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Terrain constraints to urban land use : the case of Enugu, Nigeria

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M.Sc. Project

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By

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B.Sc. (UNICAL)
(PG/M.Sc/86/4330)

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Department of Geography, University of Nigeria, Nsukka

July, 1988.

CERTIFICATION

Mr. Joel Ekwutosi Umeuduji, a postgraduate student in the Department of Geography, specializing in Geomorphology, has satisfactorily completed the requirements for course and research work for the degree of Master of Science (M.Sc) in Geography. The work embodied in this project is original and has not been submitted in part or full for any other diploma or degree of this or any other university.

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July, 1988.

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Joel Ekwutọsị Umeụdụji.

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ABSTRACT:

The quest for the best way to grapple with a myriad of topographical hurdles in the process of urban land use management in Enugu motivated this work. The empirical investigation started with air photo-interpretation and proceeded through field work involving pedo-geomorphological and morphometric examination of the landscape.

Statistically and logically verified field information revealed a high degree of terrain irregularities and hence the existence of serious terrain constraints to urban land uses. The Enugu Master Plan was seen as a planned, concerted attempt to guide urban planning process, but unfortunately, its neglect of detailed geological and geomorphological data is a serious defect.

The issue of slope instability and collapse of urban buildings generated much concern. Our sub-soil investigation revealed a sequence of over 50% clayey materials at a depth of 120cm below the ground surface. Given the area's 1,500mm-annual rainfall, a lithology with significant clayey strata sets the stage for a violent operation of catenary processes necessitated by surficial overland flow. Interaction of the catenary and surficial processes explains slope instability and collapse of buildings found in the study area, while the hazard is perpetrated by wrong land use allocation and encroachment upon the green verges.

Unprecedented increases in built-up areas are held to be responsible for decreasing infiltration, increased runoff and consequent erosion and inundation over parts of the area. In order to obviate such environmental feed backs, the need for planning becomes obvious.

Consequently, various topographical information were synthesized into a morpho-conservation map and a land capability map. These maps are of immense import for urban land use planning and management as they would help transform topographical constraints into spatial assets, and serve as invaluable tools in the attempt to decongest the down town area, effect urban renewal, plan intra-city route ways and site new growth points or layouts.

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CHAPTER 1

INTRODUCTION

1.1 The Problem:

Several problems have, in recent times, plagued urban liveability. These include the well-known problems of water supply, traffic congestion, over-crowding, environmental degradation and deterioration, a number of social problems, and the less-known but equally insidious problems that derive from the nature of urban terrain and geomorphic processes at work. The topographic disposition of any place or the landscape as it is can be viewed as being in a state of dynamic equilibrium. The morphology of the land is sequel to the cumulative effects of working and re-working by a series of landscape-forming processes that have been acting from the geologic past.

Historical facts reveal that in the field of geomorphology, such mentors and landform-analysts as W.M. Davis, W.Penck, L.C. King, A.N. Strahler and J.T. Hack have made concerted but independent attempts, through theories, to account for the pattern of landscape development. In this connection, several paradigms have been embraced and later discarded as no longer a satisfactory approximation to reality. This is quite impressive of geomorphology, in that, in a young and active discipline, concepts are continually re-modelled and refined. This idea of conceptual inconstancy necessary for methodological advancement in any virile field of enquiry, in all probability, unscathingly reduces to nothingness, an assertion in which Minshull (1975) attempted to indict geomorphologists for unclarity, inconsistency and confusion about the subject matter of their discipline. But one should not be daunted because of this myopic indictment since intellectual advancement is a continuing process of modification, rejection, addition and replacement of conceptual tools (Wrigley, 1965). However, it is interesting to note that science never pursues the illusory aim of making its answers final; instead, empirically supported propositions are fruitful for further investigations (Davies, 1969), and the results arrived at by different exponents can only progressively trace a locus which is asymptotic to the curve of absolute reality (Iloeje, 1961).

But granted that our theoretical knowledge of the landscape has become profound and sophisticated, how can we harness this knowledge to ensure a repercussion-free anthropogenic transformation of our cityscape? In historical geomorphology, a truism has it that it is what endogenic forces have brought up that exogenic processes eventually mow down. The emergent landscapes are dynamic evolutionary complexes (Markus, 1951) and in a state of delicate balance. The inherent complex interactions and relationships (Marosi and Szilard, 1964) involving the action of modifying processes on a given landform-physiography, together with process-accentuation by human interference should necessarily be unravelled and carefully studied to guide man's action on the land. This, therefore, underscores the need for terrain evaluation. According to Marosi and Szilard (1964), this evaluation or inventorization examines the physiographic environment from the standpoint of practical utilization, the chief aim being to detect and evaluate the conditions promoting or hindering economic activities. But how do we apply this kind of evaluation to Nigerian cities?

Certainly, urban spatial structures are set on the terrian and the terrain itself is being shaped, moulded and even disfigured by many geomorphic processes. The danger has been exacerbated in that the course of our urban planning experience in Nigeria seems to give credence to the opinion that geomorphic factors have been viewed as being insignificant in the planning of our landscape. If, unfortunately, the landscape of an urban centre is beset by a multiplicity of limitations militating against urban land use, how should the land be evaluated and what should be the criterion for allocating heterogeneous pieces of land to their individual best possible uses? One may yet question whether land evaluation as a geomorphological practice is even necessary before a piece of land is put to an effective definitive use. Furthermore, the extent to which the implementation of urban planning policies is constrained by difficult or hilly terrain is worth being explored. In terms of actually utilizing the land, one still wonders whether our technology and wherewithal in relation to conspicuous morphological hurdles should not merit serious consideration.

With respect to the philosophical underpinning to its methodology, geomorphology has evidently been misconstrued by non-practitioners as the study of deserted, isolated, hummocky, ragged and rugged landforms, with little or no practical social relevance to man apart from satisfying his curiosity. This situation raises an important question: Has geomorphology any practical social relevance in the planning of intra-urban route-ways, location of industries and the siting of various urban functional units in relation to the nature of terrain? It has been advocated that geomorphologists should be involved in road planning and construction and that geomorphological maps are very useful in ascertaining areas of geomorphological risks (Tricart, 1965). The knowledge of slope stability, hydraulic geometry, soil erodibility and fluvial sedimentation has been claimed to be very relevant in solving the problem of the tropical city (Douglas, 1978). The above views (by Tricart and Douglas), of necessity, require empirical investigation.

One still wonders about the place of palaeo- and present- day geological and geomorphological evidences (which are the geomorphic underpinnings of terrain dynamics) in trying to diagnose and understand landscape configuration so as to avoid chaotic and precarious urban spatial and structural expansion. Practical application of pure knowledge of the terrain to land use still seems to be a mirage. If geomorphology actually studies surficial landforms and processes, then one may question why it has, hitherto, contributed insignificantly in guiding the urban planning process that should lead to a primer on planned spatial structural organization and re-organization expedient in most Nigerian cities.

The nebulous and question-generating issues about the methodology and application of geomorphology to terrain evaluation in the area of urban space planning constitute an axe for this research to disinter and grind. The need to provide a rational explanation for the issues mentioned above forms the focus of this work. To generate an awareness of the severity of the problem presupposes the choice of an empirical case. In quest for answers and explanation for the above stunning questions and puzzling issues, certain specific intentions are borne in mind.

1.2 Objectives of the Study:

They are:

(i) Identifying areas liable to terrain hazards (or active processes) such as flooding, erosion and structural instability, and giving guidelines on how best to obviate such hazards.

(ii) Highlighting static topographical constraints posed by very steep, rugged and dissected slopes and searching for the best way of coping with these constraints in the process of maximizing conventional urban land uses.

(iii) Attempting to make some geomorphological contributions (guided by Environmental Impact Statements (EIS)) to the crucial issue of relocating some functional units for more effective and convenient urban activities.

(iv) Appraising constrained and apparently unusable terrains especially of the suburbs and city-sections that have not yet been put to effective definitive land uses with a view to converting these topographical liabilities into spatial assets.

Hopefully, this study will open up new vistas and constitute a valid contribution to the advancement of geomorphological thought and enquiry particularly in the area of urban terrain management in cities of the Humid Tropics. To realize these specific objectives, a suitable method for empirical work has been adopted and the issue of concern to this work has been reduced to a theoretical model.

1.3 Theoretical Background:

When the relationships between variables in a system are resolved into a model, the relative contributions of those different variables can then be elucidated. A model is a simplified structuring of reality in which supposedly significant features or relationships are presented in a generalized form (Chorley and Haggett, 1967). Conceptually, therefore, the 'systems approach' will be appropriate to x-ray the interactions of geomorphic factors in the city landscape system. This idea is crystallized in a model schematically shown in Figure 1.

A system is viewed as a set of objects together with the relationships existing between those objects and their attributes (Coffey, 1981). In asserting the systems thinking as the key to explanation, Harvey (1969) argues that the concept has been favourably applied in several areas of empirical investigations in the Twentieth Century. It has, however, been noted that although systems planning is not a panacea for environmental problems, it is a decided improvement over a lack of planning. Systems analysis involves specifying possible alternatives, determining the consequences of adopting any of them and also using objective statements to show which outcome might be preferred to another (Pantell, 1976). These possible alternatives have been clearly built into a model which we used to investigate the research problem already stated.

Also the systems approach can be further extended through the use of matrix concept. Hence the landscape and functional relationships in a city can be mathematically defined and algebraically rendered as the vector of inputs $X = (x_1, x_2, \ldots x_n)$ serving as stimuli to the system and another vector of outputs $Y = (y_1, y_2, \ldots y_n)$ serving as response of the system. The inputs are the stimuli introduced by man's decisions to locate or site various functional activities or phenomena in urban space, and these can be both planned and unplanned and range from x_1 to

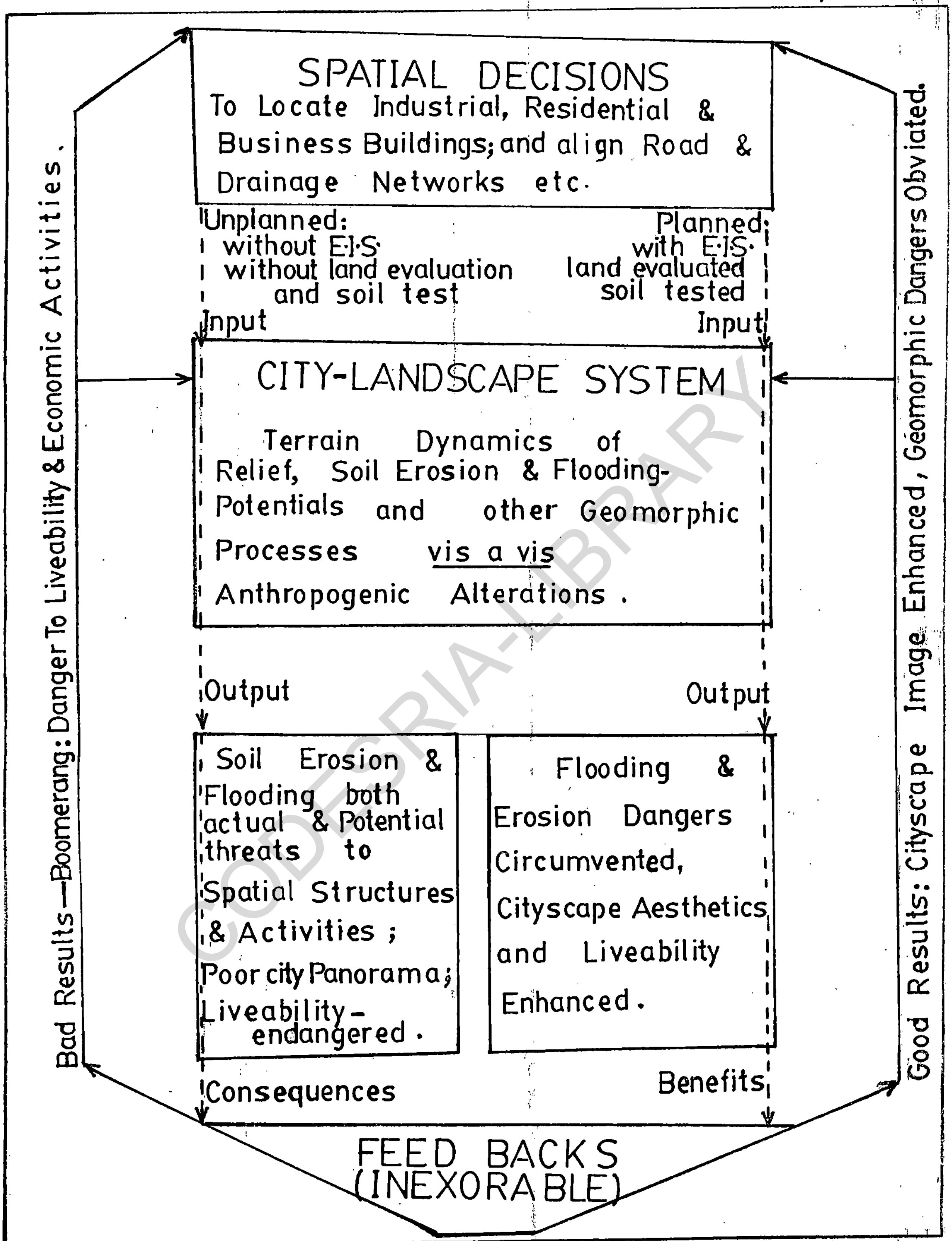

FIGURE 1: "SYSTEMS APPROCH"— CITY REAL WORLD-RELATIONSHIPS CONCEPTUALIZED AND ABSTRACTED (WITH SOME GEOMORPHOLOGICAL BIAS).

x_n. The outputs are the responses in the form of consequences and benefits, and these largely depend on the nature of inputs. These responses range from y_1 to y_n, representing the various feedback effects of man's actions in the urban space (whether good or bad.).

A cursory look at Figure 1 obviously reveals that the system modelled is an open one. 'Real life' systems are 'open' since they interact with their environment. However, it has been strongly but deviantly argued that as an intellectual construct used "in analysis, a system must of necessity, be 'closed'" (Hagen, 1969, p. 145). In the same vein, recognizing the 'closed system' concept as a pedagogical inevitability, Harvey (1969, p. 448) boldly concluded that "systems analysis cannot proceed, therefore, without abstraction and without closure". But modern developments in General Systems Theory clearly show that the open systems thinking is more dynamic, realistic and scientific and therefore preferred to the static, old-fashioned closed systems thinking. The above assertion is confirmed by the works of Coffey (1981) and also by Ofomata's (1987) soil erosion model which followed the tenets of modern scientific systems analysis. The suitability of systems analysis in the abstraction of important relationships from complex interacting variables was demonstrated by Umeụdụji (1985) while dealing with the problem of urban solid waste management in Onitsha. From the foregoing, it would not be an over-statement to assert and insist that systems approach not only appears useful and appropriate but also expedient to our present investigation.

In accordance with the standard model of scientific explanation which Harvey (1969) described as the setting up and observing of decent intellectual standards for rational argument, we shall be highly empirical and so an urban centre with a seemingly high degree of terrain irregularities has been chosen for detailed investigation.

1.4 The Study Area:

Enugu, 'the Coal City' ($6^{O}27$'N, $7^{O}29$'E), a scarp-foot town, was founded by W.J. Leck and his mining crew in 1915 (Okoye, 1975). It is sited on a foundation of shales (Figure 2) which crop out at the base of the 180m-Enugu Escarpment, underlain by False Bedded Sandstones of the Upper Cretaceous System and Lower Coal Measures (Jennings, 1959).

According to Udo (1978), it is located on the Scarplands of South-central Nigeria heavily dissected by headwaters flowing into the Cross River. Several eastward flowing streams rise from the escarpment and flow in incised courses hence dissecting the area into an undulating topography (Okoye, 1975). The area is characterized by sharp-edged projecting spurs already breached by erosion to form sandstone outliers of which an excellent example is the Juju Hill facing Uwani area (Plate 1).

Coal was discovered in the area in 1906 and its mining started in 1915. Udo (1978) believes that Enugu owes its origin and early growth to coal-mining. Ajaegbu (1976) affirms that coal-mining provided the initial economic impetus which was enhanced by the completion of the coast-bound railway line in 1919 and the town's role as an administrative centre, providing further stimulus for growth. 1929 saw the town as the headquarters of the Southern Provinces of Nigeria; in 1939 it became the headquarters of the Eastern Provinces; after 1945 it was further developed as the Eastern Region administrative seat; in 1967 it

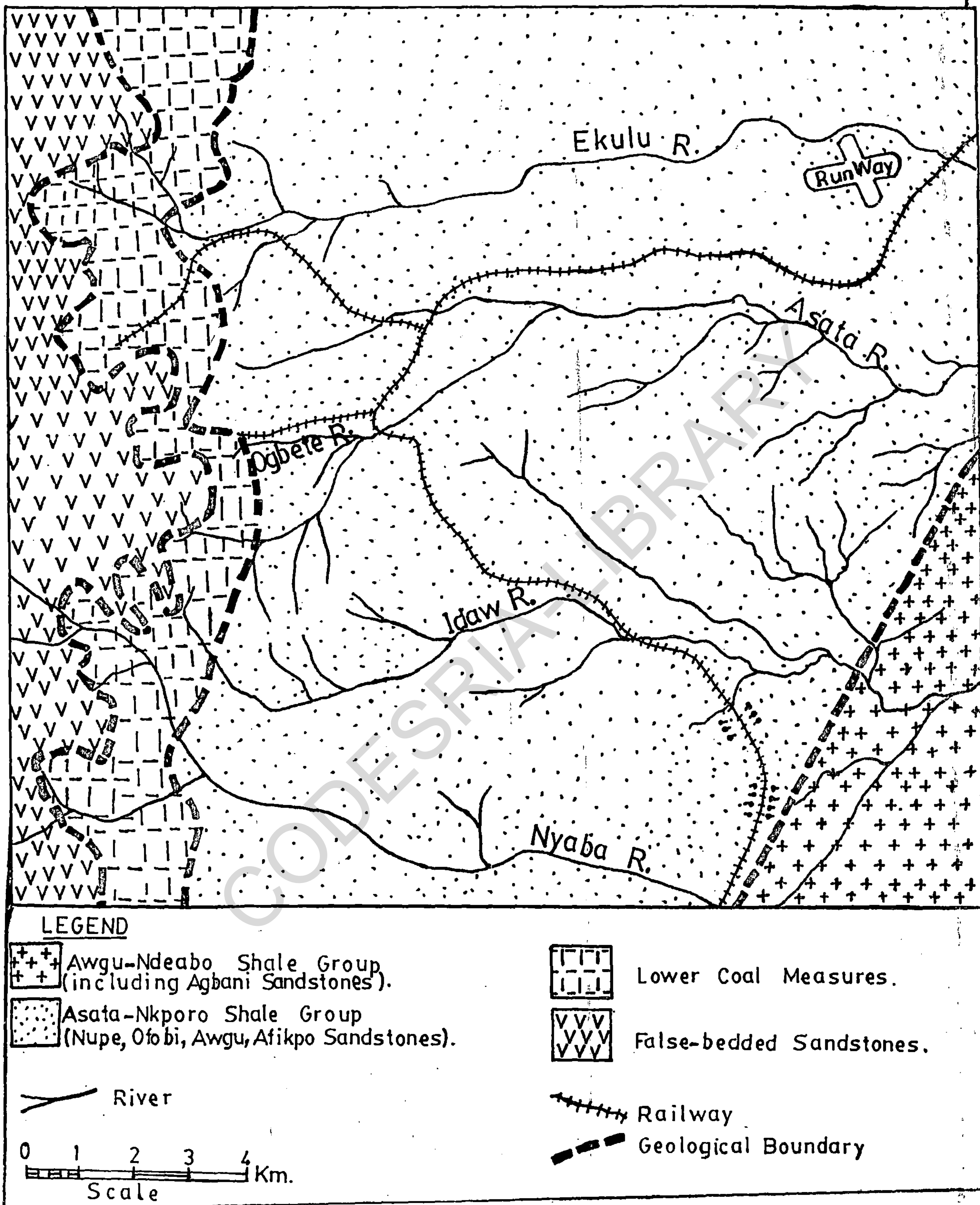

FIGURE 2 : A GEOLOGICAL MAP OF ENUGU EXTRACTED AND CRYSTALLIZED FROM NIGERIA, 1:250,000 (GEOLOGICAL SERIES) ENUGU SHEET 72.

