PHYSICAL LAND SUITABILITY EVALUATION FOR URBAN DEVELOPMENT IN THE FRINGE OF NAKURU MUNICIPALITY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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This thesis has been submitted for examination with my approval as the principal University supervisor.

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ABSTRACT

The land around Nakuru town is coming under pressure for urban development. Much of the urban expansion has taken place on environmentally sensitive areas. The purpose of this study was to assess the physical land and related resources in order to determine urban land use strategies for directing future growth to the most appropriate places. Data was compiled from field surveys, interpretation of aerial photography, existing reports and maps. From these inventories, the area was divided into 11 uniform land units in which opportunities and constraints for urban development were identified. Land suitability classification for general urbanization was based on: slope, soil depth, existing soil erosion, surface stones, agro-ecological potential, land subsidence hazards, sensitivity of the watershed, density of surface drainage channels and depth to ground water.

Suitability assessment indicated that 54 per cent of the region is unsuitable for urbanization. The remaining land is only marginally or moderately suitable. The most limiting physical land factors include: unstable soils, land subsidence hazards, sensitive watershed and ground water recharge areas and conflicts with wildlife conservation. Results are compared to the current land use patterns and trends and aspirations of the local people to derive land use planning guidelines for the region suggestions are made for strategies to implement rational land use planning in order to maintain a balance between urban development and environmental conservation. The study concludes that land suitability evaluation has important role to play in urban land use planning process but required further research.

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TABLE OF CONTENTS

CHAPTER FIVE: IMPLICATIONS FOR LAND USE PLANNING

CHAPTER SIX: SUMMARY AND CONCLUSION

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

LIST OF APPENDICES

CHAPTER ONE

1 INTRODUCTION

1.1 Background

Rapid population growth and urbanization are creating environmental problems of global concern. One requirement to avoid land degradation associated with urban development is to include adequate land resource information in urban land use planning. World population projections for the year 2000 and beyond suggest that more than 50 per cent of the total population will live in urban areas (UNHCS, 1994). This will have important implications for urban land use development and the environment. The challenge is to make urban areas more ecologically sustainable in order to meet the land needs of the future urban population in the twenty first century and beyond.

Unfortunately, many developing countries, including Kenya, lack sufficient, accurate and timely data on land resources essential for urban planning (Berstein, 1993). This inhibits the formulation of effective land use strategies and policies, and undermines adequate environmental impact assessment for proposed urban development projects. Without reliable and relevant data land use planning decisions are liable to be made without full awareness of land resources available and the environmental issues that need to be addressed. Furthermore, without land resource data, it is difficult to: understand the implications of policies and strategies adopted, identify trends in land use conditions; or to evaluate the significance of changes observed.

Contemporary environmental issues associated with urban land use include: occupation of hazard-prone areas; conversion of high potential agricultural land; degradation of ecologically fragile ecosystems and; excessive urban sprawl (Hardoy et al 1992; Bernstein, 1993; UNCHS 1996; WRI 1996). Some of these problems occur outside the built up areas themselves and often outside the city or municipal boundaries. The areas beyond the municipal boundaries where physical expansion of built up areas has occurred in unplanned manner, is commonly referred to as the rural-urban fringe, urban fringe or peri-urban areas. The urban fringe is the transition area where full urban services cease to be available, and the point where agricultural land use predominate, but people commute to the city for work or other purposes (Ramachandran, 1991).

Urban fringe areas are characterized by physical urban expansion. The people in the fringe have land which they are willing to sell for urban land use at a comparatively low price. Therefore most urban land developments are attracted to the fringe. Furthermore, because fringe areas cover the interface between urban and rural areas, they are not covered by conventional sectoral land use planning policies and institutional framework. For example, in Kenya, the urban planners concentrate on the inner-city while agricultural, wildlife and forestry land use planners concentrate in rural areas. In this situation, urban fringe areas have tended to be neglected. The result is urban development expansion into fringe areas taking place in haphazard, spontaneous, unplanned and uncontrolled manner.

For sustainable urban development, efforts must be made to ensure that land use activities are matched with land resources in the fringe areas. In areas selected for urbanization, land resource assessment must be carried out to prevent urban growth from destroying valuable land resources. Land use planning has an important role to play in providing the guidelines for sustainable urban development. Land use planning is concerned with providing the right sites in the right place at the right time for the right people (Ratcliffe, 1981). Similarly, Chapin and Kaiser (1979) views land use planning as concerned with identifying location, intensity and amount of land development required for various space using activities such as residential, industrial or commercial.

Urban land use planning must recognise the existence of limited land resources to which both urban and non-urban development must be allocated. Emphasis on the natural land resource base is necessary if better urban settlement patterns are to be achieved and irreparable damage avoided. Therefore the selection of desirable land use plans from among the alternatives available must be based, in part, upon a careful analysis of the effects of each particular alternative plan on the land resources. This calls for inventory and analysis of more information about land resources and their ability to sustain urban development. Such information must include definitive data on topography, geology, soils, climate, hydrology, land use and other relevant factors.

Land evaluation is a useful tool that can provide such information needed for land use planning. Section 10 of the World Conservation Strategy (IUCH, 1980) specifically proposes the integration of conservation and development through land suitability evaluation. Land evaluation has been defined as the process of assessment of land performances when used for a specific purpose (FAO, 1976). It is essentially a procedure for comparison between land resources and land use with emphasis on the natural environment. The process of land evaluation involves: identification of land uses and defining the needs for each use, mapping and description of land resources: and the determination of the level of fitness of a given area of land for the given land use. The fitness assumes long-term environmental stability, social acceptability and economic viability.

The purpose of land evaluation is to support land use planning decisions by providing qualified land resource information. The results of land evaluation can provide information on: cost and benefits of land development; land management specification; need for infrastructure improvement; and effects of land use development on the environment. This can give land use planning a more thorough base by supplying information on alternative land resource uses. However, decisions on desirable land use and planning interventions in the form of policies, programmes and projects to implement such land use are part of the land use planning process.

Land suitability evaluation in itself does not determine the land use changes that are to be carried out, but provides data on the basis of which such decisions can be made. The present study seeks to apply this approach to address strategies for directing urban expansion in Nakuru town. Urban development and environmental conservation are in conflict within and in the immediate surrounding of Nakuru municipality.

1.2 Statement of the Problem

Nakuru municipality is currently the fourth largest town in Kenya, after Nairobi, Mombasa and Kisumu. As in most Kenyan towns, the built-up urban area in Nakuru town has expanded rapidly without proper planning resulting in land degradation and environmental deterioration. Land use problems in Nakuru are similar but more urgent than those experienced across the country due to its geographical location. The town is located on the floor of the Great Rift Valley, in a narrow gap between Menengai Crater to the north and Lake Nakuru to the south. Therefore the town can only expand in a linear pattern to the west and east. The situation is further compounded by the presence of unstable geology and poor soils which results in frequent land subsidence.

The population of Nakuru is currently estimated at more than 300,000 people in the municipal area covering 78 square kilometres (Jica, 1994). However, Nakuru town does not have a current structure plan that can guide land use development to suitable areas. The one that exists was prepared in 1975 but has not been updated to cope with the present development situation.

Before the 1980s, Nakuru town was regarded as the most clean and well planned town in Kenya. However, currently the town is ranked among the worst, and is one of the urban environmental "hotspot" in Kenya. In 1992 the municipal boundaries were extended to include the whole of Lake Nakuru National Park and peri-urban agricultural settlements to the south-west. This has resulted in a distinction between the official town and non-official town or the inner town and the outer town. A large population live in the recent settlements located outside the official municipal boundary to the north-east

Lake Nakuru National Park is world famous for its millions flamingoes but now facing environmental deterioration due to urban development. Lake Nakuru is the lowest point in the region and receives all the surface run-off from the town. Studies have identified pollutants derived from run-off and sewage from town reaching Lake Nakuru (Thampy, 1995). Although the municipal sewage treatment works was recently rehabilitated and expanded (Jica, 1994), a large part of the town is unsewered. Most of the peri-urban population use pit-latrines and other on-site sewage disposal facilities while drinking water is obtained from boreholes. Furthermore, the area is covered with porous soils that can easily lead to polluted sewage water passing into the surface and underground waters. Without proper land use planning, to guide development to appropriate sites, there is fear that groundwater might be polluted and the National Park will not achieve its conservation goals.

Land use pattern in the Nakuru urban region has undergone drastic changes in the last two decades. Urban population pressure has resulted in uncontrolled subdivision of former large-scale agricultural land for high density urban settlement. Syagga and Malombe (1995) observed that almost 70 per cent of Nakuru urban population live in the informal settlements. Most of these unplanned urban settlements are taking place in geologically unstable land areas prone to land subsidence. Removal of vegetation from sensitive water catchment areas has led to soil erosion and poor natural drainage. This situation might be associated with the current frequent occasions when Lake Nakuru dries out completely.

Nakuru town is expanding rapidly and population projections for the year 2020 is expected to be about 1 5 million people. This increase in urban population will be expected to be accompanied by increased demand for urban land in the immediate surrounding of the town. In light of these conditions, studies are required to identify land areas suitable for urban expansion in the fringe areas. Comprehensive land resource assessment is needed for land use planning and management to avoid further land and environmental degradation.

Despite the pathetic condition of urban land use in Nakuru town, there has been no attempt to address the issues. Recent environmental studies in the region have concentrated on Lake Nakuru National Park and urban infrastructure (Jica 1994, KWS, 1995; WWF, 1992). Lake Nakuru Conservation and Development Programme, sponsored by World Wide Fund for Nature (WWF), is in the process of compiling environmental information for environmental planning, management and monitoring (WWF, 1992). The programme has initially concentrated on Lake Nakuru and the National Park. However, urban settlement has the worst negative impact on the Lake Nakuru catchment area.

This thesis is concerned with ecological or environmental resource assessment for urban land use planning and management. The impetus for this study is provided by recent initiatives by United Nations Centre for Human Settlement (Habitat) in collaboration with the Nakuru Municipal council, to prepare a structure plan for the town. Nakuru is the first town in Kenya that has been selected to become a laboratory for the sustainable city programme of the Habitat

(UNHCS, 1996). In a workshop held in November 1995 the municipal council officials and local communities were eager to establish Nakuru as an "eco-city" or "Green-city"

Since Nakuru town is in search of sustainable urban development approaches, the present study is geared to contribute towards this. The present study deals with analysis of land resource information needed for land use planning to direct urban development into suitable sites while protecting environmentally fragile land areas. The results of this study can also form a baseline for environmental planning, management and monitoring in the Lake Nakuru catchment area. Furthermore, the Nakuru Municipal Council can use the results as a basis to initiate discussions with land developers and users on sustainable urban land development co-ordination. The central purpose of this study is to demonstrate the process of selecting urban land use alternatives and their consequences based on the results of land suitability evaluation. In addition to contribute to understanding of the influence of natural land resources on urban development.

1.3 The Objectives

This study will seek to fulfil the following objectives:

1. To describe, classify and map physical land characteristics such as soil, geology, hydrology, physiography, climate and land use and other factors important for urban land use development activities in the peri-urban areas of Nakuru town;

2. to determine the physical land resource potentials and

limitation for urban development;

3. to apply the land evaluation procedures and techniques in the comparative evaluation of the land as a means of determining the suitability of the fringe areas for urban land use activities, and

4. to propose land use planning, management and development control measures necessary to reconcile urban development and environmental conservation in the areas affected

1.4 Assumptions and Research Questions

As a framework for this study, the main assumption is that urban land use activities are expanding into land areas unsuitable for urban development. This is the cause of environmental degradation and conflicts between competing land uses. Based on this and the above objectives, the following questions were formulated to guide the study: 1) What are the biophysical and environmental land resource characteristics of the study area? 2)What is the current pattern of land use? 3)What has been the past changes in urban settlement development, and what will happen if the trend continues? 4) Where are the land areas suitable for urban expansion? 5) For a given area of land what are the most appropriate forms of urban land use? 6) How does urban land use compare with use of the same land for other purposes? 7) What is the risk of environmental degradation in different land areas? 8)What are the land use planning, management and development control measures necessary to overcome site specific limitations and enhance physical potentials for urban development?

1.5 Scope of the study

Integrated land evaluation involves not only the analysis of the physical environmental factors but also detailed analysis of the social, political, economic and cultural factors. However, the present study is limited to physical land evaluation in which socio-economic factors are considered in general context. The study is not an attempt to produce an urban land use plan, neither is it exhaustive in dealing with all physical land resource matters. It largely addresses broad-scale and long-term land resource issues that affect physical urban expansion into the fringe areas. The study does not deal with contemporary short-term issues in the inner urban areas, but long-term issues on the outer urban areas.

There was general lack of detailed data on land and natural resources in the Nakuru municipal region. The reports and maps of land resources inventory available are very old and too generalized. These cannot act as baseline information to support detailed land evaluation study necessary for land development in urban areas. Thus this study provides a relatively broad scale data frame, presenting information not on local conditions but on general regional pattern.

The thesis is organised into six chapters. Chapter 1 has set the stage by presenting issues in urban development and environmental degradation. It discusses the problem to be addressed, objectives and general methodology and ends by discussing the outline of the study. In chapter 2, the state of the art of land use planning and land evaluation is briefly reviewed with regard to principles an practices. It also covers a brief review of important physical land characteristics critical in land use planning.

Chapter 3 describes the study area. The physical environment and socio-economic factors of the area relevant for land use planning and necessary for land suitability classification are discussed. The nature and extent of pressing physical environmental problems associated with urban development in the urban-rural fringe of Nakuru town is also summarized.

The analysis of data is made in chapter 4. Land suitability classification is established and maps presented illustrating the constraints and opportunities for urban development. In chapter 5, the results are interpreted for physical land use planning. The results of physical classification are compared with the current land use and visions or concerns of the local residents to provide policies and concepts for land use planning. Chapter 6 finally summarizes the findings and draws conclusions and recommendations for sustainable urban development.

1.6 Research Methodology

This study is based on data obtained from fieldwork, aerial photo interpretation and literature review. The data collected was analysed using simple techniques based on framework for land evaluation (FAO 1976), and results presented in form of maps, tables, charts and the text.

Topographical maps at scales of 1:50,000 and 1:10,000 covering Nakuru municipality and the environs were available as base maps. The Exploratory soil map of Kenya (Sombroek et al. 1982) provided the general soil database which includes information on soil characteristics, landforms, slope gradient and surface geology. Information on climate and agro-ecological zone maps were compiled from meteorological and Agricultural Handbook of Kenya (Jaetzold and Schmidt 1983). Borehole data and reports on the geology and groundwater conditions of the Nakuru area provided information on geology and hydrology (McCall, 1957,1967). Black and white air photos covering the area were available at scales of 1:50,000, 1:20,000 and 1:12500 for the years 1969, 1975 and 1993 respectively. Land use data were obtained from existing maps, field observations and air photo interpretation.

The main activities consisted of pre-survey land resource inventory, field survey, and post-survey land suitability analysis. The first stage was literature study and collection of relevant data. The purpose was to get acquainted with the study area and develop a theoretical framework through studying reports and literature from former studies. Local references concerning land resources and land use of the study area were also helpful for building up a consistent air photo interpretation.

Air photos were interpreted manually using mirror stereoscope resulting in identification and mapping uniform land areas based on physical land characteristics. The land units were described from interpretation of air photos in combination with existing maps and reports. A series of thematic maps were compiled and transferred on to the base maps by tracing on transparent overlays. The preliminary maps with land units, thematic information and legend description were used for planning of the fieldwork. During the fieldwork the information obtained from air photo interpretation was checked and modified.

Field survey in Nakuru was done between November 1995 and February 1996. Data was collected on land characteristics, land use issues and trends through direct observation, interviews, discussions and administration of semi-structured questionnaires. Administration of questionnaires and on-site interviews with the local residents provided information on current land use and trends, land tenure, land size, land use conflicts and other issues. Discussions were held with officials in various departments of Nakuru Municipality, central government, Kenya Wildlife services, Lake Nakuru Conservation and Development Programme, and other agencies in the area.

A prepared field data form was used for recording field information on land characteristics for each land unit. The field survey was designed to cover as many of the delineated land units as possible. In practice, fieldwork was restricted to access along existing roads and tracks. After fieldwork, the land units map was re-assessed and corrections made based on field experience and re-interpretation of the air photos. The land units map was then transferred to a base map and a series of thematic maps drawn.

The urban land suitability analysis was based on the comparison between physical land characteristics and urban land use needs. This involved the systematic arrangement of the land units into various categories according to their fitness to sustain urban development without long-term land degradation. Physical land factor considered in the analysis include: geology, hydrology, soils, climate, land use and topography among others. The analysis was first based on ranking individual land factors then combining all the factors to arrive at the physical land suitability classification. The results are combined with pertinent information to arrive at the urban land use planning and management strategies.

CHAPTER TWO

2 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Land Resources and Land use

Land degradation and environmental problems associated with urbanization continue due to the failure to include adequate information in the development planning phase. Land is the foundation of most human activities and its wise use is crucial for economic, social and environmental well-being of the present and future generations. The definition of land adopted in this thesis is that land is the interface between the Earth's solid surface and the atmosphere consisting of all characteristics of the biological and physical environment that have influence on land use (Davidson, 1980). The elements of land include soils, landforms, geology, hydrology, climate, vegetation, wildlife and effects of current and past human activities. (FAO, 1976)

The amount of habitable land is fixed while the intensity of its use is increasing with population growth. Land can be used for different purposes for which urban development is just one, therefore it is important to ensure that land use activities are carefully matched with the natural conditions of the land. This is particularly urgent in urban settlements where expansion of population and industrialization has generated rapid rise in urban land use activities. Increasing population pressure and changing human needs and aspirations have played a crucial role in competition between different land uses resulting in conflicts (Bernstein, 1993). Land use planning can minimise these conflicts and helps decision-makers to create a condition in which specific social, economic an environmental goals can be met.

There are many elements of an economic, social and political nature that must be considered in planning for land development. These have been deciding factors in the past and will definitely continue to be so. Nonetheless, the physical environment and land resources deserves increased consideration. The soils, geology, hydrology, climate, natural hazards, topography and other natural features are often so familiar that they are overlooked in urban development planning. A better understanding of these factors and recognition of their implications for urban development lead to intelligent land use planning. Some of these factors are briefly considered in the following sections.

2.1.1 The soil

Soil is an important and valuable element of the natural environment that influence urban development. It serves as a foundation for building, roads and all other man-made land-based structures and its properties serve to stabilize waste and purify water (Simonson, 1973). Failure to consider the potentials and limitations of soils during the planning stage of urban development may create serious health, safety and pollution problems. Such problems include instability or failure of building foundations, soil erosion, lake sedimentation, failure of septic tank sewage disposal systems, cracking roads, and surface and groundwater pollution. Soil depth to bedrock and presence of stones or rock on the soil surface will influence the cost and ease of construction and site preparation for building and installation of underground utilities such as water supply and sewage disposal systems (Bartelli, 1966).

Development on unstable soils will incur extra costs to overcome the soil limitations such as the removal of poor soils and their replacement with stable material. Soils susceptible to erosion will also limit suitability of a site for urban development due to the need for special design to avoid further erosion. Planning based on understanding of soils can guide urban development to avoid soil-related problems. Information is required on the geographical location of various kinds of soils, their properties, and potential and constraints to support urban land uses.

2.1.2 Geology

Consideration of geological conditions is essential in planning and construction in urban areas. Rocks give the land its foundation so that it can support heavy structures on the surface, they are sources of water, and they serve as disposal sites (Legget, 1973). Improper use of this resource results in jeopardized water supplies and damaged construction structures. Land areas with surface rocks poses excavation problems and may drain poorly. Because of high costs, rocky sites will influence decisions on excavation and below-ground services. Local residents may find it impossible to dig latrines or drains and may require mechanical diggers. Conversely, if an area has loose or unconsolidated surface material, proper support will be required for structures. Most urban development originally occur on the most favourable land available, but are later forced to expand on to less desirable geological conditions such as active faults and subsiding areas. Planning based on understanding of geological environment can aid in anticipating and providing pre-development solutions to land use problems.

Changes in the geological environment resulting from growth of cities have been discussed by Kotlov (1972). Properties of rocks may be changed as a result of urban development, especially as structures are enlarged downwards into the bedrock. Changes may occur in the rock and geological processes by transforming stress conditions of rocks under the influence of dynamic and static loads. This may result in compression of rock and settling. With the increase of concrete construction and in the number of floors of buildings the loads are increasing. The understanding of negative influence of cities on the geological environment is important for land use planning.

2.1.3 Hydrology

Urban development on any site will always have some effect on the existing hydrological conditions. Impacts of urban development on natural hydrological systems have been emphasised by Hannan and Rick (1980) and UNEP (1996). Underground water systems influence the perfomance of rocks or soils and is a major source of water supply. The underground water is recharged by surface water which seeps down through the soil and rocks.

Development or building over land areas where rainwater seeps into the ground can lead to rapid run off and hence reduce groundwater recharge. The development or building on an area always leads to increased surface run off and can lead to flash flooding. The restriction of groundwater recharge and rapid may also result in decreased dry-weather flow in rivers down stream and drying up of wetlands.

Any new development adds to the total urban activities and will also add to urban water pollution. If the surface water is contaminated the underground water will also be contaminated by the recharging process. Water pollution problems caused by inadequate waste water treatment may be critically increased by additional urban development. In order to maintain the quality of underground water, building over aquifer recharge areas should be avoided and waste disposal on the land surface where recharge of underground water occurs must be controlled. This requires consideration of the hydrological conditions in urban development planning. Urban development should be directed away from groundwater recharge areas and away from surface streams.

2.1.4 Slope

Slope influences many aspects of land use and environmental components of the land. Therefore slope should be one of the most important criteria for regulating land development. Level or gently sloping sites are usually ideal for urban development. An area with very steep slope will pose problems for the design and construction of buildings, communication, water supply and sewage services. Slope gradients of over 15 degrees have low suitability for development because of the cost of roads, buildings and high risk of soil erosion (Marsh, 1991). Slope is an important criteria commonly used for evaluating land suitability for development proposals by planning agencies in America (Table 4.3).

In urban areas, stormwater runoff rates are higher on steeper slopes and quality of stormwater tend to decline with higher runoff rates. The performance of septic drainfields for residential on-site sewage disposal also decline with steeper slopes. Both very steep and very flat sites will thus require special engineering design which will increase the cost of development. To avoid costly development and damage to the environment it is necessary to make the proper match between land uses and slopes.

Table 2.1 Slope requirement for various urban land uses (Marsh, 1991)

Land use	Slope gradient (%)		
	Maximum	Minimum	Optimum
House sites	20 - 25	0	2
Playgrounds	2 - 3	0.05	1
Septic drainfields	15	0	0.05
Sidewalks	10	0	1
Parkings	3	0.05	1
Industrial sites	3 - 4	0.05	1
Lawns	25	—	2 - 3

2.1.5 Natural Hazards

Consideration of natural hazards is very important in urban planning. Common natural hazards such as flooding, soil erosion and sedimentation, volcanic eruption, faulting, dust storm, rockfall, landslide, land subsidence, expanding soils and wildfires can pose major threats to urban development (Bernstein, 1993). These hazards occur irregularly and have sudden onset. Poor planning may contribute to urban settlement occupying hazard-prone areas leading to land degradation and catastrophic events.

Natural hazards can lead to the disruption of critical services, destruction of property and productive facilities and impair socio-economic functions necessary for overall urban development. For example sewage and solid waste disposal sites located in land subsidence and active fault areas could contaminate groundwater. Hazards and associated disasters may result in social instability and serious setback to overall socio-economic progress (UNCHS, 1989).

In responsible land use planning it is essential to obtain local information on the nature and extent of acute natural hazards. These planning parameters can support decision-making in prevention, management and preparedness measures for natural hazards. Resilience to disruption through natural disaster promotes socio-economic stability that in turn is a necessary condition for sustainable urban development and management.

2.1.6 Natural landscape and Open space

As urbanization occurs, land development exerts pressure on surrounding areas. Uncontrolled urban growth can lead to deterioration or loss of unique natural landscapes and other open spaces adjacent to the city. Open space or non-built green areas can serve as a buffer zone to provide separation between conflicting land uses or to protect vulnerable areas. Open space and unique natural landscapes can promote aesthetic values and create community identity. The scenic beauty or scientific value of such areas can also bring economic benefits when they attract tourists.

Although the need for recreation and scenic beauty may be less critical than for other urban purposes, the loss of space for these amenities prevents both present and future generations from enjoying the benefits (Taboroff, 1990). Destruction of these resources is generally irreversible and may represent a loss of not only local identity but also threaten the integrity of internationally significant natural resources.

2.1.7 Prime Agricultural Land

One of the unavoidable impacts of land conversion for urban development is the loss of prime agricultural land. When this occurs, not only will additional farmland have to be found elsewhere but food and raw materials have to be carried greater distances or imported and stored for longer periods at higher energy costs (Douglas, 1992). Peri-urban agriculture in many developing countries usually contribute significantly to supply of cheap food to urban population. In Kenya, many urban households grow a significant portion of their own food or derive income from selling agricultural products produced just outside the municipal boundaries (Lee Smith 1987). Therefore good quality farming land should not be taken up for urban development.

2.2.0 Land use planning

2.2.1 Land Use Planning Purpose

Planning to make the best use of land is not a new idea, decisions on land use have always been part of the evolution of human society (Marsh, 1991). Historically, man has consciously and unconsciously evaluated the physical environment in selecting areas of settlement. In the past land use decisions came about as a result of individual subjective judgment based on incomplete information but often incorporating high degree of experience. Through trial and error land use became localized in some places long before scientific knowledge exited. However, with increased environmental awareness and overcrowding in urban settlements, land use planning is a prerequisite for sustainable development (Habitat, 1994). Good information about land resources and about environmental consequences of alternative land uses is essential. Land suitability evaluation is a tool for translation of land resource information into a form useable for land use planning, especially in early stages when a large number of alternative land use patterns have to be screened (FAO, 1976).

Land use planning has been described as the centre piece of urban and regional planning (Roberts, 1988; ISCRP, 1995). It is directed at the bets use of land in view of accepted objectives and environmental and societal opportunities and constraints. Lovejoy (1973) defines land use planning as the planning for the most appropriate and efficient use of land. Chapin (1979) views land use planning as concerned with the location, intensity and amount of land development required for various space using activities. In a similar sense Dent (1988) defines land use planning as a systematic process for guiding land use decisions in such a way that land resources are put to the most beneficial use for man while conserving the resources for the future. It is meant to indicate what is possible in future with regard to land use and land resources, and what should be done to go from the present situation to the desired future one.

The central concern of land use planning is the formulation and implementation of plans, projects, programs and policies to reach sound use of land (FAO 1994). The specific objectives of land use planning will depend on the local situation. However general objectives include: efficiency in the use of land resources; equity between groups in the society and competing uses, balance between short term benefits and long-term conservation of land resources of the future. According to Dawson (1984), Held and Visser (1984) and Okpala (1982), the justification for control over land use and physical development are: 1) to preserve or protect desired elements of the existing environment; 2) to reduce or eliminate certain hazards; 3) to achieve greater efficiency in the use of land resources; 4) to discourage certain uses which are incompatible with existing uses; 5) to control the aggregate allocation of land among alternative uses; and 6) to ensure and allow for predictability in urban growth and development so as to make for adequate provision of public services.

Land use planning may be undertaken by any level of government, private individuals and corporate bodies. To differentiate land use planning from land management planning and land development project planning, Samson (1975) describes land use planning as the governmental process that directly regulates or influences the use of land not owned or directly controlled by the planning agency.

2.2.2 Land use Planning Process

General urban land use planning process consists of a series of interacting activities. Six distinct elements are distinguished in operationalized rational land use planning process (Chapin and Kaisser, 1979). These include: problem identification, identification of goals and objectives; determination of what alternative solutions exist; formulation of plans, selecting and implementing the best plans; and monitoring the progress.

A very important stage in any land use planning process involves definition and analysis of the problem. As a part of this task, inventories of natural environment in the area, existing land use and many other factors are traditionally analysed as information input to land use planning. Common natural environmental factors inventoried include geology, soils, climate, hydrology, vegetation, wildlife and others. Although most environmental resource inventories touch on some aspects of all of these factors, they vary in their specific focus and interpretation depending on the reasons for which the information is gathered. There has been much recent emphasis in developing better methodologies for inventorying natural environmental as an input in land use planning (Steiner, 1981).

However, in the traditional approach to use of environmental data in land use planning, focus is to determine environmental constraints to development. The natural environment is viewed as posing constraints, particularly in economic terms to development. This type of resource inventory and analysis which stresses major conflicts between natural features and land development is still useful as well as realistic. Furthermore, such information is necessary to ensure sound development practices. However this traditional approach places highest priority on development, mainly for economic gain but partially neglecting environmental protection.

The increasing emphasis on sustainable urban development and environmental conservation is challenging the traditional land use planning process. New methodologies for inventorying and analysis of natural environmental factors in land use planning are required. These methods need to emphasise the protection of the natural environmental resources. Such methods of land use planning have been developed in agricultural land use planning (FAO 1993) and being developed for landscape planning (Steiner, 1991).

FAO (1993) has produced framework of principles and procedures that give general guidelines to land use planners and that can be adapted to local needs. It provides an overview of the land use planning process in ten steps: 1) establish goals and ground rules; 2) organize the work; 3) analyse the problem; 4) identify opportunities for change; 5) evaluate land suitability; 6) appraise the alternatives; 7) choose the best option; 8) prepare the land use plan; 9) implement the plan; 10) monitor and review the plan.

The first three steps involve identifying the issues to be addressed. In step 1 the basic information about the areas is acquired. An issue or group of related issues is identified which are problematic or present an opportunity to the people and or the environment of the region. Broad goals and objectives and scope of the land use plan are set out. This leads to step 2 which involves deciding on what activities are needed, drawing up a programme of work, and ensuring that everyone who may be affected by the plan or will contribute to it is consulted. In step 3 the existing land use and land situation is analysed. Inventories and analyses of biophysical and socio-economic and cultural processes are conducted first at the regional level and second at the local level. Discussions are held with land users and developers to find out their needs and views. Government policies and regulations are also analysed. Problems are identified and their causes analysed in addition to identification of constraints to changes.

Existing alternative solutions are determined in step 4-6. In step 4 alternative future land uses that might address the problems and achieve the goals of the plan are identified. These development possibilities should be presented for discussion. In step 5 detailed studies are made that link the inventories and analyses information to the problems and goals. Such studies attempt to relate broad regional and local information to specific sites. Land suitability evaluation is one such type of detailed studies. In step 6 the environmental, social an economic impacts are assessed for each physically suitable combination of land use and land. Other studies may include cost-benefit analysis, social impact analysis and environmental impact assessment.

The next two steps decide on which is the best alternative and prepares the plan. In step 7 the suitable plan is reassessed and final decision taken based on development policies and concepts, and political decisions or issues of priority resource allocation. This is achieved through holding public and executive discussion of the viable options and their consequences. Based on these discussions and appraisals, decisions are made on which changes in land use should be made or worked towards in the new plan. Detailed land use plans are then designed in step 8. Activities in step 8 include: making allocations or recommendations of selected land uses for specific areas of land: plans and policies for appropriate land management; plans of how the selected changes are to be brought about; and how the plan is to be put into practice. Policy guidelines are drawn, budget prepared and any necessary legislation drafted. It is important to involve decision-makers, sectoral agencies and land users throughout the process.

