ASSESSMENT OF COMPLIANCE TO REGULATIONS OF RIGHT-OF-WAY FOR NIGERIAN NATIONAL PETROLEUM CORPORATION PIPELINES NETWORK IN NORTHERN NIGERIA

BY

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Declaration

I declare that the work in this Thesis entitled: "Assessment of Compliance to Regulations of Right-of-Way for Nigerian National Petroleum Corporation Pipelines Network in Northern Nigeria" has been performed by me in the Department of Geography. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other Institution.

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Signature Date

Certification

This Thesis entitled: ASSESSMENT OF COMPLIANCE TO REGULATIONS OF RIGHT-OF-WAY FOR NIGERIAN NATIONAL PETROLEUM CORPORATION PIPELINES NETWORK IN NORTHERN NIGERIA by Dele Joseph Jacksolomon MEJABI meets the regulations governing the award of the degree of Masters in Remote Sensing (RS) and Geographic Information System (GIS) in Geography of the Ahmadu Bello University, and is approved for it's contribution to knowledge and literary presentation.

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Dedication

I hereby dedicate this work to God Almighty, who in His infinite mercy has made me completed this course of study and to my dearest Parents Mr. and Mrs. (Late) Solomon Mejabi, for their encouragement and financial support on this project and for the academic background given to me.

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TABLE OF CONTENTS

Title Page ---------- i

Declaration ---------- ii

Certification ---------- iii

Dedication ---------- iv

Acknowledgement ---------- v

Contents ---------- vii

List of Figures ---------- xiii

List of Tables ---------- xv

List of Appendices ---------- xviii

Definitions of Terms ---------- xix

Abstract ---------- xxii

CHAPTER ONE: INTRODUCTION

1.1 Background to the study ---------- 1

1.2 Statement of the Problem ---------- 6

1.3 Aim and Objectives of the Study ---------- 10

1.4 Justification for the Study ---------- 11

1.5 Aspects and Scope of the Study ---------- 12

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction ---------- 13

2.2 Conceptual Framework for the Study ---------- 13

2.2.1 Petroleum Refineries ---------- 13

2.2.1.1 Nigerian Oil and Gas Pipelines Network Development ------- 16

2.2.1.2 Attacks on Oil Transport Pipelines in Nigeria (Sabotage, Vandalization and Pilferage) ---------- 22

2.2.2 Remote Sensing Technology (RST) ---------- 25

2.2.3 Geographic Information System (GIS) ---------- 27

2.2.4. Data Acquisition Techniques for GIS Operation ---------- 29

2.2.4.1 Ground Survey Method ---------- 29

2.2.4.2 Photogrammetry Method ---------- 29

2.2.4.3 Graphic Digitizing Method ---------- 30

2.2.4.4 Remote Sensing Technique ---------- 30

2.2.4.5 Questionnaire Method ---------- 30

2.2.5 Remote Sensing (RS) and Geographic Information Systems (GISs) in Encroachment into Pipelines Right-of-Way ---------- 31

2.2.5.1 Regulations on Pipelines' Right-of-Way ---------- 40

4.2.5.2 Diameters/Sizes of Oil Pipelines ---------- 40

4.2.5.3 Setbacks ---------- 41

2.2.5.4 Standard Marking Colour Code ---------- 44

2.2.5.5 Criteria for Evaluating Right-of-Way Condition ---------- 45

2.2.5.6 Compliance to Environmental Laws ---------- 47

2.3 Review of Relevant Literature ---------- 49

CHAPTER THREE: THE STUDY AREA AND METHODOLOGY

3.1 Introduction ---------- 59

3.2 Physical Background of Study the Area ---------- 59

3.2.1 Location, Position and Size ---------- 59

3.2.2 Historical Background ---------- 60

3.2.3 Geology and Landforms ---------- 64

3.2.4 Relief and Drainage ---------- 67

3.2.5 Soils ---------- 68

3.2.6 Climate ---------- 70

3.2.7 Flora and Fauna ---------- 74

3.3 Human geography ---------- 77

3.3.1 Population and Demographic Characteristics ---------- 77

3.4 Research Methodology ---------- 80

3.4.1 Field Reconnaissance Survey ---------- 80

3.4.2 Type and Sources of Data ---------- 80

3.4.2.1 Primary Sources of Data ---------- 81

3.4.2.2 Secondary Sources of Data ---------- 81

3.4.2.3 Instruments Used ---------- 82

3.4.3 Methods of Data Collection---------- 84

3.4.3.1 Ground Truthing ---------- 84

3.4.3.2 Personal and Oral Interview ---------- 85

3.4.3.3 Questionnaire Administration ---------- 85

3.4.4 System Wares Used for the Study ---------- 87

3.4.5 Data Processing ---------- 89

3.4.5.1 Sub-setting ---------- 89

3.4.5.2 Image Enhancement ---------- 89

3.4.5.3 Rasterization ---------- 90

3.4.5.4 Vectorization ---------- 90

3.4.5.5 Edge Matching ---------- 91

3.4.5.6 Digital Elevation Model Operation ---------- 91

3.4.5 Data analysis ---------- 92

3.4.5.1 Overlay Operations ---------- 92

3.4.6 Database Design ---------- 93

3.4.6.1 View of Reality ---------- 94

3.4.6.2 Conceptual Design ---------- 95

3.4.6.3 Logical Design ---------- 97

3.4.6.4 Physical Design ---------- 98

3.4.6.5 Spatial Query ---------- 100

3.4.6.6 Cartographic Model ---------- 100

3.4.7 Criteria for Assessing the Compliances of various Land-Uses

Types with the NNPC Pipelines ---------- 102

3.4.7.1 Proximity ---------- 102

3.4.7.2 Area extent (Buffering Requirements) ---------- 103

3.4.7.3 Relatively Gentle Terrain ---------- 103

3.4.8 Linear Measurements ---------- 103

3.4.9 Geo-referencing Properties of the Images and Maps ------- 105

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction ---------- 107

4.2 Database of NNPC Pipeline Networks and Associated Right-of-Way ---------- 107

4.3 Buffering Operation---------- 116

4.4 Level of Compliance to NNPC Pipelines' Right-of-Way ----- 116

4.4.1 Pipeline Segments' level of Right-of-Way Compliance Assessment ---------- 120

4.4.2 System 2C (Warri-Kaduna Crude Line) Segment ---------- 120

4.4.3 System 2D (a) Kaduna-Zaria- Kano Segment ---------- 121

4.4.4 System 2D (b) Zaria-Gusau Segment ---------- 122

4.4.5 System 2D (c) Kaduna-Jos Pipeline Segment ---------- 122

4.4.6 System 2D (d) Gombe-Maiduguri Pipeline Segment ---------- 123

4.4.7 System 2D (e) Jos-Gombe Pipeline Segment ---------- 123

4.4.8 System 2CX (b) Auchi-Suleja Pipeline Segment ---------- 124

4.4.9 System 2CX (c) Suleja-Minna Pipeline Segment ---------- 124

4.4.10 System 2CX (d) Suleja-Kaduna Pipeline Segment ---------- 125

4.4.11 System 2DX Jos-Gombe Pipeline Segment ---------- 126

4.4.12 System 2E (b) Enugu-Makurdi Pipeline Segment ---------- 126

4.4.13 System 2EX (c) Makurdi-Yola Pipeline Segment ---------- 126

4.4 Classification Scheme for Land Use Types ---------- 127

4.5 Elevation and Slope Aspect ---------- 134

4.6 Problems and Challenges of Non-compliance to NNPC Pipelines'

Right-of-Way ---------- 145

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONs

5.1 Introduction ---------- 157

5.2 Summary of Finding ---------- 166

5.3 Conclusion ---------- 159

5.4 Recommendations ---------- 160

5.5 Critique of the Study ---------- 163

5.6 Suggestions for Further Study ---------- 163

References---------- 164

LIST OF FIGURES

Figure 2.1 Framework of the Monitoring System ---------- 37

Figure 2.2 Protection for Above-ground Pipelines Facilities -------- 43

Figure 2.3 Pipelines' Right-of-Way Condition ---------- 47

Figure 3.1a Study Area-Northern Nigeria ---------- 61

Figure 3.1b Study Area-NNPC Pipeline Network ---------- 62

Figure 3.2 Geology and Landforms of Northern Nigeria ---------- 66

Figure 3.3 Mean Annual Rainfall of Northern Nigeria ---------- 73

Figure 3.4 Vegetation of Northern Nigeria ---------- 76

Figure 3.5 Design and Implementation Phases of a Spatial Database - 95

Figure 3.6 ROW Entity and its Attributes ---------- 96

Figure 3.7 Pipeline Entity and its Attributes ---------- 96

Figure 3.8 Linear Entity and its attributes ---------- 97

Figure 3.9 Area Entity and its Attributes ---------- 97

Figure 3.10 Cartographic Model Design ---------- 101

Figure 4.1a Land Use Classification for Zaria-Gusau and Zaria-Kano Axes of the Study Area ---------- 129

Figure 4.1b Land Use Classification for Zaria-Gusau and Zaria-Kano Axes of the Study Area ---------- 130

Figure 4.2 Land Use Classification for Warri-Auchi-Kaduna Axis (Crude Oil Pipeline) of the Study Area ---------- 131

Figure 4.3 Land Use Classifications for Warri-Auchi-Kaduna Axis (New Product Pipeline) of the Study Area ---------- 132

Figure 4.4 Digital Elevation Model (DEM) (Panchromatic and Multi-spectral Colours) of the Study Area 3D-Perspective- 135

Figure 4.5 Contour Profile Graph from A, B, C-Orientation of the Study ---------- 136

Figure 4.6 NNPC Refineries (Kaduna) in the Study Area ---------- 137

Figure 4.7 NNPC Depots in the Study Area ---------- 138

Figure 4.8 NNPC Pump Stations in the Study Area ---------- 139

Figure 4.9 NNPC Retail Stations in the Study Area ---------- 140

Figure 4.10 NNPC Booster Stations in the Study Area ---------- 141

Figure 4.11 NNPC Pipelines Network in the Study Area ---------- 142

Figure 4.12 Overlaid Map of NNPC Pipelines' Super-imposed Feature ---------- 143

Figure 4.13 Proposed Locations for New NNPC Refineries in Nigeria - 144

LIST OF TABLES

Table 2.1 Nigerian National Petroleum Corporation (NNPC) Refineries in Nigeria ---------- 13

Table 2.2 NNPC Pipelines Distribution Network Systems in Nigeria - 20

Table 2.3 Summary of Pipelines Rupture/Vandalism from January 1993-2011---------- 24

Table 2.4 Recorded Pipeline Explosions and Deaths Resulting from Pipeline Rupture Vandalism in Nigeria ---------- 25

Table 2.5 Minimum Sizes of Objects to be Detected, Recognized and Identified for Various Condition of Contrast with their Background in Various Type ---------- 33

Table 2.6 Sample "Distance of Concern" for Natural gas Pipelines - 42

Table 2.7 Summary of some Setback Requirements in Codes, Standards and other Guides ---------- 44

Table 2.8 Standard Marking Colours and their Associated Underground Installations ---------- 45

Table 2.9 A Five-level Scheduled and Criteria for evaluating ROW Condition ---------- 46

Table 3.1 Rainfall and Temperature Values of Northern Nigeria -- 73

Table 3.2 Population Distribution and Demographic Characteristics of Northern Nigeria ---------- 79

Table 3.3 Types and Sources of data required for the Study and GIS Analysis ---------- 83

Table 3.5 Geo-Relational Data in the Study Area and their Attributes - 98

Table 3.6 Relations (Table) for Pipeline DBF ---------- 99

Table 3.7 Relations (Table) for Road DBF ---------- 99

Table 3.8 Built-up Area in the Study Area and their Attributes - 100

Table 3.9 Coordinates of the Study Area ---------- 105

Table 4.1 Data Set for Nigerian National Petroleum Corporation Depots in Northern Nigeria ---------- 108

Table 4.2 Data Set for Nigerian National Petroleum Corporation Pump Stations in Northern Nigeria. ---------- 109

Table 4.3 Data Set for Nigerian National Petroleum Corporation Retail Stations in Northern Nigeria ---------- 110

Table 4.4 Data Set for Nigerian National Petroleum Corporation Booster Stations in Northern Nigeria ---------- 111

Table 4.5 Geographical Coordinates for NNPC Depots in Northern Nigeria ---------- 112

Table 4.6 Geographical Coordinates for NNPC Pump Stations in Northern Nigeria ---------- 113

Table 4.7 Geographical Coordinates for NNPC Booster Stations in Northern Nigeria ---------- 114

Table 4.8 Query for NNPC Depot, Pump, Booster and Retail Stations and their Coordinates in Northern Nigeria ---------- 115

Table 4.9 Major Land Use Types encroaching into NNPC Pipelines' Right-of-Way. ---------- 119

Table 4.10 A modified Anderson's (1967) Classification Scheme for Land Use/Land Cover Code and Colours Categories -- 128

Table 4.11 Data Set for Level of Compliance to NNPC Pipelines' Right-of-Way ---------- 139

Table 4.12 Distribution of Respondents, according to Oil Workers, Environmentalists, Staff of Nigerian National Petroleum Corporation and Ministry of Environment,Farmers, Fishermen/Women, Market Men/Women Class ---------- 145

Table 4.13 Concept of Remote Sensing and Geographic Information System and Environmental Issues on Oil Pipelines ---------- 147

Table 4.14 Roles of NNPC, Construction Companies and Planners in the Planning, Control and Management of Oil Pipeline Right-of-Way in Nigeria ---------- 150

Table 4.15 Government and Private Sectors involvement in the Monitoring, Control and Mitigation against Oil Pipelines Vandalism in Northern Nigeria ---------- 154

APPENDICES

Appendix I The sample of Questionnaire administered to Respondents Residing in the Communities where NNPC Pipelines Criss-crossed ---------- 172

Appendix II Some of the commonly applied Pipeline Inspection and Survey Techniques ---------- 176

Appendix III Preliminary and Laboratory Work ---------- 177

Appendix IV Landsat SRTM Satellite Imagery of Nigeria --------- 178

Appendix V Landsat SRTM Mirrored Satellite Imagery of Nigeria - 179

Appendix VI Composite SRTM Satellite Imagery of Band 1 ------ 180

Appendix VII Composite SRTM Satellite Imagery of Band 2 ----- 181

Appendix VIII Composite SRTM Satellite Imagery of Band 3 ----- 182

Appendix IX Nigeria-its Thirty Six (36) States and LGAs -------- 183

Appendix X NNPC Pipelines Networks in Nigeria ---------- 184

Appendix XI NNPC Kaduna Refinery ---------- 185

Appendix XII NNPC's Rupture/Vandalized Pipeline ---------- 186

Appendix XIII NNPC Pipelines Fire Outbreak due to Vandalism - 187

Appendix XIV Proposed Locations for New NNPC Refineries in

Definition of Terms

Some terms are used here with specific meanings, different from the way they are conventionally used. Hence, it is necessary to define them as used in this study.

1. Aerial Photographs (Air Photos): A photograph of the earths' surface taken from the air. It is usually taken from a moving air-craft in a systematic pattern and at a desired altitude. A mosaic of such air photos is often made and used for mapping land divisions and physical attributes e.g. geology, soil, vegetation, topography of the area.

2. Brightness and Contrast: Brightness (as applied to Remote Sensing) refers to attribute of sensation by which an observer is aware of differences of luminance and contrast refers to the ratio of two of two adjacent scene radiances expressed as a number equal to or greater than one.

3. Contrast Ratio: On an image, the proportion of reflection of reflectance of the brightness to darkest parts of the image.

4. Digital Elevation model (DEM): Are data commonly provided in a grid format in which an elevation value is stored for each of a set of regularly spaced positions. Each datum point represents the elevation of the grid cell in which bit is located.

5. Digitization: Process of converting an analog display (features) into a digital display.

6. Digitizer: Device for scanning an analog image and converting it into numerical format.

7. Geographic Information System (GIS): Are computer-based systems that are used to store and manipulate, analyze and retrieve geo-spatial data/information for effective and efficient decision making.

8. Global Positioning System (GPS): A hand-held electronic device use for picking coordinates (longitude and latitude) of a location on the surface of the earth.

9. Imagery: A visual representation of energy recorded by Remote Sensing instruments.

10. Landsat: An unmanned earth-orbiting NASA Satellite that transmits multi-spectral images in the 0.4 to 1.1 μm region to the earth receiving stations. It was formally called Earth Resource Technology Satellite (ERTS).

11. Map Crossing: A process (mostly computer-based) for overlaying two or more maps of different factors, in order to calculate two or more maps of different factors, in order to calculate or derive new values or units for some specific purposes.

12. Monochromatic (Film): Black and White film that is sensitive to all visible wavelengths.

13. Multi Spectral Scanner (MSS): An instrument (Sensor) used to obtain imagery from different portions of the Electromagnetic Spectrum.

14. Oil Depot: Sometimes called a tank farm, installation or oil terminal. It's an industrial facility for the storage of oil and/or petrochemical products and from which these products are usually transported to users or further storage facilities.

15. Oil Theft: the act of illegal siphoning or stealing of oil from the oil depot/reservoir or through vandalism of oil pipelines by Oil Thieves or Saboteurs for their own benefit.

16. Panchromatic (Film): a multi-variant colour gradation film that is sensitive to all visible wavelengths.

17. Pipeline: A conduit or hose-like object made from plastic/rubber, concrete or metal connected end-to-end for long-distance fluid e.g. fuel or gas transport.

18. Pipeline System: A pipeline segment length constructed at a given phase/time and network to other segment length, Depots or Pump Stations for the efficient and effective pumping and distribution of petroleum products.

19. Pixel: A picture element having both spatial and spectral aspects.

20. Pumping Station: are facilities including pumps and equipment for pumping fluids from one place to another. They are used for variety of infrastructure systems, such as the supply of oil/petrol products to tanks.

21. Resolution: The ability of a Remote Sensing System to distinguish signals that is close to each other spatially, temporally, or spectrally. It refers to the pixel diameter (pixel diameter is the equivalent pixel size).

22. Retail Station: is place/station where the corporation dispenses or sells Oil/Gas to the public or end-users.

23. Right-of-Way (ROW): A ROW is the land on which transmission lines and/or pipelines are located. The ROW is usually acquired in widths that vary with the kilovolt (KV) size of the transmission line, diameter of the pipeline, or number of collocated transmission lines and/or pipelines.

24. Sensor: Device that receives electromagnetic radiation and converts it into a signal that can be recorded and displayed as either numerical data or an image.

25. Setback: An indispensable design and development control tool in the land use planning generally. It denotes the minimum permissible distance from the centre of a road to other uses or developments immediately adjourning the ROW.

26. Terrain: The character of a tract or region of the earth's surface.

27. Terrain Mapping Unit: Unit of a tract or region with similar characteristics such as slope, drainage and geomorphic condition. They are defined as units of land.

28. Vandal: someone who illegal vandalizes or breaks Oil pipelines to siphon in order to sell it to make money.

Abstract

In countries with insufficient investments in infrastructure and weak environmental governance, oil leakage from pipelines often occurs as a result of encroachment by land uses into its right-of-way, poor management and maintenance. Nigeria has its share of such incidents, and also suffers a large number of deliberate attacks ('interdictions') on oil pipelines. This work assessed the Compliance to the Regulations of Right-of-Way of the Nigerian National Petroleum Corporation Pipelines Network in Northern Nigeria. Landsat imageries of the SRTM and SRTM Band 1, 2, and 3 with 15 m and 30 m resolution respectively, Cadastral Map of Nigeria and Administrative map of Northern Nigeria at the scales 1:2, 000,000 and 1:25, 000,000 respectively were used, including some topographic and geological maps of the study area. These satellite

series were those taken between 2012 and 2013 and Questionnaire was administered to 200 respondents. Stratified Random Sampling Technique was employed to select the respondents. Data where analysed based on descriptive data analysis, where each respondent was weighed against responses from respondents using 4 Likert Scale System of Grand Point and Grade Mean to summarise data. A planned field check was carried out in order to update the interpretation, as well as verifying certain features of the pipelines and terrain. The main land use types that were found to have encroached into NNPC Pipelines' Right-of-Way included Agriculture (70.0%), Built-ups (14.0%), Roads (10.0%) and Water Bodies (6.0%). The findings also showed a strong negative correlation between pipeline interdiction and monitoring, planning, controlling and management with Grand Means of 3.58, 3.55 and 2.19. Finally, highlighted is the need for much better data collection and reporting for the mitigation of the negative socio-environmental impacts of interdiction incidences. The study concludes with a design recommendation that can address the key findings; such as putting in place a proper monitoring system of pipelines and its ancillaries using Remote Sensing and GIS techniques.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

This research work is all about the application of Remote Sensing and Geographic Information System in the Assessment of Compliance to Regulations of Right-of-Way for Nigerian National Petroleum Corporation's Pipelines Network in Northern Nigeria. Pipeline development and transportation which began in the early 1970's in Nigeria has witnessed a relatively accelerated expansion over the years. Presently, a network of oil and gas pipelines exists in the country.

In 1956, Shell British Petroleum (now Royal Dutch Shell) discovered crude oil at Oloibiri, a village in the Niger Delta, Nigeria, and commercial production began in 1958. Today, there are about 606 oil fields in the Niger Delta, of which 360 are on-shore and 246 offshore. These have been parceled out to the oil multinationals for extraction (Nigeria Country Analysis Brief, 2005 and Egberongbe, 2006). The country is now the largest oil producer in Africa and the sixth largest in the world, averaging 2.7 million barrels per day (bbl/d) in 2006. As a result of the numerous small fields, an extensive and well-developed pipeline has been constructed to transport the crude (Jiriko, 2007).

In general, Nigeria has a total network of about 5,001 kilometers of oil pipelines, consisting of 4,315 km of multi-product pipelines and 666 km of crude-oil pipelines (Brume, 2002). However, statistics on the actual number of kilometers of pipelines already built in the country vary. Citing available data,

the figure is put at over 3, 000 km (Nnah and Owei, 2005). Omorogbe (2001) says they range from 4,000-5,000 km while Olukesusi (2005) put the number of existing pipelines at over 7, 000 km (flow-line inclusive). They snake from the Lagos area, all the way through the East and Delta Region, on to the North (Saturday Punch, December 9, 2000 in Jiriko, 2007).

These pipelines criss-cross the country and inter-link the twenty two petroleum storage depots strategically dispersed across the country including the refineries at Port Harcourt, Kaduna and Warri, the off-shore terminals at Escravos and Bonny, and the four jetties at Okrika, Atlas Cove, Warri and Calabar. Presently, Nigeria has six export terminals including Forcados and Bonny (operated by Shell), Escravos and Pennington (ChevronTexaco), Qua Iboe (ExxonMobil), Brass (Agip), and Bonny Island LNG (Nigeria LNG). Shell's Bonny terminal has currently undergone a $600 million expansion that exports 1.5 million barrels per day (bbl/d) in 2006 (NNPC, 2010).

At the moment, the corporation operates 37 Mega Stations, 12 Floating Mega Stations and over 500 Affiliated Stations, all in effort to address the Nigerian petroleum products supply need (NNPC, 2014).

The pipeline system links the nation’s four refineries to the crude oil production points and the depots. The Shell Petroleum Development Company, for example, owns the 95 km Nembe Creek-to-Cawthorne Channel oil fields trunk pipeline that passes through 35 communities and transverses 60 rivers and/to creeks of varying sizes along its route with set of right-of-ways depending on the size or diameter of pipes (Jiriko, 2007).

A ROW is the land on which transmission lines and/or pipelines are located. The ROW is usually acquired in widths that vary with the kilovolt (kV) size of the transmission line, diameter of the pipeline, or number of collocated transmission lines and/or pipelines (e.g. they may range from as little as 25 ft to hundreds of feet wide). They provide a safety margin between the transmission line or pipeline and surrounding structures or vegetation. Beyond the Niger Delta region, oil (and gas) pipelines convey crude and/or refined petroleum products to its depots in Aba, Enugu, Mosimi, Ore, Ibadan, Ilorin, Markurdi, Kaduna (refinery), Gasau, Kano Jos, Gombe and Maiduguri.

Also, as at 1992, distributor depots were proposed for Suleja, Yola and Minna (in which some are currently completed while some are still on-going). Pump stations exist in Biu, Lokoja and Abaji, amongst other towns (NSF, 1998). For reasons of safety and security, these pipelines are buried about one metre beneath the surface along a 25-metre wide Right of Way (ROW), specifically acquired by Government for the purpose. This ROW is regularly cleared by the host community acting as contractors (Omonisini, Eludoyin and Salami in Nigeria Country Analysis Brief, 2005).

There are procedures to be followed and requirements to be met in the planning, designing and development as well as operation of pipeline projects. A prospective pipeline developer in Nigeria must first apply for two things- a grant or permit to survey a pipeline route and a license to construct and operate a pipeline and its ancillary installations and facility. The application for a permit to survey and a license should be routed through the Department/ Federal Ministry of Petroleum Resources to the Minister. The regulations

further require that the applicant must undertake an environmental impact assessment (EIA) study of the project.

The EIA Act equally requires full EIA report for Kilometres of pipelines exceeding 50 km and a partial EIA for lesser lengths. The Federal Ministry of Environment (FME)/FEPA as Well as the Federal Urban and Regional Planning Authorities too has their requirements to be met by the applicant. The grant of a permit to survey and, particularly, a license to build and operate a pipe gives the license quite extensive rights and privileges (Oil Pipelines Act S. 11 (1)-(4)).

The license is equally empowered to dig and get free of charge any sand, clay, stone or other similar substance (excluding a 'mineral' as defined in the Mineral Act) within any land in the area covered by the license in so far that such gravel, sand, clay, stone or other substance, will facilitate the construction or maintenance of a pipeline or any ancillary installation. A license expires after 20 years and is not renewable; a new license must be applied for and obtained if the holder desires to continue with the pipelines business (Pipeline Act CAP 338 of the Law of the Federation of Nigeria 1990 in Jiriko, 2007).

Design consideration would include Design Code for the demarcated/zoned ROW**,** set-back of other developments from the ROW or the ROW development activities from High Ways, Railways etc space requirements for the ancillary installations and facilities. Pipeline Stations are of different sizes. Larger ones, such as pump and compressor or tank farms, can cover several hectares of land. A greater proportion of station facilities

could be more accessible than a buried pipeline, for this reason, typical measures (setback) to forestall unauthorized access to such facilities are or should include fencing, locked gates, barbed wire, concrete barriers, beams and lighting and security systems. All these are essentially design and developmental control measures.

Setback is indispensable design and development control tool in the land use planning generally. It denotes the minimum permissible distance from the centre of a road to other uses or developments immediately adjourning the ROW**.** In this context of the subject matter, "setback" is the minimum allowable distance from the centre of the pipeline ROW to the abutting developments (Jiriko, 2007). The function of setbacks is to ward-off encroachments by other potentially injurious land use developments onto the pipeline ROW and its ancillary installations and facilities, thereby protecting them from potential human and environmental damages. Detailed hazard zone calculations (based on oil and gas spills from faulty/damaged pipelines) are difficult to come by. For this reason, some default distances can be set based on regulatory requirements or conservatively fixed.

In Nigeria, a combined team of PPMC, Community Leaders, Police and local security outfit provide surveillance to guard the pipelines. Regular aerial surveillance of critical sections of the pipelines is also carried out by PPMC/NNPC (Nigeria Country Analysis Brief, 2005). In spite of these security measures, statistics on oil pipeline vandalisation remain staggering.

According to Nwalo *et al.,* (2005) about 50 per cent of the cases of oil spillage is due to corrosion, 28 per cent sabotage and 21 percent oil production

operations. Only 1 per cent of the cases have been adduced to problems associated with engineering drills, inability to effectively control oil wells, failure of machines, and inadequate care in loading and unloading oil vessels. In all the forms, it has been gathered that the significant number of cases of encroachment into the right-of-way of NNPC pipelines were due to vandalism of pipelines by Oil Bunkers Operations, infringements by Farmers and in some cases through constructions of structures-built-up areas (Nigeria Country Analysis Brief, 2005).

1.2 Statement of the Research Problem

Nigeria's hydrocarbon resources are the mainstay of the country's economy but development of the oil and natural gas sectors is often constrained by instability in the Niger Delta and other areas in Nigeria were these pipelines criss-cross. The Nigerian economy is heavily dependent on the oil sector which, according to the International Monetary Fund (IMF), accounts for over 95 percent of export earnings and 40 percent of government revenues (Remote Sensing of Environment, 1995). All companies, that drill all over the world must meet certain pre-defined environmental conditions and requirement of their host countries so as not to interfere with the community's fragile resources, as little as possible. This however, is less obvious based on the Nigerian context (Roland, 2007).

Despite the need for the recognition of good oil and gas transportation and its significant contribution to our economy, the management, planning, construction and rehabilitation of our pipelines networks and right-of-way are still being marred by encroachment by the various land-use types, such as

built-ups, farmlands, wetlands, fishing grounds, roads, markets, hard-to-evaluate facilities, utilitarian and insensitive political, environmental and physical considerations. Daily wave of attack are being launched on oil facilities in Nigeria as un-identified people attack and set fire on petroleum pipelines and vandalize them.

The country has thus become a scene of a series of pipeline explosions, as a result of non-compliance with the right-of-way of these pipelines by the various stakeholders concerned, particularly by communities where these pipelines criss-crossed, for buildings, agricultural practices, bunkering and illegal siphoning of crude-oil and petrol products, most especially in the Niger-Delta axis.

In addition, the country's mass media had sad news relating to victims of oil pipeline explosions and other related home accidents. All these are evidences of inefficiency in the operation and management of the nations' pipeline system. Had the construction of pipelines facilitated the distribution of petroleum product in Nigeria? What are the strategies for improving the nation's pipeline system? These questions amongst others, present the problems that necessitated this research.

Nigeria has experienced an average of 500 pipeline related disasters a year. In year 2000 alone 764 cases were reported to be on the case files on burst pipes of the PPMC (Jiriko, 2007). The massive environmental problems, socio-economic dislocations and loss of human lives that accompany every pipeline burst in the country only further worsened the already precarious

condition of the masses as they pollute the environment causing irredeemable distortions to the ecosystem.

GOCON's Escravos and SPDC's Forcados Terminal tank failure in 1978, Texaco Funiwa-5's blow out in 1980, Abudu pipe line in 1982, 1979 and 1980 in Niger-Delta area. Although no lives were lost, but 340 hectare of mangrove were destroyed in 1980. In 1998 Over 2,000 people were burnt to death in Jesse (Delta State) due to oil bunkering and infringement into the right-of-way of the NNPC pipeline. While in year 2000, the Atlas Cove pipeline explosion lead to 50-60 people burnt to death. Again, in year 2000, in Oviri Court (Delta State) pipeline explosion, over 200 people were killed. Explosion at Etiama Community, Bayelsa State caused the death of over 2000 people (Jiriko, 2007).

In Kalakama Community, (Rivers State) in 2005, 11 or more people died as a result of vandalized Gas Pipeline explosion. At Ilado-Odo, Lagos State over 200 people were burnt to death. In 2007, 42 people died/burnt to death in Abog Village (Lagos state) due to vandalized Pipeline explosion. Oil spills at Bodo and Bonga (Delta State) in 2008 and in 2011 and raw gas leakage at Funiwa (Bayelsa State) in 2012 led to huge losses of aquatic plants and animals and humans lives (Nigerian Newspapers Online, 2012).

Furthermore, when oil comes ashore or offshore it kills shore animals by smothering them, or if sufficiently fresh, kills them because of its toxic constituents. Oil taints fish and interferes with fishing activities and navigation. Spilled oil makes a great mess, while, polycyclic aromatic hydrocarbons in the Crude Oil may be toxic, carcinogenic and teragenic.

Whereas the sea has enormous capacity to absorb the various attempts by man to degrade it, the streams, creeks, rivers estuaries, swamps and land have only a little capacity to do so (Fabiyi, 2001b).

The Literature is full of conventional and computer-based methods of studying, mapping and assessing oil pipelines route encroachment. For example, Fagbeja, (2008); Roland, (2007); and Yaw and Edmund, (2006) worked within NNPC pipeline using Remote Sensing and GIS technologies. Their studies are limited in areal coverage, as most of the works done were only limited to the southern regions of the five NNPC/PPMC Pipelines regions, basically the Port Harcourt, Warri and Mosimi regions. While not much studies has been carried out in the northern regions of Kaduna and Gombe or take entire regions as a whole using Remote Sensing and GIS techniques.

The present study focuses on the application of Remote Sensing and Geographic Information System in assessing the compliance to regulations of right-of-way for NNPC pipelines network in Northern Nigeria, using standard criteria as enshrined in the Pipeline Act CAP 338 of the Law of the Federation of Nigeria 1990. The statement of the problem seeks to answer the following Research Questions:

i. What are the various regulations guiding the right-of-way of pipelines in Nigeria?

ii. How large is the NNPC pipe lines' right-of-way and how is it maintained?

iii. How can Remote Sensing and Geographic Information System techniques be used to assess level of compliance to NNPC pipelines' right-of-ways?

iv. What are the environmental problems and challenges of non-compliance to the pipelines' right-of-way?

1.3 Aim and Objectives of the Study

The aim of this research is to assess the compliance to regulations of encroachment of other land-use types on NNPC pipelines' right-of-way in Northern Nigeria, using GIS and Remote Sensing technique.

The aim is achieved through the following specific objectives, which are to:

i. identify the various regulations guiding the right-of-way of pipelines in Nigeria;

ii. create appropriate digital spatial database and associated attributes of NNPC pipelines network and related right-of-way;

iii. assess the level of compliance to NNPC pipelines right-of-way directive in Northern Nigeria;

iv. identify the environmental problems and challenges due to the non-compliance to and poor management of pipelines ROW in Northern Nigeria.

1.4 Justification of the Study

By international standards, oil pipes ought to be replaced after 15 to 20 years, but most pipelines in use in Nigeria are about 20 and 25 years old, making them vulnerable to corrosion and leakage. In some cases, the pipes are laid above ground level without adequate surveillance, exposing them to wear and tear and other dangers (Oyem, 2001).

Anderson (2005), also noted that most of the facilities were constructed between the 1960s and early 1980s, to the then prevailing standards. The oil pipeline in the coast of Lagos that was buried underground is now exposed to the surface by the process of erosion. Settlements as well as farming activities have encroached on the ROW. In most cases, information about these vulnerable settlements and land use is scarce and are rarely noticed until a number of victims perish after a disaster. At the same time, oil theft, commonly referred to as "bunkering", leads to pipeline damage that is often severe, causing loss of production, pollution, and forcing companies to shut-down production.

The industry has been blamed for polluting air, soil and water leading to observed losses in arable land and decreasing fish stocks.

The findings and recommendations to be made in this study, when implemented, will benefit all Nigerians as well as the government for one thing, the implementations of the recommendation of this study will reduce the incidence of pipeline vandalism and explosion in Nigeria. Thus, the average Northern Nigerian will have access to petroleum products and longetivity of life.

1.5 Aspects and Scope of the Study

This research work seeks to demonstrate the capabilities of Geographic Information System and Remote Sensing techniques in the assessment of encroachment on the right-of-way of NNPC pipelines by various land use types in Northern Nigeria. The study covers the northern areas within the context of Nigeria territory where the NNPC pipelines transverse.

The study covers Depots in Jos, Gusau, Gombe, Kaduna, Kano, Maiduguri, Minna, Suleja, Yola and Pump Stations in Abaji, Biu, Dikko/Suleja, Izom, lafia, Sakin Pawa and Zaria. The study covers five kilometres away from the refinery and each of the depots on field work by the researcher and the entire length of the pipeline networks on the satellite imageries in the study area as at 2014. This is because at five kilometres, man's anthropogenic activities can be fully assessed and that the pipelines passes through unexploited environments where some of the land use types do not pose a threat.

Aspects of the study include the assessment of compliance to regulations of right-of-way for pipelines, identification, mapping and creation of a data base for the existing NNPC pipelines in the study area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter entails the Conceptual Framework and various literatures that were reviewed for the purpose of the study. It is concerned with the studies that used GIS and Remote Sensing for oil pipeline transportation monitoring, planning and management purposes. Several researches were cited in this context; however, only recent studies were reviewed.

2.2 Conceptual Framework for the Study

2.2.1 Petroleum Refineries

There are four refineries in the country owned by Government through the Nigerian National Petroleum Corporation (NNPC) commissioned between 1965 and 1989 with the under listed installed capacities:

Table 2.1: Nigerian National Petroleum Corporation (NNPC) Refineries in Nigeria.

S/No.	Refinery	Date Commissioned	Installed Capacity (Bpd)
1.	Port Harcourt I	1965	35, 000
	Port Harcourt expanded	1971	60, 000
2.	Warri	1979	125, 000
3.	Kaduna	1980	110, 000
4.	Port Harcourt II	1989	150, 000
	Total		**445, 000**

Source: Nigerian National Petroleum Corporation (NNPC) (2000).

The product slate from the four refineries are white products-Premium Motor Spirit (PMS), Dual Purpose Kerosene (DPK), Automotive Gas Oil (AGO) and Liquefied Petroleum Gas (LPG), Low Pour Fuel Oil (LPFO), High Pour Fuel Oil (HPFO), Bitumen, Base Oils, Paraffin Wax and Sulphur. In addition, the Warri Refinery has a petrochemical plant for the production of Polypropylene and Carbon Black, While Kaduna Refinery has a petrochemical plant for the production of Linear Alkyl Benzene, Solvents and Benzene (NNPC 2000).

Each of the refineries has been afflicted by accidents, maintenance and operational problems that have negatively affected the output and the ability to meet domestic demand. A summary of the current status of the refineries is indicated below:

I. Port Harcourt Refineries

The first Port Harcourt Refinery was built in 1965. It was commissioned, operated and managed by SHELL PB. The capacity was 35,000 bpd. However ownership passed to the Nigerian Government in 1970. The refinery was upgraded in 1971 to 60,000 bpd. The second Port Harcourt Refinery, a deep conversion facility, with an installed capacity of 150,000 bpd was built and commissioned in 189, bringing the combined capacity of the refinery to 210,000. The refinery is currently operating at about 66% of the total installed capacity due to the on-going TAM. The Turn Around Maintenance (TAM) was last carried out in 2000 before the current TAM which began in 2012. Currently the two refineries are in operation as

internally and public generated power has appreciated fairly (NNPC 2000, Punch Newspapers 2012, Ogbuigwe 2013).

II. Warri Refinery

The refinery was commissioned in 1979 with an initial capacity of 100,000 bpd. It was de-bottle-necked to its current capacity of 125,000 bpd in 1988. It was further expanded in 1988 with the addition of a petrochemical plant with a capacity to produce 35,000 metric tones and 18,000 metric tones per annum of Polypropylene and Carbon Black respectively. The refinery is currently running at 63% due to on-going TAM. The last TAM was carried out in 1994. The refinery operated from January to February 2000 at about 10.3% of the installed capacity and was shut down because the Main Heater blew up. Four capital projects have been identified and implement for optimizing the performance of the refinery at a total of $220.77 million and ₦351.15 million (NNPC 2000, Punch Newspapers 2012, Ogbuigwe 2013).

III. Kaduna Refinery

The refinery was commissioned in 1980 with an initial capacity of 100,000 bpd. In 1985, it was de-bottle-necked to 110,000 bpd. The refinery was integrated with a petrochemical plant in 1988 with a capacity for the production of 30,000 metric tones of Linear Alky Benzene. It was shut in August 2000 partly to allow rehabilitation of the heaters and because the TAM which started in 1998 was yet to be completed. The last TAM carried out before then was in 1998 which means that two consecutive

TAM (1994, 1996), were not carried out. Eighteen capital projects have been identified for optimizing the performance of the refinery at a total cost of two billion naira (NNPC 2000, Punch Newspapers 2012, Ogbuigwe 2013).

From the above statements, it is conspicuous that these refineries are operating below their installed capacities due to poor maintenance, misappropriation of funds for TAM and vandalization of pipelines in Nigeria.

According to the Nigerian National Petroleum Corporation spent ₦152 billion on the repair of three of the nation's refinery in 2013. The amount was contained in the National Assembly Joint Committee on petroleum (Downstream). Details of the budget show that the total cost for the Port Harcourt refinery by its original builders, basic engineering design for the Fluid Catalytic Cracking unit and RFCC plant project is estimated at ₦76.77 billion. The total estimated expenditure for the maintenance of the Warri refining and petrochemical company is put at ₦43.12 billion. The corporation has budgeted ₦32.106 billion on the Kaduna Refining and Petrochemical Company (Punch Newspapers, 2012).

2.2.1.1 Nigerian Oil and Gas Pipelines Network Development

There is some argument as to when the first crude oil pipeline was built. However, some say pipeline transport was pioneered by Vladimir Shukhov and the Branobel Company in the late 19th Century. Others say oil pipelines originated when the Oil Transport Association first constructed a 2-inch (51 mm) Wrought Iron Pipeline over a 6-mile (9.7 km) track from an oil

field in Pennsylvania to a railroad station in Oil Creek, in the 1860s. Pipelines are generally the most economical way to transport large quantities of oil, refined oil products or natural gas over land.

Nevertheless, the discovery of oil and natural gas in commercial quantities in 1956 saw the rising production and export of crude oil from a modest start of 5, 100 barrel per day in 1958 to 2.4 million barrels per day in 1979 (NNPC, 1989).

Since then, the production and export of crude oil has been in millions of barrels per day. This has necessitate the development of the required infrastructure, facilities and services for both the production and refining of crude oil as well as for the conveyance of the crude to refining centers and transporting the end products and by-products to centers of consumption. Oil and gas pipelines and their ancillary facilities constitute vital components of these infrastructure/facilities.

In the mid 1970s the Government of Nigeria decided to construct nearly 2,000 miles of pipelines, a new refinery and 19 storage depots throughout Nigeria. The programme was initiated to meet future fuel demands and to overcome current shortages caused by the inadequacy of existing road and rail services.

Numerous projects were put into motion representing an investment of £450 million at 1977 values. One of the projects was Nigerian National Petroleum Corporation's (NNPC) Pipeline System 2C, a 370 mile pipeline from Warri to Kaduna. Starting in the Rain Forest the pipeline crosses through savannah type terrain before reaching desert conditions surrounding Kaduna.

Initially the pipeline was designed for crude oil but used on a batch basis carrying refined fuel such as Gasoline, Kerosene and Gas Oil from the refinery at Warri to Kaduna. Later the pipeline was used to pump crude oil to the refinery at Kaduna.

Installation of 25 Allen S37 engines for the pipeline system was undertaken in two phases. Phase 1 began in 1977, when upon construction each of the three pumping stations were equipped with three Allen 8-cylinder, 1,684 bhp engines driving high-speed multi-stage Centrifugal Pumps, through Epicyclic Gearboxes. The speed range of each engine is maintained between 350 and 600 rpm as the flow of crude oil is dictated by demand at the Kaduna refinery.

Accessibility for construction of the pipeline was a major problem because the roads were not made for heavy construction equipment and there were numerous river crossings to overcome. Despite this, by April 1980, a new refinery at Kaduna became operational allowing pipeline 2C to pump crude oil for refining and then distribution from Kaduna itself.

There is at present about 5,001 of pipeline network nationwide. The PPMC uses the network of multi-products pipelines to move products from the refineries/import receiving jetties to the 21 Storage Depots all over the country. All the systems are multi-purpose pipelines except for Mosimi-Satellite depots lines. The distribution network is made up of a number of numbers of systems as follows:

The table 2.3 is classified into five (5) basic systems, referred to as 2A, 2B, 2C, 2D and 2E. Added to these are four sub-systems, which are

actually extensions of the basic systems. These are sub-systems 2AC, 2CX, 2DX and 2EX. Pipeline system 2A runs from Warri through Benin and Ore depots and terminates at Mosimi depots. System 2EX originates at Port Harcourt runs through Aba and Enugu depots, up to Makurdi terminate at Yola Depot.

The Federal Government also deposited that two of the refineries is scheduled to be completed within 12 months, while the others will be completed within the short-term. However, only three States have been selected to serves as locations where some of these refineries are to be sited. The three beneficiary States are: Bayelsa, Lagos and Kogi State (NNPC, 2012).

Table 2.2: NNPC Pipelines Distribution Network Systems in Nigeria.

S/No.	System	Pipeline Network	Segment Length (Km)	Flow Rate (M3/Hr)
1.	System 2A	(a) Warri-Benin.	90	300
		(b) Benin-Ore.	114	300
		(c) Ore-Mosimi.	151	300
2.	System 2AX	Auchi-Benin.	107	380
3.	System 2B	(a) Atlas Cove-Mosimi.	40	750
		(b) Mosimi-Ibadan.	79	300
		(c) Ibadan-Ilorin.	128 (ATK)	60
		(d) Mosimi-Ikeja.	(PMS, AGO,	75
		(e) Mosimi-Lagos Satellite (Ejigbo in Lagos).	DPK)	150
4.	System 2C	Escravos-Warri-Kaduna (Crude Lines).	606	150
5.	System 2D	(a) Kaduna-Zaria-Kano.	140	160
		(b) Zaria-Gusau.	177	40
		(c) Kaduna-Jos.	165	90
		(d) Gombe-Maiduguri.	297	90
		(e) Jos-Gombe.	265	90
6.	System 2E	Port Harcourt-Aba-Enugu.	210	120
7.	System 2EX	(a) Port Harcourt-Aba-Enugu.	210	170
		(b) Enugu-Markurdi.	180	165
		(c) Makurdi-Yola.	470	70
8.	System 2CX	(a) Enugu-Auchi.	109	130
		(Interconnection).	250	105
		(b) Auchi-Suleja.	90	80
		(c) Suleja-Minna.	150	135
		(d) Suleja-Kaduna.		
9.	System 2DX	Jos-Gombe.	165	85

Source: Nigerian National Petroleum Corporation (NNPC) (1998 and 2000).

The evacuation of refined petroleum products by pipelines stood at 70% of production before the completion of the inter-link, while water, road and rail transportation modes shared the remaining 30% among themselves. It is expected that that when the commissioned interlink system becomes well-established, the bridging (use of tankers for transportation) of White

Petroleum Products would stop. This would help to save the nation costs and the wear and tear of highway infrastructures.

The first phase of pipelines system was built over 20 year ago. However, despite the fact that the pipelines are generally known to have a terminal life span of 50 years if well maintained, the pipelines and associated equipment such as pumps, valves, loading arms and meters, generators etc. have aged and are at various stages of deterioration. Contributing to the deterioration is lack of a proper maintenance schedule, as well as the incessant and deliberate acts of vandalism. Table 2.4 below shows the number of line breaks indicating the natural ruptures and willingful vandalization frequencies.

2.2.1.2 Attacks on Oil Transport Pipelines in Nigeria (Sabotage, Vandalization and Pilferage)

This sub-section gives a quantitative and possible explanation of observed patterns of the activities of Oil Saboteurs and Pilferers in Nigeria. Sometimes, Miscreants and Saboteurs tamper with petroleum pipelines in order to cause damage or steal products (such as during acute shortage).

This often results in a lot of wastage and loss of lives. According to PPMC (2014), Nigeria lost up to ₦6 billion due to deliberate damage to its pipelines in the country between January and August 2000 alone. This problem has for some years now been intractable and had become very alarming to the Federal Government.

Pollution and exposition due to pipelines damages (accidental or deliberate) cause a lot of pollution in the areas where they are

laid. When such damage occurs in refined product pipelines, they are usually accompanied by fire explosions and loss of lives and properties. The precautionary measure normally taken in order to prevent deliberate damage to pipelines and reduce the effects of such an occurrence is the burial of pipes many meters in the ground. But this is not always possible in some places, most especially across rivers and deep gullies.

Oil spillage from pipelines has become a daily experience. Crops and aquatic lives are lost as a result of this, leading to the impoverishment of the people in the study area. Actually, this is one of the major complaints of the indigenes of the Niger Delta areas of the country. It cost the oil-producing companies operating in these areas billons of Naira to clean the environment and pay for the damages arising from oil spillages.

The socio-environmental consequences of oil exploration and production have been widely reported both locally and internationally (Finer, Jenkins, Pimm, Keane, & Ross, 2008; Ikporukpo, 1983; O'Rourke & Connolly, 2003; Orubu, Odusola, & Ehwrieme, 2004; Watts, 2005 in Anifowose *et al.*, 2012). However, very few studies are dedicated to oil pipeline transport systems (Anifowose *et al.*, 2012).

According to Walker, Kucklick, Steen, and Fritz (1995) in Anifowose (2012) depicted that:

> ***Pipelines represent critical infrastructure for the smooth running of the oil and gas industry and are pivotal to sustained energy supply and economic growth. The construction and operation of oil pipelines can create significant social and environmental impacts. However, severe environmental impacts can arise when pipelines are damaged during operation, as spills (e.g. crude oil) can result in significant long-lasting environmental problems (Aroh et al., 2010; Dadiowei, 2009; Osuji, Erondu, & Ogali, 2010). Such pipe-line damage may be caused by natural disasters (such as landslides, earthquakes), poor maintenance,***

For example, the 2001 rifle shot in the Trans-Alaskan Pipeline led to an oil spill of 6143 barrels (258,000gallons or 976.8 m^3) lasting long before repairs(Alyeska 2007, p.99; Holland, 2010).

Many lives have been lost and properties worth millions of Naira have been burnt in the aftermath of deliberate pipeline attacks within this network (appendix XI). In this study, were fret such deliberate attacks as interdiction (Church, Scaparra, & Middleton, 2004 in Anifowose *et al.*, 2012), a term which is value neutral. Interdiction is also commonly referred to as vandalism or sabotage. Between 2000 and 2010, the Federal Government of Nigeria had lost the amount of 174.6 billion Naira to pipelines vandalism.

Severity of pipeline attacks can be measured using many variables e.g. number of events, number of incidents per pipeline km year (e.g. Anifowose *et al.*, 2010), or per head or per GDP, fire-outbreaks, injuries, fatalities, environmental contamination and the number of prosecutions per incident. The table below show a summary of pipeline vandalism, amount of crude oil lost and the value of the oil lost.

Table 2.3: Summary of Pipelines Rupture/Vandalism from January 1993-2011**.**

S/No.	Year	Value of Crude Lost ($)	No. of Pipeline Vandalism	Crude Oil Lost (bbl)
1.	2006	35, 334, 344	4	3, 914, 826
2.	2007	16, 138, 350	50	179, 315
3.	2008	196, 896, 495	153	2, 187, 739
4.	2009	87, 657, 483	360	1, 753, 150
5.	2010	152, 170, 959	864	2, 113, 486
6.	2011	632, 749, 512	899	6, 327, 495
	Total	**1, 437, 947, 142**	**2, 330**	**16, 476, 011**

Sources: Pipelines and Products Marketing Company (PPMC) (2012).

October 1, 2012, ThisDay Online Newspaper reported that, between 2012 and 2013 crude oil lost of 109, 050, 000 bbls valued at $1, 23, 000, 000.

Table 2.4: Recorded Pipeline Explosions and Deaths Resulting from Pipeline Rupture Vandalism in Nigeria.

Date	Event	Victims
October 1998	Pipeline explosion in Jesse, Delta State.	1, 000 people killed
March 2000	Explosion in Osisioma LGA, Abia State.	**50 people killed.**
10 July, 2000	Pipeline near town of Jesse village, Delta State.	**250 people killed.**
10 July, 2000	Explosion of rupture pipeline in Warri, Delta State.	**100 people died.**
3 0 November, 2000	A leaking pipeline caught fire near fishing village of Ebute near Lagos.	**50 people killed.**
June, 2011	Pipeline explosion at Atlas Cove, Takwa Bay.	**50 people died.**
19 June, 2003	Explosion of a pipeline punctured by Thieves in Umuahia, Abia State.	**125 people died.**
21 December, 2005	Pipeline explosion in Ehor.	**5 people died.**
12 May, 2006	A vandalized oil pipeline exploded in Lagos.	**500 people killed.**
1October, 2012	Pipeline fire at Umueze, Osisioma LGA, Abia State.	**15 died, 20 wounded.**
12 January, 2013	Pipelines explosion at Arepo Village, Ogun State.	**30 people feared dead.**
3 May, 2013	Pipelines fire at Ekorinim Village, Calabar, Cross River State.	**2 people killed.**

Source: American International Journal of Contemporary Research and This Day Online Newspaper (2012).

2.2.2 Remote Sensing Technology (RST)

According to Canada Centre for Remote Sensing (2010:1), defines Remote Sensing as:

> ***"The science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information. The process involves an interaction between incident radiation and the targets of interest".***

It is a power for surveying, mapping and monitoring earth resources and changes. This technology with GIS which excels in storage; manipulation

and analysis of geographic information and socio-economic data provide a wider application (Medis and Wadigamangawa, 1996). Remote Sensing technology is used in the acquisition of spatial data of earth resources, environmental, hazards and resourced monitoring etc. which are processed mapped out and used to formulate projects at the pre-feasibility and feasibility levels. It is a veritable technique for the collection of multi-temporal, multi-spatial data sets, which are captured by camera and sensors using platforms such as:

A. **Satellites:** Locate at different altitudes above the earth surface such as LANDSAT (Land Observation Satellite) by the American Government, SPOT (*Systeme pour I'Observation de la Terra*) by France supported by Sweden and Belgium, IKONOS by Greece supported by United States, EUROSAT by European Government and NIGERIASAT-1, NIGERIASAT-X and NIGCOMSAT-1R by the Nigeria Government. This information which is transferred to earth receiving stations on the earth surface which are then fed into GIS as inputs; this could be either soft or hard copies.

B. **Aircrafts:** which make use of photographs and a mosaic is made of the photographs and features are mapped which are input into computer information system with the use of special devices. The contribution of RST to GIS includes:

    - As potentials for uniformity, compatibility within and between data sets.
    - It timelines and flexibility.

- Its maintenance of up-to-date data in GIS.
- It is an ideal source of data for change detection because of continual monitoring of environmental resources.

The remotely sensed data are mostly in digital form, soft and hard copy etc. which are then interpreted and manipulated by special software such as ERDAS, IDRIS, ARCVIEW, ARCMAP etc. In a nutshell, RST contributes to GIS are in use. Satellite imageries are prefers and employed in this study.

A remote sensing device records response which is based on many characteristics of the land surface, including natural and artificial cover. An interpreter uses the element of tone, texture, pattern, shape, shape, size, shadow, site and association to derive information about land cover.

Thus, Remote Sensing techniques have quickened with the invention of photography which has continued to improve. It has been useful in different fields: for resource inventory and data acquisition which are processed for better management, exploration and exploitation and monitoring of resources. This is possible by the application of different methods and techniques of Geographic Information System.

2.2.3 Geographic Information System (GIS)

GIS provide the ability to store and display maps and associated information. It has the capability to integrate geographical data with other data from various sources to provide the information necessary for decision making. In the strictest sense, it is any information system capable of integrating, storing, editing, analyzing, sharing and displaying geographically

referenced information. In a more generic sense, GIS applications are tools that allow users to create interactive queries (user created searches), analyze spatial information, edit data, map and present the results of all these operations. Geographic Information Science is the science underlying the geographic concepts, applications and systems, taught in degree and GIS certificate programmes at many universities (Meyer, 1995).

GIS technology was developed as a result of the need to solve environmental problems, it requires spatial data and it origin is traced to independent origins. It was developed in 1960 for vector based digital mapping automated cartographical systems which were operational in many military and natural mapping systems by the addition of a relational database for the storage of attribute data and analysis functionality. It was designed for Canadian Government in 1963, in which overlay vectors polygons of resource information for applications such as pipelines' right-of-way and land assessment for degraded land rehabilitation and agriculture.

Furthermore, the role and function of GIS is inevitable in the setting-up of pipelines network and right-of-way information system. In addition to the geographic database which formed the core of GIS product, other functionalities includes; the subsystem for cartographical data acquisition, subsystem for data management (Huxhold, 1991). These are the four functions of GIS that need to be focused on in order to ensure the continuity of the information system.

2.2.4 Data Acquisition Techniques for GIS Operation

Data needed for GIS project could be compiled from various sources; some of these sources are;

i. Ground Survey method

ii. Photogrammetry method

iii. Graphic Digitizing methods

iv. Remote Sensing technique

v. Questionnaire survey

2.2.4.1 Ground Survey Method

The ground survey method of data acquisition include; traversing (compass and theodolite), triangulation, trilateration, spirit leveling or trigonometrically heighten, tachometry, chain surveying, plain tabling and inertial surveying method. The basic aim of these methods is for the determination of coordinate of points on the earth's surface from which a graphic representation in form of maps, plans, and charts can be made or which the shape and size of the earth could be derived (Ndukwe, 2001).

2.2.4.2 Photogrammetry Method

This is a measurement technique for which the coordinates of the point in 3-dimensions of an object are determined by the measurement made in two photographic images or more taken, starting from different positions, usually from different passes of an aerial photography flight (Ndukwe, 2001), Although, this method will not be implemented in this research work.

2.2.4.3 Graphic Digitizing Method

Digitizing refers to the conversion of information or data which are in analogue form into a digital format. Two types of data which are usually digitized are, point data (such as individual objects, spot heights, trees, etc.) and line data (such as roads, rivers, fences and rail-roads (Ndukwe, 2001).

2.2.4.4 Remote Sensing Technique

Remote Sensing is a technology that employs electromagnetic energy as a means of detecting and measuring characteristics of targets or terrain features. Satellite images are often use as data sources. Various techniques are used to extract from these sources and to geo-reference them (Ndukwe, 2001).

2.2.4.5 Questionnaire Survey

This is "a prepared set of questions in which Respondents record their answers in an administered survey". Questionnaires have been widely used for descriptive and analytical surveys in order to find facts, opinions and views on what is happening, who, where, how many or how much. They could be conducted personally, though post or internet, were classified as either "open" form/ unrestricted type or the "close" form/restricted type. Open questions seek to encourage the respondent to provide free answers and as they offer no direct clues, they are difficult to analyze and interpret requiring some form of content analysis. Close questions often require a short response in the form of yes or no, agree or disagree, important or not important. They are easy to ask, quick to answer, their analysis is straight forward, but may introduce bias as they may force respondent to choose from given alternatives (Doko, 2008).

2.2.5 Remote Sensing (RS) and Geographic Information Systems (GISs) in Encroachment into Pipelines Right-of-Way

This section describes in brief the link between Remote Sensing and Geographic Information System (GIS) and their uses for pipeline studies. Remote Sensing (RS) can be defined as the collection of information about an object by a recording device that is not in physical contact with it (Robert *et al*, 1984).

The term is strictly used to mean methods that record reflected or radiated electromagnetic energy. The technique employs devices such as Cameras, Infrared (IR) Detectors, Microwave Frequency Receivers and Radar Systems. Any of these pieces of equipment is able to code information about large area and store in a way that it can be retrieved later, hence the phase Remote Sensing. Imagery of objects can be use to provide maps of different subjects.

Among the different techniques of RS in use, satellite imageries are preferred and employed in this study, such as Landsat, Radar, SPOT and IKONOS imageries. Other technique such has Aerial photo could have been used for comparison purpose but are limited for this present study. Detailed discussions on the advantages of Satellite technique over others are given in chapter 4. It is suffice to say that it has high resolution and geometric qualities for qualitative analysis in the study on pipeline right-of-way and mapping. There is also the added advantage that satellite photography captured images that can cover large area and can be zoomed or scaled to suit specific requirements, making them advantageous in specific subject matter.

It should be noted that reliable identification of cultural features as well as natural phenomena, requires a ground resolution of 2 to 3 m per pixel. If these features are to be derived from sensor data, the pixel size should be in order of 1 to 2 m. Conversely, this is what makes it impossible for many pipeline and other land surface features to be identified from imagery of present day electro-optical sensors, including SPOT (Naithani, 1990). Besides, where high-performance cameras with (FMC) devices are used for mapping of individual features and other details are enhanced because of the use of lower sensitivity films.

Table 2.5, illustrates the minimum Ground Scale Cell Resolution of the different types of imageries produced by different sensor devices. Indeed the aerial photography, especially those of Panchromatic (Black/White) Films, stands out as a better alternative to any other. For example, for a Landsat (MSS) imagery to be detected it requires a Ground Resolution Cell (GRC) of at least 320 meters. On TM Landsat, the GRC needed is at least 120 m to detect an object. While SPOT (XS) have GRC of 80 m; SPOT (Pan) will need a GRC of about 40 m; but on an Aerial Photo (AP) at the scale of 1:100, 000 only and GRC of 40m will be required to detect an object/feature.

Table 2.5: Minimum Sizes of Objects to be Detected, Recognized and Identified for Various Condition of Contrast with their Background in Various Types of Imagery.

		Landsat MSS	Landsat TM	SPOT XS	SPOT Pan	A.P *) 1:100,000	A.P *) 1:50,000	A.P *) 1:25,000	A.P *) 1:10,000
GROUND RESOLUTION	CELL SIZE	80m	30m	20m	10m	1m	0.5m	0.25m	0.1m
HIGH CONSTRAST	Detection	320m	120m	80m	40m	4m	2m	1m	0.4m
Feature Background	Recognition	560m	210m	140m	70m	7m	3.5m	1.8m	0.7m
	Identification	800m	300m	200m	100m	10m	5m	2.5m	1m
LOW CONTRAST	Detection	1600m	600m	400m	200m	20m	10m	5m	2m
Feature Background	Recognition	2400m	900m	600m	300m	30m	15m	7.5m	3m
	Identification	3200m	1200m	800m	400m	40m	20m	10m	4m

*): Without Forward Movement Correction **(**Values should only be used as an indication of the order of Magnitude).

Source: Rangers *et al., 1992 and Canadian Centre for Remote Sensing (2011).*

G. I. S. can be defined as any manual or computer-based devices and procedures used to store retrieve and manipulate geographically referenced data (Aronoff, 1993). The system involves data input, management (storage and retrieval), manipulation/analysis; and output in different ways. However, a computer-based GIS is a powerful tool for handling large volume of data in digital format that they may not otherwise be possible. Besides, it aids easy retrieval and data may be analyzed and manipulated for display in one piece at greater speeds and lower cost than any other manually operated geographic information.

Surely, application of computer-based GIS in assessing oil pipelines right-of-way mapping is enormous ranging from the possibility of superimposition of a set of factors maps on others and to analyze them in combination with a type of pipelines' encroachment occurrence map. Also, the combination of maps (map crossing) enables the Earth Scientist to evaluate the spatial variability of the natural environment and to extrapolate the critical combination of factors found in the analytical phase.

Complex computation techniques, necessary in the map crossing of several factor maps and for table calculations, are feasible by the use of a mathematical compressor. GIS enables the rapid preparation of table showing the area of different factor combinations. Even where most of the available parameter maps are not of the same scale, information or maps to be overlaid can be matched regardless of their original scale by simple manipulations. However it may require statistical analysis of large quantities of variable and algorithmic complexities.

In this study all procedure for data manipulation, storage, and retrieval are done mechanically and digitally. Satellite imagery and conventional would be analyzed using computer-based system and devices. Interpretations and mapping would be based on digital\tracing out of identified attributes/features of oil pipelines encroachment. This is discussed in detailed in chapter 4.

An attempt is made to perform a digital map crossing of the land use types and encroachment types. This is achieved by first carrying out detailed interpretation/mapping of individual attribute maps using Arc Map Arc Info 10.1 software thereafter they are laid upon one another (superimposed) to produce final map.

It is proposed that the development of a pipelines' right-of-way monitoring system should consider the following:

Component 1: Land use data which can be monitored are first selected based on the data availability. It also contains the output tables (in spreadsheet format) which resulted from the processing of the spatial database. If it involved land use and right-of-way policies, it needs to be translated into indicators.

Component 2: The main functionality of this module is to track and verify pipelines' encroachment by the various land use types. It is developed based on remotely sensed data (Landsat or SPOT) and the contents will be kept in raster format and later converted to vector format. The component focuses on encroachment into pipelines' right-of-way that can be monitored from the analysis of satellite images. The main output of this component will be spatial

distribution of the various land use types encroaching into the pipelines' right-of-way, which includes; built-up, agricultural area, water bodies, roads etc.

Component 3: Relate to the spatial database. It consists of various layers derived from geographical database. Such datasets are mainly on the land uses encroachment and infrastructural component of the geographic database's data layers which are further broken down into sub-components such as Agriculture, Built-up, Roads, other physical areas such as Water Bodies and Refinery, Depots, Pump Stations and Retail Stations.

Component 4: Is the analysis module. In order to perform the analysis, the base data are structured and then stored in Database System. This module takes up all the different policy indicator measures and then processes the resultant data through the GIS engines of overlaying the pipelines network over various land use types layers. By applying the model builder available, it is possible to keep track of additions and subtractions of parameters. This component essentially processes encroachment into pipelines' right-of-way for efficient monitoring purposes.

Component 5: contains both the tabular and spatial (map) outputs resulting from the analysis processed in component 4. Each intersection process is displayed in customized table format and graphic (map) format.

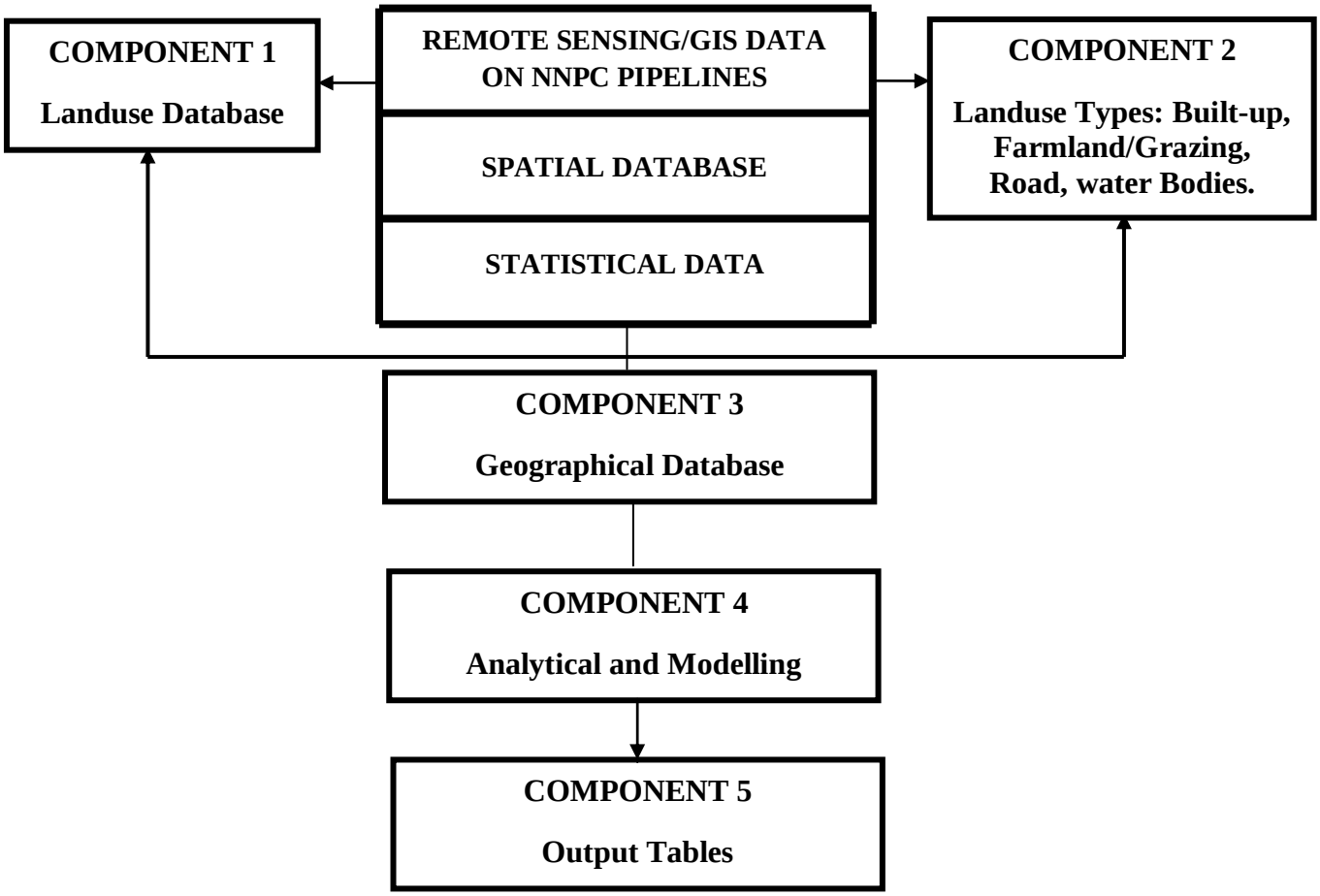


Fig. 2.1: Framework of the Monitoring System.

Source: Information Monitoring System/Researcher (2014).

On the whole, the steps involved in generating the land use policy and pipelines' right-of-way regulations' data to land use and pipelines' right-of-way output tables and maps for monitoring purposes are as follows:

i. The parameters of monitoring encroachment into pipelines' right-of-way by land use types are determined by selected existing land use type encroachers, pipelines infrastructures and land use and pipelines infrastructures indicators.

ii. Preparation of appropriate and relevant spatial data.

iii. Analysis and data processing are done utilizing model building capabilities.

iv. Data output are in: (i). Tabular format and (ii). Graphic format (maps). The tables are stored in access whilst the map outputs are stored separately in a separate folder.

v. Tabular data is copied and captured in spreadsheet format for trend and impact analysis.

The process of developing a pipelines' right-of-way and land use information system and the introduction of the monitoring system would help in promoting development in a more coordinated and comprehensive manner. Pipelines and Land Use Planning supported by an integrated information system will provide the commitments to achieve a sustainable development.

The data structure and other system components namely; the monitoring system could provide the platform for exploring the parameters of sustainable development derived through its performance indicators which later will be translated into spatial dimension. On the other hand, it can also support infrastructure planning, disaster planning, urban regeneration studies, transportation exploration and conservation planning and can be utilized for decision-making process.

In many environmental and pipeline management situations the most useful contribution of the Remote Sensing and Geographic Information System experts is the provision of a digital terrain map for a pertinent assessment of a subject matter. This is particularly true where information is required on the distribution of landform and pipelines characteristics and soil

types including operational surface processes; such maps have been used to considerable advantage for engineering, planning and management projects. While the concept of making a pipelines' terrain map is not a difficult one, the task of actually making one makes it to so.

Encroachment on NNPC pipelines' right-of-way varies from one Depot, Pump Station, Booster Station, and Retail Station and from one pipeline region to another in accordance with the forces and processes including hydro-meteorological factors and influence of man and animal. The encroachment into NNPC pipelines' right-of-way in northern Nigeria is influenced by rapid urban sprawling, poor agricultural and land management practices and hence subjected to rapid degradation, encroachment and vandalism.

As already stated the assessment of the case study required high technology device applications using computer hardware and software, satellite imageries and aerial photos. Also conventional field survey may be used to map the nature of and assess the extent of encroachment by the various land use types and pipelines degradation. However, these conventional methods can only be used in smaller areas (its coverage is limited) and extrapolation is strenuous and may result in over simplification.

2.2.5.1 Regulations on Pipelines' Right-of-Way

This section x-rays the various regulations and guidelines on oil pipelines' diameters/sizes, setbacks, standard marking colour code, criteria for evaluating right-of-way condition and level of to environmental laws as it concerns right-of-way.

2.2.5.2 Diameters/Sizes of Oil Pipelines

Petroleum pipelines are made from steel or plastic tubes with inner diameter typically from 100 to 1,200 mm (4 to 48 inches). Most pipelines are typically buried at a depth of about 0.91 to 1.8 m (3 to 6 feet). To protect pipes from impact, abrasion, and corrosion, a variety of methods are used. These can include wood lagging (wood slats), concrete coating, rock-shield, high-density polyethylene, imported sand padding, and padding machines. The oil is kept in motion by pump stations along the pipeline, and usually flows at speed of about 1 to 6 metres per second (3.3 to 20 ft/s). Multi-product pipelines are used to transport two or more different products in sequence in the same pipeline.

Crude oil contains varying amounts of wax, or paraffin, and in colder climates wax build-up may occur within a pipeline. Often these pipelines are inspected and cleaned using pipeline inspection gauges, pigs, also known as Scrapers or Go-devils. Smart Pigs (also known as intelligent or intelligence pigs) are used to detect anomalies in the pipe such as dents, metal loss caused by corrosion, cracking or other mechanical damage (NNPC, 1998).

For natural gas, pipelines are constructed of carbon steel and vary in size from 2 to 60 inches (51 to 1,500 mm) in diameter, depending on the type of pipeline. The gas is pressurized by compressor stations and is odourless unless mixed with a Mercaptan odorant where required by a regulating authority.

2.2.5.3 Setbacks

Setback is the minimum allowable distance from the centre of the pipeline ROW to the abutting development (land use type). The purpose and function of setbacks are to ward off encroachments by other potentially injurious land use developments onto the pipeline ROW and its ancillary installations and facilities, thereby protecting them from potential human and environment damages or hazards. Detailed hazard zone calculations (based on oil and gas spills from faulty/damaged pipelines) are difficult to come by.

For this reason, some default distances can be set based on regulatory requirements or conservatively fixed. A type of hazard zone for a natural gas pipeline could be based on generalized distance from given receptors (i.e. any creature, structure, land, area etc that could receive damage from pipeline failure) as indicated in the table 4.1. Such distances are in reality 'distance of concern' rather than hazard zones, since they are based more on receptor vulnerability than damage distances from pipeline release (Muhlbauer, 2004).

A setback of 375 m radius around 0.46 m oil pipelines as a hazard zone is also used but allows extra distances around specific receptors where topography supports a higher potential spill-impact radius (Jiriko, 2007). Similarly, for High Volatile Liquids (HVL) pipelines, setbacks of 303-454.5 m

are not uncommon. HVL releases incidents are very vulnerable to unconfined vapour cloud explosions, each of which can greatly extend impact zones to more than 1.6 km. Setbacks for buried high pressure gas pipelines based on thermal radiation criteria have been suggested. Generally, pipelines must be buried a minimum of 36 inches (three feet).

However, pipeline operators are not required to maintain this depth if erosion occurs after the pipeline's installation. Exposed pipelines should be reported to the Commission's Pipeline Safety Division of PPMC/NNPC.

For gas pipelines, there is no minimum setback requirement. Hazardous liquids pipelines that are within 50 feet of a structure must be buried to a depth of 48 inches (four feet), which is 12 inches more than the standard 36 inches (three feet) such pipelines must be buried when built. Examples of hazardous liquids pipelines are those transporting crude oil or a refined product, such as gasoline. Among the proposed setbacks are those for pipeline diameters ranging from 4 to 24 m and pressures from 400 to 1800 psig in 100 psig increments.

Table 2.6: Sample "Distance of Concern" for Natural gas Pipelines.

Characteristic	**Distance (m)**
Population class of 3 or 4 (i. e. more populated areas).	200
Hard-to-evaluate facilities (schools, day cares, prisons, elder cares, rehabilitation clinics etc.)	242.4
Hard-to-evaluate facilities, Pipe diameter>0.75 m and pressure>1,000 psig.	303
Areas of public assembly (religious worship areas, Town Halls, City Squares, Markets, etc.)	200
Areas of public assembly, pipe diameter. 0.75 m and pressure. 1,000 psig.	303

Psig: Pounds per Square Gauge.
Source: adapted from Muhlbauer (2004).

Guidance on safe setbacks for people and wooden buildings from the edge of a burning spill is also provided. The safe setbacks depend on the size of the burning area (of the affected pipeline) which assumed to be on open water. For humans the setbacks range from 46-3,030 m whereas for buildings they vary from 10-576 m for the same size spill. The spill radii for these setbacks range between 3 m and 606 m (Jiriko, 2007). Some of the setback requirements obtained from various sources are summarized in table 2.7 below:

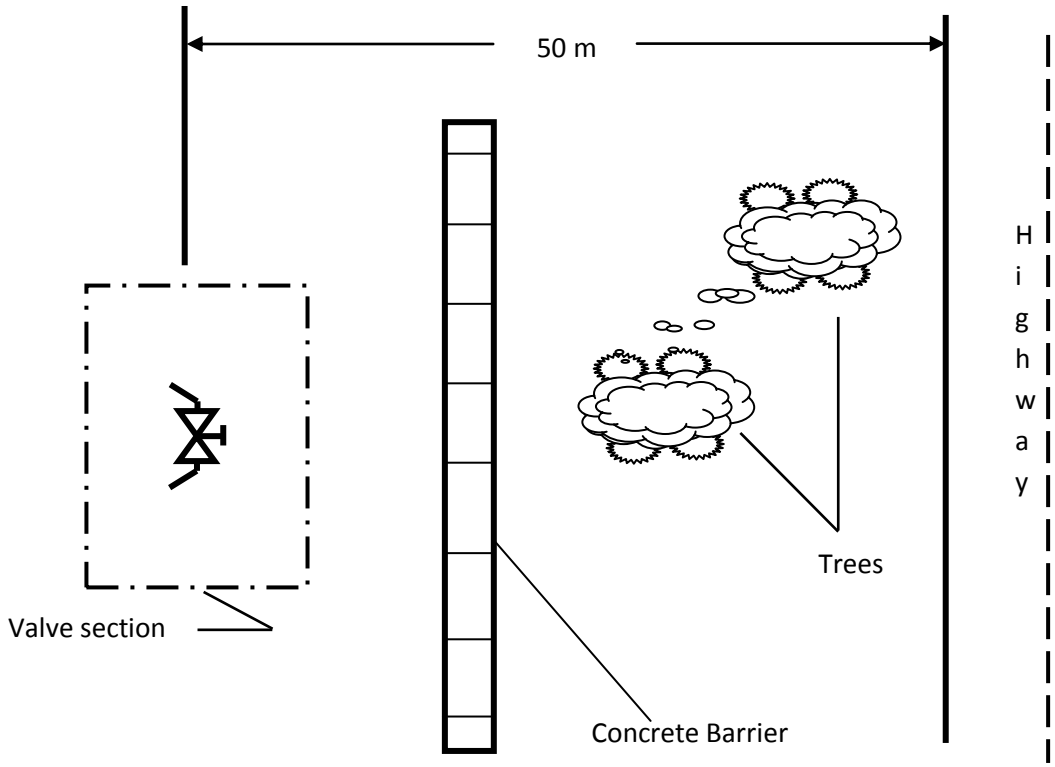


Fig. 2.2: Protection for Above-ground Pipelines Facilities.
Source: Adapted from Jiriko (2007).

Table 2.7: Summary of some Setback Requirements in Codes, Standards and other Guides.

Setback requirements for tanks from public (m)	**Variables**
1.5-53 (1, 2)	Tank size and type of adjacent use.
15-23 (3)	Type of adjacent use.
Performance Standards (4)	Site specific and process-driven.
Buildings: 39-47 (5)	Product and tank size.
People: 197-235 (5)	____ do ____
45-3, 030	Diameter of spill.

Source: (1). International Code Council (2000).
(2). Western fire chiefs Association (1997, 2000).
(3). American planning Association (APA).
(4). Department of Housing and Urban Development (HUD), U. S.
(5). U. S. Coast Guards (U. S. C. G.) Hand Book.

2.2.5.4 Standard Marking Colour Code

Locating pipelines and their depth could be better done by using detection devices i.e. instrumentation. This includes electro-magnetic signals, impressed electric signals and ground penetrating radar (Appendix II). Line marking methods are also used for locating underground pipelines. A standard marking colour has been put in place in U. S. each type of underground facility is assigned a specific colour. In practice, markings of appropriate colour for each facility are placed directly over the centerline of the pipe, conduit, cable or other feature.

The colours, relevant to this work, which the Uniform Colour Code of American Public Works Association (APWA) Utility Location Coordinating Council provides are as shown on the ensuing table 2.8.

Table 2.8: Standard Marking Colours and their Associated Underground Installations.

Standard Marking Colour	Type of Underground Utility/Facility
Red	Electric power lines, cables, conduit and lighting cables.
Yellow	Gas oil, steam, petroleum, gaseous materials.
Orange	Communications, alarm or signal lines, cable or conduit.
Blue	Water, irrigation and slurry lines.
Green	Sewers and drain lines.
Pink and Purple	Temporary survey markings and cable television, respectively.
White	Proposed excavations.

Source: International Code Council (2000).

2.2.5.5 Criteria for Evaluating Right-of-Way Condition.

Several cases of pipeline failures can be traced to flaws in the planning and design (engineering) stage of the pipeline project cycle. Pipeline design aspects should include type of material used in constructing the pipe, material strength/toughness, pipe wall thickness, external loadings, pipe diameter/wall thickness ratio and land movements such as seismic vibration, fault movement, subsidence, landslide, water bank erosion, amongst others (Jiriko, 2007).

The pipeline ROW Condition must always be stressed and maximally maintained. ROW Condition is a measure of the recognize-ability and inspect-ability of pipeline corridor. A clearly marked, easy to recognize ROW reduces the vulnerability of third party intrusions and assists in leak detection (e.g.

vapours, dead vegetation etc, easily spotted) from ground or air patrols. Clear parameters for evaluating ROW Condition should be evolved by the evaluator. A five step ranking schedule with the associated parameters for assessing pipeline ROW Condition should take the form suggested as depicted in figure 4.2 and table 4.4.

Table 2.9: A Five-level Scheduled and Criteria for evaluating ROW Condition.

Pipeline ROW Condition (Level).	**Evaluation Criteria.**
Excellent	Clear and unencumbered; route clearly indicated; signs and markers visible from any point on ROW or from above; signs/markers at all roads/rail-roads/water crossings; all changes of direction clearly marked, air patrol markers are present.
Good	Clear route-the view along ROW from ground level/above NOT obstructed by overgrowth; well marked: markers (if all in place) visible from every point of ROW and above; signs/markers present at all roads/rail-roads/waterways.
Average	ROW not uniformly cleared; more markers need for clear identification at roads/rail-roads/waterways.
Below Average	ROW is overgrown by vegetation in some places; ground is not always visible from the air or there is not a clear line of sight along ROW from ground level; indistinguishable as a pipeline ROW in some places; poorly marked.
Poor	Indistinguishable as pipeline ROW, no (inadequate) markers present.

Source: Synthesized by the Author from Muhlbauer (2004), Jiriko (2007).

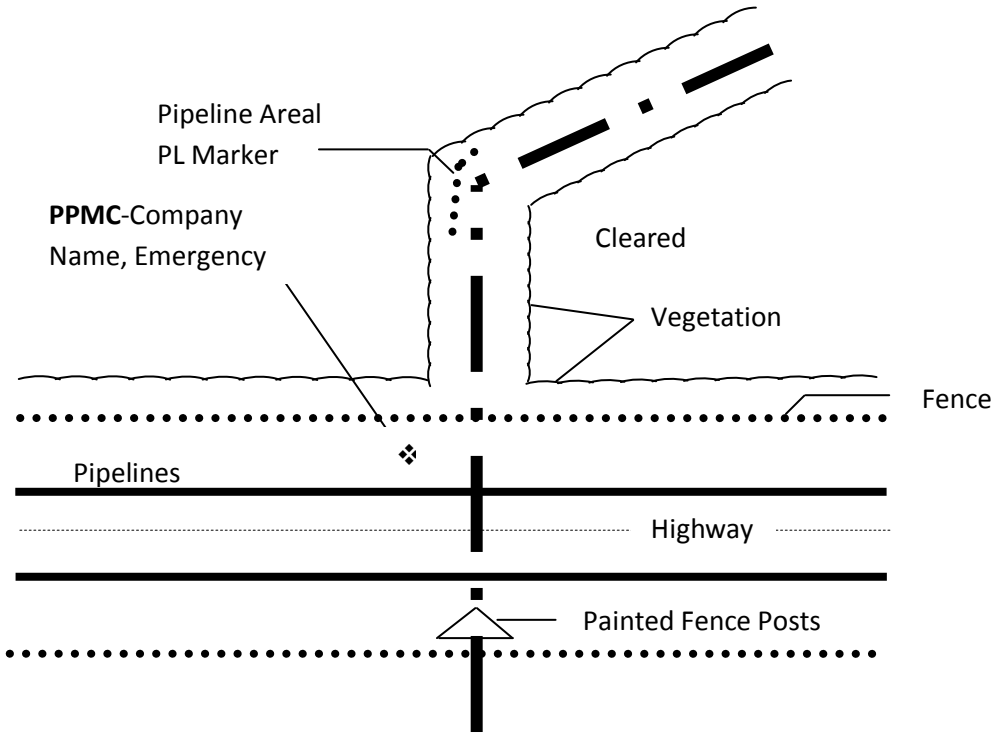


Fig. 2.3: Pipelines' Right-of-Way Condition.
Source: Modified from Jiroko (2007).

