APPLICATION OF REMOTE SENSING TO CHANGES IN STREAM CHANNEL MORPHOLOGY A CASE STUDY OF RIVER NGELL IN BUKURU, JOS PLATEAU.

BY

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FEBRUARY, 2002.

DEDICATION

This Dissertation is humbly dedicated to my brothers and sisters.

CERTIFICATION

This is to certify that this dissertation entitled "Application of Remote sensing to changes in stream channel morphology. A case study of River Ngell", was undertaken by Istifanus John Danung (M.Tech/SSSE/648/2000/2001), in the Department of Geography of the school of science and science education. Federal University of Technology, Minna and was approved for its contribution to knowledge under the supervision of:

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ACKNOWLEDGEMENT

With thanks to God almighty for His guidance, protection, as assistance through some organization and many individuals without whom the production of this Dissertation wouldn't have been possible.

I wish to first and foremost, give my profound regard to the Head and Staff of Geography Department for the best given, and the academic excellence portrayed especially Dr. M. T. Usman whose professional competence has culminated into the high quality and standard of the study. I am also fortunate to have enjoyed the advice of Dr. H. A. Shaba Dr. Okhimanhe A. A and Mr. Salihu who have un-quantifiably taken their time to teach me how to interpret images. I wish to gratefully acknowledge the support provided by the management and staff of the Plateau State Bureau for lands, survey and Town Planning for the release of the aerial photographs and the other equipment used for this study. I wish to also express my sincere appreciation to the management and staff of National Remote Sensing Centre Jos for the use of their library and especially Mr. B. Dang and MR. T. Dashan who took time to help in this study. I am also pleased to acknowledge the University of Jos community, the staff of the library and the Department of Geography and planning who have supported me with materials for the success of this study.

This work owes its success to my parents (Mr. & Mrs. John Danung) and my causing Mr. Stephen Danung and MR. Joshua Bento for their financial assistance. I sincerely appreciate the family of Mr. Dedan who have been of great support to me from the beginning of the program to the end. I am also pleased to acknowledged the contribution of friends; Mr. Emmanuel J., Mr. Raymond S., Mr. Zechariah G., Mr. Fredrick., Mr. Danjuma D., Mr. Chris, Mr. Joe., Mr. Philips; Mr.

Samson; Mr. Paul; Dr. Amos; Mr. Walshak; Mr. Katlong; etc. To my colleagues in M.Tech class; Kenneth, Chucks, Chindaba, Benedine, Salihu etc. I very much enjoyed your company and cordial relationship exhibited throughout the course.

Finally, I express my sincere appreciation to all the authors sited in the Bibliography and many others I could not acknowledge here for the help I received in one way or the other towards the realization of this dream. My prayer is that God will reward you abundantly.

ABSTRACT

For years a number of activities take place on the Jos Plateau with little or no consideration as to the effects these will have on the environment. River N'gell has significantly served as the main drainage and source of income to the people in the study area. While the environment wear a new look year by year, due to the activities, the changes that occur in the stream channel at the receiving end is given no good concern. The rate of degradation occurring and its severity has been believed to result in shifting of channels forwards gully. Hence, the need for urgent management and monitoring of the stream system.

The main purpose of the research is to, using remotely sensed data, as a potential, quick and cost effective tool to detect and map the extent of stream channel and land-use/land-cover change over a number of years. The major data source for the study are, sets of Aerial photographs of 1962, 1976 and 1991 of Bukuru. Visual interpretation method was used to determine the changes within the study area in hectores, the magnitude of changes and percentage change. The maps and diagrams produced are expected to have immediate value for the Jos Plateau Environmental Resource Development Program. And other relevant agencies.

The study revealed that, besides natural factors, human factors has contributed immensely to the changes occurring within the stream channel. Man's activities like farming, animal grazing, deforestation mining and settlement exposes the land to high run off, erosion and deposition. The study within the 29 years (1962 - 1991) have showed a significant increase in areal extent of build – up area, river bed and rock outcrop while a decrease was observed in cultivated areas and water body. The effect of the change have reveal the alteration of the ecology of the stream system.

The study concluded that, considering the present state of the environment as bare as it is coupled with human interference with the environment as well as inadequate management, the stream channel may degrade the more.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

Rivers are a dynamic and increasingly important part of the physical environment. As a source of water, is central to many planning problems concerned with natural and altered environments. Their behaviour is of interest to a wide variety of concerns, often a focus for interdisciplinary analysis.

An important point that emerges as well look back through geologic time is that terrestrial life environments have been in constant change even as plants and animals have undergone their evolutionary development. The varied denudation processes have produced, maintained, and changed a wide variety of landforms.

The stream channel. Under geomorphic and hydrologic systems have long been subjected to radical modification either directly or indirectly by the works of man. Agriculture has altered the surface properties of areas of sub continental sizes for centuries and modified the action of running water and the water balance. Urbanization is an even more sevire alteration, seriously upsetting hydrologic processes. Engineering and mining activities, construction of highways, dams and canals not only upset the hydrologic systems but can completely destroy or submerge entire drainage networks. Invariably, mans activities and attempts to control the action of running water, produce unpredicted and undesirable side effects, some of which are physical others ecological. In which case, these changes in environmental systems are trigared by the rapid population increase.

The case of Jos plateau should not be overemphasized, as the historic event is clear as to reveal that mining activities contributed to the changes in the terrain morphology. The post mining increase in population, agricultural, urbanization, industrial construction and excavation activities just to mention a few, accelerated denudation processes.

The organizations concerned with defining developmental strategies and management of our environment must have access to a precise update inventory. At present, the basic source documents are topographic maps. Which do not reveal certain details in present changes. The accuracy unfortunately depends on the scale, date of publication and constant review. Up-to-date inventories of streams using remote sensing technique will provide decision-makers with an effective and efficient means of managing our resources. The use of Remotely sensed data involves image acquisition, processing and interpretation. Harris (1989) has enumerated some significance of remote sensing in detecting and monitoring activities. These among others include.

i. Data coverage is greatly improved over the traditional sense. Remote sensing allows data collection in remote places, ocean and ice, which other wise might be data void or have a limited data supply for reasons of accessibility.

ii. Homogeneity of data: Information collected by any Remote system are uniform. For example land sat thematic mapper uses one sensor and so provides spatial consistence data.

iii. Remote sensors allow spatially continuous data compared to the point or small area sample data commonly in conventional methods.

iv. The data form is suitable for computer processing.

v. The frequency of data collection is greatly improved using set of remote sensors.

vi. The time base of a simple pass of a satellite is very restricted; so that spatial changes in environmental variables are minimized.

vii. Measurement from Remote sensors is complementary to conventional observations of an improvement of the latter

viii. Remote sensors provide a low cost of environmental data collection, although the cost of earth resources satellite data have increased steeply. The computer compatibility of remote sensor data allows reduction in the time and manpower required to produce environmental survey information etc.

Never the less it must not be conceived that remote sensing is a panacea, however, it simply is an additional but very powerful tool to be added to those which already are in use. It provides not the solution to problems but it only provides basic information necessary for arriving at solution.

However, for this research aerial photographs of 1962, 1976 and 1991 are used for the delineation of the stream channels and mapping of land systems in the study area. The Ngell stream on the Jos Plateau the main source for the river Kaduna draining into the river Niger.

1.2 STUDY AREA

1.2.1 LOCATION

River Ngell is located north of Bukuru flowing form northeast towards the southwest on the Jos Plateau. Jos plateau is a clearly defined highland area in central Nigeria. It has an approximate area of 8,600 km^2 the majority of which

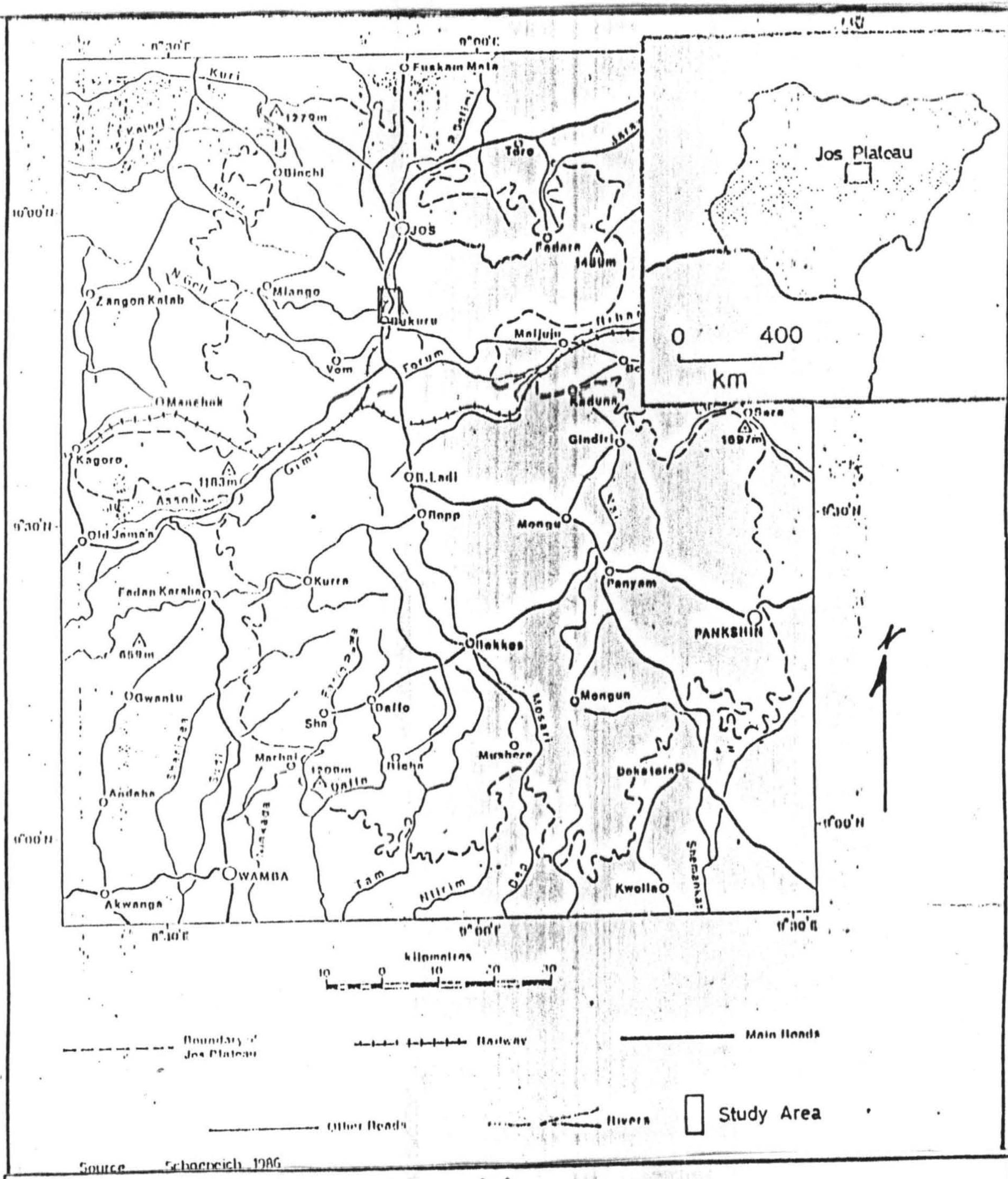
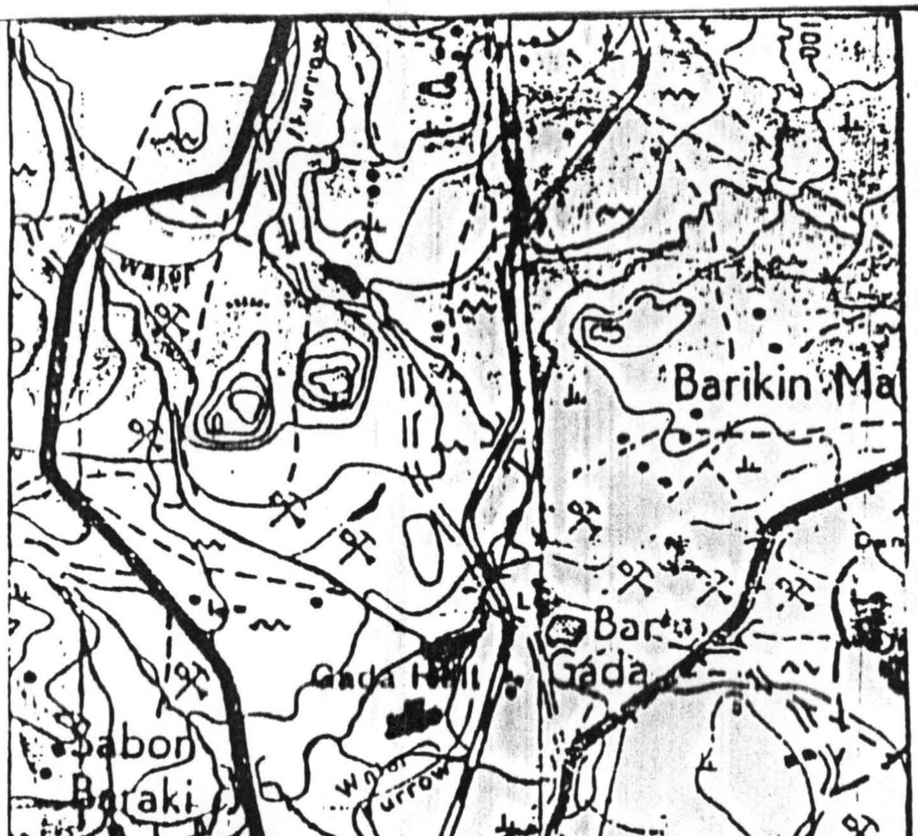


Fig 1.1 Location Map



Source 1956 Topo Map

Foot path	
Road	
Rail way	
Conture line	
Build up area	Mining
Hut	River
Water body	

0 1 km

rises above 1000m and in some places rises to 1500m above mean sea level. The Jos Plateau lies between latitudes 08^0 55' N to 10^0 11'N and longitudes 03^0 to 09^0 30'E (Fig 1.1). The study area is shown on figure 1.2.

1.2.2 TOPOGRAPHY

Generally, the Jos Plateau where River Ngell is located has a gently undulating terrain, often deeply incised by the principal rivers, which drain the Plateau in a radial pattern. It drains mostly to the Rivers Benue, Niger and lake chad. The river under study in particular flows into River Kaduna which end in River Niger. (Schoeneich et al 1993).

The main character of the surface relief of the Plateau results from the resistant cores of younger and older granite, which constitute the Plateau. The terrain is highly variable ranging from steep-sided granitic hills to flat or undulating areas of either newer basalt or sediment overlaying granite (Macleod et al 1971).

1.2.3 GEOMORPHOLOGY

The Jos Plateau is probably one of the most striking morphological features in Nigeria. It is an erosion relic since the unaffiliated younger granites are more resistant to erosion than the underlying crystalline Basement complex. In the southwest and the southeast, the Plateau terminates in a precipitous escarpment over 750m. In other places the more resistant younger granite hills rise above the general level of the Plateau.

The existence of deep weathering profiles implies weathering under a favourable set of environmental conditions, including:

i) Readily weatherable rocks

ii) Tropical humid climate, with seasonally incident rainfall of alternating wet and dry periods.

iii) Low – relief surface, which minimizes removal of the weathered mantle.

iv) Fairly long periods during which the above conditions remain stable.

Other processes of weathering on the Jos Plateau include block and granular disintegration, exfoliation, and basal sapping.

1.2.4 CLIMATE

The climate of the Jos Plateau is largely determined by: its altitude and its position across the seasonal migration of the inter-tropical convergence zone (ITCZ).

The altitude brings about its reduction in the temperature, which is the lowest in Nigeria except perhaps obudu. Average daily temperatures are about 22^0c. In particular, mean monthly temperatures are lower by 5^0 to 6^0 c ranging from 20^0 to 24^0c (Fig 1.3) the greater elevation of. Jos Plateau makes it different from, that of the surrounding plains.

The ITCZ ensures a distinct annual pattern of a dry winter season and a wet summer one. In the winter months, a very dry dusty northeasterly airflow prevails, bringing clear skies. The southwesterly flow, usually moist and that makes rain. The climate basically constitute a wet season (summer) April – September and dry season (winter) October – March with a mean annual rainfall variations somewhat throughout the Plateau but averages at approximately 1300mm $year^{-1}$ (Grame 1986).

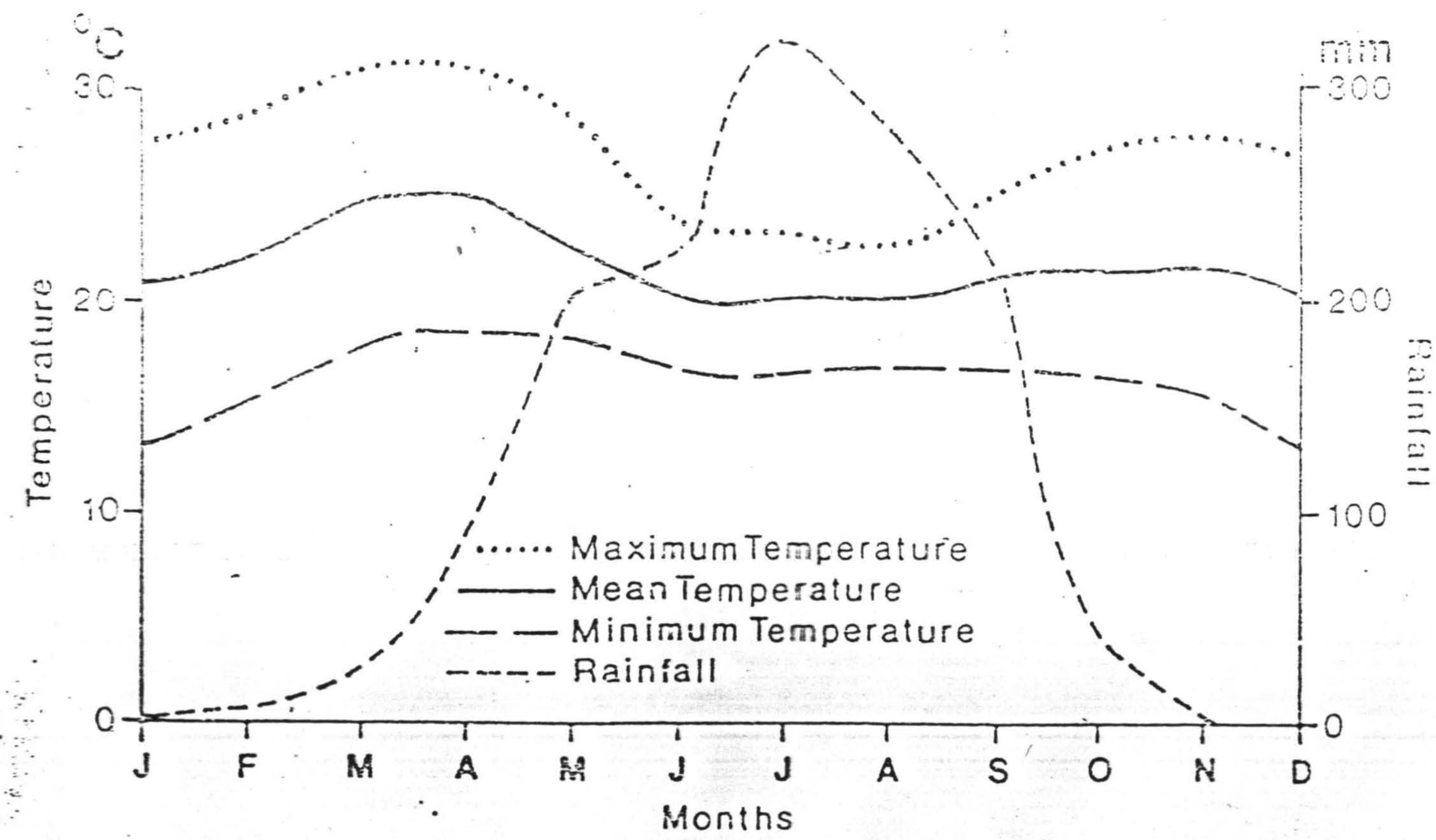


Fig 1.3 Temperature and Rainfall on the Jos Plateau

Source: Morgan (1979)

Apart form the general pattern of rainfall, the local wind system, influences the local rainfall pattern. For example, the movement of cold air from the shere hill to the surrounding valleys affect the formation of cloud and results some times in the sectional rainfall experienced in Jos and Bukuru.

The varying temperature and rainfall has important implications for certain crop cultivation and animal rearing. The climate favours cattle because it discourage tsetse files and the same area has attracted many temperate crops which are mostly grown along streams and mine ponds in the dry season.

