most GIS Web Mapping application software have extremely limited, if any analytical facilities. The polygon and linear analysis facilities in GeoMedia include all the basic GIS spatial analysis tools such as: buffering, dynamic segmentation, topology-based queries and thematic mapping.

Applications of Geomedia

GeoMedia has been implemented to create the city of Belgium street information URBIS database produced by the Service Communal de Belgique[47]. Other applications for public counter query[48], land developers[49] information service, shop window for commercial data vendors, enterprise intranet are discussed by Intergraph (1996). Some of these applications would be particularly useful to local government in the CMR[50].

The MGE-MapInfo Configuration

A second possible system configuration for implementing the Bi-level model is the MGE-MapInfo configuration. MapInfo represents a commonly used platform in local-government, it is compatible with MGE and can be extended to have Internet capabilities.

MapInfo has been used widely in local governments for crime prevention[51] and tracking, emergency response, community relations[52] and infrastructure and planning and support applications[53] (Sullivan-Liscomb, 1997). With respect to the implementation of the Bi-level model, MapInfo can serve as a basic data-capturing tool at the local-level. Once hard copy maps have been digitised on the main MGE system, the warped bitmaps can be used as backdrops for basic digitising in MapInfo. It's strength in terms of serving as a data capturing tool however lies in assisting with the capture of attribute information. A second key advantage lies in the ease with which simple queries and thematic maps can be produced rapidly. The applicability of the package for local level informal settlement upgrading work is evident from the Belo Horizonte case study. MapInfo has also shown to be an extremely useful "interlinking program" by which to transfer data from one GIS system to another while retaining topology and attribute information (chapter 6). The fact that the MGE system is fully compatible with MapInfo (an in-built two way translator is available in the MGE system), has enabled large amounts of data to be imported from the City Council GIS system onto the UCT Urban Management GIS facility. Thus it seems that MapInfo can have a very definite role in terms of supporting the MGE-GeoMedia configuration for interfacing the metropolitan-database with local-level systems. In terms of the Internet capabilities of MapInfo, initially, this was facilitated through a product called ProServer, which together with MapInfo had to reside on the server. In this configuration data was distributed by screen captures. The ProServer software was subsequently replaced by MapXtreme. Again in this case MapXtreme must reside on the server.

8.6.2 Linkages between the metropolitan-level and local-level databases

Basic linkages

Three types of connections are envisaged between the main metropolitan-level database and local-level databases. These linkage types are dictated by the GIS capabilities of the local authorities or other local organisations involved in the development of the local-level databases. In addition, the linkage types may be used to define the database development responsibilities and the location of the individual local-level databases. These connections can be described simply as linkages between the metropolitan-level project on the main system and local-level databases on:

1. the main system intranet
2. remote client machines with significant data capturing and processing facilities
3. remote client machines with very limited data capturing and processing facilities

In the case of the first linkage type, there is no computer facility situated locally (ie. at the informal settlement). Data may only be available to the community by visiting the computer facilities of adjacent informal settlements or from a visiting social worker carrying a laptop. In the case of the second linkage type, the developers of the local database are actively involved in the data capturing process. In the case of the third linkage type, the local level database for a informal settlement is largely constructed on the main system and accessed by local client PCs. Other software may be used locally eg. MapInfo. The key difference between this linkage and the first is that the data is accessed and possibly complemented by local computer facilities. For both the second and third types of linkages pre-processed data outputs from the main system may be utilised by the local systems in such manner as to accelerate the data capturing process. These outputs could include warped maps and images for the second group of database developers. In the case of the third linkage type, a basic GIS vector database template in MapInfo format would enable the local staff to attach the attribute data. Thus the developers of the main system must not only create and update the metropolitan-level of the informal settlement database, but should also act a support service for the settlements faced with very limited computing facilities. Detailed infrastructure data should reside on the local databases. Furthermore, attribute can be captured on existing desktop software, such as Access or Excell, within the local-level areas (eg. by local authorities) and subsequently imported into GeoMedia or MapInfo.

The nature of database connections is simpler in the case of databases residing on the main system intranet. Here a direct warehouse connection can be easily established via the GeoMedia wizard. In addition to the main system metropolitan-level database which resides on the high-end platform (MGE) other MGE projects may also be present for local-level databases on the main system intranet. This would be the case for informal settlement areas with very limited or no computer facilities. Such projects may also be created for settlements with limited data capturing and graphics processing facilities. In addition to these MGE projects customised Geomedia local-level databases would probably also be present on the main system. Needless to say, in the case of the first type of linkage, data transfer to and from the community will rely on community participation based methods. Standard workshop and interviewing techniques may be applied to obtain social-economic information. Most of the data capturing in this case will involve hard copy maps and aerial photography plots. The community can indicate their viewpoints on plots showing the local topography and cadastre and proposed interventions. The applicability of the local-level databases is discussed in section 8.8.

Linkage accessibility environments

The basic linkage types described above can be created using the GeoMedia Warehouse connection utility. Using the concept of a Warehouse connection these linkages can be redefined in a manner which reflects the varying degrees of accessibility of each Warehouse. The linkages can be seen to extend across four intranet- / Internet-based linkage accessibility environments. These are:

1. the corporate intranet
2. an Internet environment, which contains GeoMedia-based local sites
3. an Internet environment, which contains non-GeoMedia-based local sites, and
4. an Internet environment, which contains all other types of software sites

The first linkage type refers to linkages that can be created easily within an intranet environment. Using the in-built tools available within GeoMedia, warehouse connections can be made directly to the following software systems: ArcView, Arc/Info, Framme, Mge, Mge Segment Manager (MGSM) and Oracle (Spatial Data Option). The second linkage type extends the linkages to databases that can be directly linked to on the Internet. The third linkage type (ie. second Internet environment) holds non-GeoMedia-based informal settlement upgrading databases. These databases may reside in software environments such as MapInfo, REGIS and AutoCad. They are less accessible in terms of interfacing than sites on the first Internet-level, as a direct warehouse connection cannot be established. Instead the application of specialised conversion or server utility programs is required to create an interface to the data sets. The nature of a linkage to a local-level informal settlement database site may shift from a type 2 to a type 1 connection as further GeoMedia-based software is created to support these packages.

The fourth linkage type category contains the majority of the databases developed by government institutions such as: the Agriculture Research Institute, the Department of Water Affairs, municipal GIS systems and the Council for Scientific and Industrial Research (Watertek, Transportek and Enviromentek). These systems are based on ArcInfo and can be accessed through the Internet by creating a GeoMedia to ArcInfo Warehouse connection. It through this fourth linkage type that the majority of potential the sectoral models (see chapter 6) could be linked to a Bi-level model database.

The development of the databases in these various network environments occurs at different times and paces. Thus the time at which the linking of the main system to the remotely situated local and sectoral model databases takes place will vary as each environment has different interlinking potentials. . Nevertheless, it appears sensible to aim to develop the linkages in a progressive manner such that the connections to the most easily accessible databases (ie. those residing on the intranet) are made first. This should then be followed by connections to databases in the first and second Internet environments. The connections to the databases in the third internet environment should occur last or for specific projects only as required - as the sectoral model databases represent essentially "references extensions" to the main database model.

Evaluating linkages to local authority databases

In order to evaluate the possibility of creating Internet-based linkages to local authority database in the CMA, it is useful to briefly consider the structure of a system recently proposed for the Khayelitsha Administration. It is clear from the configuration proposed for Khayalitsha that computer facilities are becoming more and more of a reality in local authorities in informal settlement-bearing areas. The original system configuration diagram shows that at least 12 computers and three file servers are present in the network. The computer facilities are distributed between the Administration Complex in Khayelitsha and the NBS Building in Belville. No connection exists between these two networks. Despite this, the system clearly has been designed to support Internet connectivity-based software packages. This is shown by the network technologies that have been employed[54]. This implies that once the appropriate connections have been established, information can be placed on and extracted from the Internet using this system. The possibility of having Internet-based linkages to local authority databases is further enhanced by the fact that certain Internet-based GIS products are provided with free viewer software. Two factors that would greatly influence the creation of linkages to the Khayelitsha Administration database are:

- the cadastral approach to GIS which continues to prevail in local government, and
- the selected software platform (AutoCAD GIS)

The cadastral approach being followed in the development of a GIS database for the Khayelitsha Administration implies that the informal settlement areas will be essentially omitted from the local authority database. This factor alone highlights the potential for creating mutually beneficial linkages between the local authority database and a Bi-level informal settlement database. A local authority may use such linkages to extract data on settlements in and around its jurisdiction. Similarly, a metropolitan authority may use such a linkage to extract detailed cadastral information on the formal areas surrounding an informal settlement. Such data can be used by city planners to place the informal settlements in the context of the formal city. With respect to the selected software, the Internet capabilities of the AutoCAD GIS software are limited in comparison to Geomedia. While the Geomedia software is capable of accessing AutoCAD warehouses it is not clear whether the reverse is possible.

8.6.3 Security

With respect to the metropolitan-level informal settlement database, data security is viewed as less of an issue, as one of the main objectives of the system is the dissemination of information for informal settlement upgrading purposes. With respect to the local-level databases, some communities may express concern on having the results of detailed social interviews available as public domain data. In the case of the sectoral model databases, only a small portion of the database may be relevant to an informal settlement upgrading project. The bulk of the data may be corporate or project specific in nature and may have involved a high data capture cost. These factors require that any system designed for the implementation of the Bi-level model must have an in-built security mechanism.

The issue of security can be addressed both on the high-end and the low-end platform. In the case of the high-end platform, the security is maintained by customising the project environment that is accessed. On the low-end platform, security is maintained by varying the nature of the connection that is used to link different data warehouses.

When defining the schema of a project on the high-end MGE system, the RIS Schema Manager utility provides a number of ways to control access to the database. It is possible to specify passwords for accessing the schema, data dictionary and database. In GeoMedia, the nature of the connection can be changed by:

1. modifying the status of the connection, and
2. specifying a connection filter

Access to the database can be controlled by changing the status of the connection to open read only, open read / write or to closed. A connection filter defines an area in a GeoMedia map window (Intergraph Corporation, 1997c). When a connection filter is applied to a warehouse, only features in the defined area are displayed and accessible when you add them to a map window. A connection filter is particular useful when one is connecting to a large data set, but one is only interested in a specific area. Once the boundary of a connection filter has been specified, spatial operators (such as overlap and inside) may be used to define the relationship between the filter and the data.

8.7 EXTENDING THE METROPOLITAN-LEVEL OF THE DATABASE

8.7.1 Potential raster and vector data sources

Once potential source of raster data is the Surveyor General. The imagery records for a large number of aerial surveys exist dating from 1933. Using these images it would be possible to trace the development of the backyard shack bearing areas, site and service areas over the last 66 years. One could trace the origins and growth of each settlement from the beginning with the aim of understanding of the dynamics of settlement growth processes.

8.7.2 Potential attribute data sources

A preliminary guideline for the appropriate data types can be established by examining existing systems. At the metropolitan-level the Gauteng Municipality GIS provides an indication of the basic data types required. The attribute data included in this database are the town name, location, administration, area, topography, geology, population, density, plot information, access, employment and the authority's current development plans. In a number of cases, the information appears as a description, as opposed to being a single value or character string. The authority's current development plans are broken down into the number of new constructions, number of upgraded, reticulation, internal bulk and external bulk services. The data is subdivided in to annual figures and into total costs for new construction, upgrading, expanding and rehabilitating. The bulk and internal services considered are as follows: water, sanitation, roads, drainage, solid waste and electricity. The internal services considered include also: schools, clincs and other features. In addition to these preliminary guidelines, is possible to identify other potential attribute data sources by surveying previous studies on informal settlements in the CMR. These are discussed below.

8.7.3 Additional data sources

Socio-economic / demographic data

A brief overview of the local literature revealed that there were only five potential demographic data sources:

- statistical and demographic data collected by the City Council (1994, 1997)
- population estimates collected by Van Zyl (1993, 1995)
- MacroPlan (1997)

The Cape Town Metropolitan Area (CMA) study (City Council, 1994) provides data for nine informal settlement areas[55]. A total population of 735 000 was estimated for the informal settlement areas in the CMA. Age-sex structure diagrams for the various populations are presented. None of the informal settlements areas have been delineated on a map, which makes a spatially constrained comparison with the data acquired in this study difficult. Other data available in this source include: the occupational and industrial distributions of the metropolitan population, the frequency distribution of personal income (per annum) and the level of education in the metropolitan population. A comparison of the total population estimate for the Metropolitan Area quoted in the City Council (1994) and Van Zyl (1993) studies with a more recent study by Van Zyl (1995) suggest that the older data sources are unreliable[56].

A second potential data source is a socio-economic report by the City Council (1997) on Langa, Guguletu and Nyanga (Lagunya). This report provides some basic guidelines to initiate the development of a socio-economic database for this area. Lists of the members of the Development Committees and RDP forums, as well as the organisations active in these three areas are listed. Details such as the name, address and telephone of the various members are listed. This type of information forms the basic information required to initiate community participation work in a settlement. The information in this report is out of date, however, similar future publications can provide the beginnings of a community participation database. The second set of information in this report represents demographic statistics for the three areas. The low resolution of this data and the manner in which it is presented prevents its application in a metropolitan level database. At a metropolitan-level the identity of individual informal settlements is maintained. In contrast, the report provides data for a small number of informal settlement regions within the CMR. Khaylitsha and Guguletu, each of which contain a number of informal settlements have only single data values in the report. Thus the report provides data that would be more suitable for a regional layer database. Despite these constraints, this report provides a rough indication of a number of variables for the Khayelitsha, Nyanga and Guguletu areas. These include: the percentage of household heads, level of education, monthly household income, income earning and activity. The information on socio-economic statistics of the household was extracted from (Mazur, 1995), which in it self represents a regional sample[57].

The Van Zyl (1995) data provides population statistics for the White, Coloured, Asian and African population groups for 12 metropolitan districts. The data is presented for informal settlements, distinguishing in some instances between the backyard shack, free standing shack, formal, site and service and transit camp figures. This data could also be entered into the metropolitan-level database. The main limitation of this source in terms of its analysis potential is that the majority of the settlements are only represented as point locations.

A fifth potential socio-economic data source that was considered is a report by MacroPlan (1997). The MacroPlan document essentially provides a visual illustration, the development background and present issues for a number of settlements in the CMR[58]. A small section on the iSLP areas is also present. Of the 50 - 69 areas mapped for the metropolitan region, it is possible to extract some information from the MacroPlan report (1997). An advantage of this report is that it provides aerial photography and descriptions for the informal settlement areas. However, the photography has a scale that illustrates the shacks as pinpricks. This reduces its potential for scanning for 1994 backdrops.

The Census data for 1997 was not available at the time that the analysis was carried out. Further more, the above data sources seem too coarse to be of use even at a metropolitan-level.

Informal settlement upgrading data

Three sources identified for potential attribute data on Informal settlement upgrading data were the World Bank (1993), ISLPs (1996) and Macroplan (1997). With respect to the first of these, the Urban Sector Reconnaissance World Bank Mission report (November 1993) provides some guidelines on the types of data required for infrastructural services upgrading applications at the metropolitan-level. This report also provides some guidelines for financial modelling of the upgrading process on a metropolitan-level. Several technical settlement dossiers are included in this report[59]. Although the report is probably out of date it gives an idea of the attribute data required to represent the bulk and internal infrastructure services upgrading process. In addition, whereas the additional references discussed below provide some information for each of the settlements, these sources hold no information on the existing infrastructure services in the settlements. Detailed tables summarising the upgrading costs for each service in the informal settlements are also provided[60, 61]. The report also gives an idea of how vector data may be represented at the metropolitan-level of infrastructure upgrading applications[62].

The iSLP status report (1996), provides a source for information on the current status of upgrading and a number of structure plans. The structure plans have a greater relevance to local-level systems. For example it allows comparisons between the current and planned density distributions. However, the report as a whole provides information by which to analyse the iSLP upgrading initiatives on a metropolitan-wide basis.

The MacroPlan (1997) report may also serve as a reference for informal settlement upgrading data. The development plans proposed by MacroPlan for each settlement presented in the report. This data source thus provides the potential for evaluating the upgrading solutions proposed by a local consultancy / development agency. Scans of the locality and layout plans for each settlement (MacroPlan, 1997) have been entered into the exiting database. These images can be hyperlinked to the centroids of the various settlements on the metropolitan-level.

8.8 POTENTIAL LOCAL-LEVEL DATABASE APPLICATIONS

8.8.1 Disseminating information to the public

In addition to illustrating extracts from a Bi-level informal settlement upgrading database, GIS can be used to disseminate other types of information for local-level applications. In order to determine the applicability of the local-level database to a community, one must establish what types of data can serve as useful information for a community member. When considering local informal settlement upgrading related applications, one must ask the question: what choices with respect to the upgrading process does an individual have to make and what types of information could assist the individual in making these choices. By asking such questions, one can identify areas for further database development. For example, it would be useful to have information on:

1. the upgrading plans for a settlement
2. the sites available in the relocation area
3. the infrastructure in the area surrounding the relocation area
4. local political and other events
5. employment opportunities
6. housing alternatives

As a result of the upgrading process some may be families are relocated while others may remain in settlement that is to be upgraded. In case where the family may be able to remain in the same area were they currently reside, detailed information on the upgrading plans proposed for that area should be available. Where relocation is inevitable, a family may often have more than one choice of relocation site. In order to enable individuals to evaluate their options, information on the potential relocation sites should be available. Further more, information on infrastructure networks, the location of public services and amenities surrounding the relocation area should be provided[63,64]. In addition to providing information on upgrading and relocation issues, a local-level system can provide information to advertise and organise local political and other events in a community. The communication-based applications can also be developed specifically for assisting in dealing with the unemployment crisis[65].

Another area for providing information on is the various housing alternatives. For example information on which funds can be accessed by a family[66].

The majority of this data could be in the form of bitmaps and attribute tables. It is envisaged such an initiative would enhance the communication process between local organisations and communities. The local public would be empowered the not only in terms of establishing their rights, but also in terms of having easy access to information which would enable them to independently evaluate the various options available to them[67]. In order to ensure the collaboration of the various potential data capturing partnerships, the implementation of this process would have to attain support from higher levels of government. In view of the fact that the availability of such data would act as a medium by which to enable community members to make better informed decisions this proposal should have good chance for approval in the current political climate.

8.8.2 Using GIS as a platform for negotiation

In addition serving as a mechanism for disseminating information, an Internet-based GIS database can also be used as a tool for negotiation. One potential location for such a database is at the local authorities serving informal settlement area represented by the database. Using the GeoMedia database development tool, it would be possible to construct such a negotiation-based database. In the first instance, one can envisage that a warehouse would have to be constructed for each infrastructure type. Subsequent to this, a number of Geoworkspaces could be created for illustrating:

- upgrading proposals by local authorities
- upgrading proposals by consultancies
- upgrading proposals by the community
- problem areas detected by the community

By developing such an information infrastructure, the community leaders could be kept informed of: the latest local authorities development plans, and all the upgrading possibilities available from different consultancies. In turn, the local authorities could be kept up to date on the community's views and on the various consultancy options.

There are two key implications arising from implementing a local-level GIS database in this way. Firstly it can reduce the degree to which the engineering-based job market is monopolised by certain consultancies or contacts. Secondly it inspires a more collaborative planning approach towards upgrading an informal settlement. The community feels that it is inputting into the planning process as opposed to simply adding to the development of a database.

CHAPTER 9: APPLYING THE BI-LEVEL MODEL CASE STUDY 1: INFORMAL SETTLEMENTS IN THE CAPE TOWN METROPOLITAN REGION (CMR)

9.1 INTRODUCTION

In chapters 7 and 8 the prerequisites for the Bi-level model and the first step towards implementing the model (ie. the development of the databases) were addressed. In chapter 8 it was shown how the Bi-level model can be used to address the issue of GIS diffusion both in terms of linkages and in terms of local-level applications. In this chapter the applicability of the metropolitan-level database developed in chapter 8 is demonstrated through a series of comparisons with previous data sets and through the calculation of several variables that may be used to characterize informal settlements in the Cape Metropolitan Region.

Van Zyl (1995) comments on the uncertainty and differing results of existing shack count studies and highlights the need for reliable data for planning and projection applications[1]. In this chapter the results of the 1996 shack count are presented. This data is then compared with a number of previous studies (Van Zyl, 1995; Dewar, 1991; City Council, 1994 and MacroPlan, 1995) through a series of vector data overlays. The comparisons are carried out both at a metropolitan-level and at a smaller scale to enable vector overlay comparisons for the major informal settlement areas (Guguletu, Nyanga, Brown's Farm, Crossroads and Khayelitsha).

The settlement densities calculated on the basis of the 1996 data are used to generate a settlement density-based classification of the settlements. The shack count data are also used to obtain net growth rate and population estimates. The net growth rate data is subsequently used to highlight the key areas of growth in the Ikapa area. The chapter then considers two potential indicators for prioritizing the upgrading process in the Cape Metropolitan Region. The first is a minimum relocation analysis tool based on the existing sub-settlement densities and on the proposed planning densities. The second is based on a qualitative informal settlement spatial pattern analysis. The chapters ends by high-lighting the need for following the Bi-level approach. In the last section (9.9) the critical need to utilize the metropolitan-local-level linkage defined in sections 6.7 and 8.6.2 is discussed. This section illustrates that while metropolitan-level analyses, such as the density-based analysis in section 9.8.1, can be useful as a broad-based planning tool there remains a critical need for developing linkages to local-level informal settlement databases. Such linkages are essential in order to place strategic-level planning into the context of reality.

9.2 PREVIOUS STUDIES

A number of previous studies of informal settlements have been carried out in the Cape Metropolitan Region. These have all been considered in this work and are classified as follows:

- Dewar et al. (1991)
- Cape Town City Council (1994)
- Van Zyl (1995)
- MacropPlan (1995)

The contents of each of these studies have already been discussed in section 8.7.

The study by Dewar et al. (1991) indicates that thirty-seven informal settlements were already in existence in the CMR by 1991 (see appendix 6 figure 1). The squatter statistics report by the Cape Town City Council (1994) provides additional information on some of the smaller informal housing structures not considered in Dewar (1991) (see appendix 6 table 1). The total number of informal housing structures within the Cape Town Municipal area (excluding structures in the major informal settlement areas) listed by the City Council (1994) was 958 [2]. In addition to the population estimates, density calculations are presented for formal housing, site and service and backyard shack areas. The shack count by Van Zyl (1995)[3] indicates that at least 52 settlements existed by 1995. In addition to providing some of the more recent shack count data on freestanding shack areas, the study by Van Zyl also provides the most recent information available on backyard shack- bearing areas in the CMR. The total number of backyard shacks and informal (freestanding) shacks listed by Van Zyl (1995) were respectively 15938 and 53336.

9.3 RESULTS OF 1996 COUNTS

9.3.1 Results

The informal settlements considered in the 1996 shack count are shown in maps 1 - 3 in appendix 5[4]. The creation of these maps and the delineation of the informal settlement boundaries has been discussed in chapter 8. The quantitative results of the 1996 shack counted are listed in appendix 6 table 2. It should be noted that the 1996 shack count data excludes counts for the backyard shack-bearing areas and that some of these results differ very slightly from a more recent recount based on the same imagery (Abbott et al., 1999). In appendix 6 table 2, the data for some of the settlements are presented for a large number of sub-settlements (eg Klipfontein Glebe, Blackheath, Trevor Vilakazi and Victoria Mxenge). This sub-divisioning of the settlements was carried out intentionally to enable more accurate area estimations. The MSLINK column in appendix 6 table 2 refers to the centroid number of the sub-settlement area in the GIS database. Also shown are the area (in hectares) and the density[5] (in dwelling units per hectare) for each sub-settlement.

The individual sub-settlement counts (iscounts) have been summed into a total shack count value for each settlement. A total area and an average density have also been calculated for each settlement area. In total 65 settlements and 59 868 freestanding shacks were mapped in the CMR. These settlements extended over a total area of 873.83 ha. The settlements with the highest and lowest shack counts were Victoria Mxenge (5171 shacks) and the Ottery and the Palm Tree Settlement (both with 49 shacks).

9.3.2 Methodology used in preliminary comparisons with previous studies

The settlements mapped in this study were compared to the previous settlement studies listed in section 9.2. In appendix 6 table 3 the results obtained in this survey are listed in conjunction with the shack count data reported in Van Zyl (1995), City Council (1994) and DeWar et al. (1991). The comparison was conducted by overlaying the 1996 data on the settlement location maps presented in different studies (figures 9.1, 9.2, 9.3) and by comparing the data in appendix 6 table 3. This comparison was carried out at a metropolitan-level was restricted to settlements within the Cape Metropolitan Region (CMR) boundary as defined in 1997. As a result settlements lying outside this area have not been compared (eg. Mbekweni, Paarl)[6].

The comparisons between the different shack count studies were conducted in the following order:

- Martinez (1996) and Van Zyl (1995)
- Van Zyl (1995) and Dewar (1991)
- Martinez (1996) and Dewar (1991)
- Martinez (1996) and City Council (1994)

The 1996 data was first compared with Van Zyl (1995) as the latter provided the most recent statistics on informal settlements in the CMR prior to the current study. The settlements listed in Van Zyl (1995) were then compared with those in Dewar et al. (1991) to determine if there were any previously detected settlements that had been omitted from Van Zyl (1995). This in fact turned out to be the case for a number of very small settlements. The 1996 data was subsequently compared with Dewar et al. (1991) and the City Council (1994) squatter statistics data to determine whether the settlements that were listed in Van Zyl (1995) had been previously detected or not.

9.3.3 Results of preliminary comparisons

<u>Martinez (1996) - Van Zyl (1995)</u>

- In Van Zyl (1995) a map for the metropolitan region and two larger scale maps for the Ikapa (1:35000) and Khayelitsha areas are presented. In figure 9.2 the 1996 survey data is compared to the informal settlements on Van Zyl's (1995) metropolitan map. A number of

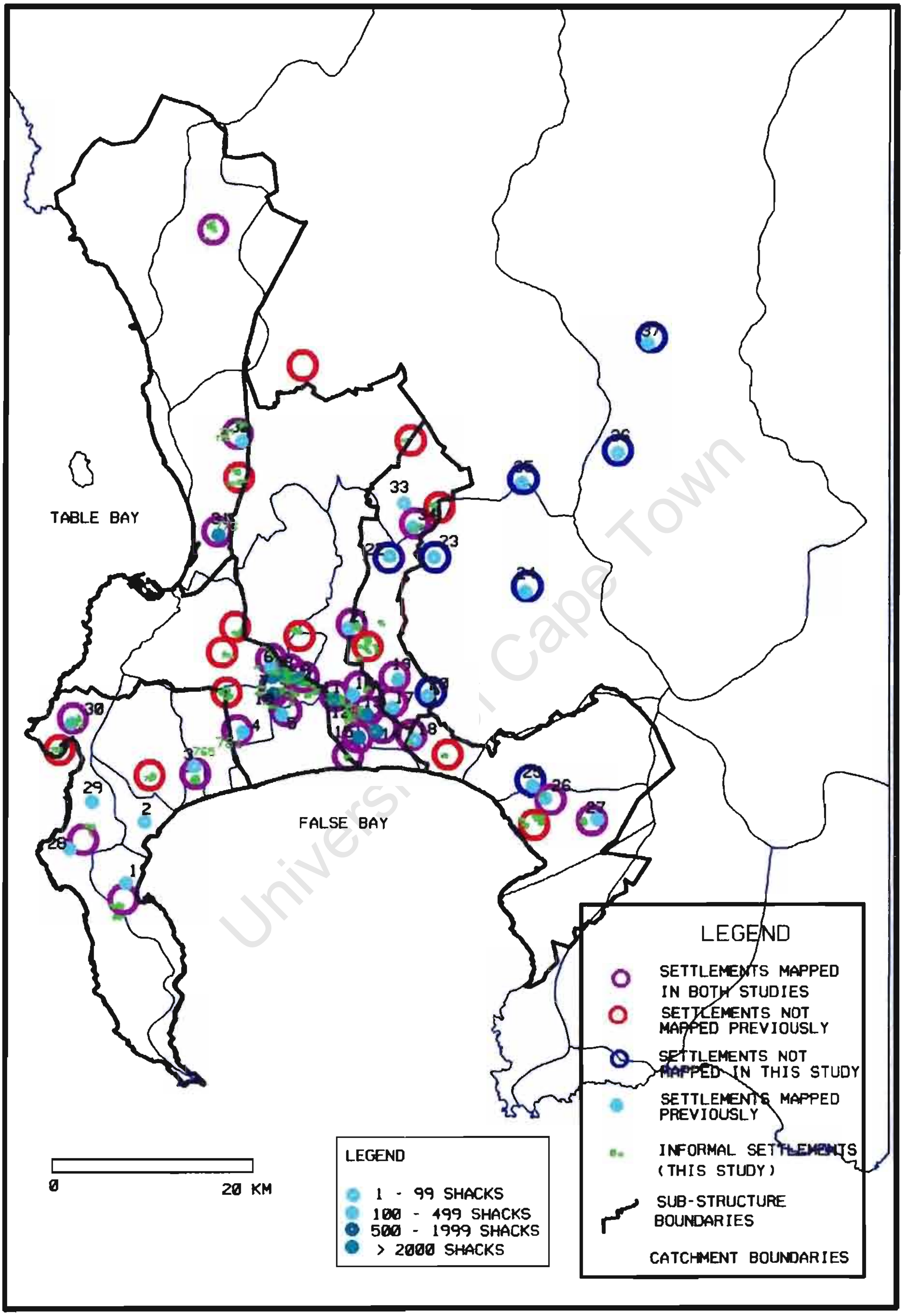
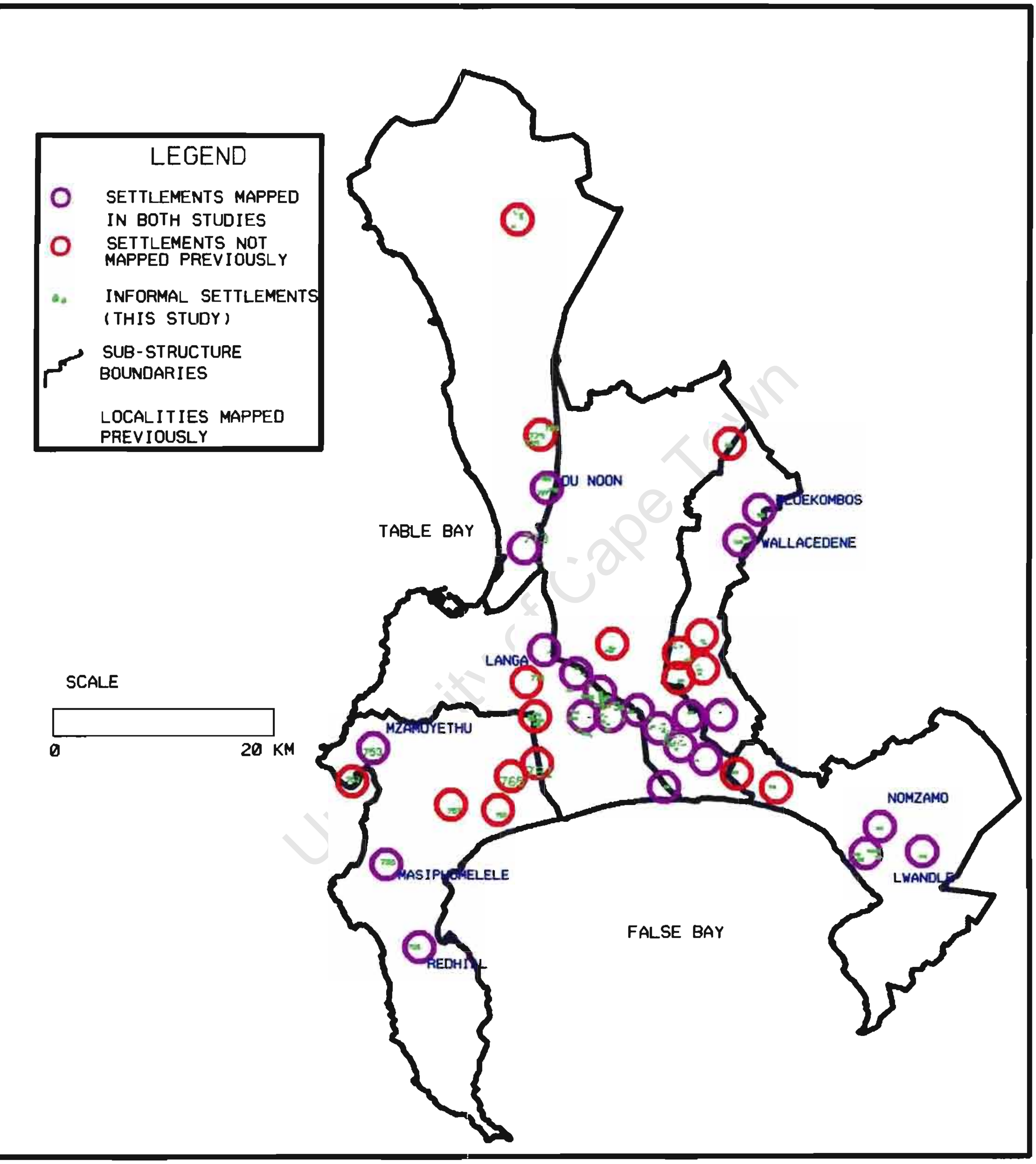


FIGURE 9.1 A COMPARISON OF THE DATA COLLECTED IN THIS STUDY WITH DEWAR ET AL. (1991).



GURE 9.2 A COMPARISON OF THE DATA COLLECTED IN THIS STUDY WITH VAN ZYL (1995).

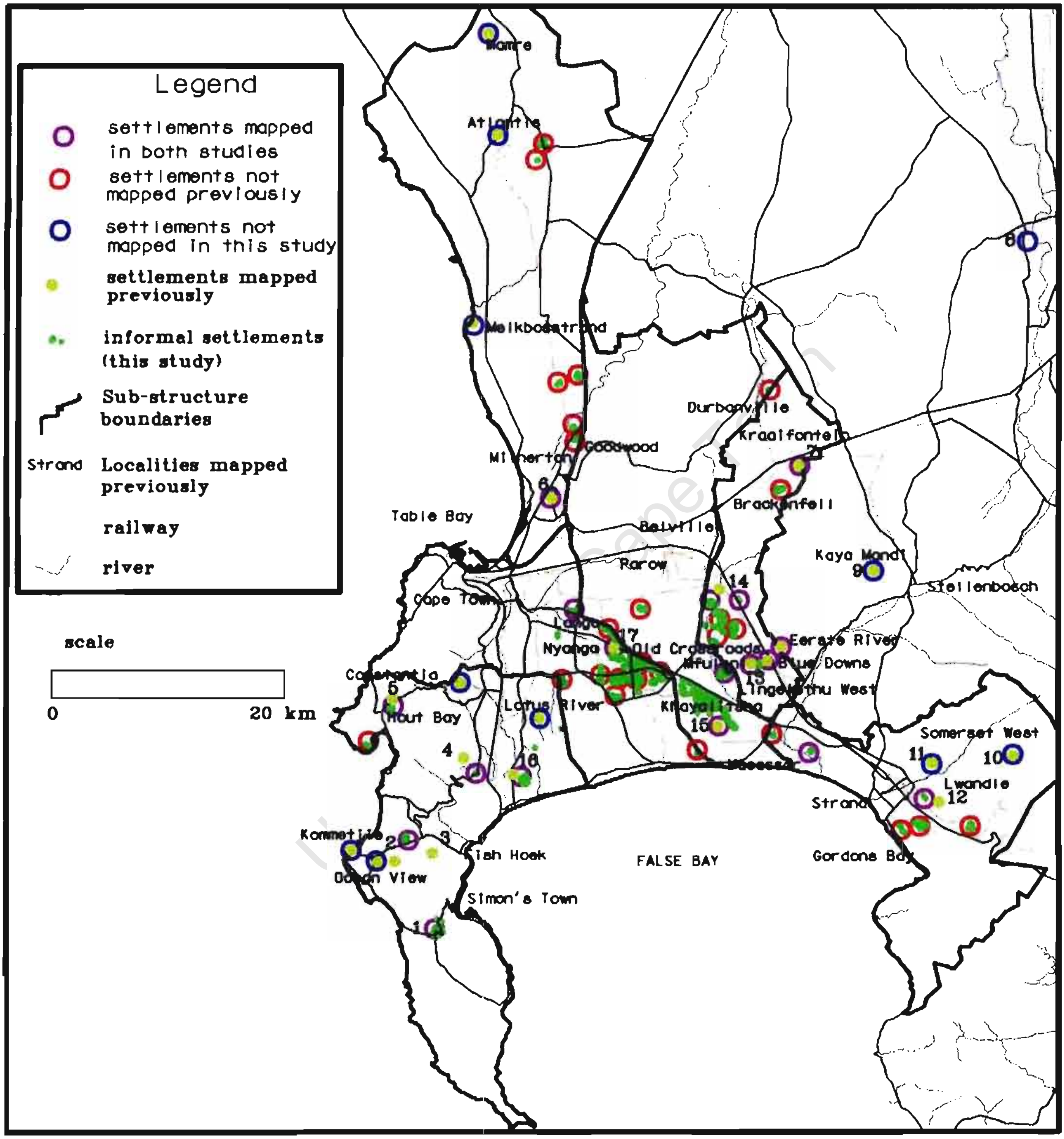


Figure 9.3 A comparison of the data collected in this study with MacroPlan (1995).

the freestanding shack settlements detected in the 1996 survey were omitted from Van Zyl (1995)[7]. This may be due to any one of the following reasons:

- The settlement was not picked up by the survey.
- The settlement did not exist at the time of Van Zyl's survey.
- The settlement did exist, but lay beneath the settlement size (ie. number of shacks) detection limit used by Van Zyl.

The settlement was situated in an area outside the previous Cape Metropolitan Region boundary[8]. In some cases either a different settlement name has been used or the shack counts for several settlements have been grouped under one area name. For example, the terminology "other informal settlements north of Milnerton" used by Van Zyl (1995) may be referring to Du Noon and / or other settlements. In other cases, such as the Kalanyoni settlement, Kiki (between the hostels), and an area in Guguletu referred to as "Between the hostel and bus terminus" in Van Zyl (1995), settlements have been omitted as they consisted only of backyard shacks on the 1996 imagery. Further more, although the backyard shack areas were not mapped in detail in the 1996 survey, it was possible to detect a number of backyard shack areas not listed previously in Van Zyl (1995)[9].

Van Zyl (1995) - Dewar (1991)

Settlements listed by Dewar et al (1991) but not by Van Zyl (1995) include: Fishoek, Vrygrond, Bush Estates, Weltevreden Valley[10], Kuils River (Antonies Bos), Macassar Zandvlei (Madala's Camp), Eerste River school site, Melton Rose Spandau, Belville Belhar Extension[11], Brackenfell, Stillehoop, Die Bos, Kommetjie, Vissershok and Joostenberg[12,13]. In total, Van Zyl (1995) omitted 16 locations previously listed in DeWar et al. (1991). Most of these settlements had shack counts below 100. It is not surprising that a number of the settlements detected by Dewar et al. (1991) do not appear in Van Zyl (1995) as a large minimum settlement detection limit (200 shacks) was used in the latter study. This comparison enables the existence of a number of the recently mapped settlements to be verified. It also enables the question of how rapidly are some of the smaller settlements growing to be addressed (section 9.6).

Martinez (1996) -Dewar (1991)

The 1996 survey data is compared with Dewar et al. (1991) in figure 9.1 [14]. The informal settlements mapped for 1996 (in this study) which do not appear in De War et al. (1995) include: Airport, Eastern Kayalitsha, Houtbay Extension 15, Michell's Plain / Tafelsig, Ottery, Raapekraal / Westlake, Tambo Village, Langa and Vygekraal. In the case of Langa, the 1996 survey revealed that two sub-settlements (Mpuku Park and Joe Slovo) existed in this area by 1996.

Martinez (1996) – City Council (1994)
This comparison was hampered by the fact that the City Council (1994) data set does not distinguish between freestanding and backyard shack-bearing areas. Nevertheless, the comparison enabled the verification of a number of settlements that were listed in the 1996 data but not in Van Zyl (1995). These settlements[15] were as follows (see Table 9.2): Mitchell's Plain / Tafelsig, Ottery, Pelikan Park, Philippi (Heinz Park), Vrygrond. Other settlements which were not mapped in the 1996 survey, but which appear in the 1994 City Council Squatter statistics report include: Vygiekraal stadium (Athlone), Maitland, Athlone, Malay Quarter, Diep River, Parkwood, Hanover Park[16], Retreat, Hazendale, Rylands, Strandfontein, Woodstock and Zonnebloem. Even though these settlements are small, the present study suggests that the rapid settlement growth rate in the CMR merits the mapping of even the smallest settlements. These settlements must be included as they reveal settlement growth points on a regional scale analysis.

Martinez (1996) - MacroPlan (1995)
The 1996 survey data is compared to the MacroPlan data[17] in figure 9.3 . In the Milnerton area, the MacroPlan reference recognizes the following settlements in addition to Marconi Beam: Du Noon, Doornbach, West Beach and Bloubergvlei. These settlements may be what was referred to as "other settlements north of Milnerton" by Van Zyl (1995). Other settlements listed in the MacroPlan report that were not picked up in the 1996 survey are the "Prison site"[18] and Kuils River[19] settlements.

9.3.4 Discussion on comparisons

A number of problematic issues arose when making comparisons between the 1996 data and the previous studies. These issues were largely due to the fact that previous studies often:

- do not present maps with informal settlement area boundaries
- differ in terms of the definition of area covered by a settlement
- do not differentiate between freestanding a backyard shack-bearing areas
- differ in terms of the nomenclature used to refer to the same settlements

One of the key difficulties facing the overlay comparisons is that many of the settlements referred to in the 1991 and the 1995 studies are not clearly illustrated on a map. Unlike in the present study where settlement boundaries and areas are shown, the previous studies simply illustrate the settlement as a point. In Dewar et al. (1991) the settlements are indicated as points on a 1: 500 000 scale map. In this case it was particularly difficult to verify the presence certain small settlements during the vector overlay process. Where settlement are boundaries are depicted, the definition of such an area may differ from study to study. In the case of Van Zyl (1995) the Crossroads area shack count includes the counts for Crossroads, Boys Town and Klipfontein Glebe.

Comparisons with previous studies are also hindered where previous studies have not clearly indicated whether the counts refer to freestanding or backyard shack areas, or whether a summation of the two types of shack areas have been presented. In Van Zyl (1995) the data on backyard shacks is presented separately from the freestanding shack data for the following areas: Guguletu (9981), Nyanga (2600), Langa (3286) and Crossroads (71)[20]. This enables quantitative comparisons to be made between the 1996 data and the 1995 data for these areas. However, in the case of Khayelitsha, for the vast majority of the settlements, the backyard shack data has not been separated from the freestanding shack data in Van Zyl (1995).

Another problem facing comparative analyses with previous shack counting studies is the variation the nomenclature used to refer to the same settlements. Some examples of these variations include: Somerset West / Waterkloof / Lwandle, Sir Lowry's Pass / Sun City / Nomzamo, Noordhoek / Masiphumele, Houtbay / Mzamoyethu and Vissershok / Brickfields. The variation in names for identical areas complicates the process of comparing shack counts for the same areas. There is also sometimes a duplication of a settlement name. For example, the Khaya Mandi area is referred to under the Stellenbosch MD and under the Lower Crossroads area in Van Zyl (1995, Table 2)[21].

9.3.5 New settlements detected

A total of 65 freestanding shack-bearing areas were mapped in the 1996 study (see appendix 5 map1). Previous estimates of the total number of settlements previously detected in the region have been 37 (Dewar et al., 1991) and 64 (Van Zyl, 1995). It should be noted that in the case of the Van Zyl (1995) study, the area of Khayelitsha has been sub-divided into 19 settlements. In the present study, the same number of sub-settlements were recognised in Khayelitsha (see appendix 5 map 3), however, the data has been listed as only 8 distinct settlements. Thus in comparison to Van Zyl (1995), the 1996 study has identified a total of 12 additional informal settlement locations in the CMR.

The comparative analyses in section 9.3.3 suggest that at least 7 new settlements were detected by the 1996 survey. The list of the minimum number of newly detected settlements includes the following areas (listed in brackets is the number of shacks in 1996):

1. Airport (369 shacks)[22]
2. Eastern Khayelitsha (53 shacks)
3. Ottery (49 (shacks)
4. Witsand (312 shacks)
5. Heinz Park / Philippi South (207 shacks)
6. Hout Bay Ext 15 / Hangberg (203 shacks)
7. The Palm Tree Settlement (49 shacks)

In the case of Heinz Park / Philippi South (3 shacks) and Ottery (1 shack) a small number of isolated shacks were previously detected by the City Council (1994). The present study indicates that by 1996 these isolated shack occurrences had grown into small settlements of 207 shacks and 49 shacks in size. The remaining areas listed above have not been listed by previous informal settlement studies.

9.4 DETAILED COMPARISONS FOR MAJOR INFORMAL SETTLEMENT AREAS

9.4.1 Methodology used in vector overlay-based comparisons

Before discussing the methodology it is appropriate to briefly refer the reader to several maps in the thesis that may be used for orientation[23]. The major informal settlement areas in the CMR are situated predominantly in the Ikapa and Khayelitsha. Firstly, map 1 in appendix 5 illustrates all the informal settlements in the CMR. Secondly, map 2 in appendix 5 illlustrates the settlements in the Ikapa (also referred to as the Cape Town Metropolitan Area). While thirdly, map3 in appendix 5 illustrates settlements in Khayelitsha. For a better understanding of the Ikapa area, the reader may also refer to figure 2 in appendix 6.

In terms of the methodology discussed in this section, detailed vector overlay comparisons for the major informal settlement areas in the CMR were carried out using the 1996 data and a data set acquired for 1995 from the City Council. The latter data consisted of detailed topographical and cadastral vector data covering the main informal settlement bearing areas in the CMR and was captured during November 1995. Thus the time difference between the 1996 and 1995 data sets is 7 months (November 1995 - May 1996). In the first instance an attempt was made to quantify the comparative process by extracting shack counts for each settlement in the 1995 data. This procedure was hampered by the fact that the shack data present in the 1995 data set is in the form of linestrings[24]. A number of tests were carried out to determine whether a conversion factor could be calculated for transforming the number of shack linestrings into the number of shacks. For a selected portion of Mkonto Square 106 linestrings were counted using the Microstation "display level usage" tool. By using the shack vectors represented by these linestrings, points were placed inside each shack. A total of 53 points were placed, thereby indicating that approximately 2 linestrings represented the equivalent of 1 shack. This suggested that since 1192 linestrings represented the whole of Mkonto Square, there should be 596 shacks. The 1996 data indicated 706 shacks, suggesting that this factor was acceptable provided the settlement had experienced a growth of about 100 shacks. As no obvious growth outwards is detectable from the vector overlay, one would have to assume densification had occurred. The test was repeated with Barcelona, where 695 linestrings were determined to represent the equivalent of 169 shacks, thereby suggesting a factor of 4.1. It is clear that the great variation in the calculated number of linestrings per shack prevents the application of such a conversion factor in this case.

Given the problems facing the quantification of the 1995 vector data, it was decided to simply overlay the two georeferenced data sets and thereby use the data to highlight areas of growth in a qualitative manner. Where the settlement growth has clearly resulted in an extension beyond the 1995 settlement boundaries, the number of new shacks (represented by the 1996 data) have been counted. While some comparisons have been made between the 1996 data and Van Zyl (1995), these two data sets are compared more comprehensively and in a quantitative manner in the discussion on net growth rates (section 9.6).

9.4.2 Guguletu, Nyanga, Brown's Farm and Crossroads

The Ikapa (also referred to the Cape Town Metropolitan Area) is comprised of four key informal settlement areas. These are Guguletu, Nyanga, Brown's Farm and Crossroads (see map 2 in appendix 5). The total number of shacks in the main informal settlement areas in the CMR are shown in table 4 in appendix 6. The informal settlement area boundaries in Van Zyl (1995) (see appendix 6 figure 2) have been used to ascribe each settlement in appendix 6 table 4 to one of the main informal settlement areas. From table 4 in appendix 4 it can be seen that the total number of shacks increased significantly from 1995 to 1996 in Brown's Farm (831 new shacks), Crossroads (1616 shacks), Lower Crossroads (387 shacks) and Nyanga (397 shacks)[25]. In the case of Langa, the 1995 shack count is greater than the 1996 count by 1356 shacks. This is due to the fact that the 1995 value represents a summation of freestanding and backyard shack counts, whereas the 1996 data represents only the freestanding shacks. Comparisons with Dewar et al. (1991) indicates significant increases in the total number of shacks from 1991 to 1995 in Brown's Farm, Guguletu, Langa and Lower Crossroads (see table 4 appendix 6).

The comparative vector overlays illustrated in figures 9.4 to 9.6 provide an indication of where the settlement growths (identified above) have taken place. A brief analysis of the 1995 - 1996 vector overlays clearly illustrates the influx of informal settlement dwellers in the northern section of Ikapa (Cape Town Metropolitan Area). In figures 9.4 to 9.9 the settlement growth areas extending beyond the 1995 settlement boundaries have been crosshatched. Shack counts for the crosshatched growth areas (based on the 1996 vector data) are shown below. In addition the total area of the growth sub-areas is listed for each settlement. In the case Guguletu, the overlays suggest that most of the growth has occurred along the northern and eastern margins of: Kanana (384 new shacks over an area of 10.2 ha), New Rest (164 new shacks over an area of 2.1 ha) and Barcelona (265 shacks over an area of 5.9 ha) (see figure 9.4). In Brown's Farm, the growth has occurred in an interspersed manner over 39 small localities within the settlement (see figure 9.5). This settlement provides an example of growth by settlement densification as opposed to

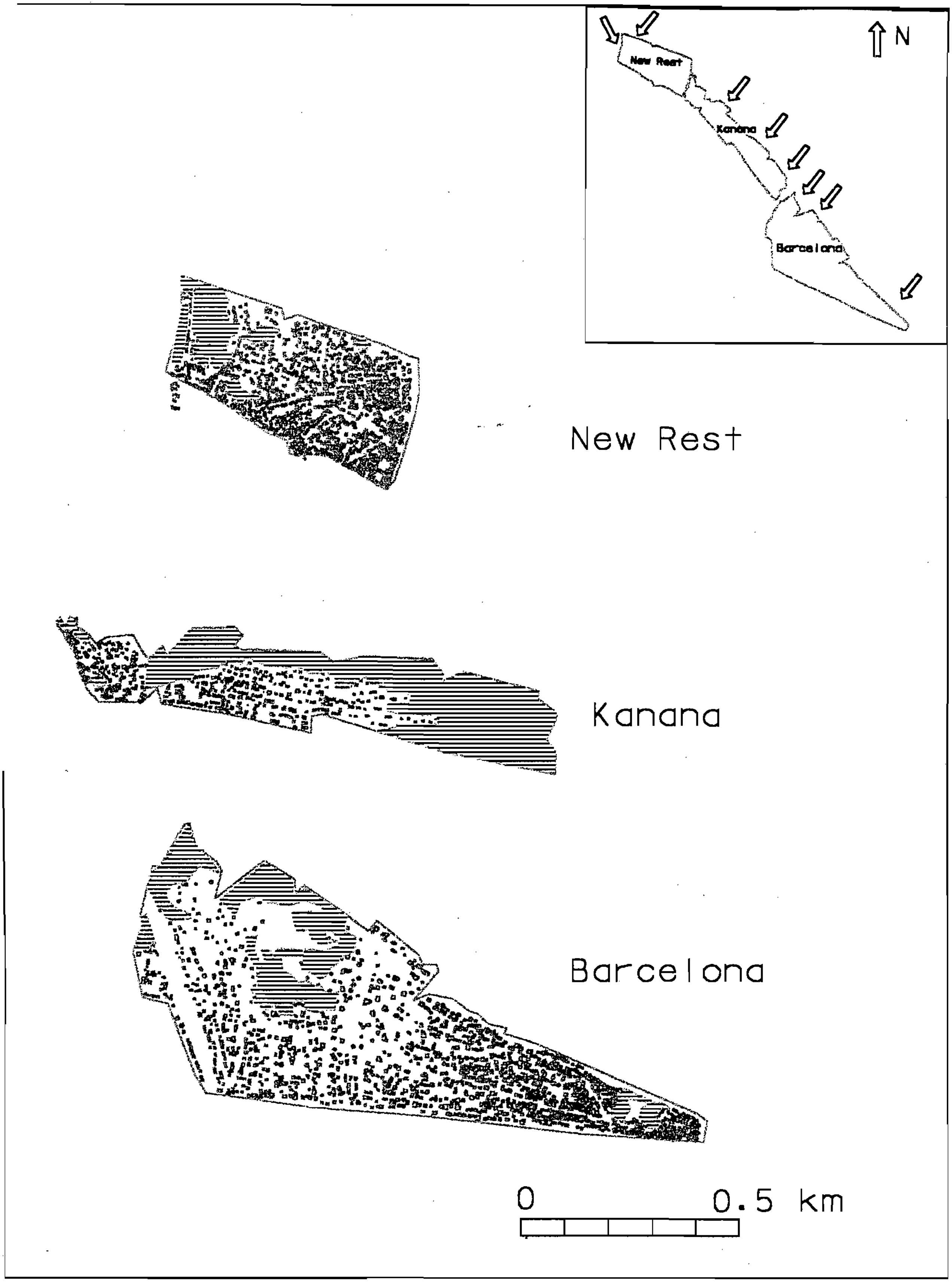


Figure 9.4 Vector overlays of the 1996 (this study) and the 1995 Cape Town City Council data sets for New Rest, Kanana and Barcelona. (Note that the settlements have been rotated for the digrams. The insets in figures 9.4 to 9.13 show the true orientation of the areas. The hachured areas indicate areas of growth.

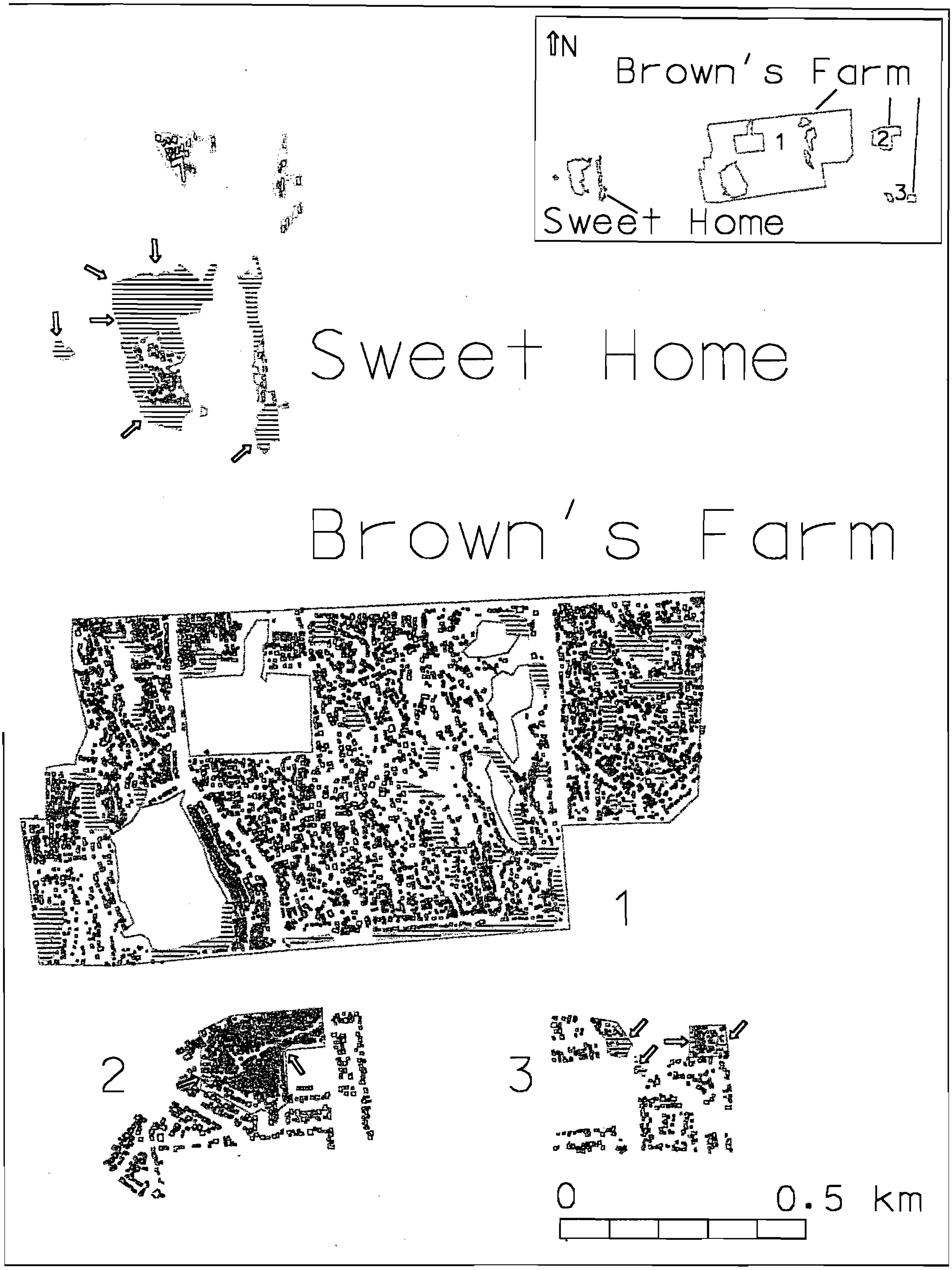


Figure 9.5 Vector overlays of the 1996 (this study) and the 1995 Cape Town City Council data sets for Brown's Farm and Sweet Home. The hachured areas indicate areas of growth.

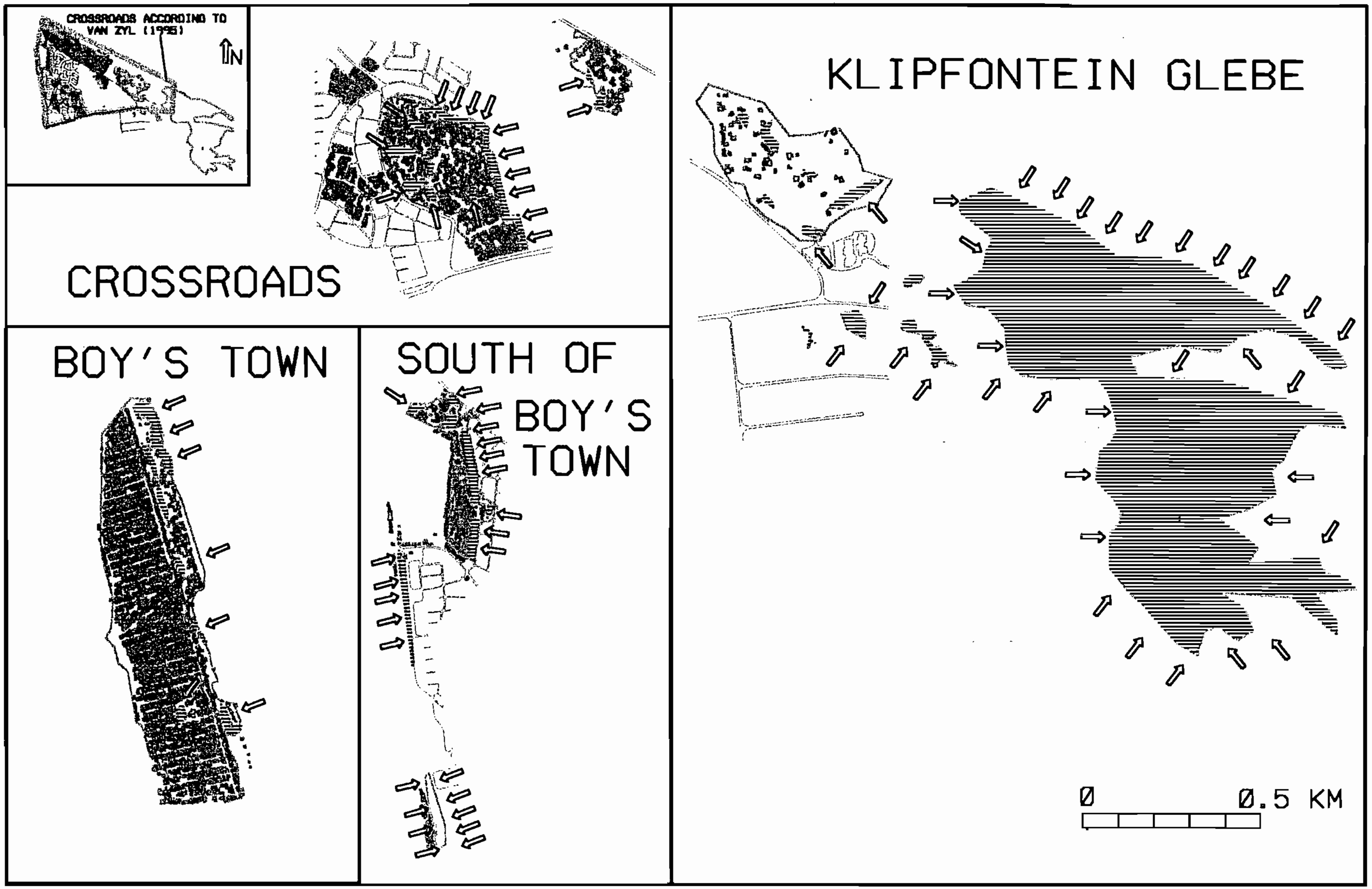


FIGURE 9.6 VECTOR OVERLAYS OF THE 1996 AND 1995 CAPE TOWN CITY COUNCIL DATA SETS FOR BOY'S TOWN, CROSSROADS AND KLIPFONTEIN GLEBE.

marginal growth process occurring in Guguletu. West of Brown's Farm, a marginal growth process is suggested by figure 9.5 for Sweet Home (260 new shacks over an area of 3.8 ha). Both the marginal growth and densification processes are visible in Crossroads and Boy's Town. In places linear sections of Boy's Town previously consisting of two rows of shacks have been replaced by three rows of shacks. The Klipfontein Glebe area lies significantly beyond the area boundary defined by Van Zyl (1995) for Crossroads (see insert of figure 9.6) and as such can be regarded as a new settlement. In summary, in the Ikapa area the following three settlement growth processes are indicated by the vector overlay comparisons:

- An extension of the existing settlement by marginal growth.
- A densification of the existing settlement by interspersed growth.
- A development of new settlements.

9.4.3 Khayelitsha

A detailed comparison for the Khayelitsha area is hampered by the fact that the majority of the shacks in this area are of the backyard shack type. As previously stated, Van Zyl (1995) does not differentiate between backyard and freestanding shack areas for all the settlements listed. A second problem facing the comparison of the two data sets in this area is the difference in settlement boundary definitions and settlement names[26].

A comparison of the two different data sets was made possible for some settlements through an overlay procedure. The 1996 shack point data was overlain on top of a warped image illustrating the settlement boundaries used by Van Zyl (1991) (see map3 in appendix 5) [27,28]. In this manner the enumerator area boundaries applied by Van Zyl (1995) for Khayelitsha could be mapped. New settlement boundaries were subsequently placed around the 1996 shack settlement data in the Khayelitsha area and the counting data was modified appropriately. In appendix 6 table 4, the settlements referred to as Trevor Vilakazi, Victoria Mxenge and Victoria Mxenge South in the 1996 survey lie within the Town 1 - Town 3 areas referred to in Van Zyl (1995). The key difference between the two studies is that few freestanding shack informal settlements were detected in the Town 1 area, and none in the Town 2 and Town 3 areas[29]. In the 1996 imagery these areas are dominated by backyard shacks. Only the Town 1 Village 1 area could be included in a freestanding shack comparison.

Despite the problems listed above, appendix 6 table 4 indicates that following areas have experienced a net growth in the number of freestanding shacks: Bongwani (628 new shacks), Greenpoint (100 new shacks) and Silvertown (769 new shacks). A new settlement consisting of 53 shacks was detected to this east of Khayelitsha and has been referred to as Eastern Khayelitsha. The vector overlays for the Khayelitsha area (figure 9.7) clearly indicate that a marginal growth process has taken place in Silvertown,

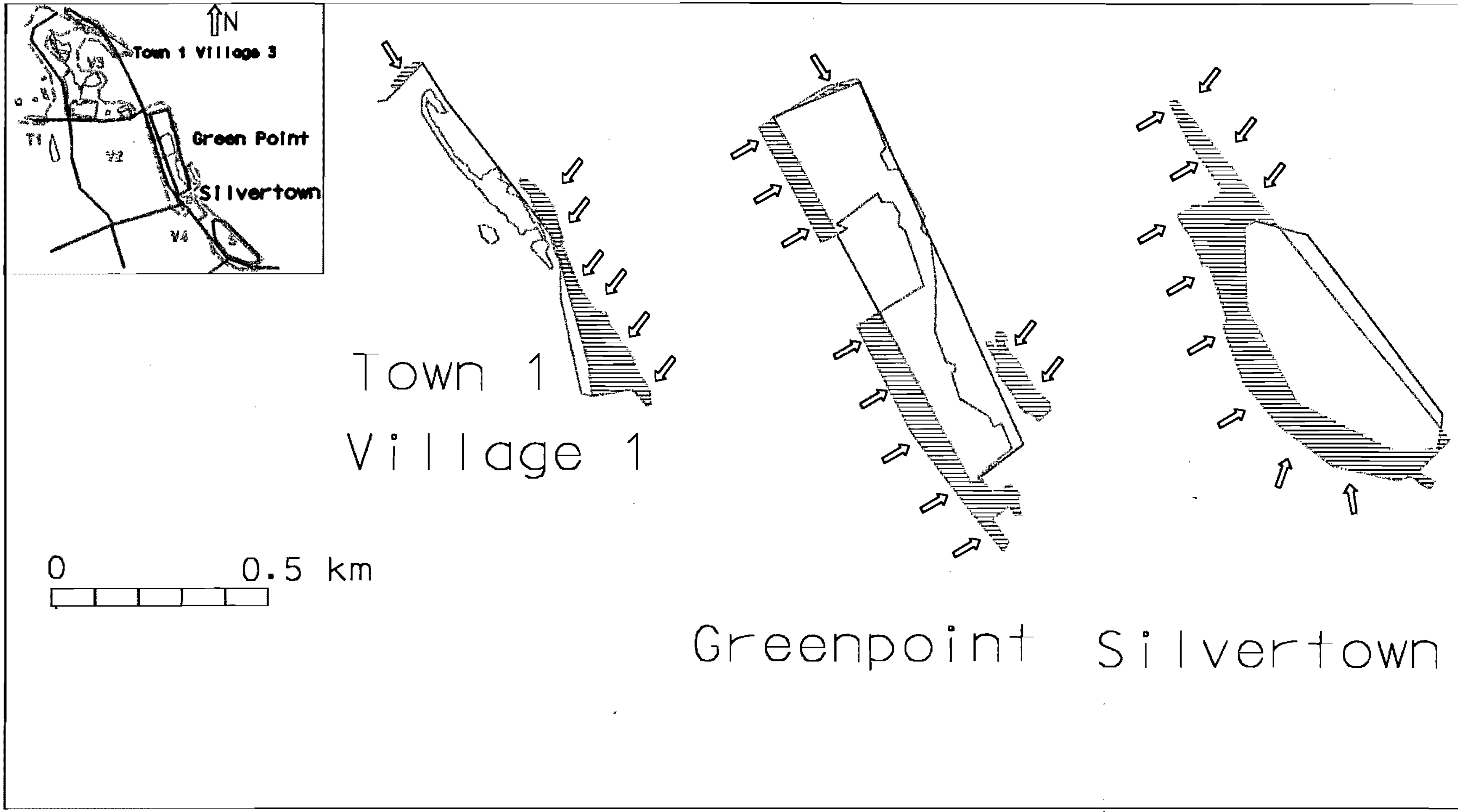


Figure 9.7 Vector overlays of the 1996 (this study) and the 1995 Cape Town City Council data sets for Greenpoint, Silvertown and Town 1 Village 1 (Victoria Mxenge / Trevor Vilakazi).

Greenpoint and in the area Town 1 Village 1 as defined by Van Zyl (1995). Green Point has been extended along the western and south eastern margins (650 new shacks over an area of 5.7 ha). Silvertown has been extended mainly to the western margin (2340 shacks over 8.5 ha). While the Town 1, Village 1 area has been extended mainly along the eastern
margin (307 shacks over 2.9 ha). The data for Khayelitsha suggests that the existing policy of site and service merely results in a shifting or dislocation of the informal settlement towards the settlement fringe. This can be seen in marginal growth that has occurred in Silvertown, Greenpoint and Town 1 Village 1, and in the growth of a new settlement (Eastern Khayelitsha) adjacent to Khayelitsha.

9.4.4 Other areas

In appendix 6 table 4, it can be seen that a net increase in the number of shacks occurred in Lower Crossroads (153 new shacks), Samora Machel (75 new shacks) and Sweet Home (279 new shacks). The vector data overlays reveal that settlement growth has occurred in Vietnam, Philippi South and in Lower Crossroads (figure 9.8). In Vietnam the overlays suggest that a marginal growth process has taken place (282 new shacks over an area of 3.7 ha). In the Lower Crossroads transition camp area, the growth[30] appears to have occurred by densification as the area of the settlement has not been visibly extended. South Vietnam, the growth process has led to the development of a new settlement namely, Philippi South / Heinz Park[31]. The Van Zyl (1995) data for Langa suggest that only hostels and serviced sites existed in December 1995. The vector overlays indicate that a marginal growth of informal settlement shacks occurred adjacent to a river in south eastern part of the area (figure 9.9).

9.4.5 Areas showing a decline in the number of shacks

In areas where there has been an apparent decline in the number of shacks (see appendix 6 table 4), the imagery suggests that backyard shacks have replaced freestanding shacks. Two settlements listed by Van Zyl (1995) which were not detected in the 1996 survey, are Kiki (575 shacks) and Kalayoni (131 shacks) (see Figure 9.10). These settlements are present as backyard shack-bearing areas in the 1996 imagery. Similarly, the Sikhumbule settlement (500 shacks according to Van Zyl, 1995) has been excluded from the 1996 data as no freestanding shack informal settlement was observed in this area on the 1996 photography. This area was upgraded and can thus be recognized as serviced sites in the 1996 imagery.