2.2.5.6 Compliance to Environmental Laws

Attitudinal problems, including refusal to comply with or undertake Environmental Impact Analysis Report(s) required by law, can be an important cause of many of the socio-economic and environmental problems plaguing the planning, design and management of the pipelines' ROW network in Nigeria.

Pipeline failures or releases contaminate damage or destroy environmental resources (Jiriko, 2007). They contaminate, for example potential drinking water sources-both surface and underground. The impact of

a release to an area or water source depends on various location-and-time specific determining factors. These include distance to surface water or Karst feature, flow rate in the receiving stream or river, saturation of soils, temperature and wind speed and nature of the event causing the release. Pipeline spills or releases also do and have actually impacted negatively on creational water ways and bodies. They impact surface water quality and contaminate or kill fish which limit contact recreation and recreational fishing respectively

Regarding contamination of prime agricultural land, a spill volume of 500 is set as the threshold for impacts of such lands in the U. S. (Muhlbauer, 2004). A spill of the size from a rupture could be expected to contaminate about 1,000 sq. m of land/soil. Distance from prime agricultural land along the pipeline that could be impacted from a pipeline accident was put at a maximum of 379 m from the point of release. This gives a band of impact of 758 m along the pipeline for evaluating any point of rupture. In the case of wetlands contamination, the same spill volume with that of the prime agricultural land is set as the threshold for pipeline rupture impacts to the wetlands.

This means the potential for impact of a pipeline failure to any wetland resource is represented by the distance across the wetland plus 379 m to either side along the pipeline.

2.3 Review of Relevant Literature

Many authors or researchers, who have vested interest on the Subject Matter, have carried out researches on oil pipeline and its environmental complexities. Relatively, fewer works had been done in Nigeria, particularly on NNPC Pipelines' right-of-way compliances by the various land use types, Geographic Information System and Remote Sensing. Works already done in Diaspora and in Nigeria, as regards pipelines includes:

Ajide and Isaac (2013) assessed the physical impact of Oil spillage in Town, Delta State, Nigeria using GIS and Remote Sensing technologies; empirical evidence from Jesse. Their study relied majorly on secondary data sources from existing classified Landsat imagery of the study area at 28.5meter resolution. The findings revealed that oil spillage is increasing unabated in the study area. Over 6000 spills had been recorded in the 50 years of oil exploitation in Nigeria, with an average of 150 spills per annum. In the period between1976–1996, 647 incidents occurred that resulted in the spillage of 2,369,407.04 barrels of crude oil. With only 549,060.38 barrels recovered, 1,820,410.50 barrels of oil were lost to the ecosystem. Oil spills degraded most agricultural lands in the State and have turned hitherto productive areas into waste lands.

Abdul-Lateef, Abdul-Nasir, Dano Umar and Imtiaz (2012) selected optimal oil pipe line route using GIS. A community participation in weight derivation and disaster mitigation used GIS technique to generate an optimal oil pipeline route in Malaysia's oil rich Baram Field. It shows how ARCGIS

software can be integrated with a multi-criteria decision analysis (MCDA) in getting the best route. The strength of this study lies on the fact that weight derivation of the variables in order of their importance was done by the whole community. A realistic and reliable pipeline route, which meets all concerned parties and weighed the variables based on their variability to environmental degradation were developed. However, their challenge was how to overcome naturally existing obstacles on the ground on the route simulated.

Khaili and Pandey (2012) developed an onshore integrated pipeline system using GIS. The major challenge in the project was extraction of data from alignment sheets. However, Smart automation was done towards capturing of data from alignment sheets, and automatically cleaning the pipe centerline data adhering to ADCO CAD manual, automatically.

Anifowose, Lawler, Horst and Chapman (2012) assessed attacks on oil transport pipelines in Nigeria, a quantitative exploration and possible explanation of observed patterns. This study presents the first quantitative and regional exploration of the problem of oil pipeline interdiction in Nigeria. It illustrates geographic patterns through choroplethic and bivariate Geographical Information Systems (GIS) map overlays. Their findings includes; strong negative correlation between pipeline interdiction and poverty and statistically and non-statistically significant mean differences in the pattern of interdiction occurrence amongst the five geographic regions. They also highlight the need for much better data collection and reporting for the mitigation of the negative socio-environmental impacts of interdiction incidences.

Tobenna (2013) developed a pipeline routing using GIS and Remote Sensing depicting how remote sensed data was used to develop a geo-database using GIS for pipeline development to help in minimizing public health hazards, environmental degradation, and destruction of the ecosystem. The study showed how GIS can help oil, natural gas companies and pipeline manufacturers develop a cost effective and effective routing plan for end users. ArcGIS software was used in pipeline routing analyses. Its core strength is it broad range of powerful spatial modeling and analysis of features. The major challenge of this research is the reliability of GIS; the researcher expressed concerns, that it lacks a more powerful analytical tool, which limit his level of locating suitable lines for pipelines' placement.

Cheng *et al.* (2012) developed a frame work for research and implementation of oilfield Basic Platform based on integrated 2D with 3D of GIS, uses 2D and 3D integration technology in pipeline planning. It shows how ArcGis 9.2 and RS (ERDAS IMAGINE 8.7 image processing software) work by generation of parameters (land use, land cover and slopes). The use of false color composite and supervised classification to generate land use and land cover maps was a great example of GIS and RS capacity. This work presents the versatility of GIS and RS to calculate and manage different variables for instance the vegetation index, DEM, slopes and moreover the ease of operations among layers of information. It also review how GIS and RS help to classify the study zones was very useful because each subzone has a particular management program in function of its properties and risks. Cheng noted that GIS and RS performance was limited in this context, due to unavailability of data.

Volkan and Tahshin (2011) compared a GIS-based Approach to Traditional Route Selection on the NABACCO pipeline route through Turkey. They carefully compare a GIS based approach of routing a pipeline to the conventional traditional route selection approach in Turkey. They were able to prove that the cost of a GIS based pipeline route selection would decrease the cost of the project by 14 percent relative to the manual pipeline route approach. The work show a conceptual and real model where the pipeline was routed using GIS. The results showed that weight values determined with this method were in agreement with real land data. They further compared the route formed by using GIS to the route formed by the Pipeline institution; the GIS route crossed 151 roads, while the institutions route crossed 169 roads. The route formed by the institute was in a first-degree earthquake region, which posed environmental hazard.

William and Dutta (2010) assessed oil spill and pipeline condition using remote sensing and data visualization management systems. Here they systematically showed beginners and experts how the GIS and Remote Sensing techniques can be used to assess pipelines' oil spills.

Foroushania and Damadib in Wagner and Szekély (2010) applied Remote Sensing technique for the physical protection of the pipeline network online of corridor based infrastructure. Here they worked on existing service that locates invasions along a petroleum pipeline, informs an intrusion or warns about a disaster on the Petroleum Pipeline and Telecommunication corridors by using data from the Rights of Way (ROW), which is a buffer zone on each side of a petroleum pipeline.

Fagbeja (2008) applied Remote Sensing and GIS techniques in assessing air quality and carbon management of gas flaring in the Niger Delta. Identified the various sources of air pollution in the Niger Delta and reviews some of the possible management strategies available to the authorities. Gas flaring in the region was identified as one of the main sources of both CO_2 and CO, and it was said to be a major contributor to NOx, and NMVOC concentrations in the Niger Delta. Challenges confronting air quality and carbon management in Nigeria were also highlighted.

Oliveira, Soibelman and Garrett (2008) assessed spatial analysis of water distribution pipeline breakage and condition applying GIS. In their work, they were able to predict breakage rates and remaining service life of pipes. The goal of the research was to present the preliminary results of a study of the use of GIS for the analysis of breakage data taking into consideration the spatial interdependencies of breaks points. More specifically, they present the issues for data preparation, integration and exploratory analysis, and investigate the usefulness of GIS spatial analysis capabilities for the assessment of failure patterns and trends in water distribution networks.

Mohd and Ruszaidi (2008) developed a framework on oil and gas exploration in Ethiopia and Kaula Lumpur, Malaysia using GIS; they used digital elevation models, strikes and dips, satellite images to identify the best route of a pipeline and other oil and gas exploration problems in Ethiopia. Data collection from the subsurface of the material was done manually, without the use of satellite imagery. The work emphasized how GIS helps in storing data in a centralized database for revision in future changes of the pipeline route. Mohd *et al*. shows how GIS can be used to calculate the

components of pipeline laying models faster, with more quality and clarity. According to them, GIS provides an efficient way for Pipeline management strategies and reduces the cost from seismic survey design. However, they were very clear to mention that the results of the study were not calibrated or validated.

Roland (2007) developed a prototype for construction and rehabilitation of Nigerian oil and gas pipeline routes using GIS. He proposed pipeline operators with a management system based up on remote satellite surveillance and GIS application that is capable of minimizing potential pipeline damage and show how Geographical Information System (GIS) decision process can be use to locate to oil and gas pipeline route as an elements of a sound decision making strategy.

William and Subijoy (2007) assessed pipeline security using Remote Sensing and GIS. In their assessment they merged both GIS and RS tools for pipeline security assessment. This research is interesting because it depicts how terrain analysis is important in the whole pipeline structure, precisely bathymetry maps which show ocean depths. The study illustrates how pipelines flow rate can be affected by poor elevation data. It also shows a new dimension towards using GIS technology in pipeline routing, which is the usage of Global Positioning Systems (GPS) for locating pipeline characters, detecting pipeline movement and collecting geospatial data. The authors highlight one of the key advantages of using remote sensing approach to pipeline routing and pipeline management as its ability to predict oil spill vaguely.

Bayramov (2009) monitored vegetation cover (VC) percentage along Bakur-Tbilisi-Ceyhan oil export pipeline in 2007 and 2008 and VC re-growth rate between two years in Azerbaijan, using high-resolution Multi Spectral Images; IKONOS 2007 and FORMOSAT 2008 NDVI. The research covered area of 444 m wide and 442 km long. Detailed map of VC percentage was developed along pipeline corridor. VC percentages were quantified within the predefined classes for the general evaluation of re-growth rates.

Twumasil and Merem (2006) assessed change within the coastal environment in the Niger Delta Region of Nigeria. This study stresses a mix scale approach involving the integration of primary and secondary data provided through government sources and data bases from other organizations. The raw spatial data and satellite images used in the research came from the United States National Aeronautical and Space Administration (NASA). Two Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images of 4 May 1985 and 12 June 2000 were obtained for this study. The Landsat TM and ETM+ satellite data were processed using ERDAS IMAGINE 8.7 image processing software. To answer some of the research questions pertaining to the study area, the spatial data was analyzed with descriptive statistics and Remote Sensing Technology. The results revel that the study area experienced some significant changes in its coastal environments.

Omonisini, Eludoyin, and Salami (2005), demonstrated how Remote Sensing and Geographical Information System can be used in creating efficient scenario towards the management of oil spillage, induced fire disaster

in the study area. They made a comprehensive study on efficient disaster management in Oil Pipeline Corridors in Nigeria.

Xiaoge (2001) applied GIS Technology in the construction of Oil-Gas pipeline to provide a high-tech method for construction operation and management in the study. He used the new oil-gas pipeline construction in China to aim at high standards, good quality, advanced technology and best efficiency for the study using the GIS technology as a powerful tool to accomplish the target. The GIS and remote sensing technologies are used on route selection of the West-East Nature Gas Transportation Cross Continent Pipeline. The Remote Sensing images and revising maps of 1:50000 based on new SPOT images, produced from a GIS system are offered to the planning department of the pipeline and used for in situ investigation to obtain wonderful results.

Kirsanov (2003) advanced methods of monitoring of Oil and Gas pipelines by Integrated GIS. Advances ways on how to environmentally monitor pipeline, construct and maintain routes for quick and effective response to emergency. The Author Integrated Geographical Information Systems (IGIS), based on geological-landscape and topographic maps and Data, obtained through Remote Sensing (RSD). High-resolution (5m) images, KFA-1 000, obtained from Russian satellite "Resurs-F" obtained from satellites, are used to compile large-scale environmental maps that serve as a base for monitoring. Comparison was made thereof with maps compiled in the process of monitoring that would permit Researchers to trace spatial and temporal landscape variations in a pipeline-impacted area and to compile

sketch maps of prediction of development of negative processes. The study makes good use of digital models of the country, which allows making modern software used in IGIS to develop three-dimensional models of the area under control. Studies carried out in some areas of the North-West of Russia, showed a great potential of using IGIS in environmental monitoring along pipeline routes.

Sandra *et al*. (1995) designed a Prototype for Pipeline Routing using Remotely Sensed Data and Geographic Information System Analysis, a designs prototype least cost analysis was performed for pipeline routing using remotely sensed data and GIS analysis. A small section of the proposed Caspian Oil pipeline was chosen for development of the prototype. The results of this analysis demonstrate the benefits of integrating remotely sensed data with GIS analysis as a first look for pipeline routing.

Feldman, Pelletier, Walser, Smoot and Ahl (1995) designed a prototype for pipeline routing using remotely sensed data and geographic information system analysis. A least cost analysis was performed for pipeline routing using remotely sensed data and GIS analysis. A small section of the proposed Caspian oil pipeline was chosen for development of the prototype. The entire proposed 700-km Caspian pipeline would connect with existing pipelines and carry oil from the Tengiz oil field in Kazakhstan on the Caspian Sea to Novorossiysk in Russia on the Black Sea. A model was developed incorporating pipeline length, topography, geology, land use, and stream, wetland, road, and railroad crossings to identify a least cost pathway. The straight line path was 42 km long, and the least cost pathway was 51 km long.

Although longer in length, the least cost pathway (in the area considered) is 14% less expensive to construct than the straight line path. The results of this analysis demonstrate the benefits of integrating remotely sensed data with GIS analysis as a first look for pipeline routing.

Davey GIS Services (2002) in Hancock (2006) assessed the impact of vegetation along the rights of way (ROW) and how to manage it for outage prevention (electrical transmission), maintenance access (pipelines) and safety (highways) in the environmentally sensitive areas of United States America. These areas are identified using specific attributes of hydrology, slope, and soils data. Enhanced management control measure was arrived at by deriving a map of environmentally sensitive areas using existing GIS data, incorporating advance knowledge of environmentally sensitive areas into ROW management plans to help bolster public sentiment, reduce costs, foster environmental stewardship, contribute to regulatory compliance, and provide legal defense assistance. The challenge of this work was certain management techniques such as herbicide use and heavy equipment are incompatible with various ROW landscapes.

However, not much works has been done as regards land-use planning, design, management of pipeline right-of-way and environment complexities affecting these pipelines done at a larger scale in Nigeria.

It is against this background that this research is formulated to use Geographic Information System and Remote Sensing techniques, in assessing the extent of encroachment and compliances of the various land uses to NNPC pipelines right-of-way in Northern Nigeria.

CHAPTER THREE

THE STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This chapter presents and describes the general physical background of Northern Nigeria and the study approach and method that were adopted for data collection and analyses in this study. There are several published and unpublished texts/literature on the general geography of the study area especially regarding; location, extent, history, background, climate, relief, drainage, geology, soil and vegetation, topology and population. The detail given in this chapter includes information obtained from field observations, air photo interpretation, satellite imagery, in addition to relevant information already published. Fig. 3.1a and Fig. 3.1b presents the digitized diagram of the study area.

The method employed for this study, involves the use of computer-based GIS's techniques and Remote Sensing Systems, to analyze the satellite imageries provided for the study area. Data sources, sampling techniques of data collected are inclusive.

3.2 Physical Background of the Study Area

3.2.1 Location, Position and Size

Northern Nigeria is a geographical region of Nigeria. It occupies about two-third land mass of Nigeria. The region includes Kogi, Kwara, Benue and Taraba State towards the south. The people are largely Muslim, and many are Hausas. Much of the north was once politically united in the Northern Region, a federal division disbanded in 1967. Hausa and Fulani makes up the

Dominant Tribes. The area in focus covers approximately 60% of the Nigeria's land area. It is confined within latitudes 6^0 37' North - 13^0 40' North and longitudes 3^0 40' - 13^0 37' East (Times Atlas, 2012).

3.2.2 Historical Background

Northern Nigeria was a British colony formed in 1900. The basis of the colony was the 1885 Treaty of Berlin which broadly granted Northern Nigeria to Britain, on the basis of their Protectorates in Southern Nigeria. This was achieved through the activities of the Royal Niger Company, whose interior territories spread north from about where the Niger River and Benue River joined at Lokoja.

Britain's chosen Governor, Fredrick Lugard, with limited resources, slowly negotiated with, and sometimes coerced, the emirates of the north into accepting British Rule, finding that the only way this could be achieved was with the consent of Local Rulers through a policy of Indirect Rule which he developed from a necessary improvisation into a sophisticated political theory.

Lugard left the protectorate after some years, serving in Hong Kong, but was eventually returned to work in Nigeria where he decided on the merger of the Northern Nigeria Protectorate with Southern Nigeria in 1914.

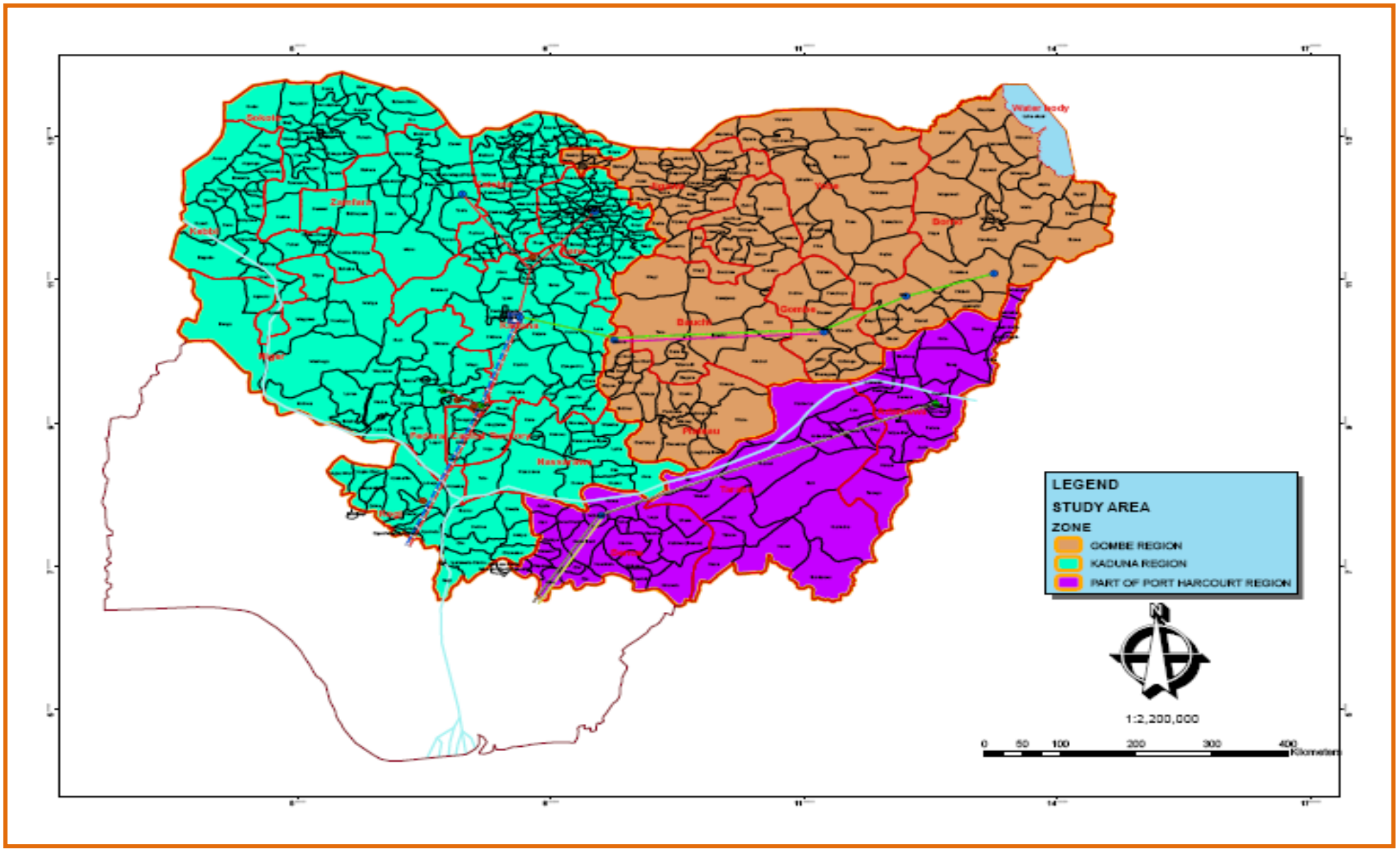


Fig. 3.1 (a): Study Area-Northern Nigeria.

Sources: Modified from Department of Urban and Regional Planning, Kaduna State Ministry of Environment (2012).

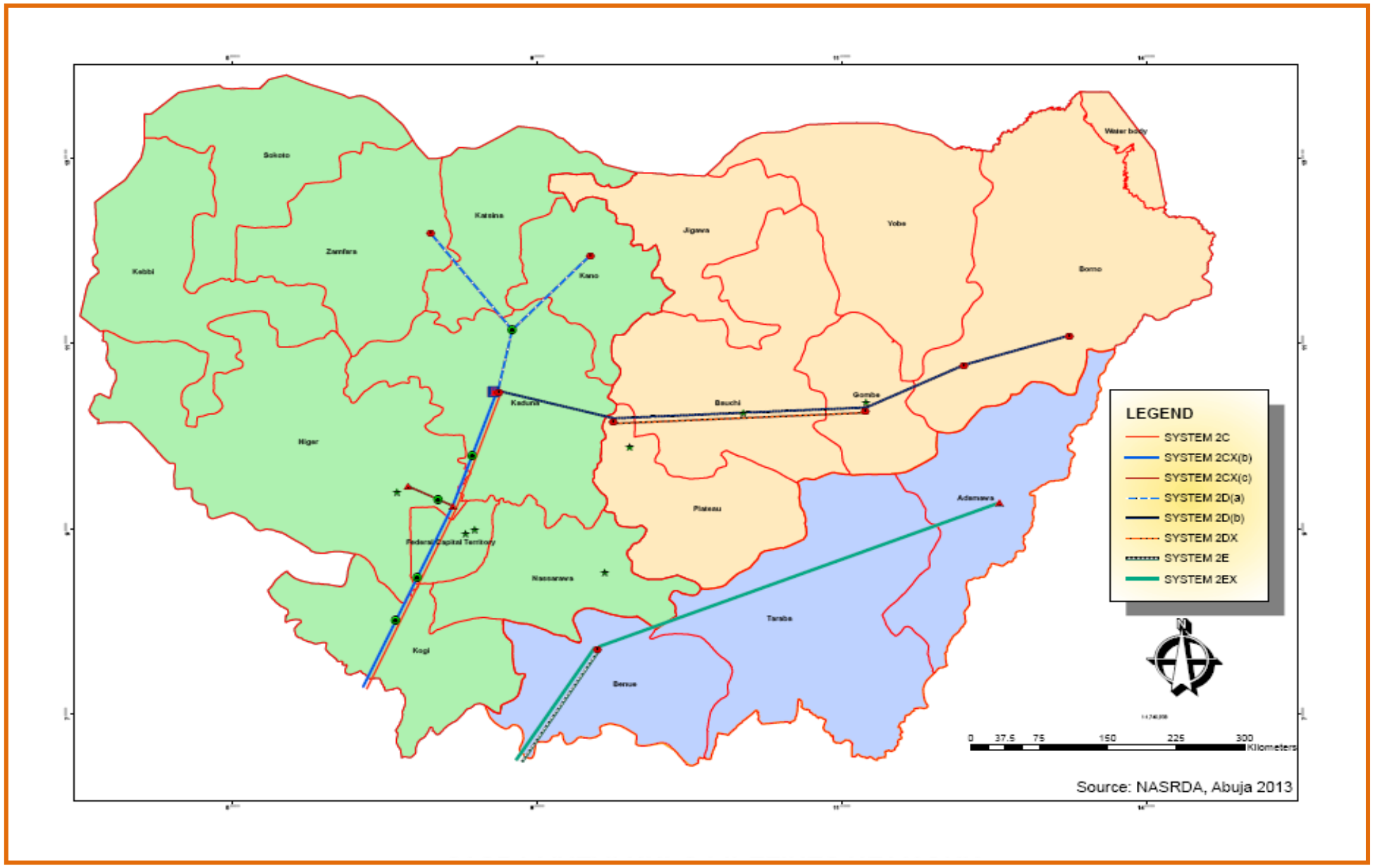


Fig.3.1 (b): Study Area-NNPC Pipeline Network.
Source: Modified from NARSDA, Abuja, 2013.

Before then there have been an existence of Hausa States. Between 500 CE and 700 CE Hausa people, who had been slowly moving west from Nubian and mixing in with the local Northern and Central Nigerian population, established a number of strong States in what is now Northern and Central Nigeria and Eastern Niger. Closely linked with the Kanuri people of Kanem-Bornu (Lake Chad), the Hausa aristocracy adopted Islam in the 11th century CE. By the 12th century CE the Hausa were becoming one of Africa's major powers. The architecture of the Hausa is perhaps one of the least known but most beautiful of the medieval age.

The Hausa Kingdoms emerged in the 13th Century as vibrant trading centers competing with Kanem-Bornu and Mali. The primary exports were Leather, Gold, Cloth, Salt, Kola Nuts, Animal Hides, and Henna. Except for minor alliances, the Hausa city-states functioned independently. Rivalries generally inhibited the formation of one centralized authority. There were fourteen Hausa Kingdoms: The "Hausa Seven" and the "Bastard Seven"

The Hausa Kingdoms began as Seven States with a shared mythology with its founders being the Sons of a Queen. They are known as the Hausa Bakwai meaning Hausa Seven. The States included: Daura ? – 1806, Kano 998 – 1807, Katsina c. 1400 – 1805, Zazzau (Zaria) c. 1200 - 1808, Gobir ? - 1808, Rano, Biram c. 1100 – 1805 (Times Atlas, 2012).

The growth and conquest of the Hausa Bakwai resulted in the founding of additional States with rulers tracing their lineage to a concubine of the Hausa founding father, Bayajidda. Thus they are called the 'Banza Bakwai

meaning Bastard Seven. The Banza Bakwai adopted many of the customs and institutions of the Hausa Bakwai but were considered unsanctioned or copy-cat kingdoms by non-Hausa people. These States include: Zamfara, Kebbi, Yauri (also called Yawuri), Gwari (also called Gwariland), Kwararafa (a Jukun State), Nupe (of the Nupe people), Ilorin (a Yoruba State)

Usuman dan Fodio led a jihad against the Hausa States and finally united them into the Muslim Fulani Empire, the Caliphate of Sokoto. Under him the Empire was bi-cephalous and divided into two territories each controlled by an appointed Vizier. Each of the territories was further divided into autonomous Emirates under mainly hereditary local Emirs. The Bornu Empire was initially absorbed into the Fulani Empire of Usman dan Fodio, but broke away after a few years later (Wikipedia, 2013).

3.2.3 Geology and Landforms

The study area is underlain by formations of three geological periods. The Basement Complex of the Precambrian periods dominates the southern part of Northern Nigeria. While the Sedimentary Zone of the Sokoto basin which belongs particularly to the cretaceous period and partially to the tertiary period, is to be found in the North.

Most of the region is underlain by a complex igneous and metamorphic rock of the pre-Cambrian ages. Furthermore, some parts of the study area are underlain by the Chad formation (unconformity), Kerri Kerri formation (unconformity), Gombe Sanstone, Fika Shales, Gongila formation, Bima Sandstone (unconformity) of the Pleistonecene, Maesticht, Senonian,

Turonian, and Cenomanian Ages in the Lacustrine Strata, Continental Strata and Eustaurine-Deltaic Strata environments in North-eastern part of Northern Nigeria. The Chad basin was a Tectonics Cross Point between a NE-SW trending 'Tibesti-Cameroon trough and NW-SE trending 'Air-Chad trough.

The Basement Complex has been described as having been composed of older high grade Igneous and Metamorphic rocks of the Precambrian to lower Paleozoic periods interspersed by belt of high younger Metamorphic rock. The predominant rocks are of the acidic and alkaline crystalline type such as Gneisses, magmatites and Granites, Schist. Quartzite and Hyalites occur extensively in the Western part of the complex. Granite is present in its old and young types in the study area; the old type of Granite presents a distinct feature in the form of inselbergs. These are smoothly grayish bare domed-rock which rises a hundred meters from amidst the wide undulating plains.

The study area is also underlain by undifferentiated Older and Younger Laterite with bed rock exposed in some places. The superficial deposits are by-products of various materials including crystalline igneous rock sediment and dentrital products. These superficial deposits of the young and older alluvium rest almost every where on the weathered basement. The younger laterite interwoven with alluvial deposits is characterized by accumulation of fine-grain grey brown sand, clay with silts and gravels in some parts of the study area. Distinctly banded sands, silts and clays along stream channels are cut to form bluffs which Higgins (1965) described as having a very typical Aeoilan drift appearance, being vertical and of a stable nature.

The plains is which is undulating in nature is largely compound of Biotite, Granite, Gneiss, Pyroblastic, Porphyriblastic with subordinate Migmatite. There are older rocks which are frequently exposed on the land surface weather in the form of doomed-hill (inselberg) or as low outcrops (Christopher, 2001).

Physical limitation to development in this study area, therefore consists of land liable to flooding and usually restricted to the broad valley floors, steep slope and gullies which occur along the smaller river valleys (Ministry of Land Survey Division, Kaduna 2014). Figure 3.2 Shows the geological and landforms characteristics of the study area.

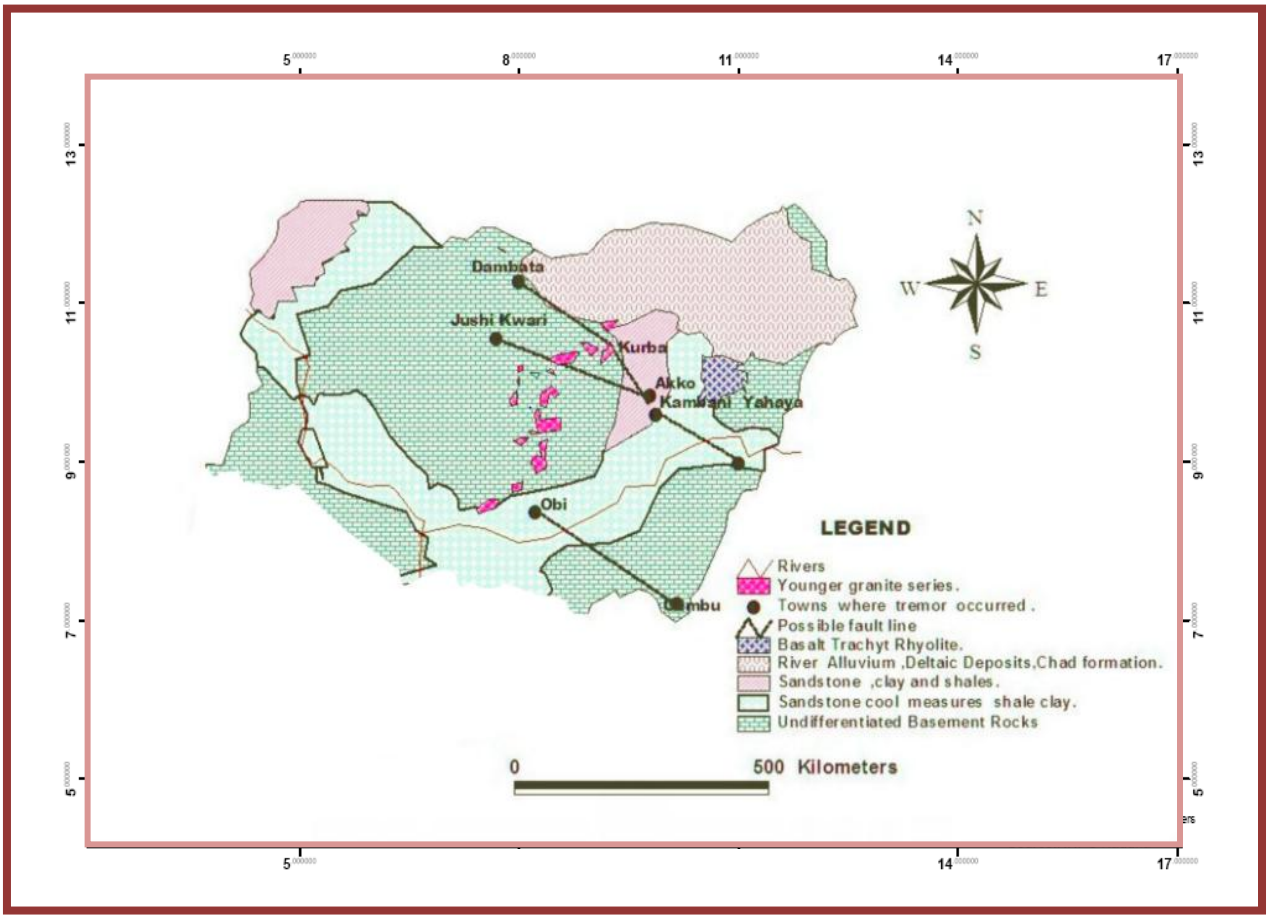


Fig. 3.2: Geology and Landforms of Northern Nigeria.
Source: Modified from Nigeria's Geological Map, 2014.

3.2.4 Relief and Drainage

The relief of the study area is a highlands (plateaux) and plains. The North-central are areas over 300 m above sea level. The area lies within the centre of Northern Nigeria and covers nearly one-fifth of the area. The highland is made up of two different platforms which lie at different levels. The high plains of Hausa land, whose average elevation stands at 750 metres from the lower step.

The Jos plateau is the highest platform with h an elevation of 1500-1800 metres. The Jos Plateau is a great hydrological centre or watershed with radial pattern of drainage in which many rivers take their source. The highest part is the Shere-hills, north-east of Jos where the elevation exceeds 1650 metres above sea level.

The plain, is an extensive gentle rolling peneplain which extends from Sokoto to Lake Chad, northward from south of Kogi and Benue to Tigueddi scarp near Agades, Niger Republic. The plains vary in height, reflecting both regional slopes to the south and local relative heights of 30-60 metres. The main low land areas include the Sokoto plains, in the North-west (200-300 metres), the Niger-Benue trough, wrapping round the North-central plateau (100-300 metres) and the Chad Basin or Borno, in the North-east extremity (100-300 metres). Hill features of two kinds surmount the plains-rock inselbergs and lateritic ironstone capped Messa. The inselbergs vary considerably in dimension and shape from the prominent landmark of the area.

The drainage of Nigeria is dominated by two great river systems, the Niger-Benue and the Chad systems. With the exception of a few rivers that

empty directly into the Niger-Benue, all other flowing waters ultimately find their way into the Chad basin or down the lower Niger to the sea. Many rivers in northern Nigeria rise from the north-central plateau. The river Hadejia, Yedseram, Komadugu, Gana and Gongola flow from the east, the Sokoto, Kaduna, Mariga and Gurara flow westwards to the Niger, while other small rivers like Mada and Gbako flow south-wards.

The two river systems; that are the Niger and the Benue are separated by a primary watershed extending northeast and north-west from the Bauchi plateau which is the main source of their principal tributaries. North-west of the plateau laid the elevated, drift-covered plains of central Hausa-land which is drained by numerous streams all flowing outwards to join the major tributaries (Kuruk, 2004).

3.2.5 Soils

The soil types as found and distributed in northern Nigeria have been greatly influenced by the climatic elements of precipitation (rainfall), temperature and wind (Ajayi 2003). The soil in northern Nigeria can be grouped into three (3) major zones, which are: the Coastal swamp or alluvial soil zone, lateritic soil zone and loess and sandy soil zone. coastal swamps/alluvial soil zone found along the flooded plains of rivers particularly the Niger and Benue coastal plains, Chad basin and Lokoja, lateritic soil zone has the largest area of coverage in Nigeria, as they are found occupying the interior part of the country covering places like Benue, Kwara, Plateau, Niger, Kogi, Kaduna, Kebbi, Bauchi, Adamawa, Taraba State etc.

They occur in areas with long period of dry season alternating with wet season. The soils over Northern Nigeria plains are generally of the laterite, formed from drift deposits which mantle the solid sedimentary and pre-Cambrian basement granite rocks. They are generally reddish in colour due to the presence of iron content in them. They are of little use for farming purposes, because of their poor fertility. Thus, fertilizer is constantly added to it to enhance its performance. Some minerals like iron and aluminum compounds are found contained in the soil. The zone of lateritic soils present in some fertile and productive soils is due to the accumulation of nutrients at the B-horizon are strongly influenced by the action of the parent materials. Thus, the soil supports the cultivation of tuber crops like Cocoyam, Cassava and Yam (Ajayi, 2003).

The loess and sandy soil zones are found mainly in the extreme part of Northern Nigeria in places like Kano, Katsina, Bornu, Yobe, Jigawa, Sokoto and part of Kaduna State, occurring in the Sudan and Sahel savanna belt of the country. They are formed directly from the parent material due to dryness and are transported and deposited by wind. Crops like Groundnut, Millet, Maize, Guinea-corn and Cotton are widely grown. Topographical factors appear to play vital role in determining their detailed characteristics. In some hills in the study are the young coarse or weakly developed soils (Regosols). The soil in the valley bottom lands (Fadama) belong to the Intragonal group especially hydromorphic soils or vertisoils (Klinkenberg, 1970) due to accumulation of both organic matter and alluvium.

They are confined mainly to the water courses of the major rivers. They are characterized by dark-grey clay with poor to very poor drainage. Generally, the character of the soils is such that as soon as rainfall starts, infiltration could be quite high but the pores soon get sealed up with fines and further infiltration is impeded resulting in over land flow, sheet flow and channel initials (Makeri, 1989). Many parts of the Fadama in the studied areas are therefore used for cultivation of fruits, Vegetables, Rice and Sugarcane. Adequate drainage is often a problem, while the lower temperature during the dry season can also be harmful to some crops (Ministry of Survey, Kaduna).

3.2.6 Climate

Northern Nigeria possesses a Tropical Continental (TC) climate consisting of pronounced long dry season alternating with a distinct but short rainy season. The high amount of radiation received by this area has contributed to its high temperature which varies from about 28^{o}C to 42^{o}C, depending on the atmospheric condition prevailing at that particular point in time. Temperatures are high daily Maximum Temperature rises generally from as low as <13^{o}C in January to its peak of >35^{o}C in April/May. A secondary high is often encountered in October. Also the mean Minimum Temperature rises from is lowest value in December/January (15^{o}C-20^{o}C) to its highest (35^{o}C-42^{o}C) in March-April.

During the dry season's months, the Tropical Continental (Tc) North Easterly which is cool dry and dust laden 'harmattan' blows from the Sahara, bringing low humidity, and cool temperatures may go below 10^{o}C at night in

some parts of the study area. Temperature during the summer month in extreme Northern Nigeria in areas like Sokoto, Kebbi, Yobe, Borno States temperatures may reach as high as 48^{o}C during which moisture laden winds blow from the Gulf of Guinea in the south bringing higher humidity and rains. The Monsoon rains in general show high spatial and temporal variability over the extremes of the study area.

Rainfall is generally less-than 500 mm annually the rains at their peak in August. Evapo-transpiration is over 2000 mm annually, with an annual average of about 2300 mm annually (Abdulkarim, 2003). In the study area the annual temperature range is greater, about 6^{o}C while the diurnal range is quite considerable, about 15^{o}C.

Thus Northern Nigeria lies within a region that has a tropical rainy climate of Tropical Grassland (Savanna) (Aw) and a superficial presence of Tropical Rainforest climate of the Am-type particularly at the southern part of the region with distinct wet and dry seasons, the wet season occurring in the high Sun period (May-September) with an average annual total of above 1100 mm, with the region having a single maximum, which comes during the month of august. The dry season is practicably rainless. But currently due to the effects of climate change the single maximum is being experienced in September.

The rainfall distribution over Northern Nigeria, Nigeria and West Africa is determined by the position of the Meteorological Equator and its two associate structures; the Inter-Tropical Front (ITF) and the Inter-Tropical Convergence Zone (ITCZ) also known as the Inter-Tropical Discontinuity

(ITD). These two form a discontinuity zone at their boundary. The surface position of the ITD moves north and south of the study area, in an oscillatory movement-the part of Nigeria where Northern Nigeria lies is invaded by two distinct air-masses, one from the north-dry and continental origin, and the other from over the Atlantic in the south-most, cool and equatorial maritime in nature.

Over much of Nigeria's interior, rainfall often experiences conventional origin, the air being forced to rise by intense heating of the land or by relief features like the Jos plateau. The generalized annual rhythm of weather in Northern Nigeria follows the annual march of the surface position of the ITD. Thus the seasonality of the area is stratified into:

Dry season (harmattan)	-	November to February.
Hot season	-	March to April.
Season of thunderstorms and qualls	-	May to June.
Wet season	-	July to October.

The Sahelian rainfall depends exclusively on the position of the ITF rainfall often convective in origin (Goni, 2006). The rainfall depth in the study during wet season (May-October) is between <500 mm->1250 mm. The low relative humidity experienced in dry season is a product of dry, dusty and cold harmattan air. The table shows the rainfall and temperature statistics of northern Nigeria. Table 3.1 and figure 3.3 below summarized the rainfall-temperature characteristic of the study area.

Table 3.1: Rainfall and Temperature Values of Northern Nigeria.

Climate Types	Land Cover	Rainfall	Temperature Maximum	Temperature Normal	Temperature Minimum
	(%)	(mm)	(°C)	(°C)	(°C)
Semi-arid	4	400-600	13	32-33	40
Dry sub-humid	27	600-1,000	12	21-31	49
Sub-humid	26	1,000-1,300	14	23-30	37
Humid	21	1,100-1,400	18	26-30	37
Mountainous	4	1,400-2,000	5	14-29	32
Plateau	2	1,400-1,500	14	20-24	36

Source: Kundell, 2008.

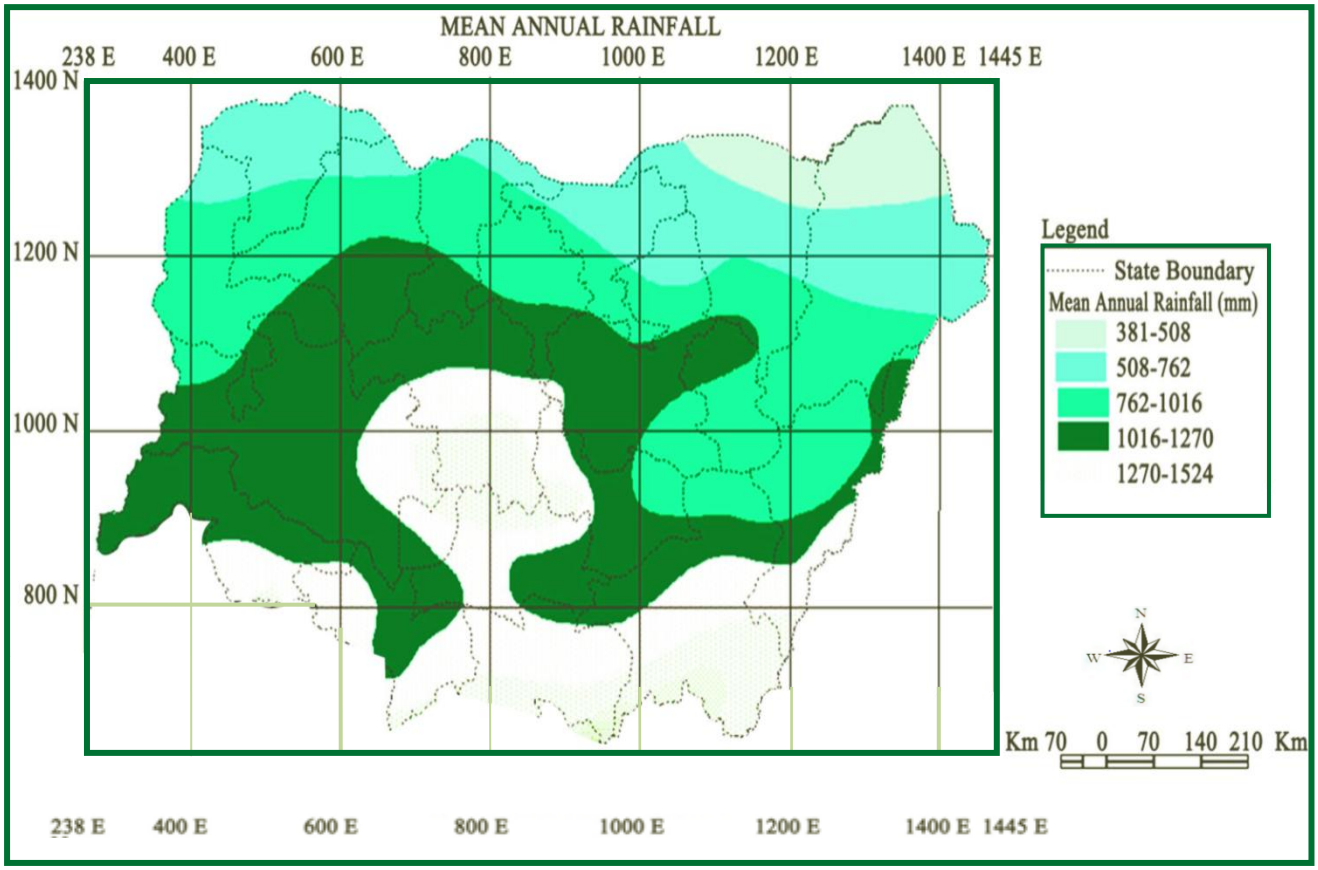


Fig. 3.3: Mean Annual Rainfall of Northern Nigeria.
Source: Modified from Nigeria's Rainfall Map, 2014.

3.2.7 Flora and Fauna

The seasonal characteristics of the rainfall makes its mark on the vegetation of the area which assumes various shades of green in the wet season and turns brown, pale or yellow in the dry season. Northern Nigeria is located within the Guinea savanna in places like Abuja, Adamawa, Benue, Kogi, Niger, Taraba States etc, Sudan savanna in Bauchi, Gombe, Kaduna, Kano States etc and Sahel Savanna-Borno and some part of Sokoto. The vegetation patterns show that, the pattern owes it existence largely to land use management practices over a very long period of time.

The areas that lies within the Guinea savanna zone, the vegetation consist of a wide varieties of communities which includes; commonly of woody plants and grasses which are fire-hardy species consisting of several woody species alone, occurring from the southern area towards the north wherever firing of savannah woodland takes place. The chief trees are *Isoberlina*, *Mangigera Indica*, *Psidium Guava* and *Parkia Bigloboza*, Acacias, Baobab and Shea-butter among others. While grasses includes *Clenium Newtoni* etc. There are also shrubs such as *Boswellia Dalzielli* etc. the vegetation in spots of forest in the study area commonly consist of trees such as *Albizia Zygia*, *Khaya Grandrofiola*, *Urania Chamaca* and *Chlorophora Esccelsa*.

The major agricultural practice includes; the cultivation of grain crops and some fruits. The main towns are mostly the Capital City of the States that falls within this vegetation zone. In the Sudan Savanna vegetation zone, found north immediately north of the Guinea savanna, has grasses as its dominant

vegetation. The grasses found are shorter in size than those found in the Guinea Savanna. The height of the grasses is greatly affected by decrease in rainfall. The major trees found within this zone include Acacias, Dumb-palms, Fan-palms and Shea-butter.

The grasses are multivariate in nature and have developed durable roots, which remain underground after the tops have been burnt by fire during the dry season. After the dry season the grass sprawl again with the onset of rain. The Riparian Vegetation (along stream valleys) is usually dense and made up of savanna woodland. The Sahel Savanna vegetation belt is located north of the Sudan Savanna. This vegetation belt has rainfall less than 450 mm and this gives way to the poor grasses, scanty short shrubs/trees. Few drought-resistant trees like Baobabs, Acacias and Date palms are found (Ajayi, 1998). Ornamental vegetation is now common around residential and administrative corridors. Botanic gardens have increased the greening of decline in the natural vegetation (National Bureau of Statistics, 2009).

The fauna in study area consists of a variety of Mammals, Birds, Reptiles, Amphibians, Fishes and some Insects. These no longer inhabit in area, now largely influenced by man, but are mainly restricted to peripherals of human habitation and to areas unexploited yet (Lewis, 1962). Some over 370 species of birds have been recorded from the study area of residents, Palaeartic migrants and African migrants. The Bushbuck, Grey Duiker, Oribi, Warthog and Western Hartebeest, Bush Cow, Water Buck, Bush Pig, Antelope, Monkey and Lions and Elephant found in sound in the Games Reserves and National Parks-Yankari (Bauchi), Gashaka Gumpti (Taraba),

(Kaduna), Kainji (Niger) and Kamuku (Kaduna) in the study area constitute some of the large mammals. Varieties of insects make up the terrestrial and aquatic fauna moths, the Tachinid fly, Termites (T. *Trinervetermes*, T. *Ebenerianns*, T. *Oeconomus*), Centipedes and Millipedes (Myriapods), Leach and Pocock, Snakes, Lizards, Toads, Frogs and Chameleons, Alligators, Crocodiles, Hippotamus, each of different species make up the amphibian and reptilian life.

There is considerably variety of habita t types in the study area: mature and degraded savannas, farmlands, fadama, fringing forests, inselbergs, open streams, lakes and temporary pools. Each must pose particular problems for its fauna but the main problem confronting many animals must be the modification of the environment by man and his action (Lewis 1962). Fig. 3.4 below show the vegetation types of the study area.

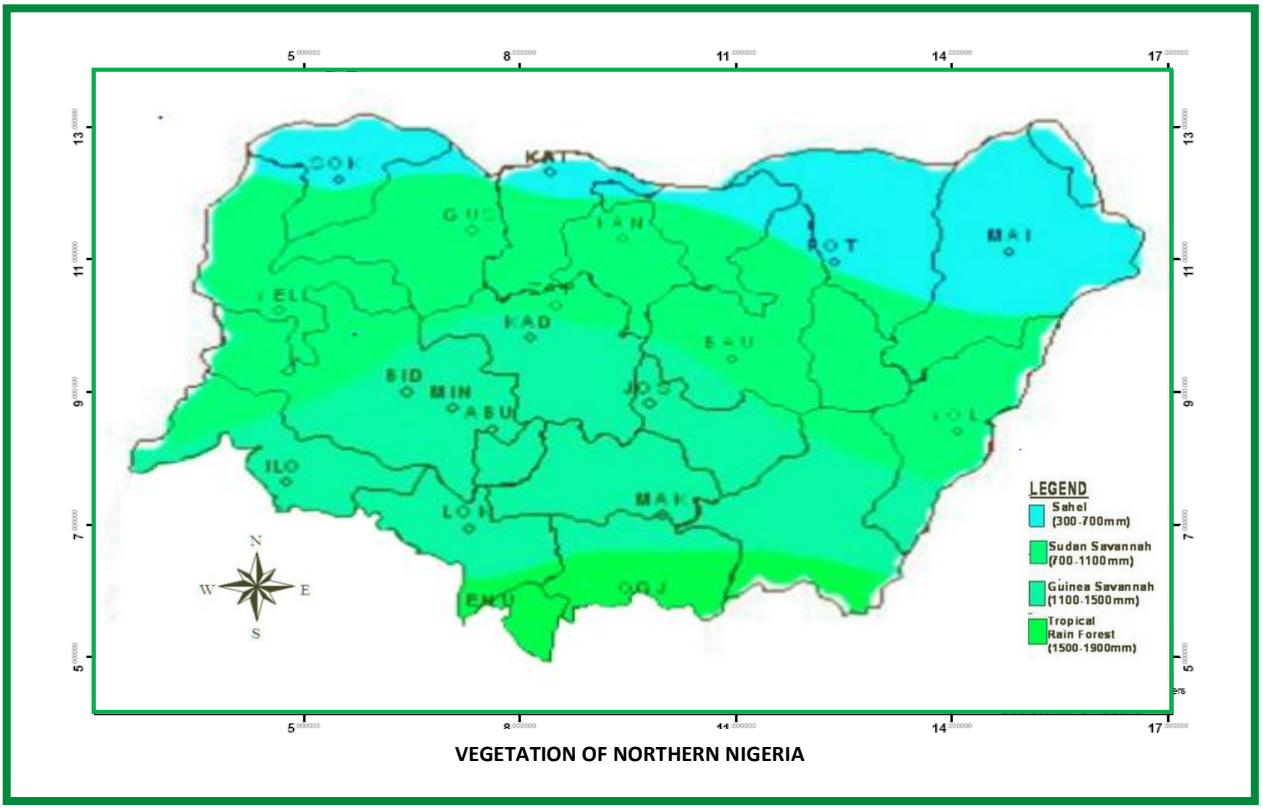


Fig. 3.4: Vegetation of Northern Nigeria.
Source: Modified from Nigeria's Vegetation Map, 2014.

3.3 Human geography

The improvement in basic facilities and more quality in social amenities have brought about an improvement in the standard of living of the populace. Urban land use does not just occur; it is formed through processes and therefore, depicts regulation and order in space use and organization. Due to increase in population, there is a major impact upon the plant communities, which now bear the profound mark of anthropogenic influence.

3.3.1 Population and Demographic Characteristics

Population constitutes a vital component of the potentials for land use and impact on the terrain of the study area. Most relevant elements of the population are its size, rate of growth and spatial distribution.

The study area according to National Population Commission has a population of 73,637,065 people, excluding the Federal Capital Territory (Nigerian News, 2006) 48% of these numbers are Women. The rate of growth of population (per annum) follows a similar trend to that of the Northern Nigeria's States during the 1991 Census. The population of the study area is not even. Northern Nigeria comprises of several ethnic groups. Almost all different races (tribes) within the country are fairly represented in the towns.

The indigenous ethnic groups includes Kataf, Igala, Nupe, Basage, Latang, Idoma, Okun, Igirra, Jukun, Tiv, Kanuri, Shuwa Arab, Hausa and Fulani, while the migrants or settlers are made up of Yoruba, Igbo, Edo, Calabar, Ijaw, Urhobo etc (Max, 1967).

Islam and Christianity are the predominant religions in the towns, also there are few Customary or Traditional Believers (Udo, 1978). Reconnaissance surveys showed concentration in major settlement in the capital city of the states and along the major roads. Most urban developments are concentrated also along the same axis. Father away from major roads we have scattered or isolated settlement of between a few and hundreds people mainly Fulani herdsmen and sedentary farmers. Table 3.1 below shows the population distribution and demographic characteristics of the people domicile in the study.

Table 3.2: Population Distribution and Demographic Characteristics of Northern Nigeria.

NORTH-CENTRAL					
S/NO.	**STATE**	**MALE**	**FEMALE**	**TOTAL**	**% OF THE NATION**
1.	BENUE	2,164,058	2,055,186	4,219,244	3.01
2.	KOGI	1,691,737	1,566,750	3,258,487	2.33
3.	KWARA	1,220,581	1,150,508	2,371,089	1.69
4.	NASARAWA	945,556	917,719	1,863,275	1.33
5.	NIGER	2,032,725	1,917,524	3,950,249	2.82
6.	PLATEAU	1,593,033	1,585,679	3,178,712	2.27
	SUB-TOTAL	**9,647,690**	**9,193,366**	**18,841,056**	**13.46**
NORTH-EAST					
	STATE	**MALE**	**FEMALE**	**TOTAL**	**% OF THE NATION**
7.	ADAMAWA	1,606,123	1,561,978	3,168,101	2.26
8.	BAUCHI	2,426,215	2,250,250	4,676,465	3.34
9.	BORNO	2,161,157	1,990,036	4,151,193	2.97
10.	GOMBE	1,230,722	1,123,157	2,353,879	1.68
11.	TARABA	1,199,849	1,100,887	2,300,736	1.64
12.	YOBE	1,206,003	1,115,588	2,321,591	1.66
	SUB-TOTAL	**9,830,069**	**9,141,896**	**18,971,965**	**13.55**
NORTH-WEST					
	STATE	**MALE**	**FEMALE**	**TOTAL**	**% OF THE NATION**
13.	JIGAWA	2,215,907	2,132,742	4,348,649	3.11
14.	KADUNA	3,112,028	2,954,534	6,066,562	4.33
15.	KANO	4,844,128	4,539,554	9,383,682	6.70
16.	KATSINA	2,978,682	2,813,896	5,792,578	4.14
17.	KEBBI	1,617,498	1,621,130	3,238,628	2.31
18.	SOKOTO	1,872,069	1,824,930	3,696,999	2.64
19.	ZAMFARA	1,630,344	1,629,502	3,259,846	2.33
	SUB-TOTAL	**18,270,656**	**17,516,288**	**35,786,944**	**25.56**
ABUJA (FEDERAL CAPITAL TERRITORY)					
		MALE	**FEMALE**	**SUB-TOTAL**	**% OF THE NATION**
20.	ABUJA	**740,489**	**664,712**	**1,405,201**	**1.00**
TOTAL POPULATION FOR NORTHERN NIGERIA					
		MALE	**FEMALE**	**SUB-TOTAL**	**% OF THE NATION**
	NORTHERN NIGERIA	**38,488,904**	**36,516,262**	**75,005,166**	**53.37**

Source: National Population Commission, 2006.

3.4 Research Methodology

3.4.1 Field Reconnaissance Survey

A reconnaissance survey was carried out in order to observe the trend of human activities and the pattern in which the land is being used, as it affects pipelines' right-of-way and to get a better perspective of the study area, have overview of the spatial distribution of NNPC pipelines and to collect ancillary data, which would be useful for the study was also collected in the process. The interpretation processes were carried out using both software and hardware.

Also, planning and gathering of relevant materials and going round the study area to identify major land use types encroaching into NNPC pipelines' right of ways were also done. The study area which composes of northern Nigeria, have witnessed significant changes in its landscape over time and encroachment due to human-induced land degradation of a complex nature (Christopher, 2001). Hence areas that are rapidly encroaching into the NNPC pipelines' right-of-way, urbanization, increasing population growth rate, etc were noted.

3.4.2 Types and Sources of Data

In order to achieve the aim of this study, in line with the stated objectives, data were sourced for and collected from satellite imageries, topographic and administrative maps and questionnaire administered from both primary and secondary sources. These types and sources of data are tabulated in table 3.3:

3.4.2.1 Primary Sources of Data

The required data that are necessary and essential for this research work such as data on Depot, Pump Station, Booster Station, Retail Station and Pipelines' locations (coordinates) and features were collected, collated and gathered from the sites of depots, pump stations and retail stations where these pipelines are laid and networked using handheld GPS. Satellite imagery was used for acquisition of data on land use/land cover classification. The present state of pipelines and environmental complexities affecting these pipelines are collected through oral interview and administration of questionnaire.

3.4.2.2 Secondary Sources of Data

The secondary data on Topography, Contours, Aspects, Slopes and Elevations, Agriculture, Built-up, Roads, and Water Bodies' features & areas, National & States' Boundaries, NNPC Pipelines that falls within the study area, pipelines vandalized and oil spillages are obtained from topographic maps, and from other relevant documents and literatures explaining the nature of the study area. These include administrative map and land use map amongst others. Trained GIS's operation assisted in the production of composite maps from the topographic map, administrative map and from the satellite imageries of the study area.

3.4.2.3 Instruments Used

The data which were used for this research work are from two imagery sources, namely; Landsat-SRTM and Landsat–SRTM (layers 3:2:1). The landsat–SRTM was imaged in the 2012s while the Landsat–SRTM (layers 3:2:1) was imaged in the 2013s.

The Landsat was launched by the National American Space Agency (NASA) in 1982 and is equipped with three channel Return Beam Vidicom (RBV) working in a panchromatic mode and a multi-spectral scanner with four band that is designed specifically for earth resource survey (Howard, 1991). The SPOT-XS satellite was conceived and developed by the French centre; *National de Etude Spatial* (NES). It was launched in 1986 by the French and is equipped with a multi-spectral linear sensor which can operate in three spectral bands (Howard, 1991). The imageries were brought to Universal Transverse Marcator (UTM) projection in zone 32 with the aid of the handheld GPS Garman 72CSX which converted the degrees to UTM to ease the geo-referencing of the images.

Table 3.3: Types and Sources of Data required for the Study.

S/NO.	DATA TYPE	DATA SOURCE	DATE OF PRODUCTION	SCALE AND RESOLUTION	DATA VENDOR	USES
1.	Data on Topography, Contours, Aspects, Slopes and Elevations.	Landsat Image SRTM.	2012	30 Meters	NASRDA (Primary)	For Land Use Classification and for creation of Digital Elevation Modelling (DEM).
2.	Data on Agriculture, Built-up, Roads, and Water Bodies' features & areas.	Landsat Image SRTM (band 1, 2, and 3).	2013	15 Meters	GRFL (Primary)	For Land Use Classification.
3.	Data on Refinery, Depot, Pump Station, Booster Station, Retail Station and Pipelines' locations and features.	Cadastral Map of NNPC Properties.	2013	1:2,000,000 (View Scale)	Kaduna Polytechnic Survey and Geo-informatics Department's Map Section (Secondary).	For Mapping of Refinery, Depot, Pump Station, Retail Station and Pipelines.
4.	Data on National & States' Boundaries.	Cadastral of Nigeria.	2012	1:5,000,000 (View scale)	NASRDA (Primary)	For Mapping of National boundaries.
5.	Data on NNPC Pipelines' Regions and for Cross-matching data on States' Boundaries that falls within the Regions.	Administrative Map of Northern Nigeria.	20012	1:25,000,000 (View scale)	Department of Urban and Regional Planning, Kaduna State Ministry of Environment (Secondary)	For Mapping of State, Local Government and Administrative boundaries and for Identification, Mapping and placement of Object/features.
6.	Data on Refinery, Depot, Pump Station, Booster Station, and Retail Station's coordinates.	GPS (Coordinate points).	2001	-	GPS 72CSX Manufacturer	For picking up of coordinates of locations/feature.
7.	Data on existing Object/features on pipelines' plan.	The Skeletal Design Layout (plan) of Pipelines.	2013	1:100, 000, 000 (View scale)	NNPC Official Website.	To aid and to guide in the placement of objects/feature.
8.	Data for reviewing past and existing works and for scholarship.	Literatures, Documents, Periodical, Journal and Conference Paper.	1978-2014	-	Federal Government, NNPC, Authors, Academia and Publishers.	To identify regulations and Act on pipeline by FGN, Land Use Act, and to reviewed relevant literatures.

Source: Researcher's Work, 2014**.**

3.4.3 Methods of Data Collection

To achieve this objective, the following techniques were used for data acquisition and collection from both primary source (field work) and secondary source.

3.4.3.1 Ground Truthing

This stage involved performing surface observation and measurements of various properties of the features of the ground resolution cells that are being studied on the remotely sensed digital image.

It involves taking geographic coordinates of the ground resolution cell with GPS technology and comparing those with the coordinates of the pixel being studied provided by the remote sensing software to understand and analyze the location errors and how it may affect the study.

Also, other information are collected on location by taking pictures of striking non-compliance to NNPC right-of-way sites in term of their dimension and character and measurement of the distance of setbacks of pipelines' right-of-way.

The materials used for this study include measuring Tape, Pegs, Ranging Poles, Global Positioning System (GPS) (Garmin 72X) and Camera (Canon Digital camera) to determine and up date the existing situation on base map and on the nature of satellite images such as the imageries acquired in both soft and hard copy. The hard copy were scanned first before they were imported into the system, while the soft copy were directly imported into the

system using ILWIS for land-use classification and ArcMap ArcInfo GIS mapping interpretation. The two sets of imageries for the year 2012 and 2013 are Landsat-SRTM Band 1, 2 and 3 of 30 m resolution for land-use classification and DEM mapping and Landsat-SRTM of 30 m resolution which was resample to 15 m resolution.

3.4.3.2 Personal and Oral Interview

Interviews were conducted with the Staff of Nigerian National Petroleum Corporation and Ministry of Environment within the study areas. Personal interviews were conducted with Farmers, Fishermen, Oil Workers, Environmentalists, Staff of Nigerian National Petroleum Corporation and Ministry of Environment, Fishermen and Women, Market Men and Women one on one. Questions were asked verbally in order to determine the critical parameters and variables as well as problem associated with the encroachment into the right-of-way, vadalization, monitoring of pipelines in the study areas.

3.4.3.3 Questionnaire Administration

The objective four (4) was achieved via the administration of copies of questionnaire to respondents, mostly to Community Members where these pipeline criss-crosses in the study area, such as; Oil Workers, Environmentalists, Staff of Nigerian National Petroleum Corporation and Ministry of Environment, Farmers, Fishermen/Women, Market Men and Women.

Two Hundred and fifteen (215) copies of a designed questionnaire was stratifiedly shared in proportional to the sampled population of

Correspondents in the setback zones of the study areas, where these pipelines criss-crossed. A Non-probability Sampling was adopted in selecting the population of this study. The Sampling Technique that was used is the Purposive or Expert Choice/Judgment Technique. This is because of the specialty of the study and the frame in selecting the recipient.

For the purpose of administering the questionnaire, the questionnaire was administered on the basis of quality that one must posses (Bernard, 2002). As part of the quality one must posses, is that Correspondents must be of age of thirty-five (35) years and above and who must have lived at least, twenty (20) years within the study area was indentified and issued a copy of the questionnaire. The reason for this decision is that those within the age bracket will have the information needed about encroachment into the NNPC Pipelines' right-of-way and other environmental issues.

The selection of respondents was based on the following criteria:

i. Their occupations and activities as it affects NNPC pipelines network.
ii. Their knowledge and experience on the impacts of environmental complexities as regards pipelines' right-of-way.

Pertinent consultation to past works of different authors, who had worked on the subject matter, particularly on pipeline right-of-way were also referred to and reviewed. The content of the questionnaire was structured into three sections as follows:

i. Perception of Respondents on the concept of Remote Sensing, Geographic Information System and environmental issues associated with oil Pipelines in Nigeria.

ii. Assessment of the role of NNPC, Construction Companies and Planners in the planning, control and management of oil pipelines' right-of-way in Nigeria.

iii. Willingness to address problems associated with oil pipelines in Nigeria by Stakeholders: Government and Private Sectors.

The data that will be gathered and collated from respondents, was computed, manipulated, analyzed and statically presented to reveal the responses from the use of descriptive and Influential Statistics (applying the frequency and percentage formula) to summarize the responses, using Four Likert Scale System of Strongly Agree (SA), Agree (A), Disagree (DA), Strongly Disagree (SDA) and Grand Mean (X).

3.4.4 Hardware Used for the Study

Hardware Used for Analysis of Data

The hardware used to perform; this operation was a high plug-speed, memory digital electronic HP Laptop PC, processor Core i7 CPU (8 Processor), Intel Memory (RAM) 8.00GB and a Pentium based Personal Computer with the following configuration was used: 4 MB RAM, 1 HP Hard Disk, H.D.D 1,000 GB, 3.2MHz Core i7 Intel Processor, 14.1" W x GA wide TFTLCD, DDR 3, Scanner, Screen Digitizer, A2 & A3 Laser

Printer/Plotter, UPS (Uninterrupted Power Supply) and Garmin map 72CSX hand held GPS.

The Laptop Computer through the softwares installed was used for data analysis of the research work and type setting of the research Thesis, while the Desktop Computer was used as stand-by and Backup System. The Scanner was used to convert the remote sensed imagery and analogue map into a digital format for digitization and victimization operations to be carried on the map hard and soft copy substrates of the study area. The Global Positioning System, GPS, was used for taking or calculating coordinates, control points and for ground truthing. Finally, the Plotter was used for the production of large format and high quality of maps in vectors form.

Software Used for Analysis of Data

Basically, two softwares were used for this project; ArcMap ArcInfo Version 10.1 and Microsoft Access version 2007. However, other softwares such as Windows XP/2007-2010 Operating System, Microsoft Word, SSPS and Notepad were used to compliment the functions of the two major softwares used. The 'modus operandis' of these softwares are:

(a) ArcMap ArcInfo Version 10.1: this software was used for importing, displaying and subsequently processing and enhancement of image. The software was used in the conversion of satellite acquired images into digital format. The digitizer was run over line and recorded in series of zeros and ones. It was also used for the development of land use/land cover classification. The digitized features were edited in the same software.

(b) Microsoft Access Version 2007: this software was used to create database, as a reservoir of attributes that support as well as contain the information that gives room for integration, manipulation and analysis of graphical data observing the logical stages that must be followed. Database was created in tabular forms (attribute table) linked to vector data for NNPC Refinery, Depot, Pump Station, Retail Station and Pipelines in the Northern Nigeria which comprises of the Kaduna, Gombe and part of the Port Harcourt region. Microsoft Word software is used for the preparation of the project report.

3.4.5 Data Processing

3.4.5.1 Sub-setting

Coordinates of the study areas were picked from the acquired imagery and map and are registered to create a box which defines the subset made up of the study using ArcMap Arcinfo GIS 10.1 software.

3.4.5.2 Image enhancement

The linear contrast stretch was used in the ArcMap ArcInfo modelling functions to increase visual discrimination amongst objects in scenes of all images for better visual perception and interpretation. All images filtered to reduce stripping effect.

Image thinning was carried out through contrast; contrast generalizes an image by reducing the number of rows and columns, while simultaneously decreasing the cell resolution. Contraction may take place by pixel thinning or pixel aggregation with the contracting factors in X and Y

being independently defined. With pixel thinning, every n^{th} pixel is kept while the remaining is thrown away.

3.4.5.3 Rasterization

Data conversion from analogue to raster map was accomplished by editing the segment map for common digitizing errors (Calistus, 2000). Having edited the segment, it was then polygonised and subsequently rasterized. Attribute data operation was carried out using the keyboard. The classification of the various land use and mapped encroachment into NNPC pipelines' right-of-way was done using various colours to identify each type of land use types encroaching into pipelines' right-of-way. The use of pixel however, cannot be over-emphasized because it aided the classification of features without much problem.

3.4.5.4 Vectorization

vectorising depends on the programme that is available. There are some softwares that operate in automatic vectorizing environment, that is when a computer cursor is clicked on any of the line it could automatically trace the whole section in a matter of seconds, where as some operate in manual digital format where tracing is done manually. This gives chance for error correction. On the spot correction is done before a system is saved and printed. For this study, after the geo-referencing, image enhancing and conversion format. The major features on the satellite imagery and base map are traced through the clicking of cursor. The features being trace in different sizes and shapes comprises of dotted lines join together which

could only be detected by zooming the system, this encourages or make possible certain over stretched line to be erased. In this operation, the arrangement of higher points above the other, editing of coordinate list, plotting or printing out of digital data for visual editing (e.g. zooming an error in line digitizing) and topological editing i.e. removal of dead ends e.g. over shoot or joining under shoot.

3.4.5.5 Edge Matching

Edge matching is an editing procedure use to ensure to ensure that all features along share borders of the imagery/map have the same edge location; coordinates of the objects along share borders are adjusted to match the neighbouring data sets. This processes was carried out for each of the imagery and map used for the assessment of the subject matter (right-of-way)

3.4.5.6 Digital Elevation Model Operation

The Digital Elevation Model, DEM operation is used in performing analyses or calculation on wide range of parameters relating to elevation slope, in X and Y directions, slope in degree or percentages, flow direction etc. for this study, DEM operation was applied for the analysis of slope and topography through which these pipes are laid within the context of the study area, putting into consideration the slope angle of the terrain through which these pipelines are laid. In this work the slope angle that was selected was equal to or not less than 20^{o}. The slope ranges of the selected sites should be between 10 m–80 m.

3.4.5 Data Analysis

3.4.5.1 Overlay Operations

This is the integration of data from different sources using map overlay operation. It is a major key GIS function. In Arc Map aArc Info version 10.1, all data were stored and the criterion values and factor map are generated for all criteria as map layers. The criterion maps are converted into grids and mathematical processes are applied to the criteria.

The first layer that was retrieved in this work was the boundary layer with which the buffered pipeline layer away from the various land-use types, was overlaid, in line with the guidelines or criteria of assessing of oil pipelines, thereby revealing the level of compliances or how the oil pipelines' right-of-way have been encroached upon. The remaining three buffered layers, which are roads, built-up area, wetland/rivers will also be overlaid to create a new map layer. From the new map layer that will be generated, the level or degree of compliance and extent of encroachments into the approved setbacks for NNPC pipelines, based on planning and management perspective was identified.

Furthermore, the contour layer was overlaid in the new map layer to determine the topographic terrain with not less than 20^{o} slope angle, on which the pipelines criss-crosses or transverses within the study area. The six newly proposed refineries and potential pipeline routes was superimposed together alongside other buffered map layers to generate new base map or composite map for NNPC pipelines. Two dichotomized pipeline maps were designed

from the southern axis and northern axis of the country, which was also overlaid on a single map substrate.

3.46 Database Design

ArcMap ArcInfo 10.1 software version was used to digitize the existing topo-sheet to create a digital database. A Database is an organized collection of non-redundant data stored so as to allow its use via relevant application with the data capable of being accessed by different logical paths.

In other words, a database design is the process by which the real world entities and their inter-relationship are analyzed and modeled in such a way that maximum benefits are derived with minimum amount of data or the actual creation/construction (such as graphic and attribute data input) of a proposed system based on the specifications of the design stages. It includes digitizing of feature (graphic data entry) editing and leading of the created attribute table with data.

A data is use to refer to the values physically recorded in the database. This shows that improper database design leads to implementation problem and thus leads to low cost recovery (Kufoniyi, 1998). For the purpose of the project, the following entities were recognized and digitized i.e. blocks of built up areas, roads, administrative boundaries, contours, and water bodies to create the database. After the necessary planning and consideration of the constraints, the database design was carried out in the following order:

- View of reality
- Conceptual design
- Logical design
- Physical design

3.4.6.1 View of Reality

According to Kufoniyi (1998), the view of reality is the phenomena as they naturally exist in the area of study including all aspect which may or may not be perceived by individuals. The view of reality is the mental abstraction of real world for a particular application or group of applications.

The spatial objects in the study area were viewed as roads, built-up areas, rivers and water bodies as they exist in real life. These objects were modeled as point, line and polygon (Area). The spatial objects in the study area were viewed as roads, built-up areas, and rivers as they exist in real life. These objects were modeled as point, line and polygon (Area).

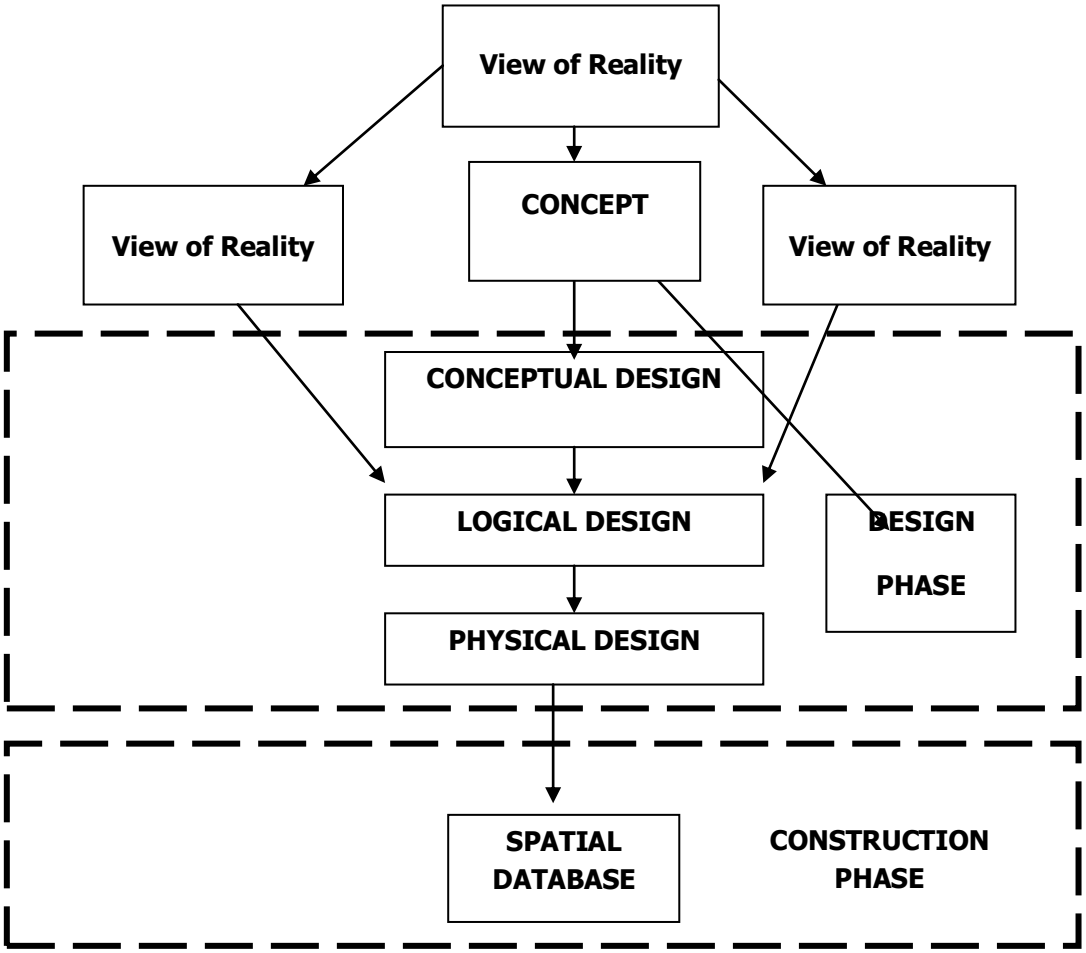


Fig. 3.5: Design and Implementation Phases of a Spatial Database.

Source: Kufoniyi, 1998.

3.4.6.2 Conceptual Design

This is the representation of the reality i.e. data abstraction. It is the process of creating an abstract database structure that represents real world objects in the most distinct possible way by converting the analogue map into digital format using on screen digitizing method of a computer using Arc Map ArcInfo 10.1 Software. The data input were later converted into raster model for further analysis which culminated into the generation of

digital Elevation Model (DEM) and buffering. The conceptualization stages of this work involve:

- Conceptualization of reality (view of reality) and the choice of its representation.
- Identification of Geographic features and their attributes.
- Identification of Basic geometric objects.

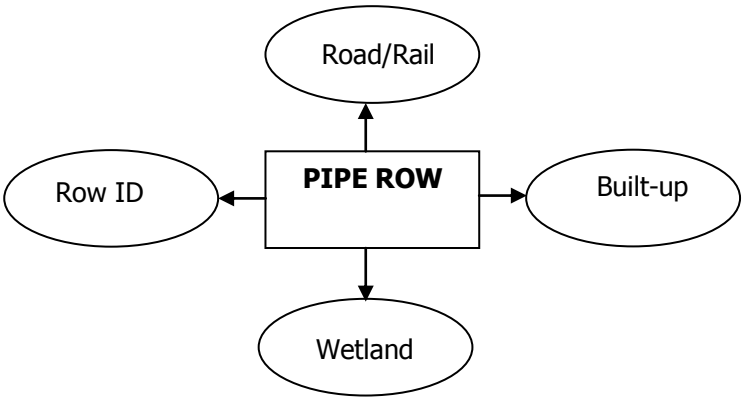


Fig. 3.6: ROW Entity and its Attributes.
Source: GIS Researcher's Work**.**

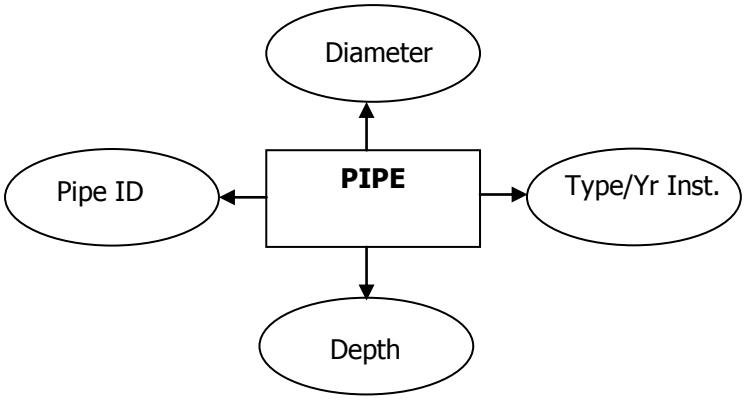


Fig. 3.7: Pipeline Entity and its Attributes.
Source: GIS Researcher's Work**.**

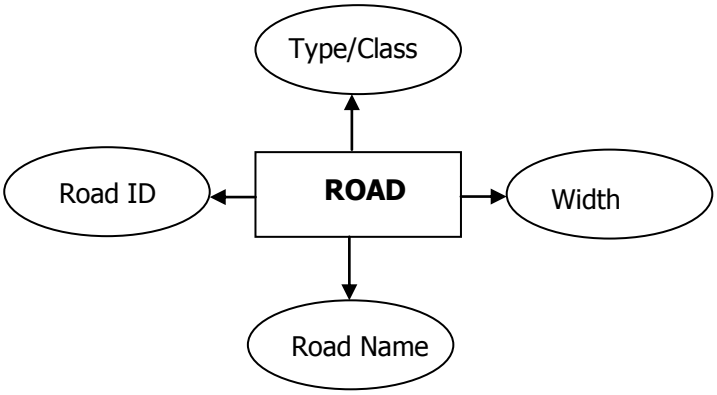


Fig. 3.8: Linear Entity and its attributes.
Source: GIS Researcher's Work.

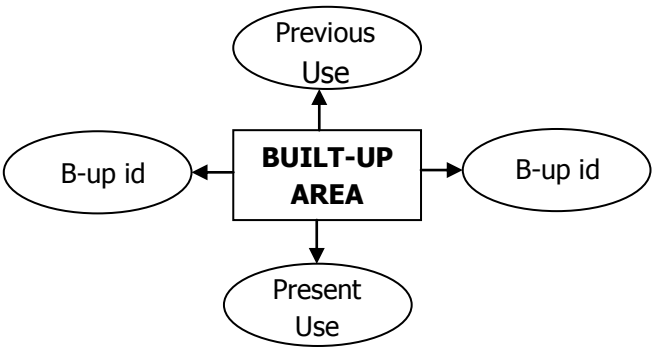


Fig. 3.9: Area Entity and its Attributes.

Source: GIS Researcher's Work.

3.4.6.3 Logical Design

Logical design is the translation of conceptual design (data model) into a selected data structure (such as relational geo-relational, network, hierarchical etc,) that can be represented in a computer form. The conceptual model was translated into a geographic-relational (as in Arc Info) data structure. This following relation however, will be derived.

- Road (Rid, R-name, R-width, R-type, R-class).

- Built-up area (Build-up id, Built-up name).
- Water sources (water id, water source name, type).
- Land use (Land cover, land use).

Table 3.5: Geo-Relational Data in the Study Area and their Attributes.

Item Name	Identification
ROW	**RW-ID, object distance away from land-use types.**
Pipe	**P-ID, diameter, node, length, year of installation.**
Road/Rail	**R-ID, with, node, parcel, type, class, year constructed.**
Built-up	**Bl U-ID, area, perimeter, population, cover, use.**
River/Wetland	**W-ID, source name, type, length.**

Source: GIS analysis & Reconnaissance Survey**.**

3.4.6.4 Physical Design

Physical design is the representation of a data structure in the format of implementation software. This was performed at the beginning of the implementation phase. Arc Map ArcInfo 10.1 software was used to consider item name, item width, item types, items, decimal place. This design defines data item in terms of parameters such as number of bytes of storage they occupy and the address in which they are to be found in physical memory.

Table 3.6: Relations (Table) for Pipeline DBF

Serial No.	Attribute Name	Width	Data Type
1.	P-ID	-	**Numeric (3,0)**
2.	Diameter	-	**Numeric (2,2)**
3.	Type	-	**Character (0)**
4.	Depth	-	**Numeric (2,2)**
5.	Length	-	**Numeric (3,2)**
6.	Year of Installation	-	**Numeric (4,0)**

Source: GIS analysis & Reconnaissance Survey**.**

Table 3.7: Relations (Table) for Road DBF

Serial No.	Attribute Name	Width	Data Type
1.	R-ID	-	**Numeric (3,0)**
2.	Type	-	**Character (3,0)**
3.	Class	-	**Character (3,0)**
4.	Depth	-	**Numeric (2,2)**
5.	Length	-	**Numeric (3,2)**
6.	Year of Constructed	-	**Numeric (4,0)**

Source: GIS analysis & Reconnaissance Survey**.**

Table 3.8: Built-up area in the Study Area and their Attributes

TSD-ID	Attribute Name	Data Type
1.	Building	**Bl-Id**
2.	Area	**Numeric (7,3)**
3.	Perimeter	**Numeric (6,3)**
4.	Use: Residential, Commercial, Industrial Agricultural	**Character (3,0)**

Source: GIS Analysis & Reconnaissance Survey.