The six-month rainy-season of the plateau is long for the latitude. The extended period has much of it in intense storms especially at end of season. Okechukwu (1986) observed that such rainfall is associated with high runoff and represents a threat to Agriculture and the environment through sheet and gully erosion. At the same time the intense rainfall can over flood the banks of rivers so that the short-term benefits form efficient drainage may outweigh the long-term ones form erosion control.

1.2.5 GEOLOGY

There are three main rack types that exist on the Plateau; the Basement complex rocks including older Granites and metamorphic rocks (gneisses and magmatites); The younger granites from which tin ore (cassiterite) originated; and the older and Newer basalts. The granites, and to a lesser extent the basalt, are quarried for construction purpose. The younger Granites consisting of heavily fractured rocks holes considerable amount of water. (Schoeneich 1986). The Plateau rocks yielded a varied landscape comprising an undulating plain of heavily weathered older Granites and metamorphic rocks into which the younger ranites and Basalts intruded. The intrusions become either granite hill with nselbergs and spectacular tors or basaltic lava flows associated with volcanic cones, the features which contribute to the seenic beauty and tourist potential of the Plateau (Adepetu, 1986 a). Rock weathering on the Plateau has produced various other useful products including kaolinite, duricrust (laterite) and quartz sand. It also released the tine over and colombite, which becomes deposited in alluvium along river channels, as did some precious stones such as amethyst, emerald and topaz. This deposition has encouraged mining along the stream channels.

1.2.6 DRAINAGE

Being the hydrographic centre of Nigeria the Jos plateau is drained by a dense network of streams, which constitute headwaters of the major rivers draining Nigeria (Fig 1.4). The catchment area of these streams are characterized by their small sizes, rugged topography, high run off and low infiltration capacity. Because of its gently undulating nature, most of the streams have relatively wide plains where they have their highest flows in August and their lowest flows in March, the period of highest flow or flood usually recede leaving behind the deposits of eroded materials like silt of varying extent. Many of the streams are perennial, especially when they originate in areas of younger Granite or basalt. These rivers are usually, strongly controlled by the prevailing joint and fracture systems and change directions frequently and abruptly. The edge of the Plateau is often marked by water falls when these streams descent the steep escarpment. However, river Ngell which starts from Rayfield is the beginning of river Kaduna on the Jos Plateau.

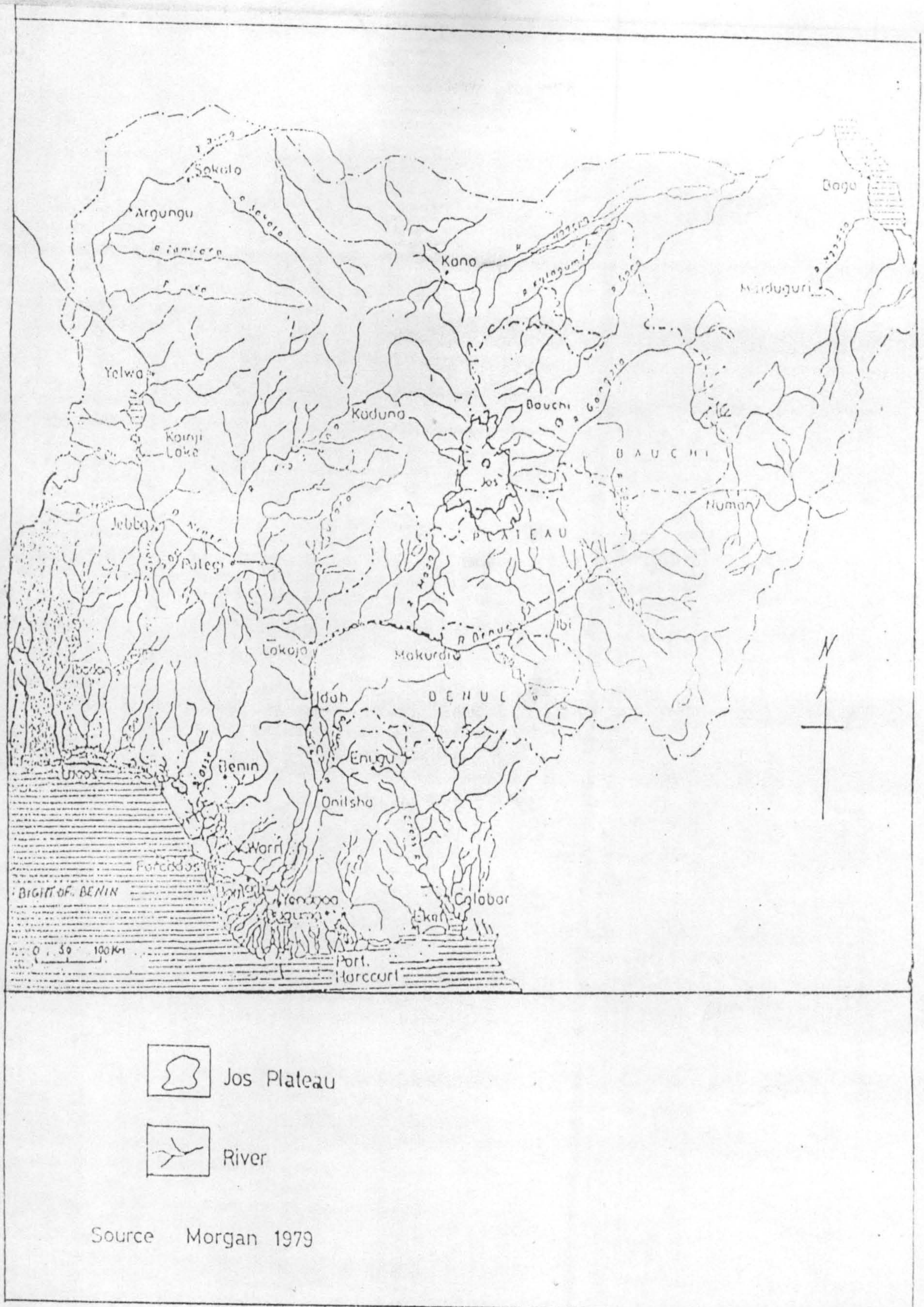


Fig 1.4 The Drainage System of Nigeria

1.2.7 SOILS

The interaction of the various state factors has produced a series of soils that reflect the particular influence of parent material and topography. Four major soil types on the Plateau in response to these factors have been identified by Hill and Racham (1978):

a) Soil on newer basalt:: A variety of soils occur on this material some, particularly on steeper slopes and foot slopes of volcanic cones, are deed well drained and well structured. On shallow slopes, soils vary in depth and are strongly mottled. All however, are more base rich than those on either the unconsolidated deposits or granite.

b) Soil on Granite: These are invariably coarse textured well-drained, shallow solids.

c) Soils on unconsolidated deposits: On interfluves soils associated with rock outcrops or lateritic Ironpan are common. These grades down slope into deeper, well to imperfectly drained strongly mottled solid often with a surface layer of yellow Aeolian loam. Down slope from rock or lateritic outcrops layers of gravel or iron stone are common in the surface horizons

d) Solid on the basement complex: The pattern and type of this soils are very similar to those developed on consolidated deposits. The principal difference is that these basement soils are usually only 1.0 to 1.5 meters deep over decomposing bedrock.

Hill and Rackhman (1973) have identified a number of soil phases and series within the above associations (designation after) F. A. O (F. A. O.)

Nevertheless, given the high intensity of rainfall and the poor vegetation cover, the prevalence of law slope angles not exceeding 7 to 10^0 does not prevent the development of extensive galley erosion other extensive office on streams in the plains of the Plateau.

1.2.8 VEGETATION

The vegetation of the Jos Plateau originally falls within the Northern Guinea savanna woodland, where as according silviconsult (1991), about $53^{O}/_{C}$ of the Jos Plateau is actively cultivated, the non-cultivated vegetation comprises woodland, $37\,^{O}/_{0}$ shrub/grass land, $6\,^{O}/_{C}$ shrubland, $4\,^{O}/_{o}$.

Years of Agricultural activities and demand for fire wood and building timber has reduced the original vegetation of the Plateau to either scattered patches on the higher peaks and less hospitable granite out crops or to the few forest reserves such as that at Naraguta and wild life park.

Deforestation is often attributed to the 20th century tin mining, although this process has actually occurred on the Plateau since before mining but minimal due to the small population. Hunter et al (1992) observed that much of the fuel wood consumed on the Plateau today is from the adjacent northern edge of the Plateau.

1.2.9 DEVELOPMENTAL GROWTH

A lot of changes have taken place on the Jos Plateau during the 20th century. These changes included: the growth and decline of large scale tin miming; urbanization and the development of a modern economy the expansion and intensification and continued deforestation, with some afforestation as observed by Phillips – Howard (1993).

A. MINING ACTIVITIES

The history of tin mining on the Jos Plateau has been well explained by Olaniyan (1986). It was by tracking down the source of the tin "straws" on sale at kano market in the early 20th century by the colonial masters that mining stated in commercial quantity. Since then, the improvement in world price and production of tin increased. Until the mid 1980^{S} when large-scale mining had virtually collapsed. Small – scale mining continued and subsequently began to thrive as the decline in the value of the Naira. Tin mining took large areas of land out of agricultural production creating 316 km^2 of mine spoil on the Jos Plateau with heaps, tailings and paddocks. Environmental changes associated with it includes: accelerated erosion (Okechukwu 1986); impacts on water storage; channel slope and stream flow regimes (Okechukwu et al 1986). Mixing of soils with sub-soils and disruption of pedogenesis (Alexander 1986) and changes in the distribution and composition of vegetation (Jumbo 1986). These are encouraged by the mining technique adopted. The mining technique used is the open cast technique. Haven created highly irregular landscape and the through, there has been some effect towards redeeming disturbed land, the majority remains in the form it was heft by the miners.

This situation has enhanced easy removal and deposition of the loosed spoils into the stream channels. Coupled with the fact that the soil which cannot support any form of vegetation is left entirely exposed to the various agents of denudation. Beside the small scale mining activities which still take place along streams is one of the major causes of the changes in the stream channels.

B. AGRICULTURE

Despite the loss of land to tin mining, forestry and urbanization, the expansion of agriculture persist on the Jos Plateau throughout the 20th century. It those operate a farming calendar sharply divided into a rainy season and a dry season such that the end of rain-base cultivation marks the beginning of dry season farming while the end of dry season farming coincides with the start of rain-fed farming. According to Adepetu (1986 b), the traditional subsistence oriented agriculture of the area was transformed by the development of tin mining and population growth. These increased the area cultivated, number of farmers and variety of crops grown, and production became more intensive and market – oriented. Such changes have been reflected recently in increased cultivation density.

A comparison of results from land use surveys in 1971 and 1990 suggests that the density of cultivation as a percentage of land cultivated, increased substantially in the 20 year period.

Rapid expansion has, however, occurred in the land used for dry season farming over the past years with about 47,000 ha (Phillips – Howard and schoercich, 1992).

Although less certain about changes in livestock production on the Jos Plateau, the environment has been attractive for cattle because of its low human population the absence of tsetse flies and maleria and unlimited grass land (Rim, 1991). These increases in virtually all aspect of agriculture has however had increasing impact on the morphology of the streams. This occur in the form of deposition of eroded soils into the stream channels or by the reduction in the rate of infiltration and increase in the rate of runoff causing more or sevire erosion on the banks and floors of the streams as well as over flooding.

C. FORESTRY

Deforestation has evidently taken place on the Jos Plateau over two millennia through activities such as burning, land clearance for cultivation, grazing and the collection of fire wood (Barkley 1986). More recently, rapid population growth, tin mining and urbanization have also contributed to this process. Thou much of the plain is virtually treeless, eucalyptus plantations wooded ravines and rocky outcrops make $40^{O}/_{C}$ of the area of the Jos Plateau covered with woodland (silviconsult, 1991).

Afforestation on the Jos Plateau began in 1917 when plantations of both indigenous and exotic species were established in trials at Naraguta in an attempt to reclaim the rapidly devastated land, due to tin mining activities, Among the species included was Eucalyptus introduced in the 1920's which immediately proved successful and was established in a few community forest Areas (C. F. A. 'S) in the 1930'S. Subsequently, the world bank Afforestation II project became operational in Plateau State. This was in an attempt to reduce the degradation effect of mining activities. However, the continuity the sustainability of these programmes were not enhanced and the majority of the land remain in the form they were kept by the miners.

D. URBAN GROWTH

The advent of commercial tin mining at the beginning of the 20^{th} century resulted in the creation of towns and establishment of a modern economy on the

Jos Plateau. The Anaguta settlement was the main-town on the Plateau. It was the headquarters of the Nigerian tin field until 1910 when the headquarters was moved to Bukuru. As tin mining continued to grow so did the number and size of th mining settlements.

The growth of the mining industry involved the construction of hundred of kilometers of roads and other activities which included excavation for construction activities. It also developed the public services and agriculture and tertiary activities, which serve the miming and the administrative centres. The decline in tin mining was replace as the economic base of the Jos Plateau and the functions of Jos continued to expand with proliferation of institutions and industrial areas.

The growth has thus increased the area of low or zero infiltration capacity and increase the efficiency or speed of water transmission in channels.

1.3 PROBLEM STATEMENT

The evident trends in recent years studies of fluvial processes is an emphasis on the broader implications of natural river channel adjustments and the longer-term geomorphologic consequences of major engineering works and land use changes. As present rates of channel changes can only be considered as a legacy of the total range of a channel's behaviour it is important to place present process responses into a spatio-temporal dimension. However, when man make changes on the land surface or its vegetation. They alter some aspect of the hydrologic cycle with some effect on the water collecting in the channel system. These effects may include the amount, timing and location of water reaching the channels thus causing erosion, channel migration, sedimentation and sometimes flooding.

The ability to recognize the possibilities of such effects depends on knowledge of the normal characteristics of channels their internal processes and their probable reaction to imposed changes by environmental changes. These changes overtime affect the channel shape and stability which is often greatest immediately downstream of the deforested, overgrazed, cultivated or urbanized areas but decreases or fades away with distance downstream. Because mans use of the land usually alters stream channel factors, land managers, environmentalists, planners, and engineers should have a special interest in how channels react to changes on the basin upstream. Even when the principles are well understood, the difficulty is that forecasting the specific nature of the streams reaction to a basins alteration is tenuous at best. Therefore the more widespread the understanding of those facts that are firmly established the more likely that handling the channel system will at least be given some thoughtful consideration.

Although, attempts have been made to improve on the various erosion and flood control measures on the Jos Plateau, less attention is given to the reaction of the streams at the receiving end. This research intend to use aerial photographs to delineate stream channel morphology and land used in the Ngell rive area in Bukuru.

Serious measures need to be taken in form of sound data base in order to succeed in managing our streams as a resource and to ensure adequate protection of our environment these tasks can be accomplished with the aid of data that can be obtained using existing maps and remote sensing data supplemented with adequate ground truth data. This study demonstrate or assess the significance of aerial photograph interpretation to monitor the stream channel changes at Ngell river over the 1962, 1976 and 1991 periods and by careful examination of the dynamic nature of the environment. With its relative importance and advantages, it is expected that similar investigations could be used elsewhere both nationally and at international spheres using aerial photographs. This work will serve as a tool for further evaluation and awareness of the changes on our stream systems. Further research may be carried on the effects of changes on the ecology, and other potentials of streams as well, to enable the ministry of water resources and other land developers improve on their technique on the use of lands and streams.

1.4 AIM AND OBJECTIVES

The aim of this research is to evaluate using sequential aerial photographs the changes in stream channel morphology and the probable man-made environmental changes on the River Ngell.

The specific objectives thus include:

1. To assess the lateral and vertical changes that might have occurred in the stream with relation to the changes in the environment
2. To assess the time – step changes that have occurred in the stream channel and the immediate environment.
3. To make a composite description of the channel geometry.

1.5 JUSTIFICATION OF THE STUDY

The primary evidence for change in fluvial systems comes from morphologic remnants such as abandoned channels and from sediment sequences which reveal a complex and usually incomplete record of changing conditions. Direct observations of streams have reveal changes at specific location over period of time (Knighton, 1972). However, direct observations are seldom maintained for more than a decade, topographical maps have not been produced and the changes which we expect might have occurred overtime is still not uncovered. Even at the scale of topographic maps, they may fail to indicate a wide range of erosional and depositional events to be representative of a long-term change. While the main value of short-term records, which lies in establishing relationships between applied stresses and stream channel response, and in evaluating the significance of individual extreme events.

Records from history including documents, sequential survey notes, maps, aerial photographs and other remotely sensed data can provide valuable information about channel and related changes. Thus direct comparisons of channels at different times using Remotely sensed data will be the best for decision makers. The advent of satellite raises the possibility of repeated large-scale observations made of river channels but as yet applications are few. The application of this tool in terrestrial inventory will be beneficial for water planning, reduction of flood losses, land cover monitoring and other planning purposes.

Aerial photographs have been proposed for this study because it offers a unique synoptic view of the environment and can be observed so that prolonged and rapid changes can be assessed with ease and with accuracy. Furthermore, the choice of the Ngell river in Bukuru was based on the magnitude of environmental changes taking place in the area and the need for awareness and resource information.

1.6 SCOPE AND LIMITATIONS

The interest of this research is to mainly determine by delineation the extent and rate of stream channel and land cover changes. However, this research found it extremely difficult to obtain images and other remote sensing tools for work. Hence a relatively small area of stream in Bukuru was selected for identification and delineation of the stream morphology and land use.

Another constrain in the research has to do with inadequate published literature especially using remote sensing in both field and area of study. However for the purpose of this research, aerial photographs of 1962, 1976 and 1991; topographic maps and computer facilities at the National centre for remote sensing (NCRS) Jos is used to accomplish the tasks set.

1.7 ASSUMPTIONS

This study was based on the following assumptions

a. Aerial photographs has capabilities and at the very least will provide a visual clue for identification of land systems for defining stream channels, and the land uses.

b. Land use / land cover changes have some form of indirect effect on the stream channel.

c. Mans direct impact in the form of mining activities, agriculture etc. are sources of change in stream channel.

With these assumptions, attempts were made on achieving the set objectives using remote sensing technique in stream delineation and change analysis as reviewed in the following chapter.

1.8 EXPECTED OUTPUT OF THE STUDY

The expected output of the study include

i) Sequential maps of the study area revealing the land-use /land-cover and the Morphology of River Ngell and environs. For 1962, 1976 and 1991.

ii) The rate of change in land use/land-cover and stream morphology.

iii) Good understanding of the geometry of the terrain.

However, the expected results listed above will be incomplete and baseless without a review of various concepts, tools and literature of related applications to the present one in various locations. The chapter that follows therefore takes a thorough look at the various related literatures and applications.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 THE CONCEPT OF STREAM CHANNEL

Before beginning, the definitions, of the term streams and river should be clarified. Since dictionaries make little distinction between the words "river" and stream" Although river is associated with "larger" and stream with "smaller" as general terms. Colloquially one is up a creek but send down the river, implying relative sizes. This relative definition will be retained but the word "stream" will be used as a generic term for flowing water.

Knighton (1993) find that the definition of stream channel is difficult since there is discrepancies particularly in the length properties of head water streams. knighton further explain that consistent and objective criteria for stream channel definition are needed if comparisons of results from different sources are to be meaningful. However, strahler and strahler (1983) have define stream channel as a narrow trough shaped by the forces of flowing water to be highly effective in moving the quantities of water and sediment supplied to the stream, may be as narrow that a person can jump across them, or as wide as 1.5km for a great river such as the Mississippi. On the other hand Davis (1899) building upon Gilberts ideas developed the concept that stream rather early in the geomorphic cycle attains that slope or gradient which under existing conditions of discharge and channel characteristics is just sufficient for transportation of its loads, such a stream is called graded stream or at grade.

The character of a stream channel is thus base on its ability and quantity of material carried along. A stream channel is confined within a definite channel incised in to the surface of the land, with a distinctive pattern and cross section which varies from source to mouth and changes its form as the drainage system develops (Monkhouse 1990). In other to introduce some definitiveness, Monkhouse cited that a distinctive if somewhat obvious terminology has been developed mainly by civil engineers. the depth and width of the water in streams measure from bank to bank are not always easy to specify, since unless the stream has been regularized for flood control navigation or power production the cross-section is really distinct rectangle.

2.2 STREAM CHANNEL MORPHOLOGY.

The origin of channels are in variety of ways related partly to the history of the land surface on which they develop. Knighton (1993) observed that we cannot overemphasize the fact that initial channels which existed in forms of rills are maintained and enlarged to form a permanent channel. Water reaching the ground surface can follow several parts on its way down slope. where the maximum rate of absorption exceeds the rate of receipt, water infiltrates the surface and either moves down word to replenish the ground water reservoirs or flows laterally as through flow. Bunting (1961) asserted that through flow may diffuse when water flows through the matrix of the soil.

