
APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) IN WASTE MANAGEMENT AT OWERRI AND ENVIRONS, IMO STATE, SOUTHEASTERN NIGERIA

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ABSTRACT

In Nigeria, waste disposal has been a problem both in the urban and rural areas. Wastes are indiscriminately dumped on open plots of land and particularly along streets rendering the roads impassable and reducing the aesthetic value of the area. Optimum selection of waste collection points is therefore necessary in order to prevent the indiscriminate dumping of waste which is hazardous to human health and also to effectively and efficiently manage the solid waste to promote hygienic environment. The factors to be considered in evaluating site for waste disposal include: climate, topography, drainage, soil properties, groundwater and surface water. GIS consists of a set of computerized tools and procedures that can be used to effectively store, retrieve, overlay, correlate, manipulate, analyze, query, display (both graphically and numerically) and disseminate land related information. This study used Geographic Information Systems (GIS) as a solution to select suitable locations for solid waste assemblage points and disposal land use options in New Owerri. A total of 5 thematic maps determinants obtained from different sources were employed for GIS operation. These include road map, river map and three different land use maps (residential, commercial and public use land uses) of the study area. These maps are the thematic data layers for GIS operation and were collected as existing maps from different sources to serve the purpose of manipulation and analyses so as to procure the most suitable site for collection point of solid waste generated in New Owerri. The maps were scanned, digitized, georeferenced, and polygonized using AutoCAD drawing package to convert them into vector format and later exported to Arc View 3.2a software for analysis. The final analysis like buffering, overlay by union, clipping and query operations display areas of preferred collection point for solid waste but which further led to the study of the land use and land cover in Owerri. Based on these, site for modern sanitary landfill system that will protect the environment and aquifer from contamination was sited.

Keywords: Geographic Information System (GIS), Solid Wastes.

1.0 INTRODUCTION

As indicated by World Health Organization, municipal solid waste is characterized as futile, undesirable or disposed of materials emerging from residential, exchange, business, mechanical and horticultural just as from open administrations. And these wastes are assembled into two viz: biodegradable and non-biodegradable waste. The biodegradable squanders are the squanders that can undoubtedly be disintegrated by the activity of anaerobic microscopic organisms for example, nourishment, foods grown from the ground squander. The non-biodegradable squanders then again are those that can only with significant effort be disintegrated by the activity of the anaerobic microorganisms. For example, metal waste, elastic waste, plastic waste, restorative waste, electronic waste (e-squander). The accumulation and transfer of these waste, is today a significant general environmental and medical problem, an indispensable factor influencing the nature of our Nigerian urban communities.

Likewise, in Owerri Metropolitan, significant solid waste produced is from private and business exercises. The volume has as of late developed above arranged breaking points, turning into a danger to the underlying adequate and successful accumulation and transfer of waste. The unbelievable fast populace development together with poor people and unsustainable arranging has given the region less critical and no reasonable strong waste accumulation point. Solid waste are discarded unpredictably; frequently on open spaces, for example, markets places, street sides "as in Aladimma" and zone A of World Bank dump, in the middle of double significant streets "as in Douglas Street dump", boulevards, waterway banks, canals and so on, and during overwhelming precipitation falls. This causes congested road, forces dangers to the strength of man and his condition on the loose.

2.0 LOCATION AND GEOLOGY OF THE STUDY AREA

The investigation zone is New Owerri inside Owerri City, Imo State. New Owerri via land mass covers over 55% of Owerri city territory. It is situated on the south west piece of Imo State in the dug deltaic arrangement of the Niger Delta bowl, south eastern Nigeria. The territory is limited by longitudes $7^{\circ} 00'E$ and $7^{\circ} 05'20"E$ and scopes $5^{\circ} 27'4"N$ and $5^{\circ} 32'20"N$. New Owerri is bound in the north by New Street, Irete, in the east by Old Owerri (along Nworie Waterway), in the south by Nekede (along Otamiri) zone and in the west by Umuguma. New Owerri contains World Bank zones, Government Minimal effort Lodging Domain region, Accord Inn zone, the new State Secretariat territory, Bureaucratic Secretariat zone, Nekede augmentation, zoo zone, Umugwueze and Umuejechi Nekede region, New Mechanical Format and different designs recognized as Zone A, B, C to Y and that's only the tip of the iceberg.

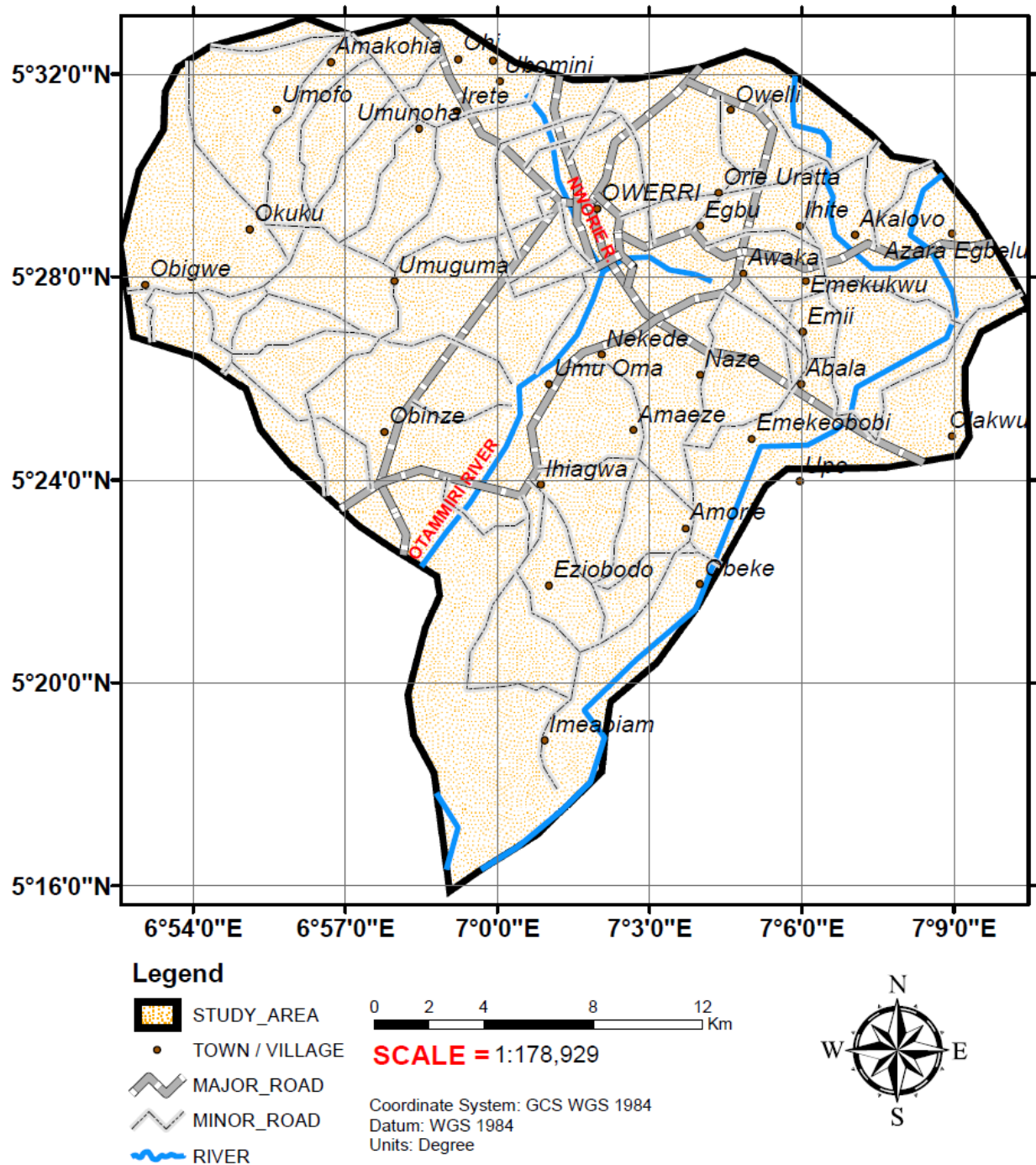


Fig 1.1: Location Map of the Study Area

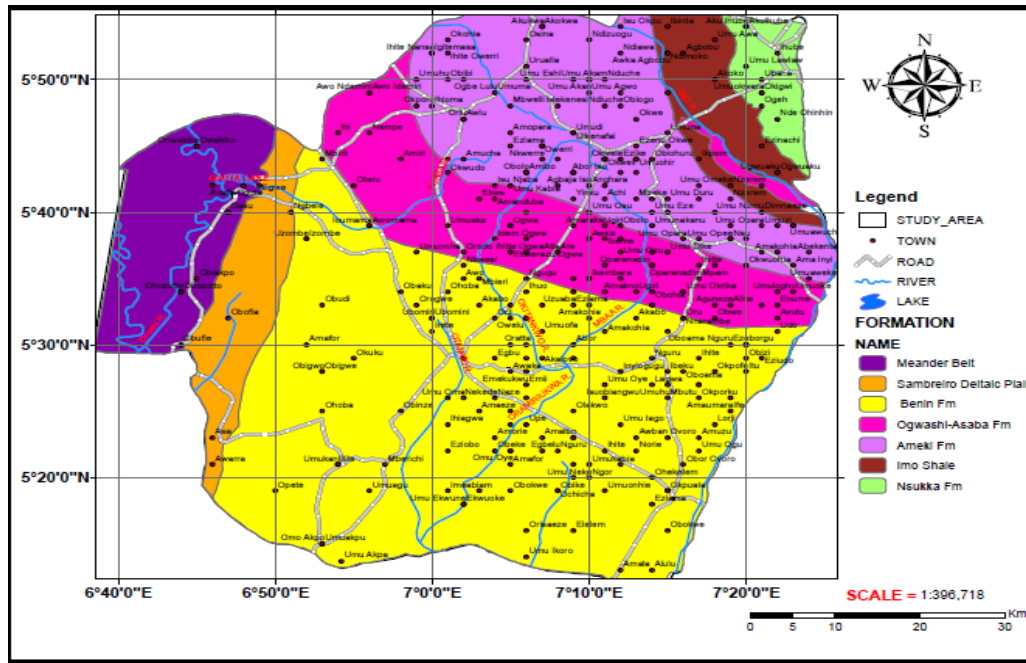


Fig 1.2: Geology Map of the Study Area

Geographically, the examination territory is underlain by a grouping of sedimentary rocks. The lithological and geologic setting of the investigation region controls the event and stream of the ground water. Besides, the zone is underlain by the beach front plain sands of the Benin Formation (Simpson, 1955), extending from Miocene to recent in age (Reyment, 1965). The Benin Formation is comprised of thick friable sands with minor intercalations of dirt beds and focal points. The Benin Formation is comparably underlain by the Ogwashi - Asaba arrangement. The Ogwashi–Asaba Formation comprises of a lignite arrangement and dominantly made up of sands with minor shale units. Its normal thickness is 200m. The age is somewhat Oligocene (Kogbe, 1974).

3.0 MATERIALS AND METHODS

3.1 DATABASE DESIGN/WORKFLOW

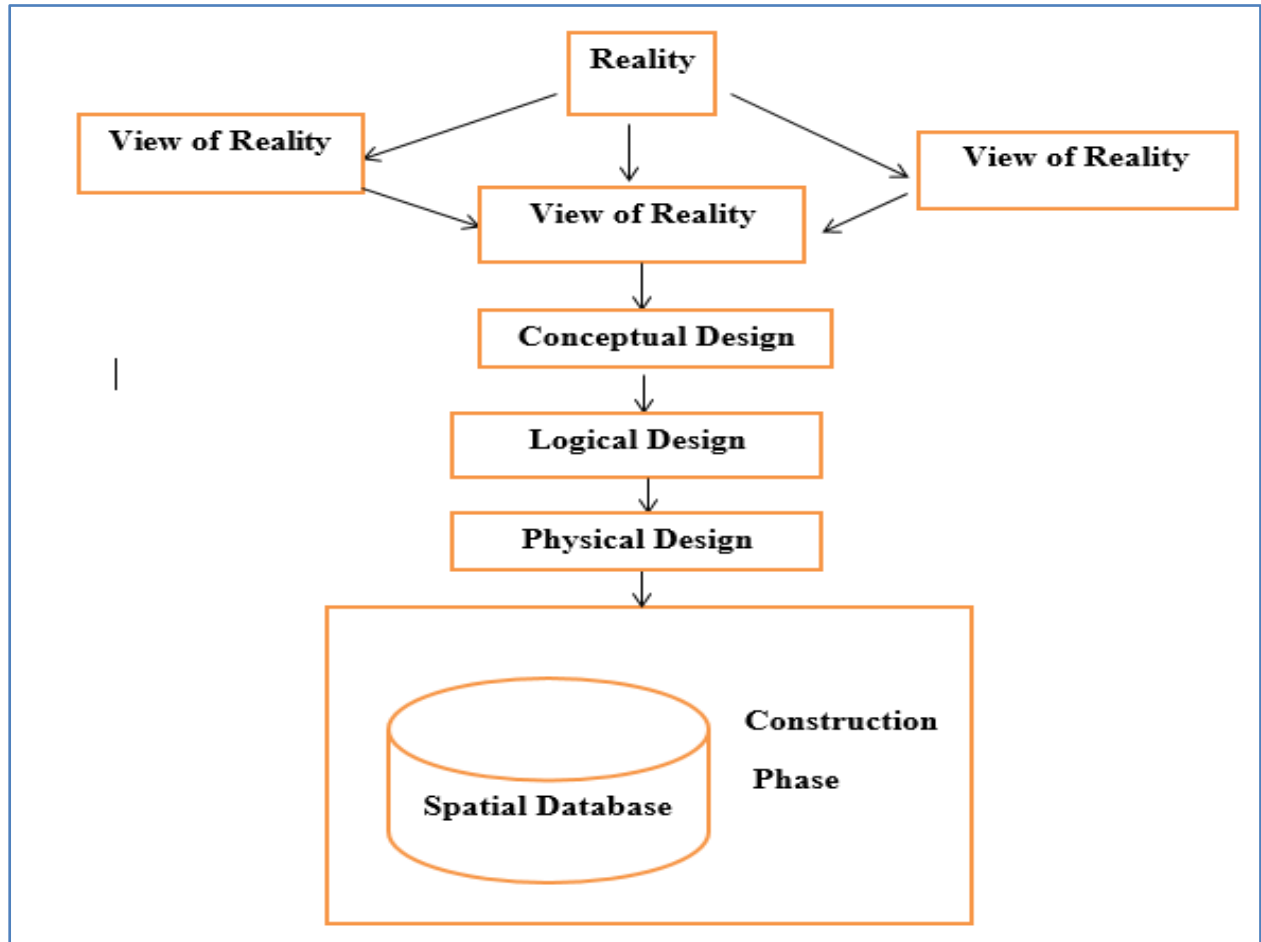


Fig. 3.1: Designs and Construction of Phases of Spatial Database (After Kufoniya, 1998)

3.2 Software Requirements

The following software were used for this project;

- Microsoft Window 2019, windows 10pro, Service pack 3, version2018-2019.
- Arc View GIS Version 3.2a for spatial analysis of site selection.
- AUTOCAD Land Development 2i for georeferencing and digitizing the scanned map
- GEO CALC (Geographic Calculator 3.09) Software for conversion of coordinates from geographical to rectangular and vice – verse.
- Google Earth Software for acquiring satellite imageries and geographical coordinates.

The project was attempted with 1:100,000 regulatory map of Imo State covering the investigation area which was gotten from the Ministry of Lands and Urban Development, Owerri Nigeria. The map was utilized for the upgrade of LU and LC classification, orientation and geometric registration of the imageries during interpretation. The satellite symbolisms were gotten from National Space Research and Development Agency [NASRDA] Abuja, Nigeria. The LU and LC on the guide were utilized as the beginning stage

of the contemporary LU and LC order in the present examination. This done, the consistency of LU and LC change of the various classes were broken down.