3.4.6.5 Spatial Query

In performing queries on GIS database, data retrieval is an essential part of GIS projects. Queries offer a method of data retrieval and can be performed on data that are part of GIS database or on new data produce as a result of data analyses.

For this project, each of the layers of information were created, retrieved one after the other, and were queried accordingly to be ready for further analyses.

3.4.6.6 Cartographic Model

Cartographic modeling is the use of basic manipulation functions in logical sequences to solve complex spatial problems (Tomlin, 1983). It was developed to model land use planning alternatives and applications that require integrated analysis of multiple geographically distributed factors, as it was done for the study. It has the following attributes: Entirety in Raster

Domain, Ability to Form a Logical Sequence and Map Algebra. Figure 3.7 below depicted the work flow in which the Author of this thesis followed to achieve his aim and objectives of the study.

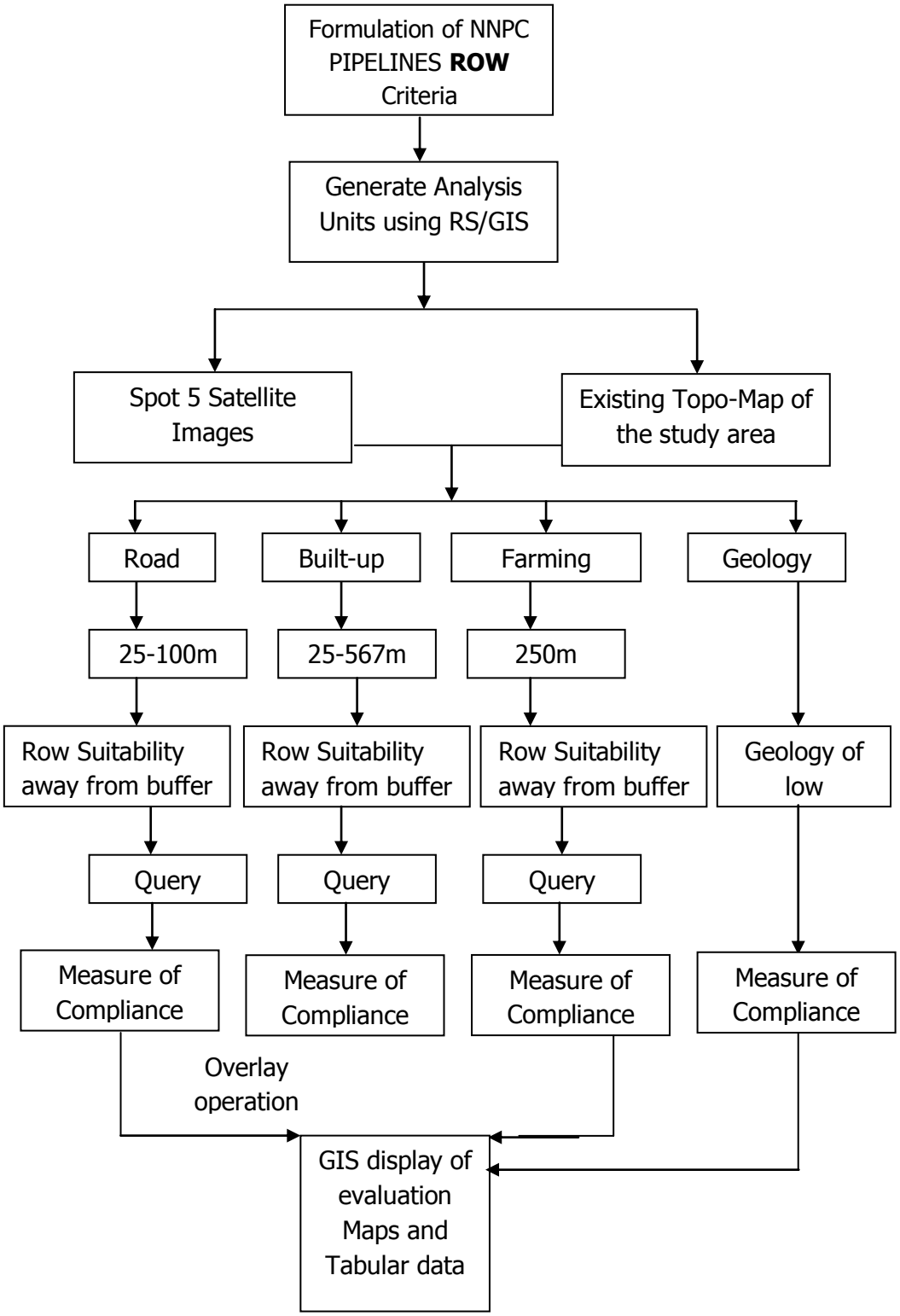


Fig. 3.10: Cartographic Model Design
Source: Researcher's Work.

3.4.7 Criteria for Assessing the Compliances of various Land-Use Types with the NNPC Pipelines

For the analysis of data that was obtained for the classic use of GIS techniques in assessing the Compliances of Various Land-use Types with the NNPC Pipelines, the following criteria are put into consideration:

- Proximity
- Area extent (buffer zone)
- Relatively gentle terrain

3.4.7.1 Proximity

- The right-of-way for pipelines should not be less than 25 m, 200 m, 500 m away from the roads/high ways
- The setback should be distance of not less than 250 m-576 m from the water/wetland areas
- The setback should be distance of not less than 25 m-576 m from the built-up areas, depending on type of fluid transported, volatility and vulnerability tendency to encroachment.

Note: A 25-metre wide Right of Way (ROW), specifically was acquired by Government for the purpose of NNPC Pipelines as provided for in the oil pipelines Act of 1956 cap 145 (Ehiorobo, 2010) and Pipeline Act CAP 338 of the Law of the Federation of Nigeria 1990.

3.4.7.2 Area Extent (Buffering Requirements)

- The Selected built-up area should not be less than 25 m^2 from pipes lines
- The Selected built-up area should not be less than 250m^2 from pipes lines.
- The Selected built-up area should not be less than 420m^2 from pipes lines.
- The Selected built-up area should not be less than 576m^2 from pipes lines.

3.4.7.3 Relatively Gentle Terrain

- The slope angle of the terrain of site to be selected should not be less than 20^o except in areas where there are steep gradient.
- The slope ranges of the selected sites should be between 10 m – 80 m.

3.4.8 Linear Measurements

Two different types were involved, i.e. linear measurements in flat areas and those on hilly areas.

a. On flat areas, the procedure followed is described below. The tools needs are the measuring tape, parallax bar, ruler, needle and drawing materials. First, the distance into NNPC pipelines' right-of-way was determined by taking measurement of the standardized setbacks and the distances at which the different land use type encroaches into the pipelines' right-of-way in the study areas. The satellite imageries scale was determined

automatically by satellite component and the software in used synchronizes the scale and can be adjusted at the leverage of the software user. Second, measure the distance between the selected points a-b in meters. Third, the distance measurement of point a-b is possible after the digitization process. As measurement is done automatically by the software in relation to the scale of the imagery/map. Similarly, is to multiply the measured distance (a-b) between the selected points by the satellite imagery's scale number (mp), which gives the distance of the points in the field, a-b:

Therefore, ab = a-b ---------- (equation 1)

$ab = mp_{ab}$ ---------- (equation 2)

b. On a hilly area the following procedure was used. Using the same instrument listed above:

- Determine the height differences of the selected points, this gives the values h_{ab} etc. in meters;
- Next, use the slope between the selected points, this gives the values, d_{ab}, etc.;
- Calculate the slope length in the field (ab, etc.) using the results of the first two steps, i. e.

$$ab = \frac{h_{ab}}{\text{Sin } d_{ab}} \quad \text{---------- (equation 3).}$$

3.4.9 Geo-referencing Properties of the Images and Map

The geo-referencing properties of both the acquired Landsat imagery SRTM (band 1, 2 and 3) 2013 and Landsat SRTM-2012 imagery are the same because the two are of the same resolution of 30 m while image thinning was applied to the 1987 photos which has resolution of 30 m using a factor of two to modify its properties and resolution to conform to the other two as given below:

Data Type File System: Raster, File Type: Binary Columns: 1441 Row: 1155.

Referencing System: UTM-32, Reference Units: M, Unit Distance: 1.

Table 3.9: Coordinates of the Study Area.

Minimum X	**2.668437**
Maximum X	14.6767663853
Minimum Y	4.2704180000000
Maximum Y	13.895417615000

Source: Satellite Imagery Geo-referencing/Global Positioning System

Min Value: 0, Max Value: 430, Display Minimum: 0, Display Maximum: 430

Screen Resolution: 1366 x 7768.

Images were geo-referenced using Ground Control Points (GCPs) obtained from GPS, using image-to-GPS techniques. A total of four GCPs were collected for each of the study area using GPS on the field. These points were

distributed to ensure images are balanced on the entire four axes and centralized at the centre.

The choice of images to GPS techniques is based on the fact that most of the data used was collected in the field using GPS and this reduced the error during the map composition and allows for this point to fit-in. the coordinates of these reference points were converted from geographic degrees to UTM, in order to aid precise measurement later. The same projection was used for the vector layer extracted from the administrative map of northern Nigeria (Department of Urban and Regional Planning, Kaduna State Ministry of Environment, 2009) by using image to map technique.

It was also the same for the vector layer extracted from the Master Plan of northern Nigeria (Department of Urban and Regional Planning, Kaduna State Ministry of Environment 1977). The result of the geo-referencing is shown above. After all layers of features have been digitized and edited on checking on checking the following: Some of the errors are dead end (i. e. over shoot or under-shoot, self overlap, intersection, code consistency exercise of pipelines route and land use types encroachment) and data retrieval (quarries, browsing) is done, then map overlaying (putting different entities on a particular map) is performed on these layers.

Map generalization or reclamation is done on the overlaid map. Also projection charge-coordinate transformation, centroid (centre line) calculation, vector, raster, buffer generation on pipelines, digital terrain analysis (interpolation, contouring) of suit angle for laying pipelines and finally output or presentation of the maps either in soft or hard Copy.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION

4.1 Introduction

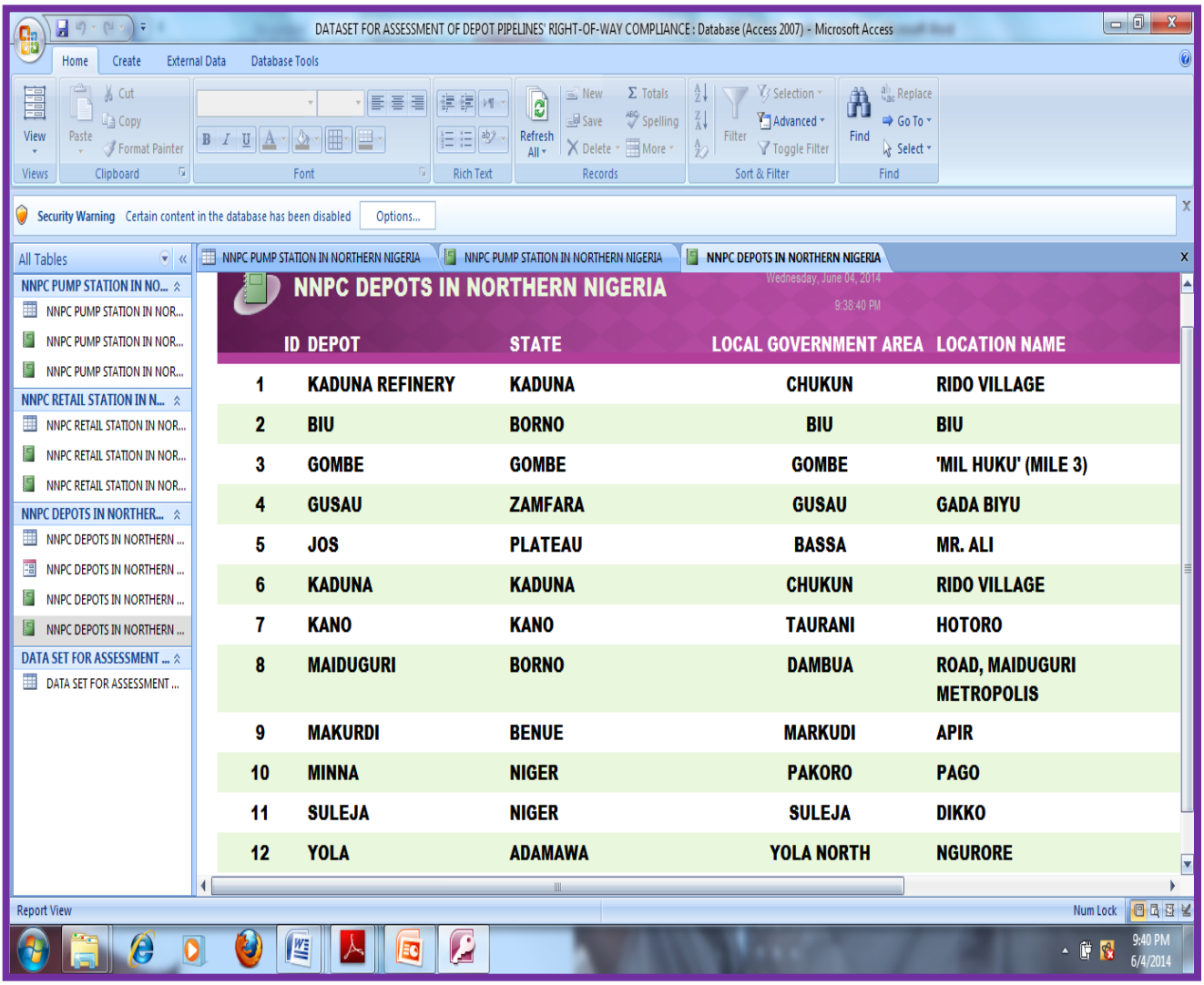
This chapter presents the results and discussion of the study. All data collected from the field survey and periodicals and those generated from the satellite imageries were collectively analyzed.

Regulations on Pipelines' Right-of-Way were established in Section 2.8 and were used to address objective one of the study Sub-section 4.4.1. In Section 4.2 the Database of NNPC Pipelines and Associated Right-of-Way was created and tabulated. Sections 4.3 assess the level of compliance of land use/cover types to NNPC Pipelines' Right-of-Way. While Section 4.6, discusses the problems and challenges of non-compliance to NNPC pipelines' right-of-way.

4.2 Database of NNPC Pipeline Networks and Associated Right-of-Way

The tables 4.1-4.7 and 4.11 below, gives the data sets and geographical coordinates for Depots, Pump Stations, Retail Stations and Booster Stations of NNPC in Northern Nigeria.

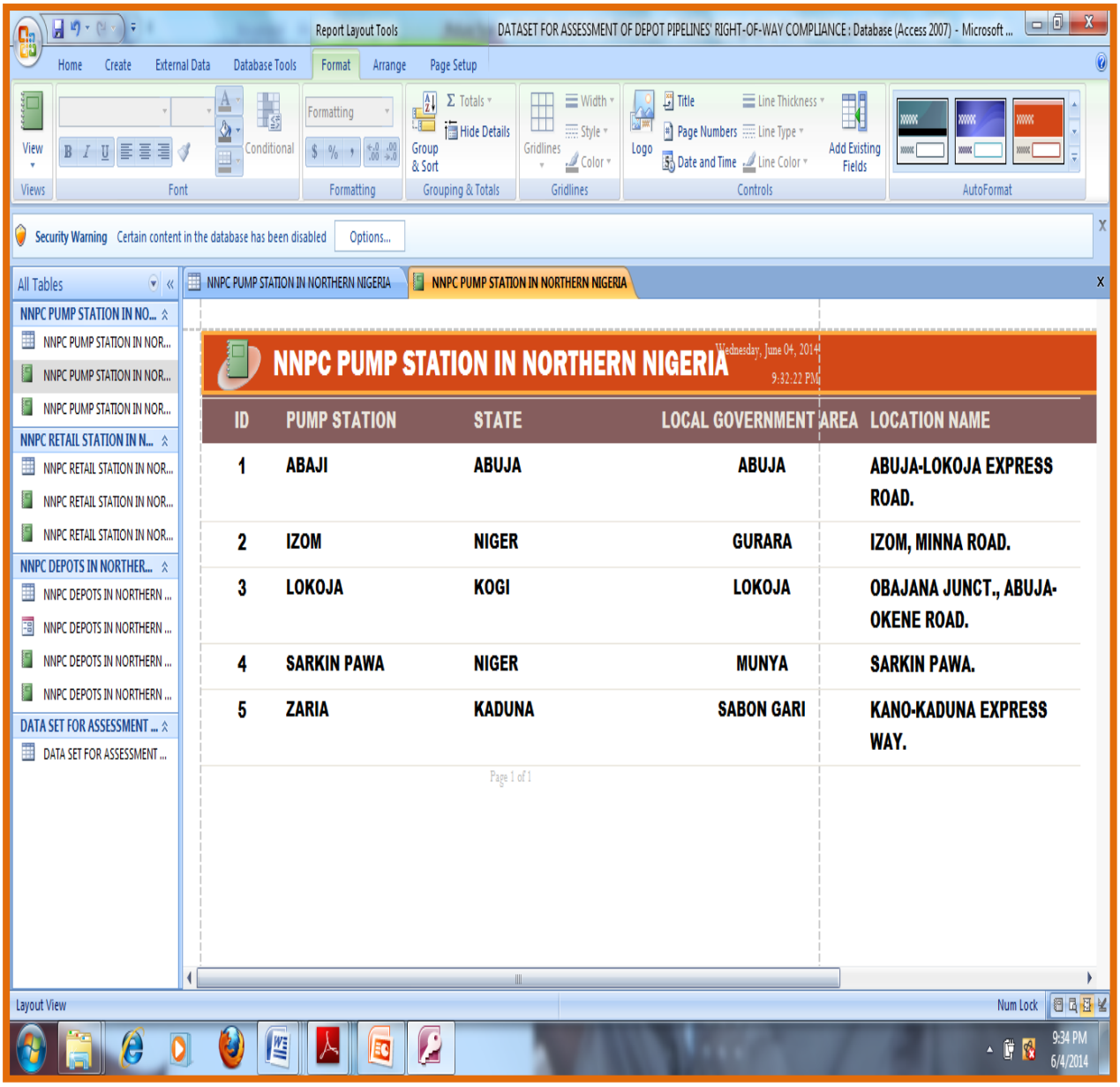
Table 4.1: Data Set for Nigerian National Petroleum Corporation Depots in Northern Nigeria.



ID	DEPOT	STATE	LOCAL GOVERNMENT AREA	LOCATION NAME
1	KADUNA REFINERY	KADUNA	CHUKUN	RIDO VILLAGE
2	BIU	BORNO	BIU	BIU
3	GOMBE	GOMBE	GOMBE	'MIL HUKU' (MILE 3)
4	GUSAU	ZAMFARA	GUSAU	GADA BIYU
5	JOS	PLATEAU	BASSA	MR. ALI
6	KADUNA	KADUNA	CHUKUN	RIDO VILLAGE
7	KANO	KANO	TAURANI	HOTORO
8	MAIDUGURI	BORNO	DAMBUA	ROAD, MAIDUGURI METROPOLIS
9	MAKURDI	BENUE	MARKUDI	APIR
10	MINNA	NIGER	PAKORO	PAGO
11	SULEJA	NIGER	SULEJA	DIKKO
12	YOLA	ADAMAWA	YOLA NORTH	NGURORE

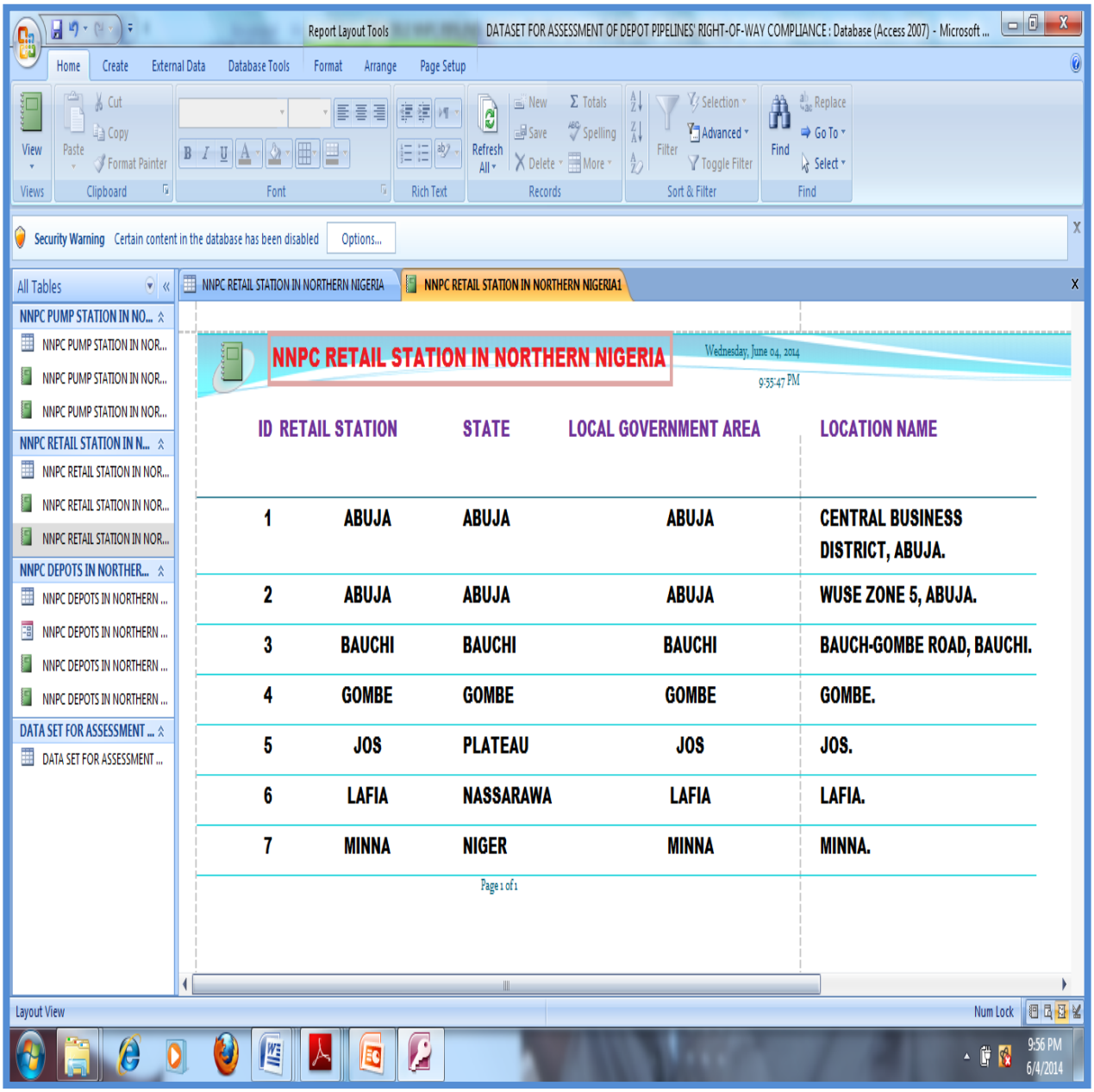
Source: Researcher's GIS Analysis Work, 2014.

Table 4.2 Data Set for Nigerian National Petroleum Corporation Pump Stations in Northern Nigeria.



Source: Researcher's Database Analysis Work, 2014.

Table 4.3: Data Set for Nigerian National Petroleum Corporation Retail Stations in Northern Nigeria.



NNPC RETAIL STATION IN NORTHERN NIGERIA

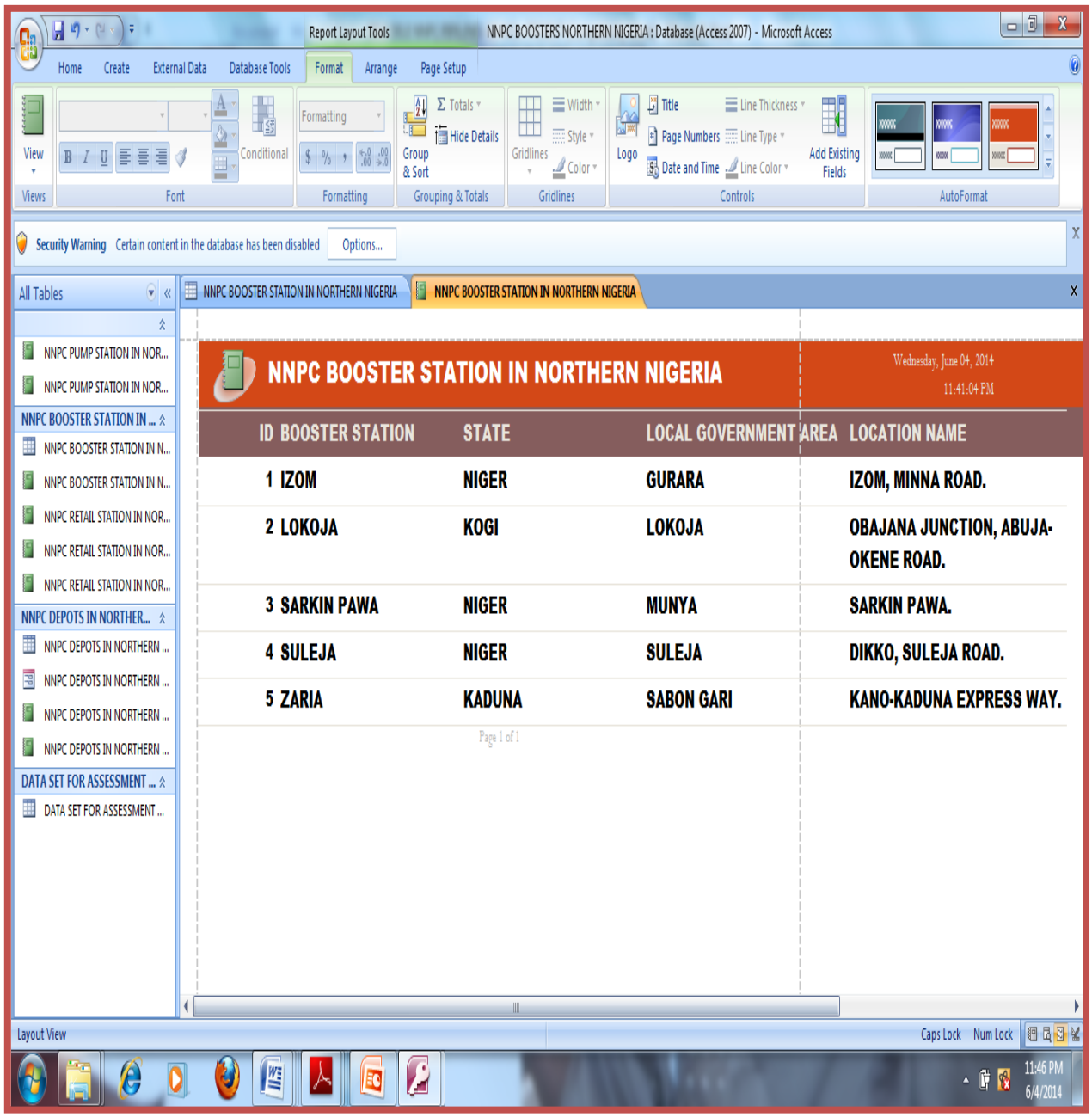
Wednesday, June 04, 2014 9:55:47 PM

ID	RETAIL STATION	STATE	LOCAL GOVERNMENT AREA	LOCATION NAME
1	ABUJA	ABUJA	ABUJA	CENTRAL BUSINESS DISTRICT, ABUJA.
2	ABUJA	ABUJA	ABUJA	WUSE ZONE 5, ABUJA.
3	BAUCHI	BAUCHI	BAUCHI	BAUCH-GOMBE ROAD, BAUCHI.
4	GOMBE	GOMBE	GOMBE	GOMBE.
5	JOS	PLATEAU	JOS	JOS.
6	LAFIA	NASSARAWA	LAFIA	LAFIA.
7	MINNA	NIGER	MINNA	MINNA.

Page 1 of 1

Source: Researcher's Database Analysis Work, 2014.

Table 4.4: Data Set for Nigerian National Petroleum Corporation Booster Stations in Northern Nigeria.



Source: Researcher's Database Analysis Work, 2014.

Table 4.5: Geographical Coordinates for NNPC Depots in Northern Nigeria.

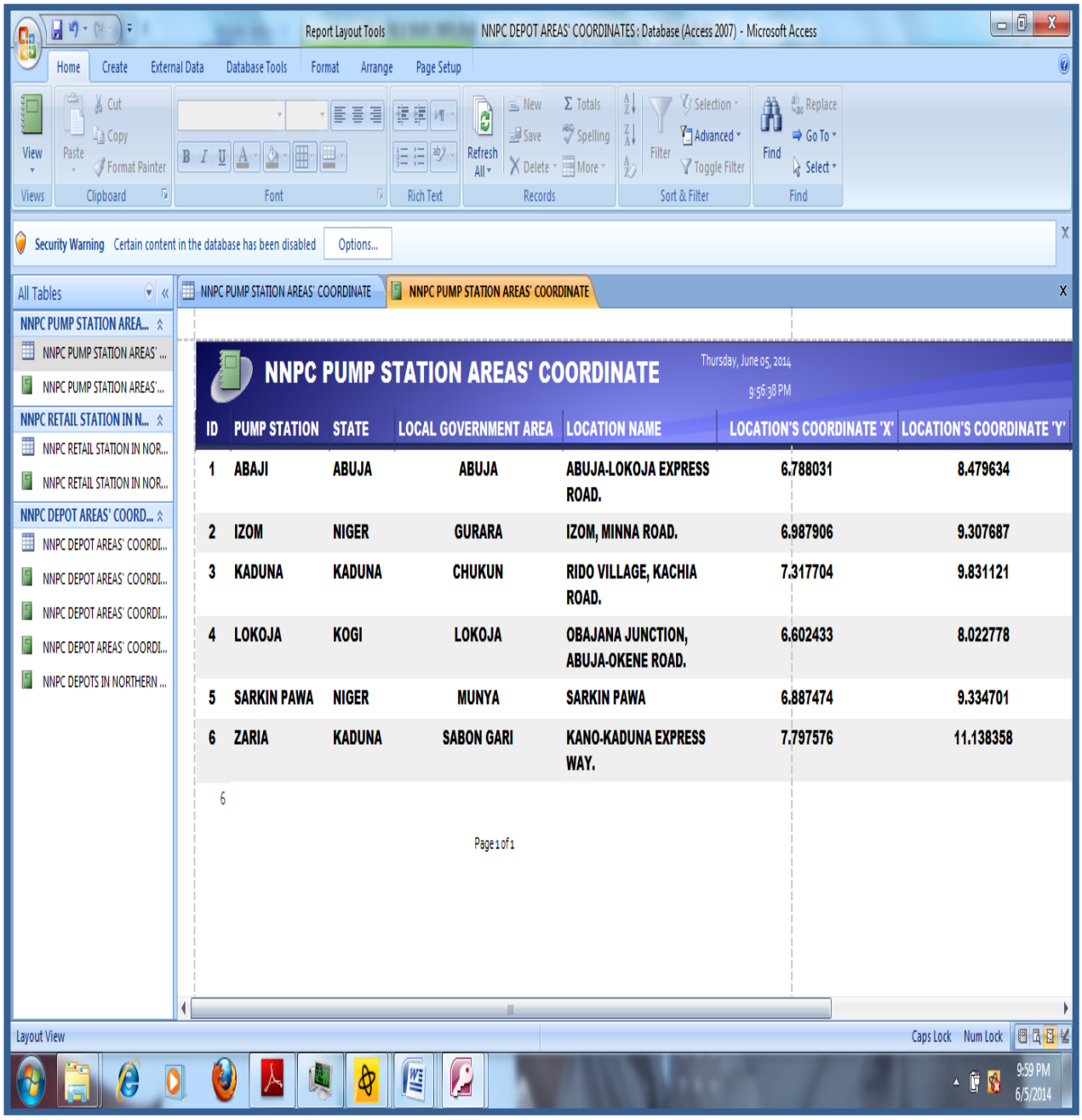
NNPC DEPOT AREAS' COORDINATE

Tuesday, June 10, 2014
4:42:39 PM

ID	DEPOT	STATE	LOCAL GOVERNMENT AREA	LOCATION NAME	LOCATION'S COORDINATE 'X'	LOCATION'S COORDINATE 'Y'
1	KADUNA REFINERY	KADUNA	CHUKUN	RIDO VILLAGE	7.562784	10.461725
2	BIU	BORNO	BIU	BIU	13.225094	11.121811
3	GOMBE	GOMBE	GOMBE	'MIL HUKU' (MILE 3)	11.222870	10.310993
4	GUSAU	ZAMFARA	GUSAU	GADA BIYU	6.970211	12.197386
5	JOS	PLATEAU	BASSA	MR. ALI	8.740773	10.162067
6	KADUNA	KADUNA	CHUKUN	RIDO VILLAGE	7.532819	10.493013
7	KANO	KANO	TAURANI	HOTORO	8.476016	11.982271
8	MAIDUGURI	BORNO	DAMBUA	ROAD, MAIDUGURI METROPOLIS	12.232256	10.757770
9	MAKURDI	BENUE	MARKUDI	APIR	8.575300	7.746159
10	MINNA	NIGER	PAKORO	PAGO	6.854379	9.351249
11	SULEJA	NIGER	SULEJA	DIKKO	6.887474	9.334701
12	YOLA	ADAMAWA	YOLA NORTH	NGURORE	12.29156	9.120345

Source: Researcher's Database Analysis Work, 2014.

Table 4.6: Geographical Coordinates for NNPC Pump Stations in Northern Nigeria.



NNPC PUMP STATION AREAS' COORDINATE

Thursday, June 05, 2014 9:56:38 PM

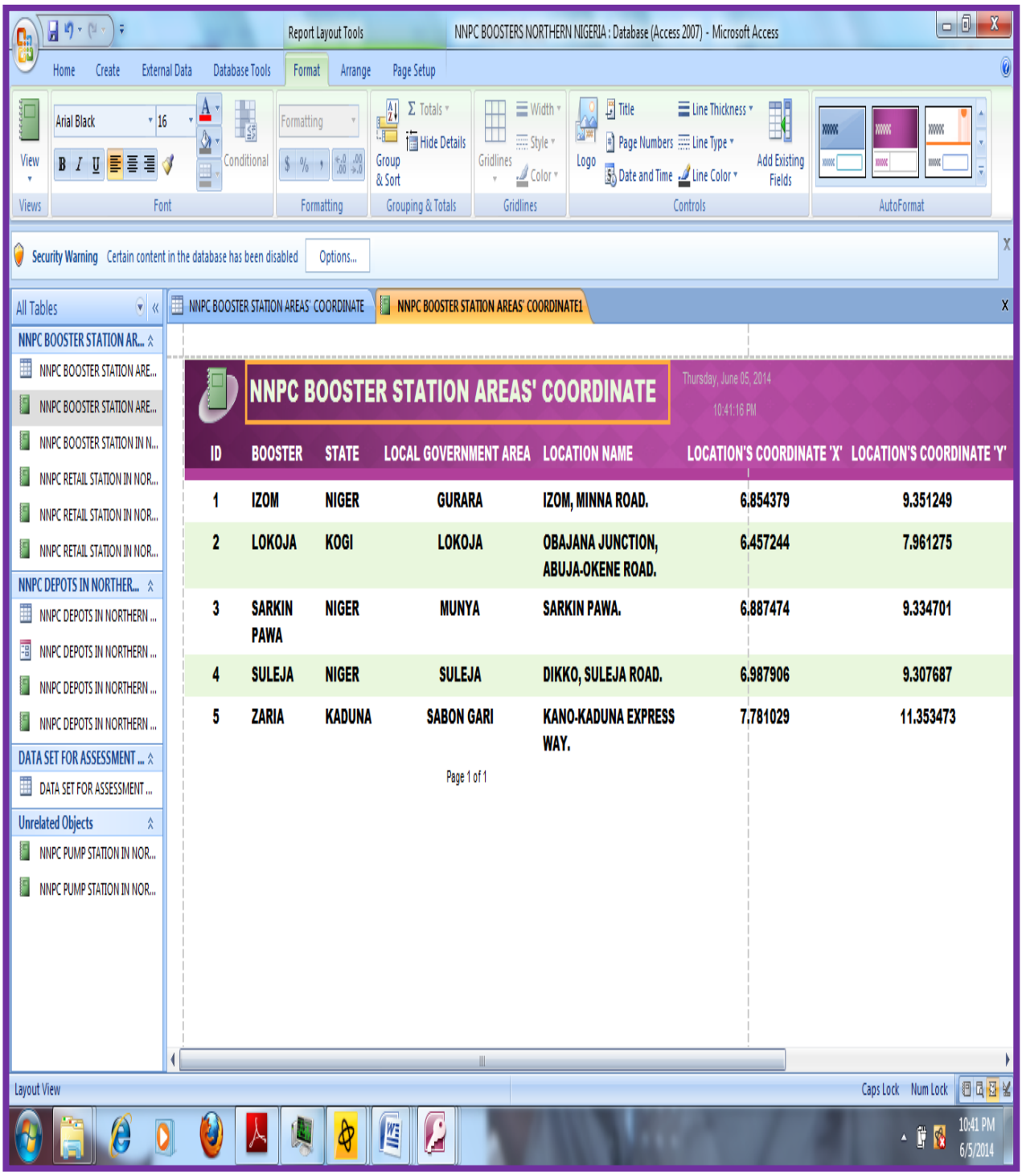
ID	PUMP STATION	STATE	LOCAL GOVERNMENT AREA	LOCATION NAME	LOCATION'S COORDINATE 'X'	LOCATION'S COORDINATE 'Y'
1	ABAJI	ABUJA	ABUJA	ABUJA-LOKOJA EXPRESS ROAD.	6.788031	8.479634
2	IZOM	NIGER	GURARA	IZOM, MINNA ROAD.	6.987906	9.307687
3	KADUNA	KADUNA	CHUKUN	RIDO VILLAGE, KACHIA ROAD.	7.317704	9.831121
4	LOKOJA	KOGI	LOKOJA	OBAJANA JUNCTION, ABUJA-OKENE ROAD.	6.602433	8.022778
5	SARKIN PAWA	NIGER	MUNYA	SARKIN PAWA	6.887474	9.334701
6	ZARIA	KADUNA	SABON GARI	KANO-KADUNA EXPRESS WAY.	7.797576	11.138358

6

Page 1 of 1

Source: Researcher's Database Analysis Work, 2014

Table 4.7: Geographical Coordinates for NNPC Booster Stations in Northern Nigeria.



NNPC BOOSTERS NORTHERN NIGERIA : Database (Access 2007) - Microsoft Access

NNPC BOOSTER STATION AREAS' COORDINATE

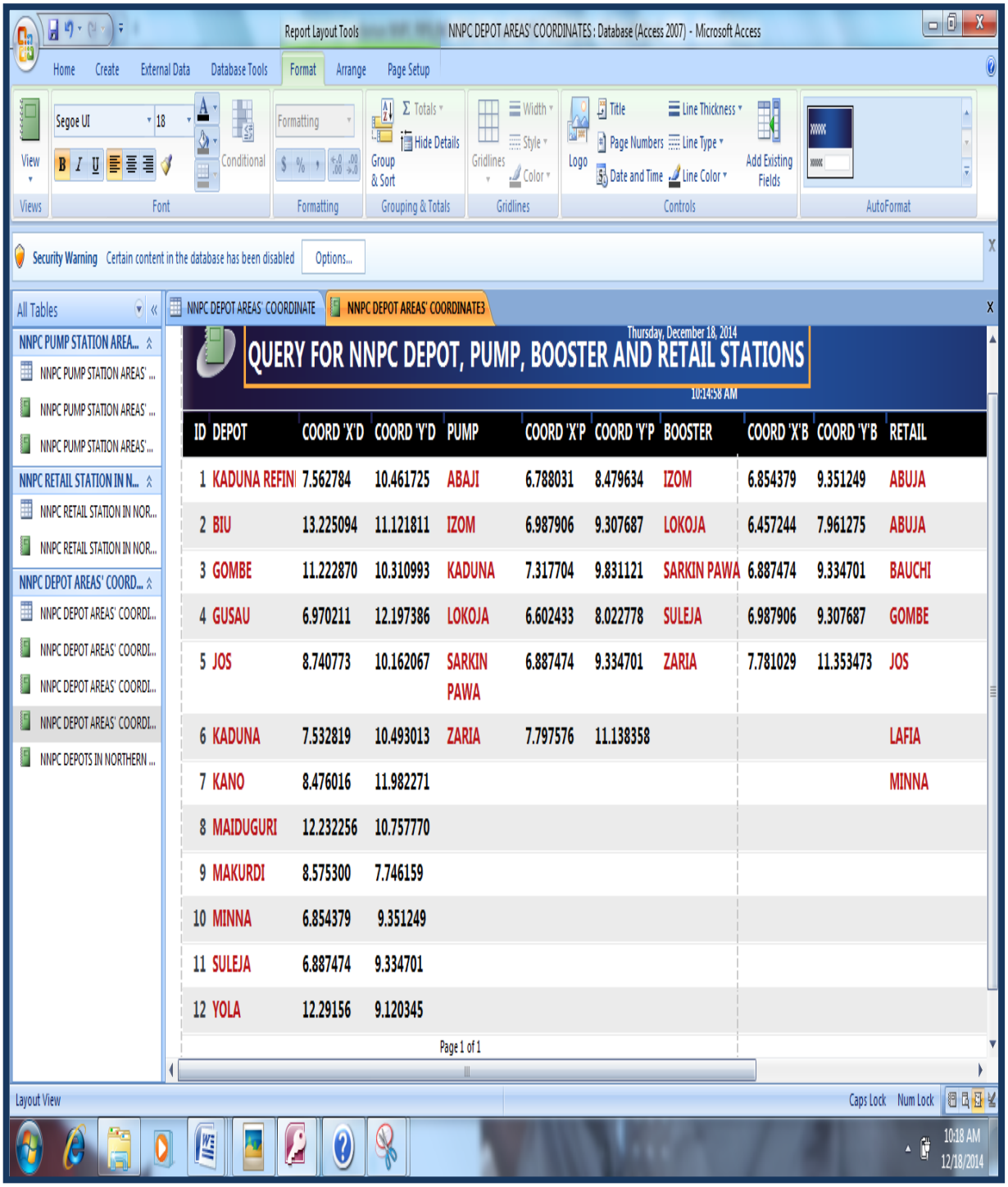
Thursday, June 05, 2014 10:41:16 PM

ID	BOOSTER	STATE	LOCAL GOVERNMENT AREA	LOCATION NAME	LOCATION'S COORDINATE 'X'	LOCATION'S COORDINATE 'Y'
1	IZOM	NIGER	GURARA	IZOM, MINNA ROAD.	6.854379	9.351249
2	LOKOJA	KOGI	LOKOJA	OBAJANA JUNCTION, ABUJA-OKENE ROAD.	6.457244	7.961275
3	SARKIN PAWA	NIGER	MUNYA	SARKIN PAWA.	6.887474	9.334701
4	SULEJA	NIGER	SULEJA	DIKKO, SULEJA ROAD.	6.987906	9.307687
5	ZARIA	KADUNA	SABON GARI	KANO-KADUNA EXPRESS WAY.	7.781029	11.353473

Page 1 of 1

Source: Researcher's Database Analysis Work, 2014.

Table 4.8: Query for NNPC Depot, Pump, Booster and Retail Stations and their Coordinates in Northern Nigeria.



ID	DEPOT	COORD 'X'D	COORD 'Y'D	PUMP	COORD 'X'P	COORD 'Y'P	BOOSTER	COORD 'X'B	COORD 'Y'B	RETAIL
1	KADUNA REFIN	7.562784	10.461725	ABAJI	6.788031	8.479634	IZOM	6.854379	9.351249	ABUJA
2	BIU	13.225094	11.121811	IZOM	6.987906	9.307687	LOKOJA	6.457244	7.961275	ABUJA
3	GOMBE	11.222870	10.310993	KADUNA	7.317704	9.831121	SARKIN PAWA	6.887474	9.334701	BAUCHI
4	GUSAU	6.970211	12.197386	LOKOJA	6.602433	8.022778	SULEJA	6.987906	9.307687	GOMBE
5	JOS	8.740773	10.162067	SARKIN PAWA	6.887474	9.334701	ZARIA	7.781029	11.353473	JOS
6	KADUNA	7.532819	10.493013	ZARIA	7.797576	11.138358				LAFIA
7	KANO	8.476016	11.982271							MINNA
8	MAIDUGURI	12.232256	10.757770							
9	MAKURDI	8.575300	7.746159							
10	MINNA	6.854379	9.351249							
11	SULEJA	6.887474	9.334701							
12	YOLA	12.29156	9.120345							

Source: Researcher's Database Analysis Work, 2014.

4.3 Buffering Operation: Buffer, generates zones with pre-defined distance from a specified set of data. Buffering is act of processing zone of interest usually of specified width around a map element such as road, streams, rivers, marshy area, etc. In order to achieve this objective, buffer zone was created around the pipelines to assess compliance or degree of encroachment into the right-of-way of pipelines by the various land-use types in the study area. Also in this study, a buffer zones was created around water bodies (rivers, wetlands, streams, delta, lagoon), road/rail networks to satisfy the set criteria of distance. The guidelines, as provided for in the oil pipelines Act of 1956 cap 145 and as amended by Oil Pipeline Act of 1965 and Pipeline Act CAP 338 of the Law of the Federation of Nigeria 1990, Land Use Act Cap 202 0f 1990 and the Nigeria Urban and Regional Planning Act of 1990, was also used to assess degree of compliances or failure to NNPC pipelines row, in line with the approved setbacks, as stipulated in the criteria stated above.

4.4 Level of Compliance to NNPC Pipelines' Right-of-Way

An unclassified Landsat band 1, 2 and 3 satellite imagery (Appendix VI-VIII) was being provided and processed for the classification of the various land use types. From the classification adopted for the study area as shown on map for land use/land cover classification. The farmland and grazing area occupies a large area of 125,673.00 km^2 representing a (70%), built-up has 25,134.62 km^2 (14%). Road network in the study area accounts for 17,953.30 km^2 (10%) encroachment extent while the water bodies accounted for the remaining 10,771.98 km^2 (6%), which is summed up to an area size of 179, 533.00 km^2 (100%). A large proportion of the urban population in the study

areas is engaged in farming activities to support their livelihood. In some States like Adamawa, Bauchi, Benue, Gombe, Sokoto, Taraba, Zamfara State etc has some forms of mechanized farming.

Based on the individual land classification and superimposition of pipelines and land use type features and reconnaissance survey carried out by the Researcher on each of the study area, as shown in figure 4.2 to figure 4.4 it was observed that agriculture; such as farming activities around the study points and rearing and grazing of cattle around the study area; as observed in Abaji, Biu, Kaduna, Gombe, Gusau, Izom, Minna, accounts for the highest percentage of land use type encroaching into the NNPC Pipelines' right-of-way.

Thus, agricultural land uses accounts for 70% (125,673.00 km^2) land use type that encroaches into NNPC pipelines' right-of-way. The built-up area is ranked or rated as the second land use type that encroaches into the pipelines' right-of-way, with a percentage constituent of 14% (25,134.62 km^2). This observation in figure 4.2a and figure 4.2b is justified by some superstructures constructed that infringed into the setback zones in the study area, particularly, in some parts of Kamanzo Settlement of Kaduna State, Hotoro Settlement of Kano State, Apir Settlement of Benue State and Mr. Ali Settlement of Plateau State.

The roads constructed in the study areas, particularly untarred, motorized, non-motorized roads and foot paths were noticed to encroach into the NNPC Pipelines' right-of-way in areas such as; Kamanzo Settlement; Kaduna, Apir settlement; Makurdi, 'Mil 3' Settlement; Gombe, Mr. Ali

settlement; Jos, Zaria Settlement; Kaduna, Hotoro Settlement; Kano and Dikko Settlement; Suleja, Lokoja Settlement; Kogi, and Abaji Settlement; Abuja. It accounts for 10% (17,953.30 km^2) of the total land area that have been encroached by the various land use types in the study area.

While the remaining 6% (10,771.98 km^2) accounts for water bodies as a form of land use type that also encroaches into the right-of-way of these pipelines. This encroachment was noticed at the tributary of the Kaduna River, around the Angwan Rimi Settlement; Kaduna State, Lokoja settlement; Kogi State and the crude line pipelines network coming from Escravos-Warri, which criss-crossed the Niger River (figure 4.3 and figure 4.4).

It is however, expedient to state here clearly, that pipeline platforms are built over the surface of water bodies and to serves as support for the pipelines particularly where the water bodies cannot negotiated or avoided.

The Encroachment Sizes and Percentages by the various Land Use type was determined using the Simple Percentage Formula:

$$\text{Percentage of encroachment by Land use type (\%)} = \frac{X}{\sum(N)_1} \times 100$$

Where X = Land Area occupied by a Land Use Type.

$\sum$ (N) = Total Land Area by the various Land Use Types.

Encroached Land Area occupied by Agriculture in the Study Area = **125,673.00 km^2**.

Encroached Land Area occupied by Built-up in the Study Area = **25,134.62 km^2**

Encroached Land Area occupied by Road in the Study Area = **17,953.30 km^2**

Encroached Land Area occupied by Water Bodies in the Study Area = **10,771.98 km^2.**

Percentage of encroachment by Agriculture (%) = 125,673.00 x 100
179,533.00 1 **= 70.00%**

Percentage of encroachment by Built-ups (%) = 25,134.62 x 100
179,533.00 1 **= 14.00%**

Percentage of encroachment by Road (%) = 17,953.30 x 100
179,533.00 1 **= 10.00%**

Percentage of encroachment by Water Bodies (%) = 10,771.98 x 100
179,533.00 1 **= 6.00%**

Table 4.9 below, shows the summary of the major land use types that has encroached into NNPC pipelines right-of-way in the study area in terms of area cover and percentage.

Table 4.9: Major Land Use Types encroaching into NNPC Pipelines' Right-of-Way.

Land Use Type	Land Area Covered (km^2)	Percentage (%)	Rating
Agriculture (Farming/Grazing).	125,673.10	70.0	First
Built-ups	25,134.62	14.0	Second
Roads	17,953.30	10.0	Third
Water Bodies	10,771.98	6.0	Fourth
Total	179, 533.0	100.0	

Source: Researcher's Work 2014.

*Rating = the level of encroachment by land use type into the pipelines' right-of-way is in the ascending order.

4.4.1 Pipeline Segments' level of Right-of-Way Compliance Assessment

The choice of sampled areas and points of reference have been described in chapter 3, different types of pipeline segment points and network were mapped and land use types encroaching into the NNPC Pipelines right-of–way are identified and described. Here, results of the detailed analysis of the satellite imageries are explained.

4.4.2 System 2C (Warri-Kaduna Crude Line) Segment

It is 606 km (370 miles) pipeline from Warri to Kaduna. Starting in the rain forest the pipeline crosses through savannah type terrain before reaching savannah conditions surrounding Kaduna. Initially the pipeline was designed for crude oil but used on a batch basis carrying refined fuel such as gasoline, kerosene and gas oil from the refinery at Warri to Kaduna. Later the pipeline was used to pump crude oil to the refinery at Kaduna.

The pipelines right of way is 25 m^2 buried at 6 feet below the earth surface. The sampled point, 5 kilometres from the refinery/depot shows encroachment into pipelines' right-of-way due to farming and grazing activities. This is illustrated by the visible differences between the image tones for the pipelines and the setback zone for the pipeline as shown in figure 4.3. Present field observation in a Kamazo Settlement 2 Km away from the refinery, where the distributing pipeline networked to Zaria Pump Station, where they are exposed, show that untarred road and built-ups are gradually and rapidly encroaching into the pipelines' right-of-way as shown in the Landsat Earth imagery in Appendix VI-VIII. Also observation and oral

interview conducted at the Rido Village, show that over time pipeline vandalism has been carried out in the area.

Also the attacks on these pipelines system by vandals has led NNPC to have spent over US $42.952 million to execute a two-phase repair work which started in September, 2009 on 74 damaged points in System 2C-1. Escravos–Warri Crude Oil Pipelines to enable the start up of the Warri and Kaduna refineries. Between 2010 and 2012, it was reported by NNPC, that the Kaduna's system recorded a total of 571 cases of pipeline vandalism (NNPC, 2013).

4.4.3 System 2D (a) Kaduna-Zaria- Kano Segment

The pipeline segment length is about 250 km; the segment set back is characterized by farming and grazing along the pipeline route and Kaduna River tributary (water bodies). However, a protector is placed or wrapped and set at the pipeline where it criss-crossed the river. Some few measurements from the satellite imagery (dark-grey portions) and from the field using a tape rule and ranging pole give a 50 m and 126 m radius encroachment by farmland/grazing land and structure at 500 m and 1 km from the Zaria Pump Station and 4 km along its route to Kano. At the Hotoro Depot; Kano, 2 km-5 km, field check revealed also built-up and unauthorized minor roads encroachment into NNPC Pipelines' right-of-way (figure 4.2a).

4.4.4 System 2D (b) Zaria-Gusau Segment

This pipeline has segment length of 177 km and a flow rate of 40 m^3/hr. The pipelines transverses Zaria Pump Station, along Zaria-Kano Express Way, through parts of Katsina State to Gusau in Zamfara State. The satellite interpretation as shown in figure 4.2b and field work linear measurement 500 m^2 away from Pump Station revealed intensive and extensive agricultural cultivation and grazing activity around the pipelines. While in some areas these cultivation infringed into the setback of the pipelines. Also, it was observed that minor road (foot path) was seen to have encroached into the pipeline' right-of-way. In some areas, along the pipeline route, some superstructures were seen built closer to the pipelines, which might in the future, exposed the pipelines to the act of vandalism.

4.4.5 System 2D (c) Kaduna-Jos Pipeline Segment

This pipeline segment has a distance 165 km and a flow rate of 90 m^3/hr, which the Kaduna Refinery pumps products through to Jos Depot. The pipeline transverses southern part of Kaduna State, via Zonkwa-Manchok to Mr. Ali, Jos. At 3 km away from the depot, it observed from field check done in studied area in figure 4.2a, that Agricultural activities-farming and grazing was observed to be common in this area. Animal trampling is also common; hence the events of rill and sheet wash become active processes near the pipelines. It was also observed that the pipeline took advantages of the low plain of the undulating and high topography of the area. At 1.0-2.5 km within the jurisdiction of the depot and pipeline some built-up structures were seen around the pipeline's right-of-way.

4.4.6 System 2D (d) Gombe-Maiduguri Pipeline Segment

The pipeline has a segment length of 297 km and 90 m^3/hr flow rate, where oil products are pump from Gombe Depot to Maiduguri Depot via the Biu Pump Station. From the satellite imagery analysis and field work, at this segment line, active animal grazing and cultivation of arable land were observed to be encroaching into the setback portion of the laid oil pipelines, particularly along Maiduguri-Damboa road. This segment line has also bedevilled by number of vandalism by Saboteurs and Bunkers. It is worthwhile, to state that in some areas along the pipeline route, built-up structures were seen to be encroaching into NNPC pipeline's right-of-way. Presently, for some years now, there hasn't being pumping of petroleum products into this segment to Maiduguri Depot because of Security reasons, emanating from the activities of the terrorist insurgents that has in couple of times attempted to attacked and vandalized oil depot and pipeline infrastructures.

4.4.7 System 2D (e) Jos-Gombe Pipeline Segment

The 265 km length and 90 m^3/hr flow rate pipeline segment, was the first pipeline constructed that pumps petroleum products from Jos Depot to Gombe Depot. By the evidences of the satellite imagery and field check analyses, two land use types were identified as encroachers to the pipeline's right-of-way; that is agricultural land use and built-up areas. The farmlands/grazing and vegetal growth areas displayed dark-greyed tones satellite imagery when wet but are grey-light toned when dried. However, the Jos-Gombe oil pipeline is one of the pipeline segments that Federal

Government has spents 1.32 billion naira, between year 2011 and 2012 in clearing and in grading pipelines' right-of-way in Nigeria. 3 km Bulyde Jos-Gombe pipeline route in Gombe and 4 km Zonkwa-Jos pipelines' right-of-way were amongst those cleared.

4.4.8 System 2CX (b) Auchi-Suleja Pipeline Segment

The system 2A product pipeline route which conveys product from Warri-Benin-Suleja/Ore Depots ranks second on the scale of pipeline break points with 3,259 cases representing 20.2% of the total volume products pipeline breaks in Nigeria. The figure also came with a loss of over ₦20.39 billion in products and pipeline repairs (NNPC, 2013). From the satellite interpretation, it was observed, that one of the major land use type infiltrating and intruding into the crude line to Suleja is the water bodies that the pipelines criss-crossed at the Lokoja Confluence (River Niger) which occupies a larger portion of the various types of land use encroaching into the pipeline's right-of-way, as indicated by the bluish toned pattern. Farmlands/grazing lands were observed during ground checks to have encroached into the pipeline's right-of-way. Also at the urban areas, specifically at the southern part of the pipeline routes (Auchi and some other settlements in the middle-belt region of Nigeria), where this pipeline transverse, built-up structures were seen to have encroached into the pipeline's right-of-way.

4.4.9 System 2CX (c) Suleja-Minna Pipeline Segment

Warri Refinery pumps products to Benin, Auchi, Abaji, Suleja and Minna. The major land use type observed to have encroached by 50 m^2into the pipeline's right-of-way is agricultural land use. Cultivation of crops and

grazing of animals by farmers and cattle herdsmen at a close proximity to the pipeline route was observed during field checks. It also reported by NNPC that pipelines, conveying products from Warri-Auchi-Suleja Crude Line en-route the Minna Depot in Niger State, have been vandalised in more than 20 points, leading to the stoppage of pumping of the products. While at the Dikko-Suleja area and in Minna, it was observed that built-up structures were responsible for the non-compliance to the right-of-way of the oil pipelines, as some of this built-ups encroached by 50-70 m into the setback of pipelines. This pipeline system segment has witnessed series of vandalisms by pipelines vandals and saboteurs particularly at the Dikko settlement.

4.4.10 System 2CX (d) Suleja-Kaduna Pipeline Segment

The newly laid Suleja-Kaduna NNPC Pipeline's segment has a length of 150 km and flow rate of 135 m^3/hr. The Suleja Depot further helps in pumping crude oil from the Warri Refinery to Kaduna Refinery. The major land use types that was observed to encroached to the pipelines' right-of-way is agriculture and built up. However, the built-ups were seen mainly within the Kaduna and Suleja Settlement heartlands. Minor Road as a form of land use was observed to be encroaching into the pipeline's right-of-way particularly at the urban environment of the study area. It is note worthy to state that the Suleja-Kaduna line is amongst the segments that the Federal Government has spent 1.32 billion naira, between year 2011 and 2012 in clearing and in grading pipelines' right-of-way in Nigeria. But this has not stopped agriculture as a form of land use type from encroaching into NNPC Pipelines' right-of-way in the study area.

4.4.11 System 2DX Jos-Gombe Pipeline Segment

This segment is the newly constructed pipeline to augment the existing pipeline. It has a length of 165 km and 85 m^3/hr. Between 2010 and 2012 a total of 2,787 lines breaks were reported on pipelines belonging to the Nigerian National Petroleum Corporation (NNPC, 2013), resulting in a loss of 157.81 million tonnes of petroleum products worth about ₦12.53 billion. Pipelines along the Gombe axis recorded 850 cases of pipeline break.

4.4.12 System 2E (b) Enugu-Makurdi Pipeline Segment

Port Harcourt Refinery; System 2E Crude Line, pumps products through Aba, Enugu and to Markurdi. In all, 8,105 breaks were recorded along the system 2E within the period representing about 50.3 percent of the total number of petroleum products pipeline breaks in the country (NNPC, 2013), which the Phase II Enugu-Makurdi pipeline segment constituted a proportion of these pipeline breaks. The attacks left the NNPC with a cost of N78.15 billion in product loses and pipeline repairs. The Yola-Enugu-Auchi appears to be the haven of pipeline vandalism in the country particularly the Port Harcourt-Aba/Isiala-Ngwa axis.

4.4.13 System 2EX (c) Makurdi-Yola Pipeline Segment

The System 2EX(c); which conveys products from system 2E: Port Harcourt refinery to Aba-Enugu-Makurdi Depots onwards to Yola Depot. It has a diameter of 8”c = 0.25”, with 475 km and concrete pipeline of 7,000 m length (NNPC, 1993). According to records obtained from linear measurement, it was observed there was about 58 m encroachment into the

pipelines' right-of-way by built-up area at Apir, within 1 km radius, and at 3 km away from the depot, farming/grazing land use was observed to have encroached into the pipeline' right-of-way. The land use types; built-up and tarred and untarred road are responsible for the encroachment into the pipeline's right-of-way. NNPC pipelines, conveying products from Enugu to Makurdi, enroute the Yola Depot in Adamawa State, have been vandalised in more than 20 points, leading to the stoppage of pumping of the products.

Thus, analysis as shown in figure 4.2a-4.4 below gave the summary of the level of compliance by the various land use/cover types to the NNPC pipeline segments' right-of-way in Northern Nigeria. The table revealed that the assessed land use/cover types in the study area do not comply with the right-of-way of these pipelines.

4.4 Classification Scheme for Land Use Types

A classification scheme was developed for the study area after Anderson *et al.* (1967). The classification scheme developed gives a rather broad classification where the land use/land cover were identified by a single digit. But for the purpose of this research, it was modified to suit the classification scheme adopted by the Planning Authorities world wide. This is classification is used for land use zoning, mapping and regulations in Nigeria. This also includes the colour codes for each of the various land uses adopted; this is shown in the table 4.10 below.

Table 4.10: A Modified Anderson's (1967) Classification Scheme for Land Use/Land Cover Code and Colours Categories.

S/NO.	LAND COVER	COLOUR CODE	S/NO.	LAND USE	COLOUR CODE
1.	Farmland	Purple	**1.**	Industrial	Purple
2.	Wasteland	Green	**2.**	Recreational	Green
3.	Built-up Land	Yellow	**3.**	Public/Semi-public	Yellow
4.	Forest Bodies	Greenish Brown	**4.**	Residential	Brown
5.	Water Bodies	Blue	**5.**	Organized and unorganized open space	Green
6.	Bare Surface	Brown	**6.**	Commercial	Red
			7.	Water Bodies	Blue

Source: Anderson, 1967 and Canada Centre for Remote Sensing, 2012.

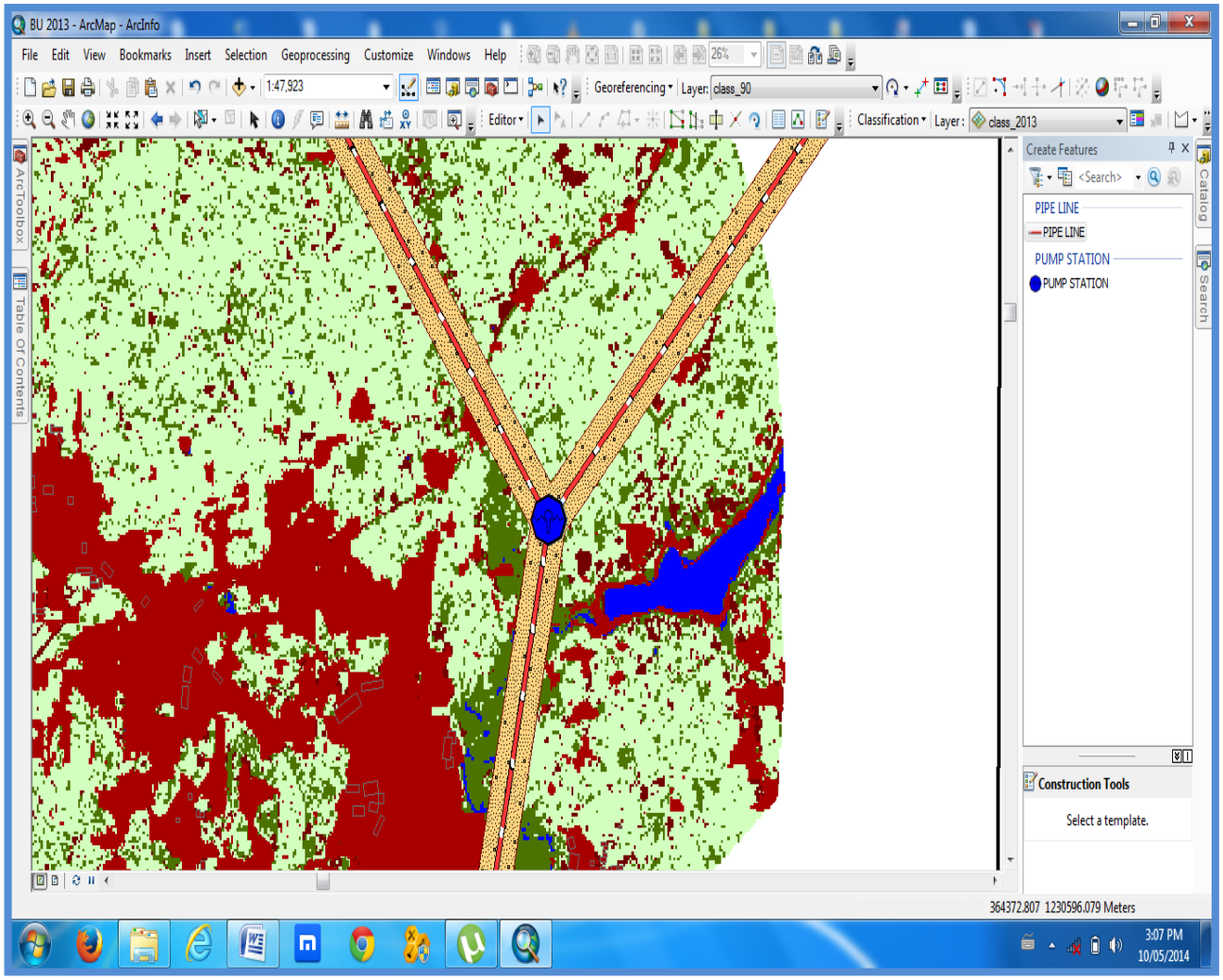


Fig. 4.1(a): Land Use Classification for Zaria-Gusau and Zaria-Kano Axes Study Area.

Source: Researcher's Work, 2014.

Figure 4.1(a) above, depicts 576 m^2 buffer zone from the Agricultural area, Built- up area, Water Bodies and Roads**.** The query was carried out to show Agriculture, Built-up areas, Water Bodies and Roads that is available outside the buffered zone. Based on the buffer analysis done and measure measurement carried out on the field, it was observed that the various land use types encroached into the pipelines' right-of-way as explained in sub-section 4.33 above.

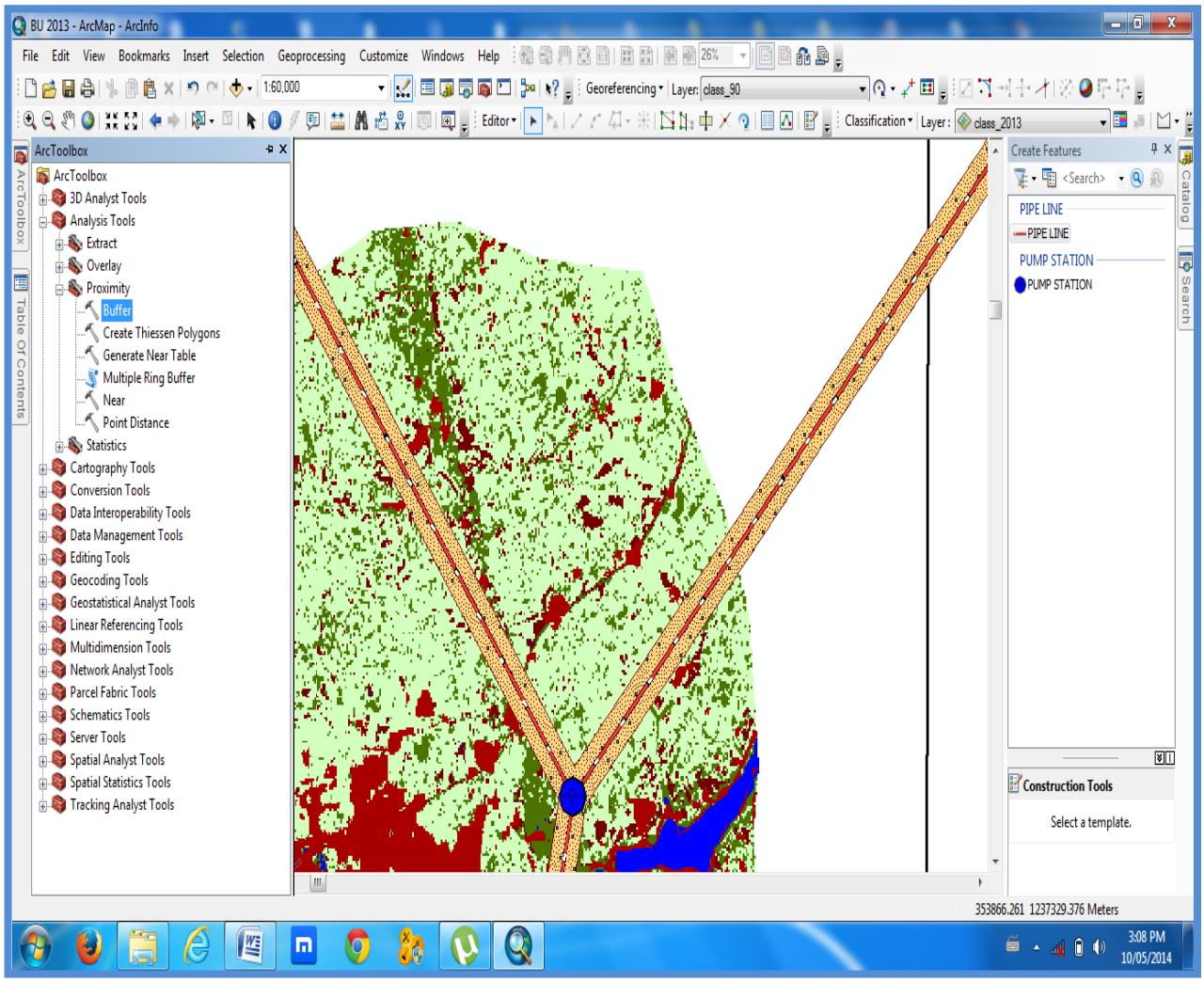


Fig. 4.1(b): Land Use Classification for Zaria-Gusau and Zaria-Kano Axes Study Area (Magnified).

Source: Researcher's Work, 2014.

Figure 4.1 (b) above, shows 450 m^2 buffer zone from the Agricultural area, Built-up area, Water Bodies and Roads**.** The above query was carried out to show Agriculture, Built-up areas, Water Bodies and Roads that is available outside the buffered zone. The buffer zone analysis as explained in sub-section 4.3.3 and sub-section 4.3.4 shows that the various land use types encroaches into the pipelines' right-of-way by larger encroached size more than when buffer zone criteria of 576m^2 was used.

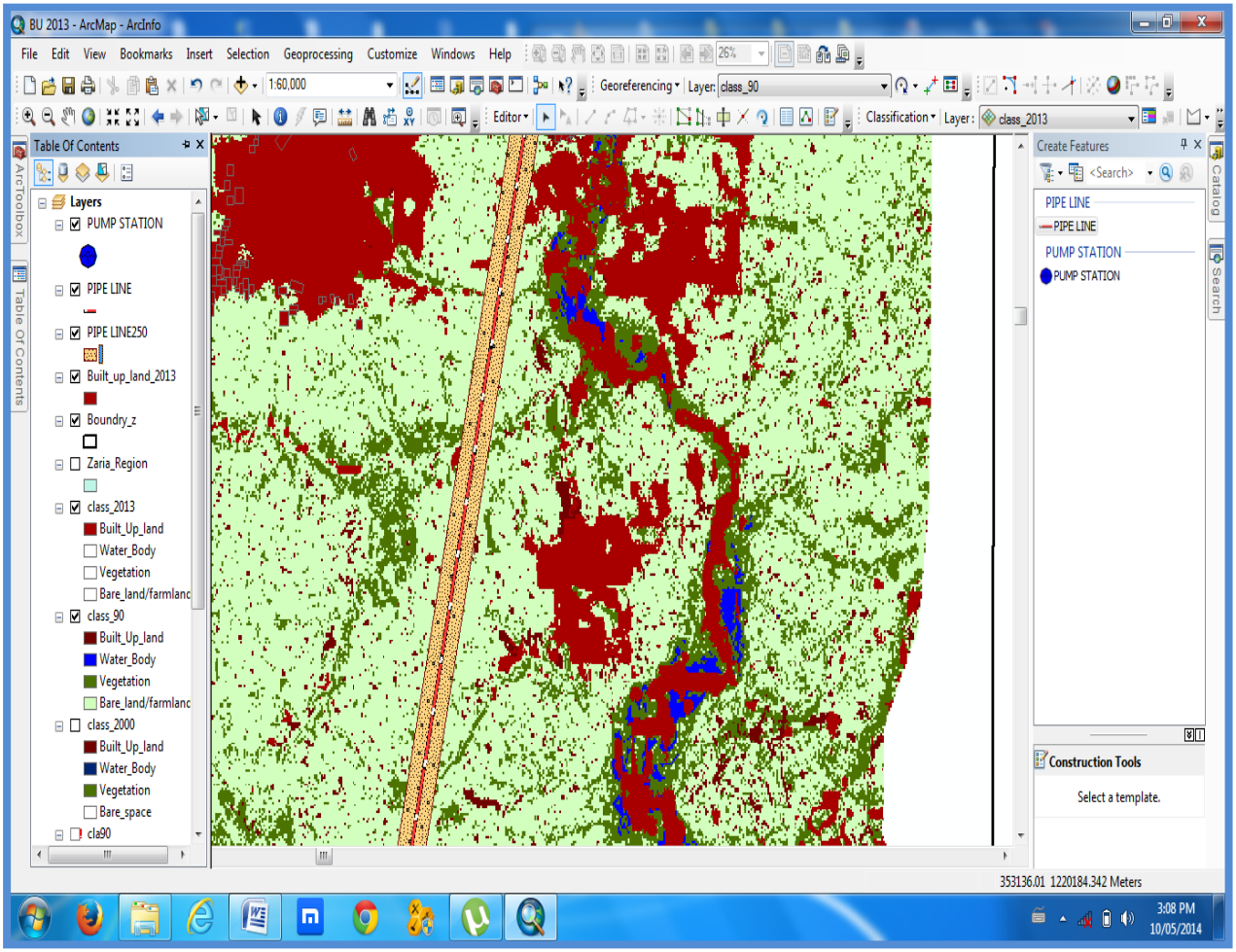


Fig. 4.2: Land Use Classification for Warri-Auchi-Kaduna Axis (Crude Oil Pipeline) of the Study Area (Magnified).

Source: Researcher's Work, 2014.

450 m^2 buffered from the Agriculture, Built-up area, Water Bodies and Roads**.** The above query was carried out to show Agriculture, Built-up areas, Water Bodies and Roads that is available outside the buffered zone. The buffering analysis along the Old Crude-Oil Line segment showed that all the various land use types encroaches into the pipelines' right-of-way. A detail explanation on the encroachment extent has been elucidated in Sub-section 4.3.2 of this section above.

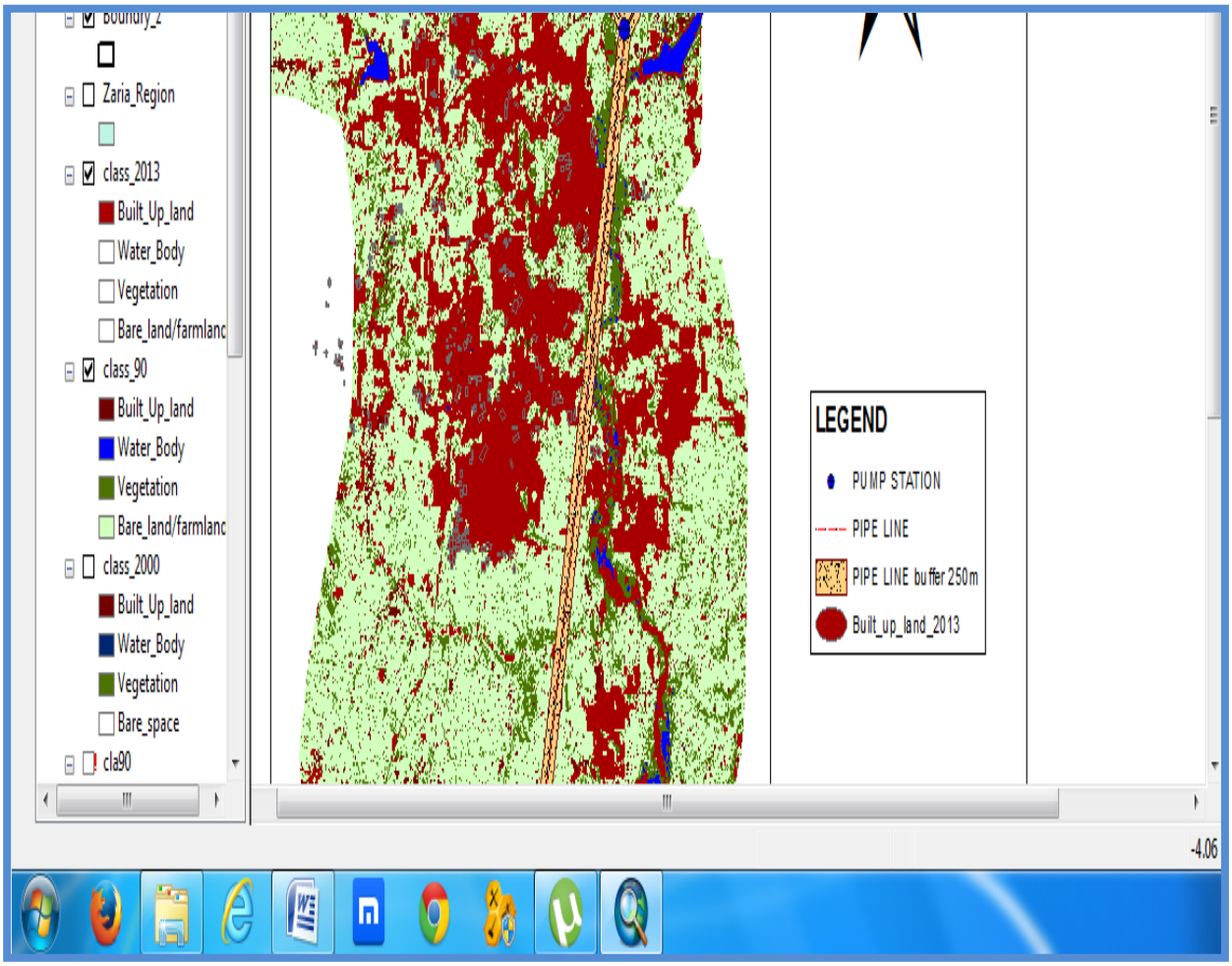


Fig. 4.3: Land Use Classification for Warri-Auchi-Kaduna Axis (New Product Pipeline) of the Study Area (Magnified).

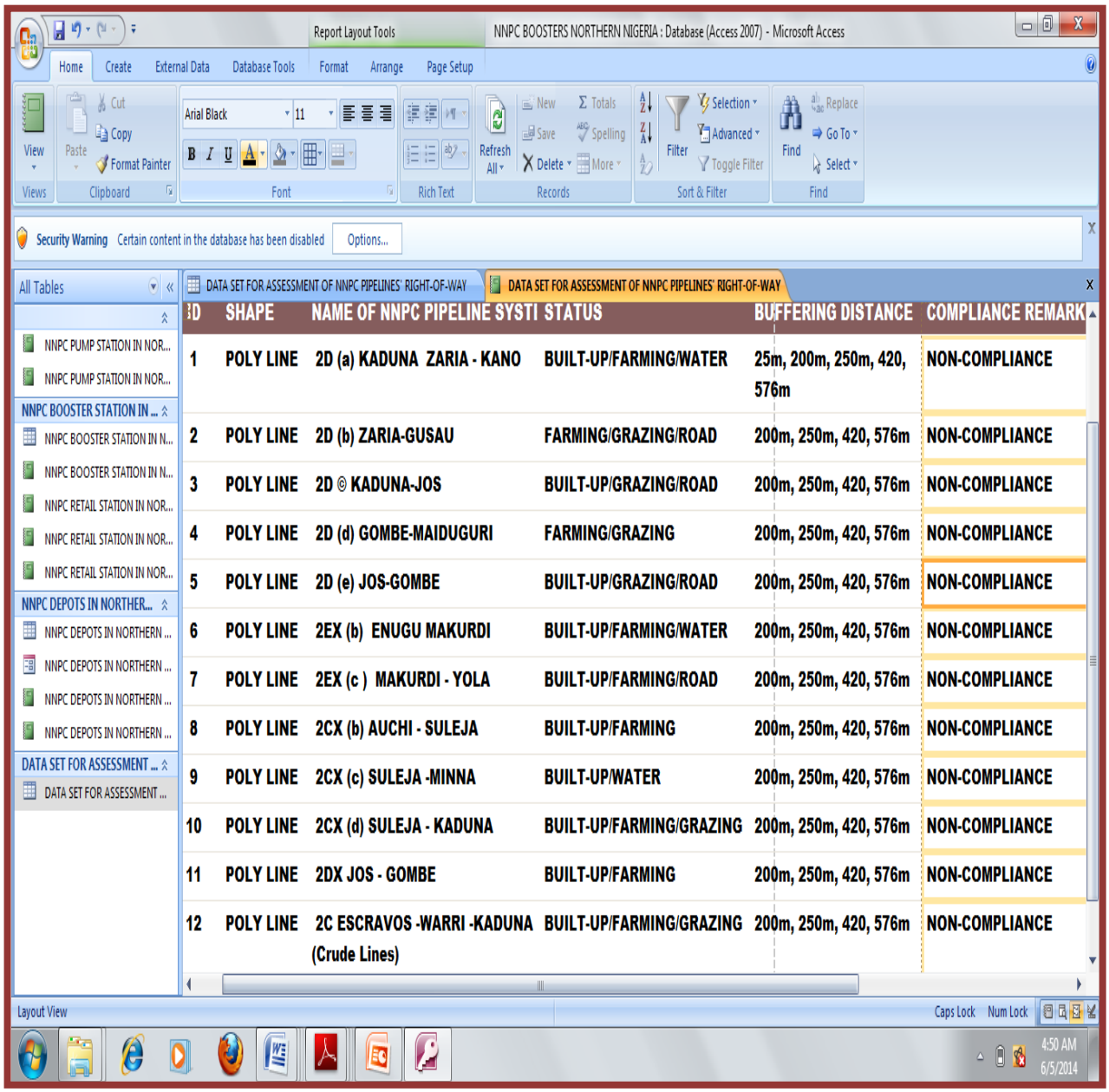
Source: Researcher's Work, 2014.

200 m^2 buffer zone from the Agriculture, Built-up area, Water Bodies and Roads**.**

The above query was carried out to show Agriculture, Built-up areas, Water Bodies and Roads that is available outside the buffered zone. When this analysis is zoomed to screen, it virtually showed that all the various land use types encroached into the pipelines' right-of-way along the studied segment points. The encroachment features

or characteristic is similar to the Old Product Pipeline. This is because the new product pipeline was laid at close proximity to the existing pipeline.

Table 4.11: Dataset for Level of Compliance to NNPC Pipelines' Right-of-Way.



ID	SHAPE	NAME OF NNPC PIPELINE SYSTI	STATUS	BUFFERING DISTANCE	COMPLIANCE REMARK
1	POLY LINE	2D (a) KADUNA ZARIA - KANO	BUILT-UP/FARMING/WATER	25m, 200m, 250m, 420, 576m	NON-COMPLIANCE
2	POLY LINE	2D (b) ZARIA-GUSAU	FARMING/GRAZING/ROAD	200m, 250m, 420, 576m	NON-COMPLIANCE
3	POLY LINE	2D © KADUNA-JOS	BUILT-UP/GRAZING/ROAD	200m, 250m, 420, 576m	NON-COMPLIANCE
4	POLY LINE	2D (d) GOMBE-MAIDUGURI	FARMING/GRAZING	200m, 250m, 420, 576m	NON-COMPLIANCE
5	POLY LINE	2D (e) JOS-GOMBE	BUILT-UP/GRAZING/ROAD	200m, 250m, 420, 576m	NON-COMPLIANCE
6	POLY LINE	2EX (b) ENUGU MAKURDI	BUILT-UP/FARMING/WATER	200m, 250m, 420, 576m	NON-COMPLIANCE
7	POLY LINE	2EX (c) MAKURDI - YOLA	BUILT-UP/FARMING/ROAD	200m, 250m, 420, 576m	NON-COMPLIANCE
8	POLY LINE	2CX (b) AUCHI - SULEJA	BUILT-UP/FARMING	200m, 250m, 420, 576m	NON-COMPLIANCE
9	POLY LINE	2CX (c) SULEJA -MINNA	BUILT-UP/WATER	200m, 250m, 420, 576m	NON-COMPLIANCE
10	POLY LINE	2CX (d) SULEJA - KADUNA	BUILT-UP/FARMING/GRAZING	200m, 250m, 420, 576m	NON-COMPLIANCE
11	POLY LINE	2DX JOS - GOMBE	BUILT-UP/FARMING	200m, 250m, 420, 576m	NON-COMPLIANCE
12	POLY LINE	2C ESCRAVOS -WARRI -KADUNA (Crude Lines)	BUILT-UP/FARMING/GRAZING	200m, 250m, 420, 576m	NON-COMPLIANCE

Source: Researchers' Work, 2014.