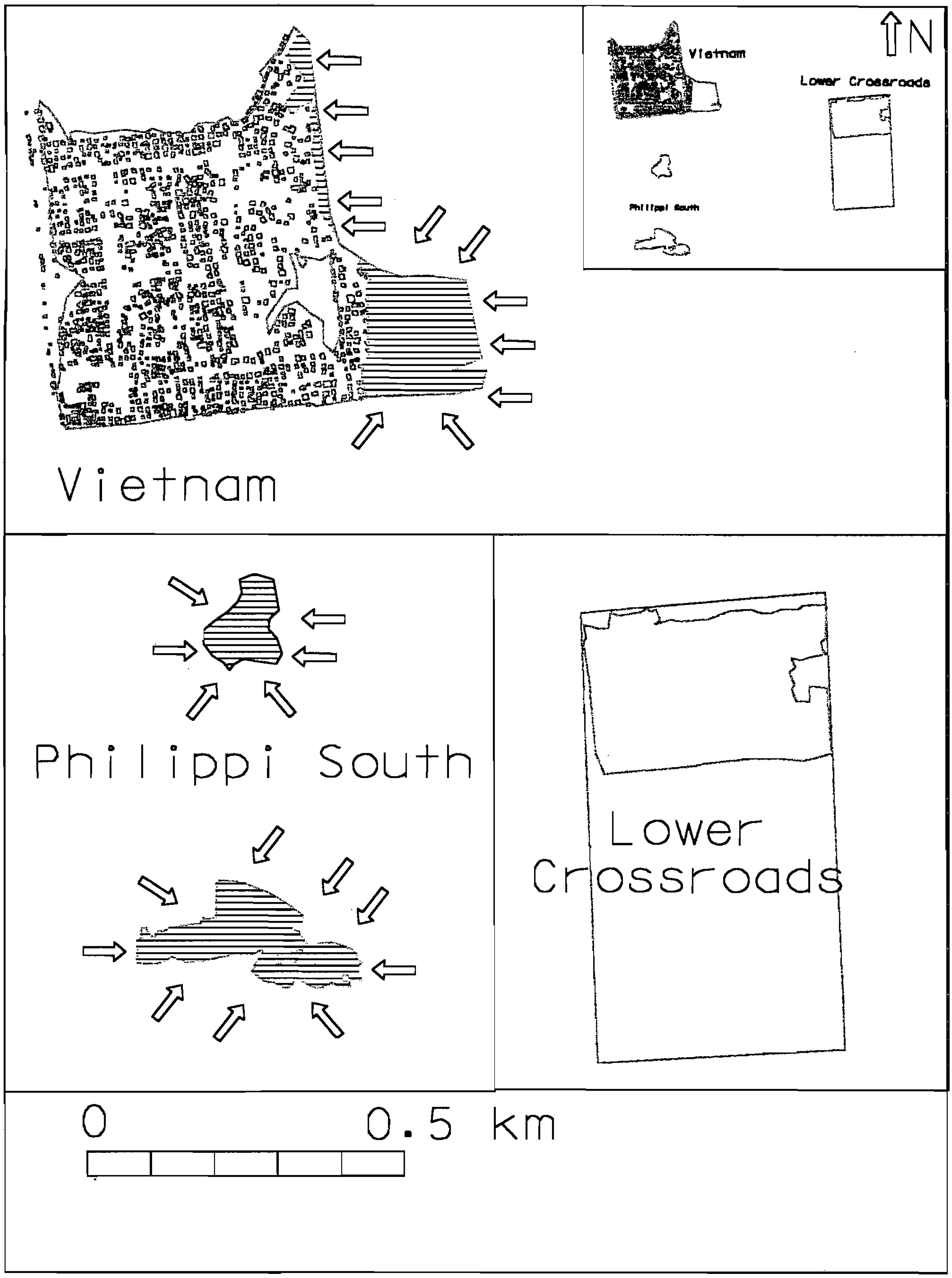
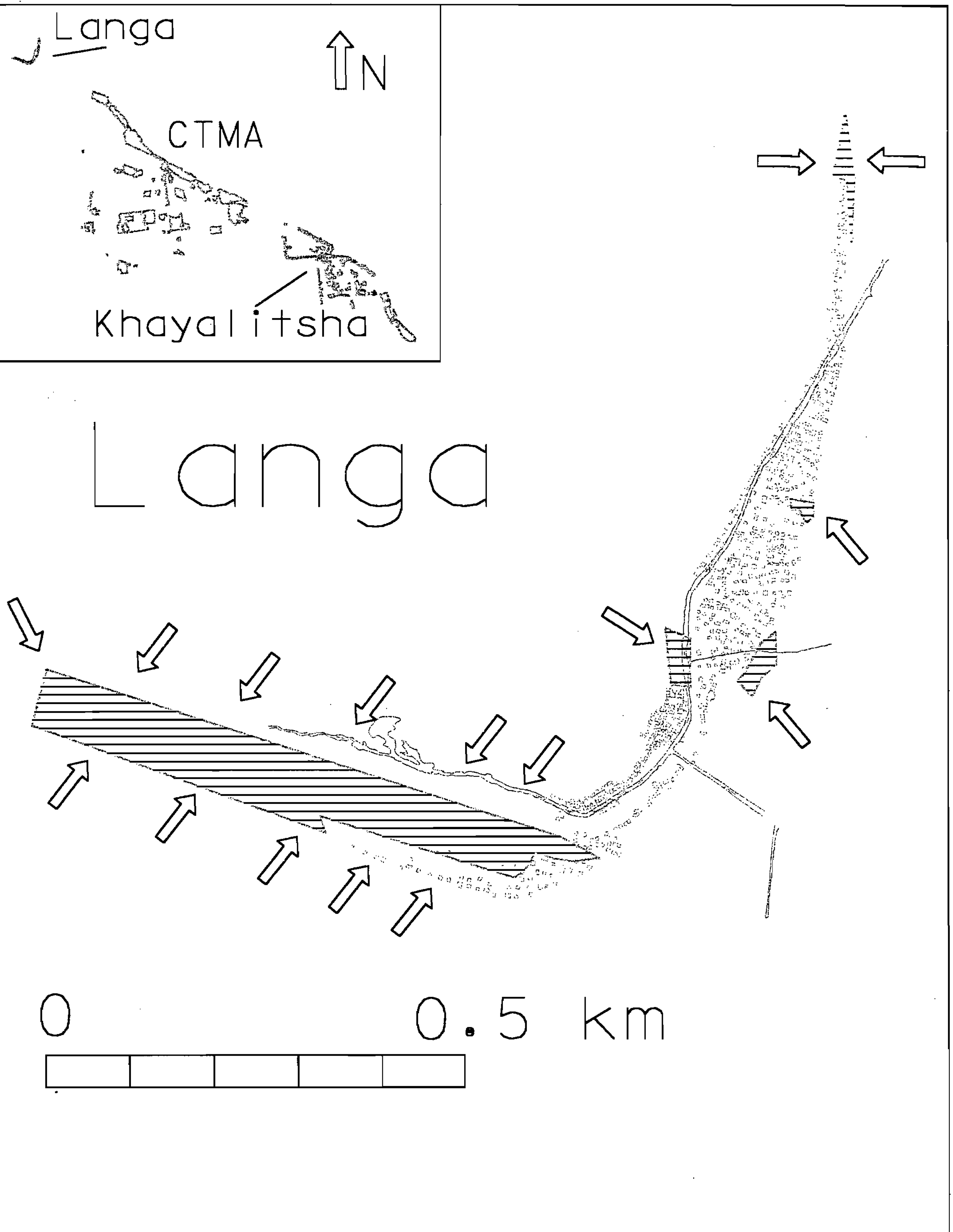
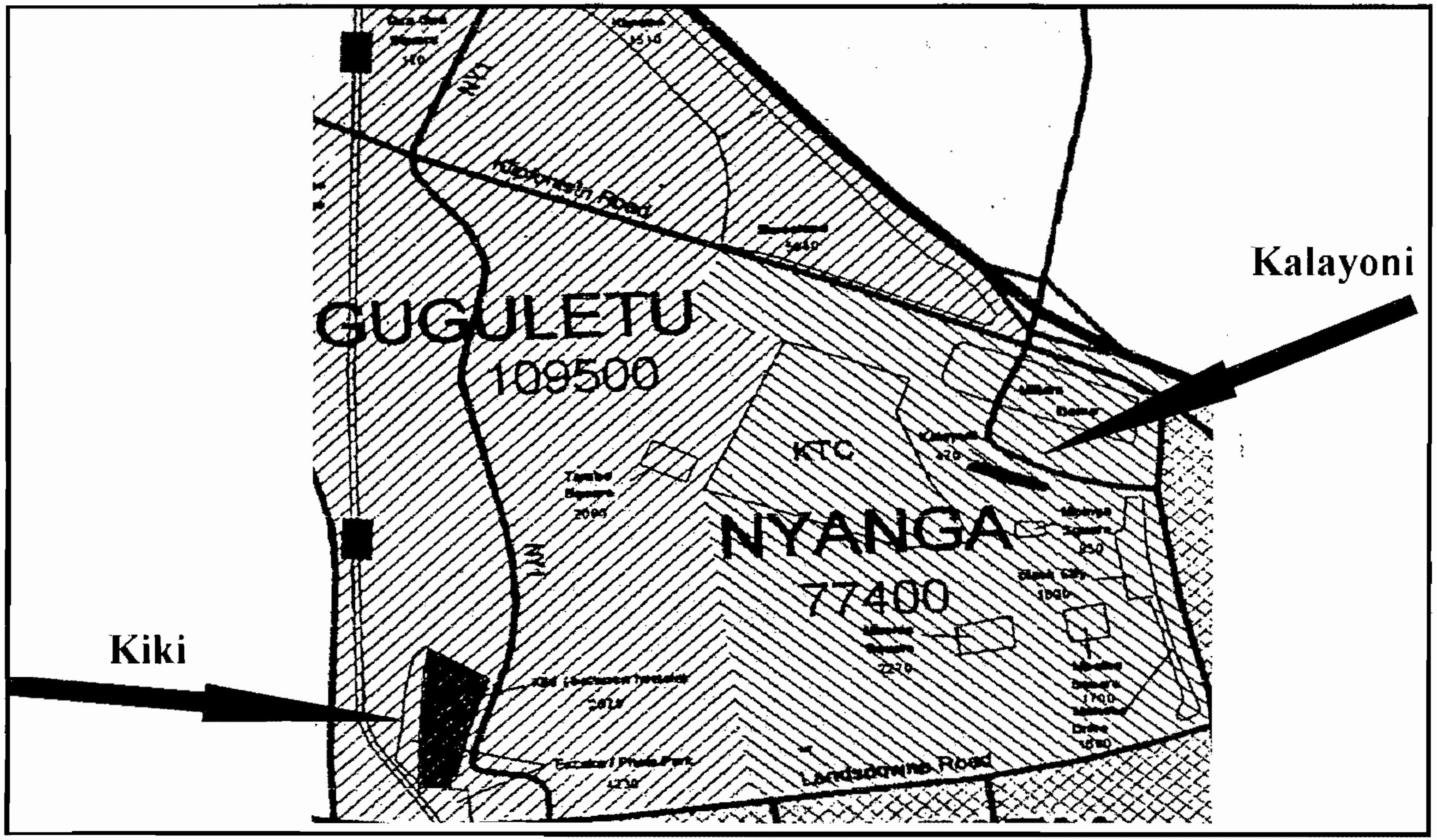


Figure 9.8 Vector overlays of the 1996 (this study) and the 1995 Cape Town City Council data sets for Vietnam, Philippi South and Lower Crossroads.



igure 9.9 Vector overlays of the 1996 (this study) and the
995 Cape Town City Council data sets for Langa.

Figure 9.10 Freestanding shack areas listed by Van Zyl (1995), which were not mapped in the 1996 sur These locations represent previous freestanding shack areas which have potentially been replaced by backyard shack bearing areas .



9.5 SETTLEMENT DENSITY

9.5.1 Methodology and results

In section 8.4.4 and specifically on figure 8.11, the procedure that was used to calculate the sub-settlement densities is discussed and illustrated in detail. This section discusses how these sub-settlement densities were combined in order to arrive at an average settlement density value.

Firstly, the shack sub-clusters were identified in each settlement area and used to designate sub-settlement boundaries. The sub-settlement areas and densities were then calculated and summed to produce an average density per settlement, that was calculated according to the following relation:

$$\text{Average density } p = \frac{(p_1x_1+p_2X_2+p_3x_3+\text{........}p_nx_n)}{x} \text{...............Equation 9.1}$$

where:

x = the total shack count for the settlement area

x_n = the total shack count for the nth sub-settlement of a settlement area consisting of n sub-settlements

p_n = the density (shacks / hectare) of sub-settlement n

In this manner an average settlement density was calculated for each settlement. The densities calculated for the sub-settlements are listed in appendix 6 table 2. The average settlement density is also listed[32]. The density distribution is highly variable. It ranges from: 3 du/ha to 247 du/ha and has an average of 99 du / ha $\pm$ 60 (n=65). The densities calculated for freestanding shack areas using the 1996 data are significantly higher than the densities calculated in previous studies. There are two reasons for this. Firstly, there is a three year time difference between the data on which the two studies are based. Secondly, unlike the previous studies (eg. iSLP Reports, 1996; World Bank Mission Report,1994; MacroPlan,1995), the densities calculated in the present study are exclusively for freestanding shack areas. The open spaces within the individual settlements were mapped out and the areas were subtracted from the settlement area[33].

9.5.2 A Density-based classification of informal settlements

Using the average settlement densities calculated using equation 9.1, a density-based classification was devised for informal settlements in the CMR. The following density ranges were used in the classification scheme:

- 200 - 250 du / ha (dwelling units per hectare)
- 150 - 199 du / ha
- 100 - 149 du / ha
- 50 - 99 du / ha
- 0 - 49 du / ha

This classification scheme was applied to produce appendix 6 table 5. This table illustrates that the majority of the settlements (43 %) lie in the 50 - 99 du / ha category. An approximately equal number of settlements lie in the 0 - 49 du / ha (22 %) and 100 - 149 du / ha categories (19 %), and less than 13 % of the settlements lie in the 150 - 199 du / ha (11 %) and 200 - 250 du / ha (1 %) density categories. The results of applying the density classification scheme is shown graphically in figure 9.11. The figure illustrates that in Ikapa (the Cape Metropolitan Area), the highest density settlements are situated in Nyanga (Mpetha, Mpinga and Mpuku). The lowest density settlements are situated north of Guguletu (Kanana) and east of Crossroads (Klipfontein Glebe). In Khayelitsha, the highest density settlements occur towards the centre of the area (Trevor Vilakazi, Victoria Mxenge and Victoria Mxenge South).

9.6 NET GROWTH RATES

Net growth rates have been calculated for a number of settlements[34]. The annual growth rate (increase in number of shacks / year) was calculated using the difference in shack counts for the 1996 survey and Van Zyl (1995). The time difference between the two data sets is 17 months (December 1994 - May 1996). Thus the annual growth rate can be calculated if one multiplies the difference in shack counts by a factor of 0.7058823 (ie. 12/17). One can the express the annual growth rate as a percentage of the number of shacks in Van Zyl (1995). If one ignores relatively small informal settlements (ie. those consisting of 120 shacks or less)[35], the settlement areas with the highest annual growth rates were as follows:

1. Sweet Home (188 %)
2. Kanana (75 %)
3. Bongweni (49.4 %)
4. Silvertown (39.7 %)
5. Barcelona (35.6 %)
6. Crossroads (34.4 %)

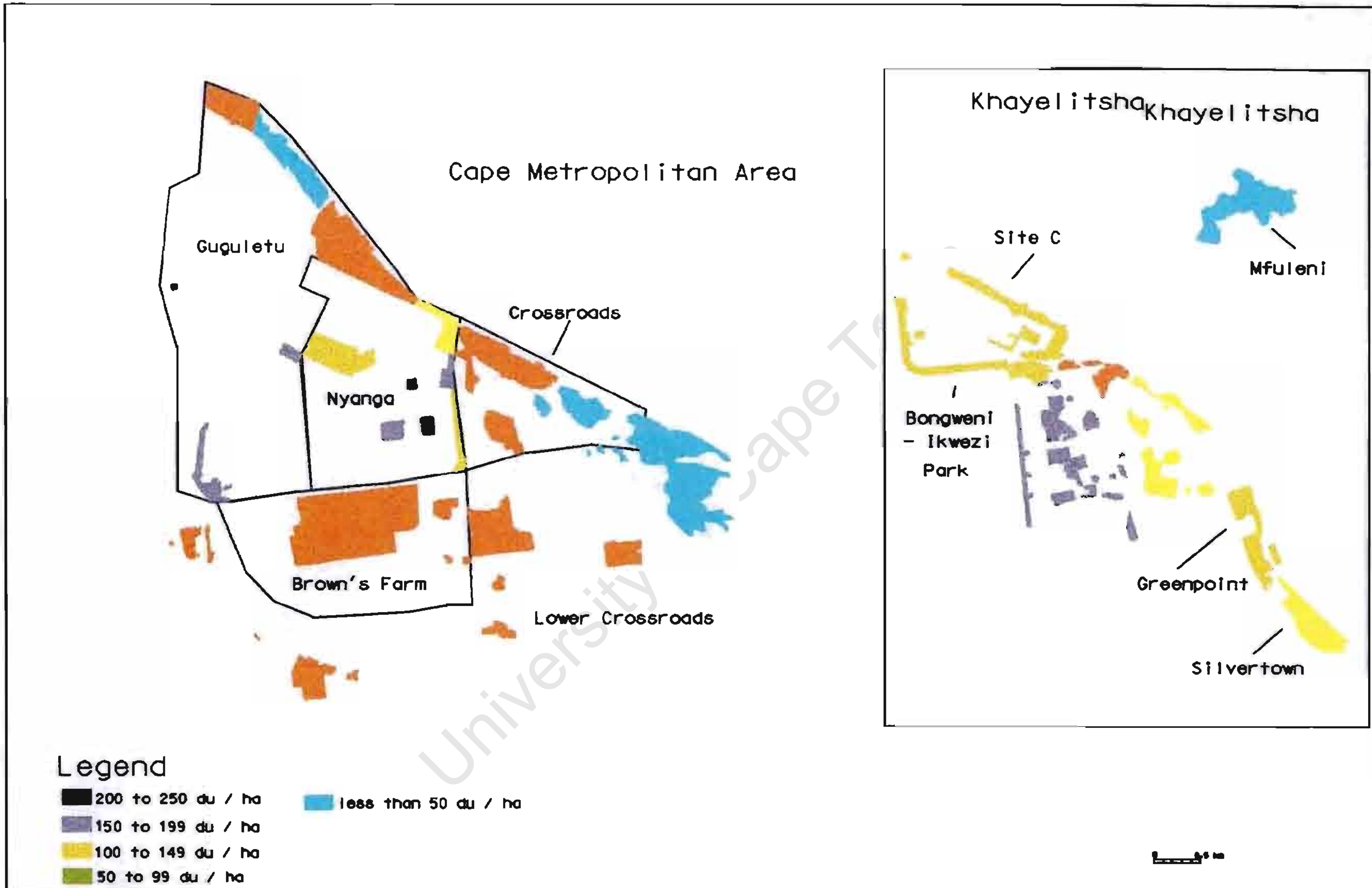


Figure 9.11 The density distribution of informal settlements in the Cape Metropolitan Area and in Khayelitsha.

7. Bloekombos (29.6 %)
8. Miller's Camp (24.2 %)
9. Lower Crossroads (15.4 %)
10. Phola Park (14.6 %)

The variation in the annual growth rates in the main informal settlement areas in the Cape Metropolitan Area (CMA) (Ikapa) is shown in figure 9.12. The key areas of growth in this area are highlighted in figure 9.13. In figure 9.14 annual growth rate trend lines have been extrapolated for a number of settlements in the Cape Metropolitan Region. This figure enables one to compare at a glance the rate at which one settlement is growing relative to a number of other settlements.

9.6.1 Guguletu, Nyanga, Brown's Farm and Crossroads

It can be seen from figure 9.12 that the annual growth rates in this area extend over a large range. From figure 9.13 it can be seen that the key areas of growth in the CMA lie mainly along the north-eastern margin of Guguletu. In Guguletu the settlements that have experienced a positive growth rate and that are over 120 shacks in size are as follows:

1. Kanana (75.7 %)
2. Barcelona (35.6 %)
3. Phola Park (14.6 %)
4. New Rest (7.3 %)

The average annual growth rate for these settlements is 33.3 %. The settlement Gxa-Gxa (91 shacks) has experienced a growth rate of 66 %.

Nyanga displays a mixture of static (less than 2 % per year), increasing and decreasing freestanding shack area growth rates. Settlements that appear to have a static growth rate are:

1. Mpinga Square (1 %)
2. KTC informal (1.3 %)
3. Black City (1.6 %)
4. Mpetha Square (1.7 %)

The high densities for these areas suggest that they have not experienced any significant growth over the 17 month period, simply due to a lack of space. Settlements that appear to have grown significantly are:

1. Miller's Camp (24.2 %)
2. Mkonto Square (10.1 %)

The average annual growth rate for these two settlements is 17 %. The annual growth rates experienced in Crossroads[36] and Brown's Farm are 34.4 % and 13.7 % respectively.

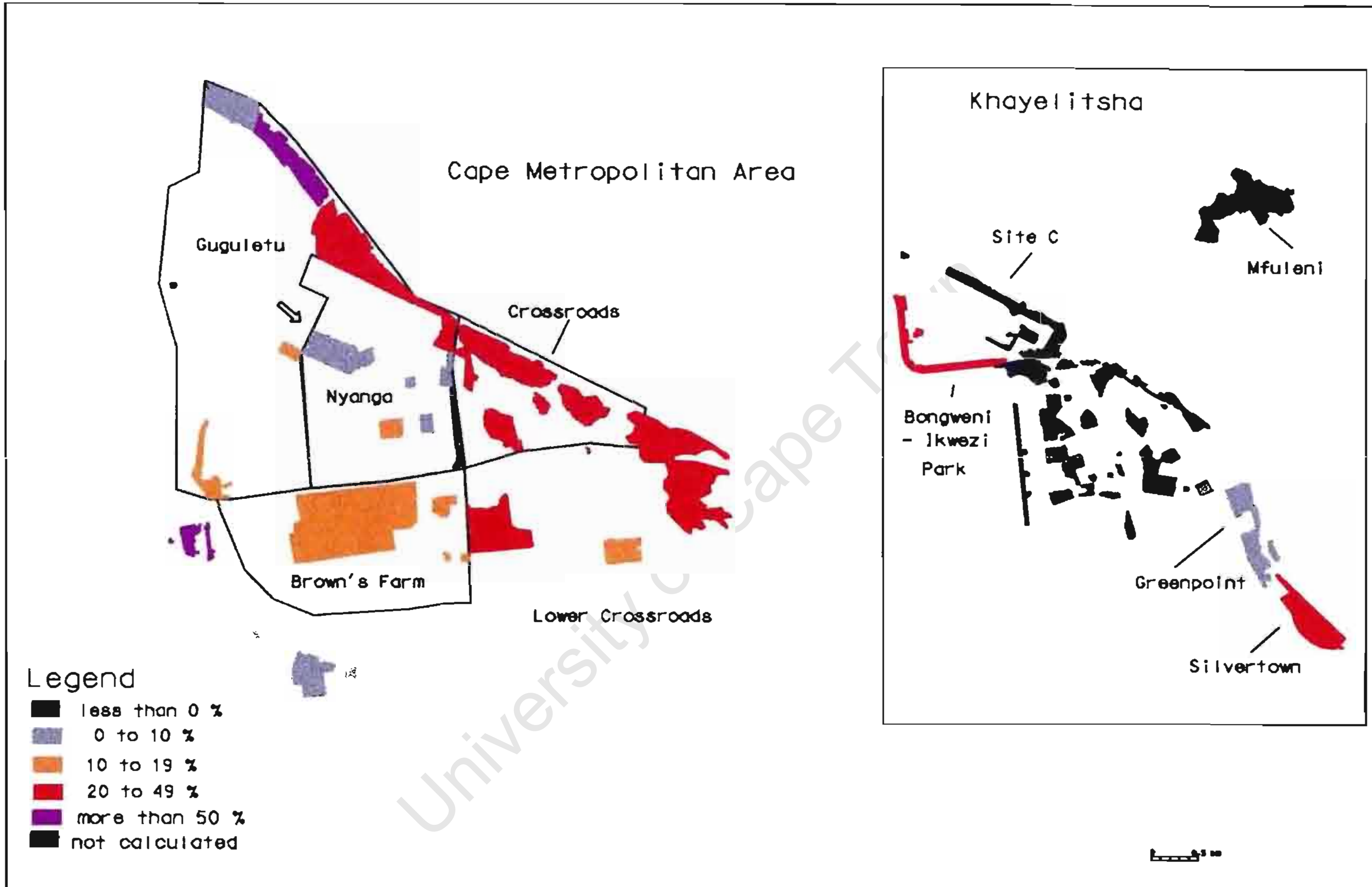


Figure 9.12 The annual growth rates of informal settlements in the Cape Metropolitan Area and in Khayelitsha.

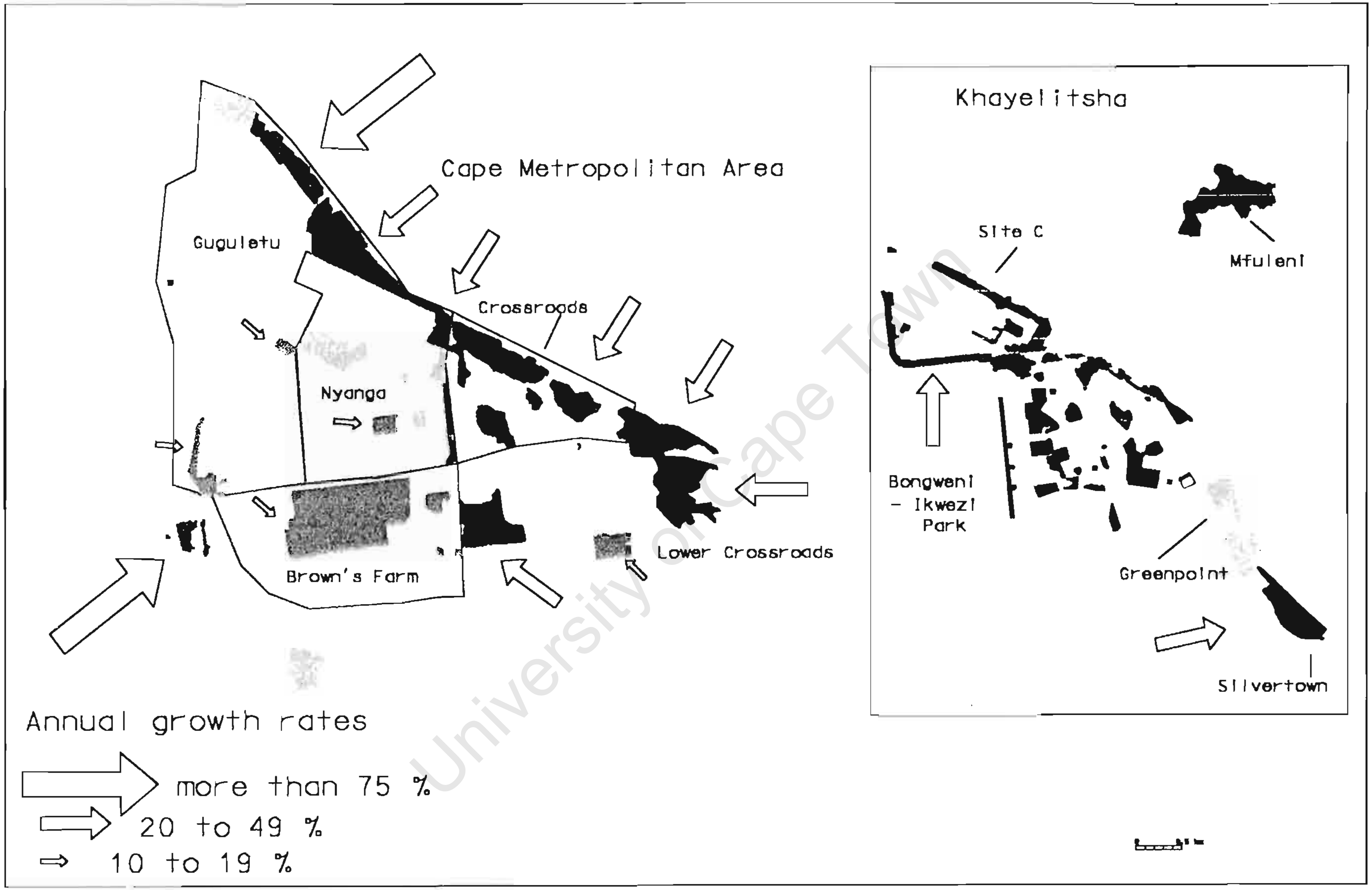


Figure 9.13 Key areas of informal settlement growth in the Cape Metropolitan Area and in Khayelitsha.

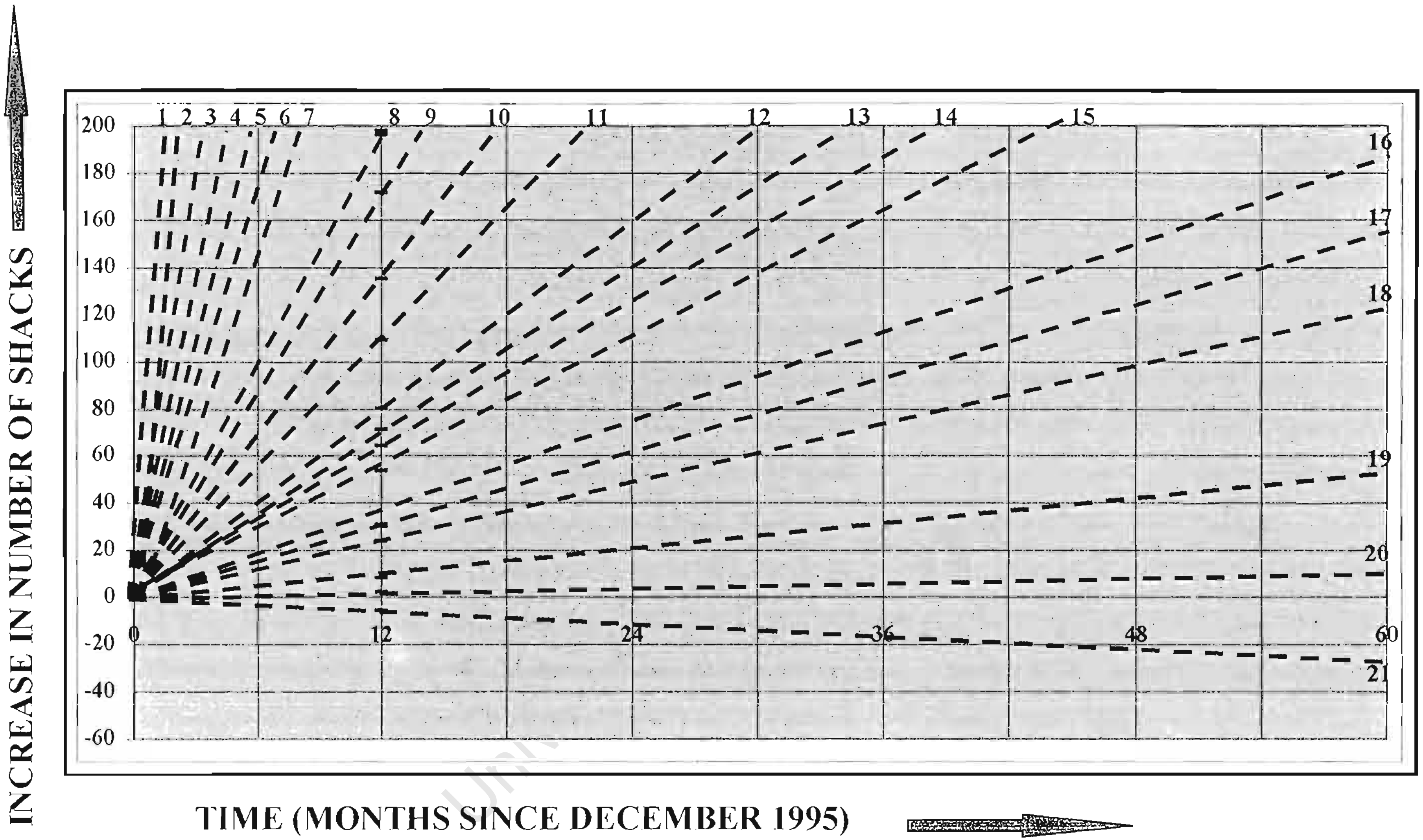


Figure 9.14 Annual growth rate trend lines calculated for informal settlements in the Cape Metropolitan Region. Annual growth rate lines are shown for the following settlements: Brown's Farm (1), Silvertown (2), Bloekombos (3), Barcelona (4), Bongweni - Ikwezi Park (5), Vietnam (6), Kanana (7), Sweet Home (8), Miller's Camp (8), Phola Park (9), Marconi Beam (10), Lower Crossroads (11), New Rest (12), Green Point (13), Mkonto Square (14), Samora Machel (15), Gxa-Gxa (16), KTC (17), Red Hill (18), Black City (19), Mpetha Square (20), Mpinga Square (21) and Sunnydale (22).

9.6.2 Khayelitsha

Annual growth rates were calculated for the settlements discussed in section 9.43 [37]. From figure 9.13 it can be seen that the key areas of growth in Khayelitsha are the Bongweni - Ikwezi Park and Silvertown areas. The following growth rates were calculated for these settlements:

1. Bongweni – Ikwezi Park (49.4 %)
2. Silvertown (39.7 %)
3. Green Point (4.5 %)

The average annual growth rate calculated for these settlements was 31.2 %. In figure 9.12, it can be seen that the central parts of Khayelitsha have experienced no positive net growth, whereas the marginal areas have experienced a significant increase in the number of freestanding shacks. One possibility is that the relocation enforcement is resulting in a natural shift (ie a "self-relocation " process) of the population towards the margins of the informal settlement area centres.

9.6.3 Other areas

In Lower Crossroads the following annual growth rates were calculated:

1. Sweet Home (188 %)
2. Lower Crossroads (15.4 %)
3. Samora Machel (5.2 %)

The average annual growth rate for these settlements is 69.5%. Another area near to Lower Crossroads that has experienced a positive growth rate is Vietnam (29.2 %).

A comparison of the 1996 data with the 1994 City Council study (see appendix 6 table 3) enabled growth factors to be calculated for a number of relatively small settlements that were unlisted by Van Zyl (1995). In appendix 6 table 6 the approximate growth factor has been calculated by dividing the number of shacks in 1996 by the number of shacks in 1994. This factor has been calculated as in some cases, "settlements" that were extremely small in 1994 (eg. comprised of only 1 shack) have increased by over an order of magnitude in size. The growth rates calculated in this manner were as follows:

1. Heinz Park (69)
2. Ottery (49)
3. Pelican Park (3.8)
4. Vrygrond (2.1)
5. Wallace Dean (1.4)
6. Mitchell's Plain (1.3)

The above growth rates illustrate the importance of mapping even the smallest settlements. In the case of Ottery, 1 shack was detected in 1994. By 1996, this location had grown to a settlement of 79 shacks.

Areas further away from the main informal settlement region in the CMR which have experienced a net growth are:

1. Bloekombos (29.6 %)
2. Marconi Beam (12.3 %)
3. Samora Machel (5.2 %)

The relatively small settlement Redhill (113) has also experienced a positive growth rate (70.6 %).

9.6.4 Areas showing a decline in the number of shacks

A number of areas have experienced a negative growth rate. In Guguletu, Tambo Square has experienced an annual decline rate in settlement size of –16.5 %. In Nyanga, Mahobe Drive has declined in size by 13.7 % per annum. Excluding Khayelitsha, other areas that have experienced a negative growth rate include:

1. Mfuleni (-17.6 %)
2. Lwandle (-12.2 %)
3. Imizame Yetha (-9.3 %)
4. Sunnydale (-1%)
5. Nomzamo / Sun City (-50 %)
6. Wallacedene (-40 %)

Where a large decrease has occurred this is most likely to be associated with the removal of freestanding shacks for the implementation of site and service schemes.

9.7 POPULATION ESTIMATES

The calculation of population estimates based on household size estimates is riddled with problems. Van Zyl (1995) highlights the following factors that inhibit the calculation of population estimates[38]:

1. the uncertainty of the household size estimates
2. the dynamic nature of informal settlements, and
3. the unquantifiable nature of intra-migration

One of the reasons for the variations in the average household size estimates is the resettlement process[39]. A typical example of the controversy that exists on the current population data is provided by Mbekweni. The figure listed formally by Van Zyl (1995) for Mbekweni is 17400. As a footnote Van Zyl states "The figure for Mbekweni is under dispute. Informally a figure as high as 27 000 is quoted." (Van Zyl, 1995: 13).

Despite these problems, population estimates have been calculated for each settlement using Van Zyl's average household size values[40] (see appendix 6 table 7). Where a household size estimate was not listed by Van Zyl (1995), a value of 3.6 has been used. The value of 3.6 was selected as it is by far the most frequently occurring lowest informal household size estimate listed by Van Zyl (1995). The value of 3.6 can thus be considered as indicating the minimum population in these areas[41]. The total population calculated for all the informal settlements in the CMR was 251799. Thus 8.8 % of the total CMR population (2.87 million) resides in informal settlement areas.

9.8 SELECTING INDICATORS FROM THE PRESENT STUDY TO ASSIST IN PRIORITIZING THE UPGRADING PROCESS IN THE CMR

9.8.1 Settlement densities

The current policy applied by local government in informal settlement areas is one of relocation. In appendix 6 table 8 the percentage of relocation and relocation distances planned for a number of informal settlements in the iSLP Programme are shown. On average, 54 % of each settlement is planned for relocation. In a few cases the entire settlement is planned for relocation (eg. Samora Machel, Tambo Square, Vietnam, Mahobe Drive). The percentage of relocation planned for the majority of the settlements in appendix 6 table 8 lies between 50 % and 90 % (eg. Black City, Boy's Town, Gxa-Gxa, Lower Crossroads, Miller's Camp, Mkonto Square, Mpetha Square, New Rest and Sweet Home). By using density-based indicators it is possible to reduce or optimize the amount of relocation required for each settlement[42].

According to the iSLP Programme documentation, settlements with a density of 60 - 110 du / ha have the potential for in situ upgrading. If one considers the settlements listed in appendix 6 table 8 in the light of this comment, the density classification scheme (appendix 6 table 5) indicates that the following settlements have the potential for upgrading: Barcelona (50 du/ha), Boy's Town (97 du/ha), Gxa-Gxa (83 du/ha), Joe Slovo (105 du/ha), Kanana (45 du/ha), Lower Crossroads (81 du/ha), New Rest (77 du/ha), Samora Machel (81 du /ha) and Vietnam (65 du /ha). Thus the density-based classification scheme presented in appendix 6 table 5 provides a first means of establishing those settlements that can be considered for in situ upgrading. In appendix 6 table 5, the settlements in the lowest density categories: 0 - 49 du / ha, 50 - 99 du / ha and a number of the settlements in the 100 - 149 du / ha category "have the potential for in situ upgrading". Table 5 in appendix 6 indicates that in essence, 69 % of the informal settlements in the CMR should be investigated for in situ upgrading possibilities.

A limited amount relocation can be applied to reduce the density of the remaining settlements in the higher density categories. In fact, it is possible to create a spreadsheet to minimize the amount of relocation to achieve the required planning densities. One can use the relation:

$S_r = S - (S_a * D_r)$........................Equation 9.2

where:

S_r = total shacks for relocation from all sub-settlements in a settlement
S = the present number of shacks in the settlement
S_a = the total settlement area for all the sub-settlements in the settlement
D_r = the required average settlement density (a value between 60 - 110 according to the iSLP).

In the case where the average density has been calculated for sub-settlements with significantly different densities a more refined approach is required.

$S_r = S_{r1} + S_{r2} +$..$+ S_{rn}$...........Equation 9.3

where:

S_{rn} is the number of shacks which must be removed from the nth sub-settlement to ensure that it has the required density.

The above equation can be rewritten as:

$S_r = ([S_1 - (S_{a1}*D_r)] + [S_2 - (S_{a2}*D_r)] +$ ....$+ [S_n - (S_{an}*D_r)]$)........Equation 9.4

where:

S_r = total shacks for rellocation from all n sub-settlements comprising the total settlement area
S_n = the present number of shacks in the nth sub-settlement
S_{an} = the sub-settlement area for the nth sub-settlement
D_r = the required average settlement density (a value between 60 - 110 according to the iSLP).

Using the individual sub-settlement components required for equation 9.4, one can easily determine the number of shacks that must be removed from each sub-settlement to attain the required planning densities (appendix 6 table 9). As an example, KTC consists of three sub-settlements each having a shack count of 1496 (area A), 660 (area B) and 168 (area C). Table 9 in appendix 6 indicates that to achieve a density of between 60 and 110 du / ha for the whole settlement: 808 to 235 shacks must be removed from area A, 294 - 49 shacks from area B and 113 to 67 shacks from area C. The same type of observations can be carried out to optimize the amount of relocation listed in appendix 6 table 8 for the following settlements: Black City, Mahobe Drive, Miller's Camp, Mkonto Square, Mpetha Square, Mpinga Square, Phola Park and Tambo Square.

By following this approach one can begin to apply a true minimum relocation policy as opposed to the present policy implemented in the iSLPs. Currently the iSLP process appears to involve an arbitrary relocation of a large number of shacks from each settlement. Using tools such as table 9 in appendix 6, it is possible to begin to optimize the relocation process.

9.8.2 Spatial patterns of settlements

A third, less quantifiable indicator, that may be used to prioritize the upgrading process is the settlement pattern. Hillier and Hanson (1984) have argued that the development of settlement morphology is controlled by a set of simple rules of growth. A product of their work is a table of typologies of settlement arrangements. In particular, four types of distributed patterns were recognized (clusters, clumps, central space patterns and ring street patterns) (see appendix 6 figure 9.3). The data captured for the present study, has facilitated the recognition of at least three, and possibly four, distinct shack cluster morphologies in the Ikapa area alone. The four settlement pattern classes shown in figure 9.15 provide a first order, qualitative and visual tool for beginning to organize a regional informal settlement upgrading program.

The first class (Type 1) is characterized by a very high shack density. The individual shacks are tightly clustered and represent areas that are highly inaccessible in terms of the provision of urban services. The cluster morphology of these areas may also be expected to result in a highly constricted stormwater runoff pattern. Informal settlement areas in Ikapa that may be placed into this class include: KTC (figure 9.15), Black City, Mkonto Square, Tambo Square, Phola Park, Mpinga Square, and Mahobe Drive. The second class (Type 2) is represented by a linear arrangement of shacks. The best candidate for this class is the Boy's Town area (figure 9.15), north of Old Crossroads. The distribution of shacks in this area is expected to have a channellizing effect on the overland stormwater runoff.

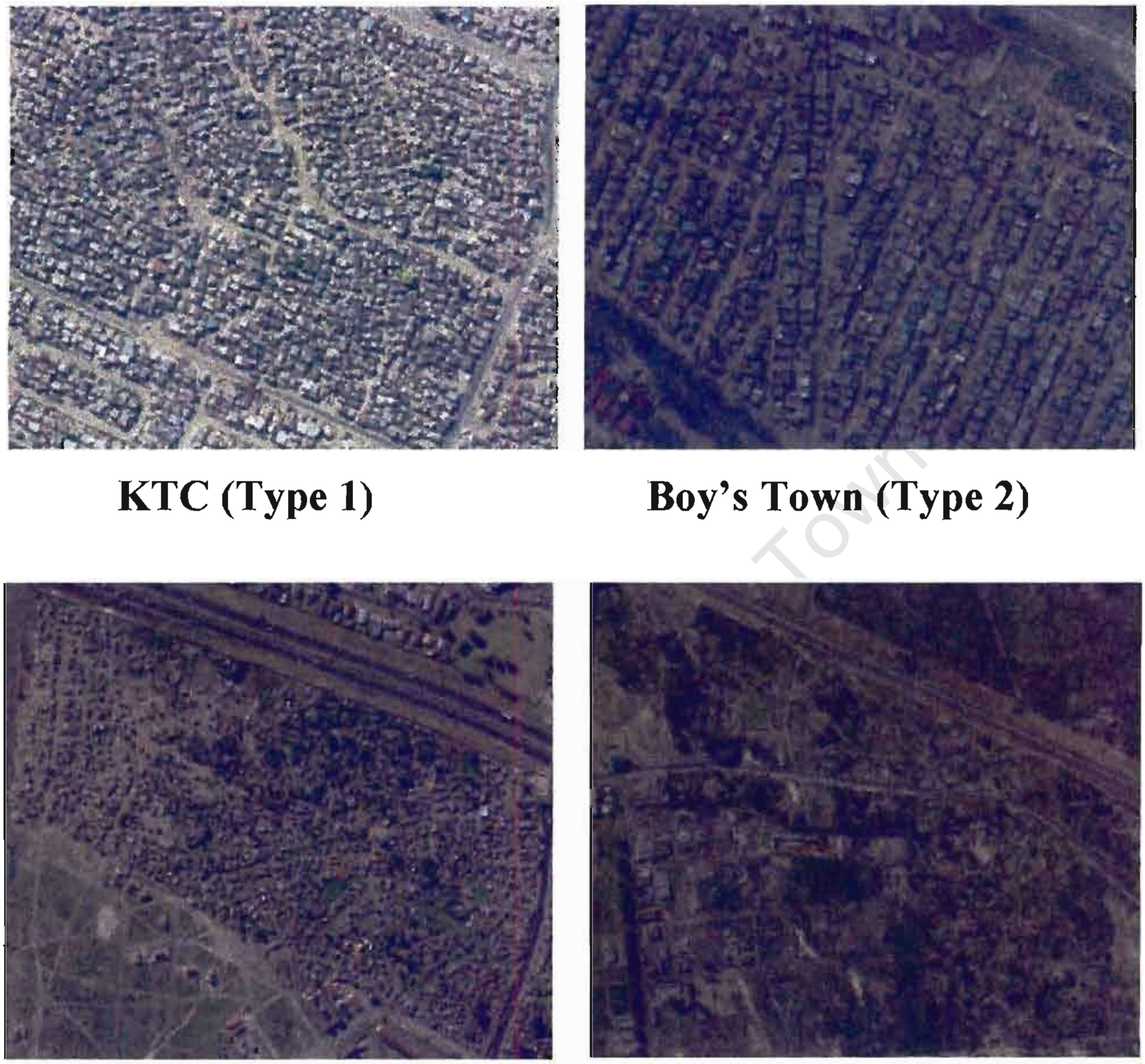


Figure 9.15 Examples of the four different shack cluster types occurring in the Cape Metropolitan Area (Ikapa). Each of these types may be simply characterized as follows: type 1 has a very high density, type 2 has a distinctive linear arrangement of the shacks, type 3 has an intermediate shack density and type 4 has a very low shack density.

A third class (Type 3) may be recognized, which is characterized by a shack density that is lower than types 1 and 2. This class lacks the highly linear arrangement of the Type 2 class. An example of a settlement in this class is New Rest (figure 9.15). The fourth class (Type 4) is characterized shack density that is significantly lower than that of the Type 3 class. The low shack density suggests that these areas may be highly accessible for the development of urban service infrastructures. The overland flow in these areas is expected to be unchannellized by the shacks, in contrast to Type 2 shack areas. The Klipfontein Glebe (figure 9.15) area typifies this class. The Type 3 class is expected to represent the intermediate stage of a gradational transition from the Type 4 to the Type 1 class. The Vietnam area, which lies just beyond the boundary of Ikapa, may fall into this class. A gradational change from a Type 4 to a Type 1 morphology also is strongly suggested by the area extending from Mpuku park into Joe Slovo park (Langa), immediately north of Ikapa.

9.9 USING THE METROPOLITAN-LOCAL-LEVEL BI-LEVEL MODEL DATABASE LINKAGES TO TEST INFORMAL SETTLEMENT UPGRADING PLANNING INITIATIVES

9.9.1 Introduction

The relocation optimization methodology discussed in section 9.8.1 is acceptable in principle. However, it needs to be done in conjunction with an upgrading implementation strategy that tests the maximum number of people that can be upgraded. It is here that the linkages between the metropolitan-level and the local-level databases in the Bi-level model (discussed in sections 6.7 and 8.6.2) has a critical role to play. The metropolitan-level database is faced with the limitation that not all of the settlements have been sub-divided into clusters. This constrains the full potential utility of the density-based approach described in section 9.8.1. In this section, the potential utility of the metropolitan-local-level linkage in overcoming this and other limitations is illustrated using New Rest as an example.

9.9.2 Evaluating the potential for upgrading New Rest using the metropolitan-level data

In comparison to many other informal settlements in the Cape Town Metropolitan Region, New Rest has a relatively low average density of approximately 77 shacks per hectare. Within the density-based scheme proposed in section 9.5.2 (table 5 in appendix 6), it lies within the second lowest density category. Given this relatively "low" settlement density value, one would expect that the upgrading potential for New Rest should be relatively high. Yet, according to the integrated Serviced Land Project (iSLP), less than half of New Rest is suitable for upgrading. As shown in table 8 in appendix 6, the iSLPs has designated a total of 54 % of the current population in this area to be relocated to sites in Weltevreden (17%) and Southern Delft (37 %). A further 37 % of the population would be temporarily relocated and resettled on New Rest after the site had been developed, while 9 % of the population have no options available. The iSLP figures refer to a specific date (August 1996). No allowance was made for population growth. As a result the 9 % increase in the population has not been planned for. The iSLP figures listed above are in sharp contrast to the potential degree of upgrading that could take place in New Rest as indicated by the density-based methodology discussed in section 9.8.1. According to table 9 in appendix 6, less than 12 % of the total number of households in New Rest need to be rellocated in order to obtain a planning density of 70 dwelling units / hectare.

9.9.3 Utilizing the metropolitan-local-level linkage to aid the evaluation process

While the application of the density-based methodology, as applied here, has shown that New Rest is largely an upgradable settlement, it still leaves many practical questions unanswered. Issues such as exactly how many shacks and which shacks should be removed remain unanswered. The resolution of the New Rest data on metropolitan-level database is too coarse to address the upgrading potential question more rigorously. More specifically, for a detailed analysis of the upgrading potential of the area an understanding of the variation of the density across the settlement is required. Secondly, before any upgrading proposal can be laid down, the upgrading potential defined on a purely spatial basis must be placed in the context of the socio-economic characteristics and the communities views. For these reasons it is essential to utilize the metropolitan-local-level linkage discussed in section 8.6.2 to aid the evaluation process.

An example of such a linkage was created between the metropolitan-level of the Bi-level model for Cape Town and a local-level database recently created for New Rest through the New Rest / Kanana Development Trust. Through this linkage the basic cadastre and socio-economic data for New Rest was made accessible. Three issues arise from a brief consideration of the potential of utilizing this linkage to further evaluate the upgrading potential of New Rest. The first is that the field areas, which were created to designate different sectors of the settlement during the socio-economic data field survey, may be used to refine the density-based approach. Essentially these areas can be used to illustrate the density variation across the settlement (see figure 9.16). Secondly, the density-based optimal relocation approach can finally be placed in the context of reality. The metropolitan-local-level linkage enables this by giving the user of the metropolitan-level system access to information on servitudes, the variation in the household sizes, land ownership etc (see figure 9.17).

These two factors alone will significantly enhance the evaluation process described in section 9.9.1. However, the third, and perhaps the most import issue, is that the metropolitan-local-level database connection opens the door towards community involvement in the decision making process. In the same way that the local-level data can be accessed by metropolitan-level planners, the upgrading proposals made by these planners can be viewed from the local-level platform (see section 8.8.2). This is a critical factor as the success of an upgrading proposal will inevitably rely on the long-term support of the community involved.

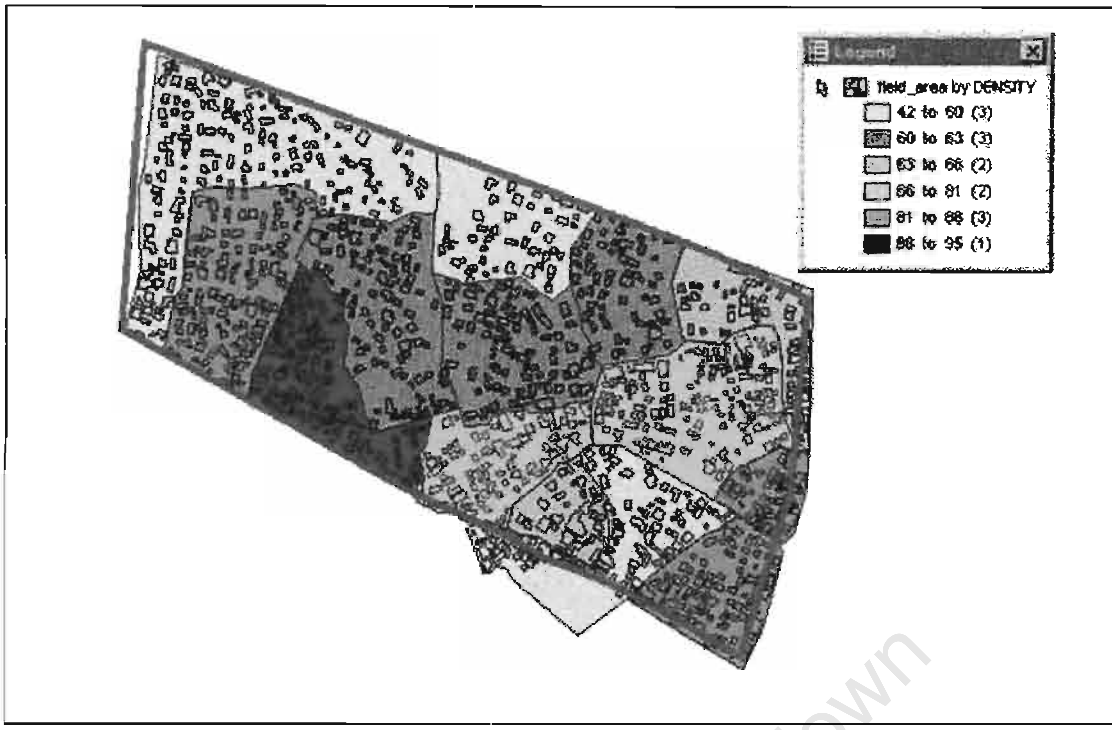


Figure 9.16 An example of how the metropolitan-local-level linkage of the Bi-level model can be used to aid the evaluation of settlement for in situ upgrading. From the metropolitan-level database, only one density value could be obtained for New Rest. Here the linkage to the local-level enables the metropolitan-level users to access data on the variation in density across the New Rest settlement.

Figure 9.17 Here the utility of the metropolitan-local-level linkage is further illustrated. Several additional layers of local-level data have been overlain on top of the thematic map showing the density variation. These additional layers include a thematic map showing the variation in household sizes, storm water runoff servitudes and flood areas.

analysis must be of sufficient detail to enable the development of GIS-based vegetation management and rehabilitation strategies. The research also highlights that one of the key problems facing hydrological modeling at the sub-catchment–level is the lack of detailed cadastral data for informal settlements. The creation of linkages between the local-level informal settlement databases and sub-catchment-level ICM databases can be instrumental in overcoming these issues.

10.1.2 Introduction to Integrated Catchment Management (ICM)

Current discussions on Integrated Catchment Management (ICM) focus predominantly on conceptual and philosophical issues. The definitions for ICM provided by Görgens (1998)[2] and DWAF (1996)[3] tend to be broad and all encompassing. These definitions are discussed in detail in Grobicki et al. (in press)[4]. These studies provide an invaluable conceptual and philosophical reference for the development of ICM methodologies. However, within the current literature, very little is written on how these principles and objectives can be obtained in practice. Nothing has been written on the technological issues that must be considered to arrive at these objectives. The current study contributes to this field by providing <u>practical</u> guidelines for the development of a database to enable the implementation of the principles discussed in the previous work.

10.1.3 GIS in Integrated Catchment Management (ICM)

In addition to its potential functionality as a mechanism of integrating multiple data sources associated with all the stakeholders of the ICM process (see section 10.3.3), there are several other ways in which GIS can contribute to ICM. The Digital Elevation Model (DEM) and land use database components are key advantages of a GIS-based approach for developing hydrologic modelling applications. DEMs include topographical data useful for building slope and aspect maps, determining catchment properties and delineating water-path networks. The land use data enables detailed sub-catchment characteristics to be described. In addition, the grid structure utilised in many GIS software is coherent with the grid structure of distributed hydrologic models.

The advantages of GIS from a communication tool point of view is highlighted by Makropoulos et al.(1998). He concludes that GIS has a significant potential as a tool for site specific source control implementation, analysis and quantification, not only due to its inherent spatial information handling capabilities, but also due to "<u>its "human readability" because it provides a common language between specialists and non-specialists (ie. local authorities).</u>" (Makropoulos et al.,1998: 59). However, the importance of GIS in terms of facilitating communication through clearer visual representations of reality is only one aspect of this issue. The communication related issue is that certain GIS software have excellent Internet capabilities. This factor on its own places the GIS platform as a medium by which information can be diffused throughout a wider user community. A number of other key advantages in a GIS-based approach to ICM are discussed in Grobicki et al. (in press)[5].

10.2 REVIEW OF GIS-BASED TECHNIQUES EMPLOYED IN URBAN CATCHMENT MANAGEMENT

10.2.1 Hydrological and non-point source pollution modeling[6]

Hydrological modeling

The advantages and utility of GIS for hydrological modeling are described by Marsalek et al. (1994), Zech et al. (1993) and Ross et al.(1993). GIS applications which have been designed for hydrologic analyses fall into four categories: 1) calculation of input parameters for existing hydrologic models; 2) mapping and display of hydrologic variables[7],[8]; 3) watershed surface representation[9]; and 4) identification of hydrologic response units (Greene & Cruise, 1995). The majority of the current applications fall into the first two categories. Examples of these applications include a utilization of GIS to: produce input parameters for the HEC-1 model (Moeller, 1991), determine time area curves (Sicar et al., 1991) and to display the spatial distribution of hydrologic variables (Loucks et al., 1985).

More recently, a model designed by Greene et al.(1995), for a 12.2 km2 area, enables the impacts of proposed land-use changes on the runoff to be predicted. In contrast to previous methods, the co-ordinate values defining the location of features were used to include the spatial heterogeneity of the drainage basin characteristics in the modeling process. In essence this model is based on detailed topographical and cadastral GIS data. This base data is used to identify lots and / or polygons as hydrologic response units. Subsequent to a series of co-ordinate geometry transformations, the GIS data for a particular street block may be converted into a routing schematic. Zech & Escarmelle (1998) describe the use of existing municipal GIS data, captured specifically for cartography, for urban-catchment characterisation in GIS-based distributed hydrological models.

In addition to the above mentioned aspects of hydrological modeling, a brief literature review revealed that significant work has been in three other areas relating to urban catchment management GIS applications. These areas included the following:

- Digital elevation models (DEMs)[10, 11]
- Hydrologic parameter estimation in urban areas[12]
- GIS / Urban runoff model linkages[13 ,14,15]

Non-point source pollution modeling

The application of GIS-based techniques for the assessment of non-point source loads has been discussed in detail by several authors (Heidtke et al., 1993, 1986, 1992; Kim & Ventura, 1993; Horn & Grayman, 1999; Xu et al., 1993; DeBarry & Carrington, 1990;.Vieux & Needham, 1993, Zech et al., 1994). An overview of these studies is provided in Grobicki et al. (in press). Here only a paper by Bendoricchio et al. (1993) that deals with a multi-scale GIS-based approach for the simulation of diffuse loads generated in the Lagoon of Venice[16] watershed is summarized. The work by Belyaeva et al. (1993) discusses how GIS may be used for water quality management in the

Upper Volga River Basin. The key aspect of the conceptual model which has been developed for this application is that data are managed at three levels depending on the scale and detail (ie. regional, watershed and local). Level I (Upper Volga River Basin) contains basic information for a large region (scale >1:1000000). Level II contains data useful for resource management applications in catchment areas (scale: 1:100000 to 1: 1000000). Level III contains information for small areas such as individual problems, causes and solutions for nonpoint pollution sources (scale < 1: 100 000)[17]. A multi-scale system approach has also been followed by Schaller (1993) in the development of a GIS-based ecosystem model for watershed management the Berchtesgaden area, Germany. In this case, the Hierarchical Systems Method[18] proposed by Grossman (1983) was adopted.

10.2.2 Internet-based group decision making support systems for urban catchment management

The usefulness of the Internet for disseminating public information has already been highlighted (Courteau, 1996): "....Also crucial are questions of information, communication and information dissemination. The Internet can become a strategic tool for consolidating these functions." Furthermore, Ostrowski & James (1998) discuss the requirements and possible approaches for group decision - making using computer networks like the Web for urban catchment management. Ostrowski & James (1998) argue that there is a tendency towards decentralised systems. Associated with decentralised urban drainage solutions (such as integrated optimum individual solutions on the house or neighbourhood scale) is a more complicated planning process. "Transparency and continous information are compulsory for its acceptance.". Furthermore, "....The introduction of locally and regionally optimum solutions, however, <u>requires the participation of citizens and citizen groups concerned</u>." (Ostrowski & James, 1998: 569).

Ostrowski & James (1998) have designed a GDSS called STEEL[19,20] for sustainable development. "STEEL" refers to "the working title of the GDSS under design, summarising its major fields Science, Technology, Ecology, Economy and Law under the umbrella of sustainability." (Ostrowski & James, 1998: 571). The STEEL system has apparently been designed "as a participatory system involving the public", in which the medium for interaction is supposed to be the Internet. However, Ostrowski & James (1998) does not discuss in much detail how exactly the public can participate in the decision making process.

10.2.3 Constraints facing current GIS-based ICM applications

The brief literature review in section 10.2.2 suggests that the development of GIS-based applications for ICM has been faced with at least three of the problems facing other existing urban GIS database models (see chapter 2-4 and section 6.8). Firstly, most hydrological GIS models are single-scale. Secondly, where a cadastre-based approach has been implemented, has proved impractical and time consuming. Thirdly, most hydrological GIS models operate as isolated databases.

The limitations facing ortho-photo and satellite GIS-based techniques in urban catchment management are discussed in detail in Grobicki et al. (in press) [21,22]. With respect to the hydrological modeling applications discussed in section 10.2.1, most of these tend to be designed for single-level applications. Furthermore, these models generally follow a lumped parameter approach that does not incorporate the spatial variation of watershed characteristics in the modeling.

Where more detailed methods have been adopted in the modeling process, a series of problems have been encountered. The main difficulty with methods that rely on the use of detailed cadastral data, such as the techniques by Greene et al.(1995) and Zech et al. (1998), is the necessity to use a refined mesh (5m) to reach the accuracy required by distributed models. A number of other key disadvantages are associated with using cartographic data. These disadvantages are related to the structure of the database that has been designed specifically for cartographic purposes[23].

Both the lumped parameter a higher resolution approaches to hydrological modeling described above, can be treated in essence simply as some of the components of a broader multi-scale GIS database for ICM. Some of the very few exceptions to this single-level based approach are the GIS initiatives developed by Belyaeva et al. (1993), Schaller (1993) and Grossman (1983). These initiatives followed a multi-scale approach and are discussed in section 10.2.1.

In addition to the single-scale approach, as was the case for informal settlement database development initiatives (see chapter 4), the vast majority of ICM based GIS systems operate as isolated databases. Again, the recent system proposed by Ostrowski & James (1998) provides an exception to the rule. Even so, while the "STEEL" system directs some information towards a community in a developed country, it still is a far cry away from the concept of community participation in developing countries. The education (EDMOD[24]) and public awareness (POAM)[25] modules do address the needs of an Internet-based community to a limited extent. However, there seems to be no GIS-based bi-directional linkage that is necessary for using the GIS as a mechanism for negotiation (see chapter 8). Furthermore, the community is not actually *involved* in the database development process.

10.3 THE APPLICATION OF THE BI-LEVEL MODEL IN THE LOTUS RIVER CATCHMENT

10.3.1 The role of the Bi-level model

As pointed out in section 10.2.3, the current GIS-based approaches to urban catchment management suffer from at least three of the problems facing existing urban GIS database models (section 6.7). These problems include the single-scale nature of most approaches, the lack of connectivity, and problems relating to the use of the digital cadastre. In the same way the the Bi-level model was applied to address these problems for informal settlement upgrading applications, the model can be applied here to deal with these problems facing urban catchment management.

10.3.2 Characteristics of the Lotus River catchment database

In order to test the applicability of the Bi-level model to ICM , the Lotus River catchment, which is situated in the Cape Metropolitan Region (CMR) was selected as the second case study for the model. The Lotus River catchment was selected for this case study for several reasons. These were as follows:

1. The fact that the Lotus River catchment represents an urban catchment as opposed to a rural catchment.
2. The large size of the Lotus River catchment (8437 ha) in comparison to sizes of catchments which have been analysed using high resolution automated mapping methods (11 to 125 ha) and methods based on detailed topographical and cadastral databases (12 km^2) (Frankhauser, 1998; Greene et al, 1995).
3. The restrictions imposed on the methodology by the fact that its is being designed for a catchment situated in a developing country as opposed to a catchment situated in a developed country.
4. At the time of this thesis a major WRC funded was being conducted on the Lotus River catchment. Part of this project involved the search for a new GIS-based approach to ICM.
5. About one third of all the informal settlements in the CMR drain into the Lotus River catchment. In view of the earlier focus on informal settlements in the CMR (chapter 9), this catchment seemed particularly relevant.

10.3.3 Preliminary data capturing methodologies

In the first instance a survey of all the available data types that could be used in the Lotus River catchment database development process was carried out. The aim was identify the extent of the existing data and to determine if any of this data could be used. The methodologies employed to capture the storm water drainage network, sub-catchment boundaries and land use data are discussed in detail in Grobicki et al. (in press). In the case of the land use data, an attempt was first made to try and use the existing digital cadastre acquired from the Cape Town Metropolitan Council[26]. The type of features that are typically present in this cadastral database are shown in appendix 7 table 4. It should be noted that none of these features had been captured for the informal settlement areas. In addition, where data was available, it had been captured in a manner requiring a great deal of manual data conversion for area calculations. This data required significant pre-processing before it could be used for land use analysis[27]. The implementation of this methodology was eventually terminated as it proved to be far too time-consuming to carryout on a catchment-wide basis. However, this methodology has relevance to the present chapter as the municipal database provides some of the detailed cadastral data (ie. for the formal settlement areas) required for sub-catchment-level hydrological modelling.

10.3.3 Applying the conceptual framework of the Bi-level model to ICM

From section 10.3.2 it is clear that the development of a GIS-based approach to ICM for the Lotus River catchment is faced with the problem of "gaps" in the digital cadastre, which correspond to informal settlements within the catchment. In view of the problems that were faced when an attempt was made to use the existing municipal digital cadastre, it was decided to apply the multi-scale concepts developed in the Bi-level model (see section 6.7) to the Lotus River catchment.

The application of the Bi-level model for ICM that resulted from this testing process, provides tools for the analysis and assessment of catchment data in an integrated manner. In addition, the database management strategies based on the Bi-level model application for ICM in section 10.4 has been designed for a <u>multi-scale approach</u> involving the interaction of metropolitan- / regional-, catchment- and local-level databases. The proposed software configuration (previously described in section 8.7) has been selected to facilitate an <u>effective co-ordination and integration</u> of data from multiple data sources. Finally, the proposed database content and analytical capabilities of the software can be used to address the issues of <u>distribution of costs and benefits</u> amongst all stake holders and to define the <u>roles and responsibilities</u> and accountabilities of the stake holders.

<u>A multi-level approach</u>
One of the principle functionalities of GIS with respect to ICM should be the integration of a multitude of data sources. Ideally each stakeholder involved in the ICM process should have a role to play in the development and use of the database. The discussion on GIS above has highlighted a number of differences that will always exist between different GIS systems. In particular it can be seen that any conceptual framework designed for GIS-based ICM applications must follow a multi-scale approach. Yet there are limitations in terms of the number of scales that should be considered. As the number of working levels incorporated in the design of the database increases, so does the complexity of the database structure. Ideally one wishes to incorporate the *minimum* number of levels which suffices at least the basic needs of all stakeholders.

The multi-scale GIS database framework proposed in this study for ICM consists of three key levels: the metropolitan-level, the catchment-level, and the sub-catchment-level. Each level has a specific functionality and several potential users associated with it (see Table 10.1). The metropolitan-level is envisaged as a strategic-level analysis and management tool. More specifically it can be used to address water resource and demand management issues on a metropolitan-level. Potential users of this level are institutions such as DWAF and the CMC. The catchment-level of the database is envisaged as a planning tool for project specific committees (ie. catchment management committees) and other institutions involved in catchment level projects. This level of the database can be used for constructing lumped parameter hydrological models. Other applications could include water quality monitoring and site selection for source control applications. The sub-catchment level of the database can be used for distributed parameter hydrological modelling.

The nature of the proposed database framework is such that all the stakeholders involved in the ICM process are also involved in the database building process.

Different institutions are involved to varying degrees in the development of each level. For example at the metropolitan level community representatives for multiple communities are envisaged, whereas at the sub-catchment level, multiple representatives from individual communities are envisaged. The involvement of other institutions is summarised in Table 10.1. The concept of the multi-scale approach is illustrated schematically below (Fig.10.1). C1 - C6 represent a number of catchment-level GIS databases, and L1 - L5 represent a series of sub-catchment-level databases situated inside one of these catchments (C1)[28]. The linkages and content of each level of the database are discussed in detail in section 10.4.

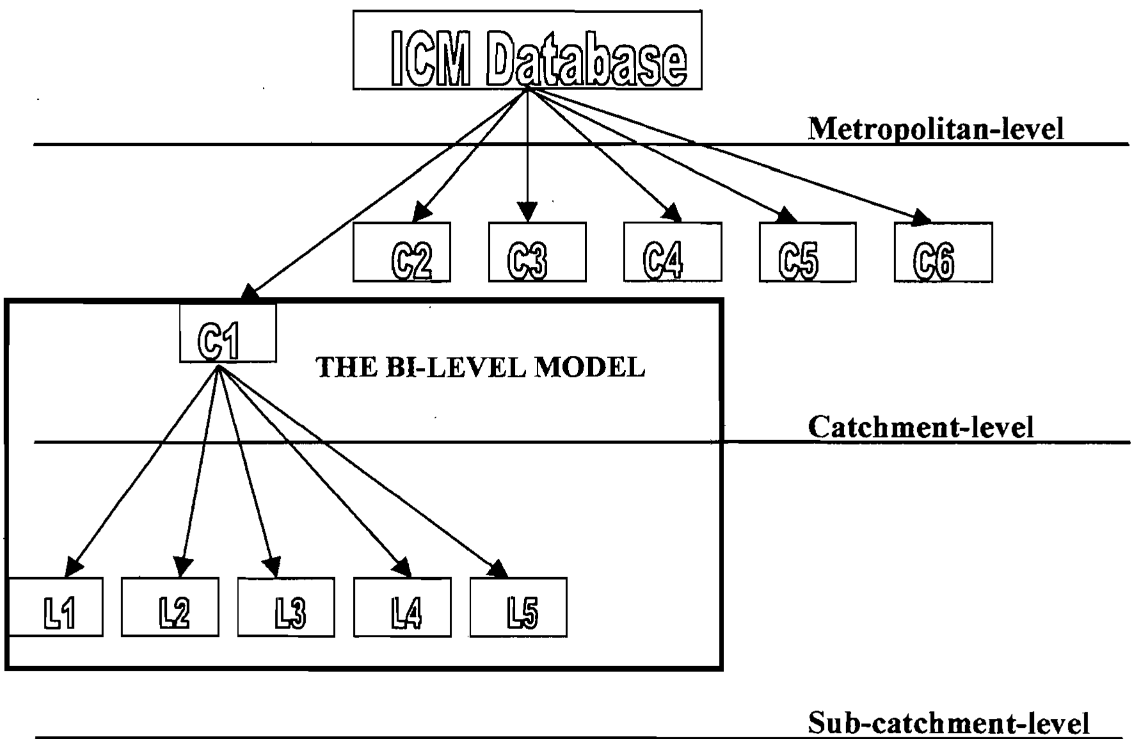


Figure 10.1 Applying the Bi-level model to a multi-scale GIS database framework for Integrated Catchment Management (ICM).

Figure 10.1 illustrates how the Bi-level model can be applied to a multi-scale GIS database framework for Integrated Catchment Management (ICM). In this case, the Bi-level model consists of a catchment and a series of sub-catchment databases. For the case where a metropolitan area is comprised of more than one catchment, as in the Cape Metropolitan Region CMR, the Bi-level model will be replicated for each catchment. In the case of the CMR, the Catchment Management Department of the Cape Town Metropolitan Council (CMC) is concerned with the allocation of resources to the different catchments at a metropolitan-level and is primarily involved with catchment-level projects. Both of these tasks require the resolution of the data captured at the catchment-level. of the Bi-level model applied in the context of ICM. From a GIS point of view, the three-tier ICM framework can be reduced to a two-tier system. On the one level is data that is utilized for metropolitan and catchment-based analyses, as both these types of analyses can be done using data at the catchment-level of resolution. On the second level is data that is utilized for sub-catchment-based analyses. This level requires data at a much higher resolution than the metropolitan and catchment-based applications.

10.3.4 Applying Bi-level model in the database development process

Once a conceptual framework had been established which specified which levels of the ICM process would be incorporated into the Bi-level model application, the next step was to create an appropriate database development strategy. In this respect, the most important contribution lay in alternative land use mapping strategy that was developed to overcome the problems facing a cadastral based approach.

The database structure and contents

The database which has resulted from application of the Bi-level model to the Lotus River catchment resides on two software platforms (see section 6.7). The first software environment, which is the MGE project environment, has been used primarily to capture vector data from images that have been georeferenced, and to obtain area measurements for the land use classification analysis work. The second platform, Geomedia has been used to archive the data onto an easily accessible and user friendly system. The various data types listed below have been placed into individual database warehouses within the Geomedia environment. A list of the types of data which have been collected for the Lotus River catchment database are shown in appendix 7 table 3.

An alternative landuse mapping strategy for implementing the Bi-level model

The second methodology that was carried out is based on the use of digital orthophotography[29]. A number of land use classification maps were produced for the Lotus River catchment based on 1996, 1983 and 1938 aerial photography imagery. The following classes were applied: formal, informal, serviced site, open and not vegetated, vegetated by grass, dense vegetation (including grass and shrubs), cultivated, industrial / built-up areas, agricultural buildings, parking lots, rail, detention ponds, dry ponds and wet ponds. Examples of these classes have been extracted from the imagery used and are shown in figure 10.7. This methodology proved to be much quicker than the first and was used to collect all of the land use data for the Lotus River project. Furthermore, this methodology yields results similar to the first methodology. The results obtained for a selected sub-catchment[30] using the two methods are compared in detail in Grobicki et al. (in press).