The last two steps in land use planning should put the plan into action, see how it works and learn from its experience. Most plans prepared by external agencies do not reach these last two steps. In step 9 the plan in implemented either directly within the planning process or as separate development project. In step 10 the development of the land is monitored to learn from the success or failure of the project.

These steps are not clearly separated in time but overlap (FAO, 1993). There is never enough knowledge about the land and its response to management, and as more information and experience are gained, plans have to be changed. Furthermore, land use planning seen as an iterative process, conclusions in later steps may throw new light on conclusions arrived at in earlier ones, leading to review. The guideline is not a prescription for land use planning but it only meant to be a flexible guide from which more detailed local procedures can be developed. Field testing of this land use planning process has resulted in amendments to the guidelines and methods (FAO 1991). The guideline has been intended to help all those involved in rural land use planning, development and management that emphasize environmental conservation.

An example of landscape planning process which emphasizes development based on natural environmental conservation is given by Steiner (1991) in the Teller County and the city of Woodland Park, Colorado, U.S.A. The opportunities and constraints for development and conservation were first identified. The recognition of these issues resulted in the goal to direct future growth to the most appropriate places. To determine best places for new development, thorough ecological inventories were conducted for the county as well as for the city area. From these inventories, environmentally sensitive areas were considered constraints in conducting suitability analyses for a variety of potential land uses. The suitability analyses resulted in the identification of opportunities for future growth and served as a decision guide in making policy recommendations for optimum landscape plan. This represents a major revision in urban land useplanning, characterised by emphasis to conserve the most important natural features of the planning area.

2.2.3 The need for a new approach inland use planning

Conventional land use planning has been criticized for not delivering what it promises (Habitat, 1995). One point of criticism is that very little attention has been paid to integrate biophysical information into social, cultural, economic and political information in land use planning. Traditionally, socio-economic factors have decided the use of urban land irrespective of the ecological considerations. Roberts and Roberts (1984) observe that since the time of Geddes the place of natural factors has declined in urban land use planning circles as other considerations have become more central. While many models exist that deal with the economic and social aspects of land use planning relatively few models address the ecological aspects.

More recently, concerns are being raised about the effect of urban development on land and related resources (Bernstein 1993; Hardoy et al 1992). This has given rise to the concept of sustainable urban development. Clarke (1995) defines sustainable urban development as the condition of maximizing economic efficiency, social equity and unnecessary foreclosure of future development options. Contemporary response to sustainable urban development gives too little attention to sustainable use of land and related resources. There is a risk that ecological dimension of sustainability will be ignored within the context of sustainable urban development.

With the broad goals of sustainability now clarified in Agenda 21 (Habitat, 1994), attention is now turning to practical methods for their attainment. FAO (1993) describes sustainable land use management as involving a combination of socio-economic principles with environmental concerns so as to maintain services, reduce risks, protect the environment and achieve economic viability and social acceptability. Sustainable urban development should emphasise the application of ecological principles and information to urban land use planning. This is one mechanism for harmonising and making compatible the interrelationship between urban development and the natural environment. Such ecological or environmental concern can best be introduced in the land use planning process which give the guideline to all other development activities. However in conventional land use planning very little emphasis is given to ecological or environmental concerns. Inclusion of ecological information in urban land use planning and management decisions is now actively accepted but there still remains difficulty in how to assess, organize and incorporate such information into the land use planning process.

There are several reasons for the sad situation where urban land is developed for short-term economic gains with little regard for long-term ecological and economic issues. According to Miller (1992) ecological issues are not given priority especially in time of economic difficulty when different interests are forced to compete for scarce resources. Socio-economic concerns usually take precedence over ecological concerns because ecological projects are not vote winners for politicians. Furthermore, ecologically sound land use plans require long-term focus, but local officials seeking election every few years usually focus on short term rather than long term problems. In addition, socio-economic changes are also easier to recognise and deal with unlike ecological changes. The other major constraint in environmentally sensitive urban land use planning is the lack and inadequacy of ecological information, and effective models for integrating the information with social, cultural, economic and political information (Bernstein 1993; Roberts and Roberts, 1984)

Ecological sustainability in urban development planning is now emphasized although ecological requirements for various urban land uses still remain unstated. Land use planners have found it difficult to specify the information which they must have in quantitative form from land resource surveys. On the other hand, the scientists have problems in translating their scientific jargons into practical terms useful for practical land use planning. Therefore there is a problem to relate biophysical land characteristics to urban land use activities.

However, the premise of many urban land use plans is that natural landscape is not uniform surface but is a complex natural system with varying ability to support different land uses (Steiner, 1991). Even in a small planning unit there can be a great variety of environmental units. Each of these units requires a slightly different planning response. Rational management of this natural landscape requires a methodology that evaluates the attributes of the land in such a way that a parcel of land can be rated according to its suitability for a given land use.

Environmental Impact Assessment (E.I.A.) has been successfully applied as a tool for incorporating environmental information into development projects (UNEP, 1988). However, little experience exist of the use of EIA in land use planning, although land use planners have long argued that all land development proposals should be subjected to environmental appraisal (Huang 1989; Koslowski, 1989). The major weakness of EIA is that it is only applied to major development projects such as construction of dams, roads, factories and related projects. Therefore environmental impact assessment is a special type of appraisal involving detailed analysis of the likely implication of development. However undertaking EIA at the project appraisal stage of development planning is too late and too localised for certain environmental considerations to be addressed. The type, scale and location of a project will often already have been decided, based on maximizing economic and social benefits at the point when EIA is commissioned. It is only recently that the importance of extending the process of EIA to land use planning has been recognized (Therivel, 1994). However, Conarchev (1994) argues for alternative methods for integrating environmental protection into land use planning.

In Kenya, formal environmental impact assessment is still in its infancy stages (Government of Kenya, 1994b). Standard procedures and guidelines for EIA have not been prepared yet. Urban land developers need only to prepare plan proposals with details of development features before applying for permission. The local authorities then consider the development applications in relation to its conformity with the short- and long-terms plans. Considerations of environmental impact reports are only required for large scale projects such as factories. However since there are not standard guidelines, decisions are made to meet the individual needs of each situation.

Due to escalating urban environmental problems. There have been initiative to establish an urban environmental planning system in Kenya (Duchhart, 1989). The Green Town Project or the Environment and Urban Development project is a collaborative programme of the Kenya Government and the Agricultural University of Wageningen, of the Netherlands. The main emphasis of the project is to create awareness and train local people in environmental planning (Green Town Project, 1994). The Green Town project has developed simple urban environmental planning procedures based on local problems and practical solutions for Kenyan towns. Although the approach is experimental, it is flexible, action-oriented and open to learning. However the techniques used are non quantitative and lack theoretical background, thus only useful for general urban development planning and management. It is mainly based on the application of landscape analysis and planning techniques. Therefore, the method does not address the full scope of the urban land use planning process comprehensively. It cannot provide decision-making support for urban land use planning.

One approach that holds the potential to meet the demand for integrating environmental protection into urban land use planning is land suitability evaluation.

2.3.0 Land Evaluation

2.3.1 Nature and purpose of Land Evaluation

Land evaluation can be considered as an analysis method for making land use decisions that emphasize environmental concerns. There are several techniques that may be used to accomplish the analysis. The earliest variations of the method were developed by ecologist seeking means of classifying land characteristics that affect alternative land uses. MacHarg (1969) popularized the overlay technique of suitability analysis. This work has been widely read and cited and was an influence on the environmental thought of the 1970s. The overlay technique involves maps of inventory information superimposed on one another in order to identify areas that provide opportunities and constraints for particular land use. McDougall (1975) has criticized the accuracy of map overlays and made suggestions on who they may be made more accurate.

Land evaluation has been subsequently refined and is today widely used in urban land use planning (Atkinson et al 1995; Chapman et al 1992; Dumanski et al 1979). Section 10 of the world conservation strategy (IUCN, 1980) specifically proposes the integration of conservation and development through land suitability evaluation.

United Nations Food and Agricultural Organization (FAO) has been the pioneer and champion in the field of land evaluation. FAO has established a variety of land evaluation methods including: the Framework for Land Evaluation (FAO, 1976), Agro-Ecological Assessment (FAO, 1983) and Framework for Sustainable Land Management (FAO, 1994) among others. Traditional landscape analysis is related to but different from land evaluation. Landscape analysis has long been used as a tool for incorporating environmental concerns into urban development planning. However it is more of an exercise of beautification in which environmental protection focuses on aesthetic and emotional issues.

Land evaluation is the process of assessment of land performance when used for specific purpose (FAO, 1976). The main aim of land evaluation is to assess the suitability of different types of land, usually shown on maps as land mapping units, for selected and specified land uses. The process of land evaluation involve the execution and interpretation of basic land resource surveys on climate, geology, soils, hydrology, vegetation and other aspects of the land, in terms of the requirements of alternative land uses. The evaluation takes into consideration the economic, social and other consequences, beneficial or adverse, of the people and the environment. Land evaluation supports land use planning by integrating environmental protection into land development. The results indicates the natural suitability of a range of land areas to various land uses, accompanied by land management measures required to overcome limitations posed by the land. This provides qualified information that can support various decision-making aspects of land use planning such as land use policy formulation, land use zoning, development control and project site selection.

2.3.2 The Framework for Land Evaluation

Various procedures for land evaluation have been developed in different part so the world. The differences between them arise from the differences in land use problems to be solved, prevailing physical and socio-economic conditions and the constraints encountered. The concepts, principles and outline of land suitability, assessments are established in the FAO Framework for Land Evaluation (FAO, 1976). Most of the other methods are modelled from this. The framework provides the structure by which any land can be evaluated for any defined purpose as long as the land use requirements are known and the necessary data about the land is available.

The framework for land evaluation rests on six basic principles: 1)land suitability only refers to use on a sustainable basis; 2) evaluation is made in terms relevant to the physical, economic and social context of the area concerned; 3) land suitability is assessed and classified with respect to specified kinds of land use; 4) evaluation requires comparison of inputs and benefits; 5) evaluation involves a comparison of more than one use and, 6) a multidisciplinary approach is required.

Land suitability evaluation is made with respect to specified kind of land use. This is the most fundamental principle of land evaluation which requires the comparison of land use requirements with quality of the land. Each kind of land use has different requirements and conditions under which it will perform best. Similarly different types of land areas are best suited to different land uses. Therefore land use requirements are compared with the relevant land characteristics of the land mapping units. If the characteristics fulfill all requirements, the land is classified as highly suitable. If one or more characteristics do not meet the requirements, the land is classified as moderately suitable, marginally suitable or not suitable.

Land evaluation is made in terms relevant to the physical, economic, political, cultural and social context of the study area. The results of one evaluation cannot be applied globally, nationally and often not even throughout a region. This is due to large local variations so it is not realistic to recognise as suitable forms of land use which although successful elsewhere, depend for success on different factors. The structure of the evaluation will remain the same but the relevant land characteristics and their critical values forming boundaries between classes will vary from one area to another. What is assessed as suitable land in one area may be unsuitable in another locality where the environment is similar.

Land suitability refers to use on a sustainable basis. This principle requires that the environmental conservation aspect should be given priority although the primary objective may be development. This principle does not require that the environment is maintained in its unaltered state since it is unrealistic to expect that land development will have no effect on land. Any land use proposal if implemented must not result in severe or progressive degradation. A form of land use may be regarded as suitable if no permanent or progressive deterioration of its fitness to the land is foreseen over a reasonable lengthy period of future time.

2.3.3 Land Suitability Evaluation Procedure

Land evaluation involves the analysis of biophysical and socio-econmic data. The methodology consists of integrating a number of concurrent and sequential activities which include the collection, analysis and integrating different data sets. The outline of land evaluation procedure based on the FAO framework is presented in Figure 2.1 below. The procedure starts with identification of problems to be addressed and setting the objectives to be achieved. The level of analysis depends on the objectives which determines the map scale and degree of details.

The study of land use and inventory of land characteristics are major activities. The study of the land use leads to the description of land uses which appear to meet the objectives and to be relevant to the context of the area. The inventory of land factors may either be undertaking as an integral part of land evaluation or the evaluation may be based on the existing data. The study of the land leads to identification and mapping of relativity uniform land areas, or land units. Each land mapping unit is described in terms of physical and socio-economic characteristics.

These two activities are brought together in the comparison of land use with land. The first stage of comparison is matching in which the physical requirement of each kind of land use is compared with the properties of each area of land. Further comparison involve bringing together social and economic information or environmental impact assessment to arrive a the final suitability classification. In essence land evaluation involve assessment of land units with respect to specific land use alternatives which are environmentally sound, physically practicable, economically viable and socially appropriate.

The result of the evaluation are usually presented in maps showing land units, their suitability ranking and the physical constraints of the land units for land use and description of land use activities. The maps show the level of suitability of the land units for the land use and location and extend involved. The classification results of land evaluation can be given in either qualitative or quantitative terms.

In qualitative classification the suitability classes are only defined in qualitative terms without any economic calculations. This type of study is useful at regional level scale covering a large area. It allows the qualitative integration of many aspects of the physical, social and environmental. In detailed studies specific monetary values can be assigned to all data from the qualitative evaluation so that the cost of land development can be compared with the benefits. This type of evaluation is only possible at very large scale covering small areas and where all the land use requirements can be readily determined. The results of land evaluation makes is possible to determine the consequences of the implementation of a specific land use in terms of environmental impact, infrastructure requirement or management specifications. These are the basic criteria used in the preparation of land use plans.

The framework for land evaluation (FAO, 1976) is widely accepted as an international basis for land evaluation because it is comprehensive, flexible, quantifiable and globally applicable. The procedure assumes that specific requirements of land use activities are known, but detailed information is often not available. Therefore the task might simply involve providing a map showing specific problem areas for particular land use.

2.3.4 Land Evaluation in Practice

Although land evaluation has developed in the field of agriculture, practical experience has been gained in applying the method in non-agricultural settings. The adoption of the method is feasible because the core of the framework is a set of concepts and principles that can be adapted to different land evaluation situations. A comparable land suitability assessment for urban land use is being developed in Australia (Chapman et al, 1992). This has been adapted from FAO framework and designed to indicate urban land suitability information as a basis for negotiation between land developers and local authorities. The system include two levels of broad urban land

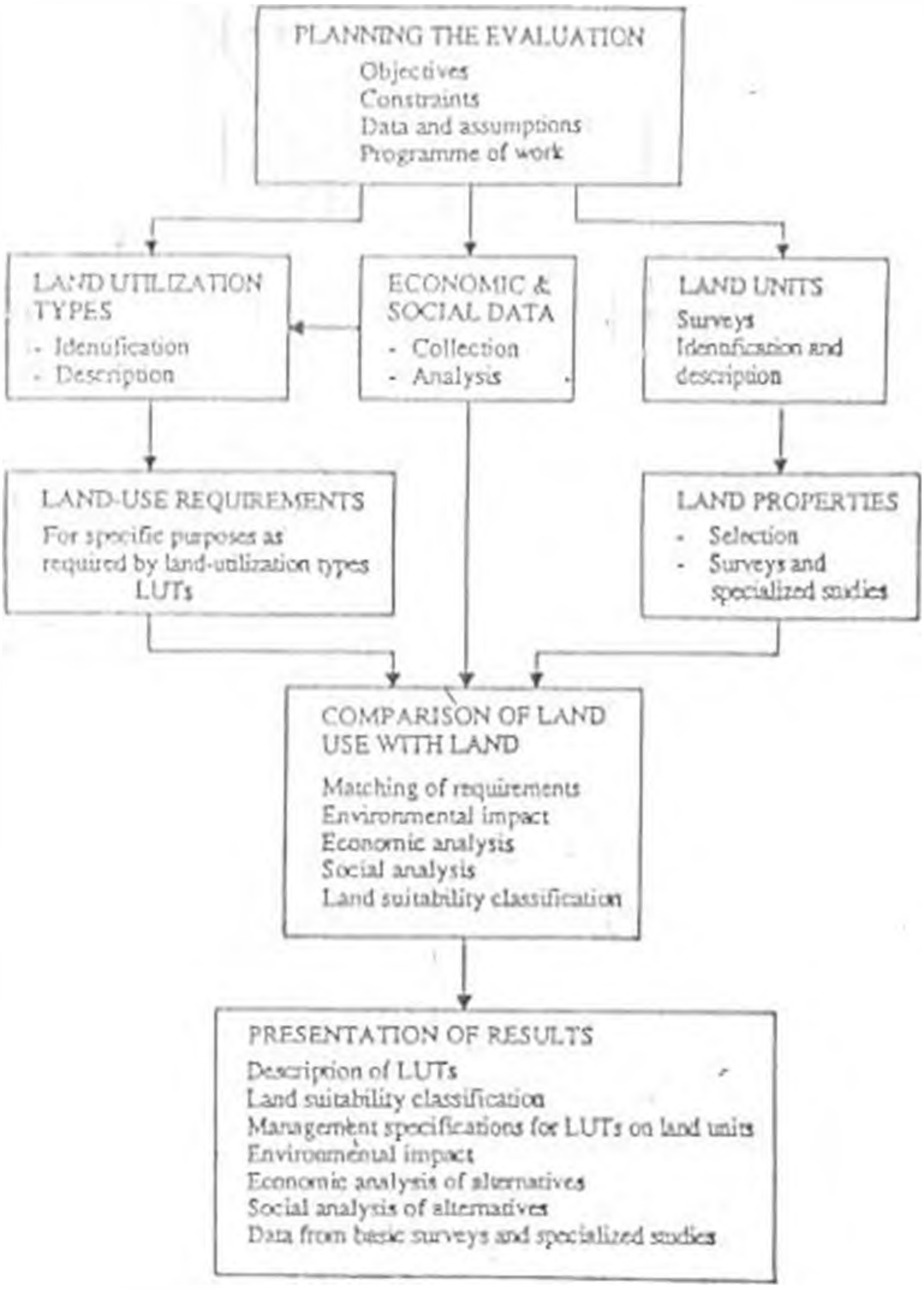


Figure 2·1 The Land Evaluation procedure.
(source: FAO, 1984)

capability assessment based on how specifically the land use is defined. Urban land suitability assessment framework, like framework for land evaluation does to offer a methodology worked out in detail which can be applied, but comprises valuable concepts and procedures which can lead to a better applicable system.

Dumanski et al (1979) have used a form of land evaluation based on soil survey data in an attempt to derive an urban suitability map for Ottawa urban fringe in Canada. The major land factors relative to urban land use were analysed along with other data to show the suitable land areas for urban expansion. The procedure used was to progressively eliminated from the map those physical land factors most serious for construction as well as prime agricultural land. The land factors considered are: drainage; topography; rockiness; organic soils; and surface gravel among others. The results were compared to the regional development plan for alternative land use pattern.

In the United States, Lyle and von Wodtke (1974) describe the derivation of a best-action model, which is essentially a land evaluation concept derived from data provided by an environmental information system. Atkinson et al (1995) have used a form of land suitability evaluation in their attempt to assess potential sites for location of sanitary landfills in the Denton County, Texas. The distinctive quality of this work is its computerized manipulation of the base data using Geographical Information System (GIS).

In Kenya, the system of land evaluation has been modified from the FAO framework to suit the local situation (Weeda, 1987; Weg Van de, 1978). Land resource surveys are carried out at different scales for multipurposes. However, most of the land evaluations have strong bias towards agricultural considerations. The Kenya Soil survey (K.S.S) carries out inventory of soils, vegetation, climate, topography and land use factors which are relevant for specific land uses (K.S.S., 1987). Although the application of land evaluation for non-agricultural land uses are few in Kenya, there have been some outstanding examples.

Land evaluation based on soil survey was carried out to locate the potential site for Jomo Kenyatta University of Agriculture and Technology (Muchena et al, 1978). The analysis considers the land factors, important for building foundation, such as soil depth, soil texture, slope, risk of flooding and soil drainage conditions. Similar studies were carried out for the potential location site of Moi Sports Complex Kasarani in Nairobi (Pouw Van der, 1981) and Meru College of Technology in Meru (Kanake and Kinyanjui, 1981). Most of these studies based on soil information have provided data for preliminary planing before detailed project design studies are initiated. However the Kenyan system of land evaluation although comprehensive requires major modification to be useful for non-agricultural land uses.

2.4 Summary

The land constitutes the physical medium in which urban development takes place. Land is not uniform everywhere therefore a spatial knowledge of land conditions is a prerequisite for sound urban development and management. Land use planning is the context within which the potential and limitations of the physical environment for development is furthered. The most important physical factors that determine urban land use include geology, soils, hydrology, climate, topography and existing land use and their interactions. Land evaluation has evolved as a method of incorporating bio-physical land information into land use planning.

Land evaluation involves comparison between biophysical needs of a land use activity and the properties of different land areas. It is based on the premise that each land use has specific bio-physical requirements with respect to land conditions under which the land use activity will perform well. These requirements are compared with the relevant land characteristics of homogenous land areas. For every relevant land characteristic there is a critical value or set of critical values which are used to define the suitability class limits. If the land characteristics of a given land area meet all the requirements the land is considered to be suitable. Otherwise if one or more characteristics do not meet the requirements the land is considered unsuitable.

Traditionally, land evaluation has evolved in the field of agricultural land use planning where relevant land characteristics and their critical values for specific land uses are well documented. Application of land evaluation methods in urban land use planning is still in the infancy stages and the bio-physical land use planning standards are not yet specified. There is need of continued research and case studies to refine suitability land evaluation for urban land use. This study might be the first time to apply land evaluation for urban land use planning in Kenya.

Experience gained in urban land suitability is still limited but the existing literature has been very useful in shaping this study. The methodology used in this study is based on the concepts and principles outlined by the framework for land evaluation (FAO 1976) and adopted by Kenya Soil Survey (K.S.S. 1987) and Urban Suitability Assessment (Chapman et al, 1992). As applied to urban land use, the method of land evaluation provides baseline information that describes land resources and land management and control measures necessary to avoid land degradation. Its role in land use planning is to ensure that land use decisions are taken in light of a full appreciation of the bio-physical consequences of land use alternatives. Some common terms are used with special meaning in land evaluation. The definition of selected terms is given below.

Land: An area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic, attributes of the biosphere, vertically above and below this area, including those of the atmosphere, the rocks, landforms, soils and underlying ecology, the hydrology, the plants and animal population and the results of past and present human activity, to the effect that these attributes exert a significant influence on present or future uses of the land by man.

Land characteristics: An attribute of land that can be measured or estimated, and which can be employed as a means of describing qualities or distinguishing between land units of deferring suitability for specified land use.

Land Development: All the activities leading to a durable modification of land conditions with a view of deriving higher benefits of the land.

Land Evaluation: The process of assessment of land performance when used for specified purpose.

Land Information System: A system of capturing, storing, checking, integrating, manipulating, analysing an displaying data about land and its use.

Land Management: Practices and inputs which are introduced on a recurrent basis and ensure over the years the maintenance of land conditions favourable to the land use considered.

Land Quality: A complex attribute of land which affect its suitability for specific uses in a distinct way.

Land Suitability: The fitness of an area of land for a specified kind of land use.

Land suitability classification: A classification of land areas in terms of their absolute or relative suitability for specified land use.

Land unit: An area of land possessing specified land qualities and characteristics, which can be demarcated on a map and which is employed as a basis in land evaluation.

Land use: The management of land to meet human needs. It is the function of land determined by natural conditions and human interventions.

Land use plan: A coherent set of decisions about the use of land and the ways to achieve the desired use. Land use planning is a systematic assessment of land potentials, constraints and alternative patterns of land use based on physical, social, economic, cultural and political conditions in order to select and adopt land use options which achieve specific goals.

Land Use Requirements: The land conditions necessary or desirable for the successful and sustained practice of a given land use.

Limiting value: The value of land quality or land characteristic identified as marking the boundary between land suitability classes.

Limitation Land quality or characteristic which adversely affects the potential of land for a specified land use.

Matching: The process of comparing land use requirements with land qualities to arrive at land suitability classification Also refers to the process of adaptation of land use and land management in order to achieve land use suited to land.

Qualitative land suitability classification: Land suitability grouping in which the results are expressed in qualitative terms only, without specific estimates in economic terms. this is in contrast to quantitative grouping which results are expressed in numerical terms.

Sustainable land management: A combination of technologies, policies and activities aimed at integrating socio-economic and environmental concerns in order to simultaneously maintain or enhance production or services, reduce level of risk or uncertainty, protect the potential of natural resources or prevent degradation, attain economic viability and social acceptability.

Physical: the abiotic elements of the environment including geology, soils, topography, hydrology and climate.

CHAPTER THREE

THE STUDY AREA

3.1 Geographical Background

Nakuru town is located about 150 km north-west of Nairobi, on the floor of the Great Rift Valley (Map 3.1). The centre of the town is nestled on the footslopes between Menengai Crater to the north and Lake Nakuru to the south. The gazetted Municipal boundary covers an area of 78 square kilometres at an average altitude of about 1800 m above sea level. Menengai Crater covers an area of about 60 square kilometres rising to an altitude of 2300 m above sea level at its rim. Lake Nakuru occupies 40 square kilometres depression at the lowest point in the region with an average altitude of 1750 m above sea level.

The study area covers a 30 km by 24 km rectangle bounded by latitudes 0°11' and 0°30' south, and longitudes 36°00' and 36°12' east. The present land assessment for urban development covers the land area immediately surrounding the municipality but excludes the inner town, Menengai Crater, and Lake Nakuru National Park (Table 3.1).

Nakuru town is currently the fourth largest town in Kenya. It is among the four towns for which there are proposals for upgrading from Municipality to city status. Nakuru town is the headquarters of both the Rift Valley Province and Nakuru District (Map 3.2). Nakuru has been designated as a growth pole in the past Kenya National settlement Policy (Republic of Kenya 1978), while other small towns like Naivasha, Gilgil and Molo as the growth centres for the region. The study area covers 720 square kilometres within the 1800 square kilometres Lake Nakuru catchment area (Map 3.3).

The economy of Nakuru town is dependent on agriculture, tourism, commerce and industry. The hinterland of the town consists of agriculturally high potential areas commonly referred to as the granary of Kenya. The region plays an important role in the Kenyan economy by contributing high quality agricultural products such as barley, wheat, pyrethrum, maize and livestock products. Agricultural land uses include small scale mixed farming, large scale cereal farming, ranching and dairying. There are a number of large industrial plants, small scale factories and service industries in Nakuru town. Many agro-based industries produce goods such as processed food, textile, tanned leather, timber products and other goods. Important service industries such as wholesale and retail, motor vehicle repairs and other facilities serve the town and its hinterland.

Lake Nakuru is internationally famous for its millions of flamingoes and attracts many tourists into the town. It was the most visited park in Kenya, in 1992, receiving about 200,000 visitors (KWS, 1995). In the last two decades, the town has experienced growth as an industrial, agricultural, tourism and administrative centre. The resulting population increase both due to immigration and natural growth has led to expansion of urban settlement into the surrounding areas.

Table 3.1 Extent of the study area

Region	Extent (km^2)	Proportion of Area (%)
Evaluated Area	420	58
Nakuru Municipality	78	11
Lake Nakuru N. Park	162	23
Menengai Crater	60	8
Total	**720**	**100**

(Land Evaluation 1996)

3.2 Geology and Soils

The study area is located on the floor of the Great Rift Valley, in what has been described as the Nakuru trough by Baker (1970). The Rift Valley consists of valleys, escarpments, faulted plains and volcanoes. According to McCall (1967,1957) the geologic structures of Nakuru area developed from a series of faulting and volcanic eruptions along lacustrine deposits. Movements in the earth's crust resulted in a series of fault with displacement of blocks of land to form the giant valley. This was combined with the effect of volcanic eruptions and geologic erosion. The depressions in the floor of the giant valley slowly filled with water forming lakes. Further volcanic activities and sedimentation of eroded materials divided the water bodies into smaller lakes such as Nakuru, Naivasha and Elementaita.

The geology of the area is made up of volcanic rocks of Tertiary and Quaternary ages, and sediments of recent age filing the

Nakuru trough. The rock units consist of lava flows, tuffs and pyroclastics forming the bedrock. These rocks were affected by faulting parallel to the Rift Valley, running in the north-south direction This resulted in the formation of ridges escarpments and faulted plains such as Bahati escarpment and Bahati plains. The lava flow rocks are made up of phonolites and trachytes found around Menengai crater. Pyroclastic volcanic rocks are found in localized areas forming cones and stratified tuffs (Map 3.3).

Lacustrine materials and surface soil deposits are common in relatively flat areas. Faultlines, joints and fissures dominate the structural geology of the region. The faults are well defined in areas such as Lion Hill ridges, Ronda hill and Bahati escarpment They all show a north-south orientation. However, in flat plains covered with deep layers of soils, these faultlines and fissures are not recognizable. The frequent land subsidence cases in the region have been reported to occur along the faultlines in the same north-south orientation.

Most of the landsubsidence cases have been observed to the West and south-west of Nakuru town centre Previous studies have tried to delineate areas prone to landsubsidence and postulate possible causes (Pulfrey 1951; McCall 1957, 1967; Pandit 1976; and Kagasi et al 1988). These studies agree that landsubsidence occurs on cracks and fissures along or above faults or fractures of tectonic origin. Most of the reported cases of landsubsidence occur during heavy rain seasons. There have been no noticeable earth tremors associates with any of the recorded land subsidence in the area. It is therefore believed that landsubsidence in Nakuru area is associated with existing faultlines but no concrete explanation has been given.

Soils of this area have been greatly influenced by the geology. Most of the soils are developed from highly porous and unconsolidated materials. The soil profiles are very deep in most areas but thin out to bare rocks in isolated areas. In lower lying plains and depressions, the soil parent materials are sorted debris from the rocks, tuffs and lacustrine sediments. This sedimentary materials extend over most of the area except the higher lying grounds such as Menengai crater, isolated hills and ridges. Most of the soils are young, poorly developed, porous, light and poorly structured.

According to Sombrock et al (1982) large parts of Nakuru town, Bahati plains and Elementaita are covered by a complex of andic-phaeozems and gleyic-Cambisols. These are well drained, moderately deep, dark -brown and sandy clay loan soils. The volcanic plains just above these areas in Kabatini and flat footslopes of Mau scarps are covered with Vertic-Andosols, which are well drained, moderately deep, brown to dark brown soils. They consist of loam to sandy clay loam soils with high agricultural fertility levels.

The step-faulted volcanic plains beyond Ronda and Mbaruk ridges are covered by Regosols and verto-luvic Phaeozems. These are soils with dark brown colour, clay loam to clay texture, well-drained and moderately deep to shallow. They are developed from undifferentiated volcanic rocks and lacustrine material resulting in moderate to high soil fertility but they are stony in places (Map 3.5).

semi-official document. The short term plan which was supposed to be of immediate action for implementing the structure plan was still in the process of being prepared in 1996 by the provincial Physical Planning office in Nakuru.

In recent years, urban development in Nakuru town has been expanding without guidelines of long-term physical development plan. Urban expansion has continued beyond the boundaries of the Municipal area as defined in the 1975. Worst examples of uncoordinated and unplanned urban development and land degradation has occurred in the rural-urban fringe areas of Nakuru town. The existing structure plan is now out-dated and cannot reflect the current development situation.