Table 4.11 above, shows the query for all the pipelines system's buffer zone criteria to ascertain the right-of-way compliance by Agricultural area, Built-up area, Water

Bodies and Roads**.** The results indicated that the various land use type in the study area do not complied with the regulations guiding pipelines' ROW in the study area.

4.5 Elevation and Slope Aspect

Distribution of land use encroachment types was observed to be associated with altitude in the study area. This can be supported by the fact that elevation is positively correlated with rainfall and humidity regime of soil (Damen, 1993). The Digital Elevation Modelling (DEM) of satellite imageries (the Nigeria Landsat STRM and Northern Nigeria Landsat SRTM Band 1, 2 and 3) gives the Elevation points of the study area. The use of the Remote Sensing and GIS techniques revealed the elevation of the study area with interval of 50 m a.s.l

The influence of slope steepness on the laying of pipelines and land use type encroachment and occurrences was found to be prominent in the study area and that the laying of pipelines takes advantage of flat topography and a steepness of 20^{o}. Figure 4.4 and figure 4.5 below clearly explain the relationships. In general, the steeper the slope the more the forceful the pumping or transported oil products and the lesser the encroachment into pipelines' right-of-way taking place. The slope classes measured on satellite imageries are grouped below:

i. < 1 degree.
ii. 1 - 5 degree.
iii. 5 - 10 degree.
iv. 10 - 15 degree.
v. 15 - 20 degree.

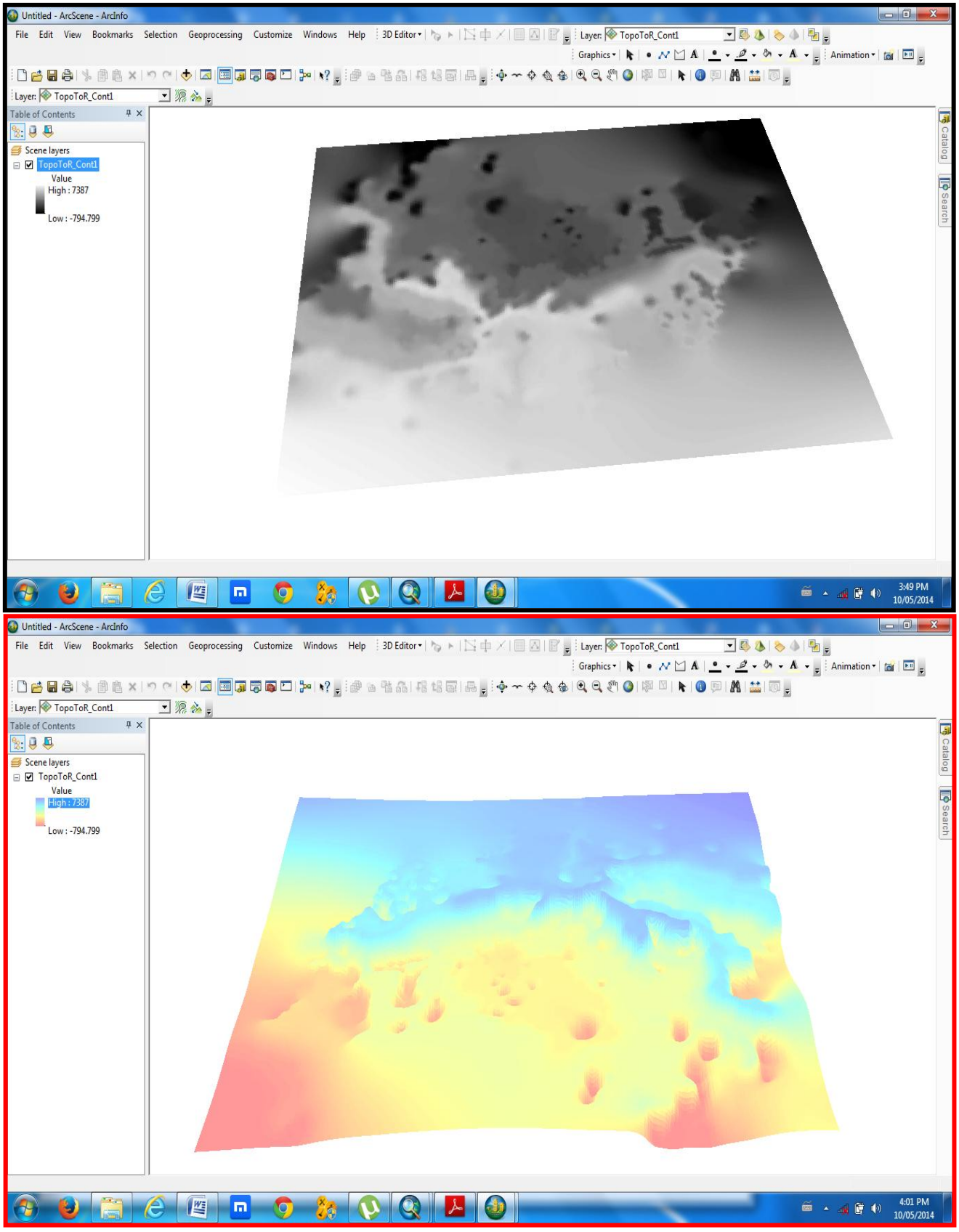


Fig. 4.4: Digital Elevation Model (DEM) (Panchromatic and Multi-spectral Colours) of the Study Area 3D-Perspective.
Source: Researcher's Work, 2014.

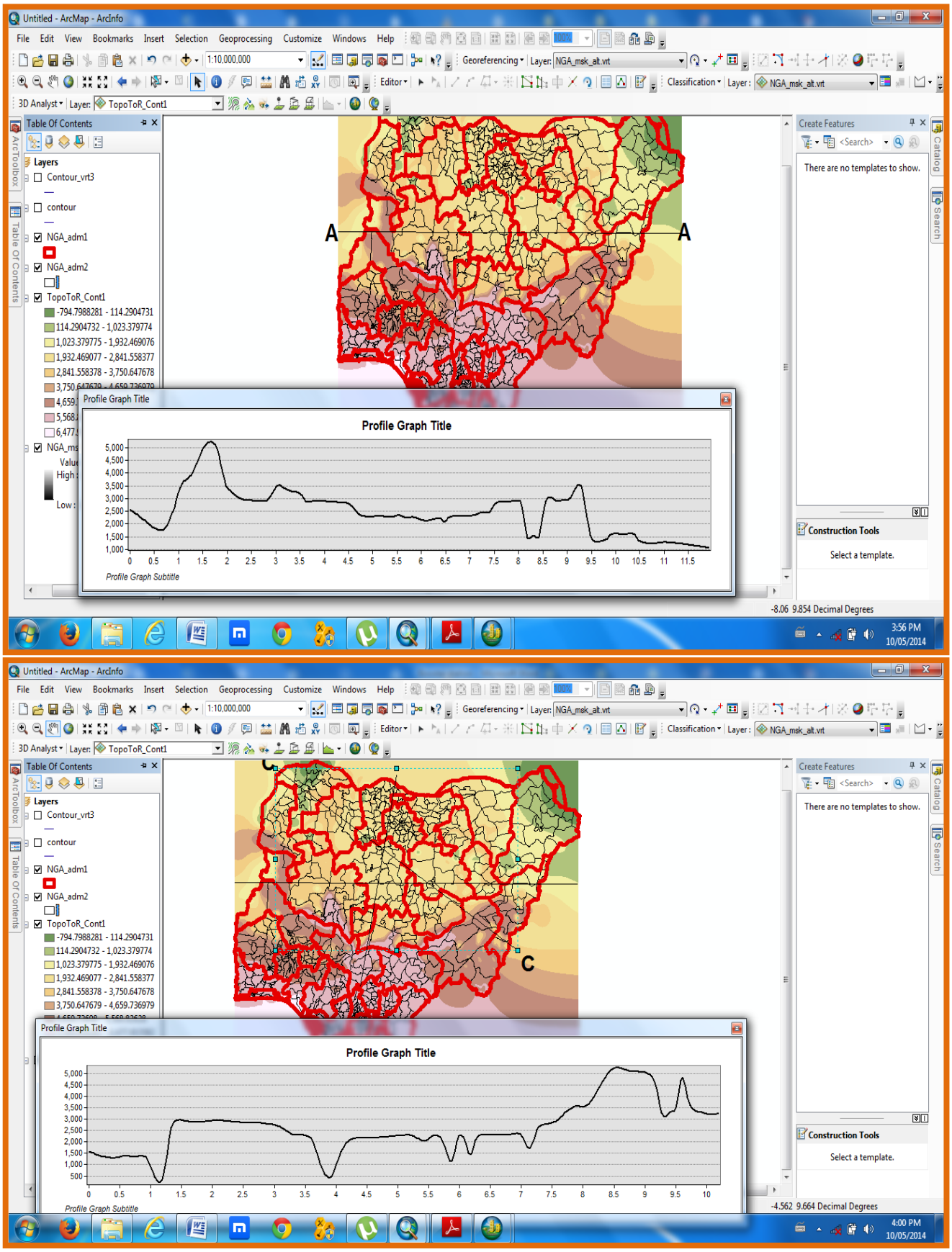


Fig. 4.5: Contour Profile Graph from A, B, C-Orientation of the Study Area.
Source: Researcher's Work, 2014.

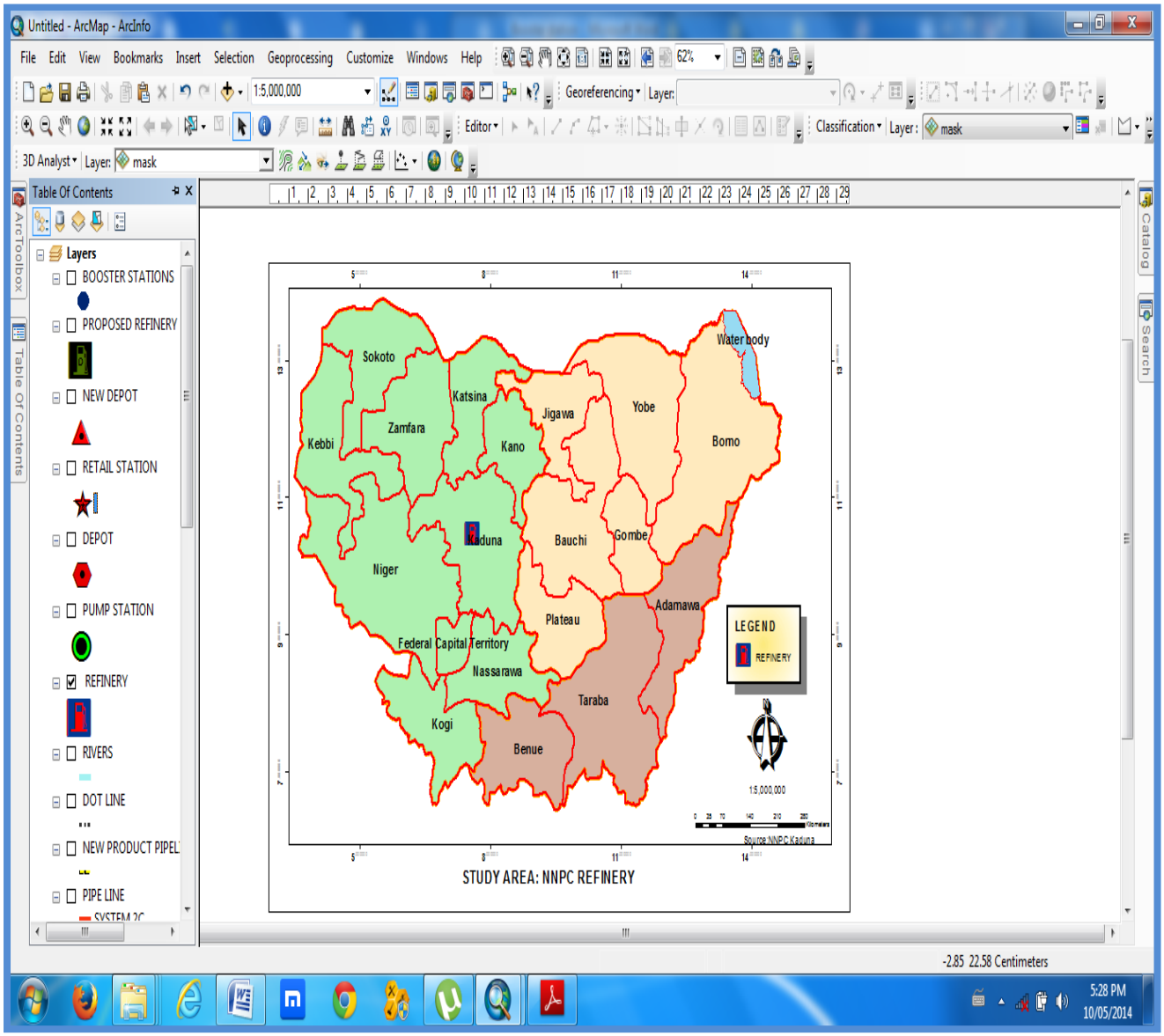


Fig. 4.6: NNPC (Kaduna) Refinery in the Study Area.
Source: Researcher's GIS Analysis Work, 2014.

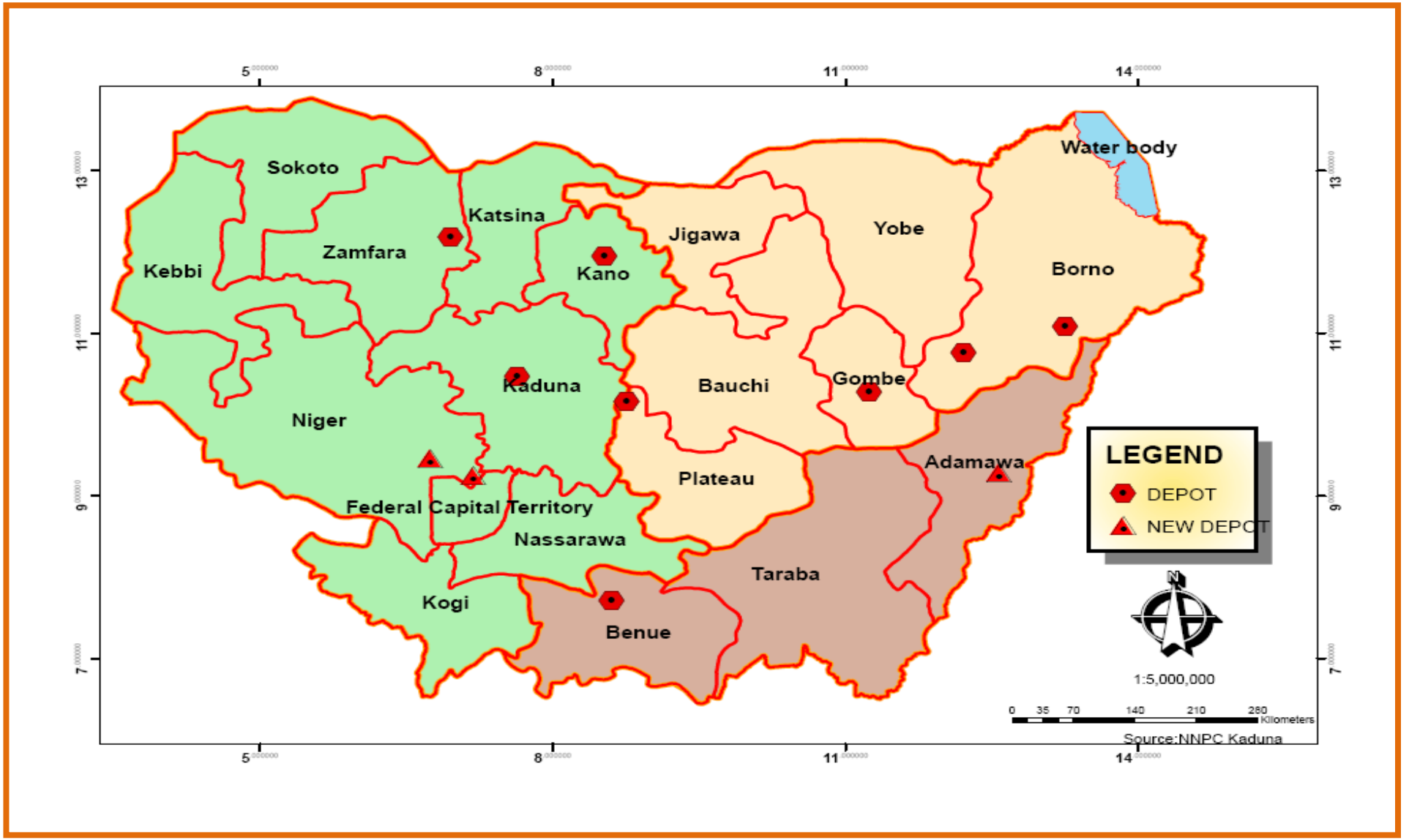


Fig. 4.7: NNPC Depots in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

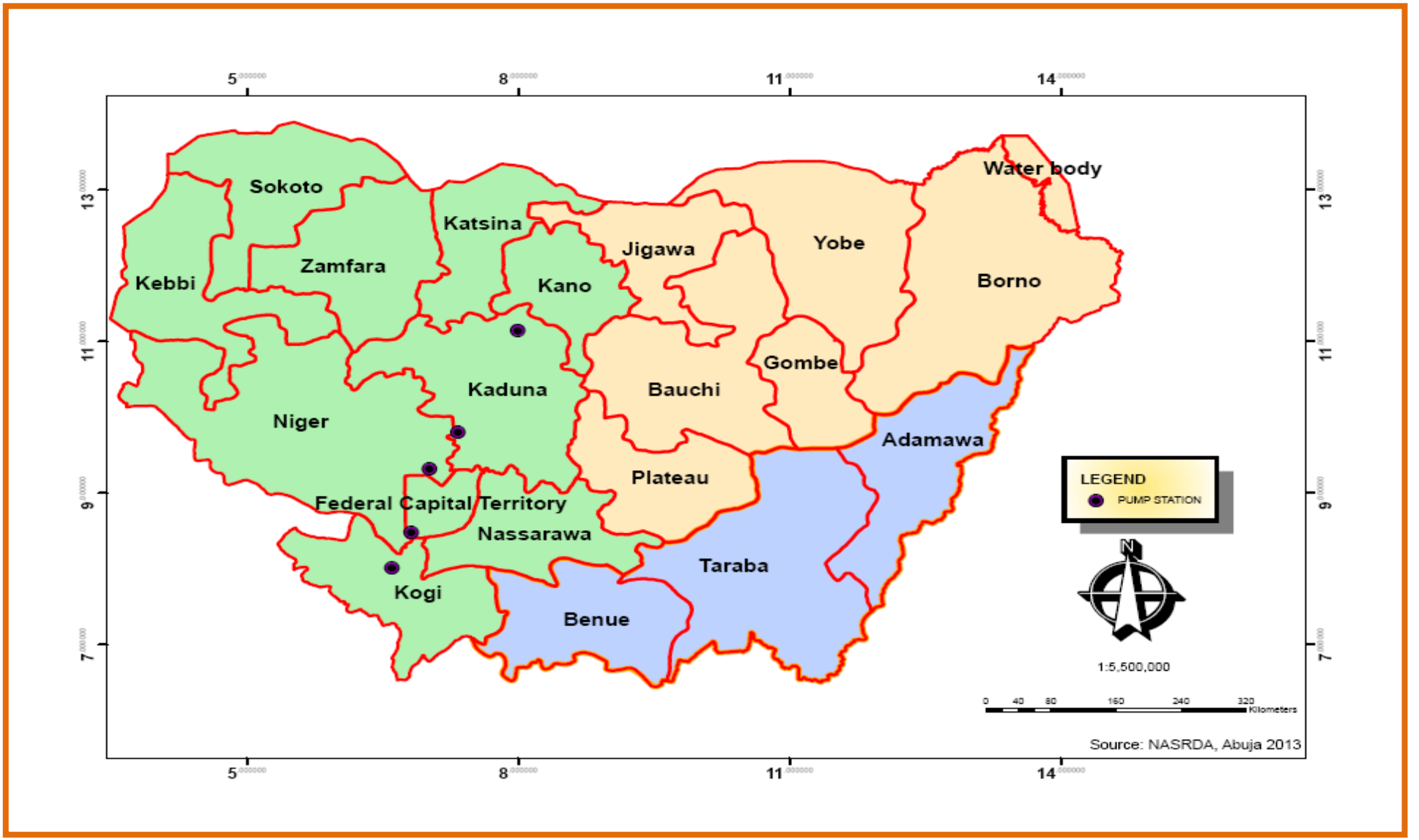


Fig. 4.8: NNPC Pump Station in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

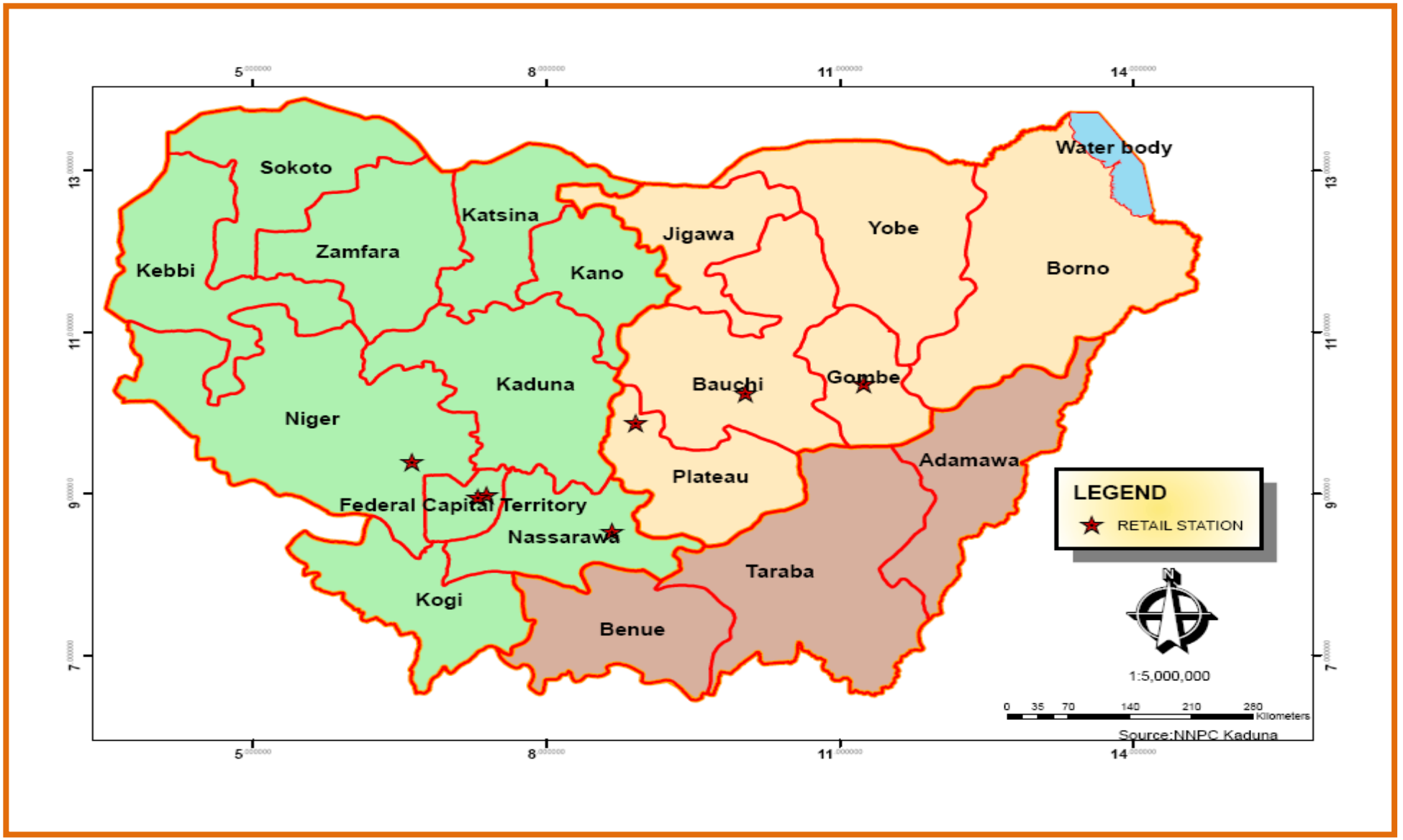


Fig. 4.9: NNPC Retail Station in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

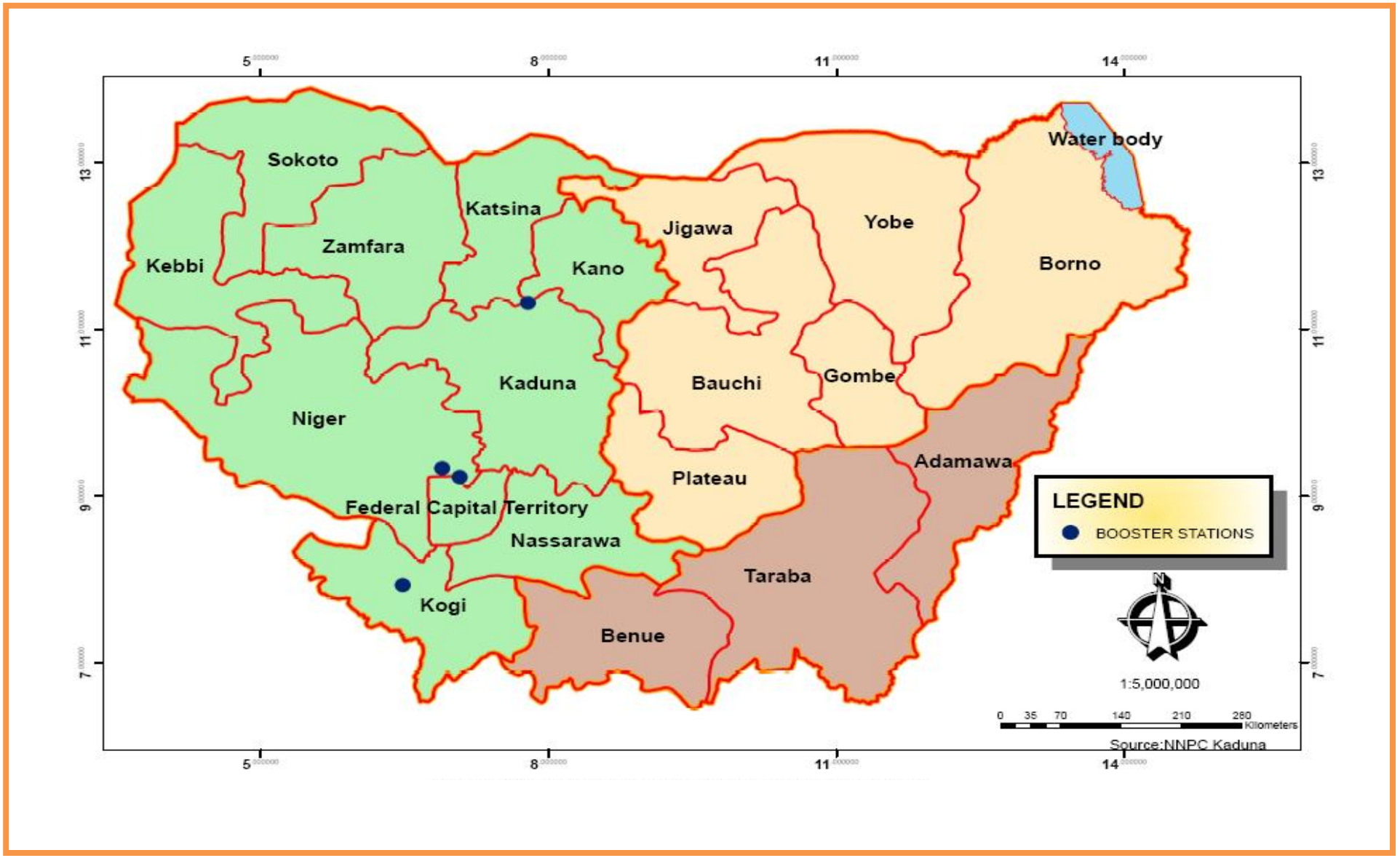


Fig. 4.10: NNPC Booster Station in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

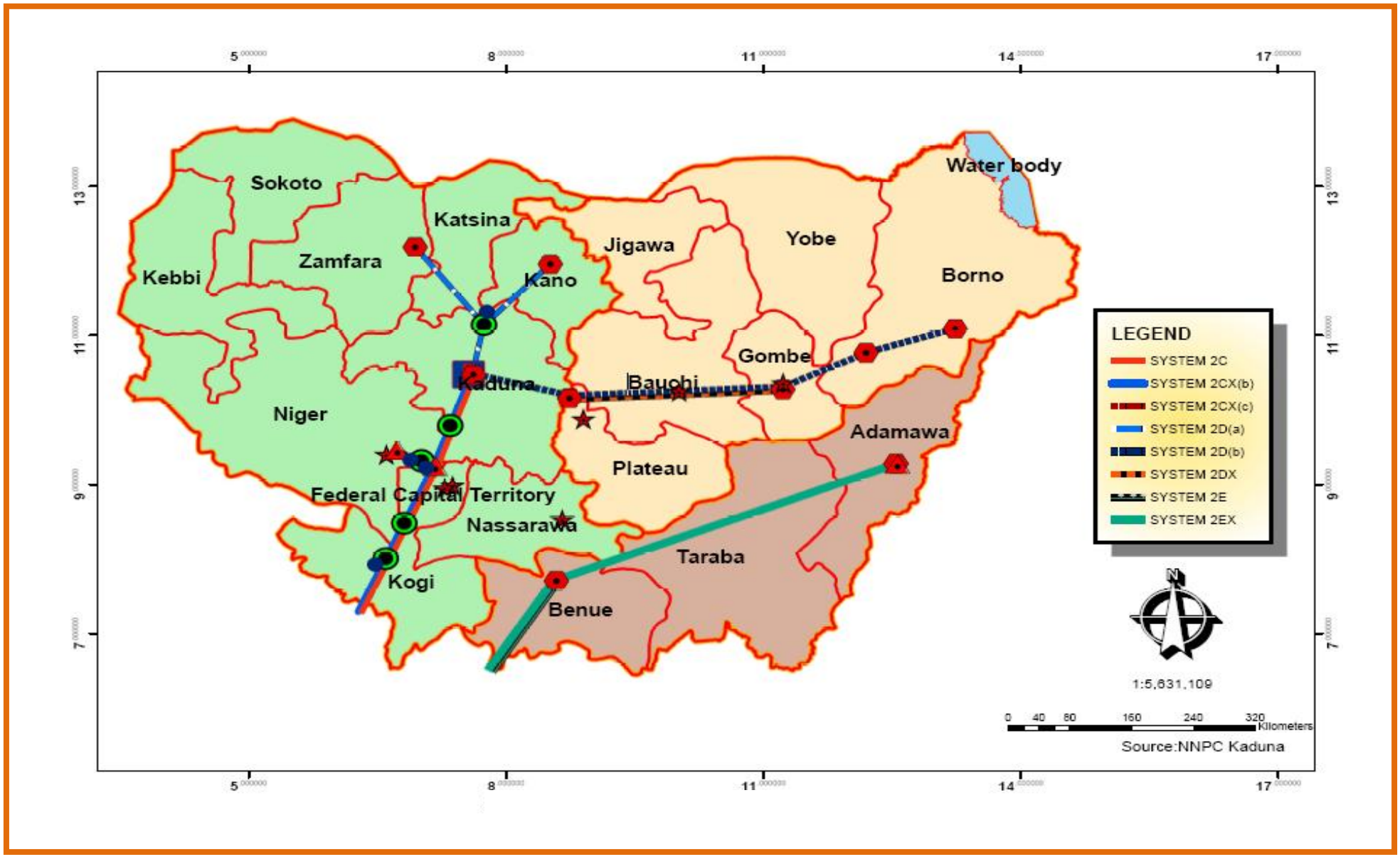


Fig. 4.11: NNPC Pipelines Network in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

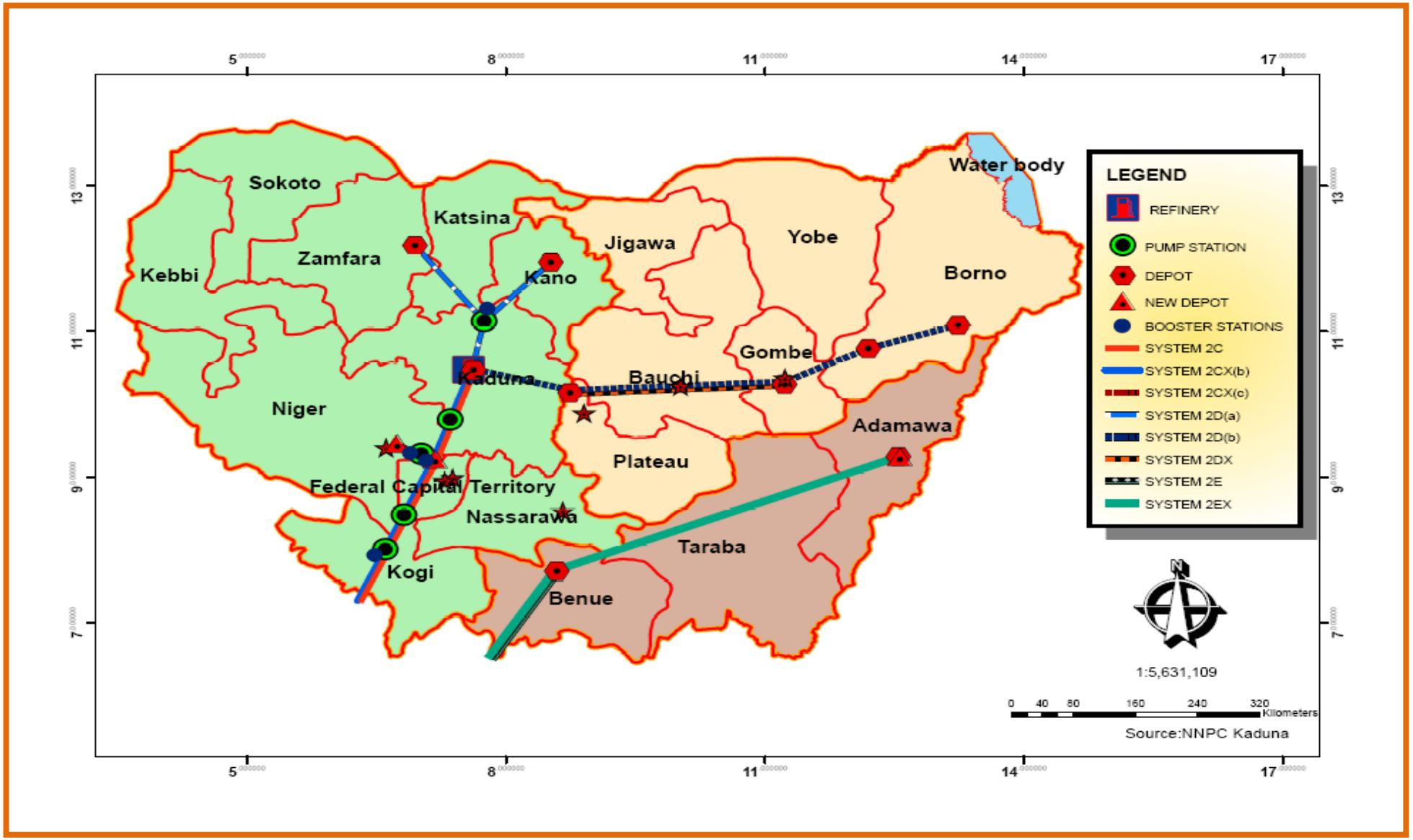


Fig. 4.12: Overlaid Map of NNPC Pipelines' Super-imposed Features.
Source: Researcher's GIS Analysis Work, 2014.

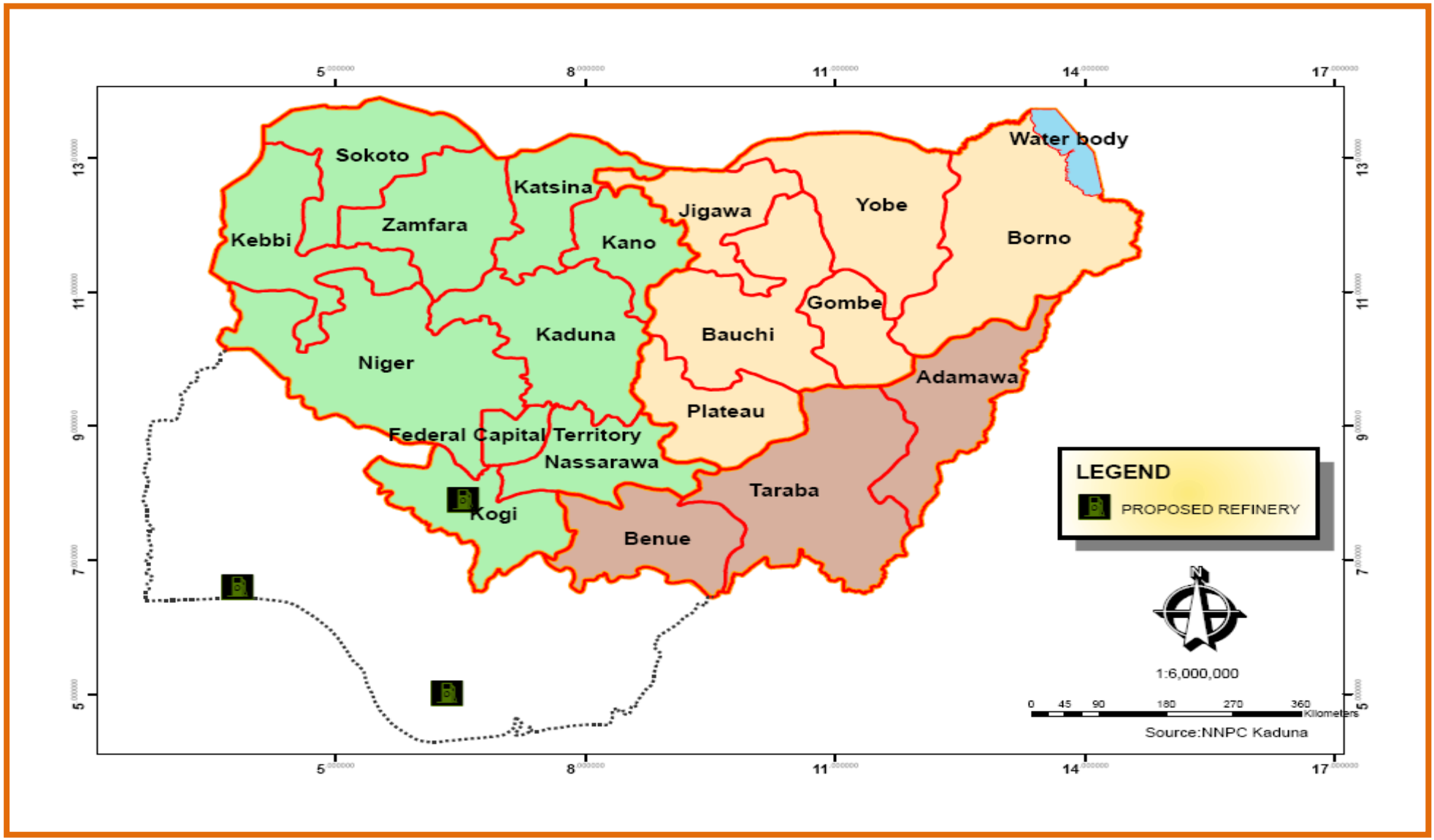


Fig. 4.13: Proposed Locations for New NNPC Refineries in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

4.6 Problems and Challenges of Non-compliance to NNPC Pipelines' Right-of-Way

This section assesses the problems and challenges of non-compliance to the pipelines' right-of-way and it attendant environmental complexities. The data collected and collated from the Respondents through questionnaire administration and interviews, were represented and analyzed, using both descriptive and inferential statistics under the following headings:

Table 4.12: Distribution of Question to Respondents in the Study Area.

S/No.	Profession	Number of Copies of Question Administered	Numbers of Returned Copies of Questionnaire	Percentage (%)
1.	NNPC Staff.	35	35	**17.5**
2.	Oil Workers.	30	28	**14.0**
3.	Staff of Ministry Environment.	30	29	**14.5**
4.	Environmentalists.	30	28	**14.0**
5.	Farmers.	30	27	**13.5**
7.	Fishermen/Women.	30	28	**14.0**
8.	Market Men/Women.	30	25	**12.5**
	Total	215	200	**100**

Source: Researcher's Work.

A total of 215 copies of questionnaires where administered in the study area, only 200 copies questionnaires were returned. The above shows that NNPC Staff accounts for 17.5%, Ministry of Environment had 14.5%, Oil workers, Environmentalists and Fishermen/Women make up the 14.0% each. While the

remaining percent of 13.5% and 12.5% was shared between Farmers and Market Men/Women, which sum up to a total of 100%.

Table 4.13: Concept of Remote Sensing and Geographic Information System and Environmental Issues on Oil Pipelines.

S/NO.	ITEM	SA	A	DA	SDA	NA	MEAN (X)	REMARK
1.	Oil Bunkering, theft, Vandalism and Spillages and Pollution are common Environmental issues that pose danger to human life.	113	78	7	2	200	3.51	**Strongly Agreed**
2.	Impact of non compliance to NNPC Pipelines ROW by the land-use type in your Community has led to Oil, Bunkering, Theft, Vandalism, Oil Spills and Fire Inferno in Northern Nigeria.	125	70	4	1	200	3.60	**Strongly Agreed**
3.	Nigerians are vulnerable to health related problems as a result of Gas Flaring and Oil Pipe leakages and outbreaks.	135	62	1	2	200	3.65	**Strongly Agreed**
4.	Communities along the Pipelines Network System through out the Country should be provided with essential infrastructure, utilities and services to dampen the urge to vandalize pipelines to attract compensation or scoop oil to earn a living.	118	76	3	3	200	3.55	**Strongly Agreed**

Source: Author's Field Work (2014).

Cut-off Point= 2.50.

Grand mean= $\frac{\sum(X)}{N}$

Where $\sum(X)$ = Summation of Number of Means.

N = Number of Variables.

Grand Mean= $\frac{\sum(X)}{N} = \frac{14.31}{4} = 3.58$.

Table 4.13 above shows the responses of all the Respondents on Item 1-5. The respondents agreed on the following Item numbered 1, 2, 3 and 4 with Mean of 3.51, 3.60, 3.65 and 3.55. Thus, they were all rated 'Strongly Agreed'. The Grand Mean for Table 1 is 3.58. This shows that Respondents

understood the concept of Remote Sensing, Geographic Information System and its capabilities in addressing environmental issues associated with oil Pipelines in Nigeria.

The analysis of the data based in mean statistics, revealed that there is a fairly understanding of the concepts, principles, methods and techniques of Remote Sensing and Geographic Information System, rupture and vandalism of pipelines and oil spillages. According to Momoh (2012), posited that: "It is in Nigeria that such practices (pipeline vandalism) are carried out at an alarming rate". He identified well over 2,330 number of line vandalism on crude oil pipelines from Escravos-Warri, Port Harcourt to Kaduna pipeline segments between 2006-2011, described as hot spot areas. A total of 16,476,011 barrels of crude oil has been lost during the said period.

Backed with data to buttress the point, the NNPC GMD, Engr. Austen Oniwon informed that a total of 16,083 pipeline breaks were recorded within the last 10 years adding that while 398 pipeline breaks representing 2.4 per cent were due to ruptures, the activities of unpatriotic vandals accounted for 15,685 breaks which translates to about 97.5 percent of the total number of cases.

Anagboso (2012) buttressed that;

> ***"oil pollution causes danger to the ecosystems, making it difficult to support and sustained life, such essential services as provisioning services (e.g. of food, wood), supporting services (soil formation, nutrient cycling and primary production), cultural services (education and aesthetics) as well ecosystem regulating services like climate regulation, food regulating, diseases regulation and water purification are greatly impaired by crude oil pollution".***

The activities of oil thieves have not only caused pollution of some rivers and lands in the study areas, but have also resulted in the outbreak of diseases and deaths in some communities. This heinous crime has continued to take a toll on the Nigeria's economy. In spite of the danger posed by pollution arising from oil theft and vandalism to the environment, oil thieves continuously engaged in wanton degradation of the environment in the study area. It would probably take some years to restore degraded environment in the oil region studied, assuming oil thieves stop pollution in the first instance.

Against the backdrop of these unwholesome and incessant acts of pipeline vandalism in the study areas and its attendant effects, losses and inevitable downtimes, PPMC pipeline have remained active and available to ensure crude oil/petroleum products delivery and availability to the refineries and the nation as a whole, due to fairly enhanced right-of-way (ROW) surveillance and accessibility. Hence, the opinion of the researcher is that all concern to report any act of pipeline vandalism around them to the appropriate authority.

Table 4.14: Roles of NNPC, Construction Companies and Planners in the Planning, Control and Management of Oil Pipeline Right-of-Way in Nigeria.

S/NO.	ITEM	SA	A	DA	SDA	NA	MEAN (X)	REMARK
5.	There is need for synergy between NNPC/PPMC planning Authorities to enhance the planning and control, monitoring of the development and operation of pipelines ROW in Nigeria.	132	65	2	1	200	3.64	**Strongly Agreed**
6.	Nigerians Policy Makers, Planners and Managers of Oil and Natural Gas pipelines products need to evolve pipeline-materials' toxicity and reactivity Rating Scales to suits Nigeria's situation.	116	73	7	4	200	3.51	**Strongly Agreed**
7.	Lack of monitoring and management of pipelines Infrastructures is responsible for the corrosion of pipelines, leading to oil spillages that cause pollutions.	121	68	6	5	200	3.53	**Strongly Agreed**
8.	Emission of pipelines and Gas Flaring from Refineries can reduce Air Quality, causes Health related symptoms and reduce productivity of Community in concern in Nigeria.	144	48	2	6	200	3.60	**Strongly Agreed**
9.	There is need for suitable Partnership Strategy between the pipeline authorities and the various communities affected by pipeline developments to detect pipeline leaks and checkmate the activities of pipeline Vandals.	112	76	8	4	200	3.48	**Agreed**
10.	There is need for flexibility in fixing pipeline setbacks and there is need for existing pipeline ROW be adequately maintained and be clear of all over-growth using Signs and Markers.	108	82	5	5	200	3.47	**Agreed**
11.	Need for the replacement of segments of pipelines that have corroded, worn-out and lived their full life span, to prevent chronic hazard associated with oil spills.	132	59	7	2	200	3.61	**Strongly Agreed**

Source: Author's Field Work (2014).

Cut-off Point= 2.50.

Grand mean= $\frac{\sum(X)}{N}$

Where $\sum(X)$ = Summation of Number of Means.

N = Number of Variables.

Grand Mean= $\frac{\sum(X)}{N} = \frac{24.84}{7} \sim 3.548 = 3.55$.

From the above table 4.14, Items 5, 6, 7, 8 and 11, of the responses were rated as 'Strongly Agreed' with Mean of 3.64, 3.51, 3.53, 3.60 and 3.61, while Item 9 and 10 are rated 'Agreed' with Mean of 3.48 and 3.47. The Grand Mean (X) for the table is 3.55.

From the responses of Respondents in the study areas, it opines that NNPC, Construction Companies and Planners are fully involved in the planning, control and management of oil pipeline right-of-way in Northern Nigeria. However, their roles have been passive and have invariably led to environmental problems. The operation and management of oil and gas pipelines transport network corridors in Northern Nigeria have witness a diversity of problems and obstacles of varying intensities.

Many of these problems have had disastrous impacts on the environment. The key ones among these include damage to or destruction of the pipelines or their ancillary installations/facilities and their attendant negative impacts on the total environment.

Jiriko (2007) advances some factors responsible for damage to pipelines as;

> ***"Equipment failure, human error and third-party damage" the term 'third-party damage' normally refers to any accidental damage done to the pipe (or its ancillary installation due activities of non-pipeline personnel). The third-party damage to pipelines persists despite several mitigating measures, particularly, in urban area possible factors behind this state of things include: ignorance of the requirement for planning/development permit or notification process on the part of the contractors, lack of incentive to motivate excavators to avoid damaging the lines when the repair cost is less than the avoidance cost, in accurate maps and records, poor or sour relationship between pipeline management and their employees-sacked, forced to resign or retired and imprecise locations or locating buried especially plastic-pipelines by operators" .***

Hence, there is need for synergy between NNPC/PPMC planning Authorities to enhance the planning and control, monitoring of the development and operation of pipelines ROW in Nigeria. It is pertinent and expedient that the Nigerians Policy Makers, Planners and Managers of Oil and Natural Gas pipelines products need to evolve pipeline-materials' toxicity and reactivity Rating Scales to suits Nigeria's situation. Responses from Respondent also brought to knowing that lack of monitoring and management of pipelines Infrastructures is responsible for the corrosion of pipelines, leading to oil spillages that cause pollutions and that emission of pipelines and Gas Flaring from Refineries has reduce air quality, causes Health related symptoms and reduce productivity of Community in concern in some of the studied areas.

Furthermore, there is need for suitable Partnership Strategy between the pipeline authorities and the various communities affected by pipeline developments to detect pipeline leaks and checkmate the activities of pipeline Vandals. Respondents also see the need for flexibility in fixing pipeline

setbacks for existing pipeline ROW to be adequately maintained and be clear of all over-growth using Signs and Markers and the replacement of segments of pipelines that have corroded, worn-out and lived their full life span, to prevent chronic hazard associated with oil spills.

Table 4.15: Government and Private Sectors involvement in the Monitoring, Control and Mitigation against Oil Pipeline vandalism in Northern Nigeria.

S/NO.	ITEM	SA	A	DA	SD A	NA	MEAN (X)	REMARK
12.	Government participation in the Crusade in curbing Environmental Pollution and its effect on the socio-economy activities of Nigeria is sufficient enough.	6	8	73	113	200	1.54	**Strongly Disagreed**
13.	Privately-owned Oil Companies has fairly helped in combating oil Bunkering, theft, Vandalism but has not done much in contributing to address the issue of control of Oil Spillages and attendant disasters in Nigeria.	112	76	8	4	200	3.48	**Agreed**
14.	The implementation of Government Policies on monitoring Oil Pipelines, ROW**,** control of Oil Spillages and Fire Disasters has been successful in Nigeria.	12	15	75	98	200	1.71	**Strongly Disagreed**
15.	There is need for Collaboration and Partnership between the NNPC, Nigerian Government and NGO's in combating and controlling Oil Spills and other related Environmental Hazards in Nigeria.	124	73	2	1	200	3.60	**Strongly Agreed**
16.	Need for Government to disburse more funds in to procurement and purchase of pipelines monitoring devices/equipment for the monitoring and checkmating the activities of Oil Bunkers, Thieves, Vandalizers and detecting Oil Spills that often caused environmental Disasters.	126	69	2	3	200	3.59	**Strongly Agreed**
17.	There is need for flexibility in fixing pipeline setbacks and there is need for the existing pipelines ROW be adequately maintained and be clear of over-growth using Signs and Markers.	120	74	4	2	200	3.56	**Strongly Agreed**

Source: Author's Field Work (2014).

Cut-off Point= 2.50.

Grand mean= $\frac{\sum(X)}{N}$

Where $\sum(X)$ = Summation of Number of Means.

N = Number of Variables.

Grand Mean= $\frac{\sum(X)}{N} = \frac{17.48}{6} = 2.91.$

Table 4.15 above, shows the response of all the respondents concerning government and Private Sectors involvement in the Monitoring, Control and Mitigation against Oil Pipelines and Pipelines Vandalism in Nigeria. The Respondents 'Strongly Agreed' on, items 15, 16 and 17 with Mean of 3.60, 3.59 and 3.56. Thus, they were rated as 'Strongly Agreed', Item 12 and 14 with Mean of 1.54 and 1.71 are rated 'Strongly Disagreed', while Item 13 with a Mean of 3.48 were rated 'Agreed'. The Grand Mean of the table is 2.91. This shows that currently, Government and Private Sectors involvement in the Monitoring, Control and Mitigation against Oil Pipelines and Pipelines Vandalization in Northern Nigeria is ineffective and inefficient.

It is agreed that Federal Government, through NNPC's Department of Petroleum Resources is vested with necessary powers by the various legal principal laws and regulations pertaining to petroleum as well as in some other legislations of the country, which includes the Oil Pipelines Act 1965, Land Use Act 1979 to identify infringements and making them known to the Government agencies which possess the appropriate enforcement authority. Government participation in the Crusade in curbing Environmental Pollution and its effect on the socio-economy activities of Nigeria is sufficient enough.

Activities of the private sector in Oil and Gas industry in Nigeria are 'age mates' with the industry itself.

Private sector participation was pioneered by the Nigerian Bitumen Corporation (NBC), A German Company, which was granted a license to exploit bitumen in Araromi, near Okitipupa in 1900s. Others are Mobil (1955), Gulf now Chevron (1961), Texaco1961, Saptrap (now ELF 1962) and AGIP, Teneco, Philips, Esso, Deminex, Union Oil, Great Basin and Ashland Oil between 1960s-1970s. A number of indigenous companies made their debut though long after the entrance of the foreign ones. These indigenous entrants include Henry Stephens, Delta Oil, Niger Petroleum Company and Niger Oil Resources, Alfred James, AMNI, Consolidated Oil, Dubril Oil Company Limited, Summit Oil, Yinka Folawiyo Petroleum, Allied Oil Privately-owned Oil Companies has fairly helped but not a proactive approach in combating oil Bunkering, Theftry, Vandalization but has not done much in contributing to address the issue of control of Oil Spillages and attendant disasters in Nigeria. There is need for Collaboration and Partnership between the NNPC, Nigerian Government and NGO's in combating and controlling Oil Spills and other related Environmental Hazards in Nigeria.

Need for Government to disburse more funds in to procurement and purchase of pipelines monitoring devices/equipment for the monitoring and checkmating the activities of Oil Bunkers, Theft, Vandalizers and detecting Oil Spills that often caused environmental Disasters. There is need for flexibility in fixing pipeline setbacks and there is need for the existing pipelines ROW be adequately maintained and be clear of over-growth using Signs and Markers.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONs

5.1 Introduction

The study aims, i.e. application of satellite imageries and related geo-informatics data such as maps and other relevant periodical/texts in assessing compliance to regulations of right-of-way for Nigerian National Petroleum Corporation pipelines network in Northern Nigeria by land use types has been achieved. The study is borne out of the need for safety and healthy environment. The various land-use types encroaching into these pipelines' right-of-way were identified, classified and mapped. A spatial distribution map of the pipelines, the generalized classification map of land use types and Pipeline Encroachment Units (PEUs) were prepared (figures 4.1a-4.3 and figures 4.6-4.13 respectively).

5.2 Summary of Findings

This research work demonstrates the ability of Remote Sensing and GIS in capturing spatial temporal data. Attempt was made to capture as accurate as possible four land use/land cover types as they affects compliance to NNPC pipelines' right-of-way in the study area.

Results from this study have revealed that the amount or intensity of encroachments in the study area is attributed to increasing farming/grazing activities, rapid urbanization, population growth, high poverty level and institutional forces etc. The amount of encroachment was measured using set

criteria of buffer zones of 25m^2, 200m^2, 420m^2, 450 m^2 and 576m^2. The farmland and grazing area occupies land area of 125,673.00 km^2 (70%), built-up has 25,134.62 km^2 (14%), road network occupies 17,953.30 km^2 (10%) and water bodies accounted for 10,771.98 km^2 (6%) with encroached total land size of 179, 533.00 km^2 (100%). Thus reveals that the assessed land use/cover types in the study area do not comply with the regulations guiding the right-of-way of these pipelines. This means that with all these proofs it is evident that the various land use types are not complying with the regulations on NNPC pipelines' right-of-way in the study area.

Also, Government and Private Sectors involvement in the monitoring, control and mitigation against oil pipelines, pipelines' right-of-way and pipelines Vandalization in Northern Nigeria has not being proactive and efficient.

Furthermore, it was discovered that only few depots in the study area are functional and operational, resulting from pipeline breaks and vandalism. According to THISDAY (2013), it was reliably gathered that only five of the 31 receiving depots across the country are currently functional, a development that has forced most marketers to depend on the available functional depot for products.

5.3 Conclusion

The study revealed that the major factors responsible for pipelines vandalism in the study areas were largely due to land use systems (farming, grazing cultivation methods, bush burning, un-motorized and motorized road, built-up area), and hydro meteorological factors in some studied areas. It was discovered that the severity of one form of pipelines encroachment or the other depended upon the intensity of land use type as well as surface lithology of the soil which particularly encouraged cultivation and grazing in the study area, the tendency for severe pipelines vandadalization and encroachment into it right of ways was high.

It can therefore be concluded that the major land use/land cover types encroaching into the NNPC Pipelines' right-of-way in Northern Nigeria include; agriculture, built-up, roads and water bodies. In all the forms, it has been gathered that the significant number of cases of encroachment into the right-of-way of NNPC pipelines were due to vandalism of pipelines by Oil Bunkers Operations and infringements by Farmers and in some cases through constructions of structures-built-up areas.

Man's agricultural practices and urban construction works and sprawling were found to have exacerbated the nature and intensity of non-compliance to NNPC Pipelines' right-of-way, especially on the fridge of urban areas (figure 4.).

The possible implications of these encroachment and non-compliance to the pipelines' right-of-way include vandalism, pollution, environmental degradation, loss of lives and properties. These might eventually have effects

on land resources, hydrological resources, increased government financial expenditure, ecosystem functioning etc.

Effort should be made to carry out air coverage of the terrain where these pipelines criss-crossed at least once in every two year period. By this it is possible to clearly monitor pertinent land use that encroaches on NNPC pipelines' right-of-way.

5.4 Recommendations

Based on the findings of this study the following recommendations are here by suggested as means by which Stakeholders and Government can monitor and enforce compliance to the regulations guiding the NNPC pipelines' right-of-way in the study area. There should be:

- A reorganization and reorientation on the attitude of the people base on land use management and their relationship to the environment, as it affects pipelines' right-of-way should be put in place and sustained. This could be achieved through workshops, seminars or conferences.

- There should be a proactive institutional framework, which would include all Stakeholders and resource person, on measures to be taken on protecting the environment and how to diversify the usage of environmental resources, without one land use or the other encroaching into NNPC pipelines' right-of-way. Hence, this would lead to improvement on setback compliance of the pipelines in the study area.

- The existing pipelines' ROW should be adequately maintained. They should be cleared off all overgrowth and be provided with the required

signs and markers which should be visible along the ROW, from above and at all types of crossings.

- The NNPC/PPMC and the oil companies should evolve harmonious and sustainable partnership strategy between pipeline authorities and the various communities affected by pipeline developments for the daily patrol of the pipeline corridors and their related facilities. This will serve three purposes: (a). to detect and report pipeline leaks. (b). check-mate the activities of pipeline vandals. (c). provide employment for some members of the communities.

- There should be flexibility in fixing pipeline setbacks. Setbacks should be commensurate with the size of the pipes used and the types of ancillary installations and facilities required. Setbacks for, especially gas, pipelines in densely populated areas (towns/cities) should be particularly flexible but provided with high safety systems due their demand for cooking, heating and lighting purposes.

- There should be cogent environmental management policy that makes provision for upgrading the level of knowledge in management NNPC pipelines. In addition, the relevant sections of the 1992 EIA Act, as they affects major pipeline developments and transport should be implemented to the letter.

- The use of Remote Sensing/GIS in mapping of encroachment into pipelines' right-of-way has proven to be very relevant; hence it is recommended that this tool is taken advantage of by the Government in

mapping and monitoring encroachment into NNPC pipelines' right-of-way and vandalization. Map presentation are easy to interpret; therefore it can serve as a potent tool in policy implementation as regards effective and efficient pipelines monitory, encroachment control and in the allocation of funds for pipelines inspection, security and where funds are better need.

- The federal government should, as matter of urgency, in collaboration with Stakeholders evolve a comprehensive National Oil/Gas Policy that will make specific provisions for the designating, planning, designing and development of Oil and Gas ROW as well as the size of pipes to be used in urban areas and in country-side.

- Government and Non-governmental Organizations that are Oil and Gas oriented sector should therefore encourage the utilization of mapping applications by investing more in training and acquisition of the technology to pipeline to solve oil/gas related problems.

- As a precautionary measure for preventing deliberate damage to pipelines, the NNPC Authorities/Management, should wherever possible, bury petroleum product pipelines many meters under the ground.

5.5 Critique of the Study

Some limitations imposed constraints on this study, ranging from data collection to data analysis and resting. One is that adequate cooperation was not given to the Researcher in accessing data on pipeline network in the study area by the NNPC Management for a research of this nature. There was also a scarcity of research materials; hence the researcher was forced to limit himself to the available materials. Furthermore, problem is encountered in accessing satellite imagery that can helped in assessment of study of this nature due to the ground scale of the imageries used and area extent of the study, which further delay the progress of the work.

5.6 Suggestions for Further Studies

The need for further studies in pipeline transport is no closed by this pioneer work in Northern Nigeria. Hence the following are suggested by the Researcher for further work should be carried out on:

- Assessment on right-of-way of longer distance Pipeline segment from Depots/Pump Stations.
- The scope of the study should cover the entire Nigeria landmass.
- Pipeline maintenance as its affects pipelines' right-of-way.

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Appendix I

Ahmadu Bello University, Zaria, Nigeria, Faculty of Science

Department of Geography

The sample of Questionnaire administered to Respondents residing in the Communities where NNPC Pipelines criss-crossed.

Dear Sir/Ma,

This Questionnaire is designed to collect pertinent and relevant information for a ***Post Graduate*** research which seeks to assess compliances/encroachment of other land-use types on NNPC pipelines' Right-of-Way of using Remote Sensing (**RS**) and Geographic Information System (**GIS**).

Information supplied will be used mainly for academic endeavors alone and shall be treated as highly confidential. A total of 200 Questionnaires will be administered.

Personal Profile:

Administration point: _____

Name of respondent: _____

Sex: Male ( ) Female ( )

Age: Age: 35-39[ ] 40-44[ ] 45-49[ ] 50-54[ ] 55-64[ ] 60-64[ ] 65> [ ]

Occupation: _____

Level of Education: _____

Instruction:

Please tick (√) in the space provided, appropriate to your response on every question. The acronyms given in the boxes stand for:

SA: Strongly Agree. **A:** Agree.

D: Disagree. **SDA:** Strongly Disagree.

ROW: Right-of-Way.

Sample 1: *To what extent does Respondents understand the concept of Remote Sensing, Geographic Information System and environmental issues associated with oil Pipelines in Nigeria?*

S/NO.	ITEM	SA	A	DA	SDA	NA
1.	Oil Bunkering, theft, Vandalism and Spillages and Pollution are common Environmental issues that pose danger to human life.					
2.	Impact of non compliance to Oil Pipelines **ROW** by the land-use type in your Community has led to Oil, Bunkering, Theftry, Vandalization, Oil Spills and Fire Inferno in Northern Nigeria.					
3.	Nigerians are vulnerable to health related problems as a result of Gas Flaring and Oil Pipe leakages and outbreaks.					
4.	Communities along the Pipelines Network System through out the Country should be provided with essential infrastructure, utilities and services to dampen the urge to vandalize pipelines to attract compensation or scoop oil to earn a living.					

Sample 2: *An assessment of the role of NNPC, Construction Companies and Planners in the planning, control and management of Oil Pipeline Right-of-Way in Nigeria.*

S/NO.	ITEM	SA	A	DA	SDA	NA
5.	There is need for synergy between NNPC/PPMC planning Authorities to enhance the planning and control, monitoring of the development and operation of pipelines **ROW** in Nigeria.					
6.	Nigerians Policy Makers, Planners and Managers of Oil and Natural Gas pipelines products need to evolve pipeline-materials' toxicity and reactivity Rating Scales to suits Nigeria's situation.					
7.	Lack of monitoring and management of pipelines Infrastructures is responsible for the corrosion of pipelines, leading to oil spillages that cause pollutions.					
8.	Emission of pipelines and Gas Flaring from Refineries can reduce Air Quality, causes Health related symptoms and reduce productivity of Community in concern in Nigeria.					
9.	There is need for suitable Partnership Strategy between the pipeline authorities and the various communities affected by pipeline developments to detect pipeline leaks and checkmate the activities of pipeline Vandals.					
10.	There is need for flexibility in fixing pipeline setbacks and there is need for existing pipeline **ROW** be adequately maintained and be clear of all over-growth using Signs and Markers.					
11.	Need for the replacement of segments of pipelines that have corroded, worn-out and lived their full life span, to prevent chronic hazard associated with oil spills.					

Sample 3: *Distribution, according to government and Private Sectors involvement in the Monitoring, Control and Mitigation against Oil Pipelines and Pipelines Vandalization in Nigeria.*

S/NO.	ITEM	SA	A	DA	SDA	NA
12.	Government participation in the Crusade in curbing Environmental Pollution and its effect on the socio-economy activities of Nigeria is sufficient enough.					
13.	Privately-owned Oil Companies has fairly helped in combating oil Bunkering, Thiefvering, Vandalization but has not done much in contributing to address the issue of control of Oil Spillages and attendant disasters in Nigeria.					
14.	The implementation of Government Policies on monitoring Oil Pipelines, **ROW,** control of Oil Spillages and Fire Disasters has been successful in Nigeria.					
15.	There is need for Collaboration and Partnership between the NNPC, Nigerian Government and NGO's in combating and controlling Oil Spills and other related Environmental Hazards in Nigeria.					
16.	Need for Government to disburse more funds in to procurement and purchase of pipelines monitoring devices/equipment for the monitoring and checkmating the activities of Oil Bunkers, Thiefvering, Vandalizers and detecting Oil Spills that often caused environmental Disasters.					
17.	There is need for flexibility in fixing pipeline setbacks and there is need for the existing pipelines **ROW** be adequately maintained and be clear of over-growth using Signs and Markers.					

Appendix II

Table 1: Some of the commonly applied Pipeline Inspection and Survey Techniques.

Inspection/Survey technique	Purpose	Attributes
Pressure testing (hydrostatic pressure testing).	Commonly used as pre-service integrity validation of the pipe and components by pressurizing to a level above the intended operating pressure. Destructively "detects" defects so they do not subsequently fail while in service. Allows the establishment of the real minimum strength of the pipeline and components, as opposed to the mill tensile test, which is based on a sample of pipe.	A regulatory requirement for new pipe sections, to update existing pipe sections and conversion from vapor to liquid service. Done by sectioning line according to terrain elevations. One or more valve sections can be included within test segment. Requirements and procedures defined in regulation and industry standards. Hydro-testing service is usually provided by a specialty contractor overseen by operating company staff.
Cathodic Protection (CP) Inspections and Surveys.	Determines the adequacy of cathodic protection voltages and currents for protecting the pipeline against corrosion and to detect areas of potentially defective coating.	Rectifier inspections are done to ensure that the rectifiers are in service and providing the required impressed current for cathodic protection. Station tests or surveys are done to measure CP voltages at stations locations. This also includes readings taken at pipeline casings under roads and railway crossings. Various forms of close interval surveys (CIS) are taken at interval of $^{3}/_{4}$ to 3m along a pipeline to provide a profile along the line to greater resolution than can be obtained with a station survey.
In-line inspection (ILI)	Detects areas of anomalies, such as metal loss, deformations, cracks, dents, gouges and laminations.	Automated internal inspection tools or "smart pigs" vary in anomaly types that can be detected and terms of degree of resolution. Services are provided by a specialty pigging contractor. Common technologies are ultrasonic and magnetic flux leakage. Results often require expertise in interpreting data. Either part or all of a pipeline is inspected depending on the location of pig launching and receiver equipment and the size and geometry of the pipeline system.
Manual ultrasonic wall thickness measurement.	Determines wall thickness and identifies areas of metal loss by direct measurement of pipe wall thickness.	Manually held instrument used in conjunction with exposed pipe inspections. Requires coating removal.
Leak Surveys.	Finds active leaks over a hydrocarbon pipeline.	Usually includes handheld instrumentation to detect hydrocarbon vapour.
Water Crossing Surveys.	Determines elevation profile and depth of cover beneath waterway.	May require divers to probe or use instrumentation to locate depth of pipe below stream or lake below.
Depth of Cover Surveys.	Determines actual amount of cover over pipeline.	Depth is measured by instrument or physical "probing" of the pipeline.
Acoustic Monitoring.	Finds discontinuities in metallic pathways: used in reinforced concrete pipe.	Impressed sound waves are analyzed for discontinuities or active failure.
Subsurface coating Condition.	Evaluates coating condition of buried steel pipeline.	Impressed a signal onto a pipeline and measures attenuation of signal to determine signal to determine signal leakage through coating.
Non-destructive testing.	Uses techniques such as ultrasonic, magnetic particle, dye penetrate, etc., to find pipe wall flaws that are hard to detect with naked eye. It can also include testing of coating properties such as thickness and numbers of holidays.	Usually done in conjunction with visual inspection; can be done on coating or on pipe wall.
Ground Patrols and Aerial Surveys.	Identifies external conditions that might adversely affect the pipeline, such as third party activity and ROW encroachments. Also used as a means of detecting leaks.	These apply more to the effects of external factors on the pipeline and the detection of leaks than to factors associated with the conditions of the pipe itself. They complement visual surveys.

Source: Muhlbauer (2004), Jiriko (2007), Researcher (2014).

Appendix III

A: PRELIMINARY AND LABORATORY WORK

Material	Action	Output
Remotely Sensed Aerial Photograph, Topographic Map Approx. scale 1:100,000, 000 1:50,000, 000	Differential of Environment of the Sub-nits of Map and Description of Attribute	Spatial Distribution of Sub-units and Characterization.

B: FIELD WORK

Satellite, Topo-Maps, Geological Maps, Administrative Maps, Questionnaire, Literature/Secondary Data	Terrain Classification, Scoring, infrastructure, mapping (for use in the field), Ground-truthing and Field Work Planning.	Preliminary Classification of Terrain Map of the Area (four Refineries and Pipelines **ROW** in Nigeria infrastructure/Route Map.

Checking and Updating Preliminary Maps, Collection of Attributing Data using Remote Sensing and Topographic Data in the Field as Tool.

C: MAPPING AND REPORTING

Final Map Analysis	Preparation of Final Map, GIS Manipulation using Software, Analyzing of Administered Copies of Questionnaire, Reporting/Writing	Spatial Distribution of Sub-units and Characterization, Mapping details.

Plate I: Schematic Plane of the Study.
Source: Researcher's Work.

Appendix IV



Plate I: Landsat Satellite Imagery of Nigeria.
Source: NARSDA 2012.

Appendix V



Plate III: Landsat SRTM Mirrored Satellite Imagery of Nigeria.
Source: GCLF 2012.

Appendix VI

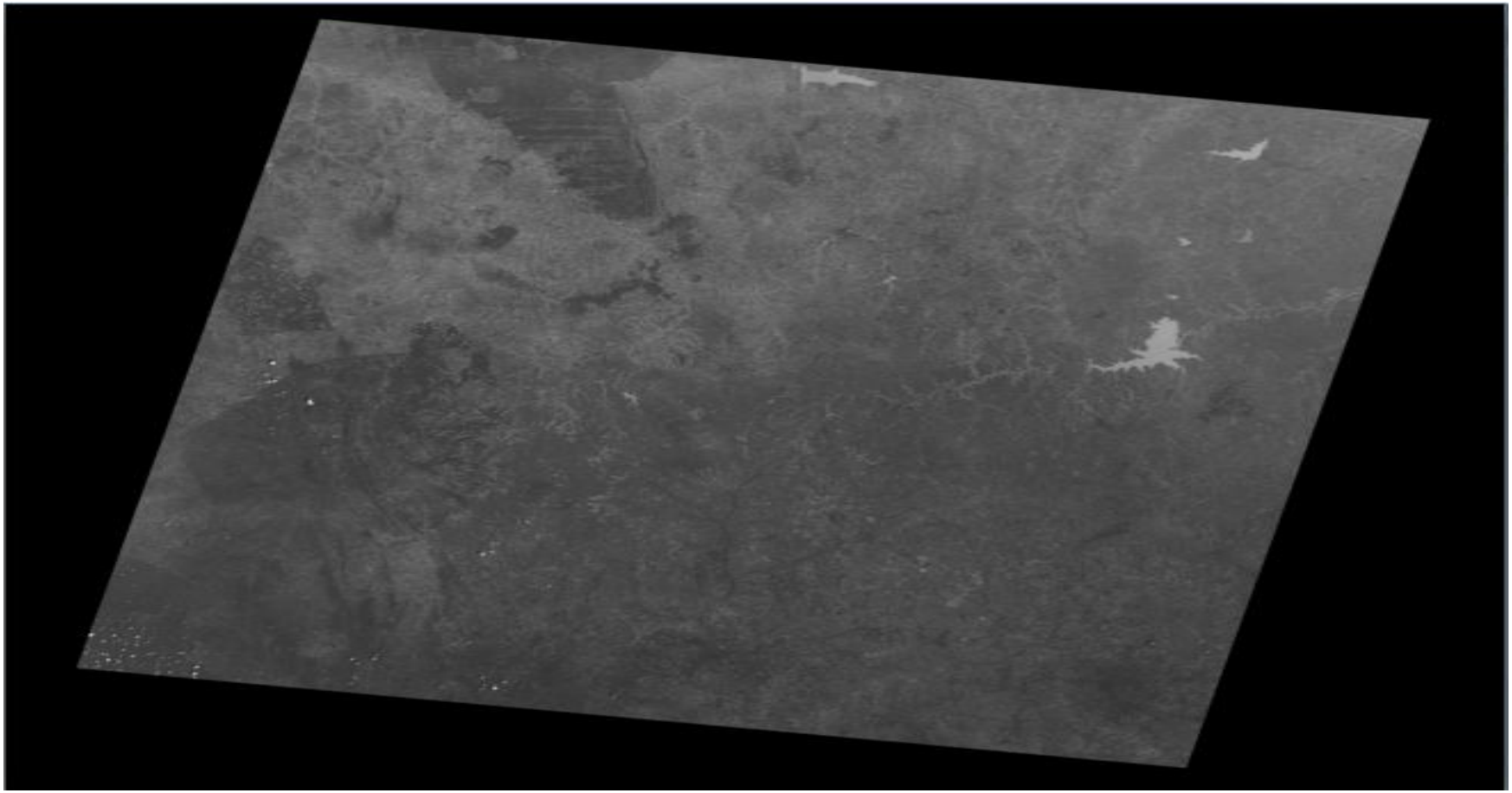
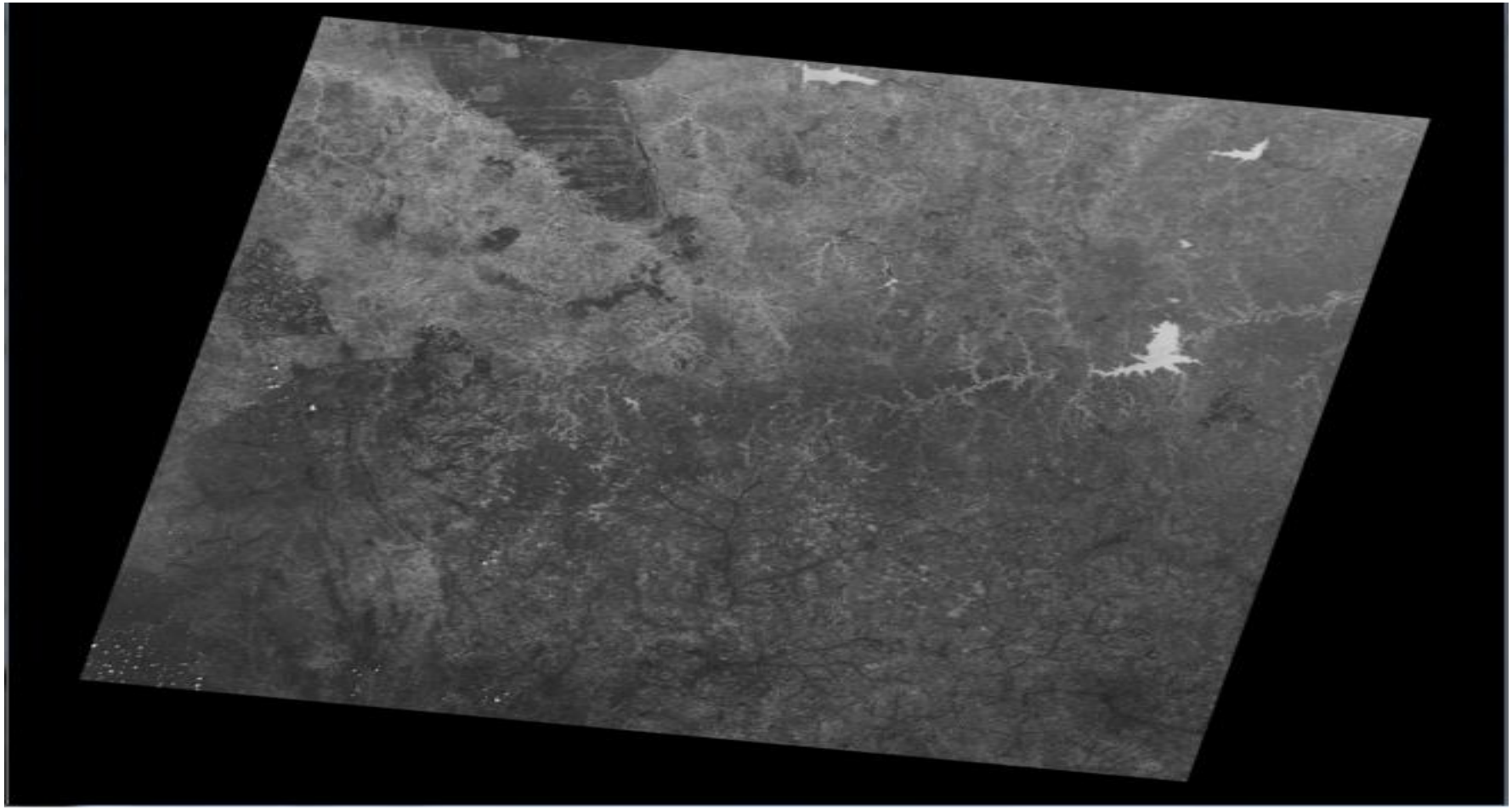


Plate IV: Composite SRTM Satellite Imagery Northern Nigeria; Band 1.
Source: GCLF 2013.

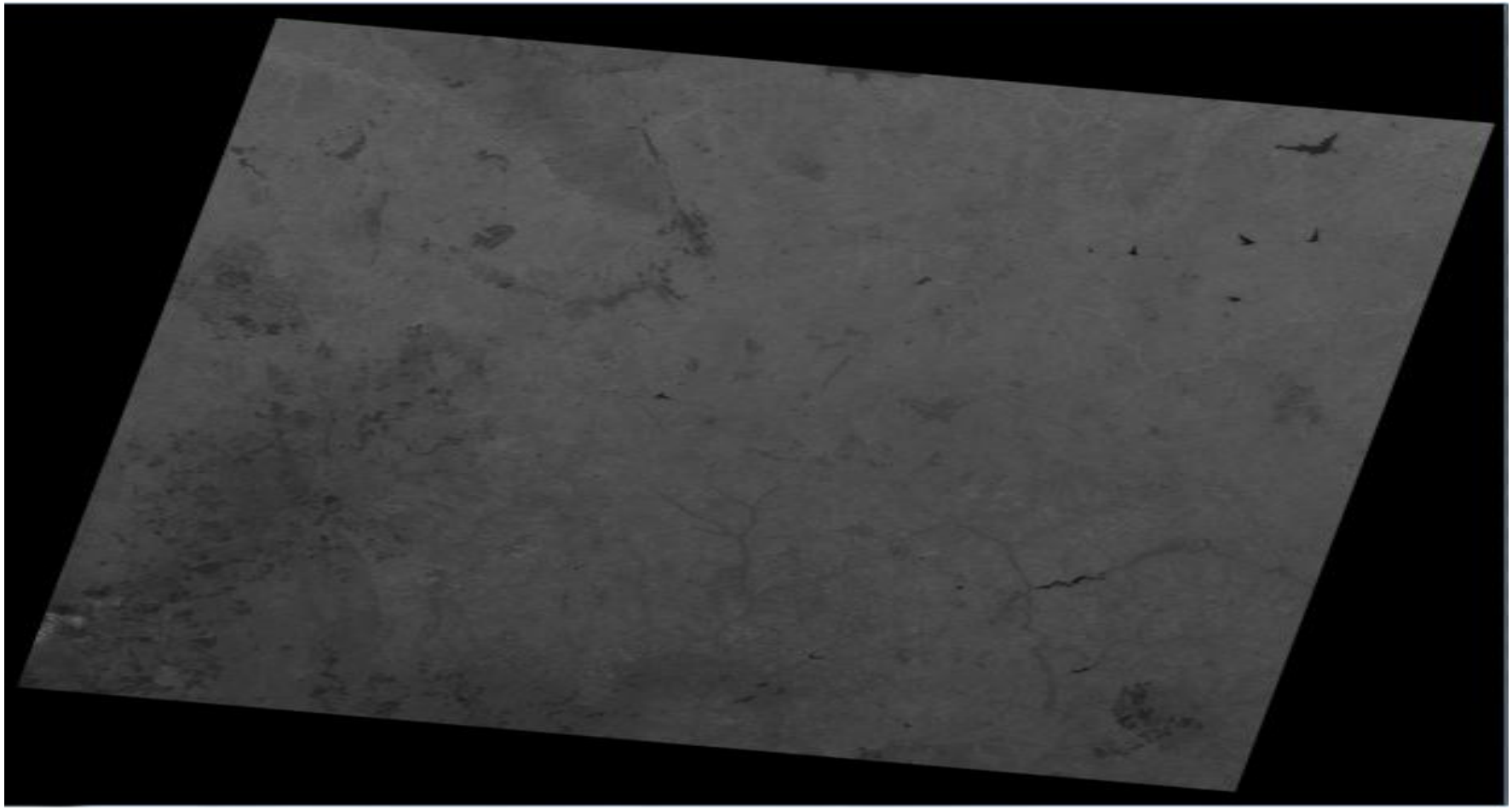
Appendix VII



181

Plate V: Composite SRTM Satellite Imagery of Northern Nigeria; Band 2.
Source: GCLF 2013.

Appendix VIII



182

Plate VI: Composite SRTM Satellite Imagery Northern Nigeria; Band 3.
Source: GCLF 2013.