While this new mapping methodology is very coarse compared to a cadastral-based approach, it significantly higher in resolution in comparison to the land use data that is typically used in catchment-based (see section 10.3.5). Using this new approach, it was possible to rapidly capture the land use data, and to analyse this data on a catchment-wide basis and in the context of previous catchment studies (section 10.3.5). In terms of the analyses, the data enabled hydrological parameter estimations, and the development of a new ICM data visualization methodology, and the analysis of the land use data (discussed below). It is important to note that this again an example of where the application of the Bi-level model has enabled the delays involved in the capture of detailed cadastral data to be circumvented.

Parameter estimation methodologies

The primary parameters estimated via GIS for input into SWMM correspond essentially to the topographical data requirements of the model. These requirements include the following parameters: sub-catchment area (ha), % imperviousness, sub-catchment width (m) and the overland slope (m/m)[31, 32].

Data visualization methodologies

The data visualization methodologies employed involved the use of coupled raster-vector-based and thematic mapping methods. A series of thematic maps were constructed to illustrate the variation in the hydrological data (TPON, TP, SRP, COD, TSS, TVS and EC) along the Lotus River and the variation in a number of other variables (eg. population densities, degree of urbanization) across the catchment area. To illustrate the variation in the hydrological variables along the canal in a manner that is easily compared with land use and population density data for the area adjacent to the canal, a polygon-based BSU was used. A polygon thematic map template was constructed in Microstation and subsequently imported into Geomedia. This template was later modified so as to represent the polygon width as a function of the flow velocity for two sampling dates.

Analysis of land use data

The 1996 land use mapping data enabled the sub-catchments in the Lotus River catchment area to be grouped into five key regions[33] (see figure 10.3). In addition the land use data enabled estimates for the following parameters: population density, land use heterogeneity, land use change and the degree of urbanisation[34]. The manner in which these variables were defined and calculated are discussed in detail in Grobicki et al. (in press). With respect to the degree of urbanisation, in the case of most sub-catchments the estimated permeability has declined. For example for sub-catchment 101 the estimated permeability for 1983 was 95 %. In 1996 this value had declined to 67.7 %.

10.3.5 Comparison with previous sub-catchment land use data and permeability estimates

The sub-catchment boundary and land use allocations in previous stormwater runoff modelling applications for the Lotus River catchment (eg. Taylor, 1994), are faced with certain limitations. The catchment was previously subdivided into 25 subcatchments. These sub-catchment boundary definitions disregarded numerous variations in the slope across sub-areas divided by the Lotus River canal. Previous land use allocations have also tended to be designed so as to simplify or homogenise sub-catchment land use definitions for the purposes of stormwater runoff modelling

Taylor, 1994; Schmitz & de Villiers, 1997). Single land use allocations have been assigned to the majority of the subcatchments considered. In addition, the presence of other key land use features, potentially useful for integrated catchment management applications (eg. informal settlements) or for investigating rehabilitation (/river restoration) possibilities (eg. small dry or wet ponds scattered throughout the agricultural region) have been completely ignored.

In the previous land use based permeability estimates, a large number of sub-catchments in the Lotus River Catchment areas were assumed as homogenous "residential" (110, 120, 127, 167, 169, 170, 180, 185, 195) or "agricultural" (175, 190, 160, 150, 145, 140, 135) areas. Graphs (see Grobicki et al. (in press)) of percentage land use data for sub-catchments previously placed into one of these categories show significant variations from one sub-catchment to another within a single category. The graphs indicate that simplified land use allocations[35] approach can result in a grouping of subcatchments that are in actual fact very different from one another in terms of the land use percentage data [36].

The study by Taylor (1994) lists values for the percentage of a sub-catchment that is impermeable for five land use combinations[37]. Each sub-catchment is categorised in terms of one of these land use type combinations, thereby enabling a " standard " percentage impermeable value to be employed. Instead of retaining information that would reflect the heterogeneity of the sub-catchments there is a clear tendency to homogenise the land use descriptions of the sub-catchments under consideration. In the majority of the cases only one land use category has been assigned to a sub-catchment. It is clear that no attempt was made to incorporate an area weighted estimation of the various land uses within a sub-catchment, in the process of obtaining an estimate for the impermeability of the sub-catchments. Further more, informal housing areas are not considered within conventional hydrological modelling (eg. Taylor, 1994). Previous studies have also ignored inter-subcatchment land use variations[38]. Secondly extreme heterogenous nature of land use distributions within individual subcatchments are often overlooked[39].

10.3.6 Conclusions

The research conducted for the Lotus River project indicated that previous catchment studies are faced with several limitations. These studies tend to simplify or homogenize sub-catchment land use definitions for the purpose of stormwater runoff modeling Taylor, 1994; Schmitz & de Villiers, 1997). Further more, informal housing areas are not considered within conventional hydrological modeling (eg. Taylor, 1994). One way of incorporating the land use information at greater level of detail in the hydrological modeling process is to utilize the existing municipal cadastral GIS database. Detailed cadastral data exists for formal settlement areas. However, the lack of detailed data for informal settlements remains a key problem facing the application of detailed hydrological modeling methods at a sub-catchment level.

10.4 APPLYING THE BI-LEVEL MODEL FOR THE DEVELOPEMNT OF ICM DATABASE MANAGEMENT STRATEGIES FOR THE CAPE TOWN METROPOLITAN AREA

One of the key concepts of the Bi-level model is that of the linkages between the different database components (see section 6.7). The experience of ICM via the Web discussed by Ostrowski & James (1998) is based on the status of GIS and Internet infrastructures within developed countries. The discussion by Ostrowski & James (1998) indicates that ICM through the Internet is a feasible scenario for a developed country. However, modifications are required to facilitate the implementation of these concepts to a catchment in a developing country such as South Africa. The following section takes the ideals described by Ostrowski & James (1998) and evaluates the feasibility of applying such an approach within a developing country context. The system requirements for converting the proposed Internet based ICM approach into a functional reality for the Lotus River catchment are also highlighted.

10.4.1 A database model for Integrated Catchment Management

Any database model designed to aid the implementation of integrated catchment management in the Cape Town area must consider database management issues at both the catchment and metropolitan levels at least. A third level, the sub-catchment level, also needs to be considered when local level implementation work is to be carried out. In addition the model must facilitate the exchange of spatial and other (e.g. educational) types of information amongst various parties such as: the Cape Metropolitan Council (CMC), the Metropolitan Local Councils (MLCs), other government organisations, and non-government organisations such as: planning and development agencies, engineering consultancies, environmental groups and community groups. In this section the potential contributors to such a database are identified, the appropriate structure and data types for such a database are also investigated. The database management framework proposed for GIS-based ICM (Grobicki et al., in press) is summarised in Table 10.1.

<u>Key role players</u>

The CMC recently established a new department (Catchment Management Department) to co-ordinate the management of riverine systems in the Cape Metropolitan area. This department recognises the need to integrate ICM related initiatives between all the key role players (ie. CMC, MLC's, community groups, other authorities, other private sector groups). " To assist in the achievement of the goals of Integrated Catchment Management, the CMC: Catchment Management Department is in the process of establishing broadly representative Catchment Committees, which will co-ordinate activities within the individual catchments. These committees will be tasked with the development of Catchment Management Plans **through consultation and negotiation.**" (CMC, 1998: 24)

Table 10.1 Applying the Bi-level model to ICM in the Cape Town Metropolitan area

ICM database level	Envisaged utility & potential users	Conceptual functionality	General applicability	Institutions involved
Metropolitan- level	A management tool for the CMC and DWAF.	Strategic level analysis and management.	Water resource and demand management.	MLC, LMC, WRC, DWAF Consultancies, NGO's & Multiple Community representatives.
Catchment-level THE BI-LEVEL MODEL	A planning tool for project specific committees and team members.	Lumped parameter hydrologic modeling.	Water quality monitoring and site selection for source control applications.	MLC, LMC, Consultancies, NGO's & Individual community representatives
Sub-catchment-level	An implementation tool for local-level pilot project team members.	Distributed parameter hydrological modeling.	Implementation of intervention strategies.	LMC, LA, Consultancies, multiple representatives from individual communities.

The development of an appropriately designed Internet-based ICM database would be one way of accelerating information flows between the key role players involved in ICM. In addition to increasing the effectiveness of communication between the different parties, it could extend the capacity of non-governmental groups by facilitating access to spatial data captured by or for local authorities. Such data, which is often referred to as "public domain data" is not available in a form that is easily accessible by the public. A list of some of the potential contributors to the development of an ICM database for Cape Town is shown in appendix 7 table 5. The organisations that have contributed to the development of the Lotus River Catchment database, are keen to contribute (ie. schools), or that have contributed information which has yet to be incorporated into the database (South African Police Service) are shown in bold.

10.4.2 Catchment-level database management strategies

Database structure

At a catchment level there are essentially two of ways of attaching the attribute data to the spatial features. The attribute information can be attached either to sub-catchment polygons or to municipal area polygons. The selection of which spatial element should be used in order to structure the database will depend on a number of factors such as: the availability of certain data types, the dominant application of the database, etc. Ultimately it is determined by the primary focus of the organisation conducting the database building process. In the case of the Lotus River catchment there are about twenty municipal area polygons to which the data could be attached. The number of sub-catchments is slightly higher (about 30).

In addition to the issue of data availability, the concept of a "basic spatial unit" is useful when deciding upon the database structure to apply. A basic spatial unit (BSU) can be simply defined as the smallest spatial area feature to which attribute data is attached in a database. This should logically be selected as the smallest spatial unit at which heterogeneities need to be detected. Clearly for ICM applications at the catchment level, heterogeneities as one moves from one sub-catchment into another sub-catchment need to be visible. The discrepancies between the municipal area boundaries and the sub-catchment boundaries are such that these heterogeneities would not be detectable if a municipal area based BSU were to be applied. Municipal areas often contain a number of sub-catchments. In the case of the Lotus River catchment, the majority of the municipal areas contain between 2 to 12 sub-catchments[40]. Two other reasons exist for avoiding the use of municipal areas as the BSU. Firstly the municipal areas often extend beyond the catchment boundary. In the case of the Lotus river catchment, between about 5 % and 70 % of the following municipal areas actually lie <u>within</u> the catchment boundary: Lansdowne, Hanover Park, Sand Industria, Guguletu, Wynberg, Philippi, Grassy Park. Thus from a database management point of view, in order to reduce the amount of data in the database which does not lie within the catchment, a sub-catchment BSU is more appropriate. Secondly, one of the key functions of the GIS has been to provide primary and secondary parameter estimates for the hydrological modelling of the catchment. Parameters such as slope variations, concentration times, sub-catchment widths, the percentage impervious area etc., need to be estimated on a sub-catchment basis. Again, from a hydrological modelling point of view, it makes more sense to utilise the sub-catchment polygon as the BSU.

<u>Database contents</u>

The key data types essential to catchment-level database applications are described in detail in Grobicki et al. (in press). In summary these data types are as follows: 1) Sub-catchment and catchment boundaries, 2) Municipal area boundaries, 3) Land use data, 4) Stormwater network data, 5) Road network data, 6) Elevation data, 7) Groundwater data, 8) Soil data, 9) Hydrological data and 10) Ecological data.

The need for the sub-catchment, catchment and municipal area boundaries is self-evident and has been discussed in some detail above. The sub-catchment and catchment boundaries are needed for the hydrological modeling process and to delineate the boundaries of the GIS database. The municipal area boundaries are needed to identify which areas of the catchment fall under which municipalities. This has wider implications when the database starts being used to issue maintenance responsibilities to local authorities and communities. The land use, stormwater and road network data are schematic in nature and can be obtained from imagery and existing schematic maps. Relying on automated digital mapping methods to arrive at low resolution map (> 5 m) which distinguishes between permeable and impermeable areas is unsuitable. Such a solution may be rapid but it does not provide the land use classes required for ICM. On the other hand utilizing the detailed municipal cadastral data (> 0.5m) to estimate hydrological parameter inputs based on land use data has proven ineffective chiefly for several reasons[41]. It is more effective to implement a simplified land use classification scheme based on manual digitizing of digital ortho-photos. The land use classification scheme should incorporate at least the following classes: vegetated, not vegetated, cultivated, industrial / commercial buildings, formal housing and informal housing. The above database contents listing covers the majority of data types required for source control site selection analyses. The data types required for this work are listed by Makropoulos et al (1998).

Database location

It is envisaged that a number of catchment databases will exist within the metropolitan area – essentially at least one for each catchment which is being managed. Further more, one would expect that a number of organisational committees, such as the catchment management committees referred to in the *1997 False Bay and Table Bay Water Quality Committee Annual Report* (CMC, 1997: 18), would have stewardship of these catchment databases. The location of the catchment databases would be determined by the catchment management committees. In some cases, a database could reside in a consultancy or in another key organisation carrying out the bulk of the ICM related projects for a specific catchment. Thus a single catchment database could have warehouses distributed amongst a number of organisations working on the same catchment. Each catchment database would be updated to keep track of the developments and needs of the catchment. Other information, such as the results of sub-catchment level hydrological models should also be incorporated.

Database linkages

There are essentially three types of database linkages which are associated with the catchment level database. Firstly there are the linkages with other databases situated on the catchment level (ie. catchment warehouse – catchment warehouse connections). For example, three different consultancies and a project team within the Catchment Management Department (CMD) who are working on the same catchment, could all share information on the same catchment via a series of warehouse connections. Secondly, there are linkages between the catchment level database and the metropolitan level database situated at the CMD. Through these catchment warehouse – metropolitan warehouse connections information collated locally on suggested proposals and needs can be written to the metropolitan database, and information on development proposed by the metropolitan authorities can be read off the metropolitan database. The third type of linkage which can be constructed is that of catchment warehouse – sub-catchment warehouse connections. For each catchment level database there can exist a number of connections to sub-catchment databases within the specific catchment.

Database applications

Through the catchment warehouse – sub-catchment warehouse linkages, information can be collated on sub-catchment level problems and requests. The developers of the catchment level databases have the responsibility of reorganising sub-catchment level information in a manner which can be easily accessed by the metropolitan level database developers.

10.4.3 Metropolitan-based ICM database management strategies

It is important to note that GIS users at the metropolitan-level can use, and most cases require data at the resolution of the data captured for the catchment-level database. Furthermore, from a metropolitan point of view, the catchment boundaries can be treated as essentially geographically defined boundaries to the data of interest. In the first case study, political boundaries were omitted from the model to enable a bi-level approach. The metropolitan-level was connected directly to local-level databases. In same way, the metropolitan-level user of the ICM Bi-level model application can momentarily ignore the catchment boundaries if he wishes to, in order to access low resolution data for particular sub-catchments.

Database structure

The data acquired through the application of the Bi-level model can be reorganized into a lower resolution on the metropolitan-level. Such a reorganization of data may be useful for metro-wide resource allocation applications. It is this "reorganized" database structure that is discussed here. At a metropolitan-level attribute data can be attached either to polygons defined by the Metropolitan Local Council (MLC) boundaries or to polygons defined by the various metropolitan catchments. There are six MLC areas. The distribution of the catchments with respect to these MLC areas are summarised in appendix 10 table 2.6. From this table, the consequences of applying either approach may be investigated. It can be seen that several catchments lie within the area boundaries of a number of Metropolitan Local Councils (MLC). To address catchment analysis related applications, the database management approach which should be adopted is one that ensures the most homogenous database structure for the spatial data sets which are to be analysed. In other words the attribute data should be attached to catchment databases as opposed to MLC databases.

Database contents

A large number of different types of cadastral and topographical data can be acquired from the Directorate of Information Services (within the CMC). However, in order to not overburden the system with data the initial data contents proposal for this level of the database should be kept to the required minimum. The "skeleton" vector coverages which should be present are as follows: 1) Catchment boundaries, 2) LMC boundaries, 3) Built-up areas, 4) Main drainage system, 5) Service areas, 6) Informal settlement areas, 7) Formal areas and 8) Main roads. In addition it is envisaged that the database should be designed to cater for the display of four types of data. These are: 1) Development proposals, 2) Proposed service schedules, 3) Development needs and 4) Requested service schedules.

Database locations

The metropolitan level database should be situated within the Catchment Management Department at the CMC. The Catchment Management Department (CMD) would have the responsibility of collating and converting information from other departments within the CMC (eg. Storm water and Drainage, Cleansing etc.) and placing this information into the metropolitan level database.

Database linkages

Linkages should exist between the metropolitan database and any existing catchment level databases within the metropolitan area. In addition to placing the internal data on proposed development plans and services schedules onto the metropolitan database, the CMD would be responsible for creating linkages to catchment level warehouses. From the catchment level database warehouses, the CMD would be able to import data on development needs and requested services schedules. The key authorities in the metropolitan area (MLCs) should have linkages to the database as well. In this manner the authorities with funding and development responsibilities will bne able to access information on local needs and opinions.

Database applications

The proposed database contents and linkages would enable the metropolitan database to serve as a **platform for negotiation**. The database provides a platform 1) for internal CMC departments to display proposed service schedules and development plans, and 2) for information on locally requested developments and services (which has been collated and negotiated by the developers of the lower level databases). By placing both types of information on the same system the needs and the proposals can be compared on a regular basis.

10.4.4 Sub-catchment-based ICM database management strategies

The complexity of the database structure will vary with the number and type of applications the database is designed for. Unlike the metropolitan- and catchment-level where only one basic spatial unit may be sufficient for the required analyses, at the sub-catchment-level the number of basic spatial units will vary with the number and type of applications. At the sub-catchment level the "database" will actually comprise an interaction of databases. These interacting databases are in effect a series of interacting database warehouses. Some of these warehouses may include: a detailed cadastral database, a specialized sewer design system database, a local level informal settlement upgrading database etc....In the case of a specialized sewer design system database, detailed data is required for various elements of the sewer network. Data needs to be attached to the pipes and nodes of the system. Thus the required basic spatial units will be the "pipe" line element and a "node" point elements. In the case of a local-level socio-economic database a "shack" polygon will be used as the basic spatial unit. For the database approach followed by Rodriguez et al. (1998) a "base hydrological element" is used. This base hydrological element includes a geographic zone composed of a property block, a house and a street portion, adjacent to the property block. Thus the scenario can arise where a GIS user may construct a Geoworkspace in Geomedia where a number of basic spatial units of different morphologies (point, line or polygon) are simultaneously displayed. The sub-catchment level database content, locations and linkages are discussed in further detail in section 10.5.

10.4.5 Conclusions

The application of the Bi-level model for the development of ICM database management strategies in the CMR has several advantages. Some of these advantages are that:

- it enables a multi-scalar approach to ICM
- it encourages the diffusion of data through Internet connectivity
- it enables a sub-catchment land use variations to be mapped in greater detail than in previous hydrological studies

10.5 LINKAGES BETWEEN THE ICM APPLICATION OF THE BI-LEVEL MODEL AND POTENTIAL SECTORAL MODELS

In this section the benefits and practicalities of linking the two applications developed on the basis of the Bi-level model are tested.

10.5.1 Reasons for linkages

Lack of data for informal settlements

One of the key restrictions facing the implementation of GIS-based ICM strategies in developing countries is the lack of several types of digital data. While South Africa is relatively advanced in having digital cadastral data available for the metropolitan areas (when compared to other developing countries) there remain large gaps in this cadastral database. These gaps correspond to the informal settlement areas. In addition, there tends to be absolutely no subsurface infrastructure data available for the informal settlement areas and only a limited amount of subsurface infrastructure data available for the formal areas. Where paper base maps are available for the storm water drainage network in former township areas, these maps tend to be unreliable and out of date. The research conducted for the Lotus River project has shown that there is a need to incorporate land use information at greater level of detail in the hydrological modeling process (section 10.3). However, the lack of detailed data for informal settlements hinders the application of existing municipal cadastral databases for carrying out hydrological modeling at a sub-catchment level. By creating linkages to local-level informal settlement databases it is possible to access cadastral data for these areas.

The regional nature of ICM

The GIS platform provides a medium for co-ordinating information diffuse amongst users at a regional level. For ICM the transfer of resources between local boundaries must be considered at the same time. Wastewater and stormwater emissions from a single community may not be critical, however, "the accumulation of several communities along a small or medium size river might still cause manifold downstream problems...it seems compulsory to establish integrated watershed management plans. Local micro-scale impacts can be integrated and averaged and be input to meso-scale GDSS. Although some approaches have been developed much work needs to be done to build up meso-scale GDSS." 576. By creating linkages between the catchment-level ICM database and the metropolitan-level of the Bi-level model database, the regional distribution of informal settlement communities can be viewed in the context of ICM. It is particularly important to be able to map the location of informal settlements in a catchment as the cumulative effect of sewage out-fall arising from these settlements can result in the water quality of a river to become highly toxic.

Community-based sustainable development

The discussion by Ostrowski & James (1998) highlights the feasibility of Internet-based ICM applications. It also highlights the need for ICM approaches that incorporate the concept of community-based sustainable development. The definitions of DSS designed for ICM discussed by Lemons & Brown (1997) and Ostrowski & James (1998) reveal two issues. Firstly, that GIS is an essential component to ICM. Secondly that even though community participation is listed as a requirement the manner in which this may be achieved is not discussed. Instead the focus of the system seems to lie in serving the scientific and planning communities specifically. This is evident from the discussions of Lemons & Brown (1997) and Ostrowski & James (1998).

Ostrowski & James (1998) reproduce a table initially published by Tomalty and Pell (1994) which lists the requirements for planning process for community-based sustainable development. The same table has been reproduced here in order to identify issues that must be incorporated into the design of a ICM DSS for a catchment situated within a developing country (Table 10.2). The key issues have been placed in bold type. The local-level database approach developed for informal settlement upgrading by Urban GIS (Department of Civil Engineering, UCT), has been designed specifically for community-based sustainable development. It is only by creating linkages between the ICM database and local-level informal settlement upgrading databases that ICM can truly begin to include the process of community-based sustainable development.

10.5.2 Metropolitan-level ICM-Informal settlement database linkages

The issues of database structure, contents, locations and database linkages involving the metropolitan- and the catchment-level of an ICM database have been dealt with in sections 10.4.2-10.4.3. These two ICM database warehouses can easily be linked to a warehouse containing the metropolitan-level of the informal settlement application of Bi-level model by creating Access warehouse connections between the different databases. By using a connection linking the metropolitan-levels of the ICM database and the informal settlement Bi-level model database, all the informal settlements in the Cape Metropolitan Region can be viewed in the context of all of the catchments in this region. The linkage between the catchment-level ICM data warehouse and the metropolitan-level of the informal settlement database can be used to examine the relationships between the informal settlement within an individual catchment and all of the data types comprising the catchment-level ICM database. A number of applications based on these linkages are discussed in section 10.5.4 and illustrated in figures 10.2 and 10.3.

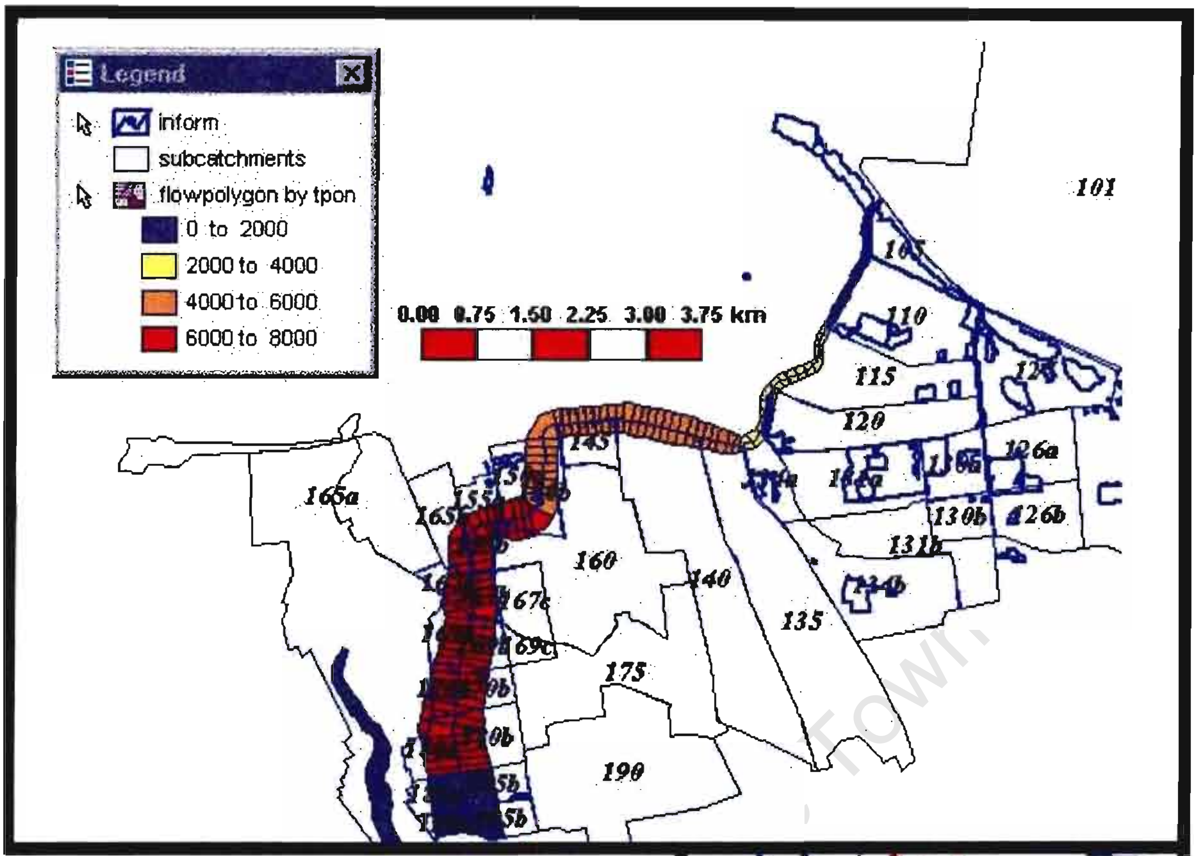
Table 10.2 : Requirements for planning process for community-based sustainable development (source: Tomalty and Pell, 1994)

Principles	Requirements
Community	**Is the decision process explicitly community- based?** **What ongoing consultation with community residents have been included?** **Does the planning process address community concerns?** **What rationale is there for the process in the stated concern of community residents?** **How does the process include consideration of identified social issues?**
Equity	Is the process democratic? Does the process promote equality of opportunity? Does it clarify or make explicit its basic values and beliefs? Are those values and beliefs consistent with a sustainability perspective?
Self-determination	**Is the process open and accessible to those who will be affected by it?** **Does it promote self-management at a local-level?**
Integration	Is the process systematic in orientation? Is the process synergistic, taking into account a variety of perspectives? Does the process acknowledge and account for inter-dependencies among social, environmental and economic well being?
Balance	Is the process cyclic and reflective? Does it include ecological principles, such as geographical boundaries, cross-general timeliness, and social and physical carrying capacity?
Diversity	Is the process inclusive? Can it embrace apparently opposing views, such as persistence and change? Does it anticipate and expect divergent points of view? Does it provide mechanisms for achieving consensus or otherwise resolving disagreement in situations where differences of opinion occur?

10.5.3 Sub-catchment/local-level ICM-Informal settlement database linkages

As previous stated (section 10.4.4) in the proposed ICM database framework Grobicki et al. (in press) the sub-catchment-level database is actually an interaction of databases and these interacting databases are in effect a series of interacting database warehouses. Some of these warehouses may include: a detailed cadastral database, a specialized sewer design system database, a local-level informal settlement upgrading database etc. In this section the benefits and practicalities of linking a sub-catchment-level ICM database designed for hydrological modeling and a local-level informal settlement upgrading database is investigated.

Initially, the basic contents of the sub-catchment-level ICM database hydrological database component can follow the guidelines implemented by Rodriguez et al. (1998). The following features were incorporated in the database for the Rodriguez et al. (1998) study: 1) Property block, 2) Houses, 3) Street segments, 4) Street sections, 5) Elevation data, 6) Sewer segments and rivers, 7) Base hydrological element, 8) Roads, 9) Surface flow path and 10) Pipe flow path. While several of these data types are readily available for formal settlement areas, very little data is available for informal settlements. Three of the five key elements required for hydrological purposes are typically missing from the GIS databases for informal settlement areas. In particular very little or no sewer network and elevation point data exist for the



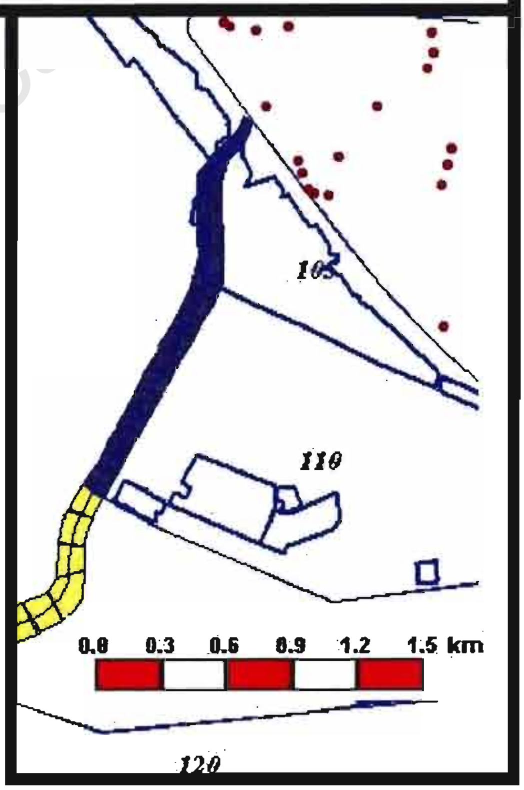


Figure 10.2
Top: Here one of the possible linkages between the two applications of the Bi-level model is shown. Here the Metropolitan-level (informal settlement application) and the Catchment-level (ICM application) data warehouses are linked. The informal settlements in the Lotus River Catchment are shown here in the context of the sub-catchment boundaries. Also shown is the variation in one of the hydrochemical parameters along the Lotus River canal.
Right: This inset shows the relationship of the canal to settlements in the northern area of Guguletu (Barcelona, Tambo Square, Kanana and KTC are shown). Dumping sites in Boquin (north of sub-catchment 105) are also shown

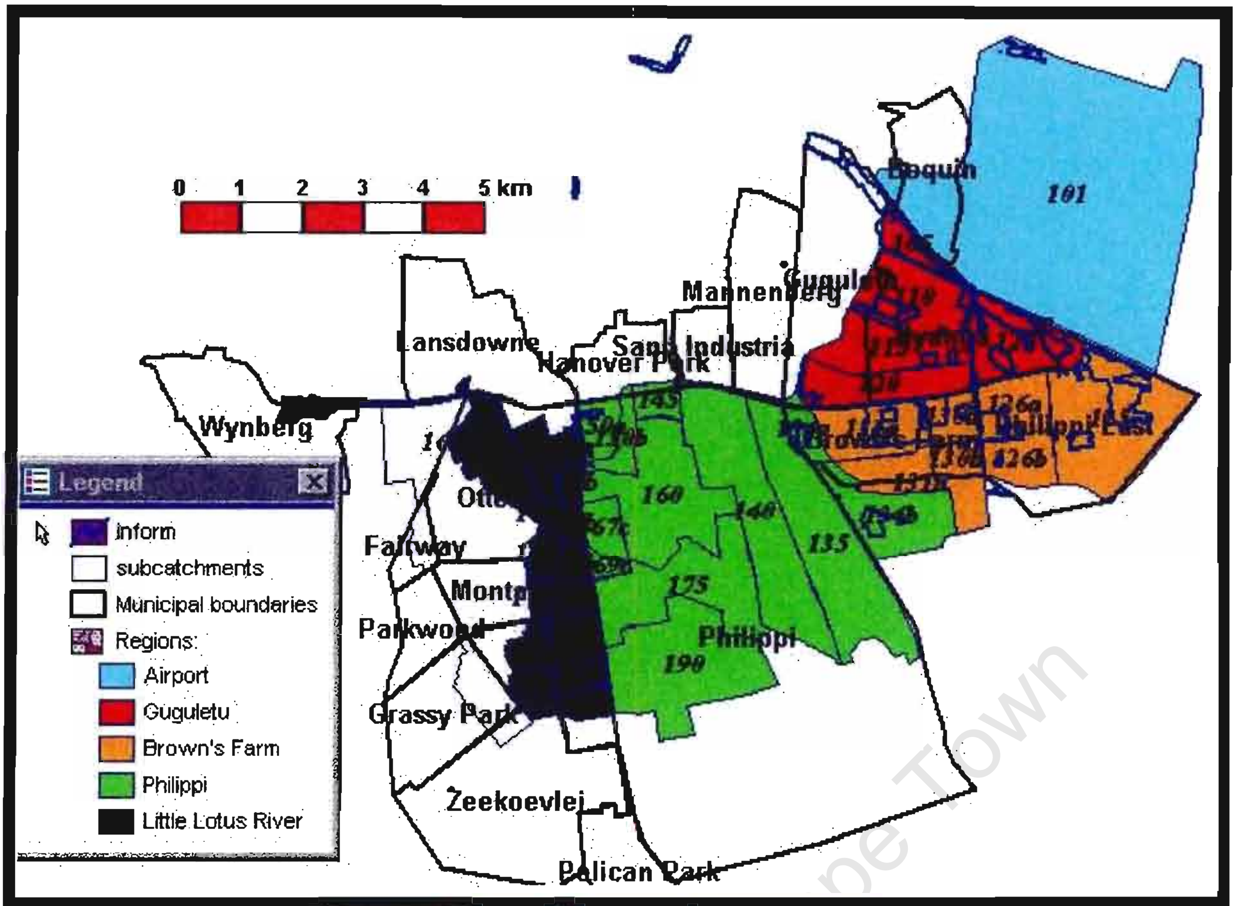


Figure 10.3
Top: An example of the Metropolitan-level to Catchment-level linkage. Here the municipal, sub-catchment and informal settlement boundaries are overlain. Also shown in the top figure are the five key land use regions into which the sub-catchments may be grouped.

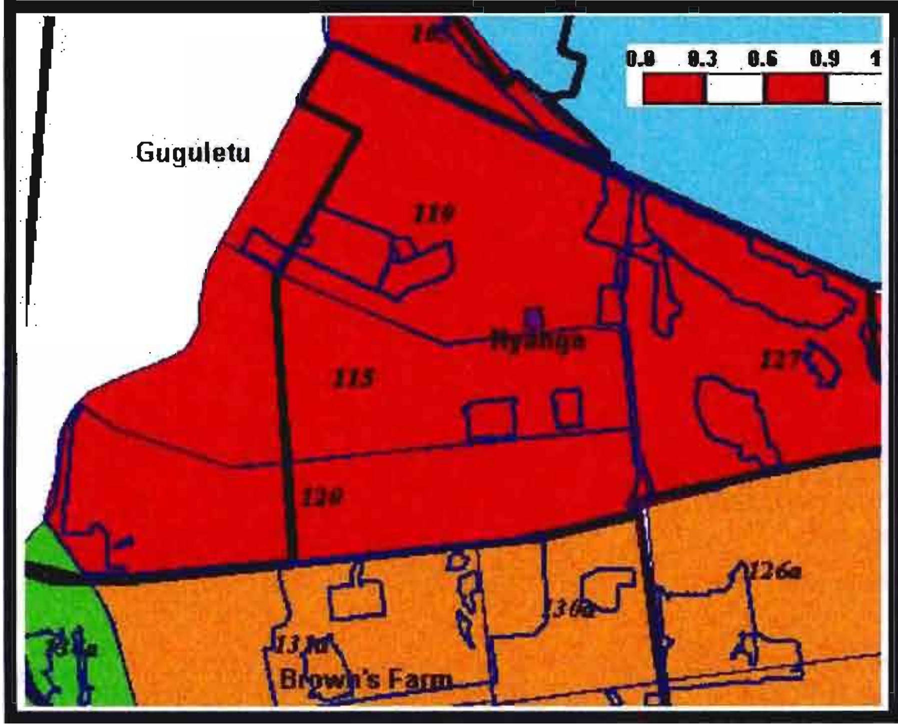


Figure 10.3 Bottom: A zoom view of the Nyanga, Guguletu and Brown's Farm areas. These diagrams illustrate the management potential created by linking the two database models.

informal settlement areas. In addition, parcels are often not defined or not adhered to by the population in these areas. The definition of street is also unclear in these areas.

Database contents

The creation of linkages to local-level databases representing informal settlements within a particular sub-catchment may be used to extend the contents of a sub-catchment-level ICM database. A local-level informal settlement upgrading database can provide vector data for the 1) shacks, 2) public buildings, 3) access tracks, 4) road layout, 5) flood risk areas, 6) geotechnical data, 7) contours and 8) previously planned: servitudes and cadastral boundaries within an informal settlement area. Figure 10.4 illustrates how detailed cadastral data for the formal settlements can be linked to a local-level informal settlement vector database.

In addition to the hydrological component of a sub-catchment level database, there must be an additional database component to ensure that the ICM process involves community-based sustainable development. It is here where the principles outlined by Tomalty and Pell (1994) (Table 10.2) can be incorporated into the ICM database model. One may extend the sub-catchment-level ICM database to include this non-hydrologic database by creating a second linkage between the sub-catchment-level database and the local-level informal settlement attribute database. The hydrological modeling data can then be seen in the context of detailed socio-economic data. This data includes various types information (eg. whether flooding occurs, the sanitation type used, the number of occupants etc..) for each shack. Figure 10.5 illustrates some of the attribute data types that can be accessed through this linkage.

A fourth component of the sub-catchment-level database can be comprised of a series of vector data layers that reflect: 1) development proposals, 2) proposed service schedules, 3) development needs, and 4) requested services. For each infrastructure type a "development" warehouse can be created with each of these vector layers. Thus at the sub-catchment-level contents of the database can be derived from:

1. a primary sub-catchment-level hydrological modeling database
2. linkages to local-level informal settlement cadastral vector databases
3. linkages to local-level informal settlement socio-economic attribute databases
4. a secondary sub-catchment-level development proposal database

Database locations

The locations of the following two key databases need to be considered: 1) the sub-catchment-level database and 2) the local level informal settlement database. The sub-catchment level hydrologic database should reside in a local authority. The local-level informal settlement database should reside within the community undergoing upgrading, or within an institution which facilitating the upgrading process.

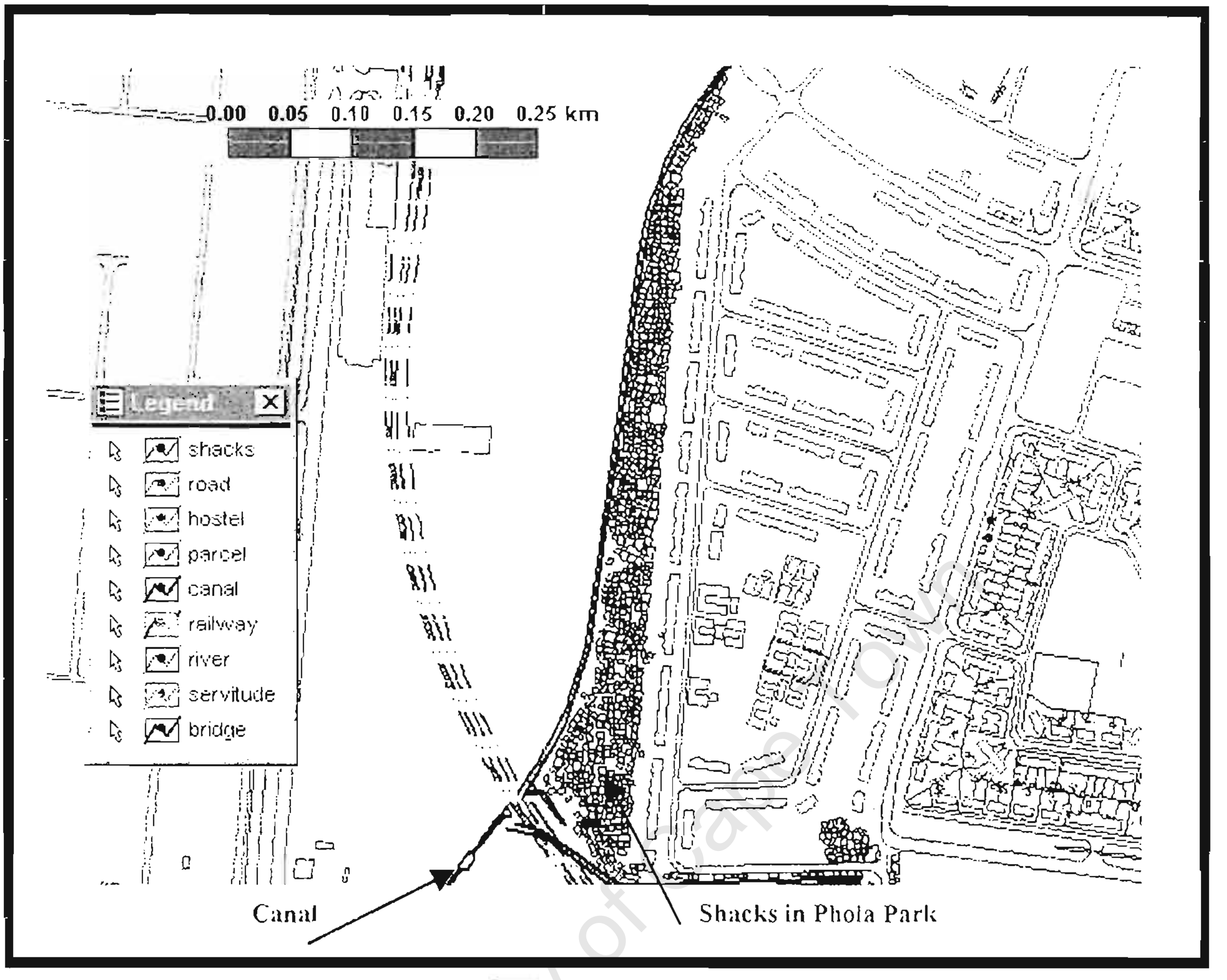


Figure 10.4 An example of the detailed cadastral data for the formal settlements (available in municipal databases) can be linked with the cadastral vector data being collected for local-level informal settlement upgrading databases. The area shown here forms part of sub-catchment 120 of the Lotus River Catchment and contains the Phola Park informal settlement.

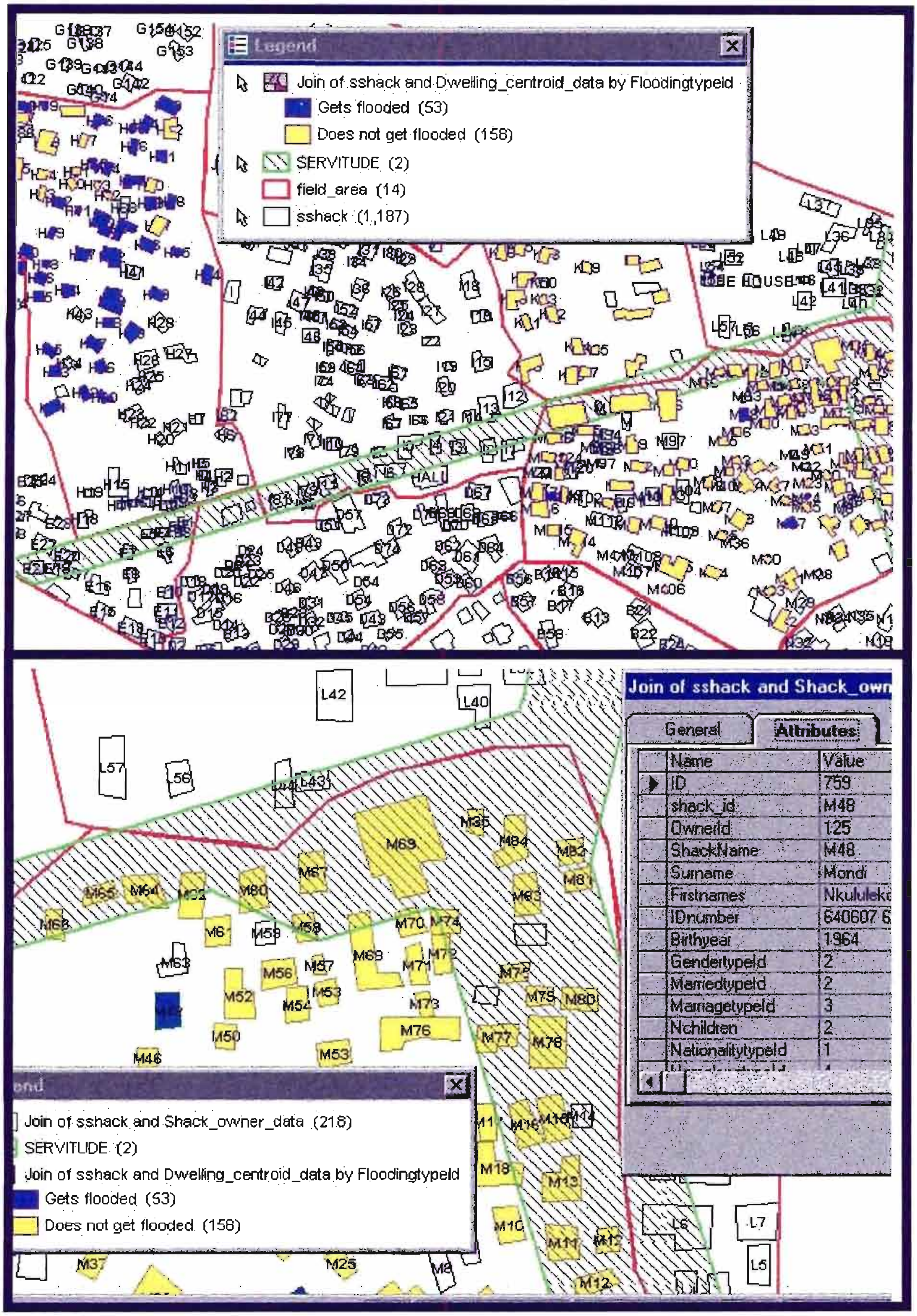


Figure 10.5 This diagram illustrates a linkage between a sub-catchment-level and a local-level database. The top diagram illustrates a thematic map showing shacks that are flooded in winter. The bottom diagram illustrates shacks that should be considered for relocation as they are situated within the planned stormwater runoff servitude. This diagram also illustrates the type of detailed social-economic data that can be accessed on a per shack basis once a linkage between the sub-catchment-level database and the local-level informal settlement attribute database exists.

Database linkages

The number and nature of linkages at the sub-catchment level changes to accommodate the different types of data sources. At this level the majority of the data sources will not be in a computer format. Thus computer-based and non-computer-based database linkages are envisaged. Computer-based linkages may exist between the sub-catchment database and the nearest MLC system. This depends whether the sub-catchment database is linked to the Internet. The same is true for the sub-catchment database – local level upgrading database linkage. If Internet connections are not available, the information will simply have to be manually transferred from one database to the other. Non-computer based linkages are also envisaged between the sub-catchment database and several institutions within the sub-catchment. These institutions include: schools, police stations, community groups, NGOs and DFAs. Inputs should include the results of other ongoing water related community projects. For example, the results of local development programs as discussed by Schoeman (1997) should be incorporated into the database.

The potential for extending the contents of sub-catchment-level database to allow detailed hydrological modeling to include informal settlement areas in a sub-catchment has already been referred to. In order to do this, a linkage would have to be made between a sub-catchment ICM vector warehouse and one or more informal settlement cadastral vector data warehouses. The creation of such a linkage within GeoMedia has a bi-directional functionality. Thus not only can the linkage be used to extend the area of sub-catchment to be modeled in detail, it can also be used to place the informal settlement in the context of the surrounding roads and services. In this manner the linkage can be seen as a medium by which one can investigate planning potentials for integrating the informal settlement with the formal city.

The creation of a linkage between the sub-catchment ICM vector warehouse and the informal settlement socio-economic attribute data warehouse is slightly more complex. Within GeoMedia, the shack outlines and the socio-economic attribute database are linked by creating joins based on a common shack identification name. The joins created in this manner are stored as queries. These queries can be used to create thematic maps that in turn can accessed as new features within the informal settlement vector data warehouse.

Database applications

The database linkages and information inputs described above can facilitate a number of essential applications. For example, the database can be used for local quality of service monitoring. Specifically the community can input into the database by delivering information on local problems such as blocked pipes, inadequate garbage removal services etc. The proposed database contents and linkages would enable the metropolitan database to serve as a **platform for negotiation**. The database provides a platform 1) for internal CMC departments to display proposed service schedules and development plans, and 2) for information on locally requested developments and services (which has been collated and negotiated by the developers of the lower level databases). By placing both types of information on the same system the needs and the proposals can be compared on a regular basis.

The main advantage of working with higher accuracy data at the sub-catchment level is that it can be used to guide local-level interventions. The above database contents list can be extended if or when it is certain that the database will be used to evaluate the sewer network for future development. The database contents for such local-level applications are discussed by Hora et al (1998) and Pryl et al. (1998).

10.5.4 Environmentally sustainable development

In chapter seven, it was indicated that the environmental component of the Urban GIS models was placed second to the formal and informal sectors in the Bi-level model. May et al. (in press) provide the option of a "Quantifiable City" model, however, for reasons already discussed this option is not viable for a developing country. The creation of linkages between the ICM and informal settlement database warehouses ensures one way of incorporating the environmental component into the development planning process.

The community can observe the implications of its own planning proposals within the context of ICM. It can begin to see how local interventions and day-to-day living habits (eg washing clothes in a river, dumping garbage or sewage into a river etc.) can have detrimental effects downstream and regionally. In other words, the at a local-level the linkage can be used in an educational manner. Further more, "community-based development" implies that it is the community that decides how the informal settlement should be upgraded. The linkage between the sub-catchment-level database and the local-level informal settlement database provides a medium in which the community can examine its own planning proposals. This linkage can help the community to choose more environmentally friendly development options.

The linkages based on the metropolitan and the catchment database-levels can also be used to encourage environmentally sustainable development. In chapter nine it was illustrated how the relocation process can be optimized by examining the densities of sub-settlements. In Chapter 9 it was illustrated how the average density of a settlement can be reduced to a range proposed planning densities by removing quantifiable numbers of shacks from different sub-settlements. Even though appendix 6 table 9 provides a means of minimizing the number of shacks to be removed there is still an infinite number of ways in which the shacks from an informal settlement could be removed. By placing the sub-settlement in the context of the catchment and sub-catchment ICM databases, the minimum relocation process can be further refined into an "environmentally friendly minimum relocation process". Further more, these linkages enable a series of administrative and hydrological boundaries to be overlain for purpose of managing the catchment. These boundaries include: the sub-catchment boundaries, municipal service boundaries, informal settlement boundaries etc. It is only by creating such boundary overlays that the responsibilities of all of the stakeholders in ICM can be laid down in an effective manner that will ensure environmental sustainability.

CHAPTER 11 CONCLUSIONS

11.1 INTRODUCTION

In chapter 1 three hypotheses were proposed for investigating the use of GIS in the field of informal settlement upgrading within the context of a city-wide planning framework. The validity of these hypotheses was examined through two case studies and an extensive literature review in part 1 of the thesis. One of the issues that arose from this research is that there was a need for the development of a new urban GIS database model for informal settlement upgrading. In view of this need, part 2 of the thesis was designed to focus on the development of such a model, which was termed the Bi-level model. Once the model had been developed, part 3 of the thesis was designed to test its applicability. For this two real-life applications-based case studies were created. The first case study concentrated on applying the Bi-level model for informal settlement upgrading planning in the Cape Town Metropolitan Region. The second case study was concerned with testing the applicability of the Bi-level model in the context of Integrated Catchment Management.

In this chapter, the conclusions of all the foregoing research chapters in parts 1 to 3 are summarised. The conclusions to the thesis are presented in three sections. The first section provides a discussion of the hypotheses in the light of the research findings. This is followed by discussions on the feasibility of multi-scale approaches in other countries and on the applicability of the Bi-level model. The second part provides a summary of the main findings of the thesis that are relevant to both local and international researchers. The third part of the chapter identifies five areas for future research. These potential areas of research deal with the allocation of financial resources, spatial-temporal analyses, the use of satellite and digital ortho-photo imagery for land use mapping, and GIS-based ICM analyses.

11.2 REVIEW OF HYPOTHESES

11.2.1 Discussion

Several conclusions arising from chapters 2 to 4 support the first hypothesis, which was formulated in chapter 1 as follows:

H1:

Existing GIS implementation approaches in developing countries have led to the development of municipal GIS systems based on similar systems originally designed for developed countries. These systems have been designed to meet the needs of formal settlements within the city. They are not well suited to the informal settlement areas or to the urban areas of physical decay and / or economic decline.

The problems associated with the cadastral approach followed in a number of European countries were highlighted in section 2.4. These countries include Germany, Italy, Denmark, France, Poland, Netherlands and Greece. While informal settlements are absent from the developed European countries, the developing European countries are characterised by areas of physical decay and / or economic decline. The research from France in particular (section 2.4.5) showed that the cadastral approach is not meeting the needs of the communities in these areas.

In chapter 3 it was shown that the Cape Town City Council GIS in South Africa follows a cadastral approach based on the cadastral systems encountered in the developed European countries[1]. Furthermore, chapter 3 showed that the current organizational structure[2] is inappropriate for the development of an effective GIS system[3]. In particular section 3.12 illustrated that the cadastral approach has resulted in an absence of GIS applications for informal settlements in the Cape Metropolitan Region (CMR). The problems facing the application of the cadastral approach in informal settlement areas were discussed in section 6.8. In summary, these areas lack accurate cadastral data. In addition, there is a complete lack of reliable base maps for sub-surface infrastructure services. Yet these are the areas with the greatest need for development, and are clearly the areas that could benefit the most from GIS. Thus the literature review of developed country experience, together with the case study of the CCC, demonstrated that the cadastral approach has problems providing a suitable primary database for large formal areas, and is totally inappropriate in areas with large numbers of informal settlements.

In terms of other developing countries, chapter 4 it has shown how several authors have questioned the validity of existing GIS systems in these countries (Dangermond, 1988; Taylor, 1991, Singh, 1989)[4, 5]. The problems facing GIS in developing countries have been discussed in section 4.7. In summary, there are data availability, political and bureaucratic, socio-economic, technical, implementation and database design problems. In particular, the problem of "gaps" in the digital cadastre has been encountered in Kenya, Cambodia, Ghana and the Middle East (Williams et al., 1997; Strand, 1993; Larbi et al., 1997; Bell et al., 1993). Bell et al. (1993: 32) specifically comments that in addition to other problems[6], "there are gaps in the higher accuracy layers of the database", and that "..the upgrading and inclusion of these parcels to an acceptable accuracy is one of the more difficult areas of current investigation." In addition to the incomplete and incoherent nature of the land ownership data, the lack of security of tenure in informal settlements and rapidly changing nature of informal settlements make it difficult to maintain a cadastral approach in these areas. Fourie (1998, p 4) states clearly that the cadastral systems in the African developing countries are a product of colonial histories of these countries and that they are not meeting the needs of the population in these countries[7]. Furthermore, Fourie (1998) highlights a number of key problems that face cadastral systems in these countries (see section 4.5.1).

In addition to the cadastral based approaches described above, a large number of the GIS initiatives in developing countries are designed either to meet the needs of the environment or of specific planning agencies. The needs of the community are usually not considered at all in the system design process. Examples of GIS systems with an environmental focus include: the Global Resource Information Database in Kenya, the Environmental Information System Development in Ghana, and a large number of environmental systems in the CIS. Systems catering for the needs of the planning communities are discussed below in the context of the second and third hypotheses. A final group of GIS applications typically found in developing countries include those applications initiated for research purposes. These applications tend to be "one-off" events, and have often been developed at an overseas university - thereby making local implementation of the application more difficult. Examples of these applications include the health facilities study by the University of Nottingham, the repatriation application developed by the University of Finland and the housing plan analysis system developed by the University of Newcastle.

The conclusions from chapters 4, 9 and 10 support the second hypothesis, which was formulated as follows:

H2:

There is a demand for the development of GIS-based strategic-level applications for informal settlement upgrading worldwide. This demand is particularly great in areas such as the CMR, where the upgrading policy is primarily one of relocation to new formal areas. It can be shown that GIS can play a key role in formulating and managing a strategy for informal settlement upgrading at the strategic metropolitan-level.

With respect to the second hypothesis, the reviews on the local and international GIS-based upgrading programmes revealed that, globally, very few GIS systems dedicated to informal settlement upgrading have been developed specifically for metropolitan-level strategic management and planning applications[8]. In chapter 4 it was shown that the strategic-level systems which do exist have been designed to address the needs of planning agencies and provincial government. More specifically in South Africa, the PROLAND system has been developed to identify vacant land available for the implementation of the *relocation* policy in the Western Cape. No consideration is given to in situ upgrading in the GIS database model. Where in situ upgrading *is* being considered in South Africa, as in the case of Gauteng, GIS remains greatly under-utilized in terms of strategic-level applications for informal settlement upgrading. In summary, both locally and internationally, there is no mechanism for coordinating local-level informal settlement upgrading programmes with city-wide metropolitan planning processes. Furthermore, the unsuitable nature of the current relocation policy in South Africa, discussed in section 1.3, highlights the urgent need for such a tool. The second hypothesis is also strongly supported by parts 2 and 3 of this thesis. These parts illustrate that the Bi-level GIS database model can be used to collect and interpret data on informal settlements which can play a vital role in the formulation and the management of a strategy for informal settlement upgrading at a strategic metropolitan-level. Section 11.2.3 below discusses the applicability of the Bi-level model further.

Finally, chapters 4 to 6 largely support the third hypothesis, which was formulated as follows:

H3:

The information processing tasks associated with informal settlement upgrading work involves localised detailed mapping, as well as broad based planning and management decisions. This necessitates that data processing be carried out at two levels, namely at the metropolitan level and at the informal settlement level. In order to meet this requirement a Bi-level approach must be followed for the development an informal settlement upgrading database.

It is clear from these discussions that current GIS systems developed for informal settlement upgrading by government, development agencies and other organisations, tend to function on only one spatial level. These systems are generally dedicated either to local or to metropolitan level applications. In South Africa, PROLAND is an example of a metropolitan-level GIS system developed by the Provincial Administration (PA:WC, 1997). In this system, only the needs of metropolitan spatial planners, who are primarily concerned with environmentally friendly policies and the requirements of imposing a relocation policy have been met. Other weaknesses of this system were that there is no community input into the database and that the system is dependant on the permanency of politically defined sub-structure boundaries. It is specifically important to note that the PROLAND system has no *local-level* applicability. The Megasub HELP database is faced with similar limitations (see section 4.4.5).

With respect to other developing countries, the PADCO case studies discussed in section 4.3 revealed systems that have been designed for regional or metropolitan planning. In Jamaica, the Shelter Sector Monitoring System was designed for the Planning Institute of Jamaica (PIOJ). A subsequent GIS-based system for the Montego Bay area was designed again for metropolitan-level work. In the Philippines the RLA methodology catered for the metropolitan planning needs of the City Planning and Development offices. Similarly, the AFRICAGIS proposed as a LIM system by Fourie (1998) for the developing countries in Africa has been designed primarily for the subregional-level. In contrast, chapter 5 indicated that in the case of Brazil, while the need for databases at a local-level was recognised, there remained a need for metropolitan-level co-ordination of these databases.

Similarly in the case of other developing countries, where the need for local-level GIS databases has been recognised, these databases remain as isolated systems. Sections 4.4 and 4.6 indicated that this was true for local-level systems in Africa, India and China. In the case of Africa, the housing transformation database developed by Napier (1994) provides such an example. This system focuses entirely local detailed housing issues. No consideration is given to strategic-level processes or the provision of other infrastructure services at the local-level. In India, the Asian Institute of Technology (AIT) has developed one or two isolated local-level systems (Computer Assisted Regional Planning, CARP). There is no metropolitan level co-ordination of these databases. Consequently, the local-level platform configuration that has been adopted for the implementation of the CARP methodology has resulted in a disjointed information system. The same is true for the limited number of local-level databases in China and other countries.

Furthermore, while the AFRICAGIS system does not provide a multi-level approach, it is clear from Fourie (1998) that such an approach is essential. Statements are made in the discussion that are clearly in support of a multi-scalar approach (ie. one of varying scales / accuracies)[9] to urban modeling that places the land office at the local level[10] (Fourie 1998, p 7,10). In particular, Fourie (1998, p. 9) states:" The LIM system should include the data sets being created at the centre by the macro, broad brush or initial planning exercises and surveys. It should also include the information created on the ground, as an outcome of the stakeholders negotiations. It should also manage the information flows between the centre and the local level, as these are critical to the success of such a participatory land use decisions and the knowledge sharing process."

It is clear that where as the metropolitan-level can assist in regional strategic-level planning, local interventions and the evaluation of in situ upgrading projects require the development of local-level databases. According to PA:WC (1997), the current government theoretically supports the philosophy of a minimum relocation policy. The planning issues associated with a philosophy of minimum relocation needs to be addressed at both the metropolitan and the local levels. A Bi-level approach is thus absolutely essential for the development of local metropolitan municipal systems if the government is at all serious about evaluating potential in situ upgrading scenarios within a GIS environment.

In summary, the literature review and case studies in part 1 of the thesis showed that the current Urban GIS models are characterized by certain limitations. These include the lack of the following: a mechanism for community participation, a multi-scale approach, a mechanism for project management, linkages to the formal sector, linkages to the environmental sector and a mechanism for coordinating initiatives at a global-level. In order to address these problems, and the more generally defined problems raised the first and second hypotheses, the Bi-level GIS database model was designed. This model was then used to validate the utility of GIS for formulating and managing strategy for informal settlement upgrading at a metropolitan-level, and more generally the utility of a Bi-level GIS approach to informal settlement upgrading.

11.2.2 The feasibility of multi-scale approaches

The creation of a GIS database for the Cape Town Metropolitan Region based on the methodology developed for implementing the Bi-level model (see chapter 8) has shown that the implementation of such a model is feasible in South Africa. While it would be practically impossible to test the feasibility of the model in the same manner for other countries in this thesis, it is possible to test the feasibility of one of the key aspects of the model. The Bi-level model is in essence a multi-scale GIS database model. Thus before one can consider the feasibility of the model, one must first consider the feasibility of multi-scale GIS approaches in other developed and developing countries.

The trend towards multi-scale GIS approaches in the developed European countries has been highlighted in chapter 2 [11]. This trend is particularly evident in Germany and France. Amongst a number of the developing countries considered in chapter 4, there appears to be an eagerness to embrace multi-scale GIS database approaches. These countries include China, the Middle East and India. While the importance of a multi-scale approach to GIS is recognised in China, there remains a need to develop local-level systems to a far greater extent (Taylor, 1991; Chen, 1987)[12, 13]. In the Middle East the GIS proposed for the Ministry of Municipal and Rural Affairs (MOMRA) Municipal Information System (MIS) is comprised of a local, a regional and a national level. Similarly, the more recent Qatar Societal GIS system has also followed a multi-scale approach. While these systems are multi-scale, they have not been designed to cater for informal settlement upgrading work. As a consequence they neglect other issues crucial for informal settlement upgrading such as community participation and the development of a detailed socio-economic database.

In India, the macro-level GIS is embodied in the Digital Cartographic Database. At a micro-level, there are systems in single districts, which are either part of the Natural Resources Database Management System or part of the Computerised Rural Information Systems Project (CARP). A quotation from Parthasaradhi and Kirshnanunni (1989: 321) emphasises the need for a multi-scale approach: " The suggestion has been made that at least six <u>different databases at various level and scales will be required since no single level of database would meet all the diverse requirements of planners for macro-, regional- and micro-level planning</u> for the management of resources." As the quotation and text illustrate, macro and micro level applications are present in India. However, the implementation remains predominantly a "top down approach", with the development of local-level databases occurring to a far more limited extent than higher levels of the database. Furthermore, the scale restriction imposed on thematic mapping in India for large parts of the country by the presiding national data security data policies, could provide a problem to the Bi-level approach proposed in chapter 6. Finally, as shown in sections 4.5.1 and 11.2.1, the most recent literature on LIM systems for the African developing countries, does not suggest that "a multi-scalar approach is feasible", but rather that "*only a multi-scalar approach* (which incorporates the cadastral system as a sub-system) is feasible."

11.2.3 The key features of the Bi-level model

The key features of the Bi-level model are discussed in detail section 6.7. In this section a brief summary of these features is provided. Firstly, the Bi-level model is a GIS database design which has been developed to enable GIS to be used for informal settlement upgrading applications by municipal organizations and other key role players involved in the upgrading process. The model consists of a series of inter-linked GIS databases. It provides the framework for linking a multitude of local-level informal settlement upgrading databases and can also be interfaced with existing municipal cadastral databases. This in turn enables informal settlements to be analysed in the context of the existing formal settlement urban infrastructure.

At the centre of the Bi-level model is a metropolitan-level database. Attached to this basic reference framework are a series of local-level databases. All of the databases are constructed so as to ensure compatibility with local authority GIS and other government systems. The Bi-level model itself resides within a Universal Reference Framework, which is essentially the set of all the information systems databases on earth. Many specialised information systems feed into the universal reference framework. In this case, the Bi-level model represents a system specialised for informal settlement upgrading applications. Within the Universal Reference Framework, there are a number of databases that can serve as useful extensions to the Bi-level model. These may be termed as potential sectoral models to the Bi-level model, which are in essence models that have been developed to model sub-systems within the city.

The metropolitan-level database consists of a combination of raster, vector and attribute data types. The raster data is comprised of ortho-rectified aerial photography images at a scale of 1: 10 000 to 1: 20 000 or better. These images have been scanned to have a pixel resolution of approximately 1 - 2 m. The images cover all of the informal settlement bearing areas in the metropolitan area and are used as a backdrop for digitising the vector data. The vector data itself is comprised of shack points, settlement and sub-settlement area boundaries and centroids. The basic spatial unit implemented in the metropolitan-level database is the sub-settlement centroid. Again each local-level database is comprised of a combination of raster, vector and attribute data. The raster data consists of low-altitude helicopter photography at a scale of 1:200 to 1: 500. These images are georeferenced using the ortho-rectified imagery in the metropolitan-level database[14]. The mosaic is used to create a basic digital cadastre and to capture the existing infrastructure for the settlement. The features that are captured include shacks, shack centroids, toilets, stand pipes, tracks and streams. The basic spatial unit implemented at the local-level is the shack polygon. Once a basic digital cadastre has been developed it is checked through on the ground confirmation. This vector database is then populated with detailed socio-economic data on the settlement. The types of attribute data that are attached to the shack polygon provide information on the dwelling, shack owner, the spouse and children of the shack owner and other residents of the shack. These data sets are entered onto the system by the community using a specially developed user-interface.

The linkages form an integral part of the model as they control the development and the functioning of the Bi-level model. These linkages may be defined both in terms of the characteristics of the databases that are linked and in terms of the accessibility these databases. On the basis of the content of the databases linked, three types of database linkages form part of the Bi-level model. These are the:

- metropolitan-level to local-level database linkages
- metropolitan-level to sectoral model database linkages, and
- local-level to sectoral model database linkages

In addressing the issue of implementation of the Bi-level model, it is more useful to define the linkages in terms of the location and the type of software in which the databases reside. In view of these criteria linkage between the main metropolitan-level and local-level databases may be broken down into a further three types dictated by the GIS capabilities of the local authorities or other local organisations involved in the development of the local-level databases. These connections can be described simply as linkages between the metropolitan-level project on the main system and local-level databases on:

- the main system intranet
- remote client machines with significant data capturing and processing facilities
- remote client machines with very limited data capturing and processing facilities

Further characteristics of these linkages are discussed in detail in chapter 8. It is more important here to note that these basic linkage types can be created through the low-end GIS platform database connection utility. Using the concept of a database connection these linkages can be redefined in a manner that reflects the varying degrees of accessibility of each database. The linkages can be seen to extend across four intranet- / Internet-based linkage accessibility environments. These are: the Corporate Intranet and three types of Internet environments that may characterised by containing local sites based on:

- a standard low-end GIS platform
- other GIS platforms supported by the standard low-end GIS platform
- all other types of software

The degree of accessibility declines as one moves away from databases residing on platforms that are not supported by the low-end standard GIS platform selected to implement the Bi-level model. The linkages to sectoral models can be particularly useful in extending the applicability of the model. Systems that can be accessed using this linkage type include those developed by government institutions such as: the Agriculture Research Council, the Department of Water Affairs, municipal GIS systems and the Council for Scientific and Industrial Research. Many of these systems are currently based on ArcInfo and can be accessed through the Internet by creating a database connection from the standard low-end platform.

<u>Problems addressed by the Bi-level model</u>

The problems facing existing urban GIS models and current informal settlement upgrading models (such as the PADCO, ViSP, Urban Modeller and PROLAND) were discussed in detail in section 6.8.1, which provides a useful background for gauging the significance of the Bi-level model. The Bi-level model addresses the short coming facing current informal settlement upgrading models by providing:

- a mechanism for community participation
- a multi-scale approach
- a mechanism for project management
- linkages to the formal sector
- linkages to the environmental sector
- a mechanism for co-ordinating initiatives at a global-level

Internationally, the Bi-level model provides a significant contribution in terms of providing a mechanism for addressing some of the problems that have hindered the diffusion of GIS not only in the developing countries but also in European and in other developed countries. More specifically, it provides a generic model for inter-linking and co-ordinating the development of GIS databases for those areas of the city that are characterised by a lack of digital data. While the "black box" approach to informal settlement upgrading facilitates the implementation process, it also results in a series of disjointed local-level databases. This problem is circumvented from the outset start in the Bi-level model. Furthermore, the Bi-level model represents a generic tool that can be applied more widely than to just informal settlement areas. While the model was initially devised as a tool for managing local-level informal settlement upgrading databases, it can be applied to manage the development of any type of local-level database created to compensate for gaps in the digital cadastre.

Comparisons with other multi-level models

While chapter 4 has shown that there is a growing tendency towards multi-scale approaches in the developed countries, these models are based on data management strategies that would be extremely difficult, if not impossible, to implement in the vast majority of developing countries. The key difference between the multi-scale database models under development in Europe (MERKIS, Plan Topo-Foncier and Urban Data Bank) and the Bi-level model lies in the principle focus or functionality of the model. The principle aim of the European models lies in a nation-wide integration of all local authority GIS databases. In contrast the principle aim of the Bi-level model lies integrating the data sources of associated metropolitan-level and local-level databases. The primary goal of the Bi-level model is not a nation-wide integration of all local authority GIS databases (which would decades), but rather to provide a realistically obtainable mechanism for accelerating processes relying on data that are generally absent from the digital cadastre. In South Africa, the informal settlement upgrading process is an example of such a process.

Amongst the developing countries, the Qatar Societal System is probably the world's leading multi-scale system. Yet even this system has been developed with a focus on the formal sector of the city. Unlike all of the other multi-scale approaches, both in the developed and developing countries, which focus on either the formal or environmental sectors of the city, the Bi-level model has been designed specifically for the sectors of the city that are typically omitted from the digital cadastre.

Thus while even the latest multi-scale models amongst the developing countries conveniently ignore the gaps in the digital cadastre, the Bi-level model has been designed to specifically address these gaps. The implementation of the Bi-level model starts with an identification of the "gaps" or "holes" in the digital cadastre. These areas correspond to informal settlements or to areas of no data. A boundary is then drawn around the hole and a centroid is placed in the hole. Basic attribute data on the area corresponding to the "digital data gap" is then attached to this centroid. Furthermore, to this centroid, a linkage is established to a local-level database when the latter has been developed. Thus the first linkage is between the metropolitan and local level database components of the model. It should be noted that these two database components are *application specific.* This linkage forms part of the internal mechanism of the Bi-level model. In addition to the first linkage, there is a second linkage that connects the Bi-level model to other specialised database models (potential sectoral models).

11.2.4 The applicability of the Bi-level model

The practical application of the Bi-level model has been demonstrated in this thesis through two case studies. The first case study discussed in chapter 9 has illustrated that GIS can play a very significant role in guiding the informal settlement upgrading process at a strategic-level. The overlay capabilities of GIS make it an essential tool for comparing statistics and other data on informal settlements at a regional scale. Different studies have different boundaries for counting data. Meaningful comparisons can only be possible if an exact knowledge of how these boundaries relate to one another is obtained. Furthermore, through this case study, it has been shown how the data acquired using the Bi-level model can be applied in at least three ways. Firstly it can be used to calculate net growth rates[15] and settlement densities. Secondly it can be used to detect variations in informal settlement area patterns. And thirdly, it can be used to optimise the relocation process by taking into consideration the sub-settlement and planned settlement densities.