As the land available for urban development declined, the Municipal authority had to look for further territory on which to expand. In 1992 the municipal boundary was extended to cover the whole of lake Nakuru National Park and suburban farm land to the south-west of the town. The boundary expansion has been made apparently without consideration of the physical environment and long-term quality of the environment.

The latest effort was in 1995 when the Provincial Physical Planning office in collaboration with Habitat and the Municipality initiated the informal settlement upgrading project. A plan has been prepared for Ronda area, designed to regularise land tenure and improve the infrastructure. The innovative methodology employed is quite effective and should be extended to other informal settlement areas in the unplanned urban areas of the municipality.

imperfectly drained, very deep, dark greyish brown and silt loam to clay with gravel. They are slightly claceous, saline and strongly sodic Solonetz.

The Lion Hills, Bahati scarps and footslopes of Menengai Crater are covered by humic-Andosols. These are well-drained soils, dark reddish brown, clay loam to clay textured soils. In many places the soils are shallow, over rocks and stony. Menengai Crater is covered by recent lava flows made up of boulders and rocks with very little soil development (Table 3.2).

Table 3.2 Landforms and associated Soils

Land Unit	Landform	Soils
1	Hills and Minor scarps	Humic Andosols
2	Footslopes	Humic Andosols
3	Faulted volcanic plains	Eutric Regosols and Verto-luvic Phaeozems
4	Faulted volcanic plains	Eutric Regosols and Verto-luvic Phaeozems
5	Faulted volcanic plains	Eutric Regosols and Verto-luvic Phaeozems
6	Faulted volcanic plains	Eutric Regosols and Verto-luvic Phaeozems
7	Volcanic plains	Vertic Andosols
8	Upper lacustrine plains	Andic Phaeozems
9	Mid lacustrine plains	Andic Phaeozems
10	Mid lacustrine plains	Andic Phaeozems
11	Lower lacustrine plains	Solonetz

(adapted from Sombroek et al 1982)

Menengai crater is the largest volcanic crater is Kenya, covering an area of 60 km^2. It is roughly trapezoidal in shape with about 9 km long axis, located about 3 km from the centre of Nakuru town. According to McCall (1967) the crater was formed about 10,000 years ago by rapid emptying of magma chamber during the late stages of a sequence trachyte lave eruption when a series of explosive eruptions scattered ash over the surrounding area. These series of eruptions left the superstructure unsupported and the central area of the volcano sunk piecemeal until a vast crater was formed. This was followed by secondary eruption which has pilled stony lava flows within the crater. These eruptions are believed to have continued until about a hundred years ago. Steam vents were reported to be still active in a few isolated zones within the crater (McCall, 1967).

The crater forms the centre of an extensive volcano with a rounded profile, smooth slopes rising at first steeply from the surrounding land, but easing off to a very gently slope near the crater rim. The crater walls are formed of abrupt cliffs, exposing tiers of successive lava flows. The floor of the crater is covered by broken and fissured lava of recent age with very little vegetation. Menengai crater is one of the largest formations of the kind in the world and is a major tourist attraction in Nakuru.

3.3 Hydrology

The area is characterized by very low run-off due to the porous nature of the soils. Lake Nakuru is the lowest point in the region, at an altitude of about 1758 metres. Therefore all the rivers in the region end up in the lake. It is a shallow saline lake covering an area of about 40 km^2 with a catchment of 1800 km^2. Lake Nakuru catchment is drained by six main rivers including Njoro, Lamudiak, Enderit, Naishi and Makalia (Map 3.6).

The drainage system in the area is controlled by faults and deep sedimentary materials (McCall, 1957). This is evident by the sudden changes in the direction of water courses. Most of the rivers do not flow directly into the lake, instead they disappear underground and re-emerge as springs near the lake. River Njoro is the largest and the main contributor of inflow into Lake Nakuru. The lake does not have any outlet and most of the water losses are through evaporation. The lake water levels monitored since 1930 have fluctuated from 4 to 1.3 metres (Vaucher 1973). Since 1930 the lake has completely dried out in 1945, 1961, 1987 and 1996.

The groundwater occurrence is variable and localized (McCall, 1957). Boreholes often strike two or more separated water bearing rocks with varying water rest levels. The shallow aquifers generally represent perched water table while the deeper ones are confined aquifers which are more productive (McCall, 1957). The groundwater recharge is achieved through deep percolation of rainwater and infiltration of stream run-off through faults and lacustrine plains. The important water catchment areas in the region include Menengai crater forest, Bahati forest and Mau forests.

3.4 Climate, vegetation and Agro-ecology

The climate of the region varies from subhumid to arid with long-term average annual rainfall of about 800 mm. The rainfall has a trimodal distribution with peaks in April, August and November months, decreasing in magnitude in that order. The rainfall pattern shows a general decrease towards the south-east, reliability and amount increases in the higher altitude zones. In general, the rainfall pattern is erratic and unreliable, with an average of one year in every four being recorded as drought year. Evaporation and temperature have annual means of 1800 mm and 17°C respectively (Jaetzold and Schmidt 1983).

It has been suggested that the climate of the region has not always been as arid as it is today (McCall, 1957). Periods of wet climate have alternated with periods of dry climate. It is hypothesized that about 10,000 years ago, a large freshwater lake covered the region. The tectonic activities and climate changes in the region have contributed to the recession of water resulting in the formation of three separate lakes of Nakuru, Naivasha and Elementaita, which are continuing to dry up (Washbourn 1968).

Vegetation

The natural vegetation of the highland areas was formerly mountain forest but most of it has been cleared. The natural trees that still remain in isolated areas include Junipa, Podo, and African olive. In the lower altitude zones, the forest changes into woodland dominated by olive and Acacia species, interspersed with patches of open grassland. All the plains, where there has been little human influence are covered by grasslands with scattered trees mostly of Acacia species. Inside Lake Nakuru National Park most of the natural vegetation can still be observed A distinct Euphorbia species forest is found on Lions hills inside the Park

Agro-ecological zones

The study area can be classified into major zones based on the agro-ecological zones of Kenya (Jaetzold and Schmidt 1983). The highland areas above 2000m altitude represent the Lower Highlands of Wheat - Pyrethrum zone (LH2). This zone has very long cropping season, wheat or maize is grown depending on the farm size and topography. In flat areas with large parcels of land, wheat is the major crop In slightly sloping areas and where land is small, maize is the common crop grown. This is the agriculturally most productive zone with good yields potential for other crops (Map 3.7).

The other productive agro-ecological zone is the Lower Highland Wheat(maize-Barley zone (LH3). This zone has weak long to very long cropping season and can also support sunflower and vegetables. The Lower Highland cattle-sheep-barley zone (LH4) has weak long cropping season with high variability of rainfall resulting in frequent crop failures. This zone is suitable for ranching with about 2 hectares of natural pastrureland required for each livestock unit. The Upper Midland sunflower-maize zone (UM4) has similar climatic conditions. But UM4 zone is found in lower altitudes of about 1700 - 1800 metres while LH4 zone occur at 1900 - 2000 metres altitude (Table 3.3 and Map 3.7)

The low agricultural potential areas consist of the Upper Midland cattle-sorghum zone (UM5) and Lower Highlands and Upper Midland ranching zones (LH5 and UM6). These are the arid and semiarid zones with short and unreliable rainfall uneconomical for rain-fed agriculture. They are suitable for ranching with more than three hectares of natural pasture land needed for each livestock unit (Map 3.8 and Table 3.3).

Table 3 Agro-ecological zones

Zone	Agricultural	Altitude (m)	Rainfall (mm)
LH2	Wheat (Maize)- Pyrethrum	2070-2400	1000 - 1100
LH3	Wheat (Maize)- Barley	1890-2190	800 - 1100
LH4	Cattle - sheep - Barley	1890-2010	800 - 900
LH5	Ranching	1840-2010	700 - 800
UM4	Sunflower - Maize	1700-1830	800 - 100
UM5	Livestock - sorghum	1700-1890	750 - 850
UM6	Ranching	1700-1820	600 - 700

(adapted from Jaetzold and Schmidt 1983)

3.5 Infrastructure

Water supply in the study area is obtained from both underground water and surface water sources. More than a half of all the water supply used in the municipality and almost all the water supply used in the peri-urban areas is derived from boreholes. Municipal council of Nakuru operates about ten boreholes with an output of about 22,000 m^3 of water per day. Another 7,000 m^3 of water per day from Malewa and Mereroni rivers is administered by the Municipality. This is in addition to about 10,000 m^3 from Trusha river managed by the National Water Conservation and Pipeline Corporation. This total water supply of about 40,000 m^3 per day does not meet the current demand estimated at about 50,000 m^3 (MCN, 1996).

Shortage of water supply has been a major problem in Nakuru town since 1985. The Municipal council has found it expensive to transport water from long distance rivers since there are no permanent freshwater sources nearby. Water intake from Malewa river is pumped for 8 km to Gilgil treatment works before flowing by gravity for another 43 km to Nakuru town. The Mereroni river intake is located about 14 km east of Nakuru while the water supply from Trusha river is pumped from about 50 km east of Nakuru town. This importation of water is not only costly but may also cause disposal problems in the Nakuru basin since all the sewage effluent and drainage will end up in the lake. In view of this, the groundwater system will remain the most sustainable source of water supply for Nakuru town for sometime in the future.

The demand for water resources in Nakuru is high and rising, yet underground water supply is threatened by urban settlement pressure. Urban settlement development has encroached on water catchment and groundwater recharge areas in addition to possible pollution. Currently only about 12 km^2 in the central part of the town is served with sewage system, out of the total gazetted Municipal area of 78 square kilometres. The remaining population in the unsewered municipal areas and the whole of peri-urban areas use pit latrines and septic tanks for sewage disposal. However the area is underlain by highly permeable soils and volcanic faultlines which might lead to contamination of groundwater systems. There is need to identify and protect groundwater sources from urban development impacts.

There are two sewage treatment works operated by the Municipal council which were recently rehabilitated and expanded (JICA 1994). Some septage collected from on-site disposal facilities is also finally disposed into the sewerage. A number of factories in town are provided with simple waste water treatment facilities, but most of them are none functional resulting in discharge of pollutants into the sewerage. All the waste water from the sewage treatment works is finally disposed of into lake Nakuru. Since lake Nakuru receives all the sewage effluent and drainage water from Nakuru town, the expansion of urban land use, especially industrial activities need to be planned cautiously.

Solid waste collection and disposal is the responsibility of the Municipal council. However, currently only the town centre and formal residential housing areas get the municipal refuse collection services. Both the domestic and industrial waste collected is openly dumped at a collapsed ground area on the footslopes of Menengai Crater (Map 3.6). The open dump site is located along an old volcanic faultline where run-off water down the slope joins underground water systems. There is fear that the leachate from the dump might pollute underground water. Therefore urgent need exists to identify suitable land fill sites for sanitary disposal of municipal solid waste. Innovative community-based solid waste collection and recycling has been started in some informal residential housing areas. However, very little concern has been focused on where and how safely the waste is disposed of.

Nakuru town is well linked with the international, national and regional transportation system. The international trans-African trunk road linking Nairobi and Kampala and the main line of the Kenya-Uganda railway passes through the centre of Nakuru town. These provide both freight and passenger services. Nakuru town centre itself has a network of roads laid out in grid-iron pattern providing access throughout the town. The suburban areas are directly connected to the town centre, but without direct linkage between different suburbs. Menengai crater is a popular destination for visitors while in Nakuru but the access road to the site is not well maintained. Although the terrain is rugged and steep, a regularly maintained earth road running along the contour is all that is required.

3.6 Urban Development and Population Growth

The development of Nakuru town is synonymous with the construction of the Kenya and Uganda Railway around the year 1900. Before this period, the area was natural savannah grassland and forest, mainly inhabited by nomadic pastoralist Maasai. The present site of Nakuru town, because it is on flat plains with water springs, was chosen as a railway camp when the construction of the railway line from Mombasa to Kisumu crossed the steep escarpment of the Great Rift Valley (Ominde, 1968). The nearby Bahati springs where freshwater flows into the northern shore of Lake Nakuru is marked on early maps because it was used as a stopping point by traders on the old caravan route from the coast to Lake Victoria (Vaucher, 1973).

The railway camp developed into a busy railway centre with a large workshop where trains crossing the steep escarpment could refuel and be repaired. The construction of the railway line opened up the hinterland and increased accessibility led to settlement by European farmers who established large scale ranches and mixed farms in the region. The population of the railway centre increased and it became the commercial centre for European farmers and later administrative centre for the Rift Valley Province.

Nakuru was declared a township in 1904 with boundary area comprising 10 square miles (26 km^2). It was elevated to Municipality status in 1929. In 1934 the Municipal boundary was extended to 12 square miles (32 square kilometres). Further extension to 78 square kilometres occurred in 1975 (Map 3.9). Finally the current Municipal boundary area is 290 square kilometres gazetted in 1992.

The urban population of Nakuru township in 1926 was 896 people (Government of Kenya, 1927). In 1948 when the first national census was taken the population of Nakuru Municipality was 17,000 people. By 1962 the population had reached 38,200 people. This further increased to 47,000 and 93,000 in 1969 and 1979 respectively. The last national census puts the population of Nakuru municipality at 163,900 people in 1989 (Table 3.4). This makes Nakuru to be the fourth largest town in Kenya, after Nairobi, Mombasa and Kisumu.

The current population in Nakuru Municipality is estimated at more than 360,000 people (Nakuru Municipal council 1996). The population of the rural-urban fringe area is about 50,000 people as recorded in the 1989 national census. The most densely settled sublocation is Kabatini with 698 persons per square kilometre. Kimaina is next with 502, followed by others, and Mbaruk is the lowest settled with density of 66 persons per square kilometre.

Due to constant changes in census boundaries, it is difficult to project present and future population from the past trends for the study area. Furthermore, urban population to the north-east of the town was left out of the municipality while the whole of lake Nakuru National Park and sparsely populated suburban farmland to the southwest was included within the Municipal population census boundary of 1989. This implies that the census statistics do not give reliable figures for real urban population. There is need for fairly accurate and reliable estimate of the present and future urban population for comprehensive land use planning. However, on the basis of the national annual population growth rate of about 7% for major urban centres, a population of about 1.5 million can be expected in Nakuru town by the year 2020.

Land use in the study area has changed significantly in the past twenty five years. In early 1970s, forestry, ranching and mixed arable farming occupied equal land areas within the Lake Nakuru basin (Vaucher, 1973). A land use study in 1989 indicates that between 1970 and 1986 forested area decreased by 400 km^2, large-scale farms by 377 km^2 and ranchland by 192 km^2 (Kimani et al

1989). All this land has been subdivided into small scale farms which never existed before 1970. Most of the former large scale European farms and ranches in the urban fringe were bought by African land-buying companies and co-operatives after the end of the colonial era.

Field surveys indicted that about 75 per cent of local residents in the urban fringe interviewed settled less than 26 years ago (Table 3.5). The average plot size in the fringe area now is about 2 acres (Table 3.6; Map 3.10). Most of the small scale suburban farms are now intensively cultivated while those close to Nakuru town are being subdivided and developed into urban plots for residential housing especially to the east of the town. These suburban settlements are purely residential and enjoy the services and facilities in Nakuru Municipality but free of any development control. This uncontrolled land subdivision has led to unplanned and uncoordinated urban development in the peri-urban areas of Nakuru town. All the land incorporated in the Municipal boundary extensions did not change tenure status and remained under private ownership. Land subsidence is not uncommon in the newly incorporated municipal areas to the south-west of the town centre.

Table 3.4 Municipal Area and Population

Year	Population	Municipal Area (km^2)
1926	896	26
1934	4890	32
1948	17000	32
1962	38200	32
1969	47151	32
1979	92851	78
1989	163927	290
1995	360000	290
2020	1500000	—

(Land Evaluation 1996)

Table 3.5 Period of Residence

Year of settlement	Duration of stay (years)	No of residents	%
Before 1971	More than 26	4	7
1971 - 1975	21 - 25	17	28
1976 - 1980	16 - 20	5	8
1981 - 1985	11 - 15	9	15
1986 - 1990	6 - 10	15	25
After 1991	less than 5	10	17
Total		60	100

(Land Evaluation 1996)

Table 3.6 Land Holding Size

Land size (acres)	No. of households	%
Less than 1	6	10
1 - 3	28	47
3 - 10	21	35
10 - 100	3	5
More than 100	2	3
Total	60	100
Average = 2.8		

(Source: Land evaluation 1996)

3.7 Urban Development Planning

Nakuru's growth and shape it took in the early stages of urban development was largely based on sectoral plans. The town grew organically without any comprehensive physical development plan to direct its expansion. However, some of the early sectoral plans were quite outstanding in design and still gives the town its present identity. These include the well-laid out town centre roads in a chessboard pattern and the railway station square adjacent to the civic centre formulated in 1931. It was in 1917 that the town planning advisor to the colonial government visited Nakuru and made useful suggestions in a provisional development scheme for the municipality.

The first comprehensive physical development plan for

Nakuru town was formulated in 1968 (Government of Kenya 1968). Although the plan was mainly centred on short-term land use and infrastructural development demands, it also outlined a long-term growth pattern up to the year 1995. Essentially the plan was concerned with the physical layout of the street network and proceeded to show which areas were most suitable for residential, industrial, commercial and institutional development. Space for specific urban land use activities was scientifically estimated and projected.

The plan envisaged the main structure of the town to expand in the east-west direction in a linear pattern. A by-pass highway to allow for fast through traffic was proposed to the south of the town adjacent to the boundary of the national park. In the linear pattern of the extended town, the network of main traffic communication was to comprise two urban motor roads running east-west through the town, linked at intervals by north-south streets, one which continued as a parkway linking the national park with the town centre.

Further selection of land for expansion was to be subjected to the following requirements: that soil conditions should be suitable for economic building; and urban extension on to existing productive agricultural land should be restricted to the minimal and delayed until other suitable areas were utilized. therefore most large scale farms were designed as deferred land. The plan recommended that buildings should be less than four storeys because of earth quake risks. A need for balanced land use policy based on detailed ecological survey of the whole urban region was emphasized.

Most of the strategies of the 1968 physical development plan were implemented except the proposed by-pass road that was abandoned due to possible conflict with the national park. This plan was important because it made Nakuru to occupy the special status of being the best planned town in Kenya in 1970s.

Two more plans were formulated for Nakuru town although for academic purposes. The Study by Department of urban and Regional Planning, University of Nairobi (DURP, 1972) addressed contemporary problems of the time which included: realignment of roads within the town; provision of by-pass for the Trans African Highway from Nairobi to Uganda; allocation of land fore residential areas and; organising industrial area. The need for rational housing policy was emphasised due to expected population increase. The second study by Alela (1972) focused on interaction between the national park and the town with emphasis on transportation.

A long-term structure plan was drafted for Nakuru town in 1975 (Government of Kenya 1975). The visions of the plan was a town of about 250,000 people by the year 2000. The main aims of the plan may be summarized as : to estimate the land use requirements and suggest principles and strategies for urban development and ; to provide an overall structure which will accommodate the land use requirements of the town considering the need for flexibility. The plan suggested a strategy incorporating road system and land use pattern based on a linear growth model. The plan was meant to serve as the basis for more short-term plans and local plans. Due to lack of financial backing and shortage of personnel the plan was not completed and remained a private or semi-official document. The short term plan which was supposed to be of immediate acti for implementing the structure plan was still in the process of being prepared in 1996 by the provincial Physical Planning office in Nakuru.

In recent years, urban development in Nakuru town has been expanding without guidelines of long-term physical development plan. Urban expansion has continued beyond the boundaries of the Municipal area as defined in the 1975. Worst examples of uncoordinated and unplanned urban development and land degradation has occurred in the rural-urban fringe areas of Nakuru town. The existing structure plan is now out-dated and cannot reflect the current development situation.

As the land available for urban development declined, the Municipal authority had to look for further territory on which to expand. In 1992 the municipal boundary was extended to cover the whole of lake Nakuru National Park and suburban farm land to the south-west of the town. The boundary expansion has been made apparently without consideration of the physical environment and long-term quality of the environment.

The latest effort was in 1995 when the Provincial Physical Planning office in collaboration with Habitat and the Municipality initiated the informal settlement upgrading project. A plan has been prepared for Ronda area, designed to regularise land tenure and improve the infrastructure. The innovative methodology employed is quite effective and should be extended to other informal settlement areas in the unplanned urban areas of the municipality.

The need to maintain a balance between the conservation of natural resources and the environment and the pressure of urban development in Nakuru town has been recognised. Currently the Municipal Council in collaboration with the United Nations Centre for Human Settlements (Habitat) have initiated the Agenda 21 project in Nakuru town. The project is in the process of a preparing action plan for sustainable urban development and management (Habitat 1996). The project will soon prepare a long-term structure plan which will become a new statutory instrument for urban development. This provides opportunity within which a long-term framework of environmental quality can be optimized.

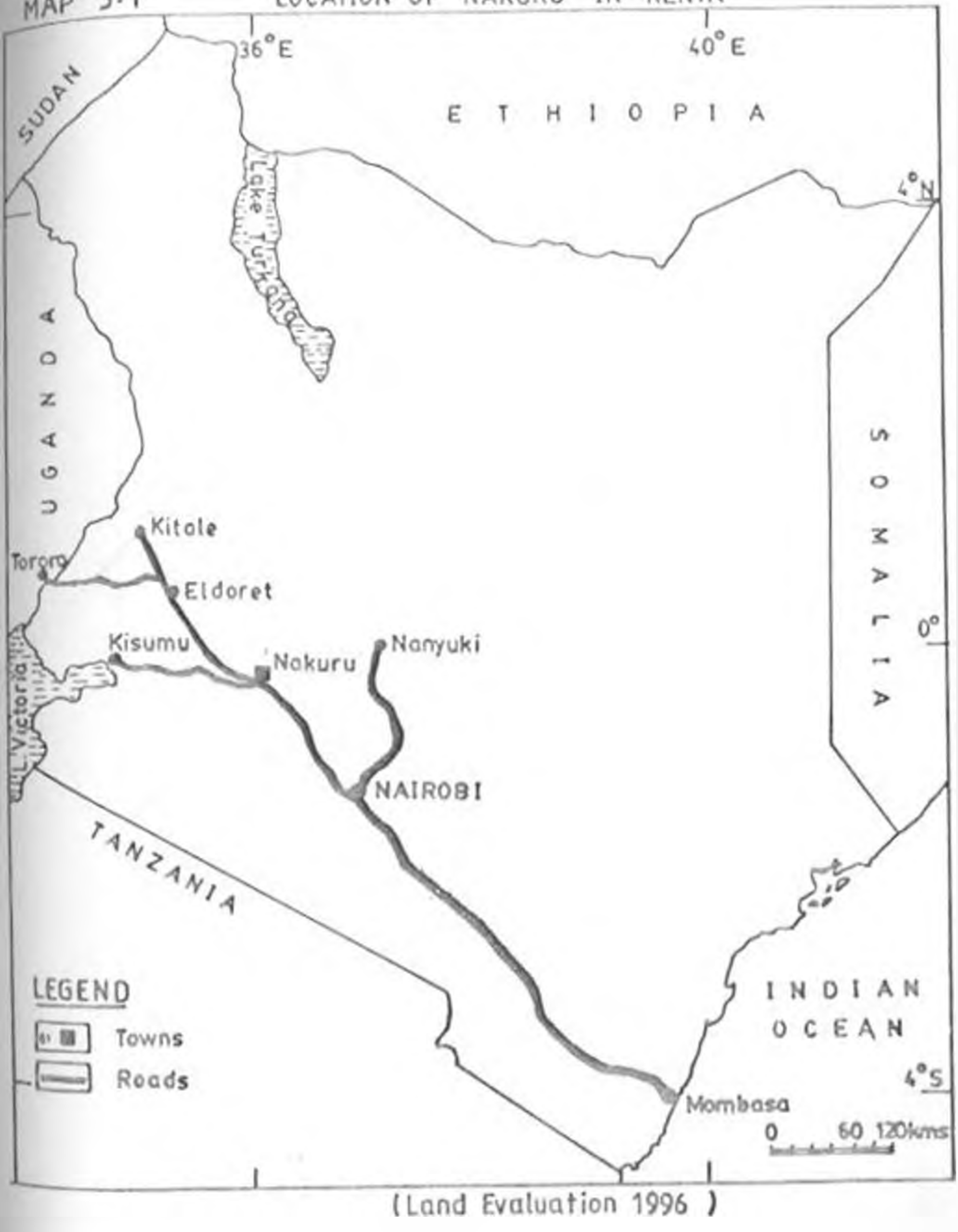
Therefore, the need to acquire data for land use planning in the Nakuru urban region is real. Urban population growth is expected to continue and land degradation will worsen. One step towards limiting further land degradation is to accommodate growth in the fringe areas based on the analysis of the physical environment for land use planning. Land evaluation is one of the most important building blocks of land use planning. Land evaluation contributes to land use planning by providing physical land resources information and possibilities for their sustained use.

3.8 Summary

Nakuru is the fourth largest and one of the most rapidly expanding towns in Kenya. The town is popular because it is strategically located on the major transportation route, within agriculturally rich hinterland and surrounded by unique natural features on the floor of the Great Rift Valley. The world famous

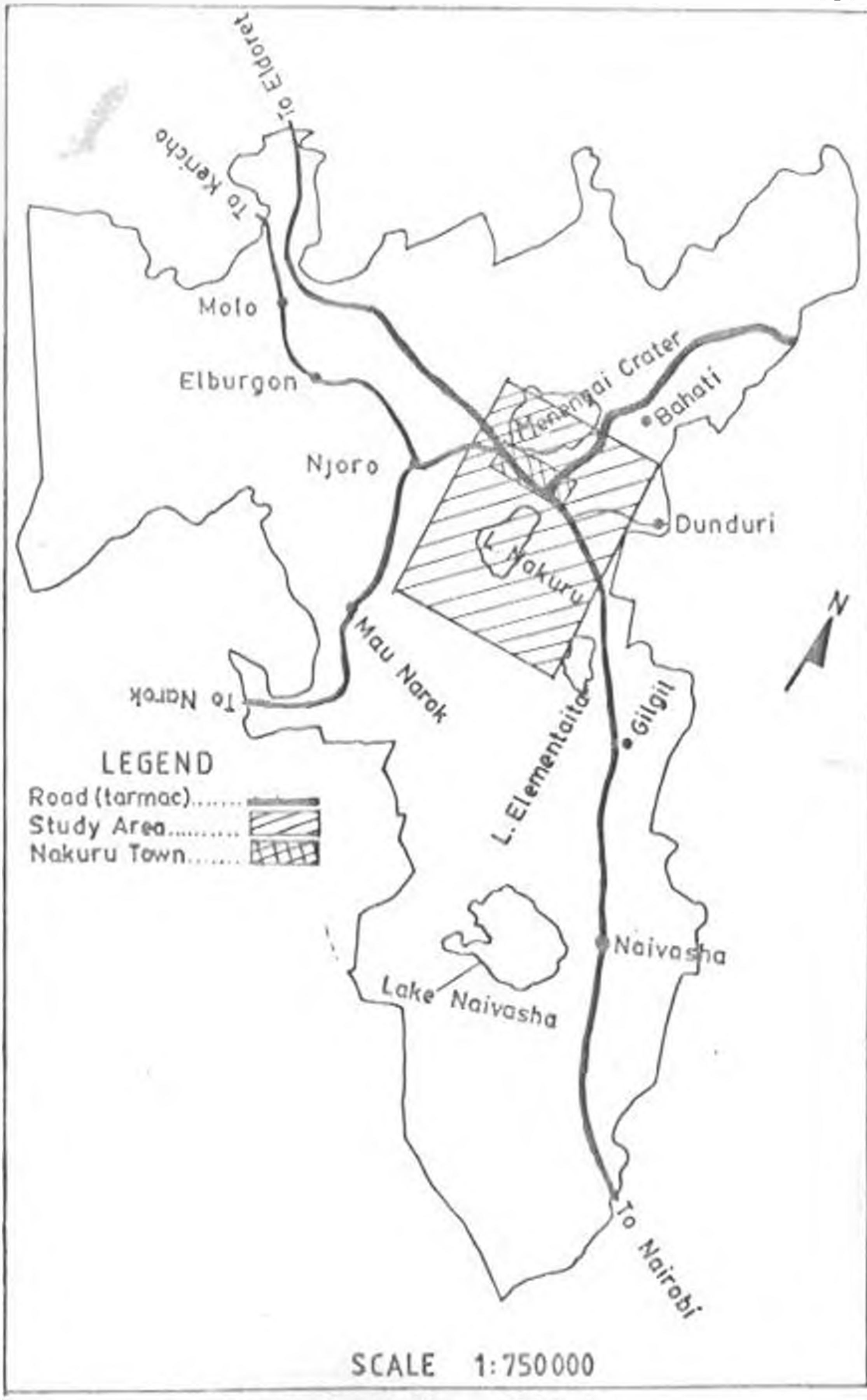
Lake Nakuru with its million flamingoes and the natural scenic Menengai Crater gives Nakuru town its local identity. In the recent past, urban expansion in Nakuru town has occurred at a very rapid rate but without proper planning. This has resulted in a number of problems that threaten the prospects for future urban development. Issues of concern include: urban settlements expanding into land areas prone to land subsidence, sensitive water catchment and groundwater recharge areas; subdivision of agricultural land and clearing of forests on steep slopes; high density urban settlement along the perimeter of the national park; unsanitary disposal of waste and general land degradation. How can a region which is of such national and international significance be allowed to deteriorate? There is urgent need to identify environmentally appropriate site where future urban expansion can be direct through proper land use planning. This is the subject of the next chapter.