Appendix IX

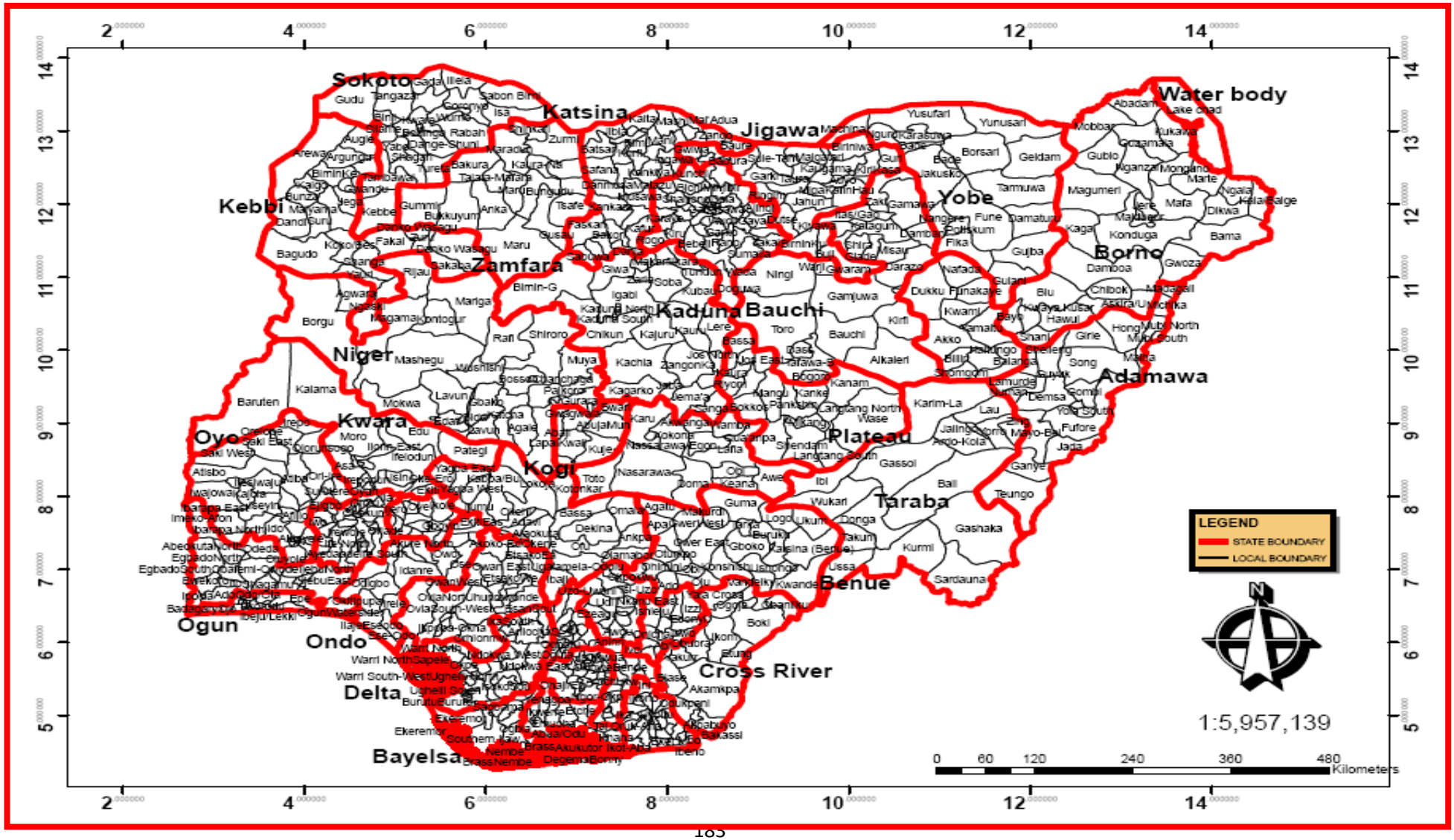


Plate VII: Nigeria-its Thirty Six (36) States and LGAs.
Source: Adapted from NASRDA, Abuja 2013.

Appendix X

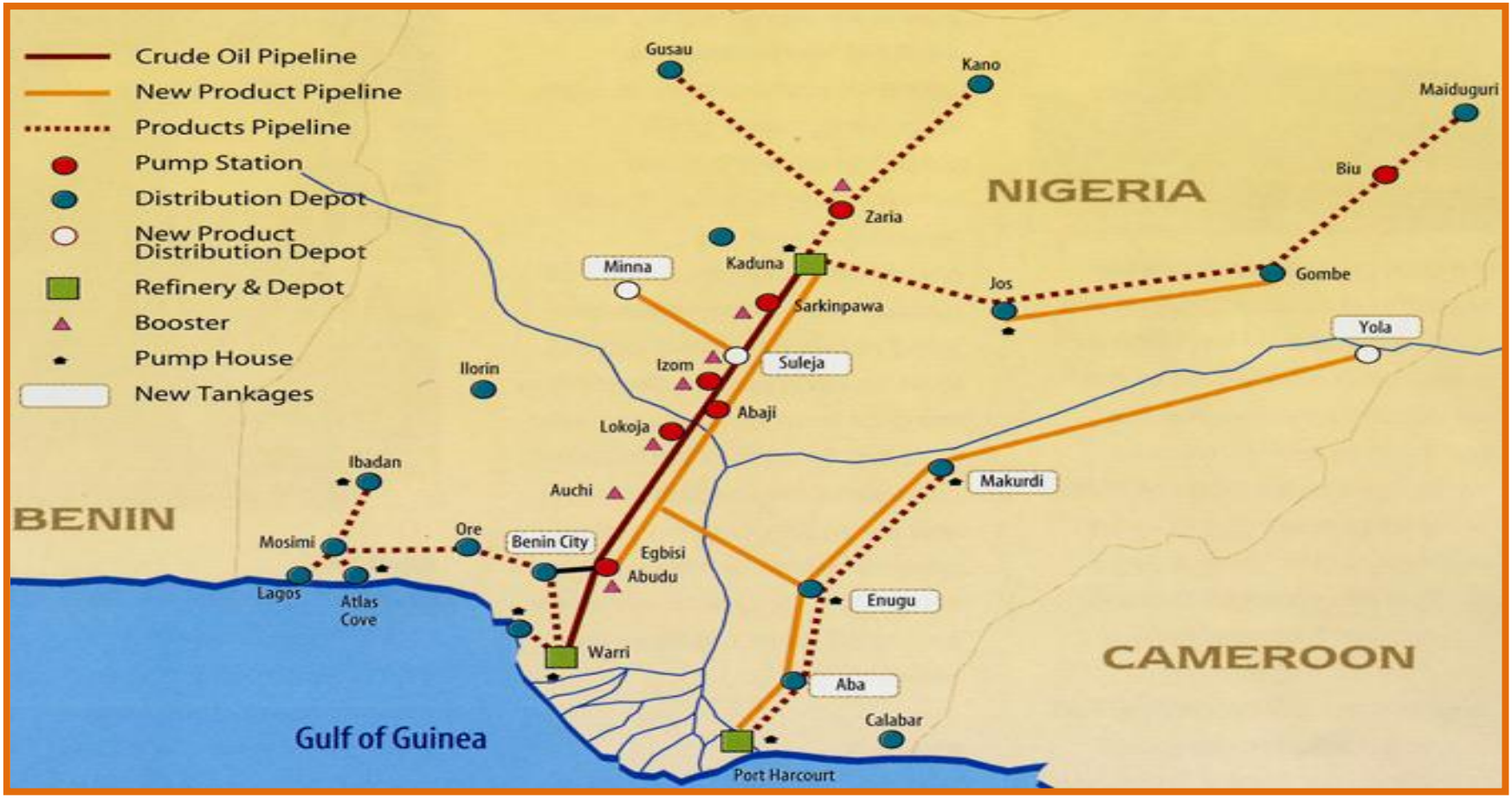


Plate VIII: NNPC Pipelines Networks in Nigeria.
Source: PPMC 2001, Researcher's Field Work 2014.

Appendix XI



Plate IX: NNPC Kaduna Refinery.
Source: Kaduna Refinery Petrochemical Company 2000.

Appendix XII



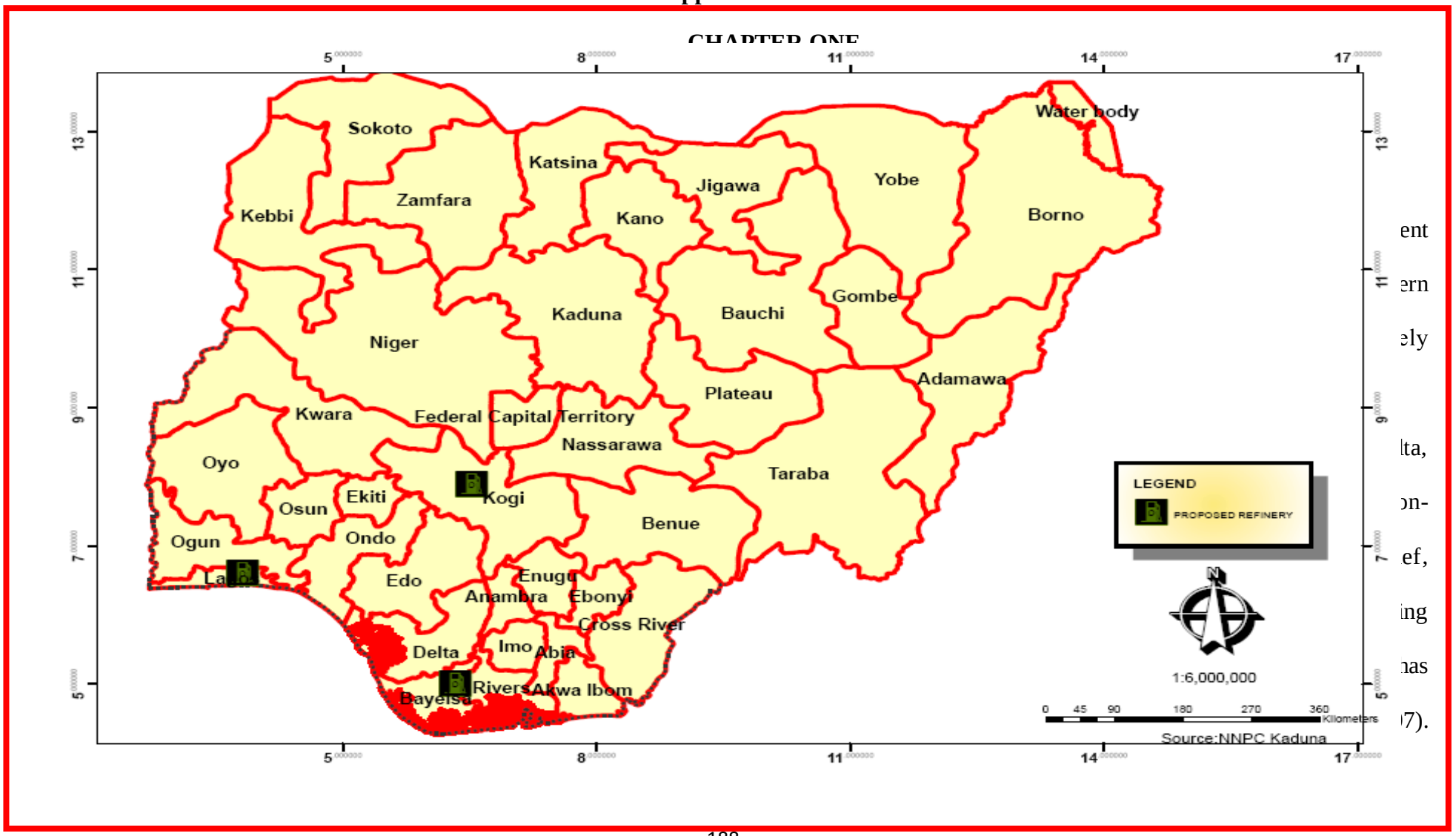
Plate X: NNPC's Rupture/Vandalized Pipeline.
Source: www.nnpc.ng.org copied May 2014.

Appendix XIII



Plate XI: NNPC Pipelines Fire Outbreak due to Vandalism.
Source: Roland 2007.

Appendix XIV



188

Plate XII: Proposed Locations for New NNPC Refineries in Nigeria.
Source: adapted from NNPC 2012.

In general, Nigeria has a total network of about 5,001 kilometers of oil pipelines, consisting of 4,315 km of multi-product pipelines and 666 km of crude-oil pipelines (Brume, 2002). However, statistics on the actual number of kilometers of pipelines already built in the country vary. Citing available data, the figure is put at over 3, 000 km (Nnah and Owei, 2005). Omorogbe (2001) says they range from 4,000-5,000 km while Olukesusi (2005) put the number of existing pipelines at over 7, 000 km (flow-line inclusive). They snake from the Lagos area, all the way through the East and Delta Region, on to the North (Saturday Punch, December 9, 2000 in Jiriko, 2007).

These pipelines criss-cross the country and inter-link the twenty two petroleum storage depots strategically dispersed across the country including the refineries at Port Harcourt, Kaduna and Warri, the off-shore terminals at Escravos and Bonny, and the four jetties at Okrika, Atlas Cove, Warri and Calabar. Presently, Nigeria has six export terminals including Forcados and Bonny (operated by Shell), Escravos and Pennington (ChevronTexaco), Qua Iboe (ExxonMobil), Brass (Agip), and Bonny Island LNG (Nigeria LNG). Shell's Bonny terminal has currently undergone a $600 million expansion that exports 1.5 million barrels per day (bbl/d) in 2006 (NNPC, 2010).

At the moment, the corporation operates 37 Mega Stations, 12 Floating Mega Stations and over 500 Affiliated Stations, all in effort to address the Nigerian petroleum products supply need (NNPC, 2014).

The pipeline system links the nation’s four refineries to the crude oil production points and the depots. The Shell Petroleum Development Company, for example, owns the 95 km Nembe Creek-to-Cawthorne Channel

oil fields trunk pipeline that passes through 35 communities and transverses 60 rivers and/to creeks of varying sizes along its route with set of right-of-ways depending on the size or diameter of pipes (Jiriko, 2007).

A ROW is the land on which transmission lines and/or pipelines are located. The ROW is usually acquired in widths that vary with the kilovolt (kV) size of the transmission line, diameter of the pipeline, or number of collocated transmission lines and/or pipelines (e.g. they may range from as little as 25 ft to hundreds of feet wide). They provide a safety margin between the transmission line or pipeline and surrounding structures or vegetation. Beyond the Niger Delta region, oil (and gas) pipelines convey crude and/or refined petroleum products to its depots in Aba, Enugu, Mosimi, Ore, Ibadan, Ilorin, Markurdi, Kaduna (refinery), Gasau, Kano Jos, Gombe and Maiduguri.

Also, as at 1992, distributor depots were proposed for Suleja, Yola and Minna (in which some are currently completed while some are still on-going). Pump stations exist in Biu, Lokoja and Abaji, amongst other towns (NSF, 1998). For reasons of safety and security, these pipelines are buried about one metre beneath the surface along a 25-metre wide Right of Way (ROW), specifically acquired by Government for the purpose. This ROW is regularly cleared by the host community acting as contractors (Omonisini, Eludoyin and Salami in Nigeria Country Analysis Brief, 2005).

There are procedures to be followed and requirements to be met in the planning, designing and development as well as operation of pipeline projects. A prospective pipeline developer in Nigeria must first apply for two things- a grant or permit to survey a pipeline route and a license to construct and

operate a pipeline and its ancillary installations and facility. The application for a permit to survey and a license should be routed through the Department/ Federal Ministry of Petroleum Resources to the Minister. The regulations further require that the applicant must undertake an environmental impact assessment (EIA) study of the project.

The EIA Act equally requires full EIA report for Kilometres of pipelines exceeding 50 km and a partial EIA for lesser lengths. The Federal Ministry of Environment (FME)/FEPA as Well as the Federal Urban and Regional Planning Authorities too has their requirements to be met by the applicant. The grant of a permit to survey and, particularly, a license to build and operate a pipe gives the license quite extensive rights and privileges (Oil Pipelines Act S. 11 (1)-(4)).

The license is equally empowered to dig and get free of charge any sand, clay, stone or other similar substance (excluding a 'mineral' as defined in the Mineral Act) within any land in the area covered by the license in so far that such gravel, sand, clay, stone or other substance, will facilitate the construction or maintenance of a pipeline or any ancillary installation. A license expires after 20 years and is not renewable; a new license must be applied for and obtained if the holder desires to continue with the pipelines business (Pipeline Act CAP 338 of the Law of the Federation of Nigeria 1990 in Jiriko, 2007).

Design consideration would include Design Code for the demarcated/zoned ROW**,** set-back of other developments from the ROW or the ROW development activities from High Ways, Railways etc space

requirements for the ancillary installations and facilities. Pipeline Stations are of different sizes. Larger ones, such as pump and compressor or tank farms, can cover several hectares of land. A greater proportion of station facilities could be more accessible than a buried pipeline, for this reason, typical measures (setback) to forestall unauthorized access to such facilities are or should include fencing, locked gates, barbed wire, concrete barriers, beams and lighting and security systems. All these are essentially design and developmental control measures.

Setback is indispensable design and development control tool in the land use planning generally. It denotes the minimum permissible distance from the centre of a road to other uses or developments immediately adjourning the ROW**.** In this context of the subject matter, "setback" is the minimum allowable distance from the centre of the pipeline ROW to the abutting developments (Jiriko, 2007). The function of setbacks is to ward-off encroachments by other potentially injurious land use developments onto the pipeline ROW and its ancillary installations and facilities, thereby protecting them from potential human and environmental damages. Detailed hazard zone calculations (based on oil and gas spills from faulty/damaged pipelines) are difficult to come by. For this reason, some default distances can be set based on regulatory requirements or conservatively fixed.

In Nigeria, a combined team of PPMC, Community Leaders, Police and local security outfit provide surveillance to guard the pipelines. Regular aerial surveillance of critical sections of the pipelines is also carried out by PPMC/NNPC (Nigeria Country Analysis Brief, 2005). In spite of these

security measures, statistics on oil pipeline vandalisation remain staggering.

According to Nwalo *et al.,* (2005) about 50 per cent of the cases of oil spillage is due to corrosion, 28 per cent sabotage and 21 percent oil production operations. Only 1 per cent of the cases have been adduced to problems associated with engineering drills, inability to effectively control oil wells, failure of machines, and inadequate care in loading and unloading oil vessels. In all the forms, it has been gathered that the significant number of cases of encroachment into the right-of-way of NNPC pipelines were due to vandalism of pipelines by Oil Bunkers Operations, infringements by Farmers and in some cases through constructions of structures-built-up areas (Nigeria Country Analysis Brief, 2005).

1.2 Statement of the Research Problem

Nigeria's hydrocarbon resources are the mainstay of the country's economy but development of the oil and natural gas sectors is often constrained by instability in the Niger Delta and other areas in Nigeria were these pipelines criss-cross. The Nigerian economy is heavily dependent on the oil sector which, according to the International Monetary Fund (IMF), accounts for over 95 percent of export earnings and 40 percent of government revenues (Remote Sensing of Environment, 1995). All companies, that drill all over the world must meet certain pre-defined environmental conditions and requirement of their host countries so as not to interfere with the community's fragile resources, as little as possible. This however, is less obvious based on the Nigerian context (Roland, 2007).

Despite the need for the recognition of good oil and gas transportation and its significant contribution to our economy, the management, planning, construction and rehabilitation of our pipelines networks and right-of-way are still being marred by encroachment by the various land-use types, such as built-ups, farmlands, wetlands, fishing grounds, roads, markets, hard-to-evaluate facilities, utilitarian and insensitive political, environmental and physical considerations. Daily wave of attack are being launched on oil facilities in Nigeria as un-identified people attack and set fire on petroleum pipelines and vandalize them.

The country has thus become a scene of a series of pipeline explosions, as a result of non-compliance with the right-of-way of these pipelines by the various stakeholders concerned, particularly by communities where these pipelines criss-crossed, for buildings, agricultural practices, bunkering and illegal siphoning of crude-oil and petrol products, most especially in the Niger-Delta axis.

In addition, the country's mass media had sad news relating to victims of oil pipeline explosions and other related home accidents. All these are evidences of inefficiency in the operation and management of the nations' pipeline system. Had the construction of pipelines facilitated the distribution of petroleum product in Nigeria? What are the strategies for improving the nation's pipeline system? These questions amongst others, present the problems that necessitated this research.

Nigeria has experienced an average of 500 pipeline related disasters a year. In year 2000 alone 764 cases were reported to be on the case files on

burst pipes of the PPMC (Jiriko, 2007). The massive environmental problems, socio-economic dislocations and loss of human lives that accompany every pipeline burst in the country only further worsened the already precarious condition of the masses as they pollute the environment causing irredeemable distortions to the ecosystem.

GOCON's Escravos and SPDC's Forcados Terminal tank failure in 1978, Texaco Funiwa-5's blow out in 1980, Abudu pipe line in 1982, 1979 and 1980 in Niger-Delta area. Although no lives were lost, but 340 hectare of mangrove were destroyed in 1980. In 1998 Over 2,000 people were burnt to death in Jesse (Delta State) due to oil bunkering and infringement into the right-of-way of the NNPC pipeline. While in year 2000, the Atlas Cove pipeline explosion lead to 50-60 people burnt to death. Again, in year 2000, in Oviri Court (Delta State) pipeline explosion, over 200 people were killed. Explosion at Etiama Community, Bayelsa State caused the death of over 2000 people (Jiriko, 2007).

In Kalakama Community, (Rivers State) in 2005, 11 or more people died as a result of vandalized Gas Pipeline explosion. At Ilado-Odo, Lagos State over 200 people were burnt to death. In 2007, 42 people died/burnt to death in Abog Village (Lagos state) due to vandalized Pipeline explosion. Oil spills at Bodo and Bonga (Delta State) in 2008 and in 2011 and raw gas leakage at Funiwa (Bayelsa State) in 2012 led to huge losses of aquatic plants and animals and humans lives (Nigerian Newspapers Online, 2012).

Furthermore, when oil comes ashore or offshore it kills shore animals by smothering them, or if sufficiently fresh, kills them because of its toxic

constituents. Oil taints fish and interferes with fishing activities and navigation. Spilled oil makes a great mess, while, polycyclic aromatic hydrocarbons in the Crude Oil may be toxic, carcinogenic and teragenic. Whereas the sea has enormous capacity to absorb the various attempts by man to degrade it, the streams, creeks, rivers estuaries, swamps and land have only a little capacity to do so (Fabiyi, 2001b).

The Literature is full of conventional and computer-based methods of studying, mapping and assessing oil pipelines route encroachment. For example, Fagbeja, (2008); Roland, (2007); and Yaw and Edmund, (2006) worked within NNPC pipeline using Remote Sensing and GIS technologies. Their studies are limited in areal coverage, as most of the works done were only limited to the southern regions of the five NNPC/PPMC Pipelines regions, basically the Port Harcourt, Warri and Mosimi regions. While not much studies has been carried out in the northern regions of Kaduna and Gombe or take entire regions as a whole using Remote Sensing and GIS techniques.

The present study focuses on the application of Remote Sensing and Geographic Information System in assessing the compliance to regulations of right-of-way for NNPC pipelines network in Northern Nigeria, using standard criteria as enshrined in the Pipeline Act CAP 338 of the Law of the Federation of Nigeria 1990. The statement of the problem seeks to answer the following Research Questions:

v. What are the various regulations guiding the right-of-way of pipelines in Nigeria?

vi. How large is the NNPC pipe lines' right-of-way and how is it maintained?

vii. How can Remote Sensing and Geographic Information System techniques be used to assess level of compliance to NNPC pipelines' right-of-ways?

viii. What are the environmental problems and challenges of non-compliance to the pipelines' right-of-way?

1.3 Aim and Objectives of the Study

The aim of this research is to assess the compliance to regulations of encroachment of other land-use types on NNPC pipelines' right-of-way in Northern Nigeria, using GIS and Remote Sensing technique.

The aim is achieved through the following specific objectives, which are to:

v. identify the various regulations guiding the right-of-way of pipelines in Nigeria;

vi. create appropriate digital spatial database and associated attributes of NNPC pipelines network and related right-of-way;

vii. assess the level of compliance to NNPC pipelines right-of-way directive in Northern Nigeria;

viii. identify the environmental problems and challenges due to the non-compliance to and poor management of pipelines ROW in Northern Nigeria.

1.4 Justification of the Study

By international standards, oil pipes ought to be replaced after 15 to 20 years, but most pipelines in use in Nigeria are about 20 and 25 years old, making them vulnerable to corrosion and leakage. In some cases, the pipes are laid above ground level without adequate surveillance, exposing them to wear and tear and other dangers (Oyem, 2001).

Anderson (2005), also noted that most of the facilities were constructed between the 1960s and early 1980s, to the then prevailing standards. The oil pipeline in the coast of Lagos that was buried underground is now exposed to the surface by the process of erosion. Settlements as well as farming activities have encroached on the ROW. In most cases, information about these vulnerable settlements and land use is scarce and are rarely noticed until a number of victims perish after a disaster. At the same time, oil theft, commonly referred to as "bunkering", leads to pipeline damage that is often severe, causing loss of production, pollution, and forcing companies to shut-down production.

The industry has been blamed for polluting air, soil and water leading to observed losses in arable land and decreasing fish stocks.

The findings and recommendations to be made in this study, when implemented, will benefit all Nigerians as well as the government for one thing, the implementations of the recommendation of this study will reduce the incidence of pipeline vandalism and explosion in Nigeria. Thus, the average Northern Nigerian will have access to petroleum products and longetivity of life.

1.5 Aspects and Scope of the Study

This research work seeks to demonstrate the capabilities of Geographic Information System and Remote Sensing techniques in the assessment of encroachment on the right-of-way of NNPC pipelines by various land use types in Northern Nigeria. The study covers the northern areas within the context of Nigeria territory where the NNPC pipelines transverse.

The study covers Depots in Jos, Gusau, Gombe, Kaduna, Kano, Maiduguri, Minna, Suleja, Yola and Pump Stations in Abaji, Biu, Dikko/Suleja, Izom, lafia, Sakin Pawa and Zaria. The study covers five kilometres away from the refinery and each of the depots on field work by the researcher and the entire length of the pipeline networks on the satellite imageries in the study area as at 2014. This is because at five kilometres, man's anthropogenic activities can be fully assessed and that the pipelines passes through unexploited environments where some of the land use types do not pose a threat.

Aspects of the study include the assessment of compliance to regulations of right-of-way for pipelines, identification, mapping and creation of a data base for the existing NNPC pipelines in the study area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter entails the Conceptual Framework and various literatures that were reviewed for the purpose of the study. It is concerned with the studies that used GIS and Remote Sensing for oil pipeline transportation monitoring, planning and management purposes. Several researches were cited in this context; however, only recent studies were reviewed.

2.2 Conceptual Framework for the Study

2.2.1 Petroleum Refineries

There are four refineries in the country owned by Government through the Nigerian National Petroleum Corporation (NNPC) commissioned between 1965 and 1989 with the under listed installed capacities:

Table 2.1: Nigerian National Petroleum Corporation (NNPC) Refineries in Nigeria.

S/No.	Refinery	Date Commissioned	Installed Capacity (Bpd)
1.	Port Harcourt I	1965	35, 000
	Port Harcourt expanded	1971	60, 000
2.	Warri	1979	125, 000
3.	Kaduna	1980	110, 000
4.	Port Harcourt II	1989	150, 000
	Total		**445, 000**

Source: Nigerian National Petroleum Corporation (NNPC) (2000).

The product slate from the four refineries are white products-Premium Motor Spirit (PMS), Dual Purpose Kerosene (DPK), Automotive Gas Oil (AGO) and Liquefied Petroleum Gas (LPG), Low Pour Fuel Oil (LPFO), High Pour Fuel Oil (HPFO), Bitumen, Base Oils, Paraffin Wax and Sulphur. In addition, the Warri Refinery has a petrochemical plant for the production of Polypropylene and Carbon Black, While Kaduna Refinery has a petrochemical plant for the production of Linear Alkyl Benzene, Solvents and Benzene (NNPC 2000).

Each of the refineries has been afflicted by accidents, maintenance and operational problems that have negatively affected the output and the ability to meet domestic demand. A summary of the current status of the refineries is indicated below:

IV. Port Harcourt Refineries

The first Port Harcourt Refinery was built in 1965. It was commissioned, operated and managed by SHELL PB. The capacity was 35,000 bpd. However ownership passed to the Nigerian Government in 1970. The refinery was upgraded in 1971 to 60,000 bpd. The second Port Harcourt Refinery, a deep conversion facility, with an installed capacity of 150,000 bpd was built and commissioned in 189, bringing the combined capacity of the refinery to 210,000. The refinery is currently operating at about 66% of the total installed capacity due to the on-going TAM. The Turn Around Maintenance (TAM) was last carried out in 2000 before the current TAM which began in 2012. Currently the two refineries are in operation as internally and public generated power has appreciated fairly (NNPC 2000, Punch Newspapers 2012, Ogbuigwe 2013).

V. Warri Refinery

The refinery was commissioned in 1979 with an initial capacity of 100,000 bpd. It was de-bottle-necked to its current capacity of 125,000 bpd in 1988. It was further expanded in 1988 with the addition of a petrochemical plant with a capacity to produce 35,000 metric tones and 18,000 metric tones per annum of Polypropylene and Carbon Black respectively. The refinery is currently running at 63% due to on-going TAM. The last TAM was carried out in 1994. The refinery operated from January to February 2000 at about 10.3% of the installed capacity and was shut down because the Main Heater blew up. Four capital projects have been identified and implement for optimizing the performance of the refinery at a total of

$220.77 million and ₦351.15 million (NNPC 2000, Punch Newspapers 2012, Ogbuigwe 2013).

VI. Kaduna Refinery

The refinery was commissioned in 1980 with an initial capacity of 100,000 bpd. In 1985, it was de-bottle-necked to 110,000 bpd. The refinery was integrated with a petrochemical plant in 1988 with a capacity for the production of 30,000 metric tones of Linear Alky Benzene. It was shut in August 2000 partly to allow rehabilitation of the heaters and because the TAM which started in 1998 was yet to be completed. The last TAM carried out before then was in 1998 which means that two consecutive TAM (1994, 1996), were not carried out. Eighteen capital projects have been identified for optimizing the performance of the refinery at a total cost of two billion naira (NNPC 2000, Punch Newspapers 2012, Ogbuigwe 2013).

From the above statements, it is conspicuous that these refineries are operating below their installed capacities due to poor maintenance, misappropriation of funds for TAM and vandalization of pipelines in Nigeria.

According to the Nigerian National Petroleum Corporation spent ₦152 billion on the repair of three of the nation's refinery in 2013. The amount was contained in the National Assembly Joint Committee on petroleum (Downstream). Details of the budget show that the total cost for the Port Harcourt refinery by its original builders, basic engineering design for the Fluid Catalytic Cracking unit and RFCC plant project is estimated at ₦76.77 billion. The total estimated expenditure for the maintenance of the Warri

refining and petrochemical company is put at ₦43.12 billion. The corporation has budgeted ₦32.106 billion on the Kaduna Refining and Petrochemical Company (Punch Newspapers, 2012).

2.2.1.1 Nigerian Oil and Gas Pipelines Network Development

There is some argument as to when the first crude oil pipeline was built. However, some say pipeline transport was pioneered by Vladimir Shukhov and the Branobel Company in the late 19th Century. Others say oil pipelines originated when the Oil Transport Association first constructed a 2-inch (51 mm) Wrought Iron Pipeline over a 6-mile (9.7 km) track from an oil field in Pennsylvania to a railroad station in Oil Creek, in the 1860s. Pipelines are generally the most economical way to transport large quantities of oil, refined oil products or natural gas over land.

Nevertheless, the discovery of oil and natural gas in commercial quantities in 1956 saw the rising production and export of crude oil from a modest start of 5, 100 barrel per day in 1958 to 2.4 million barrels per day in 1979 (NNPC, 1989).

Since then, the production and export of crude oil has been in millions of barrels per day. This has necessitate the development of the required infrastructure, facilities and services for both the production and refining of crude oil as well as for the conveyance of the crude to refining centers and transporting the end products and by-products to centers of consumption. Oil and gas pipelines and their ancillary facilities constitute vital components of these infrastructure/facilities.

In the mid 1970s the Government of Nigeria decided to construct nearly 2,000 miles of pipelines, a new refinery and 19 storage depots throughout Nigeria. The programme was initiated to meet future fuel demands and to overcome current shortages caused by the inadequacy of existing road and rail services.

Numerous projects were put into motion representing an investment of £450 million at 1977 values. One of the projects was Nigerian National Petroleum Corporation's (NNPC) Pipeline System 2C, a 370 mile pipeline from Warri to Kaduna. Starting in the Rain Forest the pipeline crosses through savannah type terrain before reaching desert conditions surrounding Kaduna. Initially the pipeline was designed for crude oil but used on a batch basis carrying refined fuel such as Gasoline, Kerosene and Gas Oil from the refinery at Warri to Kaduna. Later the pipeline was used to pump crude oil to the refinery at Kaduna.

Installation of 25 Allen S37 engines for the pipeline system was undertaken in two phases. Phase 1 began in 1977, when upon construction each of the three pumping stations were equipped with three Allen 8-cylinder, 1,684 bhp engines driving high-speed multi-stage Centrifugal Pumps, through Epicyclic Gearboxes. The speed range of each engine is maintained between 350 and 600 rpm as the flow of crude oil is dictated by demand at the Kaduna refinery.

Accessibility for construction of the pipeline was a major problem because the roads were not made for heavy construction equipment and there were numerous river crossings to overcome. Despite this, by April 1980, a

new refinery at Kaduna became operational allowing pipeline 2C to pump crude oil for refining and then distribution from Kaduna itself.

There is at present about 5,001 of pipeline network nationwide. The PPMC uses the network of multi-products pipelines to move products from the refineries/import receiving jetties to the 21 Storage Depots all over the country. All the systems are multi-purpose pipelines except for Mosimi-Satellite depots lines. The distribution network is made up of a number of numbers of systems as follows:

The table 2.3 is classified into five (5) basic systems, referred to as 2A, 2B, 2C, 2D and 2E. Added to these are four sub-systems, which are actually extensions of the basic systems. These are sub-systems 2AC, 2CX, 2DX and 2EX. Pipeline system 2A runs from Warri through Benin and Ore depots and terminates at Mosimi depots. System 2EX originates at Port Harcourt runs through Aba and Enugu depots, up to Makurdi terminate at Yola Depot.

The Federal Government also deposited that two of the refineries is scheduled to be completed within 12 months, while the others will be completed within the short-term. However, only three States have been selected to serves as locations where some of these refineries are to be sited. The three beneficiary States are: Bayelsa, Lagos and Kogi State (NNPC, 2012).

Table 2.2: NNPC Pipelines Distribution Network Systems in Nigeria.

S/No.	System	Pipeline Network	Segment Length (Km)	Flow Rate (M3/Hr)
1.	System 2A	(d) Warri-Benin. (e) Benin-Ore. (f) Ore-Mosimi.	90 114 151	300 300 300
2.	System 2AX	Auchi-Benin.	107	380
3.	System 2B	(f) Atlas Cove-Mosimi. (g) Mosimi-Ibadan. (h) Ibadan-Ilorin. (i) Mosimi-Ikeja. (j) Mosimi-Lagos Satellite (Ejigbo in Lagos).	40 79 128 (ATK) (PMS, AGO, DPK)	750 300 60 75 150
4.	System 2C	Escravos-Warri-Kaduna (Crude Lines).	606	150
5.	System 2D	(f) Kaduna-Zaria-Kano. (g) Zaria-Gusau. (h) Kaduna-Jos. (i) Gombe-Maiduguri. (j) Jos-Gombe.	140 177 165 297 265	160 40 90 90 90
6.	System 2E	Port Harcourt-Aba-Enugu.	210	120
7.	System 2EX	(d) Port Harcourt-Aba-Enugu. (e) Enugu-Markurdi. (f) Makurdi-Yola.	210 180 470	170 165 70
8.	System 2CX	(e) Enugu-Auchi. (Interconnection). (f) Auchi-Suleja. (g) Suleja-Minna. (h) Suleja-Kaduna.	109 250 90 150	130 105 80 135
9.	System 2DX	Jos-Gombe.	165	85

Source: Nigerian National Petroleum Corporation (NNPC) (1998 and 2000).

The evacuation of refined petroleum products by pipelines stood at 70% of production before the completion of the inter-link, while water, road and rail transportation modes shared the remaining 30% among themselves. It is expected that that when the commissioned interlink system becomes well-established, the bridging (use of tankers for transportation) of White

Petroleum Products would stop. This would help to save the nation costs and the wear and tear of highway infrastructures.

The first phase of pipelines system was built over 20 year ago. However, despite the fact that the pipelines are generally known to have a terminal life span of 50 years if well maintained, the pipelines and associated equipment such as pumps, valves, loading arms and meters, generators etc. have aged and are at various stages of deterioration. Contributing to the deterioration is lack of a proper maintenance schedule, as well as the incessant and deliberate acts of vandalism. Table 2.4 below shows the number of line breaks indicating the natural ruptures and willingful vandalization frequencies.

2.2.1.2 Attacks on Oil Transport Pipelines in Nigeria (Sabotage, Vandalization and Pilferage)

This sub-section gives a quantitative and possible explanation of observed patterns of the activities of Oil Saboteurs and Pilferers in Nigeria. Sometimes, Miscreants and Saboteurs tamper with petroleum pipelines in order to cause damage or steal products (such as during acute shortage).

This often results in a lot of wastage and loss of lives. According to PPMC (2014), Nigeria lost up to ₦6 billion due to deliberate damage to its pipelines in the country between January and August 2000 alone. This problem has for some years now been intractable and had become very alarming to the Federal Government.

Pollution and exposition due to pipelines damages (accidental or deliberate) cause a lot of pollution in the areas where they are

laid. When such damage occurs in refined product pipelines, they are usually accompanied by fire explosions and loss of lives and properties. The precautionary measure normally taken in order to prevent deliberate damage to pipelines and reduce the effects of such an occurrence is the burial of pipes many meters in the ground. But this is not always possible in some places, most especially across rivers and deep gullies.

Oil spillage from pipelines has become a daily experience. Crops and aquatic lives are lost as a result of this, leading to the impoverishment of the people in the study area. Actually, this is one of the major complaints of the indigenes of the Niger Delta areas of the country. It cost the oil-producing companies operating in these areas billons of Naira to clean the environment and pay for the damages arising from oil spillages.

The socio-environmental consequences of oil exploration and production have been widely reported both locally and internationally (Finer, Jenkins, Pimm, Keane, & Ross, 2008; Ikporukpo, 1983; O'Rourke & Connolly, 2003; Orubu, Odusola, & Ehwrieme, 2004; Watts, 2005 in Anifowose *et al.*, 2012). However, very few studies are dedicated to oil pipeline transport systems (Anifowose *et al.*, 2012).

According to Walker, Kucklick, Steen, and Fritz (1995) in Anifowose (2012) depicted that:

> ***Pipelines represent critical infrastructure for the smooth running of the oil and gas industry and are pivotal to sustained energy supply and economic growth. The construction and operation of oil pipelines can create significant social and environmental impacts. However, severe environmental impacts can arise when pipelines are damaged during operation, as spills (e.g. crude oil) can result in significant long-lasting environmental problems (Aroh et al., 2010; Dadiowei, 2009; Osuji, Erondu, & Ogali, 2010). Such pipe-line damage may be caused by natural disasters (such as landslides, earthquakes), poor maintenance,***

For example, the 2001 rifle shot in the Trans-Alaskan Pipeline led to an oil spill of 6143 barrels (258,000gallons or 976.8 m^3) lasting long before repairs(Alyeska 2007, p.99; Holland, 2010).

Many lives have been lost and properties worth millions of Naira have been burnt in the aftermath of deliberate pipeline attacks within this network (appendix XI). In this study, were fret such deliberate attacks as interdiction (Church, Scaparra, & Middleton, 2004 in Anifowose *et al.*, 2012), a term which is value neutral. Interdiction is also commonly referred to as vandalism or sabotage. Between 2000 and 2010, the Federal Government of Nigeria had lost the amount of 174.6 billion Naira to pipelines vandalism.

Severity of pipeline attacks can be measured using many variables e.g. number of events, number of incidents per pipeline km year (e.g. Anifowose *et al.*, 2010), or per head or per GDP, fire-outbreaks, injuries, fatalities, environmental contamination and the number of prosecutions per incident. The table below show a summary of pipeline vandalism, amount of crude oil lost and the value of the oil lost.

Table 2.3: Summary of Pipelines Rupture/Vandalism from January 1993-2011**.**

S/No.	Year	Value of Crude Lost ($)	No. of Pipeline Vandalism	Crude Oil Lost (bbl)
1.	2006	35, 334, 344	4	3, 914, 826
2.	2007	16, 138, 350	50	179, 315
3.	2008	196, 896, 495	153	2, 187, 739
4.	2009	87, 657, 483	360	1, 753, 150
5.	2010	152, 170, 959	864	2, 113, 486
6.	2011	632, 749, 512	899	6, 327, 495
	Total	**1, 437, 947, 142**	**2, 330**	**16, 476, 011**

Sources: Pipelines and Products Marketing Company (PPMC) (2012).

October 1, 2012, ThisDay Online Newspaper reported that, between 2012 and 2013 crude oil lost of 109, 050, 000 bbls valued at $1, 23, 000, 000.

Table 2.4: Recorded Pipeline Explosions and Deaths Resulting from Pipeline Rupture Vandalism in Nigeria.

Date	Event	Victims
October 1998	Pipeline explosion in Jesse, Delta State.	1, 000 people killed
March 2000	Explosion in Osisioma LGA, Abia State.	**50 people killed.**
10 July, 2000	Pipeline near town of Jesse village, Delta State.	**250 people killed.**
10 July, 2000	Explosion of rupture pipeline in Warri, Delta State.	**100 people died.**
3 0 November, 2000	A leaking pipeline caught fire near fishing village of Ebute near Lagos.	**50 people killed.**
June, 2011	Pipeline explosion at Atlas Cove, Takwa Bay.	**50 people died.**
19 June, 2003	Explosion of a pipeline punctured by Thieves in Umuahia, Abia State.	**125 people died.**
21 December, 2005	Pipeline explosion in Ehor.	**5 people died.**
12 May, 2006	A vandalized oil pipeline exploded in Lagos.	**500 people killed.**
1October, 2012	Pipeline fire at Umueze, Osisioma LGA, Abia State.	**15 died, 20 wounded.**
12 January, 2013	Pipelines explosion at Arepo Village, Ogun State.	**30 people feared dead.**
3 May, 2013	Pipelines fire at Ekorinim Village, Calabar, Cross River State.	**2 people killed.**

Source: American International Journal of Contemporary Research and This Day Online Newspaper (2012).

2.2.2 Remote Sensing Technology (RST)

According to Canada Centre for Remote Sensing (2010:1), defines Remote Sensing as:

> ***"The science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information. The process involves an interaction between incident radiation and the targets of interest".***

It is a power for surveying, mapping and monitoring earth resources and changes. This technology with GIS which excels in storage; manipulation

and analysis of geographic information and socio-economic data provide a wider application (Medis and Wadigamangawa, 1996). Remote Sensing technology is used in the acquisition of spatial data of earth resources, environmental, hazards and resourced monitoring etc. which are processed mapped out and used to formulate projects at the pre-feasibility and feasibility levels. It is a veritable technique for the collection of multi-temporal, multi-spatial data sets, which are captured by camera and sensors using platforms such as:

C. **Satellites:** Locate at different altitudes above the earth surface such as LANDSAT (Land Observation Satellite) by the American Government, SPOT (*Systeme pour I'Observation de la Terra*) by France supported by Sweden and Belgium, IKONOS by Greece supported by United States, EUROSAT by European Government and NIGERIASAT-1, NIGERIASAT-X and NIGCOMSAT-1R by the Nigeria Government. This information which is transferred to earth receiving stations on the earth surface which are then fed into GIS as inputs; this could be either soft or hard copies.

D. **Aircrafts:** which make use of photographs and a mosaic is made of the photographs and features are mapped which are input into computer information system with the use of special devices. The contribution of RST to GIS includes:

    - As potentials for uniformity, compatibility within and between data sets.
    - It timelines and flexibility.

- Its maintenance of up-to-date data in GIS.
- It is an ideal source of data for change detection because of continual monitoring of environmental resources.

The remotely sensed data are mostly in digital form, soft and hard copy etc. which are then interpreted and manipulated by special software such as ERDAS, IDRIS, ARCVIEW, ARCMAP etc. In a nutshell, RST contributes to GIS are in use. Satellite imageries are prefers and employed in this study.

A remote sensing device records response which is based on many characteristics of the land surface, including natural and artificial cover. An interpreter uses the element of tone, texture, pattern, shape, shape, size, shadow, site and association to derive information about land cover.

Thus, Remote Sensing techniques have quickened with the invention of photography which has continued to improve. It has been useful in different fields: for resource inventory and data acquisition which are processed for better management, exploration and exploitation and monitoring of resources. This is possible by the application of different methods and techniques of Geographic Information System.

2.2.3 Geographic Information System (GIS)

GIS provide the ability to store and display maps and associated information. It has the capability to integrate geographical data with other data from various sources to provide the information necessary for decision making. In the strictest sense, it is any information system capable of integrating, storing, editing, analyzing, sharing and displaying geographically

referenced information. In a more generic sense, GIS applications are tools that allow users to create interactive queries (user created searches), analyze spatial information, edit data, map and present the results of all these operations. Geographic Information Science is the science underlying the geographic concepts, applications and systems, taught in degree and GIS certificate programmes at many universities (Meyer, 1995).

GIS technology was developed as a result of the need to solve environmental problems, it requires spatial data and it origin is traced to independent origins. It was developed in 1960 for vector based digital mapping automated cartographical systems which were operational in many military and natural mapping systems by the addition of a relational database for the storage of attribute data and analysis functionality. It was designed for Canadian Government in 1963, in which overlay vectors polygons of resource information for applications such as pipelines' right-of-way and land assessment for degraded land rehabilitation and agriculture.

Furthermore, the role and function of GIS is inevitable in the setting-up of pipelines network and right-of-way information system. In addition to the geographic database which formed the core of GIS product, other functionalities includes; the subsystem for cartographical data acquisition, subsystem for data management (Huxhold, 1991). These are the four functions of GIS that need to be focused on in order to ensure the continuity of the information system.

2.2.4 Data Acquisition Techniques for GIS Operation

Data needed for GIS project could be compiled from various sources; some of these sources are;

vi. Ground Survey method

vii. Photogrammetry method

viii. Graphic Digitizing methods

ix. Remote Sensing technique

x. Questionnaire survey

2.2.4.1 Ground Survey Method

The ground survey method of data acquisition include; traversing (compass and theodolite), triangulation, trilateration, spirit leveling or trigonometrically heighten, tachometry, chain surveying, plain tabling and inertial surveying method. The basic aim of these methods is for the determination of coordinate of points on the earth's surface from which a graphic representation in form of maps, plans, and charts can be made or which the shape and size of the earth could be derived (Ndukwe, 2001).

2.2.4.2 Photogrammetry Method

This is a measurement technique for which the coordinates of the point in 3-dimensions of an object are determined by the measurement made in two photographic images or more taken, starting from different positions, usually from different passes of an aerial photography flight (Ndukwe, 2001), Although, this method will not be implemented in this research work.

2.2.4.3 Graphic Digitizing Method

Digitizing refers to the conversion of information or data which are in analogue form into a digital format. Two types of data which are usually digitized are, point data (such as individual objects, spot heights, trees, etc.) and line data (such as roads, rivers, fences and rail-roads (Ndukwe, 2001).

2.2.4.4 Remote Sensing Technique

Remote Sensing is a technology that employs electromagnetic energy as a means of detecting and measuring characteristics of targets or terrain features. Satellite images are often use as data sources. Various techniques are used to extract from these sources and to geo-reference them (Ndukwe, 2001).

2.2.4.5 Questionnaire Survey

This is "a prepared set of questions in which Respondents record their answers in an administered survey". Questionnaires have been widely used for descriptive and analytical surveys in order to find facts, opinions and views on what is happening, who, where, how many or how much. They could be conducted personally, though post or internet, were classified as either "open" form/ unrestricted type or the "close" form/restricted type. Open questions seek to encourage the respondent to provide free answers and as they offer no direct clues, they are difficult to analyze and interpret requiring some form of content analysis. Close questions often require a short response in the form of yes or no, agree or disagree, important or not important. They are easy to ask, quick to answer, their analysis is straight forward, but may introduce bias as they may force respondent to choose from given alternatives (Doko, 2008).

2.2.5 Remote Sensing (RS) and Geographic Information Systems (GISs) in Encroachment into Pipelines Right-of-Way

This section describes in brief the link between Remote Sensing and Geographic Information System (GIS) and their uses for pipeline studies. Remote Sensing (RS) can be defined as the collection of information about an object by a recording device that is not in physical contact with it (Robert *et al*, 1984).

The term is strictly used to mean methods that record reflected or radiated electromagnetic energy. The technique employs devices such as Cameras, Infrared (IR) Detectors, Microwave Frequency Receivers and Radar Systems. Any of these pieces of equipment is able to code information about large area and store in a way that it can be retrieved later, hence the phase Remote Sensing. Imagery of objects can be use to provide maps of different subjects.

Among the different techniques of RS in use, satellite imageries are preferred and employed in this study, such as Landsat, Radar, SPOT and IKONOS imageries. Other technique such has Aerial photo could have been used for comparison purpose but are limited for this present study. Detailed discussions on the advantages of Satellite technique over others are given in chapter 4. It is suffice to say that it has high resolution and geometric qualities for qualitative analysis in the study on pipeline right-of-way and mapping. There is also the added advantage that satellite photography captured images that can cover large area and can be zoomed or scaled to suit specific requirements, making them advantageous in specific subject matter.

It should be noted that reliable identification of cultural features as well as natural phenomena, requires a ground resolution of 2 to 3 m per pixel. If these features are to be derived from sensor data, the pixel size should be in order of 1 to 2 m. Conversely, this is what makes it impossible for many pipeline and other land surface features to be identified from imagery of present day electro-optical sensors, including SPOT (Naithani, 1990). Besides, where high-performance cameras with (FMC) devices are used for mapping of individual features and other details are enhanced because of the use of lower sensitivity films.

Table 2.5, illustrates the minimum Ground Scale Cell Resolution of the different types of imageries produced by different sensor devices. Indeed the aerial photography, especially those of Panchromatic (Black/White) Films, stands out as a better alternative to any other. For example, for a Landsat (MSS) imagery to be detected it requires a Ground Resolution Cell (GRC) of at least 320 meters. On TM Landsat, the GRC needed is at least 120 m to detect an object. While SPOT (XS) have GRC of 80 m; SPOT (Pan) will need a GRC of about 40 m; but on an Aerial Photo (AP) at the scale of 1:100, 000 only and GRC of 40m will be required to detect an object/feature.

Table 2.5: Minimum Sizes of Objects to be Detected, Recognized and Identified for Various Condition of Contrast with their Background in Various Types of Imagery.

		Landsat MSS	Landsat TM	SPOT XS	SPOT Pan	A.P *) 1:100,000	A.P *) 1:50,000	A.P *) 1:25,000	A.P *) 1:10,000
GROUND RESOLUTION	CELL SIZE	80m	30m	20m	10m	1m	0.5m	0.25m	0.1m
HIGH CONSTRAST	Detection	320m	120m	80m	40m	4m	2m	1m	0.4m
Feature Background	Recognition	560m	210m	140m	70m	7m	3.5m	1.8m	0.7m
	Identification	800m	300m	200m	100m	10m	5m	2.5m	1m
LOW CONTRAST	Detection	1600m	600m	400m	200m	20m	10m	5m	2m
Feature Background	Recognition	2400m	900m	600m	300m	30m	15m	7.5m	3m
	Identification	3200m	1200m	800m	400m	40m	20m	10m	4m

*): Without Forward Movement Correction **(**Values should only be used as an indication of the order of Magnitude).

Source: Rangers *et al., 1992 and Canadian Centre for Remote Sensing (2011).*

G. I. S. can be defined as any manual or computer-based devices and procedures used to store retrieve and manipulate geographically referenced data (Aronoff, 1993). The system involves data input, management (storage and retrieval), manipulation/analysis; and output in different ways. However, a computer-based GIS is a powerful tool for handling large volume of data in digital format that they may not otherwise be possible. Besides, it aids easy retrieval and data may be analyzed and manipulated for display in one piece at greater speeds and lower cost than any other manually operated geographic information.

Surely, application of computer-based GIS in assessing oil pipelines right-of-way mapping is enormous ranging from the possibility of superimposition of a set of factors maps on others and to analyze them in combination with a type of pipelines' encroachment occurrence map. Also, the combination of maps (map crossing) enables the Earth Scientist to evaluate the spatial variability of the natural environment and to extrapolate the critical combination of factors found in the analytical phase.

Complex computation techniques, necessary in the map crossing of several factor maps and for table calculations, are feasible by the use of a mathematical compressor. GIS enables the rapid preparation of table showing the area of different factor combinations. Even where most of the available parameter maps are not of the same scale, information or maps to be overlaid can be matched regardless of their original scale by simple manipulations. However it may require statistical analysis of large quantities of variable and algorithmic complexities.

In this study all procedure for data manipulation, storage, and retrieval are done mechanically and digitally. Satellite imagery and conventional would be analyzed using computer-based system and devices. Interpretations and mapping would be based on digital\tracing out of identified attributes/features of oil pipelines encroachment. This is discussed in detailed in chapter 4.

An attempt is made to perform a digital map crossing of the land use types and encroachment types. This is achieved by first carrying out detailed interpretation/mapping of individual attribute maps using Arc Map Arc Info 10.1 software thereafter they are laid upon one another (superimposed) to produce final map.

It is proposed that the development of a pipelines' right-of-way monitoring system should consider the following:

Component 1: Land use data which can be monitored are first selected based on the data availability. It also contains the output tables (in spreadsheet format) which resulted from the processing of the spatial database. If it involved land use and right-of-way policies, it needs to be translated into indicators.

Component 2: The main functionality of this module is to track and verify pipelines' encroachment by the various land use types. It is developed based on remotely sensed data (Landsat or SPOT) and the contents will be kept in raster format and later converted to vector format. The component focuses on encroachment into pipelines' right-of-way that can be monitored from the analysis of satellite images. The main output of this component will be spatial

distribution of the various land use types encroaching into the pipelines' right-of-way, which includes; built-up, agricultural area, water bodies, roads etc.

Component 3: Relate to the spatial database. It consists of various layers derived from geographical database. Such datasets are mainly on the land uses encroachment and infrastructural component of the geographic database's data layers which are further broken down into sub-components such as Agriculture, Built-up, Roads, other physical areas such as Water Bodies and Refinery, Depots, Pump Stations and Retail Stations.

Component 4: Is the analysis module. In order to perform the analysis, the base data are structured and then stored in Database System. This module takes up all the different policy indicator measures and then processes the resultant data through the GIS engines of overlaying the pipelines network over various land use types layers. By applying the model builder available, it is possible to keep track of additions and subtractions of parameters. This component essentially processes encroachment into pipelines' right-of-way for efficient monitoring purposes.

Component 5: contains both the tabular and spatial (map) outputs resulting from the analysis processed in component 4. Each intersection process is displayed in customized table format and graphic (map) format.

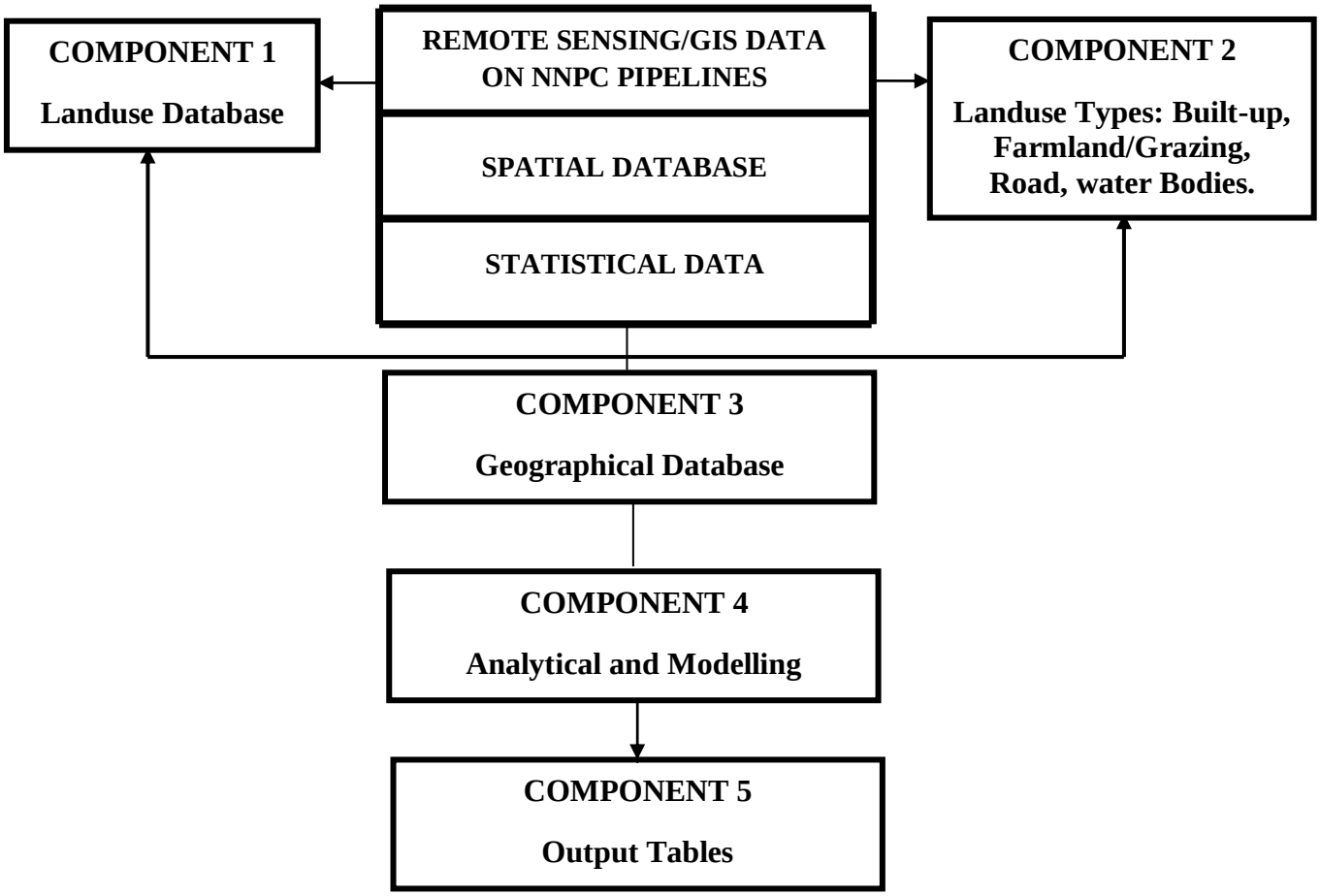


Fig. 2.1: Framework of the Monitoring System.

Source: Information Monitoring System/Researcher (2014).

On the whole, the steps involved in generating the land use policy and pipelines' right-of-way regulations' data to land use and pipelines' right-of-way output tables and maps for monitoring purposes are as follows:

vi. The parameters of monitoring encroachment into pipelines' right-of-way by land use types are determined by selected existing land use type encroachers, pipelines infrastructures and land use and pipelines infrastructures indicators.

vii. Preparation of appropriate and relevant spatial data.

viii. Analysis and data processing are done utilizing model building capabilities.

ix. Data output are in: (i). Tabular format and (ii). Graphic format (maps). The tables are stored in access whilst the map outputs are stored separately in a separate folder.

x. Tabular data is copied and captured in spreadsheet format for trend and impact analysis.

The process of developing a pipelines' right-of-way and land use information system and the introduction of the monitoring system would help in promoting development in a more coordinated and comprehensive manner. Pipelines and Land Use Planning supported by an integrated information system will provide the commitments to achieve a sustainable development.

The data structure and other system components namely; the monitoring system could provide the platform for exploring the parameters of sustainable development derived through its performance indicators which later will be translated into spatial dimension. On the other hand, it can also support infrastructure planning, disaster planning, urban regeneration studies, transportation exploration and conservation planning and can be utilized for decision-making process.

In many environmental and pipeline management situations the most useful contribution of the Remote Sensing and Geographic Information System experts is the provision of a digital terrain map for a pertinent assessment of a subject matter. This is particularly true where information is required on the distribution of landform and pipelines characteristics and soil

types including operational surface processes; such maps have been used to considerable advantage for engineering, planning and management projects. While the concept of making a pipelines' terrain map is not a difficult one, the task of actually making one makes it to so.

Encroachment on NNPC pipelines' right-of-way varies from one Depot, Pump Station, Booster Station, and Retail Station and from one pipeline region to another in accordance with the forces and processes including hydro-meteorological factors and influence of man and animal. The encroachment into NNPC pipelines' right-of-way in northern Nigeria is influenced by rapid urban sprawling, poor agricultural and land management practices and hence subjected to rapid degradation, encroachment and vandalism.

As already stated the assessment of the case study required high technology device applications using computer hardware and software, satellite imageries and aerial photos. Also conventional field survey may be used to map the nature of and assess the extent of encroachment by the various land use types and pipelines degradation. However, these conventional methods can only be used in smaller areas (its coverage is limited) and extrapolation is strenuous and may result in over simplification.

2.2.5.1 Regulations on Pipelines' Right-of-Way

This section x-rays the various regulations and guidelines on oil pipelines' diameters/sizes, setbacks, standard marking colour code, criteria for evaluating right-of-way condition and level of to environmental laws as it concerns right-of-way.

2.2.5.2 Diameters/Sizes of Oil Pipelines

Petroleum pipelines are made from steel or plastic tubes with inner diameter typically from 100 to 1,200 mm (4 to 48 inches). Most pipelines are typically buried at a depth of about 0.91 to 1.8 m (3 to 6 feet). To protect pipes from impact, abrasion, and corrosion, a variety of methods are used. These can include wood lagging (wood slats), concrete coating, rock-shield, high-density polyethylene, imported sand padding, and padding machines. The oil is kept in motion by pump stations along the pipeline, and usually flows at speed of about 1 to 6 metres per second (3.3 to 20 ft/s). Multi-product pipelines are used to transport two or more different products in sequence in the same pipeline.

Crude oil contains varying amounts of wax, or paraffin, and in colder climates wax build-up may occur within a pipeline. Often these pipelines are inspected and cleaned using pipeline inspection gauges, pigs, also known as Scrapers or Go-devils. Smart Pigs (also known as intelligent or intelligence pigs) are used to detect anomalies in the pipe such as dents, metal loss caused by corrosion, cracking or other mechanical damage (NNPC, 1998).

For natural gas, pipelines are constructed of carbon steel and vary in size from 2 to 60 inches (51 to 1,500 mm) in diameter, depending on the type of pipeline. The gas is pressurized by compressor stations and is odourless unless mixed with a Mercaptan odorant where required by a regulating authority.

2.2.5.3 Setbacks

Setback is the minimum allowable distance from the centre of the pipeline ROW to the abutting development (land use type). The purpose and function of setbacks are to ward off encroachments by other potentially injurious land use developments onto the pipeline ROW and its ancillary installations and facilities, thereby protecting them from potential human and environment damages or hazards. Detailed hazard zone calculations (based on oil and gas spills from faulty/damaged pipelines) are difficult to come by.

For this reason, some default distances can be set based on regulatory requirements or conservatively fixed. A type of hazard zone for a natural gas pipeline could be based on generalized distance from given receptors (i.e. any creature, structure, land, area etc that could receive damage from pipeline failure) as indicated in the table 4.1. Such distances are in reality 'distance of concern' rather than hazard zones, since they are based more on receptor vulnerability than damage distances from pipeline release (Muhlbauer, 2004).

A setback of 375 m radius around 0.46 m oil pipelines as a hazard zone is also used but allows extra distances around specific receptors where topography supports a higher potential spill-impact radius (Jiriko, 2007). Similarly, for High Volatile Liquids (HVL) pipelines, setbacks of 303-454.5 m

are not uncommon. HVL releases incidents are very vulnerable to unconfined vapour cloud explosions, each of which can greatly extend impact zones to more than 1.6 km. Setbacks for buried high pressure gas pipelines based on thermal radiation criteria have been suggested. Generally, pipelines must be buried a minimum of 36 inches (three feet).

However, pipeline operators are not required to maintain this depth if erosion occurs after the pipeline's installation. Exposed pipelines should be reported to the Commission's Pipeline Safety Division of PPMC/NNPC.

For gas pipelines, there is no minimum setback requirement. Hazardous liquids pipelines that are within 50 feet of a structure must be buried to a depth of 48 inches (four feet), which is 12 inches more than the standard 36 inches (three feet) such pipelines must be buried when built. Examples of hazardous liquids pipelines are those transporting crude oil or a refined product, such as gasoline. Among the proposed setbacks are those for pipeline diameters ranging from 4 to 24 m and pressures from 400 to 1800 psig in 100 psig increments.

Table 2.6: Sample "Distance of Concern" for Natural gas Pipelines.

Characteristic	**Distance (m)**
Population class of 3 or 4 (i. e. more populated areas).	200
Hard-to-evaluate facilities (schools, day cares, prisons, elder cares, rehabilitation clinics etc.)	242.4
Hard-to-evaluate facilities, Pipe diameter>0.75 m and pressure>1,000 psig.	303
Areas of public assembly (religious worship areas, Town Halls, City Squares, Markets, etc.)	200
Areas of public assembly, pipe diameter. 0.75 m and pressure. 1,000 psig.	303

Psig: Pounds per Square Gauge.
Source: adapted from Muhlbauer (2004).

Guidance on safe setbacks for people and wooden buildings from the edge of a burning spill is also provided. The safe setbacks depend on the size of the burning area (of the affected pipeline) which assumed to be on open water. For humans the setbacks range from 46-3,030 m whereas for buildings they vary from 10-576 m for the same size spill. The spill radii for these setbacks range between 3 m and 606 m (Jiriko, 2007). Some of the setback requirements obtained from various sources are summarized in table 2.7 below:

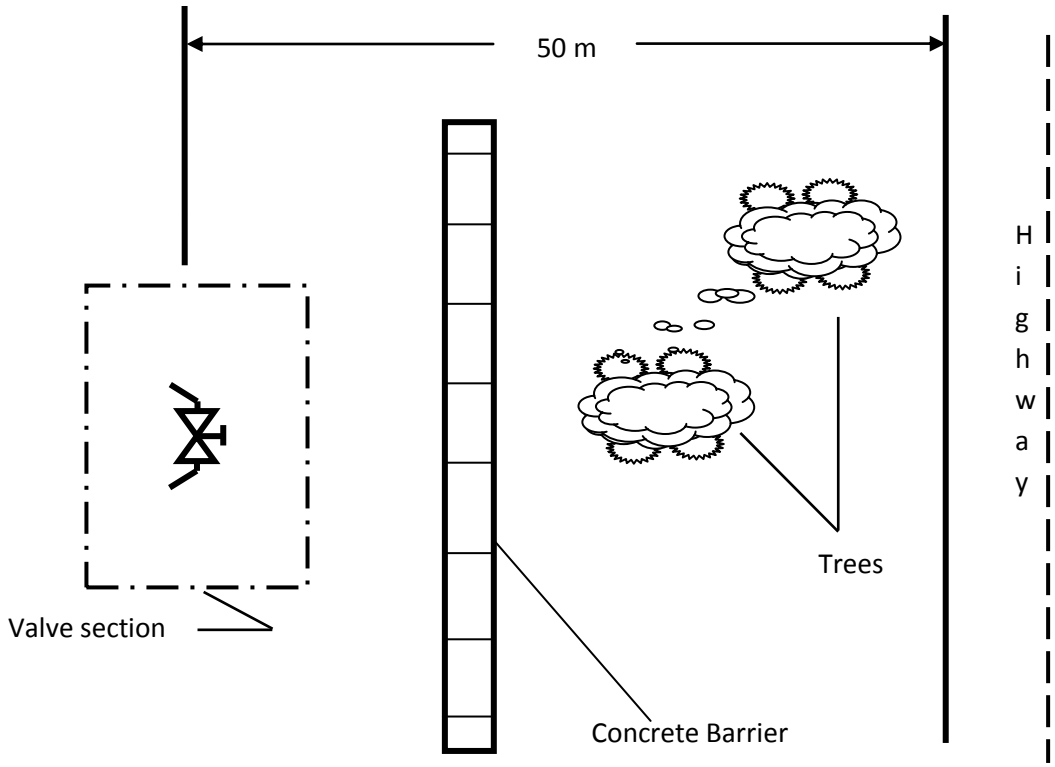


Fig. 2.2: Protection for Above-ground Pipelines Facilities.
Source: Adapted from Jiriko (2007).

Table 2.7: Summary of some Setback Requirements in Codes, Standards and other Guides.

Setback requirements for tanks from public (m)	**Variables**
1.5-53 (1, 2)	Tank size and type of adjacent use.
15-23 (3)	Type of adjacent use.
Performance Standards (4)	Site specific and process-driven.
Buildings: 39-47 (5)	Product and tank size.
People: 197-235 (5)	____ do ____
45-3, 030	Diameter of spill.

Source: (1). International Code Council (2000).
(2). Western fire chiefs Association (1997, 2000).
(3). American planning Association (APA).
(4). Department of Housing and Urban Development (HUD), U. S.
(5). U. S. Coast Guards (U. S. C. G.) Hand Book.

2.2.5.4 Standard Marking Colour Code

Locating pipelines and their depth could be better done by using detection devices i.e. instrumentation. This includes electro-magnetic signals, impressed electric signals and ground penetrating radar (Appendix II). Line marking methods are also used for locating underground pipelines. A standard marking colour has been put in place in U. S. each type of underground facility is assigned a specific colour. In practice, markings of appropriate colour for each facility are placed directly over the centerline of the pipe, conduit, cable or other feature.

The colours, relevant to this work, which the Uniform Colour Code of American Public Works Association (APWA) Utility Location Coordinating Council provides are as shown on the ensuing table 2.8.

Table 2.8: Standard Marking Colours and their Associated Underground Installations.

Standard Marking Colour	Type of Underground Utility/Facility
Red	Electric power lines, cables, conduit and lighting cables.
Yellow	Gas oil, steam, petroleum, gaseous materials.
Orange	Communications, alarm or signal lines, cable or conduit.
Blue	Water, irrigation and slurry lines.
Green	Sewers and drain lines.
Pink and Purple	Temporary survey markings and cable television, respectively.
White	Proposed excavations.

Source: International Code Council (2000).

2.2.5.5 Criteria for Evaluating Right-of-Way Condition.

Several cases of pipeline failures can be traced to flaws in the planning and design (engineering) stage of the pipeline project cycle. Pipeline design aspects should include type of material used in constructing the pipe, material strength/toughness, pipe wall thickness, external loadings, pipe diameter/wall thickness ratio and land movements such as seismic vibration, fault movement, subsidence, landslide, water bank erosion, amongst others (Jiriko, 2007).

The pipeline ROW Condition must always be stressed and maximally maintained. ROW Condition is a measure of the recognize-ability and inspect-ability of pipeline corridor. A clearly marked, easy to recognize ROW reduces the vulnerability of third party intrusions and assists in leak detection (e.g.

vapours, dead vegetation etc, easily spotted) from ground or air patrols. Clear parameters for evaluating ROW Condition should be evolved by the evaluator. A five step ranking schedule with the associated parameters for assessing pipeline ROW Condition should take the form suggested as depicted in figure 4.2 and table 4.4.

Table 2.9: A Five-level Scheduled and Criteria for evaluating ROW Condition.

Pipeline ROW Condition (Level).	**Evaluation Criteria.**
Excellent	Clear and unencumbered; route clearly indicated; signs and markers visible from any point on ROW or from above; signs/markers at all roads/rail-roads/water crossings; all changes of direction clearly marked, air patrol markers are present.
Good	Clear route-the view along ROW from ground level/above NOT obstructed by overgrowth; well marked: markers (if all in place) visible from every point of ROW and above; signs/markers present at all roads/rail-roads/waterways.
Average	ROW not uniformly cleared; more markers need for clear identification at roads/rail-roads/waterways.
Below Average	ROW is overgrown by vegetation in some places; ground is not always visible from the air or there is not a clear line of sight along ROW from ground level; indistinguishable as a pipeline ROW in some places; poorly marked.
Poor	Indistinguishable as pipeline ROW, no (inadequate) markers present.

Source: Synthesized by the Author from Muhlbauer (2004), Jiriko (2007).

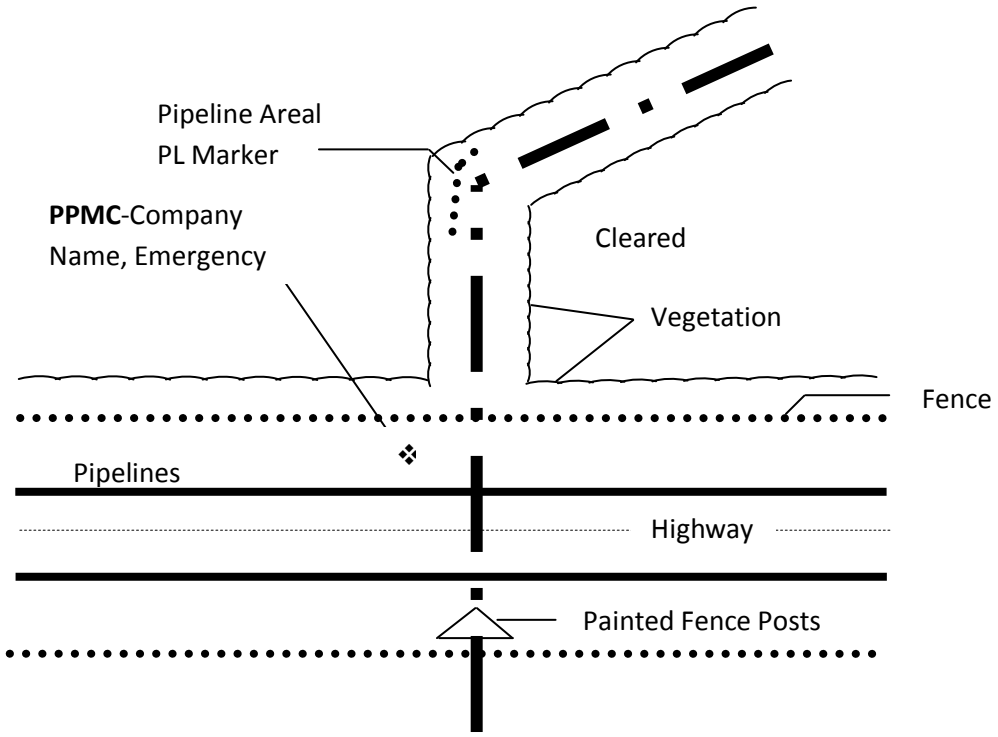


Fig. 2.3: Pipelines' Right-of-Way Condition.
Source: Modified from Jiroko (2007).

2.2.5.6 Compliance to Environmental Laws

Attitudinal problems, including refusal to comply with or undertake Environmental Impact Analysis Report(s) required by law, can be an important cause of many of the socio-economic and environmental problems plaguing the planning, design and management of the pipelines' ROW network in Nigeria.

Pipeline failures or releases contaminate damage or destroy environmental resources (Jiriko, 2007). They contaminate, for example potential drinking water sources-both surface and underground. The impact of

a release to an area or water source depends on various location-and-time specific determining factors. These include distance to surface water or Karst feature, flow rate in the receiving stream or river, saturation of soils, temperature and wind speed and nature of the event causing the release. Pipeline spills or releases also do and have actually impacted negatively on creational water ways and bodies. They impact surface water quality and contaminate or kill fish which limit contact recreation and recreational fishing respectively

Regarding contamination of prime agricultural land, a spill volume of 500 is set as the threshold for impacts of such lands in the U. S. (Muhlbauer, 2004). A spill of the size from a rupture could be expected to contaminate about 1,000 sq. m of land/soil. Distance from prime agricultural land along the pipeline that could be impacted from a pipeline accident was put at a maximum of 379 m from the point of release. This gives a band of impact of 758 m along the pipeline for evaluating any point of rupture. In the case of wetlands contamination, the same spill volume with that of the prime agricultural land is set as the threshold for pipeline rupture impacts to the wetlands.

This means the potential for impact of a pipeline failure to any wetland resource is represented by the distance across the wetland plus 379 m to either side along the pipeline.

2.3 Review of Relevant Literature

Many authors or researchers, who have vested interest on the Subject Matter, have carried out researches on oil pipeline and its environmental complexities. Relatively, fewer works had been done in Nigeria, particularly on NNPC Pipelines' right-of-way compliances by the various land use types, Geographic Information System and Remote Sensing. Works already done in Diaspora and in Nigeria, as regards pipelines includes:

Ajide and Isaac (2013) assessed the physical impact of Oil spillage in Town, Delta State, Nigeria using GIS and Remote Sensing technologies; empirical evidence from Jesse. Their study relied majorly on secondary data sources from existing classified Landsat imagery of the study area at 28.5meter resolution. The findings revealed that oil spillage is increasing unabated in the study area. Over 6000 spills had been recorded in the 50 years of oil exploitation in Nigeria, with an average of 150 spills per annum. In the period between1976–1996, 647 incidents occurred that resulted in the spillage of 2,369,407.04 barrels of crude oil. With only 549,060.38 barrels recovered, 1,820,410.50 barrels of oil were lost to the ecosystem. Oil spills degraded most agricultural lands in the State and have turned hitherto productive areas into waste lands.

Abdul-Lateef, Abdul-Nasir, Dano Umar and Imtiaz (2012) selected optimal oil pipe line route using GIS. A community participation in weight derivation and disaster mitigation used GIS technique to generate an optimal oil pipeline route in Malaysia's oil rich Baram Field. It shows how ARCGIS

software can be integrated with a multi-criteria decision analysis (MCDA) in getting the best route. The strength of this study lies on the fact that weight derivation of the variables in order of their importance was done by the whole community. A realistic and reliable pipeline route, which meets all concerned parties and weighed the variables based on their variability to environmental degradation were developed. However, their challenge was how to overcome naturally existing obstacles on the ground on the route simulated.

Khaili and Pandey (2012) developed an onshore integrated pipeline system using GIS. The major challenge in the project was extraction of data from alignment sheets. However, Smart automation was done towards capturing of data from alignment sheets, and automatically cleaning the pipe centerline data adhering to ADCO CAD manual, automatically.

Anifowose, Lawler, Horst and Chapman (2012) assessed attacks on oil transport pipelines in Nigeria, a quantitative exploration and possible explanation of observed patterns. This study presents the first quantitative and regional exploration of the problem of oil pipeline interdiction in Nigeria. It illustrates geographic patterns through choroplethic and bivariate Geographical Information Systems (GIS) map overlays. Their findings includes; strong negative correlation between pipeline interdiction and poverty and statistically and non-statistically significant mean differences in the pattern of interdiction occurrence amongst the five geographic regions. They also highlight the need for much better data collection and reporting for the mitigation of the negative socio-environmental impacts of interdiction incidences.

Tobenna (2013) developed a pipeline routing using GIS and Remote Sensing depicting how remote sensed data was used to develop a geo-database using GIS for pipeline development to help in minimizing public health hazards, environmental degradation, and destruction of the ecosystem. The study showed how GIS can help oil, natural gas companies and pipeline manufacturers develop a cost effective and effective routing plan for end users. ArcGIS software was used in pipeline routing analyses. Its core strength is it broad range of powerful spatial modeling and analysis of features. The major challenge of this research is the reliability of GIS; the researcher expressed concerns, that it lacks a more powerful analytical tool, which limit his level of locating suitable lines for pipelines' placement.

Cheng *et al.* (2012) developed a frame work for research and implementation of oilfield Basic Platform based on integrated 2D with 3D of GIS, uses 2D and 3D integration technology in pipeline planning. It shows how ArcGis 9.2 and RS (ERDAS IMAGINE 8.7 image processing software) work by generation of parameters (land use, land cover and slopes). The use of false color composite and supervised classification to generate land use and land cover maps was a great example of GIS and RS capacity. This work presents the versatility of GIS and RS to calculate and manage different variables for instance the vegetation index, DEM, slopes and moreover the ease of operations among layers of information. It also review how GIS and RS help to classify the study zones was very useful because each subzone has a particular management program in function of its properties and risks. Cheng noted that GIS and RS performance was limited in this context, due to unavailability of data.

Volkan and Tahshin (2011) compared a GIS-based Approach to Traditional Route Selection on the NABACCO pipeline route through Turkey. They carefully compare a GIS based approach of routing a pipeline to the conventional traditional route selection approach in Turkey. They were able to prove that the cost of a GIS based pipeline route selection would decrease the cost of the project by 14 percent relative to the manual pipeline route approach. The work show a conceptual and real model where the pipeline was routed using GIS. The results showed that weight values determined with this method were in agreement with real land data. They further compared the route formed by using GIS to the route formed by the Pipeline institution; the GIS route crossed 151 roads, while the institutions route crossed 169 roads. The route formed by the institute was in a first-degree earthquake region, which posed environmental hazard.

William and Dutta (2010) assessed oil spill and pipeline condition using remote sensing and data visualization management systems. Here they systematically showed beginners and experts how the GIS and Remote Sensing techniques can be used to assess pipelines' oil spills.

Foroushania and Damadib in Wagner and Szekély (2010) applied Remote Sensing technique for the physical protection of the pipeline network online of corridor based infrastructure. Here they worked on existing service that locates invasions along a petroleum pipeline, informs an intrusion or warns about a disaster on the Petroleum Pipeline and Telecommunication corridors by using data from the Rights of Way (ROW), which is a buffer zone on each side of a petroleum pipeline.

Fagbeja (2008) applied Remote Sensing and GIS techniques in assessing air quality and carbon management of gas flaring in the Niger Delta. Identified the various sources of air pollution in the Niger Delta and reviews some of the possible management strategies available to the authorities. Gas flaring in the region was identified as one of the main sources of both CO_2 and CO, and it was said to be a major contributor to NOx, and NMVOC concentrations in the Niger Delta. Challenges confronting air quality and carbon management in Nigeria were also highlighted.

Oliveira, Soibelman and Garrett (2008) assessed spatial analysis of water distribution pipeline breakage and condition applying GIS. In their work, they were able to predict breakage rates and remaining service life of pipes. The goal of the research was to present the preliminary results of a study of the use of GIS for the analysis of breakage data taking into consideration the spatial interdependencies of breaks points. More specifically, they present the issues for data preparation, integration and exploratory analysis, and investigate the usefulness of GIS spatial analysis capabilities for the assessment of failure patterns and trends in water distribution networks.

Mohd and Ruszaidi (2008) developed a framework on oil and gas exploration in Ethiopia and Kaula Lumpur, Malaysia using GIS; they used digital elevation models, strikes and dips, satellite images to identify the best route of a pipeline and other oil and gas exploration problems in Ethiopia. Data collection from the subsurface of the material was done manually, without the use of satellite imagery. The work emphasized how GIS helps in storing data in a centralized database for revision in future changes of the pipeline route. Mohd *et al*. shows how GIS can be used to calculate the

components of pipeline laying models faster, with more quality and clarity. According to them, GIS provides an efficient way for Pipeline management strategies and reduces the cost from seismic survey design. However, they were very clear to mention that the results of the study were not calibrated or validated.

Roland (2007) developed a prototype for construction and rehabilitation of Nigerian oil and gas pipeline routes using GIS. He proposed pipeline operators with a management system based up on remote satellite surveillance and GIS application that is capable of minimizing potential pipeline damage and show how Geographical Information System (GIS) decision process can be use to locate to oil and gas pipeline route as an elements of a sound decision making strategy.

William and Subijoy (2007) assessed pipeline security using Remote Sensing and GIS. In their assessment they merged both GIS and RS tools for pipeline security assessment. This research is interesting because it depicts how terrain analysis is important in the whole pipeline structure, precisely bathymetry maps which show ocean depths. The study illustrates how pipelines flow rate can be affected by poor elevation data. It also shows a new dimension towards using GIS technology in pipeline routing, which is the usage of Global Positioning Systems (GPS) for locating pipeline characters, detecting pipeline movement and collecting geospatial data. The authors highlight one of the key advantages of using remote sensing approach to pipeline routing and pipeline management as its ability to predict oil spill vaguely.

Bayramov (2009) monitored vegetation cover (VC) percentage along Bakur-Tbilisi-Ceyhan oil export pipeline in 2007 and 2008 and VC re-growth rate between two years in Azerbaijan, using high-resolution Multi Spectral Images; IKONOS 2007 and FORMOSAT 2008 NDVI. The research covered area of 444 m wide and 442 km long. Detailed map of VC percentage was developed along pipeline corridor. VC percentages were quantified within the predefined classes for the general evaluation of re-growth rates.

Twumasil and Merem (2006) assessed change within the coastal environment in the Niger Delta Region of Nigeria. This study stresses a mix scale approach involving the integration of primary and secondary data provided through government sources and data bases from other organizations. The raw spatial data and satellite images used in the research came from the United States National Aeronautical and Space Administration (NASA). Two Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images of 4 May 1985 and 12 June 2000 were obtained for this study. The Landsat TM and ETM+ satellite data were processed using ERDAS IMAGINE 8.7 image processing software. To answer some of the research questions pertaining to the study area, the spatial data was analyzed with descriptive statistics and Remote Sensing Technology. The results revel that the study area experienced some significant changes in its coastal environments.

Omonisini, Eludoyin, and Salami (2005), demonstrated how Remote Sensing and Geographical Information System can be used in creating efficient scenario towards the management of oil spillage, induced fire disaster

in the study area. They made a comprehensive study on efficient disaster management in Oil Pipeline Corridors in Nigeria.