A stream is an emphasis of the fact of flow. However, Davis (1899) from his study of the development of streams observed that streams can be classified as youthful, mature and old according to their stage of development in the cycle of erosion and as consequent, subsequent and obsequent according to their hierarchical position in the evolutionary sequence of drainage networks. Both are time base. Thus, the development of a stream can be monitor using remote sensing technique which gives a synoptic coverage, its expansion and depth which can also be determined. This is best with aerial photographs.

According to Nancy et al (1993) it is importance to be aware of the hydrological, geological, morphological and vegetation setting of a stream while climate has been observed to be the major controlling factor in stream flow pattern and shaping of landforms. Curran (1985) observed the importance of the applications of aerial photographs to the study of geology, soil and hydrology in relation to drainage in UK National Nature Reserve. However, Cummins, (1986) noted that adjustment of a stream to its climate and geology takes place continuously causing changes in slope, rate of sediment transport and channel configuration. The (1980) aerial survey of the Lox Yeo River shows the active participation of soil erosion graduating small channels into large rivers (Curran 1985). Geoffry (1983) from his study of gravitational path of water reveal that, water flowing down a slope under gravity will follow the path of least resistance. Thus, flow within a channel provides a more efficient path than flow as a sheet over a slope. The efficiency of a channel may be expected to change downstream because the hydraulic radius of the stream is significantly influenced by the size of the channel.

The morphology of a stream may be described by its dimensions in plan and in cross section. The character produced by flowing water is related to the "power of the stream to remove and transport sediment- a function of discharge and slope-and to the quantity and size of material supplied. Streams however, also transport large quantities of sediment and it is the coarser material carried as bed-load which has the dominant effect upon the channel dimensions of the channel but do not uniquely define cross-sectional shape (Hey, 1978). Pick up (1967a) observed that though the width – depth ratio remains the most commonly used index of channel shape, it is not always the most appropriate. Rivers carrying large bed-loads commonly exhibit a braided platform within the river channel split into several separate sub-channels. Rivers carrying smaller amounts of bed material load will commonly have a well defined, straight or meandering platform, and a narrower and deeper cross –section with a higher hydraulic radius (Geoffrey 1983). Meanders were monitored using aerial photographs in the Beatton Rivers by Hickin (1977) and discovered that ridges formed depend on the stream bed cloth material.

The morphology of a stream channel is directly related to the discharges and sediment loads experienced under stable climatic and drainage basin conditions such that balance exists between the fluvial processes and channel form. Geoffrey as well observed that the dominant discharge with which the channel form is in "equilibrium" has been a major topic for research because of its obvious importance for stream channel. Deposition of sediments along the sides of a channel typically occurs up to a particular elevation and it is this process that serve to maintain the stream channel in a state of quasi-equilibrium.

Leonardor and MacCurdy, (1938) noted that the winding which rivers make through their valleys known as meanders cause the bank to form curves, and in the course of time seek out the whole valley. Channel curvature have an important effect on the rate of channel migration from a detailed study of bars developed over 250 years along the beatton, river in British Columbia, Hickin and Nanson (1975) demonstrated that the rate of Migration was at a maximum. However, migration occurs at widely different rates which vary directly with discharge and indirectly with bank resistance according to Daniel (1971). The evidence available from studies of streams subject to high flood discharges or altered hydrologic conditions indicates that cross-sectional form is one of the most adjustable components of channel geometry, at least in the width dimension. Burkham's (1972) study of historical changes along the Gila River in Arizona shows that between 1905 and 1917, a series of large winter floods carrying low sediment loads significantly widened the channel from about 90m to 610m. These were easy to detect and relate using aerial photographs were special instrument are also use to measure the depth of streams.

Bed-forms range from riffle-pool features in gravel-bed streams to dune forms in sand-bed streams. Typical bed-form indices for dunes are described by Nordin and Richardson (1968) that the statistical variation of these indices makes their estimation hazardous.

In studies for which the stream channel is important, one must have adequately detailed maps or special field surveys and now better with aerial photographs which will satisfactorily define the information needed over extensive areas and delineation of stream channel morphology.

2.3 STREAM CHANNEL MAPPING.

Stream channel management involves many discipline of importance to managers is evaluation of surface water maps for water sources and the design and operation of resource projects.

Measurements of stream flow and stage provide the basis for most analysis but there are many other valuable data sources such as field surveys and aerial photography. Many maps are derived from other information such as those for water surplus which are computed form climatological measurements and assumed soil characteristics. However, stream channels have been delineated using remotely sensed data to inform the changes in the configuration of the channels, vegetation and other works in the stream. The state of surveys was a major collaborative effort of several water resource agencies to conduct an inventory of all the rivers in Victoria, Austrialia (Mitchell, 1990). The study identified the current status of the streams; additionally, it provided base line data for future monitoring work.

Horton (1945) attempted a description and mapping of stream pattern using aerial photographs. He inspected from the air to see if reaches were sufficiently responsible for channel configuration. Ceplesha 1965 recommends the use of Horton's (1945) system of stream orders as a criterion as to what streams should appear on maps. By a suitable combination of stream symbols and colour, stream flow properties such as the magnitude of the average discharge, the permanence of flow, the seasonal distribution of stream flow, the dominant source of water, duration of ice cover in cold climates and salinity can be shown in broad classes without using more map space than ordinarily required for the stream pattern.

Because of the linear nature of stream flow point and linear symbols are the simplest methods of depiction. Maps which identify the seasonal flow and its extremes at the gauging station are fundamental and of utility not only in assessing conditions at intermediate locations but also in determining areas of data deficiency. Hickin (1977) have traced the pattern of meander development along the Beatton River in British Columbia over 250 years by mapping point bar ridges formed during bend migration and defining erosion path lines as orthogonal through the ridge system using a 35mm photograph.

Runoff is an integrated value representative of contributing area and for purposes such as (Liebscher 1970) has used climatic data to obtain directly supplementary estimates of runoff. Using measured and estimated values he obtained the depth of runoff. The area extent of flooding is often depicted as isolines on a mosaic prepared from aerial photographs. In more formal mapping, the flooded areas are identified by different types of aerial symbols. Shading or colour tints, according to their probability of occurrence. One can reasonably expert better results and more accurate delineation for the morphology of stream channels with aerial photographs with high resolution.

2.4 REMOTE SENSING AS A TOOL

The term "remote sensing" was first coined in 1960. It simply referred to the observation and measurement of an object without touching it. Since that data remote sensing has taken discipline dependent meanings in the environmental sciences in which geography, geology forestry, engineering agriculture etc are subject to. It is referred to as" The use of electromagnetic radiation sensors to record images of the environment which can be interpreted to yield useful information "(Curran, 1985)". Andrew et al (1990) see remote sensing to include all representations of the Earths surface generated without direct human measurement, regardless of the type of imagery (visible spectrum, thermal infrared) or radar waveband). However short (1982) defines it as "the acquisition of data and derivative information about objects or materials located at the earths surface or its atmosphere by a device separated form it".

Information about the earths surface is obtained from sensors on the different platforms in space known as satellites orbiting the platforms carry the sensors which scan or image the objects (target) through electromagnetic waves and they eventually convey information in form of photographic imageries. Remote sensing gain interest when the first earth resources technology satellite (ERTS - 1) now LANDSAT-1 was lunched in July 1972. Today LANDSAT 7 is in orbit with 8 spectral bands. Resolution ranging from 15 to 30 meters and an instantaneous field of view (I FOV) of 185 x 185 kilometres. It provides prospects of better imagery with fine resolution more frequent coverage, faster processing etc. however this is an optional sensor. It is affected by some atmospheric conditions.

The advent of radar sensors today is termed the best sensor as it is operational in all weather. Radar operate at Microwave frequencies and the higher radio frequencies. Sensors like the synthetic aperture radar (SAR) were developed to take care of the losses by the optical sensor. It has a spatial resolution of about 10metres and a swath width of 100km. However the increasing important emphasis placed on resolution has brought other new sensor of better resolution (Spatial and temporal).

The conventional aerial cameras as used for this research has lens and operate in the visible part of the spectrum and the near infrared and ultraviolet and can record senses very nearly as man sees them. Photographic systems being relatively simple, can be made to rigorous standards and can be employed to measure accurately the locations shapes, and sizes of objects stereoscopic photography, in which the same scene is recorded simultaneously from two slightly different angles making it possible to measure in three dimensions.

For the fact that the satellite sensors are gaining more recognition, aerial photography remain the most widely used type of remotely sensed data (Curran 1985). It has also presented developing nations like Nigeria with an opportunity that was not there before. Estes, et al (1980) stated that, "remote sensing is a reality whose time has come. It is too powerful a tool to be ignored in terms of both its information potential and the logic implicit in the reasoning processes employed to analyze the data. We predict it could change our perception, our methods of data analysis our models and our paradigms".

Sensing with aerial photography has six unique characteristics.

1. Availability: aerial photographs are readily available at a range of scales for much of the world.
2. Economy: aerial photographs are cheaper than field surveys and are often cheaper and more accurate than maps for many countries of the world.
3. Synoptic New point: they enable the detection of small features and spatial relationships that would not be evident on the ground.
4. Time Freezing Ability: an aerial photography is a record of the earths surface at one point in time and can therefore be used as an historical record.
5. Spectral and spatial resolution: aerial photographs are sensitive to radiation in waved lengths that are outside of the spectral sensitivity range of the human eye as they can sense both ultra-violet (0.3 – 0.4um) and dear infrared (0.7-0.9um) radiation. They can also be sensitive to objects outside the spatial resolving power of the human eye.
6. The dimensional perspective: a stereoscopic view of the earths surface can be created and measured both horizontally and vertically, a characteristics that is lacking for the majority of remotely sensed images.
7. Repetitive coverage: a repeated coverage can be made to provide the opportunity to monitor dynamic phenomena such as changes in vegetation cover hydrology and landuse.

The choice of aerial photography as a proper tool for the preliminary assessment of the terrain, stream channel mapping and delineation of the morphological features stemmed form the above characteristics, its relatively easy accessibility and generalization to other parts of the world.

2.5. MAPPING STREAM CHANNEL MORPHOLOGY USING REMOTE SENSING

Nancy et al noted that stream channel patterns are dynamic and aerial survey and satellite image analysis methods have contributed to the ability of hydrologist to monitor catchment changes. The power of remote sensing for detailed analysis of low relief erosion topography is enormous, but little studies, allowing classification of features and possibly mapping of spatial concentration of suspended solids and flow lines over inundated areas. Doornkamp (1993) demonstrates this potential using sequential aerial photographs. The analysis of change using their sources depends heavily on repeat imagery. In USA; the availability of repeat imagery ground based photography has been reviewed. Anderson and Culver ([illegible], 1980) used evidence form aerial and ground photographs taken between 1946 and 1977 to identify how a natural channel has adjusted to a major flood in 1952 and during the posts-flood period of lower discharges. Satellite photographs in recent years raised the possibility of repeated large-scale observations of stream channels but as yet few applications. However, on the other hand, Hamilton et al (1992) using Radar imagery demonstrated potential on the Amazon and Orinoco flood plain. Their measurement indicated that flooded topographic cons have statistical self-similarity with respect to area implying that relief on the flood plain displays fractal characteristics.

Dury 1976 has seen the potential of remote sensing to studying the reminants of former channels. Evident from aerial photographs reveal to him that when frequently used in reconstructing stream histories and, especially where they take the form of abandoned meanders, estimates of previous discharges can be made based upon contemporary. Wavelength-discharge relationships. Plats et al (1987) have observed the significance of baseline photographs when compared with monitoring photographs taken five to ten years later to evaluate changes, either natural or due to management effect.

Direct comparisons of channels at different times are readily made using aerial photograph although most early photographs were not taken for that purpose, various photographs taken of the Platte river in Nebraska show the spectacular reductions in channel width which have resulted form river regulation schemes since 1900 (Williams, 1978). According to rice (1989), consistent recording of small head streams is crucial to proper ordering of a drainage net, and many geomorphologists have undertaken their own survey using remote sensing technique. Rich still noted that aerial photographs are important in monitoring channel migration. He noted that the migration is clearly attested on many flood plains by the numerous meander surolls visible on aerial photographs.

As noted above several studies have been conducted on stream channels not only using conventional technologies but also through the use of remotely sensed data on the international scene. These studies have attained high level of sophistication, which is yet to be matched by the local studies. Nigeria has a national coverage of aerial photography obtained in the past 50 to 60 years, having different dates of acquisition and scales but today space sensing permit an adequate triplet data using satellite image, air photographs and ground control. These have made this research relevant in closing the gaps in channel mapping and analysis.

Some other closely related studies include the following. The use of false colour near infrared film in a variety of applications, which include mapping of soil (Frenziee, et al (1973). In recent years too, this kind of film has been applied to mapping the relatively inaccessible wetland zone great successes by Gammon and Carter (1979).

The management of our stream channels is important since it is regarded as having national and economic values. A sound database is greatly needed if we need to successfully manage these resources. The advent of remote sensing has broadened our view of the natural resources. It has therefore brought a new line of research integrating GIS into remote sensing. Integration of some up-to-date information is useful in monitoring and mapping of earth phenomena, as will be applied in this study using visual and computer assisted methods. This surely will fill or reduce the gaps created by the lack of local studies in channel morphology.

2.6 LANDUSE/LANCOVER CHANGE AND STREAM HYDROLOGY

Surface runoff has important effects on erosion and the transport of materials. Water moves materials either in a dissolved state or as suspended particles, and surface water can dislodge soil and rocks particles on impact. The amount of surface water runoff from the water shade or drainage basin and the amount of sediment carried vary significantly. This variation may result from the geologic physiographic, climatic, biologic and land-use characteristics of the particular drainage basin together with variation of these factors which affect infiltration and runoff with time (Keller 1992), although erosion may be affected by unconcentrated runoff as well as by concentration. Horton (1945) concluded that erosion by sheet wash will not begin until the available erosion force exceeds the resistance of the soil to erosion.

The principal factors in the surface water runoff and sedimentation include rock and soil type, degree of weathering and structural characteristics of the soil and rock. Fine grained dense day soils and exposed rock type generally alow little infiltration of water, conversely sandy and gravelly soils well fractured rocks, and soluble rocks absorb a large amount of precipitation and have less surface runoff (Keller 1992).

Physiographic factors that affect runoff and sediment transport include climate, shape of the drainage basin, relief and slope characteristic, the basin's orientation to prevailing storms and drainage pattern. Keller have observed that climatic factors that influence runoff and stream sedimentation include the type of precipitation that occurs, the intensity the duration and storms. In general, Knighton (1993) associates discharge to geology of the area. The effect of shape on runoff and sedimentation is its role in governing the rate at which water is supplied to the main stream as well as the materials carried and deposited (Keller 1992).

Biological factors are capable of affecting stream flow in general ways. Vegetal cover decreases runoff by interception and evaporation Animals affected the streams by removing vegetal cover exposing the land to erosion while the soil organism alter the physical structure and allow greater percolation (Monkhouse 1990).

Bronowski (1973) have suggested that "man is not a figure in the landscape, he is a shaper of the landscape". Bronowski further stress from the history of man that directly altered character of streams and drainage basins are mans handwork. Stream channels have been straightened and deepened to aid navigation and for flood control and land-use changes involving agriculture, forestry, urbanization and water supply development have markedly altered the pattern of water and sediment movement (Geoffrey 1983). According to Geoffrey the form of the stream channel is adjusted to the fluvial processes so that the numerous changes that have taken place during settlement and allied land-sue change and industrialization resulted in changes of landform. The most intensive change in land-use would be urbanization, which would bring large increase in runoff from urban surfaces and storm water sewers (Marsh 1991).

Gregory and Madew (1982) conducted a study of runoff changes due to land clearing, said such changes gives rise to enlarged and or entrenched channels. They further suggested that urbanization can increase peak flows and enlarge channels.

Davies et al (1988) discovered in a study on a river system in Tasmania, Australia that a near-doubling in the amount of cleared land led to an increase in the mean annual flow but to decrease in the inter annual variability.

The above factors produce a wide spatial variation in the response characteristics streams channel to major floods (Knighton 1973). Knighton express further more that the overall extent to which channel morphology reflects the influence of extremes can not readily be assessed but rivers do seem to have long memories for past flood events.

However, the capability of aerial photographs in landuse mapping is an important tool in the sequential change detection in this research.

2.7 INFERENCES FROM STUDIES AND LITERATURE REVIEW

It is clear from the literatures reviewed that aerial photograph applications has long been in use for study of change detection and mapping both developed and undeveloped worlds.

However, applications in Nigeria has been on urban development. The cities that have benefited from this kind of study in Nigeria include Lagos and Ibadan according to Areola (1986) these are the two cities that have been studied and have references in Nigeria.

This thus explain that little published research work have been carried in Nigeria using sequential aerial photographs. Most of which were in other developing countries. Example is the Nile River in Africa. However, from the review the potential of remote sensing to monitoring changes can never be over emphasized.

River Ngell even though small is similarly important as rates of landuse change and other local activities in the rivers alter the morphology. As a result of these alteration they deserved regular or periodic assessment.

From the review, the remotely sensed data used for most of these studies are aerial photographs probably due to its availability and resolution. The following chapter thus considers this materials or remotely sensed data as the primary data for the research and other secondary data and information acquisition techniques in order to achieve the aim and objectives of the research.

CHAPTER THREE

3.0 METHODOLOGY

The methodology adopted involves two major interdependent component data acquisition and data handling or procedure for analysis. The data acquisition component deals with data source, development of classification of land-use/land cover (with emphasis on stream channel morphology), data interpretation, mapping and field checking. Data handling on the other hand, involves the conversion of the data into computer acceptable forms and appropriate computer manipulations of the data.

3.1 DATA ACQUISITION

The primary data source for this study is comprised of three sets of sequential aerial photographs of Bukuru (Jos Plateau) for 1962, 1976 and 1991. However, every other available data whether maps, reports, statistics or ground base photographs were obtained and examined in order to complement and acquaint one with the area. Other valuable information obtained about the study area even though old included vegetation types, soils, settlement patterns drainage, mining, agriculture, geology, topography etc. This was possible using facilities in the university library and geography department, the state ministry of lands survey and town planning, federal mines and power and the National remote sensing centre all in Jos.

However, there is a tendency particularly in remote sensing applications to ignore the potentials of other contemporary data sources, and to carry out interpretation using only aerial photographs obtained. Fig. 3.1 is a block chart of a

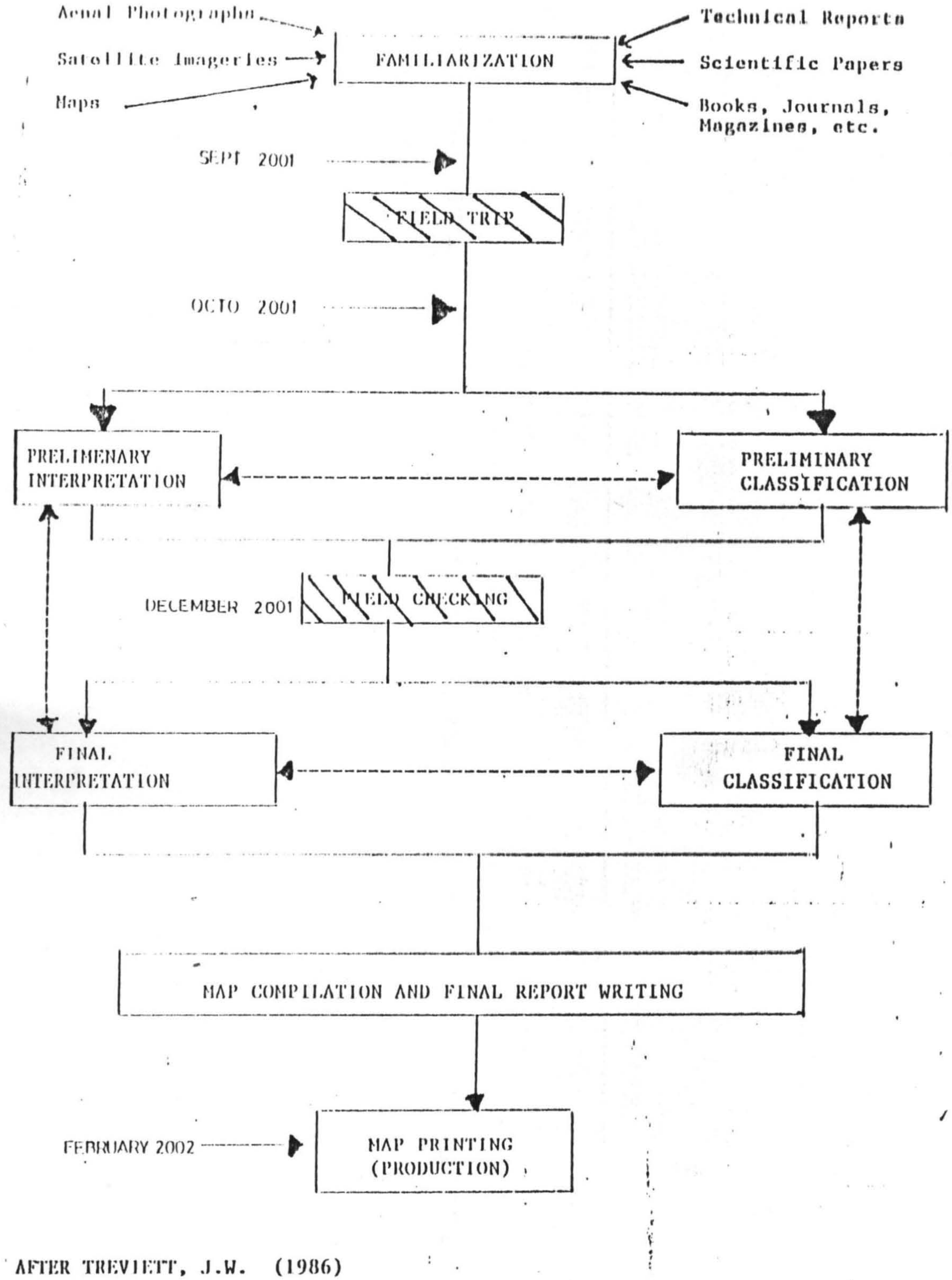


Fig 3.1 Research Operational Flow Diagram

typical survey by Trevett, J.W (1986) which will be adopted in this studies and the basic characteristics of the data sources are also illustrated on table 3.1.