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

composite map of new owerri

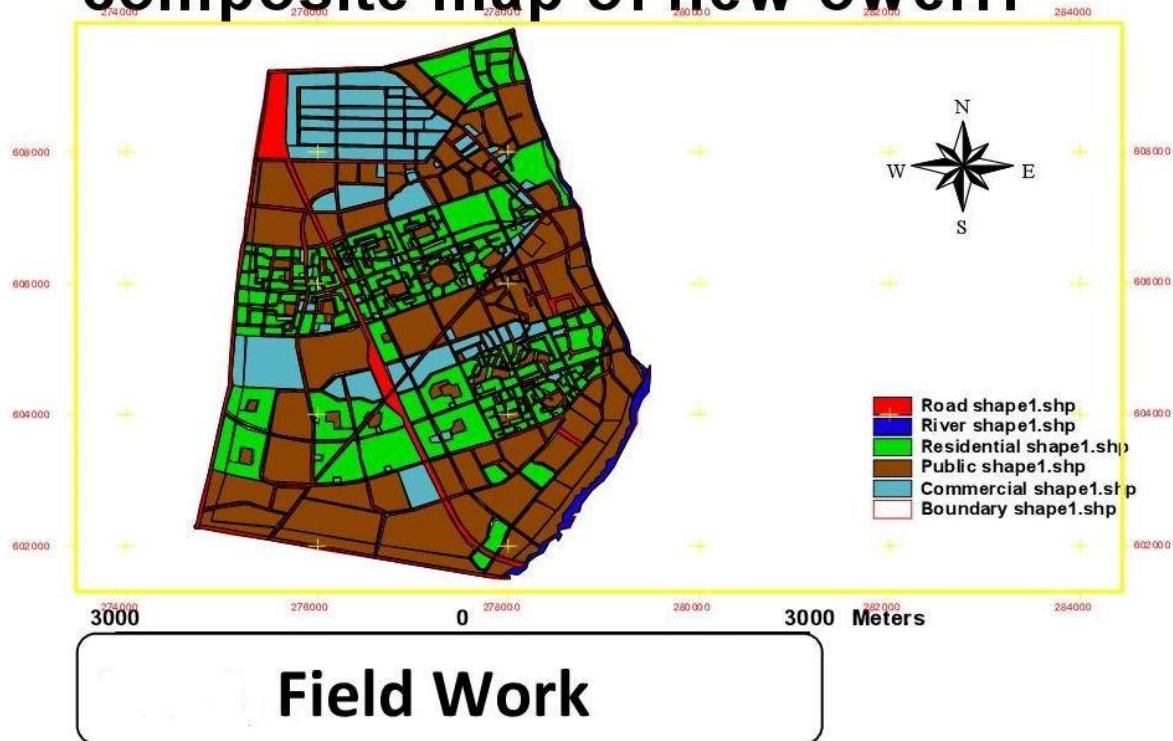


Fig. 4.1: Layout of composite map of the study area (New Owerri)

4.2 SPATIAL ANALYSES PERFORMED

4.2.1 Digital Mapping Processes On Map of New Owerri

Owerri street map was scanned and brought into the AutoCAD land development programming where it was georeferenced and digitized. Arcview GIS 3.2a was launched and the digitized map was sent out from Auto CAD to Arc view. The street, limit, rivers, residential, open and business layers were converted to shape records after which the different substances were polygonized with Arcview script. Subsequently, every one of the feature were changed over from polylines to polygons which are the satisfactory shapes for spatial analysis in the Arcview Environment.



Fig. 4.2: Georeferenced New Owerri map in an AutoCAD environment



Fig. 4.3: Digitized map of new Owerri in an AutoCAD environment

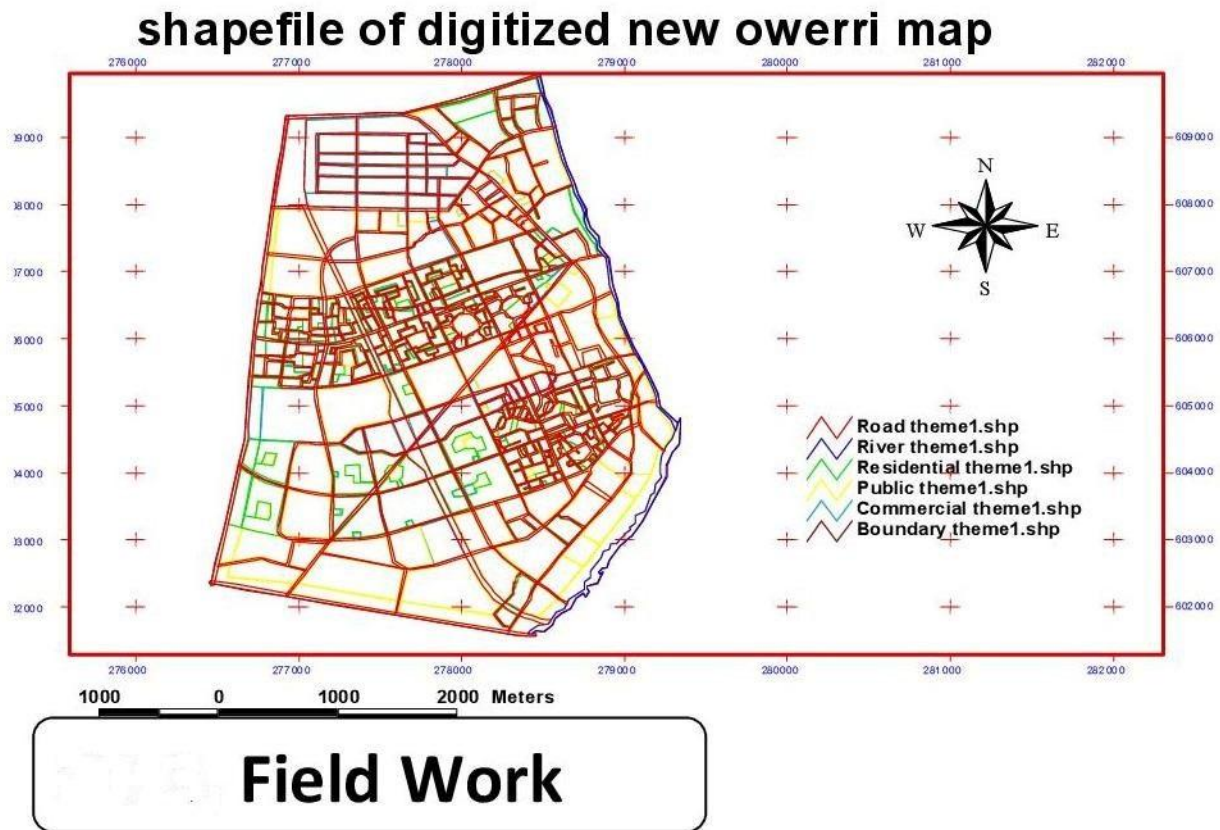


Fig. 4.4: Layouts of shape file of imported digitized map of new Owerri in Arcview3.2a

4.2.2 Buffering Operation

One significant spatial activity is the determination of spatial closeness or proximity of different geographic features. The activity performed by the buffer order produces at least one polygon encompassing geographic features and the polygon is called BUFFER ZONE. In this investigation, buffering activity of 100m at an interval of 10m was done on every one of the entities.

4.2.3 Analysis of Buffering Operation

Make the theme (feature) to be buffered e.g. river theme active click the 'theme' menu on the toll bar and select 'create buffer. A dialogue box is shown. Click 'next' and select 'as multiple rings' then input the number of rings, distance between rings and units. Click next and on the new dialogue box, click on 'yes' for dissolve barriers between buffers?' Also select 'only outside the polygon', then save in a new theme and click finish. The new theme will appear.

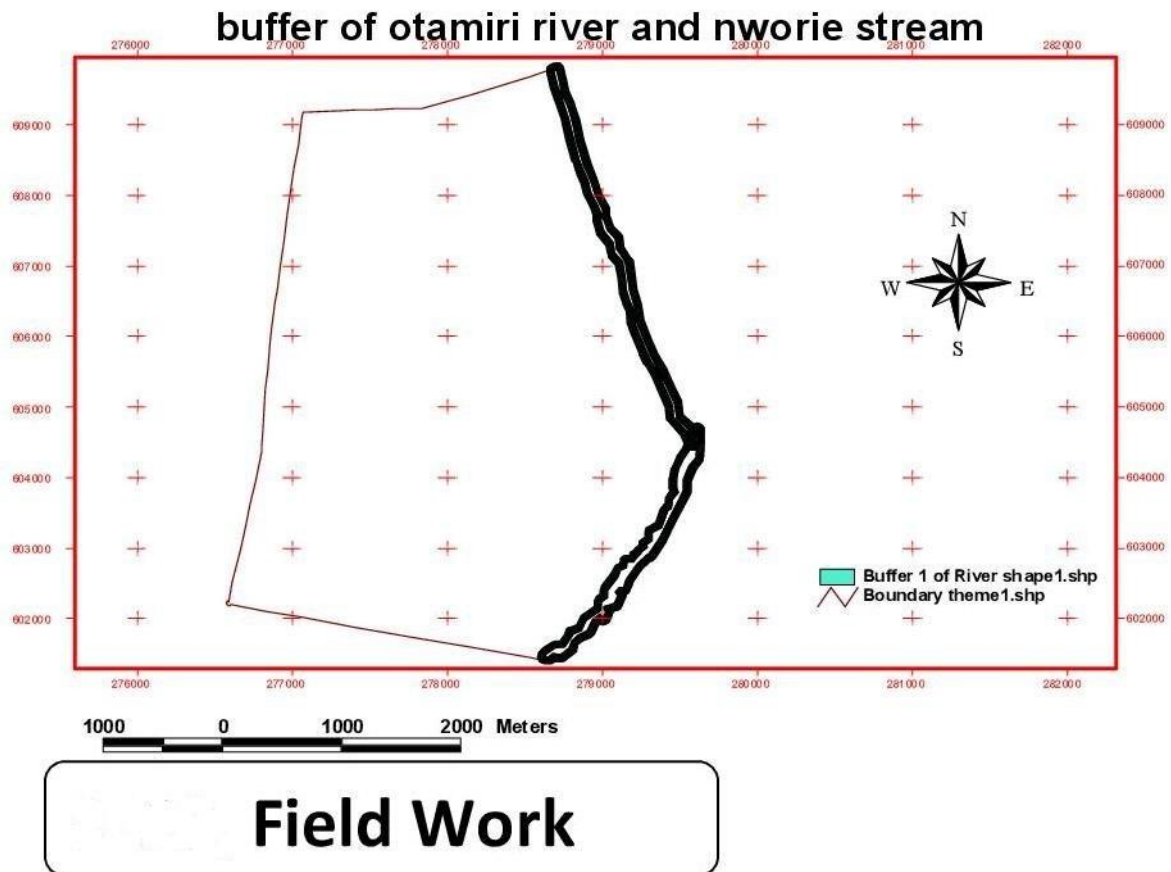


Fig. 4.5: Layout of the buffer of otamiri river and nworie stream

buffer of roads in new owerri map

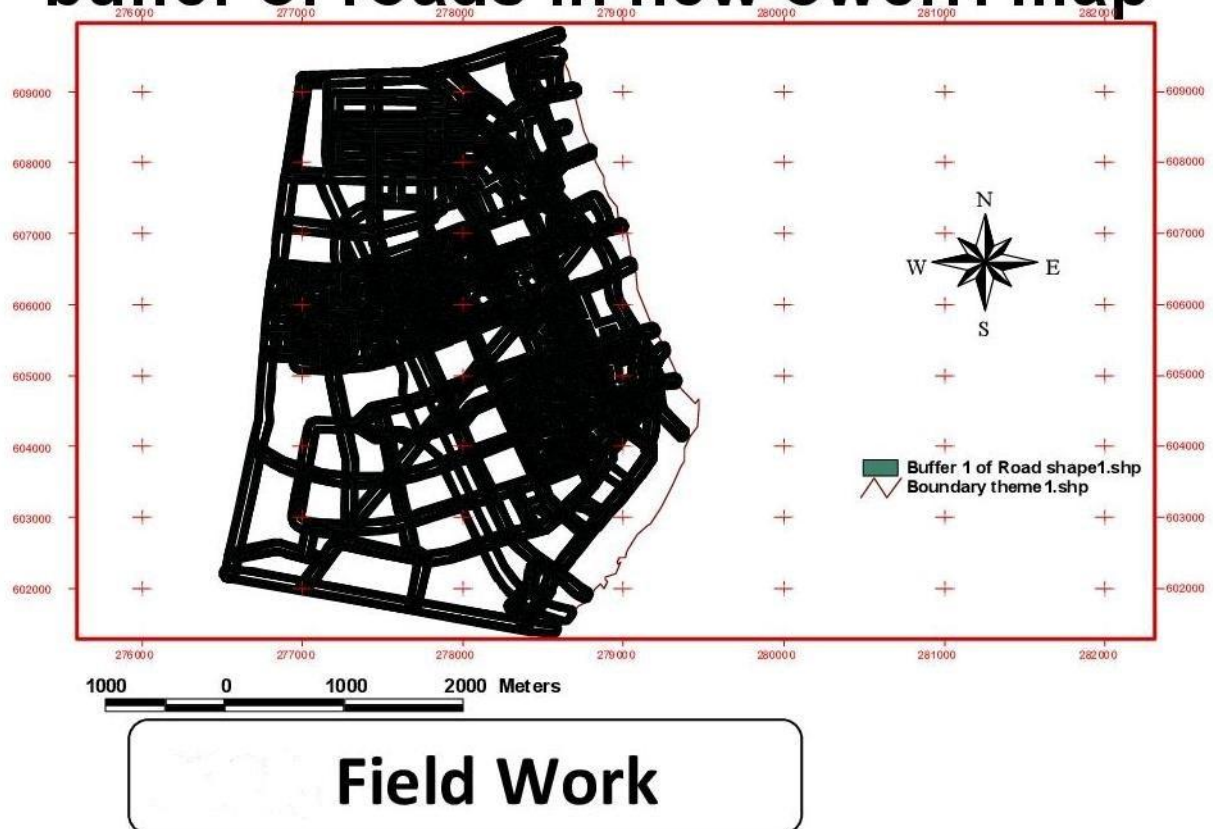


Fig. 4.6: Layout the buffer of roads in the study area (New Owerri)

buffer of roads in new owerri map

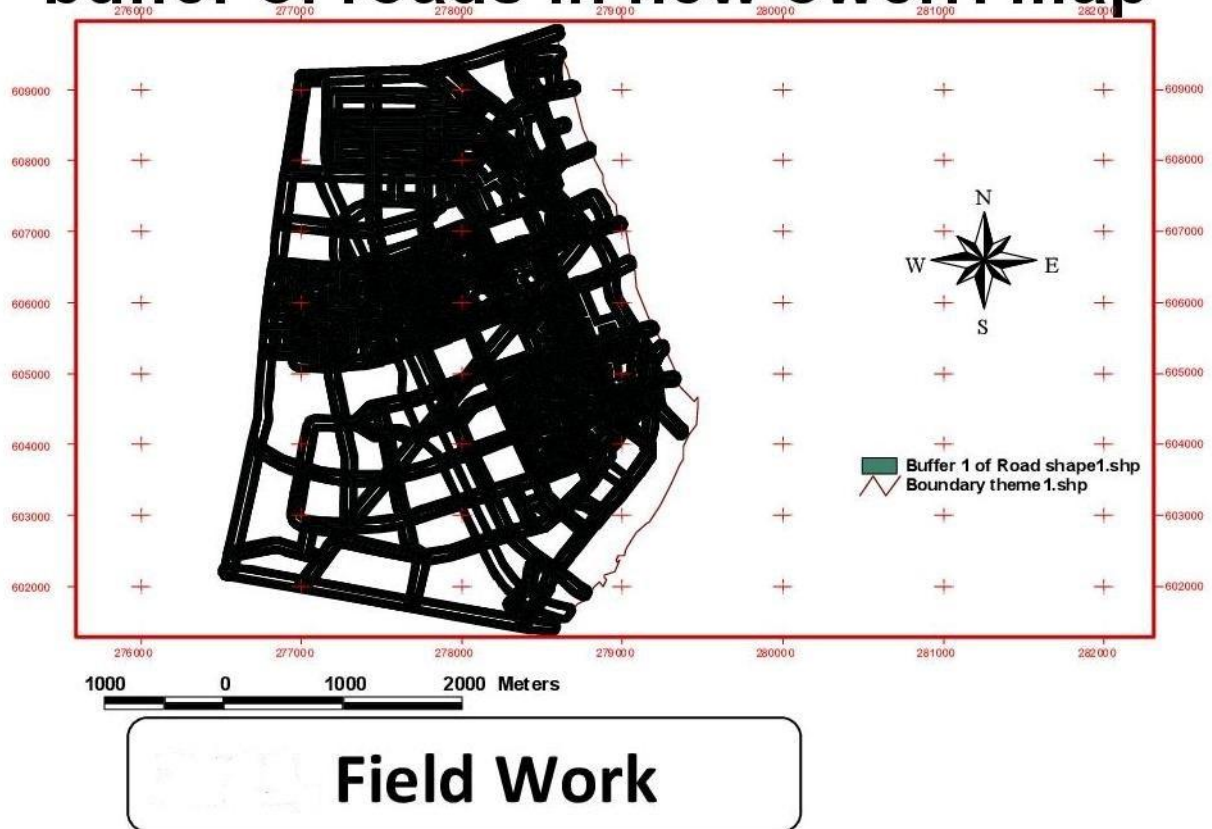


Fig. 4.7: Layout of the buffer of public use theme in the study area (New Owerri)

buffer of commercial land use in new owerri map

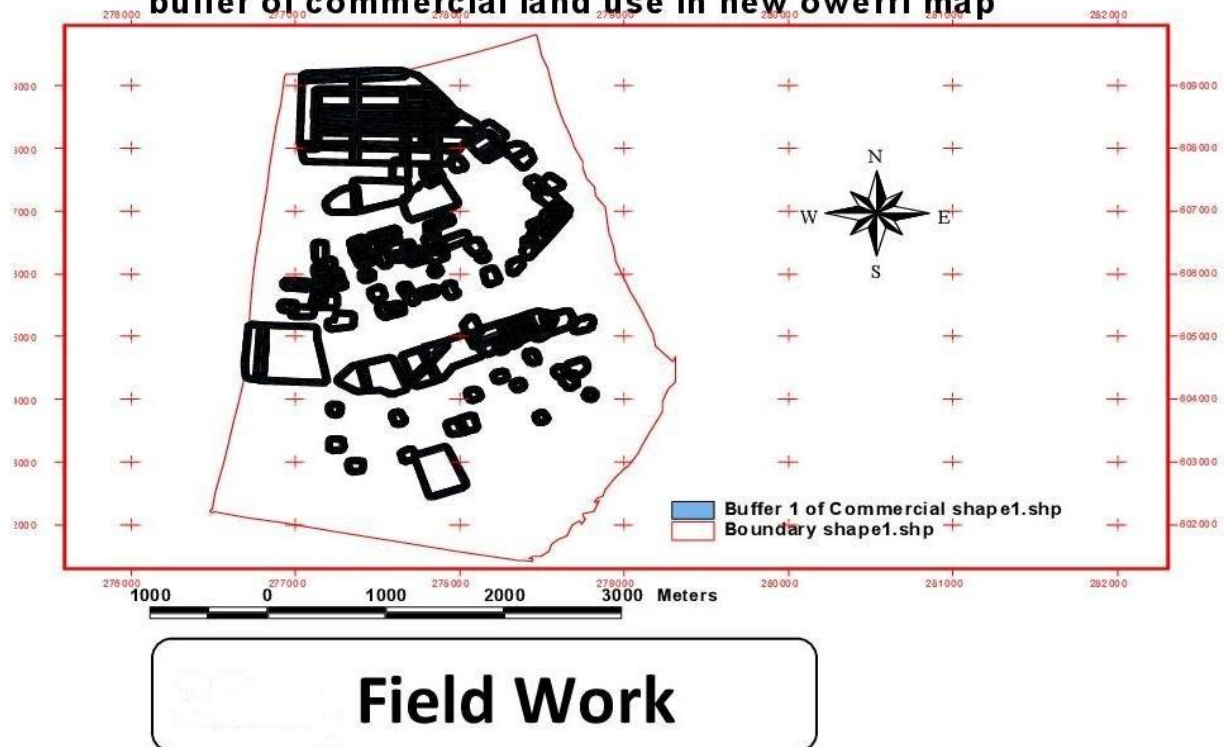


Fig. 4.8: Layout of the buffer of commercial land use in the study area (New Owerri)