MAP 3.1 LOCATION OF NAKURU IN KENYA



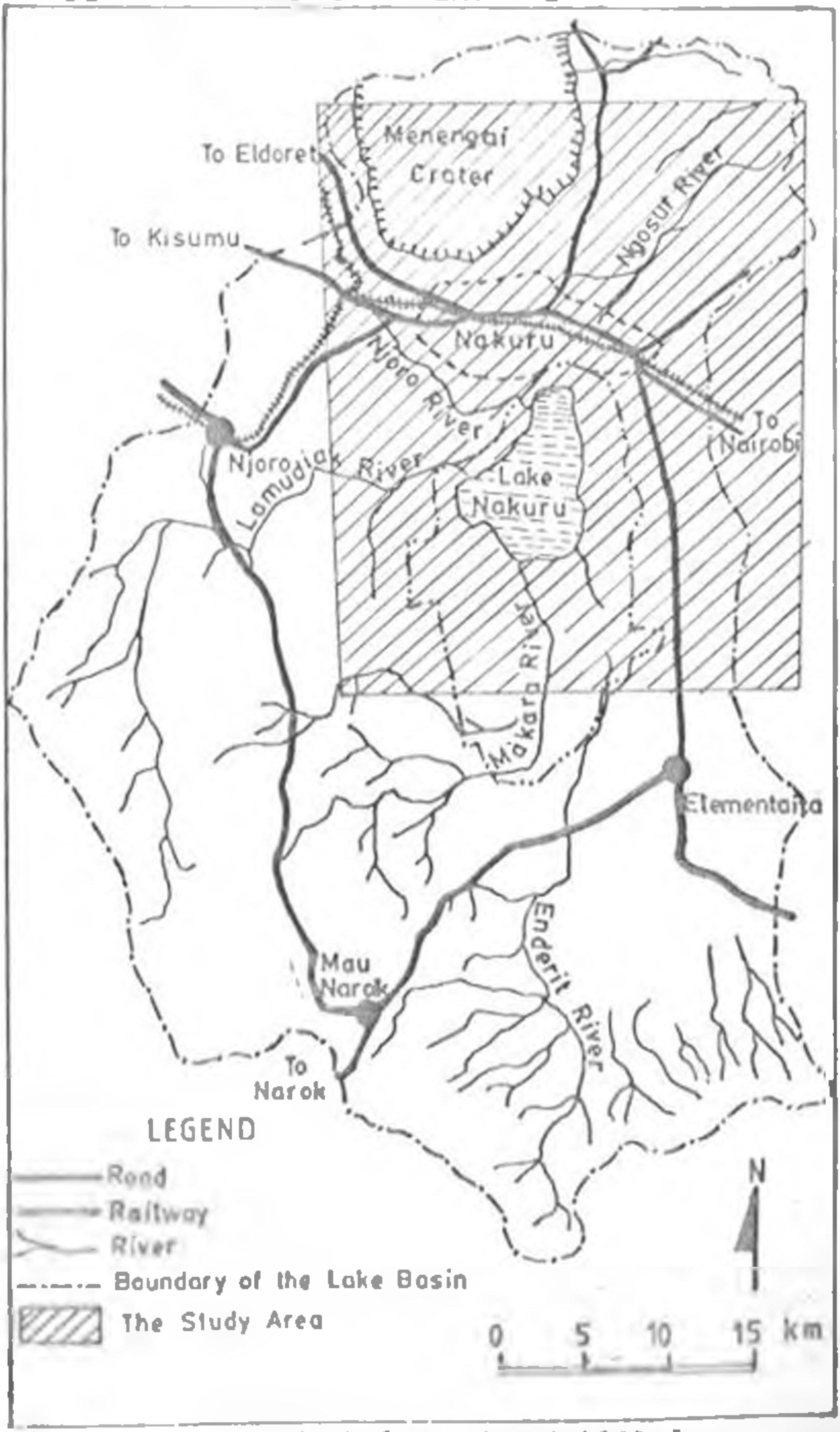
(Land Evaluation 1996)

MAP 3.2 LOCATION OF THE STUDY AREA IN NAKURU DISTRICT



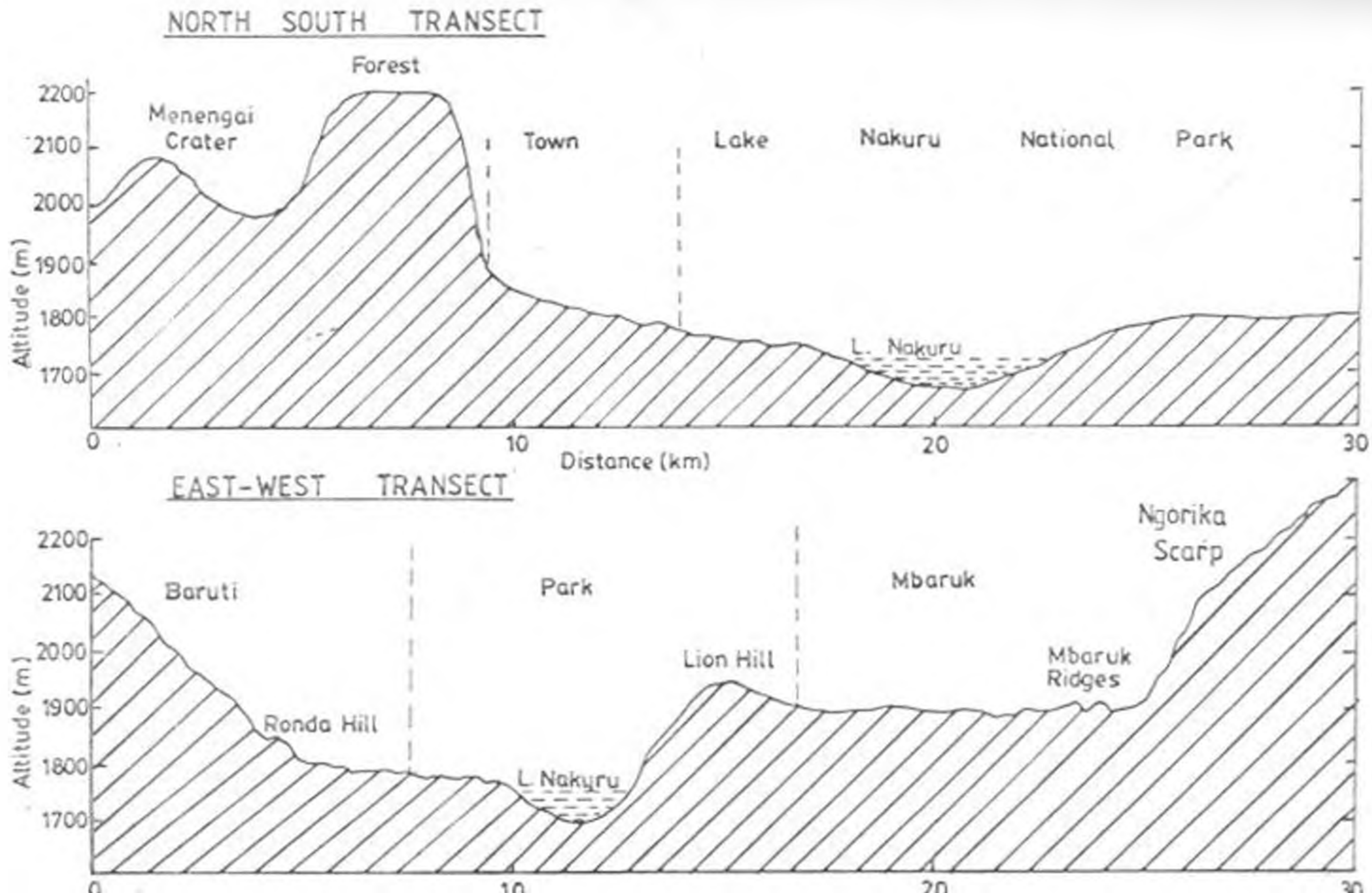
(Land Evaluation 1996)

MAP 3.3 LAKE NAKURU CATCHMENT AREA

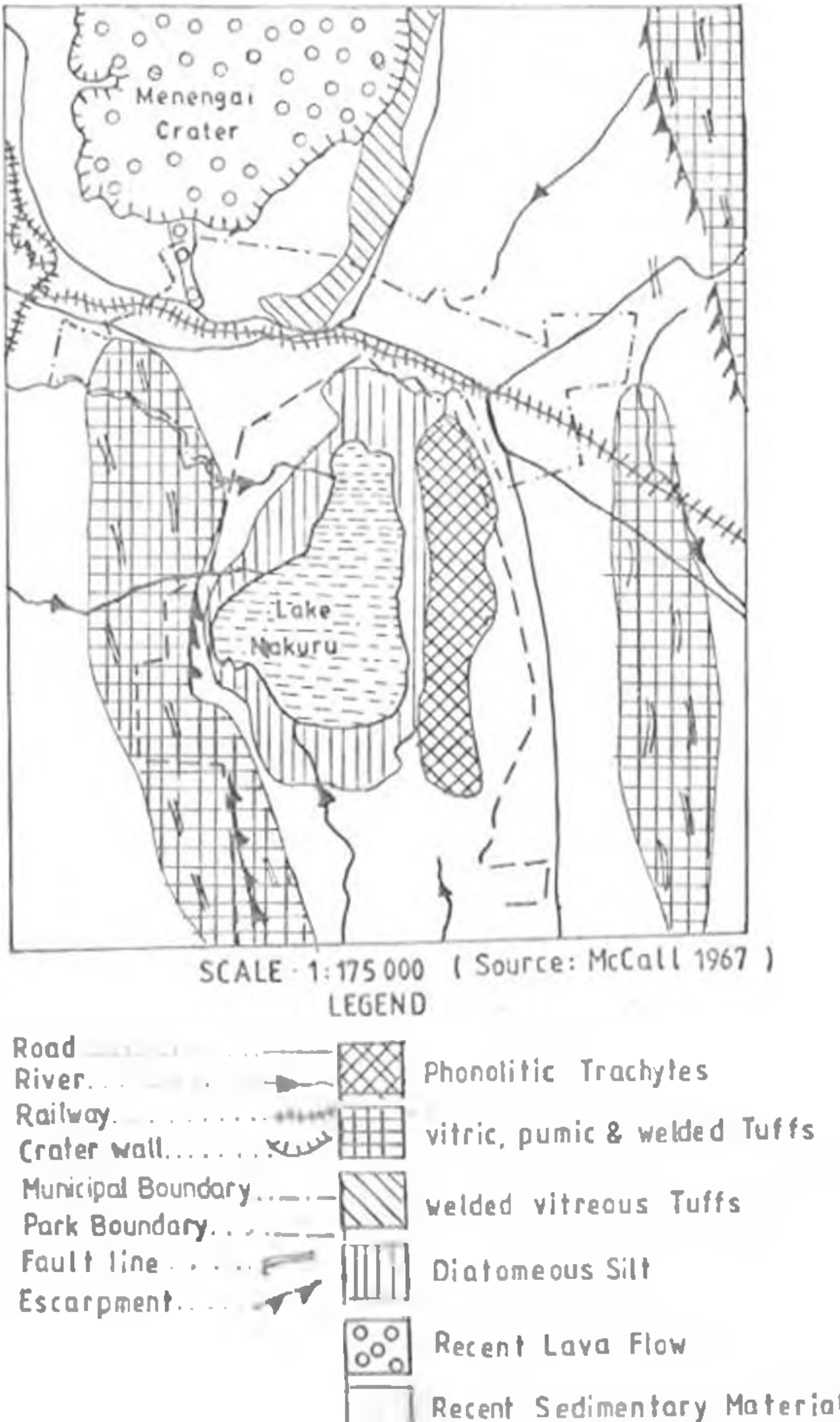


(Adapted from WWF 1992)

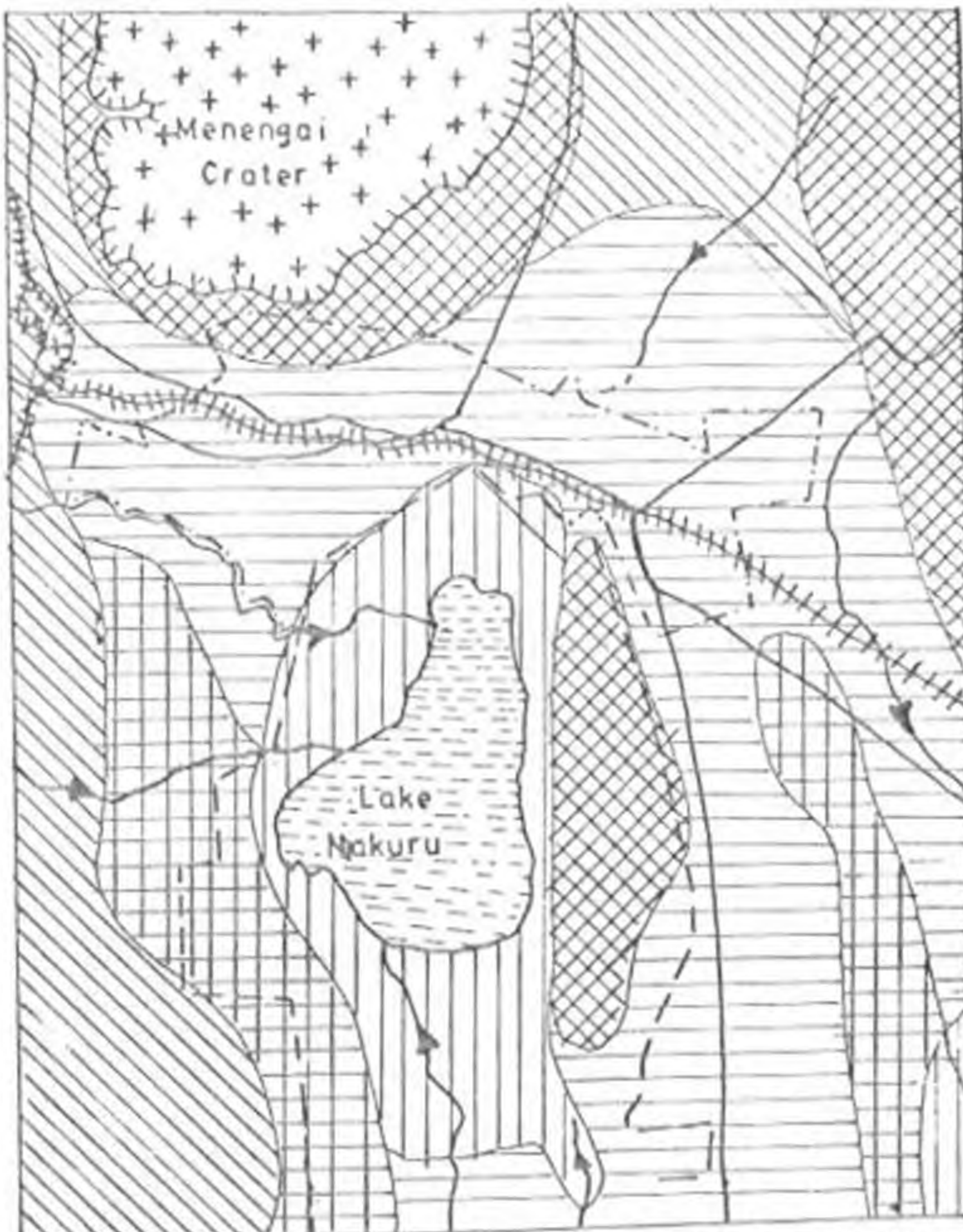
Figure 3.1 CROSS-SECTION OF THE STUDY AREA



MAP 3.4 GEOLOGY



MAP 3-5 LANDFORM AND SOILS



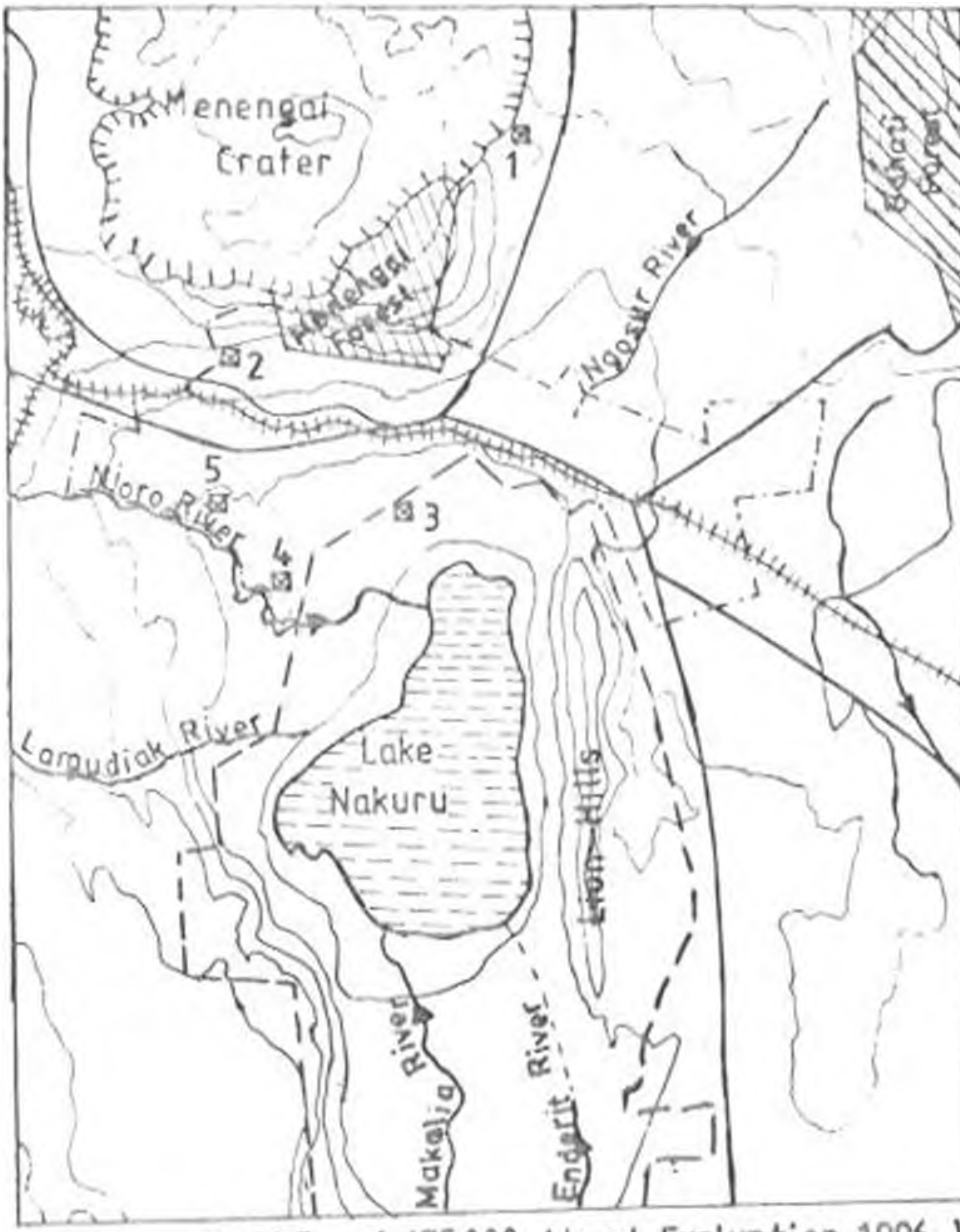
SCALE · 1: 175 000 (Adapted from Sombroek 1982

LEGEND

Road
River
Railway
Crater wall
Municipal Boundary
Park Boundary

LOWER LACUSTRINE PLAI
(Solonetz)
UPPER LACUSTRINE
(Andic Phaeozems, Cambisols
VOLCANIC PLAINS
(Vertic Andosols)
FAULTED VOLCANIC PLAINS
(luvic Phaeozems, Regosols)
HILLS AND ESCARPMENT
(lithic-humic Andosols)
CRATER

MAP 3-6 PHYSICAL FEATURES



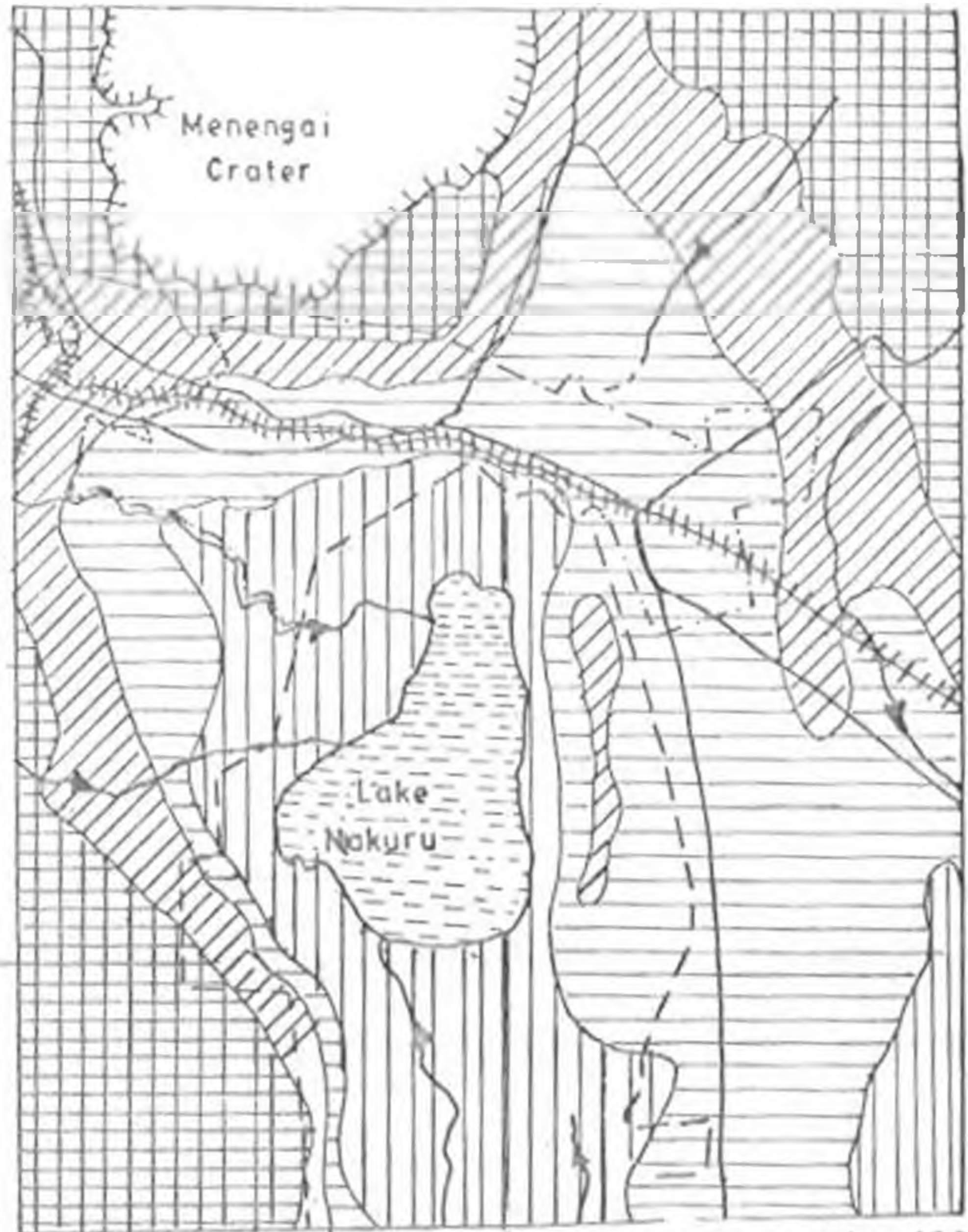
SCALE 1:175000 (Land Evaluation 1996)

LEGEND

Road ....
Railway ....
River ....
Crater walls ....
Contour ....
Municipal Boundary ....
Park Boundary ....

1 Quarry for building stones
2 Collapsed ground used as garbage dump
3 Town sewage treatment works
4 Njoro sewage treatment works
5 Collapsed ground used as quarry for sand

MAP 3-7 ALTITUDE



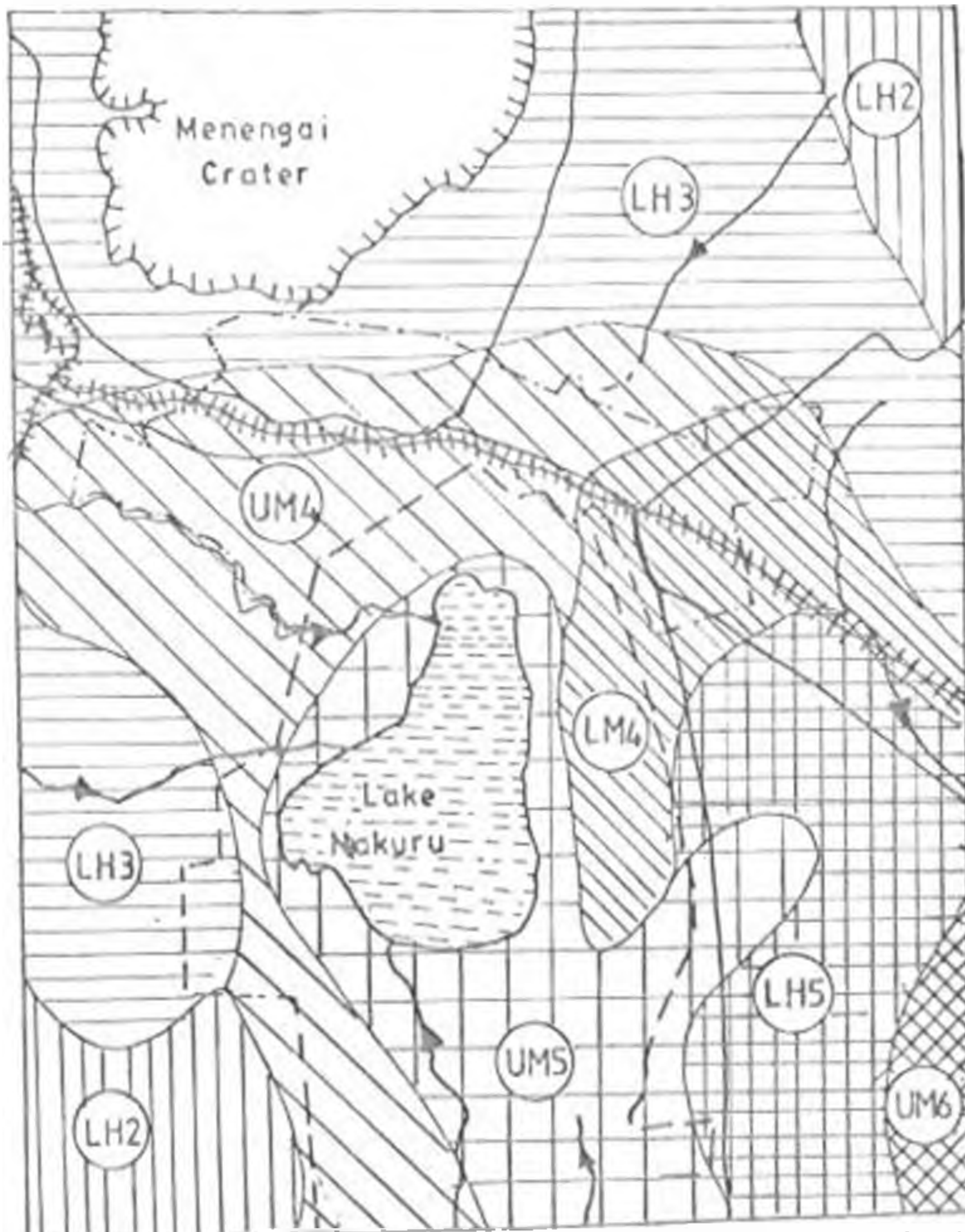
SCALE · 1:175 000 (Land Evaluation 1996)

LEGEND

Road
River
Railway
Crater wall
Municipal Boundary
Park Boundary

Below 1800 m Altitude
1800-1900 m
1900-2000 m
Over 2000 m

MAP 3-8 AGRO-ECOLOGICAL ZONES



SCALE 1: 175 000 (adapted from Jaetzold 1982

LEGEND

Road.........
River..........
Railway..........
Crater wall..........
Municipal Boundary.........
Park Boundary..........

LH2 Wheat/ Maize-Pyrethrum Zo

LH3 Wheat/ Maize- Barley Zone

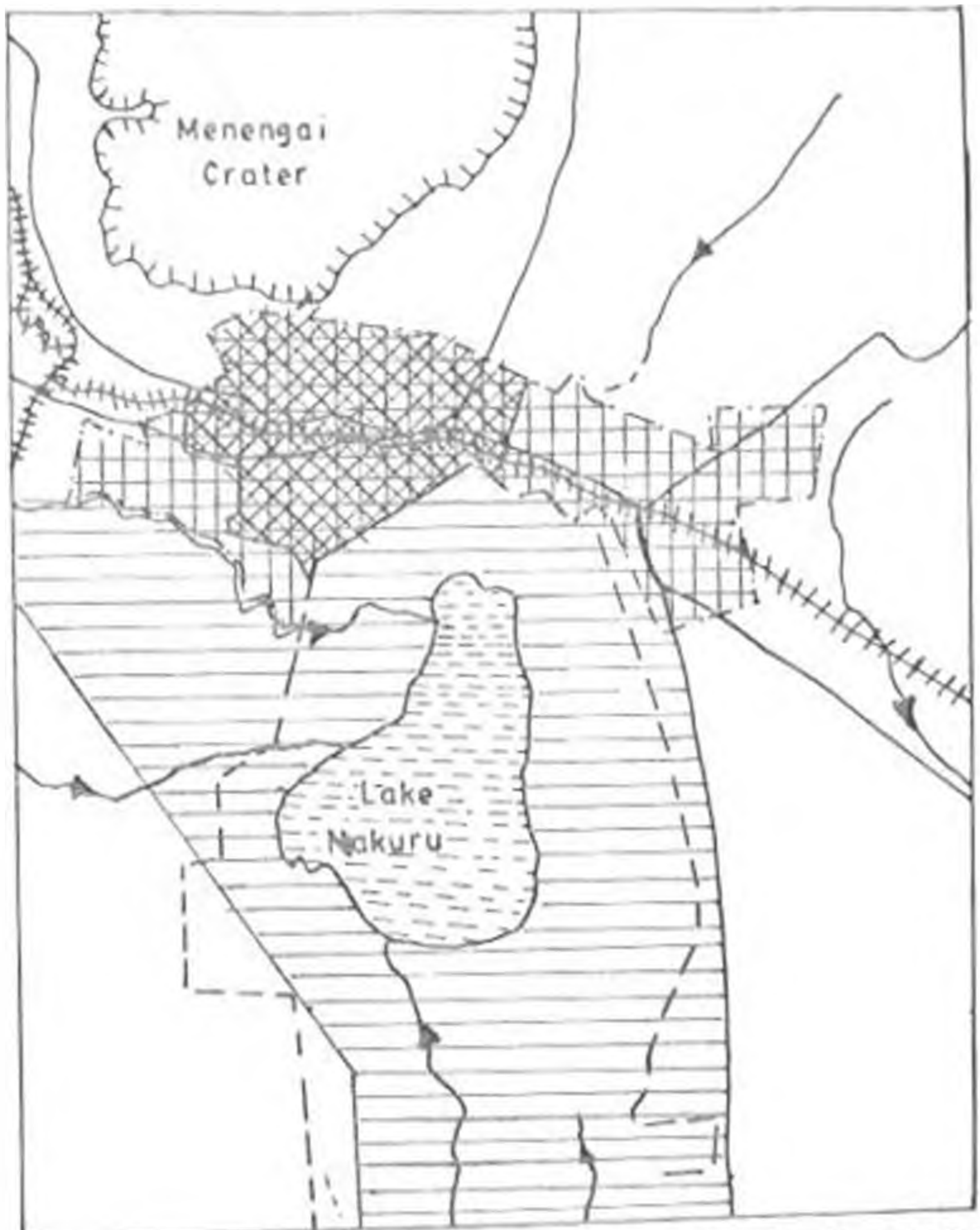
UM4 Sunflower- Maize Zone

LM4 Cattle-Sheep Zone

UM5 Livestock- Sorghum Zone

LH5

MAP 3-9 NAKURU MUNICIPAL BOUNDARY TREND



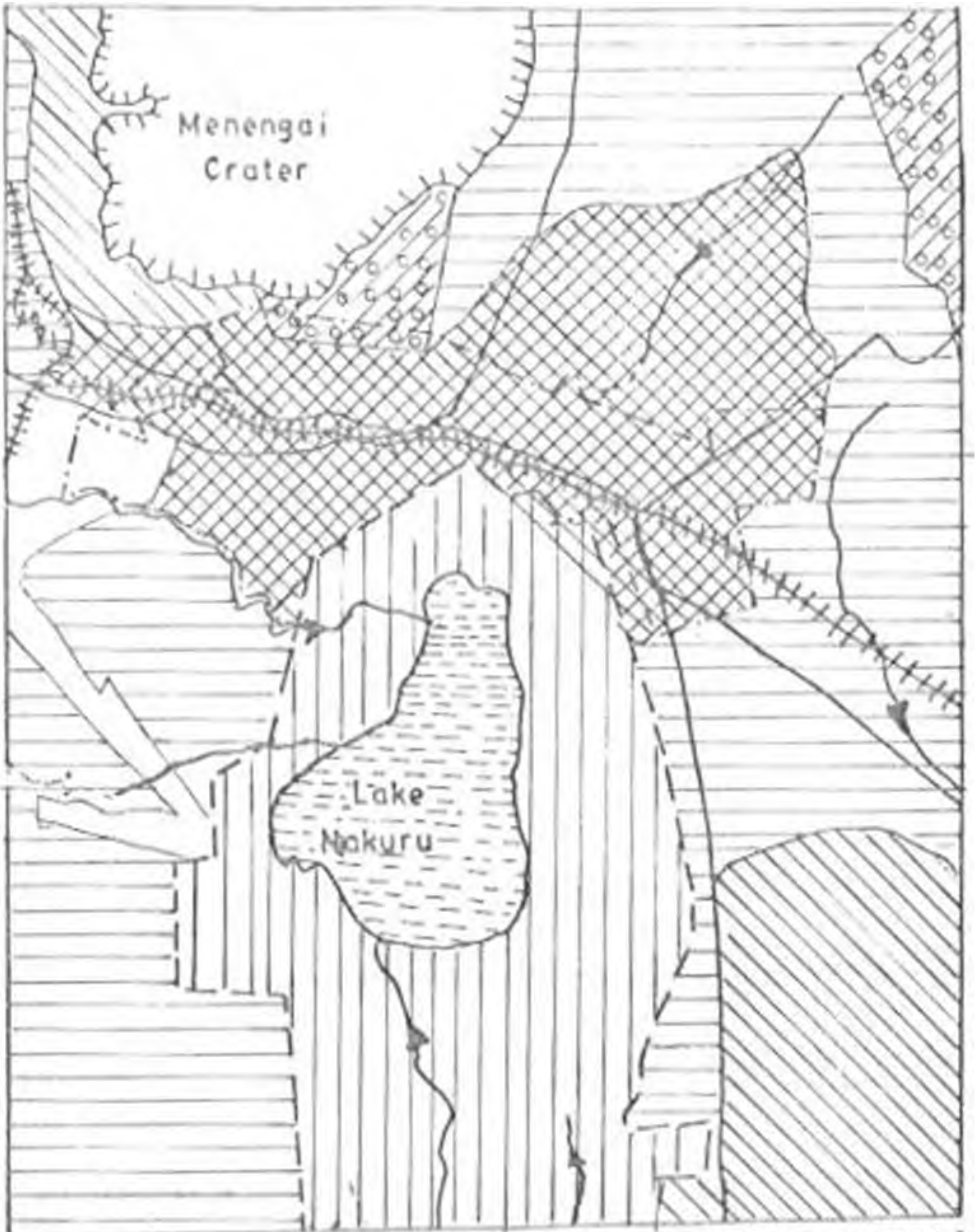
SCALE 1:175 000 (Land Evaluation 1996)

LEGEND

Road
River
Railway
Crater wall
Municipal Boundary
Park Boundary

(290 Km sq.)-1992
(78 Km sq.)-1975
(32 Km sq.)-1952

MAP 3-10 CURRENT LAND USE



SCALE · 1:175 000 (Land Evaluation 1996)

LEGEND

CHAPTER FOUR

4.1 LAND SUITABILITY ANALYSIS

4.1.1 The Mapping of Land characteristics

In the context of this study land is considered as a physical entity and is defined as the areas of the earth's surface including the climate soils, topography, geology, hydrology, vegetation animal populations and results of human activity, to the extent that these influence land use (FAO, 1976). These land attributes vary individually and in relation to each other to give local character. Land classification is used in land evaluation to impose a framework of generalization about land which enables common character to be defined, mapped and described. This involves the recognition of distinct land components with only a limited range of variations of those attributes important for land use.