The second case study discussed in chapter 10 has illustrated how the model can be used as a mechanism for diffusing GIS information. In particular, the applicability of the inter-level and sectoral model database linkages that are an integral part of the Bi-level model framework is shown. In this case a sectoral model linkage is made between the Integrated Catchment Management (ICM) application of the Bi-level model and the informal settlement application discussed in chapter 9. Through this linkage data local-level informal settlement databases in the Bi-level model are then used to fill the "gaps" in the digital cadastre required by the ICM database users. Furthermore, the linkage enables users of the local-level database to access ICM related data. This enables them evaluate alternative upgrading proposals in the context of environmental sustainability. In a similar way, a sectoral model linkage can be used to connect the metropolitan-level of the informal settlement application and the catchment-level of the ICM application. In turn, this linkage can be used for allocating on a strategic-level the responsibilities and resources associated with ICM and informal settlement upgrading initiatives.

The nature of two applications of the Bi-level model considered here reveal the generic nature of the model further. In the first case study, isolated informal settlement areas within one large metropolitan area were reduced to points. Linkages were than made between the metropolitan and local-level databases. In the second case study (chapter 10), the same metropolitan area was divided into a series of catchments, which in turn were divided into a series of sub-catchments. The Bi-level model was then applied using the catchment and sub-catchment levels as the primary database components. The first application has been designed for a series of isolated settlement centroids within a large metropolitan region. In contrast the second application deals with sub-catchment areas that cover the entire catchment area modelled. However, each sub-catchment itself may be comprised of several informal settlements. At this level, the gaps in the digital cadastre being accessed by an ICM application of the Bi-level model may be addressed by creating linkages to local-level informal settlement databases. In this case, the linkage to the local-level informal settlement database becomes an example of a potential sectoral model linkage. Thus the two case studies show not only how the Bi-level model can be applied to the different sectors of the city system (in this case the informal and the environment), but also how it can be applied across a range of modelling scales.

11.3 SUMMARY OF MAIN FINDINGS

11.3.1 Findings of relevance to local researchers

From a local point of view, two conclusions can be derived from the results of the comparative studies in chapter 9. Firstly, the comparisons enabled the detection of 7 previously unmapped and / or uncounted settlements[16]. Secondly, the comparisons have highlighted the need to distinguish between freestanding and backyard shack areas in future shack counting studies. While the current work has focused on the mapping of freestanding shack areas, which are the areas of greatest need (Spiegel et al., 1994), previous studies have often not differentiated between freestanding and backyard shack areas[17]. Furthermore, the emphasis on mapping the distinctly freestanding shack areas to the sub-settlement-level has enabled the settlement densities in these areas to be calculated in a more accurate manner than previously[18].

In addition to the settlement densities, the application of the Bi-level model here has enabled the percentage change in the numbers of shacks counted was calculated for each area during the period of 1994 - 1996. The change in the number of shacks counted is highly variable. In some cases the number has declined due to relocation. In other cases, many of the settlements have experienced a very high net growth over the above-mentioned two-year period. In particular, an increase in the number of shacks per settlement is observable in the settlements situated in the northern part of Guguletu, in the area north of Crossroads, and in the northern, south and south eastern parts of Khayelitsha (see figures in chapter 9). The results suggest that the implementation of the site-and-service schemes may be resulting in one or both of two possible processes. The first involves a net shift in the population of an informal settlement undergoing relocation-based upgrading towards the fringes of the settlement. The second process involves the eventual replacement of freestanding shack areas by backyard shack bearing areas. This may be the case for Guguletu[19], Nyanga [20]and Khayelitsha[21]. Thus the results of the comparisons of this study with previous work may have interesting implications for interpreting the effects of the current policy on the informal settlement population dynamics.

The results of a qualitative spatial pattern analysis revealed the occurrence of four distinct shack settlement patterns in the Ikapa region. Three of these are characterised by a visually detected variation in the density of shacks in each shack cluster (ie. from very high, to intermediate to very low shack cluster densities). The fourth pattern is characterised by a high shack density and a linear arrangement of shacks. Subsequent to this, the settlement densities, based on the number of dwelling units per hectare (du / ha), were calculated. Based on these values, the informal settlements were classified into five density categories as follows: 200 - 250 du / ha; 150 - 199 du / ha; 100 - 149 du / ha; 50 - 99 du /ha and < 50 du / ha. The result of applying this classification scheme indicates that the majority of the settlements (43 %) lie in the 50 - 99 du / ha category. Approximately the same number of settlements lie in the 0 - 49 du / ha (22 %) and 100 - 149 du / ha categories (19 %), and less than 13 % of the settlements lies in the 150 - 199 du / ha (11 %) and 200 - 250 du / ha (1 %) density categories. According to the ISLP plans, in situ upgrading remains feasible in areas which have densities of 60 - 100 du / ha (PA:WC, 1992). This suggests that at least

69 % of the freestanding shack settlements in the area could be considered for in situ upgrading in terms of the existing density distribution.

The results of the counting work conducted here also provide the latest detailed population statistics for freestanding shack areas in the CMR. By assuming an average household size value of 3.6, it can be shown that 8.8 % of the total population of the CMR (2.87 million - as estimated from Van Zyl, 1995), resides in the freestanding shack areas lies. This value compares favourably with the same statistic for the Gauteng metropolitan region, where 9.2 % of the total population (4.5 million) resides in the freestanding shack areas.

11.3.2 Findings of relevance to international researchers

Internationally, the Bi-level model provides a significant contribution in terms of providing a mechanism for addressing some of the problems that have hindered the diffusion of GIS, not only in the developing countries, but also in European and in other developed countries. More specifically, it provides a generic model for inter-linking and co-ordinating the development of GIS databases for those areas of the city that are characterised by a lack of digital data. While the model was initially devised as a tool for managing local-level informal settlement upgrading databases, it can be applied to manage the development of any type of local-level database created to compensate for gaps in the digital cadastre.

One of the technical problems that has particularly hindered the diffusion of GIS in both the developed and developing countries is the complexity of the high-end GIS software platform that is required to implement the cadastral approach. The Bi-level model addresses this problem by placing a strong emphasis on the fact that a coupled software system is required. The metropolitan-level database is created and maintained on a high-level GIS platform. However, the local-level databases are intended specifically to reside on a series of low-end GIS platforms characterised by a user-friendly interface and only the key GIS analysis tools. Furthermore, the *Internet-based* GIS platforms were selected specifically for the diffusion of information to a wider audience. In this way the Bi-level model is designed to encourage the diffusion of GIS amongst the majority of its potential user groups. Furthermore, in section 6.8 it was shown how the Bi-level model can be used to circumvent other problems arising from the slowness of the cadastral approach, as well as data maintenance and data under-utilisation.

More specifically, in terms of international informal settlement upgrading applications, section 6.8 illustrated how the Bi-level model addresses the limitation of existing urban GIS models. Firstly, the model circumvents the primary problem facing the implementation of the cadastral approach in informal settlement areas by proposing a multi-scale approach combined with the use of a dwelling-unit based basic spatial unit at the local-level. Unlike other Urban GIS models, the Bi-level model operates on both the metropolitan- and local-levels. Secondly the model provides a mechanism for community participation. The community is directly involved in the development of the local-level database, which subsequently provides a platform for negotiation between the community, local government, development agencies and other role players. Thirdly, the model provides a mechanism for GIS data diffusion amongst all the key role players involved in informal settlement upgrading projects. It caters for the diffusion of information amongst audiences both with and without access to the Internet[22]. Fourthly, as a result of the multi-scale approach, the model may be used not only for local-level informal settlement upgrading project management work, but also for the management of multiple upgrading projects at a metropolitan-level. Fifthly, the model has been designed to enable the informal settlement to be analyzed in the context of the surrounding formal city and the environment. Finally, the Bi-level model clearly addresses the key requirements facing a LIM system for a developing country as recently identified by the United Nations (Fourie, 1998).

11.4 FUTURE RESEARCH

11.4.1 A financial resource allocation tool

The metropolitan-level of the Bi-level GIS database can be used as an urban management tool for monitoring the progress of informal settlement upgrading projects in the Cape Town Metropolitan Region (CMR). It may also be used as a tool to prioritize the manner in which capital is allocated by Provincial Administration for construction and to identify informal settlements that should receive legislative approval[23]. Using the metropolitan-level database of the Bi-level model, it is possible to create a system that would accelerate the rate at which urban planners and managers, consultants and other interested parties could access the data for project administration processes[24,25]. This in turn would facilitate the shift the financial burdens associated with project administration to the lower levels of government and to private organizations, and would enable Provincial Administration to direct more of its capital expenditures to cover construction costs. There are four potential user groups in the present government structure, which could benefit from a metropolitan-level database designed specifically for the management of informal settlement upgrading projects. These are the Provincial Administration[26], Metropolitan Administration[27], Local Government[28] and the Community[29]. Once a basic metropolitan-level GIS system has been set up for accelerating the administrative processes, the system may be further extended for the management of funding structures. Currently there are up to 52 possible funding streams[30] available for informal settlement upgrading in the Cape Metropolitan Region[31].

The planning for budget cycles must be carried out in time to meet application deadlines. Each source of funding represents a common pool of financial resources. A GIS system that displays spatially how each resource is currently being distributed between the various informal settlements of a metropolitan region would greatly assist in the better management of these resources. In essence, by using the metropolitan-level database as the basic vector data platform, a spatial balance sheet for resource allocation can be easily created. In addition to illustrating the distribution of financial resources across the metropolitan region, the system could be used to illustrate the needs, average social-economic statistics and administrative process data for each settlement. In this regard, the vector overlay facility available in GIS shifts the system away from having a purely process monitoring function. It enables the system to gauge how effectively the resources are being allocated. The raster image backdrops also distinctly reveal the environmental impact of the site-and-service upgrading projects. Furthermore, the construction of such a database can be used to clarify what the responsibilities of each level of government should be in terms of the upgrading process.

11.4.2 Integrated Catchment Management

Several potential applications of the Lotus River ICM database have been discussed in detail in Grobicki et al. (in press). These applications involve the use of buffer zones, spatial overlays, spatial queries to produce source control suitability maps in a similar, but simpler manner to Makropoulos et al. (1998). Other applications discussed in Grobicki et al. (in press) deal with using the GIS to define boundaries of "changeability" on the basis of land use and land ownership data and to identify potential wetlands adjacent to the canal[32]. Other areas identified for future research included an automatic hydrological parameter thematic mapping tool[33], land use mapping based on supervised classification of ortho-photo imagery and an implementation of the multi-level ICM database framework proposed in Grobicki et al. (in press).

11.4.3 Spatial-temporal analyses

At least two areas of research exist where a contribution could be made in terms of the spatial-temporal analysis of informal settlements in the Cape Metropolitan Region (CMR). The first deals with the capture of new data that would help to clarify the dynamics of informal settlements in the CMR. The second deals with testing the validity of the qualitative spatial pattern analysis described in chapter 9. In terms of the first area of research, a detailed survey of the backyard shack areas in the CMR should be carried out. It would be particularly informative to map the backyard shack areas adjacent to or corresponding to freestanding shack areas that have shown a decline in the number shacks (see chapter 9). This will help to reveal whether the removal of freestanding shacks simply results in a replacement by backyard shacks. The capture of this type of information is essential to the understanding of the consequences of the current upgrading policies on the dynamics of informal settlements. This data would also help to further gauge how effective or ineffective these policies are in practice. The images on the present Urban GIS system and the existing freestanding shack data provide an excellent reference frame for mapping these backyard shack-bearing areas.

In terms of the second area of research, the validity of the cluster classes proposed in chapter 9 may be investigated via multivariate statistical analysis classification procedures[34]. The results of such an analysis would reveal which of the measurable variables are dominant in controlling the development of the different shack types. In terms of spatial parameters[35], the shack clusters may be differentiated in terms of the: degree of ordering[36], shack cluster density, locations of the shacks with respect to the transport infrastructure[37] and other reference features[38] as well as on the basis of elevation[39]. The results of a cluster analysis based on supervised[40] and/or unsupervised[41] classification procedures may be evaluated by the degree of overlapping of the clusters in multivariate space. If the validity of the various classes is verified, the characteristics of the variables used in the classification procedure, which distinguish the various classes, may be used to map out other areas susceptible to the development of the different shack cluster types. The results of the multivariate analysis will reveal which on the analyzable variables exhibit the greatest control on the development of the different shack types.

11.4.4 The use of digital ortho-photo imagery

One field of research that would contribute to the development of both informal settlement and Integrated Catchment Management (ICM) GIS-based applications is that of land use mapping based on a supervised classification of digital ortho-photo imagery[42]. The supervised classification procedures used to date in ICM have resulted mainly in the distinction of permeable and impermeable areas, which on its own is unsuitable for most ICM applications (Grobicki et al., in press). The existing ortho-rectified imagery that has been used in this study has a pixel resolution of 0.5 m. Whether or not the required results can be achieved has yet to be seen. Previously, brief investigations using 12 classes in a supervised classification procedure were carried out on this imagery for identifying individual shacks (see chapter 8). The result was a series of "agglomerated globules" for distinctly separate shack features, which was totally unacceptable. Due to the time limitations no further attempts were made to try to improve the results of this method.

11.4.5 The use of satellite imagery

The ground resolution of readily available satellite imagery up until mid-1999, such as SPOT imagery, is generally much poorer than 2.5 meters. This imagery is unsuitable for local-level informal settlement mapping GIS projects for two reasons. Firstly, such projects require that individual dwelling units can be easily resolved. In the case of the CMR freestanding shacks are typically 3 m by 3 m or smaller in size. Back yard shacks are often even smaller. Clearly if the pixel size of the satellite imagery is almost the same size as an individual dwelling unit, it will be very hard to carry proper shack counts in high shack density settlement areas such as encountered in KTC and other areas. Secondly, individual dwelling units are often occupied by more than one family. In these cases subtle differences in the dwelling unit roof, such as changes in the roof colour resulting from one type of zinc roof cover adjacent to another, would be impossible to pick up at a resolution of 2.5 meters. In view of the new 1 meter resolution imagery due later this year, the first step in future research here would be to test the applicability of this new imagery for local-level work.

While the use of SPOT satellite imagery may be inappropriate for local-level work, it has proved useful for resource management (Axes, 1997) and for mapping low-cost housing areas (Ferreira, 1997) in developing countries[43]. With respect to the former, in the "Spot approach" satellite imagery is used on rural areas for the update of the graphical data to scales of 1:50 000 (Axes, 1997). Experiences of the application of SPOT imagery in Africa reveal examples of resource management and participation. In particular, satellite image maps at scales of 1: 50 000 and 1:25 000 have been used a tool for communication and for local livestock and crop resource management. With respect to low-cost housing applications, Ferreira (1997) discusses the use of satellite imagery for identifying low-income housing trends and utilising this information for predicting needs for services and available land. The technique involves the application of LANDSAT and SPOT imagery to detect and monitor urban growth and essentially represents a spatial-temporal analysis based on satellite imagery. The resolution of the imagery enables informal low-cost housing areas to be identified. The different urban areas mapped from the imagery are verified by supportive fieldwork. The areas detected and interpreted to be informal low-cost housing areas are then mapped to determine the extent in hectares[44]. The operative word here is low-cost housing areas. This implies that the basic spatial unit of the database is a housing area.

In terms of the Bi-level model, the discussion by Ferreira (1997) suggests that satellite imagery can be used for developing or updating the metropolitan-level database at regular intervals. The main difference that would result if satellite imagery is used instead of the ortho-photography (as has been done in this project) is that the information on the location of individual shacks would not be recorded. While the results of using satellite imagery may or may not be suitable for metropolitan-level work, it is most probably suitable for the needs of the global informal settlement upgrading system proposed in chapter 6.

11.4.6 Alternative basic spatial units for cities in developing countries

Throughout this thesis, the Bi-level model has been proposed as a mechanism that has been designed not to replace, but to supplement existing cadastre- based systems that are characterised by "gaps" of digital data. The second case study is that it may be feasible to consider the possibility of an alternative to the parcel-based basic spatial unit employed in the cadastral approach for cities in developing countries. This would be particularly the case for developing cities with very weak cadastres, such as many cities in Africa. This alternative basic spatial unit would be based on a much larger area-based feature than the parcel. Land use or zoning boundaries could be used instead. On the other hand, the new BSU would have to be much finer than the land use zone employed in the Rapid Land Use Analysis developed by PADCO (see chapter 4). Most cities have some basic land use map. The research here would be to find the "pivot point" basic spatial unit, which is not hindered by the same problems as the parcel-based BSU employed in the cadastral approach (such as the slowness of the approach), but which is also of the highest resolution possible.

NOTES

CHAPTER 1

1. The cadastral GIS implementation strategy is adopted in the majority of municipal organizations throughout the world. This strategy is usually followed where the corporate GIS has been placed under the responsibility of a land surveying department. The approach focuses on the development of a detailed and highly accurate digital cadastre (accurate to less than 10 cm) for a city before the development of other GIS applications can commence. The literature review in this thesis suggests that the approach is both extremely time-consuming (data capturing projects take from 1 to 15 years) and human resource intensive.
2. Globally, more than 1 billion people live in absolute poverty, out of a total world population of six billion people (UNCHS, 1996). Approximately 600 million of these people live in informal settlements, squatter settlements, slums, peri-urban areas, shantytowns, barrios and favelas (UNCHS, 1996).
3. Derek & Assoc. (1992) describes the conditions in informal settlements in Cape Town (South Africa) as follows: "In many instances whole families occupy a single bed..... People in backyard shacks are often exploited paying rentals equivalent to formal dwelling rentals. The living conditions are the worst in the shack settlements, where diseases such as tuberculosis and gastroenteritis are common."
4. These informal settlements are often situated on physically dangerous pockets of land which have been rejected by developers. Such high risk areas include: flood plains, steep slopes, subsidence areas and areas near dumps or noxious industrial activities. In these areas, sewers and storm water drains are virtually non-existent. There are child health risk factors which include: poor water quality, poor sanitation, insufficient garbage collection/disposal, poor drainage/free standing water, crowding, air pollution, poor/under nutrition, poverty, low maternal education and the lack of nearby primary health care facilities (Environmental Health Project, 1996).
5. Other areas of the world faced with the "problem" of informal settlements include: Latin America, Caribbean, Middle East, North America, South Asia, India, East Asia , Pacific and China.
6. The Urban Management Research Group at UCT was set up in the mid 90's to address the need for the development of new engineering and management approaches which would address the needs of informal settlements.
7. The strategic-level urban planning applications which are currently being developed deal mostly with urban runoff management and pollution prevention strategies (Phillips et al., 1997), river engineering (Gardiner et al., 1997), pavement management systems (Lee et al., 1996), road and transportation research (Hovenden, et al., 1995; Ladstatter, 1997; Cook, 1993,), telecommunications (Zwart et al., 1997) and city management systems (Worrall, 1997; Elliot, 1997) for first world developed cities.
8. The literature review in part 1 suggests that these problems include amongst others:
    1. the lack of complete topographical and cadastral coverage
    2. the lack of as-built maps for storm water drainage and other infrastructure networks
    3. major institutional changes associated the country's political instability
    4. the lack of opportunity for external GIS support
    5. the absence of a computer-literate culture
    6. the lack of security of tenure facing informal settlement areas restricted financial resources and access to technical facilities
9. The high domestic fluidity, circulatory migration, lack of security of tenure and other factors provide a significant barrier to the implementation of the cadastral approach in the informal settlement areas of the CMR. There is little point in employing mapping accuracies which require 10 to 15 years to complete, when new settlements are appearing within time intervals of four months (Legal Resources Centre, 1997, pers. Comm.).
10. The implementation of GIS in the Cape Town City Council has clearly followed a first world, cadastral implementation strategy. Stavridis (1996) terms this first world approach which has been locally adopted as an "engineering" approach. This is characterised as requiring high volumes of detailed and accurate data (accurate to less than 10 cm) and complex information processing systems. The

approach is criticised for being time consuming (data capturing projects take from 1 to 15 years) and people and skill intensive. The reviews conducted on the international municipal GIS literature for this thesis indicate that this "engineering" approach is analogous to the cadastral approach adopted in Europe and in the remaining world countries implementing GIS.

11. The Serviced Land Project (iSLP) represents the primary upgrading project in the Cape Metropolitan Region which has resulted from the implementation of the current housing policy. The iSLP is a five year development project initiated by the Cape Provincial Administration (CPA) under the joint management of numerous civic organizations (Derek & Assoc.,1992). The primary objective of this project is to enable the development of accommodation for 56 000 homeless households in the Cape Metropolitan Region.
12. According to Behrens (1993), in present policy for lower income residential development, regulations are orientated exclusively towards peripheral site-and-service schemes.
13. The current housing policy summarized by Spiegel at al. (1994: 1) as follows: "Housing policy in South Africa has long tended to be formulated almost exclusively in terms of 'supply-side' concerns and issues of 'delivery'. It has thus been driven by a 'programmatic' approach which sees demand in terms of aggregate housing needs that can be quantified with reference to urban population size and an assumed 'average' household composition and size."
14. " ....the greatest potential to significantly 'compact' Greater Cape Town, lies in the high-density, 'infill' development of well located, vacant or underused land parcels - a process requiring proactive public intervention..." (Behrens, 1993)
15. "In brief, we believe that much greater recognition must be given to social-practical process affecting the demand for housing and for particular house- and tenure-type, and to developing a view of what constitutes housing-provision that can be much more dynamic than in the past and thus more responsive to people's needs as these develop over time." (Spiegel et al., 1994: 1)
16. The collection of socio-economic, political and other information for selected informal settlements within the CMR lies beyond the scope of this project. However, the importance of the inclusion of this data in the policy formulation processes associated with upgrading is repeatedly highlighted throughout this thesis. In fact one of the key advantages of adopting a GIS-based approach to deal with the information processing requirements of an upgrading project is the fact that such social-economic and other types of information can easily be attached as attribute data to the spatial features they are associated with. In other words, the GIS environment facilitates the spatial mapping of socio-economic data for policy analysis. The issue of the development of methodologies for integrating GIS with social processes for informal settlement upgrading applications has been discussed in detail by (Abbott, et al., 1997).
17. "...the greatest restriction to higher density development would seem to be policy maker's underlying perceptions of 'good city form' - most regulations have been formulated from the perspective that a suburban dwelling is ideal...." (Behrens, 1993).
18. This concept of inappropriate standards also presents itself in field of information technology for informal settlement upgrading. In particular, the appropriate computer technology and the appropriate database content are often areas of debate. Previously, a World Bank Aide Mission Report (1991) which dealt with informal settlements in South Africa questioned the suitability of GIS for upgrading applications. The debate no longer revolves around whether spreadsheet and CAD packages should be used in combination as opposed to GIS. The technological advancements in the field of GIS have left little reason for not choosing a GIS-based approach. Instead, the current debate focuses on the manner in which data are to be represented and structured within the database. The current thesis deals with this issue by proposing a unique database structuring method for informal settlement upgrading work.
19. The documentation on the iSLP highlights the project's inefficiencies (Derek & Assoc., 1992: 7): "The evaluation of current planning proposals on the study area revealed considerable inefficiencies in use. In many cases, owing to extravagant space standards, only 35 % to 40 % of available land parcels was in fact proposed for residential use. The remainder of the land being consumed by large school sites, public open space requirements and road reserves. Changes in legislation or regulations will be required to revise some of these standards."
20. The problems with the current housing policy as discussed in detail by Spiegel et al. (1994) and outlined here in brief are as follows:
    - Many of the households do not desire to reside permanently in their current locations. Temporary and flexible forms of tenure may be desired.

- Many of the households are not inclined to invest in upgrading their existing dwellings.
- Urban household sizes vary greatly.
- The economic role of urban housing is important[1].
- Homogenous residential or neighbourhood communities are difficult to define.

21. The PROFAVELA law ensures security of tenure in informal settlements in Belo Horizonte. As a consequence, this implies that a purely local level approach to GIS for informal settlement upgrading is more applicable in Belo Horizonte than in Cape Town. Nevertheless, the lack of a strategic-level approach remains a failing in the ViSP methodology (see chapter 6).
22. There are significant differences between the Bi-level model proposed here and the "dual approach to GIS for developing organizations" as discussed by Stravidiis (1996) (see chapter 6).
23. No bench mark paper on the application of GIS for informal settlement upgrading in the CMR was identified at the start and throughout the duration of the project. As a consequence, the research methodology was not rigidly defined at the out start of the project. Instead the methodology developed progressively with each stage of the project as areas of greater relevance of research were identified. Upon entering a new area of research, the author found that the identification of the research problem proved to be a major task in its own right. A considerable amount of time was spent investigating the possibility of a stormwater runoff GIS application designed to address the issue of flooding, which represents the key natural hazard facing informal settlements in the Cape Flats area. Eventually, it was decided not to follow this line of research for several reasons . Nevertheless, the research findings from this initial research contributes fruitfully to the integrated catchment management applications discussed in chapter 10 and to the discussion on future work in this thesis.
24. The Bi-level model is defined in chapter 6.
25. The Ikapa area refers to the main informal settlement- bearing area of the Cape Metropolitan Region. It is comprised of Guguletu, Nyanga, Brown's Farm and Crossroads.
26. Firstly, some of this data was seen as useful for placing any new data on informal settlements into the context of the surrounding city. Secondly, the Council's data would enable that the database for the new model to be set up so as to ensure compatibility of data sets arising from this research project and data sets utilized by the local authorities. Thirdly the potential for carrying out spatial-temporal analyses was envisaged early in the project[1]. Fourthly it was decided to avoid the duplication of data capture by acquiring all existing GIS data relevant to this project. Fifthly, from the out start, the project was viewed as a medium by which an urban database resource could be established for future projects in this field.
27. One of the key differences between the data collected on informal settlements in this study with previous studies (Van Zyl, 1995), is that this work focuses on the mapping of freestanding shack areas.
28. See chapter 6 for a definition of potential sectoral models.
29. The work referred to here derives from: Martinez, I. A. (in press) "The development of a GIS-based framework for Integrated Catchment Management (ICM).", chapter 2, 75 pp., **In**: Grobicki et al. (in press) *Integrated Catchment Management in an Urban Context: the Great and Little Lotus Rivers, Cape Town*. Water Research Commission Report.
30. The field of GIS applications for informal settlement upgrading is a rapidly changing and growing research area in South Africa. Only recently have local authorities in the South Africa and other developing countries started placing an emphasis on funding research on developmental tools and strategies by providing funding schemes such as the Research and Development Programme (RDP). Consequently there is almost no local literature what so ever for previous work in this field.
31. The authorities in the new substructures have only recently assumed office and are hence largely unorganized with respect to old records, maps and reports on informal settlements within their substructure boundaries. The recent restructuring of local government has resulted in an overall disorganization of this information. The bulk of the often outdated records and maps (particularly with respect to storm water drainage) which do exist, are scattered amongst the Cape Town City Council offices and the remaining substructure offices. In some cases, a loss of the knowledge of the location of the records has occurred as a result of the retrenchment of staff. Associated with the local restructuring process is a redefinition of which local authorities are responsible for the upgrading and for the provision of which services, to which informal settlements.
32. As a result of the previous service provision structure, it is possible for the upgrading and service provision responsibilities for a settlement to be distributed amongst a number of local substructures and the central authority. The maintenance records and maps for the particular settlement would then

be scattered amongst these authorities.

33. At the time during which the local authorities were approached for information the allocation of the responsibilities outlined above had not been finalized. A key factor which had yet to be decided was whether the substructure authorities would become financially responsible for informal settlements within their substructures or whether this responsibility would be shared or held entirely by the central municipal authority. As a result of this, a number of the local authorities remained incapable or unwilling to assist in the information gathering process discussed above.
34. Instead of considering the possibility of a collaborative venture to arrive at a database model which incorporated the best of the Bi-level approach and experiences from the PROLAND approach, the key government official behind the development of PROLAND felt that the data and database model developed for this thesis would feed usefully into the PROLAND model. The author believes that this remark undermines the model and significance of the work conducted here. This unpleasant experience however provides a prime example of the conservative mentality which continues to prevail amongst key individuals in local government. This conservative mentality refers to the unwillingness of planning officials to move away from the old school of thought with respect to spatial development planning initiatives.
35. The local demand for information within this field is so great that the author and other research colleagues were on several occasions approached by local authorities and legal agencies for information. Upon approaching organizations that had been initially identified as potential sources of information or research funding, it was often the case that these turned out to be far more receptive than giving with respect to informal settlement information. This was found to be the case with key officials within the local authority responsible for the development of the PROLAND system (PAWC, 1997).
36. The most recent maps and documentation of the status of informal settlement upgrading projects are held by engineering and planning consultancies contracted by the local government and other agencies to implement the iSLP plans and other upgrading projects respectively. It was found upon approaching consultancies for information on the status of informal settlement projects, that these organizations are generally totally unsupportive of research projects in this field. The present emphasis in the government funding of contractual work for RDP related projects has resulted in the transformation of the upgrading process from an area of avoidance to a major source of contractual work for local consultancies. Needless to say, these consultancies are reluctant to provide any information what so ever for fear of losing their knowlegde -based competative edge over other agencies.
37. Even in the cases where a consultancy had been commissioned by PAWC to gather information for the iSLPs, which implies that it is public domain property, the consultancy refused to provide the information for free. This was found to be the case when the following two consultancies were approached : Macroplan and Satmap Solutions. In both cases the consultancy referred the author back to the clients who had initially instructed that it was legally correct to request this public domain data from the consultancies free of charge.
38. One report, which could be used as a source from which to extract a very limited amount of attribute information for the metropolitan-level database was made available to the author only towards the end of the second year of the project. Even so, the information in that report covers only about 17 of the 69 settlements mapped in this thesis. Furthermore, it focuses on the historical development of the settlements, on the status of community and on funding agency negotiations relating to informal settlement upgrading for the period preceding 1995. Very little detailed information is provided on the existing level of infrastructure and on the upgrading plans for each settlement.
39. Spiegel et al.(1994: 8) describes these assumptions as follows: "...that the range of different types of household comprising any actual community or population can be represented by some hypothetical 'standard' household of an 'average' size which can then be used to compute the total number of households involved" ; and "..that housing need can be specified in terms of what are essentially or primarily 'shelter' and 'service' attributes, that is, as a standard unit of accommodation such as the one delineated above."
40. This overview has been distilled from the following papers: Junius et al. (1996), Ciancarella et al. (1996), Arnaud et al. (1996), Kiib (1996), Assimakopoulos (1996), Miellet (1996), Bartnicka et al. (1996), Graafland (1996), Masser & Craglia (1996) and Masser & Campbell (1996).
41. See section 5.4 for several definitions of the "Plano Global" concept.

42. Due to time limitations, this thesis has focussed on the creation and implementation of the metropolitan-level of a Bi-level model for the Cape Metropolitan Area. The technical discussion here thus focuses mainly on the creation of the metropolitan-level.
43. "The need for this study arose from the realization that necessary planning and population projections are hampered by uncertainty and differing results from diverse studies. It has become essential to conduct a study which will be acceptable to a broad range of authorities / institutions." Van Zyl (1995: 2).
44. The concept of potential sectoral database models is defined in chapter 6.

CHAPTER 2

1. This background is particularly relevant to Cape Town City Council (chapter 3) where the approach followed in the implementation of GIS led to the development of an extremely underutilized system.
2. The eleven assessment criteria utilized by Masser & Craglia (1996) were as follows: institutional context, structure of local government, digital data availability, coverage of findings, extent of diffusion, geographical spread, length of experience, main applications, predominant software, perceived benefits and perceived problems.
3. The original source of these tables is: Masser & Campbell, 1996: tables 13.1-13.3,)
4. These proactive measures included the establishment of a National Centre for Geographic Information to coordinate the implementation of a national geographic information system in Portugal.
5. Using this facility, the user may specify certain features to only be visible at selected scale intervals.
6. The classically corporate approach, which was followed by 15 % of British local government initiatives, generally leads to technical problems due to inappropriate software choice. The theoretically/pragmatically corporate approach, which was adopted in 35 % of all British systems and was dominant in the major metropolitan districts and shire counties, was characterized by data related and organizational problems. The remaining 50 % of British authorities followed a fiercely independent approach. However, this approach was also characterized by data related and organizational problems.
7. Multi-department systems typically involve only two or three departments.
8. Automatisiertes Liegenschaftsbuch (ALB)
9. Automatisiertes Liegenschaftskarte (ALK)
10. MaBstaabsorientierte einheitliche Raumbezugsbasis fur kommunale Infonnations-systeme
11. In Poland there are four levels of administration: central, regional, sub-regional and the local-level, with central administration retaining a large degree of control (Masser & Craglia, 1996). Poland is also characterized by a large number of local authorities (2465 at the lowest level) and poor telecommunications.
12. As part of the GIS/LIS Implementation Plan for the City of Gdansk, PADCO recommended a topologically structured system, with a Relational Database Management System (RDBMS). Core applications (eg. maintenance) should be developed early on in the implementation process. Conversion and automation procedures should be defined to reduce data duplication and redundancy, and data sharing and access should be maximised. A number of other recommendations relating to training, staff functions, protocols, administrative practices, organisational structure and funding are also discussed (PADCO: 1994 c).
13. This concept of a private / public partnership is iterated again and again throughout the PADCO reports. It is also evident in the experience of successful GIS implementations in Belo Horizonte - under the guise of " conventions". In the case of Belo Horizonte these agreements occur not only on the scale of municipal and local utility companies, but at an international scale between the central municipality of Belo Horizonte, the Italian consultancy AVSI, the University of Bologna and the United Nations Organisation (UNESCO) (see chapter 3 for further details).
14. PADCO (1994 c, -x, xi-) recommends that " the city that GIS/LIS should be operated as a "business" in support of other key "business" functions is extremely important. "
15. This is a concept which is explored in chapter 7, where the possibility of extending the metropolitan Bi-level model proposed in this study into a global informal settlement upgrading system is explored.

16. These included: increased memory storage, speeds of calculation etc..
17. Miellet (1996) remarks on the impact of the 1982 Decentralization Acts as follows: " These Acts transferred responsibilities notably in town planning, in structure plan-making and infrastructure management to local government which as a result started looking for information technology solutions to assist its decision-making in these fields. It is clear that these major institutional changes are at the root of the rapid increase in demand for GIS at all levels of local government: urban authorities, departments, and regions."
18. This database is aimed at medium scale applications such as road management, transport planning, fire-fighting and environmental management. It is compatible with satellite images which are utilized for structure planning.
19. It as a three dimensional database and is implemented in detailed structure-planning, environmental impact studies, commercial zoning and revision of land use plans.
20. This database has a topographic structure and is aimed at applications that optimize either networks or itinaries.
21. These two issues are evident from a quotation from Miellet (1996: 167):
"Faced with the size of the task at hand, the DGI has sought to develop a number of partnerships by defining an operational framework for the development and the updating of cadastral records integrated in GIS and acquired by local government organizations. The principle is simple: digitization cannot be done without the agreement of the DGI which then obtains a magnetic copy of the record and remains the data manager with regards to information up-dating. Special conventions have been agreed with major network managers (the national telecommunications, electricity and gas utilities)."
22. The application of GIS has shifted from serving as a registration system to a system for the management of urban services, service level offered to citizen, economy of the urban system and territorial organization.
23. The term failure here refers to the slowness of the project.
24. The IGMI are responsible for maps in the 1:25000 - 1:1000000 scale.
25. The first stage of the program has been to develop a new national network of control points to support ground field-work.
26. The scales of these maps range from 1:1000 - 1: 4000.
27. An example is the land use categories of the land use plan that are compiled by the local government planning departments.
28. The relative importance of the main problem types experienced in the implementation and use of GIS was as follows: 13. 5 % data related, 8.1 % technical related and 78.4 % were organizational related (Ciancarella et al., 1996: 102).
29. A good example of how the lack of awareness of the details of a GIS project can cause a project to fail is described by Ciancarella et al (1996). " ..For example, most regions did not realize that choosing a relatively large scale for their base maps (1:5000 - 1: 10 000) would delay the completion of the regional coverage for well over 10 years, reduce the number of applications possible in the meantime, and make the investment difficult to justify over many budget and electoral cycles."(Ciancarella et al., 1996: 95).
30. An example of a GIS database requiring five years to develop was the Toulouse stormwater drainage database. This database consisted of 1:200 scale - basic plans for engineering works and location of underground services.
31. The two options currently available for this process include: 1) carrying out a completely new survey and 2) implementing homogenization software to adjust digitized maps to known measurement points. Both approaches are unpractically long.
32. The Cadastre has realised that its present goals are unsatisfactory in terms of meeting the digital map requirements of local authorities throughout Italy. To extend the coverage to the provinces which remain unmapped in terms of the program initiated in 1986, the Cadastre plans to rasterize updated aerial photographs for a limited number of topographic features only (ie. road network, hydrography and limits of the built-up area).
33. "A measure of the existing variations in paper map availability is that in 1992 there were still no maps at 1:5000 - 1:10000 scale for 53% of the country with notable regional variations: 26 % of the land area Northern Italy, 49 % in Central Italy, and 82 % in the South. Moreover, the average age of the maps available was 14.5 years." (Ciancarella et al, 1996: 90; Bezoari & Selvini, 1992)

34. This has great relevance to the present study as informal settlements represent settlements with limited financial resources available for implementing computer-based information management strategies.
35. " Due to the quality of existing maps and surveys it would take decades to cover the whole country with digital maps, especially when in many regions paper base maps either do not exist, hold false information, or are very old." Bartnicka et al (1996: 188)
36. "It is not clear who would pay for data collection and digitizing". While it is more probable that the local authorities can afford to finance the data capturing, it is unlikely that they would do so if they are not involved in the project definition and if the project consequently does not address their data needs. Bartnicka et al (1996: 188)
37. To implement the central model, the central administration has favored the ARC/INFO with Oracle configuration. "Even if this chosen software does not fit the needs of final users at local levels, there is evidence to suggest that if central administration invests in the writing of applications and shells for a specific software and gets a good deal on bulk purchase it will create irresistible financial pressure on subordinate units." Bartnicka et al (1996: 188)
38. "Apparently, both the Polish commercial companies implementing the project and the administration suffer from lack of properly skilled staff and are forced to employ surveyors and computer aided design specialists in order to get the project done." Bartnicka et al (1996: 188)
39. Bartnicka et al (1996: 188) indicates this in several statements:
    - "Not all information covered on base maps is needed by all users, so it is more efficient for final users to collect and update information that is of interest to them (for example utilities companies can hold their own inventories).
    - "There is a gap between the existing Polish legislative framework and the needs of the project."
    - " The model stresses the rights of the state, but ignores the needs of many potential GIS users who do not necessarily need the kind of information included in geodetic base maps."
40. Bartnicka et al.(1996: 188) lists the problems encountered in local-level projects as follows: .
    - negative attitudes due to a lack of awareness
    - lack of computer experience
    - lack of acceptance of computer maps in place of paper maps
    - manual digitizing which was required due to lack of funds.
41. These problems are particularly relevant to the discussion on the implementation local-level databases which is proposed as part of the Bi-level (see chapters 7 - 8).
42. MaBstaabsorientierte einheitliche Raumbezugsbasis fur kommunale Informations-systeme
43. Failure here refers to the fact that the GIS project was not completed on time or did not address the needs of the users.

CHAPTER 3

1. In July of 1995, the UNCHS (Habitat), facilitated by the Water Research Commission (WRC) of South Africa, presented a seminar in Pretoria, to local authorities and research organizations active in GIS, on the ViSP (Visual Settlement Planning) approach to the upgrading of informal settlements. ViSP represented the GIS base of an integrated methodology for the upgrading of these settlements. It had been commissioned by the UNCHS and had subsequently been undergoing trials to test its appropriateness and viability in Nairobi, Kenya and in Belo Horizonte, Brazil. The results, particularly in the latter case, had been extremely successful, and the purpose of the Pretoria workshop was to demonstrate this success and to explore the potential for the application of the ViSP approach in South Africa.
2. Several developments have occurred in the implementation of GIS in the City Council since the time of the user survey. The first change that occurred was replacement of the UNIX-based Genamap system by the MapInfo software. This was also followed more recently by the implementation of the latest ArcInfo system version which has a Spatial Database Engine (SDE) facility.
3. A key problem that had faced the UNIX system had been the fact that it was not able to deploy the organization's data effectively. In order to do so when using an UNIX-based system the X-Windows software was required. This software provides a terminal emunation facility for a PC not running UNIX. The problem with this approach was that the PC would not be used for work as all of the data

processing would continue to be carried out on the UNIX machine. The price structure for this possibility made it an unviable option. Furthermore the creation of printouts proved difficult using the UNIX-based system. It was difficult to format the print and also labour intensive. The MapInfo software was introduced in order to address these problems.

4. While the change to MapInfo made the GIS system more accessible to some of the potential GIS users in the Council, there remained a key problem. Namely that the data was situated on a fileserver but not in a database engine such as Oracle. As a result problems arose as the GIS data could not be synchronized with the existing property data. To address this issue the Council has recently (since mid 1999) moved to the latest ArcInfo system version which has a Spatial Database Engine (SDE) facility. Despite these changes, the 16 bit applications (eg. Windows 3.1) remain a problem. To address this problem a Citric Server or Web Server software package would have to be implemented. The implementation of this software would be costly and is an issue that is still under debate.
5. The technical capacity which does exist is skewed in favour of the large metropolitan centres. Even in these areas, however, the number of people with good GIS knowledge and experience is limited.
6. The establishment of a GIS system within the Cape Town City Council is discussed in detail in Martinez & Abbott (1997). The reader is referred to p10 there in for details preceding 1987.
7. These tables were constructed by referring to the Engineering Guidelines (1996), the City Engineer's created the applications and City Planner's 1995 Annual Reports, ARC/INFO application software documentation and a multitude of other references. A number of applications were previously prioritised by the Property / Persons Board (a senior GIS user group within the Cape Town City Council) on the basis of funding and departmental priorities. The customised tables included these applications and a much larger number of additional applications constructed for this survey, and were developed for the following branches: Cleansing (17 applications), Drainage and Sewerage (25 applications), Water (13 applications), Roads (18 applications), Parks and Forests (8 applications) and Scientific Services (12 applications).
8. Each master project is composed of a series of index maps. For example, the cadastral project consists of: erf index, properties, servitudes, leases, annotation etc. Each index map in turn is composed of a series of spatial features of interest, which are represented by points, lines, areas and text features. In the case of the street turn index map of the cadastral master project, features such as: manhole, sluice valve, traffic light pole etc. are represented.
9. Analytical (20 sub samples per location) and air pollution (captured at approximately 1 sample measurement per minute) data are entered directly into a UNIX machine. The existing software enables factors such as samples, which lie beyond the instrumental detection limits to be recorded. This is generally not considered by GIS software currently available. Most of the data has been captured as text files in ASCII format. The analytical accuracy is ± 5 %. The sampling accuracy is more difficult to quantify. River and vleis water samples are collected at regular intervals ranging from 1 week to 1 month. Rainfall samples are collected, however, the atmospheric pollutant concentrations are generally obtained from dust out fall samples which are measured at smog stations.
10. This branch did not wish to be included in the interview process.
11. It was not clear from the interview, whether the branch head was referring to the Directorate of Information Services or to the Survey and Land Information branch, or to both branches.
12. In addition to the MapInfo GIS software, the Metropolitan Transportation branch utilises the following additional non-GIS software packages: Traffic signals - used to determine highway capacities; Transit - used by Roads Research Lab; Saturn - Used to model redistribution of traffic and traffic intersection capacities. The Cleansing branch utilises a beat routing package called ROADSHOW for sweeping and domestic waste collection applications. The Water branch are currently applying a networking package to maintain the current supply system. The Scientific Services branch has utilised non-GIS software extensively to estimate the storm water flows associated a number of vleis in the Cape Town area (Morrison et al., 1988, 1989). Water quality time series and statistical analyses are conducted on a UNIX based machine. Trade waste analyses are less frequently carried out. A continuous air quality model has also been developed, which considers 32 parameters. A large amount of air quality monitoring data has been captured in a format compatible which is compatible with this customised software. A report was produced for the Milnerton air quality project, developed for the CALTEX pollution sight. An EPA model (U.S.) is used, which takes into account wind, the Table mountain topography (generally regarded as flat for most models), and air pollutant concentrations.

13. Application systems recommended for development by Ferguson (1995) include: mowing, tree, nature reserve, amenities, weed control, flower beds systems. Amongst another list of 15 possible application opportunities (section 4.2, p3, Ferguson, May 1995), the following two should be noted: 1) ground elevation data would enable contour and slope polygon generation 2) raster GIS would enable aspect, slope and visibility studies.
14. The skills required for the following types of activities are lacking: database management and design, applications initialisation, data sharing, data capturing and the maintenance and analysis of maps on the GIS. Where a user group has relied heavily on external assistance to drive the development of GIS, there is also a lack of any form of conceptual / theoretical appreciation of the analytical capabilities and potential usefulness of a GIS system. In fact, there does not seem to be any concept amongst most of the user groups of what spatial modelling is about. Even simpler forms of spatial analyses such as buffering and overlaying, which do not require attribute data, are not being conducted by the majority of the user groups. This lack of knowledge extends to the top management level, where there is a clear lack of understanding of the analytical capabilities of the GIS and the differences between GIS and CAD are often not known.
15. In this analysis, it is clearly recognized that the data integration exercise is costly. The multi-agency GIS is intended to ensure that departments diverse needs can be met "without reducing the information to a uselessly low common denominator or a hopelessly complex cross-referencing system . . ."(Antinucci et al, 1991:18)". On the other hand, this system can have problems where departments have moved over to cost center or business center models. As Campbell and Masser (1995: 23) found in the UK where this was the case "Staff in user departments were adamant that they would not contribute to systems in which they were nett (sic) inputers of data".
16. Firstly, the data collection strategy should be an applications-driven process and not purely a cadastre database building process. Secondly, computer methods based on LISP Macros for checking and correcting networks, may be applied to update any existing infrastructural network data (Jacobs, 1993). Thirdly the data base building process may be accelerated by organizing collaborative projects which involving the provision of network information records in exchange for computer related services, consulting and training, rental of work facilities and geographic databases etc. This approach has worked well in the case of the State Company for Water Supply and Sewage Processing in Minas Gerais (COPASA MG) Brazil, (de Souza et al., 1993). The agreement essentially involved an exchange of water and sewerage network information records from COPASA MG, in return for PRODABEL's assistance in setting up a database. If a collaborative data capturing approach cannot be followed, then consultants will have to be contracted for data capturing. Fourthly, new data capturing techniques and the selective data capturing policies such as those which were employed in the construction of the municipal GheoBH GIS (FATOR GIS, 1996), should be explored. Other techniques include the combined use of Global Positioning Systems (GPS) and GIS, the implementation of head's up digitizing, auto-tracing, auto-line work processing, audio-aided, image reclassification-based mapping and other data capturing tools.
17. At best it can provide a sophisticated mapping facility, linked to a property database. But this is using only a fraction of the potential of true GIS. At the same time it must be recognized that a large amount of money has been invested in the system, and that money cannot be wasted. Hence any changes have to build on, rather than replace, the existing system. This does not, however, preclude major institutional and organizational changes.
18. At the time that the City Council purchased its system the large GIS suppliers targeted their product at the owners and maintainers of data, a group which Intergraph refers to collectively as he 'doers'. But this is a very small group. The people who should ultimately provide geographical solutions fall into different categories, which Intergraph defines as either 'users' or 'viewers'. Here the term user has a more specific meaning than that used previously. This specific meaning will be used only for this one section, in order to develop the concept developed by Intergraph. These three groups, i.e. doers, user and viewers, have widely different needs in respect of GIS.
19. At the present time the accuracy requirement of the entire system is determined by the extremely high accuracy demands of the most sophisticated user, namely the cadastre. Until this policy is changed there cannot be a meaningful expansion of GIS within the City. More likely, if there is no change in this policy, is a gradual breaking away of user groups from the central system, and these groups build GIS skills and define their own accuracy requirements.

20. In case of the water network design and telemetry divisions in the Council, the former is primarily concerned with the capture and use of static data types, whereas the latter deals primarily with dynamic data types. Although both data types are required for the efficient operation, management and planning/design of the present and future water distribution networks, the data capturing activities in these divisions appear to remain isolated from one another.
21. In the Drainage and Sewerage branch, there seemed little awareness of activities relating to dynamic data capturing, such as daily sewage flow volumes, which are essential for the optimising of sewerage systems. A reference to the data dictionaries provided by these branches clearly reflects the absence of dynamic data.
22. The Scientific Services branch, appears to be monitoring a great deal of dynamic water distribution network quality and quantity data, as well as storm water runoff flow volumes, which could be of use to the Water and the Drainage and Sewerage branches.
23. Some examples of such APLs are: C++, Visual Basic, Delphi, Cobal, Pascal, MDL etc.
24. It is useful to refer to the Open System Interconnection (OSI) reference model (a set of protocols as well as a communication reference model created by the International Organisation for Standardisation) (Novell, 1995), when considering software integration issues. The OSI model may be used to identify the system modifications which are required, in order to facilitate the software integration process, as relating to the Presentation and Application layers of the model. The Application layer refers to the software programs that are required to have their output data linked up to the Presentation layer, which in turn is composed of the Database Operating System.
25. In addition to these three levels, two other types of integration may also be considered in terms of non real-time and real-time integration. Again, it is envisaged that real-time integration could probably only be motivated for by organisations dealing with crises. On the other hand, it may be achieved by privatised utilities services, as has been case with the following major Water Boards in South Africa: Rand Water, Umgeni Water, and Goldfields Water (Ward, 1996).
26. This differs from the present approach, where the development of one application (cadastral database), selected by a single department (Survey & Land Information) has dominated (or rather hindered) the implementation of GIS throughout the Council.
27. Take the implementation of the iSLPs for example. This government initiative has been running for about five years and has resulted in very little on the ground modifications.
28. See endnotes 2-4 on the recent changes that have occurred with respect to the implementation of GIS in the Cape Town City Council.

CHAPTER 4

1. These issues include: generic issues, coverage of analysis, perceived benefits of GIS, perceived problems of GIS, environmental / physical characteristics, extent of GIS diffusion, geographic spread and the length of experience.
2. The information on software systems provides a background for the software selection discussion (chapter 6). The applications have been considered to determine whether the strategic level and /or local level applications were being implemented for informal settlement upgrading. This section contributes to the discussion on the need for strategic level applications in chapter 7. Similarly, the consideration of the scales of photography or satellite imagery used contributes to the identification of optimal scales for informal settlement upgrading work (chapter 7). Whilst the information on the structure and content of other databases provides a background to gauge the structure and requirements of the database model proposed in chapter 7. A section on generic issues has been included to identify potential ways in which the proposed Bi-level model (chapter 7) may be made generic.
3. Criteria typically discussed in other comparative studies, which fell beyond the focus of this study are as follows: coverage of findings, extent of diffusion in country, geographic spread and length of experience in GIS. The information available for these criteria are very limited in most cases. However, the situation for each of these three criteria is very similar for most of the developing countries. Generally, very little diffusion of GIS has taken place in the developing countries. With respect to geographic spread, the GIS facilities and expertise are usually extremely localised and situated in the key metropolitan cities. The time length of experience in GIS is typically very short.

4. The degree of development here refers to the degree of systems development.
5. The World Bank 1991 Mission recommended "off the shelf spread sheet software " such as Lotus 3.1 and CAD software for the development of informal settlement upgrading applications (World Bank, 1991).
6. It should be noted that these were private studies (ie. they were not published).
7. The SSMS is an output of the HG-013 programme which aimed at:1) expanding access to water and sewage to low-income households 2) expanding public sector delivery of land and services affordable to lower income families 3) expanding the role of the private sector in the provision of shelter
8. Housing typology defined by PADCO (1993) for Montego Bay included the following housing types:
   - informal high density housing on steep slopes
   - informal. high density housing with basic road access
   - traditional inner city, high density housing
   - informal semi-rural low density housing
   - formal inner city multi-family housing in mixed areas
   - formal individual housing units in subdivided areas
   - formal public sector housing projects
   - formal important buildings and new houses
   - formal villas and low density housing
9. In the case of the Greater Johannesburg Transitional Metropolitan Council (GJTMC), the cadastral-based GIS failed to achieve the main objective that the GIS was acquired for. The main motivation for following the cadastral approach initially was that it was assumed that a high accuracy would enable the system to be used by surveyors. The GIS maps remained an unacceptable substitute for conventionally produced paper maps to the surveyor. Furthermore the cadastral database has remained continually out of date.
10. For this work, research was carried out at Oxford University on the use of overlaying SPOT imagery to show changes in urban development (Wulfsohne,1995).
11. Weiner and Harris (1999, p.8) claims that the CiGIS method (amongst other things):"

- addresses questions that participant communities feel are important
- assumes that local knowledge is valuable and expert
- incorporates communities in the production of GIS
- assumes socially differentiated multiple realities of landscape
- assumes the potential for more democratic spatial decision-making through greater community participation"

12. "In this respect the system is considerably more sensitive to the forms in which local knowledge is found. Linking narratives, oral histories, photographs, moving images, and animation, to GIS provides enormous capability to increase not only the richness and diversity of the information available but also more closely parallels the manner in which communities know or conceive their space." Source: Weiner and Harris (1999, pp. 8-9).
13. The basic spatial unit may be defined as the smallest spatial unit to which attribute data is attached in a database. This concept is discussed more fully in chapter 6.
14. The most commonly used local name, local name variant traditional and alternative common name have been used in the MEGASUB data set.
15. This process is referred to as a "transformation" by Tipple (1991).
16. "4.3 An LIM system and cadastral system should be separate but linked........African conditions therefore allow new approaches, whereby the cadastre becomes a sub-system of the LIM system, rather than as is more conventional, where the LIM system is subordinate to the characteristics of the cadastral system." (Fourie 1998, p. 6)
17. Fourie (1998, pp.5-6) states: "Linking cadastral systems to other land information systems has proved to be very problematic because of:

- A lack of technical, human, financial and management capacity
- The low level of data quality and information standardisation
- Institutional fragmentation
- Power struggles over information at a number of levels
- Poor horizontal and vertical linkages – communication, institutional and technical
- A lack of parcel based information

- Ignorance of user requirements among technical people involved with the cadastral and information systems
- A general lack of awareness of the applications and implications of LIS
- Governments and departments within governments which do not treat information as a resource."

18. " ...A crucial issue that should be taken into account is that one of the major challenges confronting most counties is the issue of laws and regulations introduced by a colonial administration to serve the interests of the colonial power. Such laws were not designed to serve the needs of the whole country or population. As a result, separate cadastres have often developed, operating as informal systems in parallel to the cadastral system based on the colonial legislation. Due to the complex nature of the cadastre and property rights, these laws and regulations remain entrenched in may countries still to this day." (Fourie 1998, p. 4)
19. Fourie (1998, p7) states: " 4.5 Varying accuracies: Approaches should be put in place which make it possible to use information of varying accuracies within the same LIM system. Varying accuracies should be accepted because:-.....
20. Fourie (1998, p 10) states: "Local record systems: For land registration and/or recordal work in Africa the system itself should become more accessible, both in terms of location, cost and user friendliness. The land office should be at the local level and be user-friendly to poor, often uneducated people."
21. "The repatriation plan was drafted by USAID and involved the construction of 170 new villages to house people displaced returning from camps in Thailand. The settlement plan proposes to build 500 km of new roads to serve the villages.
22. The reliability of the database becomes important when statements such as follows are included: "Mine fields shown in the map are disregarded by the study, under the assumption that all mine fields must be cleared to make the area suitable for settlements.(USAID, 1991).
23. " The collapse of the totalitarian regimes in the now independent states of the former USSR and of its Easter-European satellites, the processes of democratic revival of their societies, removal from the political arena of the vicious organizations of communist orientation, more or less successful economic reforms establishing new relationships, demilitarization of post-communist societies, end of the "empires of fear", freedom of information and the new information order, transition to civilized forms of relations with the outer world- all these fundamental and inspiring changes have infered in a profound, and hopefully irreversible way into the patterns of modern life, science, production. They are to decide the routes of GIS progress in the current dynamic and unstable CIS environment."(p38, Koshkarev, 1993).
24. These institutions include: Moscow State University-Thematic Mapping Systems; Research Center Lesresurs-forest mapping; State Centre Priroda; Main Geodesy and Cartography Department; Institute of Geography of the Russian Academy of Sciences (IG RAS).
25. "..the ministry is considering migrating, and downsizing its topographical and cadastral digital database to mix UNIX and PC network platforms. At the same time, electronic links will enable the various authorized users to share information, and communicate more efficiently(p.Bell et al, 1993:34).
26. "Problems began to emerge of duplicated ownerships which could not be easily resolved with the records available; of very expensive conflicts of interest as the various service authorities spent money based upon individual interpretations of the master plans; of land owners with expensive development loans they were unable to use because the exact site of their land parcel could not be readily indicated. Costly events were created by cases where successive graphic surveys extrapolated from an initial misaligned development obstructed essential roads or resulted in substantial building over expensive buried services. Accidents occurred, or were narrowly averted, as high pressure water mains or high tension cabling were encountered unexpectedly."(Bell et al, 1993: 29).
27. The GISnet consists of a dedicated 100 Mbps FDDI fibre optic network.
28. This is a large GIS designed to process transactions for development applications to support planning decisions (Price, 1998: 10-1).
29. This GIS was designed to reduce the time taken in processing applications to lease industrial land and set up industries (Price, 1998: 10-4).
30. This GIS was designed to be linked to other government departments and to the public. It consists of several sub-systems for development planning, planning permission, building control, land management, billing and collection, and a legal database. These sub-systems are connected by a corporate communication system called Enterprise-wide System (EWS) (Price, 1998: 10-7, 10-9).

31. According to Price (1998: 10-26):" 'Process Engineering' is a 'hard' methodology which leaves little room for flexibility. Documents are submitted to the customer at each milestone for his approval. After the approval of a milestone document, the customer cannot re-open any matter without incurring additional costs, whether or not the customer actually understood what he was signing. A failure of communication due to language problems or culture is likely to lead to disputes in this context."
32. Price (1998: 10-29) comments:" The computerisation programme in the South African Surveyor General's Office (SGO) in the late eighties and early nineties provides a striking example of system development 'by the book' leading to a technically correct system but one which the customer did not want when it was finally completed. It no longer met the (changed) requirements."
33. Price (1998: 10-40):" The system is not fully used for the purpose of processing applications for the allocation of industrial land for which it was designed."
34. "But it's also possible that we're trying to introduce the technology into some situations where it doesn't - at least not yet - belong. Given that possibility, we need to be careful that we are not overwhelmed by approaches that have little to offer except the latest technology" (Dangermond, 1988: 18).
35. "In Europe and North America, GIS use is expanding at a time where there is a growing need to manage information and in some senses it is a 'post-industrial' technology. It cannot be simply transferred to the developing world and expected to perform functions for which it was not principally designed." (Taylor, 1991: 80)
36. "Although it is true that the development of microcomputer technology at ever-decreasing costs has had a positive impact on the availability for GIS in developing nations, it is quite possible that micro-based systems can be just as inappropriate as their mainframe or mini-based predecessors." (Taylor, 1991: 81).
37. "In some instances a decentralized approach to GIS will be the most effective solution, especially for rural development planning where a micro-based system in the hands of the individuals directly involved makes a great deal of sense. In others, such as the need for environmental monitoring and protection or flood and irrigation control over vast areas, then a top-down national approach is required. It is clear that in developing countries a mixture of both approaches is appropriate, depending upon the particular situation."p81Taylor.
38. "GIS cannot be seen in isolation from the development policies and approaches of governments, especially as these relate to technology." (Taylor, 1991, p81).
39. "...the political environment within which a GIS is to be established has considerable bearing on whether or not the top-down or bottom-up approach is adopted." (Stefanovic, 1989: p451)
40. "But a question of fundamental importance is who decides what is relevant and useful. If GIS are to useful and effective, then they must be introduced by indigenous scientists who understand both the technological and socio-economic context in which the systems are to operate. Ideally, the technology should be 'indigenized' and adapted to the needs and capabilities of the particular situation in which it is to be used." (Taylor, 1991: p80)
41. This has probably over come by now through the use of the Arclink and Shapelink MapInfo products.

CHAPTER 5

1. See section 5.4 for several definitions of the "Plano Global" concept.
2. The limitations included a lack of detailed socio-economic data for informal settlements. This lack of data would prevent the development of a micro-based approach as in Belo Horizonte. The second local constraint which influenced the initial aims was the fact that informal settlements in Cape Town are faced with flooding problems. As a result it was essential to investigate any use of GIS for surface modeling and flooding applications in the ViSP approach if possible.
3. The initial aims of the survey were established by investigating a document by Nieminen (1995) which very briefly outlined the capabilities of the ViSP system in Kenya. These aims were also set up bearing in mind the limitations and the needs facing the development of GIS applications for informal settlements in Cape Town.
4. This included the following packages: TNTMIPS, AutoCAD, Gheoraster, MapInfo, Arc/Info and Atlas GIS.
5. These included area planning maps and thematic maps.

6. A sample set of data was requested from AVSI for several reasons. The material would serve as an invaluable teaching tool to Urban Management postgraduate students at the University of Cape Town and as a proto-type model for future informal settlement micro-scale work in South Africa. In response, sample data sets were provided for the following favelas: Ventosa, Betim and Nossa Senhora Aparecida.
7. These reports were on socioeconomic projects, infrastructure provision and geotechnical projects and geological projects.
8. These included vector / raster plots and configuration file print outs. These reports were on socioeconomic projects, infrastructure provision and geotechnical projects and geological projects.
9. The main reasons for this choice were that: firstly, these products are more capable of meeting the analytical demands of an academic environment, secondly, Intergraph displayed a strong interest in supporting the research objectives of the project, and thirdly, the Intergraph software suite is by far superior to most other packages on the market in terms of its line work cleaning, heads-up digitizing and other functionalities.
10. A quotation from AVSI (1996) best summarizes all of the facets of the programme:
"The programme acts through technical and methodological presuppositions of structural intervention including urbanization, construction of social equipment, land regulation, support to housing improvements, promotion of social-economic and cultural developments with support to community-based organisations, programmes to generate employment and income and strengthen local institutions by building institutional capacity and improving management skills." (AVSI, 1996).
11. Another research organization which has been involved in the development of the methodology is the University of Applied Sciences of Sao Paulo. The initiatives of this organization however have focussed on the non-GIS aspects of the Alovorada Programme.
12. The Microstation-Intergraph software was selected for several reasons. Firstly, the experience developed in the Architecture and Town Planning /institute of the Bologna University had been carried out on Intergraph software. Secondly, limited financial funds allotted to the research encouraged the selection of Intergraph software, as Intergraph granted the University use of the software license under very favourable conditions (Moura et al., 1993).
13. A large number of small favela dweller's association also play a very important role in the upgrading process. These associations are critical to the community participation aspect of the programme. In Salvador (Bahia) for example, these organizations include groups such as: Jose Silveira Foundation, 1^{O} de Maio Company, COMONAL (Co-operative of Novos Alagados inhabitants), Dom Avelar Brandao Vila Foundation.
14. A number of additional software packages used by the University of Bologna (Italy) include: 1) TRANSCAD: Transportation AutoCAD application program, 2) MICROSTATION-Generally used to capture data for Intergraph based systems and 3) ARC2MGE: ARC/INFO - Intergraph conversion package. These packages are not used for the implementation of the ViSP approach in Belo Horizonte, instead they are primarily used in the GIS research and application development process associated with the Alovorado program and the ViSP approach.
15. The TNTMIPS software package is essentially an image processing tool with very limited other GIS capabilities. It can be used for georeferencing, mosaicing, handling alphanumeric data, and for the production of thematic maps.
16. The application of the TNTMIPS software resulted in a less accurate georeferenced image when compared to the results achievable by Gheoraster. This occurred since the TNTMIPS software does not use the least squares method adopted by Gheoraster.
17. The TNTMIPS software was also found to be suitable for dealing only with single images and specifically for single images taken over flat landscapes. Given that the informal settlements in Belo Horizonte are predominantly situated along hill slopes (often exceeding 47 % in inclination), and given that all of the settlements would require the creation of mosaic images, the TNTMIPS software was found to be unsuitable for the ViSP methodology employed in the Alvorada Programme.
18. TNTMIPS is not integrated with the primary computer aided design tool which was used in Belo Horizonte (AutoCAD). TNTMIPS had been developed principally for cartography rather than for the range of GIS applications required by the Alvorada Programme.
19. With respect to the plotting problems, the TNTMIPS software functions in a manner that combines mosaiced images into one file. This results in a rapid growth of the data files. As the images for a

settlement are georeferenced and mosaiced, the files quickly reach file sizes of 400 MB. For the system hardware configuration used in Belo Horizonte, these file sizes were unmanageable.

20. Another problem was that the software is restricted to the Windows operating system. This results in a very slow image processing rate as a Soft Engine option does not exist.
21. Gheo is a software suite distributed in a client server environment, which is provided with the AutoCAD version12 driver software and, also with the MS-DOS version of the relational database QUADBASE-SQL. The applications are written in C and the system function at 32 bits. The alphanumeric database and the cartographic database area accessible from within AutoCAD, without having to exit the program. The Gheo software has been extensively developed for creating GIS applications for the management of the infrastructural networks (water and gas) in Italy (Catasto).
22. A soft-engine is a view accelerator. It enables one to zoom into and out of images rapidly.
23. This is analogous to ARC/INFO's routines which checks for node errors such as pseudo-nodes, overshoots, undershoots etc.
24. Moura et al.(1993: 182-183) comments:" ..Greater capacities and the development of deeper analyses could derive from the use of other software packages both by other manufactures and by Intergraph itself.....Amongst them, <u>a package designed for DTM (digital terrain modeling) and for slope and aspect calculation and representation is of *fundamental importance* in marginal areas</u>, where the knowledge of the soil morphology and geology is useful to identify possible risk zones, with the possibility to manage specific reclamation actions, if the land conditions allow it."
25. The differences with respect to the spatial distribution informal settlements is reflected both in terms of the settlement size and in terms of the location of the settlements within the "urban fabric". With respect to size, the informal settlements dealt with in the Alvorada project tend to be small (eg. Villa Nossa Senhor dos Passos is 0.25 km^2) relative to settlements in Cape Town (eg Barcelona). With respect to the location of the settlements, the favelas in Belo Horizonte occur scattered throughout the city's fabric. In contrast in Cape Town the settlements are largely focussed in a large area (approximately 40 km^2) outside the city centre (Ikapa). Another difference lies in the fact that the settlements in Belo Horizonte often lie in the areas with slopes above 47 %. In contrast the vast majority of informal settlements in Cape Town are situated in an extremely flat area (Cape Flats).
26. With respect to the key physical risks, settlements in Belo Horizonte suffer from severe landslides, while settlements in Cape Town are faced predominantly with flooding and fire hazards.
27. There are also fundamental differences in the nature of the construction materials employed in the informal settlements. In Belo Horizonte, mud brick house and tiles are very common. In contrast, the housing structures in Cape Town are comprised of less durable materials such as zinc, plastic, cardboard and other cheap materials.
28. The nature of the construction materials employed by the inhabitants of informal settlements is in essence a response to the housing policy. In Belo Horizonte the informal settlement population expects a right to exercise the Profavela law. These inhabitants are thus more willing to invest in developing a more fixed and possibly permanent housing structure. In Cape Town however, the inhabitants remain aware of the relocation policy and treat the structure as a temporary abode. The differences in settlement dynamics strengthen these differences in attitude. While in Belo Horizonte, the informal settlement inhabitants have no intention of leaving the city, in Cape Town, many of the inhabitants have other homes in the interior of the country and are consequently often on the move between homeland and squatter settlement environments.
29. In Belo Horizonte taxes and payments for utility services are collected in informal settlement areas These monies represent a financial resource for carrying out the upgrading programmes discussed in this chapter. In Cape Town, however, the policy of "non-payment for services" adopted by the inhabitants of the informal settlements leaves a gap in the budget for maintaining any services which are provided.
30. Another significant difference lies in the nature of the population comprising the different informal settlement populations. In Belo Horizonte the both the informal settlement population and the formal settlement population is comprised of a mixture of Brazilian races. There is no clear-cut racial divide between the population residing in the formal settlement areas and the informal settlement areas as in Cape Town. In addition to this difference there are other very significant and racially related issues resulting from a previous apartheid regime in Cape Town. These racial issues will make the negotiation and collaboration components of the informal settlement upgrading process far more challenging and problematic for Cape Town than it has been for Belo Horizonte.

CHAPTER 6

1. Other innovative techniques such as digital videography have yet to become widely implemented and are not considered here.
2. In this project it was possible to use 1: 10 000 aerial imagery to map individual shacks. However, to retain the resolution of the original imagery, the diapositives had to be scanned at a very high resolution (over 1000 dpi). This process alone took 8 hours per image and resulted in files on the order of 250 to 300 MB in size. In turn, the processing of these images required for the mapping exercise (orthorectification, mosaicing, saving of files etc) takes longer with the increase in file size. Saving a georeferenced version of a 300 MB image file can take up to 45 minutes at a time. There are ways of reducing these time factors - see chapter 8 for a detailed discussion.
3. The individual-level is self explanatory, it involves the collection of data about each person. The areal aggregation approach stores data in administrative, functional or measurement zones. The modelled distribution approach involves a model which represents the population distribution as a continuously varying phenomenon (Napier, 1994, Martin, 1991).
4. The micro-planning measures encompasses the following:"
   - legal reforms introducing a new concept of property with regard to informal settlements
   - a realistic approach introducing property regulation that recognises terms of tenure for occupation forced by quest for livelihood and survival;
   - a layout plan for topographical upgrading of informal settlements aimed at reaching basic civic amenities like water supply, sanitation, waste disposal, restrain of infection, environmental pollution, etc.
   - a concept of shelter instead of housing as a method of high-density dwelling in informal settlements;
   - community-based organisations in the informal settlements to co-operate with local governance;
   - an organisation of education, formal and informal, health-care, preventative and curative, community welfare and recreation, with the help of community based organisation."
5. The macro-planning measures encompass the following:
   " In the field of macro-planning, a sound approach to build up an effective non-farm sector of economy in the rural hinterland of urban centres is a compulsive necessity. This will create an employment absorption base in the rural areas which will stem the tide of continuos migration to the cities and towns and stall the process that swells the informal settlement beyond a manageable capacity. The extension of communication- facilities to the rural hinterland can bring the rural community nearer to the nodal town lessening the propensity of migration. The improvement of quality of life in the rural hinterland is also an indirect answer to the scars of urban informal settlements."
6. The micro-planning measures outlined by Banjerjee (1997) give a guideline to the requirements of informal settlement communities in India.
7. Behrens (1993): ".......(2) public participation and policy formulation regarding 'infill' and 'densification' policies must be coordinated at the metropolitan level....."
8. In the case of many Latin American countries, which are undergoing agragarian reform, there is an additional need for applications designed to evaluate agragarian reform policies.
9. Zungu argues that the LEFTIE act and the Development Facilitation Act of 1995 have failed to provide people with a "cheap and accessible system to register, to transfer and allocate land locally" and that this has contributed to further development of an informal land management system.
10. The aim of this simulation is to provide an accurate model of large-scale urban features. These features include roads, buildings, landscaping, trees and shrubs, vehicles, pedestrians, street furniture, horizon features and sky. The application is based on 3d modeling of the terrain and physical structures comprising a city. The visual simulation technology employed is complex and requires techniques such as polygon rendering, texture rendering and automatic level-of-detail switching to enable the generation of 30 image frames per second. Goosen (1997: 49) describes the model as follows:
    " The completed model is one of the largest and most complex urban simulations ever built and is being used by Silicon Graphics in its Mountain View, Cailfornia Visionarium to showcase the technology. The urban simulation model of the development contains 250 buildings, thousands of trees, hundreds of pedestrians and hundreds more small objects that add detail to the simulation (including a working fountain and a flock of Canadian geese flying around the development)."
11. These include:

- a reduced time for data input,
- savings associated with the data capture process
- a reduced processing overhead as the databases are smaller and faster to manage, analyse, update and use (40 - 60 % savings), and
- a removal of the need to expend resources on resolving land geometry problems during database and system development.