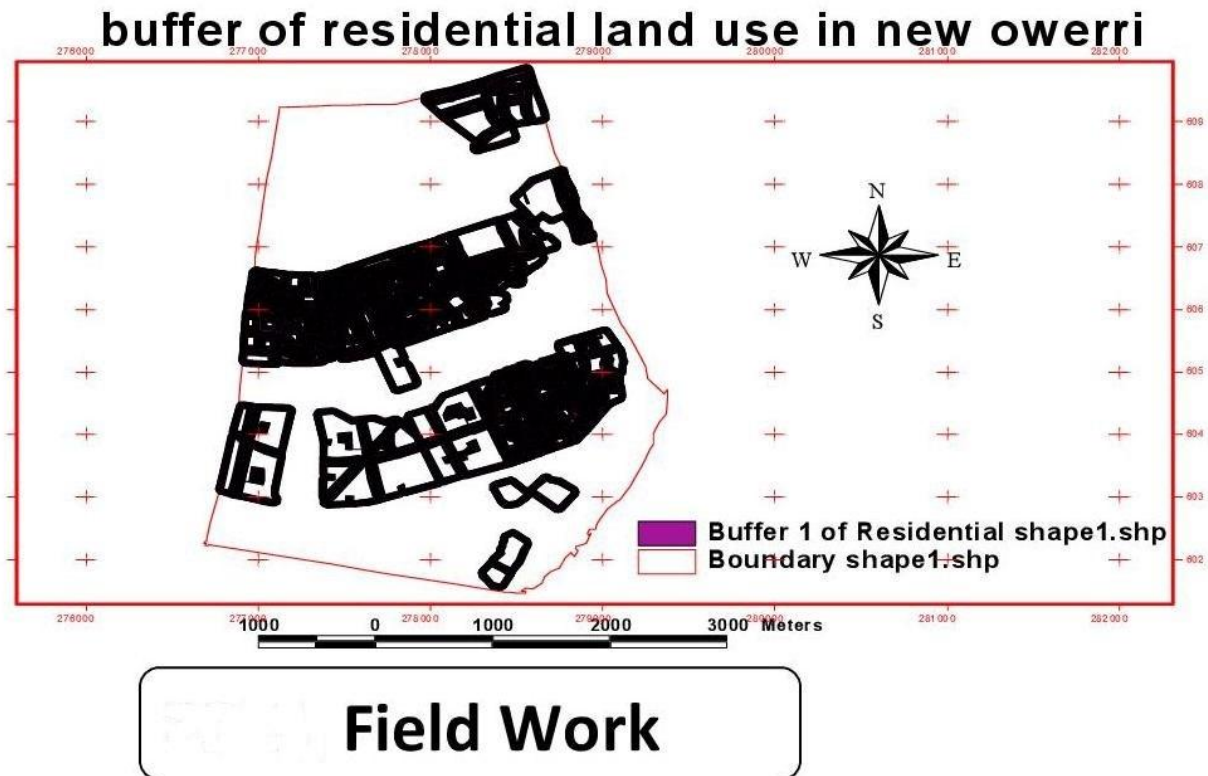


Fig. 4.9: Layout of the buffer of residential land use in the study area (New Owerri)

4.2.3 Overlay Operations

This is a GIS analytical apparatus used to combine two themes representing various data collections to produce another arrangement of data. Topological overlay can be utilized for various objectives, for example, theme updating, feature extracting, merging adjacent themes and merging feature attributes. The idea of overlay is by consolidating at least two or more themes (features), normally in anticipation of further analysis. For this project, overlay by union of entities was applied. Overlay by union is utilized to join themes (features) of an input theme with the polygons from an overlay theme, to deliver a yield theme that contains the qualities and full degree of the two themes.

For this project work, the accompanying overlay activities were performed:

(i) First Overlay: The buffered residential land use theme was overlaid (unioned) with the buffered public use land use theme to have another output theme called union of residential and public use land uses.

(ii) Second Overlay: The buffered commercial theme was overlaid with union of residential and public use theme to produce a new output theme called; union of commercial, public use and residential land uses.

(iii) Third overlay: The buffered road theme was overlaid (unioned) with the buffered river theme to have another output theme called union of road and river.

(iv) Fourth overlay: The unioned road and river were overlaid with the union of commercial, public use and residential land uses, to produce a new output theme called; **final union made up of the union of commercial, public use, residential, river and roads theme.**

4.2.4 Analysis of Overlay Operation

Click on 'view' on the tool bar menu and select 'geo processing wizard'. A dialogue box is shown; select 'union two themes' and click next on the new dialogue box, specify the two themes involved e.g. buffer of commercial layer and buffer of public use layer. Specify the output file and click 'finish'. The new theme will definitely show.

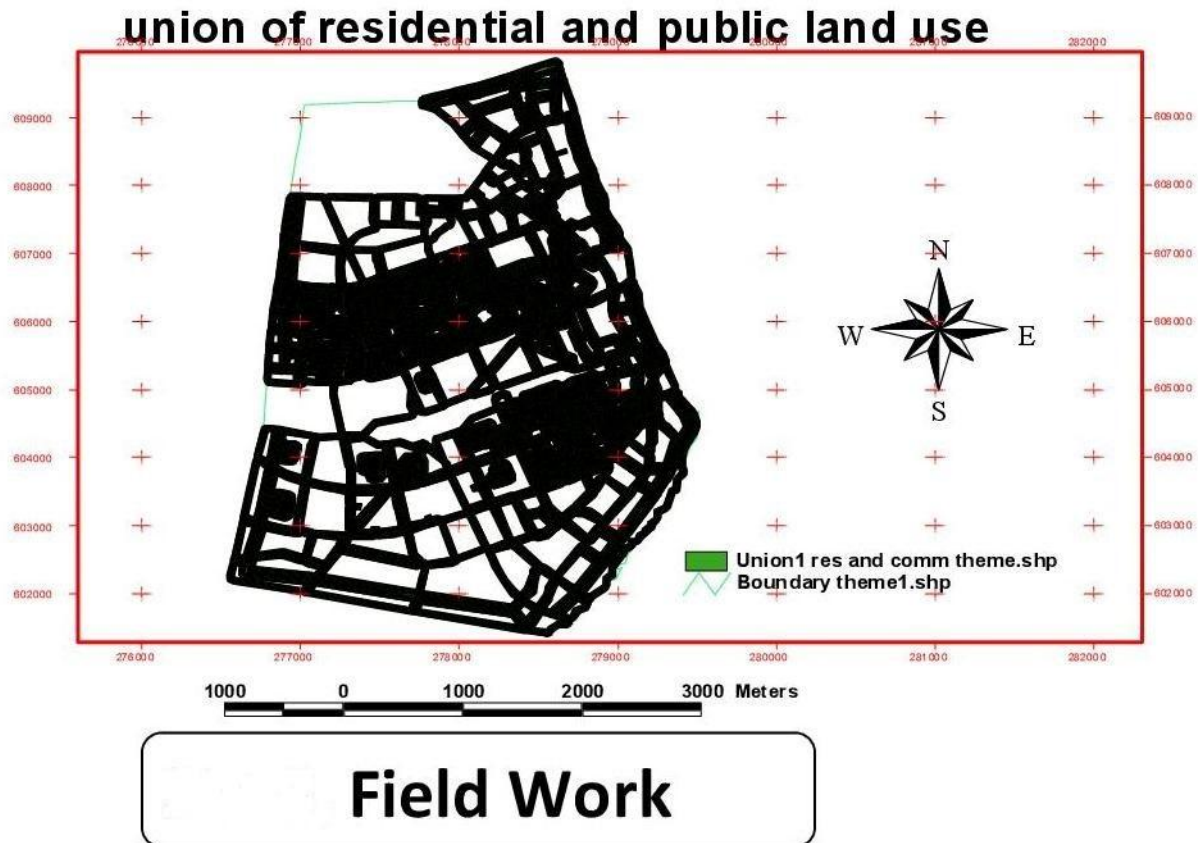
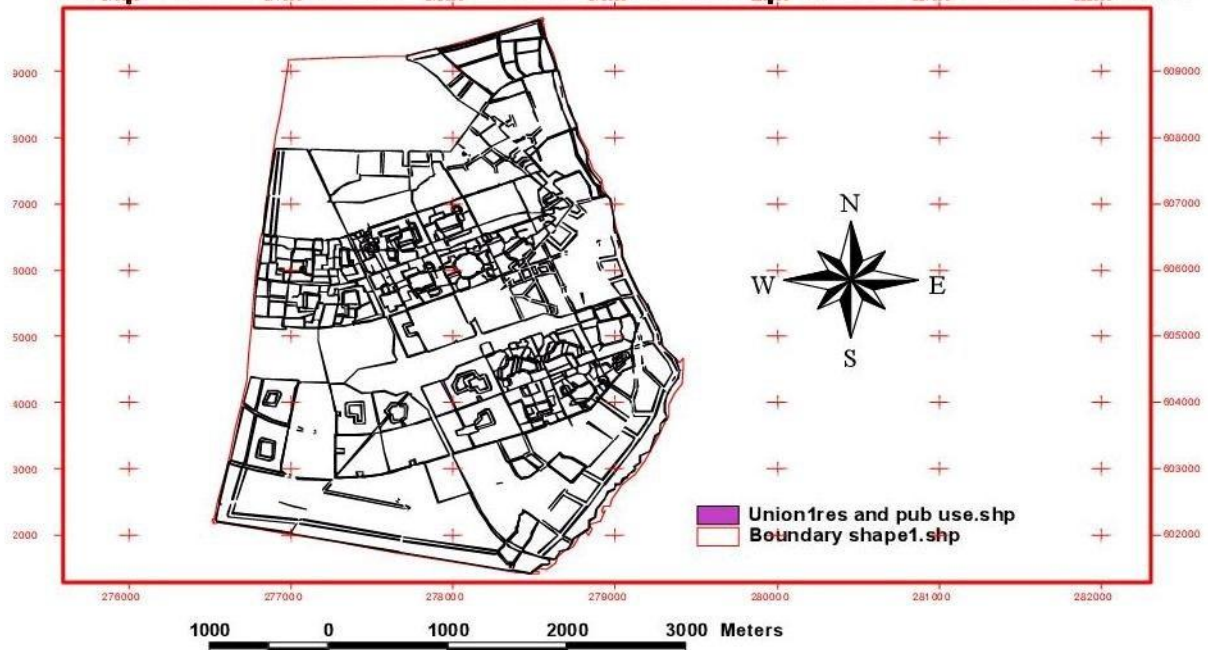


Fig. 4.10: Layout of the union of residential and public land use

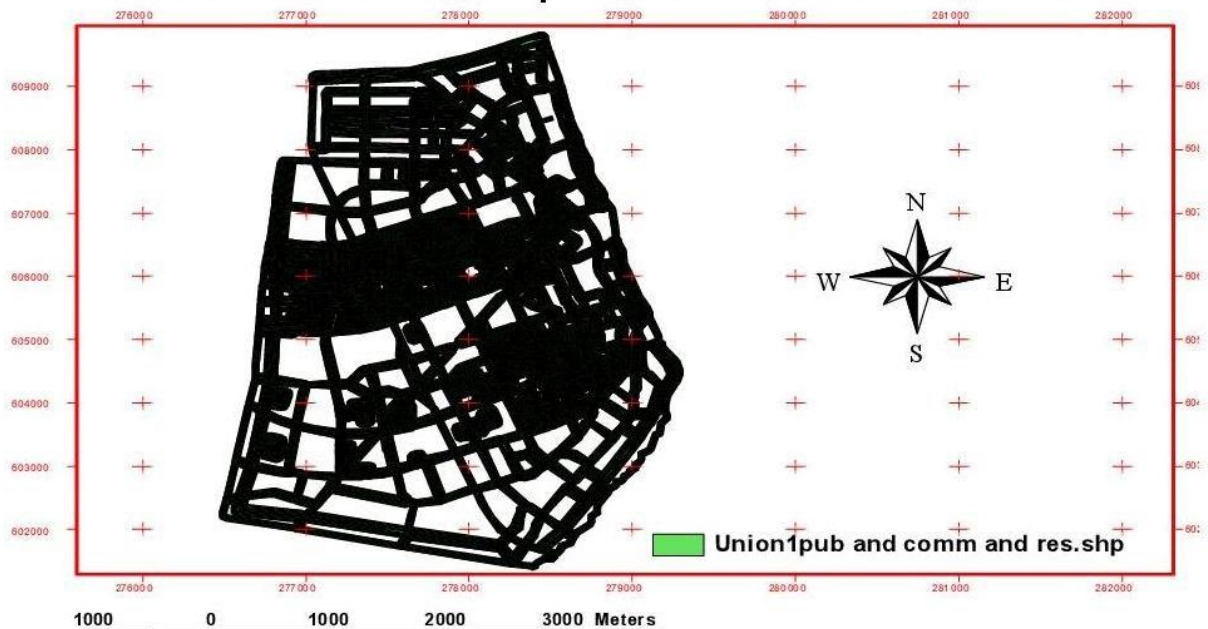
shapefile of union of residential and public land use theme



Field Work

Fig. 4.11: Shape filelayout of the union of residential and public use theme

union of residential and public and commercial land use



Field Work

Fig. 4.12: Layout of union of buffered commercial, public use and residential land uses