Throughout the interpretation, resources were made to these data bases in order to clarify points of doubt or to help in the interpretation. The flow diagram also shows that pre-interpretation field reconnaissance was carried out and study of the available data sources enable survey journeys to be planned to the best advantage and identification of areas where supplementary field studies may be required was done.

TABLE 3.1 DATA SOURCE AND THEIR CHARACTERISTICS

S/No.	Type Data	Data	Scale	Identification	Acquisition source
1.	Aerial photo	1962	1:10,000	Panchromatic B $ W	Plateau State ministry of lands and survey.
2.	Aerial photo	1976	1:12,000	Panchromatic Black and white	Plateau State ministry of lands and survey.
3.	Aerial photo	1991	1:8,000	Panchromatic Black and white	Plateau State ministry of lands and survey.
4.	Topographic Map	1956	1:50,000	Noragota N.E sheet 168	Federal mine and power Jos.
5.	Field work	10/2001	-	Observation	Observation
6.	Field check	12/02001	-	Observation	Observation

3.2 REMOTE SENSING DATA

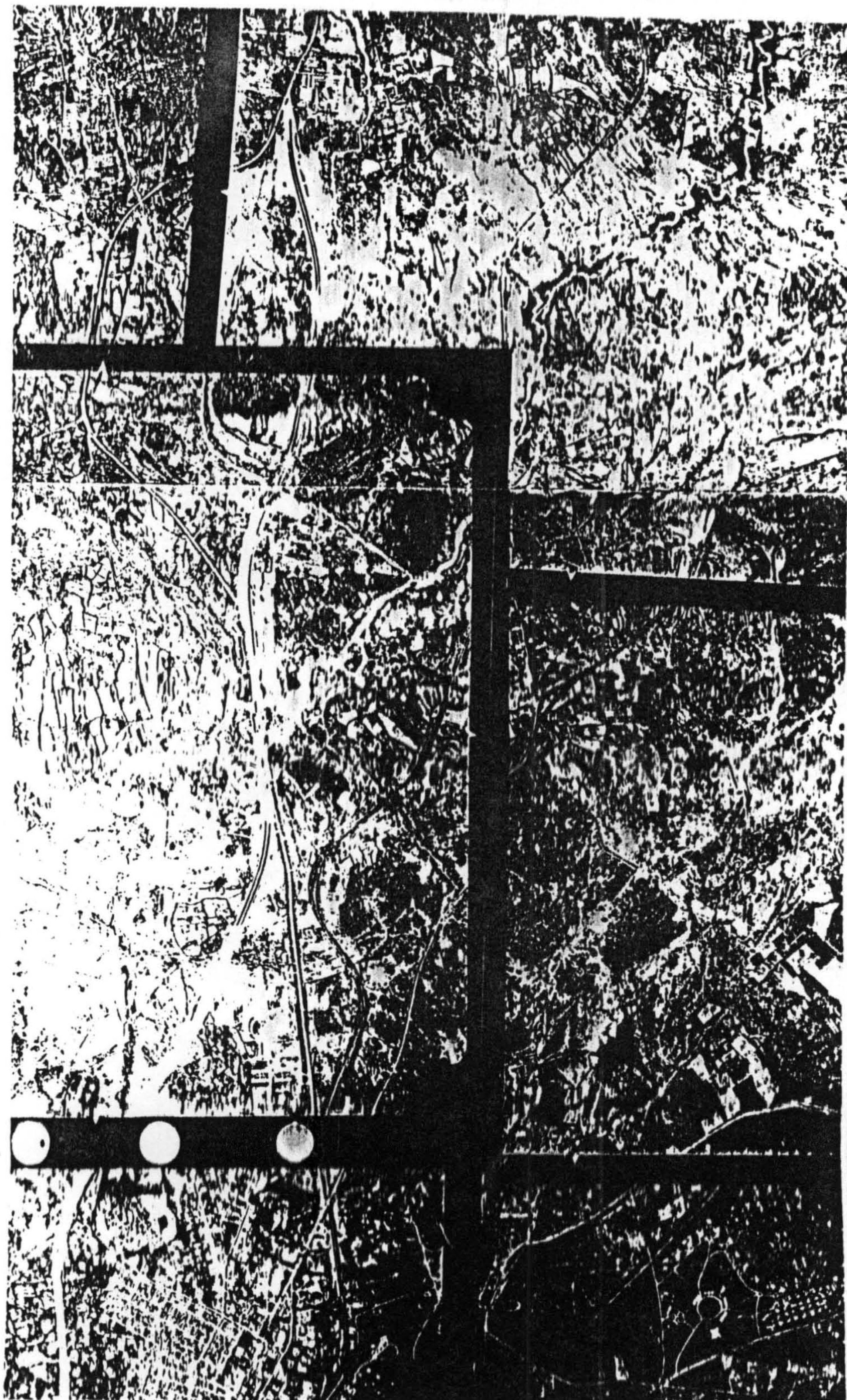
Aerial photographs constituted the primary source of data for this research. Aerial photographs for 1962 at a scale of 1:10,000; 1976 (1:12, 000) and 1991 (1:8,000). The decision to use aerial photographs is based on the coverage (vis-à-vis the size of the stream) the resolution particularly for the study of channel morphology, the availability or accessibility to this data and the ease in processing the data. However, there are constrains imposed by the characteristic of the photographs which include; the differences in scale precluded a direct comparison of the sequential photographs. The minimum mapping unit as well as the level of details was influenced by the difference in scale. Even though greater details could be interpreted from the 1991 photographs, the level of details had to be synchronized with that available in the 1962 and 1976 photographs. However, the photographs cover the study area and it was cloud free and of high quality. This was best for detail and good interpretation (fig. 3.2, 3.3, 3.4).

3.3 FIELD DATA

Efforts were made to collect ground data through field observation to complement the already acquired data since available ground data or information for this area is limited. The field observation was supported by ground photographs. Sampling of features in the stream channel with reference to the aerial photographs was difficult to perform due to the changes taking place in the stream. However, some other feature like rock out crops were used for geo-positioning. Attempts were made to study the activities taking place in and around the stream channel. Of significant importance was the daming and channelization

Source Lands & Survey Jos

Fig 3 2 Mosaic: Aerial Photographs of study Area in Bukuru (1962)



Source Lands & Survey Jos

Fig 3 3 Mosaic: Aerial Photographs of study Area in Bukuru (1976)

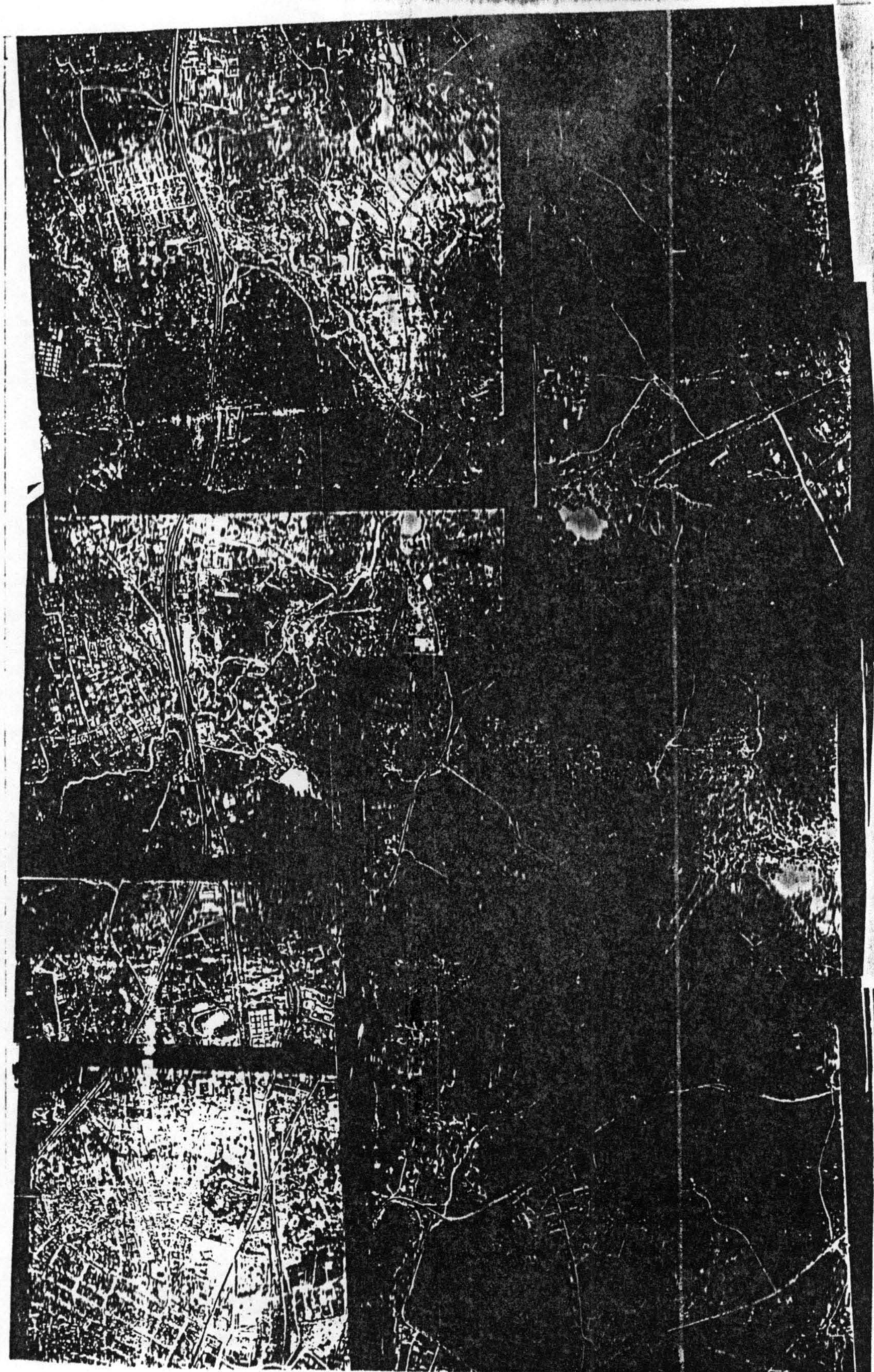


Fig3.4 Mosaic Aerial Photographs of study Area in Bukuru (1991)

Source Lands & Survey Jos

of the stream water at specific points. Others include agriculture, mining, excavation and construction activities.

3.4. INSTRUMENTATION AND PROCEDURE FOR ANALYSIS

Research that is remote sensing application based is instrument dependent. The nature, type and accuracy of the interpreted data depends to some extent on the type of instrument used. In this research, the material / instrument used include:

A *Aerial photographs of Bukuru*

Topographic map (1:50,000)

Transparent overlays .

B *Light table*

Mirror stereos copes

Parallel bar

Computer (Pentium III)

Digitizer (A_0 Size)

Colour printer

C. *ILWIS 2.1*

Arc view GIS 3.

Microsoft word,

Microsoft excel etc.

However, it is important to note that;

i. Visual interpretation of the entire aerial photographs were carried out using sets of mirror and pocket stereoscopes, magnifying glasses, etc. available at the plateau State ministry of lands and survey and the national centre for remote sensing all in Jos.

ii. Pentium III computer, with arc view GIS Microsoft Excel of the National centre for remote sensing Jos which has statistical and automatic cartographic components were used.

iii. Various complementary cartographic bar, digitizing board and transparent overlays were used at the National centre for remote sensing and the plateau state ministry of lands and survey all in Jos.

iv. Heighten measurements were carried out using the parallax bar and a pair of mirror stereoscope. This is used to determine the elevation of points for stream cross section. He heightens is determined from the equation below:

$$Dh = \frac{\Delta P \times (H - hr)}{\Delta p + b}$$

Where: Δh; is the difference in height

Δp; is the difference in parallel

hr; is the height above datum of a reference point (average datum)

H; is flight height above datum

b; is photo base (in mm).

The main emphasis in this research is on the development of an efficient classification and change detection of stream morphology as it is influenced by the change in environmental factors. The mapping is based essentially on visual interpretation of the photographs. The procedure followed here include the following;

a. Documentation of available terrain classification scheme for similar environment.

b. Compilation of a preliminary terrain classification scheme.

c. Creation of base map from topographic map sheet.

d. Interpretation of aerial photography's

e. Field work

f. Transfer of interpreted data to base map.

g. Field checking

h. Adjustment of the classification scheme and final interpretation and mapping.

i. Cartographic activities

j. Analysis of the final data.

3.5 INTERPRETATION

From the selected data; three / sets of aerial photographs, topographic map sheet covering the study area were used for base map creation. However, the three basic steps were followed. These steps are

1. Examination / detection
2. Recognition and identification
3. Field checking.
4. Classification.

3.5.1. EXAMINATION AND DETECTION

This is the very first phase in image interpretation. A general examination of the photographs was made to establish the general characteristics of the area covered. In this way, a better knowledge of the area was acquired. Thee selection of significant features from a varied spectrum of features was made where the general patterns of relief, vegetation and cultural developments and the morphology of the stream channel as the core point of study were all established and the most significant features noted. Some peculiar element of the data aid in better visual identification of features. They include spatial resolution, spectral resolution and temporal resolution.

3.5.2 RECOGNITION AND IDENTIFICATION

Examination and detection stage lead to the next stage which is normally recognition and identification. This step in the research is to identify the feature types; the stream morphology, stream pattern the rock outcrops build up areas and the terrain in general. As in any other photograph, the basic photo interpretation elements of features (tonal contrast, size shape, site association and resolution) are relevant for conventional inter relation as documented by Verstappen, (1977), etc. the use of magnify glasses and mirror stereoscope aid in the analysis.

3.5.3 CLASSIFICATION

Classification was done though the selection of a classification schems which is basic to any landuse / land cover change detection study. This organisze the needed information into the structure which would meet the research problems, objectives and the physical nature of the terrain. According to Adeniyi (1978b), there is no landuse land cover classification for Nigeria, though standardized landuse and land cover classification schemes have been developed for general purpose. To make the classification system clear the classification system used in the research is based upon categories which are particularly exhaustive (no omission of any phenomena) and mutually exclusive (no overlap of nay category). The classification scheme adopted in this study is as shown below;

LAND-USE / LANDCOVER CLASSIFICATION SCHEME FOR CHANGE DETECTION IN BUKURU.

Build-up area

Forest

River bed.

Rock out crop

Scattered cultivation

Water body.

This classification was employed in the study because of the scale provided by the aerial photographs utilized. The methodology and classification scheme employed was found appropriate and compatible with the area under investigation and the set objectives. The result generated from this methodological approach also attest to this fact.

3.5.4. FIELD CHECKING

Not withstanding the constraints imposed by the gap of 10 years between the last date of aerial photograph acquisition (1991) and field work period (2001) and the dates of photography (dates of data acquisition that is 1962, 1976 and 1991), the lack of other sources of compatible information, and the rapid land use / landcover changes on the Jos plateau, certain approaches made the verification of the accuracy of the air photo interpretation possible.

On the preliminary landuse / landcover maps, some areas doubts existed as to their correct identification were marked 'X'. The checking of these area did not present any problem in the field. Sine the availability of ground information for this area is limited, extensive efforts were made to collect data through field observations supported by ground photographs.

To ensure a fair coverage of the study area, some land-cover features (classes) which are located in many parts of the area were selected for checking. The features checked included rock outcrops, forest areas and mine-ponds. This is so because they do not undergo rapid changes and so maintain their positions in relation to the photographs. However, other land uses checked where found to be of high accuracy though with some changes in some land-use over the years.

The aid of stereoscopes can not be overemphasized since it was used to give better recognition of the features. Finally, all the errors found in the field were corrected on the preliminary land use / land-cover maps during the process of correction, the photographs had to be re-interpreted (where found necessary) to ensure that the situations represented on the final maps were interpreted photographs of 1962, 1976 and 1991.

3.6 DATA HANDLING

The line maps produced from the preceding steps represent the inventory of the land use / land-cover patterns for the three periods. Visual comparison of these maps, either by side-by side or by overlay method is considered to be time consuming considering also the variation in scale of the photographs. In order to derive optimum benefit from the information contained on the maps, a computer assisted techniques, based on a grid referencing system and digitalization were adopted.

The finally interpreted and mapped data were digitized using the 'A$_0$ size digitizing tablet and (ILWIS and Arc. View GIS 3.0 software. This transfer the information from the analogue map to computer compatible format by tracing the land-use / land-cover maps on the digitizing table to the computer system. This aid in scale adjustment and area computation. However, we can't just live out the fact that there were errors encountered in one way or the other in digitizing the maps. The final map from the digitizer usually will reflect the accuracy of the digitizer used beside the inherent errors in the aerial photographs and human errors in entering the data. Different digitizers have different error levels during data capture. There is a general convention to make all the digitizers attain a high accuracy and Wintab compatible. That is an internationally accepted open industry standard for digitizer in the Microsoft Windows. For this research, care was taking ensure high accuracy to be able to obtain the result displayed.

Area estimation and analysis under different classes made by the computer were complemented by planmetric measurements and 5mm x 5mm square grid overlays from which the following analysis were made.

1. Land-use / land-cover change pattern for 1962, 1976 and 1991 (absolute change).
2. Magnitude of land-use / land-cover change.
3. Percentage distributions of land-use / land-cover changes with estimated annual change rates (Decrease / increase).
4. Aerial distribution of each land-use / land-cover categories with their magnitude of each class and estimates of rate of change.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 IDENTIFICATION AND DESCRIPTION

The classification techniques used in this study include the comparison of independently produced land – use/land cover classes for each date. Analysis of the classification provides a direct comparison of the old and the new land use land cover classes and the nature of the change alongside the channel changes.

The set of aerial photograph used cover the ray field mining site to the east, part of Bukuru town to the south and the Sabon Gari to the west. The river Ngell and its tributaries cuts across from northeast to south west. The conspicuous appearance of the channel morphology and other man-made lakes can be visualized. This is an added advantage in interpretation.

The stream appears glaringly due to the tone, shape, texture and pattern displayed by the morphology. While, the water in the stream appears dark with some strips of vegetation along it.

Water bodies were as well easy to identify because of the dark appearance in a still state. The clear boundary it makes with the land makes it uniquely identifiable. These water bodies are a clear indication of mining activities that took place for the fact that spoils deposited besides the ponds were visible the dark gray appearance of the spoils with indication of rills clearly reveal the action of water erosion. These water bodies are found in the eastern part of the study areas that is, the ray field mining area.

Scattered cultivation observed on the photographs with distinctive pattern of artificial drainage ditches are intensively formed. These areas appear light gray since there is little or no vegetation at the time of imaging. The few native grasses, sedge and shrub vegetation has a drab gray, mottled appearance. The forest area appear dark with its distinct pattern while the bare land looks brighter.

Rock outcrops are seen as massive rounded un-beded dome-like hills with variable summit elevations and steep side slopes. They are often seen as strongly jointed with irregular or rugged and some times gently curving pattern. They appear light gray in tone due to light rock colour while some appear dark for the presence of sparse vegetation concentrated in some of the depressions that form along the joints build areas have a distinct pattern and appearance. The high (resolution of the aerial photographs enhance the easy identification and interpretation of these features. Stereospear viewing complemented by the fieldwork and field check made the identification of features possible. However the interpretation elements plaid a good role in the identification).

4.2 INTERRELATION OF AERIAL PHOTOGRAPHS

The interpretation of aerial photographs is hardly different from other small-scale high altitude satellite imageries. The most important element in the interpretation of aerial photograph remote sensing data are texture, pattern, shape and tone.