PLATE 1: The Famous Juju Hill (flat-topped): An epitome of the legacy of denudation and dissection. The relief of this landform unit attracted the siting of a water-storage and distribution tank - illustrating man's ingenuity in converting a topographical liability into an asset.

became the capital of the defunct Biafra; and now (1988) it is the capital of the Anambra State. Thus, from a mere colliery camp of 1914, Enugu has grown to a **total** built-up area extending up to about 72km^2 (Ajaegbu, 1976) as at 1976 but much wider now (1988) about 132km^2 (as will be seen in section 2.2.1).

The population of Enugu has been increasing at a phenomenal rate as shown in Table 1.

TABLE 1: Enugu's population increase in recent times.

Year	1921	1931	1953	1963	1982	1983	1984	1987
Pop.	3,170	13,000	62,764	138,457	349,873	367,367	385,735	446,535
	*	*	*	**	**	**	**	***

Sources:

* Okoye (1975)

** Anambra State Population estimates, Statistics Division, Ministry of Finance and Economic Planning, Enugu.

*** Projected with 5% annual growth-rate using 1963 as base year.

Enugu used to be sandwiched in-between the Ekulu and Nyaba rivers with the Idaw, Asata, Ogbete, Aria and other smaller rivers doing major internal morphological dissection. Enugu's Central Business District (CBD) or retail heart of the city, located between Ogbete and Aria rivers, is made up of shopping centres and the main Ogbete Market. Intensified in-migration with no room for expansion around Okpara Avenue shopping Centre led to the establishment of the Ogui New Commercial layout (Okoye, 1978). 'Hypertrophic urbanization' (Breese, 1966; Duru, 1972, 1974; Uyanga, 1982) has since manifested itself in the formation of slums around

Ogui-Asata and Coal Camp residential areas.

Because of inexorable and unprecedented expansion and since the Milliken hill makes it almost impossible for the town to extend westwards, Enugu has, perforce, spilled northwards over the Ekulu river-hence the Trans Ekulu and Abakpa Nike Layouts. It has been observed that the coal industry is no more Enugu's main economic support as the town has prominently become an administrative, educational and cultural centre. With Port Harcourt, Aba and Onitsha, Enugu forms part of the Eastern Nigeria Industrial Complex since it houses a number of industries especially in the Emene industrial layout (Okoye, 1975; Ayeni, 1982). It is when Enugu is viewed against the backdrop of relentless urban physical and population expansion, on a landscape replete with severe terrain limitations that the need to maximize the use of the land through proper land evaluation becomes clear. Making this evaluation meaningful implies a tedious field work and a careful analysis of the resulting field data: a process which is essentially preceded and enhanced by a critical review of existing related works.

1.5 Review of Cognate Literature:

1.5.1 General Principles:

In an embryonic work, Mitchell (1973) defined terrain as a tract or stretch of land especially with regard to its natural features and configuration. In terrain evaluation the suitability of the landscape is assessed at site with particular reference to its relief, rock, soil, water and vegetation, and these attributes are brought to bear on the particular land use type desired (Beckett et al, 1972; Smith, 1982).

Extant works by most scientists dealing with the skin of the earth tend to equate terrain with land. It has been observed that the term 'land' embraces all the physical and biological characteristics of the land-surface which affect land use (Thomas, 1969; Gardiner 1976). Land has both physical and social connotations including those of space, nature, location, property and capital (Dumanski et al, 1979) and its classification implies defining the value or quality of a given piece of land for any one type of use (Cruickshank and Armstrong, 1971).

Deriving information from land, land use and economics, Dent and Young (1981) aver that the process of estimating the potential of the land for alternative kinds of use is simply land evaluation. In the same vein, Way (1973) prefers to use 'terrain analysis' which he defined as the identification and interpretation of landforms, mainly through air-photographs for purposes of land planning (i.e. land use), landscape architecture and similar projects. Such an analysis needs a multi-disciplinary approach. This is because it requires a comparison of benefits with inputs and the consequences arising from one particular kind of use are examined and compared with those from other alternative uses. This is in consonance with the Food and Agricultural Organization (FAO) framework which places some emphasis on the need to incorporate economics into land evaluation (Young and Goldsmith, 1977). In simple terms, therefore, terrain evaluation is an inventorization process principally concerned with analyzing, appraising, classifying and expressing the value of terrain configuration as a spatially distributed resource.

Most land evaluation has been agronomic rather than pedogenic (D'Hoore, 1968), but no matter the taxonomy used, surficial geomorphic processes relentlessly operate on the landscape. Geomorphology as a fundamental research discipline studies the skin of the earth as the haven or home of man by focussing specifically on the mode of operation of these modifying surficial processes and the resultant landforms.

Zelinsky (1970) has proffered an idea about the geographer's role as 'diagnostician', 'prophet' and 'architect' of the future society. This order-superimposing role of the geographer illustrates both the theoretical and applied aspects of the discipline (of which geomorphology is a part) in solving the envisaged future spatial problems. Pure geomorphological works elaborated and corroborated with theoretical and mathematical models are now being applied to disentangle, explicate and resolve specific socio-economic, political and environmental puzzles in different parts of the world.

1.5.2 Global View:

Much has been done on how the principles of geomorphology can be applied to monitor and predict landform and process changes in inter-disciplanary environmental and resource management (Tricart, 1965; Doornkamp, 1971; Cooke and Doornkamp, 1974; Hail, 1977; Coates, 1981). It has been convincingly maintained by Cooke and Doornkamp (1974) that environmental geomorphology knows no traditional subject boundaries; and so embraces parts of such subjects as hydrology, engineering-geology, pedology and geography.

Contemporaneously, Mitchell (1973) and Way (1973) have attempted to deal with the issue of terrain, but their doubtful and shaky geomorphological background lowers the quality of their work and this shortcoming could get terrain classification a bad name if it is allowed to pass unchallenged (Ollier, 1977). Adequate knowledge of terrain dynamics is relevant for meaningful conservation programmes, for irrevocable engineering constructions (Thornbury, 1954) and for astute urban and rural planning (Doornkamp, 1971). The terrain or land forms a complex set of delicate resources and it is the awareness of this momentous fact that has led to meticulous land evaluation in several countries with a view to maximizing the use of the land.

In the United States of America, the process starts with a general-purpose soil survey following the method adopted by the Soil Conservation Service to study the counties (Dent and Young, 1981). The Polish Land Utilization Survey tries to maintain an equilibrium between the scientific (pure) and practical (applied) connotations of the concept (Kostrowicki, 1961). During the colonial era, the Land Resources Division of Overseas Administration (of Britain) used to carry out land resource inventories in Tanzania, Nigeria, Gambia and other colonies. The Military Vehicles Experimental Establishment (MVEE, formerly MEXE - Military Engineering Experimental Establishment) based in Oxford has been grappling with the issue of land evaluation. Also the Commonwealth Scientific and Industrial Research Organization (CSIRO) has done very voluminous and extensive works on terrain evaluation in Australia (Ollier, 1977) while concerted attempts to evaluate the land have been noticed in Malawi (Young and Goldsmith, 1977), Canada (Dumanski et al, 1979) and Union of the Soviet Socialist Republic (USSR)(Solentsev, 1962; Rode, 1962). In these countries, various land researchers and agencies have developed different modes of analyzing the terrain for the purpose of practical use.

1.5.3 Methods of Terrain Evaluation:

Geomorphologists and other environmentalists have developed standard techniques for effective communication about landforms and landscapes. Terrain potentials are highlighted in such a way that landscape units depicted are correlated with the economic aspects of the land or land use. According to Ollier (1977) terrain inventories take the form of diagrams, maps and verbal descriptive materials; and different methods of achieving this goal have become distinctly recognized.

1.5.3.1 Morphological Mapping:

Walters (1958) has opined that a morphological map is a cartographic expression of the distribution pattern of the facets of the land surface. It simply shows the surface shapes (Bridges and Doornkamp, 1963; Doornkamp, 1971), is a bit morphographic and mainly morphometric. Its compilation is chiefly through the rigorous technique of morphometry defined as

> "the measurement and mathematical analysis of the configuration of the earth's surface and the shapes and dimensions of its landforms" (Clarke, 1966, p. 235).

A major demerit of this method is its exclusive consideration and undue emphasis laid on concave, convex, rectlinear and other slope properties of landforms and consequently almost neglecting the role of structure, lithology and process.

1.5.3.2 Geomorphological Mapping:

This is more analytical, more indepth, and more embracing than morphological mapping in that it not only depicts the physiognomy of the forms but also attempts an interpretation of the forms by complementing morphometry and morphography with morphochronological and morphogenetical information about the terrain (Klimaszewski, 1956, 1963; Tricart, 1965; Verstappen, 1970; Demek, 1972). As a vital tool in the landscape analyst's arsenal, this technique supplies spatial information about terrain dynamics making it possible to fore-stall terrain hazards that could be sequel to and accentuated by wrong and unplanned locational decisions.

Nevertheless, a notable proportion of extant geomorphological mapping especially in Poland, France and USSR is done on a scale that is too small for direct application to specific urban land uses. Resultant maps contain much information not directly relevant to particular problems (Gerrard, 1981). Consequently, the technique remains pedagogical and gives general background information about the landscape, while stressing the need for a more analytical technique applicable on a relatively larger scale for urban land use differentiation and analysis.

1.5.3.3 The Landscape Approach:

According to Brink et al (1982), this stems from the concept systematically amplified and popularized by Christian and Stewart (1953) who observed that units of terrain defined with respect to their surface features and air-photo-patterns can be used to extrapolate spatial information. Two major approaches have emerged from this formulation:

1.5.3.3.1 The Land Systems Mapping:

This is a descriptive technique whereby the terrain configuration is depicted by a block diagram coupled with an explanatory note giving details of the geology, lithology, relief, slope, vegetation and other physiographic characteristics of the area being investigated. With this method, the 'land system' is the basic unit, defined as an area or group of areas throughout which a recurring pattern of topography, soils and vegetation can be recognized (Christian and Stewart, 1953) and it is correlated with the geology, geomorphology and climate of the area (Cooke and Doornkamp, 1974). The land system has a relatively uniform climate and within it, for most practical purposes, the land facet is identifiable with uniform environmental conditions. This has led to an alternative definition of the land system as an area with a recurring pattern of genetically linked land facets (Dent and Young, 1981). A major significant underlying assumption of this approach is that patterns of topography, soils and vegetation are so related that one can be used to predict the others (Gerrard, 1981).

This system was originally developed by the Land Research Division of the CSIRO, Australia, to maximize the use of various lands especially for agriculture. The method has also been independently used by the Oxford MVEE and the National Institute of Road Research (NIRR), South Africa to highlight soil-engineering properties of the land for the design of road systems (Dent and Young, 1981). Solentsev (1962) reports that a similar technique has been developed in the USSR for assessing the hydrological and biological components of the landscape.

In Papua New Guinea as in Australia, the onus of land systems mapping falls within the ambit of the geomorphologists, ecologists and pedologists. The implicit strenuous process starts with a joint air-photo-study, then ground check, and finally an integration of air-photo and field information to describe the land and broadly assess land resources and capability in terms of land systems (Blake and Paijmans, 1973).

The major advantage of land systems mapping lies in its simplicity and ease of operation while the data presented by the technique can be easily understood by those making use of the information for planning and decision-making purposes (Cooke and Doornkamp, 1974; Gerrard, 1981).

Though widely used, the land systems approach has been sharply criticized based on conceptual and practical considerations (Moss, 1969; Thomas, 1969). It has been polemized that it emphasizes static relationships in landscapes significantly neglecting the dynamic interplay between soils, climate and vegetation (Gerrard, 1981). This, therefore suggests the need for further refinement or a quest for a better alternative.

1.5.3.3.2 P.U.C.E. Classification:

The Pattern-Unit-Component-Evaluation (PUCE), developed by the Geomechanics Division of the CSIRO, Australia, provides an hierarchical terrain classification for engineering purposes at four levels: the province, terrain pattern, terrain units, and terrain component. It has been spiritedly and convincingly maintained that

> "this approach seems to provide the only practical method for the rapid acquisition of data with sufficient accuracy to permit planning over large area at project level, that is for the location, design and construction of a specific transportation line such as a road" (Brink et al, 1982, p. 221).

1.5.3.4 The Parametric Terrain Classification :

Dissatisfaction with the more descriptive PUCE and land systems mapping has led to the development of the parametric approach by the more mathematically minded land evaluators.

1.5.3.4.1 Land Capability Classification:

This is mainly based on the concepts of capability and limitations. Capability is the potential of the land for use in specified ways or with specified management practices while the limitations are land characteristics which have an adverse effect on capability (Dent and Young, 1981). Land capability mapping has been used in Canada and the United States (by the U.S. Soil Conservation Service) with capability classes ranging from I - VIII indicating increasing limitations. It has also been used in Portugal, with classes A-E indicating increasing degrees of limitation to use (Gerrard, 1981).

Guarding against the possibility of land misallocation in the rural-urban fringe of Ottawa, Dumanski et al (1979), assert that land factors such as susceptibility to inundation, rockiness, stoniness, steep slopes, drainage variability and natural soil drainage are fundamental to many non-biological uses such as housing and highway-routing which are affected slightly or not at all by soil-specific factors such as poor structure, low fertility and droughtiness. They clearly noted that refined systems of soil mapping and land capability assessment were used in their work and that the results were excellent.

1.5.3.4.2 Numerical Land Systems Mapping:

Sequel to disenchantment with genetic classifications of land, Gardiner (1976) advanced the 'numerical landform description and analysis or 'morphometry'. He maintained that the subjective elements inherent in the more traditional methods could be removed through quantification, but regretted that the fullest exploitation of this approach for practical purposes has yet to be performed or realized. Gardiner therefore went on and used Factor Analysis to illustrate the morphometric use of the drainage basin for land evaluation. His computer-aided work is very promising as he derived a map depicting scenic value of the landscape and of considerable importance in delimiting areas of outstanding natural beauty, routing of motor-ways and electricity pylons, and planning of tourism (Gardiner, 1976). The scope and importance of this technique have been further advanced by Brink et al (1981) who assert that changes in drainage patterns are particularly useful in identifying boundaries between land systems.

Quantification in land evaluation is also claimed to be more objective and based on measurements of landform properties such as altitude, slope and relative height (Ollier, 1977). Using gemorphological attributes such as relief and other slope properties to determine the co-efficient of similarity, this highly mathematical technique has been applied to investigate areas of land having a distinct pattern on aerial photographs in five adjoining areas of Papua New Guinea. The method yielded a very impressive and fascinating result (Scott and Austin, 1971). This approach is quite hopefully challenging due to the increasing use of the computer for much geographical analysis.

1.5.4 Justification for this work:

Of monumental significance to the understanding of the terrain concept is Christian and Stewart's (1953) investigation of the Katherine-Darwin Region of Australia. Attention has been drawn to the use of the principles of terrain analysis for resource surveys in the tropics (Young, 1968), Zambia (Bawden, 1965), Uganda (Doornkamp, 1971), Papua New Guinea (Haantjens 1965) and for engineering purposes in Northern Nigeria (Dowling, 1968). Peltier (1973) asserts that in Cyprus (9,100 km^2), 60 to 70 samples for terrain analysis were adequate and gave a satisfactory picture of the relationships of mean slope, relief and drainage textures with lithology.

Mortimore (1966) produced a land use classification map of Kano City without reference to terrain and geomorphic factors that could influence both spatial differentiation and integration of urban activities. It is quite obvious that terrain configuration is closely related to landscape physiography and yet without reference to this relationship, Onokerhoraye

(1977) advocates for the creation of different sizes of open spaces in the Traditional Nigerian Cities based on the concepts of threshold population and range of goods.

A number of other studies on urban landscape have focused on aesthetics and environmental perception (Fines, 1968; Brancher, 1969; Waller, 1970; Penning-Rowsell and Hardy, 1973; Anderson and Schroeder, 1973; Schmid, 1983; Schreiber and Kias, 1983). Also based on visual quality, Aoki (1983) studied Tsukuba Science City-Japan, located on a plain and with excellent views and panoramic landscape. In spite of the fact that the above cited works are important milestones and have made valid contributions to knowledge in the area of physiographic studies and aesthetics, yet the lacuna which they have left in terms of scope is distressingly conspicuous. Most extant works on terrain appraisal are ostensibly skewed, small-scaled, omnibus coverage of very large physiographic regions. Such a stance could derive from an areal integration-oriented philosophy of geography which attempted making sweeping generalizations. But current geographical enquiries are systematic, topical and mainly special-purposed. Unity does not lie so much in the objects of investigation, but in the methodology of enquiry.

In regional planning, transport network alignments, agriculture and forestry, the principles of terrain analysis have proved very useful. But it is interesting to note that the knowledge and concepts of terrain analysis have not been fully applied to the area of urban spatial planning on a large scale, especially in the tropics. Douglas (1978) only threw some light on and some challenge to the possibility and validity of applying the knowledge of some fundamental geomorphological concepts to the problems of the tropical city. However, his views on this issue have not yet been explored and amplified while the challenge he threw has not been fully taken up.

In an attempt to break an age-long lull and irresponsiveness among geomorphologists, Ofomata (1978) came up with a pace-setting and vista-opening paper on geomorphic constraints to urbanization in Nigeria with respect to Enugu, Port Harcourt, Calabar and Lagos. In an effort to arouse professional concerns, he noted, with a fleeting feeling of lamentation, that most urban spatial locational decisions are only economically and technologically guided, neglecting the geomorphic underpinnings of terrain dynamics. Apart from that embryonic work, other existing works on urban space organization, especially in the tropics, are grossly marginal to the issue of terrain. Therefore the need to expound on this incipient but highly promising field of terrain analysis in relation to urban space planning is quite obvious.

In conclusion, the methods, nature and inclination of the cognate works reviewed above reveal a palpable degree of skewness in emphasis. Scenic panorama, city-scape aesthetics together with the economic and technological ramifications of urban spatial locational decisions have unduly attracted the attention of landscape analysts, with little or no consideration for the dynamics of the terrain on which locational decisions are expressed. The need to investigate and highlight the, hitherto, neglected but equally very significant issue of urban terrain processes in order to overcome the inherent militating constraints cannot be over-emphasized. This not only justifies our study, but also makes it very imperative. Due to the nature of the problem being explored, as well as the explorer's field of interest, geomorphological mapping and land capability mapping have been chosen as analytical and elucidatory tools to facilitate an inventory of Enugu's constrained terrain. In order to vindicate the choice and validity of these two techniques, we shall proceed to the field to scout for relevant data to elucidate the substantive problem of our investigation.

CHAPTER 2

THE TERRAIN AND EXISTING LAND USES IN ENUGU.

Shown in Figure 3 is an analysis (with some temporal connotations) of the procedures systematically adopted in this work to acquire the data on which our inferences are based.

2.1 Planning Stage:

2.1.1 Aerial Photo-interpretation:

It has been argued that

> "geomorphological survey without the use of aerial photographs (in conjunction with field and laboratory investigations) is obsolete" (Verstappen, 1970, p.89).

As a well-established technique in geomorphology, air poto-interpretation was therefore used in this study at the reconnaissance level. The procedure aided the investigator to identify problem-areas, together with features of particular geomorphological interest, giving a fair idea of the degree of terrain accessibility and making it possible for the field-work to be planned efficiently, not losing site of the time and cost implications and constraints.