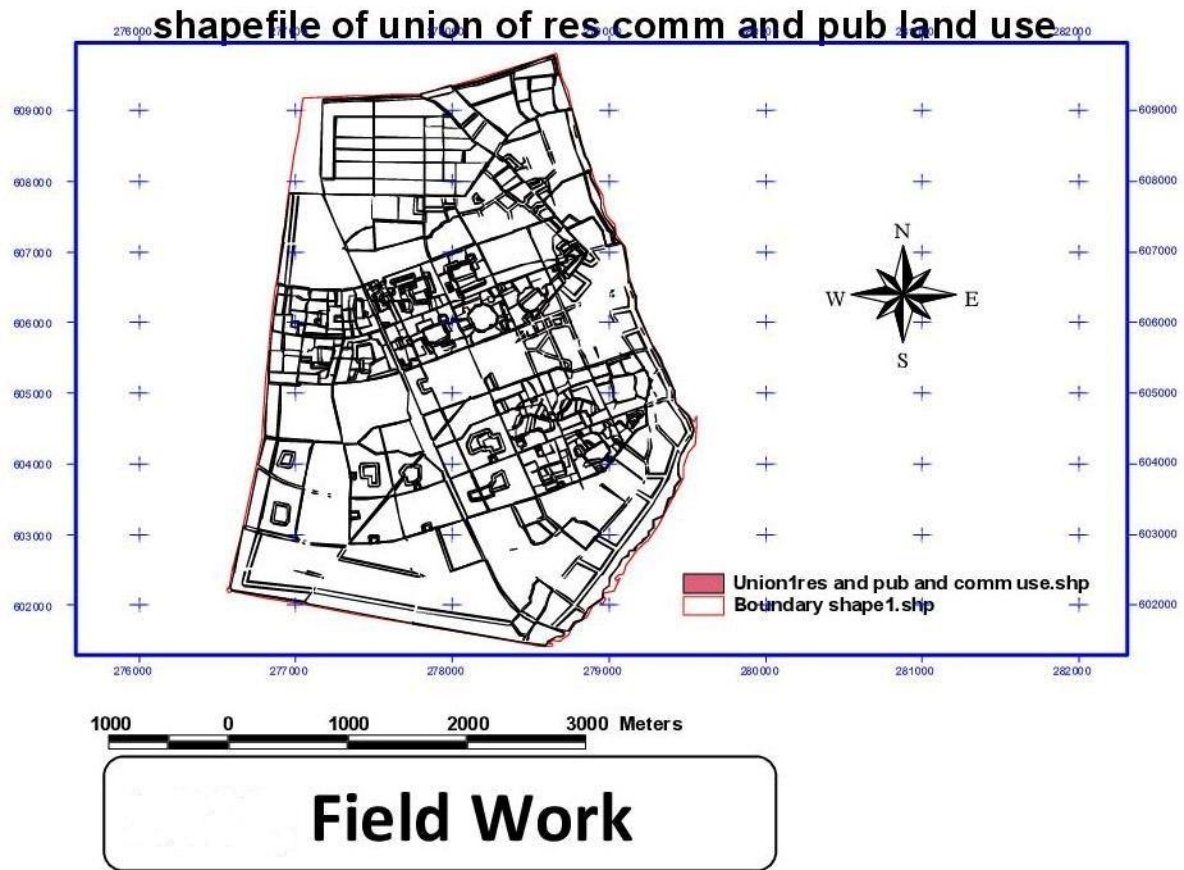
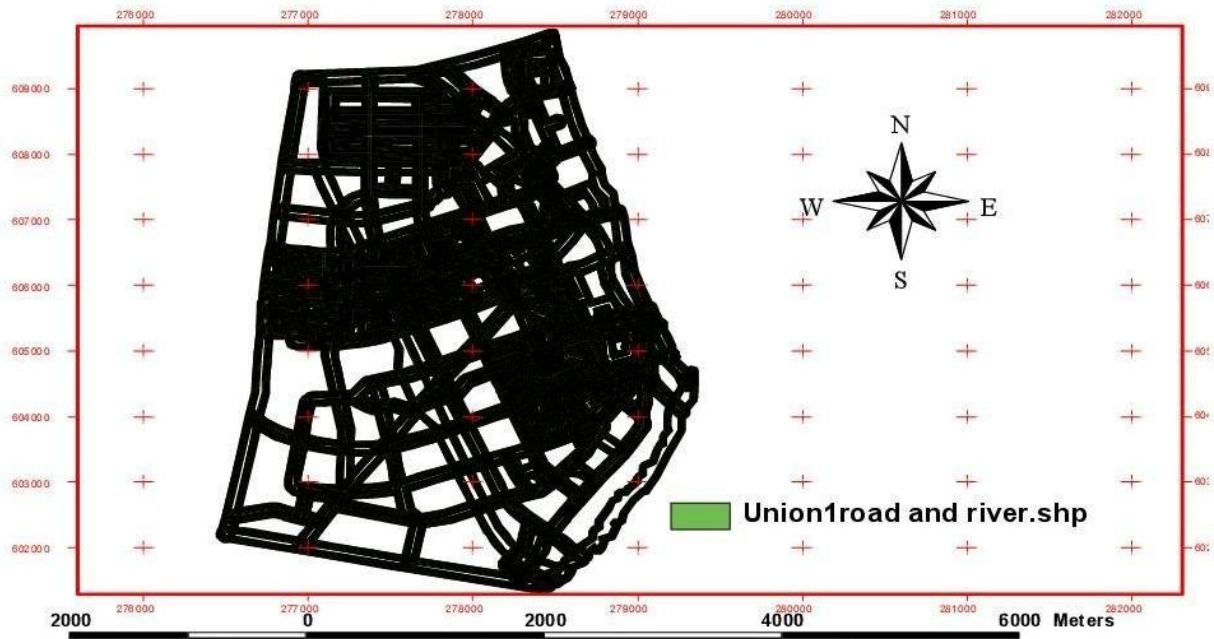


Fig. 4.12.1: Shape file layout of the union of residential and public use and commercial land use

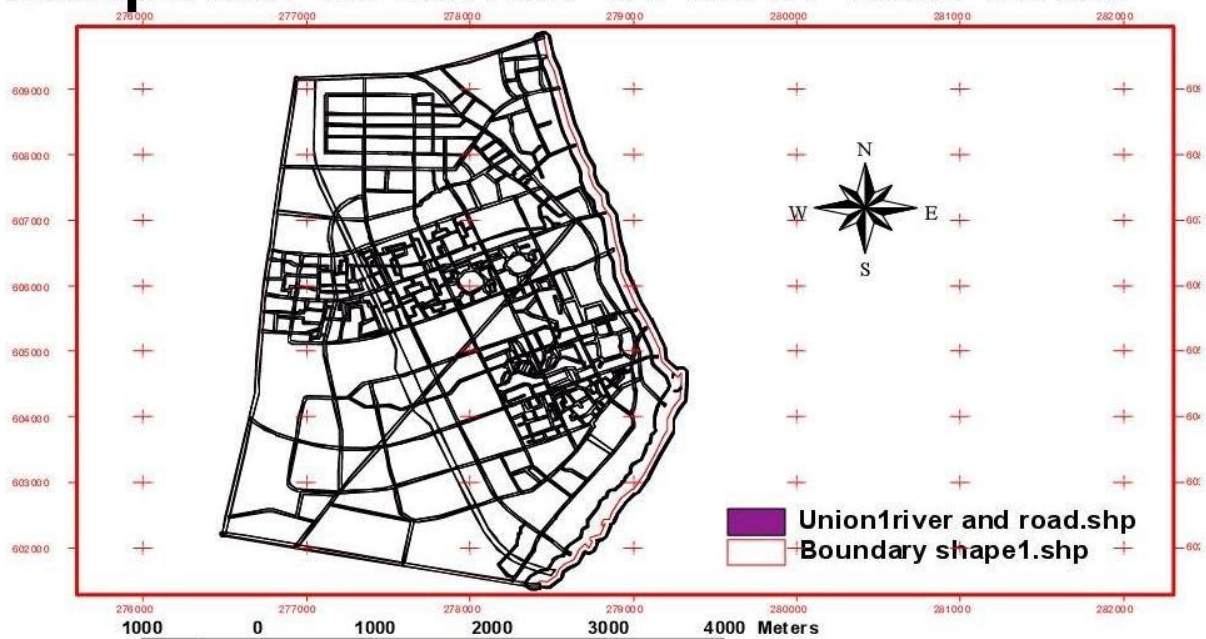
union of river and road



Field Work

Fig. 4.13: Layout of union of buffered road and river

shapefile of union of river and road



Field Work

Fig. 4.13.1: shape file layout of the union of river and road theme

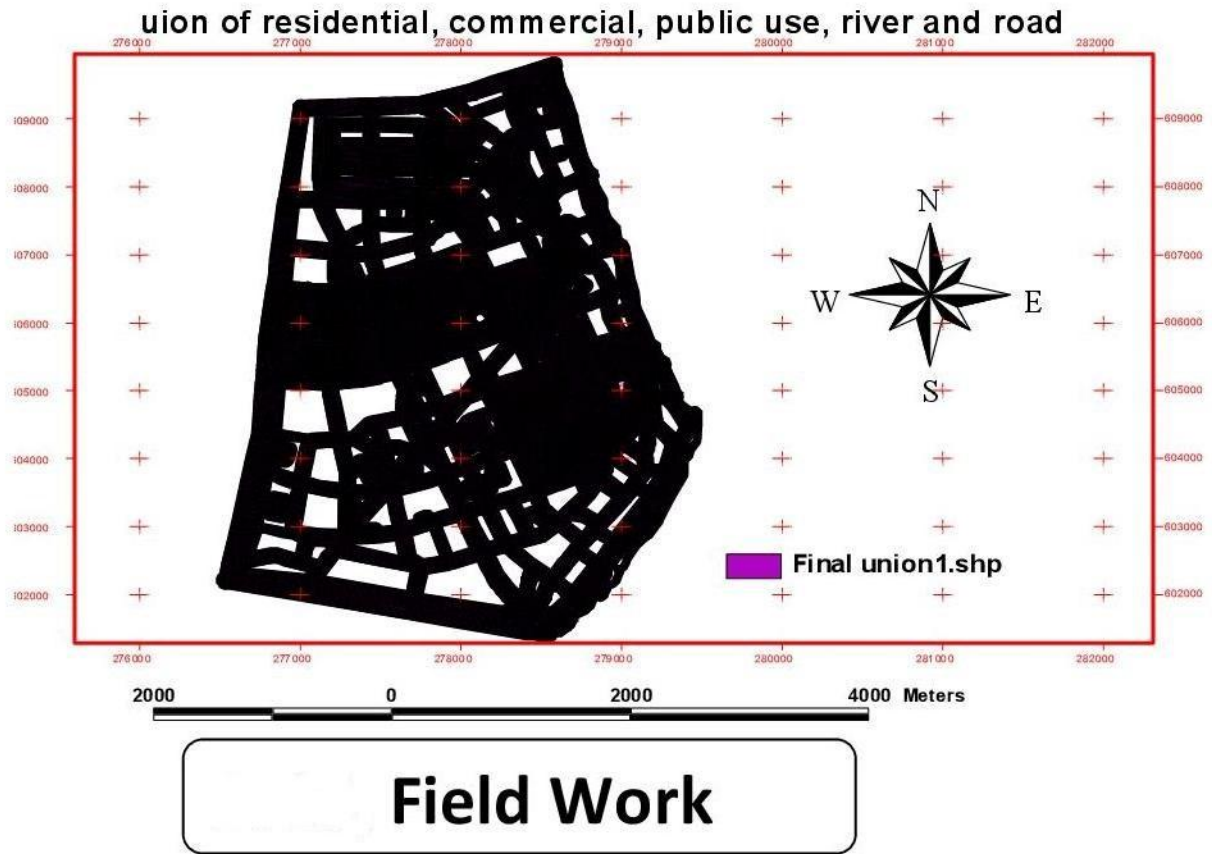


Fig. 4.14: Layout of the union of public, commercial and residential land use and road and river i.e. final union

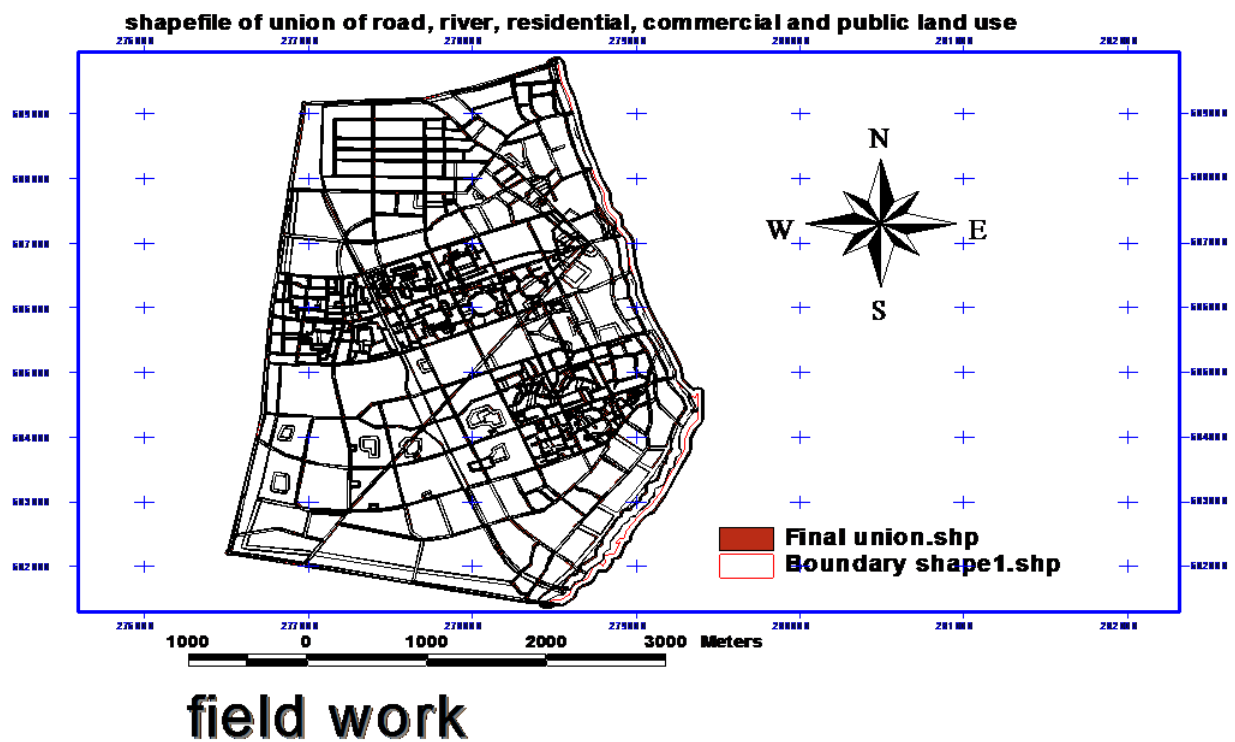


Fig. 4.14.1: shape file layout of the final union of public, commercial and residential land use and road and river

4.3 POLYGON CLIPPING OPERATIONS

This is the spatial extraction of those features from one coverage that dwells totally inside a limit characterized by features in another coverage (called clip-coverage). In accordance with analysis for this work, the limit of the investigation region was clipped with the theme; union of commercial, public use, residential and roads to create the applicant site for further research.

4.3.1 Analysis of Clipping Operation

Click on 'view' on the tool bar menu and select 'geo-processing wizard, a dialogue box is shown. Select 'clip one theme based on another' and click on 'next'. On the new dialogue box, select the input theme i.e. union of commercial, public use, residential, river and roads, as well as the polygon overlay theme i.e. boundary layer. Specify the output file and click 'finish'. The new theme will definitely show.

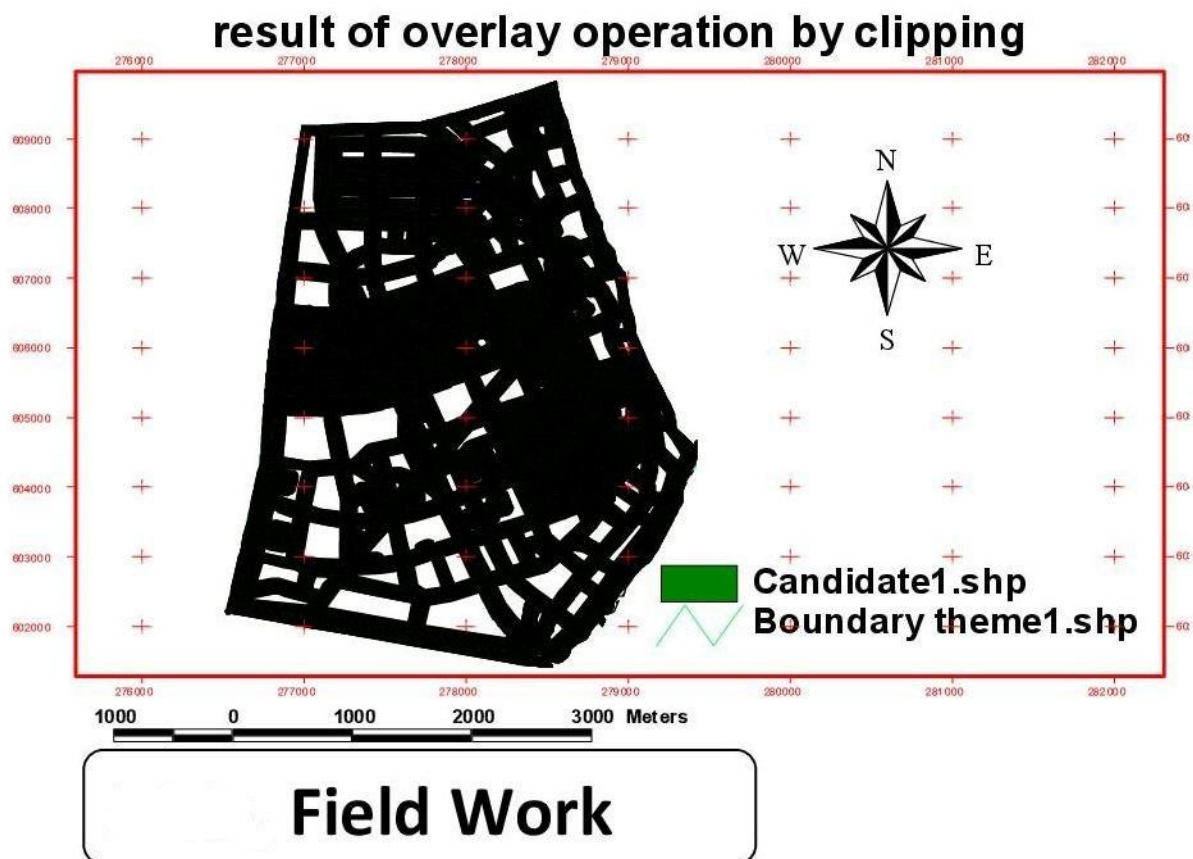


Fig 4.15 Layout of result of clipping operation (candidate site)