4.2.1 INTERPRETATION OF 1962 AERIAL PHOTOGRAPH

The land use / land cover of Bukuru interpreted from the aerial photograph of 1962 as shown on figure 4.1 was based entirely on personal interpretation ability complemented by the field work and field check carried out in October and December respectively. However, the time lag between date of photography and fieldwork made the identification of certain feature difficult. On the whole, the result of the interpretation was not too for from the right and the general land use / land cover classification. This means that, with the aid of stereoscope, it was possible to interpret and adjudged it to agree with the general land use / land cover classification of the United States geological survey (USGS) classification scheme.

The study area covers an area of 1011.1 ha as delineated from the aerial photographs. The quantification of the area coverage of each land-use / land cover has it that scattered cultivation takes the largest area with 790.6 ha spreading across the study area. This is followed by rock out crops with a total area coverage of 56.4 ha. The rock out crops are scattered on the study area proving the fact that the geology of the area is founded basically on younger granites. River bed being the main point of study covers an area of 55.6 ha having its major stream running from the north east to the south west

With it tributaries joining from all direction out mostly from the northwest. The major settlement in this area is the Bukuru town in the south of the study area even though just a part covers an area of 50.6 ha forest area is the next largest area with a total areal coverage of 32.3 ha and water bodies taking an area of 24.6 ha these distribution of areal coverage with their percentages are represented on table 4.1.

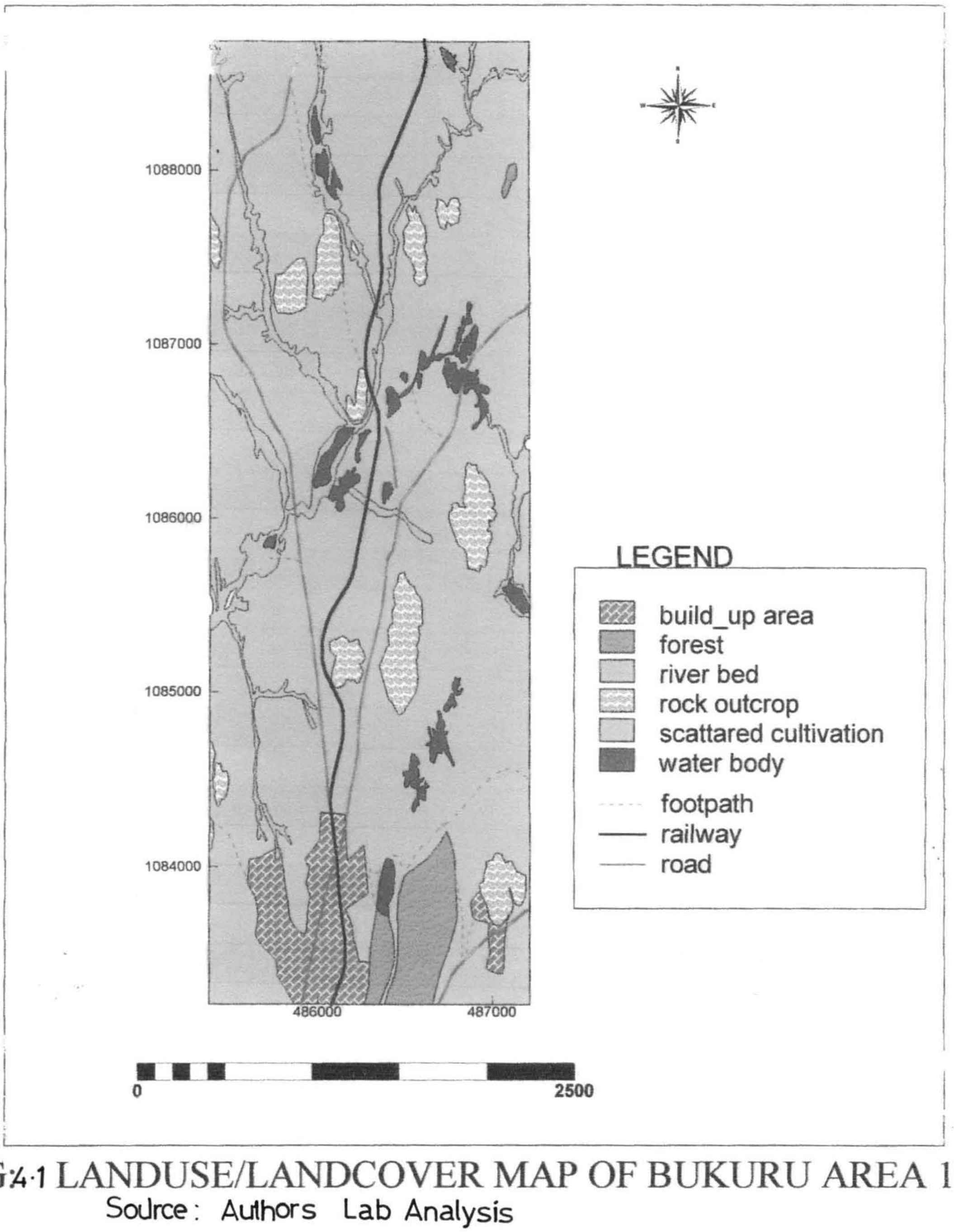


FIG 4·1 LANDUSE/LANDCOVER MAP OF BUKURU AREA 1962
Source: Authors Lab Analysis

Table 4.1 Land Use / Land Cover Situation For 1962 In Bukuru

Land use/land cover classes	Extent in hectare	Extent in km^2	Percentage (%)
Build-up area	50.6	0.506	5.0
Forest	32.3	0.323	3.2
River bed	55.6	0.556	5.0
Rock out-crop	56.4	0.564	5.5
Scattered cultivation	791.6	7.916	78.3
Water body	24.6	0.246	3.0

Source: Authors Laboratory Analysis

4.2.2 INTERPRETATION OF 1976 AERIAL PHOTOGRAPH

The 1976 interpretation is quite far from that of 1962, only for the few changes is area occupancy of the land uses. Even though scattered cultivation maintain the lead in area coverage, it has been reduced to 739.2 ha. This has thus indicated the importance of aerial photographs in the study of land use / land cover change within a period of time (figure 4.2). Table 4.2 is a summary of the

Table 4.2 Land Use / Land Cover Situation of Bukuru for 1976.

Land use/land cover classes	Extent in hectare	Extent in km^2	Percentage (%)
Build-up area	124.0	1.240	12.3
Forest	10.2	0.102	1.0
River bed	60.1	0.601	5.9
Rock out-crop	55.5	0.555	5.5
Scattered cultivation	739.2	7.392	73.1
Water body	21.9	0.219	2.2

Source: Authors Laboratory Analysis

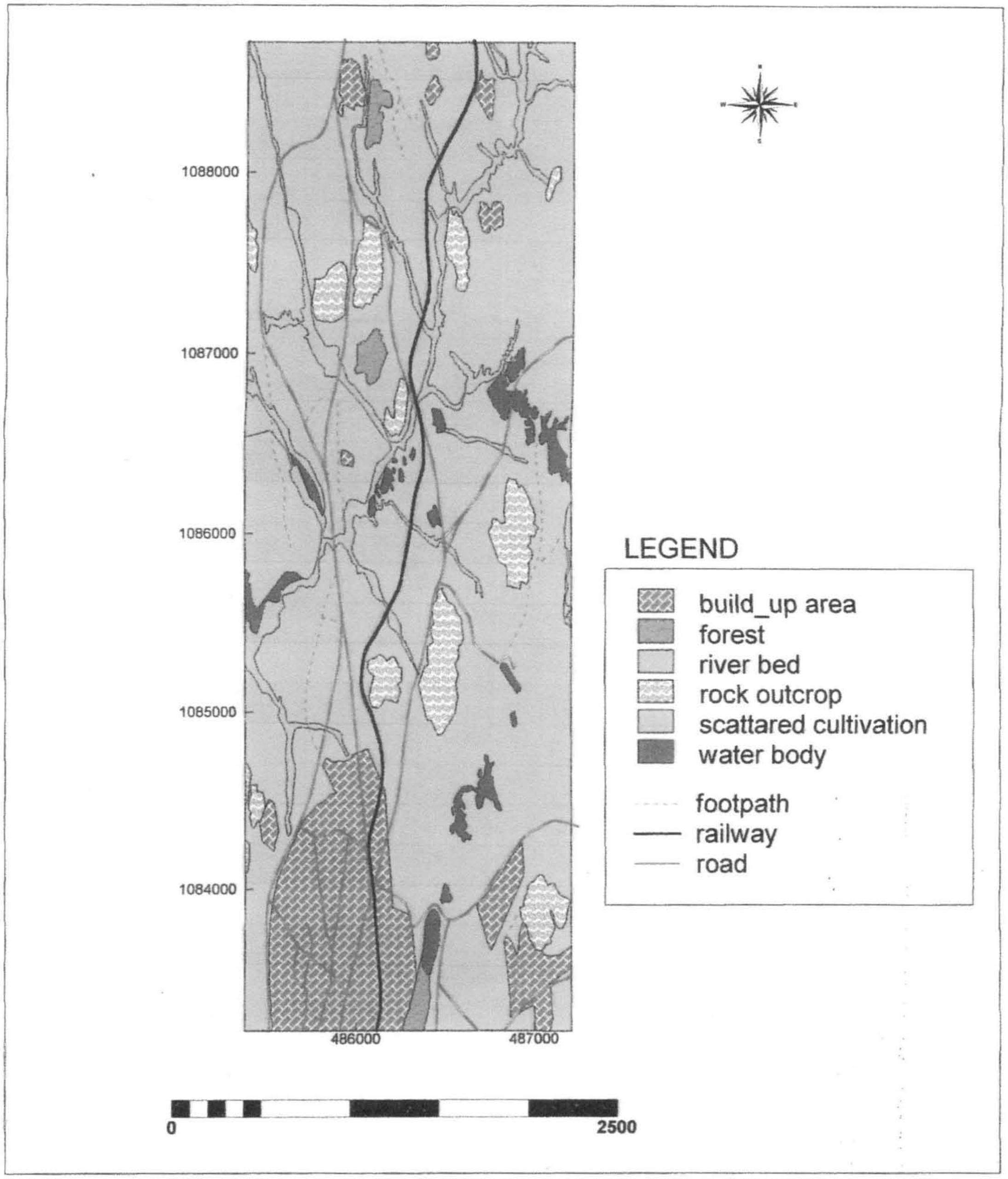


FIG:4.2 LANDUSE/LANDCOVER MAP OF BUKURU AREA 1976

Source: Authors Lab Analysis

interpreted land use / land cover for the 1976 aerial photograph. It is clear then that build up area is the next largest in the aerial coverage River bed has thus experience an increase to an area of 60.1 ha. Their percentage coverage gives a good explanation to their distribution across the study area.

4.2.3 INTERPRETATION OF 1991 AERIAL PHOTOGRAPH

The area covered by each class of land use / land cover of ff1991 was quantified form the aerial photograph to yield the results on table 4.3. The interpretation is shown on figure 4.3. only the coverage and percentage hectare are comported.

Table 4.3 Land Use / Land Cover Situation of Bukuru for 1991.

Land use/land cover classes	Extent in hectare	Extent in km^2	Percentage (%)
Build-up area	354.0	3.540	35.1
Forest	39.1	0.391	3.9
River bed	70.3	0.703	7.0
Rock out-crop	57.2	0.572	5.7
Scattered cultivation	476.3	4.763	47.2
Water body	11.0	0.110	1.1

Source: Authors Laboratory Analysis

Finally it should be noted that visual interpretation of aerial photograph is important and useful in land systems analysis it is, and using conventional procedure of interpretation, tone, texture, size, shape and pattern etc useful analysis can be obtained from the features identified. These results obtained demonstrate that Aerial photographs can provide useful data for land use / land cover analysis and mapping drainage pattern and morphology.

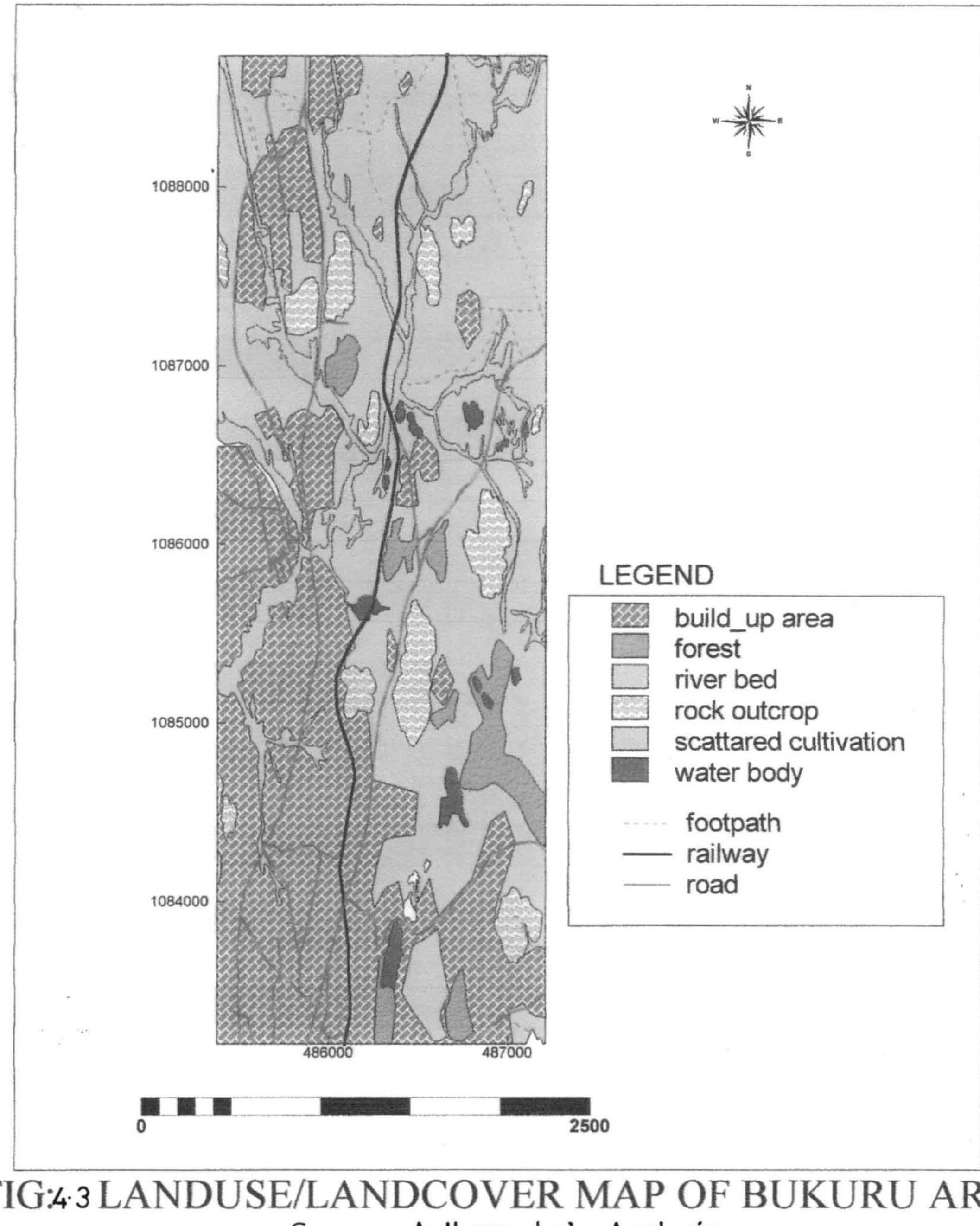


FIG:4·3 LANDUSE/LANDCOVER MAP OF BUKURU AREA 1991

Source ; Authors Lab Analysis

4.3 LAND SYSTEM DELINEATION FROM AERIAL PHOTOGRAPHS

Versteppen (1977) observed that various landscape ecological factors interrelate thus collectively considered in land systems mapping. These are best reflected in the geology and geomorphology.

The correct interpretation of these land forms. Visibly from aerial photographs has proved valuable in revealing the other aspects of the land. The very first step in delineating the land system was the mapping of the diagnostic characteristics.

The case with which these regions were recognized varies with different terrain type. The boundaries are self-evident in this case however, where land is widely cultivated for example, the resultant field pattern dominated the general appearance of the area.

Most of the land systems needed for the research could however, be recognized fully from the aerial photographs, and it was easy to establish a clear distinction between the exact boundaries of terrain features and their interrelationship. The various land systems are briefly descried below.

A) DRAINAGE PATTERN

The drainage patterns are indicators of the landform and bedrock types. This as well suggest soil characteristics and site drainage conditions. Generally, the drainage on the Jos Plateau is mainly dentritic in pattern, with rivers flowing out wards from the Plateau in all directions. This River Ngell is one of them starting from ray field. Ray field is observed as the hydrographic centre on the Jos Plateau. This drainage pattern reflect the geology and relief of the area. The younger granite and the associated deposits have resulted in an inversion of drainage. The fin mining sites are characterized by artificial lakes and ponds, drained by an interlacing system of water furrows the soils on this younger granite are typically very shallow, sandy and well drained lithosols with stones to some extend. Where the woody vegetation cover has been cleared, the soil is exposed to erosion forming numerous shallow valleys, which form the drainage channels of tributary streams flowing into river Ngell. Conditions which encourage high rate of surface run off in this area include; the broken nature of the landscape which creates considerable slopes, the low permeability of the rocks and the character of the dendrite drainage pattern.

B) RIVER BED

The preceding description of the drainage pattern may be made more understandable if coordinated by a few examples that indicate the features observed in the field (stream channel) that are of importance the river Ngell channel is neither straight nor uniform, yet its average size characteristics change in a regular and progressive fashion. The size of the sediment debris on the bed also tend to decrease often from boulders in the hilly or mountainous up stream positions to cobbles or pebbles in the middle section and sand or silty sand farther down stream (see plate 4.1). The Ngell stream even though within a given reach, the channel is not uniform, rather the bed undulates in elevation.

Plate 4.1 Sediment deposit and pebble along stream channel

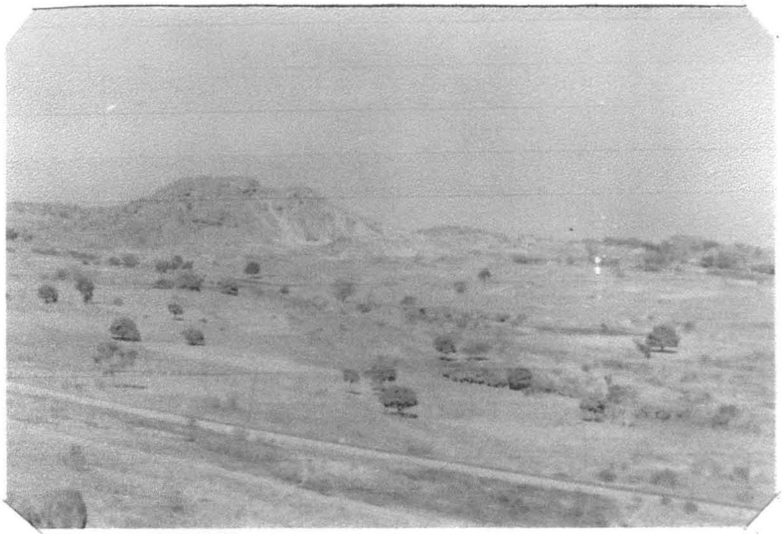


Plate 4.2 Rock out crop (inselbergs mostly of younger granites)

Plate 4 3 Mine pond as a result of tin mining

Besides. The underlying parent material contributes in shaping the channel with cataracts and riffles. In general, the continuous seasonal change in the level of flow is a factor in the location of debris. At bank full, there usually debris in suspension. The rescission of the stream flow means deposition of the debris, thus the sediment moving near the bed concentrate near the convex bank and tends then to be deposited producing meander.

Another major pattern along the riverbed is braiding. This occur when a channel is separated by a gravel bar of rapidly changing size and shape and an unstable and constantly varying distribution of channels and bars.

C) LANDFORM

Through out the Jos Plateau, there is a close relationship between geology and landforms. The older Granites are characterized by smooth rounded inset bergs. Whitest the younger granites are associated with more rugget topography with steep rock hills and abrupt breaks of slope at their margins. The lateritized older Basalts are associated with flat topped mesas and the Newer basalts are associated with flat plains and steep – sided volcanic cones. However, the study area is in a younger granite zone with sandy soil and rocky terrain as well. The terrain is undulating with conspicuous water shades. Other landforms are clearly explained with the aid of ground photographs.

i) Rock outcrop – These are inselbarg consisting of granite and gneiss, which are most outstanding in the terrain. (See plate 4.2).

ii) Lakes (ponds) though man-made, are as well prominent in the mining areas. Known as mine ponds. (See plate 4.3)

iii) Ridge – this consist of rocky areas which has resisted erosion and now forms series of undulating high lands standing above the average relief. This can be seen on plate 4.2. However, the general geometry of the terrain is explained by the relief of the area. As rocky and undulating as the area is the slope is averaged at about 1/14.