Information on land conditions of the study area was assembled based on the concept of land unit. A land unit is an area of land possessing unique set of specific land characteristics that are recognisable, can be described by concise statements and capable of presentation on maps. The Kenya Soil Survey (K.S.S. 1987) has adopted the physiographic land unit as the basis for land classification in compiling land resource information and interpretation for land use planning. In this context a land unit is an area where landform, climate, geology, soils, vegetation, land use and other physical environment conditions are uniform, within the limits significant for a particular form of land use. Therefore a land unit is an area in which land use potentials and limitations are expected to be uniform. The degree of homogeneity will depend on the scale of mapping and details required. A land unit can be mapped at any scale desired.

In this study land unit mapping and classification was based on interpretation of air photographs, field survey and existing reports and maps. Land characteristics used in distinguishing between land units included soils, landform, geology, hydrology and land use. Land characteristics considered in suitability analysis include: altitude, slope, landform, surface geology, density of fault lines, soil type, soil depth, presence of stones on surface soil, existing soil erosion, soil fertility, depth to groundwater level, density of surface river channels and streams, watershed conditions, agro-ecological zone, population density, land use and landsubsidence hazards.

The exploratory soil map of Kenya (Sombroek et al, 1982) provides the soil information for the area. Data on soil depth, soil type, soil fertility, surface stones, landforms, average slope gradient, and related data were extracted from the soil map. Existing land use, soil erosion, slope, landform, drainage density and watershed conditions were analysed from air photo interpretation and cross checked in a few places in the field. In a few places, the average slope was determined using slope meter in the field.

Agro-ecological zones were mapped and described from Farm Management handbook of Kenya (Jaetzold and Schmidt, 1983). Geology and groundwater conditions data were compiled from geological reports (McCall 1957; 1967). Areas prone to landsubsidence hazards was obtained from areas of faultlines from geological maps, interviews and observation in the field and reports of the past subsidence cases. Depth to ground water level was obtained from borehole data from the Ministry of Water reports. Altitude and other information was obtained from topographic maps.

Drainage density analysis was performed by marking one-kilometre grid on the topographic map. Five random grids were chosen on each land unit and the length of river channels and streams measured. The average value was used for each land unit.

The same one-kilometre square grid system was overlaid on the most recent air photos and five random grid squares chosen on each land unit for population density analysis. The number of houses in each land unit was multiplied by five to obtain the approximate total population. Each house unit was assumed to represent one household with an average of five people. This was cross checked by population census reports and household questionnaire surveys.

Based on this information, fourteen homogeneous land units were recognised and delineated in the Nakuru urban-rural fringe area. The land units include: Nakuru municipality, Lake Nakuru National Park, Menengai crater, Bahati Forest, Gichobo-Naishi, Baruti, Mbaruk Ridge, Mbaruk Valley, Kabatini-Bahati, Dundori-Lanet, Elementaita, Technology and Ronda (Map 4.1). The first three land units are not analysed for urban land use. The Municipal area is assumed to be built-up area while the park and the crater are permanent conservation areas in which the question of urban land expansion does not arise.

4.1.2 Land Units

Land unit 1: comprises the footslopes of Menengai Hill up to the rim of Menengai Crater. The unit varies in elevation from 1900m to 2100m with slopes up to 35 degrees and moderately dissected (Table 4.1 and 4.2). The area is underlain by volcanic rocks and sediments with faultlines. Soils are variable ranging from bare rocks to shallow and moderately deep humic Andosols. The unit is dominated by Menengai planted forest, to the west is a large ranch while to the east are found small scale farms reaching up to the rim of the crater. High and medium class urban residential housing are found in the lower footslopes merging into the forest. The unit occupies 30 km^2 (7%) of the analysed fringe area.

Land Unit 2: is the area consisting of Bahati Escarpment and its footslopes, dominated by the Bahati forest. The escarpment is very steep while the footslopes are relatively flat with elevation ranging form 1980 m to 2300 m. This is an important water shed area since it acts as origin of springs and rivers such as Ngashura and Mereroni. The bedrock geology consist of volcanic rocks and sediments with faultlines. The area falls under wheat-pyrethrum agro-ecological zone (LH2) with humid climate. The soils are variable, generally of medium fertility but susceptible to erosion. Small scale farming is common on the footslopes while the escarpment and higher lying areas are forest plantation. The unit occupies 63 km^2 (Table 4.2).

Land Unit 3: occupies the extreme south west corner of the study area around Gochobo and Naishi. The area was originally thick forest but now has been replaced by small scale farming.

Elevation ranges from 1800m to 2040 m in the rolling step-faulted volcanic plains. The area is underlain by volcanic sediments and rocks together with some lacustrine sediments and has some faultlines. It is located within the wheat-barley agro-ecological zone (LH3). The soils are moderately deep, moderately fertile but badly eroded in some places. The land unit occupies 57 km^2 (14%).

Land unit 4: is the Baruti area beyond Ronda to the south west of Nakuru town centre. The area was formerly large scale farms but are now being subdivided into small scale farms and suburban settlement is also expanding. This faulted volcanic plain landform is underlain by lacustrines sediment and volcanic rocks with many faultlines. It is located within wheat-barley agro-ecological zone (LH3) with moderately deep soils of medium to high fertility but susceptible to erosion. It occupies 31 km^2 (7%) and varies in elevation from 1840 m to 1980 m.

Land unit 5: is the Mbaruk ridge to the far east of Lake Nakuru National Park. This rolling ridge on the step-faulted plains is underlain by lacustrine sediments and volcanic rocks with many faultlines. The elevation ranges from 1800 m to 1920 m. The soils are variable ranging from shallow and rocky to moderately deep. Open grassland natural vegetation of this unit is mostly used for ranching. It falls within semi-arid and arid eco-climate zone. The unit occupies 45 km^2 (11%).

Land unit 6: is the gently sloping Mereroni river valley to the northern shore of lake Elementaita. The land unit varies in elevation from 1800 m to 1900 m within the volcanic plain. It lies within ranching agro-ecological zone (LH5 and UM6) with semi-arid and

and climate. The natural vegetation is made up of open grassland and acacia bushland. The geology is alluvial sediments with many faultlines. The soils are moderately deep and of medium fertility but in some place bare rock. Most of the area is used for ranching but to the north, on the footslopes of Mbaruk escarpment suburban settlement is expanding. The unit occupies 33 km^2 (8%).

Land Unit 7: is the gently sloping Bahati plains with altitude varying from 1940 to 2100 m to the north east of Nakuru town centre. The land unit is underlain by volcanic ash and sediments with deep light soils of high to medium fertility. This extensive gently sloping plain is located in wheat-barley agro-ecological zone (LH3). The area was formerly large scale farms but have now been subdivided into small scale farms and suburban residential settlement is increasing. It occupies 22 km^2 (5%).

Land Unit 8: comprises the flat upper lacustrine plains in Kabatini, Lanet towards Dundori area. The plains vary in elevation from 1900 m to 1980 m. Volcanic and lacustrine sediments underly this unit. The soils are deep and of medium fertility. It is located in transition agro-ecological zones of wheat-barley and cattle-sheep zones (LH3 and LH4). The area has high density of urban residential housing with a few remaining large scale farms in the process of being subdivided. It covers 62 km^2 or 15 per cent of the evaluated land area.

Land unit 9: is a flat lacustrine plain bordering Lake Nakuru National Park to the east in the Elementaita area. The area is covered by sediments of the former lake bed and volcanic sediments. The soils are deep, moderately fertile and saline in depressional area. The elevation ranges from 1800 m to 1840 m. Most of the area is occupied by the Delamere Ranch. Along the perimeter of the park, especially to the north, urban residential development is rapidly expanding. The unit covers 37 km^2 (9%).

Land Unit 10: is located to the west of Nakuru town centre dominated by large scale farms owned by the Rift Valley Institute of Science and Technology. The flat lacustrine plains vary in elevation from 1800 m to 1840 m. The area is underlain by lacustrine sediments and volcanic sediments with deep and moderately fertile soils, and many faultlines. It is located in the sunflower-maize agro-ecological zone (UM4). The unit covers 27 km^2 (6%).

Land Unit 11: is the depressional lacustrine plains of Ronda area, sloping towards Lake Nakuru, where River Njoro meanders before entering the lake. The area is underlain by lacustrine sediments with many faultlines and landsubsidence occurs frequently. The soils are deep, salty with shallow groundwater levels. The unit is located in sunflower-maize agro-ecological zone (UM4). Land subdivision for urban settlement is quite rapid in this area. It occupies 13 km^2 or 3 per cent of the total land area in the rural-urban fringe area evaluated.

Table 4.1 Extent of Land Mapping Units

Land Unit Code	Land mapping unit name	Extent (km^2)	Proportion of Area (%)
1	Menengai Footslope	30	7
2	Bahati Forest	63	15
3	Gichobo-Naish	31	7
4	Baruti	57	14
5	Mbaruk Ridge	45	11
6	Mbaruk Valley	33	8
7	Bahati	22	5
8	Kabatui Dundori	62	15
9	Elementaita	37	9
10	Technology	27	6
11	Ronda	13	3
	Total	**420**	**100**

(Land Evaluation 1996)

Table 4.2 Description of Land Mapping Units

PHYSICAL LAND FACTOR						
LAND UNIT CODE	LAND UNIT NAME	ALTITUDE (M)	SLOPE (%)	LANDFORM	GEOLOGY	PRESENCE OF FAULTLINE
1	MENENGAI FOOTSLOPE	1900 - 2100	5 - 30	HILLS, ESCARPMENT AND FOOTSLOPE	VOLCANIC ROCKS AND SEDIMENTS	SOME
2	BAHATI FOREST	1980 - 2200	5 - 30	HILLS, ESCARPMENT AND FOOTSLOPE	VOLCANIC ROCKS AND SEDIMENTS	MANY
3	GICHOBO-NAISH	1800 - 2040	3 - 10	STEP-FAULTED VOLCANIC PLAIN	VOLCANIC ROCKS AND SEDIMENTS, LACUSTRINE SEDIMENTS	VERY MANY
4	BARUTI	1840 - 1980	3 - 8	STEP-FAULTED VOLCANIC PLAIN	VOLCANIC ROCKS AND SEDIMENTS, LACUSTRINE SEDIMENTS	VERY MANY
5	MBARUK RIDGE	1800 - 1920	2 - 8	STEP-FAULTED VOLCANIC PLAIN	VOLCANIC ROCKS AND SEDIMENTS, LACUSTRINE SEDIMENTS	VERY MANY
6	MBARUK VALLEY	1800 - 1900	2 - 5	VOLCANIC PLAIN VALLEY	ALLUVIAL SEDIMENTS	MANY
7	BAHATI	1940 - 2100	0 - 4	VOLCANIC PLAIN	VOLCANIC ASH AND SEDIMENTS	SOME
8	KABITINI-DUNDORI	1900 - 1980	0 - 2	UPPER LACUSTRINE PLAIN	VOLCANIC AND LACUSTRINE SEDIMENTS	FEW
9	ELEMENTAITA	1800 - 1840	0 - 2	MIDDLE LACUSTRINE PLAIN	VOLCANIC AND LACUSTRINE SEDIMENTS	SOME
10	TECHNOLOGY	1800 - 1840	0 - 5	MIDDLE LACUSTRINE PLAIN	VOLCANIC AND LACUSTRINE SEDIMENTS	MANY
11	RONDA	1780 - 1840	0 - 2	LOWER LACUSTRINE PLAIN	LACUSTRINE SEDIMENTS	MANY

LAND UNIT	PHYSICAL LAND FACTOR					
CODE	AGRO-ECOLOGICAL ZONE	SOIL EROSION	SOIL TYPE	SOIL DEPTH	SOIL FERTILITY	SURFACE ROCKS
1	LH3	HIGH	HUMIC-ANDROSOLS	SHALLOW	HIGH TO MEDIUM	ROCKY
2	LH2	HIGH	HUMIC-ANDROSOLS	SHALLOW	MEDIUM	ROCKY
3	LH2, LH3	SEVERE	Eutric-REGOSOLS Luvic-PHAEZEMS	MODERATE TO SHALLOW	MEDIUM	VERY FEW
4	LH3	HIGH	Eutric-REGOSOLS Luvic-PHAEZEMS	MODERATE TO SHALLOW	MEDIUM TO HIGH	VERY FEW
5	LH5	HIGH	Eutric-REGOSOLS Luvic-PHAEOZEMS	SHALLOW	MEDIUM	VERY ROCKY
6	LH5,UM6	SLIGHT	Eutric-REGOSOLS Luvic-PHAEOZEMS	MODERATE	MEDIUM	ROCKY
7	LH3	MODERATE	Vertic-ANDOSOLES	DEEP	HIGH	NONE
8	LH3-LH4	SLIGHT	Andic-PHAEOZEMS	DEEP	MEDIUM TO HIGH	NONE
9	UM5, LH5	SLIGHT	Andic-PHAEOZEMS	DEEP	MEDIUM	NONE
10	UM4	SLIGHT	Andic-PHAEOZEMS	DEEP	MEDIUM TO HIGH	NONE
11	UM4	MODERATE	SOLONETZ	DEEP	MEDIUM	NONE

LAND UNIT CODE	PHYSICAL LAND FACTOR				MAJOR LAND USE
	GROUNDWATER DEPTH	DRAINAGE DENSITY (km/km^2)	WATERSHED CONDITION	POPULATION DENSITY (P/KM^2)	
1	VERY DEEP	0.5 - 0.7	CRITICAL WATERSHED	LESS THAN 50, 200 - 1000	FORESTRY RESIDENTIAL RANCHING
2	VERY DEEP	more than 1	CRITICAL WATERSHED	LESS THAN 50, 200 - 1000	FORESTRY SUBURBAN FARMING
3	MODERATELY DEEP	0.8 - 1	SENSITIVE WATERSHED	200 - 1000	SUBURBAN FARMING
4	MODERATELY DEEP	0.8 - 1	SENSITIVE WATERSHED	1000 - 2000	SUBURBAN RESIDENTIAL SUBURBAN FARMING
5	DEEP	Less than 0.3	SENSITIVE WATERSHED	200 - 1000, LESS THAN 50	SUBURBAN FARMING RANCHING
6	MODERATELY DEEP	more than 1	SENSITIVE WATERSHED	200 - 1000	SUBURBAN FARMING RANCHING
7	SHALLOW	Less than 0.3	WITHIN CATCHMENT	1000 - 2000	SUBURBAN FARMING SUBURBAN RESIDENTIAL
8	SHALLOW	0.3 - 0.4	WITHIN CATCHMENT	MORE THAN 2000	SUBURBAN RESIDENTIAL SUBURBAN FARMING
9	MODERATELY DEEP	Less than 0.3	WITHIN CATCHMENT	200 - 1000 LESS THAN 50	RANCHING SUBURBAN FARMING
10	MODERATELY DEEP	0.8 - 1	SENSITIVE WATERSHED	200 - 1000	SUBURBAN RESIDENTIAL SUBURBAN FARMING
11	MODERATELY DEEP	0.8 - 1	SENSITIVE WATERSHED	MORE THAN 2000	SUBURBAN RESIDENTIAL SUBURBAN FARMING

4.2 Land Suitability for Urban Development

4.2.1 Land Factor Rating

All the land mapping units were assessed for their suitability to sustain urban development. Broad urban land use is considered which include all possible urban land uses such as residential, industrial, commercial, infrastructure and communication among others. Some of the physical land characteristics that influence urban land use are considered in section 2.1. The urban land suitability in this study is determined by first determining the individual land factor suitability and combining all the individual factors to arrive at the physical land suitability. The individual land factor ranking or rating is considered to represent constraint or opportunity for urban development. Opportunities are characteristics that make urban land use attractive, appropriate or feasible while constraints or limitations are factors that make urban land use infeasible or may lead to land degradation.

Based on literature review, available data and local conditions applicable for the study area, nine physical land characteristics or qualities were considered important for urban land suitability analysis. These land factors include: slope gradient, landsubsidence hazards, soil depth, presence of stones on the land surface, existing soil erosion, depth to groundwater level, surface drainage channel density, watershed conditions and agro-ecological zone. Each of these land factors is rated or ranked on the basis of its relative potential or limitation to the future expansion of built-up area of Nakuru town. The rating is effected on a relative scale of 1 to 5 classes of land factor limitation levels. Each high class indicates progressively greater constraint to development or inversely degree of opportunity.

The five classes of constraint adopted are very low (class 1), low (class 2), moderate (class 3), high (class 4) and; very high (class 5). A rating of low level of constraint indicates that the land factor conditions are optimal and constraints are minimal and environmental problems will be minimum in the short-and long-term conditions. A moderate level of constraint rating denotes that there are some problems associated with the land factor but the problems may be eliminated or effectively reduced. High level of constraint rating indicates that a land factor offers extensive problems of particular nature that will require extensive remedial measures before successful urban land use can be achieved.

4.2.1 Slope

Slope is an important criteria commonly used in evaluating land suitability for development (Marsh 1991). Gently sloping areas are often ideal for urban development. A flat area might be prone to flooding while very steep slopes will pose problems for the design and construction of buildings, communication, water supply and sewage services. Steep slopes are also prone to landslides and soil erosion. Therefore steep slopes are best avoided. In the study area, slope gradients range from zero to over thirty degrees. This range was divided into five standard classes as recognised by the Kenya Soil Survey (K.S.S., 1987). Table 4.3 presents the criteria for slope gradient rating. Each land unit was ranked based on slope gradient (Map 4.2).

Table 4.3 Criteria for slope classification

Class	Slope (degrees)	Description of Relief	Level of Constraint
1	0 - 2	Flat to very gently sloping	Very low
2	2 - 5	Gently sloping	Low
3	5 - 8	Sloping	Moderate
4	8 - 16	Rolling	High
5	16 - 30	Hilly	Very High

(Land Evaluation 1996)

4.2.1.2 Agro-ecological zones

Agro-ecological factor is important for preservation of agriculturally high potential areas. Good quality farming land should not be adversely affected by inappropriate choice of urban expansion sites. Otherwise additional land has to be found elsewhere and the food and raw materials for agro-industries have to be carried greater distances and stored for longer periods. Because farming on the fringe of Nakuru town contributes significantly to the supply of cheap food and raw materials for industries, Nakuru is considered the cheapest town in Kenya.

The study area is covered by seven distinct agro-ecological zones based on Farm Management Handbook of Kenya (Jaetzold and Schmidt 1983). The agricultural potentials range from Lower Highland wheat-pyrethrum zone (LH2) to Upper midland ranching zone (UM6). The wheat-pyrethrum zone with very long cropping season has good yield potential for other crops like maize, beans, potatoes, and vegetables. These areas were considered to be the least suitable for urban development and should be maintained under agricultural land use.

The lower highland and upper midland ranching zones have low and unreliable rainfall and not suitable for rain-fed agriculture. In these areas, more than three hectares of land is required to support one livestock unit. These are the areas considered relatively suitable for urban expansion in the peri-urban areas of Nakuru town. The criteria for classification of agro ecological zones and their distribution based on land mapping units are presented in table 4.4 and map 4.3

Table 4.4 Classification of criteria for agro-ecological zones

Class	Agro-ecological zone	Level of Constraint
1	Ranching zone (UM6, LH5)	Very low
2	Livestock - sorghum zone (UM5)	Low
3	Sunflower -maize zone (UM4)	Moderate
	and Cattle-sheep-barley zone (LH1)	
4	Wheat-barley-zone (LH3)	High
5	Wheat-Pyrethrum zone (LH2)	Very High

(Land Evaluation 1996)

4.2.1.3 Landsubsidence Hazard

Natural hazards occur irregularly and have sudden effect on land development. It is essential to obtain local information of the nature of natural hazards when assessing an area for urban development. Landsubsidence has been a frequent occurrence in the study area, especially to the west and southwest of Nakuru town. This is a major limitation to urban development due to damage to property and loss of life that can result.

Land subsidence in Nakuru area have been reported to occur along geologic faultlines. Based on the presence of geologic faultlines as shown on geologic maps of the area (McCall 1967); sites of past land-subsidence occurrence; and field observation, the study area was divided into five classes of land subsidence hazard. The criteria for classification and distribution of land subsidence constrained according to land unit is presented in Table 4.5 and Map 4.4.

Table 4.5 Classification criteria for Landsubsidence Hazards

Class	Presence of faultlines	Level of constraint
1	very few	very low
2	few	low
3	some	moderate
4	many	high
5	very many	very high

(Land Evaluation 1996)

4.2.1.4 Hydrology

The hydrological factors considered in land suitability classification are: depth to groundwater level, density of surface stream channel and rivers and; conditions of water catchment area. The concern for these factors is to preserve the surface and subsurface water supply sources. Urban development on any site will always have some effect on the existing hydrological conditions. Impact of urban development on natural hydrological systems has been emphasised by Hannam and Rick (1980) and UNEP (1996). Building on a site always leads to increased surface run off and will reduce groundwater recharged from rainwater. Expansion of urban development in unsuitable areas will add to urban water pollution problem caused by inadequate waste water treatment. Therefore it is necessary to direct urban expansion away from groundwater recharge areas and away from riverbanks.

Depth to groundwater level is the maximum to which groundwater is expected to rise. This information was obtained from the borehole data and hydrological reports of the study area. According to McCall (1957), there exists a large quantity of groundwater supply in the area in thick sedimentary deposits. It is an area of internal drainage and recharge of groundwater is from watersheds on Menengai hills forest, Bahati hills and Mau hill forests. In low lying areas of Ronda and near the lake the groundwater level is as low as 13 metres while in high altitude areas the level may reach 200 metres (Table 4.7)

The land areas close to the main rivers in the study area should be protected and are considered as constraints to urban development. The footslopes of Bahati escarpment has the highest density of surface drainage and is classified as having very high limitation to urban expansion (Table 4.9 and Map 4.4)

Table 4.7 Classification criteria for Depth to groundwater

Class	Depth (m)	Description	Level of constraint
1	150 - 200	very deep	very low
2	100 - 150	deep	low
3	50 - 100	medium	moderate
4	20 - 50	shallow	high
5	less than 20	very shallow	very high

(Land Evaluation 1996)

Table 4.8 Classification Criteria for Drainage Density

Class	Drainage Density (km/km^2)	Description	Level of constraint
1	less than 0.3	None dissected	very low
2	0.3 - 0.4	slightly Dissected	low
3	0.5 - 0.7	Moderately Dissected	moderate
4	0.8 - 1.0	Strongly Dissected	high
5	more than 1.0	Very strongly Dissected	very high

(Land Evaluation 1996)

Table 4.9 Classification criteria for watersheds condition

Class	Watershed condition	Description
1	Within catchment area	very low
2	Watershade area	low
3	Sensitive watershade	moderate
4	Sensitive groundwater recharge	high
5	Critical watershade	very high

(Source Land Evaluation 1996)

4.2.1.5 Soils

Soil information is important for urban development and can be used to identify limitations to construction and provision of services. Poor soil conditions can cause structural instability of buildings, failure of on-site sewage disposal or cracking of roads (Davidson, 1980). Soil depth to bedrock and presence of stones or rocks on the soil surface will influence the cost and ease of excavation for construction of buildings or installation of utility lines such as water supply and sewage disposal (Olson, 1982). Soils susceptible to erosion will also limit suitability of a site for urban development due to need for special design to control further erosion.