12. Within Microstation 95, it takes a few seconds to update about 62 000 shack points without attribute data (approximately the number of shacks in the CMR). This is a long time in terms of computer time. Links to attribute data records residing on in Oracle database situated on a file server down the corridor can slow down even the simplest of data processing tasks tremendously. In making use of the integrated system feature of the MGE system structure one often enters other specialised software modules via a pop down applications menu. To simply access an attribute record associated a featurized element one has to load Base Mapper. This takes a few seconds. Select the feature attribute manager and wait a few more seconds, until you can click on the feature of interest and wait. All the seconds add up and the process takes longer the more the number of attribute records attached.
13. The problems associated with the application of a strictly cadastral approach has been discussed in Chapter 2 based on case studies situated in Germany and other countries.
14. "The core principal of MERKIS is that all local government GIS in Germany are to be based on a unique spatial reference system. In each municipality, only one agency is to be responsible for the administration and updating of the spatial reference system." (Junius et al., 1996: 70).
15. "Faced with the size of the task at hand, the DGI has sought to develop a number of partnerships by defining an operational framework for the development and the updating of cadastral records integrated in GIS and acquired by local government organisations. The principle is simple: digitisation cannot be done without the agreement of the DGI which then obtains a magnetic copy of the record and remains the data manager with regards to information up-dating. Special conventions have been agreed with major network managers (the national telecommunications, electricity and gas utilities)."
16. The discussion by Junius et al (1996) suggests that the implementation of the MERKIS model is faced with many difficulties.
17. Take the implementation of the iSLPs for example. This government initiative has been running for about five years and has resulted in very little on the ground modifications.
18. For example, the PROLAND model does not cater for potential informal settlement relocation evaluations.
19. The accuracy here may be greater if a high resolution digital elevation model is used to ortho-rectify the imagery instead.
20. The terms "Doers", "Users" and "Viewers" have been used by Intergraph to refer to different GIS user groups within a corporate environment. These terms are described in chapter 7.
21. There are significant differences between the Bi-level model proposed here and the "dual approach" discussed by Stravidiis (1996). The dual approach describes a broad methodology for the implementation of GIS in a large municipal organization. In this approach, no informal settlement data is represented at a metropolitan-level.
22. Stavridiis (1996: 3) describes the planning level of the present system as containing: "......basic environmental features such as rivers, lakes, dams, marshes, mountains and beaches. The system also has major roads and rail system, railway stations, bus and taxi ranks. There are also all educational facilities, police stations, fire stations, post offices hospitals and clinics, major shopping centres, industrial areas, sports facilities, civic and major halls, public swimming pools, urban and rural areas, informal markets, hotels, nature reserves, gardens, wine farms and places of special interest. " Clearly there is no significant informal settlement data and no attribute information at this level. The contents of this level have been selected to facilitate city and tourism planning applications associated with the formal city. In other words, this level of the system database structure remains defined to address the only needs of the formal city.
23. Only the Id, name and code columns exist.
24. All of the significant attribute data is to be captured for the formal settlement areas only. The basic spatial units to which these data are to be attached are building points and erven areas (situated in the cadastral data layer).
25. This permanency refers both to the dwellings and the dwellers within the settlement.
26. No strategic level work has been included in the database development process. A map illustrating

informal settlement locations in the Belo Horizonte region exists, but no consideration has been given to extending this level for strategic planning applications.

27. In the PROLAND model the high-end platform is used only in the initial database building process. In contrast, the Bi-level model necessitates a close interaction between the high- and low-end GIS platforms. Data exchange between the two systems is viewed as an ongoing process. In addition to providing a basic data processing service to low-end GIS platform information sources, the high-end platform is viewed as having its key function as a metropolitan-level analysis tool (eg.resource allocation).
28. The definition of sustainable development as defined by WCED (1987) reads as follows: " development that meets the needs of current generations without compromising the ability of future generations to meet their needs" and by IUCN-UNEP-WWF (1991) as follows: " development that improves the quality of human life while living within the limits of the supporting ecosystems."
29. In brief, the strategy includes the following steps:
    - Develop a framework of the socio-economic-environment system in the context of sustainable development.
    - Develop a matrix showing the qualitative links between the system components.
    - Develop sub-system diagrams of significant urban processes showing their relevance to the appropriate sustainability indicators.
    - Use the interaction matrix to development diagrams that show the linkages between conceptual model subsystems
    - Identify spatial and temporal scales and boundaries appropriate to the model sub-systems.
30. "A conceptual mode is required to assist in the formulation of the mathematical model of the Quantifiable City. The conceptual model simplifies the system of interest, the 'sustainable city', by identifying relevant system components, the linkages between them and to some extent the nature of those linkages. " (May et al.: 6)
31. The "sectoral models" referred to be May et al. (1997) are in essence models which have been developed to model subsystems within the city.
32. In this case, a water resource sub-system represents the sector model.
33. "Many relevant systems have been modelled in the past, and the main difficulty lies in integrating them into one comprehensive system. In particular, urban models of socio-economic processes must be linked with physical environment models." (May et al, 1997).
34. Although the survey focused on the application of GIS in the City Council, one of the aims was to establish the existing information system facilities and applications presently utilised - the aim being to ensure GIS compatibility with these systems.
35. The search for sector models has focussed on identifying potential models residing within the City Council organisation already. By utilising these models, one would hope to reduce data transfer problems associated organisational issues. One spin off of applying such a model is that it would encourage those departments presently not active in GIS within the city of Cape Town to become active.
36. ENPAT refers to the Environmental Potential Atlases funded by the Department of Environmental Affairs and Tourism.
37. ICIS stands for the Integrated Catchment Information System which has been developed by the Kruger National Park Rivers Research Programme (KNPRRP).

CHAPTER 7

1. These requirements are in essence an approximation of the requirements of the high-end platform of an informal settlement upgrading system (situated within a municipal environment) used to implement the Bi-level approach (see chapter 6).
2. The functions regarded as minimum requirements for "any GIS" and which were not included in the system evaluation process carried out by the City Council included: interface to the stereo plotter, data exchange capabilities, continuous database coverage, CADDS4 conversion and RDBMS interfaces.
3. It is clear that to enable the Bi-level model (proposed in chapter 6) to be implemented in a local government environment, the high end platform of the approach must be capable of meeting these

demands. However, in order to ensure a practical implementation of the Bi-level model, which incorporates data interchanges with smaller local authority GIS systems associated with informal settlement areas, a very different set of software requirements are envisaged. These software requirements are embodied in low-end platform GIS products. Thus the complete software requirements of the Bi-level model approach demand a coupled high-end and low-end GIS platform system configuration.

4. Data conversion / translation routines require detailed database structure inputs. Text-based parameter files must be created which outline the exact structure of the database - including details such as the feature name/code, column headings, column character lengths etc. An example is the MapInfo Translator in the Intergraph software suite. To run this translator a detailed parameter file (.MIP) must be created which describes the exact structure of the MapInfo attribute table.) Details of the project specific database structures must be specified for of the export and import software.
5. The experience in implementing Intergraph at UCT has shown how critical easy access to software support is. This is particularly important for the implementation of complex high-end GIS software platforms. The costs involved in obtaining software support include large phone bills, travel expenses and training expenses. All these costs increase exponentially if the software supplier is situated in a foreign country.
6. The image registration procedure employed in the application of the ViSP methodology in Belo Horizonte does not incorporate the capture of height information. No spot height information is entered into the GIS in any part of the methodology. This is a severe restriction in the database development methodology in terms of the development of surface analysis based applications (see chapter 5).
7. It is certain that the memory (16 MB RAM) and hard disk (1 GB IDE disk) requirements listed in the ViSP basic equipment list would not suffice the needs of the UCT Urban Management GIS research group. The cadastral and topographical data alone for Ikapa comprises about 70.5 MB in an unzipped MapInfo format. This does not include any alphanumeric attribute data nor any scanned aerial images - which presents the greatest memory storage requirements. The size of a scanned aerial photo depends on the original image resolution and can range from 2 to 300 MB. Typical imagery files captured by the Aviation Mapping and Land Information Services Computer Systems (AOC Mapping Technology (Pty.) Ltd.) can even range up to 600 MB in size (Tanner pers. comm., 1996).
8. Typical command sequences employed in the data capturing process are: "C, RETURN" for closing a polygon, and "CONTROL C" pressed twice for unselecting a polygon.
9. Each of these issues listed here is discussed more fully in section 6.3.
10. High resolutions such as 1000 or 3000 dots per inch (dpi) are required as low altitude photography acquired by helicopter may not always be available. In this case, one would have to use a high resolution to scan aerial photography contact prints or diapositives. Low scanning resolutions are required to save memory space on low altitude imagery.
11. These criteria bear not only the local municipal requirements in mind as outlined by Milne (1994) but also the technical requirements specific to addressing informal settlement upgrading GIS project work as identified in this project.
12. While the ViSP approach in Belo Horizonte does not use surface modeling software, a recent paper by Moura et al. (1993) point out the potential for utilizing such software. (A quotation on this issue appears in chapter 5).
13. The dialogue boxes serve as detailed input prompts to the user.
14. Some of the older GIS systems such as the UNIX based Arc/Info system did not cater for this requirement.
15. The practicality of developing such GUI's should not be faced with too many technical problems. One criticism of utilizing GUI's to aid the implementation of GIS in municipal environments is that the presence of such software on the system slows the whole municipal system down tremendously. However, the GUI's referred to here are not focussed on reducing the number of steps required to be conducted by a GIS user. Instead the aim of the GUI would simply be to enable the user to see the same command in Xhosa or another native language. In other words, it should simply involve a matter of changing the command name, as opposed to writing a complex macro summarizing a series of steps into a single icon. This can come later.
16. GIS-orientated municipalities generally have so much attribute data that the use of a relational database management system is essential for the effective retrieval, storage and management of such data. Such

an RDBMS enables departments across the whole organisation to share attribute data more effectively than if a large number separate small attribute databases existed.

17. It should be noted that the seamless integration referred to here deals both with an integration of data situated in warehouses of the same database source type (eg. only Access database warehouses) software package, and with an integration of multiple data sources situated in *different* GIS software and database environments (eg. Arc/Info, ArcView, Access, MGE etc.).
18. The Internet facilities incorporated into GIS packages usually only offer one-way communication. In other words the database can usually only be read from and not written to.
19. The Ikusasa CONSAS' 97 conference (Durban, 24 - 28 August 1997) enabled the latest documentation for each software to be obtained.
20. These courses are run by the Information and Technology Services (ITS) Department of the University of Cape Town (UCT): Arc/Info, ArcView and Atlas GIS. The UCT GIS UNIX Workstation was used for all the Arc/Info work.
21. The Intergraph courses are run by Intertech Systems.
22. This was obtained in Belo Horizonte at the 126 CAD laboratory.
23. Hands on experience on the Intergraph software and Microstation had been previously obtained at the Centre for Interactive Graphical Computing (CIGC) at UCT.
24. The two of the most likely systems to be selected (Arc/Info and Intergraph) were extensively examined by hands on experience prior to the selection of the software. The author had also obtained some basic experience on the Intergraph suite in 1993.
25. The MapInfo software was initially examined at the Cape Town City Council and was purchased early on in the project for the purpose of viewing vector data acquired from the City Council.
26. The discussion of software implemented in Belo Horizonte (ViSP) has been restricted to Chapter 5.
27. Other reasons included: 1) UCT's main GIS facility (ITS) is based on this software, 2) it is widely distributed amongst local government institutions and universities both in South Africa and internationally.
28. The online documentation is superb and encouraged self-education. These two factors led to the initial concepts of cluster analysis discussed in chapter 11.
29. Spatial analyst enables users to create, query, map and analyse cell-based raster data and to perform integrated feature-based and grid-based theme analyses.
30. GIS-T enables dynamic segmentation applications involving routes to be characterized by speed limits, point accident events etc. RouteSmart enables point to point vehicle routing and scheduling.
31. Dynamic segmentation refers to the capability to match user data to any portion of linear features in a coverage.
32. GIS-T Conflate enables the alignment of vector coordinates and the integration of the attribute data of two different coverages.
33. Vector data from the City Council in -DXF format was analyzed within the Arc/Info environment. This process was very instructive in highlighting practical problems associated with the Arc/Info platform. Importing the -DXF data proved to be a laborious and extremely time consuming task (see section 8.4). On the whole, the data capturing facilities of Arc/ were found to be extremely cumbersome.
34. Procedures such as ortho-rectification of aerial photography are supported by a range of products by ERDAS. The full range of image processing products available from ERDAS includes: Erdas essentials, Erdas advantage, Erdas Professional, Vector, Radar, Virtual Gis, Orthomax and Map Sheets
35. ArcPress is a recently added plotting facility which function in ArcInfo and ArcView. The previous ArcPlot facility was extremely cumbersome to use. ArcPress has a graphics rasterizer.
36. Alternatively, a C language- based SDE Application Programming Interface (API) enables scripts to be written on client workstations to integrate the ESRI software with other systems.
37. SDE moves GIS data from separately maintained propriety databases to centrally maintained databases built on open relational database management system (RDBMS) standards. It monitors all client and server connections and maintains system integrity through its own internal security system.
38. In addition, the SDE implements a client / server, co-operative process architecture. It is based on an open system access philosophy, and combines "very large spatial databases with complex spatial query tools that efficiently deliver geographic features from a relational database...."(ESRI Spatial Database Engine, 1995: 2). Key advantages of SDE include its efficient spatial object model, enabling features to be retrieved very rapidly during complex spatial queries.

39. ArcView Version1 for windows became free on the INTERNET in 1995 (Schafroth, 1995) and was initially considered as a possibility. It soon proved to be extremely limited in its functionalities, especially in terms of interfacing with local municipal systems. The evaluation of the ArcView software here is based on later versions of this software.
40. The CAD drawing reader extension AutoCAD allows ArcView users to access AutoCAD drawing files (DWG) or industry standard drawing exchange files (DXF) as data sources (ESRI, 1995, p27). A CAD Theme Builder was made available in late 1996. This module extends the CAD readers functionality and provides the capabilities to automatically create individual themes directly from layers and entities selected by the operator.
41. Visual Basic enables interfaces to be created which can access the functionality contained in other programs by communicating through a Dynamic Data Exchange (DDE) mechanism. (This is a mechanism that enables two applications to communicate to each other by continuously and automatically exchanging data.)This mechanism enables ArcView to communicate to any other application supporting DDE.
42. This extension requires ArcView Version 3.0.
43. Interactive maps can be created from different spatial data sets including shapefiles, coverages, SDE layers, DWG, DZF, DGN and graphic images. The MapObjects Internet Map Server extends the functionality of MapObjects over the Internet and corporate Internets.
44. In Greece, it accounts for over 80 % of local government applications (Assimakopoulos, 1996). In France it shares the GIS market with a French package called Apic. In Great Britain, Arc/Info occurs in 25-30 % of county and metropolitan districts. In Italy, Arc/Info is used for over half the regional and provincial applications. In Poland it is utilized for larger central government implementation.
45. The limited in-built analysis capabilities allow location analyses (Specht, 1998), territory analyses and market analysis applications.
46. With respect to image processing, a user can only register images - and even this can only be done with a low level of accuracy. Unlike many high-end platform software products one has a limited choice of transformation models, no facilities for rotating, resampling or dithering the image etc. These operations are crucial for central organization carrying out informal settlement mapping based on the image processing of aerial photography.
47. Vertical Mapper, a grid-based package, enables one to interpolate from points, construct profiles and construct contours.
48. ClusterPlus provides access to clustering and segmentation facilities.
49. This software enables image georeferencing, transformation, tiling and mosaicing.
50. One usually has to enter a special plotting application (eg Map Finisher or ArcPLOT), in addition the symbology immediately available for map production is not as easily accessed as in MapInfo. One must search through the platform's CAD software cell libraries to find the appropriate symbol. In addition to this these systems usually require that one constructs a spatial query before one can construct a map. One needs to run a number of modules (eg. Base Mapper, MGE Analyst) to featurise and construct topology etc.)
51. In MapInfo the data generally has topology constructed already and it is simply a question of creating a thematic map via a wizard. The latest version of MapInfo (4.5) will include a thematic map template to accelerate the process even further.
52. On large systems, a project must be created or modified to include the new features to be imported and a parameter file must be created. In contrast, provided the data is in one of the more widely recognized formats (dxf, shp, etc) it can be imported far more rapidly into MapInfo.
53. Several macros were created to extend the built-in import capabilities of MapInfo. These included: ArcLink for Windows, ArcLink for Sun, ShapeLink, AGLink and a comprehensive Translator Bundle. These macros have been available since 1996.
54. This product is a server software package that works with database management systems to store geographic data more efficiently in relational databases and to accelerate the query functionality. It allows organizations to place spatial data in their central RDBMS, enabling the data to be accessed by the organization's GIS clients from data warehouses or through client / server database deployment.
55. The MapInfo Corporation (1997b) MapWorld Magazine issue focusses on the Internet capabilities of MapInfo.
56. For example although Orthodraw and MapInfo are compatible packages, these products are used as separate programs. In constrast, the seamless integration found on high-end platform systems enable

such and a multitude of other functionalities to be accessed simultaneously through the same user interface.

57. The focus is on conventional engineering and military analysis applications.
58. The software allows imagery to be viewed via the Virtual Image Viewing and SpatialView modules, there are however, no other image process facilities.
59. With respect to the compatibility of the system with other software systems, despite the fact that it is an apparently open system, there remains only a limited number of export file formats available. Export file formats for some of the most widespread GIS software such MapInfo (MIF) and Arc/Info (shape files) remained unavailable until very recently. This often required that the dxf file format be used, which resulted loss of topology and attribute data linkages during the data conversion process.
60. A clear illustration of this lies in the fact that the photogrammetry laboratory of SLI in the City Council, which has GenaMap as the main GIS system, continue to use a combination of Intergraph equipment (Intervue workstations) and Microstation for the capture of detailed topographical and cadastral data from aerial photography.
61. In comparison to other systems, it has very limited Internet capabilities.
62. The lack of use of the GIS software in the City Council is partly due to the lack of ease of use. The Genius GUI has been developed to reduce this lack of ease of use.
63. Henri the Navigator is a client / server software product that enables organizations to find data from vast amounts of information stored in a range of different databases and locations (GenaNews, 1995).
64. Genius II is a graphical user interface builder allows interactive development of GUI's without requiring programming expertise. Key features of this module include: full motif 1.2 compilance, client/server architecture, user defined icon creation and interactive layout and edit tools. Genius enables users to create application menu interfaces quickly.
65. The Cape Town City Council found this software to be more suitable for its requirements than Arc/Info, Unigis, Alleymap, System9 and ReGIS (Milne, 1994).
66. With respect to compatibility, the software can import a large number of formats.
67. The layout facilities enable thematic maps, pie charts, presentations and graphs to be created.
68. In terms of its RDBMS capabilities, a bi-directional link may be established to Oracle, Sybase, Microsoft SQL Server, or any other any other supporting ODBC/DAO database.
69. The data capturing facilities of the software include a CAD functionality and heads-up digitizing tools.
70. The analytical capability is restricted to simple GIS tasks such as spatial queries, buffers and thematic mapping. On network topologies it is also possible to carry out shortest path and flood trace analysis.
71. In terms of image processing, only simple georeferencing procedures and vector-raster overlays may be carried out.
72. In terms of customization, the software can only be customized using the propriety AutoCAD Runtime Extension (ARX) software.
73. The Autodesk MapGuide software enables the data captured in AutoCAD Map to be published on the Internet. However, a bi-directional linkage mechanism is not supported via the Internet as in the case of GeoMedia.
74. These include ESRI Arc/Info, Atlas GIS, ArcView, Microstation and MapInfo.
75. Locally, the Khayelitsha Local Authorities (City of Tygerberg) utilize AutoCAD software. In Europe (in Poland, the Netherlands and Denmark), AutoCAD Map is utilized in conjunction with other predominant software packages such as Intergraph and Mapinfo.
76. The analytical capabilities of the MGE Intergraph system are comprised of GIS, engineering and other specialised applications. The civil engineering applications include modules such as Siteworks and InRoads. Other specialised analysis applications include: Network analysis, Grid Analyst (for generating DTMs and carrying out optimal path analyses and multivariate statistics), Dynamic Segmentation (transportation application) and Voxel Analyst (3d-visualization).
77. The image processing tasks which must be carried out on black and white, and color composite imagery before heads-up digitizing are facilitated by the Advanced Imager (MAI) and Base Imager (MBI) modules. These modules enable warping, resampling, clipping, contrast/brightness manipulations, frequency analyses etc.
78. The IRASB and GEOVEC modules enable bi-level bitmaps to be rapidly vectorized by heads-up digitizing and auto-vectorization procedures. The CAD capabilities of the MGE suite enable detailed engineering, planning and design work. Further tools which aid the data capturing process are the in-built line-work cleaning Microstation Development Language (MDL's) programs such as MrfClean,

MrfClean3d and MrfFlag, as well as the in-built data convertors (MapInfo Translator and ASCII convertor etc..).

79. With respect to plotting, the IPLOT software may be used to create professional map out puts. Alternatively, the data may be imported into Geomedia and plotted through Imagineer Technical. This software has superb layout, plotting and drawing facilities. The live link which is maintained to the Geomedia warehouse enables changes in the Geoworkspace to be registered automatically on an existing Imagineer drawing.
80. Other products which may be used the capabilities of this software are GeoMediaPro and Imagineer Technical.
81. All of the modules have similar user-friendly interfaces. The similarity of these interfaces makes it easy to learn how to use a large number of modules quickly.
82. The RIS 05.03 module provides a user-friendly interface between the GIS and just about any RDBMS available on the market (Oracle, DBMS, SQL etc..). This is an essential feature for the development of a detailed socioeconomic database.
83. This includes Arc/Info, ArcView and many other systems, which have only recently started supporting the concept of open GIS systems. Furthermore, the great variety of in-built translators and data import facilities present in the MGE suite and in Geomedia illustrates that the system is highly compatible with other software products.
84. A large number of applications can be accessed simultaneously from the same user interface. The ability to open 63 levels and multiple raster sets simultaneously is particularly useful for spatial temporal analyses.
85. This software enables data to be read from and written to a GIS database via the Internet. See chapter 8 for details.
86. A quotation for a selection of the available modules (40) lists the cost of an academic license for each module at R758 (03/04/96). The cost of obtaining all these modules today is well over R30 320.
87. See the following Web site for further details: <http://www.intergraph.com/geomedia/viewer.
88. In Portugal, Intergraph has been purchased by the National Centre for Geographic Information facilities. In Denmark, the Intergraph MGE shares the GIS market with AutoCAD-based systems. It is also used in the Netherlands, Spain, Canada, Japan amongst other developed countries (Intergraph Corporation ,1997c).
89. Intergraph systems are found in a multitude developing countries including: Malaysia, the Czech Republic, Brazil and in the Gulf area (Bahrain) (Bell et al., 1991; Intergraph Corporation (1997c).
90. Version 2 has only been shipping since February 1997. The Urban Management GIS facility was purchased in mid 1996, thus initially only Version 1 was briefly considered in the evaluation process. The latest information available on Version 2 of this software (http: //www.idrisi.clarku.edu) illustrates a number of improvements.
91. It lacks specialised modules for rapid vector data capture and the CAD capabilities provided by other software systems.
92. The software appears to have been designed essentially as a standalone package and is not easily compatible with other systems. Although there appear to be a wider range of export and import file formats available in the new version, there is still a number of key file formats which are not supported (eg.the Microstation .dgn format and Geotiff files).
93. This software is primarily a raster-based system. The GIS applications developed for settlement upgrading usually require that attribute data be attached to vector data types such as area centroids.
94. With respect to Internet facilities, there is no "universal GIS" capability as found in other packages such as Geomedia.
95. With respect to system integration, there is no option of extending the system to include direct access to other specialised GIS applications (eg dynamic segmentation, network analysis etc.). These types of modules simply do not exist for this system.
96. How can this be achieved with a municipal environment? PCs / terminals exist already in most local authorities wishing to purchase a GIS. Instead of only applying a benchmark testing process, each vendor should have the opportunity of loading a temporary evaluation copy onto a number of machines and the staff throughout the council should be given access to evaluate the software themselves. Secondly the non-specialists GIS departments can be given at least a weighted representation on the evaluation board. All the influential people in the various branches should feel that they have been included in the selection process. Failure to do so will result in a prolonged resistance to the

implementation of the system arising partly out of GIS ignorance and partly out of resentment from being excluded from the selection process.

97. Only recently have MDL APPs been written by Intergraph to enable the rapid raster redraw functionality of products such as Orthodraw within the MGE image processing environment.
98. This decreases the potential application of the attribute database component of the system within a municipal GIS environment. Most key municipalities in South Africa have attribute data residing in relational database management systems such as Oracle.
99. Other requirements such as engineering analysis and detailed engineering and planning design capabilities can not be supported.
100. The position of Intergraph as one of the world's leading GIS software system is indicated by the fact that it is favored by the some of the most GIS developed countries in the world. The European countries with the greatest GIS diffusion in local government, such as Germany, have either implemented their own locally developed systems or the Intergraph MGE suite. In some cases the Intergraph system is supplemented by AutoCAD-based systems and to a lesser extent by customized / local systems (Denmark and the Netherlands).
101. Most systems have application programming interfaces (APIs) which enable the parent system to be integrated with other software systems. Thus the problem of integration can be circumvented by writing special API scripts. Thus the manner in which one may evaluate the degree of integration should be rephrased to: which system provides the greatest degree of integration without necessitating the development of specialized API scripts? (ie. which system represents the most integrated one at the time of purchase?)
102. Moura et al. (1993) indicated that this was one of the reasons the University of Bologna selected the Intergraph system for the early ViSP work in Belo Horizonte.
103. It is interesting to note that the ViSP approach had had its origins on an Arc/Info system in Italy (University of Bologna). Upon implementation however, Intergraph was initially selected. This was then followed by the implementation of the Gheo suite.
104. In the initial stages of the project there seemed little sense in creating a detailed informal settlement upgrading GIS database for a specific settlement as the local government would be against any conclusions in support of in situ upgrading.
105. For example the specialised InRoads and InSewer modules can be added on in the implementation phase of an upgrading project.
106. These modules are essential to the system before any of the remaining MGE GIS software can be loaded
107. By far, the most utilized components of the system have been the image processing and data capturing components.
108. The desktop modules consist of a series of low-end platform GIS software modules. Compared to other modules in the suite, these software components are perhaps very easy to use but limited in their image processing and analysis capabilities.
109. The potential application of these modules for research in this field is very high (see chapter 12). It is envisaged that as the database building process for the Cape Metropolitan Region becomes more complete, these modules will be implemented a great deal in the very near future.
110. Before the Geomedia and Imagineer Technical packages were acquired, a combined use of Microstation and Adobe Photoshop had proved to be the most practical manner in which to plot MGE data from the system.
111. The Intergraph offices are situated in Johannesburg and the cost of attending these training courses fell outside the budget of the project. As is often the case with the implementation of GIS, the users of this system are largely self trained. Furthermore, getting university support for a Windows NT-based operating system proved impossible. The University of Cape Town Information Technology Support (ITS) services does not support the Windows-NT operating system. This meant that network consultants had to be called in to get the network up and running - leaving little money for software training and other expenses.
112. This problem arose when the Oracle 7.2 Workgroup Server software was loaded onto the system. The Intergraph MGE suite is structured in such a manner that the RDBMS, situated on the server, is accessed by local and remote client machines via an interfacing software (RIS). Setting up the system to enable the client machines to interface properly with the RDBMS resulted in a delay of weeks. One reason for the delay was that the software suppliers themselves could not help with the Oracle -

Intergraph interfacing problem in a Windows-NT environment, as they had also only recently started to test this configuration in South Africa at the time.

CHAPTER 8

1. Due to time limitations, this thesis has focussed on the creation and implementation of the metropolitan-level of a Bi-level model for the Cape Metropolitan Area. The technical discussion here thus focuses mainly on the creation of the metropolitan-level.
2. As it was only possible to develop the attribute data component of the metropolitan-level database to a limited extent, a section (8.7) has been included on other potential attribute data sources for the metropolitan-level database.
3. " ..Once a system or two using the Planning Approach have been successfully completed it should then be possible to begin on the fundamental systems needed for the detailed Engineering Approach. This can take place once an organization is ready to become more developed and has acquired the skills and responsibilities that accompany development. The opportunity is created to later upgrade the accuracy of the data produced by the Planning Approach to be more compatible with the Engineering level of information."
4. Clearly the database-building process involves a combination of multiple data source tapping and the capture of new data.
5. This is evident from the implementation of GIS in municipal organisations such as the city councils of Gdansk and Cape Town.
6. In the majority of municipal GIS projects, the development of core applications typically occurs only in the third year of the project. Implementation only starts in the early part of the fourth year.
7. Appropriate database management is required and directory structuring needs to respected when developing a large system. For example, having a large tiff file in a wrong directory can result in a message such as insufficient disk space when exporting a project. Having the project directory on the C drive places certain limitations on the size of the project. In practice it has been found necessary to remove dgns selectively from the dgn project directory when exporting or saving a back up copy of an MGE project. A separate directory should be created for design files only used for reference. These would represent design files with features not intended to be featurised. The contents of this directory could then be saved separately.
8. This was carried out by executing the SQLDBA72.EXE routine situated in the C: \ORANT\ directory.
9. A number of other features can also be employed to aid the administration of the project. These require the use of other routines such as the Table Index Manager, Domain Manager, Join Manager, View Manager and Label Manager.
10. Initially problems were experienced with the network connections. A typical error message which appeared when carrying out an MGE operation which required the database to be accessed was as follows: "Utilities Schema Manager > Ris Error: Ris_E_Client network error > unable to communicate with client process > net and local connection broken."
11. Initially, a link to the University of Cape Town's ArcInfo GIS Workstation was considered for the project. This linkage was to take the form of an OSNI-DANI LAN bridge to a Sun Workstation containing the ArcInfo software. However, the demand on the university system and the size of the imagery for the project necessitated the development of a separate system altogether. When problems were encountered during the data import process, this possibility was abandoned altogether.
12. The manager of the Arc/Info supplier in South Africa (Etienne Louw, GIMMS) was contacted in early 1996. In an E-mail message returned some time later the his response clearly illustrates the difficulty of carrying out this conversion: " Genamap to Arc/Info converters: ...After travelling the globe for weeks I have something to summarize.....there are two options: 1) a set of AML's (undocumented) to do the conversion. and 2) an awk script and a set of AML's with a "small" read-me file to do the conversion." (Etienne Louw, Tue, 27 Feb 1996 10:10:27, Pegasus Mail) Both options had apparently never been implemented in South Africa. With respect to the first option Louw writes: "Apparently it is quite easy to work through the AML's to determine how to use them. (If someone has worked it out, please forward the README to the list!)".
13. This inevitably meant that any existing attribute data linkages would be lost. However, considering that

there was no attribute data attached to the GenaMap vector files at the time, it was opted to employ this alternative conversion method instead.

14. The vector data within the Council's database is typically organised by several map themes (see appendix 5 table 2) - each feature type having a distinctive symbol. The annotation is compiled into a file again with a different symbol for each annotation type.
15. Layers in the original data have been misspelled, there are duplicate layers apparently originating from different maps (eg. house and house_4) and a number of layers lacking a clear identity (N_T_, transf). The providers of the data were contacted on numerous occasions in an attempt to acquire a clear descriptive listing of all the layers. These requests were ignored. This is typical example of the type of problem one can encounter when a collaborative database building approach is implemented.
16. This proved to be a very time consuming exercise. Each layer took about 20 minutes or more to process. Once each DXF layer had been converted into individual shape files, these files were combined within the ArcInfo Workstation environment. New shape files were created for single feature types by data for the same feature that had been captured from different maps. (eg. buildings = buildi + buildi_4). Once all the data had been simplified in this manner, it was imported into the ArcView environment to aid a visual analysis of the data.
17. The data converted was an updated version of the Ikapa data was acquired in December 1996.
18. Although the data was requested in a format that held each feature type on a different layer, it was provided as a large "data sandwich". Upon initially importing the MIF file, all the vector data appeared in a single colour and in one layer. Thus the provided format essentially rendered the data useless. MapInfo proved extremely powerful in terms of enabling the data to be viewed in a differentiated manner. A thematic map was easily created in which each feature type was displayed by a different symbology. This was made possible by the fact that the identity of each feature type was distinguishable within the ID column of the MapInfo table. The translation of MapInfo data into MGE format involves the application of the in-built MapInfo Translator tool accessible within the BASIC ADMINSTRATOR MGE module.
19. This data was captured by the Council's Surveying and Land Information branch using Microstation. Although the data should have been compatible with the existing design files on the Urban Management GIS system, this data required significant moving and scale changes in order to ensure an overlap of the data sets. This was necessitated as the Council works with positive X Y values and omits the value of 3 000 000 from the y co-ordinate.
20. For one informal settlement area of 2.6 squared kilometers the following costs were quoted by AOC:

aircraft positioning	@ R15000
B/W 1:8000 images	@ R8570
ground control	@ R7750
digital orthophoto mapping	@ R34 550

For an area of 690 m X 690 m (0.476 km2), the cost of generating aerial photos, ground control points, ortho-rectifying the imagery and creating a DEM at a scale of 1:6000 was quoted per image at: R1100-R3600 for black and white imagery and at R1700-R4500 for colour imagery. At a scale of 1:3000 the same area would require 134 photos. For the whole of Ikapa, the maximum costs would be R483 931 (B/W) and R603 000 (colour). Both figures were above the project budget.

21. The diaposatives for these two sets of images were acquired early on in the project, scanned and entered into the system. It was the preliminary analysis of these images that suggested that rapid growth areas would be detectable by a systematic overlay analysis. This imagery also supported the initial ideas relating to the different shack settlement patterns.
22. The photographs were selected only after a visual inspection by a colleague who had done a great deal of field in informal settlement areas.
23. Each image contains information for mapping shacks in free standing shack areas, site and service areas and back yard shack areas. All three shack bearing areas require upgrading, however in order to speed the development of the database it was decided to focus on the capture of only the free standing shack areas initially.
24. Examples of the training set samples selected are as follows:
    - shack1 - red roof
    - shack2 - green roof
    - shack3 - grey roof
    - shack4 - yellow roof

- shack5 - dark grey roof

Two additional feature classes were defined by applying a region growing method. These were:

- road1 - pale brown, and
- field1 – field3 - three variations of green.

25. Up to 250 classes may be defined in the classification procedure within the MAI module environment.
26. These characteristics were:
    - the small scale of the imagery (1:20 000)
    - the large file size of each image (> 239 MB)
    - the colour range variations from image to image, and
    - the shack roof colour variation within the individual sub-settlements
    - In many cases a large number of classes would have had to be defined per image.
27. The images of both levels must be positioned correctly in the MGE universal space to build a Bi-level database. However, it is not necessary to mosaic the metropolitan-level imagery. Nor is it necessary to resample the local-level imagery.
28. In this method, the images were positioned using the image to map warping facility. Control points were placed within Microstation as defined by the GEOTIFF file associated with each image. During the warping procedure a design file with the four control points was created. The co-ordinate data was obtained from the GEO text file accompanying each image. This design file was set up once and copied and renamed for all subsequent files to avoid having to reset the projection parameters each time a new image was to be warped. The error resolution was kept to a minimum. If poor, the image was rewarped 5 to 10 times. The RMS errors ranged from 0.2 to 10. The average brightness and contrast values varied greatly from image to image. In order to facilitate the warping process, where the corners of the images were not discernible from the Microstation background, the contrast and brightness parameters were modified to highlight the image. These parameters were reset to the original values before the resampling procedure was carried out.
29. This modified affine transformation routine was used to position the images by specifying 1) the co-ordinates of the image origin and 2) that no image resampling should be carried out.
30. The results of the warping procedure will differ for an image, even if only slightly, each time it is warped. In contrast, the transformation procedure produces an identical result each time since the same origin is keyed-in every time for a particular image.
31. The sizes of the original imagery files were very difficult to work with. Saving at a high resolution once warping had been conducted would take up to an hour. In view of the time and financial constraints it was decided to only save resampled version of the majority of the images once they had been warped.
32. The loss of resolution was needed to allow a far more rapid redraw rate and quicker and cheaper plots. The quality of these images proved sufficient for demonstration purposes when communicating with visiting officials who were interested in the project. Needless to say, the importance of being able to set up rapid and impressive demos were essential when seeking further collaborative initiatives in aid of the database development process.
33. Working with large raster files and entering and exiting programs rapidly results in fragmentation of the hard disk. The end result is messages reflecting that the system is low on virtual memory. The defragmentation procedure can be easily run on a Windows 95-based machine. However, through the duration of this project, there seemed no way to carryout the same procedure on a Windows NT based machine.
34. Each file has vector location information (ie. co-ordinate system and other design file specific parameters) common to one another and the merging process results in a compression of the data storage space.
35. These groupings were as follows:
    - FS1: 994: 10005, 10007, 10009, 10011, 11005, 11009, 11022, 12005, 12018, 15004
    - FS2: 994: 15006, 16004, 1n002, 2009, 2017, 28003, 3005, 4017, 5005, 6005
    - FS3: 994: 6007, 6011, 6017, 6019, 6022, 7011, 707, 709,
    - FS4: 994: 807, 809, 811, 9005, 9007, 9009
36. This value represents the total number of sub-settlement areas and the open space areas within these sub-settlements.
37. The "area" label in the table of images bearing informal settlements in the metropolitan area was used as an initial name for each settlement area mapped.

38. The New Rest Upgrading Programme forms part of a larger programme that includes Kanana.
39. Such overlaps are essential if a digital elevation model is to be constructed at a later stage.
40. The mosaic created in MGE was exported as a TIFF file to import into Adobe Photoshop.
41. These advantages may be summarised as follows:
    - it enables the most current data to be accessed
    - it is easy to use
    - it does not require the use of a proprietary language for customisation
    - it enables data to be shared in a secure, read-only environment
    - it provides multi-media support
    - it enables multiple data warehouses to be accessed
    - it supports a bi-directional linkage to the RDBMS
    - it enables basic polygon and linear analyses
    - the viewer software is freely available
42. The ActiveCGM format is an extension of the ISO and ANSI standard CGM data format. It permits the inclusion of both vector and raster data.
43. Using the ActiveCGM format has distinct advantages. "The amount of data sent over the Web is three to four times less than the amount of raster data need for the equivalent resolution.......(This enables).....faster response times and greater productivity. Users can zoom in and out or use a built-in magnifier........ This means fewer data downloads and more efficient use of server resources. At the same time, the user can see much more detail than in the normal raster images." (Intergraph, 1996, p4.).
44. " GeoMedia's data servers provide live connections to native GIS data including MGE, FRAMME, Oracles Spatial Data Option, and ESRI files. These live connections can view and analyse these multiple data sources simultaneously. This is a first for any GIS." (Intergraph, 1997b).
45. The Spatial Data Option enables GIS data to be stored, accessed, managed and manipulated in the same manner as structured data.
46. The Intergraph-Oracle GIS technology alliance provides many benefits to selecting a configuration based on these software products. Through the Spatial Data Option GeoMedia can be used to interact with large GIS databases such as the CMC database. The collaboration between Intergraph and Oracle resulted in the development of an API for retrieving GIS data from a server and allowing applications to interact with each other as well as to exchange data.
47. "The AATL-Brussels Region Administration is using GeoMedia Web Map for making the information available to local governments on an intranet and plans to extend access over the Internet to the citizens of Belgium on a fee-for-access basis." (Intergraph, 1997a)
48. "Public counter query:
    Government and public utilities around the world are required to make information available to the public. Over 80% of government information is spatially related in some way. In order to communicate with government, the public needs access to information that is often land-related. GeoMedia Web Map can cost-effectively make this data available either directly to the growing number of internet-connected citizens at home or using information-access kiosks distributed across a jurisdiction." (Intergraph, 1996)
49. "Land developers:
    Information is rarely static. Commercial organisations and professionals involved with property development and transactions (developers, surveyors, builders, appraisers, lawyers, title insurance companies, banks and so forth) spend a lot of time visiting local government agencies. They go from department to department to get the appropriate piece of information or collecting the appropriate forms. The agency carries the cost of maintaining and distributing the correct, timely information, and of employing a staff or clerical people to respond to the requests....A simple example is land use planning zones. For developers to determine what restrictions exist for a proposed development, they need to access the latest version of the city planning maps. Currently, the developer drives to the local office of the agency and purchases the latest zoning map for the area. Planning zones are not static; the agency will periodically revise them. So, the developer may lodge an application based on old maps, only to have it rejected due to a change in zoning. Now developers can get accurate information, without leaving their offices. They simply access a GeoMedia Web Map Web Site and gain secured entry to the city-provided pages of developer information services. The developers may pay a monthly fee to gain this level of access." (Intergraph,1996)

50. In particular, the public counter query and land developers information service applications are clearly relevant in the context of accelerating information transfer processes involved in informal settlement upgrading projects such as the ISLPs.
51. With respect to crime prevention, the Burough's Crimewatch Team uses MapInfo to consolidate criminal activity information and to map out crime "hot spots". An application for crime tracking has been developed by the Baltimore Police Department for analysing vehicular thefts. The software has enabled trends to be determined far more rapidly than by previous methods based on pushpins and paper maps.
52. In terms of community relations, the Richardson Independent School District in Texas uses mapping to provide residents with information on available schools in their neighbourhood. By entering a user's home address, the user can determine the various elementary, primary and secondary schools options for the address.
53. The Queensland Gold Coast City Council (GCCC) implements SpeedMap (Sullivan-Liscomb, 1997) for strategic planning and management. This MapInfo based software can produce full colour zoning maps, structure plans, including a strategic plan and development control plan.
54. Physical connection: Ethernet, 10BaseT; Supported Protocols: IPX, TCP/IP; Network operating software: Novell, Unix access via future WAN
55. These include: (Khayelitsha, Langa, Guguletu, Nyanga and New Crossroads, Crossroads, Brown's Farm, Bloekombos and Wallacedene, Mfuleni and the rest of the Metropolitan Area.
56. The total population estimate quoted in the City Council (1994) and Van Zyl (1993)(3 million) studies is significantly higher than the estimate quoted in Van Zyl (1995) (2.87 million).
57. This study is based on a sample of 800 households in "predominantly African communities in the metropolitan area. Households in free standing shacks, backyard shacks, hostels and formal houses were included. The information however was available only in percentage form."(City Council, 1997:10)
58. These include: Red Hill (Simonstown), Ocean View (East of Milky Way), Masiphumelele (Noordhoek), Westlake, Mzamoyethu (Hout bay), Marconi Beam, Du Noon, Frankdale, Doornbach, Dunkin Road and West Beach, Wallacedene and Bloekombos, Mbwekweni (Paarl), Kayamandi (Stellenbosch), Khayelitsha and Sikhumbule and Vrygrond.
59. These are as follows: Marconi Beam, Ikapa(Langa, Nyanga, Guguletu, Brown's Farm), Phillipi East, Cross Roads, Khayetlisha, Mfuleni, Imizamo Yethu (Hout Bay), Noordhoek, Wallecedene and Bloekombos, Waterkloof and Lwandle.
60. In these tables the following attribute data appear:
    - the settlement type (backyard, hostels, formal, informal)
    - built-up area (ha)
    - infrastructure type (IU1, IU1+, IPS1, IPS1+, FPS1, FPS1+, FFS1, FFS1+)
    - existing standards (minimum, basic, intermediate/partial)
    - existing service delivery capacity (non-functional, major problems, minor problems, no problems)
    - design density
    - sanitation service level
61. The costs of each service are also considered for different types of upgrading: 1->2, 1->3, 2->3, 1->4, 2->4, 3->4. For each case the unit cost is listed.
    - [1] IU1: Informal unserviced with no more than 1 backyard dwelling
    - IU1+: Informal unserviced with more than 1 backyard dwelling
    - IPS1: Informal partially serviced with no more than 1 backyard dwelling
    - IPS1+ Informal partially serviced with more than 1 backyard dwelling
    - FPS1 Formal partially serviced with no more than 1 backyard dwelling
    - FPS1+ Formal partially serviced with more than 1 backyard dwelling
    - FFS1 Formal fully serviced with no more than 1 backyard dwelling
    - FFS1+ Formal fully serviced with more than 1 backyard dwelling
62. One of the key problems with the data source is that the existing municipalities of 1993 were modified into the seven sub-structures in 1997. Nevertheless, the basic bulk infrastructure can be approximated from this source. Maps are included for the following bulk infrastructure service networks: electricity, storm water, proposed road programme, sewer, sold waste, water dams and water.
63. This information could be presented in the following manner: features such as schools, churches, shops, hospitals, and roads could be shown. This information could be available in detail for each

relocation site. A broad metropolitan outline showing the centroids of the main suburbs would enable the individual to measure the distance between the new home and previous work location. The major industrial areas (eg. Parow Industria, Sand Industria, Maitland etc.) should be visible. The majority of this information can be presented as low-resolution bitmap images. Such files can be very small provided the appropriate scanning resolution is applied. Provided the maps have been scanned and warped into place, the software (GeoMedia / MapInfo) can be used to measure distances from the work place to home. The responsibility of scanning the imagery and of exporting as a small fixed format file that can be imported into non-GeoMedia local-level platforms lies with the high-level GIS platform developers.

64. A second type of infrastructure data set that would be of use is one that holds the train timetable information as attribute data attached to each station point. This type of information would be useful for individuals to plan the best routes and travelling schedules. Both types of information can be captured by collaborative data capturing approaches. The train timetable information can be entered in collaboration with the Cape Metro Rail Services. The road information could be entered in collaboration with Map Studios.
65. One can extend the applicability of the database by combining low-end platform GIS capabilities with the Web-based E-mail and notice board facilities. The site could serve as a source of information on potential employment opportunities. This would be particularly useful to families that have lost jobs due to relocation. Potential employers can place ads on the system indicating the job location, requirements and salary details. Conversely, unemployed people can place information on: contact details, skills, job type sought after etc. In essence, this process would not only serve to improve communication between the potential employers and employees. This data could be used to map the unemployment distribution in detail. In turn this map can be interpreted essentially as the available informal sector work force. Once a human resource map is obtained, it can be analysed in the context of informal sector growth indicators (ie. in the context of the informal settlement money generating activities). It is also probable that the local unemployed population would be willing to place an ad for themselves on the system, if it were to increase the possibility of obtaining a job. Some of the parties that would be interested in this type of information would include the unemployment funding agency and trade unions. Clearly this data would also be of interest to aspiring politicians. By having a knowledge of the areas of greatest unemployment, the politician can plan his campaign in such a way so as to increase the probability of acquiring more votes from these areas. These and other advantages suggest that there is a negotiating potential for approaching political parties for funding this component of the local-level databases.
66. Provided a PMAIL link exists, it would be possible to send in application queries to funding agencies. Other types of information could include the cost, length of time for construction etc. The housing development agencies could have a direct role in capturing this information.
67. Sitting in front of a computer screen to acquire information means that there is less likelihood of having your choices influenced by community leaders, than if one has to attend a workshop to obtain the information.

CHAPTER 9

1. "The need for this study arose from the realisation that necessary planning and population projections are hampered by uncertainty and differing results from diverse studies. It has become essential to conduct a study which will be acceptable to a broad range of authorities / institutions." VanZyl(1995:2).
2. Of this figure, Vrygrond was listed to constitute 535 structures.
3. This count was commissioned by the Provincial Administration: Western Cape (PAUWC) for a population statistics study on the Cape Metropolitan Region.
4. Map 1, Map 2 and Map 3 represent the informal settlements in the Cape Town Metropolitan Region (CTMR), the Cape Town Metropolitan Area (CTMA / Ikapa) and in the Khayelitsha area respectively.
5. See section 9.5 for details on how the settlement densities were calculated.

6. Settlements listed in DeWar et al. (1991) which have been omitted from the 1996 study as they lie beyond the Cape Metropolitan Region boundary used in the 1996 data capturing include: Paar RSC, Mbekweni and Kayamandi.
7. The settlements detected in 1996 survey which were not listed in Van Zyl (1995) are as follows: Airport, Antoniesbos, Blackheath / Happy Valley, Boy's Town, Brickfields, De Bos, Du Noon, Eastern Khayelitsha, Fisantkraal, Gersham / Kalkfontein, Heinz Park / Philippi South, Houtbay Ext 15 / Hangberg, Joe Slovo Park, Klipfontein Glebe, Lavender / Steenberg, Macassar, Mitchell's Plain / Tafelsig, Mpuku Park, Ottery, Palm Tree Settlement, Pelican Park, Raape Kraal / Westlake, Spandau, Trevor Vilakazi, Victoria Mxenge, Victoria Mxenge South, Vrygrond, Vygekraal, Welbeloond / The Stables, Weltevreden and Witsand.
8. A number of settlements in Van Zyl (1995) (see Table 2 : Cape Metropolitan Region: Population: Mid-1995, p8-12) have been omitted from the 1996 survey. These include: Sikhumbule, Atlantis, Mamre, Melkbosstrand, NonUrban, Mbekweni, Masiphumelele, Redhill, Khayamandi / Khaya Mandi. None of these settlements lie within the current CMR boundary.
9. The areas bearing backyard shacks detected in 1996 survey were as follows: .Ocean View / Noordhoek, Lavender Hill / Steenberg, Grassy Park, Hanover Park, Langa, Windemere, Guguletu / Mannenberg, Mitchell's Plain, Nyanga, Bishops Lavis, Eurekaa Adriaanse, Belhar, Blanckenny, Khayelitsha, Mfuleni, Bluedowns, Macassar, Scottsdene and Weltevrede.
10. The absence of the Weltevreden Valley settlement may be due to the fact that the area had been cleared for the iSLPs and therefore was not detected by Van Zyl (1995).
11. The area north of Khayelitsha and east of Silvertown including Gersham and Blackheath may correspond to DeWar's Belville Belhar Extension.
12. These settlements appear in a CMC report table entitled: "Table: Formal housing settlements in Metropolitan Cape Town (after Dewar et al., 1991)".
13. It is not clear whether the settlement Driftsands can be recognized as Mfuleni.
14. The informal settlements listed on the original Dewar et al.(1991) map are: 1. Red Hill and surrounds, 2. Fishoek, 3. Vrygrond, 4. Bush Estates, 5. Weltevreden Valley, 6. Guguletu, 7. KTC, 8. Nyanga, 9. Crossroads & extension, 10. Brown's Farm, 11. Khayelitsha Site C, 12. Khayelitsha Site B, 13. Khayelitsha Green Point, 14. Khayelitsha Sivertown, 15. Khayelitsha Remaining area, 16. Driftsands, 17. Kuils River, Antonies Bos, 18. Macassar Zandvlei / Madala's Camp, 19. Eerste River school site, 20. Melton Rose Spandau, 21 Belville Belhar Extension, 22. Brackenfell, 23. Stillehoop, 24. Kayamandi, 25. Somerset West Waterkloof, 26. Die Bos, 27. Sir Lowry's Pass Sun City, 28. Kommetjie, 29. Noordhoek, 30. Hout Bay, 31 Marconi Beam, 32. Vissershok, 33. Joostenberg, 34. Kraaifontein, 35. Paarl, RSC, 36. Paarl RSC, 37. Mbekweni.
15. These settlements were common to the 1996 data and the City council (1994) data but absent from Van Zyl (1995).
16. It should be noted that in the 1996 survey only backyard shacks were observable in the Hanover Park and Maitland areas.
17. Townships and informal settlements discussed in Macroplan (1995)are as follows: 1. Red Hill, 2. Ocean View, 3. Masiphumelele, 4.Westlake, 5.Mizamoyethu, 6.Marconi Beam, Du Noon, Doornbach, West Beach and Bloubergvlei, 7. Wallacedene, Prison Site and Bloekombos, 8. Mbekweni, 9.Kayamandi, 10.Sun City, 11.Die Bos, 12. Lwandle, 13. Mfuleni, 14. Kalkfontein, 15. Khayelitsha, Sikumbule, 16. Vrygrond, 17.SLP - Langa, Guguletu, Nyanga, Crossroads, Brown's Farm and Philippi East.
18. This settlement is referred to in conjunction with WallaceDean and Bloekombos in the MacroPlan (1995) report.
19. This settlement is referred to in conjunction with the Kalkfontein settlement in the MacroPlan (1995) report.
20. The number of backyard shacks is listed in brackets.
21. This nomenclature problem probably arose due to the fact that the informal settlements are not recognized as formal townships and as such have not been issued with formal township names. Often settlements have been allocated names purely on the basis of location (eg. an area between hostel and bus terminus). This is also evident from an inspection of settlements in Gauteng.
22. This settlement lies to the north of the Nyanga -Guguletu area and adjacent to DF Malan Airport. It has thus been referred to as the "Airport" settlement in this study.
23. The development of these maps have been discussed in section 8.4.

24. In other words, each shack consists of four or more distinct line segments instead of being represented by a single graphical element such as a polygon.
25. The number in brackets indicates the difference between the Van Zyl (1995) and 1996 data sets.
26. The World Bank Reconnaissance Mission (1994) documentation subdivides Khayelitsha in yet another different manner. A number of formal and informal settlements are recognized. The formal settlements are as follows: K-Town 2+3, Ks-Block C, Ks-Village 4C, Ks Village 1+2, Ks Block B and Ks Tembani. Only the following areas are listed as informal settlements: Block C buffer area (3575[1]), Silvertown (1369), Bermuda (1043) and Greenpoint (1562).
27. VanZyl's map was warped onto the system using detailed aerial imagery from the NDH.
28. Mfuleni lies to the north and appears on map1 in appendix 8.
29. The total number of backyard shacks in these areas listed by Van Zyl (1995) is 40445 backyard shacks.
30. The comparison between the 1996 data and Van Zyl (1995) indicates an increase of 153 new shacks (see appendix 6 table 3).
31. Another new settlement in the Guguletu / Nyanga area detected by Abbott & Douglas (1998) using the 1996 imagery was The Palm Tree Settlement.
32. For comparison the average density calculated by dividing the total count for a settlement by its area is also listed ("density1").
33. Previous estimates of densities are listed in the City Council (1994) socio-economic report. These density values are based on data collected by VanZyl in 1993. The 1994 study lists only the densities of the suburbs containing informal settlements. As expected these densities are significantly lower than the 1996 data (as they contain open areas and formal settlement areas). For Brown's Farm, Khayelitsha, Lavender and Nyanga / Crossroads, the following densities were listed in the 1994 study: 30.1,12.51, 24.7 and 49.8 du/ha. The densities calculated for Brown's Farm, Khayelitsha, Lavender and Nyanga / Crossroads, using the 1996 survey data, were as follows: 74, 166 - 33, 100 and 299 - 95 du/ha.
34. The newly detected settlements have been excluded from these calculations as they would result in infinitely high growth rates.
35. Some small settlements tend to have very high growth rates. Examples of such settlements are Gxa-Gxa and Red Hill. While these settlements may be characterised by high growth rates, the overall impact of these settlements on the total informal settlement population size is very small.
36. The Boys Town and Klipfontein Glebe areas are not listed as individual informal settlements in Van Zyl (1995). Furthermore, the boundary defining Crossroads in Van Zyl (1995) encloses the Old Crossroads, Boys Town, and Klipfontein Glebe areas.
37. Again the comparison for this region is hampered by the lack of clarity on what areas are comprised of backyard shacks and what areas are comprised of freestanding shacks in Van Zyl (1995).
38. Van Zyl (1995, p3-p4) comments that: "controversy existed for a long time on the numbers of people living in the traditional African townships...In many instances the sizes and compositions of informal settlements change drastically over short periods of time....internal migration will have an effect if such migration resulted in significant numbers of African people having moved from the traditionally African areas into other areas. Unfortunately no hard information is available on this aspect and the effect of internal migration on population numbers could therefore not be quantified. The general impression gained from officials in various local authorities is that the extent of such intra-migration is fairly limited...This is nevertheless a potential weakness in the study and more research is required into this aspect." Further details on a number of limitations also facing the growth rate values which were used for the population estimates are discussed by Van Zyl(1995).
39. ".....It is very likely that the average household size in Sikhumbule will now be lower than what is shown since a proportion of households has been split into more than one household upon resettlement.". Van Zyl(1995, footnote 4, p13)
40. The original source of these estimates can be traced to a study done for the Western Cape Community-based Housing Trust (WCCHT) entitled "Household Dynamics and Mobility of Africans in Cape Town: Appropriate Housing Responses" (July 1995). These estimates were based on a survey of 800 African households in the CMR. For the Khayelitsha area the results of other comprehensive surveys were used by Van Zyl (1995). No household estimates were listed in Van Zyl (1995) for the following areas: Atlantis, Lwandle and Nomzamo.
41. An average household value of 4.5 ±1.1 was calculated for 50 of Van Zyl's informal settlement areas.

42. Other indices can be calculated to reflect 1) the degree of integration of the settlement into the infrastructure fabric of the city and 2) the existing level of services. The net growth rate of the different settlements may also be used as a prioritization index.

CHAPTER 10

1. For this chapter the results of a separate WRC funded project on the Lotus River catchment have been utilized.The work referred to here derives from a chapter on GIS applications written by Martinez in a WRC report entitled: "Integrated Catchment Management in an Urban Context: the Great and Little Lotus Rivers, Cape Town".
2. Görgens (1998) defines ICM as follows:
   " ICM in its widest sense is simultaneously a philosophy, a process and an implementation strategy to achieve a sustainable balance between utilisation and protection of all environmental resources in a catchment, and, through consensual management techniques, to develop a sustainable society."
3. The DWAF (1996) report entitled: " The philosophy and practice of integrated catchment management: implications for water resource management in South Africa" is another prime example of this philosophical focus to ICM research.
4. Amongst other issues, these definitions indicate that the ICM process should: 1) facilitate planning at the local-, catchment- and regional-levels , 2) accommodate the needs of all communities, 3)facilitate the definition of roles and responsibilities, and 4) ensure an equitable distribution of costs and benefits amongst all stake holders.
5. The key advantages of a GIS-based approach to integrated catchment management may be summarised as follows:
   - More accurate parameter estimations
   - More rapid parameter estimations
   - Facilitates potential for utilising existing public databases
   - Facilitates potential for grid-based distributed hydrologic modelling
   - Facilitates an integrated analysis of the various data sets through the spatial overlay capability
   - Facilitates a more realistic representation of data
   - Raster backdrops to vector data
   - Thematic representation of data
   - Facilitates effective communication medium
   - Facilitates wide spread diffusion of information
   - Facilitates spatial analysis for planning
   - Simplified spatial analysis tools
   - Complex spatial analysis tools
6. In addition to providing a platform for modeling, GIS has also played an important role in urban catchment management through remote sensing applications. Several authors have discussed the use of airborne and satellite remote sensing techniques in catchment management (Elgy et al., 1998; Frankhauser, 1998; Reid & Roberts, 1989; Bayer & Hilz, 1997; Blagojevic et al., 1994; Deguci & Sugio, 1994; Leiss, 1992; Frankhauser et al., 1993, 1994, 1998; Halounova, 1994). These studies have dealt with issues such as airborne videography and the automatic identification of impervious areas from both airborne and satellite imagery. In addition to providing information on the impervious areas for hydrologic work, satellite imagery has been used to provide data for ecological applications. A series of vegetation indices may be determined using slope-based and distance based models (Thiam & Eastman, 1997; Fortescue, 1997; Kumi, 1997).
7. DeVantier et al.(1993) summarize general indices which are frequently displayed mapped on terrain maps. These indices deal with imperviousness, natural land cover, watershed delineation and stream networks.
8. Adinarayana et al.(1994) discuss the use of muli-temporal satellite imagery, from different agricultural seasons, to produce land-cover maps for the catchment, using knowledge-based re-classification. The drainage network, elevation and other topographic and thematic data were digitized from maps. In addition various additional land use classes were developed. These included: wastelands and appropriate preventative measures.

9. An example of a watershed surface representation model is provided by Schaller (1993). In this case, a triangular irregular network (TIN) cascading calculation is conducted to combine obtain flow direction vectors with calculated soil losses and matter transportation related to the surface water flows.
10. The application of raster-based digital elevation models (DEMs) for stormwater runoff modeling has been dealt with by Smith and Brilly (1992), Moore et al. (1991), VanBlargan et al. (1990), Zech et al. (1994) and others. The digital terrain model (DTM) developed by Zech et al. (1994) incorporated both the undeveloped and urbanized areas of the catchment. This has required some modification of the conventional DTM employed. The discussion by Meyer et al.(1993) highlights the suitability of raster systems for urban watershed analysis, particularly for the calculation of slope values. Further details on the application of cell-based techniques for surface runoff modeling are discussed by Vieux (1993), Smith et al. (1992) and McKinney et al. (1996).
11. A comparison between a distributed model using GIS and other models sensitivity analysis is discussed in Zech et al.(1994). The digital terrain model (DTM) developed for this work incorporated both the undeveloped and urbanized areas of the catchment. For each cell of the DTM grid, a water budget is calculated. The model was compared with the SWMM and WALLRUS models, and proved to be the most accurate.
12. Many rainfall / runoff simulation models (eg. HEC-1, TR-20, SWMM and PSRM) employ the SCS runoff curve number (CN) method to determine initial rainfall losses (infiltration, depression storage and interception) and runoff. The manner in which a GIS catchment model may be implemented to arrive at estimates for the CN value is discussed by DeBarry & Carrington (1990) and Campana et al. (1995). Drainage utility applications have been discussed by DeVantier et al. (1993), who argue that the database for such applications need not be as extensive as for other applications as no runoff modeling is performed. One application has utilized GIS as means for fee assessment, based on the percent of impervious area of the property (Allen, 1991; Williams & Rosengren;1991).
13. The options which exist for the development of a decision support system (DSS) for urban stormwater management are outlined by Meyer et al. (1993) as follows: 1) integrated system development, 2) internal GIS modeling and 3) Model/GIS data file linkage. Integration via the first option requires the programming intensive production of customized programme interfaces. This approach has been followed by Shea et al. (1993) and Ross et al.(1993). The second option of internal GIS modeling is complicated by the fact that most GIS systems do not support the required analytical functionality. Programming languages within the GIS environment typically constitute tools for developing graphical user interfaces and other interactive control interfaces, rather than for processing the numerically intensive iterative processes associated with runoff simulations. The third option is the easiest and most cost effective method for data file transfers and is typically for integrating GIS. Meyer et al. (1993) outlines in detail the steps involved in linking the GIS and runoff modeling through this option.
14. A combination of systems was employed by Shea et al.(1993). This incorporated: a computer aided design package (CAD), a database management system, and a raster based software package. The HEC-1/HEC-2 models were linked to those packages through customized programming.
15. Ross et al. (1993) have developed a system which integrates GIS, public-domain surface-water and ground-water hydrological models and a specially written evapotransporation code.
16. It should be noted that the Venice catchment (1880 km2) is much larger than the Lotus River catchment (80 km2). Nevertheless, this work provides: a first indication of what data should be incorporated into the Lotus River GIS (Bendoricchio et al., 1993: Table 2, p73), a template for potential GIS outputs with respect to pollutant modeling applications and the theoretical background for conducting a similar application for the Lotus River catchment.
17. The key findings of this work indicated that the global contribution of diffuse pollution is about one third of the total loads generated. Urban diffuse loads constitute an average of 6 % of the total nitrogen and total phosphorus loads generated. Bendoricchio et al (1993) estimates that a drastic reduction in the nitrogen (70 %) levels is required to restore the lagoon to trophic equilibrium. In view of the intensive urbanization and high land prices, which prevents remedial solutions involving buffer areas and detention ponds, Bendoricchio concentrates on identifying options for reducing agricultural diffuse loads.
18. The hierarchical systems method employed by Grossman (1983) distinguishes two principal "functional domains" of ecological systems: the process domain (reality level) and the regulation and control domain (or strategic and dynamic levels).

19. It consists essentially of six information modules. These are: Public opinion and awareness module (POAM), Information system (INSYST), Educational modules (EDMOD), Stormwater best management practices collection (STORMBMP), Modelling expert system (MEXSY) and Evaluation and decision making module (EVADM).
20. Development of the evaluation and decision making module (EVADEM) is still in its primary stages. Ostrowski & James (1998: 573) argue that it is not the information technology which presents a problem, but rather "the missing interest in the direct linkage of private and public affairs and the inability of real interdisciplinary co-operation."
21. Zech & Escarmelle (1998) have shown that while the best ground resolution of satellite imaging systems lies at 10 m (SPOT in the panchromatic band), a resolution of 5 m is needed for the development of urban hydraulics models. Essentially the resolution of today's readily available satellite imagery is not sufficient to meet all of these demands.
22. One manner in which to obtain a higher resolution satellite image is to evaluate a hybrid 10 m SPOT image fused with 25 m LANDSAT image which results in a 10 m resolution multispectral image. This innovative technique is currently employed in the Department of Land Surveying at UCT (Ouma, 1998), and was used in the Lotus River project in order to obtain a higher resolution image than would otherwise be possible.
23. For example if a line is a common limit of two distinct areas, this limit will appear in only one of the concerned feature types. Missing contours on one level may be present as footpath limits on another layer. A second problem is that hydrologic models generally define area data (rasterisation) which is not a difficulty if the original data is a polygon. If this is not the case, the conversion from separate vectors to closed polygons is a very time consuming task, as it is a manual digitisation process. Not with standing these two issues, a land use map produced by rasterising an existing cartographic vector data file may suffer from other problems. For example roads may be no longer continuous as a result of the automatic conversion, due to the fact that some paths are too small for the set grid size which is typically greater than 5 m. A more critical failing is the absence of underground data, which means that the sewer network must be separately captured.
24. Ostrowski & James (1998) stress that the education component (EDMOD) must contain modules for all stages within the pre-school, school and university systems as well as adult education as environmental education is a life-long process.
25. For the Public opinion and awareness module (POAM) the use of a list server is recommended. Interested individuals are supposed to be able to subscribe to the module, screen opinions and form sub-groups. Ostrowski & James (1998: 572) continue " Necessarily those professionally involved in the urban water system considered must subscribe to POAM to be continuously informed about ongoing discussion. They should not be able to argue that they do not know public opinions."
26. This methodology is described and illustrated in great detail in Grobicki et al. (in press).
27. This data suffered from the lack of polygon elements for several area-based features. In particular, the formal and informal houses and other buildings were represented as linear elements. This required manual linestring (or polyline) to polygon conversions for area measurements. Similarly the road data required pre-processing before road areas could be measured.
28. In order to facilitate the development of multiple databases at the catchment-level and sub-catchment-level, the selected software should be low in cost. For this reason the primary software for GIS-based ICM framework proposed in this work should be a front-end viewer GIS package with advanced Internet capabilities.
29. This land use mapping process involves the use of high resolution digital ortho-photography (0.5 m pixel resolution), which enables landuse classes useful for development of GIS based vegetation management and rehabilitation strategies to be mapped. The user can thus use the imagery to map features at a resolution of 0.5 m or less - depending on the application and time constraints. In contrast, the highest resolution obtainable using processed LANDSAT imagery lies at 10 m (Ouma, 1998; Zech & Escarmelle, 1998).
30. The land use analysis methodology described here was carried out on one of the sub-catchments in the Nyanga - Guguletlu area. The sub-catchment which was selected (110) occurs in the Ikapa area to the south of Barcelona and to the west of Mahobe Drive and Boy's Town.
31. The area and length parameters have been determined in the Intergraph MGE project environment using Microstation tools. The average slope for each sub-catchment has been determined by referring to ortho-photo imagery (1:30000) produced by A.O.C. SYSTEMS (Pty).

32. Initially it was intended to utilize GIS to apply the SCS runoff curve number (CN) method to determine initial rainfall losses (infiltration, depression storage and interception) and runoff.estimate. However, the SWMM modelling technique employed in the Lotus River Project did not require the input of composite SCS runoff curve numbers.
33. These regions are:
    - a western formal-industrial-vegetated region
    - a central cultivated land-agricultural buildings-vegetated region
    - a north eastern formal-informal-open region
    - an eastern informal-open region, and
    - a northern industrial-open region
34. The values calculated in this study for the percentage area of each sub-catchment which is impervious represents a summation of the hydrologically effective and ineffective impervious areas. These values are a more appropriately defined as a measure of the amount of urbanisation or the percentage of hardened surfaces comprising each of the sub-catchments.
35. Simplified land use approaches generally assume 1) that subcatchments can be treated in a homogenous manner and 2) that a standard permeability can be allocated to sub-catchments within a specific category).
36. The formal component of a previously "residential" sub-catchment grouping varies from 0 (167b) to 89 % (180a). Similarly the nature of the hydrologically pervious component within the same category varies from 73 % shrubs (195b) to 77 % cultivated (167c). Parking lot areas vary significantly reaching up to 20 % in some subcatchments (167a). Similarly, subcatchments with the so called "agricultural" subcatchment category, are composed of variable combinations of cultivated, grass and shrub bearing areas. The percentage cultivated landuse varies from 24 % (150a) to 82 % (160). The percentage of shrub bearing areas varies from 4 % (160) to 40 % (150). In addition , parking lots can reach up to 12 % of the sub-catchment (145).
37. Values for the following land use combinations are listed: sportsfields / agricultural (0%); agricultural / residential (10 %); residential / light industrial / Spoornet (37 %); residential & grassed / industrial, institutional & residential (48 %) and industrial / residential (60 %).
38. This can be seen from the variation in the percentage hardened surfaces comprising a number of subcatchments which were all previously allocated a 60 % impervious value: 101 (32.2%), 115 (90.4%), 120 (75.4%), 126 (57.2 - 4.8%), 127 (51.8 %), 130 (82.8 - 65.7%) and 131 (57.5 - 68.8 %). Thus previous studies are lacking in that no consideration of the variation in the percentage hardened surfaces are taken into account.
39. Examples of where significant intra-subcatchment landuse variations have been ignored are as follows (predominant landuse listed in brackets): 130a (informal) versus 130b (formal); 126a (informal, parking lot, industrial) versus 126b (grass and shrubs); 195a (formal, industrial) versus 195b (open vegetated), 169a,b (formal, open, industrial) versus 169c (open grass and shrubs); 167a,b (industrial, parking lot) versus 167c (cultivated); and 134a (grass and shrubs) versus 134b (open not vegetated).(The land uses which have been incorporated into the hardened landuse category include: industrial, parking lot, formal, informal, school, site and service.)
40. For example, if one uses the current sub-catchment boundary definitions for the Lotus River catchment, the sub-catchments falling within some of the municipal areas are as follows: Lotus River (180a,b; 185a,b), Montague Park (170a,b), Nyanga (110,115), Philippi East (126,125), Brown's Farm (131, 130) and Philippi (190, 175, 135, 169, 167, 160, 145, 160). Clearly a great deal of information would be lost if one were to decide upon a municipal area BSU in this case.
41. Firstly the data sets are large and cumbersome to manage on a catchment wide-level. For example the parcel boundary data layer alone is 50 MB for the Lotus River catchment. This represents only one of the cadastral data layers. There are approximately 50 layers in total. The majority of these layers are much smaller in file size, however there are at least another four or five very large data layers such as: roads, formal houses and informal houses. Secondly, there are large gaps in the cadastral data. These usually correspond to the informal settlement areas. Thirdly, the large file sizes and the graphics processing (eg line to polygon feature conversion process) required before the data can be used to estimate hydrological parameters for each sub-catchment, make the use of this data for catchment wide hydrologic analysis applications extremely time consuming and ineffective.