D) AGRICULTURE (SCATTERED CULTIVATION)

It is clear from the aerial photographs that tilling for agriculture have been scanty. This is explained by the rocky nature of the land beside the mining activities that have degraded the land. However, dry season farming takes place along the coast of the river and in the stream channels as well. This has however explained man's interference with the stream system by weakening the soil, and exposing it to erosion. (See plate 4.4).

E) BUILD-UP AREA

Beside the rock out-crops as factor to low infiltration, mans construction of impermeable surfaces like roads, buildings and tiles have reduced the rate of infiltration and encourage surface runoff. This practice enhances flooding and erosion on the less protected areas. There is a continuous increase in building construction in the study area as revealed by the land use change for the three years on figures 4.1, 4.2 and 4.3. (see plate 4.5).

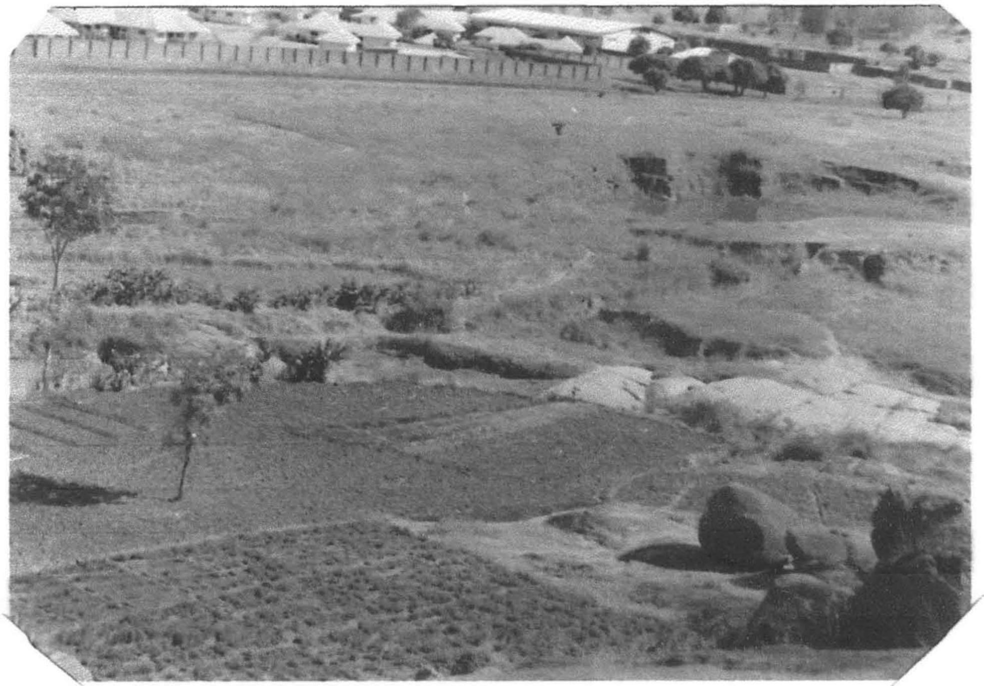


Plate 44 Cultivation along the stream coast

Plate 45 Building Construction taking over the Land

4.4 STREAM CHANNEL CROSS-SECTION

In the downstream plots the fact that the width exponent is larger than the depth exponent, in these cross sections means that downstream along the channel system, width increases faster than depth so that the width/depth ration increases. This can be seen in figures 4.4, .4.5, 4.6, 4.7 in which the cross section have been plotted at the same scales for the different years such that the width as drawn is the same for each. The depth decreases relative to the width as drainage area and this river size increases.

At section A – A', the change took place more at the stream casket with the replacement of deposits and relocation of flow at low flow. There is little change in the with of the stream. (Figure 4;4).

Section B-B reveals a significant change in the width and depth. The width increases which was more to the right tend to show more impact of water at bank-full stage along a bend (figure 4.5).

Figure 4.6 is a section across River Ngell at C – C' This cross – section is not quite far from B – B'. this thus portray a three sequential stages in progressive construction of a flood plain as stream moves laterally.

The upper stream cross – section D – D' has shown a decrease in depth with a little change in the width. This could be due to a significant in-stream deposition form ground surface erosion (figure 4.7).

4.5 CHANNEL GEOMETRY

The hydraulic geometry exhibits the consistent manner in which natural stream channels are shaped to carry water and sediment load imposed from up stream. This consistency indicates that natural channels self-formed and self-

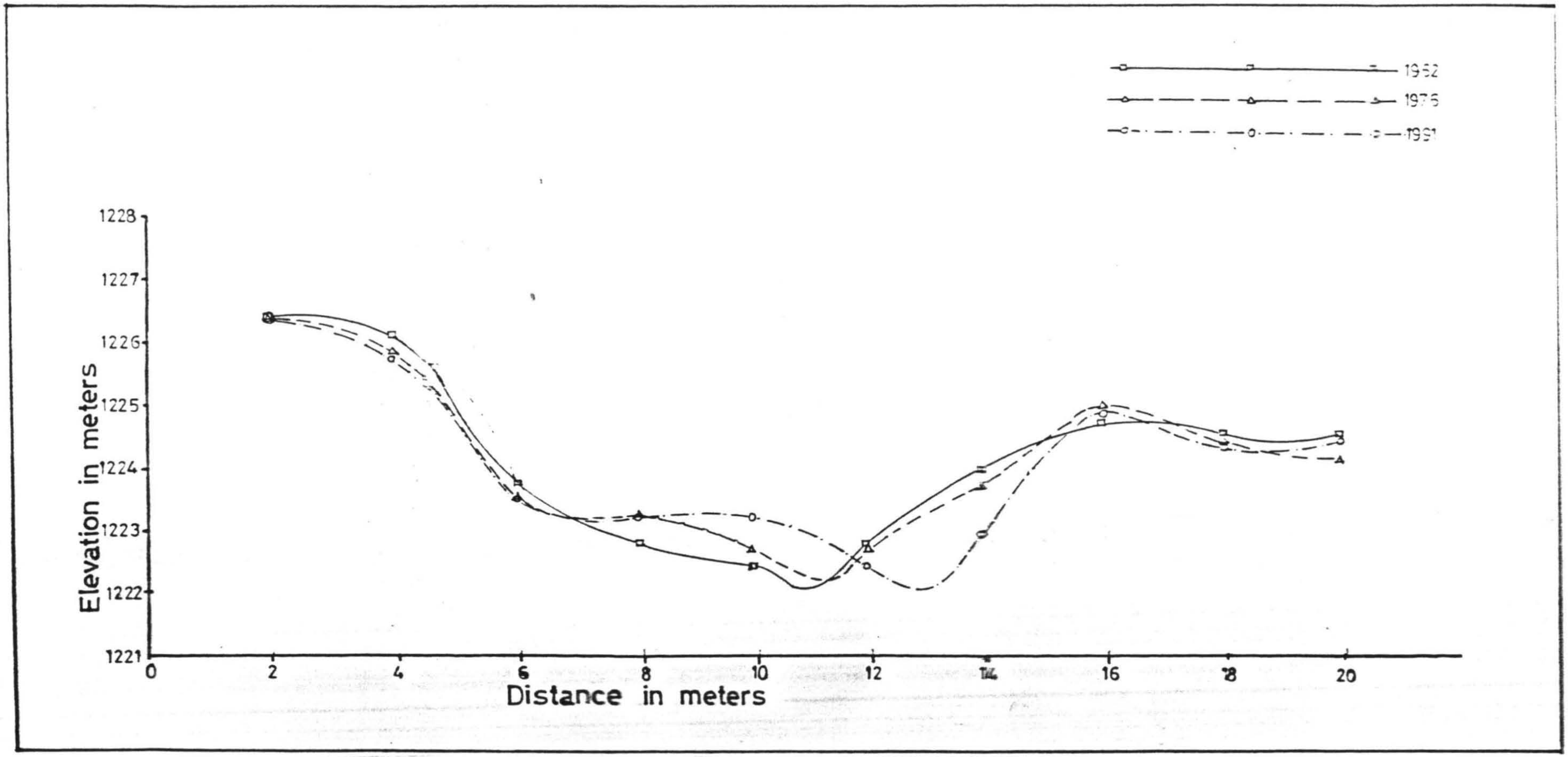


Fig 4 4 Cross Section of River Ngell at A-A'

Source AUthors Lab Analysis 2002

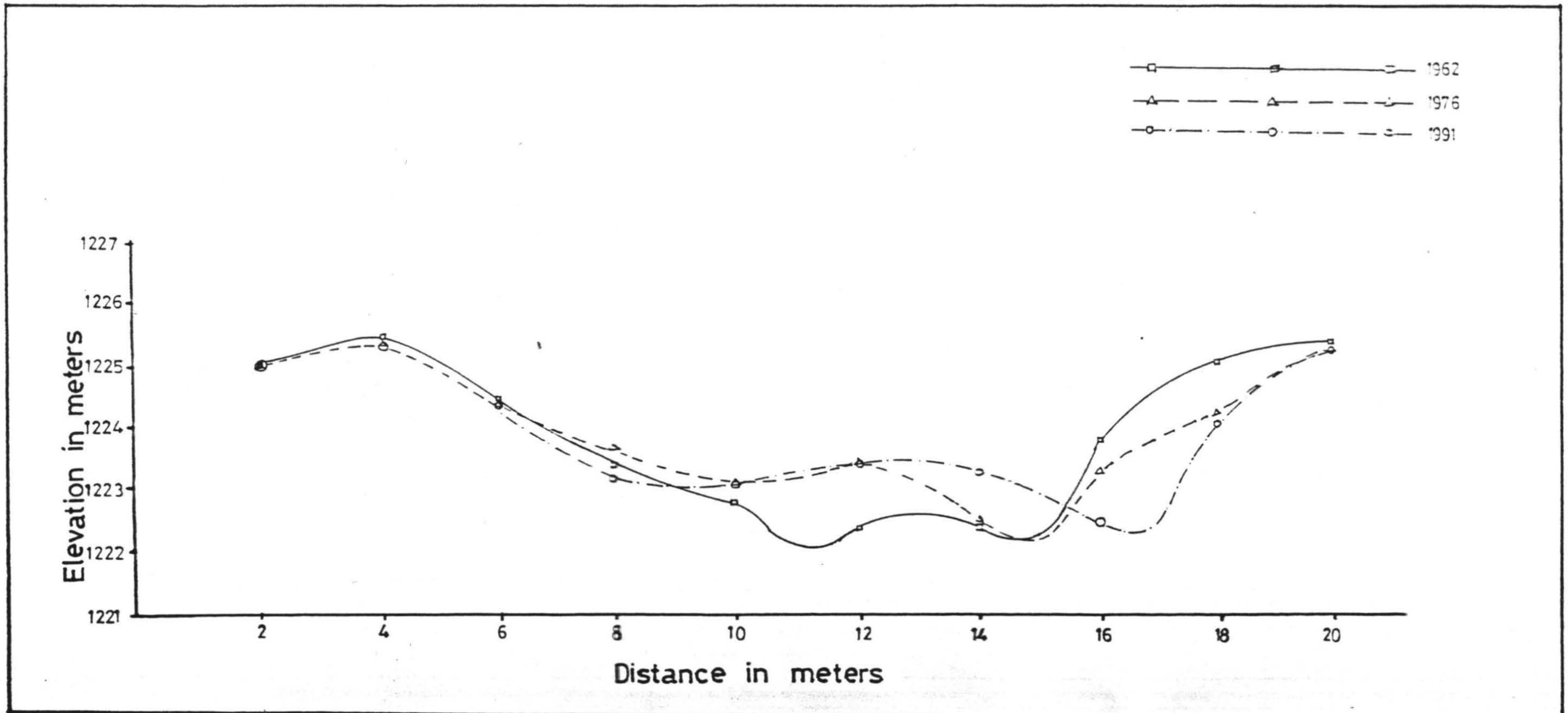


Fig 4.5 Cross section of River Ngell at B-B'

Source Authors Lab Analysis 2002

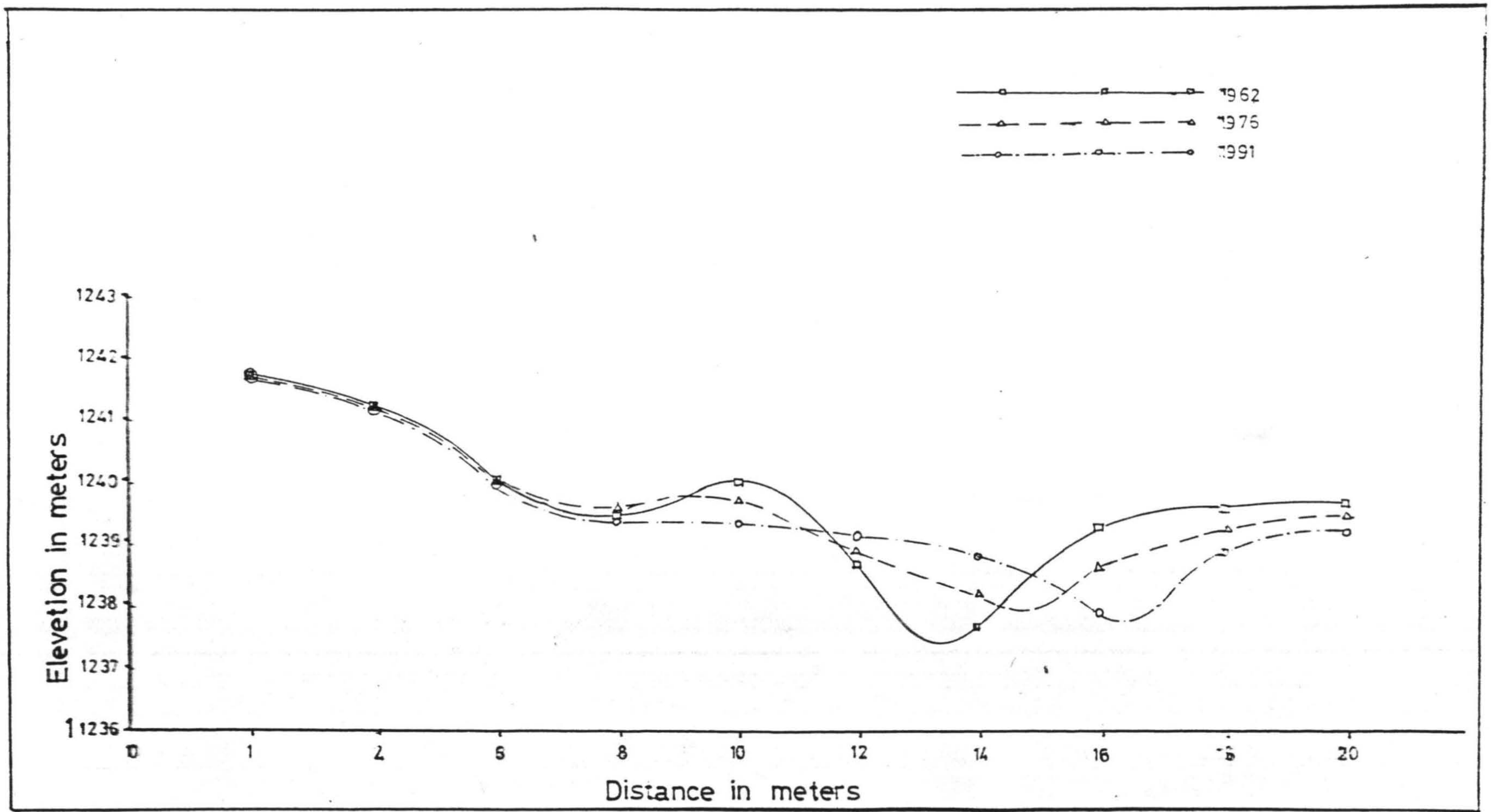


Fig 4.6 Cross-section of River Ngell at C-C'
Source Authors Lab Analysis 2002

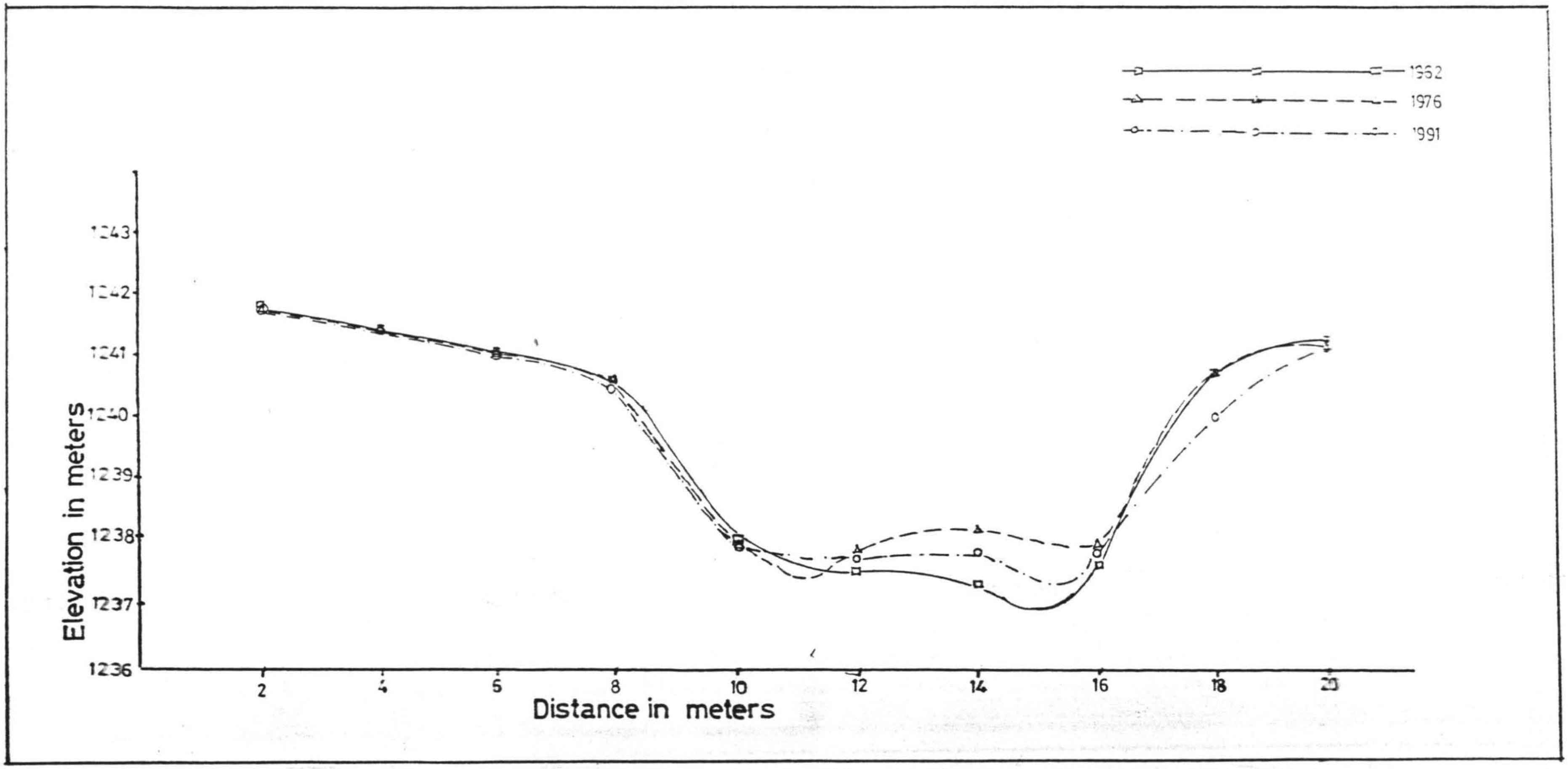


Fig 4.7 Cross-section of River Ngell at D-D'

Source: Authors Lab Analysis 2002

maintained, seek a shape and size consonant with the size of basin upstream and its sediment yield. Alteration in this preferred natural shape and size with lead to a tendency toward erosion or deposition as the channel processes operate toward reestablishment of quasi-equilibrium under the new conditions.

Despite the undulating nature of the topography in the study area, an average slope is established at about 1/14. However, the stream gradient vary from place to place, often characterized by alternating shallows (riffles) and deeps (pools) owing to the bed material. A longitudinal channel form observed from the headwaters down stream to the steam mouth reflected a progressively lower slope and an increase in total discharge (reflected by the continuous addition of tributaries and increasing drainage area down stream.