shapefile of clipping operation

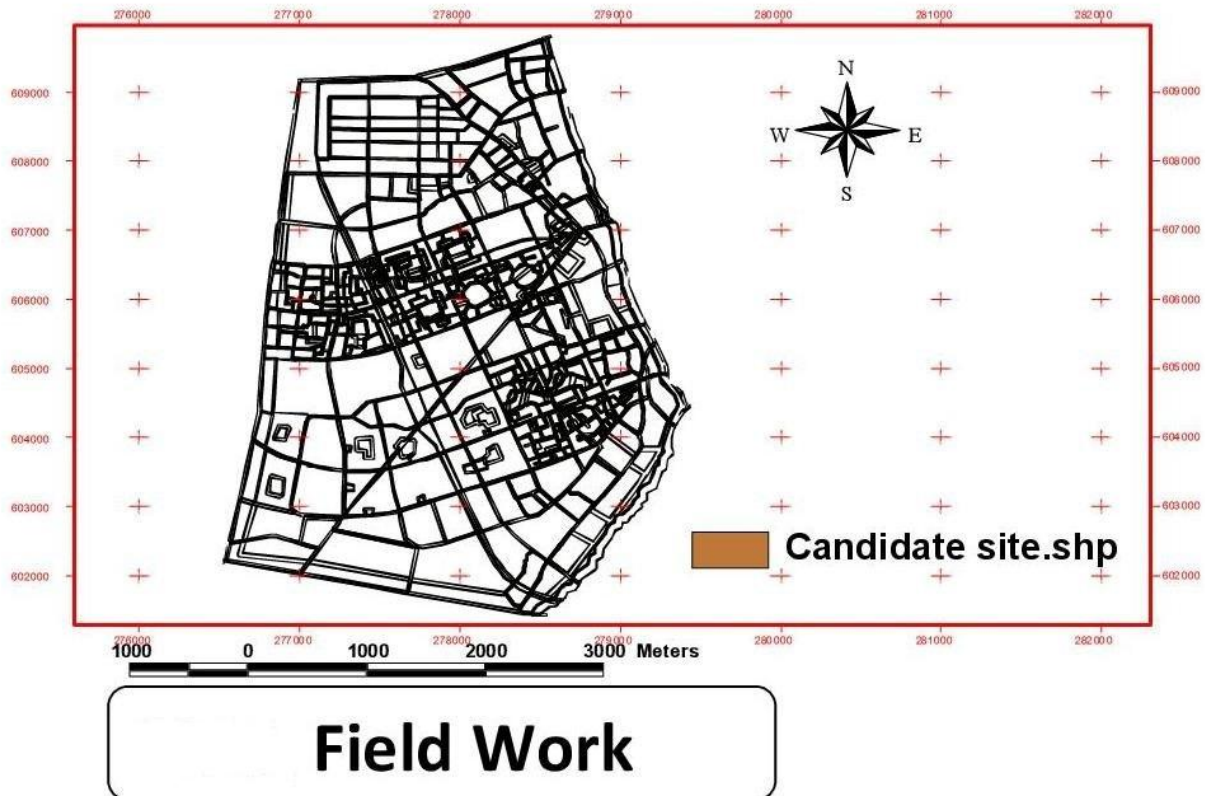


Fig 4.15.1 Shape file of the candidate's site layout of result of the clipping operation

4.4 SPATIAL QUERY/SEARCH

This is the major analytical operation carried out on the attribute table of various entities. The spatial search was performed by querying the database. It is the process of acquiring information from a GIS by asking spatial questions from the geographic data.

Spatial query is the way toward choosing features dependent on area or spatial relationship (for example choosing all territories 20m from residential areas). Database querying is accomplished through a query articulation worked to exactly characterize what to be chosen. Query articulations can either be single or different criteria.

In this project work, the single criteria query was completed in the wake of buffering and the resultant yield (in shape file) were unioned, and clipped to form a candidate shape file which was queried multiply to get most appropriate destinations for the present need as it were.

Be that as it may, the future need were likewise consolidated by overlaying the buffered land use theme without querying and clipping the last union to form a candidate site to be queried either independently (singly) or duplicate (Multiply) to acquire wanted outcome.

4.4.1 Single Criteria Query

Single criteria query was utilized to decide the potential area for solid waste collection points for all the land uses including roads. This didn't create the conclusive outcome yet gave an understanding to the potential zones where the collection containers can be located.

This was done using the set criteria as stated in 4.2. It was inputted into the query builder as follows; 10m from roads (Roads=10m) for easy collection and to prevent road blockage, 20m from residential areas (Res=20m) and 20m from commercial areas as well (com=20m) so it will be within the proximity of users and 40m from public use (public use =40m) so it wouldn't constitute nuisance to people using public facilities.

POSSIBLE AREAS FOR ROADS

(Rd Dist.=10m)

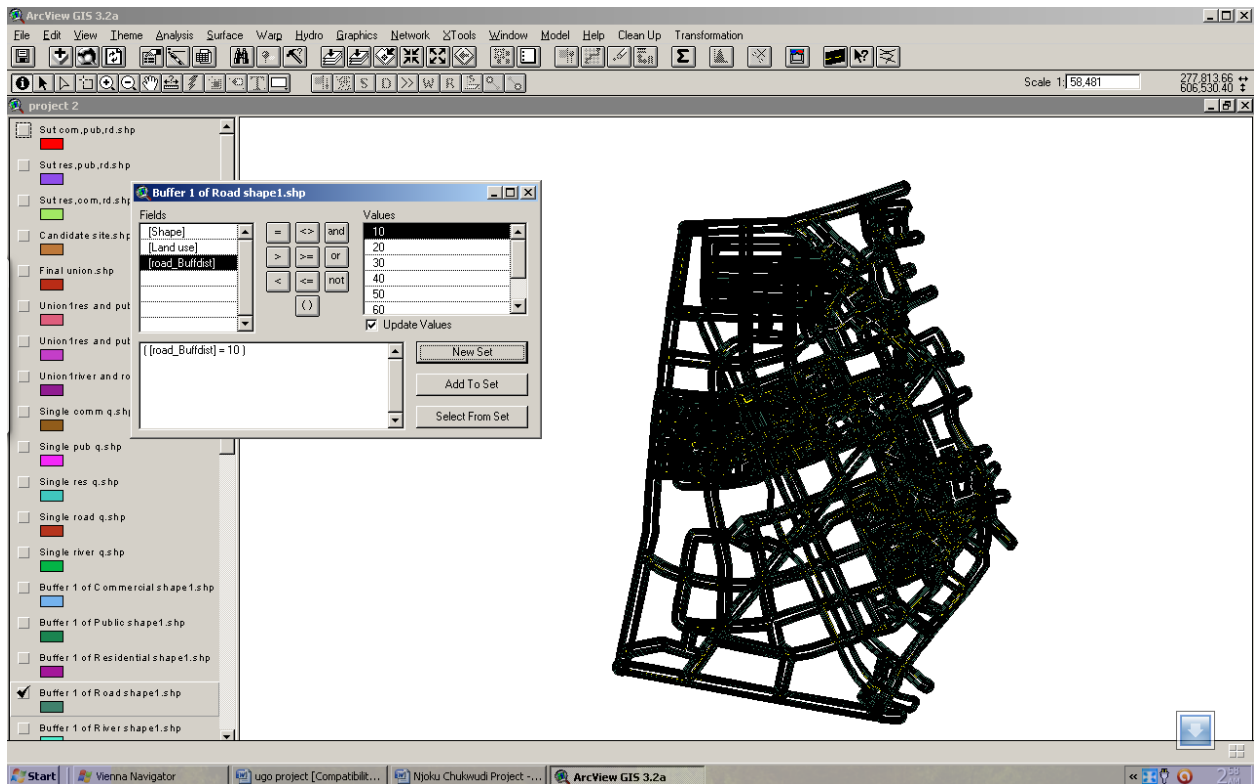


Fig 4.16 Query input and output of 10m from road

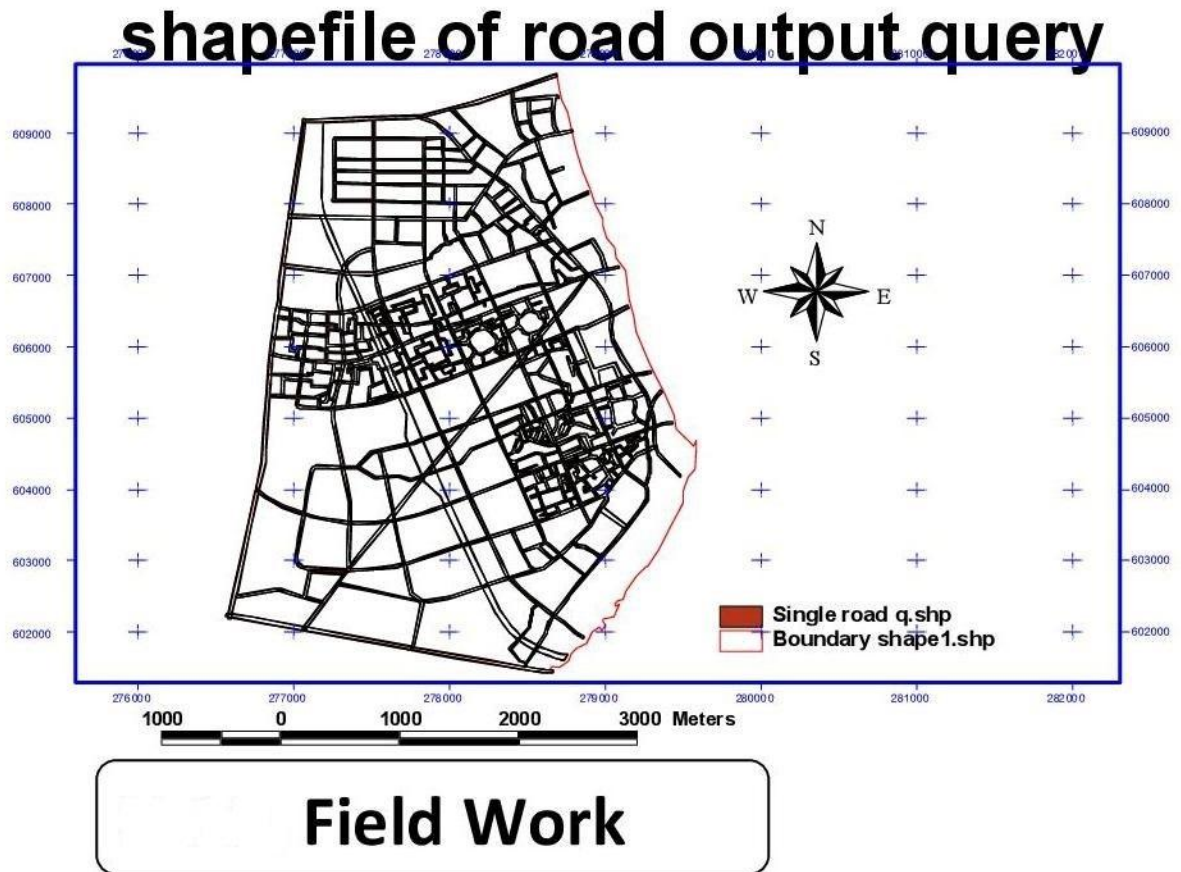


Fig 4.16.1 shape file layout of the result of road output query

AREAS WITH POSSIBILITY FOR RESIDENTIAL

(Res Dist.=20m)

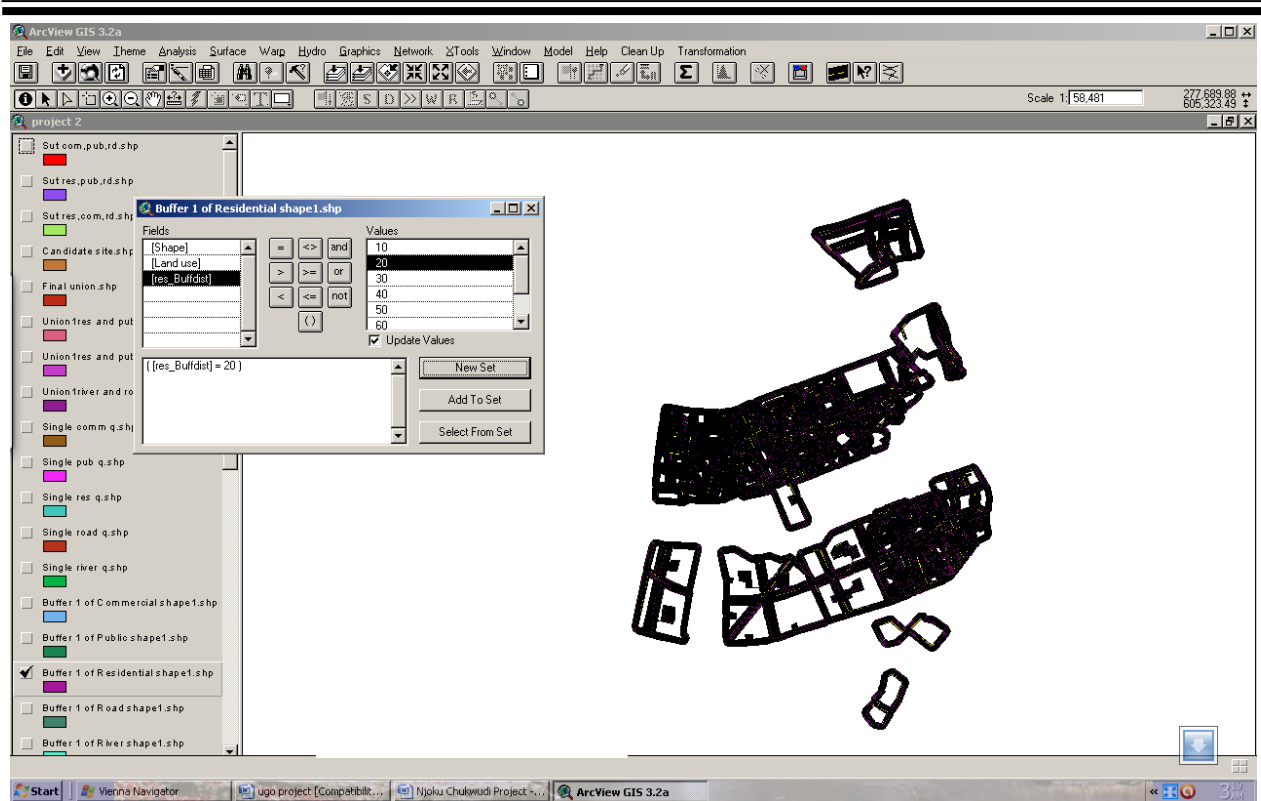


Fig 4.17 Query input and output of 20m from residential

shapefile of residential land use output query

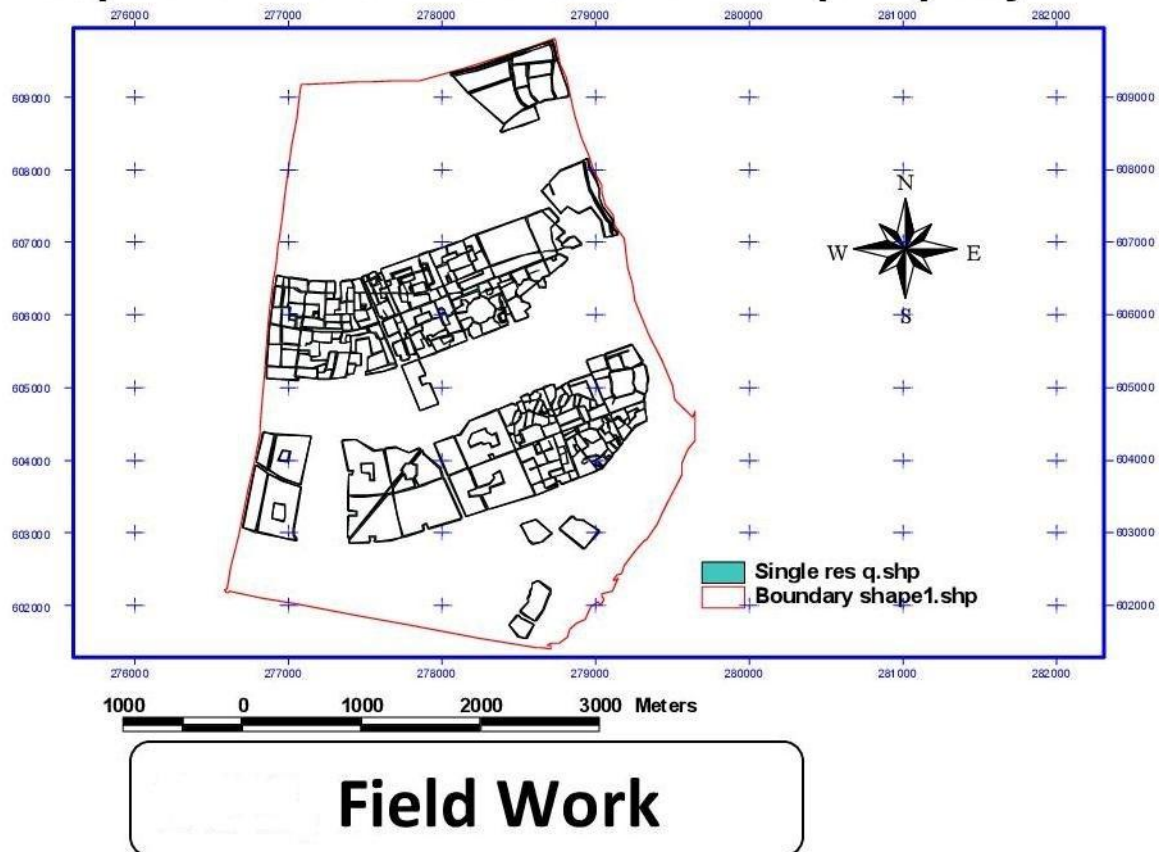


Fig 4.17.1 Shape file layout of the result of residential land use output query

AREAS WITH POSSIBILITY FOR PUBLIC USE

(Pub Use Dist. =40m)