The fact that the use of air-photographs must have to be complemented with field-work was clearly demonstrated in Papua New Guinea where it was observed that the investigator cannot so easily interpret soils directly from air-photographs since detailed topographical features that may have a bearing on soil properties are usually concealed by dense vegetation (Blake and Paijmans, 1973). At the reconnaissance level, therefore, because the air photographs show only the static

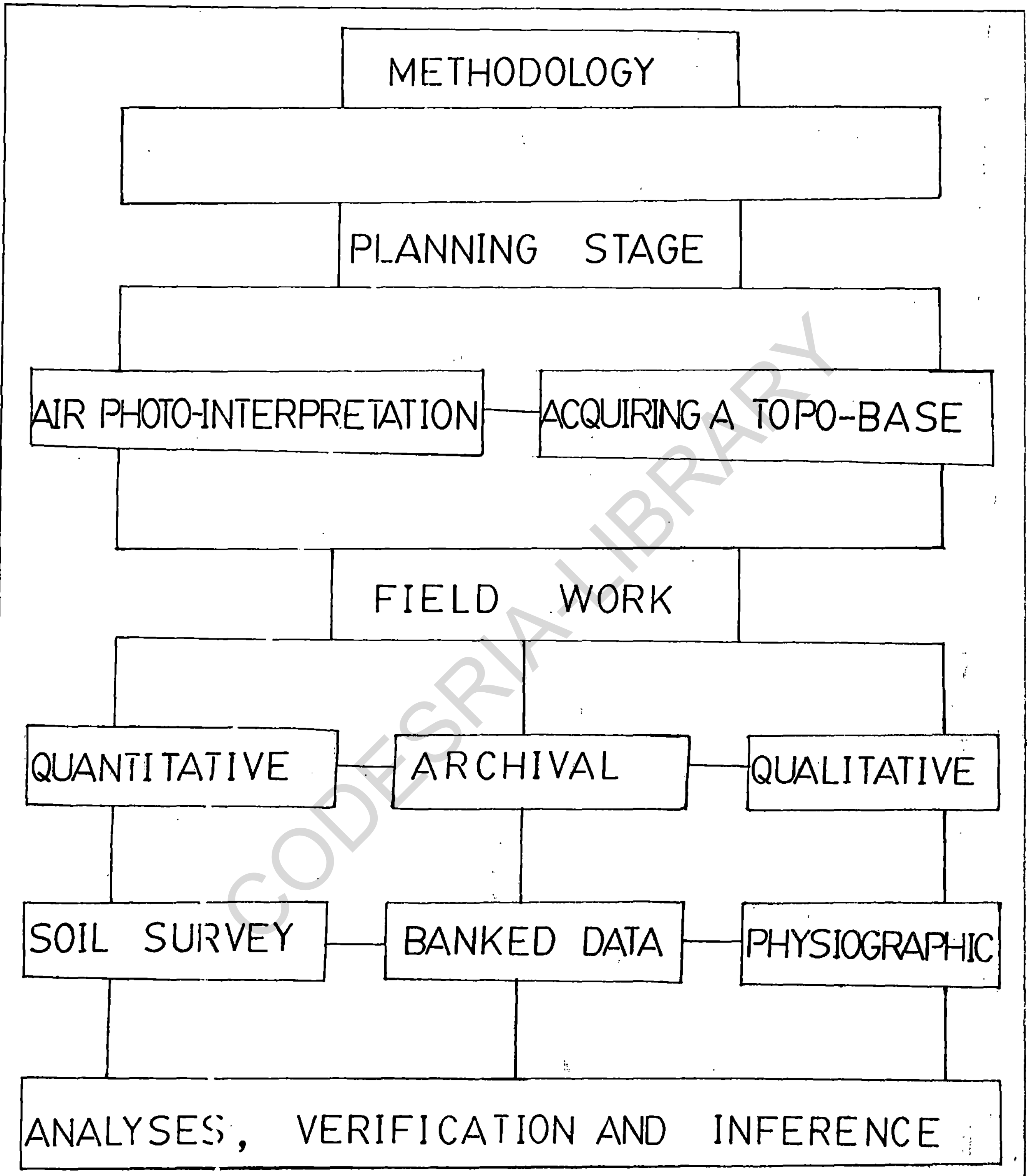

FIGURE 3: A BREAK-DOWN OF THE METHODS ADOPTED, SCHEMATICALLY PRESENTED.

aspects of the landscape, the dynamic features contingent upon interactions among morphology, structure and lithology, geomorphic process and human activities were studied in detail during field work. Aerial photographs, together with existing maps of the study area, gave a good field guide.

Due to the relentless rate of denudation and landscape evolution accentuated by the various anthropogenic transformations including coal mining, cultivation on the hill-slopes of the Milliken hill and urbanization in the Enugu area, the December, 1961 air photographs of the area by the Canadian Aero Service Limited, Ottawa and the Pathfinder Engineering Limited, Vancouver were considered obsolete. Alternatively, therefore, those of April, 1977 by Meridian Air Maps Limited on a scale of 1:6,000 were used. The specific sheets used in detail are as follows:

ENG 04 Run 16 Numbers 021 - 029,

ENG 04 Run 17 Numbers 071 - 079,

ENG 04 Run 18 Numbers 117 - 125.

These aerial photographs are in the Air-photo section of the Ministry of Works, Lands and Transport, Enugu. In order to highlight terrain constraints posed by spectacular landforms complicated by hills with very steep slopes interspersed with incised river valleys and generally undulating topography, Numbers 074 and 075 of Run 17 covering Ogbete, UNTH, Obed Camp and Udi Siding were selected and studied in more detail using a stereoscope.

Since the air-photos were taken in overlapping runs, stereoscopic examination of the selected adjoining sheets gave a clear static view of the topography. The stereoscope enabled the investigator to appraise the topographic expression of the region on three dimensions. This means that not only the length and breadth of the area became vivid but also the relative heights of buildings, constraining river-valleys and towering hills. This brings us to the question of man's adaptation to an environment replete with serious serious terrain constraints. At Ugwu Aaron, Obed Camp, Ugwu Alfred, Iva Valley, Ugbo Odogwu and Ugbo Okongwu, for example, the gradients of the hills range between about 15° and ≤ 60°. With the current level of technology and wherewithal, people in these rugged areas have attempted to defy terrain constraints posed by very steep hill slopes. In these areas mentioned above, residential buildings are constructed in a step-like manner. For instance, the rooms of, say, a three-bed room flat may each stand on a different elevation and this is how several buildings are serially located on higher elevations as one ascends the steep slope of the hills. Usually, accessibility to these hill-side residential areas is via steep concrete steps. The "picture" of the situation is illustrated in Figure 4. Even though man's attempts at combating the limitations posed by the unfriendly nature of the topography in these areas are quite commendable, yet the rigour of accessibility and the social stigma associated with living in such environments cannot be overstressed. The possibility of bringing any type of vehicle into these areas is completely ruled out although these areas are mainly occupied by the low class and dregs of the society.

2.1.2 Topographical Base:

Air photo-interpretation gives more precision to field work when used in conjunction with existing topographic and thematic maps.

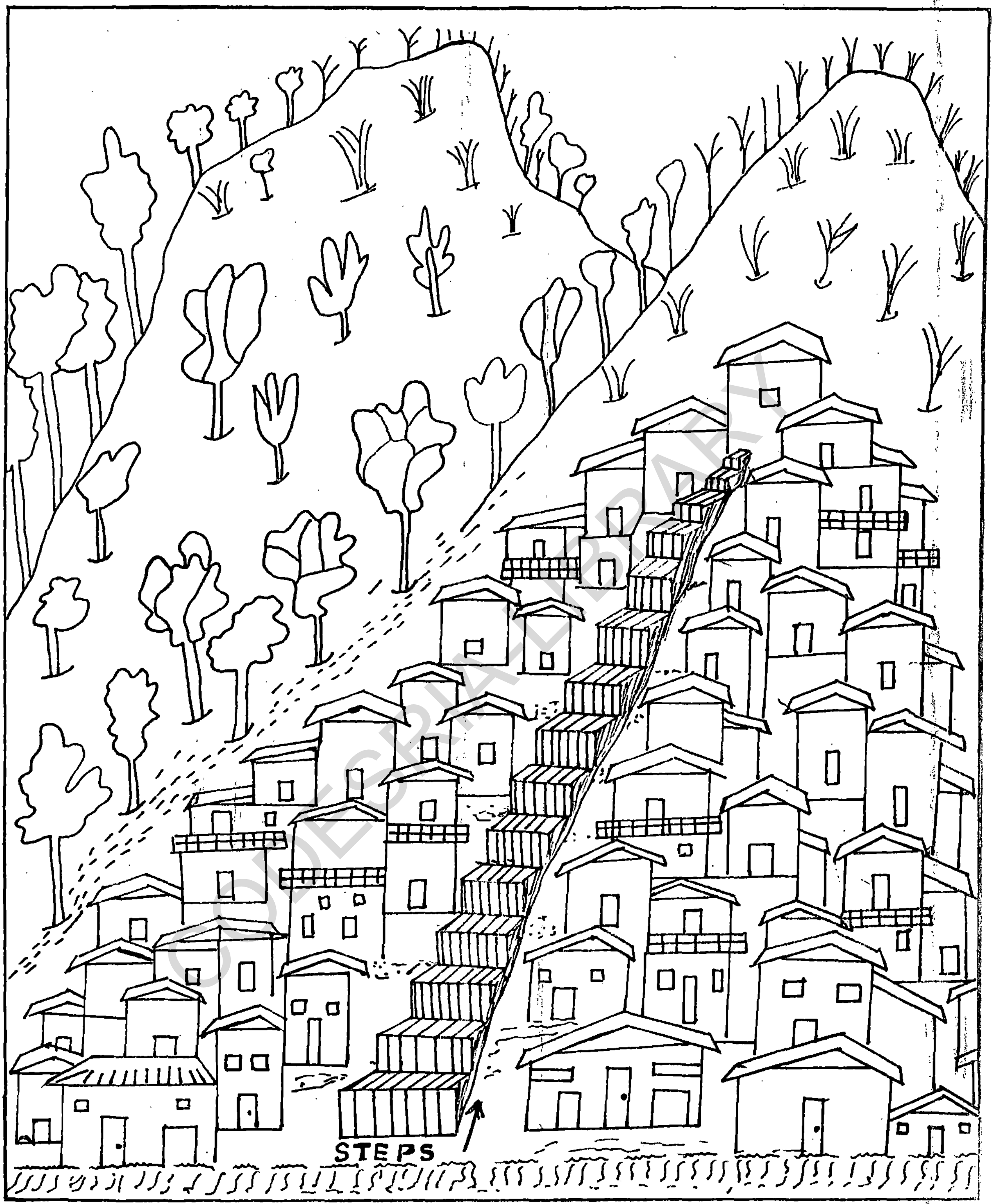

FIGURE 4 : A DIAGRAM ILLUSTRATING MAN'S ATTEMPT TO OVERCOME TERRAIN CONSTRAINTS. THIS MODEL TYPIFIES HILL-SIDE BUILDING PATTERNS IN UGWU AARON, UGWU ALFRED, OBED CAMP AND SOME PARTS OF ARIA LAYOUT. FORTUNATELY, THE HILLS ARE STRUCTURALLY STABLE.

The topographical base of the study area was established using several maps. These include:

(i) NIGERIA 1: 50,000 UDI N.E. SHEET 301 N. E;

(ii) NIGERIA 1:50,000 NKALAGU N.W. SHEET 302 N.W;

(iii) NIGERIA 1:250,000 (GEOLOGICAL SERIES) ENUGU SHEET 72;

(iv) ENUGU STREET GUIDE MAP 1:25,000;

(v) ENUGU PLANNING AUTHORITY AREA MAP 1:50,000;

(vi) NIGERIA 1:1,000 ENUGU SHEET 330/711/SE 3;

(vii) NIGERIA 1:1,000 ENUGU SHEET 330/711/SE 4.

In geomorphology, just as in many other empirical sciences, it is an indisputable fact that operator variance can only be minimized and never completely eliminated. With this in mind, the above maps were juxtaposed, compared with each other and finally up-dated with current information from ground truth. This sensorious scientific process led to the discarding of some inherent but unfortunate fundamental errors of which the most glaring example is the locational myopia orchestrated in ENUGU PLANNING AUTHORITY AREA MAP 1:50,000. Having adequately reconnoitred the area through fair topographic elucidation provided by the maps and air photographs, the ground truth and morpho-evaluation were then embarked upon.

2.2 Field Work:

Broadly, land has been viewed as a physical entity embracing the atmosphere, the soil, underlying geologic material, the hydrology and vegetation (Dumanski et al, 1979). The inclusion of the atmosphere in the definition of land is justified, especially, in areas such as Obudu and

Jos Plateaux where the altitude has created unique and easily distinguishable micro-climates which not only influence the vegetation and surficial processes but also affect or even dictate land use patterns. Land evaluation in such areas should take into consideration the relationship between the topography, elevation and meteorogical factors before deciding on how best to put individual stretches of land to different uses. Apart from such examplary and exceptional areas mentioned above, the inclusion of climate in discussing the concept of land is a fecund issue of debate. This is because climate plays a more significant role in determining the general land morphology on a small scale and it can be conversely argued to be marginal with a very negligible role in relation to the issue of terrain on a large scale, at least in the area presently being investigated. Nevertheless, universally, climate in terms of rainfall interacts with lithology to determine the rate of weathering and denudation, though in structurally unstable areas, man's exploitative tendency and intervention can bring about violent modification of the terrain through accelerated denudational activities. This is why careful planning and assessment of environmental impacts are very crucial when man is consciously intruding into the landscape system.

It has been advocated that for indepth land evaluation, the investigating team should be made up of geomorphologists, plant ecologists and pedologists (Blake and Paijmans, 1973) and the procedures for such a survey have been succinctly presented by Dent and Young (1981). Land evaluation, as has been conceptually defined in section 1.5.1, is simply an on-the-site process of analyzing, classifying and estimating the potentials and limitations of the land to various uses. Soil survey is the basis of land evaluation and soil is so important in the environment that considerable overlap and confusion exist between integrated land survey and soil survey (Gardiner, 1976). Summing and re-stating a climate of opinion about land evaluation, Dent and Young (1981, p. 246) assert that soil survey is 'the best starting point' especially when the problem has to do with the technical interpretation of morphological, physical and chemical soil properties. With the above general ideas on the concept of land, we can then proceed to soil survey as a process of terrain evaluation.

2.2.1 Soil Survey:

A soil survey tries to delve into the interaction between pedology and geomorphology, and this has been built into a 'state factor model' and described as a

> "function of topographic and litholo-function being acted upon by climatic, and biotic factors at some point in time" (Gerrard, 1981, p. 7).

A soil investigation is never an end in itself in that the result is only a stepping-stone for further investigations. Given the terrain constraints, as in Enugu, the information on lithology gathered through soil survey is used in conjunction with some information on land surface configuration. Such data on land characteristics can then be interpreted for several urban land uses including urban and regional planning, agriculture and for engineering in which case geo-technical data could facilitate construction-site choices and transportation net work alignment (Dent and Young, 1981; Brink et al, 1982). It is when the soil is fully understood that it can be both intensively and extensively utilized to our advantage whilst bearing in mind that it is a continually varying body in a dynamic equilibrium (Knapp, 1979).

From the foregoing, the place of soil survey in land evaluation cannot be over-emphasized and this is why sub-soil investigation occupies an important place in this work. Hand auger was ued to collect one hundred and twenty-three (123) soil samples from forty-one (41) spots i.e. three (3) at each spot: one on the surface, another at the depth of 10 cm and the last one at 120 cm below the surface. In geomorphology, this is an accepted and a well-established way of collecting soil samples down the soil profile (Ofomata, 1987). Through this method, the displacement (or leaching down) of silt/clay fraction by infiltration and sheet wash is highlighted. The samples were simply taken at random, but the sampling technique was, of necessity, areally biased and mainly covered the urban fringes since it is impossible to bore through totally built-up areas using the hand auger. Even though the soil survey was aimed at providing a detailed information on lithology, unfortunately aceessibility to urban fringes especially, to the west of Enugu was constrained by severe topographical limitations. Also when hard impenetrable rocks were encountered during boring, alternative sampling spots had to be sought for. However, the spatial sampling framework that eventually emerged gave a fair coverage of the 132 km^2 study area (as could be seen in Figure 5). In a similar investigation, Swan (1970) made use of 184 soil samples to study the whole of Johor State (19,000 km^2) in Malaysia and yet came up with excellent results.

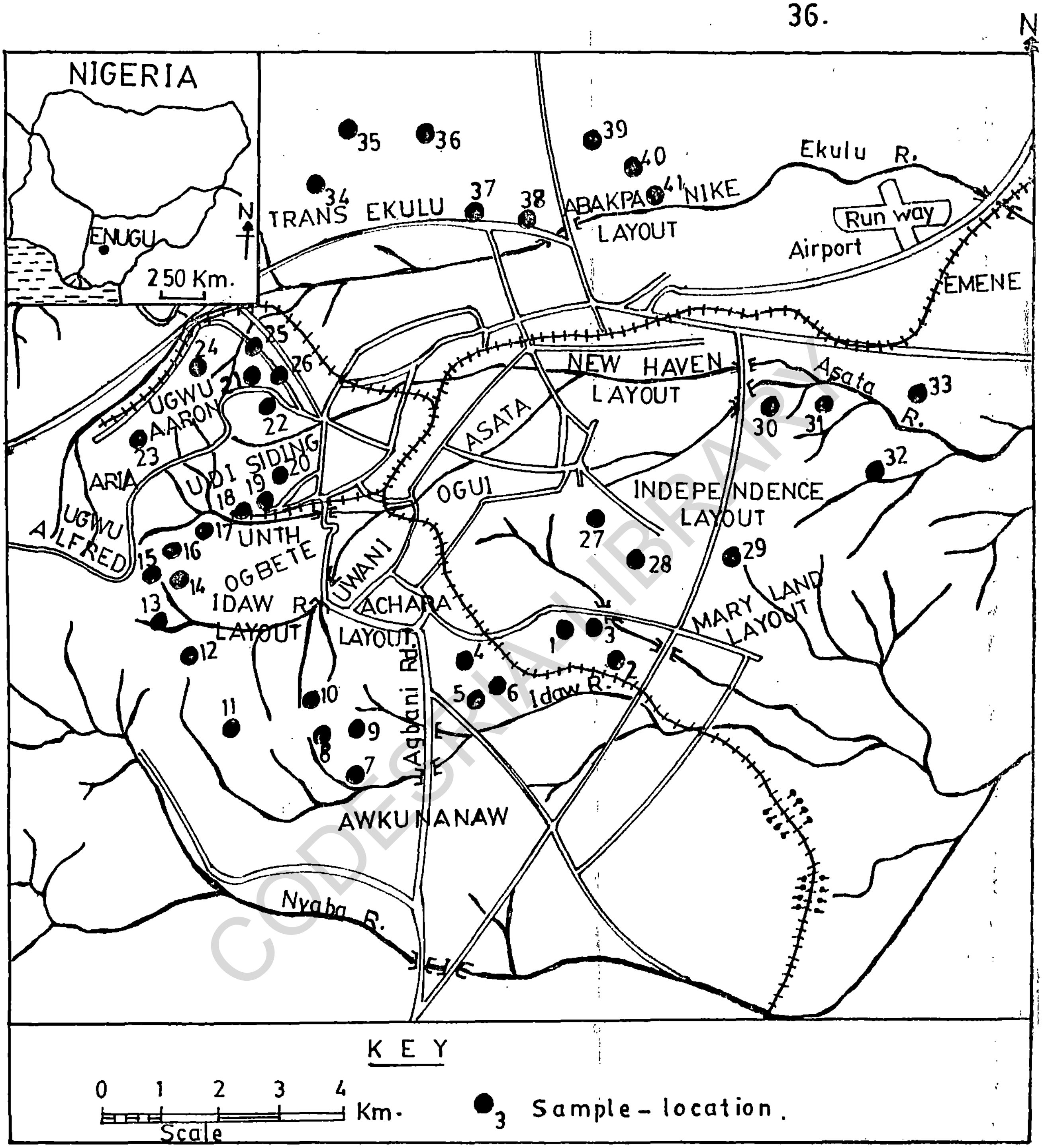

FIGURE 5 : A MAP OF ENUGU SHOWING THE LOCATIONS FROM WHICH SOIL SAMPLES WERE TAKEN.

To provide some information about the soil profile beyond 120cm below ground surface, some archival or banked data were sought for from geo-technical establishments that investigate the sub-soil horizon for engineering purposes.