4.6 CHANNEL CHANGE

The changes of channel forms of River Ngell within the context of the cross – section, the pattern or network in the drainage and measurement of change is an important force for this research. Under natural conditions, it is observed that channel form exhibits a longitudinal pattern in which the channel form parameter vary progressively down stream. The Ngell stream channels are adjusted to the characteristics of water discharge and sediment loads provided by the drainage basin. Locally, the River Ngell channel forms are modified by channel slope, bed – material composition, bank-material cohesion and vegetation character. The change which manuphase itself through the width, depth, bed material, surficial shift and area were observable from the analysis of the data. The general surficial change both in width and length is shown in table 4.4. However, the cross section reveals the changes in the width and depth at selected locations (figure 4.4, 4.5, 4.6 and 4.7) exhibit changes of stream. The cross-sections are illustrative of these, that is, the wider the stream channel the less the depth.

The action of man in modifying the stream channel was observed to have played a major role in the alteration of the stream channel. Beside the agricultural activities, the excavation of sand and grazing along the stream channel which are factors of stream alteration. Mining have taken a major role in the stream channel change.

Tin mining is a prominent activity in the Ngell River. The removal of soil and deviation of stream channels in search of tin and other minerals has contributed to the changes that have taken place. Figures 4.8, 4.9 and 4.10 have given a good picture of surficial changes of the stream channel. Figure 4.8 is an overlay of the 1962 and 1976 aerial photographs to show the changes that have taken place. Within the period 1962 and 1976, the overlay shows deviation in some areas and expansion and contraction of the stream areas.

From the visual observation and verbal discussions with a number of miners, it was understood that spoils removed are in most cases thrown into other areas that mining must have taken place or even the stream channel will cause shift in the steam. This is as well, revealed in the overlay. Table 4.4 has as well shown that there was an increase in the surficial area within this period of about 4.5 hectares.

Figure 4.9 is an overlay of the 1976 and 1991 aerial photographs showing alterations as well. This overlay still shows some deviation and shift or expansion which is more. There is an increase surficial aerial extend of 10.2 hectares within

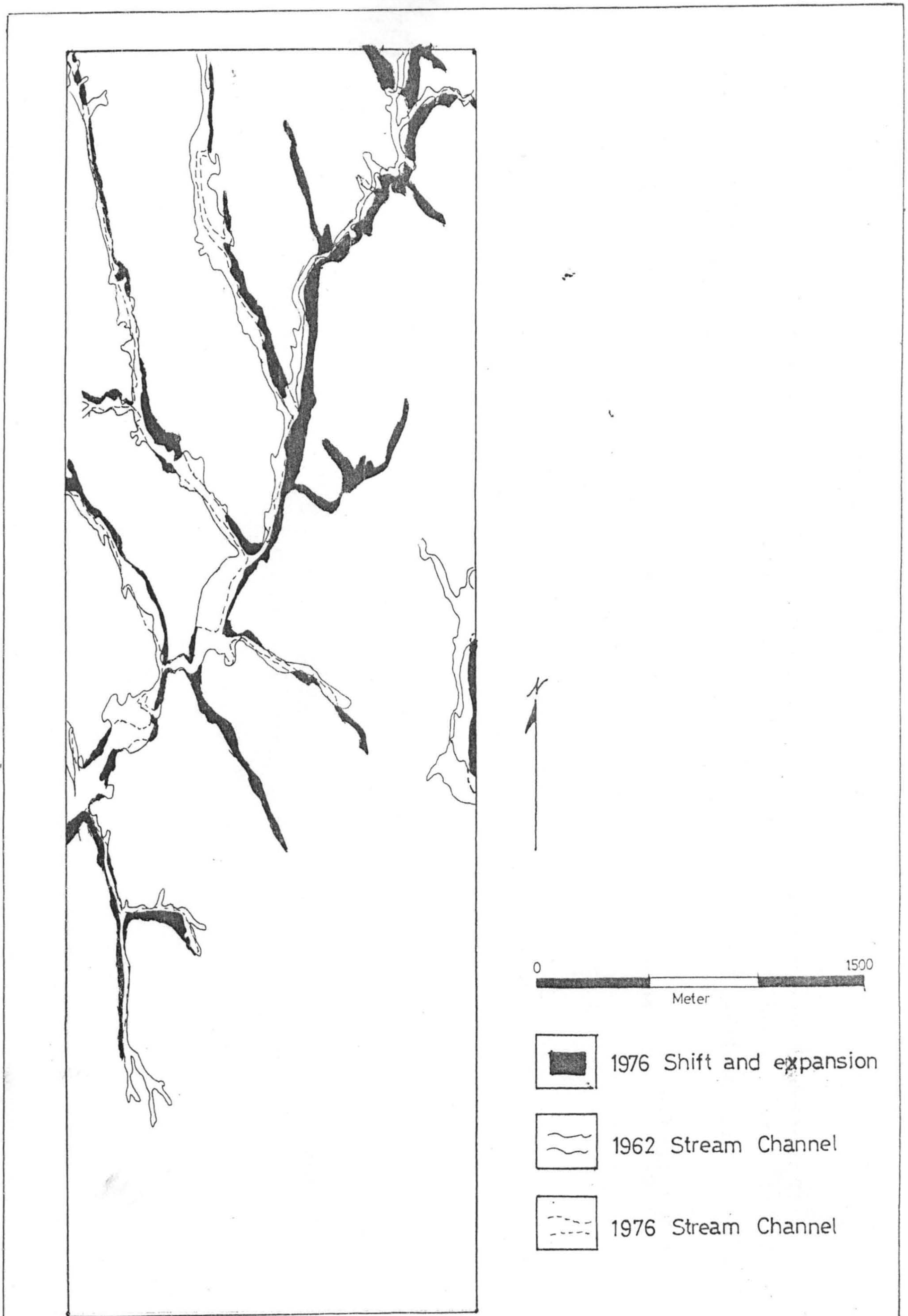


Fig 4·8 1962/1976 Overlay of River Ngell

Source Authors Lab Analysis

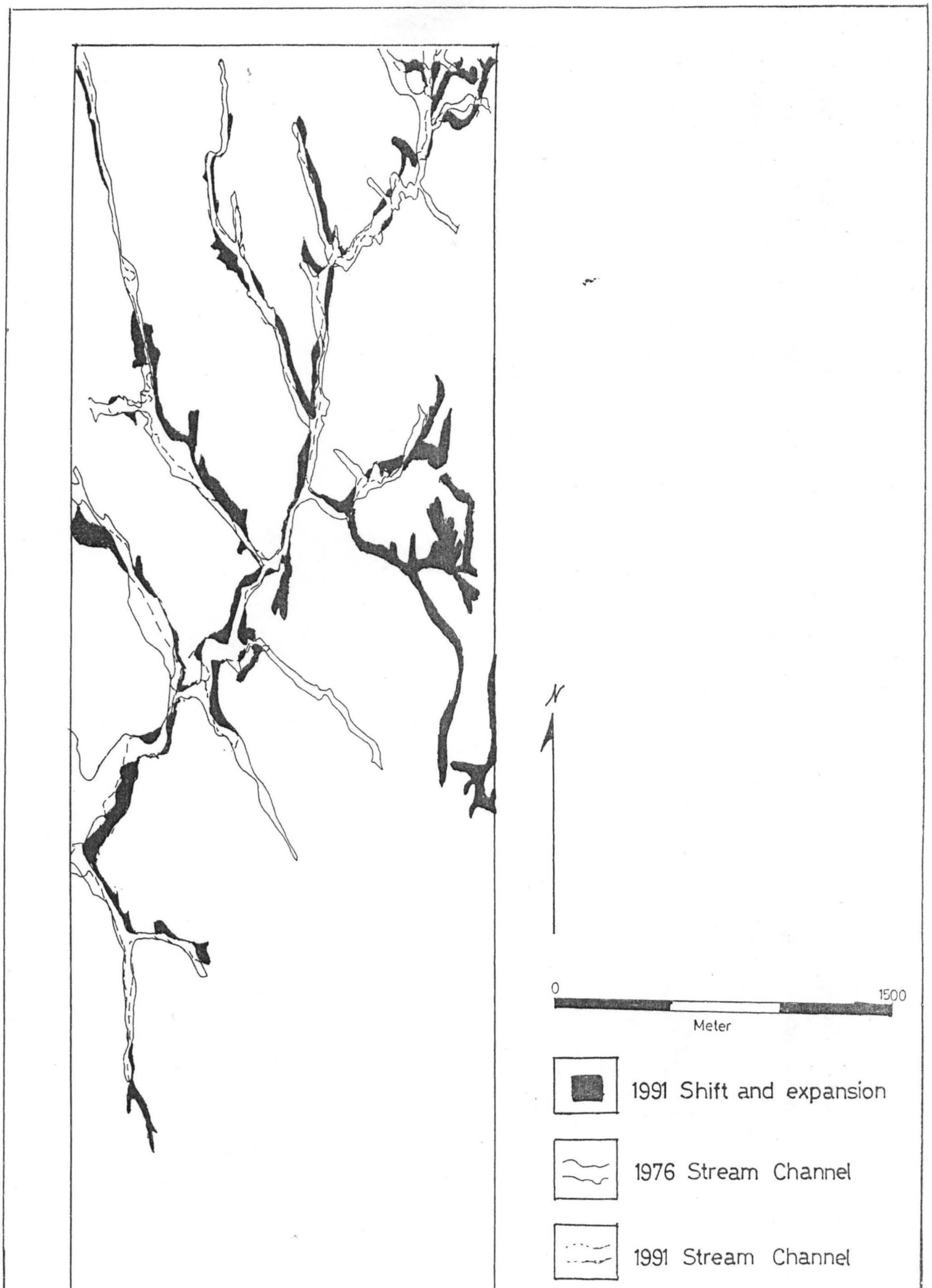


Fig 4·9 1976/1991 Overlay of River Ngell
Source Authors Lab Analysis

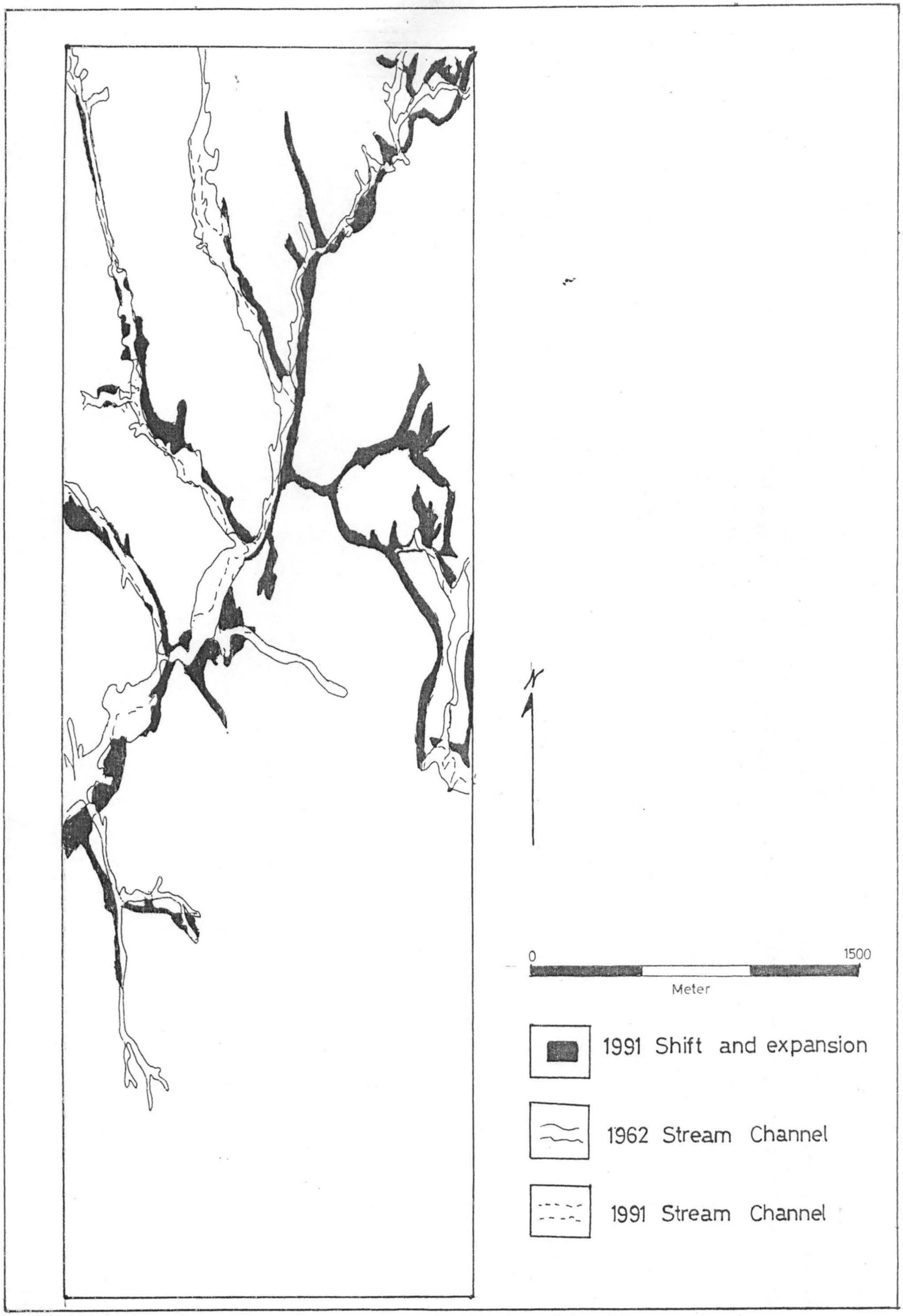


Fig 4.10 1962/1991 Overlay of River Ngell

Source: Authors Lab Analysis

Plate 4·6. Excavation for construction purpose.

Plate 4·7 Tin mining along stream channel

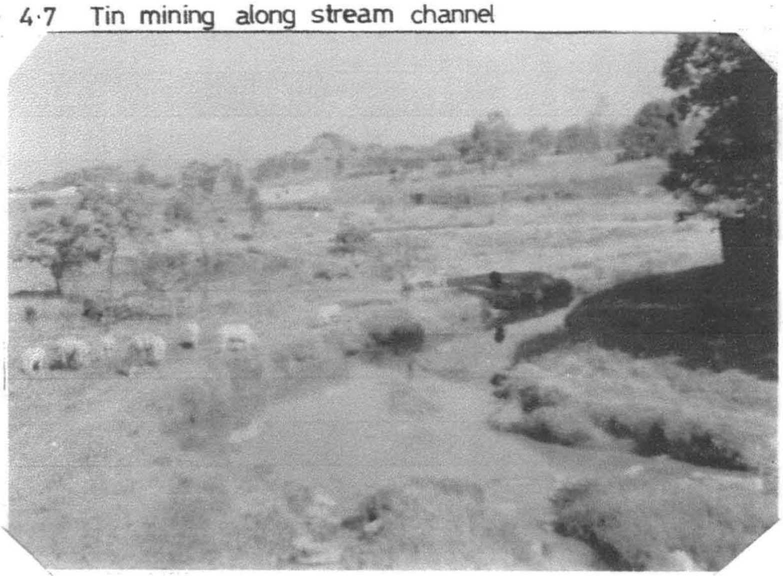


Plate 4·8 Cattle grazing along riverside

1976 and 1991. as shown in table 4.5. The increase is an indication that there is encroachment of stream channel into other land-cover.

However, the 1962 and 1991 overlay in figure 4.10 shows the change in steam channel within this periods table 4.6 reveal a surficial aerial coverage of 14.7 hectares as the increase. Plates 4.6 and 4.7 gives an indication of mans activities that have altered the stream channel. These are direct alternation caused by man Whilst.

These are direct alteration whilst, the indirect activities of man that alter channel forms include, farming up land, construction of buildings roads overgrazing and mining. These increase run off. And sediment deposition (plates4.3, 4.3 and 4.8). These alterations made on landscape alter the timing and amount of water flowing, especially peak flow condition. Overtime this affect the channel shape and stability. Often increase in the magnitude and frequency of flooding is a typical result of urbanization and such alterations as these.

4.7 CHANGE ANALYSIS

It is obvious that Bukuru town has sprawled considerably over the years. This situation altered the socio-economic status of the people of the study area, which have resulted in their altering the environmental parameters.

From the analysis of land-use/land-cover dynamics done in this chapter, it is clear that there occurred a lot of changes. These changes for various dates are shown in table 4.4, 4.5 and 4.6 the tables summaries changes in the area extent of the classes of land cover from one year to the next. Table 4.4 have reveal a positive change in three land-use/land-cover classes and three negative changes as well. However, table 4.5 has four positive and two negative changes in the land-use/ land-cover classes. This change tend to repeat itself on table 4.6 this is the result of the spatial extent of change.

Table 4.4 Landuse/Landcover charges (1962 – 1976)

Landuse/landcover classes	A 1962 (Hectares)	A 1976 (Hectares)	Magnitude of change (B - A)	Percentage change (%)
Build-up area	50.6	124.0	73.4	145.00
Forest	32.3	10.2	-22.1	68.42
River bed	55.6	60.1	4.5	8.09
Rock out-crop	56.4	55.5	0.9	1.60
Scattered cultivation	791.6	739.2	- 52.4	6.62
Water body	24.6	21.9	- 2.7	10.98

Source: Authors Laboratory Analysis

The cross – sections in figures 4.6, 4.7, 4.8 and 4.9 have indicated the charges that have occurred within these periods the changes which are either in the with or depth or both are in response to the changes both within the stream channels and the environment. Which are more associated to mans activities.

Table 4.5 Land-use/Land-cover charges (1976 – 1991)

Land-use/land-cover classes	A 1976 (Hectares)	A 1991 (Hectares)	Magnitute of change (B - A)	Percentage change (%)
Build-up area	124.0	354.0	230.0	185.48
Forest	10.2	39.1	28.9	283.33
River bed	60.1	70.3	10.2	16.97
Rock out-crop	55.5	57.2	1.7	3.06
Scattered cultivation	739.2	476.3	- 262.9	35.57
Water body	21.9	11.0	- 10.9	47.77

Source: Authors Laboratory Analysis

Table 4.6: Landuse / Landcover Change (1962 – 1991)

Land use/land-cover Classes	A 1962 (Hectare)	B 1991 (Hectare)	Magnitude of change (B - A)	Percentage change (%)
Build-up Area	50.6	354.0	303.4	599.4
Forest	32.3	39.1	6.8	21.05
River bed	55.6	70.3	14.7	26.44
Rock out-crop	56.4	57.2	0.8	1.42
Scattered cultivation	791.6	476.3	-315.3	39.83
Water body	24.6	11.0	-13.6	55.28

Source, Authors laboratory analysis

The study above demonstrates the use of remote sensing as a tool in mapping large areas of land systems. Moreover, remote sensing in the form of aerial photography served the purpose of identification, delineation and measurement of spatial extent of stream channels and their morphology.

4.8 IMPLICATIONS OF THE CHANGES

Since geomorphologically speaking, a river system functions as a process-response system within which a change in one part can have an effect on many others, its management is best conceived in a whole basin planning sense. This already has been realized in many parts of the world.

The changes in stream channels may result form may factors, however, the effects vary. The processes themselves general certain responses within the river channel. Flooding is an end member of continuous set of responses. Since flooding has such a large human impact. The changes in the land-use/land-cover practices on the hill-slopes of the drainage basin in form of deforestation overgrazing and construction activities may lead to higher runoff rates, increased soil erosion and hence an increase in both peak channel flows and sediment load.

Changes in the amount of sediment delivered have considerable impact on the nature of the streambed. Thus usually have a considerable effect on the ecology.

River Nigell has experienced quite significant changes over the years. One of the must important area of concern is that where the river channel merge upstream with gully systems that forms the surface manifestation of soil erosion, the boundary between river channel an erosional gully systems is impossible to define. The erosional processes by mans activities such as mining, agriculture, construction, deforestation, e.t.c. have increased the surficial coverage of the stream channels therefore encroaching into other land-uses.

Form the factors observed to be the causes of change in River Ngell, there is a need to adopt a regular means of checking and monitoring the environment for such changes. This can be best done using remote sensing techniques.

CHAPTER FIVE

5.0 RECOMMENDATIONS AND CONCLUSION

5.1 SUMMARY OF FINDINGS

The research aim is to detect changes in stream channel morphology with the aid of Remotely sensed data. The way in which the N'gell River channel morphology could be mapped and the changes studied in relations to the changes I the environmental conditions, which is this a practical technique by which this type of information can be derived.

The present study shows that Remote sensing data in the form of Aerial photographs visual interpretation and classification be used to successfully identify and measure variations in the extent of change in the channel morphology and Land use/land-cover. It has been demonstrated that the changes in channel morphology and many such studies can be adequately studied using aerial photographs as a comprehensive information source. The result confirm that the N'gell stream channel have undergone some changes so also the land use/land-cover within the stream catchments area. These changes are either positive or negative for the different land use/land-cover for the fact an increase in one leads to a decrease in areal coverage of another and a decrease in one leads to an increase in another. These changes in the areal coverage's are as a result of mans action, which have in turn, affected stream morphology. This, man has beside this, effected direct alterations in the stream channel. However, there will be the need for continuous mapping and monitoring of the changes in this area. This is for the protection of the river system and the resources found there in. This will help to determine the extent of change on the stream morphology for which it will aid in better information for management and utilization of stream system and its ecological potentials.