Xiaoge (2001) applied GIS Technology in the construction of Oil-Gas pipeline to provide a high-tech method for construction operation and management in the study. He used the new oil-gas pipeline construction in China to aim at high standards, good quality, advanced technology and best efficiency for the study using the GIS technology as a powerful tool to accomplish the target. The GIS and remote sensing technologies are used on route selection of the West-East Nature Gas Transportation Cross Continent Pipeline. The Remote Sensing images and revising maps of 1:50000 based on new SPOT images, produced from a GIS system are offered to the planning department of the pipeline and used for in situ investigation to obtain wonderful results.

Kirsanov (2003) advanced methods of monitoring of Oil and Gas pipelines by Integrated GIS. Advances ways on how to environmentally monitor pipeline, construct and maintain routes for quick and effective response to emergency. The Author Integrated Geographical Information Systems (IGIS), based on geological-landscape and topographic maps and Data, obtained through Remote Sensing (RSD). High-resolution (5m) images, KFA-1 000, obtained from Russian satellite "Resurs-F" obtained from satellites, are used to compile large-scale environmental maps that serve as a base for monitoring. Comparison was made thereof with maps compiled in the process of monitoring that would permit Researchers to trace spatial and temporal landscape variations in a pipeline-impacted area and to compile

sketch maps of prediction of development of negative processes. The study makes good use of digital models of the country, which allows making modern software used in IGIS to develop three-dimensional models of the area under control. Studies carried out in some areas of the North-West of Russia, showed a great potential of using IGIS in environmental monitoring along pipeline routes.

Sandra *et al*. (1995) designed a Prototype for Pipeline Routing using Remotely Sensed Data and Geographic Information System Analysis, a designs prototype least cost analysis was performed for pipeline routing using remotely sensed data and GIS analysis. A small section of the proposed Caspian Oil pipeline was chosen for development of the prototype. The results of this analysis demonstrate the benefits of integrating remotely sensed data with GIS analysis as a first look for pipeline routing.

Feldman, Pelletier, Walser, Smoot and Ahl (1995) designed a prototype for pipeline routing using remotely sensed data and geographic information system analysis. A least cost analysis was performed for pipeline routing using remotely sensed data and GIS analysis. A small section of the proposed Caspian oil pipeline was chosen for development of the prototype. The entire proposed 700-km Caspian pipeline would connect with existing pipelines and carry oil from the Tengiz oil field in Kazakhstan on the Caspian Sea to Novorossiysk in Russia on the Black Sea. A model was developed incorporating pipeline length, topography, geology, land use, and stream, wetland, road, and railroad crossings to identify a least cost pathway. The straight line path was 42 km long, and the least cost pathway was 51 km long.

Although longer in length, the least cost pathway (in the area considered) is 14% less expensive to construct than the straight line path. The results of this analysis demonstrate the benefits of integrating remotely sensed data with GIS analysis as a first look for pipeline routing.

Davey GIS Services (2002) in Hancock (2006) assessed the impact of vegetation along the rights of way (ROW) and how to manage it for outage prevention (electrical transmission), maintenance access (pipelines) and safety (highways) in the environmentally sensitive areas of United States America. These areas are identified using specific attributes of hydrology, slope, and soils data. Enhanced management control measure was arrived at by deriving a map of environmentally sensitive areas using existing GIS data, incorporating advance knowledge of environmentally sensitive areas into ROW management plans to help bolster public sentiment, reduce costs, foster environmental stewardship, contribute to regulatory compliance, and provide legal defense assistance. The challenge of this work was certain management techniques such as herbicide use and heavy equipment are incompatible with various ROW landscapes.

However, not much works has been done as regards land-use planning, design, management of pipeline right-of-way and environment complexities affecting these pipelines done at a larger scale in Nigeria.

It is against this background that this research is formulated to use Geographic Information System and Remote Sensing techniques, in assessing the extent of encroachment and compliances of the various land uses to NNPC pipelines right-of-way in Northern Nigeria.

CHAPTER THREE

THE STUDY AREA AND METHODOLOGY

6.1 INTRODUCTION

This chapter presents and describes the general physical background of Northern Nigeria and the study approach and method that were adopted for data collection and analyses in this study. There are several published and unpublished texts/literature on the general geography of the study area especially regarding; location, extent, history, background, climate, relief, drainage, geology, soil and vegetation, topology and population. The detail given in this chapter includes information obtained from field observations, air photo interpretation, satellite imagery, in addition to relevant information already published. Fig. 3.1a and Fig. 3.1b presents the digitized diagram of the study area.

The method employed for this study, involves the use of computer-based GIS's techniques and Remote Sensing Systems, to analyze the satellite imageries provided for the study area. Data sources, sampling techniques of data collected are inclusive.

3.2 Physical Background of the Study Area

3.2.1 Location, Position and Size

Northern Nigeria is a geographical region of Nigeria. It occupies about two-third land mass of Nigeria. The region includes Kogi, Kwara, Benue and Taraba State towards the south. The people are largely Muslim, and many are Hausas. Much of the north was once politically united in the Northern Region, a federal division disbanded in 1967. Hausa and Fulani makes up the

Dominant Tribes. The area in focus covers approximately 60% of the Nigeria's land area. It is confined within latitudes 6^0 37' North - 13^0 40' North and longitudes 3^0 40' - 13^0 37' East (Times Atlas, 2012).

3.2.2 Historical Background

Northern Nigeria was a British colony formed in 1900. The basis of the colony was the 1885 Treaty of Berlin which broadly granted Northern Nigeria to Britain, on the basis of their Protectorates in Southern Nigeria. This was achieved through the activities of the Royal Niger Company, whose interior territories spread north from about where the Niger River and Benue River joined at Lokoja.

Britain's chosen Governor, Fredrick Lugard, with limited resources, slowly negotiated with, and sometimes coerced, the emirates of the north into accepting British Rule, finding that the only way this could be achieved was with the consent of Local Rulers through a policy of Indirect Rule which he developed from a necessary improvisation into a sophisticated political theory.

Lugard left the protectorate after some years, serving in Hong Kong, but was eventually returned to work in Nigeria where he decided on the merger of the Northern Nigeria Protectorate with Southern Nigeria in 1914.

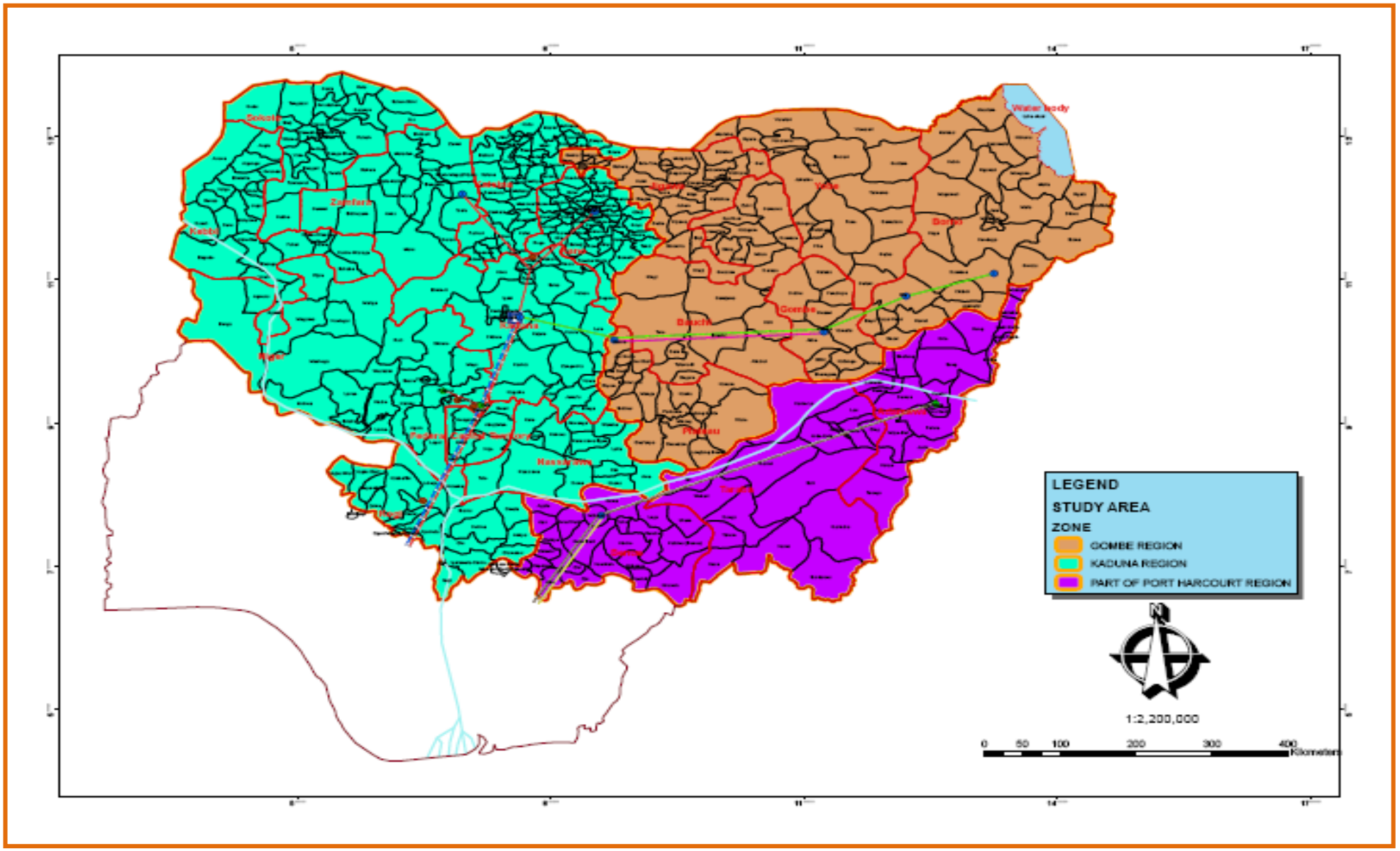


Fig. 3.1 (a): Study Area-Northern Nigeria.

Sources: Modified from Department of Urban and Regional Planning, Kaduna State Ministry of Environment (2012).

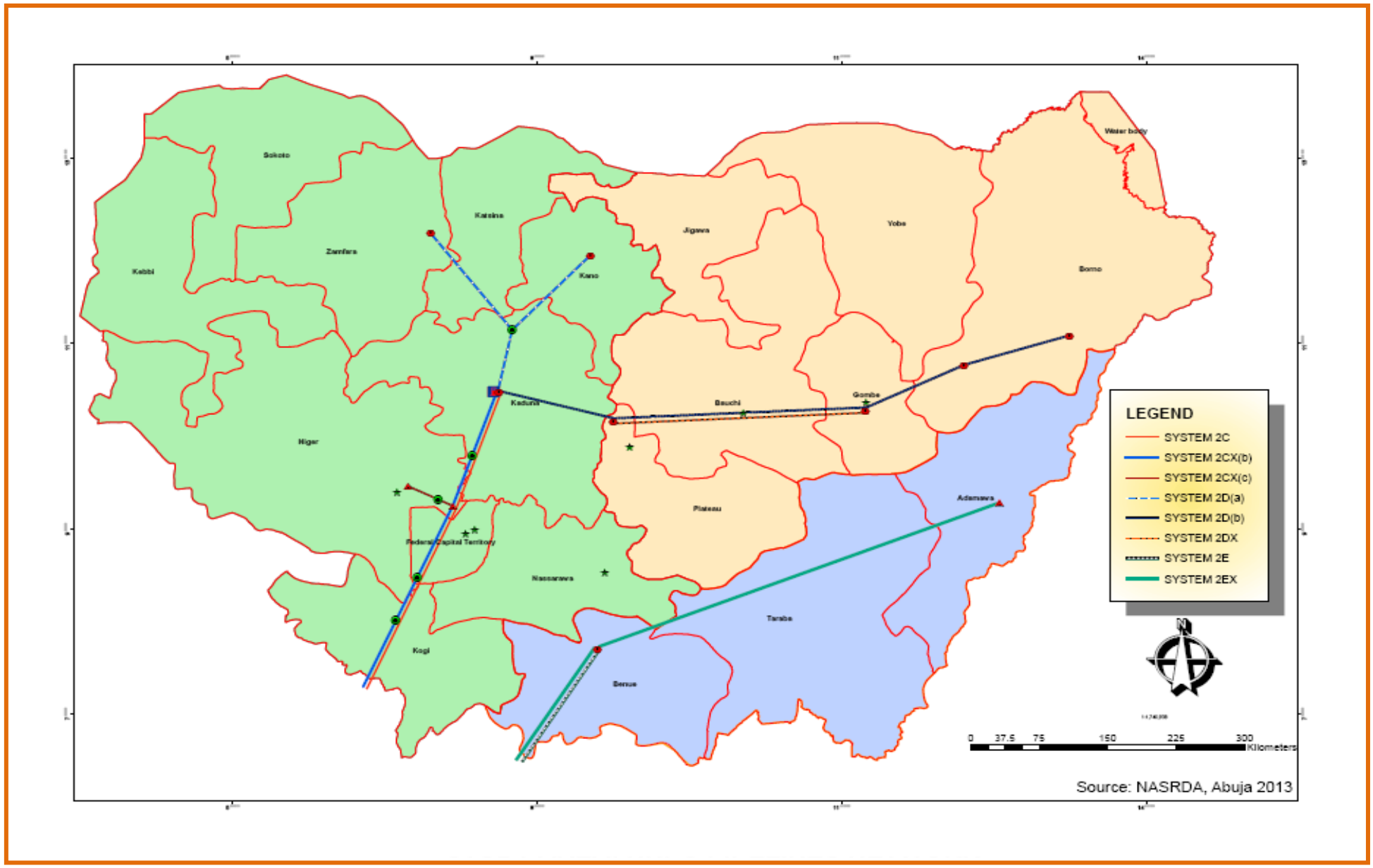


Fig.3.1 (b): Study Area-NNPC Pipeline Network.
Source: Modified from NARSDA, Abuja, 2013.

Before then there have been an existence of Hausa States. Between 500 CE and 700 CE Hausa people, who had been slowly moving west from Nubian and mixing in with the local Northern and Central Nigerian population, established a number of strong States in what is now Northern and Central Nigeria and Eastern Niger. Closely linked with the Kanuri people of Kanem-Bornu (Lake Chad), the Hausa aristocracy adopted Islam in the 11th century CE. By the 12th century CE the Hausa were becoming one of Africa's major powers. The architecture of the Hausa is perhaps one of the least known but most beautiful of the medieval age.

The Hausa Kingdoms emerged in the 13th Century as vibrant trading centers competing with Kanem-Bornu and Mali. The primary exports were Leather, Gold, Cloth, Salt, Kola Nuts, Animal Hides, and Henna. Except for minor alliances, the Hausa city-states functioned independently. Rivalries generally inhibited the formation of one centralized authority. There were fourteen Hausa Kingdoms: The "Hausa Seven" and the "Bastard Seven"

The Hausa Kingdoms began as Seven States with a shared mythology with its founders being the Sons of a Queen. They are known as the Hausa Bakwai meaning Hausa Seven. The States included: Daura ? – 1806, Kano 998 – 1807, Katsina c. 1400 – 1805, Zazzau (Zaria) c. 1200 - 1808, Gobir ? - 1808, Rano, Biram c. 1100 – 1805 (Times Atlas, 2012).

The growth and conquest of the Hausa Bakwai resulted in the founding of additional States with rulers tracing their lineage to a concubine of the Hausa founding father, Bayajidda. Thus they are called the 'Banza Bakwai

meaning Bastard Seven. The Banza Bakwai adopted many of the customs and institutions of the Hausa Bakwai but were considered unsanctioned or copy-cat kingdoms by non-Hausa people. These States include: Zamfara, Kebbi, Yauri (also called Yawuri), Gwari (also called Gwariland), Kwararafa (a Jukun State), Nupe (of the Nupe people), Ilorin (a Yoruba State)

Usuman dan Fodio led a jihad against the Hausa States and finally united them into the Muslim Fulani Empire, the Caliphate of Sokoto. Under him the Empire was bi-cephalous and divided into two territories each controlled by an appointed Vizier. Each of the territories was further divided into autonomous Emirates under mainly hereditary local Emirs. The Bornu Empire was initially absorbed into the Fulani Empire of Usman dan Fodio, but broke away after a few years later (Wikipedia, 2013).

3.2.3 Geology and Landforms

The study area is underlain by formations of three geological periods. The Basement Complex of the Precambrian periods dominates the southern part of Northern Nigeria. While the Sedimentary Zone of the Sokoto basin which belongs particularly to the cretaceous period and partially to the tertiary period, is to be found in the North.

Most of the region is underlain by a complex igneous and metamorphic rock of the pre-Cambrian ages. Furthermore, some parts of the study area are underlain by the Chad formation (unconformity), Kerri Kerri formation (unconformity), Gombe Sanstone, Fika Shales, Gongila formation, Bima Sandstone (unconformity) of the Pleistonecene, Maesticht, Senonian,

Turonian, and Cenomanian Ages in the Lacustrine Strata, Continental Strata and Eustaurine-Deltaic Strata environments in North-eastern part of Northern Nigeria. The Chad basin was a Tectonics Cross Point between a NE-SW trending 'Tibesti-Cameroon trough and NW-SE trending 'Air-Chad trough.

The Basement Complex has been described as having been composed of older high grade Igneous and Metamorphic rocks of the Precambrian to lower Paleozoic periods interspersed by belt of high younger Metamorphic rock. The predominant rocks are of the acidic and alkaline crystalline type such as Gneisses, magmatites and Granites, Schist. Quartzite and Hyalites occur extensively in the Western part of the complex. Granite is present in its old and young types in the study area; the old type of Granite presents a distinct feature in the form of inselbergs. These are smoothly grayish bare domed-rock which rises a hundred meters from amidst the wide undulating plains.

The study area is also underlain by undifferentiated Older and Younger Laterite with bed rock exposed in some places. The superficial deposits are by-products of various materials including crystalline igneous rock sediment and dentrital products. These superficial deposits of the young and older alluvium rest almost every where on the weathered basement. The younger laterite interwoven with alluvial deposits is characterized by accumulation of fine-grain grey brown sand, clay with silts and gravels in some parts of the study area. Distinctly banded sands, silts and clays along stream channels are cut to form bluffs which Higgins (1965) described as having a very typical Aeoilan drift appearance, being vertical and of a stable nature.

The plains is which is undulating in nature is largely compound of Biotite, Granite, Gneiss, Pyroblastic, Porphyriblastic with subordinate Migmatite. There are older rocks which are frequently exposed on the land surface weather in the form of doomed-hill (inselberg) or as low outcrops (Christopher, 2001).

Physical limitation to development in this study area, therefore consists of land liable to flooding and usually restricted to the broad valley floors, steep slope and gullies which occur along the smaller river valleys (Ministry of Land Survey Division, Kaduna 2014). Figure 3.2 Shows the geological and landforms characteristics of the study area.

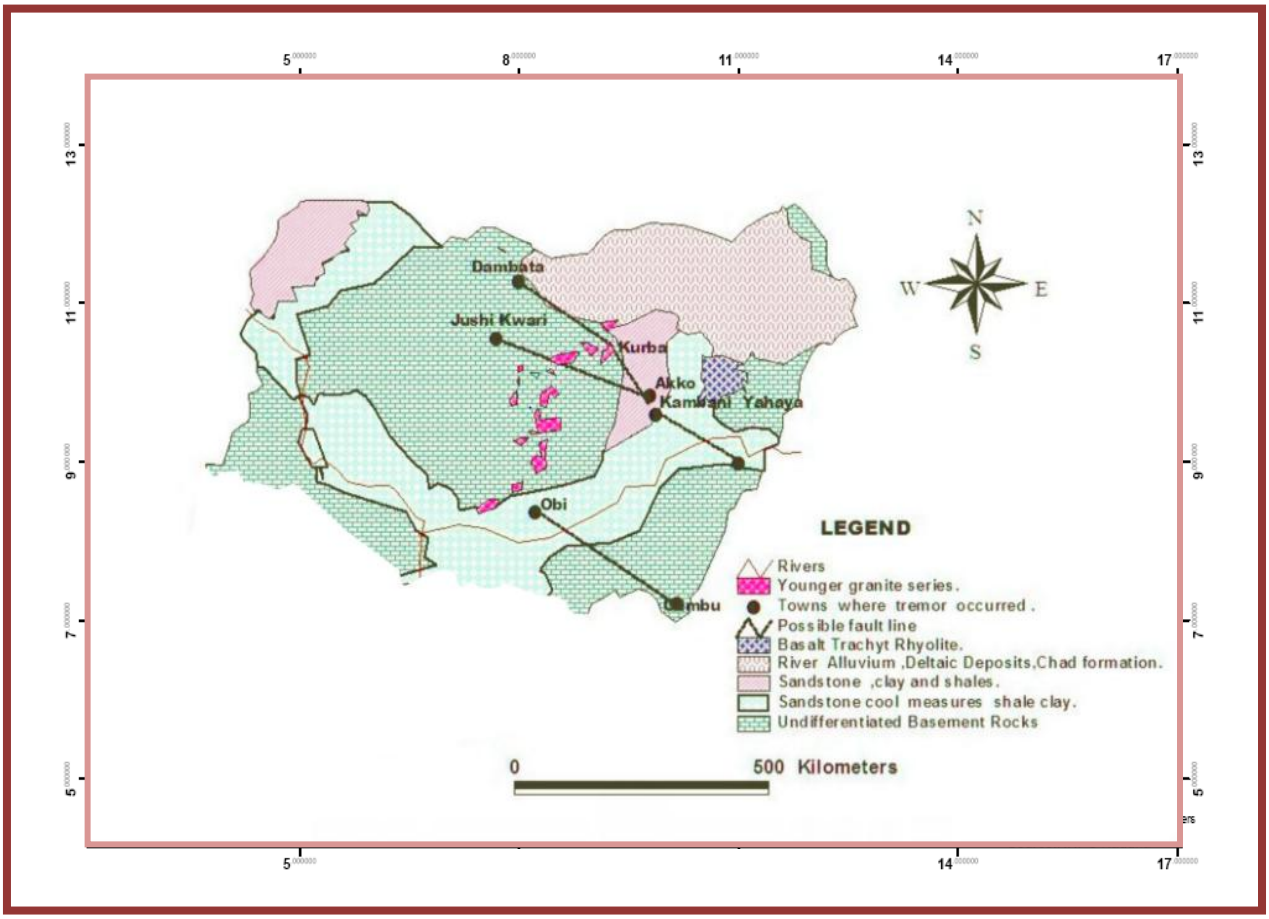


Fig. 3.2: Geology and Landforms of Northern Nigeria.
Source: Modified from Nigeria's Geological Map, 2014.

3.2.4 Relief and Drainage

The relief of the study area is a highlands (plateaux) and plains. The North-central are areas over 300 m above sea level. The area lies within the centre of Northern Nigeria and covers nearly one-fifth of the area. The highland is made up of two different platforms which lie at different levels. The high plains of Hausa land, whose average elevation stands at 750 metres from the lower step.

The Jos plateau is the highest platform with h an elevation of 1500-1800 metres. The Jos Plateau is a great hydrological centre or watershed with radial pattern of drainage in which many rivers take their source. The highest part is the Shere-hills, north-east of Jos where the elevation exceeds 1650 metres above sea level.

The plain, is an extensive gentle rolling peneplain which extends from Sokoto to Lake Chad, northward from south of Kogi and Benue to Tigueddi scarp near Agades, Niger Republic. The plains vary in height, reflecting both regional slopes to the south and local relative heights of 30-60 metres. The main low land areas include the Sokoto plains, in the North-west (200-300 metres), the Niger-Benue trough, wrapping round the North-central plateau (100-300 metres) and the Chad Basin or Borno, in the North-east extremity (100-300 metres). Hill features of two kinds surmount the plains-rock inselbergs and lateritic ironstone capped Messa. The inselbergs vary considerably in dimension and shape from the prominent landmark of the area.

The drainage of Nigeria is dominated by two great river systems, the Niger-Benue and the Chad systems. With the exception of a few rivers that

empty directly into the Niger-Benue, all other flowing waters ultimately find their way into the Chad basin or down the lower Niger to the sea. Many rivers in northern Nigeria rise from the north-central plateau. The river Hadejia, Yedseram, Komadugu, Gana and Gongola flow from the east, the Sokoto, Kaduna, Mariga and Gurara flow westwards to the Niger, while other small rivers like Mada and Gbako flow south-wards.

The two river systems; that are the Niger and the Benue are separated by a primary watershed extending northeast and north-west from the Bauchi plateau which is the main source of their principal tributaries. North-west of the plateau laid the elevated, drift-covered plains of central Hausa-land which is drained by numerous streams all flowing outwards to join the major tributaries (Kuruk, 2004).

3.2.5 Soils

The soil types as found and distributed in northern Nigeria have been greatly influenced by the climatic elements of precipitation (rainfall), temperature and wind (Ajayi 2003). The soil in northern Nigeria can be grouped into three (3) major zones, which are: the Coastal swamp or alluvial soil zone, lateritic soil zone and loess and sandy soil zone. coastal swamps/alluvial soil zone found along the flooded plains of rivers particularly the Niger and Benue coastal plains, Chad basin and Lokoja, lateritic soil zone has the largest area of coverage in Nigeria, as they are found occupying the interior part of the country covering places like Benue, Kwara, Plateau, Niger, Kogi, Kaduna, Kebbi, Bauchi, Adamawa, Taraba State etc.

They occur in areas with long period of dry season alternating with wet season. The soils over Northern Nigeria plains are generally of the laterite, formed from drift deposits which mantle the solid sedimentary and pre-Cambrian basement granite rocks. They are generally reddish in colour due to the presence of iron content in them. They are of little use for farming purposes, because of their poor fertility. Thus, fertilizer is constantly added to it to enhance its performance. Some minerals like iron and aluminum compounds are found contained in the soil. The zone of lateritic soils present in some fertile and productive soils is due to the accumulation of nutrients at the B-horizon are strongly influenced by the action of the parent materials. Thus, the soil supports the cultivation of tuber crops like Cocoyam, Cassava and Yam (Ajayi, 2003).

The loess and sandy soil zones are found mainly in the extreme part of Northern Nigeria in places like Kano, Katsina, Bornu, Yobe, Jigawa, Sokoto and part of Kaduna State, occurring in the Sudan and Sahel savanna belt of the country. They are formed directly from the parent material due to dryness and are transported and deposited by wind. Crops like Groundnut, Millet, Maize, Guinea-corn and Cotton are widely grown. Topographical factors appear to play vital role in determining their detailed characteristics. In some hills in the study are the young coarse or weakly developed soils (Regosols). The soil in the valley bottom lands (Fadama) belong to the Intragonal group especially hydromorphic soils or vertisoils (Klinkenberg, 1970) due to accumulation of both organic matter and alluvium.

They are confined mainly to the water courses of the major rivers. They are characterized by dark-grey clay with poor to very poor drainage. Generally, the character of the soils is such that as soon as rainfall starts, infiltration could be quite high but the pores soon get sealed up with fines and further infiltration is impeded resulting in over land flow, sheet flow and channel initials (Makeri, 1989). Many parts of the Fadama in the studied areas are therefore used for cultivation of fruits, Vegetables, Rice and Sugarcane. Adequate drainage is often a problem, while the lower temperature during the dry season can also be harmful to some crops (Ministry of Survey, Kaduna).

3.2.6 Climate

Northern Nigeria possesses a Tropical Continental (TC) climate consisting of pronounced long dry season alternating with a distinct but short rainy season. The high amount of radiation received by this area has contributed to its high temperature which varies from about 28^{o}C to 42^{o}C, depending on the atmospheric condition prevailing at that particular point in time. Temperatures are high daily Maximum Temperature rises generally from as low as <13^{o}C in January to its peak of >35^{o}C in April/May. A secondary high is often encountered in October. Also the mean Minimum Temperature rises from is lowest value in December/January (15^{o}C-20^{o}C) to its highest (35^{o}C-42^{o}C) in March-April.

During the dry season's months, the Tropical Continental (Tc) North Easterly which is cool dry and dust laden 'harmattan' blows from the Sahara, bringing low humidity, and cool temperatures may go below 10^{o}C at night in

some parts of the study area. Temperature during the summer month in extreme Northern Nigeria in areas like Sokoto, Kebbi, Yobe, Borno States temperatures may reach as high as 48^{o}C during which moisture laden winds blow from the Gulf of Guinea in the south bringing higher humidity and rains. The Monsoon rains in general show high spatial and temporal variability over the extremes of the study area.

Rainfall is generally less-than 500 mm annually the rains at their peak in August. Evapo-transpiration is over 2000 mm annually, with an annual average of about 2300 mm annually (Abdulkarim, 2003). In the study area the annual temperature range is greater, about 6^{o}C while the diurnal range is quite considerable, about 15^{o}C.

Thus Northern Nigeria lies within a region that has a tropical rainy climate of Tropical Grassland (Savanna) (Aw) and a superficial presence of Tropical Rainforest climate of the Am-type particularly at the southern part of the region with distinct wet and dry seasons, the wet season occurring in the high Sun period (May-September) with an average annual total of above 1100 mm, with the region having a single maximum, which comes during the month of august. The dry season is practicably rainless. But currently due to the effects of climate change the single maximum is being experienced in September.

The rainfall distribution over Northern Nigeria, Nigeria and West Africa is determined by the position of the Meteorological Equator and its two associate structures; the Inter-Tropical Front (ITF) and the Inter-Tropical Convergence Zone (ITCZ) also known as the Inter-Tropical Discontinuity

(ITD). These two form a discontinuity zone at their boundary. The surface position of the ITD moves north and south of the study area, in an oscillatory movement-the part of Nigeria where Northern Nigeria lies is invaded by two distinct air-masses, one from the north-dry and continental origin, and the other from over the Atlantic in the south-most, cool and equatorial maritime in nature.

Over much of Nigeria's interior, rainfall often experiences conventional origin, the air being forced to rise by intense heating of the land or by relief features like the Jos plateau. The generalized annual rhythm of weather in Northern Nigeria follows the annual march of the surface position of the ITD. Thus the seasonality of the area is stratified into:

Dry season (harmattan)	-	November to February.
Hot season	-	March to April.
Season of thunderstorms and qualls	-	May to June.
Wet season	-	July to October.

The Sahelian rainfall depends exclusively on the position of the ITF rainfall often convective in origin (Goni, 2006). The rainfall depth in the study during wet season (May-October) is between <500 mm->1250 mm. The low relative humidity experienced in dry season is a product of dry, dusty and cold harmattan air. The table shows the rainfall and temperature statistics of northern Nigeria. Table 3.1 and figure 3.3 below summarized the rainfall-temperature characteristic of the study area.

Table 3.1: Rainfall and Temperature Values of Northern Nigeria.

Climate Types	Land Cover	Rainfall	Temperature Maximum	Temperature Normal	Temperature Minimum
	(%)	(mm)	(°C)	(°C)	(°C)
Semi-arid	4	400-600	13	32-33	40
Dry sub-humid	27	600-1,000	12	21-31	49
Sub-humid	26	1,000-1,300	14	23-30	37
Humid	21	1,100-1,400	18	26-30	37
Mountainous	4	1,400-2,000	5	14-29	32
Plateau	2	1,400-1,500	14	20-24	36

Source: Kundell, 2008.

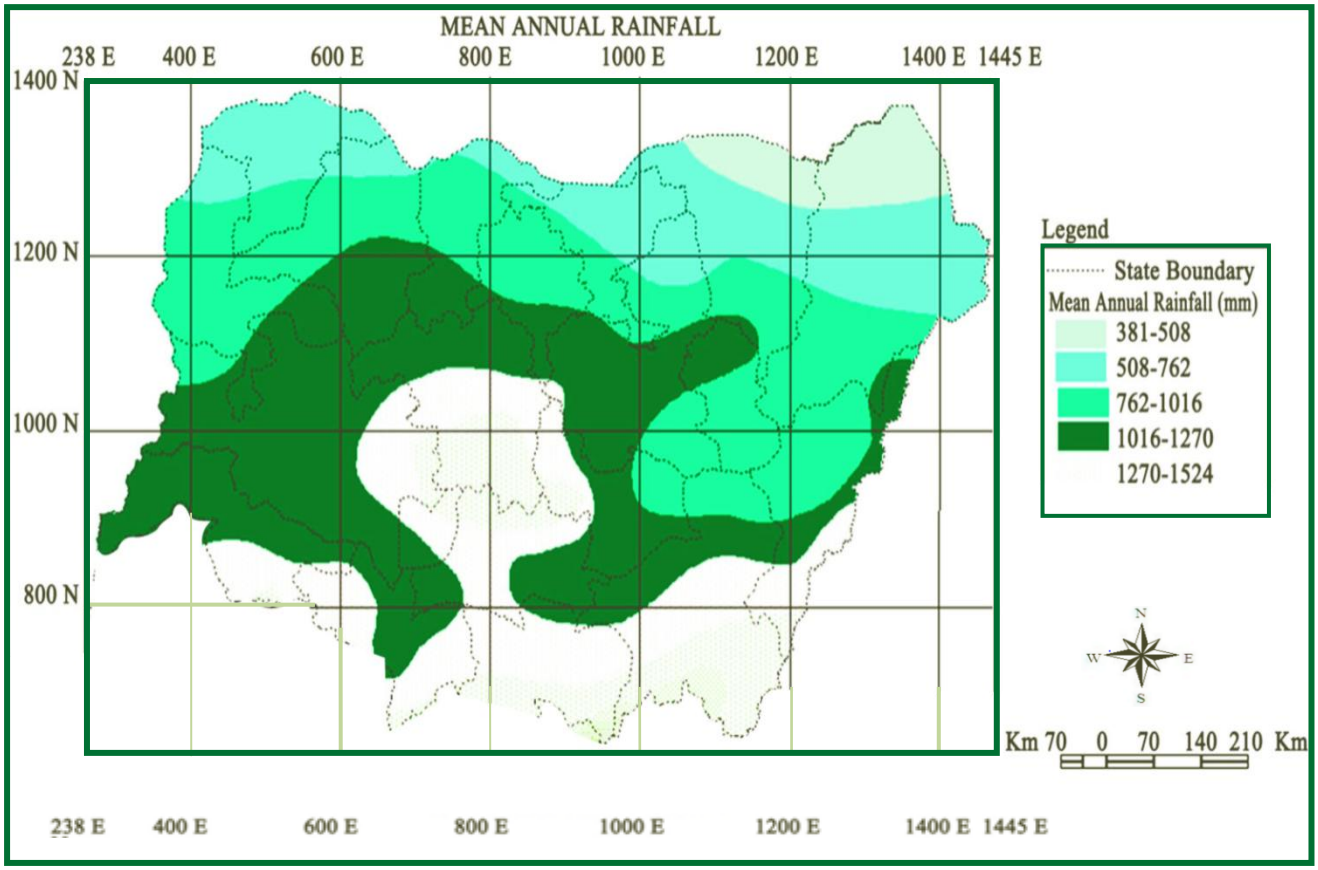


Fig. 3.3: Mean Annual Rainfall of Northern Nigeria.
Source: Modified from Nigeria's Rainfall Map, 2014.

3.2.7 Flora and Fauna

The seasonal characteristics of the rainfall makes its mark on the vegetation of the area which assumes various shades of green in the wet season and turns brown, pale or yellow in the dry season. Northern Nigeria is located within the Guinea savanna in places like Abuja, Adamawa, Benue, Kogi, Niger, Taraba States etc, Sudan savanna in Bauchi, Gombe, Kaduna, Kano States etc and Sahel Savanna-Borno and some part of Sokoto. The vegetation patterns show that, the pattern owes it existence largely to land use management practices over a very long period of time.

The areas that lies within the Guinea savanna zone, the vegetation consist of a wide varieties of communities which includes; commonly of woody plants and grasses which are fire-hardy species consisting of several woody species alone, occurring from the southern area towards the north wherever firing of savannah woodland takes place. The chief trees are *Isoberlina*, *Mangigera Indica*, *Psidium Guava* and *Parkia Bigloboza*, Acacias, Baobab and Shea-butter among others. While grasses includes *Clenium Newtoni* etc. There are also shrubs such as *Boswellia Dalzielli* etc. the vegetation in spots of forest in the study area commonly consist of trees such as *Albizia Zygia*, *Khaya Grandrofiola*, *Urania Chamaca* and *Chlorophora Esccelsa*.

The major agricultural practice includes; the cultivation of grain crops and some fruits. The main towns are mostly the Capital City of the States that falls within this vegetation zone. In the Sudan Savanna vegetation zone, found north immediately north of the Guinea savanna, has grasses as its dominant

vegetation. The grasses found are shorter in size than those found in the Guinea Savanna. The height of the grasses is greatly affected by decrease in rainfall. The major trees found within this zone include Acacias, Dumb-palms, Fan-palms and Shea-butter.

The grasses are multivariate in nature and have developed durable roots, which remain underground after the tops have been burnt by fire during the dry season. After the dry season the grass sprawl again with the onset of rain. The Riparian Vegetation (along stream valleys) is usually dense and made up of savanna woodland. The Sahel Savanna vegetation belt is located north of the Sudan Savanna. This vegetation belt has rainfall less than 450 mm and this gives way to the poor grasses, scanty short shrubs/trees. Few drought-resistant trees like Baobabs, Acacias and Date palms are found (Ajayi, 1998). Ornamental vegetation is now common around residential and administrative corridors. Botanic gardens have increased the greening of decline in the natural vegetation (National Bureau of Statistics, 2009).

The fauna in study area consists of a variety of Mammals, Birds, Reptiles, Amphibians, Fishes and some Insects. These no longer inhabit in area, now largely influenced by man, but are mainly restricted to peripherals of human habitation and to areas unexploited yet (Lewis, 1962). Some over 370 species of birds have been recorded from the study area of residents, Palaeartic migrants and African migrants. The Bushbuck, Grey Duiker, Oribi, Warthog and Western Hartebeest, Bush Cow, Water Buck, Bush Pig, Antelope, Monkey and Lions and Elephant found in sound in the Games Reserves and National Parks-Yankari (Bauchi), Gashaka Gumpti (Taraba),

(Kaduna), Kainji (Niger) and Kamuku (Kaduna) in the study area constitute some of the large mammals. Varieties of insects make up the terrestrial and aquatic fauna moths, the Tachinid fly, Termites (T. *Trinervetermes*, T. *Ebenerianns*, T. *Oeconomus*), Centipedes and Millipedes (Myriapods), Leach and Pocock, Snakes, Lizards, Toads, Frogs and Chameleons, Alligators, Crocodiles, Hippotamus, each of different species make up the amphibian and reptilian life.

There is considerably variety of habita t types in the study area: mature and degraded savannas, farmlands, fadama, fringing forests, inselbergs, open streams, lakes and temporary pools. Each must pose particular problems for its fauna but the main problem confronting many animals must be the modification of the environment by man and his action (Lewis 1962). Fig. 3.4 below show the vegetation types of the study area.

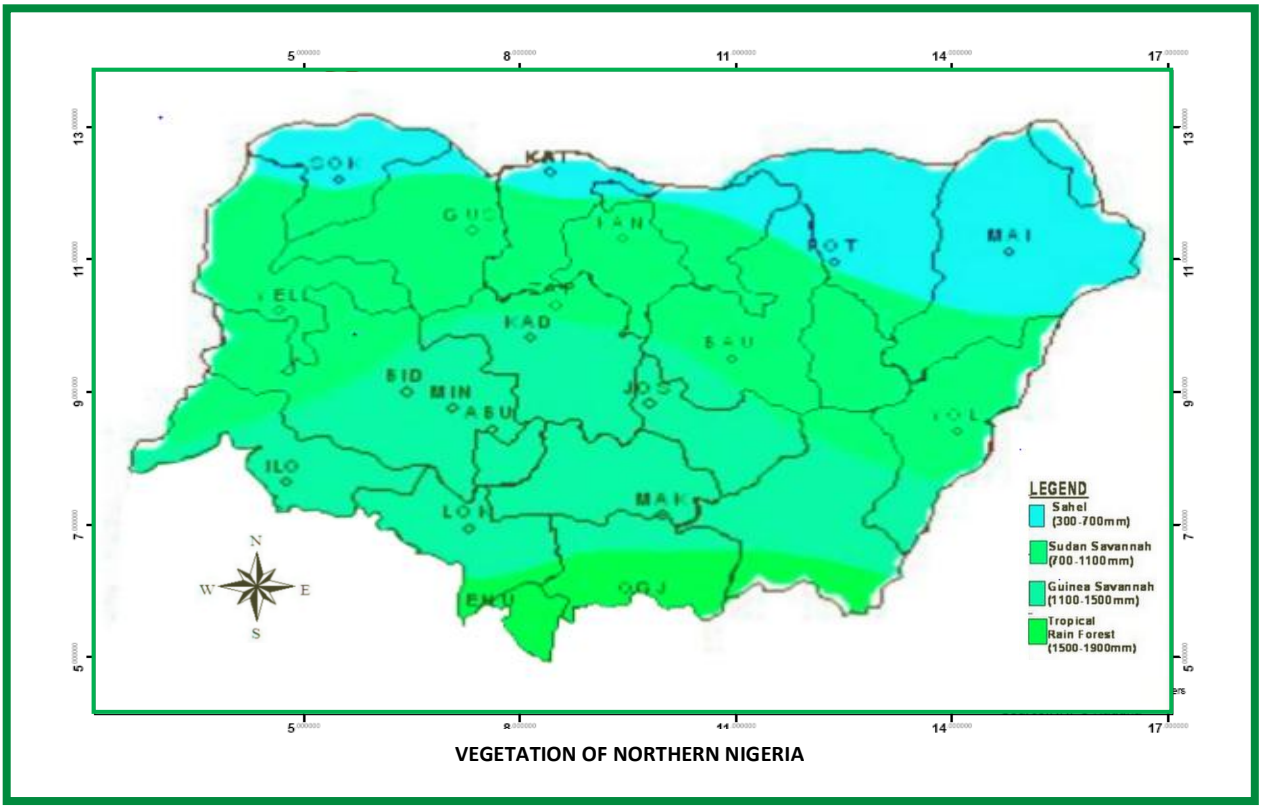


Fig. 3.4: Vegetation of Northern Nigeria.
Source: Modified from Nigeria's Vegetation Map, 2014.

3.3 Human geography

The improvement in basic facilities and more quality in social amenities have brought about an improvement in the standard of living of the populace. Urban land use does not just occur; it is formed through processes and therefore, depicts regulation and order in space use and organization. Due to increase in population, there is a major impact upon the plant communities, which now bear the profound mark of anthropogenic influence.

3.3.1 Population and Demographic Characteristics

Population constitutes a vital component of the potentials for land use and impact on the terrain of the study area. Most relevant elements of the population are its size, rate of growth and spatial distribution.

The study area according to National Population Commission has a population of 73,637,065 people, excluding the Federal Capital Territory (Nigerian News, 2006) 48% of these numbers are Women. The rate of growth of population (per annum) follows a similar trend to that of the Northern Nigeria's States during the 1991 Census. The population of the study area is not even. Northern Nigeria comprises of several ethnic groups. Almost all different races (tribes) within the country are fairly represented in the towns.

The indigenous ethnic groups includes Kataf, Igala, Nupe, Basage, Latang, Idoma, Okun, Igirra, Jukun, Tiv, Kanuri, Shuwa Arab, Hausa and Fulani, while the migrants or settlers are made up of Yoruba, Igbo, Edo, Calabar, Ijaw, Urhobo etc (Max, 1967).

Islam and Christianity are the predominant religions in the towns, also there are few Customary or Traditional Believers (Udo, 1978). Reconnaissance surveys showed concentration in major settlement in the capital city of the states and along the major roads. Most urban developments are concentrated also along the same axis. Father away from major roads we have scattered or isolated settlement of between a few and hundreds people mainly Fulani herdsmen and sedentary farmers. Table 3.1 below shows the population distribution and demographic characteristics of the people domicile in the study.

Table 3.2: Population Distribution and Demographic Characteristics of Northern Nigeria.

NORTH-CENTRAL					
S/NO.	**STATE**	**MALE**	**FEMALE**	**TOTAL**	**% OF THE NATION**
1.	BENUE	2,164,058	2,055,186	4,219,244	3.01
2.	KOGI	1,691,737	1,566,750	3,258,487	2.33
3.	KWARA	1,220,581	1,150,508	2,371,089	1.69
4.	NASARAWA	945,556	917,719	1,863,275	1.33
5.	NIGER	2,032,725	1,917,524	3,950,249	2.82
6.	PLATEAU	1,593,033	1,585,679	3,178,712	2.27
	SUB-TOTAL	**9,647,690**	**9,193,366**	**18,841,056**	**13.46**
NORTH-EAST					
	STATE	**MALE**	**FEMALE**	**TOTAL**	**% OF THE NATION**
7.	ADAMAWA	1,606,123	1,561,978	3,168,101	2.26
8.	BAUCHI	2,426,215	2,250,250	4,676,465	3.34
9.	BORNO	2,161,157	1,990,036	4,151,193	2.97
10.	GOMBE	1,230,722	1,123,157	2,353,879	1.68
11.	TARABA	1,199,849	1,100,887	2,300,736	1.64
12.	YOBE	1,206,003	1,115,588	2,321,591	1.66
	SUB-TOTAL	**9,830,069**	**9,141,896**	**18,971,965**	**13.55**
NORTH-WEST					
	STATE	**MALE**	**FEMALE**	**TOTAL**	**% OF THE NATION**
13.	JIGAWA	2,215,907	2,132,742	4,348,649	3.11
14.	KADUNA	3,112,028	2,954,534	6,066,562	4.33
15.	KANO	4,844,128	4,539,554	9,383,682	6.70
16.	KATSINA	2,978,682	2,813,896	5,792,578	4.14
17.	KEBBI	1,617,498	1,621,130	3,238,628	2.31
18.	SOKOTO	1,872,069	1,824,930	3,696,999	2.64
19.	ZAMFARA	1,630,344	1,629,502	3,259,846	2.33
	SUB-TOTAL	**18,270,656**	**17,516,288**	**35,786,944**	**25.56**
ABUJA (FEDERAL CAPITAL TERRITORY)					
		MALE	**FEMALE**	**SUB-TOTAL**	**% OF THE NATION**
20.	ABUJA	**740,489**	**664,712**	**1,405,201**	**1.00**
TOTAL POPULATION FOR NORTHERN NIGERIA					
		MALE	**FEMALE**	**SUB-TOTAL**	**% OF THE NATION**
	NORTHERN NIGERIA	**38,488,904**	**36,516,262**	**75,005,166**	**53.37**

Source: National Population Commission, 2006.

3.4 Research Methodology

3.4.1 Field Reconnaissance Survey

A reconnaissance survey was carried out in order to observe the trend of human activities and the pattern in which the land is being used, as it affects pipelines' right-of-way and to get a better perspective of the study area, have overview of the spatial distribution of NNPC pipelines and to collect ancillary data, which would be useful for the study was also collected in the process. The interpretation processes were carried out using both software and hardware.

Also, planning and gathering of relevant materials and going round the study area to identify major land use types encroaching into NNPC pipelines' right of ways were also done. The study area which composes of northern Nigeria, have witnessed significant changes in its landscape over time and encroachment due to human-induced land degradation of a complex nature (Christopher, 2001). Hence areas that are rapidly encroaching into the NNPC pipelines' right-of-way, urbanization, increasing population growth rate, etc were noted.

3.4.2 Types and Sources of Data

In order to achieve the aim of this study, in line with the stated objectives, data were sourced for and collected from satellite imageries, topographic and administrative maps and questionnaire administered from both primary and secondary sources. These types and sources of data are tabulated in table 3.3:

3.4.2.1 Primary Sources of Data

The required data that are necessary and essential for this research work such as data on Depot, Pump Station, Booster Station, Retail Station and Pipelines' locations (coordinates) and features were collected, collated and gathered from the sites of depots, pump stations and retail stations where these pipelines are laid and networked using handheld GPS. Satellite imagery was used for acquisition of data on land use/land cover classification. The present state of pipelines and environmental complexities affecting these pipelines are collected through oral interview and administration of questionnaire.

3.4.2.2 Secondary Sources of Data

The secondary data on Topography, Contours, Aspects, Slopes and Elevations, Agriculture, Built-up, Roads, and Water Bodies' features & areas, National & States' Boundaries, NNPC Pipelines that falls within the study area, pipelines vandalized and oil spillages are obtained from topographic maps, and from other relevant documents and literatures explaining the nature of the study area. These include administrative map and land use map amongst others. Trained GIS's operation assisted in the production of composite maps from the topographic map, administrative map and from the satellite imageries of the study area.

3.4.2.3 Instruments Used

The data which were used for this research work are from two imagery sources, namely; Landsat-SRTM and Landsat–SRTM (layers 3:2:1). The landsat–SRTM was imaged in the 2012s while the Landsat–SRTM (layers 3:2:1) was imaged in the 2013s.

The Landsat was launched by the National American Space Agency (NASA) in 1982 and is equipped with three channel Return Beam Vidicom (RBV) working in a panchromatic mode and a multi-spectral scanner with four band that is designed specifically for earth resource survey (Howard, 1991). The SPOT-XS satellite was conceived and developed by the French centre; *National de Etude Spatial* (NES). It was launched in 1986 by the French and is equipped with a multi-spectral linear sensor which can operate in three spectral bands (Howard, 1991). The imageries were brought to Universal Transverse Marcator (UTM) projection in zone 32 with the aid of the handheld GPS Garman 72CSX which converted the degrees to UTM to ease the geo-referencing of the images.

Table 3.3: Types and Sources of Data required for the Study.

S/NO.	DATA TYPE	DATA SOURCE	DATE OF PRODUCTION	SCALE AND RESOLUTION	DATA VENDOR	USES
1.	Data on Topography, Contours, Aspects, Slopes and Elevations.	Landsat Image SRTM.	2012	30 Meters	NASRDA (Primary)	For Land Use Classification and for creation of Digital Elevation Modelling (DEM).
2.	Data on Agriculture, Built-up, Roads, and Water Bodies' features & areas.	Landsat Image SRTM (band 1, 2, and 3).	2013	15 Meters	GRFL (Primary)	For Land Use Classification.
3.	Data on Refinery, Depot, Pump Station, Booster Station, Retail Station and Pipelines' locations and features.	Cadastral Map of NNPC Properties.	2013	1:2,000,000 (View Scale)	Kaduna Polytechnic Survey and Geo-informatics Department's Map Section (Secondary).	For Mapping of Refinery, Depot, Pump Station, Retail Station and Pipelines.
4.	Data on National & States' Boundaries.	Cadastral of Nigeria.	2012	1:5,000,000 (View scale)	NASRDA (Primary)	For Mapping of National boundaries.
5.	Data on NNPC Pipelines' Regions and for Cross-matching data on States' Boundaries that falls within the Regions.	Administrative Map of Northern Nigeria.	20012	1:25,000,000 (View scale)	Department of Urban and Regional Planning, Kaduna State Ministry of Environment (Secondary)	For Mapping of State, Local Government and Administrative boundaries and for Identification, Mapping and placement of Object/features.
6.	Data on Refinery, Depot, Pump Station, Booster Station, and Retail Station's coordinates.	GPS (Coordinate points).	2001	-	GPS 72CSX Manufacturer	For picking up of coordinates of locations/feature.
7.	Data on existing Object/features on pipelines' plan.	The Skeletal Design Layout (plan) of Pipelines.	2013	1:100, 000, 000 (View scale)	NNPC Official Website.	To aid and to guide in the placement of objects/feature.
8.	Data for reviewing past and existing works and for scholarship.	Literatures, Documents, Periodical, Journal and Conference Paper.	1978-2014	-	Federal Government, NNPC, Authors, Academia and Publishers.	To identify regulations and Act on pipeline by FGN, Land Use Act, and to reviewed relevant literatures.

Source: Researcher's Work, 2014**.**

3.4.3 Methods of Data Collection

To achieve this objective, the following techniques were used for data acquisition and collection from both primary source (field work) and secondary source.

3.4.3.1 Ground Truthing

This stage involved performing surface observation and measurements of various properties of the features of the ground resolution cells that are being studied on the remotely sensed digital image.

It involves taking geographic coordinates of the ground resolution cell with GPS technology and comparing those with the coordinates of the pixel being studied provided by the remote sensing software to understand and analyze the location errors and how it may affect the study.

Also, other information are collected on location by taking pictures of striking non-compliance to NNPC right-of-way sites in term of their dimension and character and measurement of the distance of setbacks of pipelines' right-of-way.

The materials used for this study include measuring Tape, Pegs, Ranging Poles, Global Positioning System (GPS) (Garmin 72X) and Camera (Canon Digital camera) to determine and up date the existing situation on base map and on the nature of satellite images such as the imageries acquired in both soft and hard copy. The hard copy were scanned first before they were imported into the system, while the soft copy were directly imported into the

system using ILWIS for land-use classification and ArcMap ArcInfo GIS mapping interpretation. The two sets of imageries for the year 2012 and 2013 are Landsat-SRTM Band 1, 2 and 3 of 30 m resolution for land-use classification and DEM mapping and Landsat-SRTM of 30 m resolution which was resample to 15 m resolution.

3.4.3.2 Personal and Oral Interview

Interviews were conducted with the Staff of Nigerian National Petroleum Corporation and Ministry of Environment within the study areas. Personal interviews were conducted with Farmers, Fishermen, Oil Workers, Environmentalists, Staff of Nigerian National Petroleum Corporation and Ministry of Environment, Fishermen and Women, Market Men and Women one on one. Questions were asked verbally in order to determine the critical parameters and variables as well as problem associated with the encroachment into the right-of-way, vadalization, monitoring of pipelines in the study areas.

3.4.3.3 Questionnaire Administration

The objective four (4) was achieved via the administration of copies of questionnaire to respondents, mostly to Community Members where these pipeline criss-crosses in the study area, such as; Oil Workers, Environmentalists, Staff of Nigerian National Petroleum Corporation and Ministry of Environment, Farmers, Fishermen/Women, Market Men and Women.

Two Hundred and fifteen (215) copies of a designed questionnaire was stratifiedly shared in proportional to the sampled population of

Correspondents in the setback zones of the study areas, where these pipelines criss-crossed. A Non-probability Sampling was adopted in selecting the population of this study. The Sampling Technique that was used is the Purposive or Expert Choice/Judgment Technique. This is because of the specialty of the study and the frame in selecting the recipient.

For the purpose of administering the questionnaire, the questionnaire was administered on the basis of quality that one must posses (Bernard, 2002). As part of the quality one must posses, is that Correspondents must be of age of thirty-five (35) years and above and who must have lived at least, twenty (20) years within the study area was indentified and issued a copy of the questionnaire. The reason for this decision is that those within the age bracket will have the information needed about encroachment into the NNPC Pipelines' right-of-way and other environmental issues.

The selection of respondents was based on the following criteria:

iii. Their occupations and activities as it affects NNPC pipelines network.

iv. Their knowledge and experience on the impacts of environmental complexities as regards pipelines' right-of-way.

Pertinent consultation to past works of different authors, who had worked on the subject matter, particularly on pipeline right-of-way were also referred to and reviewed. The content of the questionnaire was structured into three sections as follows:

iv. Perception of Respondents on the concept of Remote Sensing, Geographic Information System and environmental issues associated with oil Pipelines in Nigeria.

v. Assessment of the role of NNPC, Construction Companies and Planners in the planning, control and management of oil pipelines' right-of-way in Nigeria.

vi. Willingness to address problems associated with oil pipelines in Nigeria by Stakeholders: Government and Private Sectors.

The data that will be gathered and collated from respondents, was computed, manipulated, analyzed and statically presented to reveal the responses from the use of descriptive and Influential Statistics (applying the frequency and percentage formula) to summarize the responses, using Four Likert Scale System of Strongly Agree (SA), Agree (A), Disagree (DA), Strongly Disagree (SDA) and Grand Mean (X).

3.4.4 Hardware Used for the Study

Hardware Used for Analysis of Data

The hardware used to perform; this operation was a high plug-speed, memory digital electronic HP Laptop PC, processor Core i7 CPU (8 Processor), Intel Memory (RAM) 8.00GB and a Pentium based Personal Computer with the following configuration was used: 4 MB RAM, 1 HP Hard Disk, H.D.D 1,000 GB, 3.2MHz Core i7 Intel Processor, 14.1" W x GA wide TFTLCD, DDR 3, Scanner, Screen Digitizer, A2 & A3 Laser

Printer/Plotter, UPS (Uninterrupted Power Supply) and Garmin map 72CSX hand held GPS.

The Laptop Computer through the softwares installed was used for data analysis of the research work and type setting of the research Thesis, while the Desktop Computer was used as stand-by and Backup System. The Scanner was used to convert the remote sensed imagery and analogue map into a digital format for digitization and victimization operations to be carried on the map hard and soft copy substrates of the study area. The Global Positioning System, GPS, was used for taking or calculating coordinates, control points and for ground truthing. Finally, the Plotter was used for the production of large format and high quality of maps in vectors form.

Software Used for Analysis of Data

Basically, two softwares were used for this project; ArcMap ArcInfo Version 10.1 and Microsoft Access version 2007. However, other softwares such as Windows XP/2007-2010 Operating System, Microsoft Word, SSPS and Notepad were used to compliment the functions of the two major softwares used. The 'modus operandis' of these softwares are:

(c) ArcMap ArcInfo Version 10.1: this software was used for importing, displaying and subsequently processing and enhancement of image. The software was used in the conversion of satellite acquired images into digital format. The digitizer was run over line and recorded in series of zeros and ones. It was also used for the development of land use/land cover classification. The digitized features were edited in the same software.

(d) Microsoft Access Version 2007: this software was used to create database, as a reservoir of attributes that support as well as contain the information that gives room for integration, manipulation and analysis of graphical data observing the logical stages that must be followed. Database was created in tabular forms (attribute table) linked to vector data for NNPC Refinery, Depot, Pump Station, Retail Station and Pipelines in the Northern Nigeria which comprises of the Kaduna, Gombe and part of the Port Harcourt region. Microsoft Word software is used for the preparation of the project report.

3.4.5 Data Processing

3.4.5.1 Sub-setting

Coordinates of the study areas were picked from the acquired imagery and map and are registered to create a box which defines the subset made up of the study using ArcMap Arcinfo GIS 10.1 software.

3.4.5.2 Image enhancement

The linear contrast stretch was used in the ArcMap ArcInfo modelling functions to increase visual discrimination amongst objects in scenes of all images for better visual perception and interpretation. All images filtered to reduce stripping effect.

Image thinning was carried out through contrast; contrast generalizes an image by reducing the number of rows and columns, while simultaneously decreasing the cell resolution. Contraction may take place by pixel thinning or pixel aggregation with the contracting factors in X and Y

being independently defined. With pixel thinning, every n^{th} pixel is kept while the remaining is thrown away.

3.4.5.3 Rasterization

Data conversion from analogue to raster map was accomplished by editing the segment map for common digitizing errors (Calistus, 2000). Having edited the segment, it was then polygonised and subsequently rasterized. Attribute data operation was carried out using the keyboard. The classification of the various land use and mapped encroachment into NNPC pipelines' right-of-way was done using various colours to identify each type of land use types encroaching into pipelines' right-of-way. The use of pixel however, cannot be over-emphasized because it aided the classification of features without much problem.

3.4.5.4 Vectorization

vectorising depends on the programme that is available. There are some softwares that operate in automatic vectorizing environment, that is when a computer cursor is clicked on any of the line it could automatically trace the whole section in a matter of seconds, where as some operate in manual digital format where tracing is done manually. This gives chance for error correction. On the spot correction is done before a system is saved and printed. For this study, after the geo-referencing, image enhancing and conversion format. The major features on the satellite imagery and base map are traced through the clicking of cursor. The features being trace in different sizes and shapes comprises of dotted lines join together which

could only be detected by zooming the system, this encourages or make possible certain over stretched line to be erased. In this operation, the arrangement of higher points above the other, editing of coordinate list, plotting or printing out of digital data for visual editing (e.g. zooming an error in line digitizing) and topological editing i.e. removal of dead ends e.g. over shoot or joining under shoot.

3.4.5.5 Edge Matching

Edge matching is an editing procedure use to ensure to ensure that all features along share borders of the imagery/map have the same edge location; coordinates of the objects along share borders are adjusted to match the neighbouring data sets. This processes was carried out for each of the imagery and map used for the assessment of the subject matter (right-of-way)

3.4.5.6 Digital Elevation Model Operation

The Digital Elevation Model, DEM operation is used in performing analyses or calculation on wide range of parameters relating to elevation slope, in X and Y directions, slope in degree or percentages, flow direction etc. for this study, DEM operation was applied for the analysis of slope and topography through which these pipes are laid within the context of the study area, putting into consideration the slope angle of the terrain through which these pipelines are laid. In this work the slope angle that was selected was equal to or not less than 20^{o}. The slope ranges of the selected sites should be between 10 m–80 m.

3.4.5 Data Analysis

3.4.5.1 Overlay Operations

This is the integration of data from different sources using map overlay operation. It is a major key GIS function. In Arc Map aArc Info version 10.1, all data were stored and the criterion values and factor map are generated for all criteria as map layers. The criterion maps are converted into grids and mathematical processes are applied to the criteria.

The first layer that was retrieved in this work was the boundary layer with which the buffered pipeline layer away from the various land-use types, was overlaid, in line with the guidelines or criteria of assessing of oil pipelines, thereby revealing the level of compliances or how the oil pipelines' right-of-way have been encroached upon. The remaining three buffered layers, which are roads, built-up area, wetland/rivers will also be overlaid to create a new map layer. From the new map layer that will be generated, the level or degree of compliance and extent of encroachments into the approved setbacks for NNPC pipelines, based on planning and management perspective was identified.

Furthermore, the contour layer was overlaid in the new map layer to determine the topographic terrain with not less than 20^{o} slope angle, on which the pipelines criss-crosses or transverses within the study area. The six newly proposed refineries and potential pipeline routes was superimposed together alongside other buffered map layers to generate new base map or composite map for NNPC pipelines. Two dichotomized pipeline maps were designed

from the southern axis and northern axis of the country, which was also overlaid on a single map substrate.

3.47 Database Design

ArcMap ArcInfo 10.1 software version was used to digitize the existing topo-sheet to create a digital database. A Database is an organized collection of non-redundant data stored so as to allow its use via relevant application with the data capable of being accessed by different logical paths.

In other words, a database design is the process by which the real world entities and their inter-relationship are analyzed and modeled in such a way that maximum benefits are derived with minimum amount of data or the actual creation/construction (such as graphic and attribute data input) of a proposed system based on the specifications of the design stages. It includes digitizing of feature (graphic data entry) editing and leading of the created attribute table with data.

A data is use to refer to the values physically recorded in the database. This shows that improper database design leads to implementation problem and thus leads to low cost recovery (Kufoniyi, 1998). For the purpose of the project, the following entities were recognized and digitized i.e. blocks of built up areas, roads, administrative boundaries, contours, and water bodies to create the database. After the necessary planning and consideration of the constraints, the database design was carried out in the following order:

- View of reality
- Conceptual design
- Logical design
- Physical design

3.4.6.1 View of Reality

According to Kufoniyi (1998), the view of reality is the phenomena as they naturally exist in the area of study including all aspect which may or may not be perceived by individuals. The view of reality is the mental abstraction of real world for a particular application or group of applications.

The spatial objects in the study area were viewed as roads, built-up areas, rivers and water bodies as they exist in real life. These objects were modeled as point, line and polygon (Area). The spatial objects in the study area were viewed as roads, built-up areas, and rivers as they exist in real life. These objects were modeled as point, line and polygon (Area).

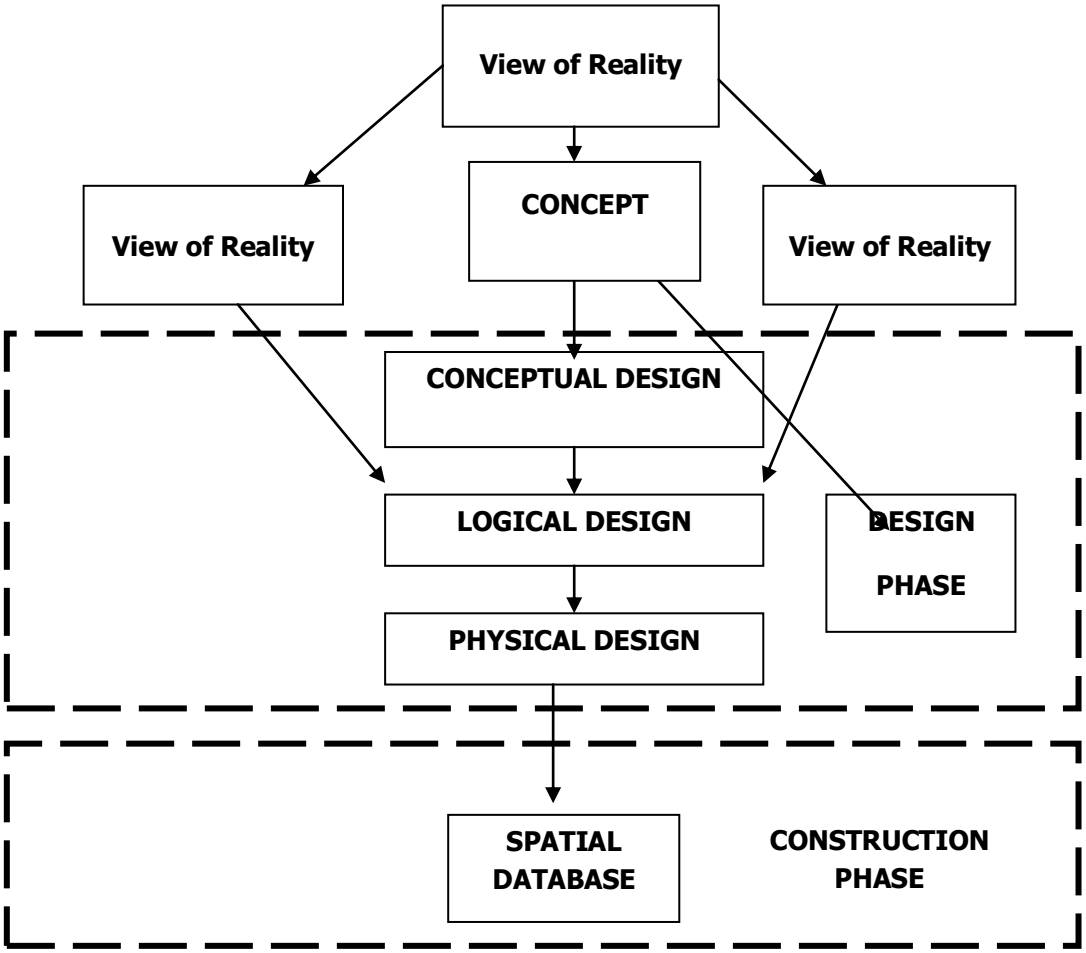


Fig. 3.5: Design and Implementation Phases of a Spatial Database.

Source: Kufoniyi, 1998.

3.4.6.2 Conceptual Design

This is the representation of the reality i.e. data abstraction. It is the process of creating an abstract database structure that represents real world objects in the most distinct possible way by converting the analogue map into digital format using on screen digitizing method of a computer using Arc Map ArcInfo 10.1 Software. The data input were later converted into raster model for further analysis which culminated into the generation of

digital Elevation Model (DEM) and buffering. The conceptualization stages of this work involve:

- Conceptualization of reality (view of reality) and the choice of its representation.
- Identification of Geographic features and their attributes.
- Identification of Basic geometric objects.

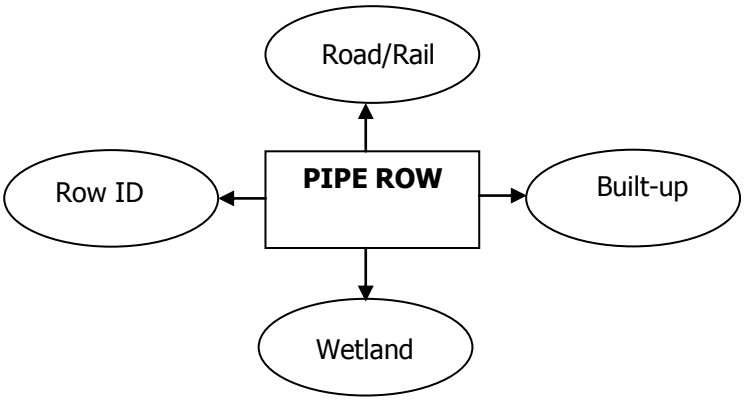


Fig. 3.6: ROW Entity and its Attributes.
Source: GIS Researcher's Work**.**

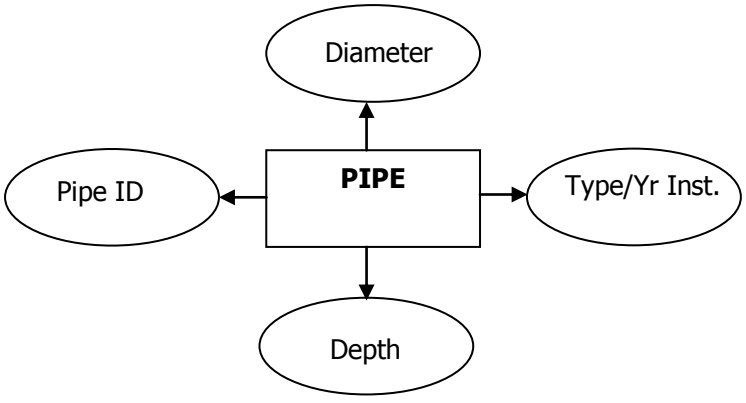


Fig. 3.7: Pipeline Entity and its Attributes.
Source: GIS Researcher's Work**.**

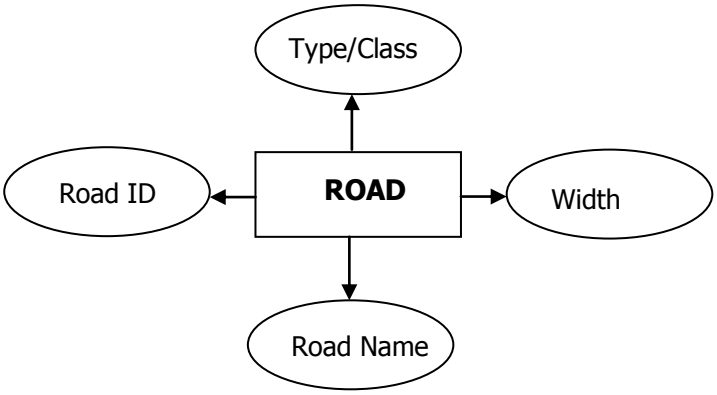


Fig. 3.8: Linear Entity and its attributes.
Source: GIS Researcher's Work.

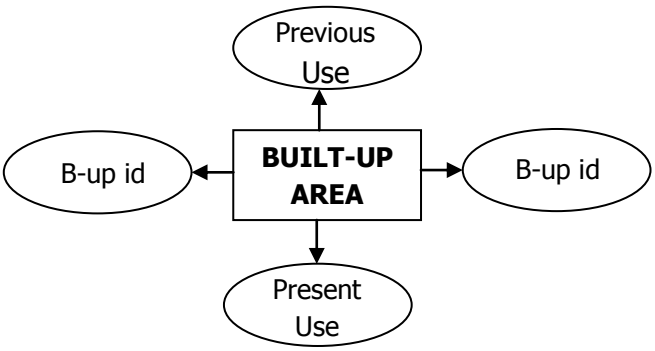


Fig. 3.9: Area Entity and its Attributes.

Source: GIS Researcher's Work.

3.4.6.4 Logical Design

Logical design is the translation of conceptual design (data model) into a selected data structure (such as relational geo-relational, network, hierarchical etc,) that can be represented in a computer form. The conceptual model was translated into a geographic-relational (as in Arc Info) data structure. This following relation however, will be derived.

- Road (Rid, R-name, R-width, R-type, R-class).

- Built-up area (Build-up id, Built-up name).
- Water sources (water id, water source name, type).
- Land use (Land cover, land use).

Table 3.5: Geo-Relational Data in the Study Area and their Attributes.

Item Name	Identification
ROW	**RW-ID, object distance away from land-use types.**
Pipe	**P-ID, diameter, node, length, year of installation.**
Road/Rail	**R-ID, with, node, parcel, type, class, year constructed.**
Built-up	**Bl U-ID, area, perimeter, population, cover, use.**
River/Wetland	**W-ID, source name, type, length.**

Source: GIS analysis & Reconnaissance Survey**.**

3.4.6.4 Physical Design

Physical design is the representation of a data structure in the format of implementation software. This was performed at the beginning of the implementation phase. Arc Map ArcInfo 10.1 software was used to consider item name, item width, item types, items, decimal place. This design defines data item in terms of parameters such as number of bytes of storage they occupy and the address in which they are to be found in physical memory.

Table 3.6: Relations (Table) for Pipeline DBF

Serial No.	Attribute Name	Width	Data Type
1.	P-ID	-	**Numeric (3,0)**
2.	Diameter	-	**Numeric (2,2)**
3.	Type	-	**Character (0)**
4.	Depth	-	**Numeric (2,2)**
5.	Length	-	**Numeric (3,2)**
6.	Year of Installation	-	**Numeric (4,0)**

Source: GIS analysis & Reconnaissance Survey**.**

Table 3.7: Relations (Table) for Road DBF

Serial No.	Attribute Name	Width	Data Type
1.	R-ID	-	**Numeric (3,0)**
2.	Type	-	**Character (3,0)**
3.	Class	-	**Character (3,0)**
4.	Depth	-	**Numeric (2,2)**
5.	Length	-	**Numeric (3,2)**
6.	Year of Constructed	-	**Numeric (4,0)**

Source: GIS analysis & Reconnaissance Survey**.**

Table 3.8: Built-up area in the Study Area and their Attributes

TSD-ID	Attribute Name	Data Type
1.	Building	**Bl-Id**
2.	Area	**Numeric (7,3)**
3.	Perimeter	**Numeric (6,3)**
4.	Use: Residential, Commercial, Industrial Agricultural	**Character (3,0)**

Source: GIS Analysis & Reconnaissance Survey.

3.4.6.5 Spatial Query

In performing queries on GIS database, data retrieval is an essential part of GIS projects. Queries offer a method of data retrieval and can be performed on data that are part of GIS database or on new data produce as a result of data analyses.

For this project, each of the layers of information were created, retrieved one after the other, and were queried accordingly to be ready for further analyses.

3.4.6.6 Cartographic Model

Cartographic modeling is the use of basic manipulation functions in logical sequences to solve complex spatial problems (Tomlin, 1983). It was developed to model land use planning alternatives and applications that require integrated analysis of multiple geographically distributed factors, as it was done for the study. It has the following attributes: Entirety in Raster

Domain, Ability to Form a Logical Sequence and Map Algebra. Figure 3.7 below depicted the work flow in which the Author of this thesis followed to achieve his aim and objectives of the study.

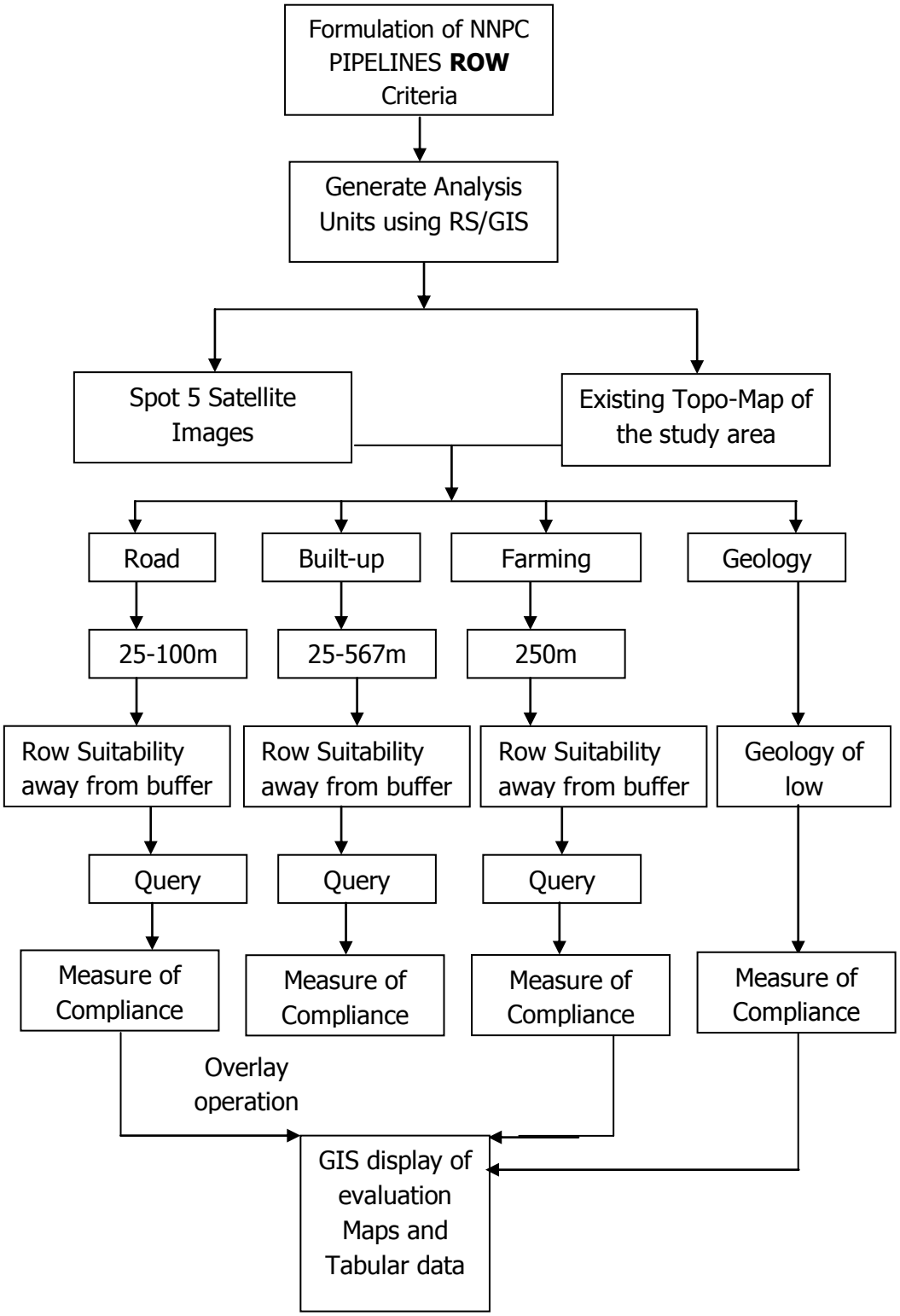


Fig. 3.10: Cartographic Model Design
Source: Researcher's Work.

3.4.7 Criteria for Assessing the Compliances of various Land-Use Types with the NNPC Pipelines

For the analysis of data that was obtained for the classic use of GIS techniques in assessing the Compliances of Various Land-use Types with the NNPC Pipelines, the following criteria are put into consideration:

- Proximity
- Area extent (buffer zone)
- Relatively gentle terrain

3.4.7.1 Proximity

- The right-of-way for pipelines should not be less than 25 m, 200 m, 500 m away from the roads/high ways
- The setback should be distance of not less than 250 m-576 m from the water/wetland areas
- The setback should be distance of not less than 25 m-576 m from the built-up areas, depending on type of fluid transported, volatility and vulnerability tendency to encroachment.

Note: A 25-metre wide Right of Way (ROW), specifically was acquired by Government for the purpose of NNPC Pipelines as provided for in the oil pipelines Act of 1956 cap 145 (Ehiorobo, 2010) and Pipeline Act CAP 338 of the Law of the Federation of Nigeria 1990.

3.4.7.2 Area Extent (Buffering Requirements)

- The Selected built-up area should not be less than 25 m^2 from pipes lines
- The Selected built-up area should not be less than 250m^2 from pipes lines.
- The Selected built-up area should not be less than 420m^2 from pipes lines.
- The Selected built-up area should not be less than 576m^2 from pipes lines.

3.4.7.4 Relatively Gentle Terrain

- The slope angle of the terrain of site to be selected should not be less than 20^o except in areas where there are steep gradient.
- The slope ranges of the selected sites should be between 10 m – 80 m.

3.4.8 Linear Measurements

Two different types were involved, i.e. linear measurements in flat areas and those on hilly areas.

a. On flat areas, the procedure followed is described below. The tools needs are the measuring tape, parallax bar, ruler, needle and drawing materials. First, the distance into NNPC pipelines' right-of-way was determined by taking measurement of the standardized setbacks and the distances at which the different land use type encroaches into the pipelines' right-of-way in the study areas. The satellite imageries scale was determined

automatically by satellite component and the software in used synchronizes the scale and can be adjusted at the leverage of the software user. Second, measure the distance between the selected points a-b in meters. Third, the distance measurement of point a-b is possible after the digitization process. As measurement is done automatically by the software in relation to the scale of the imagery/map. Similarly, is to multiply the measured distance (a-b) between the selected points by the satellite imagery's scale number (mp), which gives the distance of the points in the field, a-b:

Therefore, ab = a-b ---------- (equation 1)

$ab = mp_{ab}$ ---------- (equation 2)

b. On a hilly area the following procedure was used. Using the same instrument listed above:

- Determine the height differences of the selected points, this gives the values h_{ab} etc. in meters;
- Next, use the slope between the selected points, this gives the values, d_{ab}, etc.;
- Calculate the slope length in the field (ab, etc.) using the results of the first two steps, i. e.

$$ab = \frac{h_{ab}}{\text{Sin } d_{ab}} \quad \text{---------- (equation 3).}$$

3.4.9 Geo-referencing Properties of the Images and Map

The geo-referencing properties of both the acquired Landsat imagery SRTM (band 1, 2 and 3) 2013 and Landsat SRTM-2012 imagery are the same because the two are of the same resolution of 30 m while image thinning was applied to the 1987 photos which has resolution of 30 m using a factor of two to modify its properties and resolution to conform to the other two as given below:

Data Type File System: Raster, File Type: Binary Columns: 1441 Row: 1155.

Referencing System: UTM-32, Reference Units: M, Unit Distance: 1.

Table 3.9: Coordinates of the Study Area.

Minimum X	**2.668437**
Maximum X	14.6767663853
Minimum Y	4.2704180000000
Maximum Y	13.895417615000

Source: Satellite Imagery Geo-referencing/Global Positioning System

Min Value: 0, Max Value: 430, Display Minimum: 0, Display Maximum: 430

Screen Resolution: 1366 x 7768.

Images were geo-referenced using Ground Control Points (GCPs) obtained from GPS, using image-to-GPS techniques. A total of four GCPs were collected for each of the study area using GPS on the field. These points were

distributed to ensure images are balanced on the entire four axes and centralized at the centre.

The choice of images to GPS techniques is based on the fact that most of the data used was collected in the field using GPS and this reduced the error during the map composition and allows for this point to fit-in. the coordinates of these reference points were converted from geographic degrees to UTM, in order to aid precise measurement later. The same projection was used for the vector layer extracted from the administrative map of northern Nigeria (Department of Urban and Regional Planning, Kaduna State Ministry of Environment, 2009) by using image to map technique.

It was also the same for the vector layer extracted from the Master Plan of northern Nigeria (Department of Urban and Regional Planning, Kaduna State Ministry of Environment 1977). The result of the geo-referencing is shown above. After all layers of features have been digitized and edited on checking on checking the following: Some of the errors are dead end (i. e. over shoot or under-shoot, self overlap, intersection, code consistency exercise of pipelines route and land use types encroachment) and data retrieval (quarries, browsing) is done, then map overlaying (putting different entities on a particular map) is performed on these layers.