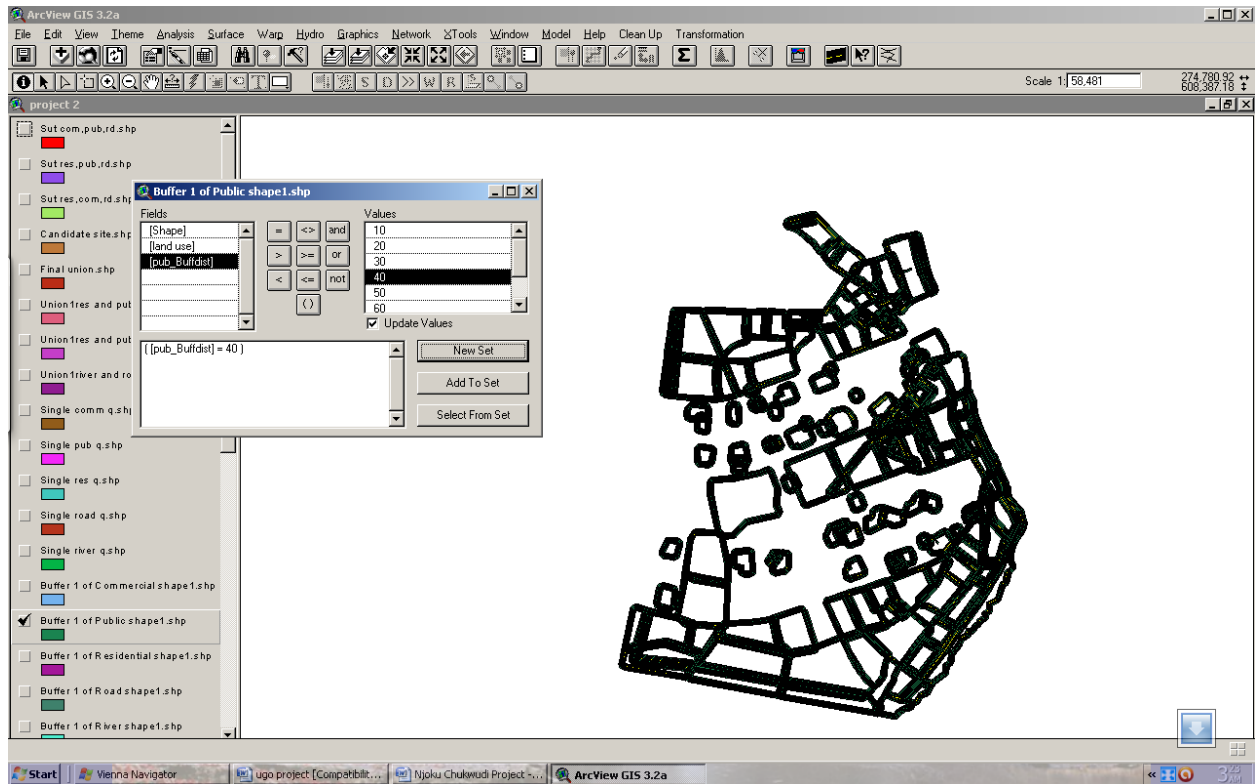


Fig 4.18 Query input and output of 20m from public use

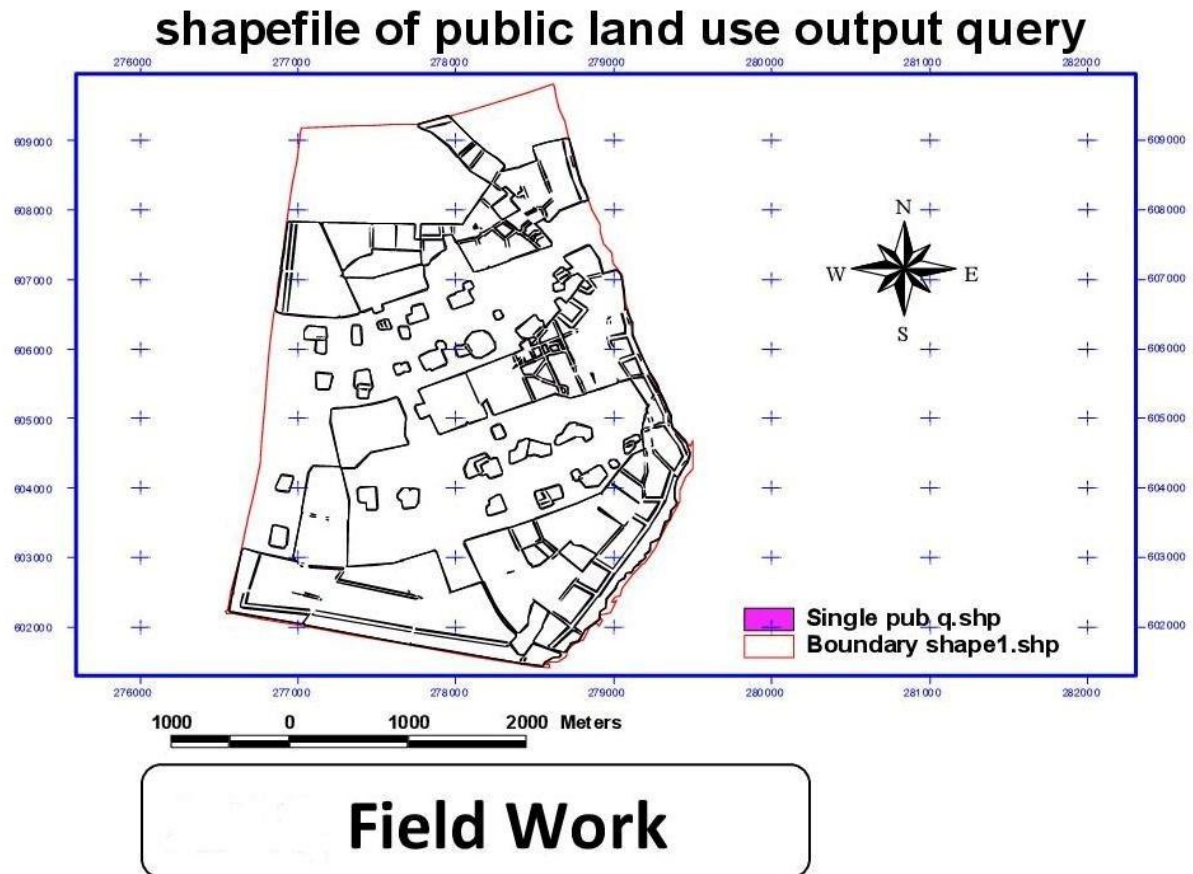


Fig 4.18.1 Shape file layout of the result of public land use output query

AREAS WITH POSSIBILITY FOR COMMERCIAL

(Com Dist. =20m)

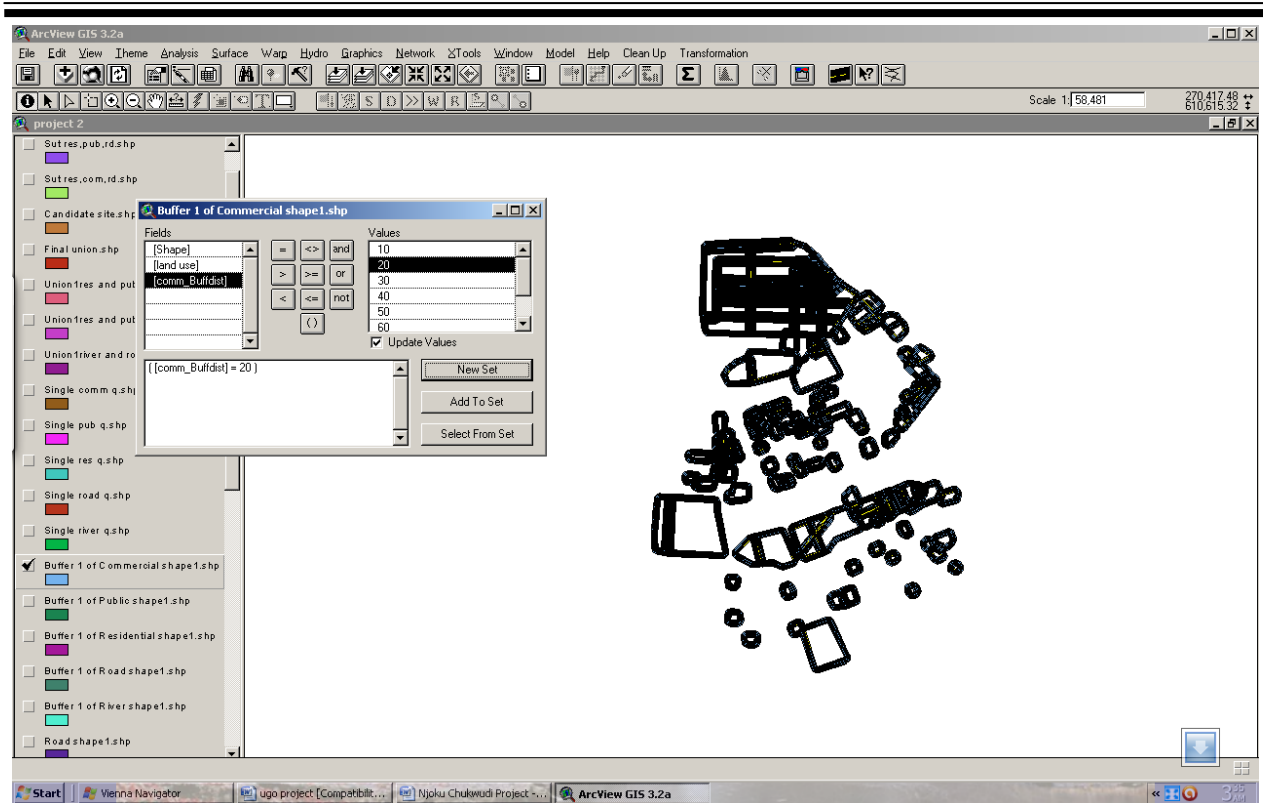


Fig 4.19 Query input and output of 20m from commercial

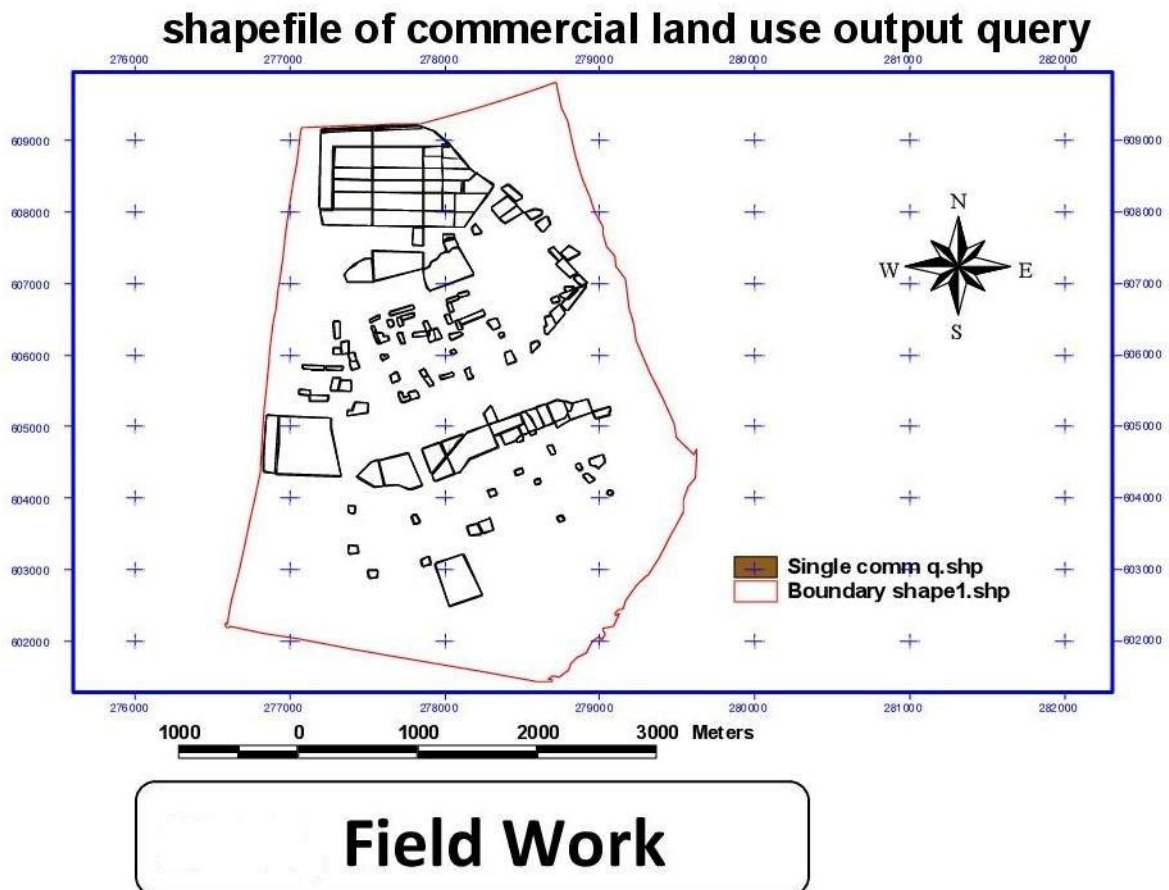


Fig 4.19.1 Shape file layout of the result of commercial land use output query

AREAS WITH POSSIBILITY FOR RIVER

(River Dist.>70m)