The exploratory soil Map of Kenya (Sombroek et al, 1982) provides the latest soil information for the study area. The data on soil depth, occurrence of stones or rocks on the land surface and soil types were extracted form the soil map. The existing soil erosion condition was observed in the field. Most of the study area is covered with deep, young, poorly developed and light soils easily carried away by winds or water runoff. However, soil erosion is not a problem in flat areas with some vegetation cover except on steep slopes and areas where natural forest has been cleared (Table 4.11 and Map 4.8). The areas most affected by shallow soils and presence of stones or rocks on the surface include Mbaruk ridges, Menengai and Bahati slopes as well as some parts of Baruti and Gichobo - Naishi area (Table 4.12 and 4.13, Map 4.8 and 4.9)

Table 4.10 Criteria for classification of soil erosion

Class	Existing Erosion	Affected Area (%)	Level of Constraint
1	No erosion	0	very low
2	slight	0 - 5	low
3	moderate	5 - 10	moderate
4	severe	10 - 15	high
5	excessive	25 - 50+	very high

(Land Evaluation, 1996)

Table 4.11 Criteria for classification of soil depth

Class	Soil depth (cm)	Description	Level of Constraint
1	more than 180	very deep	very low
2	80 - 180	deep	low
3	50 - 80	fairly deep	moderate
4	25 - 50	shallow	high
5	0 - 25	very shallow	very high

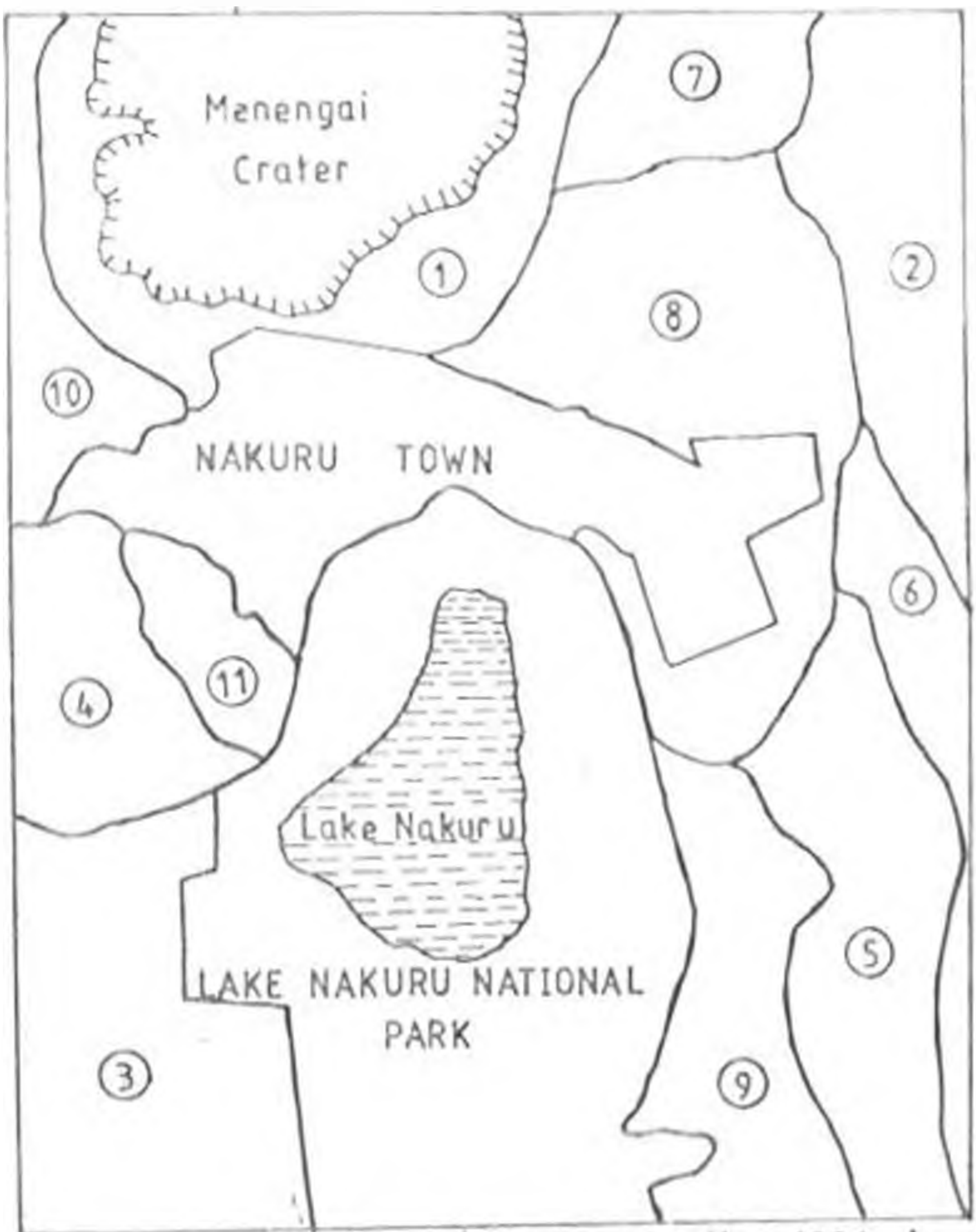
(Land Evaluation, 1996)

Table 4.12 Criteria for classification of surface rocks

Class	Surface Rockiness	Area Covered (%)	Level of Constraint
1	None rocky	0	very low
2	Fairly Rocky	0 - 10	low
3	Rocky	10 - 20	moderate
4	Very Rocky	20 - 50	high
5	Rock outcrop	more than 50	very high

(Land Evaluation 1996)

MAP 4-1 LAND UNIT NAMES



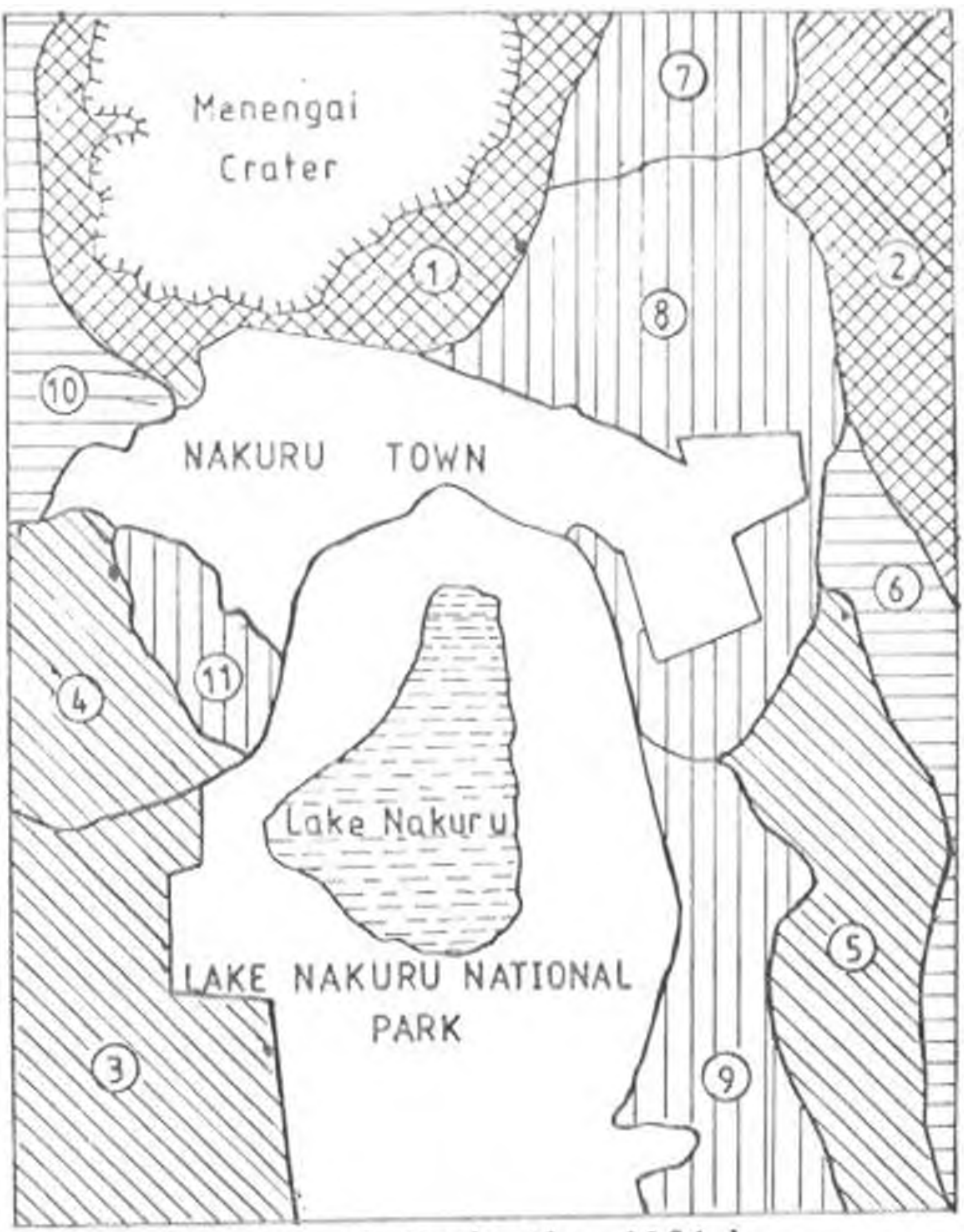
(Land Evaluation 1996)

LEGEND

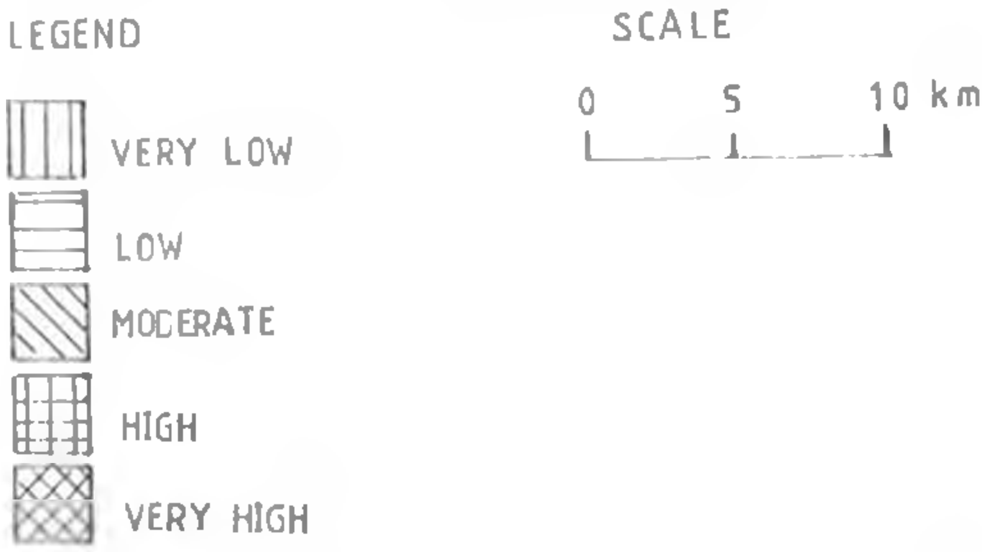
0 5 10 km

① MENENGAI FOOTSLOPE	⑥ MBARUK VALLEY
② BAHATI FOREST	⑦ BAHATI
③ GICHOBO-NAISHI	⑧ KABATINI-DUNDORI
④ BARUTI	⑨ ELEMENTAITA
⑤ MBARUK RIDGE	⑩ TECHNOLOGY
	⑪ RONDA

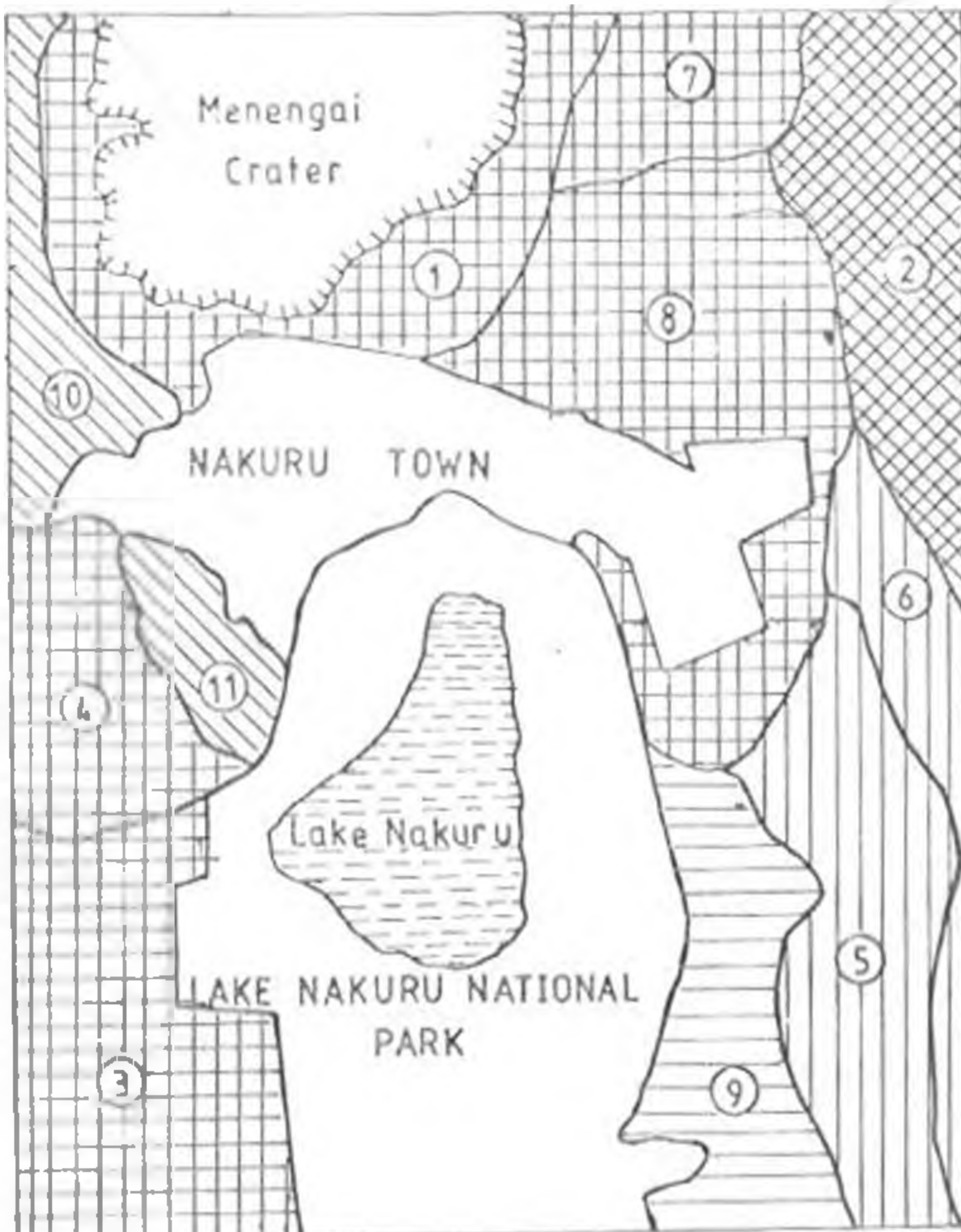
MAP 4·2 SLOPE GRADIENT CONSTRAINT



(Land Evaluation 1996)



MAP 4-3 AGRO-ECOLOGICAL CONSTRAINT



(Land Evaluation 1996)

LEGEND

VERY LOW

LOW

MODERATE

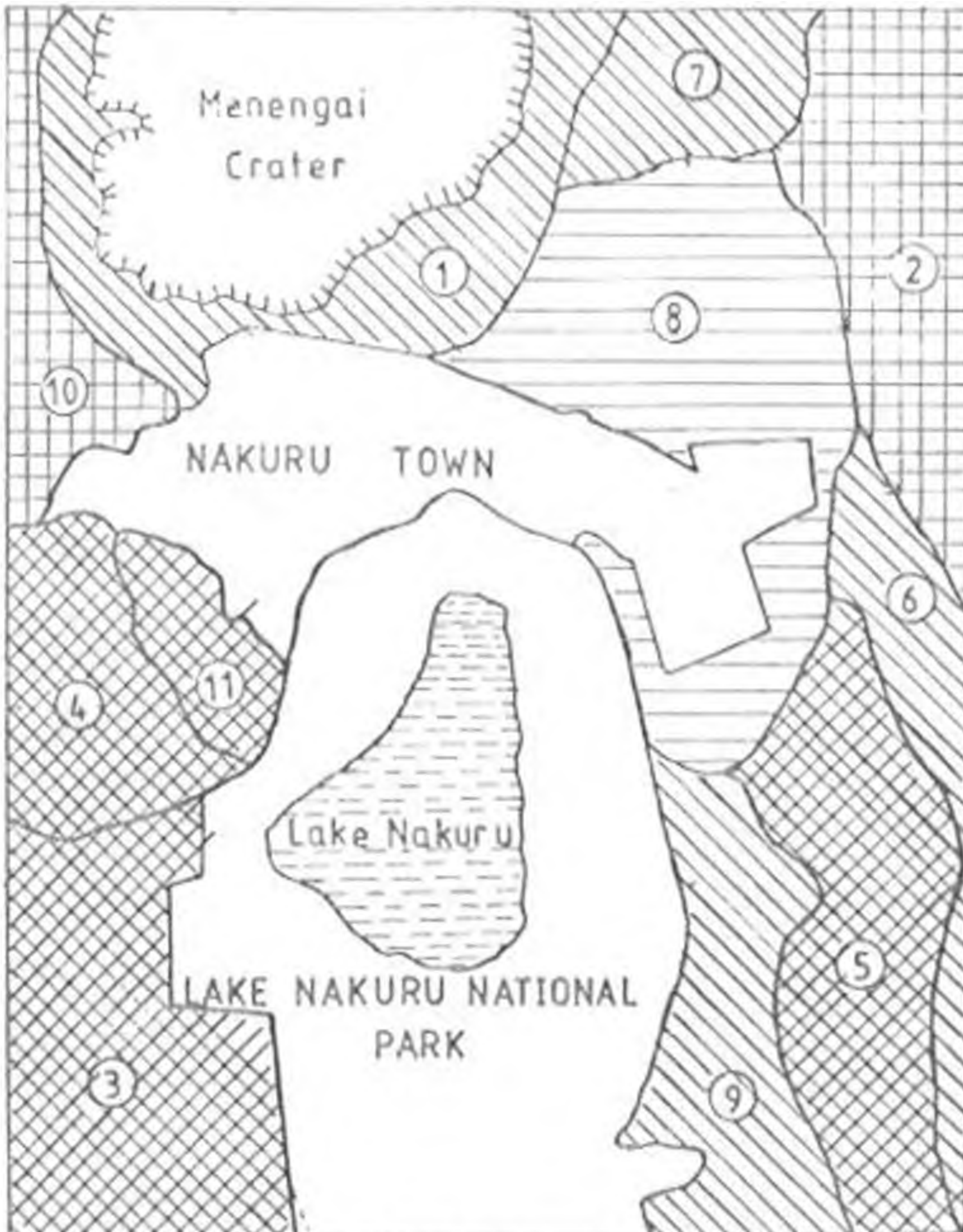
HIGH

VERY HIGH

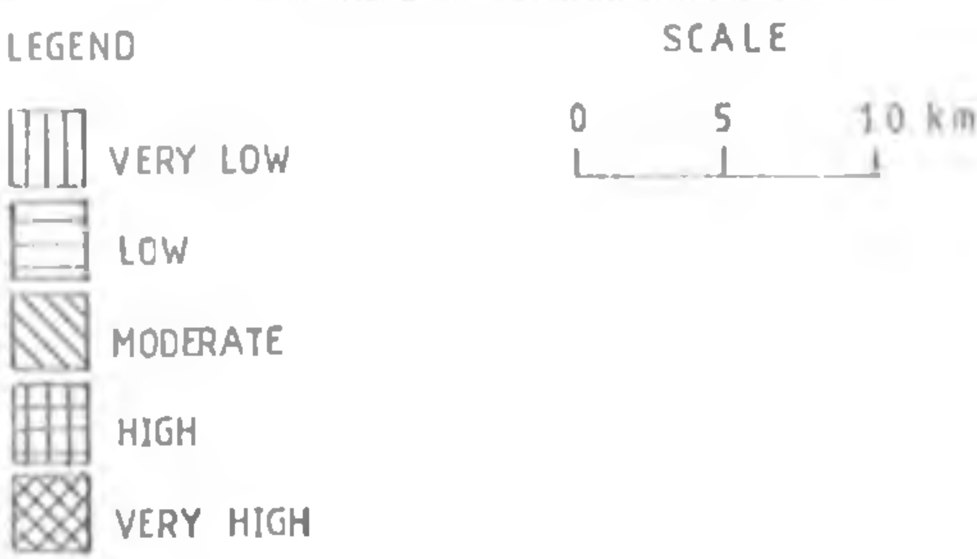
SCALE

0 5 10 km

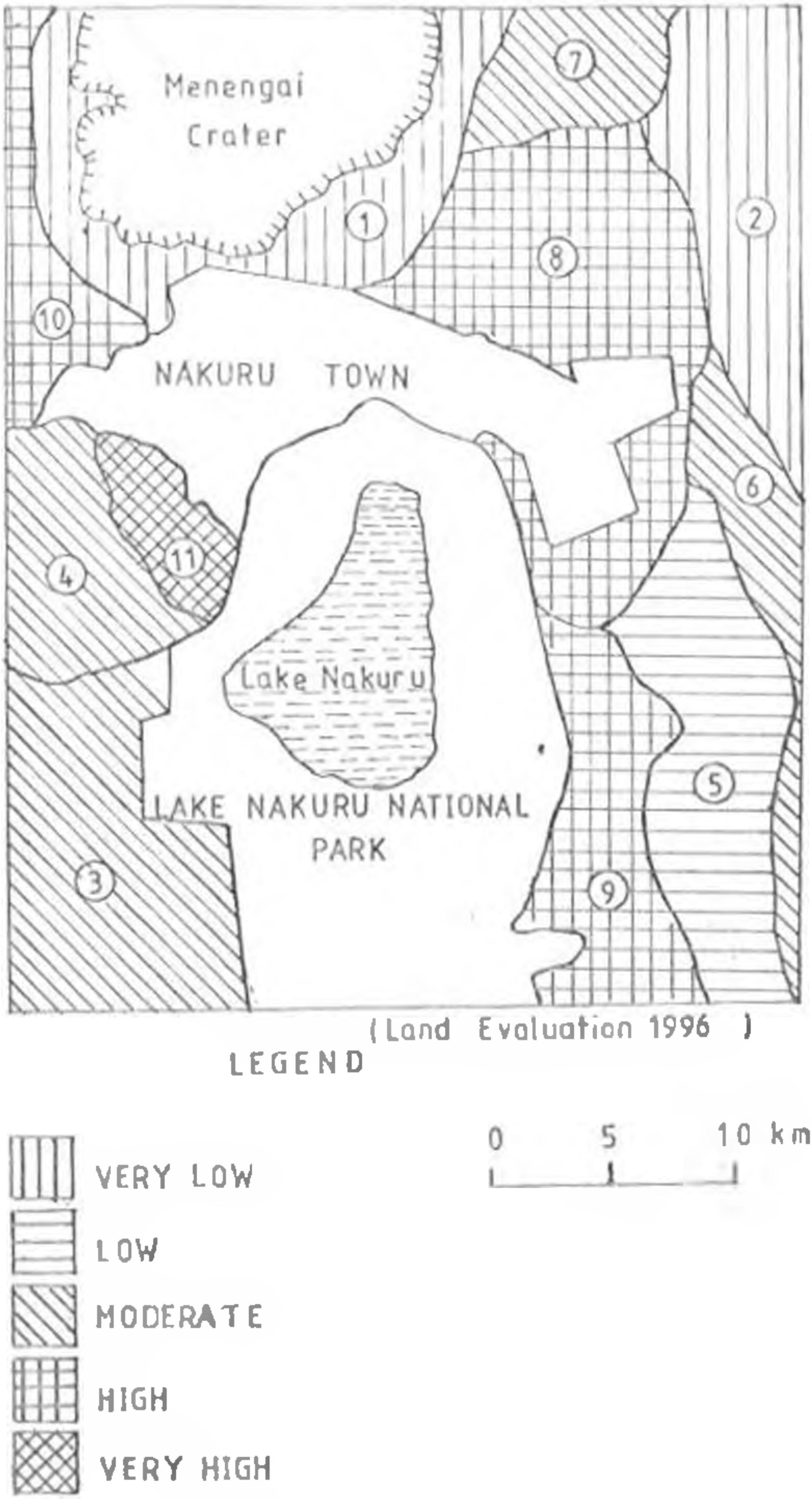
MAP 4-4 LANDSUBSIDENCE CONSTRAINT



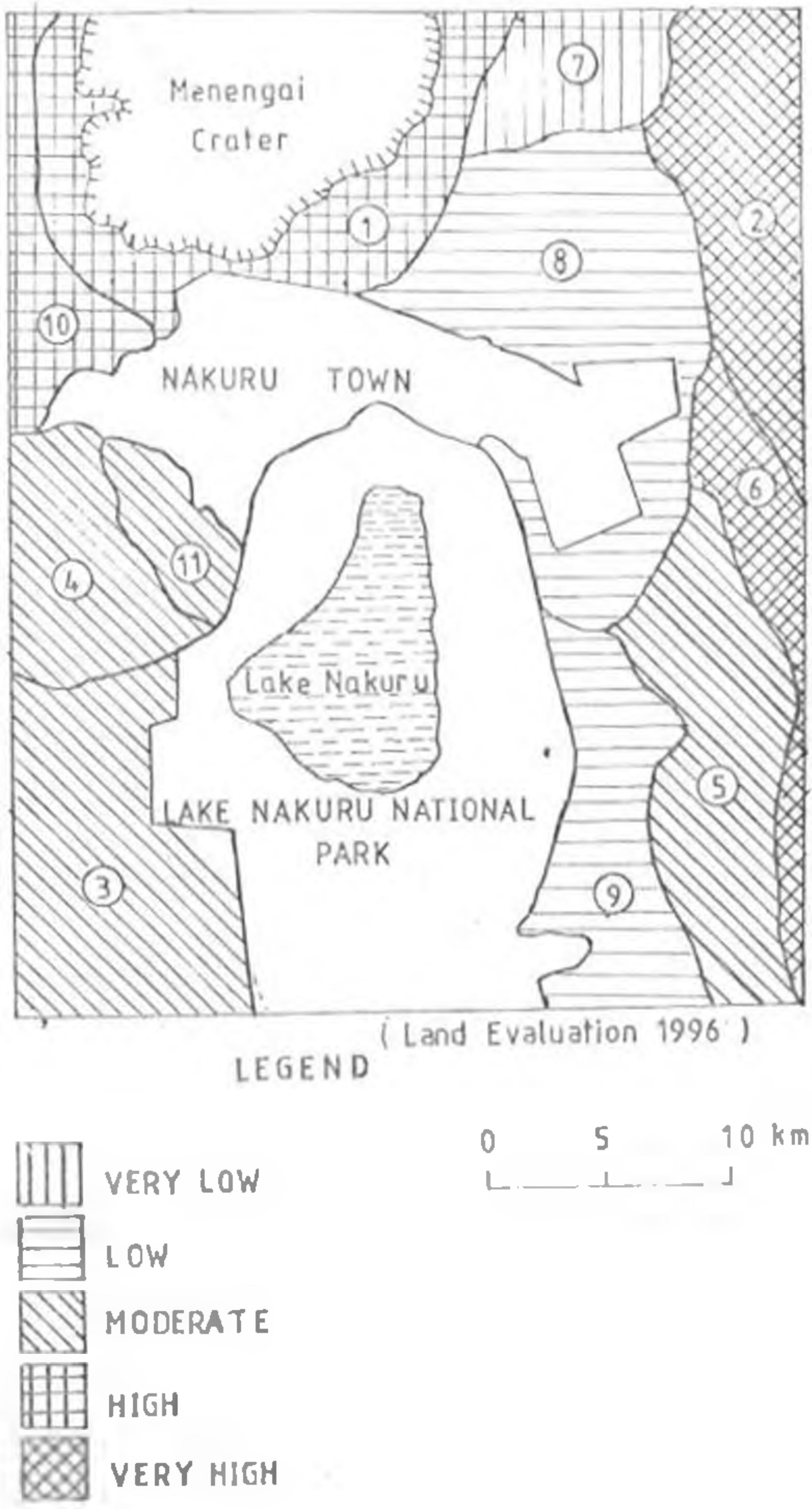
(Land Evaluation 1996)



MAP 4-5 GROUNDWATER DEPTH CONSTRAINT

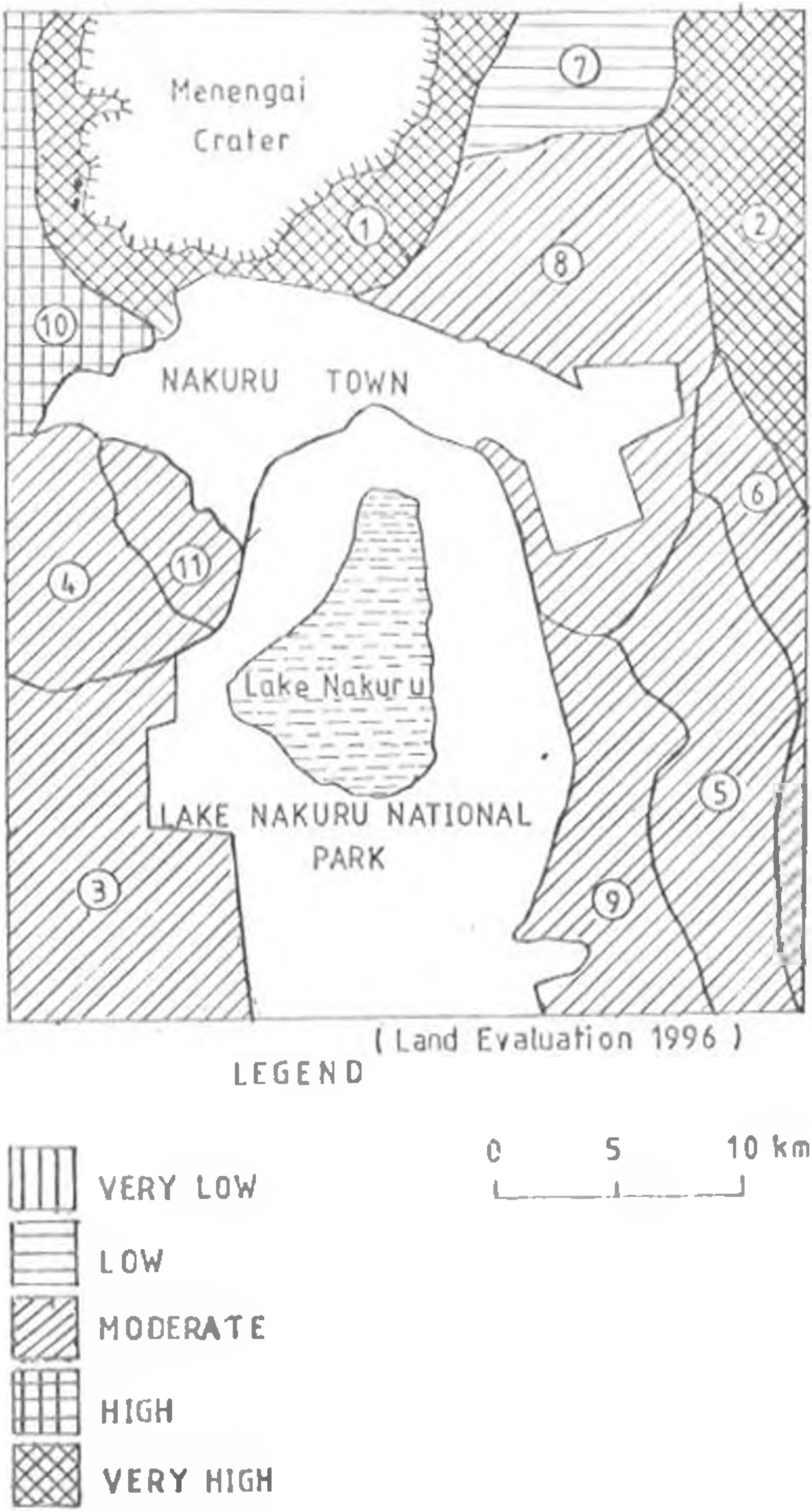


MAP 4-6 DRAINAGE DENSITY CONSTRAINT

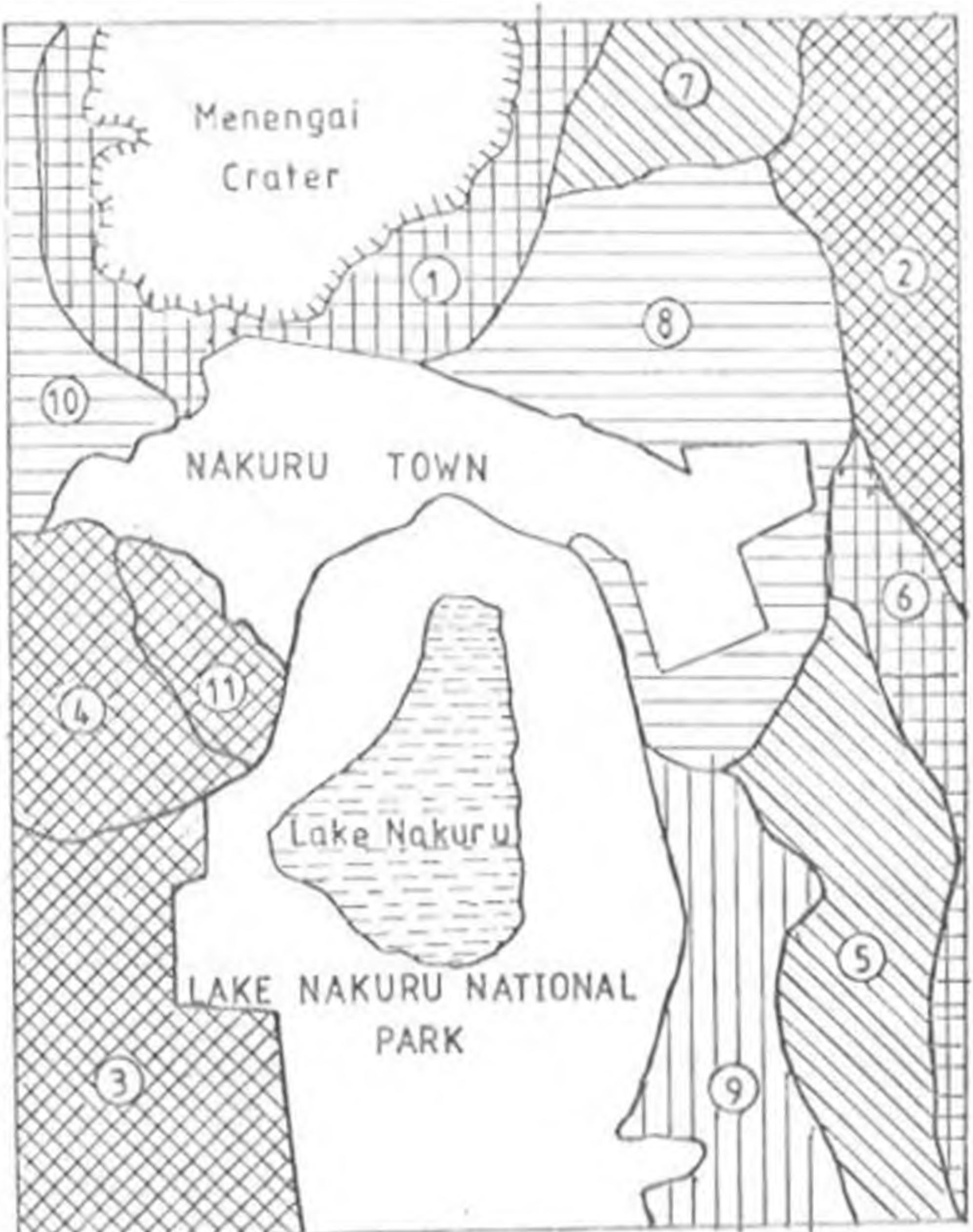


(Land Evaluation 1996)