2.2.2 Archival Information Sources:

In addition to aerial photographs and various topographic and thematic maps, borehole records (from Anambra State Water Corporation, Enugu) and sub-soil investigation records (from Materials and Research Laboratory, Ministry of Works and Housing, Enugu) were relevant archival materials simultaneously and complementarily used to probe the research problem. Such sub-soil data are very important to this work because the nature and behaviour of underlying materials normally influence surficial geomorphic processes. Information on urban physical planning and land use allocation policies were collected from the Town Planning Unit of the Enugu Local Government (Municipal Council), Anambra State Housing Development Corporation, and from both the Lands and Town Planning Divisions of the Ministry of Works, Lands and Transport, Enugu. These bits of information were jointly used to evaluate the cultural and natural attributes of the terrain.

2.2.3 Cultural and Physiographic Inventory:

The quantitative data from soil survey were complemented with qualitative cultural, hydrographical, physiographical and physiognomical examination which culminated in descriptive plates (or photographs). Visual characterization and aesthetics in relation to the natural landscape attributes were the focus. The current land use patterns were examined taking note of the restrictive impact of hilly, rugged and dissected nature of the terrain on urban land use. The relationship between topography and urban land use; and the reason why some tracts of steep slopes have not been put to effective uses were sought for in the field.

Thus, the quantitative and qualitative field information were strengthened with banked data. All these data are very crucial to this work in the sense that they x-ray the nature of Enugu's terrain as it is.

2.3 The Area's Terrain and Inherent Constraints :

Conceptually, the term 'terrain' has been defined in section 1.5.1. The land area to which Enugu can potentially extend is not too large. It only stretches for about 14km (east to west) and 15km (north to south). The releif of this relatively small area reveals a wide range of elevations. At the easternmost part, it is about 120m and at the topmost part of the Milliken hill to the west, it is over 541m above mean sea level. The slopes of the area have been calculated and will be presented in the next chapter.

As one enters Enugu through the new Enugu-Onitsha express road, the first thing that will likely catch the attention and impression of a new comer is the grotesque and irregular morphology of the landscape. The building patterns at Iva Valley, the nature of the subterranean way to Project Development Agency (PRODA) and the Fly-over towards the Relief Market, are only responses to the irregularity of the topography. Taking a view of the University of Nigeria Teaching Hospital (UNTH) from, say, the Central Police State (CPS) spectacularly reveals at the background, the indented and breached hillslopes of the various landform units that make up the famous Milliken Hill range. The urban morphology or internal structure of Enugu reveals a considerable degree of sinuosity of the roads indicating the diversity of contours within the area. The hair-pin bends of the old Enugu-Onitsha road and also along Agbani Road (near Ogbete Market) are notoriously precarious.

Enugu's topographical irregularities appear to be sustained by some natural landscape modifying processes. The overland and throughflow processes arising from the area's annual copious rainfall are intensified by a number of dissecting streams. The influence of these rivers is well expressed in terrain segmentation and in response to which residential developments in Enugu have tended to take place in isolated nuclei. Not only are these nuclei constrained in terms of space expansion but also inter-nuclei communication is hampered by accessibility bottlenecks while traversing the dissecting river valleys. Due to the nature of the terrain, Enugu is also exposed to some hydrological dangers. For instance, Enugu used to be well-drained and seldom flooded but nowadays, due to the increase in concrete and uninfiltrable surfaces, inundation incidences are no more strange to the inhabitants of Trans Ekulu and Abakpa Nike.

There is no doubt that so many inherent constraints have emerged from the above analysis of Enugu's terrain. A generalized relief of Enugu shows some plains near Emene, undulating and dissected landscapes stretching from Awkunanaw to Trans Ekulu, and the very steep Milliken hill bounding the town to the west. The characteristic hydro-geomorphology of the area has left a legacy on the terrain of Enugu. There are many sandstone outliers breached by erosion to form sharp-edged projecting spurs. All these topographical irregularities not only greatly constrain the urban use of these terrains but also sustain the operation of several surficial geomorphic terrain-modifying processes. Hence the geological superstructure and hydro-geomorphological surface modifiers have tended to intensify the adverse role of terrain constraints in relation to urban land management and use. In the light of the terrain and inherent constraints, there is an obvious need to explore the extent to which existing land uses in Enugu have been topographically constrained, and also to determine the feasibility of land use maximization through the re-organization and relocation of urban activities. This necessitates an examination of the existing land uses in the study area.

2.4 Existing Land Use Patterns:

Since Enugu is not only beset by a number of morphological irregularities but also dissected by a myriad of channelized overland flows, several urban activities have developed in different terrain compartments that derive from the irregular hydro-geomorphology of the town. These spatially and functionally associated and differentiated land uses have been observed to be often constrained and even in most cases genetically dictated by the nature of Enugu's difficult terrain. The proven principle of spatial integration of functionally associated activities and that of differentiation for repellent unassociated activities have been observed to be operating in the organization of the various urban land uses. Because terrain constraints to urban land uses form the focus of this work, we are now to explore the extent to which the various land uses have been constrained and dictated by the nature of the terrain. Whether through concerted land evaluation and allocation, or through unplanned use of urban space, certain recognizable land use patterns have emerged.

2.4.1 Transportational Land Uses:

The exploitation and evacuation of coal from Ogbete and Iva Valley coal mines had to expedite action on the completion of the coast-bound railway line. Sinuosity in the routing of the railways (as could be seen in Figure 6) to the various mines following relatively low gradients, not only attests to the restrictions posed by the topography but also shows a planned effort to grapple with, and an attempt to circumvent such constraints. The problem of topographic irregularities compounded by intense land dissection by various rivers initially led to the development of isolated settlements until costly (and at times precarious) bridges were constructed to enhance accessibility to and between these nuclei. The sinuous and precarious old Enugu-Onitsha road with hair-pin bends is a function of serious topographical limitations to both inter- and intra-- urban communication. Even the new Enugu-Onitsha express way did not find it easy in traversing the Ekulu river and the indented, ever-problematic hill-slopes of the Milliken hill.

Due to prodigious morphological undulations, several costly cuttings, embankments and bridges had to be built in the process of constructing the railways and roads; showing an obvious attempt at grappling with terrain hurdles.

Agbani road going northwards through Ogbete (Coal Camp) had to pass through a very sharp and dangerous bend before descending through the incised Ogbete river-valley (a tributary of Asata river) and then ascending and crossing the railway line to Ogbete Coal Mine (Plate 2). A general observation from Figure 6 reveals a low degree of connectivity of the various nuclei, while it could be conversely observed that there is clearly

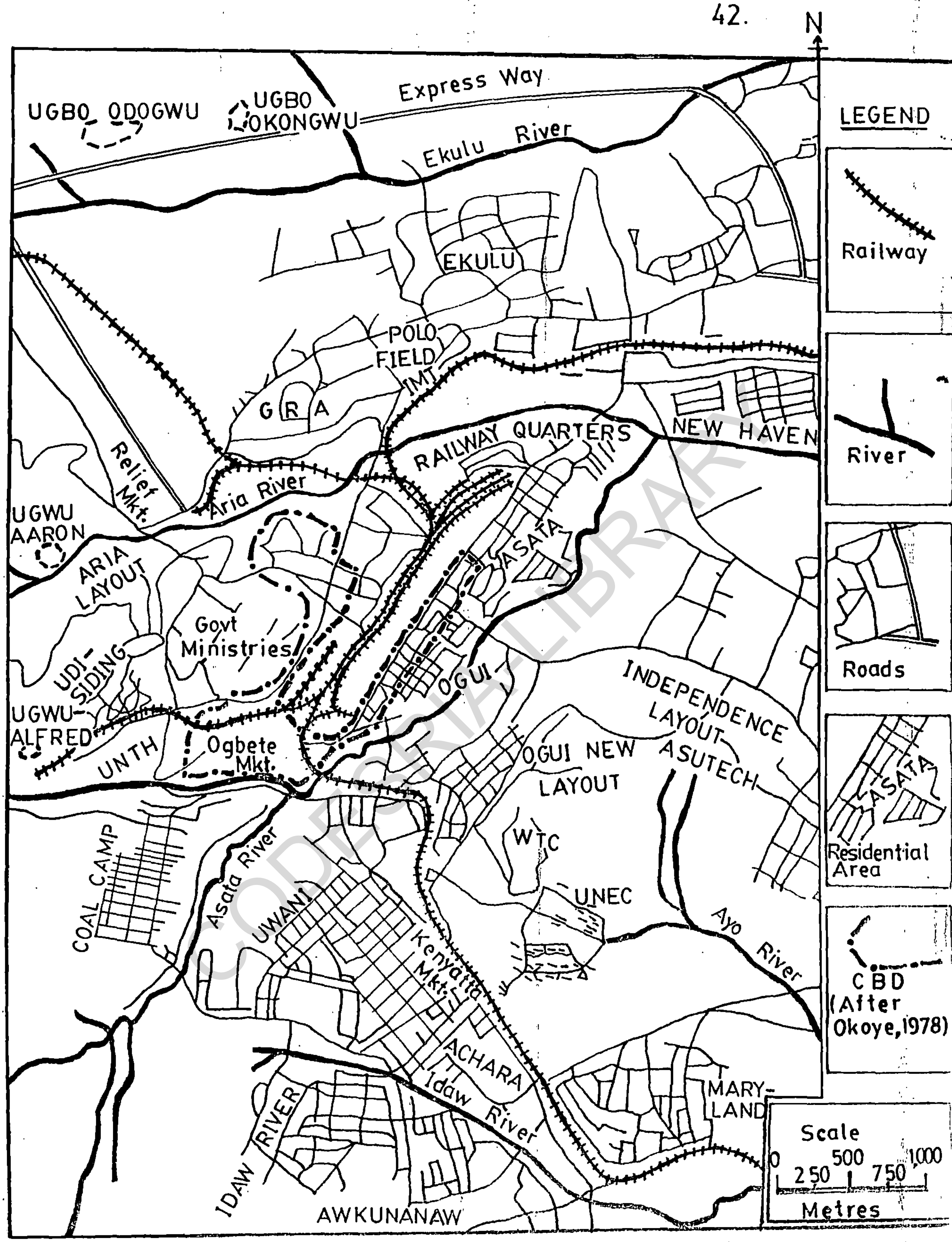

FIGURE 6: A STREET GUIDE MAP OF ENUGU INDICATING SOME MAJOR LAND USES.
(Source: Adapted from ENUGU STREET GUIDE MAP 1:25,000, Surveys Division, Ministry of Lands, Surveys and Urban Development, Enugu).

PLATE 2 : Terrain Constraints to accessibility:

Traffic flow is seriously constrained by topographical irregularities. Accessibility bottleneck across the Ogbete is compounded by sinuosity of Agbani Road and the threats from gullying near the Ogbete river valley. (The plate is backing the Ogbete Market, while the Ogbete river flows through an incised course obstructed by the drums and roofs on the foreground).

a high intensity of road connections within each nucleus. Attempts at enhancing both intra- and inter-nucleus accessibilities have been very demanding, cost-wise. A commendable feat by our route alignment engineers has been the successful connection of the sharp bend of Agbani Road near the Ogbete Colliery Quarters with Zik's Avenue. The new link traverses the steep Asata River Valley. The various nuclei are mainly for residential purposes, among others.

2.4.2 Residential Land Uses:

The need to harbour the original exploiters of the coal geologically embedded in the Lower Coal Measures was the genesis of the earliest residential district - Coal Camp. Considerable increase in in-migration necessitated the founding of other residential areas such as Uwani, Ogui and and Asata. The taking up of administrative and educational functions by Enugu led to the development of many governmental and institutional establishments and quarters. As a result, the Aria Government Reservation Area (GRA), New Haven and Independence Layouts came into prominence. Abakpa Nike and Trans Ekulu; Idaw River, Achara, Mary Land and Awkunanaw Layouts were only very recent residential developments in response to relentless urban spatial and population expansion.

The fact that the supply of residential houses falls short of the demand for housing is confirmed by the development of slums and squatter settlements in many parts of Enugu. An unfortunately blighted region covers Ona Lane, Umuchu Lane, Umueze Street and Mount Street, all in Awkunanaw, Enugu. Due to severe economic conditions and high cost of building materials, only very few residential buildings have been constructed in recent times, and Table 2 supports this assertion.

TABLE 2: Private Sector Residential Situation in Enugu;

Year	Plans			Building Completion Certificates		
	Submitted	Approved	Rejected	Submitted	Approved	Rejected
1985	357	327	30	30	30	0
1986	244	226	18	42	33	9
1987	246 (i.e. 18 spill-overs from 1986 plus 228)	244 (i.e. together with spill-overs)	2	34	28	6 (still receiving attention)

Source: Town Planning Authority, Enugu Local Government Secretariat, Okpara Avenue.

Taking cognizance of annual population growth rate of 5% giving 446,535 for 1987 and from recent yearly number of residential building plans submitted and approved, it can be simply concluded that the rate of increase in housing (which is mostly negative) is far below the exponential population growth rate. This is also corroborated by figures about buildings certified completed.

The inability of the private sector to meet the housing needs of Enugu's populace has been recognized by the Anambra State Government. This is why the Anambra State Housing Development Coporation (ASHDC) was statutorily set up by Edict No. 10 of 1976. According to the Edict, the ASHDC was empowered to build residential houses and sell or rent to the public. The contribution of the ASHDC to the provision of housing in

Enugu is summarized in Tables 3 and 4.

TABLE 3: Abakpa Nike Housing Estate (47.76 hectares):

Phases	Dates	No. of Houses	No. of housing Units	Bed-room house types							No. of Lock-up shops
				1	2	3	4	5	6	7	
1	pre-1967	178	200	✓	✓						
2	1972-74	67	103		✓	✓					
3	1975-82	308	430	✓	✓	✓	✓				54
	Total	553	733								54

TABLE 4: Trans Ekulu Housing Estate (295.18 hectares):

Phases	Dates	No. of Houses	No. of housing Units	Bed-room house types							Garrage & Boys' Qts.	No. of Lock-up shops
				1	2	3	4	5	6	7		
1	1970-75	196	330		✓							48
2	1978-80	80	160			✓					✓	
3	1980-82	201	201		✓						✓	
4	1982-83	168	259		✓	✓	✓				✓	
5	1983-	159	159		✓	✓	✓	✓			✓	
6	1987-	403	595		✓	✓		✓		✓		
	Total	1,207	1,704									48

Source of Tables 3 and 4: Anambra State Housing Development Corp., Enugu

Since residential land uses in Enugu are seriously constrained by the topography, the siting of these estates was dictated by the terrain. The hilly and dissected areas had to be avoided in favour of the gentle Abakpa Nike and Trans Ekulu areas. The reason is quite obvious because easily developable areas are always the targets so as to waive the extra high cost of grappling with constrained terrain.

2.4.3 Commercial Land Uses:

The Ogbete Main Market and its adjacent areas around Okpara Avenue form the Central Business District (CBD) of Enugu. A look at Figure 6 shows that the siting of the CBD was not necessarily dictated by centrality, rather it was by factors of inertia. The business heart had already been established before the unprecedented northward, westward and southward expansion of the town. Once a definitive functional zone such as the CBD has been established, and especially when it is completely bounded by other dissimilar land uses that are equally definitive; then with functional and population expansion of the city, the originally encased land use (ie. the CBD in this example) will be spatially constrained in terms of expansion and therefore will tend to remain and retain its original location. This is because functional re-location, especially with definitive land uses, is usually very difficult and may introduce spatial distortion in the organization of the general land use pattern. However, other smaller business centres such as the Relief and Kenyatta Markets have sprung up in order to alleviate the problem of time and cost of accessibility to the main over-stretched CBD.

2.4.4 Miscellaneous Land Uses:

Through the passage of time, Enugu acquired and gradually started providing many central place functions. This role accentuated in-migration together with the development of other ancillary land uses such as governmental, health and educational uses. Due to the topographical unfriendliness of the western part of Enugu (i.e. the Milliken hill) and the adjoining steep slopes of several traversing rivers, these associated difficult terrain-strips had to be devoted to agriculture and the planting of adorning trees for aesthetic purposes.

Several recreational spots have sprung up. Prominent among them is the Nnamdi Azikiwe Sports Stadium, near Ogui-Asata Layout, It not only occupies the centre of Enugu in order to ease accessibility, but its location also reveals a topographical raison d'etre: its slope approximates 0^o. Other recreational centres are the Murtala Muhammed Park (Aria), Ejindu Park (Coal Camp), Ngwo Park (Uwani), Polo Park (South of Ekulu layout), Igwe Edward Nnaji Park (New Haven), Michael Okpala Square, (Independence Layout), including several hotels such as the Presidential, Ikenga and other relaxation centres. Empirical investigation shows that the seemingly topographical liabilities around the steep slopes of both the Milliken hill and the several river valleys could be potential terrain resources for the enhancement of aesthetics and landscaping in order to accomodate the increasing awareness and need for leisure and recreation.

2.5 Relationship between Enugu's Topography and Land Uses:

From the terrain, constraints and land use patterns discussed above, certain issues have become clear. An examination of the topography shows that serious constraints to land uses emerged from the nature of the terrain.

The existing land use patterns have clearly been dictated and limited by these constraints. To contend with these constraints and maximize urban land uses, there is a great need for a detailed analysis of both the sub-surface and external dynamics of the terrain. The compartmentalized and isolated nature of the various land uses, especially residential, is clearly a function of the constraints of terrain and topographical disposition of the area. Intra-urban communication to the various isolated areas was was even made more difficult by accessibility bottlenecks posed by the numerous rivers that dissect the terrain.

The densities of residential areas are traceable to morphological limitations. Sule (1982) views outward and upward expansion as characteristic of urban growth. But due to topographical restrictions, Ogbete, Asata, Ogui and Uwani can no longer expand laterally. Urban structural degradation and deterioration of cultural edifice and artifacts have already set in and the need for slum clearance and urban space re-organization or renewal is becoming more expedient. Because of space problems, Land-lords with the wherewithal have started phasing out the original bungaloid houses and are replacing them with multi-storeyed buildings. Others have also sought for alternative sites in relatively more spacious and topographically less constrained areas such as Trans Ekulu and Awkunanaw new layouts. It can be adduced through empirical observations in this work that Enugu's extant transportational, residential, commercial, governmental educational, health, aesthetic agricultural and other miscellaneous urban land uses have been dictated by the nature of the terrain together with the accompanying constraints.

Right from the genesis of Enugu, most of the land uses have competed among themselves for space. It cannot be argued that each of the land uses did not take up its best location in relation to its function. The problem is that of expansion. The terrain is not only hilly but dissected by so many rivers, hence seriously constraining land use expansion as the urban centre grows functionally and population-wise. Because of the factors of inertia, no land use could give way to the other in the process of space competition. This is why the Ogbete and Coal Camp (Tinker) areas are highly congested. Relocation of some land uses therefore becomes expedient. Originally, the land uses were not wrongly sited, but urban expansion involves some elements of spatial re-organization so as to facilitate and accommodate functional growth as well as spatial convenience.

Therefore, the massive form of data so far gathered through aerial photo-interpretation, topographical maps, archival data sources, cultural and physiographic inventorization, and above all, from a detailed sub-soil survey need to be analysed and interpreted in order to strengthen inferential statements that will be made in relation to the issue being investigated. The analyses will utilize statistical tools, graph theory and logic to arrive at a rational and scientific explanation of the initially enigmatic problem of study.

CHAPTER 3

LANDSCAPE APPRAISAL FOR LAND USE MAXIMIZATION:

When land use maximization is the target, there can be no substitute for detailed analyses of information on both the internal and external dynamics of terrain physiognomy.

3.1 Pedo-geomorphological Analysis:

Scholz (1972) concedes to the prime importance of field observation in geomorphology but still argues that this must, of necessity, be supplemented with laboratory work dealing with sedimentary petrography (involving micro-morphometric and granulometric analyses) as well as geo-chemical analysis of the lithology.