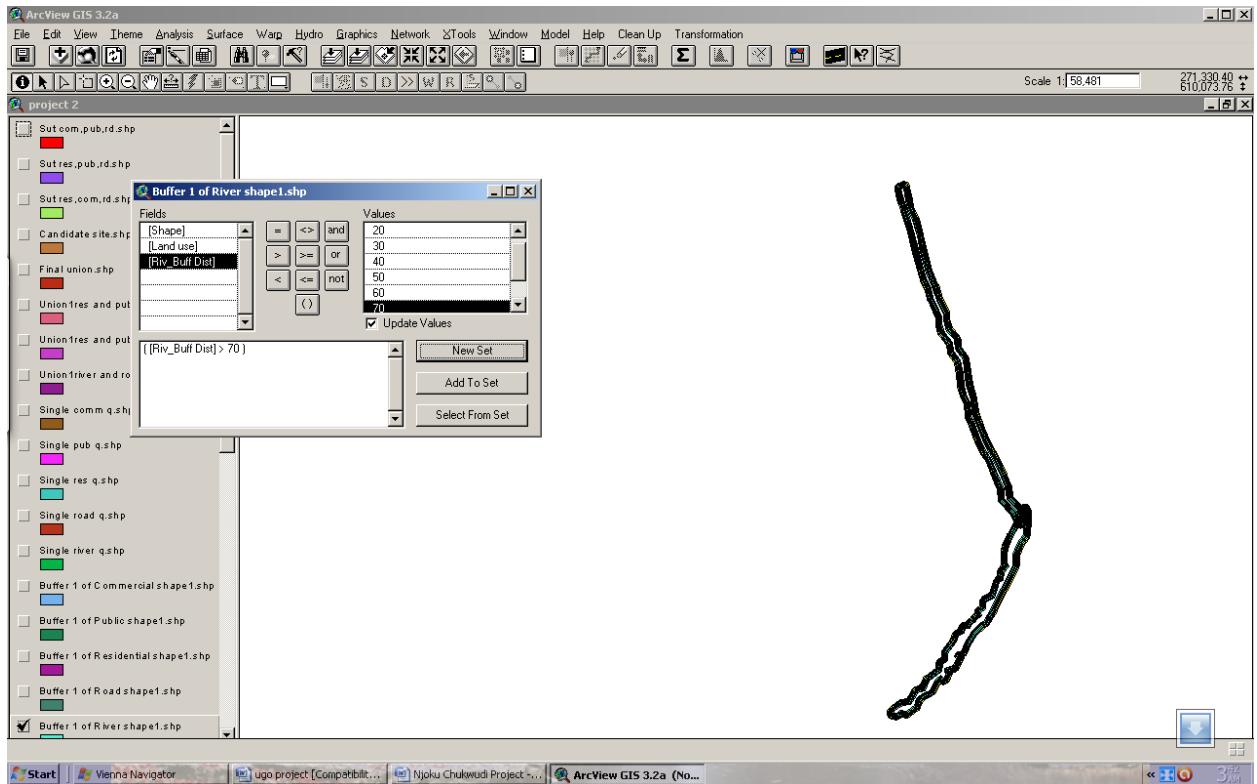


Fig 4.20 query input and output for river

shapefile of river output query

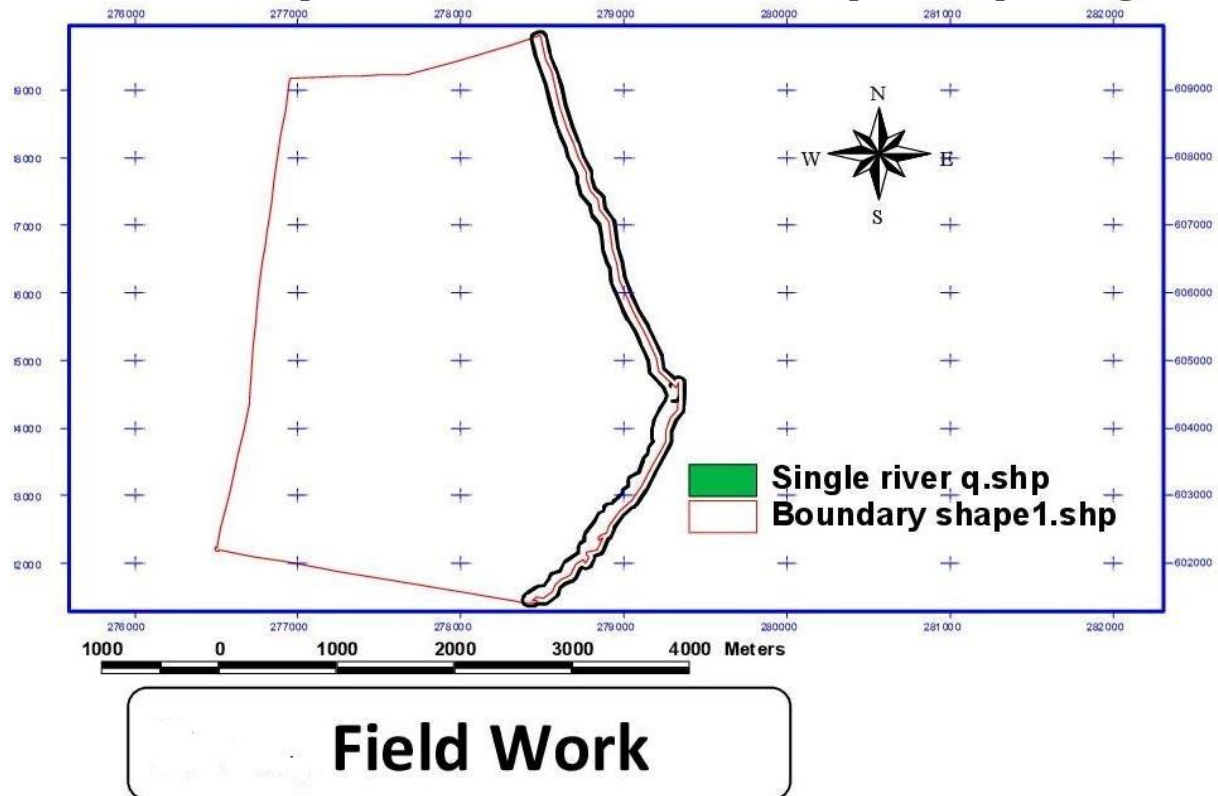


Fig 4.20.1 shape file layout of the result of river output query

4.4.2 Multi Criteria Queries

Multi criteria queries were utilized to decide the reasonable destinations just as the most appropriate sites for solid waste collection inside New Owerri area. These queries consolidate more than one entity in a specific land use to choose the appropriate destinations inside the land thereof. Three various criteria queries were done in this project.

- (i) **First;** identification of most suitable points within residential and commercial area at 20m interval respectively
- (ii) **Second;** identification of suitable points on areas within residential and public land use at 20m and 40m interval respectively.
- (iii) **Third;** identification of most suitable points on areas with commercial and public land use at 20m and 40 interval respectively

The aftereffect of these queries shows destinations that are suitable for users at the same time in the two land uses. The outcome is a union of points or regions where the land uses meet/intersect with the set criteria set up inside a specific land use type.

4.4.3 Input for Multi-Criteria Queries

- **First:** Res_Buff DIST = 20 and Com_BuffDIST=20 and RdDIST = 10
- **Second:** Res_BuffDIST=20 and Pub_BuffDIST = 40 and RdDIST = 10

- **Third:** comm._BuffDIST=20 and Pub_BuffDIST=40 and RdDIST = 10

4.4.4 Output for Multi-Criteria Queries

- Suitable Sites within Residential and Commercial

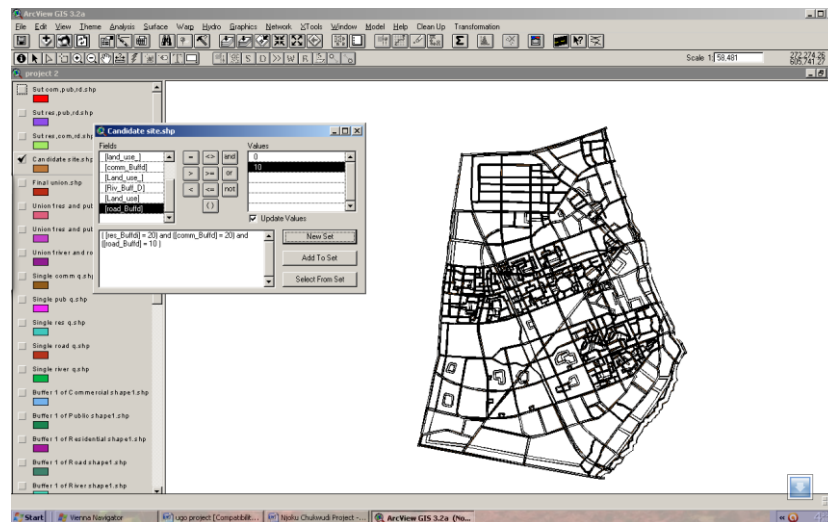


Fig 4.21 Query input and output for suitable sites within residential and commercial land use

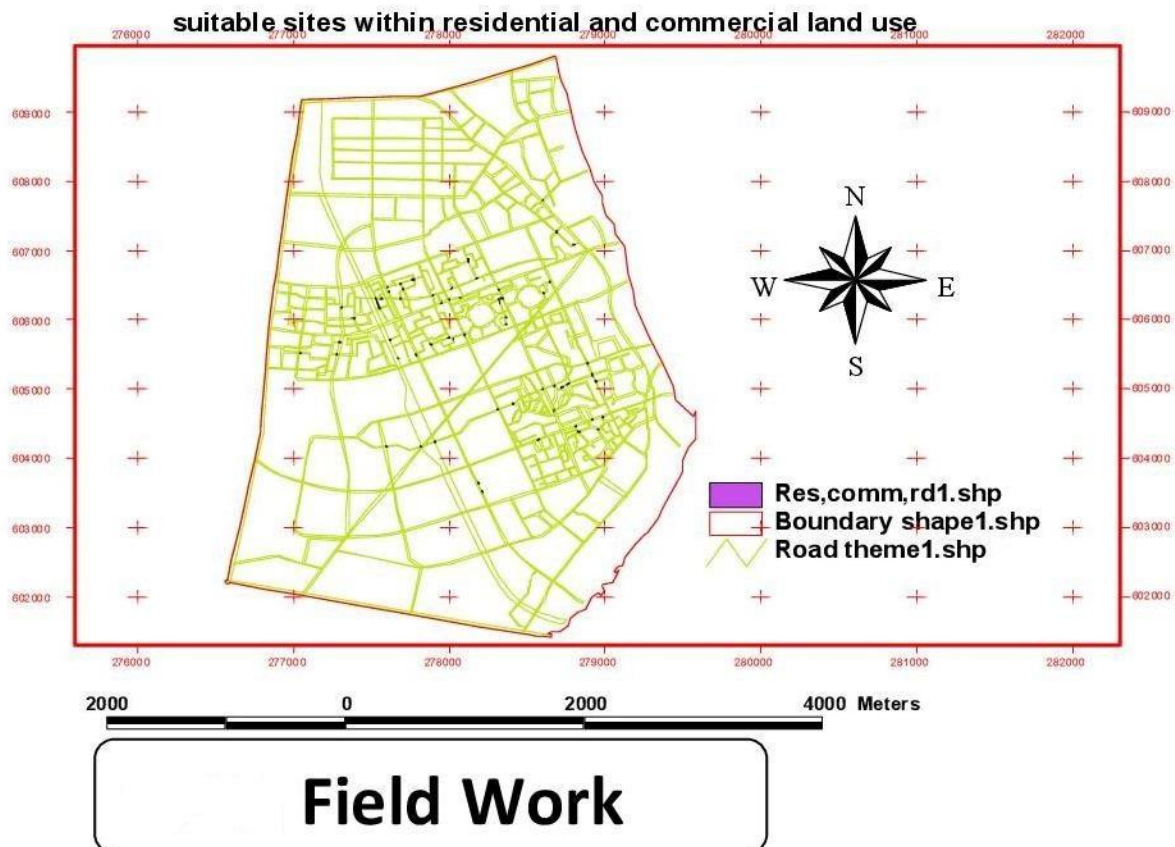


Fig 4.21.1 Layout of suitable sites within residential and commercial land use

- Suitable Sites within Residential and Public Use

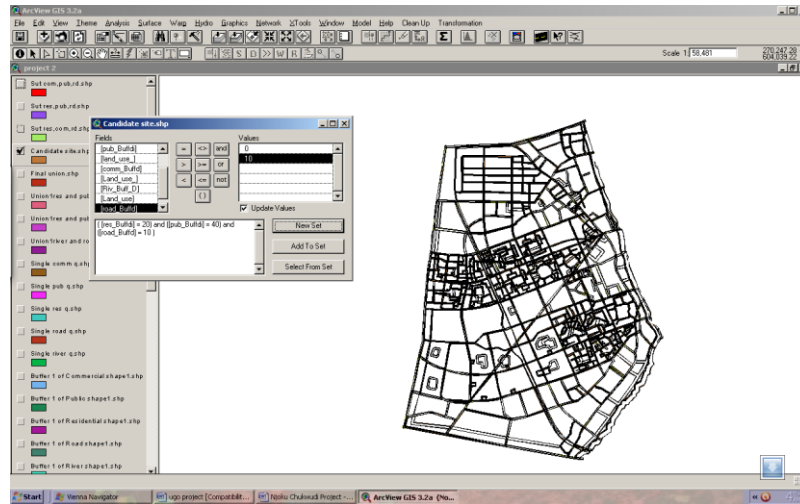


Fig 4.22 Query input and output for suitable sites within residential and public use

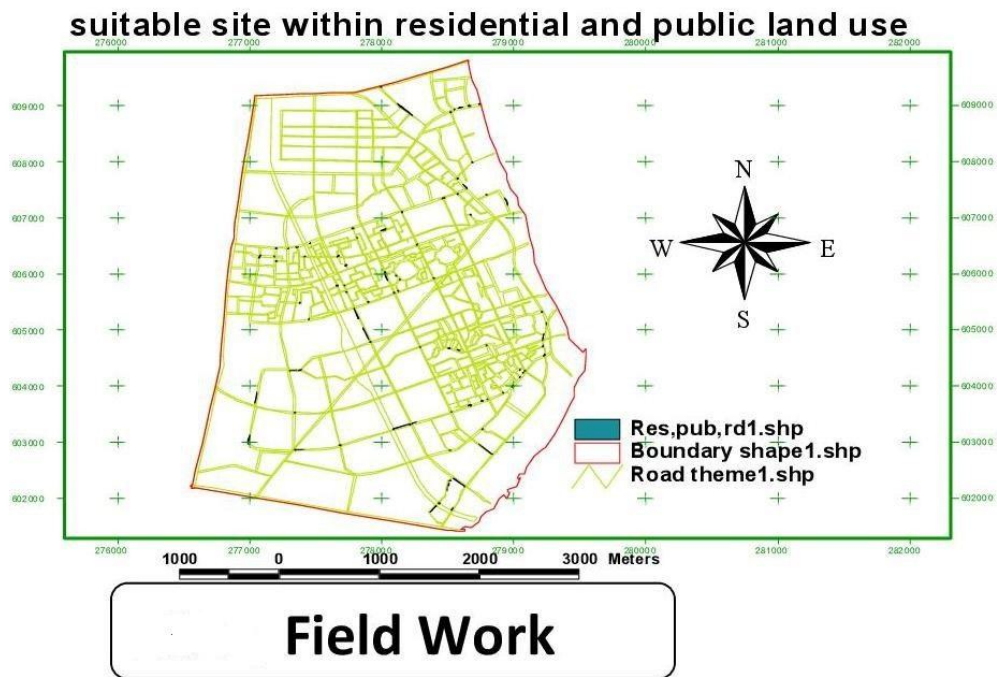


Fig 4.22.1 Layout of suitable sites within residential and public use

- Suitable Sites within Commercial and Public Use

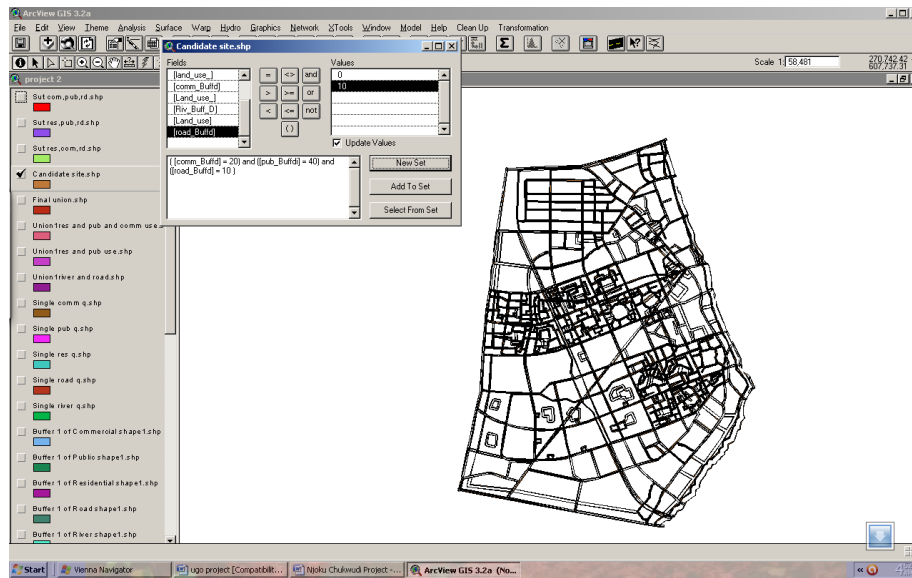


Fig 4.23 Query input and output for suitable sites within commercial and public use