CHAPTER 11

1. The current approach of capturing all the available cadastral information at the highest degree of accuracy possible (ie. ± 0.5 m) before developing applications is identical to the approaches which have been followed in a large number of developed countries. This can only be applied to the formal areas of the city for which cadastral information exists. The general inadequacy of the cadastral approach can be seen from the large number of problems facing the present system. The approach has been found to place a total hold on applications-based GIS developments. This in turn has resulted in a widespread lack of base data and the development of parallel GIS systems.
2. The present organisational structure for GIS in the Council is such that the system functions essentially as a single department system. In practice, the Survey and Land Information Directorate is the most powerful user. This is because it "owns" the cadastral and topographical layers, which form the base layers for all other users. The Project Board is responsible for co-ordination, but this body does not function effectively. The result of this effectively single department system, driven by the surveying department, has been the dominating focus on the development of the cadastral database. The multitude of problems associated with approach have already been discussed.
3. At present one user effectively controls the entire system. If the City is to move to an applications driven approach, then a distinction need to be drawn between the management of the GIS system and the users. The management of the GIS hardware needs to be separated from the cadastral base, and the setting up, and ongoing maintenance, of the cadastre, should be moved to a user group.
4. "But it's also possible that we're trying to introduce the technology into some situations where it doesn't - at least not yet - belong. Given that possibility, we need to be careful that we are not overwhelmed by approaches that have little to offer except the latest technology" (Dangermond, 1988: 18).
5. "In Europe and North America, GIS use is expanding at a time where there is a growing need to manage information and in some senses it is a 'post-industrial' technology. It cannot be simply transferred to the developing world and expected to perform functions for which it was not principally designed." (Taylor, 1991: 80)
6. These include: mutual currency of data, compatibility of level of accuracy, the provision of forward planning information for areas reserved for specific land uses and security (Bell et al., 1993). An additional problem was that each parcel of land had four systems of reference - this problem required a great of data processing to rectify.
7. " ...A crucial issue that should be taken into account is that one of the major challenges confronting most counties is the issue of laws and regulations introduced by a colonial administration to serve the interests of the colonial power. Such laws were not designed to serve the needs of the whole country or population. As a result, separate cadastres have often developed, operating as informal systems in parallel to the cadastral system based on the colonial legislation. Due to the complex nature of the cadastre and property rights, these laws and regulations remain entrenched in may countries still to this day." (Fourie 1998, p. 4)
8. In general, even amongst the developed European countries, the number of planning applications is relatively small compared to surveying-based applications. Masser et al (1996) indicate that in most cases, the GIS is used for automated cartography or digital mapping, and that in Greece, Poland and Germany, GIS is applied mainly for surveying and topographic / cadastral database management. It is only in Great Britain, Italy and Portugal that GIS is used significantly for planning applications.
9. Fourie (1998, p7) states: " 4.5 Varying accuracies: Approaches should be put in place which make it possible to use information of varying accuracies within the same LIM system. Varying accuracies should be accepted because:-....."
10. Fourie (1998, p 10) states: "Local record systems: For land registration and/or recordal work in Africa the system itself should become more accessible, both in terms of location, cost and user friendliness. The land office should be at the local level and be user-friendly to poor, often uneducated people."
11. Although not discussed in this thesis , multi-scale approaches are also common in North America. The ICMA defined three distinct levels: wide area planning (small data bases); locality analysis (more data and greater detail); and finally facilities management, tax mapping and engineering design.
12. Taylor (1991: 79) comments: "The importance of comprehensive information for local level planning has been appreciated and the plan is to have a micro-based GIS in every county to aid in decision making." However, Taylor cites only two areas where such systems exist.

13. A comment by (Chen, 1987) reflects an understanding for the need for a multi-scale approach, however, he neglects to realise the importance of including the local-level systems in this process: "A dual system combining both national and regional components in a multi-level structure."
14. The accuracy here may be greater if a high resolution digital elevation model is used to ortho-rectify the imagery instead.
15. With respect to the main informal settlement areas, the average growth rates calculated for settlements that have experienced a positive growth and that exceed 120 shacks in size are as follows (in declining order): Lower Crossroads (69.5 %), Crossroads (34.4 %), Guguletu (33.3 %), Khayelitsha (31.2 %), Nyanga (17 %) and Brown's Farm (13.7 %).
16. In the case of Ottery one shack had previously been detected by the CCC in 1994 and its location was unmapped. The number of shacks detected for 1996 by the mapping work for this study revealed a total of shacks. This very rapid increase in settlement size clearly reveals the importance of mapping even the smallest of newly formed settlements detected on aerial photography.
17. This is particularly true of the shack counting data presented for one of the most densely populated informal settlement bearing areas in the CMR: Khayelitsha. The most recent and significant previous study fails to make no distinction between freestanding and backyard shack area counts in either table or map format (Van Zyl, 1995). These findings suggest the need to impress upon local government bodies financing such projects, that they should request that the counting process involve a differentiation of the two housing typologies. Adding this level of complexity would not significantly alter the time required for the data capture process, but would result in a data set which would prove invaluable to future settlement dynamics studies.
18. Previous density calculations have lumped areas of all shack types, and have included open spaces and areas of other land uses in the calculation procedure. In this study, the freestanding shack areas have been subdivided into sub-areas and dwelling unit densities have been calculated subsequent to the subtraction of the open / vacant land use regions residing within these sub-areas . The average settlement densities which have been calculated take into account the variation in the number of shacks in each of the settlement sub-areas.
19. In declining order of net growth, the settlements which have experienced an increase along the northern fringes of Guguletu include: Kanana, Barcelona, Phola Park and New Rest. The areas which have undergone relocation upgrading lie closer to the centre of Guguletu and include: Gxa-Gxa, Kiki and Tambo Square. In the case of Gxa-Gxa and Kiki, the settlement has changed from a freestanding shack area to a backyard shack bearing area.
20. In Nyanga, the area of Kalanyoni and the freestanding shack area known as "between the hostels" (Van Zyl, 1996) have disappeared and the number of freestanding shacks in the Mahobe Drive area has declined by 30 %. The dominant presence of backyard shacks in these areas again suggests that the freestanding shacks appear to have been replaced by backyard shack bearing areas.
21. A detailed analysis of Khayelitsha was also made with respect to the settlement boundaries mapped in this work and those of Van Zyl (1995). These boundary overlays again suggested increases in the marginal areas of Khayelitsha. The percentage net growth calculations indicated that the highest growth rates were found to occur in the fringes of the Khayelitsha area: Silvertown (235 %), Greenpoint (6.4 %) and Bongweni-Ikwezi Park (63 %).
22. Two types of audiences are envisaged. The first represents audiences who have access to a well developed information infrastructure. This group contains national, provincial, metropolitan and to a lesser extent local government audiences. These user groups can have access to the system via the Internet. The second group holds potential user groups within the local-level without access to Internet facilities. This group consists of certain local authorities, consultancies, NGO's and communities.
23. Currently the Provincial Administration annually allocates money in bulk for the two main types of capital expenditure associated with the upgrading process. The first capital expenditure is set aside to cover the cost associated with the project administration process. The second capital allocation is directed towards construction costs. The responsibility of project administration shared by a number of parties. The information associated with this process lies in the hands of individual project managers, who tend to monopolize access to such data for their own convenience. This has turned the project administration process into a very costly and ineffective process. Further more, the administrative procedure must be completed before projects can be approved and included in Provincial Administration's budget.

24. There are two key requirements for extending the current Bi-level model database into an urban management tool designed to address these problems. Firstly each of the statuses for each of the six stages of the administration process must be clearly defined. Secondly, the data that defines the status of each of the stages for each informal settlement area must be entered into the metropolitan-level database. This data is should be entered as attribute data attached to the centroid of each settlement of sub-settlement.
25. There are essentially six stages associated with the upgrading project administration process. These are:
    - Detection of the informal settlement
    - Preliminary planning and design
    - Feasibility study
    - Detailed planning and design
    - Tender
    - Construction
26. The Provincial administration is primarily involved with <u>capital and legislative approval</u>. This user group is primarily interested in issues such as whether a settlement has been detected, whether it is in their GIS system, and if so how far down the line is it in terms of administration, and whether it is in their funding program.
27. The Metropolitan Administration on the other hand is primarily interested in <u>planning for capital expenditures</u> associated with the provision of bulk infrastructure. This group needs data to plan for annual budgets.
28. The Local Government user group is primarily concerned <u>with capital and operational data on the project administration process</u>. The capital cost associated with this process has been estimated at R 3 - 5 million per development project.
29. The Community user group requires data to issue mandates, make proposals, and to monitor the progress of upgrading projects in their settlement.
30. Some examples of the possible funding streams for one project are outlined below:
    - Provincial allocations / Grants > Housing subsidy> Project Funding
    - Progress> RSC levy / CMC / bulk infrastructure capital> Project Funding
    - Provincial Allocations > Local Government Rates, capital & operating subsidies > Project Funding
    - Service charge > surpluses / cross-subsidy / operational > Project Funding
31. The metropolitan-level system may be extended to include data on what funding streams are being accessed by each informal settlement, and how much is being invested through each stream for each settlement. These data would ensure a better management of the capital investments and / or grants associated with such funding streams.
32. In addition to these applications, there is a section in Grobicki et al. (in press) that deals specifically with an evaluation of various potential approaches, as identified in a detailed review on GIS-based approaches to ICM.
33. The conversion of the hydrological parameter thematic mapping process into an effective catchment modeling tool requires research in two areas. The first is to establish the extent to which the required digitization procedures can be automated within in Microstation. The possibility of constructing customized dialogue boxes which prompt the user simply for the location of hydrological data files to be plotted needs to be investigated. Associated with this dialogue box would be a series of macros designed to take the information in the hydrological data file and create a polygon based thematic map along the canal as has been done manually for this study. Currently the thematic maps require the use of Excel based interpolation programs and the digitising of flow volume proportional polygons in Microstation for each sampling date. The extent to which this process can be automated will depend on the customization potential of Microstation.
34. The procedures outlined in this section are distilled from the "Multivariate analysis with GRID" on-line ARC/INFO manual ARCDOC file (17-47).
35. The analysis procedure could be made more complex by extending and utilizing the attribute database of the metropolitan-level of the Bi-level model. However, much thought would be required in order to identify the most useful socio-economic, physical and environmental parameters to include in the analysis.
36. The degree of ordering varies from linear to highly unordered arrangements.

37. This include transport ways (ie. roads, footpaths etc.) and transport related structures (railway platforms, bridges, Nyanga bus terminus).
38. Other reference features include both abstract boundaries (such as erf and block boundaries) as well as real structural features in the landscape (such as buildings, houses, flats, hostels, construction sites, schools, out buildings and canopies).
39. Since the slope and aspect values are derived from the elevation data, most of the variance resulting from these three variables can be explained by elevation.
40. In order to conduct a supervised classification, each of the shacks in the data set would be allocated to one of the four classes identified in chapter 9. The actual locations identifying the known class locations are called the training samples. A signature file, which stores the multivariate statistics for each class or cluster would subsequently be calculated. The mean value, the number of cells, and the variance-covariance matrix could then be determined for each class or cluster.
41. An unsupervised clustering procedure could be used to identify naturally occurring clusters within the data. In an iterative self-organizing (isodata) clustering method, the mean values for the clusters are derived from the attribute values for the input grids.
42. The classification analysis proposed here differs significantly from that proposed under spatial-temporal analysis. In the latter, vector data on the digital cadastre would be used. Furthermore that application involves finding out the characteristics of settlement clusters that have already been identified. In the classification analysis proposed here, the emphasis lies in utilizing the imagery to automatically identify individual shacks and other features. In other words it would involve developing a technique to automatically produce a digital cadastre of sufficient accuracy for informal settlement or ICM-based applications.
43. Several examples exist where the use of SPOT satellite imagery has been employed for mapping in a developing country (Latin America, Argentina, Nicaragua and Africa) (Axes, 1997).
44. Ferreira (1997) suggests utilising the area coverage in conjunction with housing and population density attribute data to estimate housing and population increases Two problems may be associated with this. Firstly, such data often does not exist or is unreliable. Secondly, such estimates would be subject to the same to the same limitations facing the housing demand quantification procedures as referred to in chapter 1.

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APPENDIX 1

APPENDIX 1 TABLE 1 Key contextual factors in nine European countries. (Source: Table 13.1 in: Masser & Craglia, 1996)

	Great Britain	Germany	Italy	Portugal	Denmark
Institutional context	Increasing pressures towards privatization of local government tasks has effected GIS diffusion. Uncertain impacts of ongoing review of local government in terms of the number and functions of authorities	Stable and well established local government culture. Incorporation of former East German *Länder* presents new opportunities	The 1990 reform of local government which extends powers and degree of autonomy of lower tiers has both constrained and created opportunities for GIS diffusion. Uncertain impacts of recent political upheavals on local government. Limited use of IT in local government	Proactive Government measures to modernize local government. Establishment of a National Centre for Geographic Information to coordinate the implementation of a national geographic information system. Availability of EC funding to support modernization	Widespread decentralization of powers to local government since 1970. Extensive use of IT in local government since the 1970s
Structure of local government	Two tiers: 47 shire counties and 9 Scottish regions with 333 shire districts and 53 Scottish districts. Single tier of 69 metropolitan districts. Few districts have populations less than 100 000	Three tiers: 16 *Länder*, 543 counties and large cities and 14 809 municipalities. Most of municipalities have less than 10 000 population	Three tiers: 20 regions, 103 provinces and 8100 communes; 87% of communes have less than 10 000 population; 12 new Metropolitan Authorities	Three tiers: 7 regions (including the Azores and Madeira), 29 districts and 305 municipalities. Average size of municipality 34 000	Two tiers: 14 counties and 275 municipalities. Half the municipalities have less than 10 000 population
Digital data availability	Comprehensive digital topographic data service provided by Ordnance Survey. Service Level Agreement reached with local authorities in March 1993 boosted GIS diffusion	Strong surveying traditions and collaboration between local authorities with respect to the development and maintenance of digital topographic databases (e.g. ALK and MERKIS)	Slow progress made by National Mapping Agency and Cadastre. Nearly half the regions developing their own digital topographic data bases. Profusion of data sources	Diversity of sources; 65% of country covered by 10 000 scale orthophoto maps from the National Mapping Agency. Some digital data at 25 000 scale in vector format from the Army Cartographic Services	Municipalities are the main provider of large scale maps. They also co-manage the Cadastre with the Danish Survey and Cadastre and maintain a wide range of other register based information systems

APPENDIX 1 TABLE 1 (continued)

	Greece	France	Poland	Netherlands
Institutional context	Limited financial and manpower resources at the disposal of local government leading to contracting out of IT functions to the private sector and University laboratories. Role of EC funds in facilitating the diffusion of GIS	Long tradition of geographic information handling in large cities. Decentralization measures since 1980 have given new powers to departments and to new administrative structures for main urban areas	Very rapid change from centrally planned to market economy. Earlier attempts to decentralize power to local administration have recently been reversed leaving some uncertainty over the responsibilities of different layers of government	Strong and stable central government with local authorities retaining a high degree of autonomy. Middle layer of provinces struggling to define its role
Structure of local government	Two tiers: 51 prefectures form upper tier, 361 cities and 5600 parishes form lower tier. Average population of parish is 1800	Three tiers: 22 regions, 96 departments and 36 000 communes. Average population per commune is 1500. Variety of intercommunal structures especially in large urban agglomerations	Three tiers: 49 regions, 327 sub-regions, and 2465 local authorities having an average pop. size of some 15 500.	Two tiers: 12 provinces and local government divided between 650 municipalities and 100 polder boards in charge of water control; 50% municipalities have less than 12 000 people and 90% less than 40 000
Digital data availability	Lack of digital data; 5000 scale digital contour data available only for some cities in the Athens and Thessaloniki areas. Proliferation of data produced by private sector data bases	Small scale digital data available from Institut Geographique National. Large scale data in hands of Cadastre. Ongoing digitization programme underway in conjunction with local authorities	Almost half of the county is covered in good quality cadastral information. The process of conversion to digital format has been undertaken but slow progress and organizational difficulties have led a number of local authorities to acquire their own data often in partnership with private sector	Strong awareness of geographic information in the Netherlands and tradition of automated registers (population, etc.). Slow progress of large-scale mapping project based on Cadastre has led to local authorities acquiring thei own digital mapping individually or in partnership with utility companies and private sector

APPENDIX 1 TABLE 2 Key features of GIS diffusion in the five countries where surveys were carried out using a similar methodology. (Source: Table 13.2 in: Masser & Craglia, 1996)

	Great Britain	Germany	Italy	Portugal	Denmark
Coverage of findings	Comprehensive survey of all local authorities in England, Wales and Scotland in the second half of 1993	Survey of cities with 100 000 population in the first half of 1994	Comprehensive surveys of all regions and provinces in 1993/1994: some additional information for communes (1991) and Metropolitan areas (1993)	Survey of municipalities in late 1993/early 1994	Comprehensive survey of counties and municipalities in first half of 1993
Extent of diffusion	Almost universal in counties and Scottish regions. Half metropolitan districts. One in six shire/Scottish districts	Almost universal: 70/80 cities had GIS, 10 had firm plans	Two thirds regions—one third provinces but another 1 in 3 with firm plans. Limited in medium/large cities	12 municipalities had GIS and a further 24 had AM/FM facilities	Over 80% of all municipalities use register based systems where georeferencing present. GIS/AM/FM almost universal in authorities with 50 000+. GIS in half counties
Geographical spread	North South divide: 32% of Southern authorities had GIS, 24% of Northern authorities had GIS	No significant geographic difference	Pronounced North/South divide among the regions (90% N–37% S) and the provinces (50% N–20% S)	Adoption levels highest in urban areas and in northern parts of Portugal	Urbanized regions generally have higher take up than less urbanized regions
Length of experience	70% systems purchased since 1990	Most systems purchased since 1990	Half regional and 80% provincial systems purchased since 1990	Some municipalities began GIS projects in 1990	Most GIS systems acquired since 1990
Main applications	Automated cartography and mapping for local planning and management	Surveying and topographic data base management	Digital map production, strategic land use planning. Environmental monitoring also strong in the provinces	Land use planning: automated mapping	Digital mapping. Also extensive use for utility management

APPENDIX 1 TABLE 2 (continued)

	Great Britain	Germany	Italy	Portugal	Denmark
Predominant software	Arc/Info in 25–30% of county and metropolitan districts. Axis, Alper Records and G-GP in shire/Scottish/ metropolitan districts	SICAD and ALK-GIAP (latter free to German local authorities)	Arc/Info for over half regional and provincial applications. Greater diversity at municipal level	Intergraph purchased by National Centre for Geographic Information facilities	Intergraph MGE and Autocad based systems with Dangraf and GeoCAD
Perceived benefits	Improved information processing (60%) especially improved data integration, better access to information and increased analytical and display facilities	Improved information processing: (65%) faster information retrieval and increased analytical and display facilities	Improved information processing (51%) especially automated map production and thematic mapping	Improved information processing, administrative reorganization, data sharing with utilities	Improved information processing (66%)
Perceived problems	Technical problems including lack of software and hardware compatibility. Organizational problems especially poor managerial structures and lack of skilled staff	Organizational problems especially lack of qualified staff and insufficient motivation of staff by management	Organizational problems especially lack of awareness, poor coordination and lack of skilled personnel	Bureaucratic inertia, lack of skilled personnel digital data availability, lack of awareness, vendors attitudes and limited follow up support	Technical problems in small municipalities. Organizational problems in large municipalities

APPENDIX 1 TABLE 3 Key features of GIS diffusion in the other four countries. (Source: Table 13.2 in: Masser & Craglia, 1996)

	Greece	France	Poland	Netherlands
Extent of diffusion	About 10% of all cities have GIS facilities	Two thirds of cities with more than 100 000 population have GIS. Widespread use in intercommunal agencies	30–40 mainly in small–medium sized towns (20 000–100 000 inhabitants). Few regional/ sub-regional GIS	GIS is almost universal among municipalities above 50 000 inhabitants and in approx. 50% of those above 20 000
Geographical spread	No marked regional variations	No discernible regional variations reported	No marked regional variations	No marked variations
Length of experience	Most systems purchased since 1990	Most systems purchased since 1990	Most systems purchased since 1990	Rapid take-up since late 1980s
Main applications	Surveying and topographic data base management	Urban data base management for surveying and planning	Topographic data, parcels data, cadastral information	Mainly topographic and thematic mapping
Predominant software	Arc/Info for over 80% of local government applications	Arc/Info and Apic (French package)	Map/Info, Autocad for small systems, Arc Info for larger central government implementation	Intergraph MGE, Autocad and IGOS (Dutch package)

APPENDIX 1 TABLE 4 Results of a survey of 404 departments involved in 195 GIS facilities in 1993. (Source of data: Campbell & Masser, 1995: 70).

Type of department	Number of departments
Planning / development	106
Highways/engineers/surveyors	59
Estates	51
IT/computer services	33
Combined technical services	31
legal and related services	23
parks and recreation	20
chief executive	20.

APPENDIX 2

QUESTIONAIRE

WATER RESEARCH COMMISSION - UNIVERSITY OF CAPE TOWN (U.C.T.) - CAPE TOWN CITY COUNCIL

JOINT RESEARCH PROGRAMME

USER NEEDS ANALYSIS: CITY OF CAPE TOWN

A) INTRODUCTORY STATEMENT ON RESEARCH PROGRAMME:

A national Geographic Information System (G.I.S.) Based urban research programme is being developed for South Africa. This aims to provide a detailed analysis of the current G.I.S.-based applications to urban upgrading in the country. The research will examine the potential of the technology for improving urban settlement upgrading. The U.C.T. civil engineering component of the research programme deals with G.I.S.-based developments which are directed towards facilitating infrastructural upgrading in Cape Town. This part of the study comprises a user needs survey of the City Engineer's, City Electrical Engineer's and City Planner's Departments within the City of Cape Town. Subsequent to processing the results of the survey, an analysis will be conducted of the visual settlement planning (ViSP) approach currently being applied in Belo Horizonte (Brazil). The results of the two studies will serve as a background from which urban upgrading applications customized for Cape Town's low-income / informal settlement areas may be produced.

B) INTRODUCTORY STATEMENT ON USER NEEDS ANALYSIS:

As part of the user needs analysis, Iuma Martinez, a researcher in the Department of Civil Engineering at the University of Cape Town, will be conducting a survey of various branches within the three departments mentioned above, to establish how G.I.S. can be used to assist in upgrading infrastructural services provided to low-income and informal settlement areas. Ikapa has been selected as a case study area for the project, although Iuma will also need to consider other low-income / informal settlement areas for comparative purposes. The results of this survey will be directed to the development of G.I.S.-based approaches and methodologies to assist the upgrading of the services provided to these regions. During the interview Iuma will be making some requests for information on various data types, maps, charts, reports etc. It would also be very useful if you could refer her to any additional literature/maps/alternative data sources, which I could use to augment the information acquire during our interview.

C) INTERVIEWEE DETAILS:

Branch:____________________________________
Person interviewed:____________________________
Date of interview:_____________________________
Phone:_____________________________________
Fax:______________________________________
E-mail:_____________________________________

GENERAL QUESTIONS (25 MINUTES)

D) G.I.S. / SYSTEMS:

1) How is G.I.S. currently being used by your branch for formal and low-income/informal settlement planning and management applications?

2) What are your views and perceptions on the current application of G.I.S. in your branch?

3) Do you feel that there are additional applications of G.I.S. that should be incorporated by the present system?

4) How does this branch utilize the Council's software?
(eg. GenaMap, I.R.I.S., B.I.S., M.I.M.s, Intergraph, P.M.S.)

5) What opinion do you have of the Council's software?

6) Do you utilize/plan to utilize the data sharing capability of the GenaMap system?

7) Do you anticipate any benefits from the introduction of G.I.S.?
(eg. personal, financial..)

E) LOW-INCOME / INFORMAL SETTLEMENT AREA PLANNING:

1) What are the major problems facing the infrastructural services provided by this branch in Ikapa? (eg. flooding)

2) Which of the low-income/informal settlement areas, which have been mapped by this branch into the GenaMap system, have infrastructure problems analogous to those facing Ikapa?
(eg. Crossroads, Mflueni, Khayelitsha, Lwandle, Pumlani and other low-income/informal settlements in the Western Cape)

3) What are the planning pre-requisites required before this branch can provide services to low-income/informal settlements?

4) What are the low cost infrastructural service options for Ikapa?

5) How do you think the G.I.S. data base can be used to improve and optimize the services that your branch supplies to Ikapa?

TECHNICAL QUESTIONS (45 min)

F) MAPPING AND DATA ACQUISITION:

1) How is data currently being collected, stored and formatted in this branch (ie. what is the data flow)?

2) What do you use maps for?

3) What are the different types of maps produced and used by your branch with respect to Ikapa and other low-income/informal settlements?

Please specify:

- category (eg. network, zoning, plat, utility, other base maps)
- scale (eg. 1:2 000)
- accuracy (eg. 0.1 m)
- size (A5,A4,A3,A2,A1,A0, other)
- use
- availability (for which areas are the maps available)

4) What kinds of information are portrayed on the maps?
(eg. network elements such as: roads, sewer, water and power lines, and service connections, natural features, boundaries, properties, districts, zoning, jurisdictions, structures, overlay zones, legends, scales, sources / other)

5) How often are the maps updated?

6) Does your section use static (eg. geological) maps?

7) Are there any other static attribute data types associated with the network elements of the physical infrastructures, which you have not mentioned in questions 1 or 2 ? (eg. for a pipe: type, age, condition, diameter, flow capacity, cause for damage, if damaged etc.)

8) What types of dynamic attribute data (eg.sewage flow, population counts, leaks detected) are captured, processed and used by this branch?

For questions 7) and 8) please specify the following:

- accuracy (eg. 0.1 m)
- basic measure/unit (eg. m3/day)
- availability (areas for which data are available, or the extent of the areal coverage - eg. sparse, localized, extensive)
- frequency (annual/quarterly/monthly/daily/intermittent)
  (ie. how frequently has the data been captured)

9) What map-oriented analytical tasks are performed by your branch for informal settlement planning? (eg. suitability analysis, locating facilities, monitoring spatial patterns, impact analysis, routine operational use: sending public notices, answering public inquiries)

10) Do you need to aggregate or analyze information by geographic subareas? (eg. to represent statistics, consumption, service demands, payments to be collected, complaints etc., per site serviced / ward / enumeration district / stand)

11) Which map and value/attribute data types do you co-process? (ie.compare/overlay/inter-relate; eg. water demands, in terms of a population density contour map, and water supplies, in terms of the water supply network in a region; dwelling unit densities vs. road network)

12) Are there values that you have to recalculate or new data layers that you have to create?

13) What geographical databases does the branch use/contribute to? (eg.land parcel file, building permit file, water facilities database)

Please specify:
- name,
- size (records fields items),
- georeferencing,
- source (organizational, physical),
- routine use,
- analyses
- decision making use

BRANCH SPECIFIC QUESTIONS (45 min)

G) DATA TYPES / APPLICATIONS / LEVELS OF SERVICES

The following questions refer to branch specific tables, which will be provided during the interview where relevant.

1) Table 1 is a list of the data types possibly monitored by this branch throughout the historical Cape Town supply area.

1.1) Have I listed all the possible data types?

1.2) Which of these data types have been captured into the existing database?

1.3) For each of the captured data types, what percentage has been captured?

1.4) Can you indicate where I can look up the following data type characteristics?: - date, - record type / format (maps, tables, hard/soft copy), - accuracy, - basic measure/unit,- availability,- frequency

2) Table 2 is a listing of the potential G.I.S. applications for this branch. A number of the applications are derived from Milne (1995). The ranking scheme ranges from 0 (low priority) to 5 (high priority) and indicates the importance of the ranked application relative to 80 applications listed by Milne for all of the Council's departments.

2.1) Do you agree with the rankings of Milne?

2.2) Can you identify from this list any particularly useful application?

2.3) Are there any other applications that require more immediate attention? Suggested applications, which pertain to low-income / informal settlement areas, would be extremely useful (Table 2 B).

3) Table 3 is a list of the various levels of service. I have compiled this table from the World Bank Mission Aide Memoir Report (1991) & from the Guidelines for the provision of engineering services & amenities in residential township development (National Housing Board, 1994).

3.1) Are other levels of service recognized?

3.2) Are there level of service maps / matrices available for low-income/informal settlement areas (in particular Ikapa)?

3.3) Where can I obtain the following cost information revised for 1996?

- capital costs (R) (internal services, bulk & connector)
- operation and maintenance costs (R)
- updating costs (R)
- incremental infrastructure costs for:
    - minimal to basic (2) (R/ha)
    - to intermediate (3) (R/ha)
    - to full (4) (R/ha)

(@ 15 pers/ha; 240 pers/ha; 360 pers/ha)

4) May I obtain access to soft/hard copies of:
4.1) maps, tables, 4.2) data dictionaries, and 4.3) publications and reports, resulting from the application of the GenaMap system, or related to formal and informal settlement areas?

5) Please contact Iuma at the following address if there is any further information you could provide to assist this research project: Ms Iuma Martinez, Department of Civil Engineering, University of Cape Town, Private Bag, Rondebosch, 7700, FAX.:650-2603, E-Mail: IMARTIN @ENGFAC.UCT.AC.ZA, Phone:650-2593 or 650-2584

ADDITIONAL SHEETS TO ASSIST IN ANSWERING MAPPING AND DATA ACQUISTION QUESTIONS

A DATA USE

A1. List data (maps, reports, statistics etc.) currently used by this branch.
Please provide the following information:
Data: Name, Location, Source, Collected (C) / Not collected (N) by this branch.
Type: M - Map (Projection system and/or coordinates and features), T - text/report, S - Statistics / Table.
Format: H - hard copy, S - soft copy (Please specify format: GenaMap, ARC/INFO, CAD, Wordperfect etc)
Date: Date produced.
Use: F - frequently, N - not frequently, R - rarely.
Access: F - freely available, P - priced, U - unaccessible
Value: U - not useful, U+ - useful, U++ - extremely useful

Data	Type	Format	Date	Scale/Accuracy	Use	Access	Value
eg. roads, as-built, C	M, Long.:25°, meters	DXF, ASCII	1996	1:2000, 0.2 m	F	F	U++

B G.I.S. applications suggested by interviewee.

Application	Ranking

ADDITIONAL TABLES TO ASSIST IN ANSWERING THE POTENTIAL DATA TYPES AND APPLICATIONS QUESTIONS

TABLE DEFINITIONS

1.Definition of abbreviations used in the tables of : Potential data types monitored

() = frequency of monitoring
[] = measure / basic unit)
C = currently being captured into G.I.S. system
E = exists and will eventually be captured into the G.I.S. system

2. Definition of abbreviations used in the tables of: Potential applications

"(1)" = previously ranked, "1"= ranking by interviewee, " * " = unranked, but of interest, "-" = no reply

Ranking scheme applied: 0 = low priority, 5 = maximum priority.

Application numbers: Application numbers refer to the numbers allocated to each application appearing in the Branch Speciifc application tables listed in Table 1.

Note: The responses to the tables below and the results of the interviews are presented in detail in Martinez & Abbott (1997).

APPENDIX 2 TABLE 1: POTENTIAL DATA TYPES MONITORED BY THE ROADS BRANCH

1. Location of the following road network spatial elements:
roads, footways, pedestrian and carriage way crossings, pavement channel/pipes, excavations and building/demolition operations, traffic lights and signs, bus and taxi passenger platforms, parking areas, intersections, traffic congestion points, high accident frequency locations

2. Attributes associated with road network spatial elements:
- road category: UA, UB, UC, UD
- road maintenance: resurfaced, reconstructed, (overlays, Hot in-situ recycling, slurry seal)
- materials used in road construction
- material depth
- road name
- road directionality
- pavement: type, surface, structural maintenance, salvage value
- road design attributes: design speed, lane width, horizontal curvature, gradient, vertical curvature, forward visibility (sight distance), super elevation

3. Traffic flow data
- traffic class: E0 - E4, - initial E80's/lane/day
- vehicle / dwelling unit / hour, - catchment length
- traffic direction (2 way, tidal), - maximum capacity
- traffic composition: motorised, bicycle traffic, pedestrian traffic

4. Environmental data
- topography (gradient and contour maps)
- drainage, - depth to water table
- soil type, - climate / rainfall data
- township layout: density & housing type
- stormwater management network

5. Cost analysis / design data
- present worth, - construction costs
- future maintenance, - discount rate
- upgrading costs, - expenditure / per capita / site
- material: availability, cost
- dynamic cone penetrometer (DCP) readings for California Bearing Ratios (CBR)
- traffic data logger (TDL) data
- socioeconomic data: affordability data (household incomes), car ownership, etc
- further design related data: dwellings/road, length of road, fronting landuse permitted, routes used

APPENDIX 2 TABLE 2: POTENTIAL GIS APPLICATIONS FOR THE ROADS BRANCH

Application	Ranking
1) Planning and design of road network	
2) Maintenance of road network, including bridges and roads signs	
3) Maintenance of street register	
4) Issue of permits for excavation and crossing of footpaths	
5) Issue of indemnities for claims against properties	
6) Design & planning of road & transport infrastructure required if Olympic Games occur in Cape Town in 2004	
7) Selecting areas for hot in-situ recycling of bitumous asphalt surfaces (HIR resurfacing), lane extensions	
8) Integrated management of: the planning, design, construction and maintenance programmes, as well as for the Branch's plant, vehicle fleet and human resources	
9) GIS-based grid road network design software, which will focus on the economical use of resources by considering design indicators such as: area of roads as a % of total township, road area / residential area ratio, length of road / erf, distribution of road length / road class, number of intersections.	
10) Using GIS-based contour and gradient maps to align bus routes and roads in residential areas (eg. constraints such as follows can be applied: cul de sacs must follow contours, bus stops require gradients of < 1 : 14, channels should have a minimum gradient of 1 : 250 etc)	
11) GIS-based traffic models which incorporate the calculation of factors related to the design traffic class: load equivalency of traffic, projection to initial design year, cumulative equivalent traffic	
12) Constructing a GIS-based network model for a residential area (Ikapa?), which is constrained by the following types of spatial elements: directionality of links, stops, centres, turns and barriers.	
13) Constructing a GIS-based dynamic segmentation model, which enables multiple sets of attributes for linear features to be edited, queried and displayed, independently of arc-node topology. (ie. enables accident location, pavement type, and other attribute data to be viewed simultaneously for any linear network element)	
14) Utilizing the buffering and other spatial analytical capabilities of GIS software for: designing bus routes (eg. 300 m circle radius distance from bus stop to furthest dwelling served, 200 m bus route development buffer corridors - for viable bus operation, footpaths should radiate from bus stops, opposite bus stops should be staggered by 45 m on the same road etc.)	
15) Designing GIS software, which enables the selection of road classes, based on the types of network nodes to be linked	
16) Designing software, which enables optimal road reserve widths to be determined, based on the class of road (4, 5 a / b / c), and the spatial requirements of: continuous (eg. roadway) and non-continuous (eg. road signs) surface, and continuous underground (eg. cables, trenches) service elements situated along the road.	

APPENDIX 2 TABLE 3: POTENTIAL DATA TYPES MONITORED BY THE CLEANSING BRANCH

1.Locations of solid waste collection and disposal network spatial elements:
- waste disposal sites, complaints acted upon, litter bins, illegal dumping cleared, stercus points serviced, commercial & industrial waste disposal undertakings

2.Locations other service network elements:
- roads
- stormwater: drains, gulleys, stormwater intakes, unlined rivers, lined rivers,

3. Solid waste data:
- Tonnages received @ disposal sites
- Volumes of material removed during: river cleaning, refuse removals, street cleansing, stercus removal, disposal, production of compost and private works, illegal dumping cleared
- categories of solid waste (household refuse, street sweepings, commercial and business refuse

4. Landfill data:
- borehole / groundwater data
- surface water data
- flow volumes and pollutant concentrations
- leachate data

5. Service site specific data:
- expenditure/capita/site serviced (R)
- complaints (locations, number, nature of)
- households serviced (locations)
- streets and litter bins served (locations)
- litter accumulation prone areas (locations)
- solid waste: volume generated, volume removed (per category)
- collection level
- disposal level

5. Environment / design data:
- township layout
- affordability (household incomes)
- groundwater level
-geology (dolomitic areas)

APPENDIX 2 TABLE 4: POTENTIAL GIS APPLICATIONS FOR THE CLEANSING BRANCH

Application	Ranking
Best planning for refuse collection and street sweeping. Traffic (eg. location of taxi ranks; train & bus schedules) and cleansing data may be overlain.	
Route planning for breakdown vehicles	
Location of litter collection sites	
Beach cleaning	
Tip site management	
Co-ordinating efficient use of vehicles, labour intensive solid waste collection, local level recycling and other activities	
River cleaning and stercus removal management	
Processing and bulk transport management	
Private works (non tariff) management	
Medical and hazardous waste disposal, law enforcement, investigation of alternative disposal sites, investigations into mass transfer operations	
Management of local (domestic refuse, garden refuse, medical waste, trade and industrial waste, hazardous waste) collection and (street, gully) cleaning activities	
Management of regional transfer station facilities, beach and river cleaning, landfill sites for disposal, liquid waste disposal, emergency cleanups (eg.oil spills).	
Planning new projects (eg. refuse transport by rail scheme (Bail & Rail), sludge and refuse co-disposal research, and reuse of methane from landfill sites).	
Recognition of optimal service collection routes, based on network / routing capabilities of GIS software, which enable attributes and impedances to be associated with network links (eg. roads), turns (intersections), stops (collection points, disposal sites), centres (recycling plants, transfer stations) and barriers.	
Utilizing GIS to model waterbalances and pollutant loadings associated with a sanitary landfill site. Borehole, runoff (water quality and quantity), groundwater level, precipitation, evaporation and other environmental data can be used. Such a model would enable the long term effects of the site on the groundwater quality to be simulated.	
Design of a GRID / cell-based level of services planning model for Ikapa. Lattices of current levels of service, household affordabilities, upgrading costs, pollution related data etc may be overlain. The cell-based nature of the model would facilitate planning related mathematical operations between the diferent layers.	
Maintenance of fleet (compactor vehicles etc.) taking into account the cost of repairs and downtime.	

APPENDIX 2 TABLE 5: POTENTIAL DATA TYPES MONITORED BY THE STORMWATER & DRAINAGE BRANCH

1. Locations and numbers per site of sanitation / storm water and drains system spatial elements:
VIP Latrines, pour-flush toilets, improved aqua-privy; small bore toilets, condominial (shallow/backyard) sewers, simplified sewerage, sewer connections, principal sewage disposal points, storage facilities, open channels, levees, flood walls, flood proofing, catchment areas, wastewater treatment plants, marine outfalls, sewer reticulation, sewer connections, stormwater drains (pipes & culverts), conservancy tanks, liquid and solid waste disposal sites.

2. Locations of and associated attribute data of BMP design elements such as: extended detention pond, wet pond, infiltration trench, infiltration basin, porous pavement, filter strip, grassed swale, sandfitter, biofiltration swale.

3. Other site specific data:
- expenditure / capita [R]
- households sewered [No.,%]
- main alternative sanitation system type [No.,%]
- sewage flow [m^3/day]
- solid waste generated [tons/day]
- sewage treated [tons/day]
- sewer connections for Non-titled houses [No.; type]
- average daily flows / dwelling unit or site
- peak flows
- local attenuation or peak factors
- network capacity: surplus and deficit service provision
- costs (R) / site serviced

4. Flood related / stormwater management data:
- stream flows: velocity and volume
- flood levels
- locations and date of flooding events
- water table / water depth
- sedimentation input
- autographic rainfall data (mm), (monthly, and daily and hourly maximum values)

5. Water quality data (surface & groundwater):
- pollutant concentrations (P, N, S, BOD, TDS, etc.)
- point source locations

6. Environmental / Planning data:
- topography
- faults / primary acquifers (groundwater recharge)
- geotechnical data: soil type, strength, permeability / porosity / soil infiltration rate, erodibility, percolation capacity
- geology: fissured rock, limestone, very coarse soil
- location of soils and vegetation types suitable for short term ponding
- landscape tolerances (% soil and vegetation which can be cleared and/or covered by impervious surfaces, without affecting the ability of the remaining soil to absorb local runoff from high frequency storms)

7. Land use / other services provided:
- road network
- pavement types

- transmission lines
- township layout

8. Cost analysis / design data:
- present worth
- construction costs
- future maintenance

9. Further attribute data associated with network elements:
- Stormwater drains and sewer reticulation:
eg.feature = pipe: type (eg.concrete HDPE liner, trunk sewer, uPVC) age, condition, type, diameter, flow capacity, cause for damage - if damaged
- Wastewater treatment plants:
design capacity [Ml/d], measured waste water flows, installed power, measured power used, operation and maintenance costs
- Sludge production:
eg. volumes (m^3) of primary raw, activated sludge, digested, pasteurised and total final product produced per day
- Waste disposal sites
eg. data associated with liquid waste sites (inorganic salts, organic salts, heavy metals, solvents); data associated on co-disposal with solid waste; volumes of liquid intractable waste disposal recieved

APPENDIX 2 TABLE 6: POTENTIAL GIS APPLICATIONS FOR THE STORMWATER & DRAINAGE BRANCH

Application	Ranking
1) Siting areas for low cost sanitation to provide wastewater disposal facilities to the greatest number of new houses. Point buffers may be generated to assess the number of dwellings / population reached.	
2) Modelling on-site/near-site infiltration possibilities by means of temporary storage with slow water discharge rates.	
3) Pumped sewerage: Design, operation and maintenance of pumped sewerage system.	
4) Gravity drainage: Design and maintenance of gravity drainage system.	
5) Effluent control: Enforcement of drainage and sewerage bye-laws.	
6) Generation of flood-line maps: (1:2; 1:5, 1:20, 1:50) to site minor stormwater drains and major water courses. (Note: 1) Buffering capabilities of GIS may be used to produce maps illustrating areas suitable for residences (ie. Base flood surface buffered by 500 mm) and fringe areas (major flood level buffered by 300 mm).(The maps can be used in collaboration with planning and design activities, in view of the policy that roads and properties should ideally be above the 20 year flood level and that building floor levels be above the 50 year flood level. Also note that the water table should be shown as well.)	
7) Stormwater pollution control of point & non-point point sources. Locations suitable for the collection of water for potable and non patable use, may be determined by constructing concentration buffers. (Soakaway distance buffer of 7.5 to 30 m)	
8) Modelling effects of: on site storage, infiltration patches, grassed swales and porous pavements on net stormwater mass balance fluxes.	
9) Integrated drainage systems management (as opposed to the inadequate fragmented management policy	

currently adopted).	
10) Monitoring activities currently underway to alleviate stormwater pollution.	
11) Implementation of flood peak storage (F.P.S.) system - ie. siting and maintaining existing retention and detention ponds; siting of flood protection dykes and flaps on stormwater outlets and "local storage".	
12) Monitoring erosion and deposition along streams & channels, & damage to infrastructure	
13) Studying inter-relationships between channel network characteristics (capacity, roughness, slope) stormwater flow data	
15) Managing the conveyance and treatment of the daily wastewater derived from the city and some adjacent authorities	
16) Monitoring the net flows and qualities of water directed through sewage and stormwater pump stations, wastewater treatment works and marine outfall sewers.	
17) Overlay landscape tolerance by planned land use intensities, inorder to reduce the concentration of runoff. GRID / cell-based modelling may be suitable.	
18) GIS-based runoff - water quality models applying Best Management Design Practices, based on: 1) pollutant removal capabilities of various BMP designs (see data type 2 in Table 1 above), 2) technology-based criteria, which consider % impervious area and size of the contributing drainage area, 3) design constraints related to: buffers, water depth, slope, sedimentation input, and 4) costs: current, upgrading, capital, operating and maintenance.	
19) Applications utilizing the GRID / cell-based modelling (EG. lattices of current levels of service, upgrading possibilities, affordability, peak and design flow rate grids etc. may be used for regional upgrading programmes. The mathematical operators available would facilitate average daily, peak and design flow rate and other calculations to be carried out over regions, rapidly and in an iterative manner, as each planning option was evaluated.)	
20) Designating flood prone areas based on map overlays of the following themes: development, dwelling occupancy, flood lines, rate of increase of water level, velocity and depth of flow etc.	
21) Construction of a sanitation / stormwater drains system network model, which incorporates: attribute data associated with links (eg. pipes), flow barriers, turns (eg. pipe intersections), centres (eg. treatment plants) and stops.	
22) Automating design constraint checks such as the minmum depth and cover for sewers, sewer gradients and diameters etc.	
23) Incorporating catchment modelling data, measured flows and rainfall data, to refine the design of future flood control projects	
24) A water balance model which incorporates urban runoff, groundwater flows and pollutant loadings etc.	
25) Designing to increase capacity of existing wastewater treatment works (eg Cape Flats) & the location of sludge dewatering centrifuges	

APPENDIX 2 TABLE 7: POTENTIAL DATA TYPES MONITORED BY THE SCIENTIFIC SERVICES BRANCH

1) Inland, coastal & storm waters:
(The values, and the locations of each variable measured in terms of: 1) x, y, z co-ordinates and 2) sample environment: ie. surface, bottom, river, outlet canal, overflow pond, etc., are of interest.)

- Temperature:[°C, Ave, Min, Max]
- Dissolved Oxygen as O:[mg/l, Ave, Min, Max]
- Oxygen saturation:[%, Ave., Min, Max]
- Secchi transparency:[cm, Ave, Min, Max]
- Total suspenderd solids:[mg/l, "]
- pH value:[Ave, Min, Max]
- Conductivity:[mS/m, Ave Min, Max]
- Total Kjeldahl Nitrogen:[mg/l, "]
- Ammonia as N:[mg/l, "]
- Nitrate + Nitrite as N:[mg/l, "]
- Total Phosphorus as P:[mg/l, "]
- Total Phosphorus dissolved as P:[mg/l, "]
- Reactive Phosphorus dissolved as P:[mg/l, "]
- Reactive silicon dissolved as Si:[mg/l, "]
- Total alkalinity as $CaCO_3$:[mg/l, "]
- Chlorophyll a corr for Phaeophytin:[ug/l, "]
- Phaeophytin:[ug/l, "]
- Faecal coliforms/100ml percentiles
- Total plate count/ml

2) Waste water treatment data: (locations & values)
- Volume treatment rate: [m^3/h]
- Sedimentation period: [h]
- Filtration rate: [m/h]
- Chemical dosage: [mg/l]: (Fe, Al, Na, Cl, CO_2)
- Chemical method: Coke, Polyelectrolyte, Lime, Coagulation (settlement) filtration (liming carbonation) chlorination)

3) Chemical analysis: (values)
- O_2, $CaCO_3$, Cl, SO_4, Ca, Mg, Na, K, Al, Fe, Mn [mg/l]
- Electrical conductivity [mS/m]
- pH value
- Turbidity [NTU]
- Colour
- UV Absorbance [300 nm, 400 nm]
- Total hardness as $CaCO_3$

4)Industrial effluents and wastes:(locations)
- factories sampled for tariff purposes
- effluent samples taken
- samples not complying to Munincipal By-Laws

5) Liquids and solid wastes:(locations)
- waste samples taken
- samples not complying with land disposal permit requirements
- samples from monitoring boreholes at waste disposal sites
- samples of leachate from co-disposal project cells
- landfill gas samples

6) Industrial effluents analytical data: (locations & values)
- electrical conductivity

- dissolved inorganic solids
suspended solids
- suplhates
- pH value
- Toxic heavy metals
- Cyanides
- Oils
- Greases and fats
- Flash point
- Sulphides
- Phenols

7) Atmospheric pollution data: (locations & values)

- Average concentrations:
- SO_2, atmospheric leak :[micrograms per m^3)
- Smoke (soiling figure per m^3)
- Dustfall (kg/ha/30 days)

APPENDIX 2 TABLE 8: POTENTIAL GIS APPLICATIONS FOR THE SCIENTIFIC SERVICES BRANCH

Application	Ranking
Environmental monitoring.	
Utilizing the GRID modelling capabilities of ARC/INFO to construct pollutant loading models for a selected region.	
Constructing a cell-based water balance model to which monitors the cumulative effects of point and non-point source pollution on the storm water runoff and groundwater system of a region.	
Designing storm water runoff surface modelling software, which incorporates pollutant fluxes. Planes of constant slope in a triangular irregular network (TIN) model may be used to represent sub catchments. Sub catchment data such as: flow rates, pollutant concentrations, land use, permeability, water table height, topographic height etc., may also be incorporated into the model.	
Constructing a network-based pollutant flow model. The various elements of a network such as: links (eg. river segments or pipe conduits), barriers, centres (eg. pollution point sources), stops (eg. concentration / deconcentration points – analogous to bus stops) and turns (eg. pipe or river junctions), would have attributes and impedances defined to model pollutant fluxes. A concentration sink could be defined as a negative valued centre.	
Monitoring and operational control of the useage of chemicals & proposed forms of treatment at Water Treatment Works, as well as the of quality of the purchased, delivered and mains supply waters.	
Interpretation of wastewater treatment works analytical data.	
Monitoring factory trade effluents to ensure compliance with Municipal Drainage & Sewerage By-law, and to facilitate recommendations regarding effluent quality, illegal discharges to stormwater and representative sampling points.	
Planning with respect to: pollution resulting from landfill activities, illegal disposal of hazardous waste and domestic refuse, disposal of hazardous materials, leachate movement, evolution of landfill gas and sampling improvements.	
Analysis of bacteriological data for wastewater effluents, vleis and streams, sea water and bathing pools.	
Analysis of gaseous pollutants, lead and particulate matter.	
Assess the impact of planned low cost sanitation schemes on the environmental system.	

APPENDIX 2 TABLE 9: POTENTIAL DATA TYPES MONITORED BY THE WATER BRANCH

DATA TYPE:	EXTENT OF CAPTURE:
water connection types	
water source (eg.dam/spout)	
total water use [m^3/day]	
munincipal consumption [1/cap/day]	
industrial/commercial consumption [1/cap/day]	
households with piped water supply [number of, %]	
households with easy access to standpipe [number of, %]	
unaccounted for water [volume, %]	
Leaks detected [number of]	
Repairs Effected [number of]	
Water Connections for Non-Titled Houses [number of]	
Sites Serviced by Off Site Water Delivery Systems [number]	
Residential water payments [number of, quantities]	
Water quality data for pipe network	
Catchment area data:	
rainfall (monthly, annual) [mm] [no. days rain fell]	
run-off & stream flow [Ml]	
evaporation [mm]	
supply from reservoirs & springs (monthly, annual) [Ml]	
Water supply data:	
pumpstations [quantity pumped:Ml]	
Water consumption data:	
consumption points: locations & quantities consumed	
consumption (monthly, daily average) [Ml]	
maximum and miminum consumption [Ml]	
daily averages [Ml]	
estimated population supplied	

APPENDIX 2 TABLE 10: POTENTIAL GIS APPLICATIONS FOR THE WATER BRANCH

Application	Ranking
Distribution: Monitoring & maintenance of distribution network	
Consumer supply services: Management of consumer accounts (including meters)	
Consumer supply services: Control of water leakage	
Design: Design new works and maintain network records	
Design: Asset management	
Bulk supply: Monitoring & maintenance of bulk supply network	
Design: Augmentation schemes (the distribution pipeline for Riviersonderend/Palmiet river, and the Faure Water Treatment augmentation schemes)	
Monitoring the overall flow between the water treatment plants, storage dams, service reservoirs and pipelines	
Contract-related applications: location of service connection; supply capacity of existing network; hydraulic network analysis, to determine effect of new demand on the system; distance between network and connection point	
Customer service applications: water quality problems, locating a mains burst	
Pipe network analysis based on diameters of pipes, pipe length, coefficient of flow, used water volume and pipeline drawings	
Water quality monitoring system in pipe networks: residual chlorine concentration, turbidity, pH value, water temperature	
Quality of service queries: concentration of Cl (ppm), pressure, residence time, number of interruptions, time without service	

APPENDIX 2 TABLE 11: POTENTIAL DATA TYPES MONITORED BY THE PARKS & FORESTS BRANCH

1) Alien vegetation control:
- areas (ha) initially cleaned and recleaned (location)
- areas of post fire regeneration (location)
- vegetation (types, locations)

2) Accessibility:
- accessible areas (locations)
- numbers, of: visitors, vehicles, day visitor, overnighters, vehicles, amounts
- routes used

3) Revenue from timbre:
- raw & low grade timber (location)
- areas allocated for the production of various timber products: transmission poles, fencing poles, pulpwood, miscellaneous (locations)

4) Services provided:
- parks & forests provided stuctures (see application 2)
- road network
- stormwater management network
- waterworks network
- electricity network

5) Environmental data:
- topography (gradient and contour maps)
- drainage
- geotechnical data: soil type, strength, permeability, porosity, erodibility
- landscape tolerances: (% soil and vegetation which can be cleared and covered by impervious surfaces, without affecting ability of remaining soil to absorb local runoff from high frequency storms.)
- rainfall data
- wildlife habitats

6) Cost analysis / design data
- present worth
- construction costs
- future maintenance
- upgrading costs
- material: availability / costs

APPENDIX 2 TABLE 12: POTENTIAL GIS APPLICATIONS FOR THE PARKS & FORESTS BRANCH

Application	Ranking
1) Management of nature reserves, commercial forestry, mountain catchment areas parks, sports fields, nurseries (and all City-owned land).	
2) Planning, landscaping, design, etc. of streets (footpaths and trees); siting park furniture (benches, light poles, refuse bins) and other public utlities such as toilet block, changerooms, locker rooms, walkways, lawns, walkways, open space areas in parks, rampsflower layouts.	
3) Utilizing GIS to match landscape tolerances with planned landuse intensities, allowing areas of high erosion rates to be determined. (Soil types, vegetation, contour and gradient vector maps, land use and other coverages may be overlain.)	
4) Siting fire barriers in conservation areas.	
5) Generating sensitivity maps and functional area maps.	
6) Designing a cell(/grid)-based planning system, which would facilitate maintenance cost related, and other intra-layer mathematical operations.	
7) Probability surface models for land use and forestry applications.	
8) Network / dynamic segmentation based applications	

APPENDIX 3

APPENDIX 3 TABLE 1 SUMMARY OF INFORMATION ON GIS SYSTEMS IN DEVELOPING COUNTRIES

CRITERIA	CAPE TOWN CITY COUNCIL (SOUTH AFRICA)	PROLAND (SOUTH AFRICA)	NAPIER (SOUTH AFRICA)	GAUTENG MUNICIPALITY (SOUTH AFRICA)
1. DIGITAL DATA AVAILABILITY	Excellent - Poor : Topographical and cadastral data available in digital format at a high resolution for formal settlements in all the major metropolitan areas. Very little high accuracy data is available for informal settlements. Low accuracy data is available for the whole country. The Cape Town City Council has one of the largest formal settlement municipal databases amongst all the developing countries of the world.			Excellent – Poor
2. HARD COPY DATA AVAILABILITY	Excellent – Extremely Poor: Excellent in formal areas and extremely poor in informal settlement areas. As built maps are out of date (by up to 15 years) or non-existent for Ikapa and other informal settlements in the CMR.			Excellent – Poor
3. LEVEL OF INFORMATION TECHNOLOGY (IT) INFRASTRUCTURE	Excellent – Poor Whole country covered by Telkom telecomunications and other networks. TCP/IP-based computer networks supportable throughout nearly the entire country – again with the exception of informal settlement areas.			Excellent – Poor Gauteng CBD exceeds Cape Town by far in size and commercial activity. Supported by denser IT network.
4. INSTITUTIONAL CONTEXT	Municipality in transformation	Provincial Administration of the Western Cape (PAUWC) (developed by consultants)	Research and development University of New Castle & ODA	Municipality in transformation University of Nottingham
5. GOVERNMENT STABILITY	All levels of government undergoing major restructuring throughout the country.			
6. GOVERNMENT STRUCTURE	The government structured into a national level, nine provinces, four metropolitan councils and over 500 local authorities. The national level consists of 26 departments. Each of the metropolitan councils contains several sub-structures. In addition, there are over 30 parastatal and statutory authorities.			

CRITERIA	CAPE TOWN CITY COUNCIL (SOUTH AFRICA)	PROLAND (SOUTH AFRICA)	NAPIER (SOUTH AFRICA)	GAUTENG MUNICIPALITY (SOUTH AFRICA)
7. MAIN APPLICATIONS	Applications restricted to building a detailed cadastral for formal settlement areas. Very little engineering infrastructure data has been captured for the whole CMR, including the formal settlement areas.	Demand estimates calculated chiefly on the basis of 1995 low income housing data. Model can incorporate formal housing demand estimates.	A GIS for housing plan database creation and maintenance - designed specifically to incorporate transformations to low-income housing.	Applied for production of formal area cadastre. Applied to a limited extent in informal settlement areas.
8. PERCEIVED BENEFITS OF GIS	Data sharing, improved access to information, time saver			In addition to automated mapping functionality can provide solutions to spatial planning problems via query building utilities.
9. PERCEIVED PROBLEMS OF GIS	Organizational issues prevent data sharing			1) Integration of MapInfo with main system 2) Cadastral approach neither sustainable nor practical
10. SCALES OF PHOTOGRAPHY USED FOR MAPPING OR KEY SCALES OF MAP OUTPUTS	1: 10000, 1: 3000 aerial photography			1:2500 aerial photography
11. SELECTED SYSTEM SOFTWARE	Main system: GENAMAP Other software used: MapInfo, Intergraph, Microstation, customized packages		ARC/INFO	ARC/INFO, MAPINFO
12. SUSTAINABILITY OF SYSTEM	Unsustainable in the majority of the engineering and planning branches.			Sustainability in various branches dependent on support from LIS.

CRITERIA	CAPE TOWN CITY COUNCIL (SOUTH AFRICA)	PROLAND (SOUTH AFRICA)	NAPIER (SOUTH AFRICA)	GAUTENG MUNICIPALITY (SOUTH AFRICA)
13. INITIATORS OF SYSTEM	Survey and Land Information branch of the Planning Department		University of New Castle	Municipality of Gauteng and the university of Nottingham
14. GIS NEEDS OF INFORMAL SETTLEMENT COMMUNITY	A GIS / LIS capable of: 1) Assisting in the provision of shelter and basic infrastructural services 2) Speeding up access to the various funding structures available for financing upgrading interventions 3) Carrying out upgrading policy analyses in order to encourage changes in the CMR constitution with a view to facilitating the security of tenure in informal settlement areas.			A GIS / LIS capable of speeding up: 1) The land transfer and registration processes 2) access to the various funding structures available for financing upgrading interventions
15. GIS NEEDS ADDRESSED BY SYSTEM	Essentially addresses the cadastral base mapping needs of the Survey and Land Information Branch. Very little other needs are met within or outside the Cape Town City Council.	The system addresses only the long- term needs of: 1) the Provincial Administration of the Western Cape (PAUWC) mass housing delivery scheme and 2) the tourism industry in the CMR. The model constraints are	Addresses only one of the aspects of informal settlement upgrading - a housing plan database for recording building transformations.	No hard copy evidence to date to local level work. Interviewees indicated local level work had been initiated. Paper by Whitehead (1997) reveals a cadastral approach still favoured. Map outputs from the system suggest that the system is currently only functioning at the
16. IMPLEMENTATION	Cadastral approach followed. System remains grossly underutilized.	No details on the success of implementation available. Model development completed in 1997.	No details on the success of implementation available.	The system initially followed a purely cadastral approach and has been found to be constantly out of date. The municipality has realized the need for using lower mapping accuracies in informal settlement areas.
17. ORGANIZATIONAL ISSUES	Essentially a single department system implemented by the Survey and Land Information branch of the Planning Department			Multi-department approach followed when the new LIS/GIS introduced. LIS branch has two primary responsibilities: 1) providing GIS project support service and to a lesser extent 2) maintaining a detailed cadaster.
18. ENVIRONMENTAL / PHYSICAL CHARACTERISTICS	Informal settlements in Ikapa subject to flooding and fires.			Sinkholes and flooding

CRITERIA	CAPE TOWN CITY COUNCIL (SOUTH AFRICA)	PROLAND (SOUTH AFRICA)	NAPIER (SOUTH AFRICA)	GAUTENG MUNICIPALITY (SOUTH AFRICA)
25. GENERIC ISSUES	Four types of housing typologies require the attention of upgrading programmes. These are: 1) backyard shacks, 2) freestanding shacks, 3) serviced sites and 4) hostels.			
26. COVERAGE OF ANALYSIS	Cape Town Municipal Region			Gauteng municipal region
27. EXTENT OF GIS DIFFUSION	In South Africa, GIS is used widely at the national, provincial and metropolitan levels, and at the local level in the formal settlement areas. A recent mandate was issued by the Cabinet to the Reconstruction and Development Programme Ministry in the Office of the President to submit a proposal for the alignment of GIS for development planning at a national level in South Africa. Currently there is no structured relationship between a large number of GIS systems which have developed within the government.			Previously applied in Gauteng and Kwazulu-Natal region in voter's registration process.
28. LENGTH OF EXPERIENCE		Model development completed in 1997.	Model development completed in 1995.	15 years
29. REFERENCES	Martinez & Abbott (1997)			Interviewes and Whitehead (1997, unpublished)

CRITERIA	CAPE TOWN CITY COUNCIL (SOUTH AFRICA)	PROLAND (SOUTH AFRICA)	NAPIER (SOUTH AFRICA)	GAUTENG MUNICIPALITY (SOUTH AFRICA)
30. CONCLUSIONS	• Needs to : 1) Shift away from a purely cadastral driven approach to GIS implementation. 2) Incorporate applications for the informal settlement into the GIS • **Local example of a failed cadastral approach in a developing country. (supports hypothesis 1)**	• Weaknesses: no community input; dependant on the permanency of politically defined substructure boundaries; no local level applicability	No consideration of strategic level processes. The model is highly focused on addressing local detailed housing planning issues. Other local level issues such as the provision of engineering infrastructure services not considered.	• Leading the way with respect to the development of GIS-based informal settlement applications in the South African metropolitan council environment. • Strategic level of the database needs to be further developed. Also the development local level informal settlement databases needs to take place. In addition, there remains the potential for extracting more information from the Gauteng Upgrading Programme application form. • **Example of a failed cadastral approach (supports hypothesis 1).**

APPENDIX 3 TABLE 1 SUMMARY OF INFORMATION ON GIS SYSTEMS IN DEVELOPING COUNTRIES CONTINUED:

CRITERIA	PHILIPPINES	CITY OF LODZ (POLAND)	CITY OF GDANSK (POLAND)	(SSMS) PHASE I JAMAICA
1. DIGITAL DATA AVAILABILITY	No digital data was available. Satellite imagery was scanned at 5000 dpi by a consultancy (KIBERSO) collaborating with PADCO.	No digital data available	No digital data available. Cadastral maps were being converted by the municipal government.	No digital data available.
2. HARD COPY DATA AVAILABILITY	No hard copies of land use, or basic infrastructure maps were available. One of the aims of the GIS was to generate land use maps.	Land registers are inaccurate and out of date. Topographic map series at 1: 50 000, 1: 500000 and 1: 10 000 planned.	Available for the Vovoida (county). Map series produced and maintained by WODGIK. 1: 10 000, 1: 2000 and 1: 5000.	Hard copy of attribute type records acquired from: Ministry of Construction (Housing), National Housing Trust, National Water Commission, Bank of Jamaica, etc.

CRITERIA	PHILIPPINES	CITY OF LODZ (POLAND)	CITY OF GDANSK (POLAND)	(SSMS) PHASE I JAMAICA
3. LEVEL OF INFORMATION TECHNOLOGY (IT) INFRASTRUCTURE		Good: Polish Academic and Research Network (NASK) and fiber optics cable of the Polish Cable Television Co. exist.		Poor
4. INSTITUTIONAL CONTEXT	The City Planning and Development Offices (CPDOs) of the following four cities in the Phillipines: Cebu, Naga, Lipa and Davao.	Surveyor General	Municipality	Planning Institute of Jamaica (PIOJ)
5. GOVERNMENT STABILITY	Poor	History of invasions and 40 years of communist rule. The result has been a splintered land registration system.		Politically volatile
6. GOVERNMENT STRUCTURE		Consists of a municipal level (Gmina) and of a county level (Voivoda).		
7. MAIN APPLICATIONS	Land use and zoning analyses, mapping of major roads and road maintence, voting analyses, health analyses and tax mapping	Development of a cadastral LIS	Proposed applications for: land disposition, issue of permits of development, city planning procedures, infrastructure management, management and maintenance of the GIS/LIS database	Monitoring system for shelter sector. Calculation of medium household income.
8. PERCEIVED BENEFITS OF GIS	A land use base map and for the first time, an objective means of gauging urban expansion and development in these cities of the Phillipines.	Modernization of LIS	An effective implementation model would be extremely valuable as many municipalities currently implement systems independently with modest success.	Mobilization of private sector investments.

CRITERIA	PHILIPPINES	CITY OF LODZ (POLAND)	CITY OF GDANSK (POLAND)	(SSMS) PHASE I JAMAICA
9. PERCEIVED PROBLEMS OF GIS	Unrealistic data collection and classification schemes, inaccurate maps and plans, technological constraints, poor inter-department co-ordination and attitude problems.	Implementation of PC Arc/Info was found to be problematic and inadequate. A series of technical and organizational problems.	Still to be identified by PADCO.	Availability , quality and frequency of required data. Deficiencies were identified in the model during the first phase of the SSMS project These related to the inability to apply the of the system in the informal sector and the lack of spatial referencing of the data. This led to modifications to the approach which were incorporated into the second phase of the SSMS.
10. SCALES OF PHOTOGRAPHY USED FOR MAPPING OR KEY SCALES OF MAP OUTPUTS	2.4 m KVR Satellite data at scales of 1: 25 000 and 1: 5000, and 1: 25 000 10/20 m SPOT imagery data were used.	1: 500, 1: 2000, 1: 5000, 1: 10 000 and 1: 25 000		Not applicable. SSMS (I) did not incorporate spatially referenced data.
11. SELECTED SYSTEM SOFTWARE	ARC/CAD 11.4 and Arcview 1 in Cebu and ,IDRISI version 4.1 in Lipa	Pc Arc/Info	AutoCad 11, Cadraster, ArcInfo 6.1, Intergraph (MGE, MGA) and Microstation were used . A DBMS was identified as essential to acquire.	A series of macro-driven worksheets based on Lotus 3.1.
12. SUSTAINABILITY OF SYSTEM	Unsustainable if unsupported by PADCO.	Not sustainable. Four years after the the system was initiated, the Surveyor General was forced to request an external review of the general LIS plan for the Lodz pilot project	Institutional and organisational modifications, training and additions to staff required for sustainability.	Unsustainable. System overtaken by SSMS (II)
13. INITIATORS OF SYSTEM	PADCO, initiated by USAID funding	APLIKOM 2001 (Lodz), NEOKART GIS Ltd (Warsaw), SWEDSWEDEN, CFD	PADCO	Planning Institute of Jamaica, USAID and PADCO

CRITERIA	PHILIPPINES	CITY OF LODZ (POLAND)	CITY OF GDANSK (POLAND)	(SSMS) PHASE I JAMAICA
19. LAND TENURE ISSUES	No regularisation of land tenure. Relocation and resettlement policies still applied by the State in informal settlement areas.	Security of tenure exists in informal settlement areas.		Security of tenure not granted in informal settlement areas.
20. DATABASE STRUCTURE	Main coverages include: land use zones, roads and squatter association points.	Parcels, buildings and surface infrastructre, land use classes, water bodies, streams, utilities	The database is structured into graphics and textual database components. The graphics is comprised of : detailed planning zones, infrastructure, building footprints, street easements, hydrology, parcel boundaries, imagery and geodetic grid control.	The database is structured for utilizing short term and long term shelter indicators.
21. DATABASE CONTENT	Squatter association: id, control number, district, occupants; Land use zone : areas, perimeter, code, id, density class.	Buildings, parcels and land management records	Cadastral, deed, permit, planning record and administrative decisions, and building registration data.	Indicators are defined for: Service delivery, Access to affordable shelter Resource mobilization, and Baseline population and Economic data.
22. REQUIREMENTS OF DATABASE MODEL	Land use map	Definition of parcel boundaries.	Definition of parcel boundaries and detailed attribute records.	Requires a lot of attribute record information.
23. LEVEL OF APPLICATION	Strategic level Regional city maps are produced	Was supposed to be applied at the local and regional levels, but the system failed due to a purely cadastral approach.	Local level in short term. To be implemented at a national level in the long term.	

CRITERIA	PHILIPPINES	CITY OF LODZ (POLAND)	CITY OF GDANSK (POLAND)	(SSMS) PHASE I JAMAICA
14. GIS NEEDS OF INFORMAL SETTLEMENT COMMUNITY	Shelter and basic infrastructural services	A LIS / GIS is required to speed up the land registration and transfer processes.		Access to affordable shelter and delivery of basic services.
15. GIS NEEDS ADDRESSED BY SYSTEM	Land use, road , voting and tax mapping. The system is designed for addressing the strategic planning needs of the state.	The Surveyor General's need for a detailed cadastral database.		Caters for the needs of housing sector agencies requiring data and national level of governement planning needs. The system provides a means of tracking the performance of of the Jamaican shelter sector and provides a database resource.
16. IMPLEMENTATION	Local government staff are used to input data into the system.	A cadastral approach has been followed.		Implementation of the system revealed its ineffectiveness to dealing with housing problems at hand.
17. ORGANIZATIONAL ISSUES	There is poor coordination amongst the various CPDOs. GIS training and activities to illustrate the benefits of data co-ordination amongst departments was undertaken by PADCO.	The development of the system has been driven by a LIS department alone.		Organizational requirements include: 1) an institutional feedback mechanism, 2) relationships between PIOJ and data consolidation centers to be strengthened, and 3) a permanent housing data analyst
18. ENVIRONMENTAL / PHYSICAL CHARACTERISTICS	Flooding, earthquakes, typhoons			

CRITERIA	PHILIPPINES	CITY OF LODZ (POLAND)	CITY OF GDANSK (POLAND)	(SSMS) PHASE I JAMAICA
24. BASIC SPATIAL UNIT	Land use classification zones and squatter association points	Parcel	Parcel	
25. GENERIC ISSUES	Housing typologies mapped: 1) high density shanties, 2) medium density shanties, 3) high density residential and 4) medium density residential			
26. COVERAGE OF ANALYSIS	Four cities of Phillipines: Cebu, Lipa, Davao and Naga	City of Lodz Surveyor General's LIS	City of Gdansk Municipality	
27. EXTENT OF GIS DIFFUSION	GIS diffusion restricted largely to PADCO-based initiatives. The diffusion of GIS has been accelerated by a mandate issued in 1994 which devolved the authority of approving land use maps prepared by cities from a national to local and provincial government levels.	Diffusion has been accelerated through the LIS Modernization Program (1991). This programme advocated that LIS modernization should be implemented at the regional level using existing (though updated) information as a system base / " obligatory module".	Only starting to be implemented in municipalities.	Poor
28. GEOGRAPHIC SPREAD	Limited	Poor		Poor

CRITERIA	PHILIPPINES	CITY OF LODZ (POLAND)	CITY OF GDANSK (POLAND)	(SSMS) PHASE I JAMAICA
29. LENGTH OF EXPERIENCE	None	No previous GIS experience. GIS was introduced in 1994.	No previous GIS experience at time of report (1994)	No previous experience in GIS.
30. COUNTRY CRITERIA	Limited information infrastructure technology and financial resources	Widespread reform associated with the decline of the communist party. Complex land related problems facing POLAND and impeding important elements of reform such as privatization.		Politically unstable
31. REFERENCES	PADCO (1994a, 1994b) Rabely, P. (1995)	PADCO (1994 d)	PADCO (1994c)	PADCO (1992)
32. CONCLUSIONS	Risk assessment applications have yet to be developed.	**Another example of a failed cadastral approach in a developing country.(supports hypothesis 1)**	**No community participation input / detailed socio-economic survey..**	

CRITERIA	PHILIPPINES	CITY OF LODZ (POLAND)	CITY OF GDANSK (POLAND)	(SSMS) PHASE I JAMAICA
33. COMMENTS	• Importance of the co-ordination of information between different city planning departments stressed (hyp:4) • Environmental applications placed last in the list of key applications for development (see section 7.11).		• Supports **hypothesis 4** (that a multi-department approach is more appropriate than a single-department approach) • Suggests that the alignment of GIS at a national level is not unfeasible if a developing country if there is a suitable IS infrastructure. • Public/Private sector collaboration potentials illustrated	

APPENDIX 3 TABLE 2 INDICATORS SELECTED FOR THE FIRST PHASE OF THE SSMS PROGRAM (PADCO, 1992).