Map generalization or reclamation is done on the overlaid map. Also projection charge-coordinate transformation, centroid (centre line) calculation, vector, raster, buffer generation on pipelines, digital terrain analysis (interpolation, contouring) of suit angle for laying pipelines and finally output or presentation of the maps either in soft or hard Copy.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION

8.1 Introduction

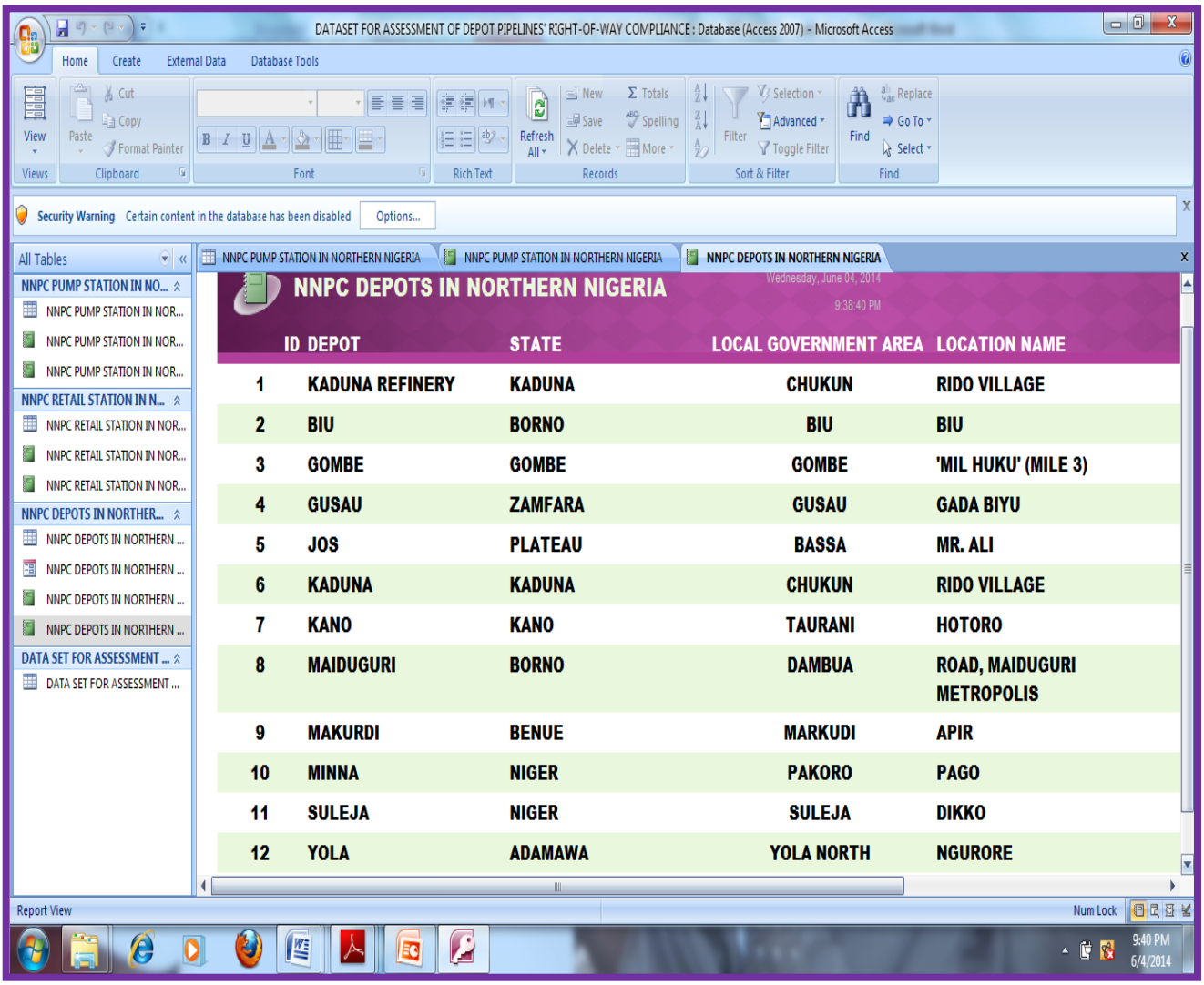
This chapter presents the results and discussion of the study. All data collected from the field survey and periodicals and those generated from the satellite imageries were collectively analyzed.

Regulations on Pipelines' Right-of-Way were established in Section 2.8 and were used to address objective one of the study Sub-section 4.4.1. In Section 4.2 the Database of NNPC Pipelines and Associated Right-of-Way was created and tabulated. Sections 4.3 assess the level of compliance of land use/cover types to NNPC Pipelines' Right-of-Way. While Section 4.6, discusses the problems and challenges of non-compliance to NNPC pipelines' right-of-way.

4.2 Database of NNPC Pipeline Networks and Associated Right-of-Way

The tables 4.1-4.7 and 4.11 below, gives the data sets and geographical coordinates for Depots, Pump Stations, Retail Stations and Booster Stations of NNPC in Northern Nigeria.

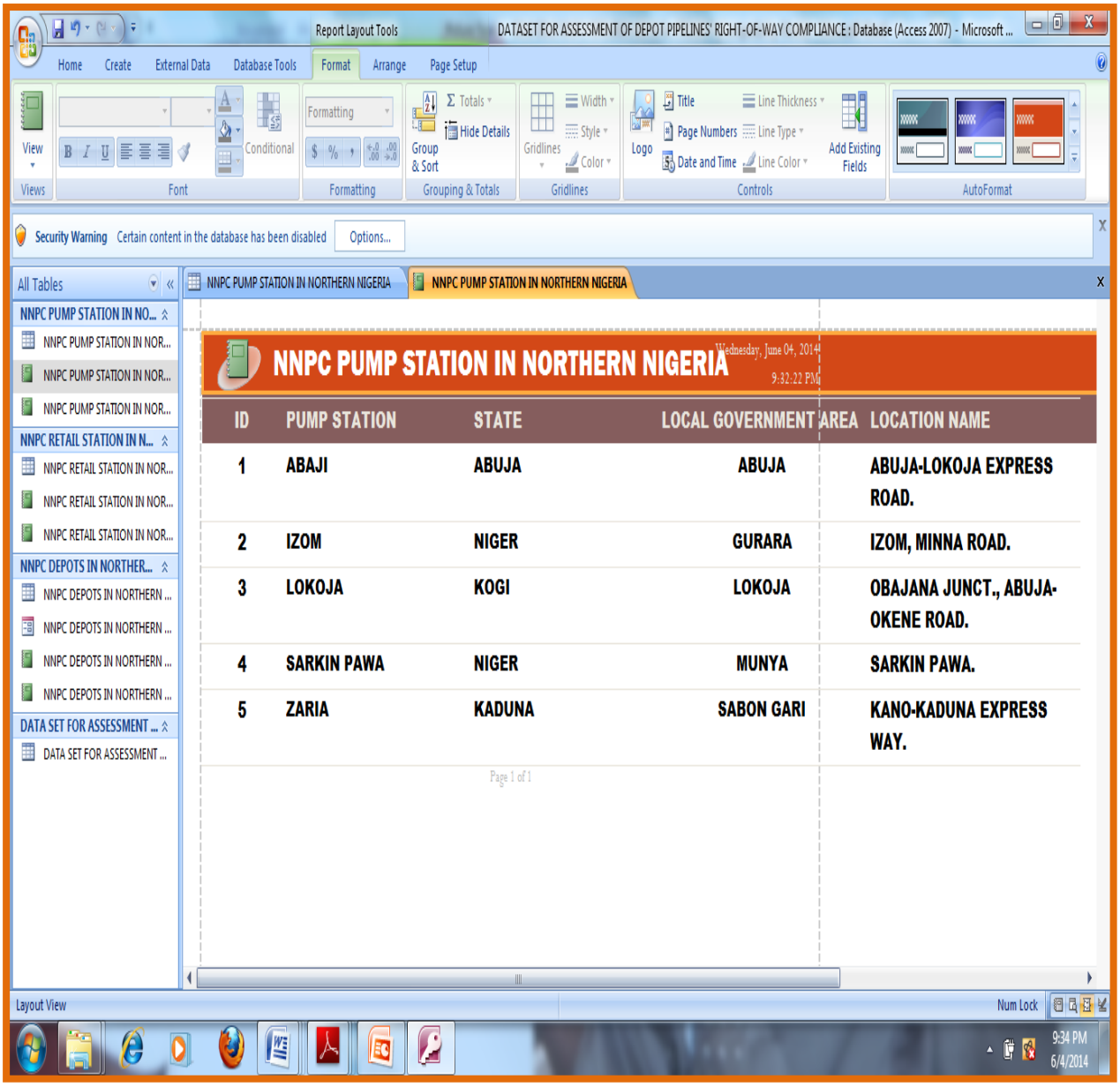
Table 4.1: Data Set for Nigerian National Petroleum Corporation Depots in Northern Nigeria.



ID	DEPOT	STATE	LOCAL GOVERNMENT AREA	LOCATION NAME
1	KADUNA REFINERY	KADUNA	CHUKUN	RIDO VILLAGE
2	BIU	BORNO	BIU	BIU
3	GOMBE	GOMBE	GOMBE	'MIL HUKU' (MILE 3)
4	GUSAU	ZAMFARA	GUSAU	GADA BIYU
5	JOS	PLATEAU	BASSA	MR. ALI
6	KADUNA	KADUNA	CHUKUN	RIDO VILLAGE
7	KANO	KANO	TAURANI	HOTORO
8	MAIDUGURI	BORNO	DAMBUA	ROAD, MAIDUGURI METROPOLIS
9	MAKURDI	BENUE	MARKUDI	APIR
10	MINNA	NIGER	PAKORO	PAGO
11	SULEJA	NIGER	SULEJA	DIKKO
12	YOLA	ADAMAWA	YOLA NORTH	NGURORE

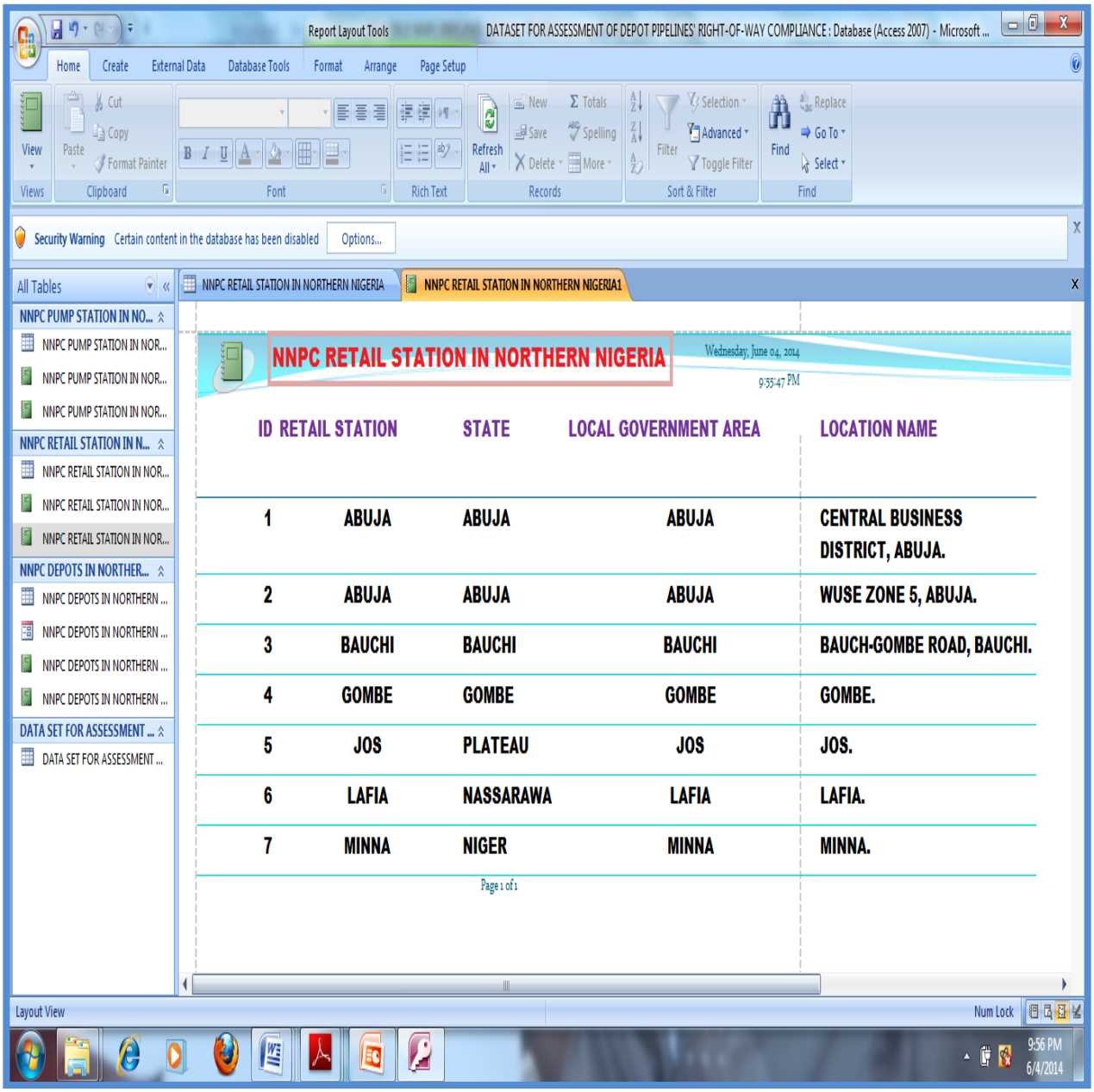
Source: Researcher's GIS Analysis Work, 2014.

Table 4.2 Data Set for Nigerian National Petroleum Corporation Pump Stations in Northern Nigeria.



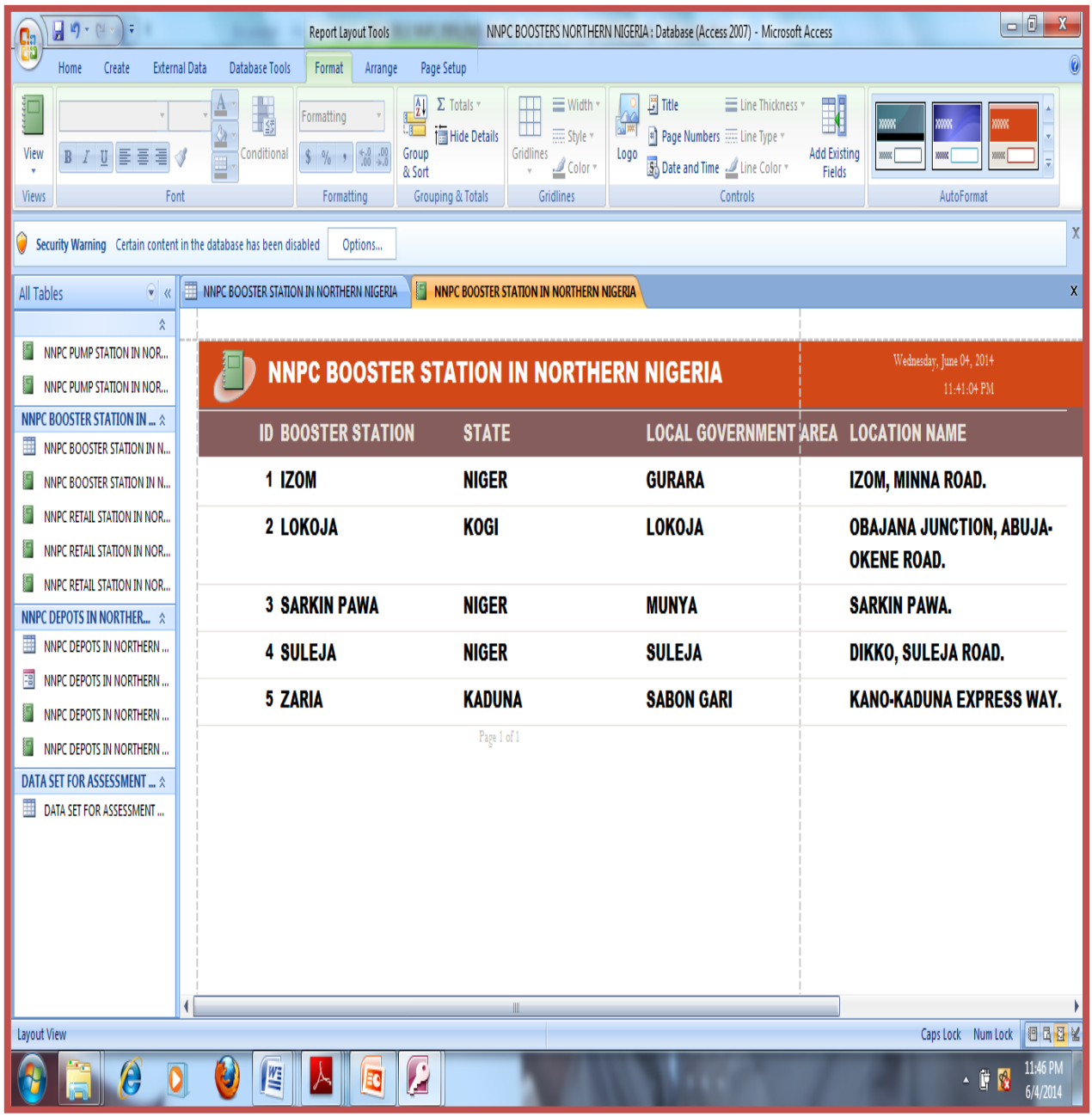
Source: Researcher's Database Analysis Work, 2014.

Table 4.3: Data Set for Nigerian National Petroleum Corporation Retail Stations in Northern Nigeria.



Source: Researcher's Database Analysis Work, 2014.

Table 4.4: Data Set for Nigerian National Petroleum Corporation Booster Stations in Northern Nigeria.



ID	BOOSTER STATION	STATE	LOCAL GOVERNMENT AREA	LOCATION NAME
1	IZOM	NIGER	GURARA	IZOM, MINNA ROAD.
2	LOKOJA	KOGI	LOKOJA	OBAJANA JUNCTION, ABUJA-OKENE ROAD.
3	SARKIN PAWA	NIGER	MUNYA	SARKIN PAWA.
4	SULEJA	NIGER	SULEJA	DIKKO, SULEJA ROAD.
5	ZARIA	KADUNA	SABON GARI	KANO-KADUNA EXPRESS WAY.

Source: Researcher's Database Analysis Work, 2014.

Table 4.5: Geographical Coordinates for NNPC Depots in Northern Nigeria.

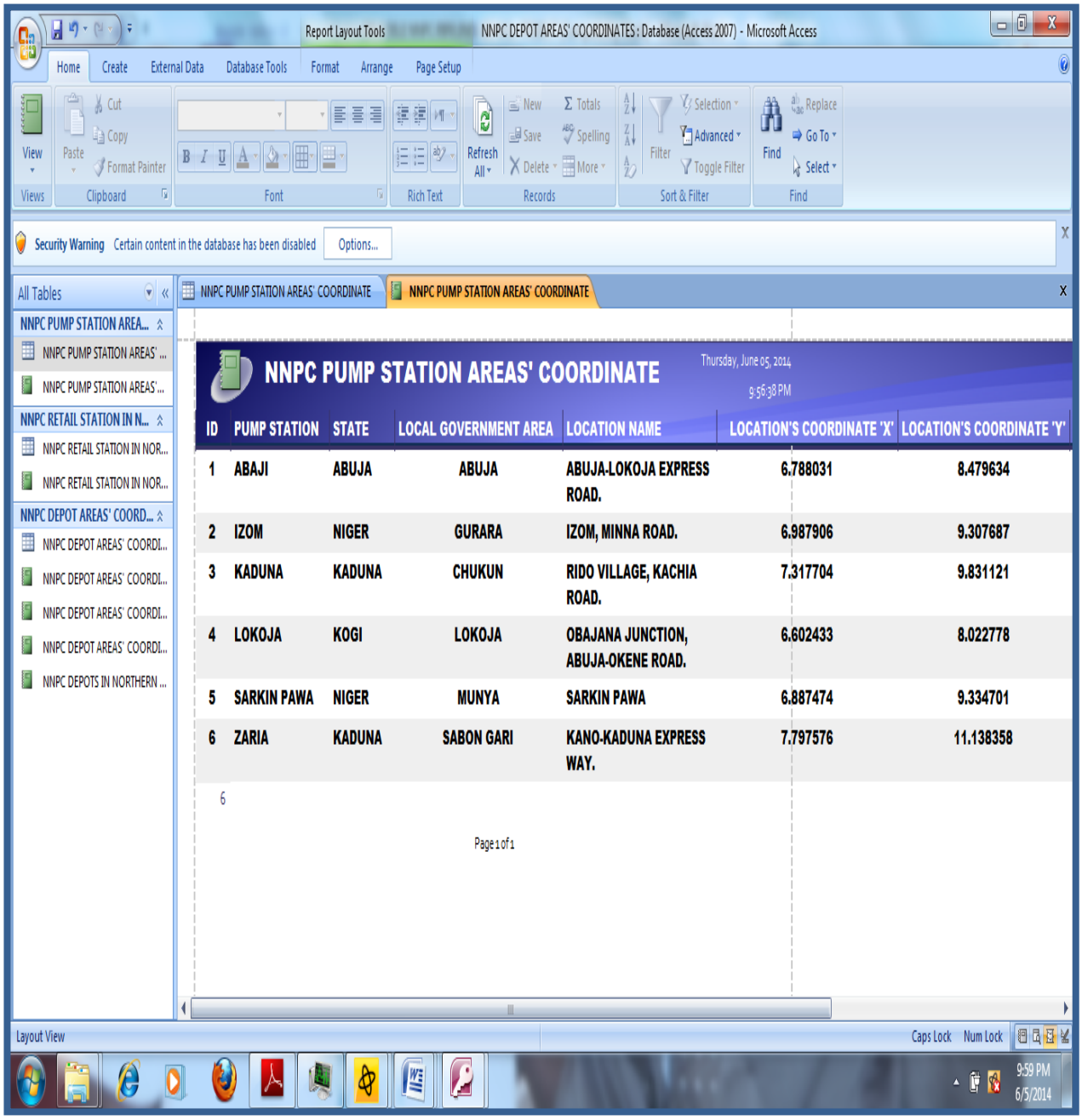
NNPC DEPOT AREAS' COORDINATE

Tuesday, June 10, 2014
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ID	DEPOT	STATE	LOCAL GOVERNMENT AREA	LOCATION NAME	LOCATION'S COORDINATE 'X'	LOCATION'S COORDINATE 'Y'
1	KADUNA REFINERY	KADUNA	CHUKUN	RIDO VILLAGE	7.562784	10.461725
2	BIU	BORNO	BIU	BIU	13.225094	11.121811
3	GOMBE	GOMBE	GOMBE	'MIL HUKU' (MILE 3)	11.222870	10.310993
4	GUSAU	ZAMFARA	GUSAU	GADA BIYU	6.970211	12.197386
5	JOS	PLATEAU	BASSA	MR. ALI	8.740773	10.162067
6	KADUNA	KADUNA	CHUKUN	RIDO VILLAGE	7.532819	10.493013
7	KANO	KANO	TAURANI	HOTORO	8.476016	11.982271
8	MAIDUGURI	BORNO	DAMBUA	ROAD, MAIDUGURI METROPOLIS	12.232256	10.757770
9	MAKURDI	BENUE	MARKUDI	APIR	8.575300	7.746159
10	MINNA	NIGER	PAKORO	PAGO	6.854379	9.351249
11	SULEJA	NIGER	SULEJA	DIKKO	6.887474	9.334701
12	YOLA	ADAMAWA	YOLA NORTH	NGURORE	12.29156	9.120345

Source: Researcher's Database Analysis Work, 2014.

Table 4.6: Geographical Coordinates for NNPC Pump Stations in Northern Nigeria.



NNPC PUMP STATION AREAS' COORDINATE

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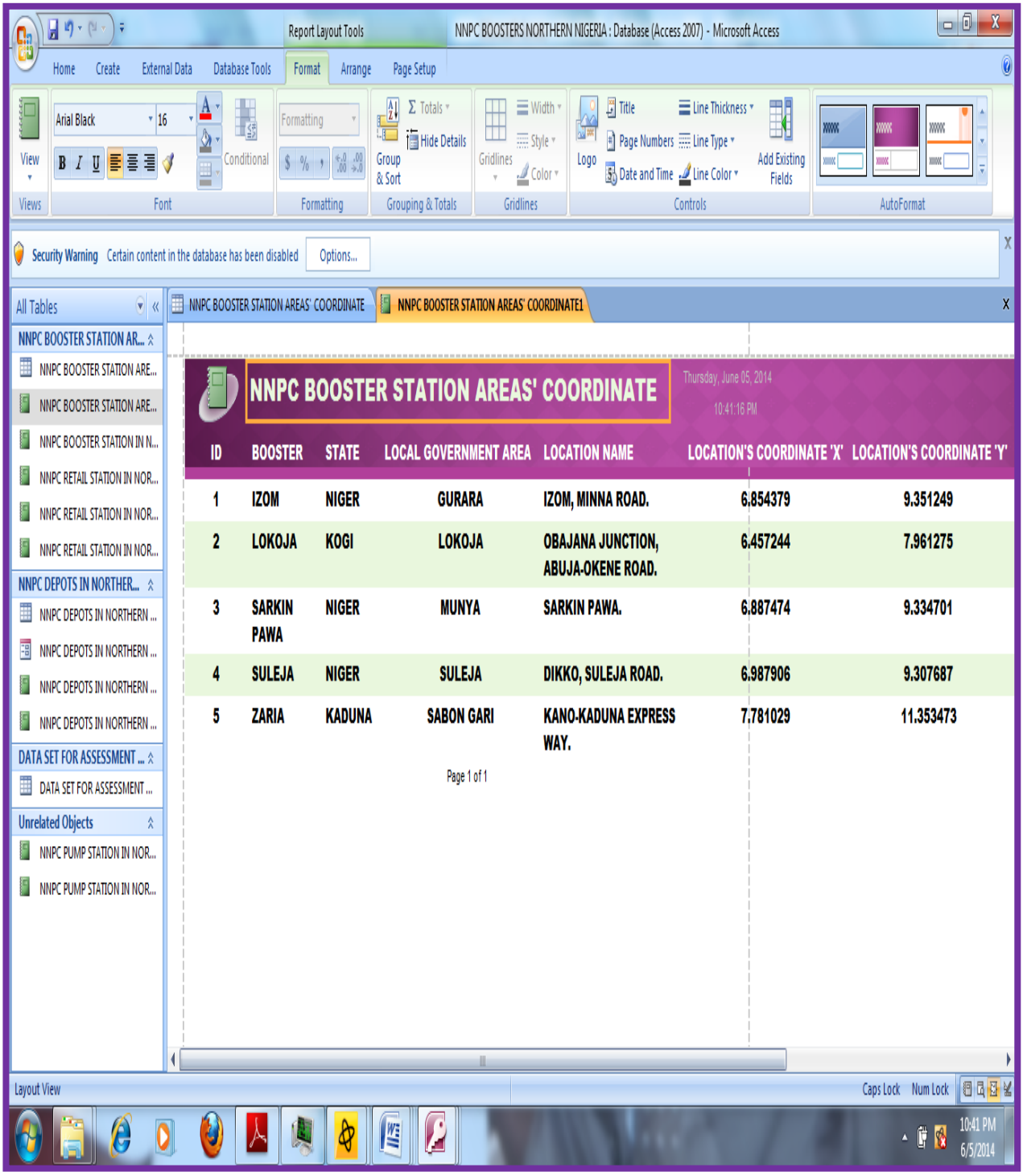
ID	PUMP STATION	STATE	LOCAL GOVERNMENT AREA	LOCATION NAME	LOCATION'S COORDINATE 'X'	LOCATION'S COORDINATE 'Y'
1	ABAJI	ABUJA	ABUJA	ABUJA-LOKOJA EXPRESS ROAD.	6.788031	8.479634
2	IZOM	NIGER	GURARA	IZOM, MINNA ROAD.	6.987906	9.307687
3	KADUNA	KADUNA	CHUKUN	RIDO VILLAGE, KACHIA ROAD.	7.317704	9.831121
4	LOKOJA	KOGI	LOKOJA	OBAJANA JUNCTION, ABUJA-OKENE ROAD.	6.602433	8.022778
5	SARKIN PAWA	NIGER	MUNYA	SARKIN PAWA	6.887474	9.334701
6	ZARIA	KADUNA	SABON GARI	KANO-KADUNA EXPRESS WAY.	7.797576	11.138358

6

Page 1 of 1

Source: Researcher's Database Analysis Work, 2014

Table 4.7: Geographical Coordinates for NNPC Booster Stations in Northern Nigeria.



NNPC BOOSTERS NORTHERN NIGERIA : Database (Access 2007) - Microsoft Access

NNPC BOOSTER STATION AREAS' COORDINATE

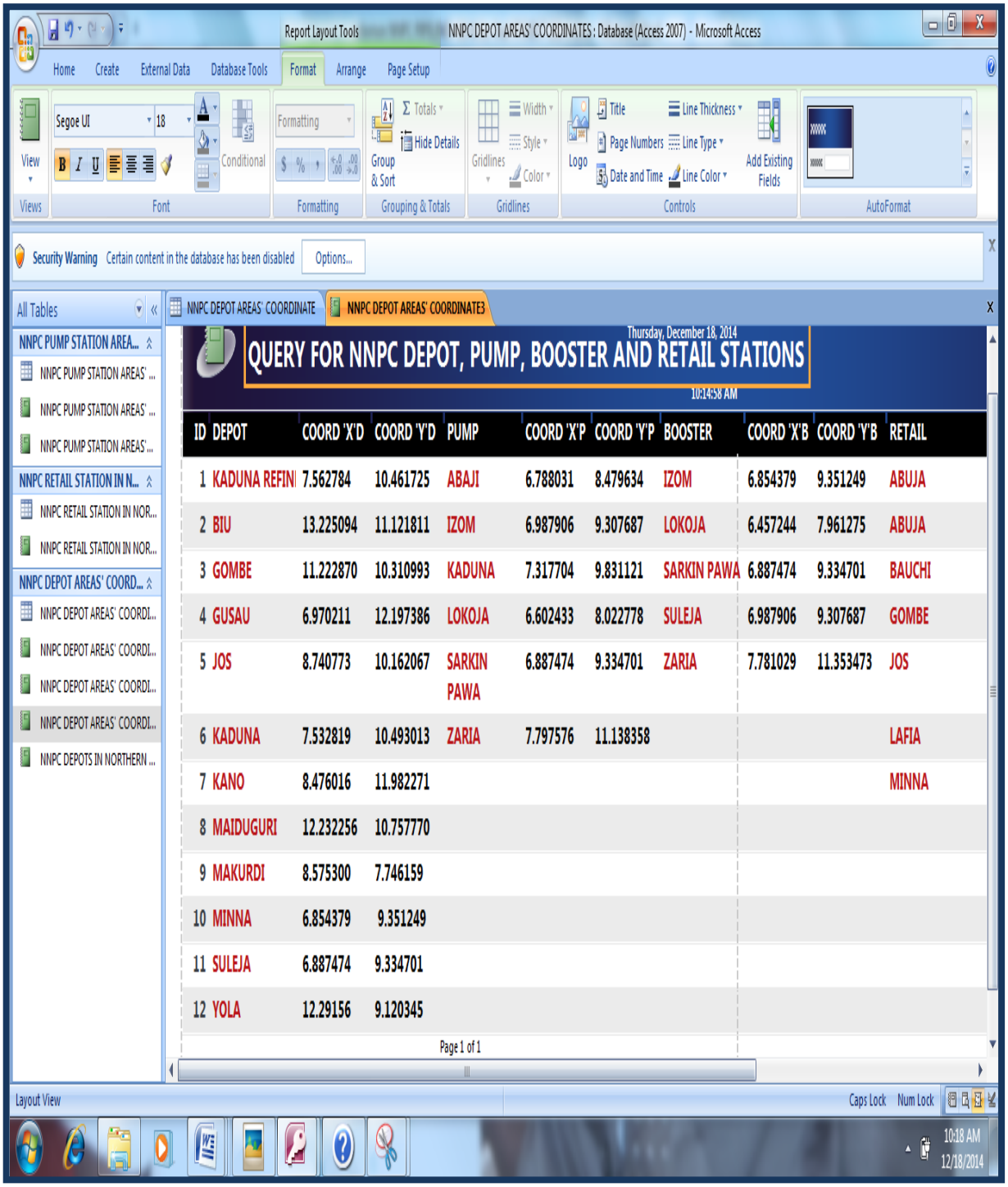
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ID	BOOSTER	STATE	LOCAL GOVERNMENT AREA	LOCATION NAME	LOCATION'S COORDINATE 'X'	LOCATION'S COORDINATE 'Y'
1	IZOM	NIGER	GURARA	IZOM, MINNA ROAD.	6.854379	9.351249
2	LOKOJA	KOGI	LOKOJA	OBAJANA JUNCTION, ABUJA-OKENE ROAD.	6.457244	7.961275
3	SARKIN PAWA	NIGER	MUNYA	SARKIN PAWA.	6.887474	9.334701
4	SULEJA	NIGER	SULEJA	DIKKO, SULEJA ROAD.	6.987906	9.307687
5	ZARIA	KADUNA	SABON GARI	KANO-KADUNA EXPRESS WAY.	7.781029	11.353473

Page 1 of 1

Source: Researcher's Database Analysis Work, 2014.

Table 4.8: Query for NNPC Depot, Pump, Booster and Retail Stations and their Coordinates in Northern Nigeria.



ID	DEPOT	COORD 'X'D	COORD 'Y'D	PUMP	COORD 'X'P	COORD 'Y'P	BOOSTER	COORD 'X'B	COORD 'Y'B	RETAIL
1	KADUNA REFIN	7.562784	10.461725	ABAJI	6.788031	8.479634	IZOM	6.854379	9.351249	ABUJA
2	BIU	13.225094	11.121811	IZOM	6.987906	9.307687	LOKOJA	6.457244	7.961275	ABUJA
3	GOMBE	11.222870	10.310993	KADUNA	7.317704	9.831121	SARKIN PAWA	6.887474	9.334701	BAUCHI
4	GUSAU	6.970211	12.197386	LOKOJA	6.602433	8.022778	SULEJA	6.987906	9.307687	GOMBE
5	JOS	8.740773	10.162067	SARKIN PAWA	6.887474	9.334701	ZARIA	7.781029	11.353473	JOS
6	KADUNA	7.532819	10.493013	ZARIA	7.797576	11.138358				LAFIA
7	KANO	8.476016	11.982271							MINNA
8	MAIDUGURI	12.232256	10.757770							
9	MAKURDI	8.575300	7.746159							
10	MINNA	6.854379	9.351249							
11	SULEJA	6.887474	9.334701							
12	YOLA	12.29156	9.120345							

Source: Researcher's Database Analysis Work, 2014.

4.3 Buffering Operation: Buffer, generates zones with pre-defined distance from a specified set of data. Buffering is act of processing zone of interest usually of specified width around a map element such as road, streams, rivers, marshy area, etc. In order to achieve this objective, buffer zone was created around the pipelines to assess compliance or degree of encroachment into the right-of-way of pipelines by the various land-use types in the study area. Also in this study, a buffer zones was created around water bodies (rivers, wetlands, streams, delta, lagoon), road/rail networks to satisfy the set criteria of distance. The guidelines, as provided for in the oil pipelines Act of 1956 cap 145 and as amended by Oil Pipeline Act of 1965 and Pipeline Act CAP 338 of the Law of the Federation of Nigeria 1990, Land Use Act Cap 202 0f 1990 and the Nigeria Urban and Regional Planning Act of 1990, was also used to assess degree of compliances or failure to NNPC pipelines row, in line with the approved setbacks, as stipulated in the criteria stated above.

4.4 Level of Compliance to NNPC Pipelines' Right-of-Way

An unclassified Landsat band 1, 2 and 3 satellite imagery (Appendix VI-VIII) was being provided and processed for the classification of the various land use types. From the classification adopted for the study area as shown on map for land use/land cover classification. The farmland and grazing area occupies a large area of 125,673.00 km^2 representing a (70%), built-up has 25,134.62 km^2 (14%). Road network in the study area accounts for 17,953.30 km^2 (10%) encroachment extent while the water bodies accounted for the remaining 10,771.98 km^2 (6%), which is summed up to an area size of 179, 533.00 km^2 (100%). A large proportion of the urban population in the study

areas is engaged in farming activities to support their livelihood. In some States like Adamawa, Bauchi, Benue, Gombe, Sokoto, Taraba, Zamfara State etc has some forms of mechanized farming.

Based on the individual land classification and superimposition of pipelines and land use type features and reconnaissance survey carried out by the Researcher on each of the study area, as shown in figure 4.2 to figure 4.4 it was observed that agriculture; such as farming activities around the study points and rearing and grazing of cattle around the study area; as observed in Abaji, Biu, Kaduna, Gombe, Gusau, Izom, Minna, accounts for the highest percentage of land use type encroaching into the NNPC Pipelines' right-of-way.

Thus, agricultural land uses accounts for 70% (125,673.00 km^2) land use type that encroaches into NNPC pipelines' right-of-way. The built-up area is ranked or rated as the second land use type that encroaches into the pipelines' right-of-way, with a percentage constituent of 14% (25,134.62 km^2). This observation in figure 4.2a and figure 4.2b is justified by some superstructures constructed that infringed into the setback zones in the study area, particularly, in some parts of Kamanzo Settlement of Kaduna State, Hotoro Settlement of Kano State, Apir Settlement of Benue State and Mr. Ali Settlement of Plateau State.

The roads constructed in the study areas, particularly untarred, motorized, non-motorized roads and foot paths were noticed to encroach into the NNPC Pipelines' right-of-way in areas such as; Kamanzo Settlement; Kaduna, Apir settlement; Makurdi, 'Mil 3' Settlement; Gombe, Mr. Ali

settlement; Jos, Zaria Settlement; Kaduna, Hotoro Settlement; Kano and Dikko Settlement; Suleja, Lokoja Settlement; Kogi, and Abaji Settlement; Abuja. It accounts for 10% (17,953.30 km^2) of the total land area that have been encroached by the various land use types in the study area.

While the remaining 6% (10,771.98 km^2) accounts for water bodies as a form of land use type that also encroaches into the right-of-way of these pipelines. This encroachment was noticed at the tributary of the Kaduna River, around the Angwan Rimi Settlement; Kaduna State, Lokoja settlement; Kogi State and the crude line pipelines network coming from Escravos-Warri, which criss-crossed the Niger River (figure 4.3 and figure 4.4).

It is however, expedient to state here clearly, that pipeline platforms are built over the surface of water bodies and to serves as support for the pipelines particularly where the water bodies cannot negotiated or avoided.

The Encroachment Sizes and Percentages by the various Land Use type was determined using the Simple Percentage Formula:

$$\text{Percentage of encroachment by Land use type (\%)} = \frac{X}{\sum(N)_1} \times 100$$

Where X = Land Area occupied by a Land Use Type.

$\sum$ (N) = Total Land Area by the various Land Use Types.

Encroached Land Area occupied by Agriculture in the Study Area = **125,673.00 km^2**.

Encroached Land Area occupied by Built-up in the Study Area = **25,134.62 km^2**

Encroached Land Area occupied by Road in the Study Area = **17,953.30 km^2**

Encroached Land Area occupied by Water Bodies in the Study Area = **10,771.98 km^2.**

Percentage of encroachment by Agriculture (%) = 125,673.00 x 100
179,533.00 1 **= 70.00%**

Percentage of encroachment by Built-ups (%) = 25,134.62 x 100
179,533.00 1 **= 14.00%**

Percentage of encroachment by Road (%) = 17,953.30 x 100
179,533.00 1 **= 10.00%**

Percentage of encroachment by Water Bodies (%) = 10,771.98 x 100
179,533.00 1 **= 6.00%**

Table 4.9 below, shows the summary of the major land use types that has encroached into NNPC pipelines right-of-way in the study area in terms of area cover and percentage.

Table 4.9: Major Land Use Types encroaching into NNPC Pipelines' Right-of-Way.

Land Use Type	Land Area Covered (km^2)	Percentage (%)	Rating
Agriculture (Farming/Grazing).	125,673.10	70.0	First
Built-ups	25,134.62	14.0	Second
Roads	17,953.30	10.0	Third
Water Bodies	10,771.98	6.0	Fourth
Total	179, 533.0	100.0	

Source: Researcher's Work 2014.

*Rating = the level of encroachment by land use type into the pipelines' right-of-way is in the ascending order.

4.4.1 Pipeline Segments' level of Right-of-Way Compliance Assessment

The choice of sampled areas and points of reference have been described in chapter 3, different types of pipeline segment points and network were mapped and land use types encroaching into the NNPC Pipelines right-of–way are identified and described. Here, results of the detailed analysis of the satellite imageries are explained.

4.4.2 System 2C (Warri-Kaduna Crude Line) Segment

It is 606 km (370 miles) pipeline from Warri to Kaduna. Starting in the rain forest the pipeline crosses through savannah type terrain before reaching savannah conditions surrounding Kaduna. Initially the pipeline was designed for crude oil but used on a batch basis carrying refined fuel such as gasoline, kerosene and gas oil from the refinery at Warri to Kaduna. Later the pipeline was used to pump crude oil to the refinery at Kaduna.

The pipelines right of way is 25 m^2 buried at 6 feet below the earth surface. The sampled point, 5 kilometres from the refinery/depot shows encroachment into pipelines' right-of-way due to farming and grazing activities. This is illustrated by the visible differences between the image tones for the pipelines and the setback zone for the pipeline as shown in figure 4.3. Present field observation in a Kamazo Settlement 2 Km away from the refinery, where the distributing pipeline networked to Zaria Pump Station, where they are exposed, show that untarred road and built-ups are gradually and rapidly encroaching into the pipelines' right-of-way as shown in the Landsat Earth imagery in Appendix VI-VIII. Also observation and oral

interview conducted at the Rido Village, show that over time pipeline vandalism has been carried out in the area.

Also the attacks on these pipelines system by vandals has led NNPC to have spent over US $42.952 million to execute a two-phase repair work which started in September, 2009 on 74 damaged points in System 2C-1. Escravos–Warri Crude Oil Pipelines to enable the start up of the Warri and Kaduna refineries. Between 2010 and 2012, it was reported by NNPC, that the Kaduna's system recorded a total of 571 cases of pipeline vandalism (NNPC, 2013).

4.4.3 System 2D (a) Kaduna-Zaria- Kano Segment

The pipeline segment length is about 250 km; the segment set back is characterized by farming and grazing along the pipeline route and Kaduna River tributary (water bodies). However, a protector is placed or wrapped and set at the pipeline where it criss-crossed the river. Some few measurements from the satellite imagery (dark-grey portions) and from the field using a tape rule and ranging pole give a 50 m and 126 m radius encroachment by farmland/grazing land and structure at 500 m and 1 km from the Zaria Pump Station and 4 km along its route to Kano. At the Hotoro Depot; Kano, 2 km-5 km, field check revealed also built-up and unauthorized minor roads encroachment into NNPC Pipelines' right-of-way (figure 4.2a).

4.4.4 System 2D (b) Zaria-Gusau Segment

This pipeline has segment length of 177 km and a flow rate of 40 m^3/hr. The pipelines transverses Zaria Pump Station, along Zaria-Kano Express Way, through parts of Katsina State to Gusau in Zamfara State. The satellite interpretation as shown in figure 4.2b and field work linear measurement 500 m^2 away from Pump Station revealed intensive and extensive agricultural cultivation and grazing activity around the pipelines. While in some areas these cultivation infringed into the setback of the pipelines. Also, it was observed that minor road (foot path) was seen to have encroached into the pipeline' right-of-way. In some areas, along the pipeline route, some superstructures were seen built closer to the pipelines, which might in the future, exposed the pipelines to the act of vandalism.

4.4.5 System 2D (c) Kaduna-Jos Pipeline Segment

This pipeline segment has a distance 165 km and a flow rate of 90 m^3/hr, which the Kaduna Refinery pumps products through to Jos Depot. The pipeline transverses southern part of Kaduna State, via Zonkwa-Manchok to Mr. Ali, Jos. At 3 km away from the depot, it observed from field check done in studied area in figure 4.2a, that Agricultural activities-farming and grazing was observed to be common in this area. Animal trampling is also common; hence the events of rill and sheet wash become active processes near the pipelines. It was also observed that the pipeline took advantages of the low plain of the undulating and high topography of the area. At 1.0-2.5 km within the jurisdiction of the depot and pipeline some built-up structures were seen around the pipeline's right-of-way.

4.4.6 System 2D (d) Gombe-Maiduguri Pipeline Segment

The pipeline has a segment length of 297 km and 90 m^3/hr flow rate, where oil products are pump from Gombe Depot to Maiduguri Depot via the Biu Pump Station. From the satellite imagery analysis and field work, at this segment line, active animal grazing and cultivation of arable land were observed to be encroaching into the setback portion of the laid oil pipelines, particularly along Maiduguri-Damboa road. This segment line has also bedevilled by number of vandalism by Saboteurs and Bunkers. It is worthwhile, to state that in some areas along the pipeline route, built-up structures were seen to be encroaching into NNPC pipeline's right-of-way. Presently, for some years now, there hasn't being pumping of petroleum products into this segment to Maiduguri Depot because of Security reasons, emanating from the activities of the terrorist insurgents that has in couple of times attempted to attacked and vandalized oil depot and pipeline infrastructures.

4.4.7 System 2D (e) Jos-Gombe Pipeline Segment

The 265 km length and 90 m^3/hr flow rate pipeline segment, was the first pipeline constructed that pumps petroleum products from Jos Depot to Gombe Depot. By the evidences of the satellite imagery and field check analyses, two land use types were identified as encroachers to the pipeline's right-of-way; that is agricultural land use and built-up areas. The farmlands/grazing and vegetal growth areas displayed dark-greyed tones satellite imagery when wet but are grey-light toned when dried. However, the Jos-Gombe oil pipeline is one of the pipeline segments that Federal

Government has spents 1.32 billion naira, between year 2011 and 2012 in clearing and in grading pipelines' right-of-way in Nigeria. 3 km Bulyde Jos-Gombe pipeline route in Gombe and 4 km Zonkwa-Jos pipelines' right-of-way were amongst those cleared.

4.4.8 System 2CX (b) Auchi-Suleja Pipeline Segment

The system 2A product pipeline route which conveys product from Warri-Benin-Suleja/Ore Depots ranks second on the scale of pipeline break points with 3,259 cases representing 20.2% of the total volume products pipeline breaks in Nigeria. The figure also came with a loss of over ₦20.39 billion in products and pipeline repairs (NNPC, 2013). From the satellite interpretation, it was observed, that one of the major land use type infiltrating and intruding into the crude line to Suleja is the water bodies that the pipelines criss-crossed at the Lokoja Confluence (River Niger) which occupies a larger portion of the various types of land use encroaching into the pipeline's right-of-way, as indicated by the bluish toned pattern. Farmlands/grazing lands were observed during ground checks to have encroached into the pipeline's right-of-way. Also at the urban areas, specifically at the southern part of the pipeline routes (Auchi and some other settlements in the middle-belt region of Nigeria), where this pipeline transverse, built-up structures were seen to have encroached into the pipeline's right-of-way.

4.4.9 System 2CX (c) Suleja-Minna Pipeline Segment

Warri Refinery pumps products to Benin, Auchi, Abaji, Suleja and Minna. The major land use type observed to have encroached by 50 m^2into the pipeline's right-of-way is agricultural land use. Cultivation of crops and

grazing of animals by farmers and cattle herdsmen at a close proximity to the pipeline route was observed during field checks. It also reported by NNPC that pipelines, conveying products from Warri-Auchi-Suleja Crude Line en-route the Minna Depot in Niger State, have been vandalised in more than 20 points, leading to the stoppage of pumping of the products. While at the Dikko-Suleja area and in Minna, it was observed that built-up structures were responsible for the non-compliance to the right-of-way of the oil pipelines, as some of this built-ups encroached by 50-70 m into the setback of pipelines. This pipeline system segment has witnessed series of vandalisms by pipelines vandals and saboteurs particularly at the Dikko settlement.

4.4.10 System 2CX (d) Suleja-Kaduna Pipeline Segment

The newly laid Suleja-Kaduna NNPC Pipeline's segment has a length of 150 km and flow rate of 135 m^3/hr. The Suleja Depot further helps in pumping crude oil from the Warri Refinery to Kaduna Refinery. The major land use types that was observed to encroached to the pipelines' right-of-way is agriculture and built up. However, the built-ups were seen mainly within the Kaduna and Suleja Settlement heartlands. Minor Road as a form of land use was observed to be encroaching into the pipeline's right-of-way particularly at the urban environment of the study area. It is note worthy to state that the Suleja-Kaduna line is amongst the segments that the Federal Government has spent 1.32 billion naira, between year 2011 and 2012 in clearing and in grading pipelines' right-of-way in Nigeria. But this has not stopped agriculture as a form of land use type from encroaching into NNPC Pipelines' right-of-way in the study area.

4.4.11 System 2DX Jos-Gombe Pipeline Segment

This segment is the newly constructed pipeline to augment the existing pipeline. It has a length of 165 km and 85 m^3/hr. Between 2010 and 2012 a total of 2,787 lines breaks were reported on pipelines belonging to the Nigerian National Petroleum Corporation (NNPC, 2013), resulting in a loss of 157.81 million tonnes of petroleum products worth about ₦12.53 billion. Pipelines along the Gombe axis recorded 850 cases of pipeline break.

4.4.12 System 2E (b) Enugu-Makurdi Pipeline Segment

Port Harcourt Refinery; System 2E Crude Line, pumps products through Aba, Enugu and to Markurdi. In all, 8,105 breaks were recorded along the system 2E within the period representing about 50.3 percent of the total number of petroleum products pipeline breaks in the country (NNPC, 2013), which the Phase II Enugu-Makurdi pipeline segment constituted a proportion of these pipeline breaks. The attacks left the NNPC with a cost of N78.15 billion in product loses and pipeline repairs. The Yola-Enugu-Auchi appears to be the haven of pipeline vandalism in the country particularly the Port Harcourt-Aba/Isiala-Ngwa axis.

4.4.13 System 2EX (c) Makurdi-Yola Pipeline Segment

The System 2EX(c); which conveys products from system 2E: Port Harcourt refinery to Aba-Enugu-Makurdi Depots onwards to Yola Depot. It has a diameter of 8”c = 0.25”, with 475 km and concrete pipeline of 7,000 m length (NNPC, 1993). According to records obtained from linear measurement, it was observed there was about 58 m encroachment into the

pipelines' right-of-way by built-up area at Apir, within 1 km radius, and at 3 km away from the depot, farming/grazing land use was observed to have encroached into the pipeline' right-of-way. The land use types; built-up and tarred and untarred road are responsible for the encroachment into the pipeline's right-of-way. NNPC pipelines, conveying products from Enugu to Makurdi, enroute the Yola Depot in Adamawa State, have been vandalised in more than 20 points, leading to the stoppage of pumping of the products.

Thus, analysis as shown in figure 4.2a-4.4 below gave the summary of the level of compliance by the various land use/cover types to the NNPC pipeline segments' right-of-way in Northern Nigeria. The table revealed that the assessed land use/cover types in the study area do not comply with the right-of-way of these pipelines.

4.4 Classification Scheme for Land Use Types

A classification scheme was developed for the study area after Anderson *et al.* (1967). The classification scheme developed gives a rather broad classification where the land use/land cover were identified by a single digit. But for the purpose of this research, it was modified to suit the classification scheme adopted by the Planning Authorities world wide. This is classification is used for land use zoning, mapping and regulations in Nigeria. This also includes the colour codes for each of the various land uses adopted; this is shown in the table 4.10 below.

Table 4.10: A Modified Anderson's (1967) Classification Scheme for Land Use/Land Cover Code and Colours Categories.

S/NO.	LAND COVER	COLOUR CODE	S/NO.	LAND USE	COLOUR CODE
1.	Farmland	Purple	**1.**	Industrial	Purple
2.	Wasteland	Green	**2.**	Recreational	Green
3.	Built-up Land	Yellow	**3.**	Public/Semi-public	Yellow
4.	Forest Bodies	Greenish Brown	**4.**	Residential	Brown
5.	Water Bodies	Blue	**5.**	Organized and unorganized open space	Green
6.	Bare Surface	Brown	**6.**	Commercial	Red
			7.	Water Bodies	Blue

Source: Anderson, 1967 and Canada Centre for Remote Sensing, 2012.

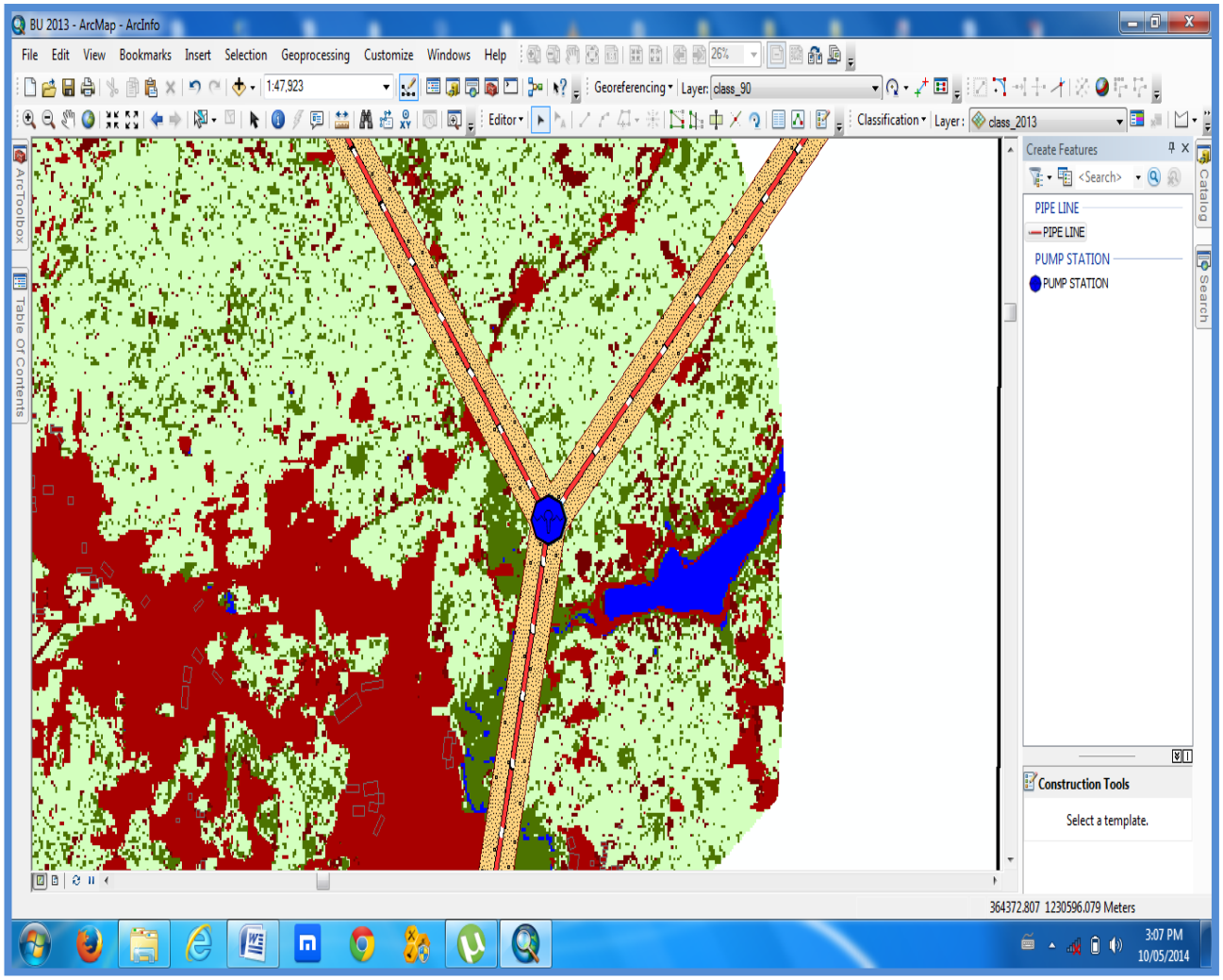


Fig. 4.1(a): Land Use Classification for Zaria-Gusau and Zaria-Kano Axes Study Area.

Source: Researcher's Work, 2014.

Figure 4.1(a) above, depicts 576 m^2 buffer zone from the Agricultural area, Built- up area, Water Bodies and Roads**.** The query was carried out to show Agriculture, Built-up areas, Water Bodies and Roads that is available outside the buffered zone. Based on the buffer analysis done and measure measurement carried out on the field, it was observed that the various land use types encroached into the pipelines' right-of-way as explained in sub-section 4.33 above.

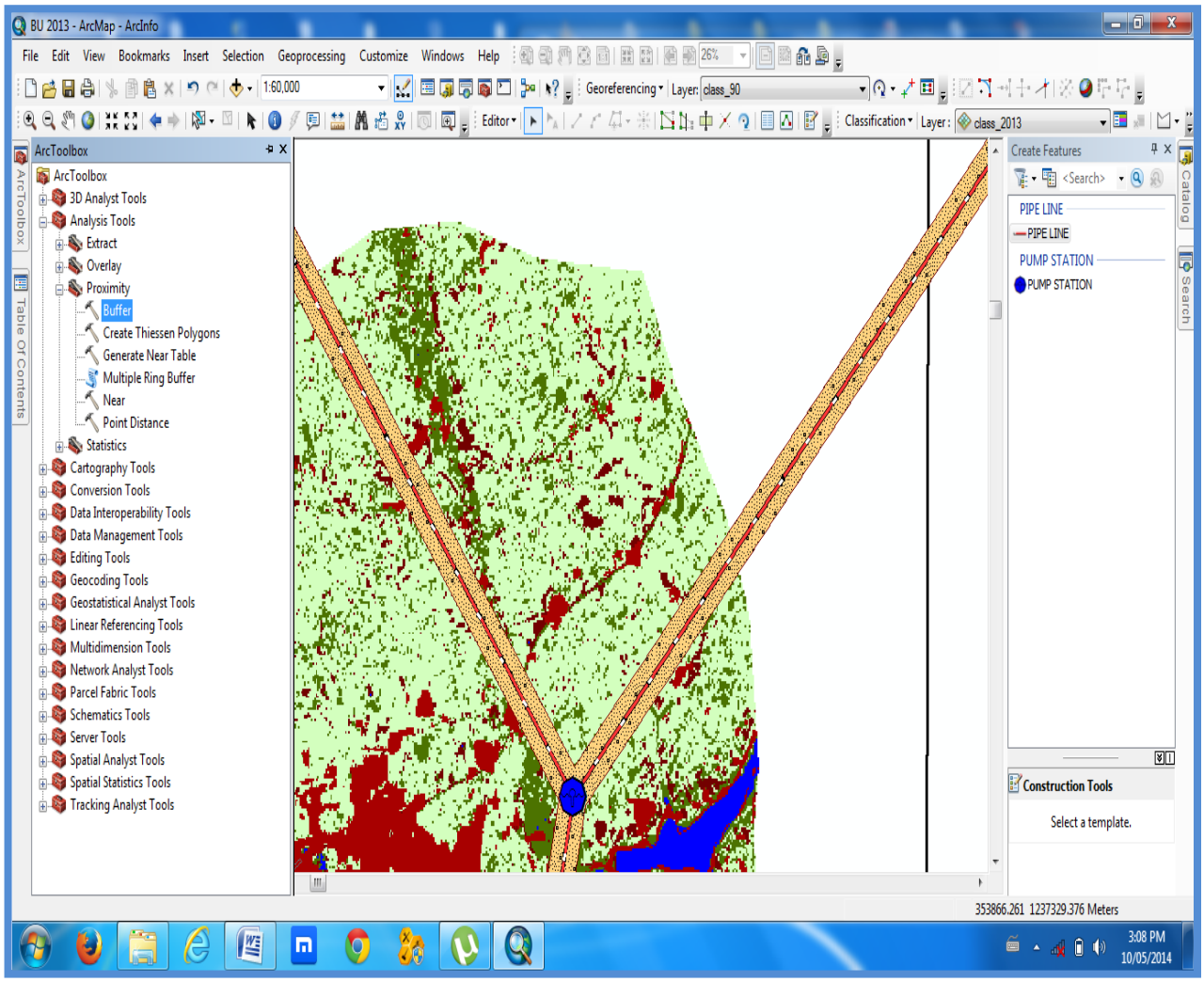


Fig. 4.1(b): Land Use Classification for Zaria-Gusau and Zaria-Kano Axes Study Area (Magnified).

Source: Researcher's Work, 2014.

Figure 4.1 (b) above, shows 450 m^2 buffer zone from the Agricultural area, Built-up area, Water Bodies and Roads**.** The above query was carried out to show Agriculture, Built-up areas, Water Bodies and Roads that is available outside the buffered zone. The buffer zone analysis as explained in sub-section 4.3.3 and sub-section 4.3.4 shows that the various land use types encroaches into the pipelines' right-of-way by larger encroached size more than when buffer zone criteria of 576m^2 was used.

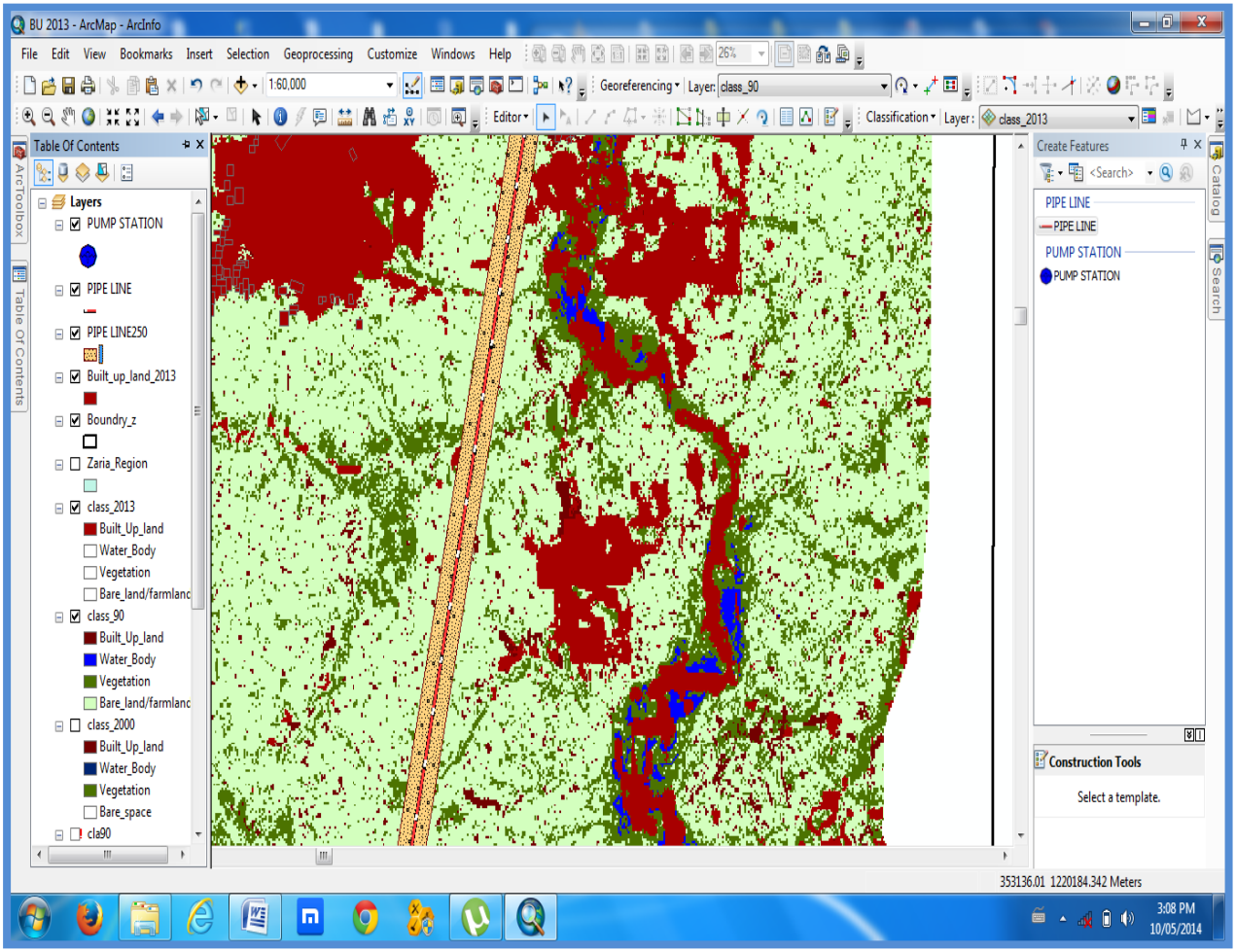


Fig. 4.2: Land Use Classification for Warri-Auchi-Kaduna Axis (Crude Oil Pipeline) of the Study Area (Magnified).

Source: Researcher's Work, 2014.

450 m^2 buffered from the Agriculture, Built-up area, Water Bodies and Roads**.** The above query was carried out to show Agriculture, Built-up areas, Water Bodies and Roads that is available outside the buffered zone. The buffering analysis along the Old Crude-Oil Line segment showed that all the various land use types encroaches into the pipelines' right-of-way. A detail explanation on the encroachment extent has been elucidated in Sub-section 4.3.2 of this section above.

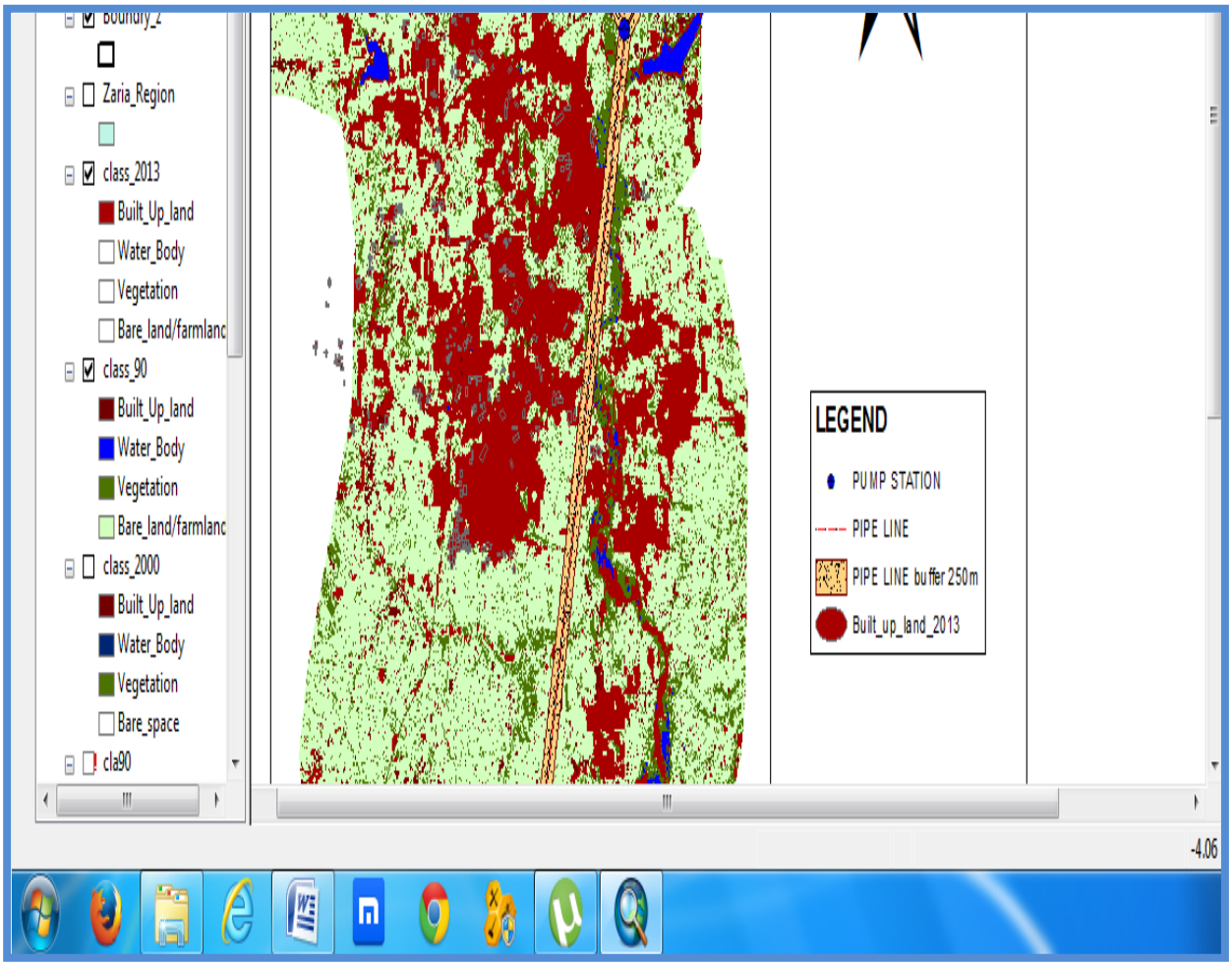


Fig. 4.3: Land Use Classification for Warri-Auchi-Kaduna Axis (New Product Pipeline) of the Study Area (Magnified).

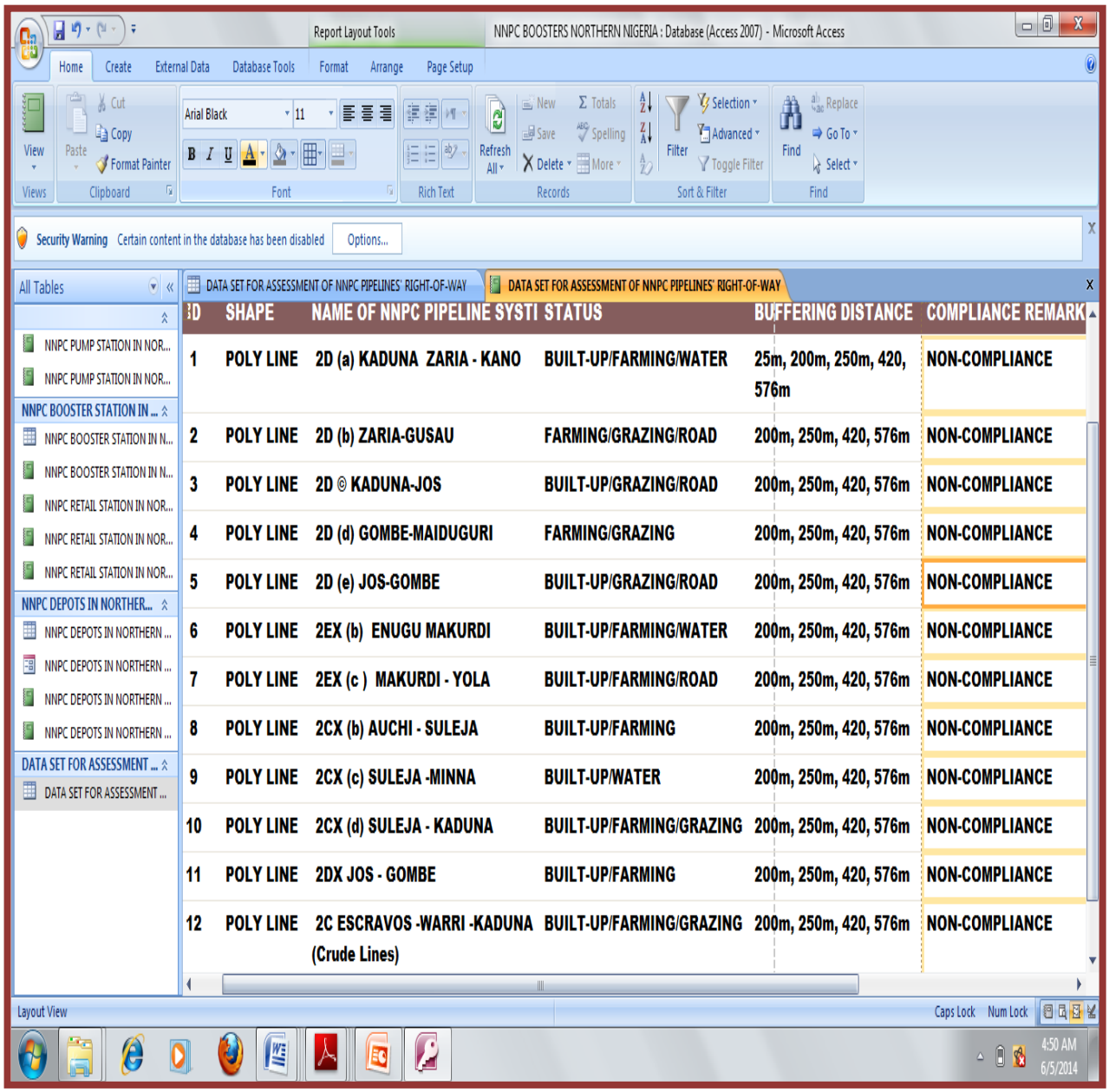
Source: Researcher's Work, 2014.

200 m^2 buffer zone from the Agriculture, Built-up area, Water Bodies and Roads**.**

The above query was carried out to show Agriculture, Built-up areas, Water Bodies and Roads that is available outside the buffered zone. When this analysis is zoomed to screen, it virtually showed that all the various land use types encroached into the pipelines' right-of-way along the studied segment points. The encroachment features

or characteristic is similar to the Old Product Pipeline. This is because the new product pipeline was laid at close proximity to the existing pipeline.

Table 4.11: Dataset for Level of Compliance to NNPC Pipelines' Right-of-Way.



ID	SHAPE	NAME OF NNPC PIPELINE SYSTI	STATUS	BUFFERING DISTANCE	COMPLIANCE REMARK
1	POLY LINE	2D (a) KADUNA ZARIA - KANO	BUILT-UP/FARMING/WATER	25m, 200m, 250m, 420, 576m	NON-COMPLIANCE
2	POLY LINE	2D (b) ZARIA-GUSAU	FARMING/GRAZING/ROAD	200m, 250m, 420, 576m	NON-COMPLIANCE
3	POLY LINE	2D © KADUNA-JOS	BUILT-UP/GRAZING/ROAD	200m, 250m, 420, 576m	NON-COMPLIANCE
4	POLY LINE	2D (d) GOMBE-MAIDUGURI	FARMING/GRAZING	200m, 250m, 420, 576m	NON-COMPLIANCE
5	POLY LINE	2D (e) JOS-GOMBE	BUILT-UP/GRAZING/ROAD	200m, 250m, 420, 576m	NON-COMPLIANCE
6	POLY LINE	2EX (b) ENUGU MAKURDI	BUILT-UP/FARMING/WATER	200m, 250m, 420, 576m	NON-COMPLIANCE
7	POLY LINE	2EX (c) MAKURDI - YOLA	BUILT-UP/FARMING/ROAD	200m, 250m, 420, 576m	NON-COMPLIANCE
8	POLY LINE	2CX (b) AUCHI - SULEJA	BUILT-UP/FARMING	200m, 250m, 420, 576m	NON-COMPLIANCE
9	POLY LINE	2CX (c) SULEJA -MINNA	BUILT-UP/WATER	200m, 250m, 420, 576m	NON-COMPLIANCE
10	POLY LINE	2CX (d) SULEJA - KADUNA	BUILT-UP/FARMING/GRAZING	200m, 250m, 420, 576m	NON-COMPLIANCE
11	POLY LINE	2DX JOS - GOMBE	BUILT-UP/FARMING	200m, 250m, 420, 576m	NON-COMPLIANCE
12	POLY LINE	2C ESCRAVOS -WARRI -KADUNA (Crude Lines)	BUILT-UP/FARMING/GRAZING	200m, 250m, 420, 576m	NON-COMPLIANCE

Source: Researchers' Work, 2014.

Table 4.11 above, shows the query for all the pipelines system's buffer zone criteria to ascertain the right-of-way compliance by Agricultural area, Built-up area, Water

Bodies and Roads**.** The results indicated that the various land use type in the study area do not complied with the regulations guiding pipelines' ROW in the study area.

4.5 Elevation and Slope Aspect

Distribution of land use encroachment types was observed to be associated with altitude in the study area. This can be supported by the fact that elevation is positively correlated with rainfall and humidity regime of soil (Damen, 1993). The Digital Elevation Modelling (DEM) of satellite imageries (the Nigeria Landsat STRM and Northern Nigeria Landsat SRTM Band 1, 2 and 3) gives the Elevation points of the study area. The use of the Remote Sensing and GIS techniques revealed the elevation of the study area with interval of 50 m a.s.l

The influence of slope steepness on the laying of pipelines and land use type encroachment and occurrences was found to be prominent in the study area and that the laying of pipelines takes advantage of flat topography and a steepness of 20^{o}. Figure 4.4 and figure 4.5 below clearly explain the relationships. In general, the steeper the slope the more the forceful the pumping or transported oil products and the lesser the encroachment into pipelines' right-of-way taking place. The slope classes measured on satellite imageries are grouped below:

i. < 1 degree.
ii. 1 - 5 degree.
iii. 5 - 10 degree.
iv. 10 - 15 degree.
v. 15 - 20 degree.

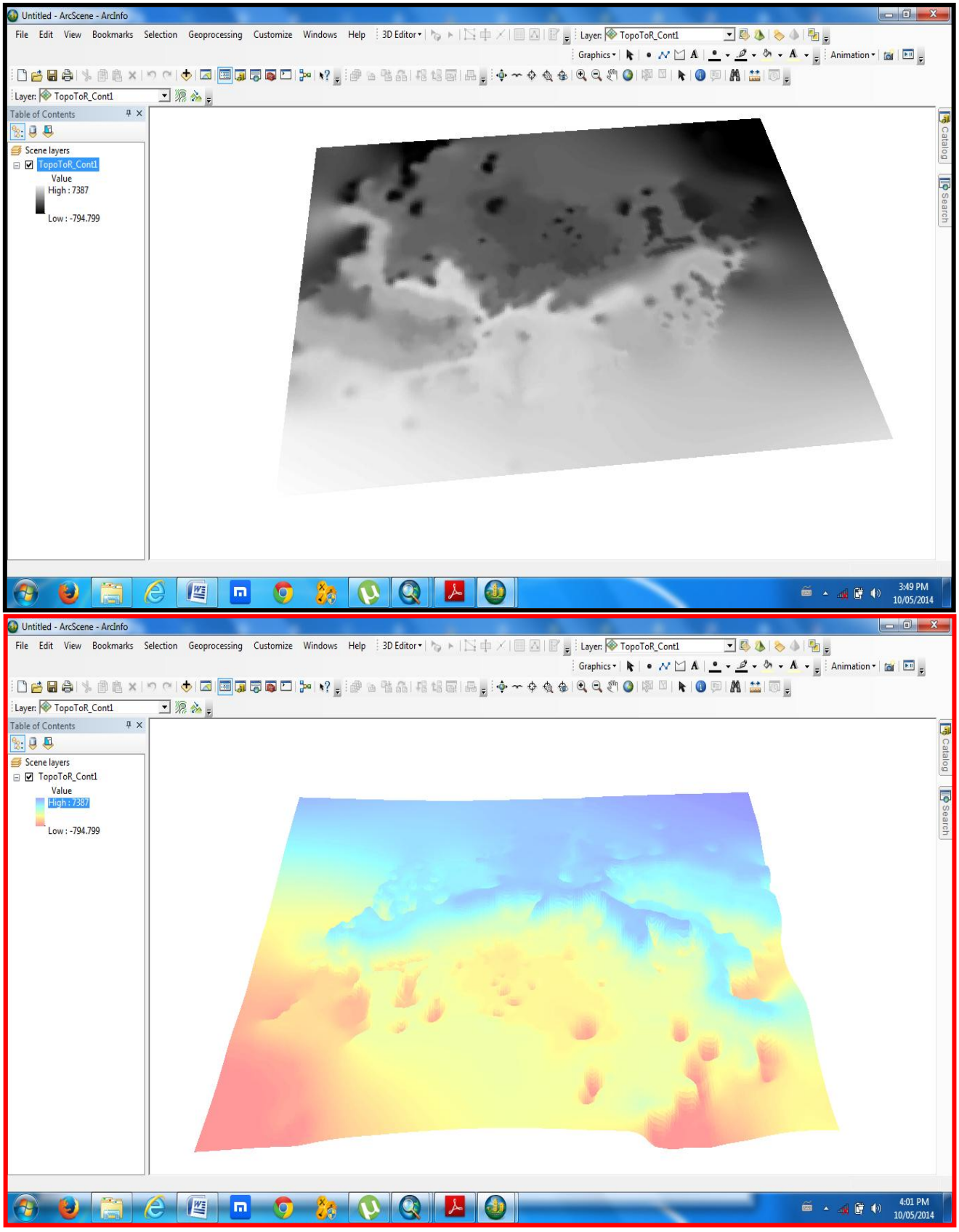


Fig. 4.4: Digital Elevation Model (DEM) (Panchromatic and Multi-spectral Colours) of the Study Area 3D-Perspective.
Source: Researcher's Work, 2014.

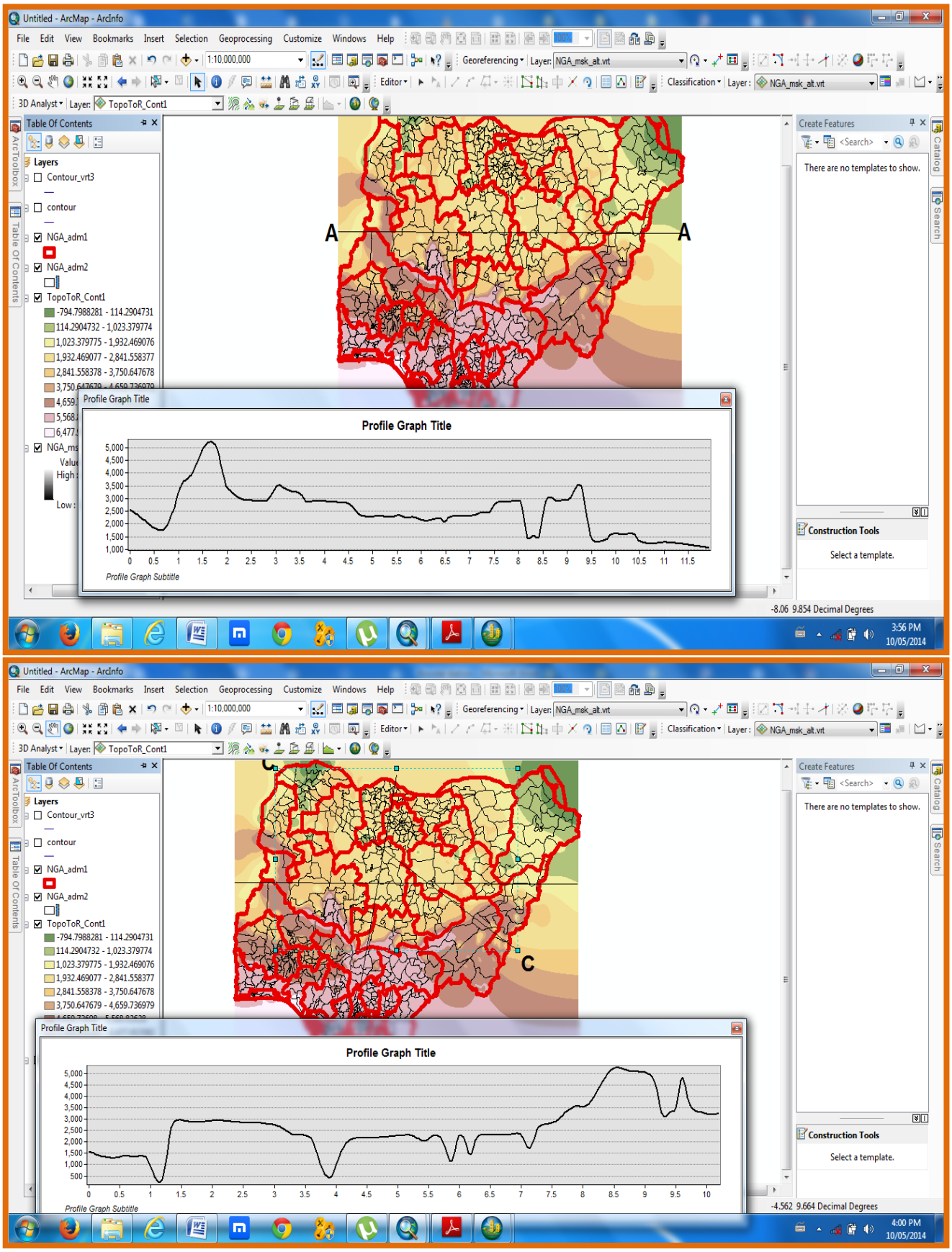


Fig. 4.5: Contour Profile Graph from A, B, C-Orientation of the Study Area.
Source: Researcher's Work, 2014.