3.1.1 Granulometric Analysis:

The soil samples were subjected to mechanical analysis to determine particulate composition. They were first oven-dried and weighed, disaggregated by soaking in water, then wet-sieved through 53 μ sieve to eliminate the silt/clay content. The remnant was then oven-dried, weighed and dry-sieved through a 2mm-aperture sieve to eliminate sand, and the particle-quentity unable to pass through the aperture (i.e. stones) was weighed. Finally, through rarefied arithmetic, the weights of silt/clay, sand and stones were calculated. The various weights were converted into percentages and shown in Table 5, while the sample-numbers bear the locational attributes shown in Figure 5. Contingent upon the nature of the data involved, the various weights were subjected to precise statistical analyses to derive the respective means ($\bar{x}$), standard deviations (s) and co-efficients of variation (V). Spatially, these indices were integrated

TABLE 5: The Laboratory results of granulometric and geo-chemical analyses of empirical sub-soil investigation in Enugu. The samples can be identified through the serial numbers locationally shown in Figure 5.

No.	On the Surface: % of Silt/clay <53µ	On the Surface: % of Sand ≥53µ <2mm	On the Surface: % of Stones ≥2mm	On the Surface: pH	10cm deep: % of Silt/clay <53µ	10cm deep: % of Sand ≥53µ <2mm	10cm deep: % of Stones ≥2mm	10cm deep: pH	120cm deep: % of Silt/clay <53µ	120cm deep: % of Sand ≥53µ <2mm	120cm deep: % of Stones ≥2mm	120cm deep: pH
1	21.04	32.68	46.28	6.38	15.43	9.96	74.61	6.00	17.84	9.62	72.54	5.25
2	21.82	20.36	57.82	4.75	13.70	51.27	35.03	5.25	37.68	20.07	42.25	5.25
3	57.69	23.08	19.23	5.25	72.44	22.84	4.72	6.00	23.56	6.77	69.67	5.25
4	54.35	34.06	11.59	5.25	65.17	30.85	3.98	6.00	77.32	19.49	3.19	6.00
5	68.90	26.32	4.78	6.00	57.14	39.29	3.57	6.00	79.05	17.91	3.04	5.25
6	4.75	89.15	6.10	7.50	12.77	71.65	15.58	7.50	81.41	14.05	4.54	5.25
7	31.25	59.37	9.38	6.00	60.40	22.82	16.78	6.00	80.95	11.91	7.14	5.25
8	37.60	52.40	10.00	6.75	40.59	42.08	17.33	6.75	59.18	21.28	19.54	5.25
9	59.20	35.59	5.21	5.63	49.20	45.45	5.35	5.63	55.74	35.66	8.60	5.25
10	79.21	3.37	17.42	5.25	58.50	22.45	19.05	5.25	74.23	9.28	16.49	5.25
11	64.02	15.90	20.08	6.00	77.12	10.17	12.71	6.00	62.79	20.93	16.28	6.00
12	46.93	11.84	41.23	5.25	57.74	11.70	30.56	5.25	81.30	14.33	4.47	4.75
13	18.50	76.80	4.70	5.25	22.59	74.45	2.96	5.25	5.48	94.52	0.00	5.63
14	39.13	52.72	8.15	5.25	43.98	44.58	11.44	6.00	47.80	45.46	6.74	6.00
15	24.58	63.75	11.67	6.75	41.83	22.55	35.62	6.38	37.26	62.74	0.00	5.25
16	19.84	29.56	50.60	6.38	10.39	23.08	66.53	5.25	59.31	18.28	22.41	5.25
17	54.45	39.44	6.11	6.38	52.66	36.70	10.64	4.50	79.47	14.45	6.08	6.00
18	20.71	68.18	11.11	5.25	23.81	63.95	12.24	5.25	49.06	41.51	9.43	4.50
19	39.69	60.31	0.00	7.50	39.34	57.38	3.28	6.00	34.71	56.41	8.88	6.00
20	59.24	29.35	11.41	6.00	38.52	23.33	38.15	5.25	82.14	12.86	5.00	6.00
21	8.72	77.95	13.33	6.38	4.84	91.61	3.55	6.00	49.43	41.61	8.96	5.25
22	27.96	69.09	2.95	5.25	45.08	49.24	5.68	5.25	51.61	44.36	4.03	6.00
23	46.43	38.21	15.36	5.25	28.13	46.56	25.31	6.38	67.86	12.66	19.48	5.25
24	18.55	78.28	3.17	7.50	36.95	57.83	5.22	6.75	55.97	40.71	3.32	6.00
25	19.37	15.21	65.42	5.63	11.45	16.52	72.03	5.25	34.91	25.44	39.65	4.50
26	27.89	70.51	1.60	6.75	25.14	62.29	12.57	7.50	33.85	60.31	5.84	6.75
27	26.93	25.07	48.00	6.38	27.00	16.75	56.25	5.63	33.42	22.61	43.97	6.00
28	37.47	26.17	36.36	6.00	53.40	27.96	18.64	6.00	34.46	23.41	42.13	5.25
29	19.64	21.73	58.63	7.50	20.75	30.05	49.20	6.75	43.70	14.75	41.55	5.25
30	8.33	73.61	18.06	7.50	7.41	74.07	18.52	6.75	21.88	20.47	57.65	6.00
31	41.79	23.58	34.63	5.25	49.50	35.35	15.15	5.25	38.59	22.59	38.82	5.25

	On the Surface				10cm deep				120cm deep			
No.	% of Silt/clay <53μ	% of Sand ≥53μ <2mm	% of Stones ≥2mm	pH	% of Silt/clay <53μ	% of Sand ≥53μ <2mm	% of Stones ≥2mm	pH	% of Silt/clay <53μ	% of Sand ≥53μ <2mm	% of Stones ≥2mm	pH
32	25.97	70.15	3.88	5.25	50.38	45.80	3.82	6.00	28.00	65.33	6.67	6.38
33	35.73	60.11	4.16	5.25	23.24	75.29	1.47	5.25	49.24	47.73	3.03	5.25
34	14.68	10.78	74.54	6.75	17.86	18.53	63.61	5.25	31.17	39.24	29.59	5.25
35	43.07	24.45	32.48	5.25	53.69	24.83	21.48	5.25	53.53	22.31	24.16	5.25
36	22.25	14.69	63.06	7.50	16.47	12.83	70.70	5.25	65.58	28.49	5.93	5.25
37	50.99	29.30	19.71	5.63	63.05	32.54	4.41	5.63	75.18	21.68	3.14	5.25
38	18.94	19.38	61.68	6.00	35.31	26.71	37.98	5.25	17.66	20.00	62.34	5.25
39	58.10	29.93	11.97	6.38	55.79	32.01	12.20	6.00	77.39	17.29	5.32	6.00
40	55.78	22.54	21.68	5.25	20.85	19.57	59.58	5.25	69.81	18.12	12.07	6.00
41	28.36	38.80	32.84	6.00	52.38	25.64	21.98	6.00	46.38	28.41	25.21	5.25
$\bar{x}$	35.61	40.58	23.81	6.04	37.85	37.77	24.38	5.81	51.36	28.90	19.74	5.49
s	18.09	22.94	21.13	0.80	19.29	20.51	22.14	0.65	20.85	18.51	20.02	0.48
V	50.80	56.53	88.74	13.25	50.96	54.30	90.81	11.19	40.60	64.05	101.42	8.74

Note: For each of the attributes:

$\bar{x}$ = the sample mean,

s = the standard deviation,

V = the co-efficient of variation.

The attributes at different depths include silt/clay, sand and stone contents as micro-morphometrically defined; as well as the acidity (i.e. pH) of the soil which is a geo-chemical property. (Source: Author's field-work - July, August and September 1987).

for the whole of Enugu while the samples were only being differentiated in terms of depth of collection and the major attributes of interest which are particle-size, and acidity. The differentiation of the samples according to depths of collection was necessary. This depth-wise differentiation makes it possible to explore the influence of infiltration and other catenary processes on the arrangement of soil particles along the profile.

For illustrative purposes, Figure 7 was produced to enhance an interpretation of the data-array in Table 5. From Figure 7, the hitherto, concealed trends or variations in particle-size composition in relation to the depth of samples become clearly appreciable or palpable. Hence, based on visual attributes of the bar graphs, some general inferential statements can be made. The percentages of both the sand and stones tend to be decreasing from the top-soil horizon downwards, while the percentage of silt/clay fraction tends to be reasonably increasing downwards. These trends have been cartographically made more vivid in Figure 8. The greatest value of granulometric analysis is its ability to reveal the degree and nature of the concentration of different particle-sizes along the soil profile. Our micro-morphometric investigation (Table 5) has thus, been graphically made more vivid in Figures 7 and 8.

Using the principles of fundamental (or theoretical) geomorphology to account for the observed general trends in differential concentration of particle-sizes in relation to the depth of samples, the concept of deep chemical weathering in a humid tropical environment offers a plausible explanation. Figure 2 shows the basic geological structure of Enugu.

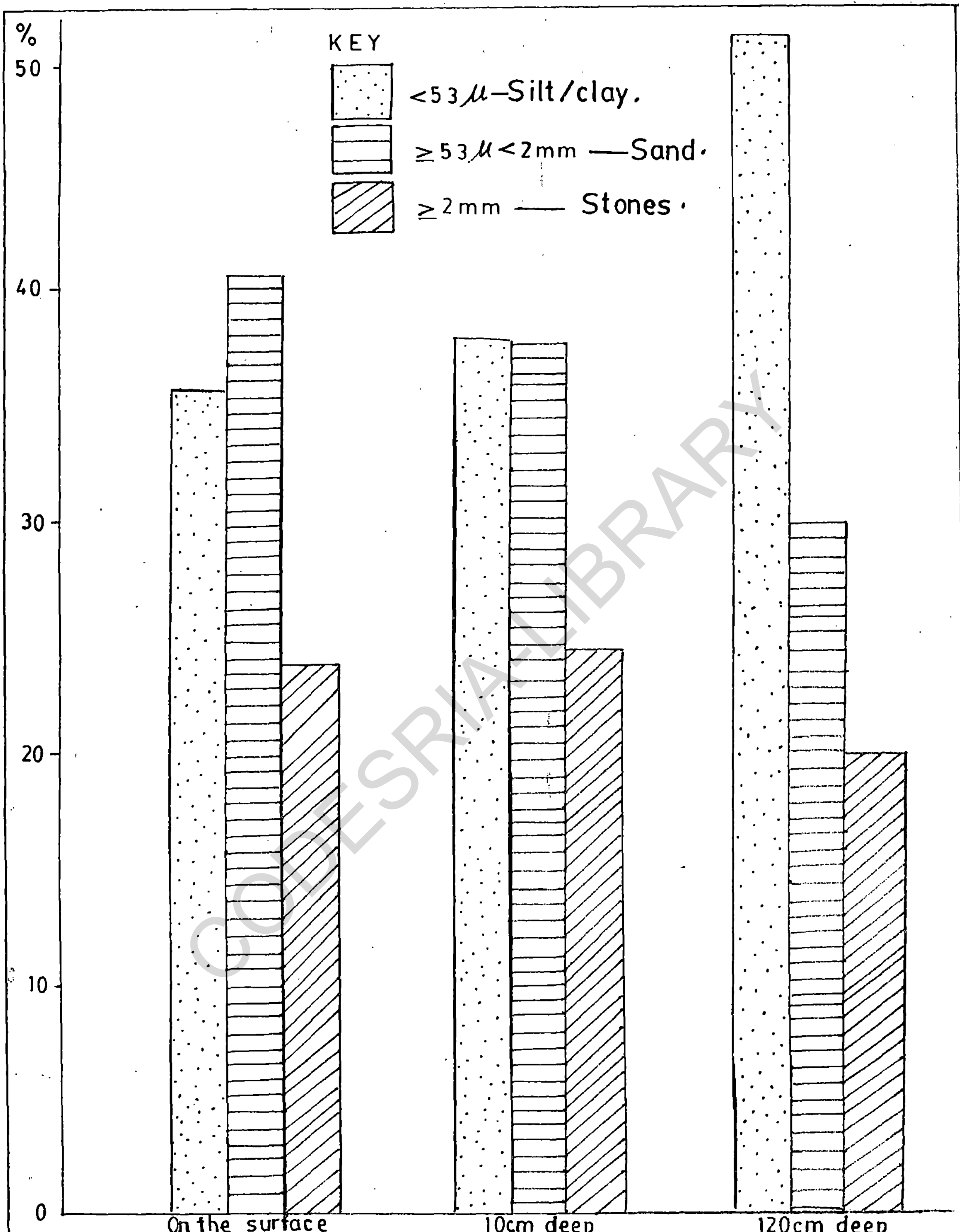

FIGURE 7: GRANULOMETRIC ANALYSIS SHOWING THE MEAN TEXTURAL COMPOSITION OF THE SOIL SAMPLES BY WEIGHT FOR ENUGU.

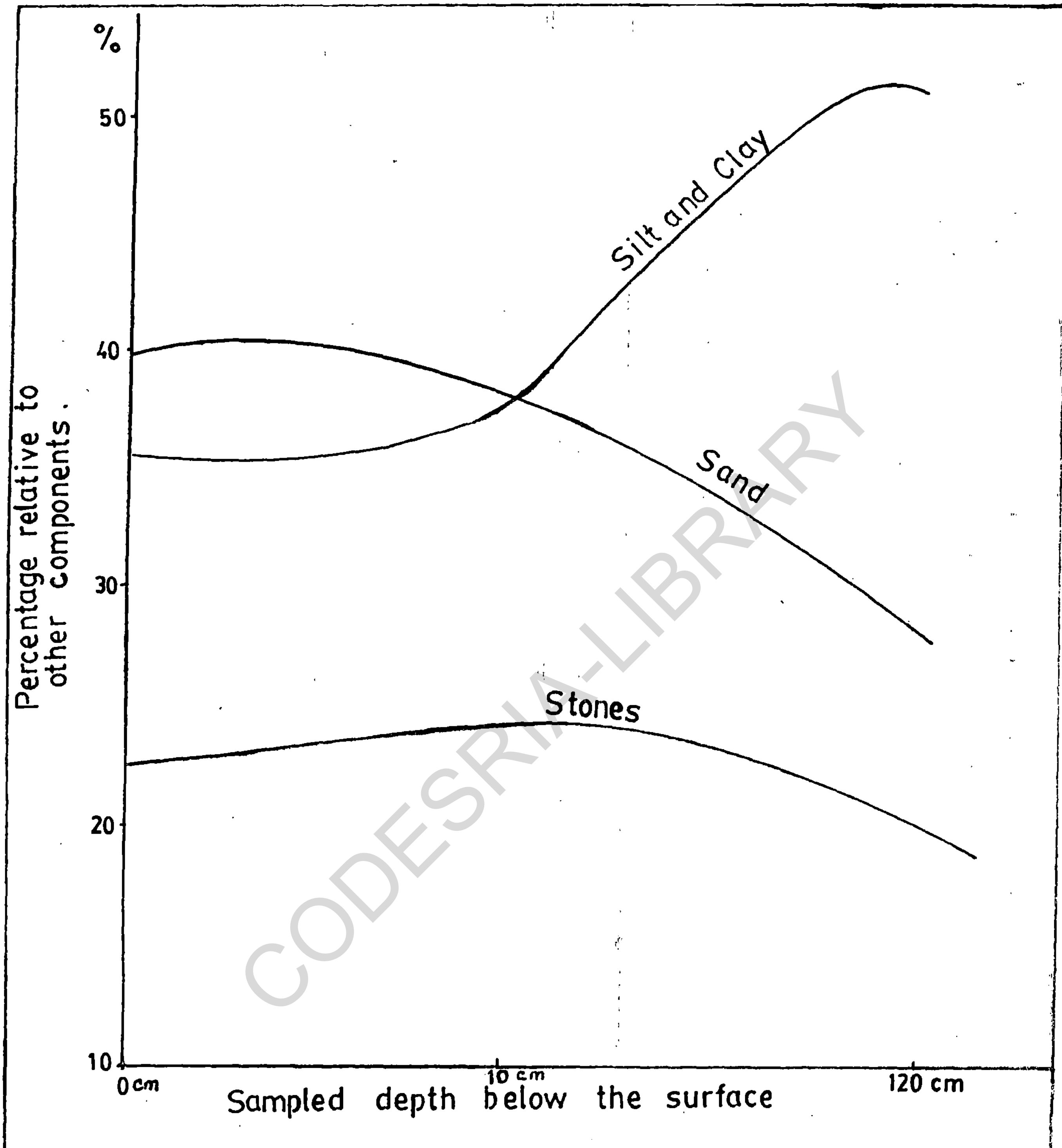

FIGURE 8 : A GENERALIZED TREND IN PARTICLE-SIZE VARIATION WITH DEPTH OF SAMPLES
(FROM FIGURE 7).

The climate of the area, with high humidity and uninterrupted, high temperature regime leaves legacy of a thick veneer of regolith. The characteristic hydrography of the well-drained study area has significantly dug into the terrain hence intensely dissecting the area.

The 1,500 mm-annual precipitation experienced in the area not only aids deep chemical weathering but also combines with various sub-surface hydrological and catenary processes to perpetuate downward leaching of the slit/clay component. This is why the general trend reveals a progressive increase in the percentage of silt/clay content downwards. Since our enquiry is for application to environmental management, we are not interested in the soil profile particle-size trends just for the sake of knowing them. It is actually the behaviours of micro-morphometrically defined soil units under certain hydro-geomorphological circumstances that interest the applied geomorphologist. In consonance with an objective of this study (i.e. to circumvent terrain hazards), the empirically established increase in silt/clay content down the soil profile is of great importance to this work and will therefore be further explored in the next chapter.

As already noted, granulometric analysis gives information on the physical properties of the soil profile especially in the areas of particle-size analysis or what is technically known as micro-morphometry. Such information is of great relevance to special-purpose engineering constructions, but inadequate in the area of landscape architecture and particularly where physiographic aesthetics needs to be enhanced. To rightly appreciate and appraise landscape-morphology as a potential resource in the enhancement of city-scape aesthetics and recreational land uses, the physical and geo-ehemical attributes of the lithology need to be cross-matched.

3.1.2 Geo-chemical Analysis:

The Milliken Hill represents an almost insurmountable constraint to urban land use. But our field investigations reveal that most of these areas unsuitable for built-up uses have great potentials for development in the area of recreation and tourism. Along the urban fringes, geo-chemical properties of the soil can be used to ascertain the potentials of the land to support different types of plant species.

> "The best single index of potential soil fertility is its capacity to exchange cations. Exchangeable cations can be artifically changed to improve soils for crop production and for engineering purposes" (Pitty, 1978, p. 154).

Cation Exchange Capacity (CEC) has a positive correlation with organic matter content. The intense action of percolating water removes soluble bases from the soil profile and results in depleted nutrient and increasing toxicity. Since soil acidity is closely related and traceable to toxicity and nutrient depletion, acidity was therefore used as a parameter to give an indication of the CEC, from which the soil's capacity to support plant growth can be inferred.

So because of the centrality of the acidity index to the determination of CEC, the pH was estimated using Sudbury Soil Test Kit. The resultant pH values have been presented in Table 5. To highlight the pattern of pH distribution, the means ($\bar{x}$), standard deviations (s) and co-efficients of variation (V) were calculated for each set of 41 samples based on depths. However, it is interesting to note that the co-efficients of variation (V) are relatively low ranging from 13.25 on the surface, 11.19 at 10 cm deep to 8.74 at 120cm deep. The lower the value of V, the less the variation and therefore the more homogeneous the samples. At 120cm deep, V = 8.74, and by interpretation this means that the variation is as little as 8.74%. The observation that the mean pH values for Enugu are slightly acidic is not surprising when viewed against the inexorable leaching effect of the 1,500mm-annual rainfall. A general impression created by our investigation and shown in Table 2 is that acidity decreases upwards to the surface. This can be attributed to the effect of organic matter which can be positively correlated with CEC. Uninterruptedly high temperatures and copious rainfall in a region replete with much vegetal cover, sustain continued addition of organic acids from decaying vegetation to the soil. But due to excessive rainfall and associated catenary processes, inherent leaching displaces much of the organic acids from the top horizon to deeper horizons down the soil profile.