SHORT-TERM SHELTER SECTOR INDICATORS

1) SERVICE DELIVERY:
No. of residential water connections; No. residential electrical connections; Infrastructure expenditure/capita
2) ACCESS TO AFFORDABLE SHELTER:
Households per Dwelling unit; Housing production; House Price to income ratio; Investment in housing (public, private, informal); Construction costs
3) RESOURCE MOBILIZATION:
No. of mortgage loans; Credit to value ratio; Housing credit portfolio
4) BASELINE POPULATION AND ECONOMIC DATA:
Total population, Population growth rates, No. households, Annual median income, Import share in construction

HG-013 INDICATORS:
No. mortgage Loans made Affordable to Low-Income groups
No. of households reached by National Water Commission (NWC) Minor Water Schemes
No. of Leaks detected by NWC
No. of Repairs Effected by NWC
No. of Water Connections for Non-Titled Houses
No. of Sewer Connections for Non-Titled Houses
No. of Sites Serviced by Off Site Water Delivery Systems

LONG-TERM SHELTER SECTOR INDICATORS:

CATAGORY I INDICATORS:
1) SERVICE DELIVERY:
% residential water connections; % housing units with sewer connections; % residential electrical connections; No. of new property titles issued; Infrastructure expenditure/capita
2) ACCESS TO AFFORDABLE SHELTER:
Households per Dwelling unit; Persons per room; Housing production; House Price to income ratio; Loan to value ratio; Percentage of loans approved below the median income; Construction costs; No. of serviced lots

3) RESOURCE MOBILIZATION:
Savings-residential, Investment in housing, No. of mortgage loans; No. home improvement/extension loans; Residential water payments; Residential electrical payments; Housing credit portfolio
4) BASELINE POPULATION AND ECONOMIC DATA:
Total population, Population growth rates, No. of households, Capital formation, Gross domestic savings; Annual domestic inflation, Annual median household income

CATAGORY II INDICATORS:
5) SERVICE DELIVERY:
Unaccounted for water; Unaccounted for electricity; % of sewage receiving secondary treatment
6) ACCESS TO AFFORDABLE SHELTER:
Housing production-informal sector; Owner occupancy rate; Permanent housing structures
7) HG-013 INDICATORS : as for short-term implementation

APPENDIX 3 FIGURE 1 HOUSING TYPOLOGIES FOR MONTEGO BAY (SOURCE: PADCO, 1993A: 33)

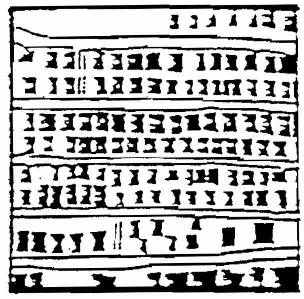
TYPE 1

Informal, high density housing on steep slopes.

TYPE 2

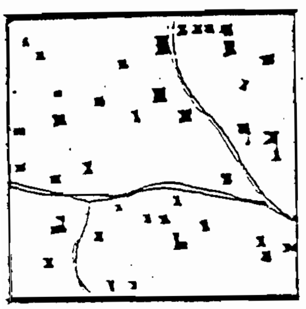
Informal, high density housing with basic road access

TYPE 3



Traditional, inner city, high density housing

TYPE 4

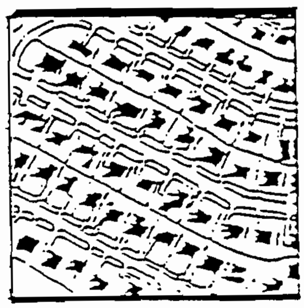


Informal, semi-rural, low density housing

TYPE 5

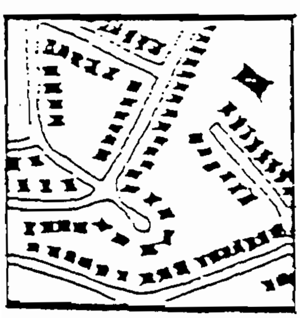
Formal, inner city, multi-family housing in mixed use areas

TYPE 6



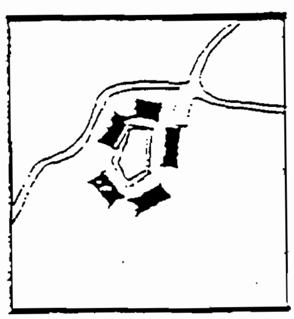
Formal, individual housing units in subdivided areas

TYPE 7



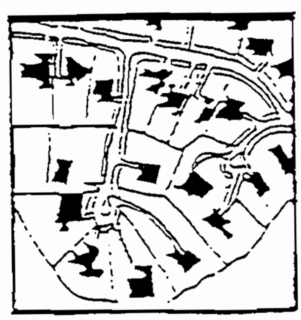
Formal public sector housing projects.

TYPE 8



Formal apartment buildings and row houses

TYPE 9



Formal villas, low density housing

APPENDIX 3 FIGURE 2 PROBLEMS ASSOCIATED WITH ADOPTING A CADASTRAL APPROACH TO GIS IN INFORMAL SETTLEMENT AREAS.

Explanatory note: For the majority of the informal settlement areas cadastral boundaries do not exist (see the areas surrounded by large circles below). Where cadastral boundaries do exist, the housing structures do not conform to these boundaries (see small circles below). The shacks often overlap two or three land parcels. In addition, there are often two shacks within a single parcel. Such problems bring into question both the usefulness and the practicality of attaching the socio-economic data associated with families in these areas to parcel boundaries or parcel boundary centroids.

APPENDIX 4

APPENDIX 4 TABLE 1 Maps, internal reports and other unpublished documents examined during the analysis of the ViSP methodology (Sources: URBEL / AVSI)

1. Villa Nosso Snhr. Dos Passos: Plano geral de drenagem (1:1000)
2. Villa Nosso Snhr. Dos Passos: Planta geral de intervencoes geotecnicas
3. Villa Nosso Snhr. Dos Passos: Projeto urbanistico (1:1000)
4. Villa Nosso Snhr. Dos Passos: Cadastro das redes (4 x 1:500 plantas)
5. Politica Habitacional Para Municipio de Belo Horizonte (1994), 16p
6. Plano Municipal de Habitacao Popular II Profavela - Legislacao do Programa de Regularizacao de favelas - comentario geral (1987), 77p
7. Conselho Municipal de Habitacao Resolucao No.III, Politica de Financiamento para Programmas de Habitacao Popular (1995)
8. Forum de Habitacao orcamento participativo (1996), 15p
9. Vila Tiradentes - Distribuicao da Terra por Familia Residente
10. Plano Urbanistico Global - Vila Sao Tomas, Belo Horizonte - Orcamento Parcipativo, 24p
11. Social Report on Snhr.dos Passos, 36p
12. Programa Alvorada diagnostics and proposal, 76p
13. Diario Obra - Vila Ventosa
14. Projetos de esgoto sanitarios em SE-4 drenagem pluvial, 37p
15. Projetos de Urbanizacao - Villa Snhr. dos Passos, 20p
16. Projetos de Urbanizacao - Villa Snhr. dos Passos, (data), 28p

APPENDIX 4 TABLE 2 Data dictionary of the sample data files acquired for the Alvorada Programme.

FILE NAME	DESCRIPTION
	FOLDER: VISP
VEN_DOMI	Original database for Ventosa Villa. Contains 135 data columns and 1436 records.
VENTBASE	Cadastral map of Ventosa. Contains 29544 records. Respective table holds only identification number for geocoding. The entire favela is shown with reference to the photo mosaic grid.
VENT_DOM	2076 records, 24 columns - Derived from VEN_DOMI (?)
VEN_DADO	2076 records, 24 columns
VEN_DOM_UR	This file holds 1437 records. Some additional data columns (not in VEN_DOMI) which hold information on infrastructure and construction materials are present (ie. Ptesgoto, Ptluz, PtAqua, SintIfra, Ptparede, Ptcorbertu, SintEdfi)
VEN_D_MP	Nothing new - deletable
DOMI_SIN	Infrastrustural data present. Synthesis data present. No map present.
DOMICI	Replicate of VEN_DOMI - check
DOMIDBF	24 meaningless fields
DOMI_DBF	24 meaningless fields
LOTE-DBF	Unable to open.
LOTE-MAP	Replicate of SRP_LOTE
NUCLEO	Unable to open.
REGIONAL	Unable to open.
SRP_D_D1	Data attributes as found in domi file description. Some additional meaningless columns present.
SRP_L_DB	Nossa Senhor dos Passos data file. Meaningless - 629 data records in a table of 25 unspecified fields.
SRP_D_DB	Same map as SRP_DOMI. File contains 24 (unspecified) fields and an id and a link column.
SRP_DOMI	A map of Vila Nossa Senhor dos Passos. Table only has id numbers.
SRP_LOTE	Map of SRP lots. Table has untitled columns.
	FOLDER: VISP1
BAMBLINE	Road network for the Bambline favela. Street names and house numbers are present in table. Holds 1032 records and from-to numbers for the left and right hand sides of the roads. The data set to illustrate. Bambline map may be labelled with the street addresses.
BETIM_G	Another street labelling example. This time the road network is more linear and the street names are present in the dataset. The streets may be easily labelled.
BETIM_NO	Street names and house number ranges per side of street.
BETIMAU	Holds additional attributes not recorded for VENTOSA. 1188 records. The additional columns relate to infrastructural data. (ie. cod_bai, telefone, redeagua etc. , detailed items which have been captured for certain roads in the vila.))
BETIM_G1	Has detailed infrastructural data for 2 Betim streets. Betim_G may be a derivative of this table.
CENSO	Avenue, code, road number. Census locations labelled in map file.
DOMICI01	1026 records - a detailed table. The favela to which this data relates is unknown at this stage.

APPENDIX 4 TABLE 3 The components of a four phase upgrading project designed in the Alvorada Program.

1. Preliminary research

- Preliminary social action group meeting
- Identification of permanent residents
- Preliminary topographic and research tasks
- Conclusion of preliminary research

2. Preliminary surveys, formulation of guidelines and urban plan

- Topographic land survey and cadastral research
- Social economic and environmental research
- Preliminary geotechnical and geological surveys
- Surveys of levels of service, problems and potentials
- Survey of guidelines and of other projects and organizations in the area
- Integrated diagnostics and program of necessities
- Formulation of action guidelines
- Social action group presents integrated diagnostics and action guidelines
- Integrated studies of alternative solutions and viabilities
- Definition of project breakdown and preliminary urban plan
- Social action group presents project breakdown and preliminary urban plan

3. Planning processes

- Final evaluation of urban plan
- Identification of public spaces
- Cadastre of remanagement, relocation, renovations
- Land surveys for roadways and drainage
- Geotechnical consolidation
- Water and sanitation networks
- Recognition of solid residuals (rubbel)
- General urbanization plan
- Preliminary construction plan
- Social action group presents general urban plan
- Planning of access and roadways
- Delimitation of public areas
- Land disappropriation process for opening of public spaces and resettlement areas
- Studies and projects for land parceling
- Approval of parcelling and registration procedures
- Elaboration of contracts, writings and registration

4. Implementation processes involving the provision of infrastructure

- Pavement project
- Drainage and canalization project
- Urban architecture project for reassessment areas
- Sanitation network project
- Water supply network
- Geotechnical consolidation
- Manual of technical specifications
- Construction plan
- Plan of quantities and prices
- Time plan
- Social action preceding commencement of construction
- Construction
- Social action accompanying construction
- Social action with special groups
- Follow up

APPENDIX 4 TABLE 4 Organisations that have contributed to the development of the Alvorada Programme GIS database.

- **AVSI** (Associazione Volontari per il Servizio Internazionale / Voluntary Association for International Service)
- **CAD 126** (Cartografia e Servicos Informatizados para o Planejamento Urbano / Cartography and Computerized Systems for Urban Planning
- **CEMIG** Companhia Energetica de Minas Gerais / Minas Gerais Power Company
- **CODESC** (Instituto de Cooperacao e Desenvolvimento Social / Social Development Cooperation Institute)
- **COPASA** (Companhia de Saneamento de Minas Gerais / Minas Gerais Sanitation Company)
- **DIAGONAL** (Diagonal Consultores Associados / Diagonal Associated Consultants)
- **PMMG** (Policia Militar do Estado de Minas Gerais / State of Minas Gerais Military Police)
- **PRODABEL** (Companhia de Processamento de Dados do Municipio de Belo Horizonte / Belo Horizonte Data Processing Company)
- **PUC** (Pontificia Universidade Catolica / Pontifical Catholic University)
- **SETAS** (Secretaria de Estado do Trabalho e Acao Social / State Department of Labour and Social Welfare)
- **SMC** (Sociedade Mineira de Cultura / Society of the State of Minas Gerais for Culture)
- **URBEL** (Companhia Urbanizadora de Belo Horizonte / Belo Horizonte Urbanization Company)

APPENDIX 4 TABLE 5 The hardware and software configuration of the ViSP approach in Kenya

(Summarized from Nieminen, 1996: Appendix 2: Basic equipment list for the ViSP approach)

COMPUTER SYSTEM
- PC/AT compatible microcomputer with ISA/VL-bus (VLB)
- Power supply: 200W, 110-240 V automatic switching
- CPU: 486DX2/66Mhz (clock doubling)
- Cache 128 KB
- Memory 16 MB RAM
- Hard disk: 1 GB IDE disk
- Floppy disk: 1.44 MB 3.5" and 1.2 MB 5.25"
- Microsoft mouse
- System software: MS-DOS 6.2 and Windows 3.1

GRAPHICS:
- Windows accelerator, VLB with 2 MB VRAM

DISPLAY:
- 17" MULTISYNCH, NON-INTERLACED, REFRESH RATE 72 Hz, colour display,
- CD-ROM: double speed, multisession XA, PhotoCD drive
- TAPE DRIVE: 250 MB compressed, ¼", QIC (eg. Colorado Jumbo)
- UPS: 600 VA capacity

INPUT DEVICES:
- Silde Scanner: 35 mm 24-bits colour scanner, resolution 2700 dpi, such as Nikon CoolScan, and supported by chosen software, such as TNTMIPS
- Photographic camera: single lens reflex 35 mm automatic camera, w/ automatic film winding and good quality 35-50 mm lens
- Flatbed scanner: A4-size 24-bits/pixel colour scanner, resolution, 300 dpi minimum and supported by chosen software such as TNTMIPS
- Digitizing table: A0-size, high resolution digitizing table with 16-button cursor, stand and supported by chosen software such as AutoCAD, TNTMIPS, ATLAS*GIS and MapInfo

OUTPUT DEVICES
- Printer: A4-size, inkjet colour printer, 300 dpi resolution, eg. HP Paint Jet XL 300 or DeskJet 1200C / w 6 MB RAM, and supported by chosen software, such as Auto CAD, TNTMIPS, Atlas*GIS and MapInfo
- Plotter: A0-size, multipen plotter, supported by chosen software

SOFTWARE
- Digitizing/Designing: AutoCAD 12 for Windows with extensions to digitize colour images on screen
- Image Processing: TNT-MIPS 5.0 or later
- Desktop mapping/GIS: ATLAS GIS for Windows
- Standard tools: Database management system, other software word processing (Word Perfect, Word), spreadsheets (Excel, Quattro) and utilities (PC-Tools, Norton)

APPENDIX 4 TABLE 6 The structure of the attribute database developed for the favela Ventosa in the Alvorada Programme.

		DOMICI.DBF				
	1	REGIONAL	Numérico	1		
	2	MODALIDADE	Numérico	1		
	3	CODNUCLEO	Caracter	8		código do núcleo
	4	SETOR	Caracter	2		identificador do lote
	5	QUADRA	Caracter	4		identificador do lote
	6	LOTE	Caracter	4		identificador do lote
	7	NUMDOMIC	Numerico	2		número do domicílio
	8	NUMSELCAD	Numerico	5		número do selo cadastral (por vila - núcleo)
	9	FRACIDEAL	Numerico	1		fração ideal
	10	ENDPROV	Caracter	40		endereço provisório
	11	ENDDEFIN	Caracter	40		endereço definitivo
	12	ENTREVIST	Caracter	40		nome do entrevistado
	13	SITIND	Numerico	1		situação do entrevistado na família
20		SITINDESP	Caracter			especificação (situação do entrevistado na família)
	14	USODOM	Numerico	1		igual ao uso do lote
	15	USODOMESP	Caracter	25		especificação do uso
	16	AREA	Numerico	8	2	aréa ocupada, em metros quadrados
	17	REGOCBF	Numerico	1		regime de ocupação da benfeitoria
20		REGOCBFESP	Caracter			esp. de outro regime de ocupação da benfeitoria
	18	PROPBF	Caracter	40		proprietário da benfeitoria
	19	TPOCPANO	Numerico	2		tempo de ocupação (em anos)
	20	TPOCPMES	Numerico	2		tempo de ocupação (em meses)
	21	COMPTMOCP	Caracter	5		comprovante do tempo de ocupação
20		COMPTMESP	Caracter			especif. de outro comprovante do tempo de ocupação
	22	PROPOUTIM	Numerico	1		propriedade de outros imóveis
	23	TOTTEST	Numerico	1		total de testemunhas
40		TEST1,2,3...	Caracter			nome da testemunha número 01
40		TESTEND1,2,3..	Caracter			endereço da testemunha número 01
	24	QUANTIM	Numerico	1		quantidade de outros imóveis
25		REGIMESP1,2,3...	Caracter			especificação de outro regime de outro imóvel
25		TPIMESP1,2,3...	Caracter			especificação de outro tipo de outro imóvel
40		ENDIM1,2,3..	Caracter			endereço do outro imóvel 01 (+ tipo, loc, regoc)
	25	NUMCOM	Numerico	2		número de cômodos
	26	MATPA1PC	Numerico	3		percentual de alvenaria no item paredes
	27	MATPA1EST	Numerico	1		estado de conservação de alvenaria no item paredes
	28	MATPA2PC	Numerico	3		percentual de adobe no item paredes
	29	MATPA2EST	Numerico	1		estado de conservação de adobe no item paredes
	30	MATPA3PC	Numerico	3		percentual de tábua/lona/latão no item paredes
	31	MATPA3EST	Numerico	1		estado de conservação de tábua/lona/latão no item paredes
20		MATPAOUTES	Caracter			especificação de outro material no item paredes
	32	MATPA4PC	Numerico	3		percentual de (outro) no item paredes
	33	MATPA4EST	Numerico	1		estado de conservação de (outro) no item paredes
	34	MATCO1PC	Numerico	3		percentual de telha cerâmica no item cobertura
	35	MATCO1EST	Numerico	1		estado de conservação de telha cerâmica no item cobertura
	36	MATCO2PC	Numerico	3		percentual de laje no item cobertura
	37	MATCO2EST	Numerico	1		estado de conservação de laje no item cobertura
	38	MATCO3PC	Numerico	3		percentual de telha amianto no item cobertura
	39	MATCO3EST	Numerico	1		estado de conservação de telha amianto no item cobertura
	40	MATCO4PC	Numerico	3		percentual de telha metálica no item cobertura
	41	MATCO4EST	Numerico	1		estado de conservação de telha metácica no item cobertura
20		MATCOOUTES	Caracter			especificação de outro material no item cobertura
	42	MATCO5PC	Numerico	3		percentual de (outro) no item cobertura
	43	MATCO5EST	Numerico	1		estado de conservação de (outro) no item cobertura
	44	MATOBS	Caracter	60		observações - material de construção
	45	ESGOTO	Numerico	1		esgoto
20		ESGOTOESP	Caracter			especificação para outro tipo de esgoto
	46	LUZ	Numerico	1		luz
	47	AGUATP	Numerico	1		tipo de água
20		AGUATPESP	Caracter			especificação para outro tipo de água
	48	AGUAAC	Numerico	1		acondicionamento da água
20		AGUAACESP	Caracter			especificação para outro tipo de acondicion. de água
	49	LIXODEP	Numerico	1		lixo (deposição)
20		LIXODEPESP	Caracter			especificação para outro tipo de deposição de lixo
	50	SUINQT	Numerico	3		criação de animais: suínos: quantidade
	51	CAPRQT	Numerico	3		criação de animais: caprinos: quantidade
	52	EQUIQT	Numerico	3		criação de animais: equinos: quantidade
	53	GALIQT	Numerico	3		criação de animais: galináceos: quantidade
	54	DOMEQT	Numerico	3		criação de animais: domésticos: quantidade
15		ANIMAL1,2,3	Caracter			criação de animais: outros: especificação + quantidade
	55	NUMPES	Numerico	2		número de pessoas no domicílio
	56	FX0006M	Numerico	2		faixa de 00 a 06 anos: pessoas do sexo masculino
	57	FX0006F	Numerico	2		faixa de 00 a 06 anos: pessoas do sexo feminino
	58	FX0712M	Numerico	2		faixa de 07 a 12 anos: pessoas do sexo masculino
	59	FX0712F	Numerico	2		faixa de 07 a 12 anos: pessoas do sexo feminino
	60	FX1318M	Numerico	2		faixa de 13 a 18 anos: pessoas do sexo masculino
	61	FX1318F	Numerico	2		faixa de 13 a 18 anos: pessoas do sexo feminino
	62	FX1930M	Numerico	2		faixa de 19 a 30 anos: pessoas do sexo masculino
	63	FX1930F	Numerico	2		faixa de 19 a 30 anos: pessoas do sexo feminino
	64	FX3150M	Numerico	2		faixa de 31 a 50 anos: pessoas do sexo masculino
	65	FX3150F	Numerico	2		faixa de 31 a 50 anos: pessoas do sexo feminino
	66	FX50MAISM	Numerico	2		faixa de 50 a xx anos: pessoas do sexo masculino
	67	FX50MAISF	Numerico	2		faixa de 50 a xx anos: pessoas do sexo feminino
	68	R1NOME	Caracter	40		1o responsável: nome
	69	R1SEXO	Numerico	1		1o responsável: sexo
	70	R1IDADE	Numerico	2		1o responsável: idade
	71	R1NAC	Numerico	1		1o responsável: nacionalidade
20		R1NACESP	Caracter			1o responsável: especificação de outra nacionalidade
	72	R1SITIND	Numerico	1		1o responsável: situação do indivíduo na família
20		R1SITINDES	Caracter			1o responsável: especificação de outra situação

APPENDIX 4 TABLE 6 The structure of the attribute database developed for the favela Ventosa in the Alvorada Programme (continued).

20		R1ESTCIVES	Caracter			1o responsável: especificação de outro estado civil
	74	R1SITCIV	Numerico	1		1o responsável: situação civil (amigado?)
	75	R1PROF	Caracter	30		1o responsável: profissão
25		R1PROFOBS	Caracter			1o responsável: observação profissão
	76	R1SITOC	Numerico	1		1o responsável: situação ocupacional
20		R1SITOCESP	Caracter			1o responsável: especificação de outra sit. ocupacional
	77	R1RENDA	Numerico	11	2	1o responsável: renda
	78	R1FTOTRD	Caracter	4		1o responsável: fonte de outras rendas
25		R1FTOTRDES	Caracter			1o responsável: especificação de outra fonte de renda
	79	R1FTOTRDVR	Numerico	11	2	1o responsável: valor de outra renda
	80	R1ESCOLARI	Numerico	1		1o responsável: escolaridade
	81	R1SABEASS	Numerico	1		1o responsável: sabe assinar?
	82	R1NUMDOC	Caracter	20		1o responsável: número do documento
	83	R2NOME	Caracter	40		2o responsável: nome
	84	R2SEXO	Numerico	1		2o responsável: sexo
	85	R2IDADE	Numerico	2		2o responsável: idade
	86	R2NAC	Numerico	1		2o responsável: nacionalidade
20		R2NACESP	Caracter			2o responsável: especificação de outra nacionalidade
	87	R2SITIND	Numerico	1		2o responsável: situação do individuo na família
20		R2SITINDES	Caracter			2o responsável: especificação de outra situação
	88	R2ESTCIV	Numerico	1		2o responsável: estado civil
20		R2ESTCIVES	Caracter			2o responsável: especificação de outro estado civil
	89	R2SITCIV	Numerico	1		2o responsável: situação civil (amigado?)
	90	R2PROF	Caracter	30		2o responsável: profissão
25		R2PROFOBS	Caracter			2o responsável: observação profissão
	91	R2SITOC	Numerico	1		2o responsável: situação ocupacional
20		R2SITOCESP	Caracter			2o responsável: especificação de outra sit. ocupacional
	92	R2RENDA	Numerico	11	2	2o responsável: renda
	93	R2FTOTRD	Caracter	4		2o responsável: fonte de outras rendas
25		R2FTOTRDES	Caracter			2o responsável: especificação de outra fonte de renda
	94	R2FTOTRDVR	Numerico	11	2	2o responsável: valor de outra renda
	95	R2ESCOLARI	Numerico	1		2o responsável: escolaridade
	96	R2SABEASS	Numerico	1		2o responsável: sabe assinar?
	97	R2NUMDOC	Caracter	20		2o responsável: número do documento
	98	R3NOME	Caracter	40		3o responsável: nome
	99	R3SEXO	Numerico	1		3o responsável: sexo
	100	R3IDADE	Numerico	2		3o responsável: idade
	101	R3NAC	Numerico	1		3o responsável: nacionalidade
20		R3NACESP	Caracter			3o responsável: especificação de outra nacionalidade
	102	R3SITIND	Numerico	1		3o responsável: situação do individuo na família
20		R3SITINDES	Caracter			3o responsável: especificação de outra situação
	103	R3ESTCIV	Numerico	1		3o responsável: estado civil
20		R3ESTCIVES	Caracter			3o responsável: especificação de outro estado civil
	104	R3SITCIV	Numerico	1		3o responsável: situação civil (amigado?)
	105	R3PROF	Caracter	30		3o responsável: profissão
25		R3PROFOBS	Caracter			3o responsável: observação profissão
	106	R3SITOC	Numerico	1		3o responsável: situação ocupacional
20		R3SITOCESP	Caracter			3o responsável: especificação de outra sit. ocupacional
	107	R3RENDA	Numerico	11	2	3o responsável: renda
	108	R3FTOTRD	Caracter	4		3o responsável: fonte de outras rendas
25		R3FTOTRDES	Caracter			3o responsável: especificação de outra fonte de renda
	109	R3FTOTRDVR	Numerico	11	2	3o responsável: valor de outra renda
	110	R3ESCOLARI	Numerico	1		3o responsável: escolaridade
	111	R3SABEASS	Numerico	1		3o responsável: sabe assinar?
	112	R3NUMDOC	Caracter	20		3o responsável: número do documento
	113	REIVIND	Caracter	7		reivindicações de melhorias desejadas pelos moradores
30		REIVINDESP	Caracter			especificação de outra reivindicação
	114	INSTAJU	Caracter	4		que instituição ajuda a comunidade?
25		INSTAJUESP	Caracter			especificação de outra instituição que ajuda a comunidade
	115	PRTINS	Caracter	6		participa, frequenta alguma instituição?
25		PRTINS4ESP	Caracter			especificação de conselho
25		PRTINS5ESP	Caracter			especificação de outra instituição
40		LIDREF1	Caracter			liderança/referência número 01
40		LIDREF2	Caracter			liderança/referência número 02
40		NECES1	Caracter			necessidade do núcleo número 01
40		NECES2	Caracter			necessidade do núcleo número 02
40		NECES3	Caracter			necessidade do núcleo número 03
	116	SALMINVIG	Numerico	11	2	salário mínimo vigente
	117	PESQUIS	Caracter	40		pesquisador
	118	DTPESQ	Data	8		data
	119	CHCAMPO	Caracter	40		chrefe de campo
	120	DTCHCAMPO	Data	8		data
	121	REVISOR	Caracter	40		revisor
	122	DTREVISOR	Data	8		data
	123	OBSPESQ	Caracter	100		observações do pesquisador
	124	OBSTECN	Caracter	100		observações do técnico
			Total	1131		
						Arquivos de indexação
Arquivo						Chave
domic1						regional(1), modalidade(1), codnucleo, numselcad(5)
domic2						regional(1), modalidade(1), codnucleo, quadra, lote, setor, numdomic(2)
domic3						regional(1), modalidade(1), codnucleo,quadra, numselcad(5)

APPENDIX 4 TABLE 7 The socio-economic and physical environment questionnaire developed as part of the Alvorada Programme methodology.

URBEL Companhia Urbanizadora de Belo Horizonte

Pesquisa Socio-Economica
Fisico-Ambiental

RONALDO DE PAULA BATISTA

REGIONAL	MODALIDADE	FRAÇÃO IDEAL	ALTERAR DIVISA	IDENTIFICAÇÃO	SELO CADASTR.
9	1	1 SIM / 2 NÃO	DESMEMBRAR / REMEMBRAMENTO	SETOR: 1; QUADRA PROVISORIA: 002; QUADRA DEFINITIVA; LOTE PROVISORIO: 0513; LOTE DEFINITIVO	011

N. DOMIC. LOTE	N. DO DOMIC.	N. SELOS CADASTRAIS DEMAIS DOMICÍLIOS DO LOTE
2	2	1185

NÚCLEO: APOLÔNIA - 021
APELIDO:

ENDEREÇO PROVISÓRIO: BECO SANTANA 50B
ENDEREÇO DEFINITIVO:

ENTREVISTADO: Graciema de Paula Batista e silva
SITUAÇÃO NA FAMÍLIA: 2
(1 CHEFE FAMÍLIA; 2 ESPOSO(A)/COMPA.; 3 FILHO(A); 4 PARENTE; 5 MORA SOZINHO(A); 6 AGREGADO(A); 7 OUTROS (ESPEC.))

I.) INFORMAÇÕES SOBRE O LOTE:

1.) USO DO LOTE

		ESPECIFIQUE
1	RESIDENCIAL UNIFAMILIAR	
X	RESIDENCIAL MULTIFAMILIAR	
3	COMERCIAL	
4	SERVIÇOS	
5	SERVIÇO USO COLETIVO	
6	INDUSTRIAL	
7	MISTO	
8	LOTE VAGO	
9	OUTROS	

2.) REGIME DE OCUPAÇÃO

PROPRIO	COM ESCRITURA	1
PROPRIO	SEM ESCRITURA	X
ALUGADO		3
CEDIDO		4
OUTROS		5

SE 5, ESPECIFIQUE

2.b.) DATA DE AQUISIÇÃO: 15 / 6 (ANOS / MESES)

2.c.) ÁREA DO LOTE

2.a.) PROPRIETÁRIO(S) DO LOTE

		MORA NA VILA SIM	MORA NA VILA NÃO	MORA NE... SIM
1.	Vicente Batista	X		X
2.	Ronaldo de Paula Batista	X		X
3.				
4.				
5.				

II.) INFORMAÇÕES DO DOMICILIO:

DADOS DE USO E OCUPAÇÃO: 1.) USO 1 Resid. unifamiliar (ESPECIFIQUE)
1.a.) ÁREA OCUP. (FRAÇÃO IDEAL)

2.) ACESSO AO DOMICÍLIO
- X DIRETO DA VIA
- 2 ATRAVÉS OUTRO TERRENO/EDIFICAÇÃO

2.a.) FORMA ACESSO
- X INDIVIDUAL
- 2 COLETIVO

3.) REGIME DE OCUPAÇÃO DA BENFEITORIA
- X PROPRIO
- 2 ALUGADO
- 3 CEDIDO
- 4 OUTROS

SE 4, ESPECIFIQUE

3.a.) CONDIÇÃO DA BENFEITORIA
- X CONCLUIDA/REFORMA SEM ACRÉ...
- 2 EM CONSTRUÇÃO
- 3 EM EXPANSÃO

3.b.) PROPRIETÁRIO(S) DA BENFEITORIA

		MORA NA VILA SIM	MORA NA VILA NÃO	MORA N... SIM
1.	Ronaldo de Paula Batista	X		X
2.				
3.				

4.) TEMPO DE OCUPAÇÃO: 6 / 11 (ANOS / MESES)

4.a.) COMPROVANTE DO TEMPO DE OCUPAÇÃO
- 1 CONTAS DE ÁGUA E/OU LUZ
- 2 NOTA FISCAL COM ENDEREÇO
- 3 RECIBO DE COMPRA E VENDA
- X TESTEMUNHAS
- X OUTROS

SE 5, ESPECIFIQUE: não tem

SE 4, ESPECIFIQUE NOMES TESTEMUNHAS	ENDEREÇO
Prudencio Miguel	Rua Santa Rita de Cássia 40?
Aristidor	Beco Fluela 93
José dos Reis	Beco Santana 25

8.) PROPRIEDADE DE OUTROS IMÓVEIS

- 1 SIM
- X NÃO

QUANTOS

I. TIPO DO IMÓVEL: 1. TERRENO/LOTE; 2. BARRACÃO/CASA; 3. LOJA COM./SALA; 4. APARTAMENTO; 5. CÔMODO(S)/CORTIÇO; 6. OUTROS (ESPEC.)

II. LOCALIZAÇÃO DO IMÓVEL: 1. MESMO LOTE; 2. MESMA VILA; 3. OUTRA VILA DA ...; 4. OUTRA CIDADE ...; 5. OUTRO ESTADO

III. REGIME DE OCUPAÇÃO: 1. ALUGADO; 2. CEDIDO; 3. ...; 4. VAGO; 5. ARRENDADO

NÚMERO DO RESPONS.	I	II	III	ENDEREÇO	ESPECIFICAÇÕES DEMAIS

APPENDIX 4 TABLE 7 The socio-economic and physical environment questionnaire (continued).

C.) CARACTERÍSTICAS FÍSICO-AMBIENTAIS DO DOMICÍLIO:

1.) CARACTERÍSTICAS DO IMÓVEL — NÚMERO DE CÔMODOS TOTAL : 7

A	RISCO	1 INUNDAÇÃO	2 DESLIZAMENTO	3 SOLAPAMENTO	4 MISTO (ESPEC.)	[X] 5 NÃO TEM	
B	PAREDES	[X] 1 ALVENARIA % 100	2 ADOBE %	3 TÁBUA/LONA/LATÃO %	4 OUTROS (ESPEC.) %		
C	COBERTURA	1 TELHA AMIANTO %	[X] 2 TELHA CERÂMICA % 40%	[X] 3 LAJE % 60%	4 TELHA METÁLICA %	5 OUTROS (ESPEC.) %	
D	FORRO	1 LAJE %	2 LAMBRI / ESTEIRA %	[X] 3 OUTROS (ESPEC.) % 100	[illegible]		
E	PISO	1 CERÂMICA %	2 TACO %	3 PEDRA %	[X] 4 CIMENTADO %	5 CHÃO BATIDO %	6 OUTROS (E %)
F	ESQUADRIA	1 MADEIRA %	[X] 2 TÁBUA % 100	3 FERRO %	4 ALUMÍNIO %	5 NÃO TEM %	6 OUTROS (E %)
G	REVESTIM. INTERNO	1 NÃO TEM %	[X] 2 REBOCADO/CHAPISC. % 100	3 PEDRA %	4 CERÂMICA %	5 OUTROS (ESPEC.) %	[X] C/ PINTU; S/ PINTU
H	REVESTIM. EXTERNO	1 NÃO TEM %	[X] 2 REBOCADO/CHAPISC. % 100	3 PEDRA %	4 CERÂMICA %	5 OUTROS (ESPEC.) %	[X] C/ PINTU; S/ PINTU

2.) CONDIÇÕES AMBIENTAIS

A	USO DO SANITÁRIO	[X] 1 INDIV. INTERNO/CONTÍGUO	2 INDIV. EXTERNO	3 COLETIVO	4 NÃO TEM		
B	ESGOTO	1 LIGADO À REDE OFICIAL	[X] 2 LIGADO À REDE NÃO OFIC.	3 LIGADO À GALERIA PLUVIAL	4 FOSSA	5 A CÉU-ABERTO	6 OUTROS (
C	CAIXA DE GORDURA	1 TEM	[X] 2 NÃO TEM				
D	FORNECIM. DE ÁGUA	1 CAVALETE	2 HIDRÔMETRO	[X] 3 BICO	4 NÃO TEM	5 OUTROS (ESPEC.)	
E	ACONDICION. DA ÁGUA	1 CX. D'ÁGUA COM TAMPA	2 CX. D'ÁGUA SEM TAMPA	3 TAMBOR	[X] 4 DIRETO DA REDE	5 OUTROS (ESPEC.)	
F	LUZ	1 PADRÃO	[X] 2 BICO	3 NÃO TEM			
G	DEPOSIÇÃO DE LIXO	[X] 1 COLETA OFICIAL	2 CAÇAMBA	3 VIA PÚBLICA	4 CURSOS D'ÁGUA	5 BOTA-FORA	6 QUEIMADO
		7 OUTROS (ESPEC.)	8 MISTO (ESPEC.)				
H	CRIAÇÃO ANIMAIS	1 SUÍNOS QUANT.	2 CAPRINOS QUANT.	3 EQUINOS QUANT.	4 GALINÁCEOS QUANT.	5 DOMÉSTICOS QUANT.	6 OUTROS QUANT.

OBSERVAÇÕES / ESTADO CONSERVAÇÃO / ESPECIFIQUE :

III.) ORGANIZAÇÃO COMUNITARIA:

1.) MORADORES REIVINDICAM MELHORIAS COMUNITÁRIAS ATRAVÉS DE

1	ASSOCIAÇÃO DE MORADORES
2	POLÍTICO CONHECIDO
3	PODER PÚBLICO
4	INSTITUIÇÃO RELIGIOSA
5	URBEL
[X] 6	NÃO REIVINDICA
7	NÃO SABE
8	OUTROS

SE 8, ESPECIFIQUE

2.) QUE INSTITUIÇÃO(ÕES) AJUDA(M) A COMUNIDADE

1	ASSOCIAÇÃO DE MORADORES
2	IGREJA
3	URBEL
4	NÃO SABE
[X] 5	NENHUMA
6	OUTROS

SE 6, ESPECIFIQUE

3.) PARTICIPA / FREQUENTA ALGUMA INSTITUIÇÃO ?

1	ASSOCIAÇÃO DE MORADORES	SE 1, ESPECIFIQUE "QUAIS"
[X] 2	INSTITUIÇÃO RELIGIOSA	
3	GRUPO DE JOVENS	
4	CONSELHOS (SAÚDE, TUTELAR, ETC)	SE 4, ESPECIFIQUE
5	OUTROS	
6	NÃO PARTICIPA / NÃO FREQUENTA	

SE 5, ESPECIFIQUE

IV.) GASTOS MENSAIS:

		VALOR (R$)
1	ALUGUEL	—
[X] 2	TRANSPORTE	25,20
[X] 3	ALIMENTAÇÃO	60,00
[X] 4	ÁGUA	1,33
[X] 5	LUZ	13,00
[X] 6	GÁS	5,00
7	SAÚDE	—
8	OUTROS	—

SE 8, ESPECIFIQUE

5.) CITE 3 NECESSIDADES DO NÚCLEO :

1	REDE DE ESGOTO / SANEAMENTO BÁSICO
[X] 2	ABASTECIMENTO DE ÁGUA
3	PAVIMENTAÇÃO DE RUAS E BECOS
4	ABERTURA / ALARGAMENTO DE RUAS, BECOS (ESCADARIAS E PAS
5	LIMPEZA URBANA / COLETA DE LIXO
6	POSTO POLICIAL / POLICIAMENTO
7	POSTO MÉDICO / ODONTOLÓGICO
8	CRECHE
[X] 9	ÁREA DE LAZER

APPENDIX 4 TABLE 7 The socio-economic and physical environment questionnaire (continued).

ARACTERIZAÇÃO SÓCIO–ECONÔMICA :

NÚMERO DE PESSOAS NO DOMICIL. : 5

	B	C				D	E	F	G	H	I	J	L
	SEXO	ESCOLARIDADE				NATURALIDADE	SITUAÇÃO INDIVÍDUO NA FAMÍLIA	ESTADO CIVIL	SITUAÇÃO CIVIL	SITUAÇÃO OCUPACIONAL	LOCAL DE TRABALHO	FONTE OUTRAS RENDAS	DOCUMENTO
		SÉRIE (I)	GRAU (II)	ESTUDA (III)	SABE ASSINAR (IV)								
...HER O COMPLE... ...MENTE ...S OCU... ...RES... ...IS PE... ...ICILIO	1) MASCULINO 2) FEMININO	1) 1 2) 2 3) 3 4) 4 5) 5 6) 6 7) 7 8) 8 9) NENHUMA	1) 1 2) 2 3) 1 SUPLETIVO 4) 2 SUPLETIVO 5) SUPERIOR OU MAIS 6) NENHUM	1) SIM 2) NÃO	1.) SIM 2) NÃO	1) MUNICÍPIO BH 2.) R.M.B.H. 3) ESTADO MG 4) SUDESTE 5) SUL 6) CENTRO-OESTE 7) NORTE 8.) NORDESTE 9) ESTRANGEIRO (SE 9, ESPEC.)	1.) CHEFE FAMÍLIA 2) ESPOSO(A)/COMPANHEIRO(A) 3) FILHO(A) 4.) PARENTE 5) AGREGADO(A) 6) OUTROS (SE 6, ESPEC.)	1.) SOLTEIRO(A) 2) CASADO(A) 3) VIUVO(A) 4.) DIVORCIADO(A) 5.) OUTROS (SE 5, ESPEC.)	AMIGADO ? 1) SIM 2) NÃO	1) EMPREG. C/ CART. ASSINADA 2) EMPREG. S/ CART. ASSINADA 3) EMPREGADOR/DONO ESTABELEC. 4.) CONTA PRÓPRIA/AUTÔNOMO 5) DESEMPREGADO 6) APOSENTADO 7.) AFAZERES DOMÉSTICOS 8) NÃO TRABALHA 9.) OUTROS (SE 9, ESPEC.)	1) MESMA VILA 2) MESMO BAIRRO 3) BAIRROS VIZINHOS 4) MUNICÍPIO BH 5) R.M.B.H 6) OUTROS MUNIC. MG 7) OUTRO ESTADO (SE 7, ESPEC.)	1.) PENSÃO 2.) ALUGUEL 3.) COMÉRCIO 4) OUTROS (SE 4, ESP.) *. ESPECIFICAR FONTE E VALOR DE OUTRAS RENDAS (R$)	*1. ESPECIFICAR ÓRGÃO/ESTADO EMISSOR *2. PREENCHER O DADO PARA TODOS OS OCUPANTES RESPONSÁVEIS PELO DOMICÍLIO

A	B	IDADE	C I	C II	C III	C IV	D	E	F	G	PROFISSÃO / OBSERVAÇÕES	H	I	RENDA VALOR (R$)	J ITEM	J VALOR (R$)	L
Ronaldo de Paula Batista	1	29	6	1	2	1	3	1	2	2	Pedreiro	4	4	300,00	–	–	M-5023807
[illegible] de Paula Batista	2	25	6	1	2	1	8	2	2	2	Do lar	7	–	–			–
[illegible] Aparecida da Silva	2	15	4	1	1	1	1	4	1	2	–	8	.				
[illegible] Batista da Silva	1	2	9	6	2	2	1	3	1	2	–	8					
[illegible] Paula Silva	1	4	9	6	2	2	1	3	1	2	–	8					

...AÇÕES GERAIS / ESPECIFICAÇÕES : – Depois que o Ronaldo casou, o terreno foi dividido em dois domicílios sendo um para sua mãe e outro para ele e sua esposa. Cada um ficou proprietário dos respectivos domicílios de onde moram.

...MÍNIMO VIGENTE : | SALÁRIO MÍNIMO (DOLAR) : | PESQUISADOR : DATA : | REVISOR : DATA :

APPENDIX 4 TABLE 8 Instructions for transferring the Gheo GIS database files to MapInfo.

gheo2.doc

Transferência de arquivos do GHEO para o MAPINFO.

1 - Carregar o GHEO - índice DB-GRAFICO

2 - interrogação DB ALFANUMÉRICA

. Executar uma query selecionando todos os elementos do geotipo do gheo para exportação no MAPINFO através do comando INT. DB ALFANUM. Ex.: select lote * from lote

3 - Estrai entitá ID

. DB GRAFICA - ESTRAI ENTITA - ID

. Gheo descarrega no DWG todas as entidades na mesma ordem do ID da tabela SQL correspondente (geotipo). Tirar o índice gráfico (cancela indice)

4 - sair do GHEO

5 - salvar as entidades estraidas (geotipos escolhidos) em um file DWG

6 - abrir o file DWG gravado e executar um PURGE ALL

7 - criar o correspondente DXF (para ser importado pelo MAPINFO)

8 - sair do Autocad e entrar em DQUERY

9 - executar a query como no punto 2 - conectar com o esquema onde estão os dados alfanuméricos.

ex.: select * from (nome da tabela do geotipo selecionado);

. dai se cria um report com todos os dados alfanuméricos do geotipo para importação no MAPINFO na mesma ordem dos elementos gráficos do DXF

. a query é salva usando F6 e escolhendo o formato DBF.

10 - sair do DQUERY

11 - antes de importar tudo (dbf e dxf) para o MAPINFO é preciso criar um campo (se já não existe) com um nome qualquer e com o ID em ordem crescente a partir do número 1, isto porque o ID da tabela SQL é progressivo mas não parte do número 1. Quando você importa o DXF no MAPINFO ele cria um ID a partir do número 1. Esta operação pode ser feita no EXCEL ou através do DBASE..

12 - o file DBF é importado para o EXCEL. Colocar um zero na primeira linha da coluna ID. Escrever na segunda linha da mesma coluna a fórmula (ex.: =B1+1 se a coluna for B). Copiar a fórmula dessa célula e colar a fórmula em todas as células da mesma coluna em todas as linhas com informações. Em fim aparece o número progressivo de 1 a N. No entanto, antes de salvar é preciso substituir a formula pelos valores. Copiar toda a coluna e dar o comando colar especial que permite substituir a fórmula pelos valores numéricos (opção valores). Salvar os dados em EXCEL IV ou Dbase III (a opção melhor é usar execel - XLS).

APPENDIX 4 TABLE 9 Listing of the attribute data types derived from the GBUILD.CFG configuration file of 7-3-1995.

A:

nucleus (nu)	Municipal (mn)	region (re)	name (na), (ap)
municipal code (cm)	Regional code (cr)	nucleus code (cn)	nucleus type (tn)
area (su)	Perimeter (pe)	population (po)	average density /ha (dm)
average lot size (m^2)	Gross medium lot (lb)	block code (cq)	public telephone (tp)
lot code (cl)	Use of lot (ul)	interviewee name ne)	number of levels (ed)
number of domiciles (nd)	No. of occupants (no)	occupation type (ro)	declivity level/band (fd)
equipment type (te)	Name (no)	road way code (cv)	segment code (tv)
road type (tv)	Road name (nv)	urban hierarchy (hu)	favela hierarchy (hf)
pavement (pv)	Conservation state(ec)	type of domain(tf)	service domain (ex)
type of course (tc)	No. of civil buildings (ne)	building type (te)	number of levels (na)
reformed (rf)	Risk (ri)	element type (te)	hole type (tp)
pole type (po)	Dead-end type (bo)	waste type (ti)	

B:

contour level (cot)			
water network code (wc)	Cadastral stamp (cs)	arrimo type (ta)	arrimo extension (ae)
tallus situation (ts)	Cod_rede_agua (cra)	raster (r)	type of infrastructure (ti)
date emplaced (dp)	Make (m)	type (t)	material (mat)
diameter (dia)	Prof_posa (pro)	poz (pozzetto)	slide (s)
allocation date (da)	Lunghezza (l)	num_sdopp (num)	note (n)
fitter (posa)	Pressure (press)	stato_man (sta)	consumption (con)

APPENDIX 4 TABLE 10 Listing of the levels with area centroids (unlabelled) and levels with points (p) and the attribute data associated with these centroids. The abbreviations refer to the above table.

Nucleus	*Mn, re, nu, na, cm, cr, cn, tn, su, pe, po, dm, lm, lb*
block	*Mn, re, nu, ap, cm, cr, cn, tn, su, pe, dm, lm, tp*
lot	*Mn, re, nu, ap, cm, cr, cn, tn, cq, cl, su, pe, ul, ne, ed, nd, no, ro*
declivity	*Mn, cm, fd,*
urban equipment	*Mn, re, nu, ap, tn, cm, cr, cn, te, su, no, r*
road structure	*Mn, re, nu, ap, tn, cm, cr, cn, cv, ct, tv, nv, hu, hf, pv, ec, r*
service domain	*Mn, re, nu, ap, tn, cm, cr, cn, tf, ex*
hydrology area	*Mn, re, nu, ap, tn, cm, cr, cn, tc, su, no*
building	*Mn, re, nu, ap, tn, cm, cr, cn, cq, cl, nv, ne, cv, ct, te, su, nd, na, ro, rf, ri, cra, r*
singular element	*Mn, re, nu, ap, tn, cm, cr, cn, te, su*
regions	*Mn, re, cm, cr, su, pe, po*
complementary elements (p)	*Mn, re, nu, ap, tn, cm, cr, cn, te, tp, po, bo*
single point elements (p)	*Mn, re, nu, ap, tn, cm, cr, cn, te, tl*
physical elements	*Mn, re, nu, ap,tn, cm, cr, cn, te, tl, ta, ae, ts*
contours	*Mn, re, cm, cr, cot*
single area elements	*Mn, re, nu, ap,tn, cm, cr, cn, te,su*
infrastructure	*Mn, re, nu, ap,tn, cm, cr, cn, nv, cv, ct, ti*
region	*Mn, re, cm, cr, su, pe*
hydrology line	*Mn, cm, tc, su, no*
water valve	*Cm, cr, cn, cd, cl, cv, nv, cra, dp, m, t, mat, dia, pro, poz, s, r*
derived water	*Cm, cr, cn, cd, cl, cv, nv, cra, pv, da, mat, dia, l, pro, num, s, n*
private	*Cm, cr, cn, cd, cl, s,r, n*
water network	*Cm, cr, cn, cd, cl, cv, nv, cra, pv, dp, posa, mat, l, dia, press, pro, sta, s*
water use	*Cm, cr, cn, cd, cl, cv, nv, cra, cs, con, s, r, n*

APPENDIX 4 TABLE 11 Standard scores allocated to various levels of urban infrastructure for the urban infrastructures and health services map (Source: Moura et al., 1993: 174)

Urban Infrastructures		**Urban Health**	
Paving:		Water Network:	
Earth	0	Present	1
Asphalt	1	Not present	0
cement, stone blocks, other	2	Sewage system:	
Electric Power:		Present	1
Present	1	Not present	0
Not present	0	Waste collection:	
Max score obtainable =	3	Not performed	0
		Individual	2
		Dust bins	1
		Street cleaning: (frequency)	
		Not performed	0
		3 or more times a week	3
		1 - 2 times a week	1or 2
		Max score obtainable =	7
Urban Infrastructures		**Urban Health**	
Good	3	Good	From 5 to 7
Medium	2	Medium	From 3 to 4
Low	0 or,1	Low	From 0 to 2

APPENDIX 4 TABLE 12 Matrix used to create the urban infrastructures and health map

	HEALTH			
INFRASTRUCTURES		Gh	Mh	Lh
	Gi	GiGh	GiMh	GiLh
	Mi	MiGh	MiMh	MiLh
	Li	LiGh	LiMh	LiLh

Good	=	Gi + Gh
Medium to good	=	Mi + Gh or Gi + Mh
Medium	=	Mi + Mh or Gi + Lh or Li + Gh
Low to medium	=	Mi + Lh or Li + Mh
Low	=	Li + Lh

APPENDIX 4 TABLE 13 Geotypes appearing in the Global plans produced in the ViSP approach

STRUCTURES & URBAN EQUIPMENT	PATHWAYS & BOUNDARIES	POINTS OF INTEREST & PROPOSALS	OTHER AREAS OF INTEREST
Commerce	Limit of vila	Convergence points	Renovation area due to risk
Service	Houses in risk area	Potential interest points	Probable renovation area
Leisure	Avenue	Relocation area	Maintenance area
Church	Vehicle roads	Proposed roads	
Final bus stop	Natural drainage	Ways linked to vehicle roads	
Public telephone	Access ways	Pavement	
Garbage depo	Contours	Renovated pavement	
Health center	Principle ways	Removable way	
	Secondary ways	Proposed drainage	
	Local ways		
	Stairs		

APPENDIX 5

APPENDIX 5 TABLE 1 The projection ellipsoid parameters used in the MGE project environments created for implementing the Bi-level Model in the Cape Town Metropolitan Region. (Source: Milford, 1997)

Co-ordinate System of South Africa

Ellipsoid of Reference

The ellipsoid used for the National Survey System is based upon the "Modified" Clarke 1880 spheroid. The fundamental parameters are:

Semi axis major   a = 6 378 249,145 326 metres

Semi axis minor   b = 6 356 514,966 721 metres

Eccentricity $e^2 = \frac{(a^2 - b^2)}{a^2} = 0{,}006\ 803\ \ 481\ 018\ 843$

Flattening $f = \frac{a - b}{a} = 1/\ 293{,}466\ 307\ 656$

Units of Length

A. South African Legal Measure

1 Cape foot	= 0,314 858 1 int. metres
	= 1,032 999 914 7 British feet
1 Cape rood	= 12 Cape feet

B. Units of the Geodetic Survey

1 South African Geodetic Foot (S. A. G. ft)	= 0,304 797 4 metres
1 British foot (B. ft)	= 1,000 008 101 58 S. A. G. ft
1 S. A. G. ft	= 0,999 991 898 49 B. ft
1 Geodetic Cape Foot	= 1,033 S. A. G. ft
	= 1,032 991 631 14 B. ft
	= 0,314 855 575 16 metres

APPENDIX 5 TABLE 2 Data dictionary of the digital cadastre data for formal settlement areas in Ikapa. This data was initially captured by the Survey and Land Information branch of the Cape Town City Council and was imported onto the UCT GIS.

boundaries	**3456a.bndr**	5	wall	Wall	L	40	7	10	3	0	0	0	655
			fence	Fence	L	24	7	11	1	0	4	0	656
ground	**3456a.grnd**	5	cont5	5m contours	L	35	3	5	4	1	0	0	737
			cont1	Other contours	L	35	3	5	6	0	0	0	738
			sptgr	Spot heights (ground)	P	43	3	35	6	0	0	0	739
			sptex	Spot heights (extra) 1:500	P	43	3	35	6	0	0	0	742
			sptbl	Spot heights (buildings)	P	43	3	35	4	0	0	0	740
			embank	Embankment	L	35	3	4	6	0	0	0	841
								4	6	0	2	0	
			rock	Rock, sand, quarry	L	36	3	23	6	0	1	0	843
	3456a.spgt	10	cont5	5m contour text	T	def	1						
			cont1	Other contour text	T	def	1						
			sptgr	Spot height (ground) text	T	def	1						7739
			sptex	Spot height (extra) text	T	def	1						7742
			sptbl	Spot height (building) text	T	def	1						7740
recreation	**3456a.recr**	5	sport	Sportsfield	L	37	4	10	2	0	5	0	985
			golf	Golf course	L	37	4	12	2	0	1	0	986
			stadiu	Stadium	L	29	4	10	13	0	2	0	987
			park	Park	L	29	4	12	2	0	1	0	988
harbour	**3456a.harb**	5	wharf	Wharf	L	def	1	10	3	0	3	0	90
			jetty	Jetty	L	def	1	10	4	0	2	0	91
			drydoc	Dry dock	L	def	1	10	5	0	2	0	92
			harbol	Bollard	P	38	1	M5					93
miscellany	**3456a.misc**	5	misc	Miscellaneous lines	L	def	1	10	6	0	1	0	783
													7783
			misc	Miscellaneous points	P	39	1	M1/M6-7/RZ/DG					83
			steps	Steps	L	def	1	10	0	0	0	0	190
			ramp	Ramp	L	def	1	10	16	0	0	0	191
			monume	Monument	L	def	1	10	0	0	1		792
			cemete	Cemetery	L	def	1	10	3	0	5	0	793
			pipes	Pipes, overhead walkway	L	def	1	7	3	2	0	0	3109
			pylon	Pylon	L	def	1	POWER					562
annotation	**3456a.annt**	10	buildi	Building text	T	def	1	LINE CODE					710
			vegeta	Vegetation text	T	def	1	LINE CODE					720
			water	Water text	T	def	1	LINE CODE					741
			substa	Sub-station text	T	def	1	LINE CODE					750
			recrea	Recreation text	T	def	1	?					790
			misc	Misc topo text	T	def	1	LINE CODE					767
	survey	5	no.	Town survey marks	P	41	1	N/A					N/A
			no.	Trig Beacon	P	42	1	N/A					N/A

APPENDIX 5 TABLE 2 (continued) Data dictionary of the digital cadastre data for formal settlement areas in Ikapa. This data was initially captured by the Survey and Land Information branch of the Cape Town City Council and was imported onto the UCT GIS.

			factry	Factory	L	20	1	10	9	0	2	0	118
			house	Houses	L	20	1	10	3	0	0	0	121
			buildi	Other buildings	L	20	1	10	13	0	2	0	122
			buildi										1122
			constr	Building under construction	L	20	1	10	3	2	1	0	124
			ruin	Ruin	L	41	1	10	3	2		0	125
			canopy	Canopy	L	def	1	10	4	0	1	0	127
			patio	Patio, pergola	L	41	1	10	238	0	0	0	128
			carprt	Car port	L	def	1	10	4	0		0	129
			utilit	Utility/service building	L	20	1	10	63	0	1	0	158
			bldiv	Building division	L	42	1	SAME & LINE 1					119
vegetation	3456a.vege	5	culti	Cultivated land, orchard	L	21	4	12	2	0	4	0	280
			culti										2280
			bush	Bush, hedge	L	21	4	12	2	0	5	0	281
			bush										2281
			trees	Trees	L	21	4	12	2	0	5	0	282
			trees										2282
			plant	Plantation	L	21	4	12	2	0	7	0	284
			plant										2284
			trees	Planted trees	P	40	4	TREE					220
transport	3456a.tran	5	rail	Railway	L	23	1	8	4	0	5	0	396
			road	Made roads	L	31	5	7	3	0	0	0	3100
			track	Tracks	L	42	1	7	3	1	4	0	3101
			foot	Footpath	L	41	1	17	3	0	2	0	3102
			bridge	Bridge	L	31	5	7	3	0	3	0	3104
			gravel	Gravel road, unmade road	L	42	1	7	3	0	0	0	3105
			access	Access road	L	41	1	7	3	0	3	0	3108
			pavmnt	Pavement	L	41	1	17	3	3	0	0	3103
			sheltr	Bus/rail shelter	L	31	1	10	63	0	1	0	183
			sheltr										189
			subway	Subway	L	31	1	10	32	0	0	0	3110
			platfm	Platform	L	40	1	10	48	0	0	0	1107
water	3456a.wate	5	coast	Coastline	L	22	60	9	1	1	0	0	444
			river	Furrow, river, spruit	L	25	60	6	1	1	0	0	445
			dam	Dam, lake	L	22	60	9	1	0	3	0	446
			dam										4446
			canal	Canal, culvert	L	32	60	7	3	1	0	0	447
			swipub	Swimming pool (public)	L	38	60	10	1	0	0	0	448
			swipri	Swimming pool (private)	L	38	60	10	1	0	0	0	449
			marsh	Marsh, seasonal water, vlei	L	33	60	12	1	0	5	0	250
			marsh										2250
			reserv	Reservoir	L	38	60	10	1	0	0	0	451
			wtank	Water tank	L	38	60	10	1	0	0	0	453
			fount	Fountain	L	38	60						

APPENDIX 5 TABLE 3 A listing of the vector data initially exported from the Cape Town City Council's GenaMap system to the Arc/Info GIS system at UCT. This list was produced using the DxfInfo Arc command.

ER NAME	ARCS	POINTS	TEXT	ATTRIB	INSERT	TEXT LEN	DEF COLOR	DEFAULT LINETYPE
CK	18552	0	0	0	0	0	0	
	27448	0	0	0	0	0	0	
_____6_LICONTI	4	0	0	0	0	0	0	
	3	0	0	0	0	0	0	
6800001_______	1	0	0	0	0	0	0	
OCK	1	0	0	0	0	0	0	
_1_	3	0	0	0	0	0	0	
AYERS	46012	0	0	0	0	0		

: |> dxfinfo gugtop.dxf <|

ER NAME	ARCS	POINTS	TEXT	ATTRIB	INSERT	TEXT LEN	DEF COLOR	DEFAULT LINETYPE
ACK	18195	0	0	0	0	0	0	
ILDI	918	0	0	0	0	0	0	
JSE	6315	0	0	0	0	0	0	
JDE	15	0	0	0	0	0	0	
IGI	13	0	0	0	0	0	0	
ATS	469	0	0	0	0	0	0	
BLD	1561	0	0	0	0	0	0	
HOOL	55	0	0	0	0	0	0	
BLIC	41	0	0	0	0	0	0	
CTRY	2	0	0	0	0	0	0	
CTORY	4	0	0	0	0	0	0	
NOPY	1	0	0	0	0	0	0	
OWN	3	0	0	0	0	0	0	
L	1	0	0	0	0	0	0	
N	6	0	0	0	0	0	0	
JSE_4	701	0	0	0	0	0	0	
NSTR_4	13	0	0	0	0	0	0	
ILDI_4	21	0	0	0	0	0	0	
NOPY_4	3	0	0	0	0	0	0	
BSTA_4	3	0	0	0	0	0	0	
BSTA	9	0	0	0	0	0	0	
NSTR	6	0	0	0	0	0	0	
TION	264	0	0	0	0	0	0	
AD	942	0	0	0	0	0	0	
ACK	94	0	0	0	0	0	0	
AD_4	1	0	0	0	0	0	0	
OT_4	1	0	0	0	0	0	0	
OT	28	0	0	0	0	0	0	
CESS	13	0	0	0	0	0	0	
IL	98	0	0	0	0	0	0	
IDGE	32	0	0	0	0	0	0	
ATFM	42	0	0	0	0	0	0	
L LAYERS	29870	0	0	0	0	0		

APPENDIX 5 TABLE 3 (continued) A listing of the vector data initially exported from the Cape Town City Council's GenaMap system to the Arc/Info GIS system at UCT. This list was produced using the DxfInfo Arc command.

Arc: |> dxfinfo gug2top.dxf <|

LAYER NAME	ARCS	POINTS	TEXT	ATTRIB	INSERT	TEXT LEN	DEF COLOR	DEFAULT LINETYPE
ROAD	147	0	0	0	0	0	0	
RAIL	25	0	0	0	0	0	0	
N_T_	1662	0	0	0	0	0	0	
ELEPOL	3	392	0	0	0	0	0	
TRANSF	2	0	0	0	0	0	0	
HOUSE	702	0	0	0	0	0	0	
OUTBLD	585	0	0	0	0	0	0	
SCHOOL	9	0	0	0	0	0	0	
BUILDI	363	0	0	0	0	0	0	
WALL	3542	4	0	0	0	0	0	
TRAN	18	0	0	0	0	0	0	
FENCE	365	1	0	0	0	0	0	
SUBSTA	1	0	0	0	0	0	0	
FLATS	11	0	0	0	0	0	0	
CONSTR	1	0	0	0	0	0	0	
ALL LAYERS	7436	397	0	0	0	0		

Arc: |> dxfinfo gug2vec.dxf <|

LAYER NAME	ARCS	POINTS	TEXT	ATTRIB	INSERT	TEXT LEN	DEF COLOR	DEFAULT LINETYPE
BLOCK	3833	0	0	0	0	0	0	
ERF	5359	0	0	0	0	0	0	
ALL LAYERS	9192	0	0	0	0	0		

APPENDIX 5 TABLE 4 A data dictionary and diagram of the only data available at a metropolitan-level on the Cape Town City Council's system.

ESCRIPTION	Name	P,L,A,T	Table	Capture	Verified	Date
rports	airf	p		y	L. Frost	
ise Text map	basetxt	t		y		
ravan park	caravan	p		y	L. Frost	25/4/95
metries	cemetery	p		y		
aces of Worship	churches	p	y	y		
vic centres	civic	p		y		
oast of beaches and rocky areas	coast	l		y		
onservation worthy areas	conserv	a		y		
agistrates courts	courts	p		y		
ieatres and Cinemas	entert	p		y		
D boundaries	esd91	p		y		
e Stations	firestn	p		y	L. Frost	
lls and community centres	halls	p		y		
otels	hotels	p		y	L. Frost	4/4/95
ommitted & Proposed Housing	housef	a		y		
veloped & informal Housing	housep	a		y		
dustrial Areas	indust	a		y		
aces of Interest	interest	p		y	L. Frost	3/5/95
o Hives	job-hives	p		y		
ltivated, Natural & Urban Land use	landall	a		y		
oraries	library	p		y	L. Frost	26/4/95
rrent municipality boundaries	local	a		p		
arkets	market	p		y		
edical facilities	medical	p	y	y		
w Metro Boundary	metrob	a		n		
inicipal offices	moffice	p		y	L. Frost	26/4/95
iseums	museums	p		y	L. Frost	26/4/95
ture reserves and gardens	nature	p		y		
tional Monuments	nlmonu	p		y		
lice Stations	police	p		y		
st Offices	posto	p		y		
oposed dams	propdam	a		y		
ilway Stations	railstn	p		y		
creational Centres	recre	p		y		
rrent RSC boundary	rsc	a		y		
oclaimed Scenic Roads	sceniroad	l		y		
ucational Facilities	schools	p	y	y		
ajor Shopping Centres	shops	p		y	L. Frost	28/4/95
orts facilities	sports	p		p		
nsus suburbs for 1991	sub91	a		y		
affic centres	traffic	p		y		
s and taxi ranks	transp	p		y		
ne frams and Co-op's	winefarm	p		y	L. Frost	3/5/95
ajor tourist attractions	tourist	p			L. Frost	

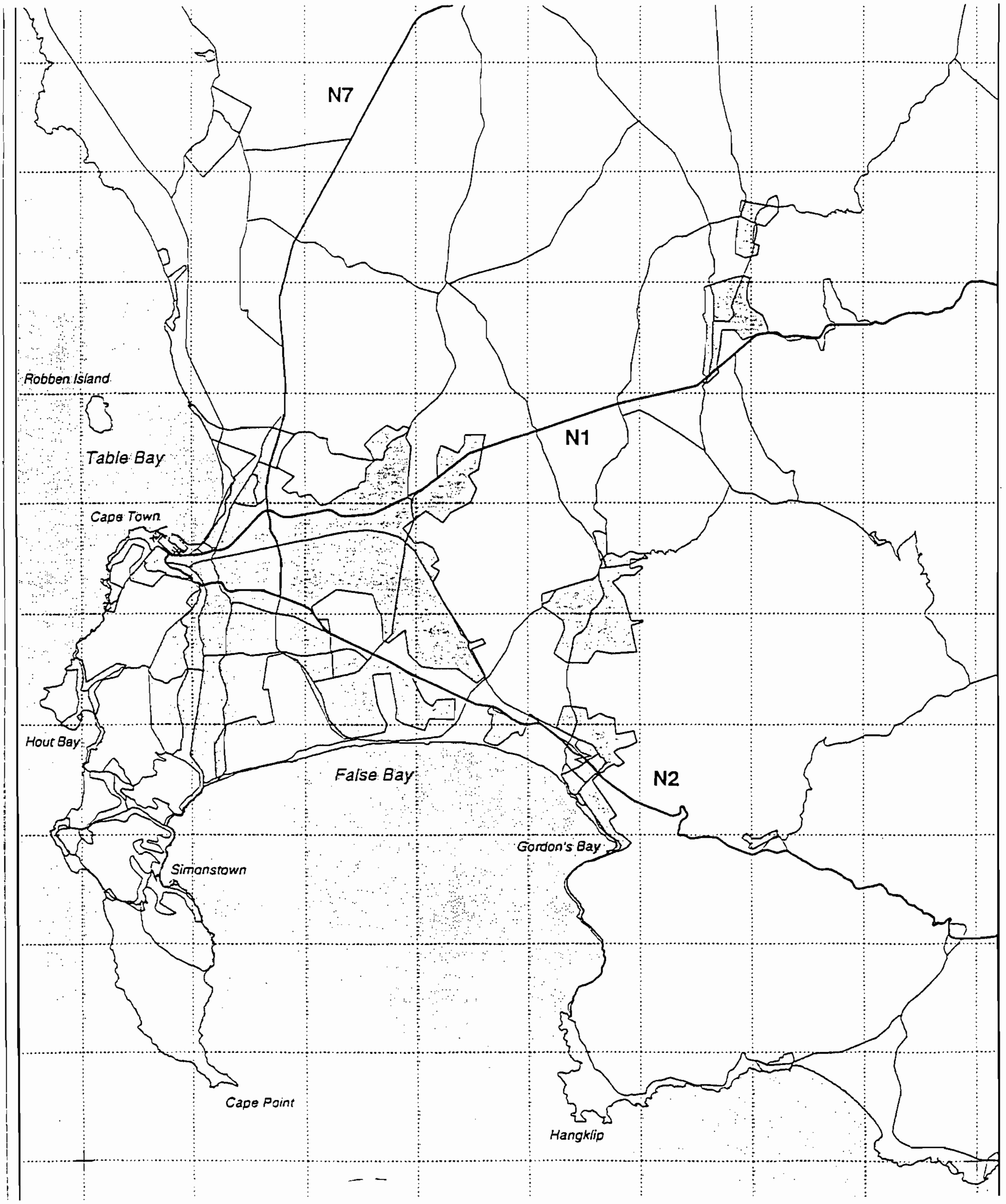
APPENDIX 5 TABLE 4 (continued) A data dictionary and diagram of the only data available at a metropolitan-level on the Cape Town City Council's system.

Aquifer							
Bulk electricity - Cape Town	blele			p			10
Bulk electricity - Eskom	eskom			p			
Bulk sewer catchment and process	blsewer			p			
Bulk solid waste sites				p			
Bulk storm water	blstorm			p			
Bulk water	blwater			p			
Dams	damsbal						
Geology							
Magisterial districts				y			10
Main roads				p			
Parks ??							

MAPS.XLS

Proposed roads				p			
Railway				p			
Rivers							
Soils							
Sports fields ??							3
Water catchment areas							
Wetlands							

APPENDIX 5 TABLE 4 (continued) A data dictionary and diagram of the only data available at a metropolitan-level on the Cape Town City Council's system.