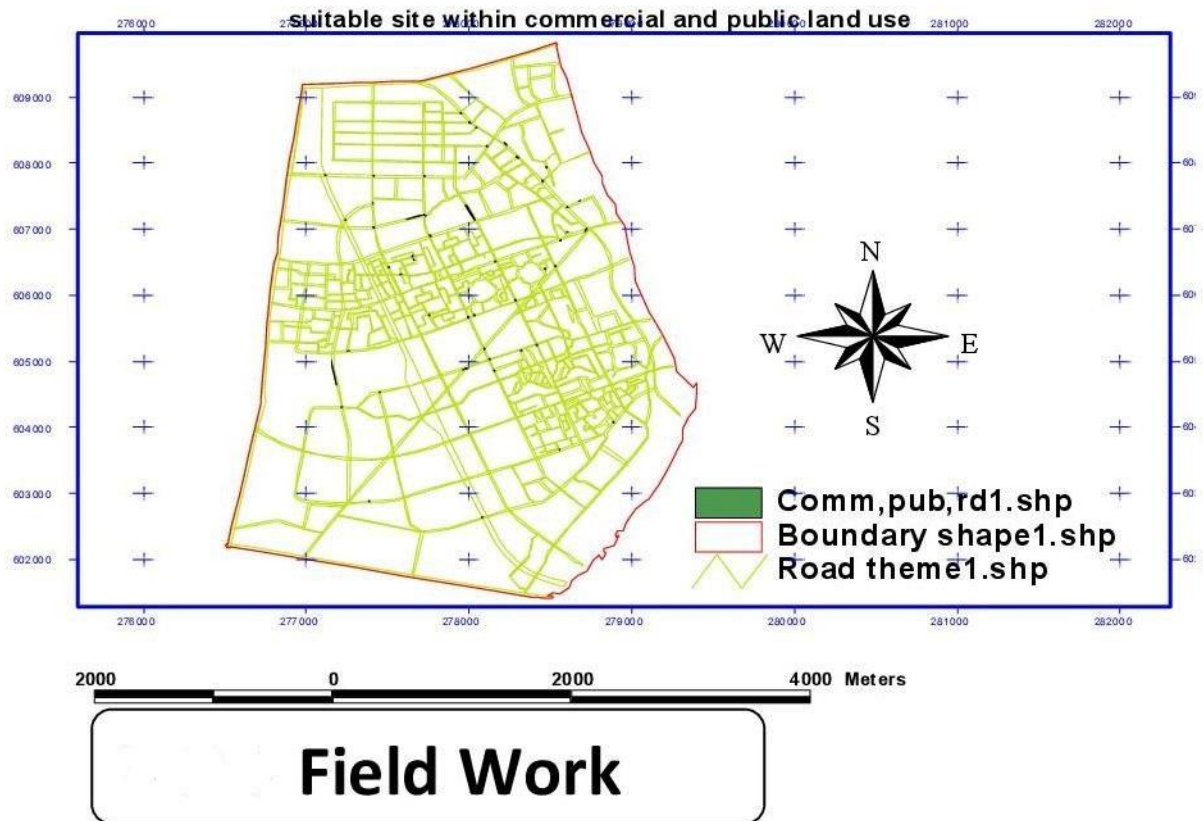


Fig 4.23.1 Layout of suitable sites within commercial and public use land use

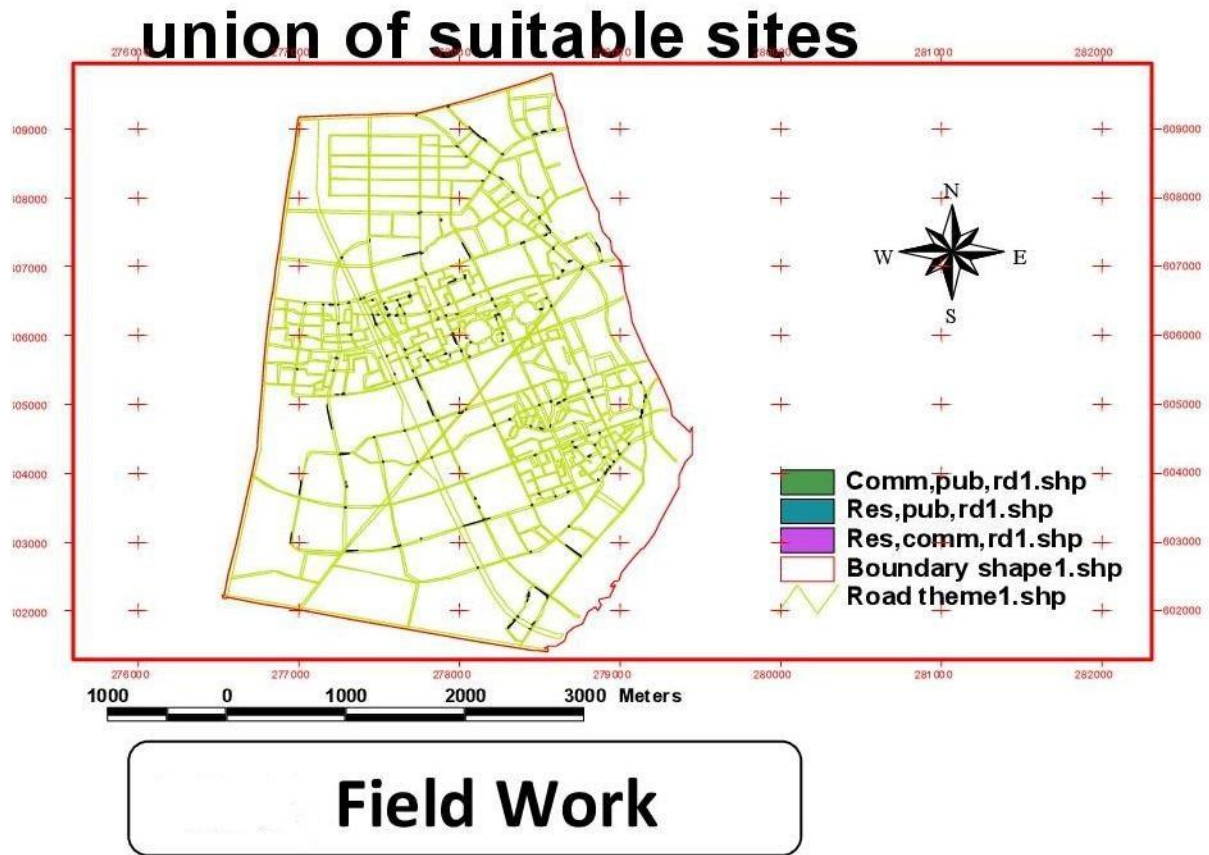


Fig 4.23.2 Layout of union of suitable sites within commercial, residential and public use land uses

According to the map sourced from State Ministry of Land & Survey and Owerri Capital Development Authority, New Owerri area is characterized mainly by residential areas, public use areas as well as commercial areas.

Thus, there is need to make available more waste bins for these areas, especially the high density residential areas. Afterwards, points that were within 100m proximity were expunged using the measure tool on ArcView window.

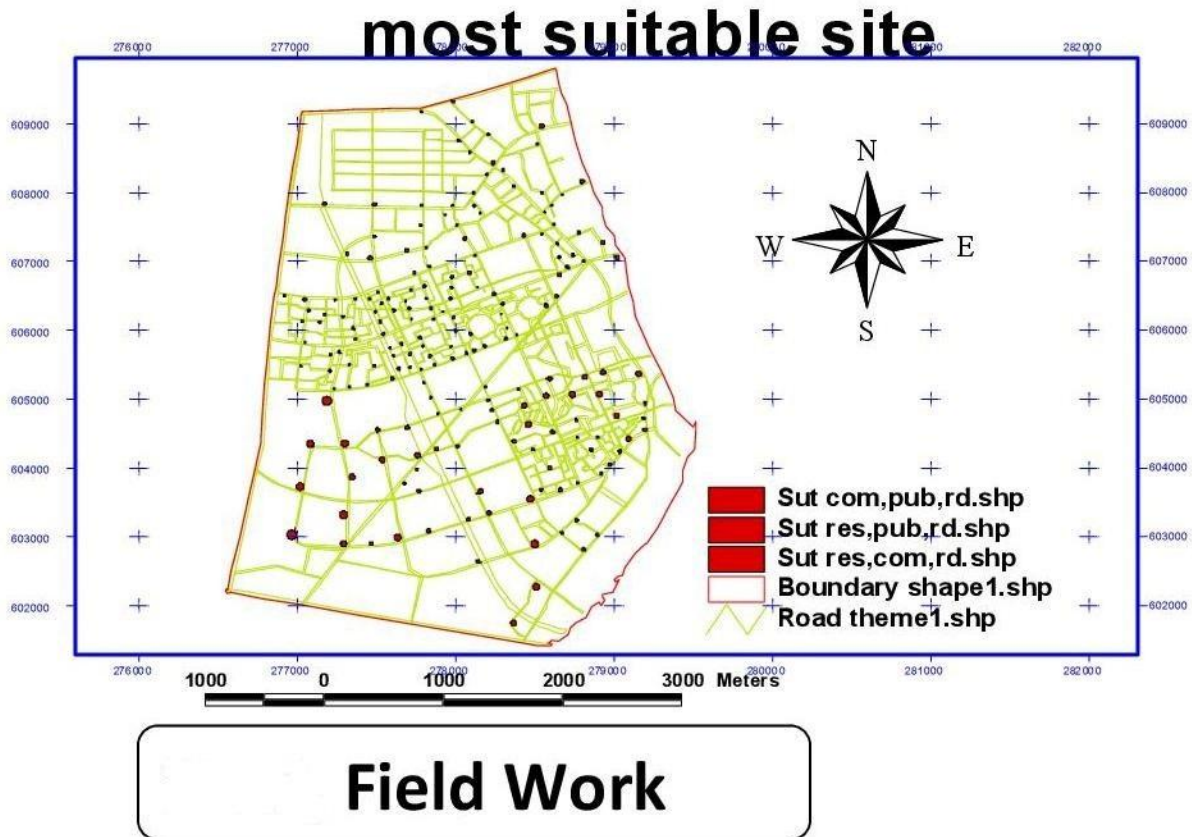


Fig 4.24 Layout of most suitable sites

4.5 INTERPRETATION OF RESULTS

Figures 4.16.1, 4.21.1 and 4.22.1 were overlaid to have a combined appropriate sites (fig. 4.23), which again was queried to have the appropriate sites, after which points that were inside 100m closeness were canceled using the measure tool on ArcView window (as found in figure 4.23.1) therefore giving the most suitable destinations for locating solid waste collection points in New Owerri.

In Fig 4.23.1, the collection points were recognized as points in connection to their coordinate values and format. The accompanying coordinate values represent the locations in specific by the Geographic Information Systems (GIS) as well as the attributes of the points. Thus, in all the sited collection points, the distances to similar land use type are the same as stated in the criteria with respective distances of; road=10m, commercial land use=20m, public land use=40m, river >70m and residential land use=20m.

(Ten Coordinate Values of Waste Collection Points)

278.584.25E&606168.18N, 278406.47E&605895.21N, 278876.21E&606001.81N,
278434.20E&605775.09N, 278819.13E&605771.83N, 278533.69E&605629.93N,
278027.90E&605678.86N, 278848.49E&605595.68N, 278598.93E&605504.34N and
278414.62E&605435.83N.

5.6 DISCUSSIONS

The database required for this project was designed using the conceptual and logical design, after which the actual implementation of the database was carried out with the physical design.

The data required were captured through scanning and georeferencing an analogue map obtained from State Ministry of Land & Survey and Owerri Capital Development Authority. The Georeferenced map was digitized using AutoCAD Land Development 2i. The digitized drawing was then exported into Arc view 3.2a, where the layers were converted to shape files and then polygonized. Afterwards, attribute tables were created for each land use and finally, the required analyses were performed using the same Arc View 3.2a.

LC is largely of natural origin or is created by LU but is characterized by the biophysical features of the terrestrial environment. It is the employment of LC and management strategy used on a specific class by human agents for land managers (Baulies and Szejwach, 1997). LC may be created by LU as defined by infrastructural facilities such as roads, buildings, etc. This implies that the LU and LC underwent massive transformation and change in the referred period. This may be as a result of massive land/physical development due to rising spate of urbanization around Owerri and environs. Apart from these, irregular and scattered LU and LC patterns characterize the study area, thereby making lack of spatial specialization a hindrance to integrated land management and development with consequent environmental problems such as soil erosion, solid waste, loss of biodiversity, soil infertility and loss of environmental aesthetics.

5.1 CONCLUSION

The use of GIS technology is a better way of decision making on complex issues related to the earth (land suitability) and the people living therein, such as agriculture, forestry, health, resource management, land administration, water resource planning, location analysis etc. In this study, GIS technology was applied for decision making in municipal solid waste management via the selection of possible and suitable points for solid waste collection. This was done in line with the purpose and set criteria for selection of suitable sites for waste collection points. The geographic database was tested by defining and executing some criteria, which gave the result as shown in section four. Thus, this has shown the capabilities of GIS as a system to solve spatial problems and provide information to aid decision making.

5.2 RECOMMENDATIONS

As a result of the findings of the study and the limitations encountered, the following recommendations are made for proper solid waste management;

Decision makers and stakeholders in the management of solid waste should adopt Geographic Information System (GIS) as a tool in decision making in their everyday operations.

Digital land use maps should be introduced in the aspect of waste collection, since it is an important tool for planning and management of waste in given geographical entities. It helps in having a holistic view of the entire area at a glance.

GIS laboratories should be introduced in higher institutions and government agencies. This will enable the production and updating of spatial data such as maps.

GIS projects should be funded by the government, private agencies and other organizations. This will enhance human development and growth especially in our developing economy.

Large scaled projects should be carried out in phases for efficient and effective actualization of good result and high visibility.

A good engineering structure like the modern sanitary landfill that incorporates the geomorphology, geology and hydrogeology of the area that will offer protection to the soil and aquifer should be designed due to the indications of possible soil and aquifer contamination as a result of leachate migration from the dumpsite.

REFERENCES

- Adesida, A. A. & Igboku, A. O. (1998). Solid Waste Management: SPDC Approach Environmental New (NES Quarterly Publication), Vol. 5, No 1, Pg 19-22.
- Alloway, B. J. (1990). *Heavy metals in soil*. John Wiley and sons Inc., New York, 339p.
- Amadi, A.N. Ameh, M. I. and Jisa, J. (2010). The impact of dumpsites on groundwater quality in Markurdi Metropolis, Benue State. *Natural and Applied Sciences Journal*, 11(1): 90 – 102.
- Awosan, S. A. (2006). GIS Application in Site Selection for Solid Waste Collection Points, A Case Study of Ajoda New Town. An Unpublished PGD Research Report, Federal School Of Surveying, Oyo, Oyo State.
- Banar, M. Aysun, O. and Mine, K.(2006). Characterization of the leachate in an urban landfill by physicochemical analysis and solid phase microextraction. *GC/MS. Environ. Monitor. Assess.*, 121: 439 – 459
- Baulies, X and Szejwach, G. eds. (1997): Survey of needs, gaps and priorities on data for Land use/ land cover change research. *Report presented at the LUCC data requirement workshop*, 11 – 14
- Bouyoucos, G.J. (1935). The clay ratio as a criterion of susceptibility of soils to erosion. *J. Amer. Soc. Agron.* 27(9): 738–41.
- Chapin, F.J. (1965). Urban land use planning, Illinois, University press pp 34 -48
- Cihlar, J. and Jansen, L. J. M. (2001). From land cover to land use: A methodology for efficient Land use Mapping over large areas, *Professional Geographer* 53 [2], pp 275 – 289, Association of American Geographers.
- Crynine, (1977). Land disposal of solid wastes CBS publishers and distributors, Darya Garji New Delhi pp. 850 – 930.
- Davis, R and Rogers, 1975. Land fill evaluation and Siting study New Jersey. John Wiley and Sons publishers. pp 240 – 285.
- ESRI (1999). *Understanding GIS*. British Library Catalogue in Publication Data Lessons 8, pg 10.
- Falade, J. F. (2000). Managing Solid Waste Developing Countries, New Nigeria Newspaper on Sunday, January 16th 2000.
- FAO (1976). A framework for land evaluation. FAO Soil Bulletin No. 32. FAO, Rome, Italy.
- Federal Government of Nigeria (2003). First National Communication on Climate Change (Final Draft), Federal Ministry of Environment, Abuja.
- FEPA (1998) Federal Environmental Protection Agency, Federal Government of Nigeria.
- Hudson, N.W. (1995). Soil conservation. 3rd Ed. Iowa State University Press, Ames, IA, USA.
- Imo State Government (2000). Imo State of Nigeria Populations Projections by Local Government Areas, Imo State Planning and Economic Development Commission, Owerri.
- Iro, S. I. (2009) Application of GIS in Mapping Otamiri River watershed in Owerri, Imo State. An Unpublished MSc Research Report Submitted to the Department of Geography and Environmental Management, Imo State University Owerri.
- Jeffrey, S. and John, E. (1989). Geographic Information Systems: An Introduction, Prentice Hall, New Jersey. Pg 18.
- Jensen (1985). Solid and Hazardous Waste Disposal Site selection using Digital GIS Technique. *The Science of Total Environment*, Vol. 56.
- Kufoniya, O. (1998). Basic Concept in GIS in Ezigbo, C. U. (ed.) Principle and Application of GIS, Lagos, Panas Press.

- Lin, Y. P. Teng, T. P. and Chang, T. K. (2002). Multivariate analysis of soil heavy metal pollution and landscape in Changhua Country in Taiwan. *Landscape Urban Plan.* **62**: 19 – 35.
- Malter P. M. (1991). *Computer Application in Geography*, widely press, New York (pg 61-62).
- Morgan, R.P.C. (2001). A simple approach to soil loss prediction: a revised Morgan-Morgan-Finney model. *Catena* 44(4): 305-22.
- Nathawat, M. S. and Shrivastava U. (2001): www.gisdevelopment.net
- NEST (1999). *Nigerian Threatened Environment: A National Profile*, Nigerian Environmental Study/Action Team (NEST) Publication, Ibadan.
- Nnabugwu, O. U. (2003): *micro Simulation Model for Evaluating and Mapping Domestic Waste Generation* (NCA Publication).
- Nwadike, O. (2004). *Solid Waste management in Owerri Municipal Area*. An Unpublished B. Tech Thesis Submitted to the Department of Environmental Technology Owerri, Imo State.