Geomorphic factors act on the terrain. Using lithological data central to geomorphic factors, we have statistically and graphically attempted to establish that an understanding of these factors will help us appreciate terrain constraints and how to grapple with such constraints while planning the urban land uses. Having dwelt so much on soil mechanics and geo-chemical properties, it is necessary to note that the hand auger used by the researcher made it possible to probe only the upper layer of the soil to the depth of 1.2m. Implicit in this is the need to complement the information gathered from this shalow region with some more detailed, indepth sub-soil investigation if the results are to be authentic for special - purpose geomorphological interpretation and application.

It is believed that having boundaries between disciplines is to make for administrative convenience and therefore the boundaries are not meant to barricade the disciplines. This is why Cooke and Doornkamp (1974) assert that environmental geomorphology transcends traditional subject boundaries. With philosophical and methodological openness, therefore, deeper sub-soil, geological and engineering details were sought for, both from government agencies and private geo-technical consultancy firms.

3.1.3 Engineering-Geological Data Analysis:

In a discourse on the conceptual development of geomorphology, Dury (1983) recounts that our field of study used to be strongly attached to geology (about 1925-1940). A prominent Davisian geologist (and later, a geographer), Wooldridge (1956) views geomorphology as a border-line study between geography and geology. Dury (1983) also observed that the weakening of the geomorphology/geology interface and the former's later strong attachment to and being housed by geography were all by default and had a retarding repercussion on the conceptual development of geomorphology. Brown (1979) ascribes geomorphology's dissociation from geology and association with geography to a mistaken belief in the first half of the present century that geomorphological enquiry had no economic value. But Dixey (1962) asserts that the new trend in the discipline is the practical application of fundamental, pure or theoretical knowledge.

He went on to argue that

> "A knowledge of geomorphology is required in many civil engineering projects, especially in connection with underground water, foundations, transport routes, hydrology regimes and so on" (Dixev, 1962, p. 5).

Here applied geomorphological mapping is complemented with geological mapping and it has been claimed that the latter

> "forms the basis for prospecting, exploration and application in fields such as hydrogeology, engineering geology and land use planning" (Gabert, 1982, p. 21).

In the process of planning an urban space transportation, given the capabilities and limitations of the terrain, the civil engineer comes into contact with practical geomorphology. This is so because he should understand surficial processes acting on geomorphological features and the natural trend of landscape evolution in order to evaluate the possible environmental impacts of the envisaged project. The implicit precaution is in consonance with Newton's Second Law of Motion which asserts that every action has an equal and opposite reaction.

With the above conceptual background, empirical engineering-geological data can now be examined for practical purposes in relation to Enugu's topography. The characteristic humid tropical climate of the area has left a superstructure of thick mantle of regolith. It is on this veneer that various pedo-genetical and denudational processes operate. The hydrological and hydrographical aftermaths of this relentless denudation (both natural and accelerated) have left a legacy of intensely dissected terrain as could besseen in Figure 2. Hydro-geological information is very relevant for underground water resource exploitation. In 1981/82, it was crucial to geo-hydrualic survey and borehole activation forecast done for Anambra State Water Corporation (ANWC) at Nine-Mile Corner near Enugu.

Terrain segmentation is a function of terrain dissection and it is on these broken micro-erosion surfaces that engineering constructions invariably proceed. Apart from the obvious problem of building on land beset with topographical limitations, there are serious water management problems. On the average, the built-up areas are 213m while the peak of the Milliken hill lies over 541m above mean sea level (as will later be seen in Figure 10). Topographical and hydro-geological irregularities are simultaneous. Most of the rivers in Enugu are not only incised (since they are in their upper courses), but are often polluted by urban sewage hence the streams cannot satisfy the urban population and industries in both the quantity and quality of potable water. The problem is even complicated by the fact that accessibility to the water table is constrained by elevation. Rich and easily accessible aquifers had to be sought for in areas of relatively low elevation.

There is a close relationship between high elevation and the location of water storage and distribution tanks. Even though the high hills impede access to the aquifers, yet the water storage and distribution tanks are better sited on these high grounds, hence making use of the natural pressure to pump the water to the often low-lying water-need areas (as illustrated in Plate 1).

In 1975, a sub-soil investigation for a proposed reservoir was carried out by the Materials and Research Laboratory of Ministry of Works and Housing, Enugu, at the University of Nigeria, Enugu Campus (UNEC). The soil profile encountered revealed laterized silty clay (0.76m - 1.52m) of medium plasticity, fairly,consolidated silty clay (especially between 2.29m and 5.33m) and consolidated hard silty shales (at a depth of 8.38m).

In addition to a geohydrological basis for water resource management, other fluids that require natural pressure pumping to distribute, are closely tied to landscape morphology and sub-surface dynamics. A classic example in this category is the sub-soil investigation carried out in 1975 for the siting of the 10,000m^3 - Federal Fuel Dump, Akwuke Awkunanaw, Enugu. The details of the investigation are summarized in Table 6.

TABLE 6: Sub-Soil profile record for Federal Fuel Dump, Akwuke, Awkunanaw:

DEPTH BELOW THE SURFACE	SAMPLE No. AND TYPE	PENETRATION BLOWS/ FOOT (30.48cm)	PROFILE DESCRPTION
0.76 m	S P T	8	lateritic clay
1.52 m	U.4		Mottled clay with Iron indurations
2.28 m	S P T	16	" "
3.05 m	U.4		Stiff Mottled clay with iron indurations
3.80 m	S P T	20	" "
4.50 m	U.4		Dark grey shale
5.25 m	S P T	43	Very hard dark
6.10 m	U.4		grey shale
7.00 m	S P T	-	" "

Note: U.4 = Undisturbed samples 100mm diameter X 900 mm long.

SPT = Standard Penetration Test i.e. the number of blows per foot (30.48cm)

(Source: Materials and Research Laboratory Ministry of Works and Housing Enugu, 1975).

There are several other engineering projects constrained by both lithology and topography. Such projects require detailed and indepth sub-surface terrain investigation in order to forestall slope failure and structural instability. A foundation probe was carried out in 1967 with Cone Penetrometer and Pilcon Machine (for borehole) to examine the lithology and certify its suitability before the siting of Eastern Nigeria Broadcasting Corporation (ENBC) at Nine Mile Corner. The terrain was found quite suitable and the general soil profile-successions revealed by the tests are shown in Table 7.

TABLE 7: General Soil Profile Successions at 9-Mile Corner near Enugu.

Depth below the Surface	Profile Description
0 — 2 ft (60.96 cm)	Top crust of Compact sand
2 ft (60.96cm) — 20ft (609.60cm)	Loose reddish silty sand
20ft (609.60cm) — 40ft(1,219.20cm)	Compact silty sand

Source: Materials and Research Laboratory, Ministry of Works and Housing Enugu.

In 1976, mechanical analysis, Atterberg and unconfined compression tests were carried out in order to recommend the bearing capacity of the soil for the design of suitable foundation for the proposed four-storeyed 150-medical ward at the University of Nigeria Teaching Hospital (UNTH), Enugu. The usefulness of the precautionary test is illustrated in Plate 3. The soil profile in the area was found to comprise ferruginous sandy clay superimposed on deposits of laterized shales underlain by the Lower Coal Measures of the Cretaceous System.

The undulating landscape of Enugu (together with the superstructure) is in a delicate balance. Both geomorphological and pedological processes are very sensitive to human interference. In order to minimize the repercussions of urban-space transformation on a large scale and at project level, sub-soil profiles were deeply investigated at Independence Layout in 1976 as a guide or incentive to wise civil engineering decisions. The observed morphogenic and mechanical properties of the profiles investigated are summarized in Figure 9.

The principles of soil mechanics and geo-chemistry in relation to various civil engineering and landscaping activities already discussed, can only be operational on a given landform morphometry.

3.2 Morphometric Analysis:

Mathematical analysis of shape is central to the classical definition of mrophometry given by Clarke (1966) and discussed in section 1.5.3.1. Since there are several attributes of landforms or landscapes amendable to mathematical manipulation, Gardiner (1976) emphasized drainage basin morphometry, thus bringing to the lime light the influence of river-dissection on the potential use of the land. But from a much more geomorphological point of view, it has been argued that a morpho-conserva-

PLATE 3: The morphology of the University of Nigeria Teaching Hospital, Enugu. Grappling with the problem of topographical and lithological dynamics necessitates striking a balance between terrain - morphology, sub-soil bearing capacity and the nature of civil engineering projects: the example of a four-storeyed, 150-medical ward at UNTH.

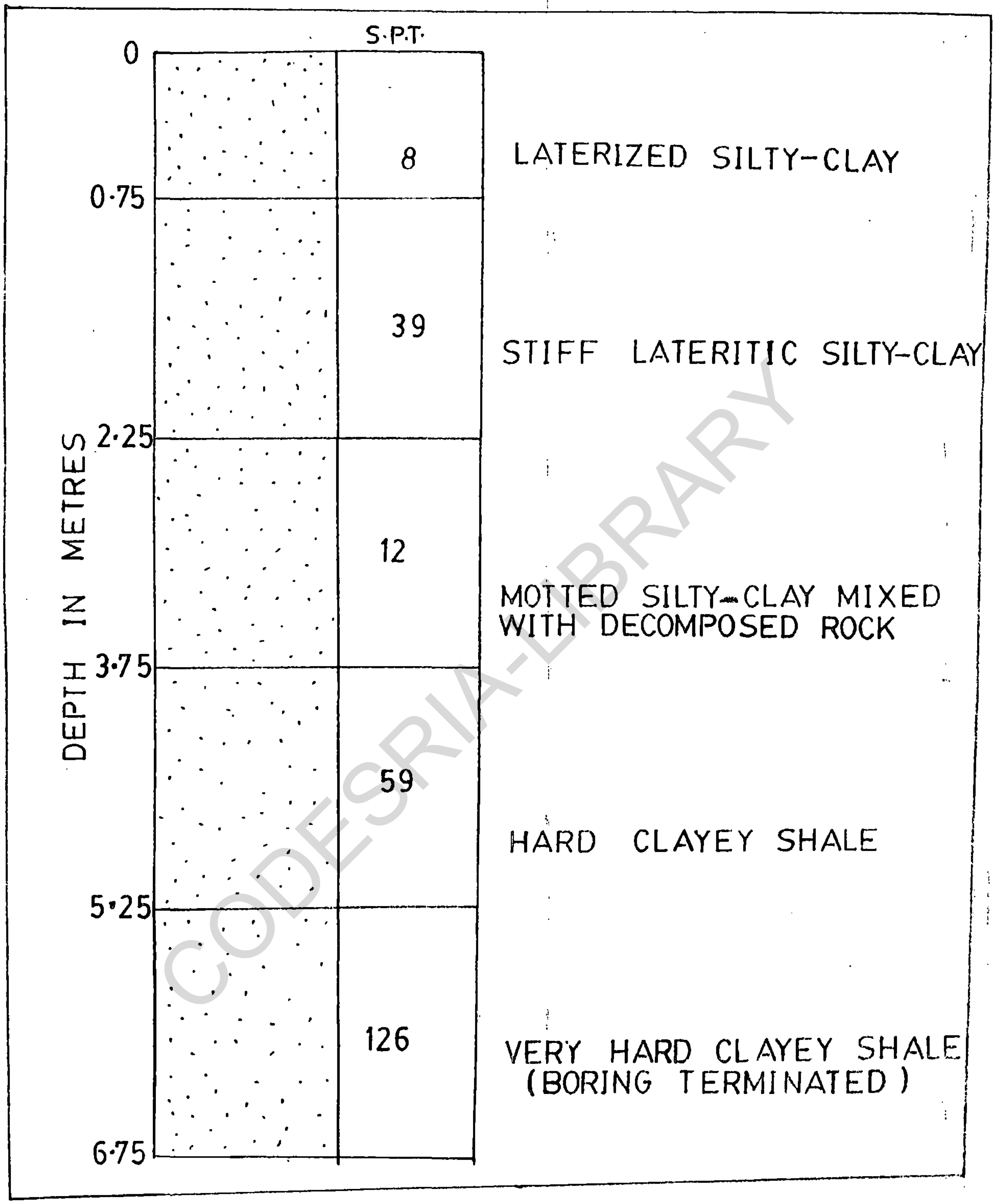

FIGURE 9 : SOIL PROFILE DESCRIPTION AND STANDARD PENETRATION TEST AT INDEPENDENCE LAYOUT, ENUGU BY AGBIM & PARTNERS 1976. (SOURCE: MATERIALS AND RESEARCH LABORATORY, MINISTRY OF WORKS & HOUSING, ENUGU).

tion map produced on an oro-hydrographical base is of much practical relevance in land management, conservation and use. Verstappen (1970), an exponent of the concept, principle and practice of geomorphological mapping has demonstrated the wide horizon of promise held by morpho-conservation mapping. The resultant map places much emphasis on slope steepness, to which is added some information on vegetation and active landscape-modifying processes. The content of such a map gives a picture of the natural rate of landscape evolution and given the lithological and surficial processes, the tendency of the land to undergo a violent transformation due to anthropogenic interference is also highlighted.

For example, a delicate landscape equilibrium is achieved through a balance between geomorphological, pedological and biotic factors, As was originally advanced in Figure 1, the terrain acts as a functionally interconnected system. Any alteration, displacement or distortion of a basic element, (or even of a sub-system) in the system will certainly be environmentally manifested. This is explanable using the canons of Newton's second law of motion already referred to. While using a practical case to explain the repercussion of any disruption in a system, Coates (1981) has argued that in urban management, the feed back effect of an <u>ad hoc</u> solution to a problem, however small, or a thoughtless, spatially expressible action, can generate, at another location, a new problem which may even be more insidious than the original one. There is a tendency for the feedback to keep intensifying following LeChatellier's Principle of a system's self adjusting mechanism, until finally the system attains a steady state. Due to lack of environmental impact assessment, urban expansion leading to undue clearance of vegetation along urban fringes can result in violent erosion by running water. Also when the influences of lithological and hydrological processes are taken for granted, violent gullying can be caused in some areas while in others, serious inundation could result. From the foregoing, it is obvious that the knowledge of landscape morphometry is very relevant if landscape equilibrium is to be maintained in the process of urban land use.

The product of a morphometric analysis of Enugu using two adjoining topographical sheets (NIGERIA 1: 50,000 UDI N.E SHEET 301 N.E. and NIGERIA 1:50,000 NKALAGU N.W SHEET 302 N.W) is shown in Figure 10. The map area (i.e. 132 km^2 on the ground) was first gridded ($2cm^2$), slopes calculated trigonometrically and a choropleth map drawn using slope values (as shown in Table 8). The information on slope steepness was complemented with that on vegetation, drainage and slope-modifying processes, all of which were superimposed on an oro-hydrographical base of a smaller scale as shown in the resultant map (Figure 10). These processes that alter the landform could be natural, but are mainly anthropic in the urban space. For example, having more built-up areas reduces infiltration, hence increasing runoff: - an inverse relationship between urban expansion and infiltration of rainfall. Along the steep slopes of the incised rivers or even along the urban fringes, overland flow and through-flow mechanisms could intensify slope failure. Also in relatively flat areas the increased concentrated or even unconcentrated runoff may result in serious flooding.

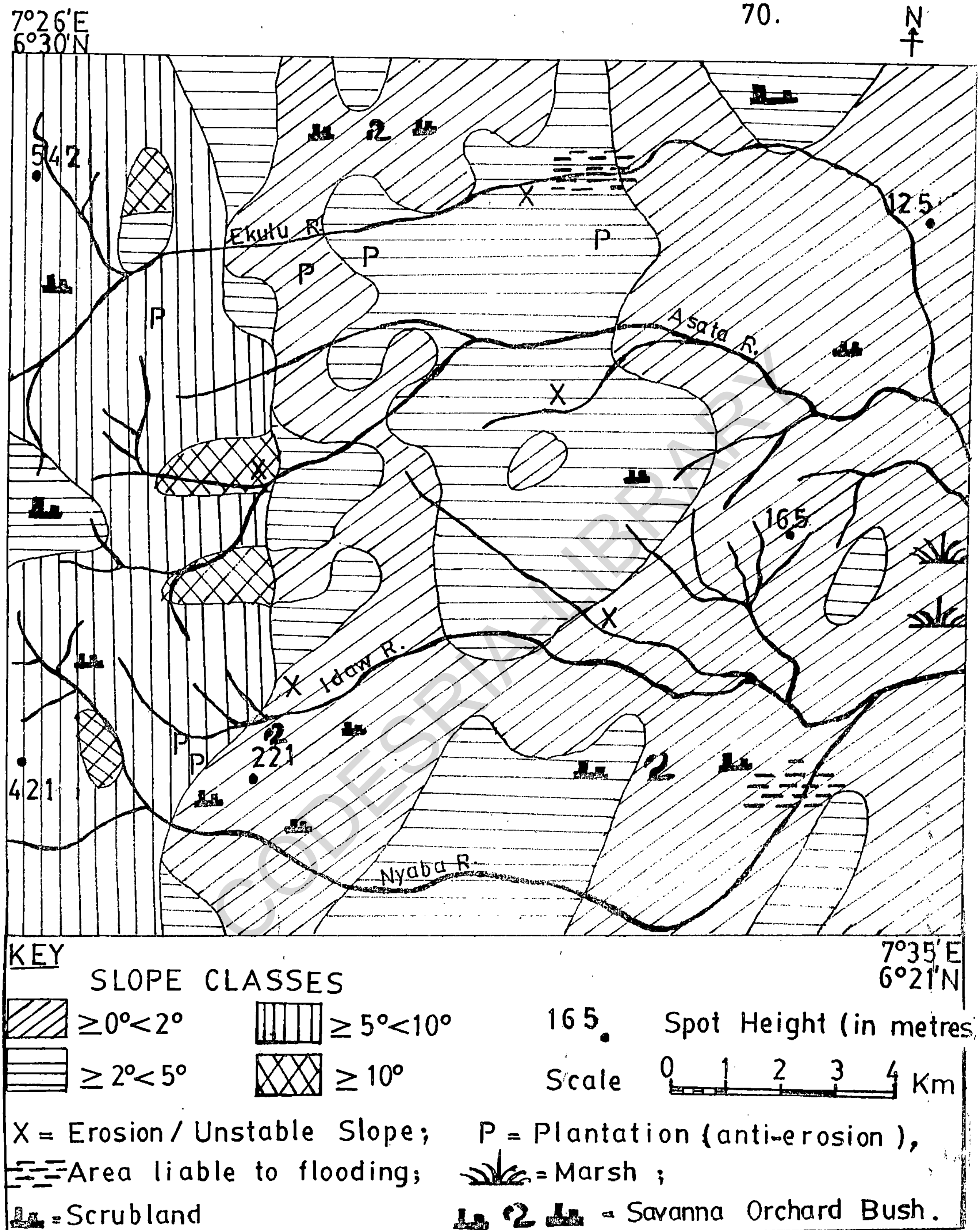

FIGURE 10 A MORPHO-CONSERVATION MAP OF ENUGU
(Major source – NIGERIA, 1:50,000 UDI N·E· & NKALAGU N·W·).

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Following the tenets of the recently developed, but fast advancing practice of geomorphological mapping, (Klimaszewski, 1956, 1965; Tricart, 1965; Verstappen, 1970, Cooke and Doornkamp, 1974) a morpho-conservation map is a special-purpose map mainly emphasizing morphometry together with the conditions and surficial processes influencing denudation. This is why Figure 10 clearly depicts slope classes, elevation, vegetation and areas with terrain hazards such as erosion and flooding. A morpho-conservation map can be directly applied to land use planning. This application can form the basis for land evaluation yielding a land capability map.