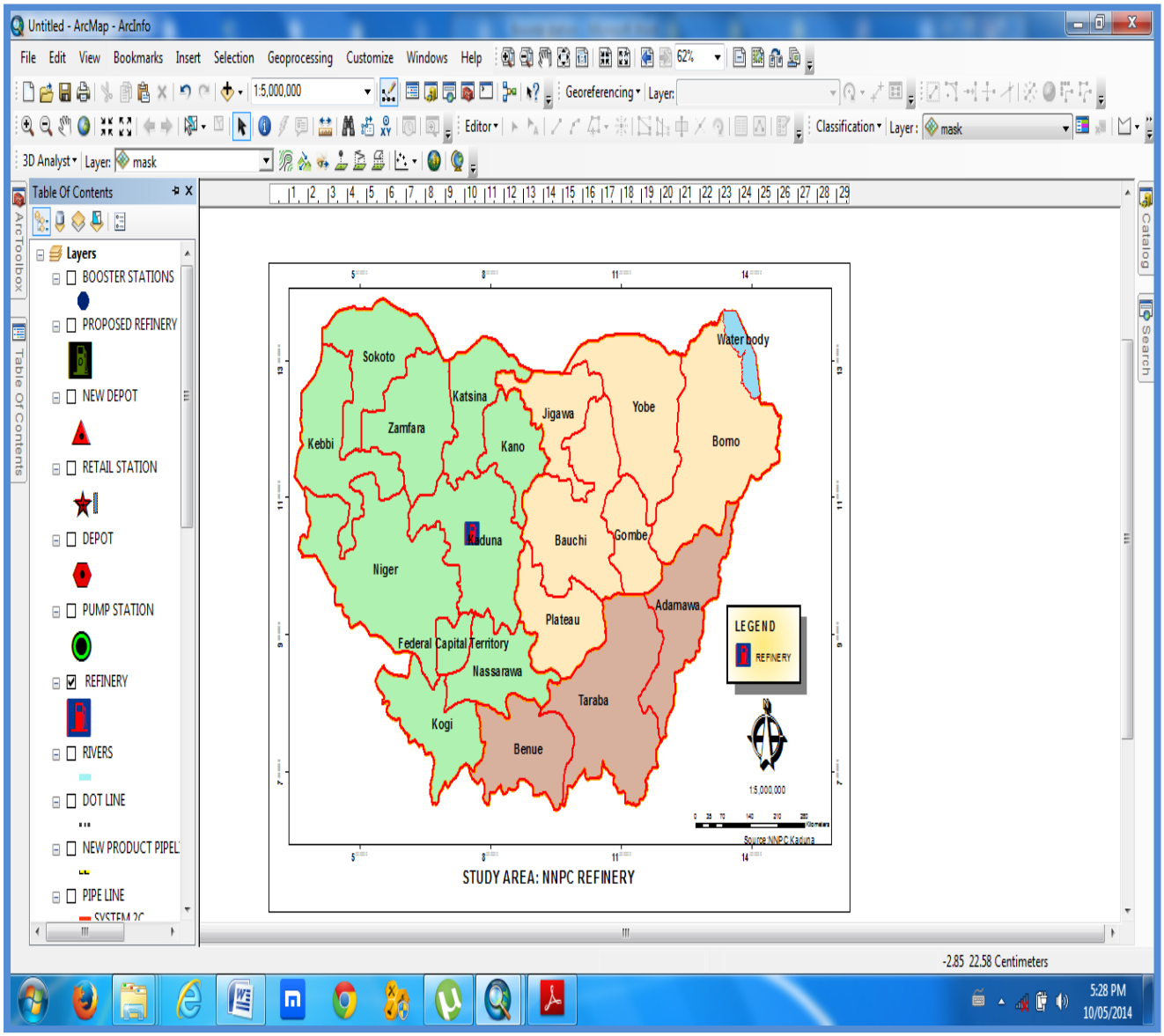


Fig. 4.6: NNPC (Kaduna) Refinery in the Study Area.
Source: Researcher's GIS Analysis Work, 2014.

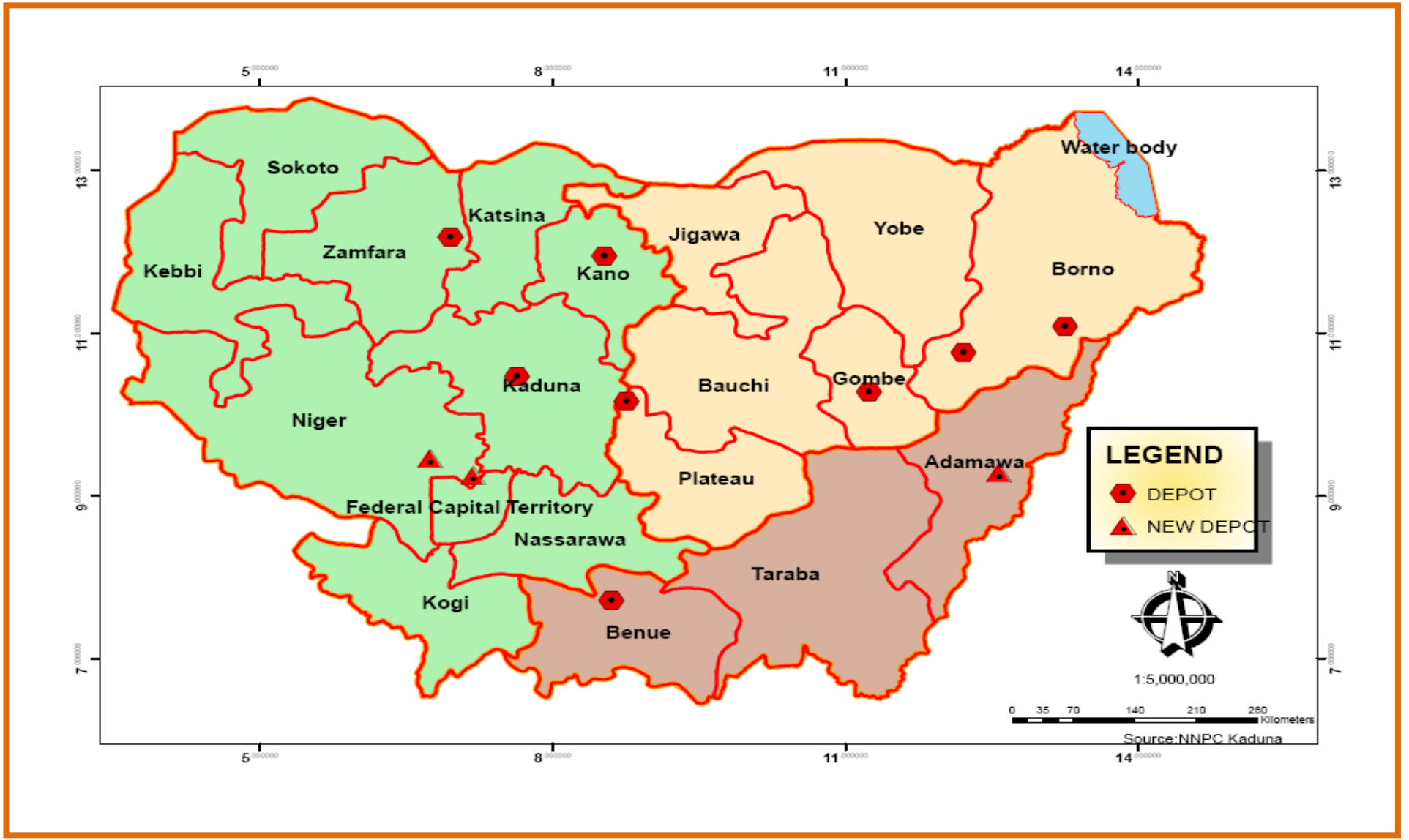


Fig. 4.7: NNPC Depots in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

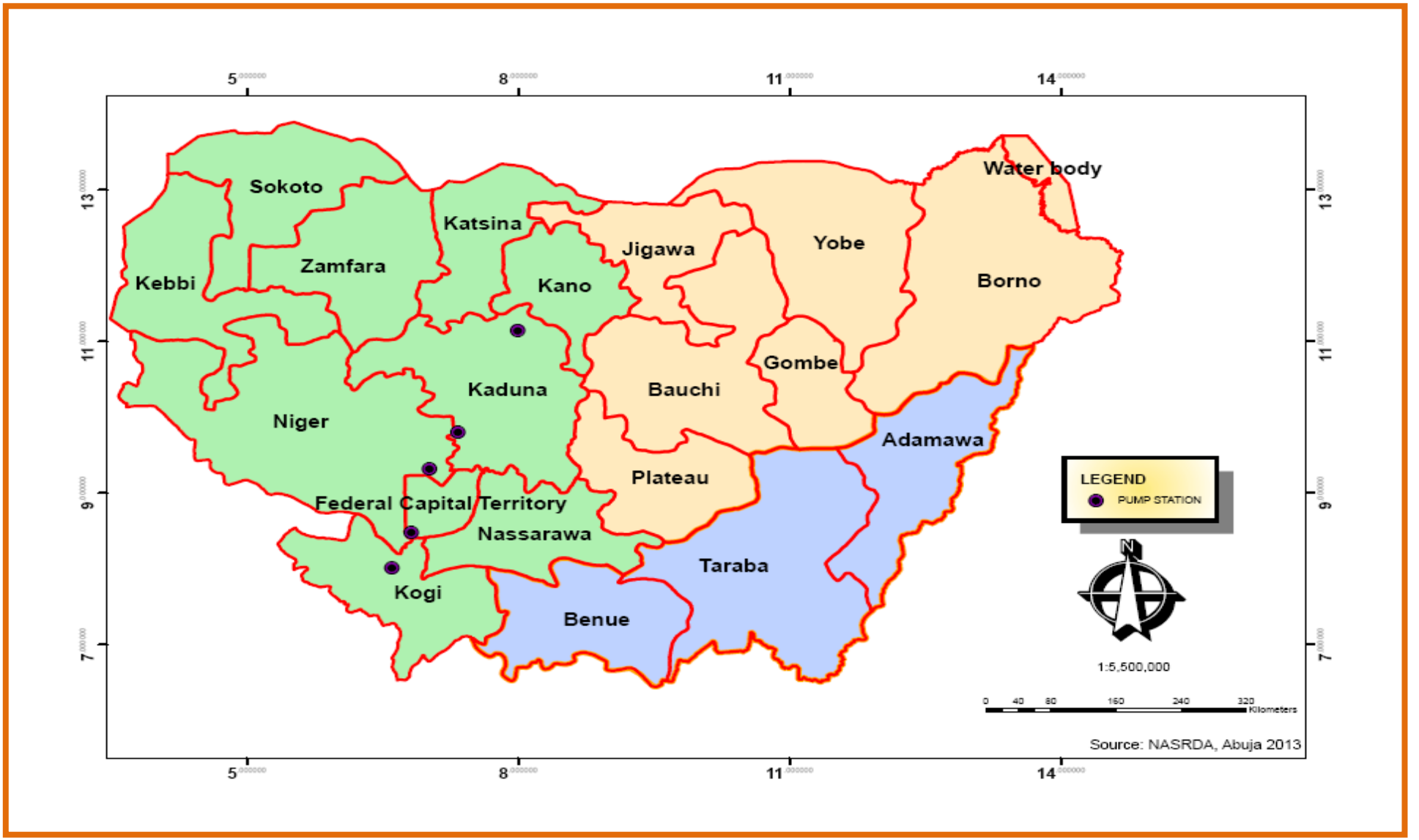


Fig. 4.8: NNPC Pump Station in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

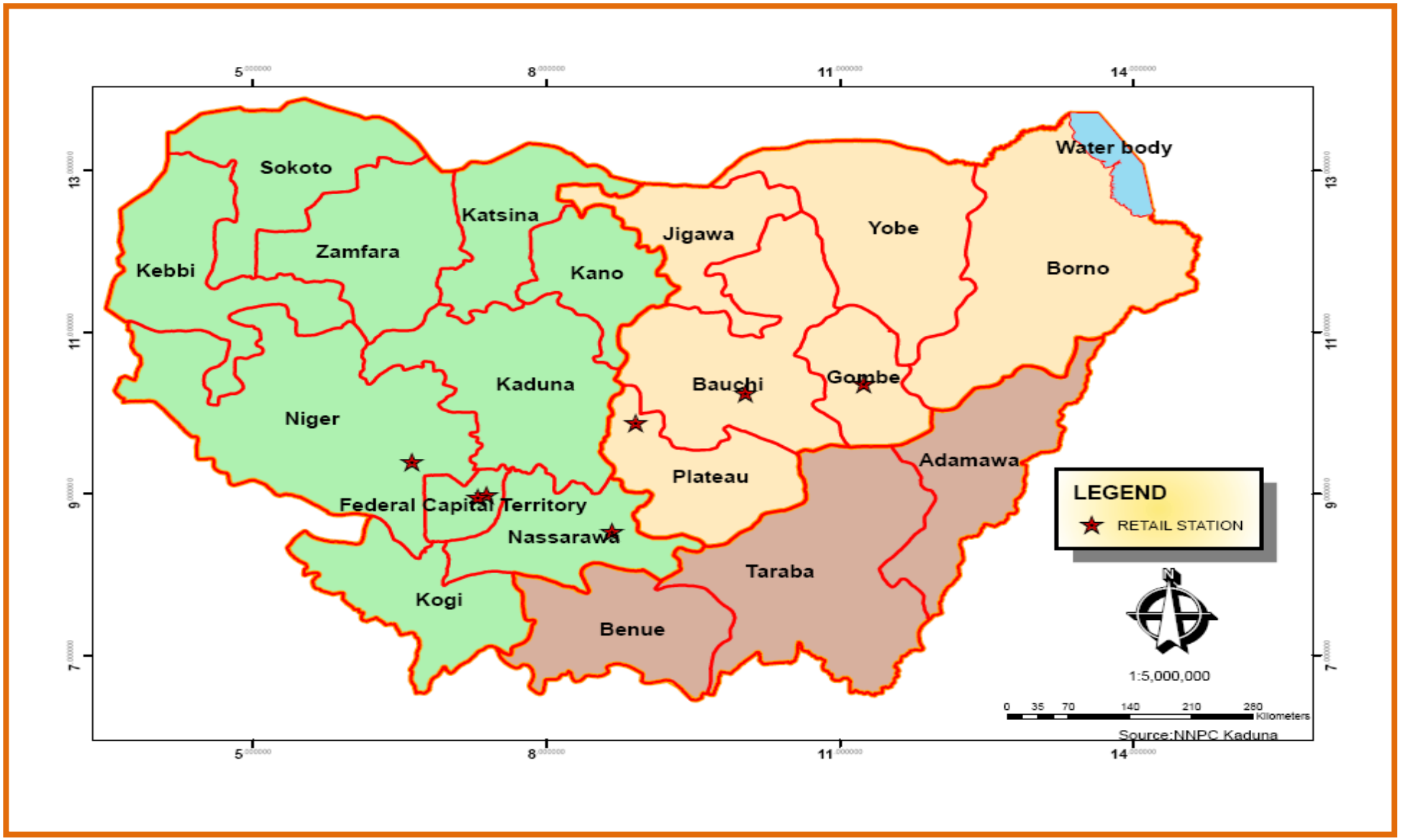


Fig. 4.9: NNPC Retail Station in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

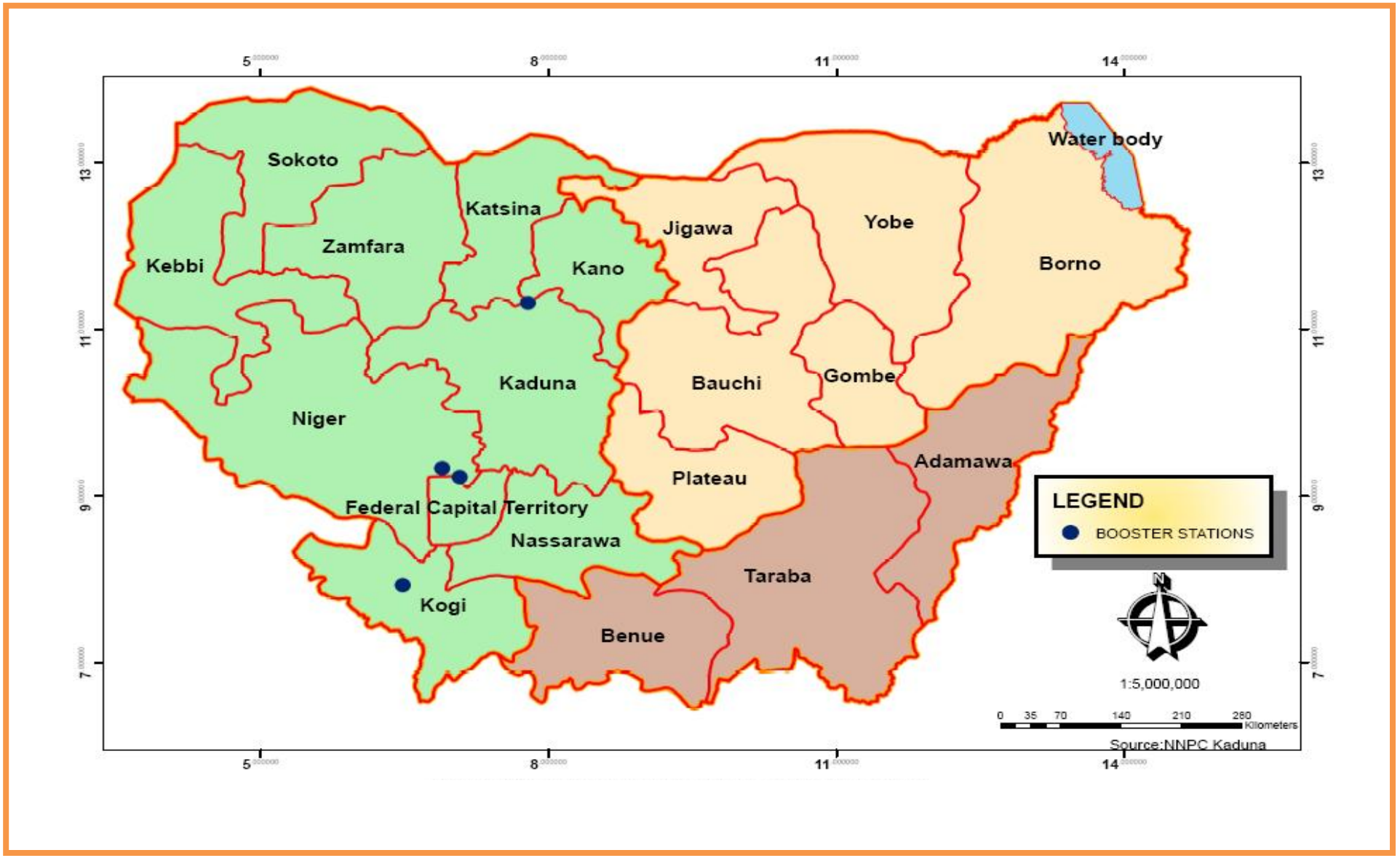


Fig. 4.10: NNPC Booster Station in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

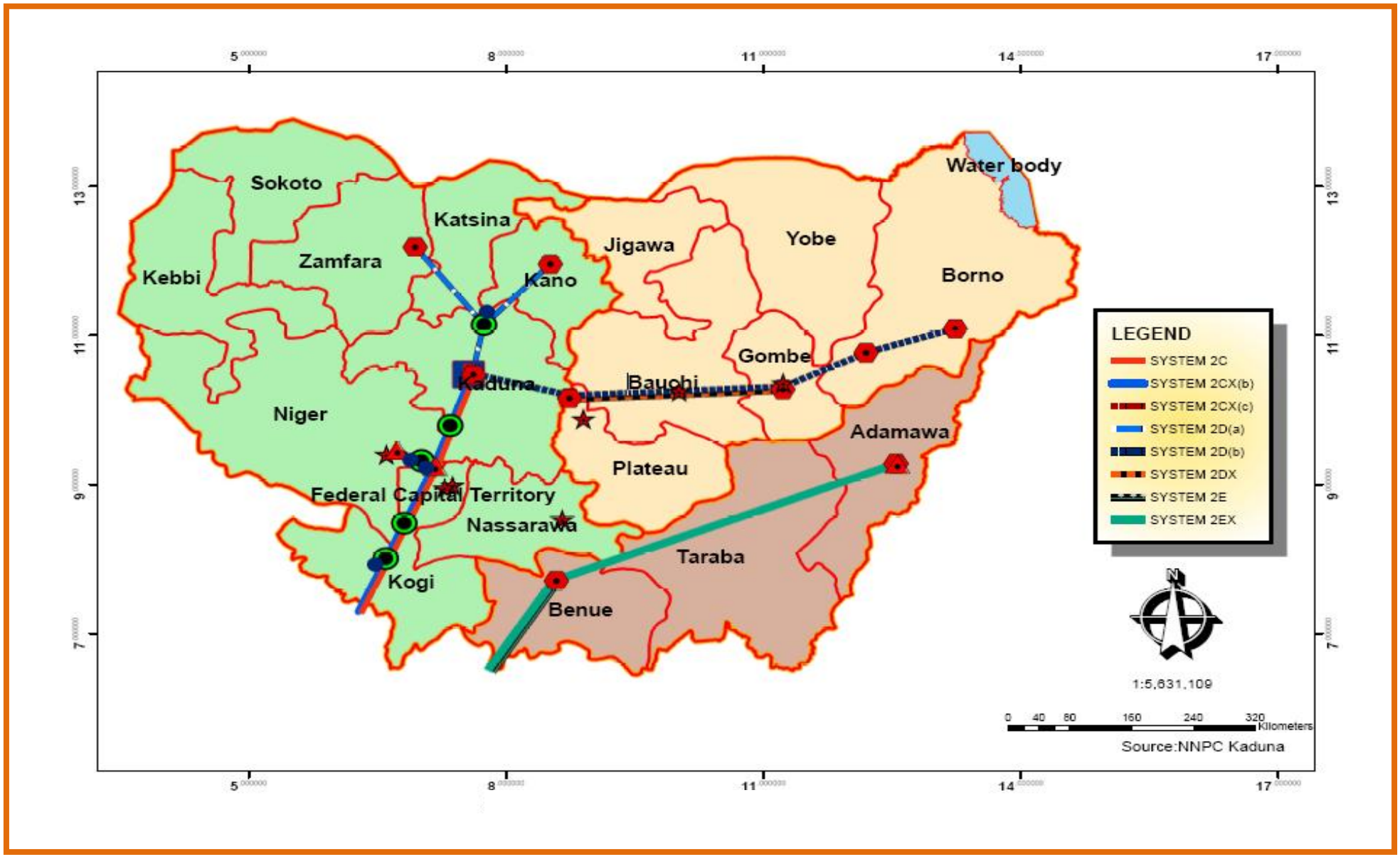


Fig. 4.11: NNPC Pipelines Network in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

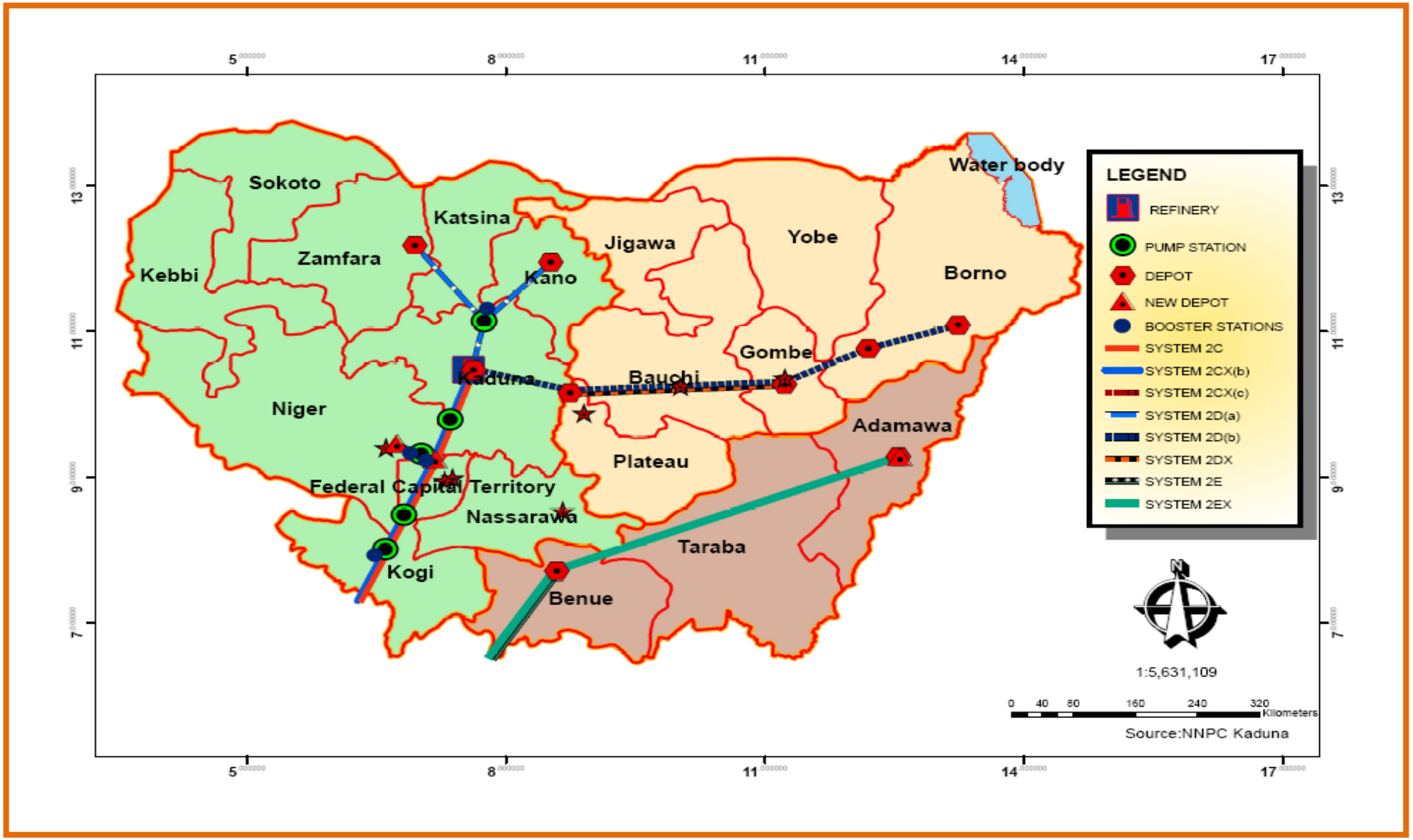


Fig. 4.12: Overlaid Map of NNPC Pipelines' Super-imposed Features.
Source: Researcher's GIS Analysis Work, 2014.

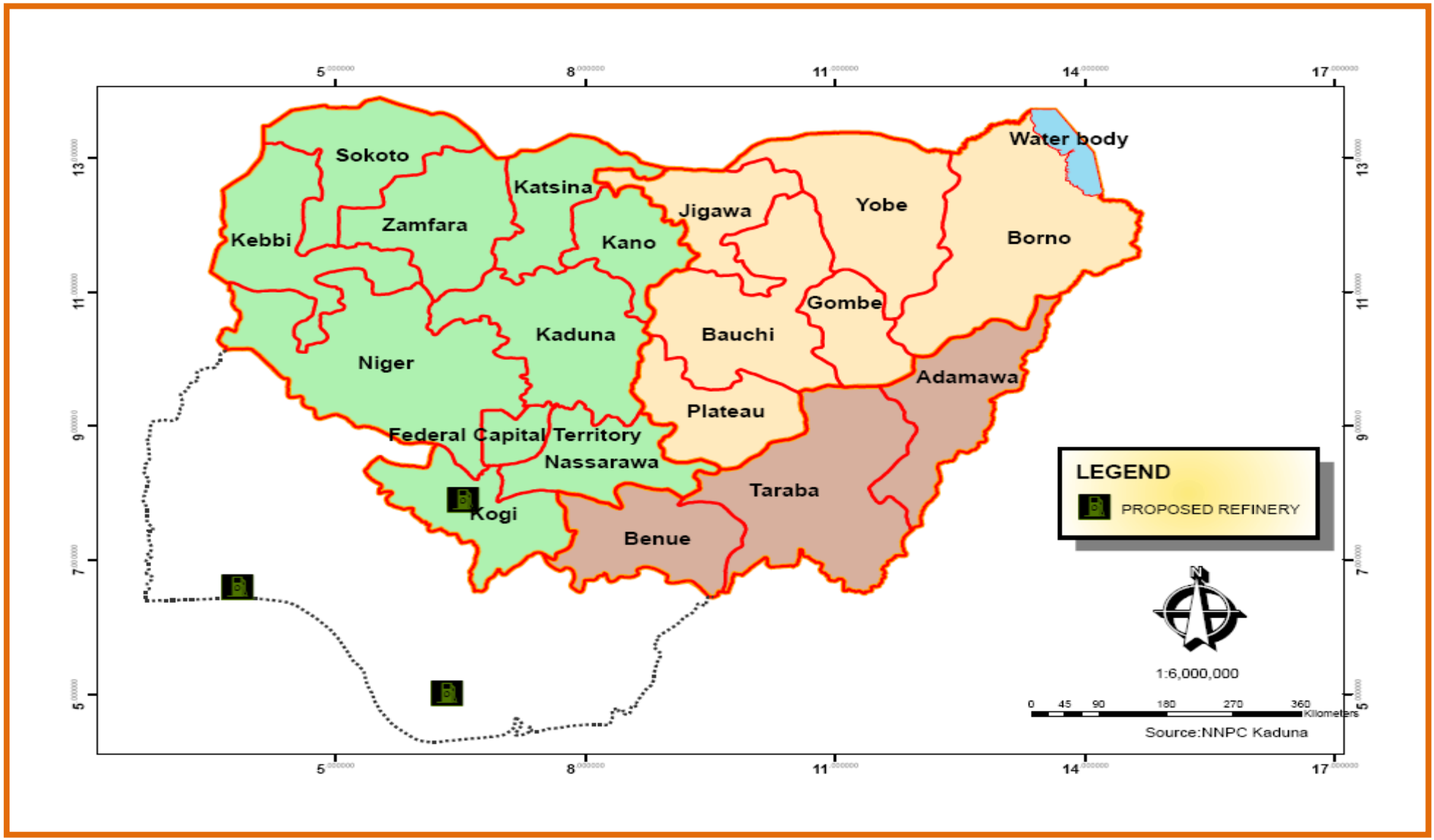


Fig. 4.13: Proposed Locations for New NNPC Refineries in Study Area.
Source: Researcher's GIS Analysis Work, 2014.

4.6 Problems and Challenges of Non-compliance to NNPC Pipelines' Right-of-Way

This section assesses the problems and challenges of non-compliance to the pipelines' right-of-way and it attendant environmental complexities. The data collected and collated from the Respondents through questionnaire administration and interviews, were represented and analyzed, using both descriptive and inferential statistics under the following headings:

Table 4.12: Distribution of Question to Respondents in the Study Area.

S/No.	Profession	Number of Copies of Question Administered	Numbers of Returned Copies of Questionnaire	Percentage (%)
1.	NNPC Staff.	35	35	**17.5**
2.	Oil Workers.	30	28	**14.0**
3.	Staff of Ministry Environment.	30	29	**14.5**
4.	Environmentalists.	30	28	**14.0**
5.	Farmers.	30	27	**13.5**
7.	Fishermen/Women.	30	28	**14.0**
8.	Market Men/Women.	30	25	**12.5**
	Total	215	200	**100**

Source: Researcher's Work.

A total of 215 copies of questionnaires where administered in the study area, only 200 copies questionnaires were returned. The above shows that NNPC Staff accounts for 17.5%, Ministry of Environment had 14.5%, Oil workers, Environmentalists and Fishermen/Women make up the 14.0% each. While the

remaining percent of 13.5% and 12.5% was shared between Farmers and Market Men/Women, which sum up to a total of 100%.

Table 4.13: Concept of Remote Sensing and Geographic Information System and Environmental Issues on Oil Pipelines.

S/NO.	ITEM	SA	A	DA	SDA	NA	MEAN (X)	REMARK
1.	Oil Bunkering, theft, Vandalism and Spillages and Pollution are common Environmental issues that pose danger to human life.	113	78	7	2	200	3.51	**Strongly Agreed**
2.	Impact of non compliance to NNPC Pipelines ROW by the land-use type in your Community has led to Oil, Bunkering, Theft, Vandalism, Oil Spills and Fire Inferno in Northern Nigeria.	125	70	4	1	200	3.60	**Strongly Agreed**
3.	Nigerians are vulnerable to health related problems as a result of Gas Flaring and Oil Pipe leakages and outbreaks.	135	62	1	2	200	3.65	**Strongly Agreed**
4.	Communities along the Pipelines Network System through out the Country should be provided with essential infrastructure, utilities and services to dampen the urge to vandalize pipelines to attract compensation or scoop oil to earn a living.	118	76	3	3	200	3.55	**Strongly Agreed**

Source: Author's Field Work (2014).

Cut-off Point= 2.50.

Grand mean= $\frac{\sum(X)}{N}$

Where $\sum(X)$ = Summation of Number of Means.

N = Number of Variables.

Grand Mean= $\frac{\sum(X)}{N} = \frac{14.31}{4} = 3.58$.

Table 4.13 above shows the responses of all the Respondents on Item 1-5. The respondents agreed on the following Item numbered 1, 2, 3 and 4 with Mean of 3.51, 3.60, 3.65 and 3.55. Thus, they were all rated 'Strongly Agreed'. The Grand Mean for Table 1 is 3.58. This shows that Respondents

understood the concept of Remote Sensing, Geographic Information System and its capabilities in addressing environmental issues associated with oil Pipelines in Nigeria.

The analysis of the data based in mean statistics, revealed that there is a fairly understanding of the concepts, principles, methods and techniques of Remote Sensing and Geographic Information System, rupture and vandalism of pipelines and oil spillages. According to Momoh (2012), posited that: "It is in Nigeria that such practices (pipeline vandalism) are carried out at an alarming rate". He identified well over 2,330 number of line vandalism on crude oil pipelines from Escravos-Warri, Port Harcourt to Kaduna pipeline segments between 2006-2011, described as hot spot areas. A total of 16,476,011 barrels of crude oil has been lost during the said period.

Backed with data to buttress the point, the NNPC GMD, Engr. Austen Oniwon informed that a total of 16,083 pipeline breaks were recorded within the last 10 years adding that while 398 pipeline breaks representing 2.4 per cent were due to ruptures, the activities of unpatriotic vandals accounted for 15,685 breaks which translates to about 97.5 percent of the total number of cases.

Anagboso (2012) buttressed that;

> ***"oil pollution causes danger to the ecosystems, making it difficult to support and sustained life, such essential services as provisioning services (e.g. of food, wood), supporting services (soil formation, nutrient cycling and primary production), cultural services (education and aesthetics) as well ecosystem regulating services like climate regulation, food regulating, diseases regulation and water purification are greatly impaired by crude oil pollution".***

The activities of oil thieves have not only caused pollution of some rivers and lands in the study areas, but have also resulted in the outbreak of diseases and deaths in some communities. This heinous crime has continued to take a toll on the Nigeria's economy. In spite of the danger posed by pollution arising from oil theft and vandalism to the environment, oil thieves continuously engaged in wanton degradation of the environment in the study area. It would probably take some years to restore degraded environment in the oil region studied, assuming oil thieves stop pollution in the first instance.

Against the backdrop of these unwholesome and incessant acts of pipeline vandalism in the study areas and its attendant effects, losses and inevitable downtimes, PPMC pipeline have remained active and available to ensure crude oil/petroleum products delivery and availability to the refineries and the nation as a whole, due to fairly enhanced right-of-way (ROW) surveillance and accessibility. Hence, the opinion of the researcher is that all concern to report any act of pipeline vandalism around them to the appropriate authority.

Table 4.14: Roles of NNPC, Construction Companies and Planners in the Planning, Control and Management of Oil Pipeline Right-of-Way in Nigeria.

S/NO.	ITEM	SA	A	DA	SDA	NA	MEAN (X)	REMARK
5.	There is need for synergy between NNPC/PPMC planning Authorities to enhance the planning and control, monitoring of the development and operation of pipelines ROW in Nigeria.	132	65	2	1	200	3.64	**Strongly Agreed**
6.	Nigerians Policy Makers, Planners and Managers of Oil and Natural Gas pipelines products need to evolve pipeline-materials' toxicity and reactivity Rating Scales to suits Nigeria's situation.	116	73	7	4	200	3.51	**Strongly Agreed**
7.	Lack of monitoring and management of pipelines Infrastructures is responsible for the corrosion of pipelines, leading to oil spillages that cause pollutions.	121	68	6	5	200	3.53	**Strongly Agreed**
8.	Emission of pipelines and Gas Flaring from Refineries can reduce Air Quality, causes Health related symptoms and reduce productivity of Community in concern in Nigeria.	144	48	2	6	200	3.60	**Strongly Agreed**
9.	There is need for suitable Partnership Strategy between the pipeline authorities and the various communities affected by pipeline developments to detect pipeline leaks and checkmate the activities of pipeline Vandals.	112	76	8	4	200	3.48	**Agreed**
10.	There is need for flexibility in fixing pipeline setbacks and there is need for existing pipeline ROW be adequately maintained and be clear of all over-growth using Signs and Markers.	108	82	5	5	200	3.47	**Agreed**
11.	Need for the replacement of segments of pipelines that have corroded, worn-out and lived their full life span, to prevent chronic hazard associated with oil spills.	132	59	7	2	200	3.61	**Strongly Agreed**

Source: Author's Field Work (2014).

Cut-off Point= 2.50.

Grand mean= $\frac{\sum(X)}{N}$

Where $\sum(X)$ = Summation of Number of Means.

N = Number of Variables.

Grand Mean= $\frac{\sum(X)}{N} = \frac{24.84}{7} \sim 3.548 = 3.55$.

From the above table 4.14, Items 5, 6, 7, 8 and 11, of the responses were rated as 'Strongly Agreed' with Mean of 3.64, 3.51, 3.53, 3.60 and 3.61, while Item 9 and 10 are rated 'Agreed' with Mean of 3.48 and 3.47. The Grand Mean (X) for the table is 3.55.

From the responses of Respondents in the study areas, it opines that NNPC, Construction Companies and Planners are fully involved in the planning, control and management of oil pipeline right-of-way in Northern Nigeria. However, their roles have been passive and have invariably led to environmental problems. The operation and management of oil and gas pipelines transport network corridors in Northern Nigeria have witness a diversity of problems and obstacles of varying intensities.

Many of these problems have had disastrous impacts on the environment. The key ones among these include damage to or destruction of the pipelines or their ancillary installations/facilities and their attendant negative impacts on the total environment.

Jiriko (2007) advances some factors responsible for damage to pipelines as;

> ***"Equipment failure, human error and third-party damage" the term 'third-party damage' normally refers to any accidental damage done to the pipe (or its ancillary installation due activities of non-pipeline personnel). The third-party damage to pipelines persists despite several mitigating measures, particularly, in urban area possible factors behind this state of things include: ignorance of the requirement for planning/development permit or notification process on the part of the contractors, lack of incentive to motivate excavators to avoid damaging the lines when the repair cost is less than the avoidance cost, in accurate maps and records, poor or sour relationship between pipeline management and their employees-sacked, forced to resign or retired and imprecise locations or locating buried especially plastic-pipelines by operators" .***

Hence, there is need for synergy between NNPC/PPMC planning Authorities to enhance the planning and control, monitoring of the development and operation of pipelines ROW in Nigeria. It is pertinent and expedient that the Nigerians Policy Makers, Planners and Managers of Oil and Natural Gas pipelines products need to evolve pipeline-materials' toxicity and reactivity Rating Scales to suits Nigeria's situation. Responses from Respondent also brought to knowing that lack of monitoring and management of pipelines Infrastructures is responsible for the corrosion of pipelines, leading to oil spillages that cause pollutions and that emission of pipelines and Gas Flaring from Refineries has reduce air quality, causes Health related symptoms and reduce productivity of Community in concern in some of the studied areas.

Furthermore, there is need for suitable Partnership Strategy between the pipeline authorities and the various communities affected by pipeline developments to detect pipeline leaks and checkmate the activities of pipeline Vandals. Respondents also see the need for flexibility in fixing pipeline

setbacks for existing pipeline ROW to be adequately maintained and be clear of all over-growth using Signs and Markers and the replacement of segments of pipelines that have corroded, worn-out and lived their full life span, to prevent chronic hazard associated with oil spills.

Table 4.15: Government and Private Sectors involvement in the Monitoring, Control and Mitigation against Oil Pipeline vandalism in Northern Nigeria.

S/NO.	ITEM	SA	A	DA	SDA	NA	MEAN (X)	REMARK
12.	Government participation in the Crusade in curbing Environmental Pollution and its effect on the socio-economy activities of Nigeria is sufficient enough.	6	8	73	113	200	1.54	**Strongly Disagreed**
13.	Privately-owned Oil Companies has fairly helped in combating oil Bunkering, theft, Vandalism but has not done much in contributing to address the issue of control of Oil Spillages and attendant disasters in Nigeria.	112	76	8	4	200	3.48	**Agreed**
14.	The implementation of Government Policies on monitoring Oil Pipelines, ROW**,** control of Oil Spillages and Fire Disasters has been successful in Nigeria.	12	15	75	98	200	1.71	**Strongly Disagreed**
15.	There is need for Collaboration and Partnership between the NNPC, Nigerian Government and NGO's in combating and controlling Oil Spills and other related Environmental Hazards in Nigeria.	124	73	2	1	200	3.60	**Strongly Agreed**
16.	Need for Government to disburse more funds in to procurement and purchase of pipelines monitoring devices/equipment for the monitoring and checkmating the activities of Oil Bunkers, Thieves, Vandalizers and detecting Oil Spills that often caused environmental Disasters.	126	69	2	3	200	3.59	**Strongly Agreed**
17.	There is need for flexibility in fixing pipeline setbacks and there is need for the existing pipelines ROW be adequately maintained and be clear of over-growth using Signs and Markers.	120	74	4	2	200	3.56	**Strongly Agreed**

Source: Author's Field Work (2014).

Cut-off Point= 2.50.

Grand mean= $\frac{\sum(X)}{N}$

Where $\sum(X)$ = Summation of Number of Means.

N = Number of Variables.

Grand Mean= $\frac{\sum(X)}{N} = \frac{17.48}{6} = 2.91.$

Table 4.15 above, shows the response of all the respondents concerning government and Private Sectors involvement in the Monitoring, Control and Mitigation against Oil Pipelines and Pipelines Vandalism in Nigeria. The Respondents 'Strongly Agreed' on, items 15, 16 and 17 with Mean of 3.60, 3.59 and 3.56. Thus, they were rated as 'Strongly Agreed', Item 12 and 14 with Mean of 1.54 and 1.71 are rated 'Strongly Disagreed', while Item 13 with a Mean of 3.48 were rated 'Agreed'. The Grand Mean of the table is 2.91. This shows that currently, Government and Private Sectors involvement in the Monitoring, Control and Mitigation against Oil Pipelines and Pipelines Vandalization in Northern Nigeria is ineffective and inefficient.

It is agreed that Federal Government, through NNPC's Department of Petroleum Resources is vested with necessary powers by the various legal principal laws and regulations pertaining to petroleum as well as in some other legislations of the country, which includes the Oil Pipelines Act 1965, Land Use Act 1979 to identify infringements and making them known to the Government agencies which possess the appropriate enforcement authority. Government participation in the Crusade in curbing Environmental Pollution and its effect on the socio-economy activities of Nigeria is sufficient enough.

Activities of the private sector in Oil and Gas industry in Nigeria are 'age mates' with the industry itself.

Private sector participation was pioneered by the Nigerian Bitumen Corporation (NBC), A German Company, which was granted a license to exploit bitumen in Araromi, near Okitipupa in 1900s. Others are Mobil (1955), Gulf now Chevron (1961), Texaco1961, Saptrap (now ELF 1962) and AGIP, Teneco, Philips, Esso, Deminex, Union Oil, Great Basin and Ashland Oil between 1960s-1970s. A number of indigenous companies made their debut though long after the entrance of the foreign ones. These indigenous entrants include Henry Stephens, Delta Oil, Niger Petroleum Company and Niger Oil Resources, Alfred James, AMNI, Consolidated Oil, Dubril Oil Company Limited, Summit Oil, Yinka Folawiyo Petroleum, Allied Oil Privately-owned Oil Companies has fairly helped but not a proactive approach in combating oil Bunkering, Theftry, Vandalization but has not done much in contributing to address the issue of control of Oil Spillages and attendant disasters in Nigeria. There is need for Collaboration and Partnership between the NNPC, Nigerian Government and NGO's in combating and controlling Oil Spills and other related Environmental Hazards in Nigeria.

Need for Government to disburse more funds in to procurement and purchase of pipelines monitoring devices/equipment for the monitoring and checkmating the activities of Oil Bunkers, Theft, Vandalizers and detecting Oil Spills that often caused environmental Disasters. There is need for flexibility in fixing pipeline setbacks and there is need for the existing pipelines ROW be adequately maintained and be clear of over-growth using Signs and Markers.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONs

5.1 Introduction

The study aims, i.e. application of satellite imageries and related geo-informatics data such as maps and other relevant periodical/texts in assessing compliance to regulations of right-of-way for Nigerian National Petroleum Corporation pipelines network in Northern Nigeria by land use types has been achieved. The study is borne out of the need for safety and healthy environment. The various land-use types encroaching into these pipelines' right-of-way were identified, classified and mapped. A spatial distribution map of the pipelines, the generalized classification map of land use types and Pipeline Encroachment Units (PEUs) were prepared (figures 4.1a-4.3 and figures 4.6-4.13 respectively).

5.2 Summary of Findings

This research work demonstrates the ability of Remote Sensing and GIS in capturing spatial temporal data. Attempt was made to capture as accurate as possible four land use/land cover types as they affects compliance to NNPC pipelines' right-of-way in the study area.

Results from this study have revealed that the amount or intensity of encroachments in the study area is attributed to increasing farming/grazing activities, rapid urbanization, population growth, high poverty level and institutional forces etc. The amount of encroachment was measured using set

criteria of buffer zones of 25m^2, 200m^2, 420m^2, 450 m^2 and 576m^2. The farmland and grazing area occupies land area of 125,673.00 km^2 (70%), built-up has 25,134.62 km^2 (14%), road network occupies 17,953.30 km^2 (10%) and water bodies accounted for 10,771.98 km^2 (6%) with encroached total land size of 179, 533.00 km^2 (100%). Thus reveals that the assessed land use/cover types in the study area do not comply with the regulations guiding the right-of-way of these pipelines. This means that with all these proofs it is evident that the various land use types are not complying with the regulations on NNPC pipelines' right-of-way in the study area.

Also, Government and Private Sectors involvement in the monitoring, control and mitigation against oil pipelines, pipelines' right-of-way and pipelines Vandalization in Northern Nigeria has not being proactive and efficient.

Furthermore, it was discovered that only few depots in the study area are functional and operational, resulting from pipeline breaks and vandalism. According to THISDAY (2013), it was reliably gathered that only five of the 31 receiving depots across the country are currently functional, a development that has forced most marketers to depend on the available functional depot for products.

5.3 Conclusion

The study revealed that the major factors responsible for pipelines vandalism in the study areas were largely due to land use systems (farming, grazing cultivation methods, bush burning, un-motorized and motorized road, built-up area), and hydro meteorological factors in some studied areas. It was discovered that the severity of one form of pipelines encroachment or the other depended upon the intensity of land use type as well as surface lithology of the soil which particularly encouraged cultivation and grazing in the study area, the tendency for severe pipelines vandadalization and encroachment into it right of ways was high.

It can therefore be concluded that the major land use/land cover types encroaching into the NNPC Pipelines' right-of-way in Northern Nigeria include; agriculture, built-up, roads and water bodies. In all the forms, it has been gathered that the significant number of cases of encroachment into the right-of-way of NNPC pipelines were due to vandalism of pipelines by Oil Bunkers Operations and infringements by Farmers and in some cases through constructions of structures-built-up areas.

Man's agricultural practices and urban construction works and sprawling were found to have exacerbated the nature and intensity of non-compliance to NNPC Pipelines' right-of-way, especially on the fridge of urban areas (figure 4.).

The possible implications of these encroachment and non-compliance to the pipelines' right-of-way include vandalism, pollution, environmental degradation, loss of lives and properties. These might eventually have effects

on land resources, hydrological resources, increased government financial expenditure, ecosystem functioning etc.

Effort should be made to carry out air coverage of the terrain where these pipelines criss-crossed at least once in every two year period. By this it is possible to clearly monitor pertinent land use that encroaches on NNPC pipelines' right-of-way.

5.4 Recommendations

Based on the findings of this study the following recommendations are here by suggested as means by which Stakeholders and Government can monitor and enforce compliance to the regulations guiding the NNPC pipelines' right-of-way in the study area. There should be:

- A reorganization and reorientation on the attitude of the people base on land use management and their relationship to the environment, as it affects pipelines' right-of-way should be put in place and sustained. This could be achieved through workshops, seminars or conferences.

- There should be a proactive institutional framework, which would include all Stakeholders and resource person, on measures to be taken on protecting the environment and how to diversify the usage of environmental resources, without one land use or the other encroaching into NNPC pipelines' right-of-way. Hence, this would lead to improvement on setback compliance of the pipelines in the study area.

- The existing pipelines' ROW should be adequately maintained. They should be cleared off all overgrowth and be provided with the required

signs and markers which should be visible along the ROW, from above and at all types of crossings.

- The NNPC/PPMC and the oil companies should evolve harmonious and sustainable partnership strategy between pipeline authorities and the various communities affected by pipeline developments for the daily patrol of the pipeline corridors and their related facilities. This will serve three purposes: (a). to detect and report pipeline leaks. (b). check-mate the activities of pipeline vandals. (c). provide employment for some members of the communities.

- There should be flexibility in fixing pipeline setbacks. Setbacks should be commensurate with the size of the pipes used and the types of ancillary installations and facilities required. Setbacks for, especially gas, pipelines in densely populated areas (towns/cities) should be particularly flexible but provided with high safety systems due their demand for cooking, heating and lighting purposes.

- There should be cogent environmental management policy that makes provision for upgrading the level of knowledge in management NNPC pipelines. In addition, the relevant sections of the 1992 EIA Act, as they affects major pipeline developments and transport should be implemented to the letter.

- The use of Remote Sensing/GIS in mapping of encroachment into pipelines' right-of-way has proven to be very relevant; hence it is recommended that this tool is taken advantage of by the Government in

mapping and monitoring encroachment into NNPC pipelines' right-of-way and vandalization. Map presentation are easy to interpret; therefore it can serve as a potent tool in policy implementation as regards effective and efficient pipelines monitory, encroachment control and in the allocation of funds for pipelines inspection, security and where funds are better need.

- The federal government should, as matter of urgency, in collaboration with Stakeholders evolve a comprehensive National Oil/Gas Policy that will make specific provisions for the designating, planning, designing and development of Oil and Gas ROW as well as the size of pipes to be used in urban areas and in country-side.

- Government and Non-governmental Organizations that are Oil and Gas oriented sector should therefore encourage the utilization of mapping applications by investing more in training and acquisition of the technology to pipeline to solve oil/gas related problems.

- As a precautionary measure for preventing deliberate damage to pipelines, the NNPC Authorities/Management, should wherever possible, bury petroleum product pipelines many meters under the ground.

5.5 Critique of the Study

Some limitations imposed constraints on this study, ranging from data collection to data analysis and resting. One is that adequate cooperation was not given to the Researcher in accessing data on pipeline network in the study area by the NNPC Management for a research of this nature. There was also a scarcity of research materials; hence the researcher was forced to limit himself to the available materials. Furthermore, problem is encountered in accessing satellite imagery that can helped in assessment of study of this nature due to the ground scale of the imageries used and area extent of the study, which further delay the progress of the work.

5.6 Suggestions for Further Studies

The need for further studies in pipeline transport is no closed by this pioneer work in Northern Nigeria. Hence the following are suggested by the Researcher for further work should be carried out on:

- Assessment on right-of-way of longer distance Pipeline segment from Depots/Pump Stations.
- The scope of the study should cover the entire Nigeria landmass.
- Pipeline maintenance as its affects pipelines' right-of-way.

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Appendix I

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The sample of Questionnaire administered to Respondents residing in the Communities where NNPC Pipelines criss-crossed.

Dear Sir/Ma,

This Questionnaire is designed to collect pertinent and relevant information for a ***Post Graduate*** research which seeks to assess compliances/encroachment of other land-use types on NNPC pipelines' Right-of-Way of using Remote Sensing (**RS**) and Geographic Information System (**GIS**).

Information supplied will be used mainly for academic endeavors alone and shall be treated as highly confidential. A total of 200 Questionnaires will be administered.

Personal Profile:

Administration point: _____

Name of respondent: _____

Sex: Male ( ) Female ( )

Age: Age: 35-39[ ] 40-44[ ] 45-49[ ] 50-54[ ] 55-64[ ] 60-64[ ] 65> [ ]

Occupation: _____

Level of Education: _____

Instruction:

Please tick (√) in the space provided, appropriate to your response on every question. The acronyms given in the boxes stand for:

SA: Strongly Agree. **A:** Agree.

D: Disagree. **SDA:** Strongly Disagree.

ROW: Right-of-Way.

Sample 1: *To what extent does Respondents understand the concept of Remote Sensing, Geographic Information System and environmental issues associated with oil Pipelines in Nigeria?*

S/NO.	ITEM	SA	A	DA	SDA	NA
1.	Oil Bunkering, theft, Vandalism and Spillages and Pollution are common Environmental issues that pose danger to human life.					
2.	Impact of non compliance to Oil Pipelines **ROW** by the land-use type in your Community has led to Oil, Bunkering, Theftry, Vandalization, Oil Spills and Fire Inferno in Northern Nigeria.					
3.	Nigerians are vulnerable to health related problems as a result of Gas Flaring and Oil Pipe leakages and outbreaks.					
4.	Communities along the Pipelines Network System through out the Country should be provided with essential infrastructure, utilities and services to dampen the urge to vandalize pipelines to attract compensation or scoop oil to earn a living.					

Sample 2: *An assessment of the role of NNPC, Construction Companies and Planners in the planning, control and management of Oil Pipeline Right-of-Way in Nigeria.*

S/NO.	ITEM	SA	A	DA	SDA	NA
5.	There is need for synergy between NNPC/PPMC planning Authorities to enhance the planning and control, monitoring of the development and operation of pipelines **ROW** in Nigeria.					
6.	Nigerians Policy Makers, Planners and Managers of Oil and Natural Gas pipelines products need to evolve pipeline-materials' toxicity and reactivity Rating Scales to suits Nigeria's situation.					
7.	Lack of monitoring and management of pipelines Infrastructures is responsible for the corrosion of pipelines, leading to oil spillages that cause pollutions.					
8.	Emission of pipelines and Gas Flaring from Refineries can reduce Air Quality, causes Health related symptoms and reduce productivity of Community in concern in Nigeria.					
9.	There is need for suitable Partnership Strategy between the pipeline authorities and the various communities affected by pipeline developments to detect pipeline leaks and checkmate the activities of pipeline Vandals.					
10.	There is need for flexibility in fixing pipeline setbacks and there is need for existing pipeline **ROW** be adequately maintained and be clear of all over-growth using Signs and Markers.					
11.	Need for the replacement of segments of pipelines that have corroded, worn-out and lived their full life span, to prevent chronic hazard associated with oil spills.					

Sample 3: *Distribution, according to government and Private Sectors involvement in the Monitoring, Control and Mitigation against Oil Pipelines and Pipelines Vandalization in Nigeria.*

S/NO.	ITEM	SA	A	DA	SDA	NA
12.	Government participation in the Crusade in curbing Environmental Pollution and its effect on the socio-economy activities of Nigeria is sufficient enough.					
13.	Privately-owned Oil Companies has fairly helped in combating oil Bunkering, Thiefvering, Vandalization but has not done much in contributing to address the issue of control of Oil Spillages and attendant disasters in Nigeria.					
14.	The implementation of Government Policies on monitoring Oil Pipelines, **ROW,** control of Oil Spillages and Fire Disasters has been successful in Nigeria.					
15.	There is need for Collaboration and Partnership between the NNPC, Nigerian Government and NGO's in combating and controlling Oil Spills and other related Environmental Hazards in Nigeria.					
16.	Need for Government to disburse more funds in to procurement and purchase of pipelines monitoring devices/equipment for the monitoring and checkmating the activities of Oil Bunkers, Thiefvering, Vandalizers and detecting Oil Spills that often caused environmental Disasters.					
17.	There is need for flexibility in fixing pipeline setbacks and there is need for the existing pipelines **ROW** be adequately maintained and be clear of over-growth using Signs and Markers.					

Appendix II

Table 1: Some of the commonly applied Pipeline Inspection and Survey Techniques.

Inspection/Survey technique	Purpose	Attributes
Pressure testing (hydrostatic pressure testing).	Commonly used as pre-service integrity validation of the pipe and components by pressurizing to a level above the intended operating pressure. Destructively "detects" defects so they do not subsequently fail while in service. Allows the establishment of the real minimum strength of the pipeline and components, as opposed to the mill tensile test, which is based on a sample of pipe.	A regulatory requirement for new pipe sections, to update existing pipe sections and conversion from vapor to liquid service. Done by sectioning line according to terrain elevations. One or more valve sections can be included within test segment. Requirements and procedures defined in regulation and industry standards. Hydro-testing service is usually provided by a specialty contractor overseen by operating company staff.
Cathodic Protection (CP) Inspections and Surveys.	Determines the adequacy of cathodic protection voltages and currents for protecting the pipeline against corrosion and to detect areas of potentially defective coating.	Rectifier inspections are done to ensure that the rectifiers are in service and providing the required impressed current for cathodic protection. Station tests or surveys are done to measure CP voltages at stations locations. This also includes readings taken at pipeline casings under roads and railway crossings. Various forms of close interval surveys (CIS) are taken at interval of $^{3}/_{4}$ to 3m along a pipeline to provide a profile along the line to greater resolution than can be obtained with a station survey.
In-line inspection (ILI)	Detects areas of anomalies, such as metal loss, deformations, cracks, dents, gouges and laminations.	Automated internal inspection tools or "smart pigs" vary in anomaly types that can be detected and terms of degree of resolution. Services are provided by a specialty pigging contractor. Common technologies are ultrasonic and magnetic flux leakage. Results often require expertise in interpreting data. Either part or all of a pipeline is inspected depending on the location of pig launching and receiver equipment and the size and geometry of the pipeline system.
Manual ultrasonic wall thickness measurement.	Determines wall thickness and identifies areas of metal loss by direct measurement of pipe wall thickness.	Manually held instrument used in conjunction with exposed pipe inspections. Requires coating removal.
Leak Surveys.	Finds active leaks over a hydrocarbon pipeline.	Usually includes handheld instrumentation to detect hydrocarbon vapour.
Water Crossing Surveys.	Determines elevation profile and depth of cover beneath waterway.	May require divers to probe or use instrumentation to locate depth of pipe below stream or lake below.
Depth of Cover Surveys.	Determines actual amount of cover over pipeline.	Depth is measured by instrument or physical "probing" of the pipeline.
Acoustic Monitoring.	Finds discontinuities in metallic pathways: used in reinforced concrete pipe.	Impressed sound waves are analyzed for discontinuities or active failure.
Subsurface coating Condition.	Evaluates coating condition of buried steel pipeline.	Impressed a signal onto a pipeline and measures attenuation of signal to determine signal to determine signal leakage through coating.
Non-destructive testing.	Uses techniques such as ultrasonic, magnetic particle, dye penetrate, etc., to find pipe wall flaws that are hard to detect with naked eye. It can also include testing of coating properties such as thickness and numbers of holidays.	Usually done in conjunction with visual inspection; can be done on coating or on pipe wall.
Ground Patrols and Aerial Surveys.	Identifies external conditions that might adversely affect the pipeline, such as third party activity and ROW encroachments. Also used as a means of detecting leaks.	These apply more to the effects of external factors on the pipeline and the detection of leaks than to factors associated with the conditions of the pipe itself. They complement visual surveys.

Source: Muhlbauer (2004), Jiriko (2007), Researcher (2014).

Appendix III

A: PRELIMINARY AND LABORATORY WORK

Material	Action	Output
Remotely Sensed Aerial Photograph, Topographic Map Approx. scale 1:100,000, 000 1:50,000, 000	Differential of Environment of the Sub-nits of Map and Description of Attribute	Spatial Distribution of Sub-units and Characterization.

B: FIELD WORK

Satellite, Topo-Maps, Geological Maps, Administrative Maps, Questionnaire, Literature/Secondary Data	Terrain Classification, Scoring, infrastructure, mapping (for use in the field), Ground-truthing and Field Work Planning.	Preliminary Classification of Terrain Map of the Area (four Refineries and Pipelines **ROW** in Nigeria infrastructure/Route Map.

Checking and Updating Preliminary Maps, Collection of Attributing Data using Remote Sensing and Topographic Data in the Field as Tool.

C: MAPPING AND REPORTING

Final Map Analysis	Preparation of Final Map, GIS Manipulation using Software, Analyzing of Administered Copies of Questionnaire, Reporting/Writing	Spatial Distribution of Sub-units and Characterization, Mapping details.

Plate I: Schematic Plane of the Study.
Source: Researcher's Work.

Appendix IV



Plate I: Landsat Satellite Imagery of Nigeria.
Source: NARSDA 2012.

Appendix V



Plate III: Landsat SRTM Mirrored Satellite Imagery of Nigeria.
Source: GCLF 2012.

Appendix VI

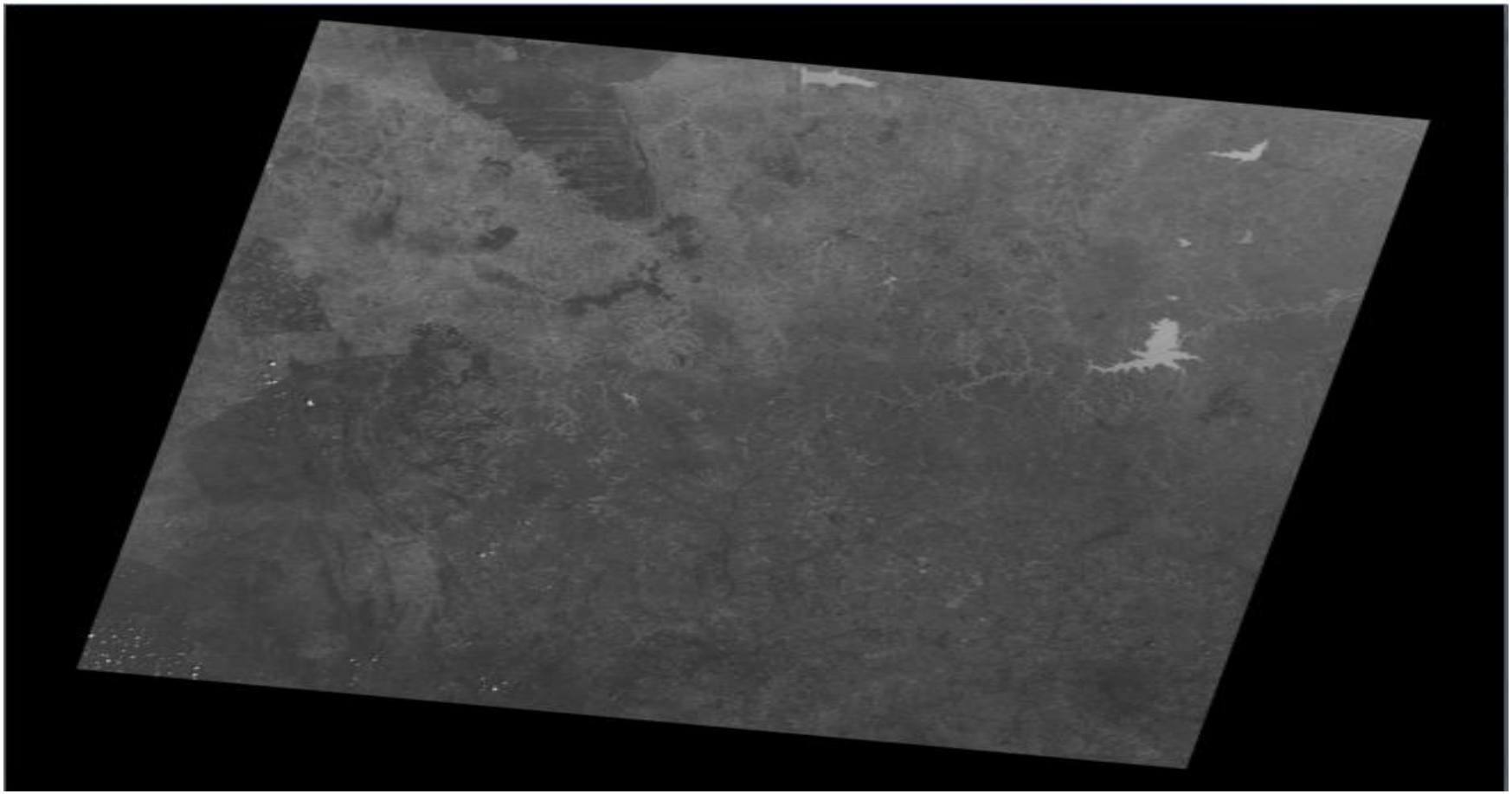


Plate IV: Composite SRTM Satellite Imagery Northern Nigeria; Band 1.
Source: GCLF 2013.

Appendix VII

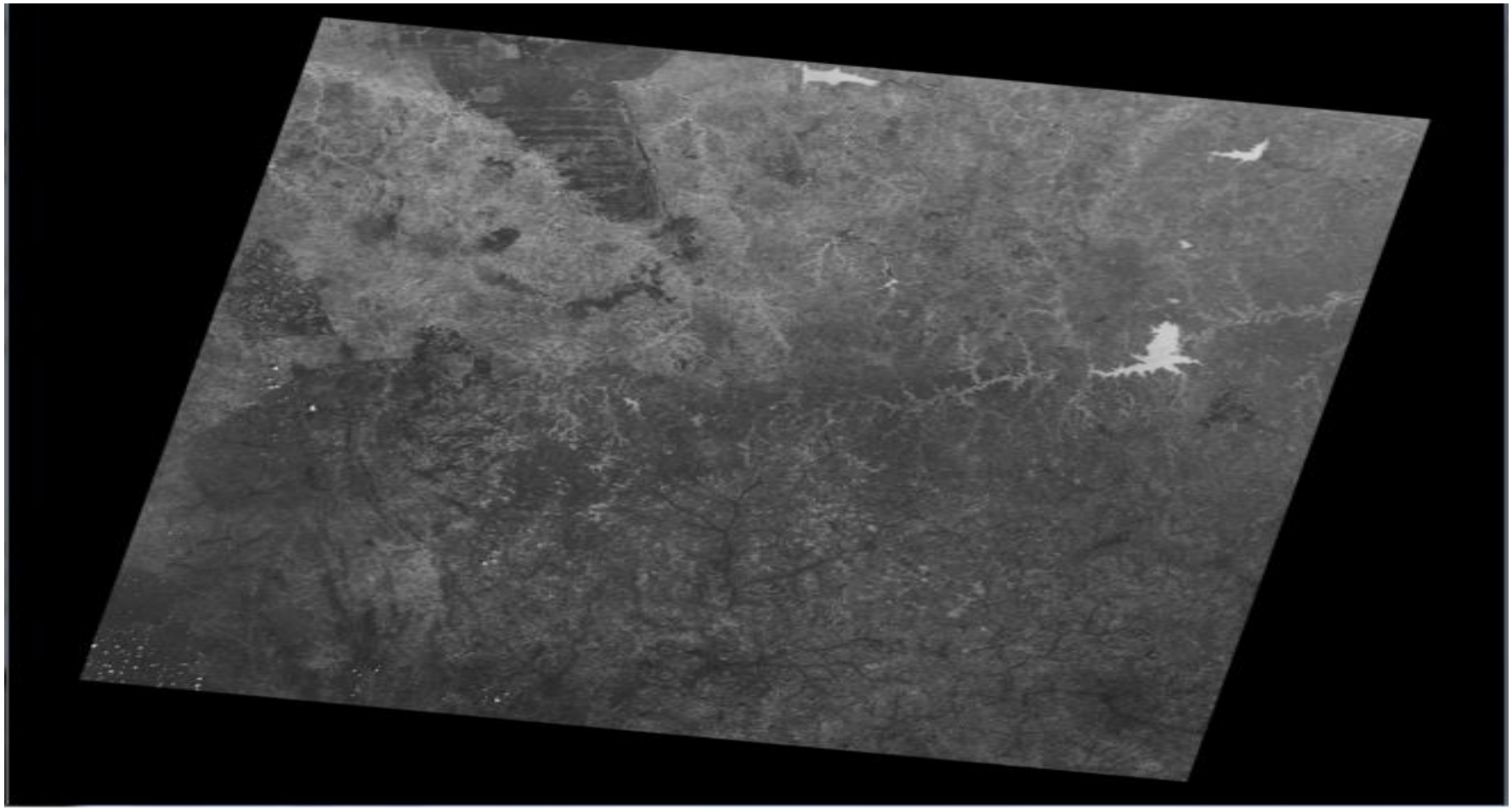


Plate V: Composite SRTM Satellite Imagery of Northern Nigeria; Band 2.
Source: GCLF 2013.

Appendix VIII

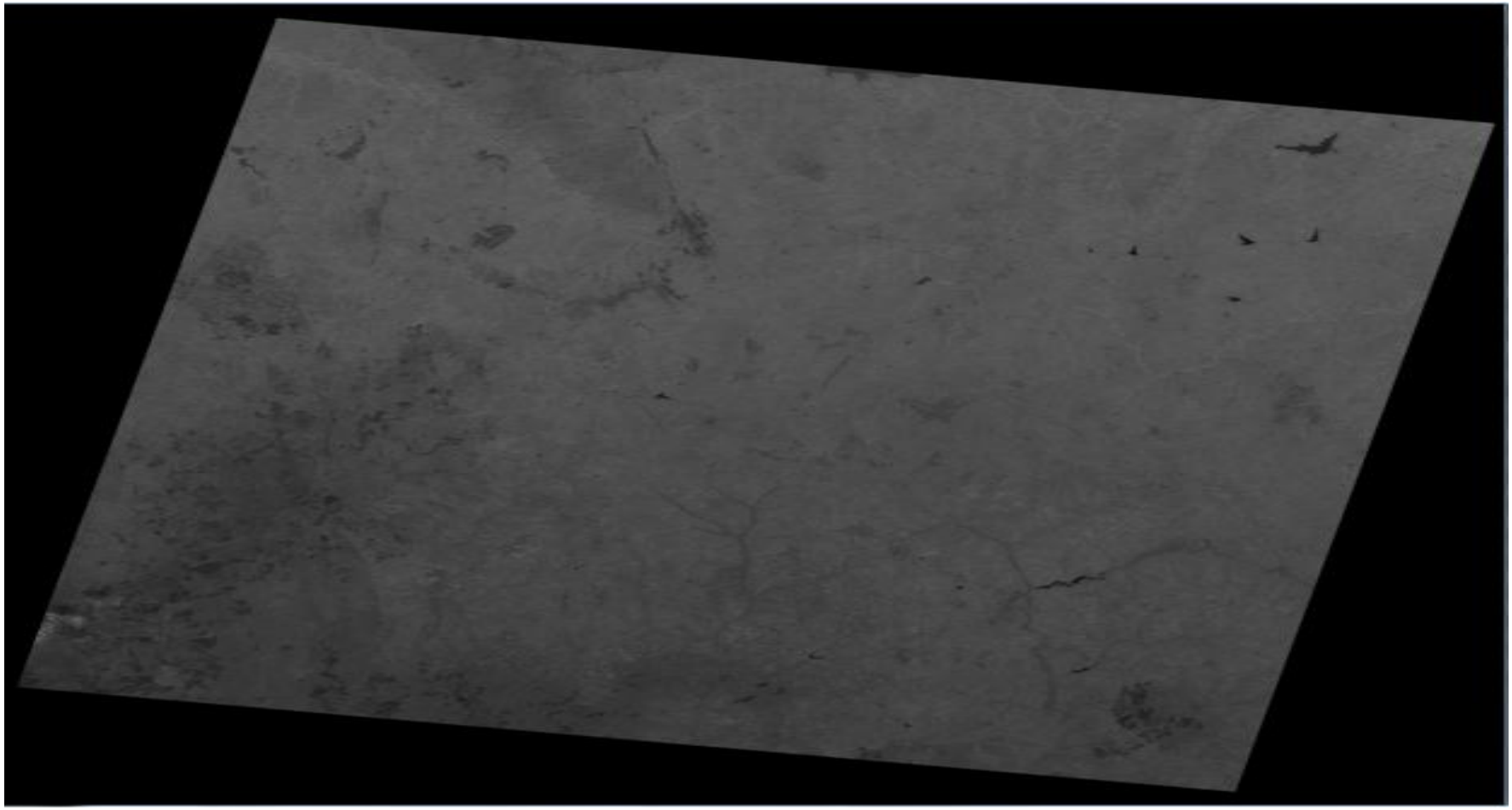


Plate VI: Composite SRTM Satellite Imagery Northern Nigeria; Band 3.
Source: GCLF 2013.

Appendix IX

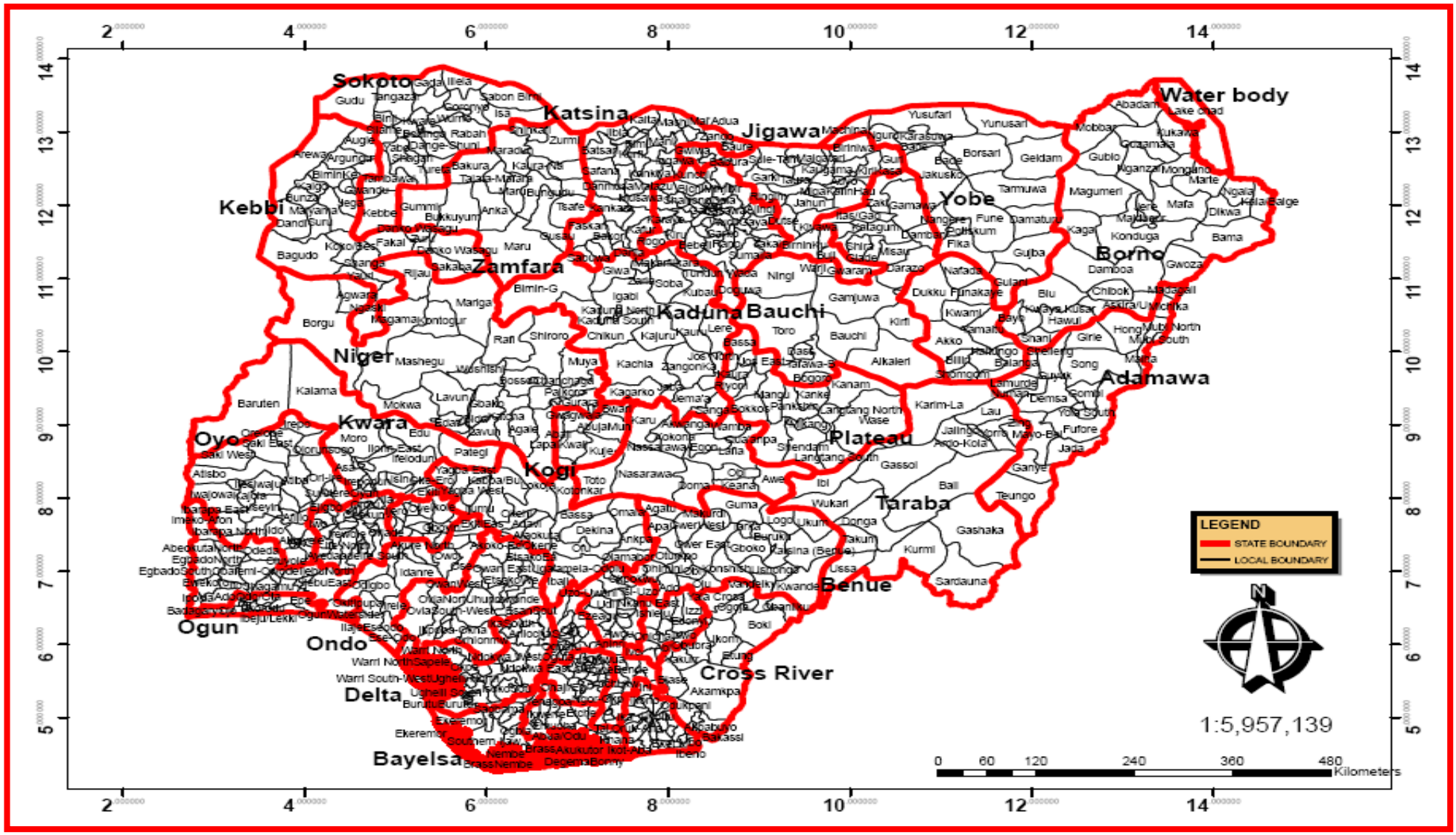


Plate VII: Nigeria-its Thirty Six (36) States and LGAs.
Source: Adapted from NASRDA, Abuja 2013.

Appendix X

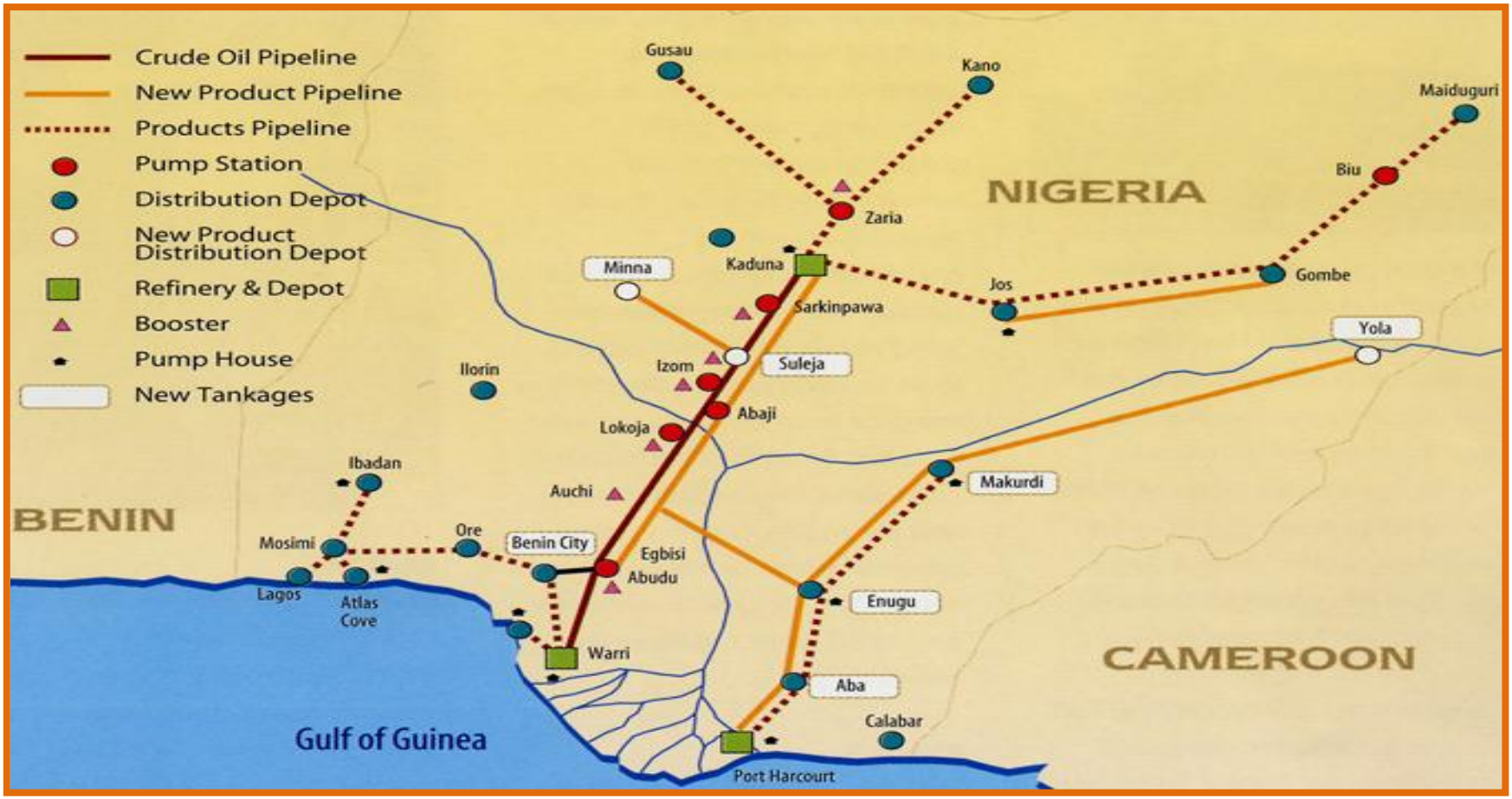


Plate VIII: NNPC Pipelines Networks in Nigeria.
Source: PPMC 2001, Researcher's Field Work 2014.

Appendix XI



Plate IX: NNPC Kaduna Refinery.
Source: Kaduna Refinery Petrochemical Company 2000.

Appendix XII



Plate X: NNPC's Rupture/Vandalized Pipeline.
Source: www.nnpc.ng.org copied May 2014.

Appendix XIII



Plate XI: NNPC Pipelines Fire Outbreak due to Vandalism.
Source: Roland 2007.

Appendix XIV

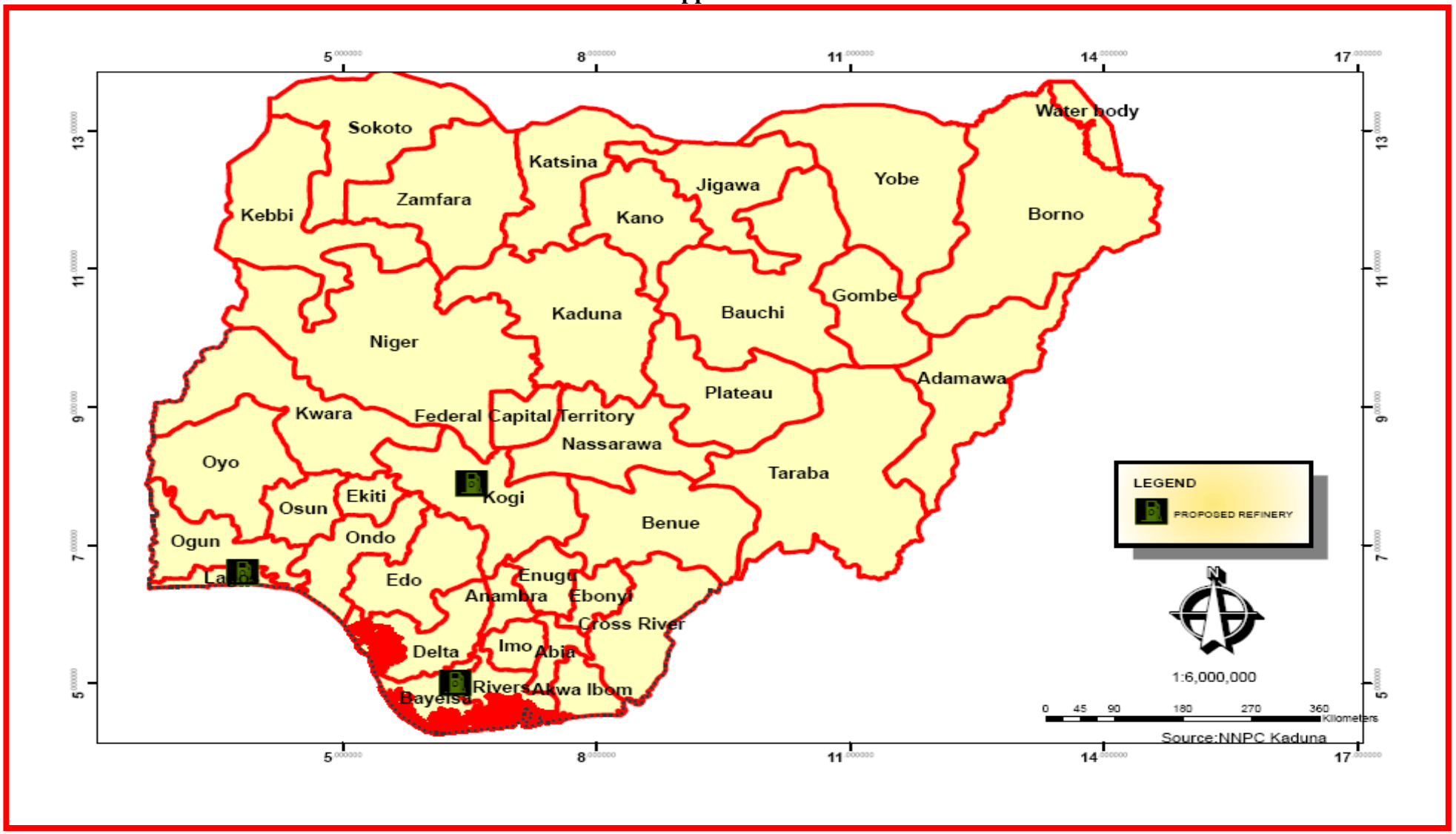


Plate XII: Proposed Locations for New NNPC Refineries in Nigeria.

Source: adapted from NNPC 2012.