APPENDIX 5 TABLE 5 Table of the 1: 20 000 December 1996 aerial images bearing informal settlements in the Cape Town Metropolitan Region. (Compiled: by Huchzemeyer, 1997)

Strip No.	Counter No.	Image No.	Inf. Settlements	Back Yard Shacks	Area	Description
1S	6333	3		X	Ocean View	Back yard shacks in Council housing
1N	6325	1	X		Hout Bay Ext. 15	Informal settlements behind Council housing
				X ?		Back yard shacks in Council housing
2	6375	9	X		Sunnydale - Kommetjie	Informal settlement next to serviced sites
2	6367	17	X		Imizamo Yethu, Hout Bay	Informal settlement next to serviced sites
3	6388	5	X		Redhill, Simons Town	Dispersed informal settlement under trees
4	6433	17	X		Raapekraal/ West-lake	Informal settlement next to Blue Route M3
5	7021	5	X		Vrygrond	Informal settlement South of Lavender Hill in the bush
			X		Lavender Hill /Steen-berg	Small informal settlement in Lavender Hill
				X	Lavender Hill /Steen-berg	Back yard shacks in Council housing in Lavender Hill
6	6568	5	X		Pelican Park	Small inf. Settlement next to Zeekoevlei Sec. School
				X	Grassy Park	Back yard shacks in Grassy Park
6	6572	7	X		Ottery	Small inf. Settlement on residential block south of Lansdown Rd, West of Jan Smuts, North of York street
6	6572	9		X	Hanover Park	Back yard shacks in Council housing
6	6574	11	X		Vygekraal	Vygekraal inf. Settlement next to Vygekraal Stadium
			X s		Langa	Inf. settlements in and around Langa
				X	Langa	Back yard shacks in Council housing & hostels
6	6577	14		X	Windemere	Back yard shacks in Council housing next to Wingfield
6	6580	17	X		Marconi Beam / Milnerton	Informal settlement next to Industrial Site and race course
6	6582	19	X		Du Noon	Small inf. Settlement between N7 & M5
			X		Welbeloond/The Stables	Larger inf. Settlement between N5 and railway line.
6	6585	22	X		Brick fields	Small inf. Settlement next to quarry
7	6964	7	X s		Phillipi South	SLP area - various inf settlements & sites and services
7	6962	9	X s		Guguletu	SLP area - various inf settlements
				X	Guguletu /Mannen-berg	Back yard shacks in Council housing
7	6960	11	X s		Guguletu (North)	SLP area- various inf. Settlements
				X	Guguletu	Back yard shacks in council housing
8	6666	3		X	Mitchells Plain	Back yard shacks or formal extensions
8	6664	5		X	Mitchells Plain	Back yard shacks or formal extensions

APPENDIX 5 TABLE 5 (continued) Table of the 1: 20 000 December 1996 aerial images bearing informal settlements in the Cape Town Metropolitan Region. (Compiled: by Huchzemeyer, 1997)

Strip No.	Counter No.	Image No.	Inf. Settle-ments	Back Yard Shacks	Area	Description
8	6662	7	X		Vanguard Drive	Informal settlements next to Vanguard Drive North of Westgate Mall
			X		Phillippi South	SLP Area - various informal settlements sites and services
				X	Mitchells Plain	Back yard shacks in Mitchells Plain
8	6660	9	X		Nyanga Old Crossroads	SLP Area - various informal settlements
				X	Nyanga	Back yard shacks in Council housing and hostels
8	6658	11	X		Airport North	Informal settlement corner Modderdam Rd & Stellenbosch Aterial Rd M12
				X	Bishops Lavis	back yard shacks in council housing Bishops Lavis
8	6656	13		X	Eureka, Adriaanse	Back yard shacks in Council housing
9	6975	5	X ?		Mitchells Plain, Tafelsig	Informal settlement with formal layout but no roads (sites and service underway)
				X	Mitchells Plain	Back yard shacks or formal extensions
9	6977	7	X		Site C	Peripheral informal settlement
			X		Driftsands	Peripheral informal settlement
			X		Site B	Interspersed & peripheral inf. settlements
9	6979	9	X		Lower Crossroads	Informal settlement (also Delft South serviced sites underway)
9	6981	11		X	Belhar	Back yard shacks in council housing
9	6983	13		X	Blanckenny	Back yard shacks east of Transnet Marshalling yard
			X?		Belhar	Inf. Settlement north of Belhar West of sewerage ponds
10	6862	5	X		Silvertown	Peripheral informal settlement in Khayelitsha
10	6860	7	X s		Site B	Peripheral and interspersed informal settlement
				X	Khayelitsha	Back yard shacks in Core ~~hsg.~~ area
10	6858	9	X		Mfuleni	Peripheral informal settlement
				X	Mfuleni	Back yard shacks in Council housing
10	6856	11	X		Blackheath Indus.	Informal settlement West of Black-heath Industrial
			X		Gersham	Informal settlement between Kuilsriver canal and R300 North of Stellenbosch M12
11	6827	5	X		East of Khayelitsha	Informal settlement off Macassar Rd East of Baden Powell Road
			Xs		Khayelitsha	Interspersed informal settlements
11	6829	7		X	Blue Downs	Back yard shacks in Blue Downs formal housing
11	6831	9	X		Kleinvlei, Blue Downs	Informal settlement South of Stadium (with rudimentory streets)
			X		Forest Heights, Blue downs	Informal settlement (small)

APPENDIX 5 TABLE 5 (continued) Table of the 1: 20 000 December 1996 aerial images bearing informal settlements in the Cape Town Metropolitan Region. (Compiled: by Huchzemeyer, 1997)

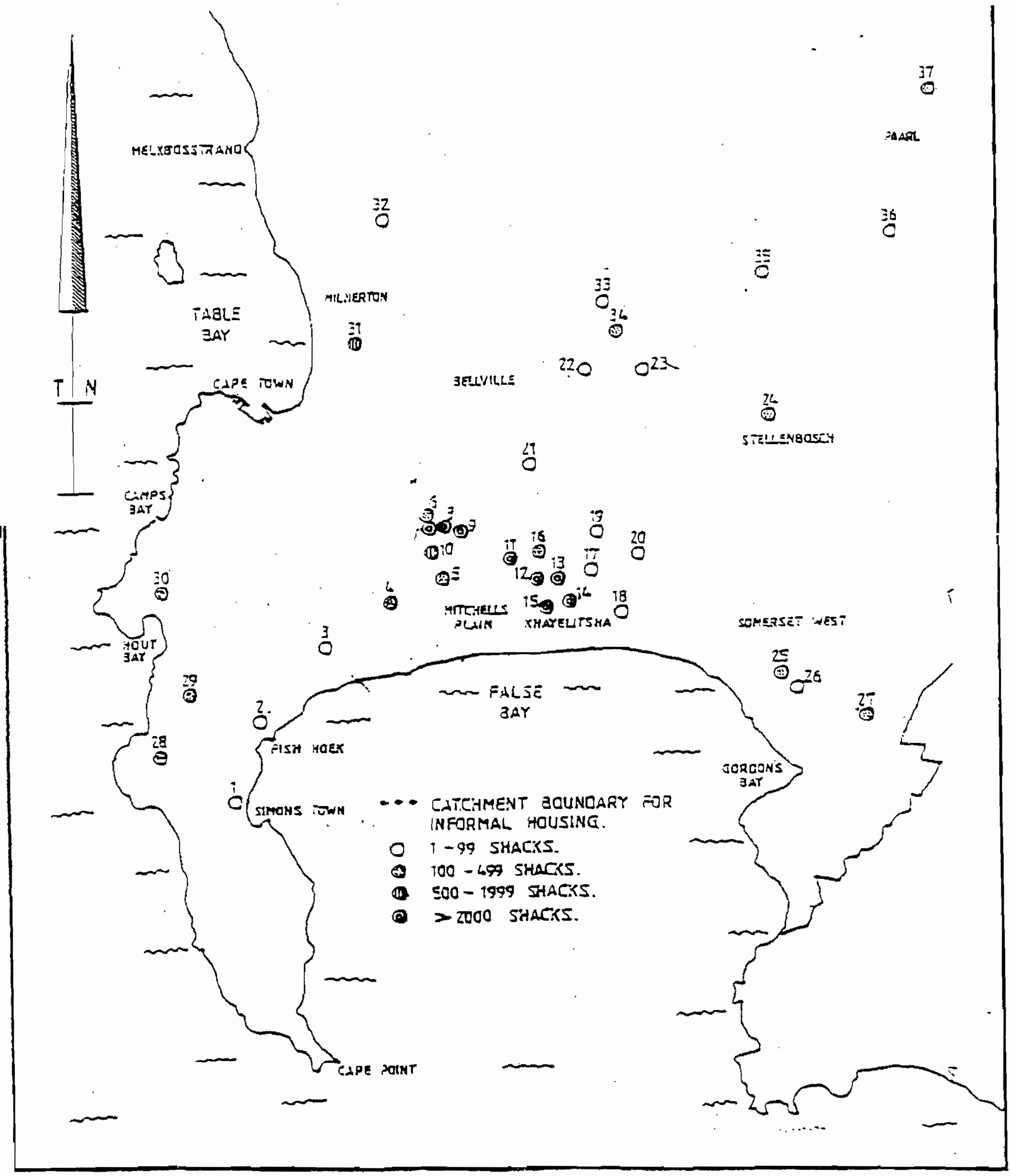
Strip No.	Counter No.	Image No.	Inf. Settle ments	Back yard shacks	Area	Description
11	6844	22	X		Fisantkraal	Informal settlement (on farm?) South of R312 east of Fisantkraal Railway Stat
12	6797	4	X		Macassar	Informal settlement next to formal area
12	6783	18		X	Macassar	Back yard shacks in formal housing
			X		Wallace Dean	Informal settlement next to serviced sites
15	6722	4	X		Bleookombos	Large informal settlement
				X	Scottsdene	Back yard shacks in Council housing
			X		Lwandle	Informal settlement in Lwandle hostels south of N2 off Broadlands road
15	6720	6	XX		Weltevrede	2 informal settlements in Weltevrede
				X	Weltevrede	Back yard shacks in Weltevrede
			X		Die Bos	Informal settlement between railway & tarred road north of Lavandle
16	6709	4	X		Sun City	Large informal settlement under trees, Sir Lowry's pass
28	6607	3	X		Welgemoed, Atlantis	Large informal settlement West of R304, north of John Dreyer Street

APPENDIX 6

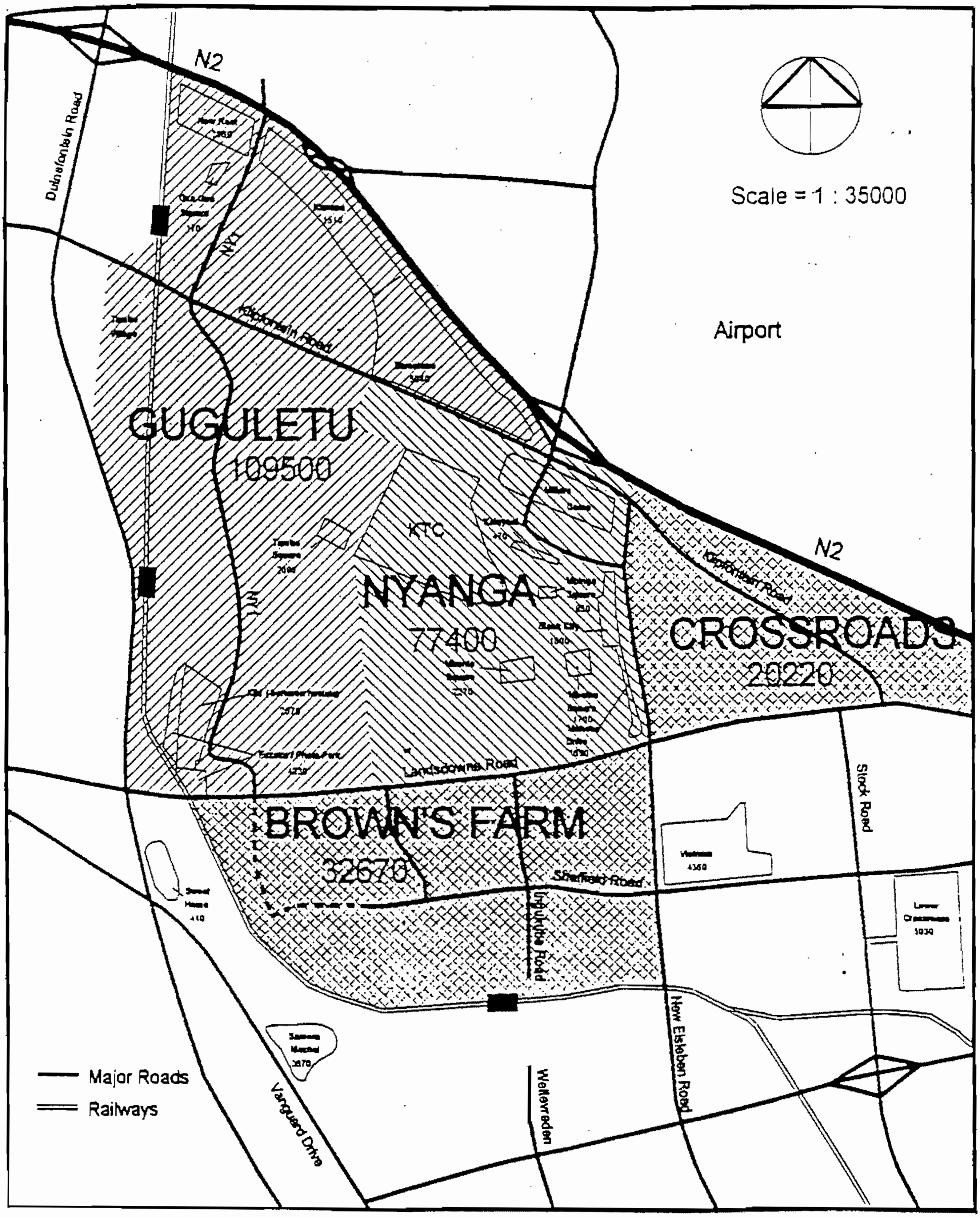
APPENDIX 6 TABLE 1 Squatter statistics of Cape Town Municipal Area as at 1994-06-24. (Source: City Council, 1994)

REST OF MUNICIPAL AREA	STRUC	FAMILIES		PEOPLE		M / ADULT		F / ADULT		U / 18	
		C	B	C	B	C	B	C	B	C	B
VRYGROND	535	439	242	1686	695	404	266	507	200	775	229
Aggregate Total		681		2381		670		707		1004	
Vygiekraal Stadium (Athlone)	66	72	18	224	38	62	18	70	14	92	6
Athlone	5	4	0	12	0	4	0	4	0	4	0
Diep River	1	1	0	1	0	0	0	1	0	0	0
Hanover Park	4	4	0	18	0	3	0	3	0	12	0
Hazendal	3	3	0	15	0	3	0	3	0	9	0
Maitland	2	2	0	4	0	2	0	2	0	0	0
Malay Quarter	13	25	0	58	0	22	0	21	0	15	0
Mitchells Plain	41	31	21	95	65	31	23	28	20	36	22
Area "L" Tafelsig MP	227	11	234	45	811	5	201	14	253	26	357
Ottery	1	1	0	4	0	1	0	1	0	2	0
Parkwood	1	1	0	5	0	1	0	1	0	3	0
Pelican Park	18	8	18	29	42	6	20	9	12	14	10
Philippi	3	4	0	18	0	4	0	4	0	10	0
Retreat	9	12	0	26	0	14	0	9	0	3	0
Rylands	24	25	0	74	0	31	0	27	0	16	0
Strandfontein	1	1	0	6	0	1	0	1	0	4	0
Woodstock	1	1	0	5	0	1	0	1	0	3	0
Zonnebloem	3	12	0	28	0	10	0	9	0	9	0
TOTAL - CCC Area (Excl. Vrygrond)	423	218	291	667	956	201	262	208	299	260	395
Aggregate Totals		509		1623		463		507		655	
GRAND TOTAL WITHIN CCC AREA	958	657	533	2353	1651	605	528	715	499	1033	624
AGGREGATE TOTALS		1190		4004		1133		1214		1657	

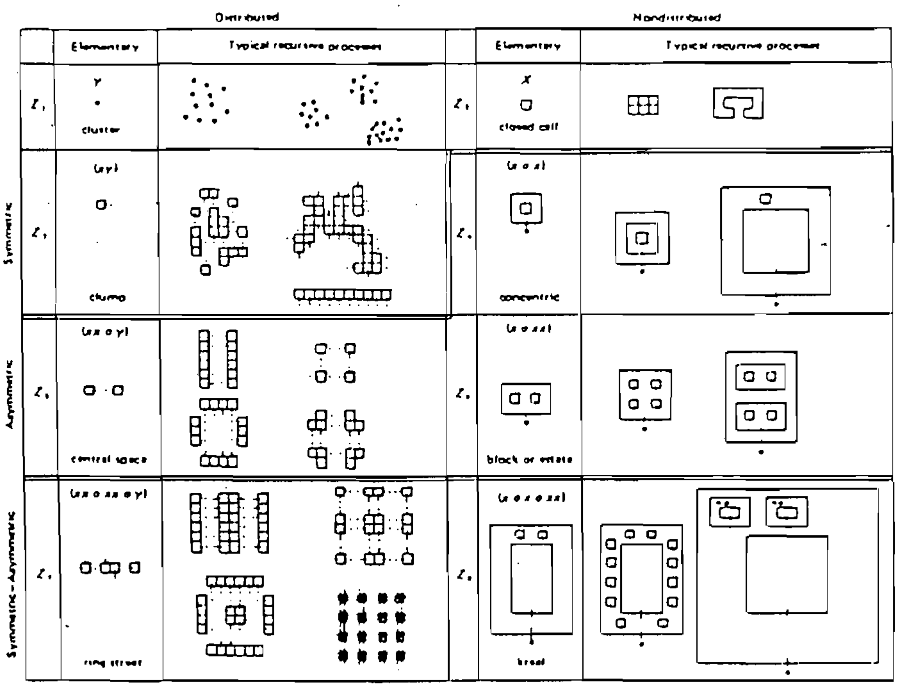
APPENDIX 6 FIGURE 1 Distribution of informal housing in metropolitan Cape Town. (Source: DeWar et al., 1991)



APPENDIX 6 FIGURE 2 Population study – Cape Metropolitan Region, locality map No.2. (Source: Van Zyl, 1995)



APPENDIX 6 FIGURE 3 Plan typologies. (Source: Hillier and Hanson, 1984: 78)



Appendix 6 Table 2 Results of the 1996 shack count for the Cape Town Metropolitan Region.

mslink	name	Area	Density	Shack	Total	Average	Total	Average
				Count	Counts	Density	Area	Density1
		(ha)	(shacks/ha)			(shacks/ha)	(ha)	(shacks/ha)
831	Airport	0.01	399	4				
833	Airport	0.1	117	15				
836	Airport	0.1	176	26				
838	Airport	0.1	134	12				
840	Airport	6.6	47	312	369	66	7.0	53
918	Antoniesbos	0.9	56	50	50	56	0.9	56
805	Barcelona	41.9	50	2105	2105	50	41.9	50
851	Bermuda	2.2	115	251				
860	Bermuda	3.3	136	448	699	129	5.5	128
821	Black City	0.9	201	180				
824	Black City	2.2	151	332	512	169	3.1	166
880	Blackheath / Happy Valley	1.1	4	4				
896	Blackheath / Happy Valley	0.4	102	38				
901	Blackheath / Happy Valley	7.6	1	11				
908	Blackheath / Happy Valley	12.4	7	85				
912	Blackheath / Happy Valley	4.0	7	28				
911	Blackheath / Happy Valley	0.1	172	24				
913	Blackheath / Happy Valley	9.7	43	414				
914	Blackheath / Happy Valley	2.0	52	105	709	45	37.255	19
928	Bloekombos	34.7	74	2555	2555	74	34.7	74
848	Bongweni - Ikwezi Park	0.3	214	71				
852	Bongweni - Ikwezi Park	11.5	126	1454	1525	130	11.9	129
837	Boy's Town	25.5	97	2475	2475	97	25.5	97
775	Brickfields	0.3	12	4				
779	Brickfields	2.6	11	28				
789	Brickfields	8.5	16	135	167	15	11.5	15
802	Browns Farm	83.1	51	4262				
822	Browns Farm	0.3	224	76				
826	Browns Farm	0.5	230	113				
823	Brown's Farm	3.8	176	674	5125	74	87.8	58
827	Crossroads	4.0	119	475				
835	Crossroads	10.1	87	878				
839	Crossroads	1.9	54	104	1457	95	16.0	91
938	De Bos	1.3	91	114	114	91	1.3	91
787	Du Noon	0.1	100	8				
790	Du Noon	1.4	70	100	108	72	1.5	72
924	Eastern Kayalitsha	1.6	33	53	53	33	1.6	33
923	Fisantkraal	0.8	89	72	72	89	0.8	89
877	Gersham / Kalkfontein	2.1	22	46				
882	Gersham / Kalkfontein	0.2	347	66				
883	Gersham / Kalkfontein	9.3	33	310				
888	Gersham / Kalkfontein	0.1	152	21				
891	Gersham / Kalkfontein	0.5	18	10				
898	Gersham / Kalkfontein	2.5	51	128				
916	Gersham / Kalkfontein	0.9	14	13				
917	Gersham / Kalkfontein	0.3	28	9	603	74	15.9	38
909	Green Point 1	15.7	100	1580				
910	Green Point 2	1.0	85	82	1662	100	16.7	100
	Gxa-Gxa	1.1	83	91	91	83	1.1	83
829	Heinz Park / Philippi South	2.9	71	207	207	71	2.9	71
752	Houtbay Ext 15 / Hangberg	5.3	38	203	203	38	5.3	38

Appendix 6 Table 2 Results of the 1996 shack count for the Cape Town Metropolitan Region.

mslink	name	Area	Density	Shack Count	Total Counts	Average Density	Total Area	Average Density1
		(ha)	(shacks/ha)			(shacks/ha)	(ha)	(shacks/ha)
753	Imizame Yetha	14.1	56	794	794	56	14.1	56
785	Joe Slovo Park	11.4	105	1195	1195	105	11.4	105
806	Kanana	19.1	45	868	868	45	19.1	45
841	Klipfontein Glebe	11.8	14	161				
842	Klipfontein Glebe	0.04	183	7				
843	Klipfontein Glebe	0.3	65	22				
845	Klipfontein Glebe	0.1	60	7				
846	Klipfontein Glebe	0.4	68	29				
847	Klipfontein Glebe	64.5	12	777	1003	17	77.2	13
804	KTC	11.5	131	1496				
809	KTC	6.1	108	660				
811	KTC	0.9	183	168	2324	128	18.5	126
765	Lavender / Steenberg	0.2	100	19	19	100	0.2	100
844	Lower Crossroads	10.5	81	853	853	81	10.5	81
933	Lwandle	4.2	80	338				
934	Lwandle	11.1	74	825				
935	Lwandle	1.1	27	31	1194	75	16.44	73
930	Macassar	3.1	85	266	266	85	3.12	85
825	Mahobe Drive	3.3	116	379	379	116	3.26	116
773	Marconi Beam	8.6	150	1291	1291	150	8.62	150
904	Mfuleni	31.0	46	1409	1409	46	30.95	46
818	Miller's Camp	3.4	141	478				
820	Miller's Camp	5.1	121	611	1089	130	8.45	129
859	Mitchell's Plain / Tafelsig	7.4	49	360	360	49	7.40	49
817	Mkonto Square	4.2	171	722	722	171	4.23	171
819	Mpetha Square	2.3	212	483	483	212	2.28	212
	Mpinga Square	0.8	299	239	239	299	0.8	299
788	Mpuku Park	0.6	247	149	149	247	0.60	247
799	New Rest	15.7	77	1214	1214	77	15.71	77
777	Ottery	0.1	140	7				
778	Ottery	0.3	120	36				
784	Ottery	0.1	120	6	49	123	0.400	123
	Palm Tree Settlement	0.2	245	49	49	245	0.200	245
781	Pelican Park	0.9	77	69	69	77	0.9	77
795	Phola Park / Fezeka	7.2	196	1408				
798	Phola Park / Fezeka	0.2	60	9	1417	195	7.3	193
757	Raape Kraal / West Lake	3.9	68	267	267	68	3.90	68
756	Redhill	42.5	3	113	113	3	42.45	3
800	Samora Machel	0.04	206	8				
803	Samora Machel	13.7	77	1056				
810	Samora Machel	0.1	36	5				
812	Samora Machel	0.4	69	25	1094	78	14.20	77
915	Silvertown	19.0	112	2138	2138	112	19.01	112
902	Site B North	1.4	136	191				
869	Site B North	1.2	117	138				
874	Site B North	0.5	65	35				
881	Site B North	5.2	85	443				
892	Site B North	0.7	119	81	888	103	9.01	99
849	Site C 1	0.6	125	70				
850	Site C 2	0.97	154	149				
853	Site C 3	0.8	32	26				

Appendix 6 Table 2 Results of the 1996 shack count for the Cape Town Metropolitan Region.

mslink	name	Area	Density	Shack	Total	Average	Total	Average
				Count	Counts	Density	Area	Density1
		(ha)	(shacks/ha)			(shacks/ha)	(ha)	(shacks/ha)
855	Site C 4	9.0	37	337				
861	Site C 5	9.4	162	1531	2113	139	20.78	102
919	Spandau	6.5	72	467	467	72	6.5	72
940	Sun City	12.6	36	454	454	36	12.57	36
755	Sunnydale / Kommetjie/ Mas	9.6	83	791	791	83	9.58	83
780	Sweet Home	0.1	131	8				
791	Sweet Home	0.1	198	18				
794	Sweet Home	4.0	73	294				
796	Sweet Home	0.02	274	5				
797	Sweet Home	1.0	59	59	384	81	5.20	74
801	Tambo Square	2.3	191	445	445	191	2.34	191
893	Trevor Vilakazi	2.6	167	437				
899	Trevor Vilakazi	0.1	182	22				
902	Trevor Vilakazi	1.4	133	191				
905	Trevor Vilakazi	3.5	105	366				
894	Trevor Vilakazi	6.8	107	723				
906	Trevor Vilakazi	0.9	158	146				
903	Trevor Vilakazi	0.2	261	46				
900	Trevor Vilakazi	1.9	206	395	2326	144	17.432	133
854	Victoria Mxenge	3.1	11	33				
857	Victoria Mxenge	5.0	99	493				
858	Victoria Mxenge	4.5	118	533				
867	Victoria Mxenge	0.6	172	100				
864	Victoria Mxenge	2.2	205	456				
865	Victoria Mxenge	3.2	175	558				
866	Victoria Mxenge	2.2	148	326				
868	Victoria Mxenge	2.5	157	387				
870	Victoria Mxenge	1.6	157	250				
871	Victoria Mxenge	0.2	176	41				
873	Victoria Mxenge	2.2	117	263				
875	Victoria Mxenge	3.5	192	665				
876	Victoria Mxenge	2.3	198	447				
878	Victoria Mxenge	0.3	177	58				
879	Victoria Mxenge	0.9	212	190				
884	Victoria Mxenge	0.2	205	34				
885	Victoria Mxenge	0.9	235	205				
886	Victoria Mxenge	0.1	237	24				
887	Victoria Mxenge	0.2	254	60				
889	Victoria Mxenge	0.2	230	48	5171	166	35.87	144
890	Victoria Mxenge South	1.7	167	283	283	167	1.699	167
828	Vietnam	26.2	65	1711	1711	65	26.20	65
762	Vrygrond	33.4	26	873	873	26	33.43	26
774	Vygekraal	2.0	46	92	92	46	1.98	46
926	Wallace Dean	7.8	133	1035				
927	Wallace Dean	1.7	168	288	1323	140	9.51	139
786	Welbeloond / The Stables	3.4	56	189	189	56	3.37	56
932	Weltevreden	2.8	50	138	138	50	2.78	50
	Witsand	13.3	23	312	312	23	13.300	23
	Totals:	883		**59868**	**59868**		870	

Appendix 6 Table 3 Comparison of the 1996 survey data (Martinez, 1996) with previous studies for the Cape Town Metropolitan Region.

Settlement name	Shack counting data			
	Martinez	Van Zyl[1]	City Council	DeWar et al.[2]
	1996	1995	1994	1991
Airport	369			
Antoniesbos	50			
Athlone			5	
Barcelona	2105	1400		
Bermuda	699	1043		
Black City	512	500		
Blackheath / Happy Valley	709			
Bloekombos	2555	1800		320?
Bongweni - Ikwezi Park	1525	897		
Boy's Town	2475			
Brickfields	167			
Brown's Farm	5125	4294		1170
Crossroads	1457	3319		6375
De Bos	114			50
Diep River			1	
Du Noon	108			
Eastern Kayalitsha	53			
Fisantkraal	72			
Gersham / Kalkfontein	603			
Green Point	1662	1562		3853
Gxa-Gxa	91	47		
Hanover Park			4	
Hazendale			3	
Heinz Park / Philippi South	207		3	
Houtbay Ext 15 / Hangberg	203			
Imizame Yetha	794	914		379
Joe Slovo Park	1195			
Kanana	868	419		
Kiki (between the hostels)		575		
Klipfontein Glebe	1003			
KTC	2324	2281		5250
Lavender / Steenberg	19			
Lower Crossroads	853	700		
Lwandle	1194	1444		450
Macassar	266			
Mahobe Drive	379	469		
Malay Quarter			13	
Marconi Beam	1291	1100		1000
Maitland			2	
Mfuleni	1409	1877		204
Miller's Camp	1089	811		
Mitchell's Plain / Tafelsig	360		268	
Mkonto Square	722	631		
Mpetha Square	483	472		
Mpinga Square	239	236		
Mpuku Park	149			
New Rest	1214	1100		
Ottery	49		1	
Palm Tree Settlement	49			

Appendix 6 Table 3 Comparison of the 1996 survey data (Martinez, 1996) with previous studies for the Cape Town Metropolitan Region.

Settlement name	Shack counting data			
	Martinez	Van Zyl[1]	City Council	DeWar et al.[2]
	1996	1995	1994	1991
Parkwood			1	
Pelican Park	69		18	
Phola Park / Fezeka	1417	1175		
Raape Kraal / West Lake	267			
Redhill	113	79		83
Retreat			9	
Rylands			24	
Samora Machel	1094	1019		
Silvertown	2138	1369		2000
Site B North	888	991		18566
Site C	2113	10506		7060
Spandau	467			
Strandfontein			1	
Sun City / Nomzamo /Sir Lowry's Pass City	454	1556		200
Sunnydale / Kommetjie/ Masiphumelele	791	800		200
Sweet Home	384	105		
Tambo Square	445	581		
Trevor Vilakazi	2326			9900
Victoria Mxenge	5171			
Victoria Mxenge South	283			
Vietnam	1711	1211		
Vrygrond	873		423	
Vygekraal	92		66	
Wallace Dean	1323	3031		35?
Welbeloond / The Stables	189			
Weltevreden	138			
Witsand	312			
Woodstock			1	
Zonnebloem			3	

Note:
1.Van Zyl (1995) lists only the summed number of backyard and freestanding shacks for Khayelitsha. Furthermore, the Trevor Vilakazi, Victoria Mxenge and Victoria Mxenge South areas have been subdivided differently in this study.
2.The shack counts listed by DeWar et al. (1991) represent a summation of freestanding and backyard shacks. Furthermore, only the total number of shacks in Guguletu (470), Nyanga (8681), Khayelitsha (41379) are listed.

Appendix 6 Table 4 Summary of the results of the 1996 shack count for the key informal settlement areas in the Cape Town Metropolitan Region. The totals for these areas in previous studies are also shown.

nformal settlement Area	Average Density (shacks/ha)	Martinez 1996	Van Zyl[1] 1995	DeWar et al.[2] 1991	
Brown's Farm	74	**5125**	**4294**	**1170**	
Crossroads		**4935**	**3319**	**6375**	
Boy's Town	97	2475			
Crossroads	95	1457			
Klipfontein Glebe	17	1003			
Guguletu		**6140**	**5297**	**479**	
Barcelona	50	2105	1400		
Gxa-Gxa	83	91	47		
Kiki			575		
Kanana	45	868	419		
New Rest	77	1214	1100		
Phola Park / Fezeka	195	1417	1175		
Tambo Square	191	445	581		
Kayelitsha		**16858**	**56813**	**11269**	
Bermuda	129	699	1043		
Bongweni - Ikwezi Park	130	1525	897		
Eastern Kayelitsha	33	53			
Green Point	100	1662	1562	3853	
Silvertown	112	2138	1369	2000	
Site B North	75	888	991	18566	
Site C	139	2113	10506	7060	
Trevor Vilakazi	144	2326		9900	
Victoria Mxenge	166	5171			
Victoria Mxenge South	167	283			
Towns & Villages 1- 3			40445		
Langa		**1344**	**2700**		
Joe Slovo Park	105	1195			
Mpuku Park	247	149			
Lower Crossroads		**3125**	**2738**		
Imizame Yetha	56	794	914	379	
Lower Crossroads	81	853	700		
Samora Machel	78	1094	1019		
Sweet Home	81	384	105		
Nyanga		**5797**	**5400**	**8681**	
Kalanyoni			131		
KTC	128	2324	2281	5250	
Black City	169	512	500		
Mahobe Drive	116	379	469		
Miller's Camp	130	1089	811		
Mkonto Square	171	722	631		
Mpetha Square	212	483	472		
Mpinga Square	299	239	236		
Palm Tree Settlement	245	49			

1.Van Zyl (1995) lists only the summed number of backyard and freestanding shacks for Khayelitsha. Furthermore, the Trevor Vilakazi, Victoria Mxenge and Victoria Mxenge South areas have been subdivided differently in this study.

2.The shack counts listed by DeWar et al. (1991) represent a summation of freestanding and backyard shacks. Furthermore, only the total number of shacks in Guguletu (470), Nyanga (8681), Khayelitsha (41379) are listed.

Appendix 6 Table 5 A density-based classification of informal settlements in the Cape Town Metropolitan Region.

Settlement name	Average density (shacks/ha)	Density range (du / ha)
Mpetha Square	212	
Mpinga Square	299	
Mpuku Park	247	200 - 250 (du / ha)
Palm Tree Settlement	245	
Black City	169	
Marconi Beam	150	
Mkonto Square	171	
Phola Park / Fezeka	195	150 - 199 (du / ha)
Tambo Square	191	
Victoria Mxenge	166	
Victoria Mxenge South	167	
Bermuda	129	
Bongweni - Ikwezi Park	130	
Green Point 2	100	
Joe Slovo Park	105	
KTC	128	
Lavender / Steenberg	100	100 - 149 (du / ha)
Mahobe Drive	116	
Miller's Camp	130	
Silvertown	112	
Site C 5	139	
Trevor Vilakazi	144	
Wallace Dean	140	
Airport	66	
Antoniesbos	56	
Barcelona	50	
Bloekombos	74	
Boy's Town	97	
Brown's Farm	74	
Crossroads	95	
De Bos	91	
Du Noon	72	
Fisantkraal	89	
Gersham / Kalkfontein	74	
Gxa-Gxa	83	
Heinz Park / Philippi South	71	
Imizame Yetha	56	
Lower Crossroads	81	
Lwandle	75	50 - 99 (du / ha)
Macassar	85	
New Rest	77	
Pelican Park	77	
Raape Kraal / West Lake	68	
Samora Machel	78	
Site B North	75	
Spandau	72	
Sunnydale / Kommetjie/ Masi	83	
Sweet Home	81	
Vietnam	65	
Welbeloond / The Stables	56	
Weltevreden	50	

Appendix 6 Table 5 A density-based classification of informal settlements in the Cape Town Metropolitan Region.

Settlement name	Average density (shacks/ha)	Density range (du / ha)
Blackheath / Happy Valley	45	
Brickfields	15	
Eastern Kayalitsha	33	
Houtbay Ext 15 / Hangberg	38	
Kanana	45	
Klipfontein Glebe	17	
Mfuleni	46	
Mitchell's Plain / Tafelsig	49	**0 - 49 (du / ha)**
Ottery	15	
Redhill	3	
Sun City	36	
Vrygrond	26	
Vygekraal	46	
Witsand	23.5	

Appendix 6 Table 6 Estimates of the net growth rate, annual growth rate and growth factors of informal settlements in the Cape Town Metropolitan Region for the period 1994 to 1996.

Settlement name	Net Growth [1]	Annual	Annual	Approximate	
		Growth Rate1	Growth Rate1	Growth Factor[2]	
	(No. shacks)	(shacks / year)	(percentage)		
Airport3					
Antoniesbos					
Barcelona	705	498	35.5		
Black City	12	8	1.7		
Blackheath / Happy Valley					
Bloekombos	755	533	29.6		
Bongweni - Ikwezi Park	628	443	49.4		
Brickfields					
Brown's Farm	831	587	13.7		
Crossroads [4]	1616	1141	34.4		
De Bos					
Du Noon					
Eastern Kayalitsha					
Fisantkraal					
Gersham / Kalkfontein					
Green Point	100	71	4.5		
Gxa-Gxa	44	31	66.1		
Heinz Park / Philippi South				69.0	
Houtbay Ext 15 / Hangberg					
Imizame Yetha	-120	-85	-9.3		
Joe Slovo Park					
Kanana	449	317	75.6		
Kiki (between the hostels)					
KTC	43	30	1.3		
Lavender / Steenberg					
Lower Crossroads	153	108	15.4		
Lwandle	-250	-176	-12.2		
Macassar					
Mahobe Drive	-90	-64	-13.5		
Marconi Beam	191	135	12.3		
Mfuleni	-468	-330	-17.6		
Miller's Camp	278	196	24.2		
Mitchell's Plain / Tafelsig				1.3	
Mkonto Square	91	64	10.2		
Mpetha Square	11	8	1.6		
Mpinga Square	3	2	0.9		
Mpuku Park					
New Rest	114	80	7.3		
Ottery				49.0	
Palm Tree Settlement					
Pelican Park				3.8	
Phola Park / Fezeka	242	171	14.5		
Raape Kraal / West Lake					
Redhill	34	24	70.6		
Samora Machel	75	53	5.2		
Silvertown	769	543	39.7		
Spandau					
Sun City / Nomzamo	-1102	-778	-50.0		
Sunnydale / Kommetjie	-9	-6	-0.8		
Sweet Home	279	197	187.6		
Tambo Square	-136	-96	-16.5		
Trevor Vilakazi					
Victoria Mxenge					
Victoria Mxenge South					
Vietnam	500	353	29.1		

Appendix 6 Table 6 Estimates of the net growth rate, annual growth rate and growth factors of informal settlements in the Cape Town Metropolitan Region for the period 1994 to 1996.

Settlement name	Net Growth [1]	Annual Growth Rate1	Annual Growth Rate1	Approximate Growth Factor[2]	
	(No. shacks)	(shacks / year)	(percentage)		
Vrygrond				2.1	
Vygekraal				1.4	
Wallace Dean	-1708	-1206	-39.8		
Welbeloond / The Stables					
Weltevreden					
Witsand					

Notes:

1. The net growth in the number of shacks during the period December 1994 to May 1996 has been calculated using the Martinez (1996) and the Van Zyl (1995) data sets (see Table 9.2). The annual growth rate has been calculated by multiplying the increase in shacks by a factor of (12/17), since there is a 17 month difference between these two data sets.

2. The approximate growth factor has been calculated by dividing the number of shacks in 1996 by the number of shacks in 1994.These values have been estimated using the Martinez (1996) and City Council (1994) data sets (see Table 9.2).

3. Settlements for which there are no shack counting data listed in Van Zyl (1995) appear in italics here.

4. Crossroads here refers to the Crossroads, Boys Town and Klipfontein Glebe areas.

Appendix 6 Table 7 Population estimates for informal settlements in the Cape Town Metropolitan Region based on the 1996 survey data (Martinez, 1996).

Settlement name	**Shack Count**	**Average Household Size**[1]	**Population Estimate**		
Airport	369	3.6	1328		
Antoniesbos	50	3.6	180		
Barcelona	2105	3.6	7578		
Bermuda	699	4.45	3111		
Black City	512	3.6	1843		
Blackheath / Happy Valley	709	3.6	2552		
Bloekombos	2555	3.2	8176		
Bongweni - Ikwezi Park	1525	6	9150		
Boy's Town	2475	3.6	8910		
Brickfields	167	3.6	601		
Brown's Farm	5125	3.6	18450		
Crossroads	1457	3.6	5245		
De Bos	114	3.6	410		
Du Noon	108	3.6	389		
Eastern Kayalitsha	53	3.6	191		
Fisantkraal	72	3.6	259		
Gersham / Kalkfontein	603	3.6	2171		
Green Point	1662	4.54	7545		
Gxa-Gxa	91	3.6	328		
Heinz Park / Philippi South	207	3.6	745		
Houtbay Ext 15 / Hangberg	203	3.6	731		
Imizame Yetha	794	5.1	4049		
Joe Slovo Park	1195	3.6	4302		
Kanana	868	3.6	3125		
Klipfontein Glebe	1003	3.6	3611		
KTC	2324	3.6	8366		
Lavender / Steenberg	19	3.6	68		
Lower Crossroads	853	3.6	3071		
Lwandle	1194	3.6	4298		
Macassar	266	4.95	1317		
Mahobe Drive	379	3.6	1364		
Marconi Beam	1291	4.5	5810		
Mfuleni	1409	3.6	5072		
Miller's Camp	1089	3.6	3920		
Mitchell's Plain / Tafelsig	360	3.6	1296		
Mkonto Square	722	3.6	2599		
Mpetha Square	483	3.6	1739		
Mpinga Square	239	3.6	860		
Mpuku Park	149	3.6	536		
New Rest	1214	3.6	4370		
Ottery	49	3.6	176		
Palm Tree Settlement	49	3.6	176		
Pelican Park	69	3.6	248		
Phola Park / Fezeka	1417	3.6	5101		
Raape Kraal / West Lake	267	3.6	961		
Redhill	113	4.8	542		
Samora Machel	1094	3.6	3938		
Silvertown	2138	4.5	9621		
Site B North	888	6.4	5683		
Site C	2113	5.5	11622		
Spandau	467	3.6	1681		
Sun City / Nomzamo /Sir Lowry's Pass City	454	3.6	1634		
Sunnydale / Kommetjie/ Masiphumelele	791	3.6	2848		
Sweet Home	384	3.9	1498		

Appendix 6 Table 7 Population estimates for informal settlements in the Cape Town Metropolitan Region based on the 1996 survey data (Martinez, 1996).

Settlement name	Shack Count	Average Household Size[1]	Population Estimate		
Tambo Square	445	3.6	1602		
Trevor Vilakazi	2326	5.9	13723		
Victoria Mxenge	5171	6.4	33094		
Victoria Mxenge South	283	6.4	1811		
Vietnam	1711	3.6	6160		
Vrygrond	873	3.6	3143		
Vygekraal	92	3.6	331		
Wallace Dean	1323	3.2	4234		
Welbeloond / The Stables	189	3.6	680		
Weltevreden	138	3.6	497		
Witsand	312	3.6	1123		
Total population in informal settlemnts:			**251799**		
Note 1. The average household size estimates are derived from Van Zyl (1995). Where no household size value has been listed for a settlement in Van Zyl (1995), a value of 3.6 has been applied.					

Appendix 6 Table 8 The percentage of relocation and rellocation distances planned in the iSLP Programme.

Informal settlemen	Shack Count	Relocation site / Upgrading site	Sites allocated	Rellocation displacement (km)	% households rellocated / upgraded	Total relocations per settlement (%)
Barcelona	2105	Southern Delft (3+4)	500	5.7	23.8	24
Black City	512	Weltevreden (1+2)	200	3.5	39.1	
Black City	512	Southern Delft (1+2)	200	4.9	39.1	
Black City	512	Black City	102	(upgrade)	19.9	78
Boy's Town	2475	Southern Delft (3+4)	400	4.4	16.2	
Boy's Town	2475	Phillipi East (2-4)	1305	2.9	52.7	
Boy's Town	2475	Boy's Town	770	(upgrade)	31.1	69
Brown's Farm	5125	Phillipi East (2-4)		3.5		
Brown's Farm	5125	Brown's Farm	3011	(upgrade)	58.8	
Brown's Farm	5125	Brown's Farm	3222	(greenfields)	62.9	0
Gxa-Gxa	91	Weltevreden (1+2)	60	4	65.9	66
Heinz Park	207	Heinz Park	374	(greenfields)	180.7	0
Joe Slovo Park	1195	Phillipi East (2-4)	500	9.5	41.8	
Joe Slovo Park	1195	Langa (B+D)	410	(infill)	34.3	42
Kanana	868	Weltevreden (1+2)	200	5.3	23.0	
Kanana	868	Kanana	140	(infill)	16.1	23
Klipfontein Glebe	1003	Philippi East Glebe	1250	(mixed)	124.6	0
KTC	2324	Weltevreden (1+2)	200	3.2	8.6	
KTC	2324	Southern Delft (1+2)	200	6.2	8.6	
KTC	2324	KTC (2+3)	926	(upgrade)	39.8	
KTC	2324	KTC	1277	(upgrade)	54.9	17
Lower Crossroads	853	Phillipi East (2-4)	783	0.5	91.8	
Lower Crossroads	853	Lower Crossroads	698	(greenfields)	81.8	92
Mahobe Drive	379	Weltevreden (1+2)	200	2.9	52.8	
Mahobe Drive	379	Southern Delft (3+4)	300	5.2	79.2	100
Millers Camp	1089	Weltevreden (1+2)	100	4	9.2	
Millers Camp	1089	Southern Delft (1+2)	100	4.8	9.2	
Millers Camp	1089	Southern Delft (3+4)	350	4.8	32.1	
Millers Camp	1089	Millers Camp (3+4)	254	(upgrade)	23.3	
Millers Camp	1089	Millers Camp	434	(upgrade)	39.9	51
Mkonto Square	722	Weltevreden (1+2)	100	2.6	13.9	
Mkonto Square	722	Southern Delft (3+4)	350	5.8	48.5	
Mkonto Square	722	Mkonto Square	200	(upgrade)	27.7	62
Mpetha Square	483	Weltevreden (1+2)	100	2.8	20.7	
Mpetha Square	483	Southern Delft (1+2)	300	5.5	62.1	
Mpetha Square	483	Mpetha Square	98	(upgrade)	20.3	83
Mpinga Square	239	Southern Delft (1+2)	200	5.4	83.7	
Mpinga Square	239	Mpinga Square	38	(upgrade)	15.9	84
New Rest	1214	Weltevreden (1+2)	200	5.9	16.5	
New Rest	1214	Southern Delft (3+4)	450	6.8	37.1	
New Rest	1214	New Rest	450	(upgrade)	37.1	54
Phola Park	1417	Weltevreden (1+2)	100	2.3	7.1	
Phola Park	1417	Southern Delft (3+4)	500	7.9	35.3	
Phola Park	1417	Phola Park	400	(upgrade)	28.2	42
Samora Machel	1094	Weltevreden (1+2)	500	0.3	45.7	
Samora Machel	1094	Weltevreden (3+4)	594	0.4	54.3	100
Sweet Home	384	Weltevreden (3+4)	200	2.3	52.1	52
Tambo Square	445	Tambo Square 1	930	1.5	209.0	100
Victoria Mxenge	5171	Victoria Mxenge (NGO)	200	(greenfields)	3.9	0
Vietnam	1711	Phillipi East K	1100	1.9	64.3	
Vietnam	1711	Phillipi East (2-4)	611	0.6	35.7	100

Appendix 6 Table 9 A table for optimizing the number of freestanding shacks within the informal settlements of the Cape Town Metropolitan Region that require relocation.

Settlement name	Area (ha)	Density[1]	Shack Count	Required planning density (shacks / ha) 30	40	50	60	70	80	90	100	110
				Number of shacks that must be removed to obtain the required planning density (shacks / ha)[2]								
Airport	0.01	399.0	4	4	4	3	3	3	3	3	3	3
Airport	0.1	116.5	15	11	10	9	7	6	5	3	2	1
Airport	0.1	175.8	26	22	20	19	17	16	14	13	11	10
Airport	0.1	134.0	12	9	8	8	7	6	5	4	3	2
Airport	6.6	47.1	312	113	47							
Antoniesbos	0.9	55.6	50	23	14	5						
Barcelona	41.9	50.2	2105	848	429	10						
Bermuda	2.2	114.9	251	185	164	142	120	98	76	54	33	11
Bermuda	3.3	136.5	448	350	317	284	251	218	185	153	120	87
Black City	0.9	201.1	180	153	144	135	126	117	108	99	90	82
Black City	2.2	151.1	332	266	244	222	200	178	156	134	112	90
Blackheath	1.1	3.7	4									
Blackheath	0.4	102.4	38	27	23	19	16	12	8	5	1	
Blackheath	7.6	1.4	11									
Blackheath	12.4	6.9	85									
Blackheath	4.0	7.1	28									
Blackheath	0.1	171.6	24	20	18	17	16	14	13	11	10	9
Blackheath	9.7	42.9	414	124	28							
Blackheath	2.0	51.7	105	44	24	4						
Bloekombos	34.7	73.6	2555	1514	1167	820	473	125				
Bongweni	0.3	214.0	71	61	58	54	51	48	44	41	38	35
Bongweni	11.5	126.1	1454	1108	993	877	762	647	531	416	301	185
Boy's Town	25.5	97.2	2475	1711	1456	1202	947	692	438	183	-72	-326
Brickfields	0.3	11.8	4									
Brickfields	2.6	10.6	28									
Brickfields	8.5	15.8	135									
Browns Farm	83.1	51.3	4262	1768	936	105						
Browns Farm	0.3	224.1	76	66	62	59	56	52	49	45	42	39
Browns Farm	0.5	229.5	113	98	93	88	83	79	74	69	64	59
Brown's Farm	3.8	176.3	674	559	521	483	445	406	368	330	292	254
Crossroads	4.0	118.7	475	355	315	275	235	195	155	115	75	35
Crossroads	10.1	87.2	878	576	475	375	274	173	73			
Crossroads	1.9	53.9	104	46	27	8						
De Bos	1.3	90.7	114	76	64	51	39	26	13	1		
Du Noon	0.1	100.3	8	6	5	4	3	2	2	1	0	
Du Noon	1.4	70.3	100	57	43	29	15	0				
Eastern Kayalitsha	1.6	32.9	53	5								
Fisantkraal	0.8	89.5	72	48	40	32	24	16	8	0		
Gersham	2.1	22.4	46									
Gersham	0.2	347.2	66	60	58	56	55	53	51	49	47	45
Gersham	9.3	33.3	310	31								
Gersham	0.1	151.9	21	17	15	14	13	11	10	9	7	6
Gersham	0.5	18.2	10									
Gersham	2.5	51.2	128	53	28	3						
Gersham	0.9	14.4	13									
Gersham	0.3	27.9	9									
Green Point 1	15.7	100.5	1580	1108	951	794	637	479	322	165	8	
Green Point 2	1.0	85.1	82	53	43	34	24	15	5			
Gxa-Gxa	1.1	82.7	91	58	47	36	25	14	3			
Heinz Park	2.9	71.4	207	120	91	62	33	4				
Houtbay Ext 15	5.3	38.0	203	43								

Appendix 6 Table 9 A table for optimizing the number of freestanding shacks within the informal settlements of the Cape Town Metropolitan Region that require rellocation.

Settlement name	Area	Density[1]	Shack	Required planning density (shacks / ha)								
	(ha)		Count	30	40	50	60	70	80	90	100	110
				Number of shacks that must be removed to obtain the required planning density (shacks / ha)[2]								
Imizame Yetha	14.1	56.3	794	371	230	89						
Joe Slovo Park	11.4	104.8	1195	853	739	625	511	397	283	169	55	
Kanana	19.1	45.4	868	295	104							
Klipfontein Glebe	11.8	13.7	161									
Klipfontein Glebe	0.0	183.1	7	6	5	5	5	4	4	4	3	3
Klipfontein Glebe	0.3	65.2	22	12	9	5	2					
Klipfontein Glebe	0.1	60.4	7	4	2	1	0					
Klipfontein Glebe	0.4	67.6	29	16	12	8	3					
Klipfontein Glebe	64.5	12.0	777									
KTC	11.5	130.5	1496	1152	1037	923	808	694	579	464	350	235
KTC	6.1	108.1	660	477	416	355	294	232	171	110	49	
KTC	0.9	183.4	168	141	131	122	113	104	95	86	76	67
Lavender	0.2	100.0	19	13	11	9	8	6	4	2	0	
Lower Crossroads	10.5	81.2	853	538	433	328	223	118	13			
Lwandle	4.2	80.4	338	212	170	128	86	44	2			
Lwandle	11.1	74.4	825	492	381	270	159	48				
Lwandle	1.1	27.2	31									
Macassar	3.1	85.2	266	172	141	110	79	48	16			
Mahobe Drive	3.3	116.3	379	281	249	216	184	151	118	86	53	21
Marconi Beam	8.6	149.8	1291	1033	946	860	774	688	602	516	429	343
Mfuleni	31.0	45.5	1409	480	171							
Miller's Camp	3.4	140.6	478	376	342	308	274	240	206	172	138	104
Miller's Camp	5.1	120.9	611	459	409	358	308	257	207	156	106	55
Mitchell's Plain	7.4	48.7	360	138	64							
Mkonto Square	4.2	170.6	722	595	553	510	468	426	383	341	299	257
Mpetha Square	2.3	211.8	483	415	392	369	346	323	301	278	255	232
Mpinga Square	0.8	298.8	239	215	207	199	191	183	175	167	159	151
Mpuku Park	0.6	246.7	149	131	125	119	113	107	101	95	89	83
New Rest	15.7	77.3	1214	743	586	429	271	114				
Ottery	0.1	140.0	7	6	5	5	4	4	3	3	2	2
Ottery	0.3	120.0	36	27	24	21	18	15	12	9	6	3
Ottery	0.1	120.0	6	5	4	4	3	3	2	2	1	1
Palm Tree Settlement	0.2	245.0	49	43	41	39	37	35	33	31	29	27
Pelican Park	0.9	76.7	69	42	33	24	15	6				
Phola Park / Fezeka	7.2	195.6	1408	1192	1120	1048	976	904	832	760	688	616
Phola Park / Fezeka	0.2	59.8	9	4	3	1	0					
Raape Kraal	3.9	68.5	267	150	111	72	33					
Redhill	42.5	2.7	113									
Samora Machel	0.0	206.2	8	7	6	6	6	5	5	5	4	4
Samora Machel	13.7	77.3	1056	646	510	373	236	100				
Samora Machel	0.1	35.9	5	1								
Samora Machel	0.4	68.9	25	14	10	7	3	0				
Silvertown	19.0	112.5	2138	1568	1378	1188	998	808	618	427	237	47
Site C 1	0.6	125.0	70	53	48	42	36	31	25	20	14	8
Site C 2	1.0	153.5	149	120	110	100	91	81	71	62	52	42
Site C 3	0.8	32.1	26	2								
Site C 4	9.0	37.4	337	67								
Site C 5	9.4	162.1	1531	1248	1153	1059	964	870	775	681	587	492
Spandau	6.5	71.8	467	272	207	142	77	12				
Sun City	12.6	36.1	454	77								
Sunnydale	9.6	82.5	791	504	408	312	216	120	24			
Sweet Home	0.1	130.7	8	6	6	5	4	4	3	2	2	1

Appendix 6 Table 9 A table for optimizing the number of freestanding shacks within the informal settlements of the Cape Town Metropolitan Region that require rellocation.

Settlement name	Area (ha)	Density[1]	Shack Count	Required planning density (shacks / ha) 30	40	50	60	70	80	90	100	110
				Number of shacks that must be removed to obtain the required planning density (shacks / ha)[2]								
Sweet Home	0.1	197.6	18	15	14	13	13	12	11	10	9	8
Sweet Home	4.0	73.0	294	173	133	93	53	12				
Sweet Home	0.0	273.6	5	4	4	4	4	4	4	3	3	3
Sweet Home	1.0	58.9	59	29	19	9						
Tambo Square	2.3	190.6	445	375	352	328	305	282	258	235	211	188
Trevor Vilakazi	2.6	167.2	437	359	332	306	280	254	228	202	176	150
Trevor Vilakazi	0.1	181.8	22	18	17	16	15	14	12	11	10	9
Trevor Vilakazi	1.4	132.6	191	148	133	119	105	90	76	61	47	33
Trevor Vilakazi	3.5	105.5	366	262	227	193	158	123	88	54	19	
Trevor Vilakazi	6.8	106.9	723	520	452	385	317	249	182	114	47	
Trevor Vilakazi	0.9	157.7	146	118	109	100	90	81	72	63	53	44
Trevor Vilakazi	0.2	260.8	46	41	39	37	35	34	32	30	28	27
Trevor Vilakazi	1.9	205.7	395	337	318	299	280	261	241	222	203	184
Victoria Mxenge	3.1	10.6	33									
Victoria Mxenge	5.0	98.6	493	343	293	243	193	143	93	43		
Victoria Mxenge	4.5	118.4	533	398	353	308	263	218	173	128	83	38
Victoria Mxenge	0.6	171.6	100	83	77	71	65	59	53	48	42	36
Victoria Mxenge	2.2	204.5	456	389	367	345	322	300	278	255	233	211
Victoria Mxenge	3.2	175.2	558	462	431	399	367	335	303	271	239	208
Victoria Mxenge	2.2	148.3	326	260	238	216	194	172	150	128	106	84
Victoria Mxenge	2.5	156.7	387	313	288	263	239	214	189	165	140	115
Victoria Mxenge	1.6	157.0	250	202	186	170	154	139	123	107	91	75
Victoria Mxenge	0.2	176.2	41	34	32	29	27	25	22	20	18	15
Victoria Mxenge	2.2	116.9	263	196	173	151	128	106	83	61	38	16
Victoria Mxenge	3.5	192.0	665	561	526	492	457	423	388	353	319	284
Victoria Mxenge	2.3	197.7	447	379	357	334	311	289	266	244	221	198
Victoria Mxenge	0.3	176.8	58	48	45	42	38	35	32	28	25	22
Victoria Mxenge	0.9	211.6	190	163	154	145	136	127	118	109	100	91
Victoria Mxenge	0.2	205.0	34	29	27	26	24	22	21	19	17	16
Victoria Mxenge	0.9	235.4	205	179	170	161	153	144	135	127	118	109
Victoria Mxenge	0.1	237.3	24	21	20	19	18	17	16	15	14	13
Victoria Mxenge	0.2	253.6	60	53	51	48	46	43	41	39	36	34
Victoria Mxenge	0.2	230.5	48	42	40	38	36	33	31	29	27	25
Victoria Mxenge South	1.7	166.6	283	232	215	198	181	164	147	130	113	96
Vietnam	26.2	65.3	1711	925	663	401	139					
Vrygrond	33.4	26.1	873									
Vygekraal	2.0	46.4	92	32	13							
Wallace Dean	7.8	132.7	1035	801	723	645	567	489	411	333	255	177
Wallace Dean	1.7	168.4	288	237	220	202	185	168	151	134	117	100
Welbeloond	3.4	56.1	189	88	54	21						
Weltevreden	2.8	49.6	138	54	27							
Witsand	13.3	23.5	312									

Notes:

1. The density is listed as shacks per hecatre.

2. These values have been calculated on a per sub-settlement basis. Where shacks would have to be added to increase the current density to a planned density, a negative value has been calculated. These negative values have been ommitted.

APPENDIX 7

APPENDIX 7 TABLE 1 Categorization of catchment characteristics for analysis of source control suitability. (Source: Makropoulos et al., 1998: 62)

PRIMARY LAYERS (parameters affecting infiltration)	Category 1 (less applicable)	Category 2 (intermediate)	Category 3 (more applicable)
LAND USE	Urbanised (impervious areas > 66 % of the total area)	Semi - urbanised (33 % < Impervious < 66 %)	Non - urbanised (Impervious < 33 % of the total area)
SOIL TYPES	Impermeable (ie. clay, fo=3*10-4)	Semi - permeable (ie. sand)	Permeable (ie. Gravel, fo = 2*10-2)
SLOPE	Steep (S > 20 %)	Medium (3 % < S < 20 %)	Mild (S < 3 %)
LAND PRICE	High	Medium	Low
INHABITANTS INCOME	Low	Medium	High
DEPTH TO WATER TABLE	Small (d<3m)	Medium (3m < d < 10m)	Large (d > 10 m)
DISTANCE FROM OUTLET	From near	To medium	To long
VEGETATION COVER	No cover	Lawn	Natural
DEPTH TO BEDROCK	Small (d<2m)	Medium (2m < d < 10m)	Large (d > 10 m)
STORM DRAINAGE SYSTEM	Buried pipes > 70 %	30 % < Buried pipes < 70 %	Buried pipes < 30 %
AVAILABILITY OF OPEN SPACE	Availability < 33 %	33 % < Av < 66 %	Av > 66 %
CONNECTION OF IMPERVIOUS AREAS TO SS	Connectivity > 70 %	30 % < Con < 70 %	Con < 30 %

APPENDIX 7 TABLE 2 Weights assigned for various source control applications (Source: Makropoulos et al., 1998: 63)

LAYERS USED	WEIGHTS for Infiltration Techniques	WEIGHTS for Porous Pavements	WEIGHTS for Detention Facilities
SOIL PROPERTIES	0.25	0.225	0.05
URBANISATION		0.25	
SPACE SUITABILITY	0.2		0.25
SLOPE	0.2	0.15	0.2
GROUND WATER	0.2	0.25	0.05
LAND PRICE		0.1	0.25
DISTANCE FROM NETWORK			0.15
CONNECTIVITY	0.1		
DISTANCE FROM OUTLET	0.05	0.025	0.05

APPENDIX 7 TABLE 3 Types of data which have been collected for the Lotus River catchment database (Source: Grobicki et al., in press)

Data type	Coverage of data
Detailed cadastral	Nyanga-Guguletu
	Lansdowne Wetton Corridor Project
Parcels	Lotus River Catchment
Elevation	
0.5 m contours	50m corridor of data along the proposed Lotus River bicycle track
5 m contours	Table Mountain
10, 20 m contours	Metropolitan area
Storm water drainage	Nyanga-Guguletu, Crossroads
Roads	Philippi, Nyanga-Guguletu
Land use	
1996, 1983	Lotus River Catchment
1938	Ikapa
Hydrological	Lotus River Canal
Groundwater	Cape Flats Aquifer
Soil	Lotus River Catchment
Waste	Lotus River Catchment

APPENDIX 7 TABLE 4 Features present in the cadastral database captured by the Cape Town Metropolitan Council (CMC). (Source: Grobicki et al., in press)

Access	Factory	Platform	Steps	Patio
Bridge	Fence	Public building	Substation	Pipes
Building	Flats	Rail	Swimming pool	Plant
Canal	Foot	Religious	Track	Gravel
Canopy	House	River	Transport	Sport fields
Construction	Hydrant	Road	Water tank	Pylon
Electricity box	Marsh	Ruin	Wall	Ramp
Electricity pole	Manhole	School	Parcels	
Embankment	Nation	Shack	Bollar	
Express	Out building	Sluice	Dam	

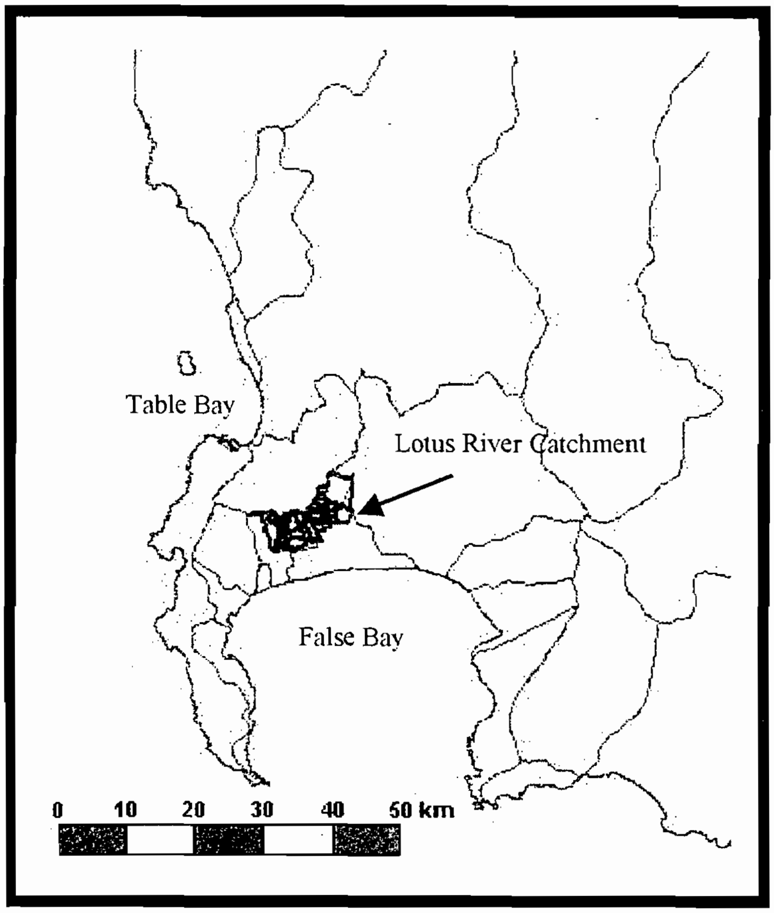
APPENDIX 7 TABLE 5 Potential contributors to an ICM database for Cape Town (Source: Grobicki et al., in press)

Cape Town Metropolitan Council	Water and Waste
	Protection Health & Trading Services
	Directorate of Information Services
	Survey and Land Information Department
Metropolitan Local Councils	South Peninsula
	Helderberg
	Blaauwberg
	City of Tygerberg
	City of Cape Town
	Oostenberg
Other Government Organisations	**Chief Director of Surveys and Mapping**
	Department of Agriculture
	Department of Water Affairs and Forestry
	Department of Environmental Affairs and Tourism
	Provincial Administration of the Western Cape
	Water Research Commission
	South African Police Service
	Agricultural Research Council
Non-Government Organisations	Portnet
	Wildlife and Environment Society
	Victoria and Alfred Waterfront
	Cape Nature Conservation
	False Bay Forum
Private Sector Organisations	**Abbott Grobicki (Pty) Ltd**
	Ninham Shand
	Watertek (CSIR)
	A.O.C. Holdings
Educational Service Groups	**Schools**
	University of Cape Town
	University of the Western Cape
Community Groups	**Civics**
	Development Forums
	Councillors

APPENDIX 7 TABLE 6 The distribution of the catchments with respect to Metropolitan Local Council areas. (Source: Grobicki et al., in press)

Metropolitan Local Council	**Catchments within MLC**
South Peninsula	Disa / Hout Bay Rivers
	Cape Point to Hout Bay
	Simons Town to Cape Point
	Sandvlei Canal to Simons Town
	Kyser & Westlake
	Diep & Sand
	Little Lotus & Lotus River
Helderberg	Eerste River
	Lourens River
	Sir Lowry's Pass River
	Steenbras River
Blaauwberg	Melkbosstrand to Milnerton
	Modder River
	Sout River
	Diep River
	Melkbosstrand to Bokbaai
City of Tygerberg	Diep River
	Elsieskraal
	Jakkelsvlei
	Kuils River
	Mitchell's Plain
City of Cape Town	Diep River
	Elsieskraal
	Jakkelsvlei
	Black
	Liesbeek
	Houtbay to Green Point
	Disa / Hout Bay Rivers
	Little Lotus & Lotus River
	Mitchell's Plain
Oostenberg	Diep River
	Kuils River
	Eerste River

APPENDIX 7 FIGURE 1 A map showing the location of the Lotus River Catchment in the Cape Town Metropolitan Region. Also shown are the other catchment boundaries in the metropolitan area.



APPENDIX 5 MAP 2

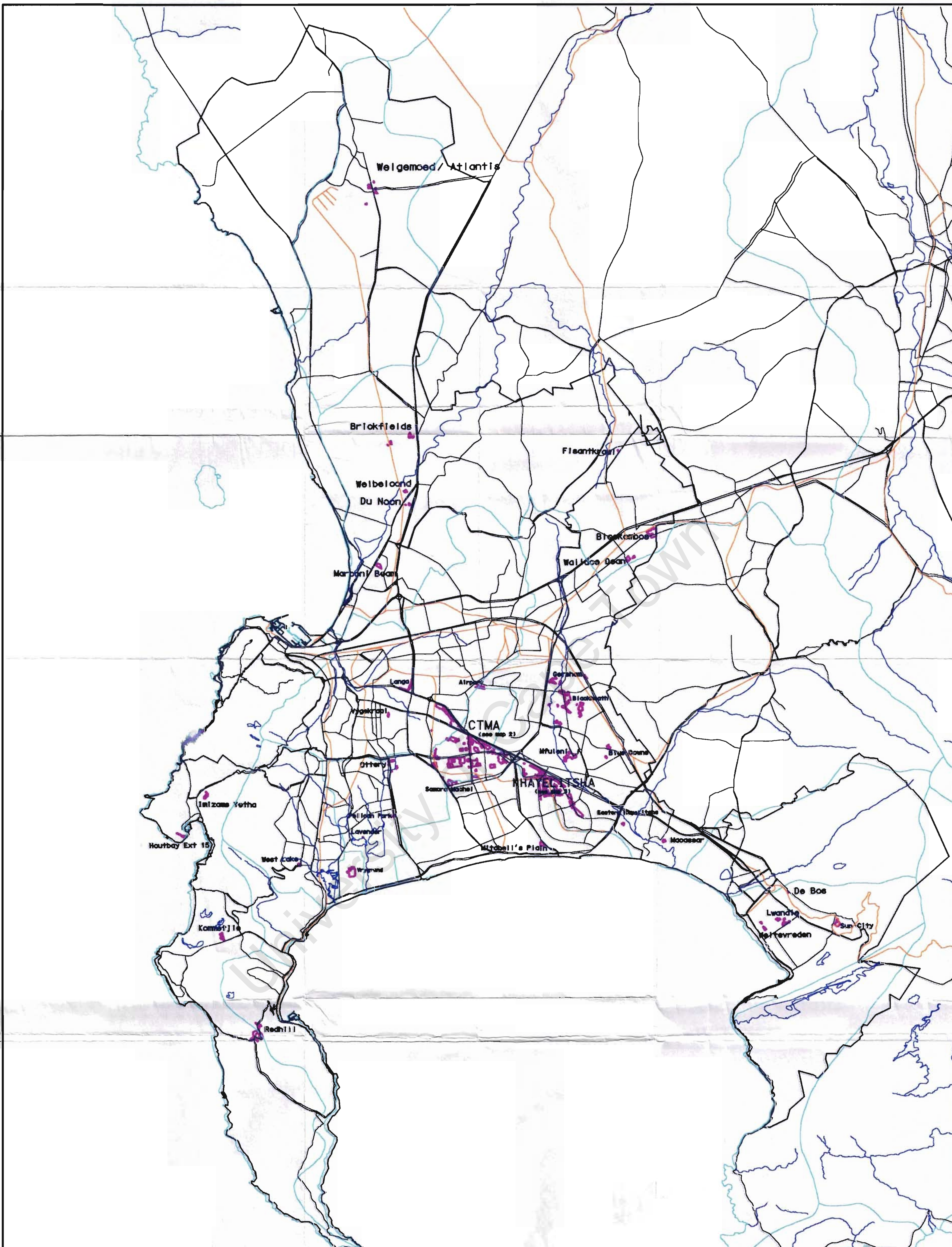
APPLICATION OF THE BI-LEVEL MODEL (CASE STUDY 1):

MAP OF INFORMAL SETTLEMENTS IN THE CAPE TOWN MUNICIPAL AREA (IKAPA) (1996)

Drawn by:
Iuma Martinez

Date:
Nov 1997

Urban Management GIS
Department of Civil Engineering, UCT



APPENDIX 5 MAP 1

APPLICATION OF THE BI-LEVEL MODEL (CASE STUDY 1):

MAP OF INFORMAL SETTLEMENTS IN THE CAPE METROPOLITAN REGION (1996)

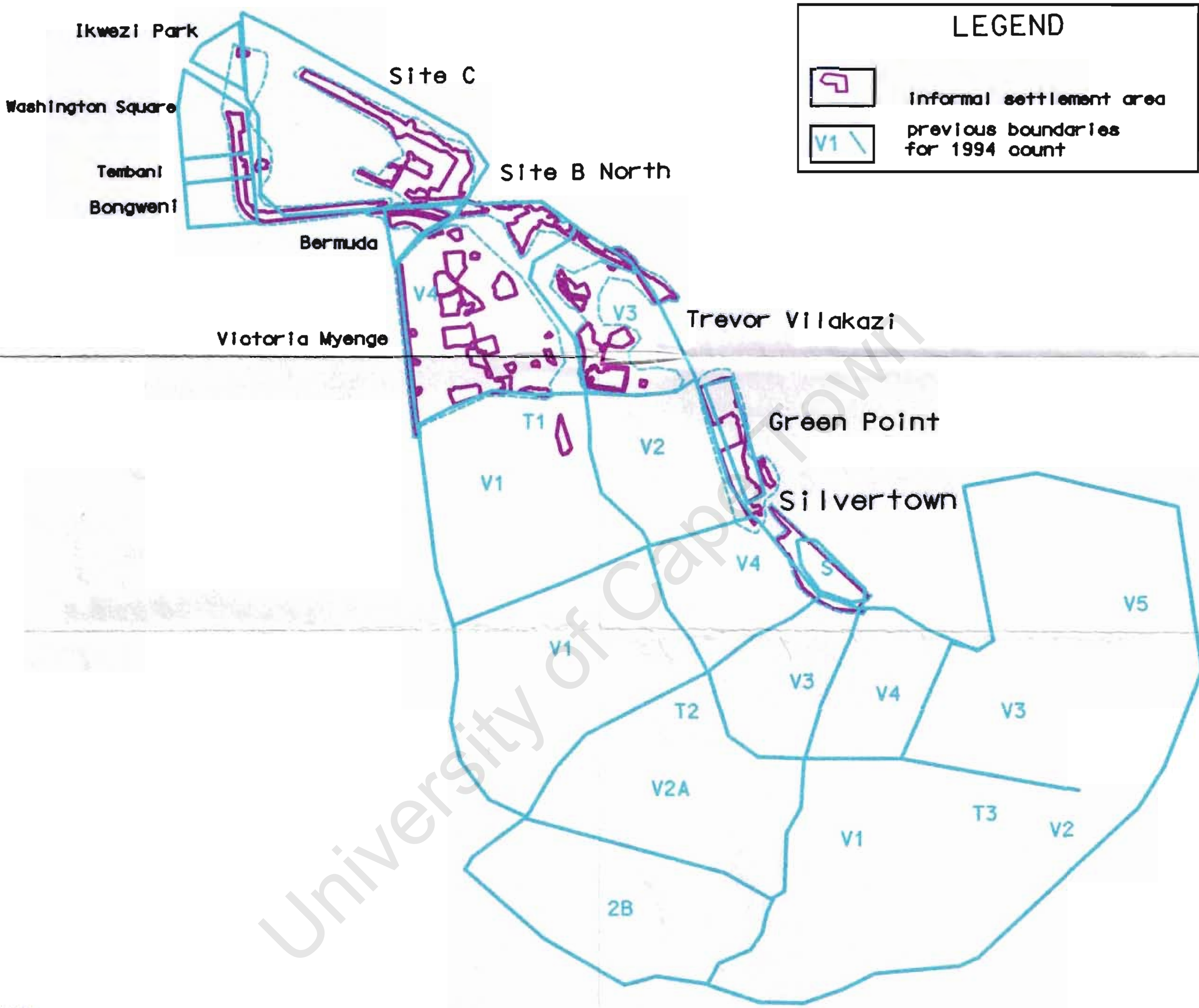
Drawn by: Iuma Martinez

Date: Nov 1997

Urban Management GIS

Department of Civil Engineering, UCT

LEGEND
- informal settlement area
- railway lines
- water catchment areas
- vleis / rivers / waterbodies
- roads



APPENDIX 5 MAP 3

APPLICATION OF THE BI-LEVEL MODEL (CASE STUDY 1):

MAP OF INFORMAL SETTLEMENTS IN KHAYELITSHA (1996)

Drawn by:
Iuma Martinez

Date:
Nov 1997

Urban Management GIS
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