3.3 Land Capability Classes in Enugu:

The concept of land capability mapping has already been discussed in section 1.5.3.4.1. The geology, lithology and geomorphology of the study area have been clearly elucidated. For terrain constraints to be effectively grappled with, the land must be properly evaluated. This is why we had to complemental the information contained in the morpho-conservation map of Figure 10 with on-the-site field inventorizon. Information on relief and hydrography contained in the topographical map of the area was up-dated and buttressed by a qualitative field assessment of the static landscape. This attempt gave rise to a land capability map shown in Figure 11. It has been earlier on noted (in section 1.5.1) that terrain evaluation is a rational process of expressing the value of terrain configuration as a spatially distributed resource. Being cognizant of several terrain-evaluation methods, we have chosen land capability mapping because with this method, the resultant map not only reveals the potentials of the land but also the limitations or

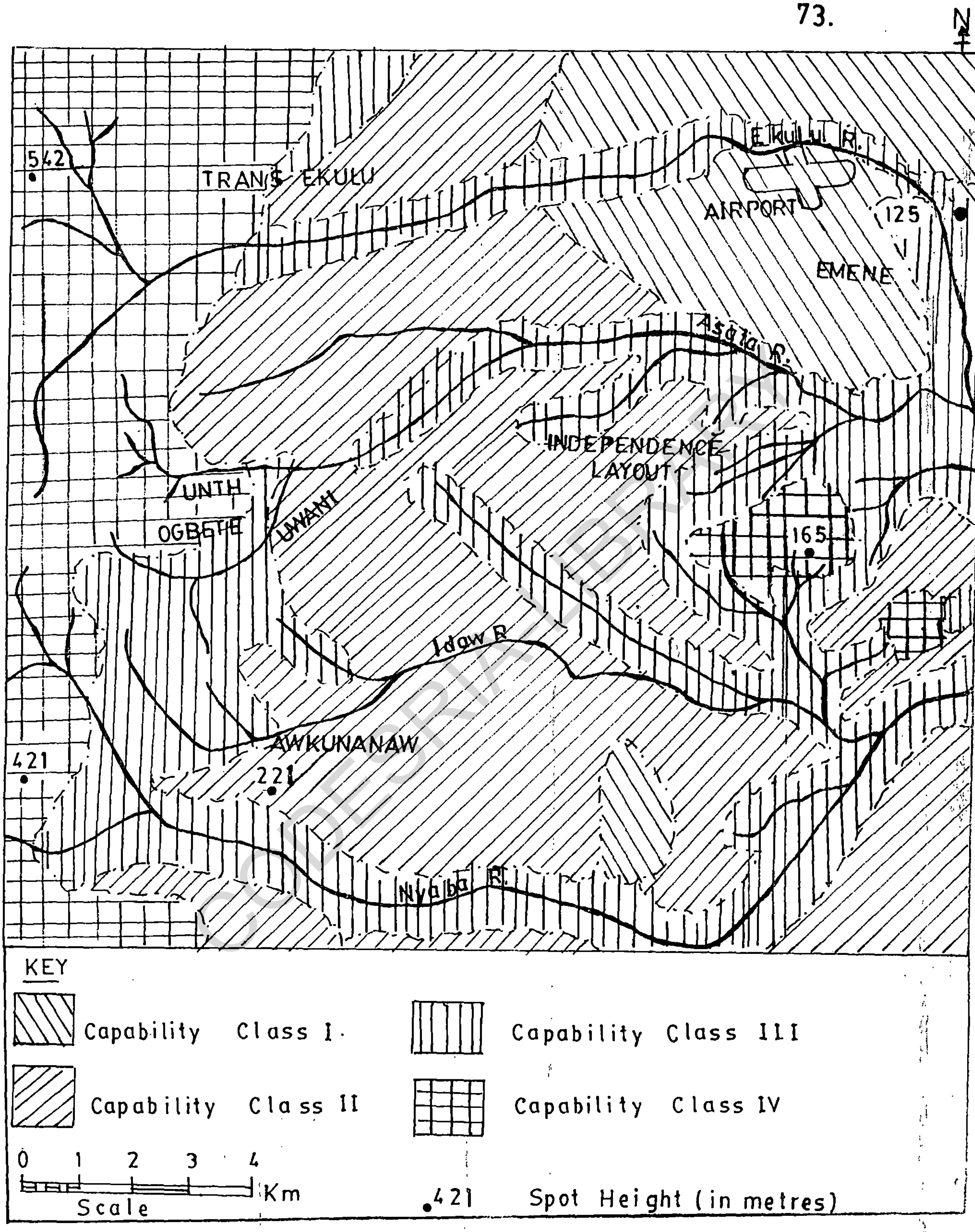

FIGURE 11: A LAND CAPABILITY MAP OF ENUGU WITH CLASSES I-IV SHOWING INCREASING DEGREES OF TERRAIN CONSTRAINTS TO URBAN LAND USE.

constraints that militate against land use. The potentialities of the land in Enugu have been broadly generalized into four land capability classes I - IV showing increasing degrees of limitations to urban land use, as could be seen in Figure 11.

3.3.1 Capability Class I:

This area with an average elevation of less than 130m mainly lies at the north-eastern corner of Enugu. It is mostly made up of relatively flat plains and rolling topography. The Enugu Airport and the Emene Inustrial Layout are located in this region. Fair accessibility to and from other areas through roads and railway; and the presence of an airport, have really enhanced this area's economic potentialities. Several industries including the Anambra Motor Manufacturing Company (ANAMCO), developing with residential, commercial, educational and other related land uses are characteristic of the area. All these cannot be divorced from the relatively flat landscape.

3.3.2 Capability Class II:

The central parts of Enugu are classed as having more limitations to urban land use than the north-eastern part. This central section has been generalized as lying within the second capability class. The area lies between 180m and 220m and is at the base of the Enugu Escarpment. The area embraces almost all the built-up areas of the town. Greater intensity of, and dissection by rivers, the sinuosity of both roads and railways connote greater terrain constraints to land use in this region.

3.3.3 Capability Class III:

As could be seen on the map (Figure 11), the short steep slopes of the many dissecting rivers fall within this category. These steep valley-side slopes have not only constrained many urban land uses but have seriously affected transportation. Intra-urban nuclei connections had to traverse these incised valleys at great costs, with resultant transportation bottlenecks at the crossings.

3.3.4 Capability Class IV:

The whole of the Milliken hill bounding Enugu to the west falls within this category. Most of the water sheds for the numerous eastward flowing rivers lie in this area. The steep slopes of the hills (as confirmed by Figure 10) constitute the greatest restriction to westward urban expansion of Enugu. Accessibility to the town had to, of necessity, go through this unfriendly topography. The new Enugu - Onitsha express way had to pass along the hill-sides in an attempt to waive or minimize the danger of going along the precarious, sinuous, old Enugu-Onitsha road.

Having analysed the geomorphological, geological, pedological and lithological details of Enugu, in order to evaluate land potentialities, it is now time to examine the extent to which their knowledge has been utilized in our urban space planning experience.

CHAPTER 4

URBAN LAND USE PLANNING IN ENUGU

It would be a travesty of sound applied geomorphology, if our exploration and appraisal of Enugu's terrain cannot be practically utilized in the planning of its urban land uses.

4.1 Conceptual Framework:

There is no substitute for a clear understanding of the geography of an urban place prior to efficient planning and use of the land. In a monumental work, Carter (1982) notes that urban geography is concerned with those processes which, in the context of a culture, operate to create spatial patterns, and that the replacement of description by interpretation of location facilitated its development as a special study. When it used to be a nascent field of specialism, Blanchard (1911) argued that it attempted to explain the origin and development of a town as a function of the physical conditions of its situation. Even now, with the aid of advanced technology, the idea of man as the master of the possibilities of the physical environment is viewed as 'nebulous'. This becomes clear when one considers Carter's (1982) conception of the content of urban geography abstracted and shown in Figure 12. Irrespective of our technology, therefore, Enugu's physical setting will certainly affect the land use.

Due to the organic (i.e. growing or expanding) nature of the urban environment, many theories have been put forward to account for the origin, development and patterns of urban land uses. Here, a theory is taken to mean a representation of our understanding of some entity and its workings which we are interested in (Wilson, 1980). The earliest

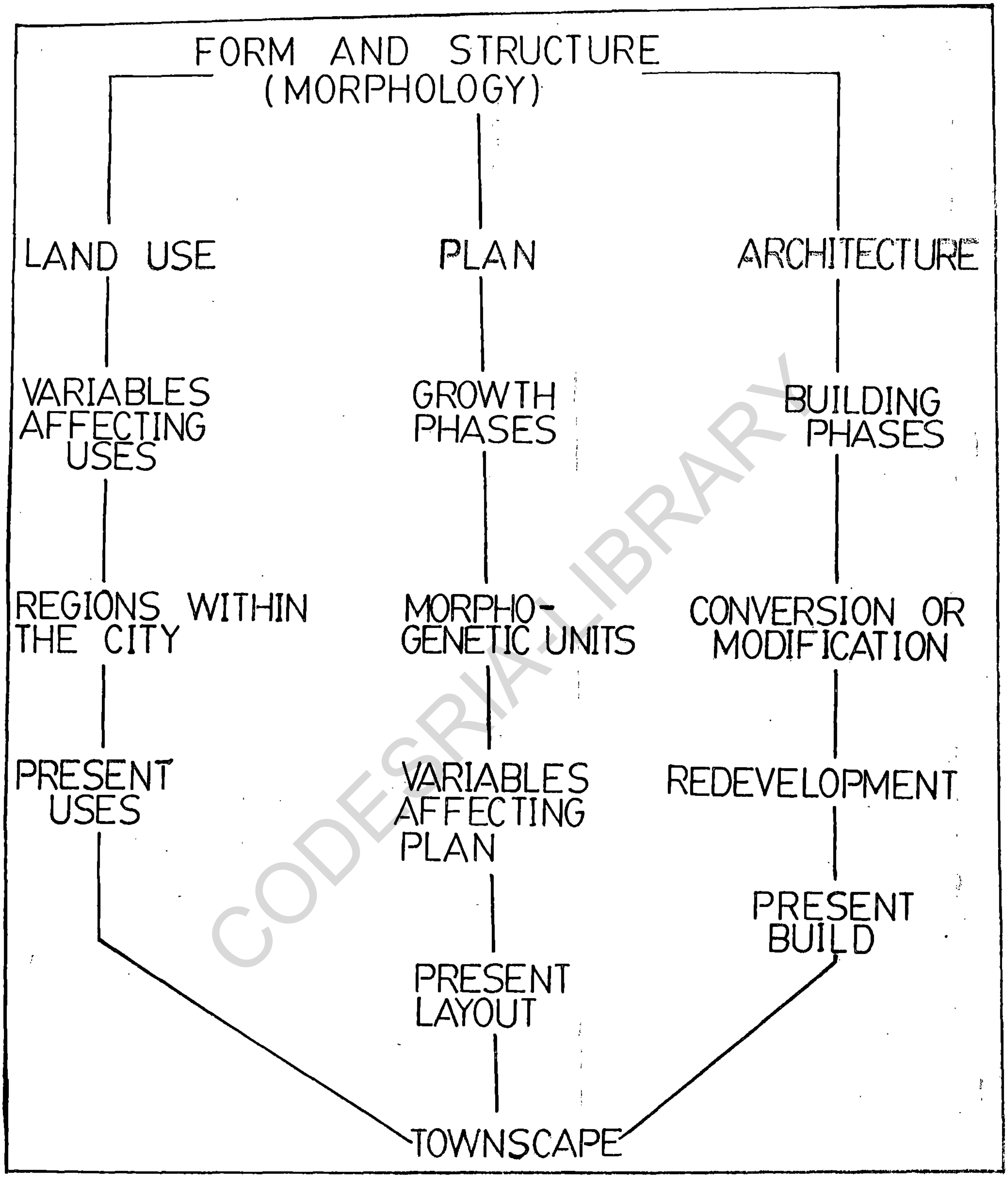

FIGURE 12 : THE PHYSICAL ASPECT OF THE CONTENT OF URBAN GEOGRAPHY (MODIFIED AFTER CARTER, 1982 p.8)

of these is Burgess' (1925) theory which conceived land uses as organized in concentric zones spreading outwards from the CBD. Later on it was argued that land uses develop axially or in sectors according to the postulation that

> "high rent districts tend to grow toward the section of the city which has free, open country beyond the edges of and away from 'dead end' sections which are limited by natural or artifical barriers to expansion" (Hoyt, 1939, p. 116).

Moving further away from massive generalization towards reality, Harris and Ullman (1945) proposed the multiple nuclei theory, which views land uses as organized in separate nuclei progressively integrated by the process of urban growth. Sule (1982) has observed that urban growth will normally be associated with both upward and outward expansion. The fact that the process of growth is inexorable points to the need for control through planning.

The Township Ordinance No. 29 of 1917 emphasizing guidelines for the physical layouts of towns, set a systematic pace for urban land use planning in Nigeria (Sule, 1982). The need for urban planning as a national policy gained wide currency after the World War II when the Nigeria Town and Country Planning Ordinance of 1946 stressed the need for replacing, improving and developing of different parts of the country (Ola, 1984). For optimal use of land, the Land Use Act of 1980 (formerly the Land Use Decree of 1978) was promulgated and, among other things, it states that:

(a) Any holder of developed land (i.e. value enhanced by building, installation of infrastructure etc.) before the decree, should notify the Governor for Certificate of Occupancy.

(b) Where not developed, the holder should continue holding but not more than half of a hectare (i.e. about 5 plots of 30.48m x 30.48m).

(c) Undeveloped urban land should not be laid out in plots or transferred without the prior written consent of the Governor (Floyd and Sule, 1979; Igbozurike, 1980; Ola, 1984; Sule, 1982, 1988).

The Act, which vested all land in the state in the Governor who acts under the advice of a Land Use and Allocation Committee, has been critized as being socialist in context but at the same time denying the masses their right and favouring the elites who could fight for Certificate of Occupancy (Ola, 1984).

With policies based on the Land Use Act of 1980, the Land Use and Allocation Committee of the Lands Division, Ministry of Works, Lands and Transport, clarifies land issues making it possible for Enugu Town Planning Authority to define and delimit its planning area. For purposes of urban planning, lands in Enugu have been categorized into private land, government land and land outside the planning authority area.

Planning is simply viewed as a process of laying out the course of action in advance. The crucial role of urban space planning as a conscious attempt to guide urban expansion through a desired path can be fully appreciated when one takes cognizance of the fact that urban expansion is inexorable. The cityscape system is an open one and therefore there is a need to exercise a certain degree of conscious control over both the elements and subsystems. In the absence of such control, urban land use allocation may become indiscriminate, urban activities and expansion could become chaotic and precarious. To avoid these unwanted repercussions, the need to achieve a meaningful organization of urban activities and structures through a careful planning becomes undoubtedly obvious. It is probably an awareness of this simple fact that led to the drafting of a master plan for Enugu.

4.2. The Master Plan for Enugu:

The document prepared for the Ministry of Finance and Economic Planning, Enugu, by the Concept Ecodesign International (1980), asserts itself as a comprehensive physical development plan or master plan. Viewed against an anticipated 300% population increase by the end of the century, the plan was geared

> "to raise the quality of life for the largest number of Enugu citizens in the most cost-effective manner possible" (Master Plan for Enugu, p. 1A-3).

In order to achieve the most effective allocation of urban land use and circulation activities, it was advanced that the Master Plan necessarily had to address other issues such as economic development trends, health-care systems, the state of urban education, physical infrastructure and the complex fiscal and administrative systems in order to achieve a truly comprehensive urban development programme.

Recognizing the differences in problem-combination from one urban centre to the other, those who drafted the instrument noted that a methodology should not be a dogmatic imposition of a monolithic and inflexible thought process, but should rather be a responsive adaptation of the best characteristics of many proven methods or simply 'a hybrid'. The choice of a particular method is dictated by the prevailing local conditions and extant statistical base, and this is why planning methodologies appear to develop in response to unique, specific problem-combinations.

In the case of Enugu, historical urban growth factors appear most domineering. Commercial and administrative institutions and facilities were observed to have formed the early core of Enugu by establishing themselves as important growth points. While neglecting the geographical factors of potential outward expansion (frequently non-concentric), the original sites of activities, such as markets, have been maintained, defying considerations of alternative sites in relation to population centres and inter-regional movement patterns. It was finally observed that the town's original commercial and institutional foci were conspicuously separated (from the newer residential developments) by rivers and other barriers, with resultant circulation bottlenecks at the limited crossings.

With the above historical and developmental background, and as a matter of methodology, the architects of the instrument proffer two major action areas: The first embodies a proposal to amend the CBD circulation system with the aid of a CBD flyover and also to renovate the settled area around the railway station. The second action area is the escarpment zone stretching from Idaw River, through Ogbete and towards the 9-Mile Corner (Figure 6). This provides the greatest barrier to expansion westwards but is ecologically of immense import. In the Master Plan, it is advocated that a moratorium be placed on any further development in this area, save those directed towards the adaptation of the area to recreational uses.

The Enugu Master Plan represents a fundamental document to guide urban physical spatial planning. The instrument is, indeed, a product of concerted attempts to grapple with the complexities of decision-making process and also to rightly evaluate the contending alternatives that bear on space allocation and utilization. Undoubtedly, it has been a milestone, making a significant degree of contribution to Enugu's physical planning process, yet the idea of its being a comprehensive document is highly questionable and therefore needs a critical re-examination. The Master Plan agrees with the United Nations Group of Experts on Metropolitan Planning by asserting that statistical and other information concerning the economic, social and physical structure of a metroplitan area and its probable evolution are clearly essential for comprehensive planning. But the quest for, and use of, information on the physical setting or landscape - morphology have not been of major concern to town planners irrespective of their importance. It has been observed that

> "physical planning is concerned with the the design, growth and management of the physical environment, in accordance with predetermined and agreed policies, whereby balanced social and economic objectives may be achieved" (Adeniyi, 1978, p.33).

Physical planning has not been strictly pursued in our urban planning experience, and this gives credence to the impression perpetrated by the Second National Development Plan which "regards physical planning as a kind of visual aid to economic planning" (Adeniyi, 1983, p. 442). The kind of bias and shallow physical background rife in most of our development plans can be identified as well in the Master Plan for Enugu. Based on apparent flaws, it is questioned whether the document viewed as a comprehensive physical development plan or master plan actually justifies or fulfils its raison d'etre. Its comprehensiveness faces stultification and the accompanying doubts become intensified when one recalls that the treatment of geological structure and soil in relation to general terrain morphology was too general and on a very small scale for Eastern Region and Nigeria as a whole. This shallow treatment which was mainly a re-statement of the views of Floyd(1969) and Iloeje (1976) with little or no criticism has proved to be the Master Plan's Achilles' heel. Not even the detailed large scale pedo-geological and hydro-geomorphological settings essential for meaningful urban land use planning were presented. Any reasonably well-drafted master plan should not have neglected such indepth and relevant information on both the surface morphology and litho-geological underpinnings of the defined area it claims to be planning for. The need to use Environmental Impact Statement (EIS) to assess the various impacts of different land uses and attempt to minimize adverse environmental feedbacks while maximizing the benefitial ones cannot be over-emphasized. This was conceptually advocated for at the onset of this investigation (as could be seen in Figure 1). No master plan can claim to be comprehensive while conspicuously omitting the large-scale, detailed information on the capabilities and limitations of the lands in the area being planned. Enugu's topographical disposition and its intense terrain dissection by various surficial hydrological processes constituting some geomorphic constraints to the use of the area's terrain have been examined in the previous chapter.

4.3 Grappling with Terrain Constraints:

Ofomata (1978) noted that the siting of Enugu at the foot of an escarpment was dictated mainly by physical considerations. Coal Camp has remained the core or CBD of the town. The rugged terrain of the indented Milliken hill makes it very difficult for Enugu to extend further westwards. Instead, settlements are spreading northwards into Trans Ekulu and Abakpa Nike layouts; eastwards into Awkunanaw, Mary Land and Achara Layouts. Attempts at westward extension of settlements have been very precarious and tasking. The term 'Enugu' (or rather 'Enu-ugwu') refers to a settlement on the hill. Other designations such as Ugwu Aaron and Ugwu Alfred are etymological nomenclatures (as 'ugwu' means 'hills' in Igbo). The severity of topographic hurdles in such areas has already been illustrated in Figure 4. Even at Coal Camp, such constrains are quite dramatic as could be seen in Plate 4. At the UNTH, the problem is of similar intensity, thus constituting a great limitation to land use as could be retrospectively inferred from Plate 3.