MAP 4-7 WATERSHED CONSTRAINT

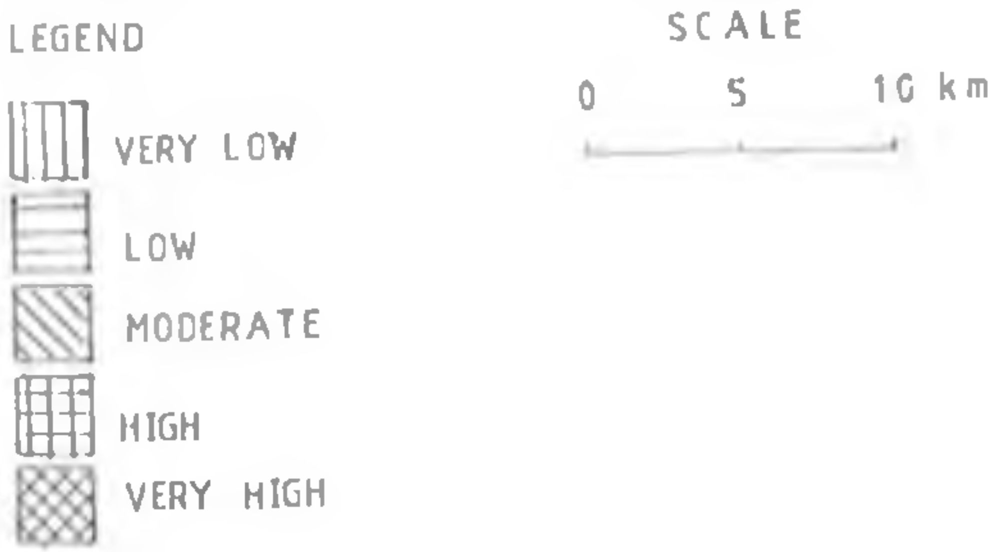


MAP 4-8 EXISTING SOIL EROSION CONSTRAINT

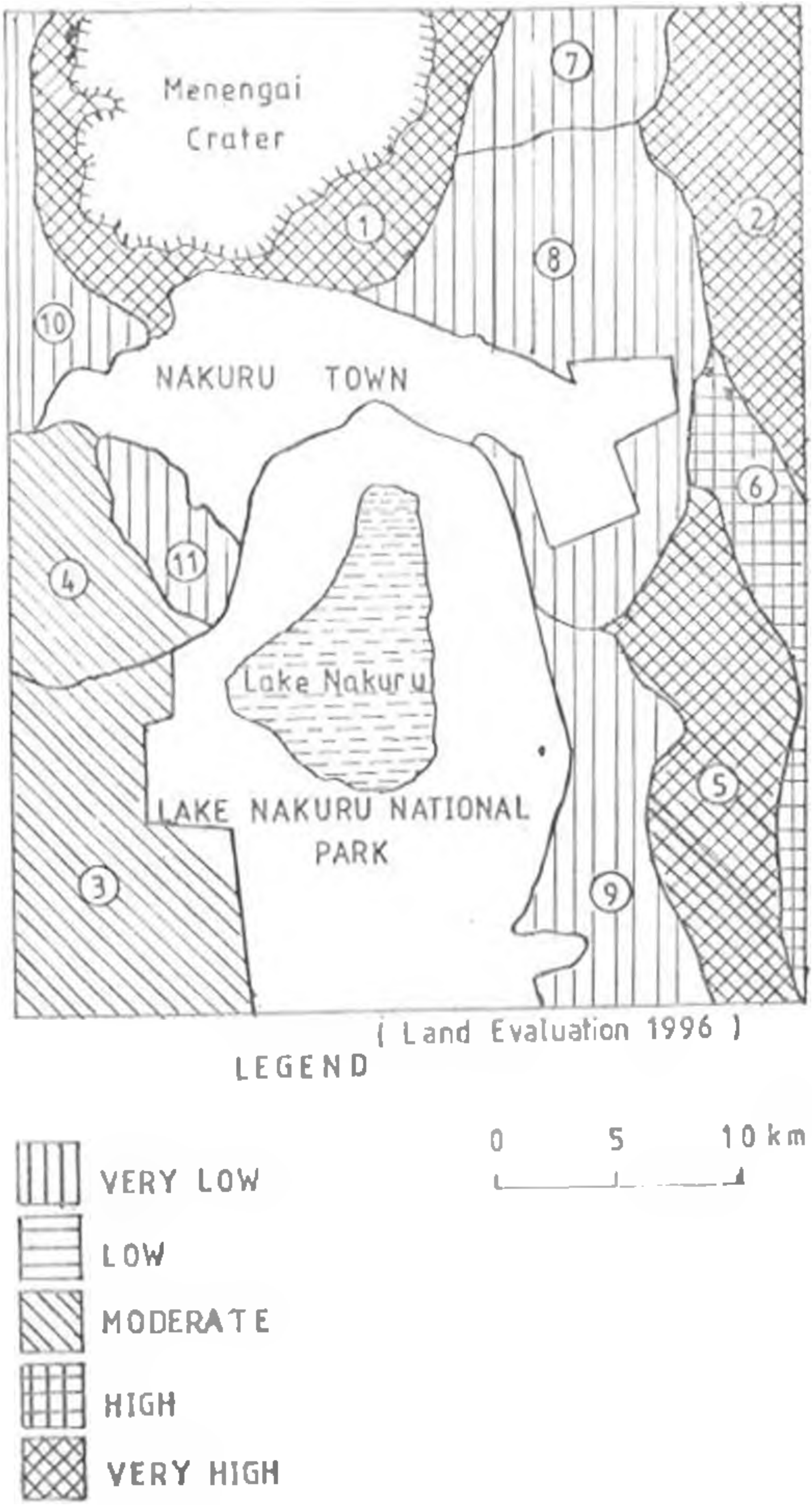


(Land Evaluation 1996)

LEGEND



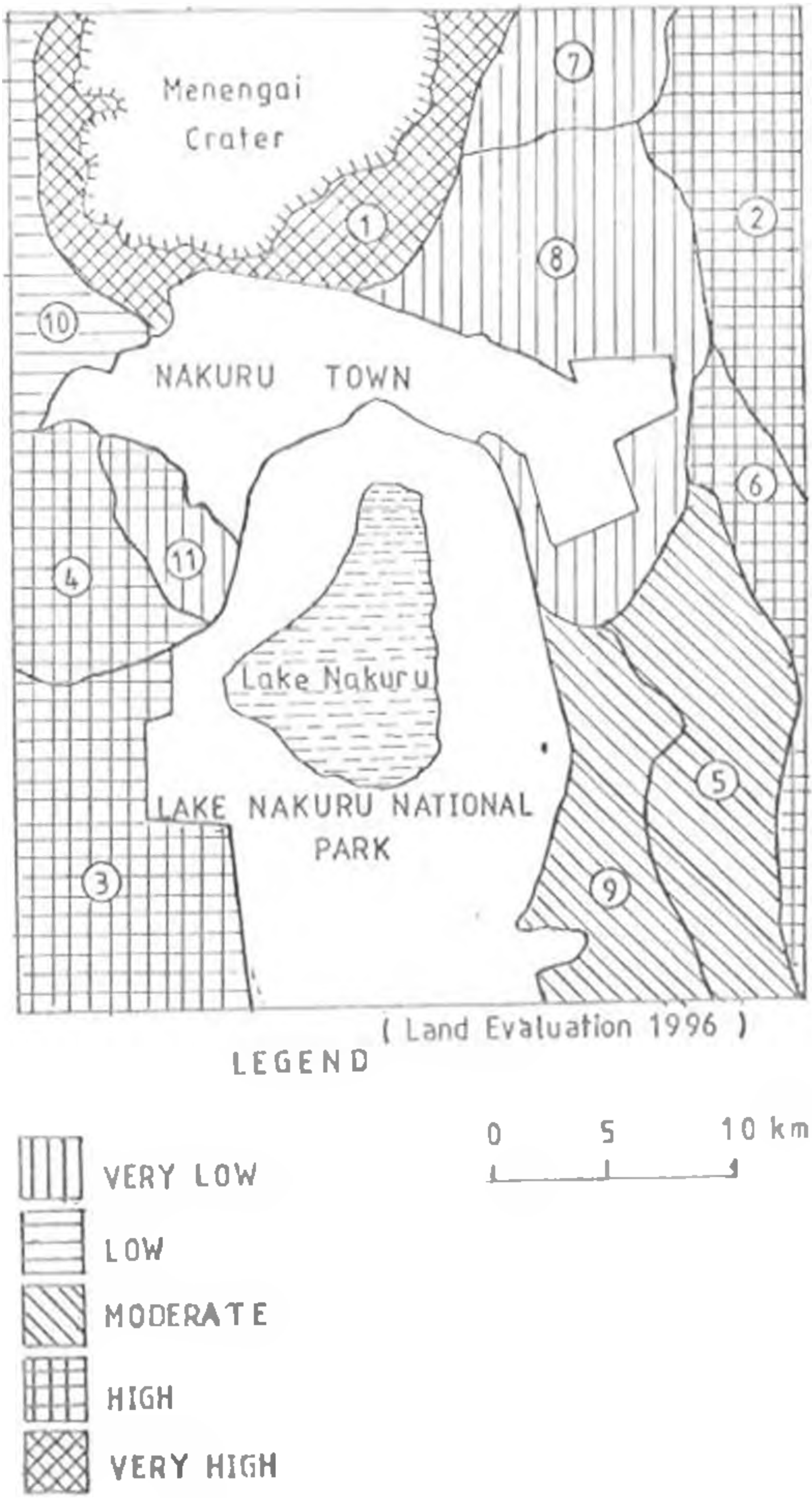
MAP 4-9 SOIL DEPTH CONSTRAINT



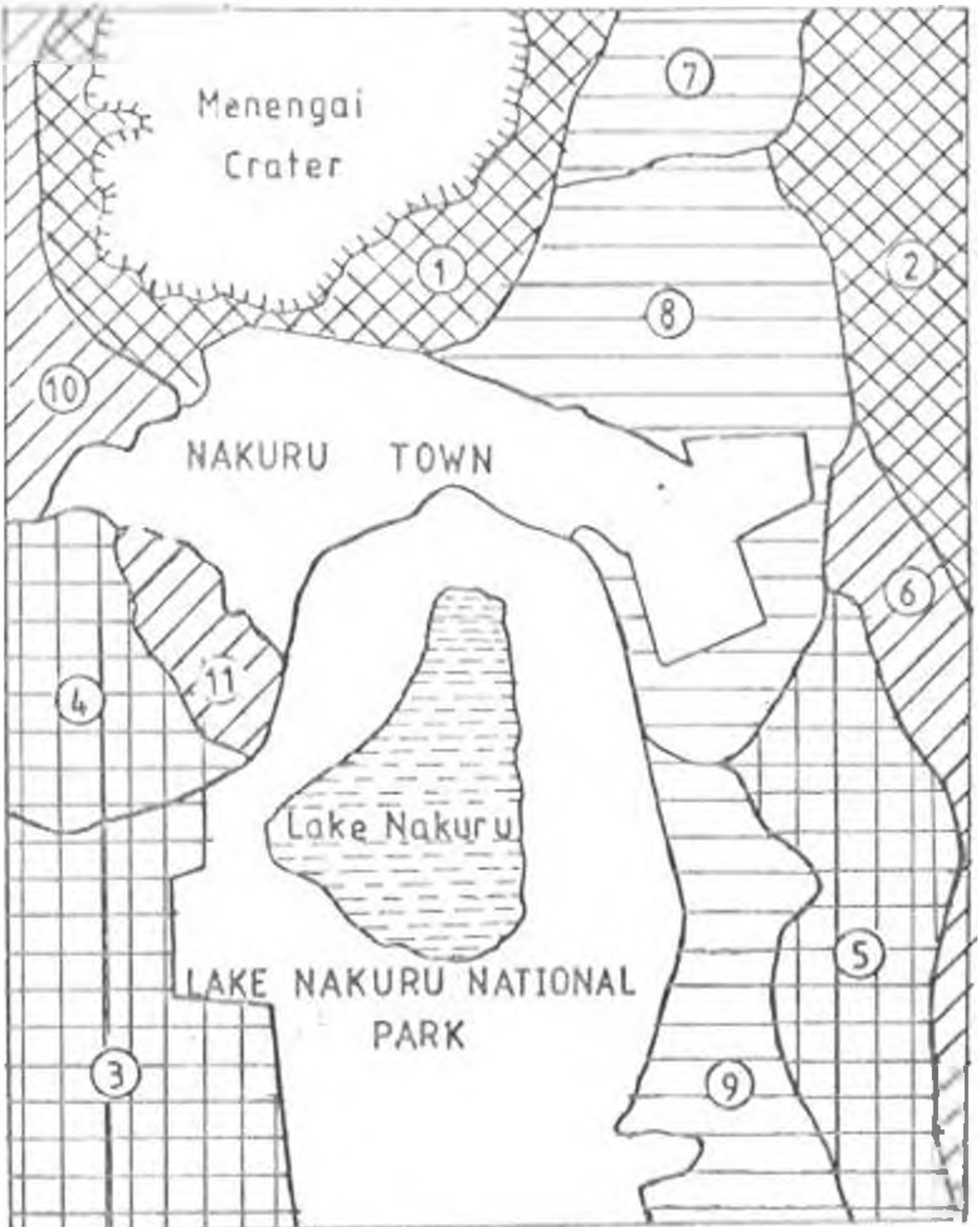
(Land Evaluation 1996)

LEGEND

MAP 4-10 SURFACE ROCK CONSTRAINT



MAP 4·11 COMBINED PHYSICAL CONSTRAINT



(Land Evaluation 1996)

4.2.2 Comparing Land with Urban Development Requirement

Individual land factor rating was compared with land characteristics of each land mapping unit. A rating of 1 to 5 was used to designate the varying levels of land factor limitations. Land unit with very low physical constraints or limitation to urban development was rated at 1 while land factor presenting very high level of limitation was rated at 5 (Table 4.13). A combined rating for each land unit was determined by calculating the sum of the individual land factor ratings (Table 4.13). A higher sum denotes greater constraints or inversely opportunities for urban development. A land unit with the highest sum is rated at 5 and represent the greatest amount of constraint to urban development, or conversely opportunities. This combined rating is then classified into five land suitability classes (Tables 4.14 and 4.15).

The five classes for urban land suitability are highly suitable, moderately suitable, marginally suitable, currently unsuitable and permanently unsuitable. Highly suitable class indicates land area where urban development may be undertaken without any physical land constraint. The opportunities for urban development are very high and there is no risk of land degradation either in the short- or long-term. Moderately suitable class indicate land areas where physical land constraints occur only at low degree. At least some moderate constraints are present but not serious enough to require special consideration. Opportunities for urban development are moderate.

Marginally suitable class indicate land areas where some physical land constraints exist which may be difficult to overcome. The land is only suitable if the significant constraints are addressed, thus suitability is borderline. The opportunities for urban development are marginal.

Currently unsuitable class represent land areas where physical land constraints occur at a high degree which cannot be overcome at reasonable costs. Currently there is no opportunity for urban development but the constraints may be overcome with time. Therefore urban development should be subjected to special approval after specialised advice. Permanently unsuitable class indicate land areas with significant and severe physical land constraints that make urban development impracticable. There are no opportunities since physical conditions are extremely difficult to overcome and urban development may result in unacceptable risk of land degradation.

Table 4.13 Result of Land Factor Rating for Land Mapping Units

	LAND MAPPING UNITS										
LAND FACTOR	1	2	3	4	5	6	7	8	9	10	11
SLOPE	5	5	3	3	3	2	1	1	1	2	1
SUBSIDENCE	3	4	5	5	5	3	3	2	3	4	5
AGRO-ECO ZONE	4	5	4	4	1	1	4	4	2	3	3
SOIL EROSION	4	5	5	5	3	4	3	2	1	2	3
SOIL DEPTH	5	5	3	3	5	4	1	1	1	1	1
SURFACE ROCKS	5	4	4	4	5	4	1	1	3	2	1
GROUNDWATER DEPTH	1	1	3	3	2	3	3	4	4	4	5
DRAINAGE DENSITY	4	5	3	3	3	5	1	2	2	4	3
WATERSHED CONDITION	5	5	3	3	3	3	2	3	3	4	3
SUM	36	39	33	34	30	27	19	20	20	26	25
FINAL RATING	5	5	4	4	4	3	2	2	2	3	3

Key to Land Mapping units

1. MENENGAI FOOTSLOPES
2. BAHATI FOREST
3. GICHOBO-NAISHI
4. BARUTI
5. MBARUK RIDGE
6. MBARUK VALLEY
7. BAHATI
8. KABATINI-DUNDORI
9. ELEMENTAITA
10. TECHNOLOGY
11. RONDA

(Land Evaluation 1996)

Table 4.14 Classification Criteria for the sum of Ratings

Class	Sum of rating	Level of Limitation
1	9 - 17	Very low
2	18 - 21	low
3	22 - 28	moderate
4	29 - 35	high
5	36 - 45	very high

(Land Evaluation 1996)

Table 4.15 Relating Land Factor Limitation to Urban land suitability classification

Class	Level of Limitation	Land suitability class
1	very low	optimally suitable
2	low	moderately suitable
3	moderate	marginally suitable
4	high	currently suitable
5	very high	permanently unsuitable

(Land Evaluation 1996)

4.3 Land suitability classification

With the individual land factor and combined land factor ratings for each land unit (Table 4.13) and their suitability classification for urban land development (Table 4.15) the overall suitability for each land unit can be established (Table 4.16 and Map 4.12).

Table 4.17 presents a summary of the urban land suitability situation in the Nakuru urban-rural fringe area. Suitability for urban development are moderately suitable, marginally suitable, currently unsuitable and permanently unsuitable. There is no land area highly suitable for urban development.

The 420 km^2 of the assessed land in the fringe area include 226 km^2 (54%) of unsuitable land. Of this 93 km^2 (22%) is permanently unsuitable and 133 km^2 (32%) is currently unsuitable. Most limiting land factors are steep slopes, shallow soils prone to erosion, surface stones and critical watershed areas that should be conserved. In addition land subsidence hazard is a major limiting physical factor. Permanently unsuitable areas include Menengai footslopes and Bahati escarpment where there should be no urban development. Currently unsuitable areas include Baruti, Gichobo-Naishi and Mbaruk ridge areas. If urban development is to take place in these areas then detailed physical land data describing limits of use and special development design will be required. Careful land management and restricted development control are in order in these areas.

According to table 4.17 about 194 km^2 (46%) of the fringe area is suitable for urban development. Of the suitable, 121 km^2 (29%) is moderately suitable, and 73 km^2 (17%) is marginally suitable. Moderately suitable are Bahati, Kabatini-Dundori and Elementaita areas. Most limiting factors are shallow groundwater depth, presence of groundwater recharge areas and high potential agricultural land. The marginally suitable areas include Ronda, Mbaruk valley and Technology areas. The most limiting factors include landsubsidence hazard, shallow groundwater depth and underground water recharge areas

Most important physical land factors limiting suitability for urban development in the Nakuru urban-rural fringe area are: landsubsidence hazard, encroachment on agriculturally high potential land; poor soils prone to erosion table 4.18. Other factors important but not considered in the above physical analysis are comparability of urban development with existing land uses; and social needs, goals, visions and aspirations of the local residents. Before arriving at the final land suitability classification the result of physical suitability classification has to be compared with these other factors.

Table 4.16 Results of Land suitability classification

Land Unit	Land mapping unit Name	Urban Land suitability class
1	MENENGAI FOOTSLOPES	Permanently unsuitable
2	BAHATI FOREST	Permanently unsuitable
3	GICHOBI-NAISHI	Currently unsuitable
4	BARUTI	Currently unsuitable
5	MBARUK RIDGE	Currently unsuitable
6	MBARUK VALLEY	Marginally suitable
7	BAHATI	Moderately suitable
8	KABATINI-DUNDORI	Moderately suitable
9	ELEMENTAITA	Moderately suitable
10	TECHNOLOGY	Marginally suitable
11	RONDA	Marginally suitable

(Land Evaluation 1996)

Table 4.17 Extent of land units according to suitability

Suitability class	Land unit	Extent (km^2)	%	TOTAL km^2	%
Moderately suitable	7	22	5	121	29
	8	62	15		
	9	37	9		
Currently unsuitable	6	33	8	73	17
	10	27	6		
	11	13	3		
Permanently unsuitable	3	57	14	133	32
	4	31	7		
	5	45	11		
Permanent unsuitable	1	30	7	93	22
	2	63	15		

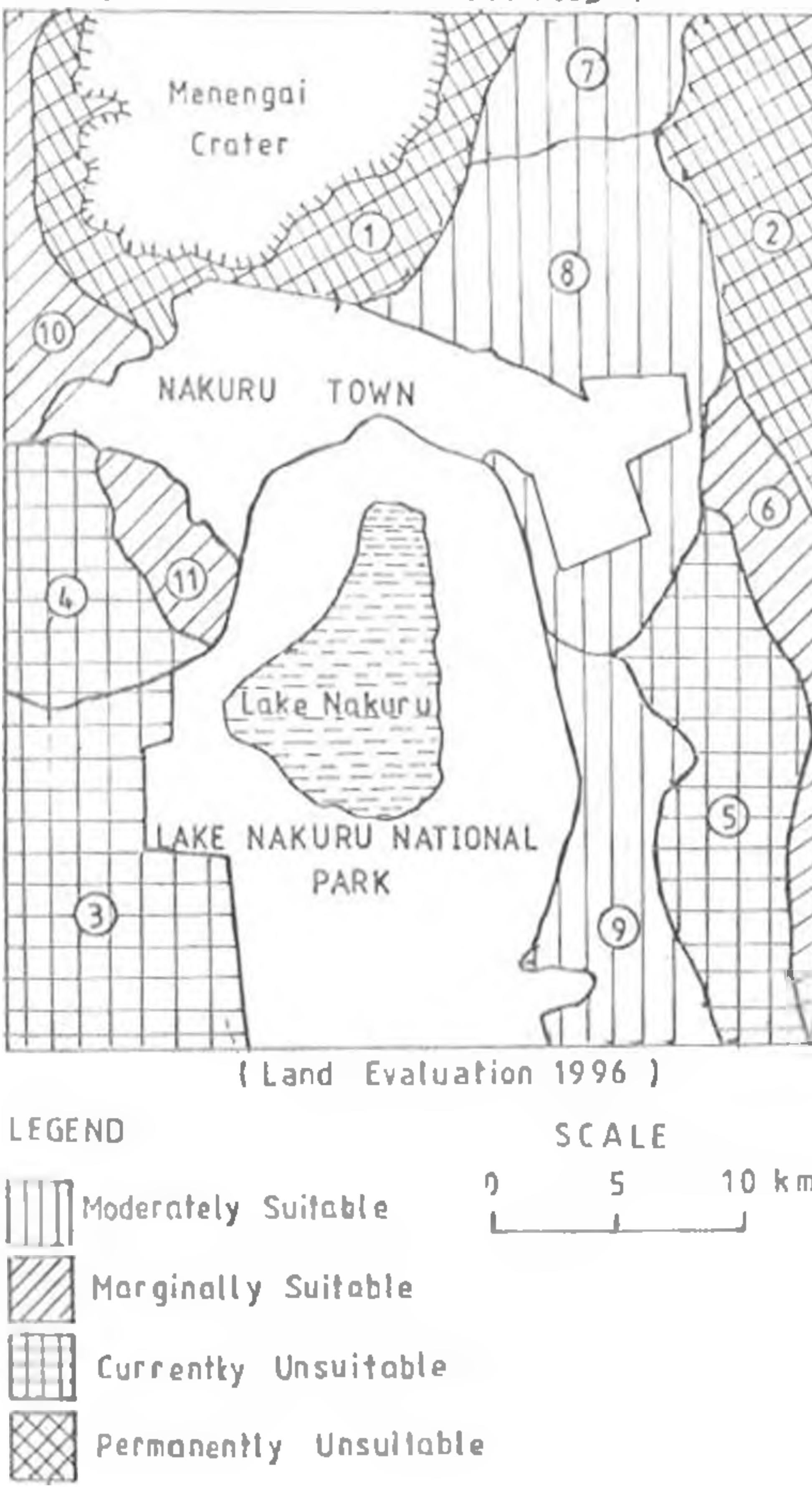
(Land Evaluation 1996)

Table 4.18 Summary of extent of physical land factor constraints

	Level of constraint					
	Low		Moderate		High	
	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)
lope	194	46	133	32	93	22
andsubsidence	62	15	122	29	236	56
gro-eco zone	115	27	40	10	265	63
oil erosion	126	30	67	16	227	54
urface Rocks	111	26	82	20	227	54
oil depth	161	38	88	21	171	41
roundwater Depth	138	33	143	34	139	33
'atershed condition	22	5	278	66	120	29
rainage Density	121	29	146	35	153	36

(Land Evaluation 1996)

MAP 4-12 URBAN LAND SUITABILITY



CHAPTER FIVE

5.0.0 IMPLICATIONS FOR LAND USE PLANNING

5.1.0 Land Use Planning Problems and Issues

The results of land suitability classification indicate that in the fringe of Nakuru town land categories range from moderately suitable, marginally suitable, currently unsuitable and permanently unsuitable for urban development. Menengai footslopes (land unit 1) and Bahati Forest (land unit 2) are classified as permanently unsuitable. Major parts of Menengai footslopes are currently planted forest, to the east are small-scale farms that almost reach the rim of the crater while to the west is a large ranch. The lower footslopes are occupied by medium and high class urban residential housing estates and an open dump for solid waste disposal. The upper slopes of Bahati Forest land unit is occupied by forest plantation while the lower footslopes are occupied by small-scale farming. These two land units are considered unsuitable for urban development and should be left under forestry to protect the steep slopes and to act as water catchment areas. The two areas have steep slopes, shallow soils, in places consist of bare rocks on the surface, prone to soil erosion and dissected by many surface drainage patterns. Because of the unique and natural landform and scenic value of Menengai Crater, the area is an important educational and recreational site.

The currently unsuitable areas consist of land units 3, 4 and 5. These are the Gichobo - Naishi, Baruti and Mbaruk ridges respectively. The Gichobo - Naish area was originally natural forest, later was cleared for large-scale farms, but now has been subdivided into small-scale farms for intensive cultivation. Baruti area was formerly large-scale farms and have now been also subdivided into small-scale farms. Soil erosion is a major problem in these two areas where intensive cultivation of the young and light volcanic soils are left bare without vegetation cover. Mbaruk area is still under natural vegetation of savannah grassland and bushland in which ranching is the main land use, although the large-scale ranches are being subdivided into small suburban residential plots. Land subsidence is a serious problem in these three areas because of old geologic faultlines covered by unstable soils. Therefore these areas are considered to be currently unsuitable for urban development unless detailed studies are undertaken to identify specific areas affected by the faultlines.

Land mapping units 6, 10 and 11 have been classified as marginally suitable for urban development. These are the Mbaruk Valley, Technology and Ronda areas respectively. These land units have some potentials for urban development however with some physical constraints that may be difficult to overcome. The Technology and Ronda areas are relatively flat plains with deep soils. The Ronda area is a depressional land area with shallow groundwater level, while technology area is relatively good agriculturally productive land but both areas are prone to land subsidence hazards. The Mbaruk Valley although relatively flat and of low agricultural potential, is a river valley prone to flooding hazards and soil erosion.

Land mapping units 7 - Bahati area; 8 - Kabatini - Lanet area; and 9 - Elementaita area are all classified as moderately suitable for urban development. These are the relatively best areas for urban development in the region since there is no area classified as optimally suitable. All these areas are flat plains with very deep soils and very few surface drainage channels. Bahati and Kabatini - Lanet areas are relatively medium agricultural potential zones but there will be little harm if they are orderly converted into urban use. All the three land units have moderately shallow ground water level but this may not interfere much with urban land use. Therefore the three areas are considered to have high potential for urban development however with low level of physical constraints that can easily be overcome.

The analysis concentrated on physical land factors not because other factors are unimportant, but because discussion of other factors such as socio-cultural, economics and politics are facilitated by a prior objective assessment of physical resources. The physical land suitability classification results were therefore compared with existing land use and visions or concerns of the local residents in order to establish the strategies for urban expansion. Current land use pattern is considered important because future urban development should conform with the existing land uses and avoid conflicts. The concerns of the local residents is considered because the plans made by the people, themselves stand the best chance of being implemented. Therefore the visions and aspirations of the local residents should form the goals and objectives of land use planning programme.

By comparing the results of land suitability classification with existing land use, irrational land use decisions can be identified in the fringe of Nakuru town. The analysis contrasts with the recently extended municipal boundary. The area of major conflict is the extension of the municipal area to the southwest of the town centre. Most of the land in this area has been classified as marginally or currently unsuitable for urban development. The analysis also indicates that the current solid waste disposal site is located in an area with poor soils, old volcanic faultlines and steep slopes. This means that the leachate from the open dump can easily reach and pollute underground water resources.

To some extend the analysis agrees with the local residents who have intensified suburban settlement development to the north-west of the town centre. This area has been classified as moderately suitable for urban development and is the best land in the region. Despite the fact that a large proportion of urban population reside in this area, the municipal council did not integrate the area into municipal jurisdiction when the boundary was extended in 1994. Instead, the municipal boundary was extended to the south to cover the whole of Lake Nakuru National Park and part of suburban agricultural land to the south-west of the town centre. The key issue in the fringe of Nakuru town is that urban land use is not based on physical environmental suitability. For sustainable urban development, emphasis in land use planning need to be directed to adjust land use to match land suitability so that both urban development needs and environmental conservation needs can be attained.