Remote sensing is indeed a highly effective method of conducting surveys, mapping and monitoring the natural and cultural environment. Both general and detail investigations can be made accurately, quickly and at a lesser cost of the conventional survey methods. From the foregoing, it is very clear that the ability to manage the stream system demands a regular mapping and monitoring changes in the land use/land-cover, which for a good detail has confirm aerial photographs to deliver. This will however, strengthen opportunities for international communication among resource scientists within and across disciplinary lines.

5.2 BENEFITS OF THE RESEARCH

The maps produced from the aerial photographs gives a general picture of the land system in Bukuru and the stream pattern. The stream cross – section thus reveal the changes vertically and horizontally. These maps and diagrams serve as data and gives useful report for further decision on land use in the area. These include the possibility of detailed terrain analysis, changes analysis etc. In fact, Aerial photographs provides a valuable tool and could be used by various disciplines repeatedly at various times as a source of data for both small and large scale analysis and planning in the future. There is a need for further work in this project area especially on a detail and more frequent studies of bio-physical parameters in the stream channels and how they are affected by the changing environment.

Depending on the level of awareness, good management and skilful utilization of the land use could reduce the impact of degradation on the stream channel. The maps and diagrams will prove useful in channel management and help to determine probable reaction of stream channels to imposed changes. This will as well help in modeling rate of discharge and areas liable to flooding. It will contribute in establishing criteria for development and utilization of the stream system and provide information aimed at reducing human impact.

The research will provide a unique source of information of direct value to the various disciplines that share common interest in adequate study, utilization, planning and management of natural resources. It will in particular, be important to the hydrologists geomorphologies, ecologists, sanitary engineers foresters, specialists in fisheries and urban designs and other relevant agencies like the urban development boards water resources managements, River Basin Development Authorities, Agricultural Development Programme (ADP) etc. They will appreciate the benefit of acquiring resource information on stream channel using Remote sensing data.

It is envisaged that the project will be of direct assistance to National Planning and water Resources institutes as it will increase awareness of the value of Remote Sensing in National Development effects and help in solving various environmental resource problems.

5.3 ACHIEVEMENTS

A major achievement of this research is the ability to successfully use a reliable cost effective tool (aerial photographs) to attempt a change analysis by mapping land systems and delineating sequentially, the stream channel morphology using visual interpretation analysis. This research provide a yardstick for further developmental purposes in the area. It is clear that the project has been able to address in part, the environmental problems of the Jos Plateau in its effort to control the effect of tin mining on the environment. This is achieved first by identifying so specific the impact of spoils on the stream ecology. This is beside the impact of other land uses. However, the Jos Plateau Environmental Resources Development Programme (JPERDP) recommended sustainable development through environmental resources mapping and careful use to ensure that the needs of tomorrow can also be met. According to this concept, the recognition of the impact through this project is a step towards sustaining resources for tomorrow.

5.4 CONCLUSION

This work suggest that the lack of relevant information on the increasing rates of destruction of stream channels is partially responsible for the charge and loss of natural stream eco system in most of our communities. Consequently, the implementation of resource exploitation in large scale especially, water, fishing, agriculture, mining etc. most be preceded by adequate monitoring of the impact. Above all the continued assessment of predicted effects, of such resource exploitation. To accomplish these, information on changes that have occurred in the stream channels and other land areas is indeed essential. It has been shown that aerial photographs as remote sensing technique provide baseline information for mapping the channels in relation to the land system.

5.5 RECOMMENDATIONS

Planning for good resource management at national scale requires, knowledge about changes in the environmental systems over a large area. Such information would help to identify regions most liable to face such problems or most effected by degradation or are under stress. As well as suggest measure for combating such problems. The most reliable and cost effective method will involve the use of remote sensing techniques using multi-temporal aerial photographs coverage of a region for monitoring as adopted in this study.

The high resolution and a good coverage of remote sensing systems, particularly aerial photographs are capable of detail delivery of primary source information for monitoring changes in areas where traditional data sources do not exist. It is also recommended that enhanced techniques such as overlay methods for sensitive change characteristics of the stream morphology. Classification techniques on the other land are able to generate valuable information about the types of change that has occurred. The result of this study suggests the need for more or widespread use of remote sensing not only in the basin but also in others, as it will help to establish the present state of the country's stream systems potentials and provide valuable information for its future management and exploitation.

Development on stream channels must proceed with extreme caution as losses of life and property are on the increase. In addition, the danger of flooding and serious limitations are imposed by variable surface material and high run off form-developed areas. If development is to take place, consideration must precede care full study of the impact it will have on the receiving end (the stream system)

Mapping stream channels for developmental planning and change monitoring has received major emphasis in the United States of America. It is also my car did suggestion that regular studies of the stream channels and land use be carried out using a chosen year interval to ensure detail examination of the effects of land use change and the changes taking place in the stream, beside limiting developments within stream channels. The hydrological department should be equipped to collect accurate information on water levels, sediment releases and most importantly velocity of flow in order to be able to apply statistical techniques with respect to in stream flow in any year.

Finally, as the most obvious threat to stable ecological stability in our stream channels, is the emergence of altered eco - system due to mans action on the environment. Streams have reacted to the changes and will lead to destruction of the natural ecology if no immediate action is taken.

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APPENDIX

ELEVATION COMPUTATION

	1962 Heighten measurement A-A′							
	1st Parallax Ready	**2nd P R**	**3RD P R**	**AV. PR**	**D P**	**P B**	**D H**	**E**
R	38.09	38.86	39.64	38.8633	0.0000	119.0000	0.0000	1226.82
1.	37.96	39.51	38.74	38.7371	-0.1262	118.8738	-0.3120	1226.51
2.	39.34	38.57	37.80	38.5680	-0.2953	118.7047	-0.732	1226.09
3.	36.90	37.65	38.41	37.6531	-0.2102	117.7898	-3.028	1223.79
4.	37.29	36.54	38.04	37.2907	-0.5726	117.4274	-3.978	1222.84
5.	37.87	37.12	36.38	37.1235	-0.7398	117.2602	-4.421	1222.40
6.	36.55	38.04	37.30	37.2962	-0.5671	117.4329	-3.982	1222.84
7.	38.49	37.74	36.99	37.7440	-0.1193	117.8807	-2.829	1223.99
8.	38.83	37.31	38.07	38.0732	-0.7910	118.2090	-1.986	1224.83
9.	38.73	37.98	37.22	37.9754	-0.8879	118.1121	-2.225	1224.60
10.	37.97	37.21	38.73	37.9709	-0.8724	118.1076	-2.238	1224.58
	1962 Heighten measurement B-B′							
	1st Parallax Ready	**2nd P R**	**3RD P R**	**AV. PR**	**D P**	**P B**	**D H**	**E**
R	38.09	38.86	39.64	38.8633	0.0000	119.0000	0.0000	1226.82
1.	37.41	38.94	38.17	38.1731	-0.6902	118.3098	-1.715	1225.11
2.	38.33	39.10	37.57	38.3349	-0.5284	118.4716	-1.319	1225.5
3.	37.93	38.68	37.17	37.9290	-0.9363	118.0637	-2.342	1224.4
4.	36.76	37.51	38.26	37.5091	-1.3542	117.6458	-3.411	1223.4
5.	38.03	37.29	36.54	37.2876	-1.5757	117.4243	-3.991	1222.8
6.	36.38	37.87	37.13	37.1271	-1.7362	117.2638	-4.421	1222.4
7.	36.39	37.14	37.88	37.1391	-1.7242	117.2758	-4.387	1222.4
8.	38.43	37.67	36.92	37.6743	-1.1890	117.8110	-3.011	1223.8
9.	38.17	38.93	37.40	38.1677	-0.6956	118.3044	-1.746	1225.
10.	37.53	38.29	39.06	38.2942	-0.5691	118.4309	-1.421	1225.4

Source, Authors laboratory analysis

	1962 Heighten measurement C-C´							
	1st Parallax Ready	2nd P R	3RD P R	AV. PR	D P	P B	D H	E
R	40.21	38.32	41.69	40.0733	0.0000	140.0000	0.0000	1242.06
1.	37.48	39.17	43.01	39.8859	-0.1874	139.8126	-0.394	1241.67
2.	38.52	39.85	39.01	39.6735	-0.3998	139.6002	-0.843	1241.22
3.	39.19	39.01	39.18	39.1253	-0.9480	139.0520	-2.010	1240.05
4.	39.78	38.98	37.95	38.9017	-1.1716	138.8284	-2.498	1239.56
5.	38.91	39.21	39.28	39.1338	-0.9395	139.0605	-2.003	1240.06
6.	38.21	39.13	38.19	38.5107	-1.5626	138.4374	-3.341	1238.72
7.	38.33	37.71	38.08	38.0401	-2.0332	137.9668	-4.382	1237.68
8.	39.60	38.49	38.24	38.7753	-1.2980	138.7028	-2.792	1239.27
9.	39.66	38.95	38.13	38.9121	-1.1612	138.8388	-2.482	1239.58
10.	38.97	38.99	38.94	38.9662	-1.1071	138.8929	-2.363	1239.70
	1962 Heighten measurementD-D´							
	1st Parallax Ready	2nd P R	3RD P R	AV. PR	D P	P B	D H	E
R	40.09	38.32	41.69	40.0733	0.0000	140.0000	0.0000	1242.06
1.	39.99	39.99	39.97	39.9843	-0.0890	139.9110	-0.187	1241.87
2.	39.79	39.87	39.83	39.8348	-0.2385	139.7615	-0.502	1241.56
3.	39.12	39.51	40.28	39.6415	-0.4318	139.5682	-0.911	1241.15
4.	39.46	39.42	39.47	39.4541	-0.6192	139.3808	-1.310	1240.75
5.	38.19	38.40	38.01	38.2018	-1.8715	138.1285	-4.001	1238.06
6.	38.03	38.01	38.01	38.0195	-2.0538	137.9462	-4.437	1237.62
7.	37.79	37.87	37.93	37.8653	-2.2080	137.7920	-4.782	1237.28
8.	38.12	38.07	38.04	38.0778	-1.9955	138.0045	-4.320	1237.74
9.	39.42	39.58	39.52	39.5076	-0.5657	139.4343	-1.210	1240.85
10.	39.52	39.79	39.77	39.6939	-0.3794	139.6206	-0.802	1241.26

Source, Authors laboratory analysis

	1976 Heighten measurement A-A´							
	1st Parallax Ready	2nd P R	3RD P R	AV. PR	D P	P B	D H	E
R	31.10	31.08	31.14	31.1033	0.0000	90.0000	0.0000	1226.82
1.	30.37	30.99	31.61	30.9886	-0.1147	89.8853	-0.375	1226.45
2.	31.46	30.84	30.22	30.8399	-0.2634	89.7366	-0.864	1225.96
3.	29.52	30.13	30.73	30.1266	-0.9767	89.0233	-3.235	1223.59
4.	30.65	30.05	29.45	30.0476	-1.0557	88.9443	-3.528	1223.29
5.	29.26	29.85	30.45	29.8543	-1.2490	88.7510	-4.187	1222.63
6.	30.49	29.89	29.29	29.8925	-1.2108	88.7892	-4.066	1222.75
7.	29.58	30.18	30.78	30.1806	-0.9227	89.0773	-3.087	1223.73
8.	31.18	30.57	29.96	30.5714	-0.5319	89.4681	-1.766	1225.05
9.	29.80	30.41	31.02	30.4097	-0.6936	89.3064	-2.297	1224.52
10.	30.90	30.30	29.69	30.2974	-0.8059	89.1941	-2.677	1224.14
	1976 Heighten measurement B-B´							
	1st Parallax Ready	2nd P R	3RD P R	AV. PR	D P	P B	D H	E
R	31.10	31.08	31.13	31.1033	0.0000	90.0000	0.0000	1226.82
1.	29.97	30.58	31.19	30.5789	-0.5244	89.4756	-1.723	1225.10
2.	31.28	30.67	30.06	30.6684	-0.4349	89.5651	-1.436	1225.38
3.	29.76	30.37	30.97	30.3654	-0.7379	89.2621	-2.442	1224.38
4.	30.77	30.17	29.56	30.1680	-0.9353	89.0647	-3.133	1223.71
5.	29.40	30.00	30.60	30.0013	-1.1020	88.8980	-3.683	1223.14
6.	30.55	29.95	29.35	29.9479	-1.1554	88.8446	-3.371	1223.45
7.	29.23	29.83	30.42	29.8257	-1.2776	88.7224	-4.289	1222.53
8.	30.66	30.05	29.45	30.0541	-1.0492	88.7508	-3.518	1223.30
9.	29.71	30.32	30.93	30.3199	-0.7834	89.2166	-2.612	1224.21
10.	31.26	30.64	30.03	30.6429	-0.4604	89.5396	-1.525	1225.30

Source, Authors laboratory analysis

	1976Heighten measurement C-C´							
	1st Parallax Ready	**2nd P R**	**3RD P R**	**AV. PR**	**D P**	**P B**	**D H**	**E**
R	40.71	40.48	40.58	40.5900	0.0000	120.0000	0.0000	1242.06
1.	39.62	40.43	41.24	40. 4294	-0.1606	119.8394	-0.394	1241.67
2.	39.44	41.05	40.24	40.2433	-0.3467	119.6533	-0.853	1241.21
3.	39.78	38.98	40.57	39.7771	-0.8129	119.1871	-2.001	1240.05
4.	40.39	39.59	38.80	39.5945	-0.9955	119.0045	-2.476	1239.58
5.	38.85	39.64	40.43	39.6395	-0.9505	119.0495	-2.367	1239.69
6.	39.25	40.04	38.47	39.2534	-1.2543	118.7466	-3.128	1238.93
7.	38.29	39.07	39.85	39.0664	-1.5236	118.4764	-3.812	1238.24
8.	40.02	39.23	38.45	39.2307	-1.3593	118.6407	-3.412	1238.65
9.	38.68	39.47	40.26	39.4703	-1.1197	118.8803	-2.801	1239.26
10.	40.35	39.77	39.56	39.5597	-1.0303	118.9697	-2.570	1239.49
	1976Heighten measurement D-D´							
	1st Parallax Ready	**2nd P R**	**3RD P R**	**AV. PR**	**D P**	**P B**	**D H**	**E**
R	40.71	40.48	40.58	40.5900	0.0000	120.0000	0.0000	1242.06
1.	39.69	40.51	41.32	40.5080	-0.0820	119.8394	-0.201	1241.86
2.	41.16	40.35	39.55	40.3327	-0.2373	119.6533	-0.538	1241.48
3.	39.41	40.22	41.02	40.2156	-0.3744	119.1871	-0.922	1241.14
4.	40.83	39.23	40.03	40.0270	-0.5630	119.0045	-1.390	1240.67
5.	38.88	38.11	39.66	38.8840	-1.7060	118.0495	-4.026	1238.03
6.	38.19	38.75	38.97	38.9711	-1.6189	118.7466	-4.079	1237.98
7.	37.31	38.07	38.83	39.0711	-1.5189	118.4764	-3.821	1238.24
8.	39.76	38.98	38.20	38.9842	-1.6058	118.6407	-4.039	1238.02
9.	40.91	40.11	39.30	40.1063	-0.4837	119.8803	-1.216	1240.85
10.	39.46	40.07	40.26	40.2620	-0.3280	119.9697	-0.802	1241.25

Source, Authors laboratory analysis

	1991Heighten measurement A-A´							
	1st Parallax Ready	2nd P R	3RD P R	AV. PR	D P	P B	D H	E
R				39.2767	0.0000	42.0000	0.0000	1226.82
1.	38.44	39.22	40.01	39.2207	-0.0506	41.9440	-0.381	1226.44
2.	39.91	39.13	38.35	39.1300	-0.1467	41.8533	-1.001	1225.82
3.	38.03	38.81	39.58	38.8072	-0.4695	41.5305	-3.235	1223.59
4.	39.53	38.76	37.98	38.7585	-0.5182	41.4818	-3.603	1223.22
5.	37.99	38.76	39.54	38.7622	-0.5145	41.4855	-3.581	1223.24
6.	39.42	38.64	37.87	38.6430	-0.6337	41.3663	-4.423	1222.40
7.	37.95	38.73	39.50	38.7283	-0.5484	41.4516	-3.831	1222.99
8.	39.78	39.00	38.22	38.9977	-0.2790	41.7210	-1.932	1224.89
9.	38.15	38.93	39.71	38.9301	-0.3466	41.6534	-2.389	1224.43
10.	39.71	38.94	38.16	38.9359	-0.3408	41.6592	-2.352	1224.47
	1991Heighten measurement B-B´							
	1st Parallax Ready	2nd P R	3RD P R	AV. PR	D P	P B	D H	E
R				39.2767	0.0000	42.0000	0.0000	1226.82
1.	38.25	39.03	39.81	39.0275	-1.2492	41.7508	-1.702	1225.12
2.	39.85	39.07	38.29	39.0687	-1.2080	41.7920	-1.428	1225.39
3.	38.15	38.93	39.71	38.9305	-2.3462	41.6538	-2.382	1224.44
4.	39.53	38.75	37.98	38.7539	-3.5228	41.4772	-3.624	1223.20
5.	38.75	37.97	39.52	38.7491	-3.5276	41.4724	-3.674	1223.15
6.	39.56	38.01	38.79	38.7876	-3.4891	41.5109	-3.403	1223.42
7.	37.99	39.55	38.77	38.7704	-3.5063	41.4937	-4.521	1223.30
8.	39.44	38.66	37.89	38.6621	-4.6146	41.3854	-3.287	1222.53
9.	38.88	39.66	38.10	38.8819	-2.3948	41.6052	-2.746	1224.07
10.	39.84	38.28	39.06	39.0578	-1.2189	41.7811	-1.508	1225.31

Source, Authors laboratory analysis

	1991Heighten measurement C-C							
	1st Parallax Ready	**2nd P R**	**3RD P R**	**AV. PR**	**D P**	**P B**	**D H**	**E**
R	34.46	33.79	33.11	33.7867	0.0000	43	0.0000	1242.06
1.	33.73	33.05	34.40	33.7274	-0.0593	42.9407	-0.394	1241.67
2.	32.98	33.66	34.33	33.6573	-0.1294	42.8706	-0.862	1241.20
3.	34.16	33.49	34.16	33.4865	-0.3002	42.6998	-2.011	1240.05
4.	32.76	34.09	33.42	33.4247	-0.3620	42.6380	-2.438	1239.62
5.	34.06	33.39	32.72	33.3894	-0.3973	42.6027	-2.682	1239.30
6.	32.69	34.02	33.36	33.3576	-0.4291	42.5709	-2.901	1239.16
7.	33.30	32.64	33.97	33.3048	-0.4819	42.5181	-3.265	1238.80
8.	32.51	33.84	33.18	33.1752	-0.6115	42.3885	-4.161	1237.90
9.	33.99	33.33	32.66	33.3278	-0.4589	42.5411	-3.121	1238.94
10.	32.70	33.37	34.04	33.3699	-0.4168	42.5832	-2.821	1239.24
	1991Heighten measurement D-D							
	1st Parallax Ready	**2nd P R**	**3RD P R**	**AV. PR**	**D P**	**P B**	**D H**	**E**
R	33.11	33.79	34.46	33.7867	0.0000	43	0.0000	1242.06
1.	34.43	33.08	33.76	33.7551	-0.0316	42.9684	-0.210	1241.85
2.	34.37	33.69	33.02	33.6945	-0.0922	42.9078	-0.613	1241.45
3.	33.65	32.97	34.32	33.6469	-0.1398	42.8602	-0.932	1241.13
4.	32.90	34.24	33.57	33.5697	-0.2170	42.7830	-1.451	1240.61
5.	32.53	33.19	33.85	33.1910	-0.5957	42.4043	-4.026	1238.03
6.	33.83	32.50	33.17	33.1667	-0.6200	42.3800	-4.231	1237.83
7.	33.84	33.18	32.51	33.1772	-0.6095	42.3905	-4.161	1237.90
8.	32.51	33.83	33.17	33.1712	-0.6155	42.3845	-4.201	1237.86
9.	34.16	32.82	33.49	33.4947	-0.2920	42.7080	-1.978	1240.08
10.	33.67	34.34	32.99	33.6654	-0.1213	42.8787	-0.812	1241.25

Source, Authors laboratory analysis

WHERE =

PR- Parallax reading
AV.PR- Average parallax reading
DP- Difference in parallax
PB- Photo-base
DH- Difference in heighten
E- Elevation