Owing to the nature and operation of geological, lithological and hydro-geomorphological factors, Enugu has been compartmentalized into sections. These are quite vivid on air-photographs of the area and can also be inferred from Figure 6. The hydrography of the area reveals compact land masses sandwiched in between the dissecting rivers. The inhabitants of Enugu are so much attached to these rivers as vital in their living environment that residential areas such as Idaw River, Ogbete, Asata, Aria, Ekulu etc have taken names after the original rivers that still traverse Enugu today. Apart from the steep hill-slopes, the steep, short slopes of the river-valleys constitute a great limitation to urban land use.

Fault planes and micro-erosion surfaces have been identified and adduced to highlight the influence of palaeo-geological and palaeo-geomorphological processes on the trend of landform evolution in the study area. For instance, it has been argued that because of faulting and minor earth tremors that occurred during the Post Maestrichtian Time (i.e the period of coal formation), Ogbete, UNTH, and some other parts of Enugu are on fault planes. Consequently, geologists and other geo-scientists warn of the danger of landslides if people continue to build houses and other structures without carefully considering the locations of mining tunnels and the geology of Enugu (Egboka, 1987). Man's intervention on the surface crust through mining can obviously instigate

PLATE 4: The Milliken hill and urban land use. This photograph, taken at Arochukwu Street, - Ogbete, speaks for itself about the restrictive impact of the Milliken hill on urbanization.

and escalate structural instability and slope failure. Such geological and geomorphological factors could offer a plausible explanation for the causes of collapse of urban buildings.

Waves of collapse of buildings have recently reached Enugu. On 27th August, 1987, tragedy hit the town when a four-year old, three - storeyed building collapsed at Ona Street, Uwani (Daily Star, August 28, 1987 and September 1, 1987). News analysts, in trying to explain such unwelcome events, attribute them to structural and constructional defects which derive from faulty architecture, engineering and surveying. At the same time such analysts assume an absence of earth tremors in the affected area. But more and more improved and sophisticated civil engineering techniques have apparently not reduced the incidence of building-collapse.

With modern technology and design, the construction of that ill-fated building at No. 6 Ona Street started in 1983. It was completed and rented out in 1985 and it finally collapsed in 1987. Obviously the fault was not with the civil engineering and construction techniques. This necessitates a quest for a more satisfactory explanation to the issue in question. If, for example, the structures near Ogbete Main Market begin to fall into the gully near the Ogbete river, definitely, faulty archirtecture and civil engineering cannot give the desired explanation to the issue.

A post-fall investigation of No. 6 Ona Street revealed the use of sub-standard rods and a poor mix of building materials. But the fact that other buildings in the same street are equally trying to cave in shows that the issue cannot necessarily and totally be accounted for by faults in structural engineering techniques. No. 9 Ona Street was almost caving in when the Town Planning Authority instructed its landlord to relieve the building of occupants so as to allow for the incorporation of supporting pillars to rescue the threatened building. At Ona, Obioma, Umueze and Mount Streets, the gradual subsidence of buildings is not a new phenomenon. But a common feature of all these hazardous areas is that contrary to sound town planning provisions and ethics, they are located on green verges. The stream-side areas delimited as capability class III in Figure 11 constitute green verges. We have already noted (in section 1.5.1) that land evaluation involves comparing the benefits and consequences of a particular land use type with those of the alternative land uses. Our investigation reveals that so many hazards leading to collapse of buildings and threats to liveability could have been circumvented if the green verges were not encroached upon for residential purposes. Apart from obviating such terrain hazards, if the vegetal cover of the green verges is improved, the beauty of the environment will be highly enhanced. The Enugu Town Planning Authority has realized this fact and so plans are in the making to ensure more strict compliance with green verge provisions and also incorporate sub-soil investigations before building plans are approved.

Apart from obvious landslides that can be attributed to lithological settlement or sagging in mined areas, factors connected with over land and saturated through-flow processes can equally account for the occurrence of Landslides in areas that have a signficant stratum of clayey materials in the soil profile. Empirical investigation summarized in Figures 7 and 8 reveals that for a greater part of Enugu, at about 120cm deep, over

50% of the soil is made up of silt/clay. This is corroborated by the information in Table 6 and Figure 9. From the foregoing, it is clear that the proportion of clayey materials in the soil profile in Enugu is very significant as to play a domineering role in determining the response of the soil profile to saturated throughflow and catenary processes. The behaviour of clay or clayey soil was used to explain the 1962 - Awgu landslide (Ofomata, 1966). Accordingly, it was argued that when clay forms part of a steep slope, it can become unstable, but since the pedologist or civil engineer would always ignore the external dynamics of landscapes, such instability

> "can only be detected through a
> systematic geomorphological analysis
> of the area in question"
> (Ofomata, 1978, p. 122).

Figure 10 shows that the western part of Enugu has relatively steep slopes. Also this western part forms the watershed for most of the eastward flowing rivers. Field observation shows that most of these rivers are incised since they flow over relatively steep slopes. Given the degree of vegetation cover length and steepness of slopes, the 1,500mm-annual rainfall experienced in Enugu favours increased erosivity while a pedo-genesis of over 50% clayey materials (i.e. in terms of soil material make-up) intensifies erodibility through landslides. Based on field evidence, it is reasonable to maintain that terrain instability can be a function of accentuated pedo-geomorphological processes operating on slopes that have clayey materials or clay strata in their profiles. In decrepitude, a building can crumble, but when a new strong one caves in or slides down, the explanation must be sought for in terrain sub-surface and external dynamics and this is where applied geomorphology plays an important role.

The topography of Enugu is characterized by a maze of traversing rivers. The resultant compact land masses separated by rivers had to be isolatedly utilized for urban development purposes. Contiguous units were either planned or gradually colonized by different urban land uses. Various nuclei such as Ogbete, Uwani, Asata, and Ogui developed, all bounded by rivers. Meaningful intra-city communication was not possible until attempts were made to connect the isolated areas with bridges. The Enugu Master Plan proposes a CBD flyover to ameliorate circulation problems (see Plate 3) but the terrain of Ogbete area is so difficult that the project, if embarked upon, may not be cost-effective. Flyovers were rather more meaningfully constructed north of the Ekulu River along the Enugu-Onitsha express road (Plate 5) and to the South near the Nyaba River along the Enugu-Aba-Port Harcourt express road.

There are still other aspects of intense dissection relevant to this investigation. Settlements have been spreading northwards across the Ekulu River, and recently (in September, 1987) this river overflowed its bank causing devastating erosional hazards at Abakpa Nike layout. One may recall that the magnitude was such that it was the talk of the town and even of ABS Radio around 30th September, 1987 when the fateful event occurred.

The Concord of September 28, 1987 observed and reported that structures in the Ogbete Market have started cracking due to devastating gullying near the small Ogbete river. It was noted that this unfortunate

PLATE 5: The Flyover after Relief Market. Relief-dissection and difficult terrain pose great problems to accessibility and intra-city communication. Shown in the plate, is a flyover along the new Enugu-Onitsha express road. The Ekulu river passes under the bridge to the left of the plate while an anti-erosion plantatin lies further on the background.

process is seriously threatening the N10m - Ogbete Market. The morpho-conservation map (Figure 10) and land capability map (Figure 11) can be used in the planning of intra-urban route net works, allocation of land uses and for spatial organization and re-organization of urban activities. They can also be used in conjunction with Figure 2 which shows the underlying geology of the area.

Topographical expression is closely related to the nature of underlying material. The relief combines with lithology to set the stage for surficial processes to act and give an indication of the rate of normal or natural denudation. When such processes operate at a normal rate, a dynamic equilibrium can exist between the landforms and agents of denudation, but such a balance can easily be disrupted by extraneous anthropogenic intereference. Exogenic processes can become intensified and accelerated leaving more violent legacies, of which a classic example is the threatening gullying near the Ogbete Market.

Enugu's urban expansion has become characterized by a progressive increase in built-up areas. The creation of Community Extension and City Layouts in Februrary, 1988 by the Enugu Town Planning Authority confirms that Enugu's built-up areas are relentlessly widening. Increasing the built-up area implies increasing concrete (and unin-filtrating) surfaces. Infiltration is drastically reduced or eliminated by the concrete surfaces, resulting in increased runoff. Such runoff eventually becomes channellized along the rivers, leading to further slope failure and incision in areas of steep gradients (such as Ogbete Market area). This is because most of the rivers in Enugu are in their upper courses. But in relatively flat areas such as Abakpa Nike near the Ekulu River, the increased runoff has led to serious erosion and inundation.

Man's disruptive influence on natural surficial geomorphic processes has already been conceptualized in Figure 1. Due to Environmental Impact Assessment based on feedback effects, the formulation (i.e. Figure 1) is an appropriate model for investigating landscape dynamics. Because of this quality, it is also a good guide for land use planning both on a large scale and at individual project level. From the foregoing, at dynamic equilibrium, terrain evolution or modification proceeds at a normal rate. But extraneous interference (i.e. human) intensifies the rate of terrain transformation leaving violent imprints represented by erosional and flooding hazards in Enugu.

Most spatial decisions to locate land use activities which might lead to the setting up of residential, commercial, administrative and industrial buildings, or to align route ways, among others, give rise to definitive land uses. Such final land use states have a considerable degree of inertia in that they rarely re-locate once established. When liveability is nettled by what Duru (1972) and Uyanga (1982) described as 'hypertrophic' urbanization, then spatial re-organization or relocation might be a feasible action. Enugu's decadent CBD (especially Ogbete area) is already being blighted. Applied urban geomorphology finds real practical expression in slum-clearance in that it can easily yield an Environmental Impact Statement (EIS) that can be used by urban planners in effecting urban renewal. A geomorphological survey can predict the best site for a particular project after taking the potentialities and limitations of the land into consideration. The much-clamoured-for slum clearance and the recommendation of a CBD flyover to improve traffic conditions in Enugu can both be subjected to a geomorphological censorship and verification. Here, environmental geomorphology not only takes into consideration the economic and social implications of an envisaged programme but also the environmental ramifications and repercussions.

It can be recapitulated that Enugu is rife with a number of terrain limitations to urban land use ranging from intense land dissection by a maze of rivers to uncircumventably rugged terrain at the western side of the town. Many of the land use activities can be sited on the relatively flat terrains existing to the north, east, and south, while landscaping can be fruitfully practised on the rugged Milliken hill to the west and also along the short steep slopes near the dissecting rivers.

The result of geo-chemical tests in Table 5 reveals mean acidity or pH values of 6.04 on the surface, 5.81 at 10 cm deep and 5.49 at 120cm deep. This shows that the soil in Enugu is a little bit acidic, but the observed acidity level is still tolerable to most humid tropical aesthetic plants with deeply penetrating rooting systems. Landscaping can therefore be used to improve the panorama of the rugged hills as well as to stabilize and beautify the threatened slopes that bear most of the urban land uses.

The lithological dangers in terms of the occurrence of clayey materials within the soil profile and its relationship with slope instability have been highlighted. The topographical hurdles militating against urban land uses have been examined. It is now time to consider how to maximize the benefits and minimize the consequences of urban land uses. Given the inherent terrain constraints it is the duty of our urban designers and planners to find the best way of grappling with these limitations. When the terrain is viewed as a ~~spatially~~ spatially distributed potential resource, then one appreciates the fact that no terrain constraint or limitation is actually insurmountable. With our technology and wisdom, such topographical disadvantages can be turned into a topographical wealth. Through proper, comprehensive land evaluation and allocation, the use of the land can be maximized. A balance can be attained and maintained between surficial processes on one hand and human structures on the other. This attainment puts the urban landscape in a dynamic equilibrium or a steady state.

The drafting of a master plan to guide urban land use in Enugu can be said to be in realization of the challenges posed by the terrain. In an attempt to grapple with such planning challenges in Witwatersrand, it has been argued that

> "As always, problems are a challenge and it is up to human ingenuity, based on a real understanding of past growth and future trends, to turn present liabilities into future assests" (Mallows, 1961, p. 47).

In developing countries, regrettably, the story is quite different, unlike in advanced countries where natural limitations can be easily surmounted with the aid of sufficient capital base and technical know-how.

Sule (1988) has noted that river-banks and river-corridors promote and enhance residential aesthetics and increase property values in cities of advanced countries, but in Calabar, because of poverty, the rivers constitute a barrier, a liability and not an asset for residential growth and development.

In Enugu, the areas categorized into capability classes III and IV (Figure 11) can still be viewed as latent resources craving for exploration and exploitation. The steep slopes of the Milliken hill and other smaller hills forming watersheds for the various eastward flowing rivers in Enugu together with the steep valleys near these rivers, are obvious liabilities. Any definitive urban land use sited on or near these difficult terrains appears precarious. Devasting gullying, and landslides can wreak their destructive weal on such urban land uses. But the wisdom of a modern astute urban planner lies in haulting the onslaught of gullying by stabilizing the slope. This is where the applied urban geomorphologist makes a relevant contribution to the interdisciplinary field of urban management. Equipped with the basic knowledge of soil erodibility and slope stability, the geomorphologist is in a better position to advise the town planner on how best to make use of these terrains with serious limitations and at the same time circumvent the adverse effects of such land uses. The steep valleys of Asata and Aria rivers together with their tributaries including the steep hill slopes to the west of Enugu can be redesigned to meet the challenges of a new technology and a new age. This is especially where the green verge has not been encroached upon. These steep slopes can be stabilized by improving the vegetal cover and hence enhancing the scenic beauty. The colossal urban land use-repelling Milliken hill can be developed aesthetically for recreation. Appropriate and attractive parks and restaurants can be sited on the foot-slopes for tourism, recreation and convalescence. The aesthetic beauty of these, hitherto, topographical liabilities can be enhanced to the extent that they can become of immense tourist import.

As a matter of fact, much of the Milliken hill, including Iva Valley, falls outside Enugu Town Planning Authority area and is claimed by Udi Local Government Area. But the latent potentials (in terms of recreation and tourism) of both the hill-sides and hill-tops of the Milliken hill zone are quite much and cannot be over-stressed.

Having extensively examined the morphometric, hydrological and pedo-geomorphological factors of terrain dynamics in the process of evaluating the terrain for urban uses, we will now summarize our key findings and suggestions to enable us conclude the work.

CHAPTER 5.

CONCLUSION :

Before bringing this project to a close, it is necessary to recapitulate the major findings that emerged in the process of the investigation.

5.1. Findings:

(i) The geomorphic underpinnings of the landscape have not been identified and reflected in the spatial organization of urban land uses as can be inferred from the Master Plan for Enugu, which only gave a broad treatment of the geology of the Eastern Region and never attempted to investigate slope classes and slope-modifying processes in Enugu. A document that leaves such conspicuous lacunae should not lay claim to comprehensiveness.

(ii) The sub-soil profile in Enugu was fairly probed and the implications of the predominance of clayey materials in terms of slope instability, given the topography and rainfall characteristics, were also empirically established. In the private sector, instead of evaluating the land to discover the potentialities and limitations, economic considerations in terms of ability to finance projects largely determine the kind of use a piece of land is put to. Because of a lack of Environmental Impact Assessment and encroachment upon green verges, collapse of buildings, erosion menance, flooding and even threats of more serious landslides and tremors are now commonplace in Enugu.

(iii) Relentless urban expansion gives rise to an unprecedented increase in concrete surfaces.

Infiltration is drastically reduced, while the resultant channellized overland flow has caused serious erosion near Ogbete Market and also inundation at Abakpa Nike near the Ekulu river.

(iv), Air-photographs, topographical maps and field investigation revealed a number of topographical irregularities. The irregularities constitute terrain constraints to urban land uses. Interestingly, this investigation has found out that most of these topographical hurdles are not absolutely insurmountable. To meet the demand of our new age, our technology can be cross-matched with our wisdom and ingenuity and the result will be that these terrain liabilities will become invaluable spatial assets.

(v) Environmental geomorphology finds practical application not only in the area of urban space organization, but also in the re-organization of spatial structures and activities. Our present investigation has come up with yet another finding: the momentous CBD decongestion is a great challenge craving for appreciation and exploration by applied urban geomorphologists. In ameliorating traffic congestion in the CBD, the geomorphological dynamics of the terrain should not be overlooked. Both the expected benefits and consequences should be compared so as to minimize the negative feed back effects of the intended action.

Based on these major findings, we are making some recommendations to help those directly involved in the process of urban space planning for Enugu.

5.2 Recommendations:

The following recommendations are made:

(i) Because of obvious flaws and conspicuous lacunae in the extant Master Plan for Enugu, a more indepth areal analysis, such as land evaluation, which takes into account the morphometry, capabilities and limitations of the urban lands is highly recommended. A complete revision of the old, and the drafting of a new comprehensive Master Plan, are imperative.

(ii) A knowledge of soil mechanics is very important for the proper execution of civil engineering projects devoid of serious repercussions. The Materials and Research Laboratory of the Ministry of Works and Housing, mostly involved in carrying out sub-soil probes, should collate, summarize and make their pedological findings available to the land use planners in the form of soil series maps or soil directory.

(iii) Due to the observed high rate of induced terrain instability and violation of green verge ethics, it wwould be appropriate for the Enugu Town Planning Authority to embark upon Environmental Impact Assessment so as to retain the urban land in a dynamic equilibrium.

(iv) Apart from the anti-erosion plantation around Iva and Ekulu Valleys, much farming still goes on along the slopes of the Milliken hill irrespective of the moratorium recommended by the Master Plan to be placed on these difficult terrains that should be reserved for landscaping. Policy enforcement mechanism should therefore be revised by the Town Planning Authority to ensure that the guiding principles of urban land use allocation as dictated by both the Master Plan and urban planning ethics are followed to the letter. No group of individuals should be allowed to derail the planning process geared towards the improvement of cityscape aesthetics. A programme should be evolved to educate and enlighten urban dwellers so as to appreciate the environmental implications of their locational actions.

(v) In response to the prodigious challenge by city-hub decongestion, a programme to re-locate some important land use activities from the CBD area should be clearly spelt out and phased over a reasonable period of time. Because of lack of capital to embark upon the construction of a CBD flyover, the Task Force on Urban Road Construction and Maintenance should carry out thorough road-side land evaluation. After considering geomorphological factors, together with the benefits and consequences of alternative uses, the Task Force should embark upon a CBD road-widening where such an action is found worthwhile. This will not only enhance traffic flow but will also minimize unwanted consequences such as road-threatening gullies near the Ogbete river. Some key urban land use activities such as vehicle spare parts - sales and maintenance lines, should be re-located from Coal Camp. Such re-location will not only decongest the city-hub but will also initiate and sustain spatial development at other locations that will form growth points. These growth points should be planned and sited at the outskirts after proper land evaluation. The planning should be future-oriented in that anticipated expansion in urban activities and future population growth as well as the morphological capability of the land to accommodate such increases, should all be taken into consideration. It is not in doubt that applied geomorphology plays a vital role in the interdisciplinary field of environmental management by yielding an Environmental Impact Statement which can guide conscious Location and re-location of urban land uses devoid of serious environmental repercussions. Finally, there should be a deliberate attempt to improve the vegetal cover so as to stabilize the slopes and enhance general urban beauty.

5.3 Conclusion:

The issues incorporated into the research problem that initially motivated this study have been investigated. The significance, methodology and application of the principles of geomorphology to urban space management have been demonstrated. To maintain an equilibrium between the urban landscape and human activities, it was inductively, deductively and even logically established that an understanding of terrain dynamics is very essential.

Enugu's topographical irregularities exhibit different degrees of capabilities and limitation to urban uses. Anthropic factors leave violent and accentuating legacies on the landscape. Any meaningful land use allocation presupposes a comprehensive approach to understand both the landscape and its modifying processes. This implies a detailed land evaluation before definitive locational decisions are made. In Enugu, such an evaluation to reveal the capabilities and limitations of the land is conspicuously lacking. This lack justifies our present investigation aimed at filling the unfortunate lacunae. This study does not, however, regard its findings as final. The wide horizon of promise held by applied geomorphology in the area of urban space management is clearly a great challenge that should be further explored by future urban land use planners and analysts. We will, therefore, consider our study successful if only its findings can contribute towards erecting a convenient platform from which the envisaged exploration can be launched.

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