5.2.0 Land Use Planning Strategies

The results of land suitability classification together with pertinent information have helped to identify strategies for urban land use planning in the fringe of Nakuru town. The main concern for the local residents is how to achieve a balance between urban growth and conservation of the environment. Some of these issues have been identified by the local residents during a workshop organized by the Agenda 21 project (UNCHS, 1996), together with questionnaire surveys and discussions with different people in the area. The vision of the local residents is an "eco-city" or "green-city" Nakuru of the future. For these reasons, the following strategies for urban land use planning in Nakuru urban fringe are considered appropriate: protect ecologically sensitive land areas including Lake Nakuru and Menengai Crater; avoid urban development in land areas prone to geological instability and land subsidence hazards; protect underground water resources by preserving water catchment and recharge areas; identify new sites suitable for sanitary landfill for solid waste disposal; and direct future urban expansion into suitable areas by orderly conversion of agricultural land into urban use.

These strategies reflect the concerns of the local residents and can contribute to the goals of sustainable urban development and environmental conservation in Nakuru town. Land use plans for the area should be able to protect ecologically sensitive land areas while enhancing the opportunities offered by the natural environment in order to achieve sustained development.

5.2.1 Protection of Lake Nakuru and Menengai Crater

The area around Nakuru town is endowed with unique natural resources that deserve to be protected. The million flamingoes of Lake Nakuru and the natural Menengai Crater not only gives the town its local identity but also attracts many visitors. As a result, tourism plays an important role in the economy of Nakuru town. However, rapid urbanization without land use planning guidelines poses many environmental and planning problems.

Lake Nakuru is internationally reknown as a conservation area for its spectacular wildlife. But urban settlements have developed haphazardly close to the perimeter of the park fence resulting in conflict between urban development and wildlife conservation. Furthermore, Lake Nakuru is the lowest point in the region therefore all the run-off from the town ends up in the lake which may cause pollution. Wild animals from the park frequently raid settlements nearby. In order to improve compatibility between wildlife conservation in the park and urban land use activities in Nakuru town, there is a need to establish an ecological belt between the two.

This may require establishing a buffer zone and formulating specific land management strategies for the land areas close to the park. Land areas unsuitable for urban development include parts of land units 3,4,9 and 11. These land areas close to the park should be used for extensive activities compatible with wildlife conservation. These may include a belt of planted trees, game or livestock ranching, or horse racing and other land uses that may limit direct contact between wild animals and human settlement. Biosphere Reserve concept offers an opportunity for environmental conservation and urban development in the region.

A biosphere reserve is a unique category of protected area combining both conservation and sustainable use of natural resources (UNESCO 1974, 1984). To carry out these complementary activities, biosphere reserves consist of three interrelated zones: core, buffer and transition zones. The core area consists of minimally disturbed ecosystem which is surrounded by a delineated buffer zone where only activities compatible with conservation can take place. The two zones are in turn surrounded by a more or less defined transition area where cooperation with human activities can be developed (Batisse 1982, 1990). The concept is dynamic and flexible in both spatial arrangement and management approach and can be implemented for the whole of Lake Nakuru catchment area.

Menengai Crater is important for its natural scenic and scientific values and gives Nakuru its local identity as the crater town. Yet these opportunities are presently under-utilized and being undermined by unplanned urban development. Unplanned informal settlements have encroached on the steep slopes up to the rim of the crater. Many tourists, both local and foreign, visit the crater but there is no well maintained road for easy access to the site. In addition, the security of the visitors is not assured and there are no facilities or guidelines for the visitors.

Land unit 1 on which the crater is located has been classified as permanently unsuitable for urban development. This study also revealed that a large segment of the local population is not aware of the significance of preserving Menengai Crater. Some local residents suggested that Menengai Crater is the best site for disposal of municipal garbage from Nakuru town. Public awareness campaigns are urgently needed to sensitise the local residents on the importance of the Menengai Crater. In addition, there is need to prepare descriptive guides for visitors to the crater site.

5.2.2 Solid waste Disposal

As population size an industrialisation increase with urbanization in the fringe of Nakuru town more waste will be produced that has to be disposed of. Presently, both domestic and industrial waste from Nakuru town is openly dumped in a collapsed ground on the slopes of Menengai Crater. The open municipal refuse dump is located along old volcanic faultline at a site where run-off water flowing down the slope connects with the underground waster system. There is fear that the leachate from the waste might pollute the underground water resources. Therefore there is urgent need to identify a safer site for solid waste disposal. The new structure plan should review the present location of solid waste disposal site and identify new sites for sanitary land fill for solid waste disposal.

5.2.3 Protection of Groundwater Resources

Demand for water resources in Nakuru town in high and rising. There are no fresh surface waters in the region therefore most of the water supply is drawn from the underground water system. However, the underground water system is threatened by pollution and urban settlement pressure. Underground water resources supply all the water requirements in the peri-urban areas yet most of the sanitation systems consist of pit latrines in the porous soils that can lead to groundwater contamination. Unplanned urban settlements on steep slopes, in water catchment areas and groundwater recharge areas has resulted in increased run-off and reduced recharge of groundwater.

Given that future water demands are expected to increase, land use planning policy should give priority to conservation of groundwater resources in the Nakuru urban fringe area. Otherwise water supply would have to be imported from long distances. Furthermore importation of all the water needed into the region from other basins is costly and may cause disposal problems in the lake Nakuru basin. Lake Nakuru is the lowest point in the region and all the polluted waters will end up in the lake.

There is need to implement land use plans specifically designed to protect water catchment areas and underground water resources in the region. In sensitive land areas such as in land units 1,2, and 11 land use planning regulations should be introduced to restrict the type of development that can take place. The need to protect ground water raises the issue for more reliable data both on the quality and quantity of ground water and on how they are changing over time. This calls for assessment and monitoring the effect of urban land use activities on the hydrology of the region.

5.2.4 Land subsidence

Landsubsidence or collapsing ground is a significant recurring problem in the fringe of Nakuru town. Future urban expansion will place even more pressure for settlement to be located on land areas prone to land subsidence. This may lead to damage of structures and loss of lives if no precaution is taken now. Any land use plan in the region should have policies and regulations to avoid directing urban development into the affected areas.

The results of land suitability classification indicates that land units 3,4,5 and 11 have very severe constraints of landsubsidences. Therefore the areas are considered marginally suitable for urban development. However, it should be noted here that the results are based on rather general information. This calls for detailed landsubsidence hazards assessment in order to identify safe areas where urban development should occur and highlight risky areas where precautions should be taken. Seismic tests should be undertaken in the region in order to identify the location, extent, and nature of old volcanic faultlines so that urban development can avoid such areas.

5.3.0 Tools for Implementing the strategies

Several measures are considered necessary for implementing the above strategies. The land use control measures considered are: provision of basic infrastructure, zoning, subdivision regulations, environmental impact assessment, educational campaigns and information programs. One of the traditional approaches to control land use is to provide basic infrastructure such as roads, sewers, water and electricity. Targeting public resources for infrastructure provision can guide development to environmentally appropriate areas in the urban fringe of Nakuru town. Therefore the desirable approach to achieve planned urban expansion in Nakuru town would be to set aside funds for public provision of urban infrastructure. This guided urban expansion can be used to improve the patchy-developed suburban areas to the north-east of the town centre. This can be achieved through such measures as widening and straightening existing roads and making new roads to open up the area for new urban development

Zoning is the most widely used instrument to regulate land use directly. It refers to the division of an area into zones or districts in which land use and development densities are controlled. By controlling urban land uses and densities, zoning can protect ecologically fragile areas, restrict development in land subsidence areas and direct urban development to suitable areas. Traditionally, zoning has often been applied rigidly involving single or limited use of land parcel (Kitay 1985; Mantell et al 1990). However there have been recent improvements in zoning techniques. Minimum plot size zoning is particularly relevant to managing land in the buffer zone of lake Nakuru national park and landsubsidence areas in the fringe of Nakuru town.

Environmental impact Assessment (EIA) also should be undertaken to provide policies and information for making decisions on development approval in the fringe of Nakuru. Urban land use activities especially industrial and high density residential housing should be accompanied by EIA reports that address specific concerns related to pollution of lake Nakuru, underground water sources, and compatibility with wildlife conservation in the national park. In addition EIA should consider whether or not the proposed land use activity will be affected by landsubsidence and measures needed to mitigate the hazards.

Most of the land use control measures rely heavily on availability of detailed information on land use, geology, hydrology, vegetation, soils, climate, geomorphology and others. This information should be supplemented with maps, aerial photos, and satellite images. Historical information both oral accounts and written, from long-term residents can also be useful. Geographic Information Systems (GIS) offers a systematic means of combining various data for land use planning. GIS enables easy and speedy access to large volumes of data and allows the data to be manipulated in order to update, select, combine, model, analyse and present information on maps and diagrams. Furthermore, this technology is now cheaply and readily available for land use planning. Therefore to achieve sustained development in Nakuru town, there is need to establish a GIS digital database for land use planning.

All these will require public information programs in order to achieve balanced urban development and environmental conservation in the fringe of Nakuru town. Public environmental education campaigns should be mounted to make the local residents, land developers and decision-makers aware of the physical environmental potentials and limitations for urban development. Public information is urgently needed on landsubsidence, Menengai Crater and Lake Nakuru national park. More than one set of the above measures and other tools will be required in different areas of urban fringe in order to promote sustainable urban development and environmental conservation.

5.4.0 Towards Land Use Pattern in Nakuru Town

A planning team is in the process of preparing a structure plan for Nakuru Town into the twenty first century. Land use plan is the core of structure plan and an important aspect of any land use plan is the physical environmental element. Population growth and expansion of urban settlement in the fringe of Nakuru town is expected to take place in large areas of mostly unsuitable land. Sustainable urban development and preservation of the natural resources in the area requires formulation and implementation of guidelines for environmentally sensitive land use planning. Guiding urban development now will avoid many issues that would have otherwise to be solved later through site selection, project design and costly maintenance.

In this context, this section contributes to this effort by providing guidelines for future land use pattern in the fringe of Nakuru town. However it should be noted that this study is not concerned with the detailed land use plan design, rather the results provide a guideline for more detailed studies and land use planning. The proposed pattern is based on the suitability of the land, the dominant problems, present land use pattern and trends, the people's attitude and the ability to maintain the balance between urban development and environmental conservation.

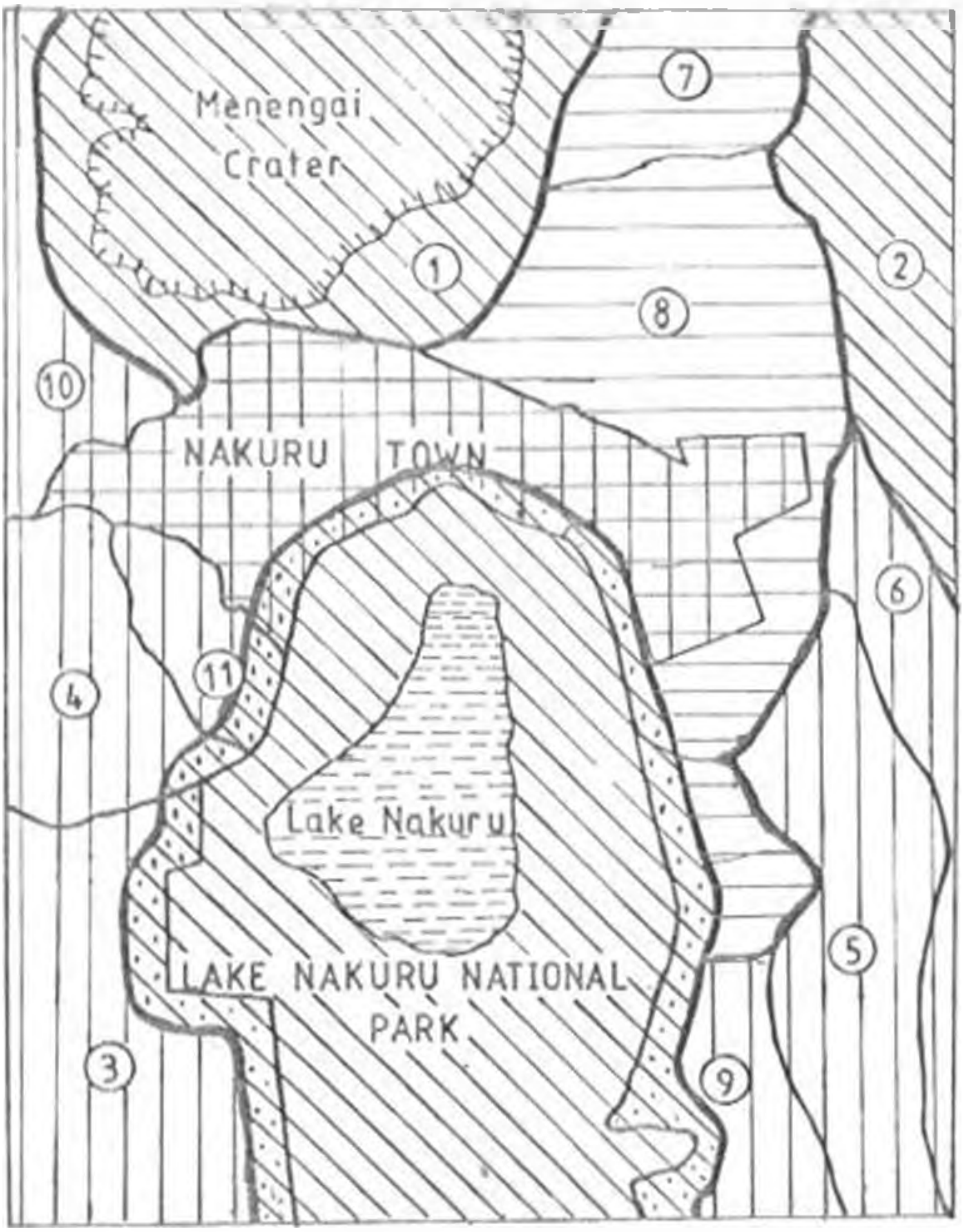
The proposed land use pattern (Map 5.1) is comprised of the following components of land use: existing municipal area, land for future extension of Nakuru town, land requiring detailed studies before further development and; conservation areas. The existing municipal area was assumed to consist of mostly built-up areas. Although there are large areas of vacant land on which new urban development can occur within the existing municipal area, most of the planning will require upgrading of the unplanned settled areas. This is particularly in the recently urbanized areas such as Kaptembwa and Ronda that are in desperate need of upgrading to improve the basic infrastructure and formalize land tenure. Large areas of land will be required in the urban fringe to accommodate increasing population and urban land use activities.

The land for future urban expansion is presented, on the proposed land use pattern, as the areas to the north-east of the town centre (Map 5.1). This area has been classified as the relatively most suitable for urban expansion in the region. Currently the area has proved attractive for suburban settlement. Planned urban expansion into this area should be actively encouraged by provision of basic public infrastructure such as roads, water supply, electricity, sewer, schools and other facilities. The area is proposed for general urbanization and it is recommended that detailed land use plan for specific activities such as residential, industrial, commercial and others should be worked out.

There are also areas designated for more detailed studies before further urban development can take place. Special attention should be given to these areas due to problems of soil erosion, landsubsidence and contamination of underground water resources. In some of these areas soil erosion is a major problem which should be addressed to avoid further deterioration. Land subsidence is one of the natural constraints to urban development in the fringe of Nakuru town. Detailed studies are required to determine the nature and extent of this problem and how to address it. Underground water is an important source of water supply in the region, therefore its preservation and protection is a pre-requisite for urban development planning. Special attention should be given to groundwater catchment and recharge areas to avoid potential damage.

Finally, the conservation areas delineate land areas considered to be in need of protection. These areas include Lake Nakuru National Park, Menengai Crater, footslopes of Menengai and Bahati Forest. The natural conditions of these area should be maintained, enhanced and promoted. The proposed land use pattern also suggests the establishment of a buffer zone around the national park in which only urban land use activities compatible with wildlife conservation in the park should be promoted. The steep slopes of Menengai crater and Bahati Forest should be left under forestry to protect the unstable land and act as water catchment areas. Otherwise additional measures are obviously necessary to ensure sustainable urban development in the region. This study is based on data that is rather general and can be improved if more detailed land resource inventories are acquired.

MAP 5-1 FURTHER URBAN DEVELOPMENT



(Land Evauation 1996)

LEGEND

Existing Municipal Area

Future Extension Area

Further Studies Area

Protection Area

Buffer Zone

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

6.1 Summary and conclusion

Land suitability evaluation is a procedure for determining the fitness of a given land area for a defined use, emphasising environmental protection. The procedure can contribute to land use planning by analysing the biophysical land characteristics and their alternative uses. The purpose of this study was to assemble land resources and physical environmental data and interpret the information to derive land use planning guidelines in the fringe of Nakuru town. Data on the land and related resources was compiled from fieldwork, maps, reports, and aerial photographs. Scarcity of up-to-date, reliable and relevant information on the land resources was a major limitation. A land suitability assessment for broad urban development was based on the physical land factors of: slope, soil depth, soil erosion, surface stones, land subsidence hazards, agro-ecological potential, depth to groundwater, drainage density, and watershed sensitivity. The area was divided into 11 homogeneous land units based on these factors and other physical land information.

It was found that four land suitability classes for urban development could be delineated in the study area. First, moderately suitable land in which physical constraints only occur at low levels and opportunities for urban development are moderate. This covers 121 square kilometres representing 29 per cent of the area. Secondly, marginally suitable land in which some constraints exist which may be difficult to overcome, and opportunities for urban development are marginal, representing 73 km^2 (17%). Thirdly, currently unsuitable land in which physical land constraints occur at high degree and can only be overcome at very high costs therefore currently uneconomical. This covers 133 square kilometres representing 32%. Finally, permanently unsuitable land where significant and severe physical land constraints exist which make urban development impracticable and may result in serious land degradation. This category covers 93 square kilometres or 22 per cent of the area.

This indicates that land unsuitable for urban development covers nearly 54 per cent (226 km^2) of the fringe areas of Nakuru town. The most limiting physical land factors include: unstable steep slopes, soil erosion, landsubsidence hazards, sensitive water catchment and groundwater recharge areas, and conflicts with wildlife conservation. Only special urban land use activities and careful land management are recommended for these areas. Land suitable for urban development covers 46 per cent (194 km^2). However, suitability is only moderate or marginal. The most promising land area for urban expansion occur to the north-east of the town centre.

Based on this results together with existing land use patterns and trends, and aspirations of the local people, guidelines are proposed for land use planning in the fringe of Nakuru town. In order to maintain a balance between urban development and environmental conservation strategies are suggested for: protecting Lake Nakuru and Menengai Crater; solid waste disposal; protection of underground water resources and; avoidance of land subsidence-prone areas. Land use planning control measures for implement these strategies are also suggested. The results provide preliminary information but is insufficient as a basis for land use planning. If more specific data are available the results can be improved using similar suitability analysis process. Land evaluation for urban land use planning has not hitherto been a common practice, especially in Kenya. Thus relevant biophysical land characteristics and their critical value for specific urban land use activities are not yet specified.

6.2 Recommendations for further research

Land use planning has the potential to direct urban development away from environmentally sensitive land areas. This should be the next step in Nakuru urban fringe area. However one of the basic requirements for such a land use planning process will be availability of detailed data on the physical environment. Without reliable and relevant data, land use planning decisions are liable to be made without full awareness of the critical resources available, or the environmental problem and issues to be addressed, and thus without a complete understanding of implications of the policies adopted.

The following research activities should receive special attention:

1. Detailed surveys should be undertaken to provide information on the existing and trends of land use pattern and urban population.

2. There is also urgent need to carry out hydrological studies in the whole of Lake Nakuru catchment area in order to identify and define groundwater source protection areas. An action plan need to be developed to restrict urban land use activities in

sensitive areas.

3 A very high priority is the geological and soil studies to identify the nature and extent of land subsidence problem and appropriate management.

4 On the wider perspective there is need for continued research and case studies in order to refine biophysical standards for land use planning.

If a land use plan is prepared without closing these and other gaps in essential data, it will be founded on a seriously inadequate environmental information

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APPENDIX 1

HOUSEHOLD SURVEY QUESTIONNAIRE

QUESTIONNAIRE NUMBER

DATE:

1. Name of the [illegible] area:
2. [illegible]
3. Relation of respondent to head of household:
   (a) [illegible] (b) Male worker [illegible]
   (c) Others (Specify) ____
4. Where does the wage earner in the household work? ____
5. Type of house:
   (a) Temporary (b) Semi-permanent
   (d) Bungalow ___ (e) Others ____ ____
6. Number of Rooms in the housing unit ___ ____
7. Housing unit ownership:
   (a) Owner-occupier __ (b) Private rented
   (c) Employer ___ (d) Others __
8. House rent per month, if rented. _ ____ ____
9. How long have you lived in this house: ____ ____
10. Where did you live previously ____ ____
11. When was this house built: _ ____ ____
12. How many people live in your household: ____ ____
13. How many household live on this compound: ____ ____
14. What is the size of this plot or farm: ____ ____
15. Other comments on housing: ____ ____ ____

    ____ ____ ____ ____ ____ ____
16. For how long have you lived in Nakuru? _ ____
17. What is the main land use on this plot?
    (a) Residential ___ (b) Wheat farming ___ (c) Others
18. What is the dominant land use in the neighbouring farms/plots?____ ____ ____ ____
19. What is the total size of this farm/plot? ____ ___
20. Nature of land tenure:
    (a) Freehold ___ (b) Trust land ___ (c) Cooperative ___
21. Does the land have tittle deed?
    (a) Yes ___ (b) No

22. How was the land acquired?
    (a) Inherited _ (b) Rented _ (c) Bought
    (d) Gift ___ (e) Others ___ _______ _
23. What crops are grown on the farm _______
24. What [illegible] the approximate income from [illegible] per year? ______ _____ ____
25. What problems are faced [illegible]
26. How can the problems be [illegible]? __ ____ ______ ______
27. What type of agro-chemicals are used [illegible]
    (a) Fertilizers _ (b) Pesticides __ (c) others___
28. What animal production enterprises are carried out on the farm? ______ ______ ______ ____
29. What is the approximate [illegible] production per year? _____ ____ ______ ______
30. What are problems with animal production? _ _____ _________ ______ ____ ___ ______
31. How can they be solved? ______ _________ ______
32. What other commercial activities take place on the plot/farm? _______ ______ ______ ______ ____
33. Are there any plans for new land use changes on this plot/farm? ____________ ___________ __________ _
34. Since you started staying here what land use changes have occurred in this area?_______ _________ ______ ______
35. What was the land use condition in this are before 1975 (eg. plot size, type of land use)? _____ _______
36. What land use do you expect in this place in the next 20 years? ________ _______ _____ __
37. What would like to see on this land in the future? _____ _______ ______ _______ ____
38. What do you think can be done in order to achieve your visions? _______ ______ ______ _______
39. What is the present market price of 1 acre of land in this area? ________ _______ __________ ____________

[illegible]. In your opinion are there any conflicts of competition [illegible] different forms of land use, what are the problems [illegible]

[illegible]. How can these land use conflicts be resolved [illegible]

[illegible]

[illegible]. What [illegible] your source of water [illegible]
[illegible]
(c) Water vendor ___ [illegible] Others ___

[illegible]. How far [illegible] the water point? ___ ___

45. What are the main water supply problems
(a) Quality ___ (b) Availability ___ (c) Others ___

46. What is the type of toilet facility used by the household?
(a) Pit latrine ___ (b) Septic tank
(c) Sewered toilet ___ (d) Others ___

47. What is the source of power?
(a) Electricity ___ (b) Fuel wood ___ (c) Others ___

48. What is the road conditions and the transportation facilities between this area and Nakuru town? ___ ___

49. How do you dispose the solid waste (garbage
(a) Compost pit ___ (b) Burning ___ (c) Dumping outside ___
(d) Collected by municipality ___ (e) Others ___

50. What are the main type of garbage produced in this dwelling unit? ___ ___ ___ ___

51. Estimate the weight of garbage generated by your household (kg) ___ ___ ___

52. What are the main garbage disposal problems experienced in this area? ___ ___ ___

53. How can the problems be solved? ___ ___

54. Which area do you think is the most safe for disposal of garbage from the whole of Nakuru? ___ ___

55. Land subsidence is major problem in Nakuru town, has there been any occurance in this place, when, how far from here?

___ ___

56. What environmental Problems are experienced in this area of Soil erosion, Land subsidance, pollution, others

57. Other Comments

APPENDIX 2

GUIDELINE QUESTIONS FOR DISCUSSION WITH PHYSICAL PLANNING OFFICER

1. What is the total land area covered by the municipality?
2. What percentage of land within the municipality is owned by government, private individuals, [illegible] and others?
3. [illegible] proposed [illegible] expected to be absorbed in to the [illegible] municipality boundaries in the near future [illegible]?
4. [illegible] and [illegible]
5. What is the land area under different land use types; low-density, medium, and high density residential; commercial; industrial and others?
6. Have land use allocation proceeded according to urban land use plan?
7. What has contributed to conflicts between incompatible land uses?
8. In your opinion, how can systematic and orderly urban land development be encouraged in the town?
9. What are the factors that hinder the implementation of land use plans in town?
10. What are the main constraints to the achievement of planned and orderly urban development in this town?
11. What strategies in your opinion need to be implemented in order to realise planned urban land development and to overcome the above constraints in the town?
12. While deciding on various land uses in the town, which are the parameters considered?
13. Give details and maps of any zoning policies adopted in this town
14. How are the members of the public currently involved in the decision making process, regarding urban land use development?
15. What in your opinion can be done regarding land-use planning and development in order to avoid future land use conflicts and misuse of land resources in Nakuru town and its environs?

16. Which land areas are most suitable for expansion of urban high-density low-cost residential housing
17. Which land areas are most suitable for disposal of the [illegible] waste from the whole of Nakuru town.
18. What major land use changes have occurred since 1975 when the [illegible] structure plan was [illegible]

APPENDIX 3

GUIDELINE QUESTION FOR DISCUSSION WITH PUBLIC HEALTH OFFICIALS IN CHARGE OF SOLID WASTE MANAGEMENT IN THE MUNICIPALITY

1. Which areas get the Municipal solid waste management servic[illegible]
2. Total or approximate number of households served
3. What is the total waste generated (tons/day) by domest[illegible] commercial, Industrial
4. What percentage of this quantity was collected by the municipality in [illegible]
5. What is the method of municipal solid waste disposal
6. Are there other disposal sites apart from the Menengai site'
7. How many improved waste chambers have been constructed, where are they located
8. Please, provide municipal statistics since 1970 on the following: Total personnel and collection vehicles, expenditure and expenses involved in solid waste management.
9. Which refuse recycling activities are encouraged [illegible] the town
10. Is there any pollution of ground/surface water resulting from the present refuse dumping site.
11. Where was the previous location of refuse dumping before coming to the present site.
12. Based on your experience, where is the land area you might consider most safe and appropriate for solid
13. What are the main problems of solid waste disposal, and how can they be solved.

APPENDIX 4

FACTORY SURVEY QUESTIONNAIRE

1. Name of the Firm
2. Location
3. Year of establishment
4. Numbers of employees
5. Types of product manufactured
6. What are the Raw materials used?
7. The size of the plot on which the industry [illegible]
8. What problems are faced in relation to:
   - water supply
   - electricity
   - transportation
   - other sources
9. What type of Industrial solid waste is generated in this factor?
10. How is the solid waste disposed of
11. How is it stored in the factory
12. How is it transported
13. What is the approximate weight of solid waste produced per (week, month, day) (in kg)
14. Is there any hazardous solid waste produced in this factory which require special disposal method
15. What are the future plans in relation to expansion of the industry and land requirements
16. What are your future plans in relation to solid waste management
17. Where do you think is the most safe area where all the industrial waste from Nakuru town can be disposed
18. Where would you prefer to locate your industry within the Nakuru municipality
19. Other comments ____________________

APPENDIX 5

QUESTION GUIDELINES FOR MUNICIPAL AND CENTRAL GOVERNMENT OFFICIALS

1. What land use problems have you encountered or expect in the immediate environs of Nakuru town?
2. What are the main land use changes that have been or is taking place in these areas?
3. What has been the population changes and settlement in the past, now an in future?
4. Are there any land use conflicts in these areas
5. Which land use forms contribute most to environmental degradation in Nakuru town and its environs?
6. Where are the most affected areas?
7. What environmental problems do you think is caused by rapid uncontrolled illegal land sub-division in the peri-urban areas?
8. What other urban land uses do you think contribute to land degradation and environmental pollution?
9. Which are the most sensitive areas that should be protected?
10. From your experience, what would you suggest as the best way for controlling excessive urban expansion, especially unplanned sub-divisions and high density low-income residential housing.
11. How can your department contribute to solving this problems?
12. Which other departments do you think can help.
13. How can the local residents be involved in solving the problems.
14 Based on your experience where are the land area most suitable for the expansion of Nakuru town, especially high density low cost residential housing.
15 Where are the most suitable land are for disposal of all the solid waste from Nakuru town.

APPENDIX 6

GUIDELINE QUESTIONS FOR DISCUSSION WITH WILDLIFE CONSERVATION AGENCIES (KWS AND WWF).

1. What are the main problems frustrating efforts to conserve wildlife resources in Lake Nakuru National Park?
2. What are the main environmental problems facing the park, especially resulting from urban activities in Nakuru town?
3. What would be the future of the park if these problems persist?
4. As a result of these problems, what changes have occurred in the park with regard to wildlife population distribution and mortality? As well as on the water quality and levels.
5. What are the main causes of flamingo migration and mass death?
6. Do you see rapid uncontrolled land sub-division and population density changes in the South Western part of Nakuru town as a threat to wildlife conservation in the park?
7. How can these problems be solved if the park is to survive?
8. In which direction do you think Nakuru town should expand towards, especially which areas are suitable for high-density, low-cost residential housing?
9. Who are the people and the agencies that should be involved most in resolving land use conflicts?
10. Where are the most safe land area suitable for dumping all the garbage from Nakuru town?

APPENDIX 7

AERIAL PHOTO INTERPRETATION AND FIELD SURVEY LAND DESCRIPTION DATA SHEET

Mapping unit symbol:
Observation Sheet No.
Location:
Coordinates (UTM):
Altitude (m)

Soil mapping unit:
Soil Classification name:
Soil Depth:
Soil Texture:
Surface soil drainage:

Surface Stoniness(%)
Surface Rockiness(%)

Geology mapping unit:
Geology formation:
Soil parent material
Presence of faultiness

Landform unit:
Drainage Density (Degree of Direction):
Slope Gradient(%)
Form of the Slope

Type of soil erosion:
Degree of Soil erosion:
Area affected (%):
Run-on/Run-off:
Flooding (ponding):
Land Subsidence
prevailing winds (direction):

Depth to Ground water Level:
Pre-source of surface water body:
Number of Boreholes:

Sensitive watersheds (Run-off quality)
Critical Aquifer Recharge area:
Critical wetlands in the water-shades:
Ground water Quality:

General Land use (1975, 1993, 1996)
Specific land use:
Population Density (1975, 1995, 1996)
Accessibility:

Vegetation type
Dominant plan species
Ground cover(%)
Interest in conservation
Planned land use zoning:
Other remarks: