UNIVERSITY OF NAIROBI

SCHOOL OF ENGINEERING

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

INTEGRATION OF ROAD DESIGN INFORMATION WITH CARRYMAP FOR MOBILE ACCESS

BY

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DECLARATION

I, NDUNGU STEPHEN MUTURA, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

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Name of student Date

This project has been submitted for examination with our approval as university supervisor(s).

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Name of supervisor Date

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ABSTRACT

Today, technological advancement is a major driving force in changing the face of the spatial information around the world. High spatial resolution satellite imagery has revolutionized the Mapping discipline. The GIS database technology for storage of large datasets, data management, and analysis and update facilities has had the greatest impact on spatial information environment. This study aims at development of road design and all road features to be displayed in mobile phone application (CarryMap). The study covered Limuru and Kabete constituency's rural roads, which are under Kenya Rural Roads Authority (KeRRA). The methodology employed in the study involved use of GIS software to develop a database which contains both spatial and non-spatial data. Cadastral maps were scanned, georeferenced, cropped and mosaicked. An overlay with high resolution satellite imagery was done to establish whether there were buildings and other developments that are constructed on the road reserves. Road design with chainage and elevation both super elevation and camber were overlaid with Kenya New Road Classification Map 2018.

Using AutoCAD application, the Topographical data was imported and plotted. The plotted data was used to create road design, then the road design was imported to ArcMap so that it can be compatible with CarryMap which can be displayed on mobile phone. Using this CarryMap mobile application you can be able to know exact chainage and real-time location while in the field. Static survey was performed to connect all the roads to the National Control Network. The project has demonstrated the benefits of integrating Remote Sensing, Cadastral Survey and Geographic Information Systems approach in Land Management and Road Construction. This study has demonstrated the use of the CarryMap application as a mobile application that can be used in design and real-time monitoring of road projects.

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LIST OF ABBREVIATIONS AND ACRONYMS

GIS- Geographic Information System

GNSS- Global Navigation Satellite System

GPS- Global Positioning System

KeNHA- Kenya National Highway Authority

KeRRA- Kenya Rural Roads Authority

KURA- Kenya Urban Roads Authority

KM- Kilometre

KWS- Kenya Wildlife Service

MTP- Medium Term Plan

RIM- Registry Index Map

RWC- Road Works Construction

SoK- Survey of Kenya

UTM- Universal Transverse Mercator

CHAPTER 1: INTRODUCTION

1.1 Background

In order to provide connectivity and equitable development in all parts of country, the construction, improvement and maintenance of transportation routes is important. The major form of transportation used in Kenya is by land either through road or railway. Road transport is the most commonly used means of transport by land in Kenya. A road is a route or a way on land between two places that has been paved or improved to ease travel either by foot or other form of conveyance such as motor vehicle, motor bike, cart or bicycle. A road consists of one or two roadways or rather carriageways each with one or more lanes and sidewalks. The road is also referred by other terminologies such as, parkways, freeways, toll-ways, highways, primary, secondary and tertiary local roads.

The Kenya Rural Roads Authority (KeRRA) is a government institution that is mandated to develop, rehabilitate, maintain and manage roads in rural the areas of Kenya. The mandate of the institution is stated in the Kenya Roads Act 2007. Part of the core activities of KeRRA include road design and implementation of the design. The Authority uses both GIS for planning and landscape-scale analysis and CAD for design and engineering functions of transportation delivery. The authority also uses GIS and CAD for linear referencing. Linear referencing is method of storing geographic locations by using relative positions along a measured linear feature. The formats and tools associated with each computing environment are different and often separate; however, GIS and CAD complement each other by encompassing the full range of scales at which the transportation agency conducts its business. Integration of GIS-CAD environments is therefore necessary.

CarryMap is a full functional application provided for viewing and editing mobile maps on smartphones and tablets even in offline mode. The mobile maps (files of CMF2 format) are created from ArcGIS map documents using CarryMap Builder an extension for ArcGIS Desktop. CarryMap makes ArcGIS maps mobile; it is a free application for smartphones and tablets with OS Android/iOS and Windows Desktop devices to work with interactive mobile maps created with CarryMap Builder. CarryMap allows to quickly transfer maps combining GIS and CAD data to any computer running Windows OS or to mobile device running iOS or Android OS without any loss of data. This study embraces the use of CarryMap as a tool that provides interoperability solutions between GIS and CAD environments, support in planning and decision making during the construction and maintenance process.

1.2 Problem Statement

It has been noted that during field (road) site visits by the Board of Directors, Surveyors, Engineers and other visitors, people often lose their way in instances where the contractor fails to maintain the references and chainages on the road. This makes it difficult to locate the exact location where there is an issue that needs to be addressed. This result walking for long distances so as to locate the exact chainage using measuring equipment e.g. tapes resulting in loss of time and effort. This project entails the use of the CarryMap mobile application during site visits. By use of CarryMap a surveyor can prepare a map that combines CAD data (road pavement design and chainages) and GIS vector and raster data road beacons, road location coordinates, road class and current world aerial imagery maps) into one map so that engineers, the board of directors, surveyors and construction supervisors are able to use to identify the area of interest on time. Such maps can be used to compare the actual state of site or performed works with the project design and to explain project details to non-technical stakeholders. This saves on time and is also in used for road assessment by the client. It also allows stakeholders to identify potential issues in transportation projects earlier during the design process

1.3 Objectives

1.3.1 Overall Objective*;*

Demonstration of the integration of road design information in CarryMap mobile map application and Kenya Roads Classification Map to ease navigation and access using the mobile phone.

1.3.2 Specific Objectives

1. To map the existing road reserve
2. To design the road alignment
3. To geo-reference Cadastral maps with the existing road reserve
4. To integrate all road design information in the CarryMap

1.4 Justification for the Study

During road construction most of the mileposts are often lost or destroyed either by local people or plant machinery in the process of construction. This makes it difficult to locate the exact chainage (milepost) marker whenever a challenge or problem arises that needs to be fixed. This not only leads to loss of time in trying to locate the markers but also inaccuracies as the markers have to be set up again probably out of their original positions. Linear referencing is beneficial because definition of points along the route feature can be done using just minimal amount of information. Linear referencing adds value to centreline mapping and offers cost effective and sub-meter accuracy. Thus, the need of a more reliable way of chainage location.

During site visits by the engineers, surveyors and the Presidential Delivery Unit (PDU), access to the problem specific location on the site will be made easier by use of the application. By the use of CarryMap Application in their mobile phones, navigation to the said area is fast and easy. Access to the road design information saves time on the problem assessment and decision making since everyone can access the same information in real time. This offers transparency on road construction. The results of this project can also be incorporated by the Ministry of Transport, Infrastructure, Housing, Urban Development and Public Works to be used by government officials and citizens.

1.5 Scope of work

The project looks into the design process of rural roads under construction by KeRRA. This entailed collection of topographical data and area of study RIMs. The topographical data collected, plotted and georeferenced using the RIMs and satellite imagery in AutoCAD. Using the plotted topographical data, the road design was made in AutoCAD.

The scope of the study includes tasks that are done in ArcGIS, where the information from the design process was fed into ArcMap and a spatial database was created that helps in input, search, manipulation and storing of spatial and non-spatial attributes. Using the CarryMap extension (CarryMap Builder) for ArcGIS desktop, the road design information was exported to CarryMap mobile application for use. The study was confined to the road which starts at Kabocha through Gikuni market, Mukui to end at Karura junction where it joins with Gitaru-Wangige-Ndenderu classified as (C63). The road that is subject of this study is 5.5km long and is found in Nyathuna Sub-location, Kabete Constituency, Kiambu County.

CHAPTER 2: LITERATURE REVIEW

2.1 Infrastructure.

Infrastructures such as roads, dams and railways are identified as a necessity in improving the living conditions of farmers, pastoralists and providing security and growth to an area. Infrastructure significantly contributes to business cost reduction and the efficient way of doing business is through good roads and connectivity of people.

2.2 Kenya Vision 2030

Kenya Vision 2030 has recognized foundation objectives which will be accomplished through Medium Term Plan (MTP) by year 2030. The objectives include: -

a. To accelerate on-going framework improvement by concentrating on quality and usefulness.
b. To build Infrastructure which add to social value and monetary objectives.
c. To improve proficiency and adequacy of framework at all degrees of arranging, contracting and developing.

2.3 Procedures required to maintain standards to the available infrastructures

The Government of Kenya has put in place several procedures that are employed to obtain the required standards to the available infrastructures to augment financial and social objectives. The procedures include: -

i. To strengthen the current system and quickening execution speed. Proficiency and quality will likewise be raised.
ii. Benchmarking frameworks offices with standard that are all around acknowledged.
iii. Targeting ventures in disregarded zones so that network and invigorate financial exercises can increment.
iv. Enhancing Public Sector Interventions to strategically complement Private Sector participation in provision of infrastructure facilities and services.
v. Financing Infrastructure through Capital Markets, the administration has communicated its aim to build private area interest in the arrangement of framework administrations to restore the national foundation.

The Government of Kenya by means of Vision 2030 will bring down the expenses of working together in Kenya, give reasonable and effective methods of transport for Kenya and increment in general expectations for everyday comforts to the residents. The Finance Act 2007 accommodates upgraded limit of the local security advertises in the arrangement of long-haul subsidizing for framework ventures. This is being accomplished by utilizing long term bonds to fund foundation projects. The framework part has been distinguished as one of the recipients from this endeavor because of the significant job quality foundation plays in national advancement.

2.4 The Road

Roads can be characterized as an avenue, course or route ashore between two spots, which has been cleared or in any case improved to permit travel by some transport including a pony, truck, or engine vehicle. The Road comprises of one or at some point two Roadways each with at least one paths and furthermore any related walkways and Road borderlines. Roads that are accessible for open use are known as open streets or intercounty. The following are definitions of commonly used words in road construction.

Route: Is a Street or highway with an assigned number, a defined beginning point (M value), a defined ending point, and a defined pathway between the beginning and end. Routes may run continuously or be separated into more than one segment.

Route Length: This is the distance measured from the starting point of the linear feature to the end point in most instances, the positive direction.

Chainage: Is an imaginary line used to measure distance often corresponding to the center of a road. In surveying it refers to the distance measured along such linear feature.

Milepost: A marker(s) that indicates or is inscribed with the chainage notation and are in series along a highway.

Attributes: Qualitative data that can be recorded in a table, then be used to label a spatial feature.

Road segment: Is the specific representation of a portion of a road with uniform characteristics.

Pavement: The applied improvement on the surface of a road, for example asphalt.

2.5 Institutional Framework in Kenya

In the year 2007, the Kenya Roads Act was instituted. The Act built up three Roads Authorities which are KeNHA, KeRRA and KURA with duty of unmistakably characterized commands on the administration of separate sub-systems. Current institutional structure prior to the proclamation of the new Constitution, the Road Authorities was overseen as follows;

2.5.1 The Ministry of Roads

The duty of the Ministry of Roads is to give essential foundation facilities to people in general. This incorporates advancement, support and the restoration of Roads organizations the Nation. The particular obligations are;

i. National Roads improvement approach
ii. Development, institutionalization and support of Roads
iii. Materials testing and exhortation on use
iv. Coordination of the exercises embraced by parastatals/specialists from KRB, KeRRA, KeNHA and KURA.
v. Research and preparing on Road development and building innovation
vi. Standardization of motor cars, plant and hardware
vii. Licensing of engineers
viii. Licensing of road contractors

2.5.2 The Kenya Roads Board (KRB).

The Kenya Roads Board supports upkeep of all roads including, endorsement of Roads Maintenance Levy Fund (RMLF) subsidized support work program, and completing of specialized and budgetary reviews of the works. The board's history began in 1992 when the Kenya Government together with the Road Maintenance Initiative (RMI) World Bank has encouraged a Road Sector Stakeholders Seminar, to address the disintegrating condition of the streets sort out in Kenya and the goals to propitious and suitable Road upkeep. The recognized prerequisites were institutional, authoritative and cash related. It was therefore settled that the present street set-up be reviewed. In 1993, the RMLF Act was requested, giving a plausible wellspring of financing for the help of the street sort out. In the year, 1995, with help of the European Commission, the study for road sector institutional framework was authorized. Its goal was to distinguish the most suitable institutional structure inside which the administration of Kenya's whole roads system would be most viably attempted. The investigation prescribed the development of an official Road Board, cooperating with distinguished road offices to adequately convey an effective road transport framework for road clients in Kenya; henceforth the Kenya Roads Board was formed. The KRB was approved by parliament Act, KRB ACT No. 7, KRB ACT was given presidential consent on sixth January 2000. The Act was initiated on first July 2000 and the Board of Directors was selected. The demonstration determines the accompanying as the commands of the board:

i. To administer the assets got from the RMLF and whatever alternative subsidizes the funds;
ii. To coordinate the advancement, restoration and support of the arrangement, with the end goal of accomplishing productivity, cost viability and security;
iii. To coordinate the execution of all arrangements identifying with the advancement, restoration and support of the road organization;
iv. To determine the assignment of monetary assets from the RMLF or from some other alternatives accessible to the Board as per road organizations for the improvement, restoration and support of the Road arrangement.
v. To monitor the tasks or exercises embraced by Road organizations in the improvement, restoration and upkeep of the Kenya Road arrangement.

The KRB arrangement was a noteworthy advance towards transforming the road segment in Kenya. The KRB's Board of Directors originate from both people in general and private segments of the economy. This portrayal gives the road clients a chance to viably take an interest in the administration of roads in Kenya while guaranteeing that usage of the assets endowed to KRB is productively and successfully did according to desires for the partners. Road Board is reinforced by Roads Authorities, which are as follows;

1) Kenya National Highways Authority (KeNHA) is answerable for the administration, advancement, recovery and upkeep of National Road delegated classes A and B Roads.

2) Kenya Rural Roads Authority (KeRRA) is answerable for the administration, improvement, restoration and support of country Road delegated classes C, D and E,

3) Kenya Urban Roads Authority (KURA) is liable for the board, progression, recuperation and upkeep of each and every open Road in urban zones and areas except for where those Roads are National Roads.

4) The Kenya Wildlife Service (KWS) is liable for Roads in National Parks and National Reserves.

5) ***County Roads*** are for the most part different Roads inside County limits not characterized as National Roads and every unclassified Road.

2.6 Kenya Classified Road Network

Kenya has a road system of around 177,800 km out of which just 63,575 km is characterized or classified (KeNHA, 2020). The characterized road network has expanded from 41,800 km to 63,575 km today, an improvement pace of under 600 km per year. During a similar period, the cleared road length developed from 1,811km to 9,273 km. It is assessed that 70% (44,100 km) of the road network is in acceptable condition and is viable while the staying 30% (18,900 km) requires recovery or reproduction. The table below gives a summary of ordered roads in Kenya.

Table 2.1: Road Network Classification Source: (KeNHA, 2020)

Road classes	**Asphalt Pre-mix (Km)**	**Surface dressing (Km)**	**Gravel (murram) (km)**	**Earth (Km)**	**Total (km)**
Global Trunk Roads (A)	1244.91	1563.81	715.11	94.48	3,618.31
National Roads (B)	350.21	1,166.26	819.29	346.14	2,681.90
Essential Roads (C)	642.89	2,198.16	3,601.64	1,552.90	7,995.59
Auxiliary Roads (D)	76.63	1,183.10	5,701.93	4,087.73	11,049.39
Minor Roads (E)	165.81	542.04	8,215.89	17,982.57	26,906.31
Unique Purpose Roads	24.88	114.63	4,929.69	6,253.78	11,322.98
All classes	**2,505.33**	**6,768**	**23,983.55**	**30,317.60**	**63,574.4**

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2.7 Geometric Design of Roads

The road geometric design is a type of study in road engineering which deals with geometrical features of the road. Geometric arrangement in like manner impacts a rising fifth objective called "tolerability". It is described as arranging roads to empower progressively broad system targets, including offering access to work, schools, associations and living courses of action. It also obliges an extent of development modes, for instance, walking, bicycling, travel, and vehicles, and constraining fuel use, releases and environmental damage. Geometric roadway design can be isolated into three rule parts: Alignment, profile, and cross-sections.

The alignment is the course of the Road, described as a movement of level diversions and curves. The profile is the vertical piece of the Road, including pinnacle and hang twists, and the straight level lines interfacing them.

The cross section shows the position and number of vehicle and bicycle ways and walkways, close by their cross slope or banking. Cross sections similarly show squander features, black-top structure and various things outside the class of geometric arrangement.

2.8 Linear Referencing

Linear referencing is a technique used by Kenya Road agencies for mapping utilities. Worldwide road agencies use linear referencing in one way or another to locate road information along the Roads (Litton, 2013). Linear referencing is method of storing geographic locations by using relative positions along a measured linear feature, it is yet to be exhaustively employed in road agencies in Kenya. Traditionally, AutoCAD has been able to fix annotations denoting road chainages along a centerline and so is widely in use across road, rail and oil pipeline mapping. ESRI (Environmental Systems Research Institute) has written many publications, such as; how to covert AutoCAD DWG file format to Shapefile and the use of linear referencing tool together with its application in the transportation sector.

Station lines that are annotated with the chainages have been in use for many years but it has not been possible to place a cursor along the centerline and identify what chainage the point is. The 'identify route' tool in ArcMAP can be clicked on a point along a route and the detailed chainage information retrieved, with the coordinates of the same obtained. ESRI uses a code which is used to place labels and marks (station lines), along the road centerline in a familiar way for those who work with Roads and Highways.

2.9 CarryMap

CarryMap is a full functional application provided for viewing and editing mobile maps on smartphones and tablets even in offline mode. The application is mostly used by engineers and surveyors when they want to view the road classification and length which they are interested in. This study will add value to the application users because it will integrate the road designs and all road features of the roads that are under construction.

2.10 CarryMap Builder

CarryMap Builder is an extension for ArcGIS Desktop that is used to create CMF2 files that can be displayed on a mobile phones or tablets maps.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study Area

The road used in this study is located in Kabete Constituency, Kiambu County. Kabete constituency is one of twelve constituencies in Kiambu County. Kabete Constituency neighbours Westlands constituency in Nairobi County. In 2012 Kabete and Kikuyu constituencies were split due to high growth of population so as to create a better representation. Kabete is number 119 of 290 constituencies according to Independent Electoral and Boundaries Commission (IEBC). The constituency has a population of 140,427 (KNBS, 2019) and occupies an approximate area of 60.20 km^2. Kabete constituency consists of five Wards, namely;

1. Gitaru ward
2. Muguga ward
3. Nyathuna ward
4. Kabete ward
5. Uthiru ward

The road used in the study passes through Nyathuna ward. The ward has a population of 28,771 (KNBS,2019) and occupies an approximate area of 17.80 Km^2. Nyathuna ward comprises of Nyathuna, Kirangari, Karura and Gathiga Sub–Locations of Kiambu County. The study road starts at Kabocha through Gikuni market, Mukui and ends at Karura junction where it joins with Gitaru-Wangige-Ndenderu classified as (C63). The road C63 forms the Nairobi Western Bypass which is currently under construction by KeNHA. The study road is classified as G21111 and G21144 previously classified as E1515 and E425 respectively under contract number RWC 499, which is part of 10,000 kilometers tarmac launched by the Jubilee Government. The road under study is categorized under county road in the newly revised road classifications in Kenya.

The area traversed by the project road is a rich agricultural area and has topographically gently rolling and flat terrains with most areas being red loam soil with the main subsistence crop been maize, beans and vegetables. The population density along the alignment is dense in most areas and new settlements are coming up. The study road is under construction by KeRRA under award to a Chinese company Shengli Engineering Construction (Group) Co. Ltd to construct.

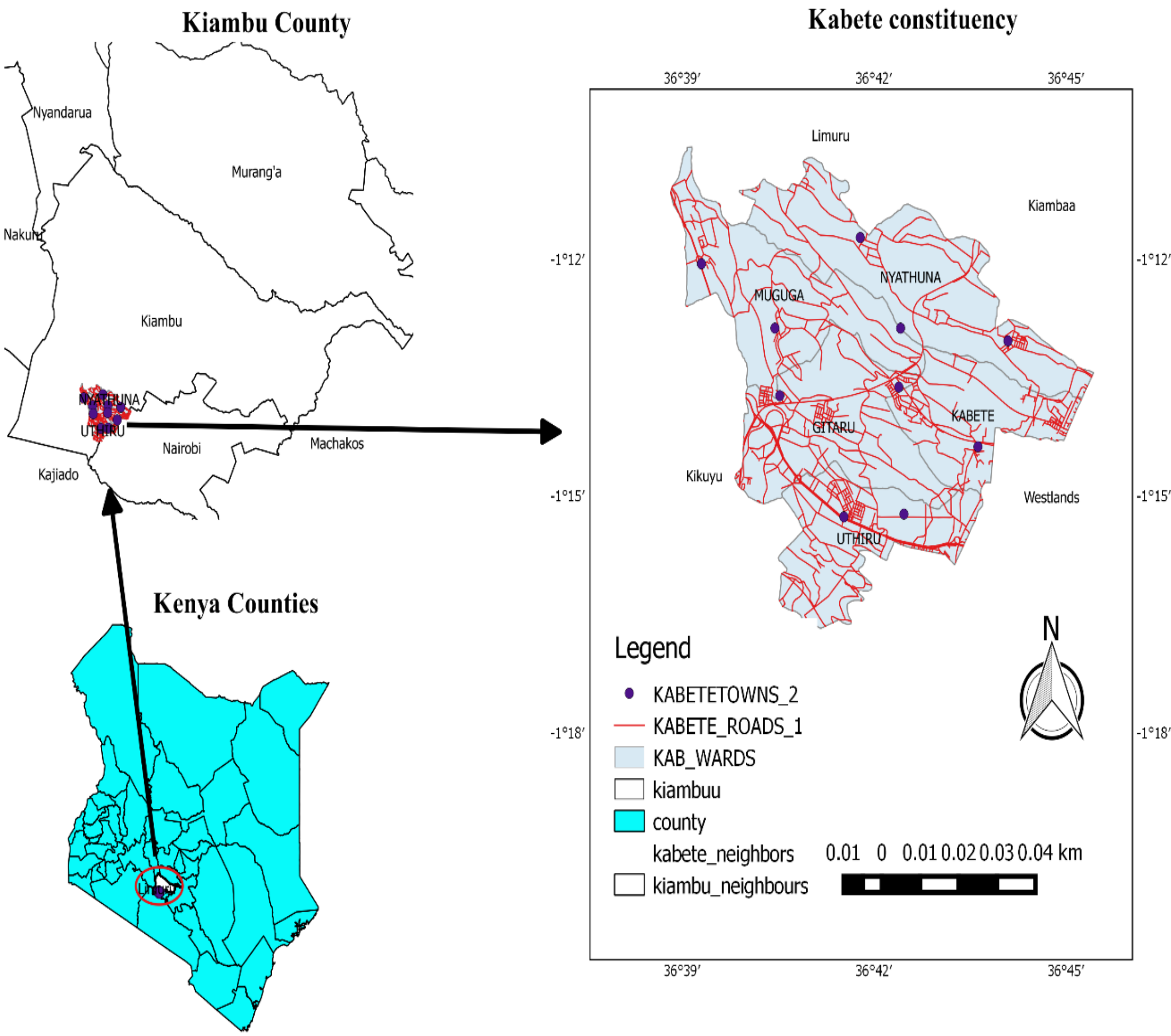


Figure 3.1 Study Area Kabete Constituency

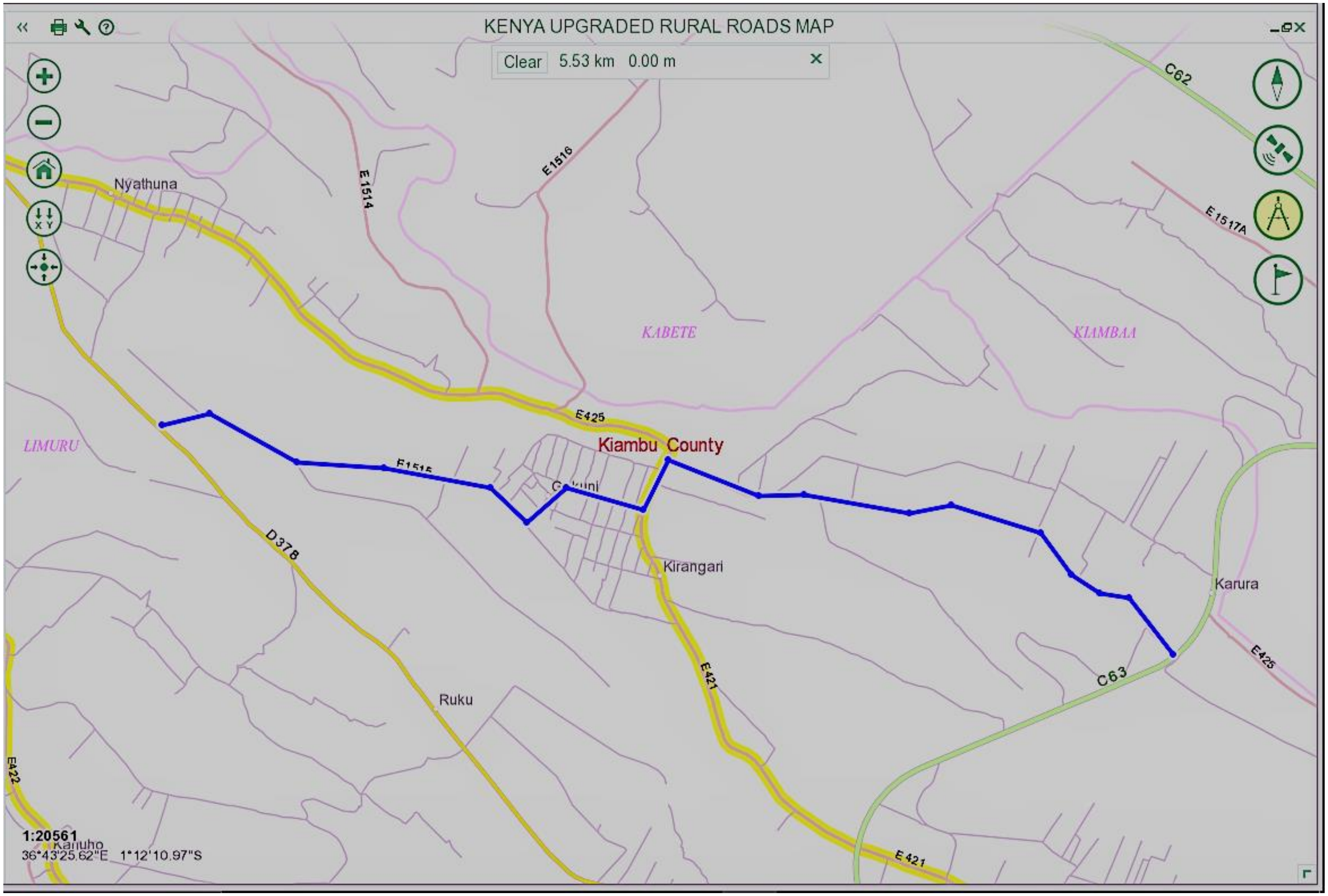
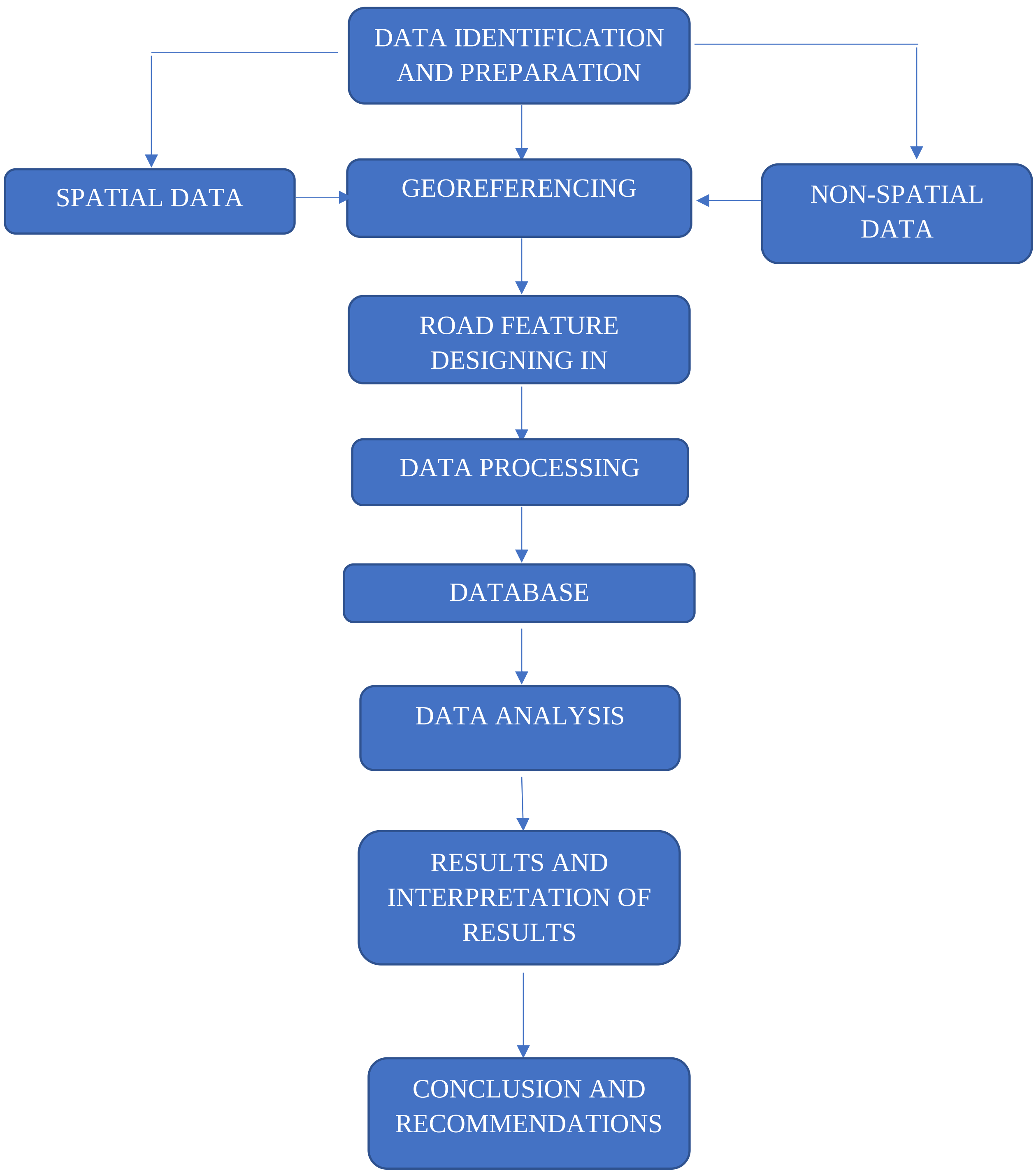


Figure 3.2: The Study Road; Kabocha-Gikuni-Karura (G21111-G21144) in colour blue.

3.2 Methodology

A sequential summary of the methodology adapted in the project is as illustrated below.

Figure 3.3. Methodology



3.3 Data

Datasets were drawn from different sources as shown in table 3.1.

Table 3. 1 Table showing type of datasets, format and source used in the project

Dataset	Format	Source
Cadastral maps	Hard copy	Survey of Kenya
Topographical data	Excel, CSV Comma	Field work survey

3.4 Equipment and Software

The equipment used in this exercise are: -

1. ***Stonex GNSS***, to be used to collect topographical data and perform static survey to control the beacons to be used in the project.
2. ***100m Measuring tape*** to measure road width
3. ***Scale rule***, to measure road width and plots area in the cadastral maps
4. ***Computer***, to perform post processing and data analysis

Software used in the project;

1. ***ArcGIS 10.5***, to perfom data processing and analysis of the results
2. ***CarryMap builder (trial version)***, used as an extension in ArcGIS to create CMF2 file that was to displayed in CarryMap mobile application
3. ***CarryMap (Mobile App)***, used to display CMF2 files that consist of road design and information.
4. ***AutoCAD Civil 3D***, used to generate road design and georeferencing
5. ***Situoli Geo Office*** use for static survey post processing of data.
6. ***Microsoft Excel***, data from GNSS are inform of CSV comma delimited and also used to import data to AutoCAD.

3.5 Data Collection

3.5.1 Datum for the survey.

Localization to UTM projection, Arc1960 datum using Survey of Kenya (SoK) control beacons before the topographic survey was done. Localization allows to define the project coordinate system, geoid usage and scale factors as well as align on local coordinate system for GNSS. Static GNSS observation was carried out using control points tied to the National Grid.

The SoK beacon used was VA/9 at Kikuyu as the known point while beacons KGK02, KGK07, KGK23 and KGK28 as the unknown points. The data was processed and the coordinates of the mentioned beacons were identified and used as check points during topographic survey.

3.5.2 Topographical survey.

A topographical survey of the study area was done using Stonex GNSS via base connection. The boundary fences, existing road-edge, the existing road center line, access roads, electricity poles, drains, permanent buildings and walls were picked as topo points. Places with definite boundary were picked so as to aid in georeferencing. The topo data was downloaded and plotted to UTM, ARC 1960 coordinates system in AutoCAD software.

3.6 Georeferencing.

The Cadastral maps were scanned and saved in PNG format. The scanned images were attached, scaled to the road topo data and mosaicked so as to provide a continuous image of the road as shown in Fig 3.3 Cadastral maps in Cassini coordinates were converted to UTM coordinates. Defined fence lines and other boundary lines such as access roads were used in alignment of the Cadastral maps with the topographical plotted data.

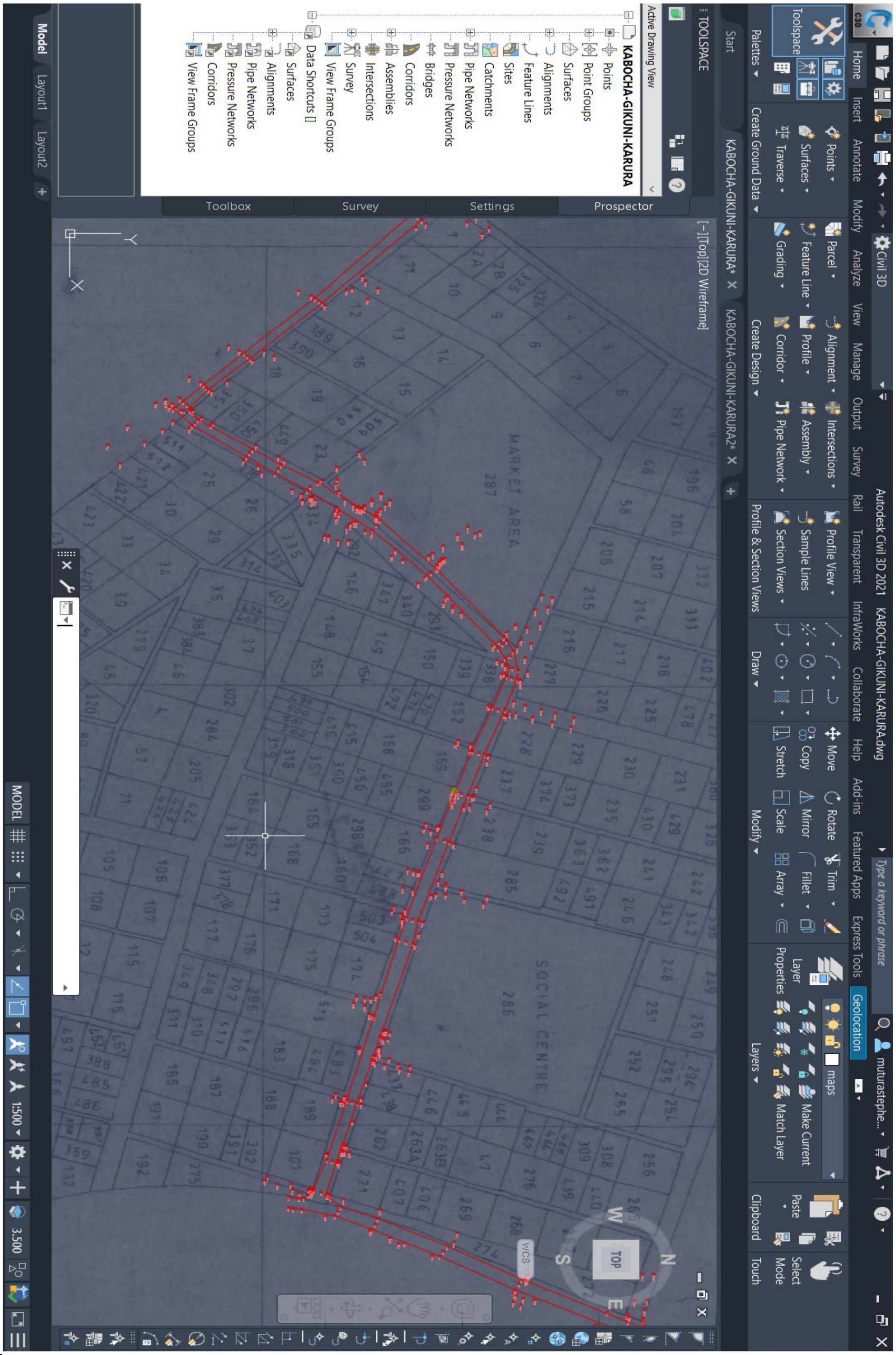


Figure 3.4_Georeferencing of the topographical data with the Cadastral map.

Geolocation tool in AutoCAD is used to insert Google Earth images. The datum was set to ARC 1960_UTM_ZONE_37S. In the Geolocation tab, Map aerial tool was used to overlay both the scanned Cadastral map and road topo data with an online satellite image so as to enable the identification of features and aid in Georeferencing. The resulting image was in Fig 3.4:

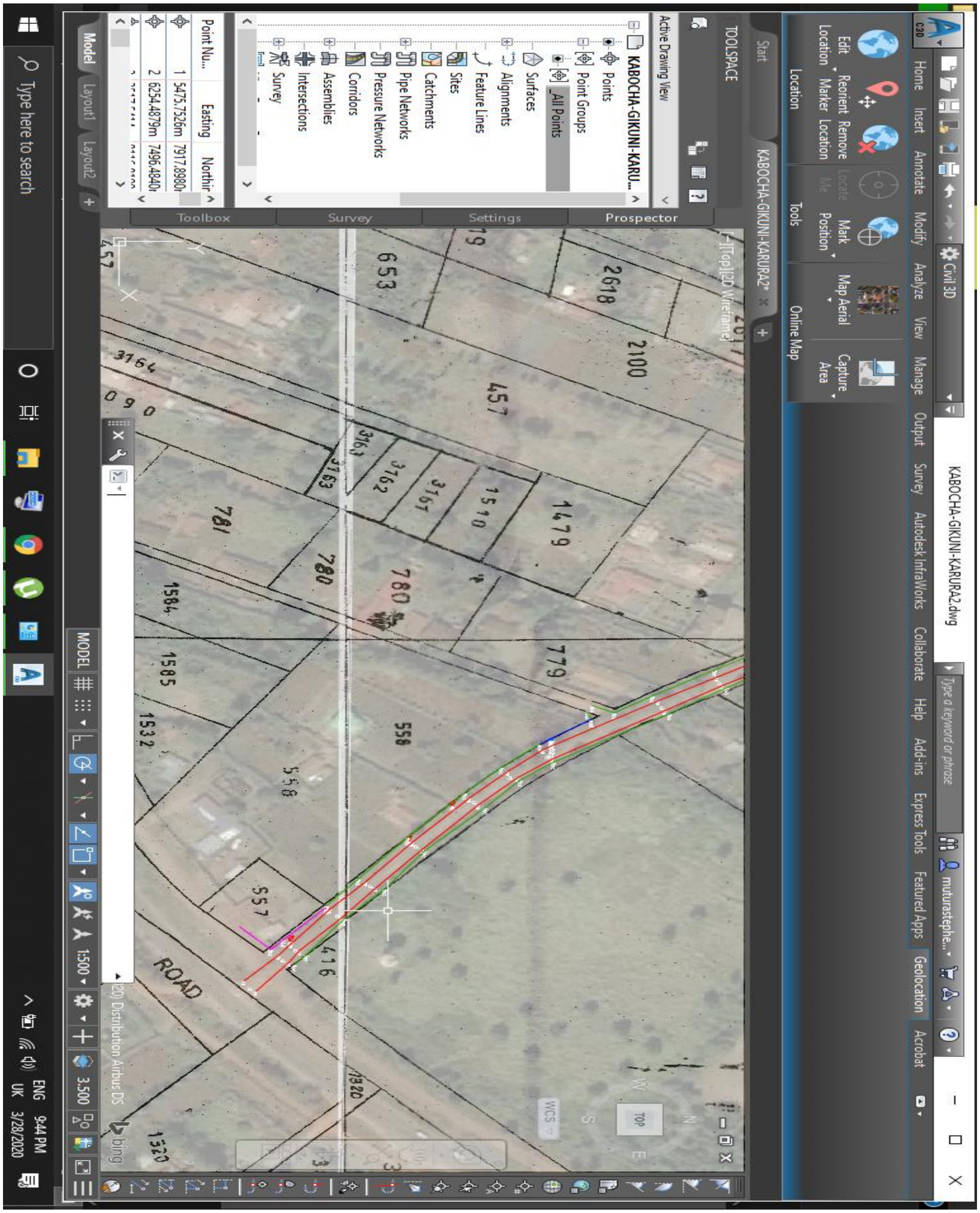


Figure 3.5: Overlay of Cadastral map and Topographical data with Google Earth

3.7 Data Processing

This process involves inputting topographical data from GNSS receiver joining the points like for example joining road edge to road edge, fence to fence and all other road features collected on the road. It also involves creation of road alignment, road design, surface creation that is contours. Other data processing is explained further below.

3.7.1 Road alignment.

Road alignment is the positioning of the centerline of the road. Alignment is used to show where the road is to be constructed. There are two types of road alignment; vertical alignment and horizontal alignment. Alignment consists of a series of points, curves and lines. Each line has a bearing and distance while each curve has a radius and length and points have known coordinates on the ground. In order to avoid errors in alignment, one must ensure that each line and curve are connected at a shared point or they are coincident. The alignments are described by stations or chainages, which gives the horizontal distance between two chainages.

A horizontal alignment of the road was done using the alignment creation tool in AutoCAD. The road alignment was done with chainages at distances of 20m. The chainage labels are expressed as km 0+000 as is usually required by users of the road data. In order to achieve smooth curves at road bends, the curves are connected at an angle of 90^o to two adjacent straight lines. Figures 3.8 and 3.9 below shows the alignment creation tool used. The following are codes used to represent features withing the study project

fnc-Fence

re-Road Edge

ep-Electricity Post

cl-Centre Line

tmc- Tarmac

bld- Building

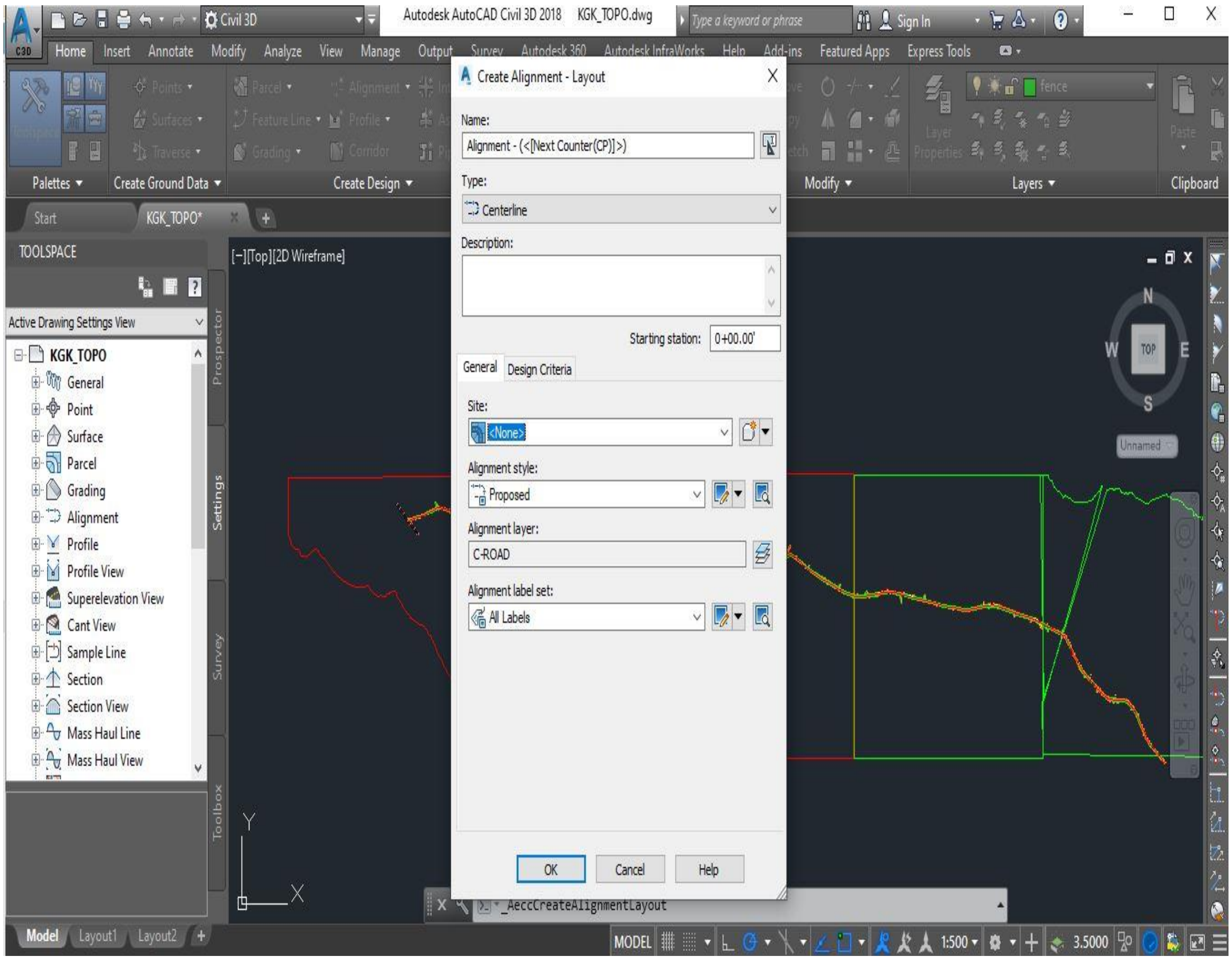


Figure 3.6: Alignment creation tool in AutoCAD

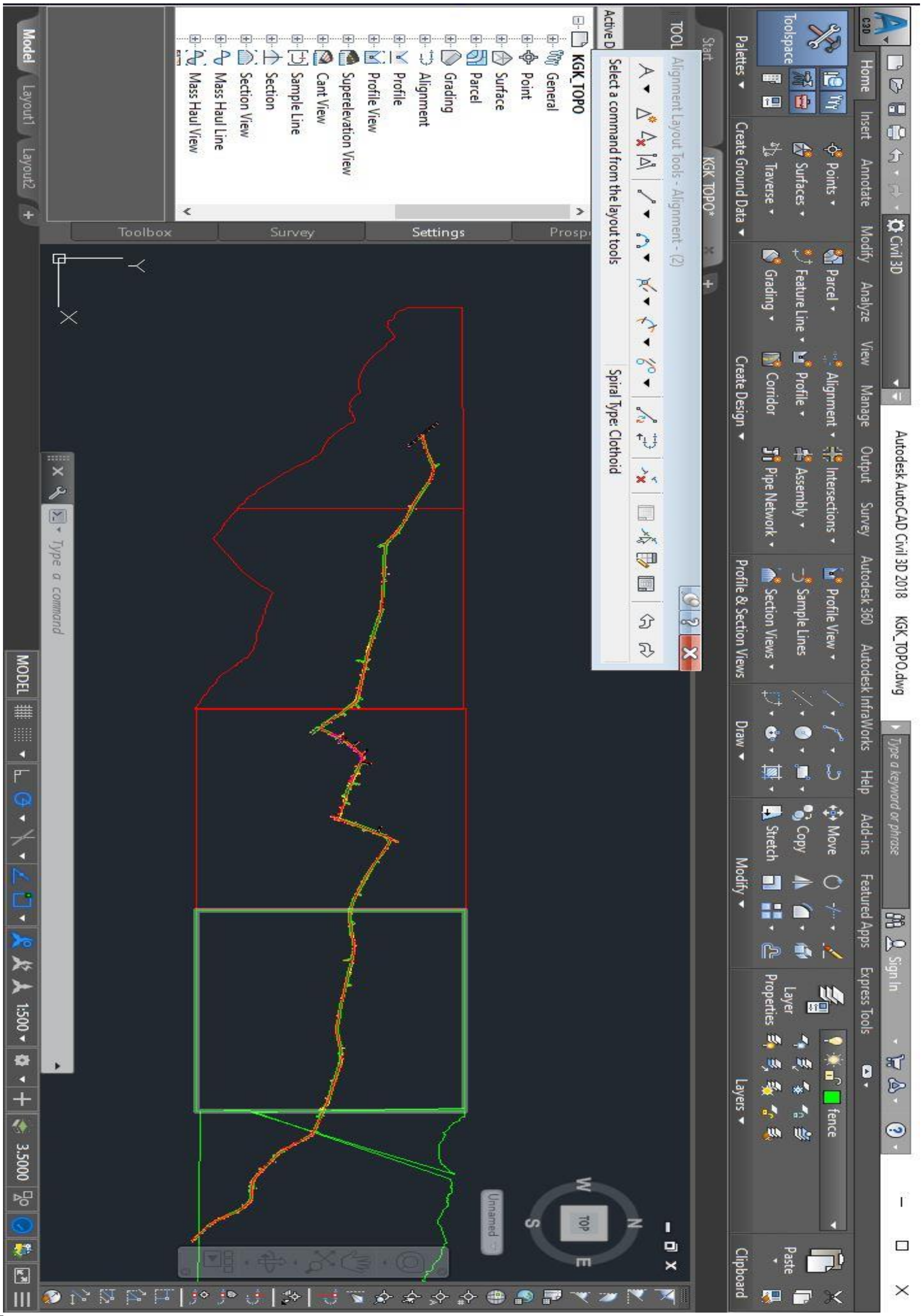


Figure 3.6: Alignment creation tool pallet

3.7.2 Surface creation.

The road surface is created using the topographical survey data collected. This gives the elevation of the road by creation of contours along the road corridor. The road surface data gives the general topographical profile of the road which is used in the design process. This was done in AutoCAD using the surface creation tool, where setting of ; name of the surface, description, style that is major and minor contours intervals and render material which was set ByBlock (the lines to be the same as entire drawing.

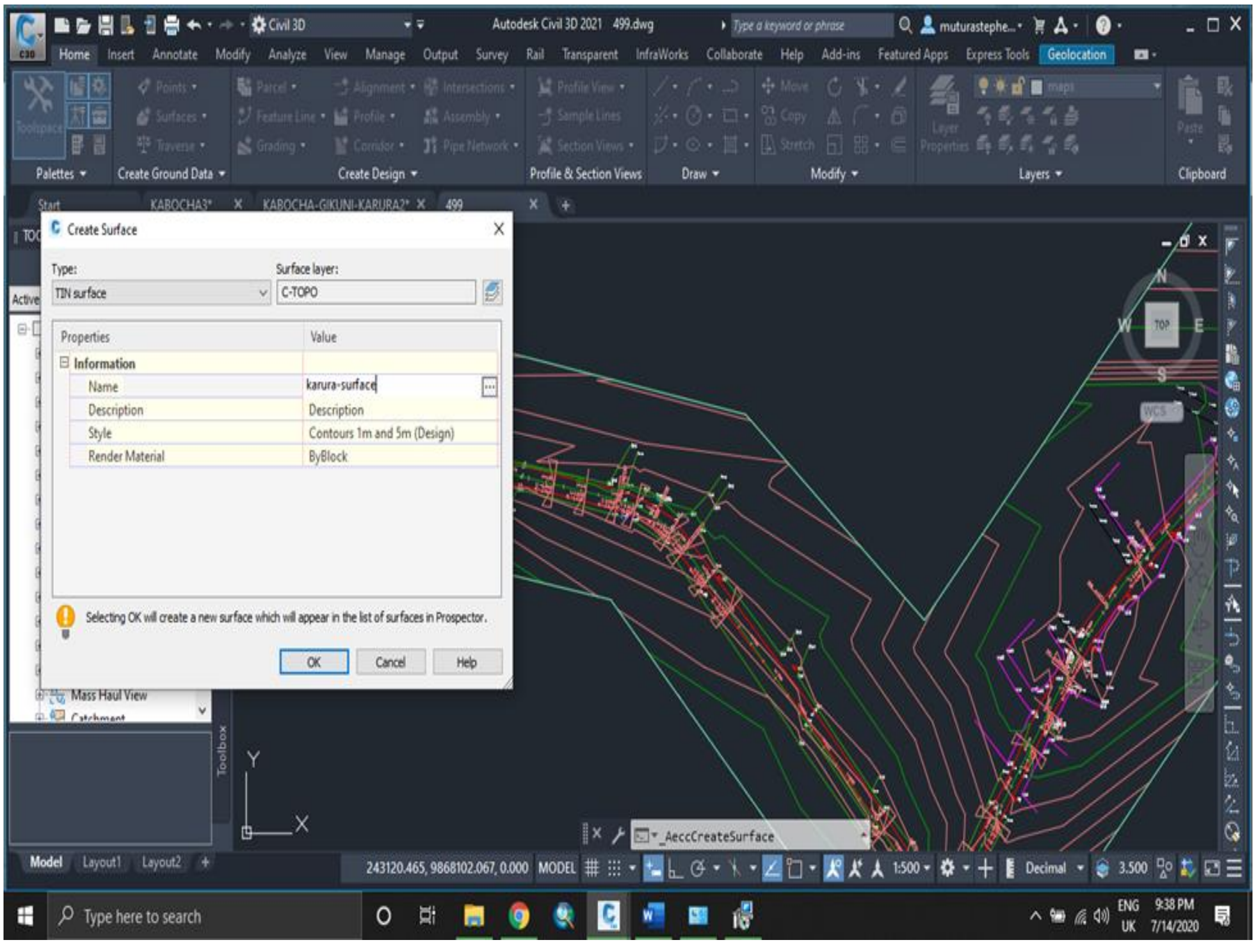


Figure 3.8. Surface creation tab; contours

3.8: Importing CAD to GIS environment.

A geodatabase was created in ArcMap and populated with CAD data. It contains details of the all the road data collected, the surface created and the alignment data for the design and construction of the road. The geodatabase is designed to hold large amounts of data and also to enable the interoperability of ArcGIS and CarryMap software. It is therefore a centralized data storage for keeping both spatial and non-spatial data. Each feature in the CAD drawing was converted from DWG to shapefile by saving it as a shapefile in the geodatabase. The results are as shown in Fig3.9:

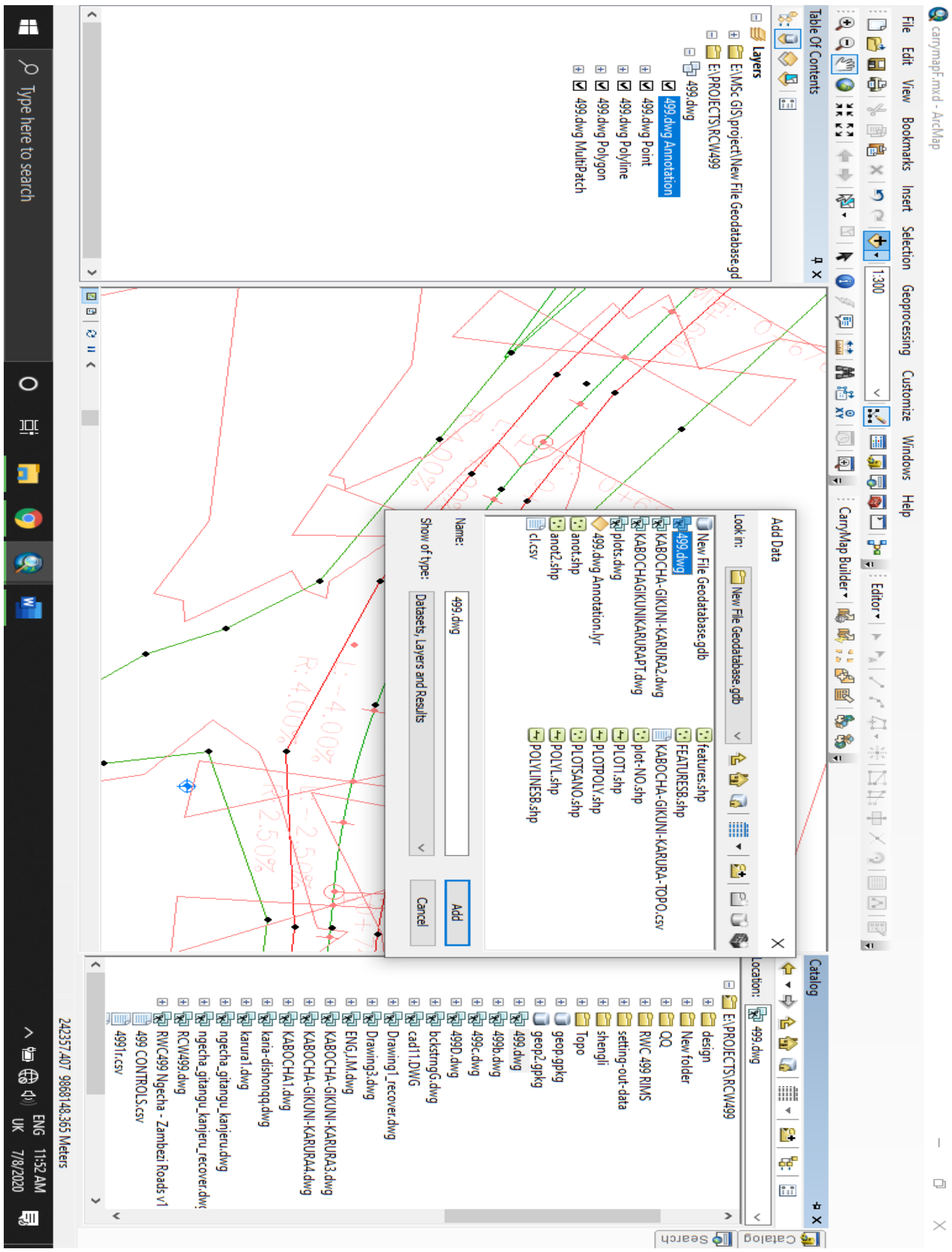


Figure 3.9: Importing CAD DWG road design data in ArcMap

The CAD file has no reference datum and projection. The projection was set by right clicking on layers at table of contents then to properties and data frame properties tab appears then coordinate system was selected. The ***ARC1960 UTM ZONE 37S*** projection or coordinate system was used. The process is shown below.

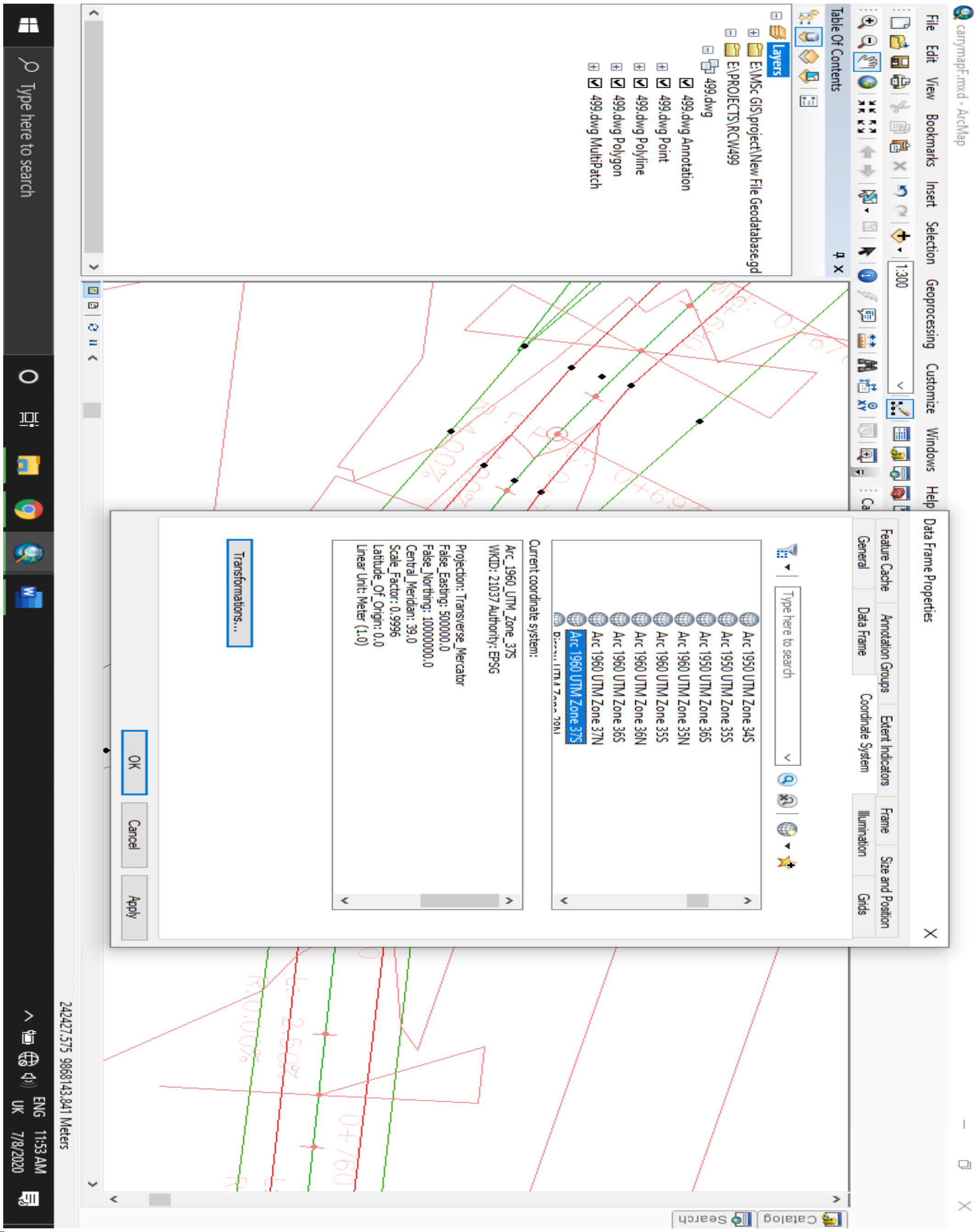
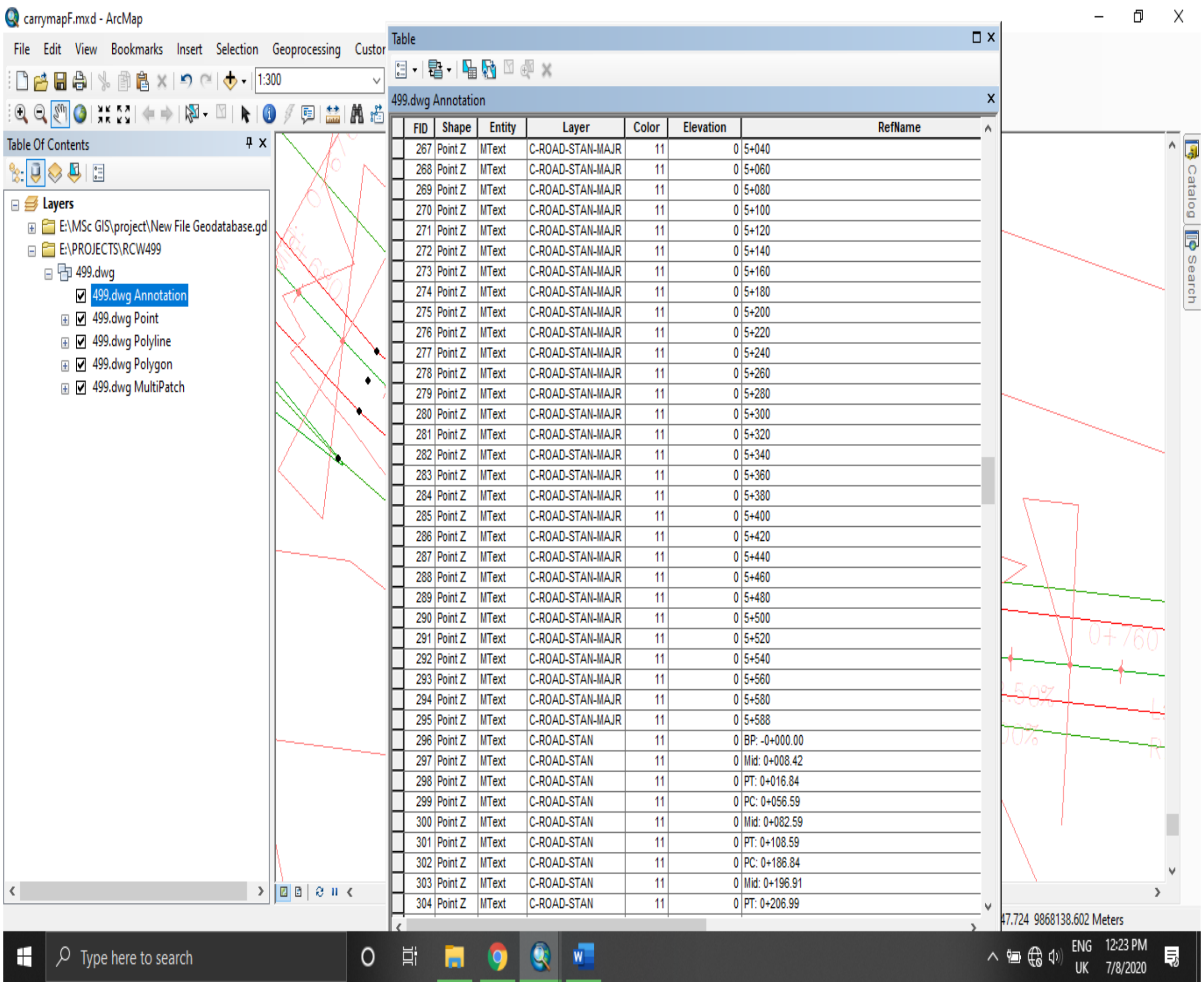


Figure 3.10: Setting Coordinates System in ArcMap

The 499.CAD DWG file contain the following layers;

a). ***499.dwg Annotation*** and it attribute table containing all chainages and super elevation data from the road design.



FID	Shape	Entity	Layer	Color	Elevation	RefName
267	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+040
268	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+060
269	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+080
270	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+100
271	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+120
272	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+140
273	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+160
274	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+180
275	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+200
276	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+220
277	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+240
278	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+260
279	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+280
280	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+300
281	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+320
282	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+340
283	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+360
284	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+380
285	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+400
286	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+420
287	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+440
288	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+460
289	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+480
290	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+500
291	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+520
292	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+540
293	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+560
294	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+580
295	Point Z	MText	C-ROAD-STAN-MAJR	11	0	5+588
296	Point Z	MText	C-ROAD-STAN	11	0	BP: -0+000.00
297	Point Z	MText	C-ROAD-STAN	11	0	Mid: 0+008.42
298	Point Z	MText	C-ROAD-STAN	11	0	PT: 0+016.84
299	Point Z	MText	C-ROAD-STAN	11	0	PC: 0+056.59
300	Point Z	MText	C-ROAD-STAN	11	0	Mid: 0+082.59
301	Point Z	MText	C-ROAD-STAN	11	0	PT: 0+108.59
302	Point Z	MText	C-ROAD-STAN	11	0	PC: 0+186.84
303	Point Z	MText	C-ROAD-STAN	11	0	Mid: 0+196.91
304	Point Z	MText	C-ROAD-STAN	11	0	PT: 0+206.99

Figure 3.11: Annotation attribute table

b). ***499.dwg Point*** and it attribute table containing all points that were picked during topographical survey on the road and all the features along the road. The figure bellow show part of point attribute table.

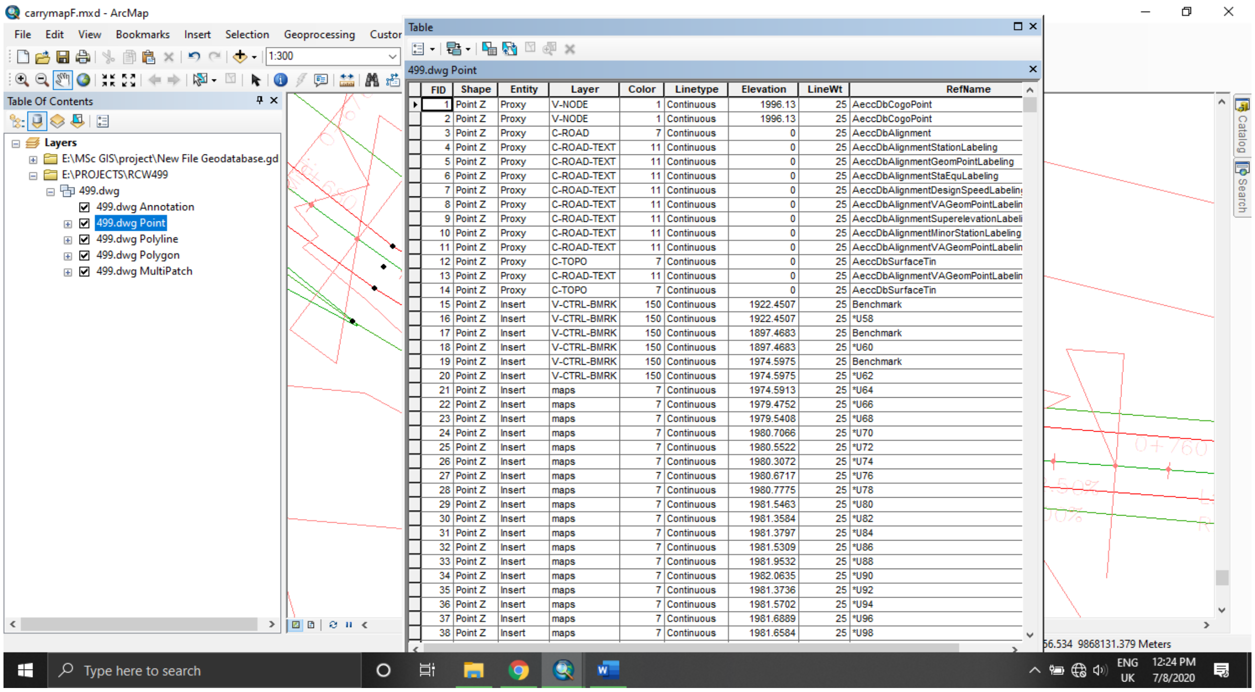


Figure 3.12: Point attribute table

c). ***499.dwg Polyline*** and it attribute table with all polylines data. The figure below shows a part of polyline attribute table.

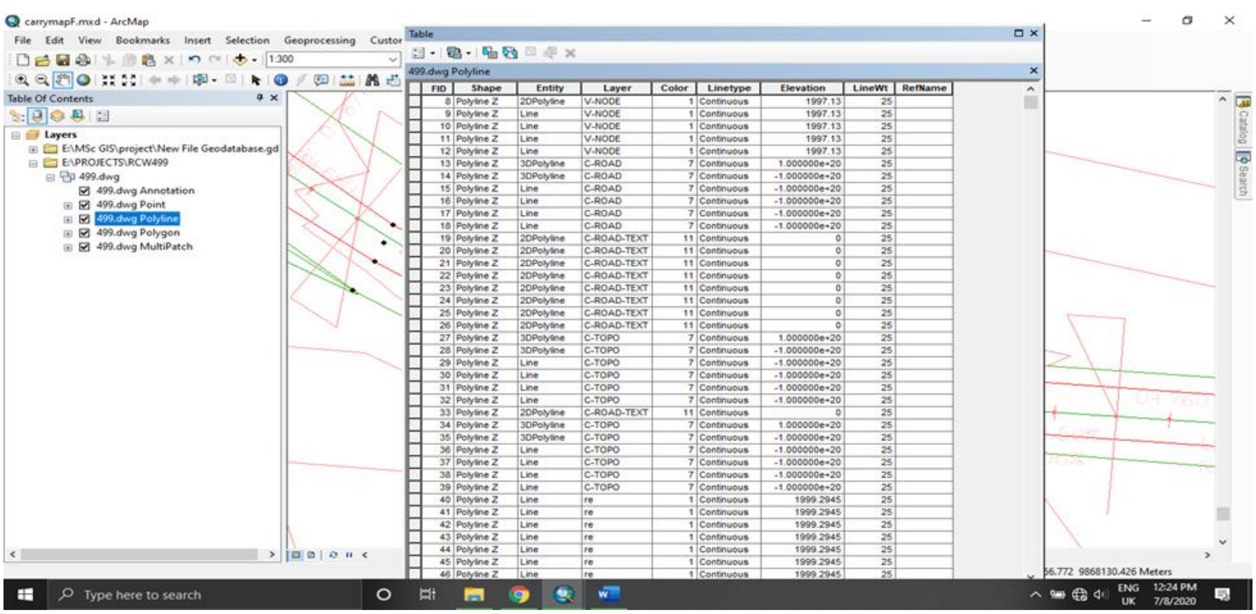


Figure 3.13: Polylines attribute table

d) ***499.dwg Polygon***. The polygon layer in this project was the boundary which the surface contours extends.

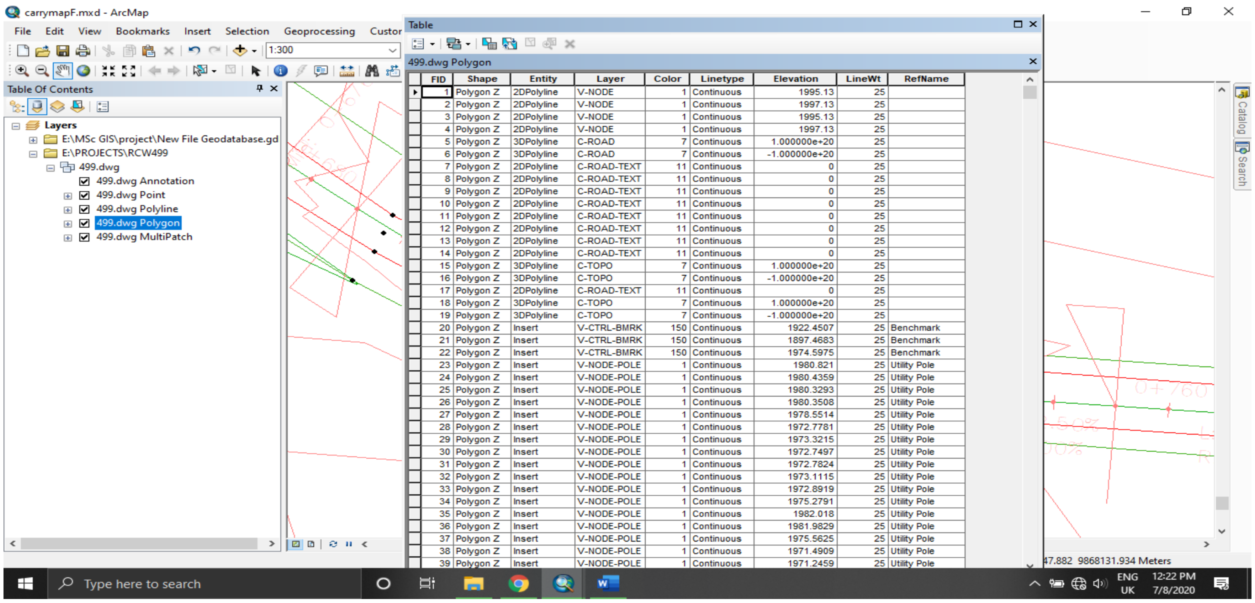


Figure 3.14: Polygon attribute table

e) ***499.dwg MultiPatch.*** This layer contains symbols such as power poles and benchmarks

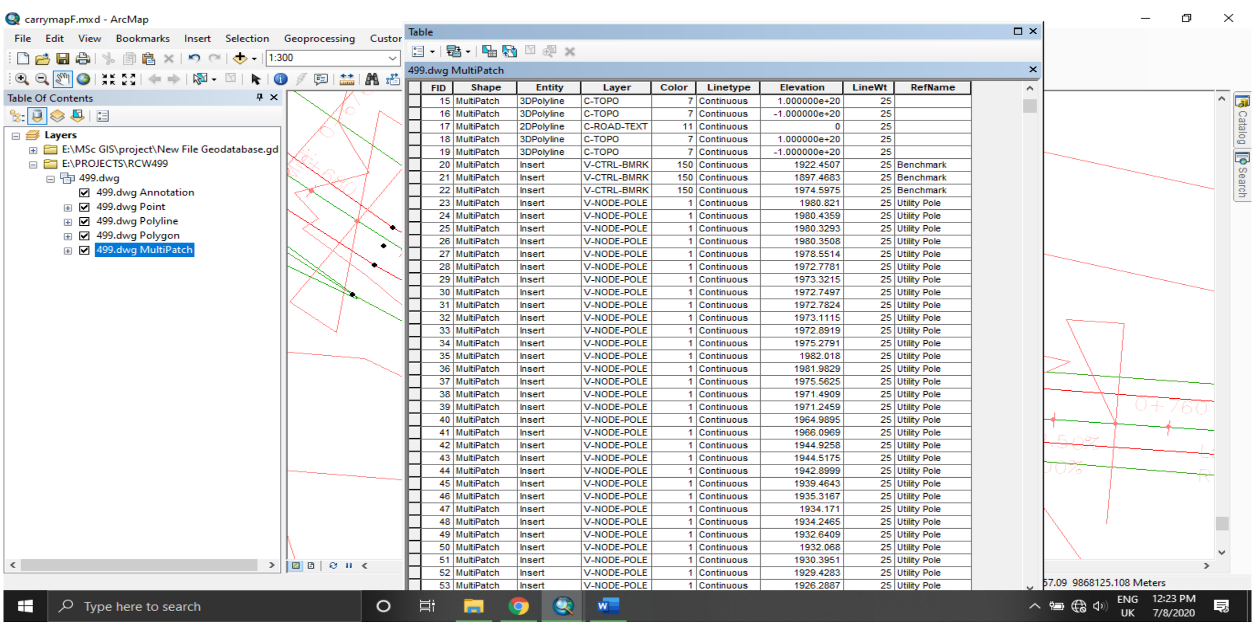


Figure 3.15: Multipatch attribute table

3.9. Conversion from CAD DWG files to Shapefile

The CAD layers were exported to shapefile by right clicking on the layer select **Data-export data** then change file location to working area the layer was displayed in ArcMap as shapefile after exporting.

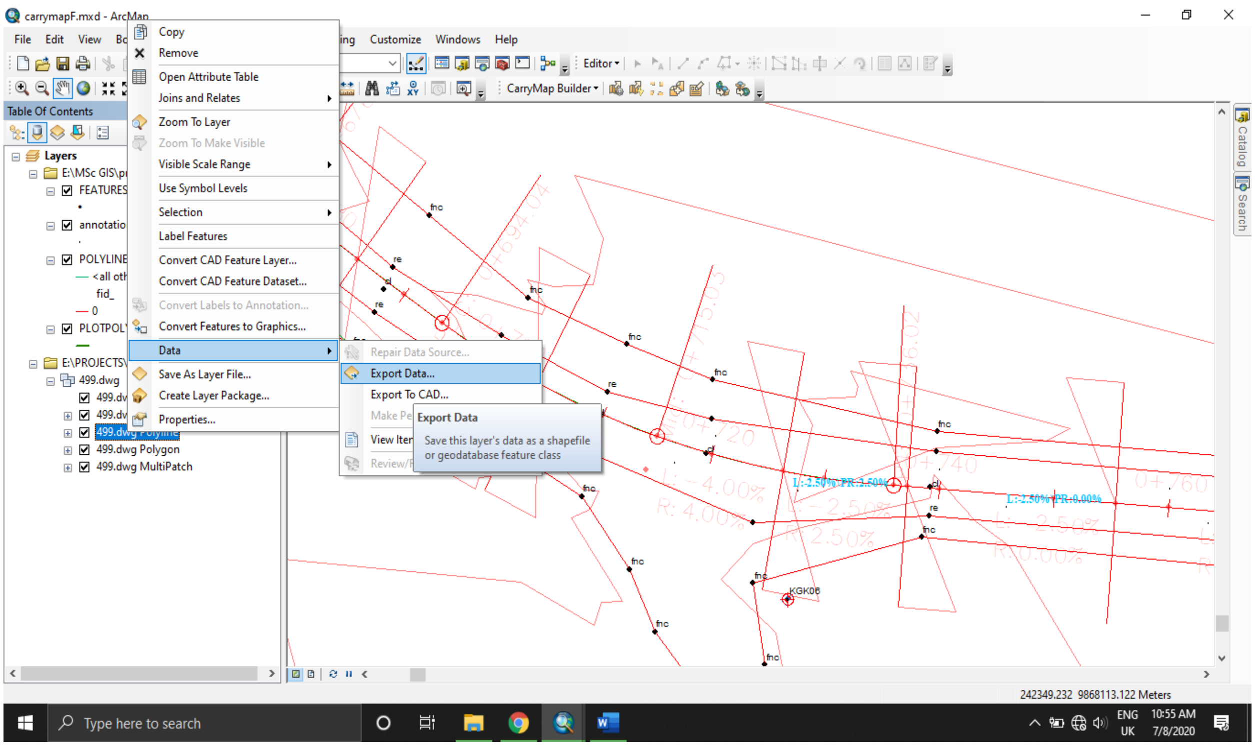


Figure 3.16: Exporting CAD layer to Shapefile

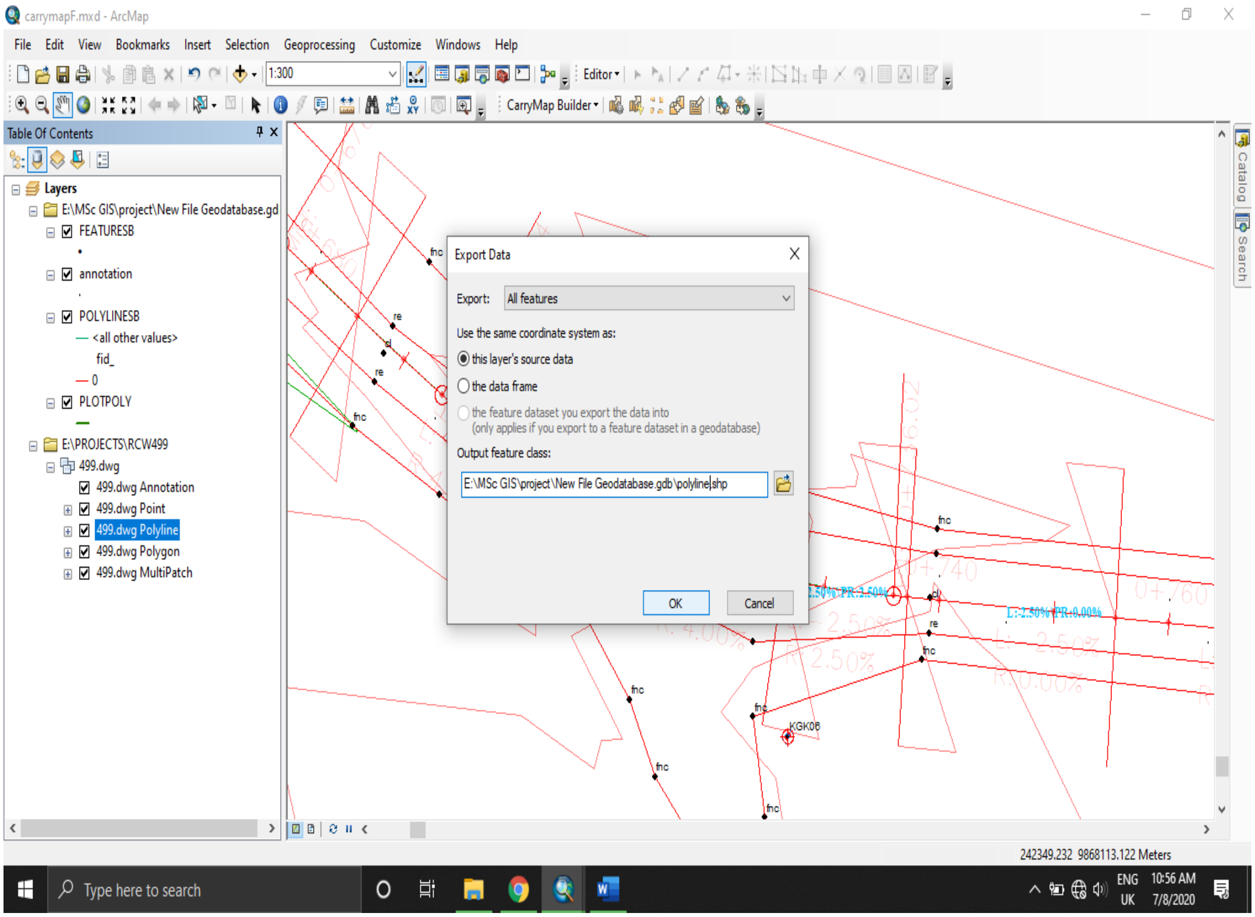


Figure 3.17: Exporting CAD layer to Shapefile tab.

Exporting CAD annotation used a different method to convert dwg to shapefile. The conversion was through **ArcToolbox-Data Management Tool-Feature- Feature to Point**. In Feature to Point tab Annotation layer was selected and by clicking **OK** the conversion was executed and annotation was saved as point shapefile.

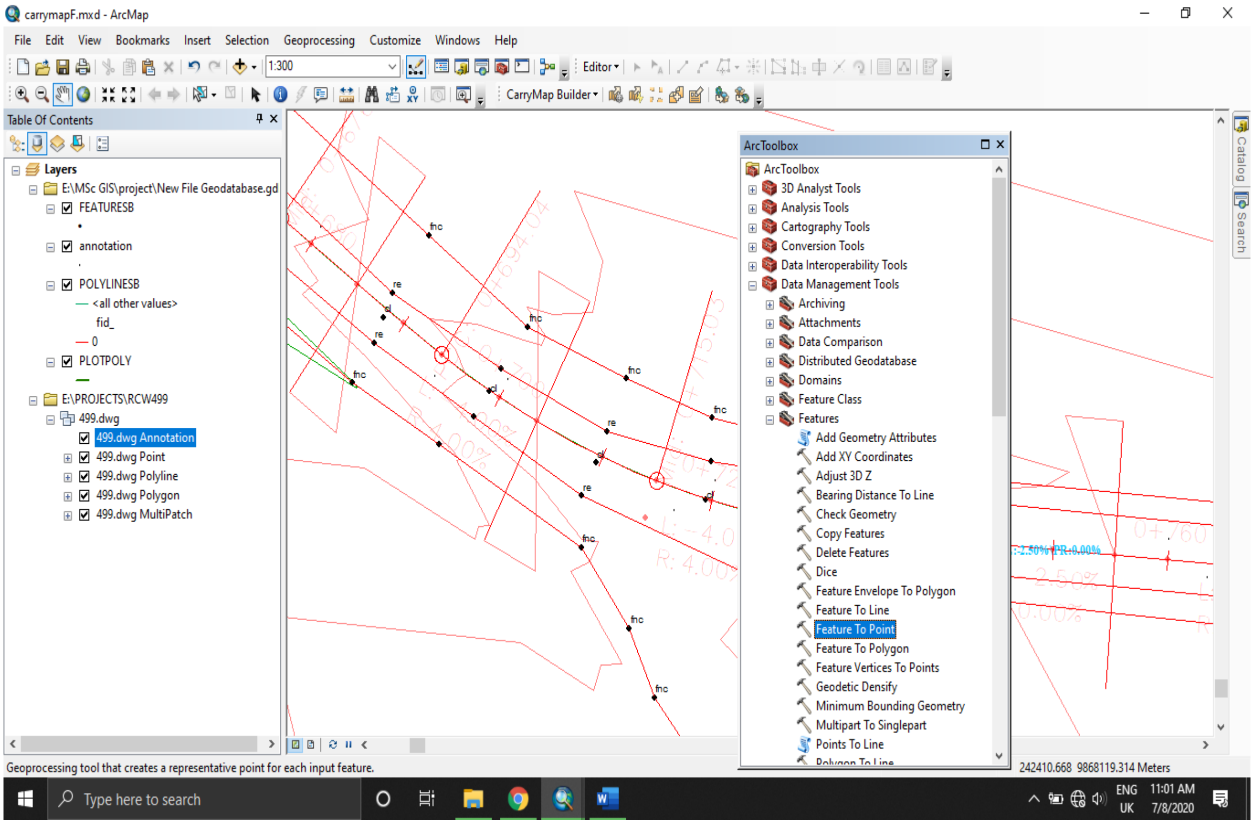


Figure 3.18: Exporting Annotation CAD layer to Shapefile; ArcToolbox.

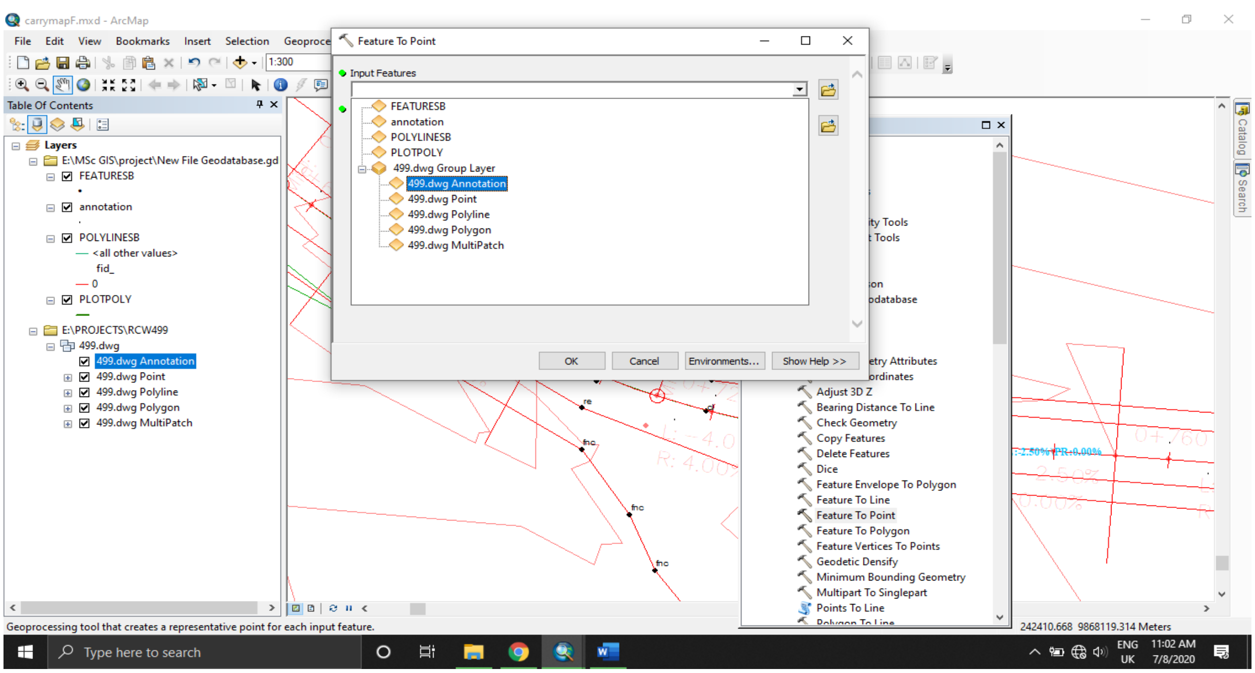


Figure 3.19: Exporting Annotation CAD layer to Shapefile; Feature to Point tab.

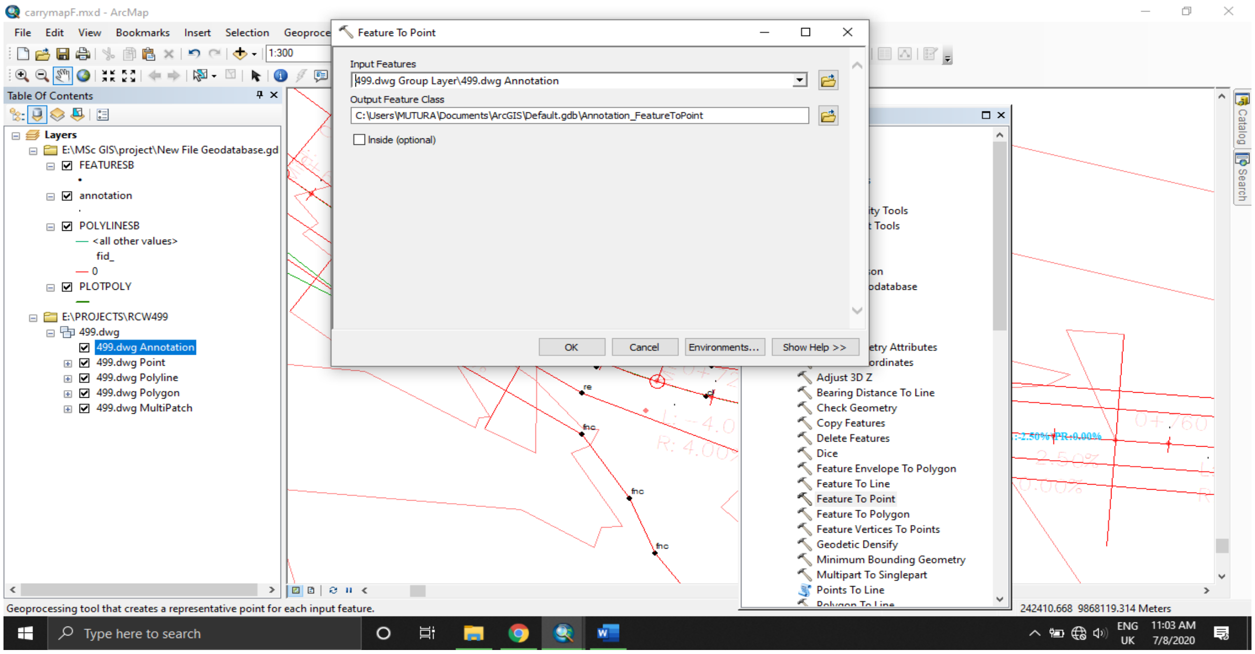


Figure 3.20: Exporting Annotation CAD layer to Shapefile; Feature to Point tab

3.10: Importing to CarryMap

Feature extraction tool in CarryMap builder is used to export the drawing to CMF2 file format. This is a file format used by CarryMap to display features. The customize extraction tool is used to extract map. Upon selection a dialog box is opened as shown:

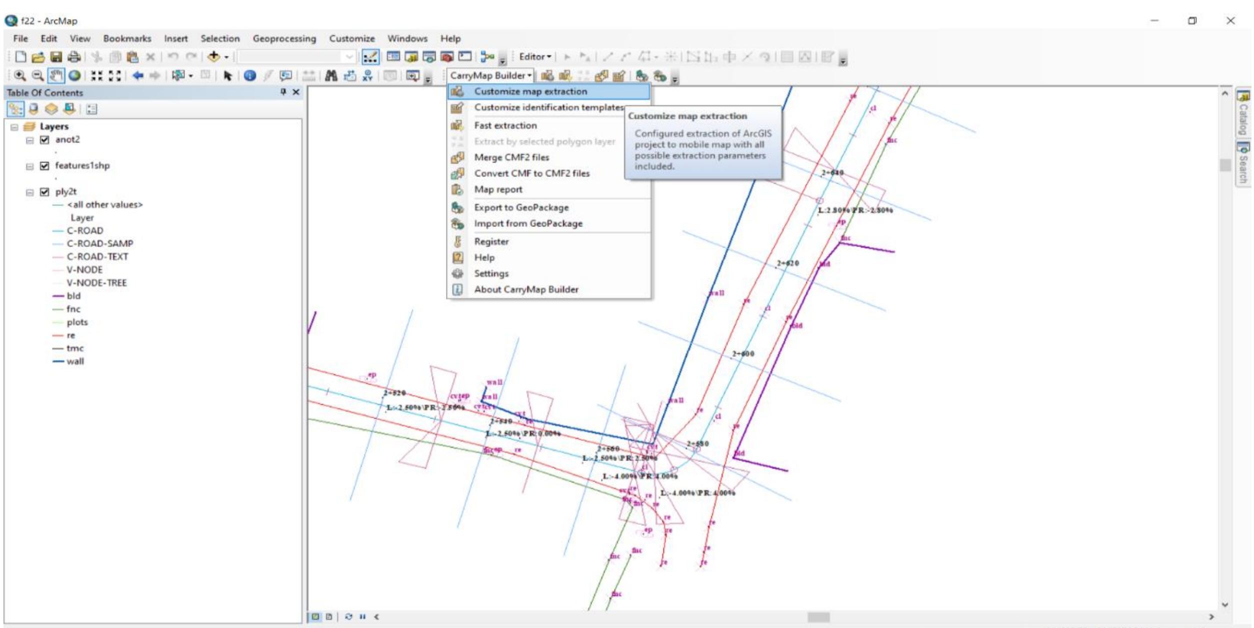


Figure 3.21: CarryMap builder extension/plugin in ArcMap.

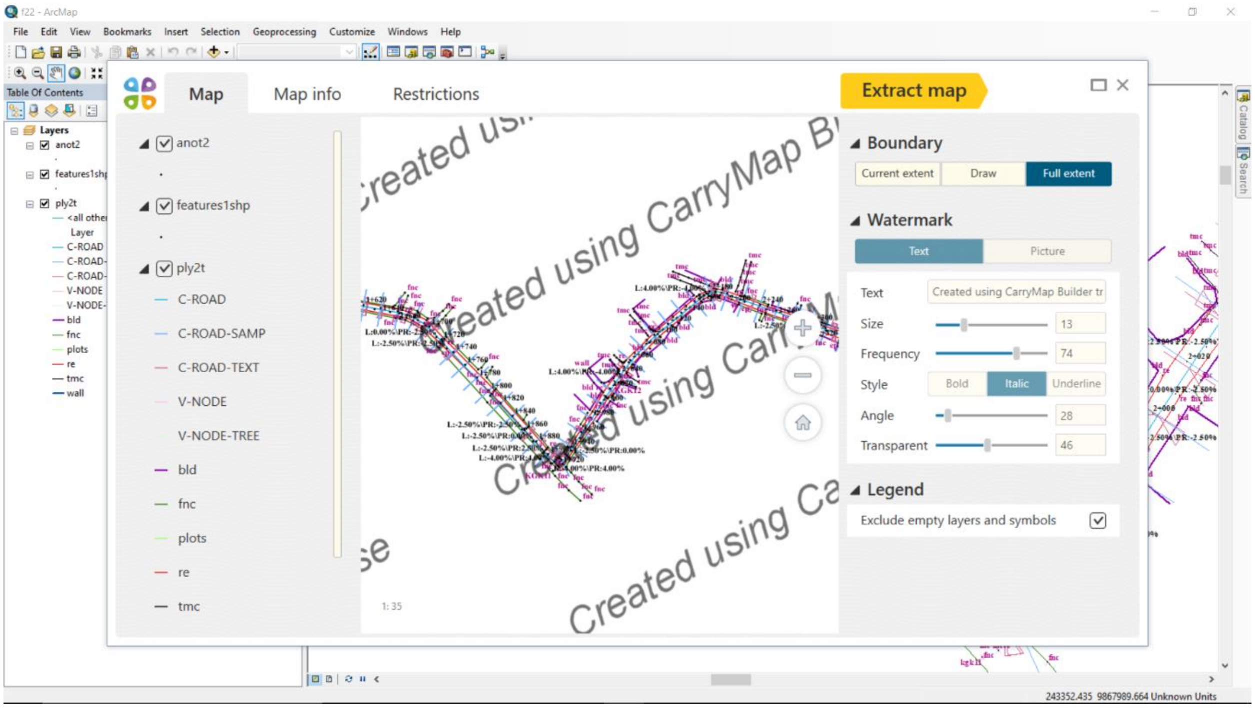


Figure 3.22: CarryMap builder dialog box

The drawing in ArcMap was displayed. The map tab was used to customize the map output. One can specify the boundary, watermark and legend of the map being extracted. The map info tab was used to input attribute data such as name, publisher, email and URL.

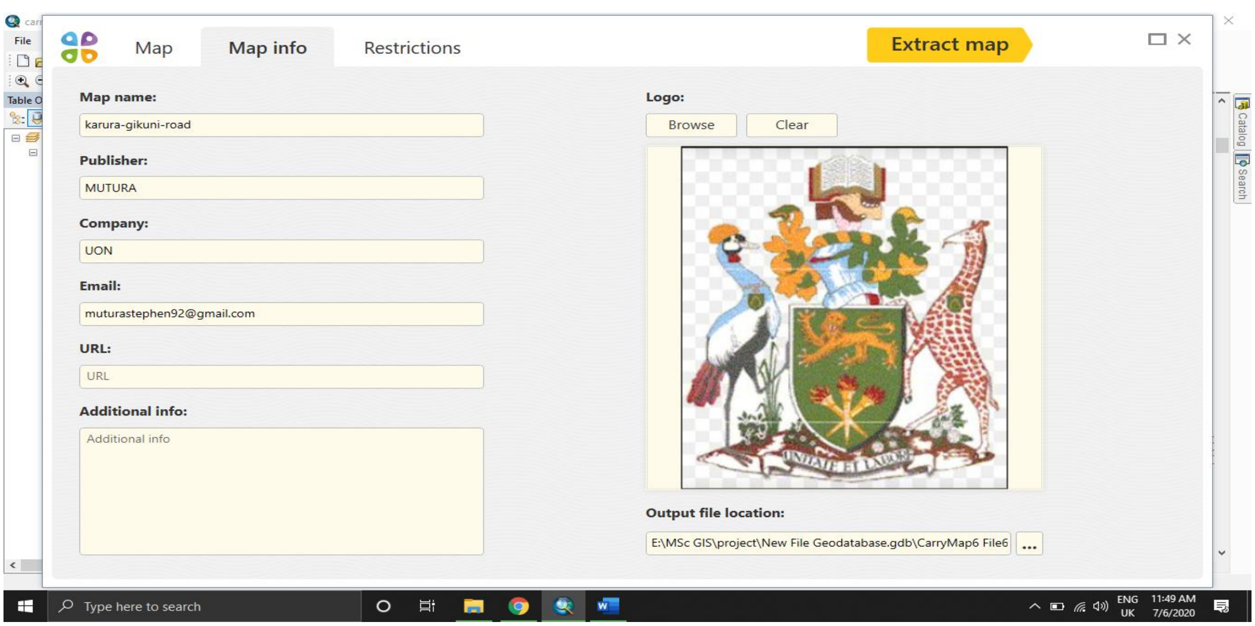


Figure 3.23: Map info tab in CarryMap builder

Restrictions such as passwords and validity period are set in the restrictions tab so as to protect the document from misuse and theft. A watermark can be placed on the map so as to prevent it from being copyrighted.

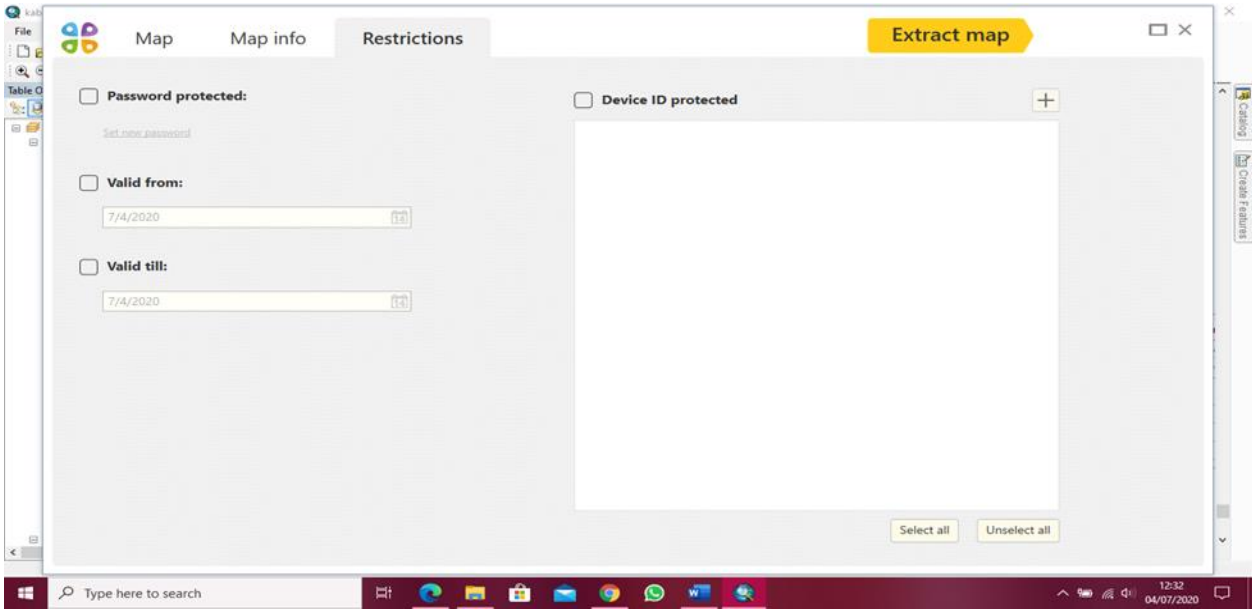


Figure 3.24: Restriction tab on CarryMap builder

The map was then extracted and saved to the output folder in CMF2 file format.

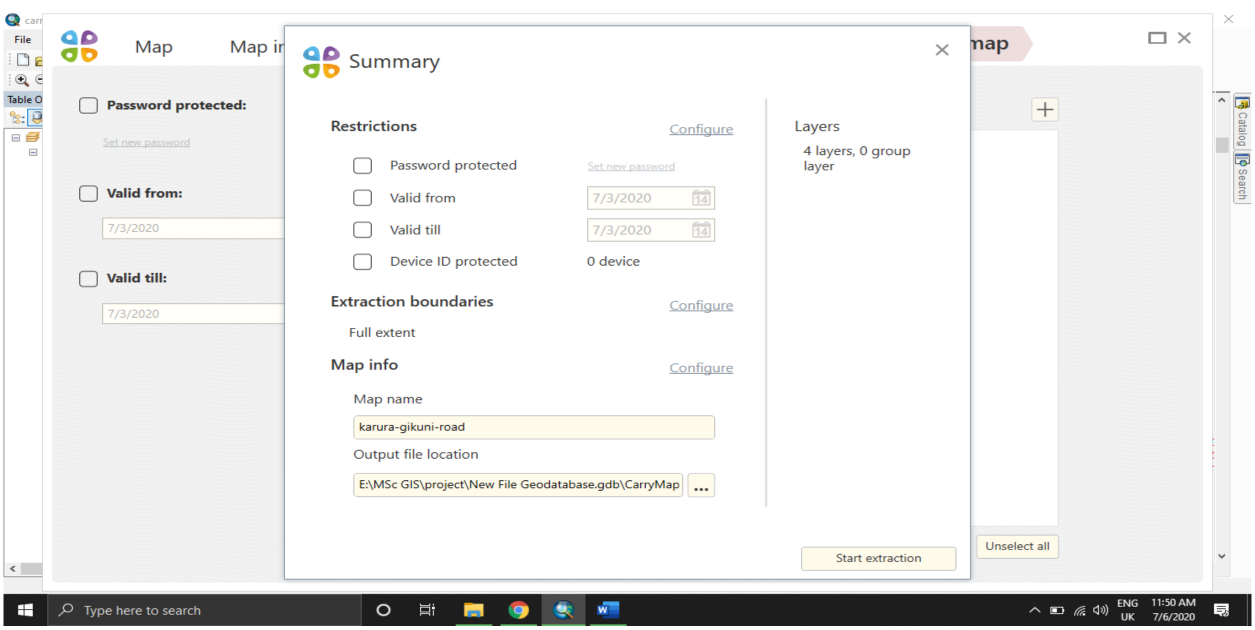


Figure 3.25: CarryMap builder summary settings

The figure 3.26 shows the data extraction in the process

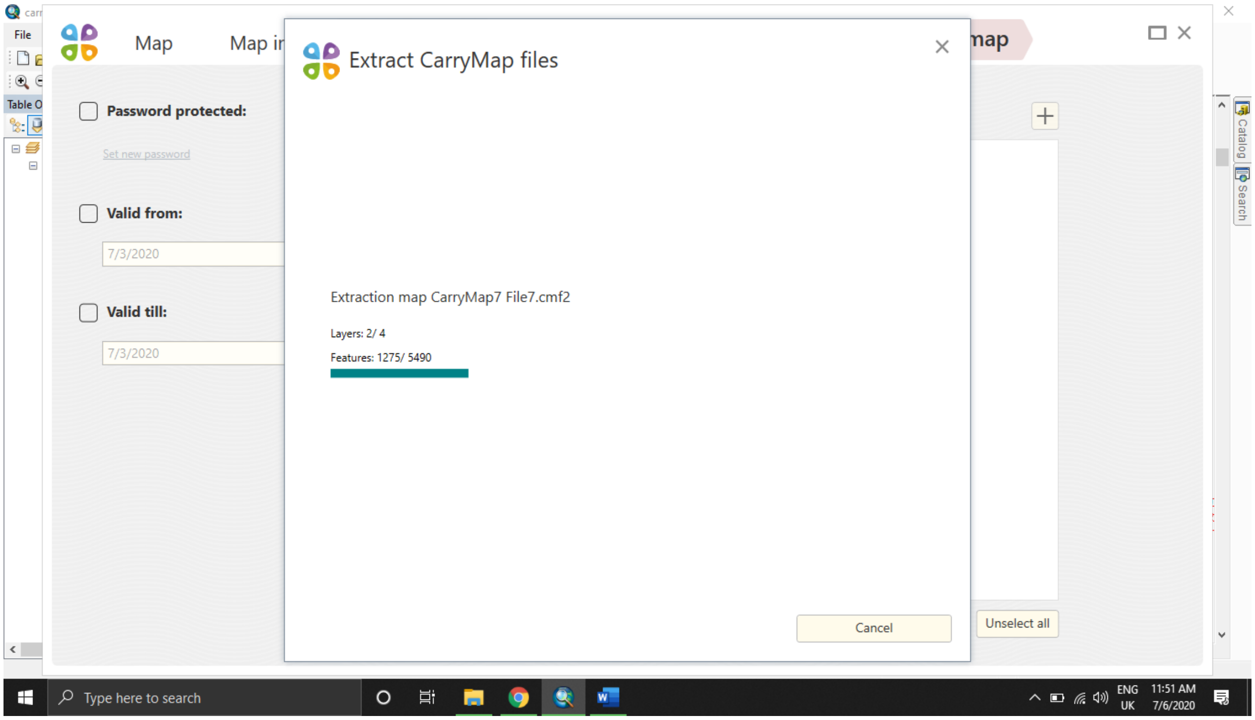


Figure 3.26: CarryMap cmf2 file extraction in process

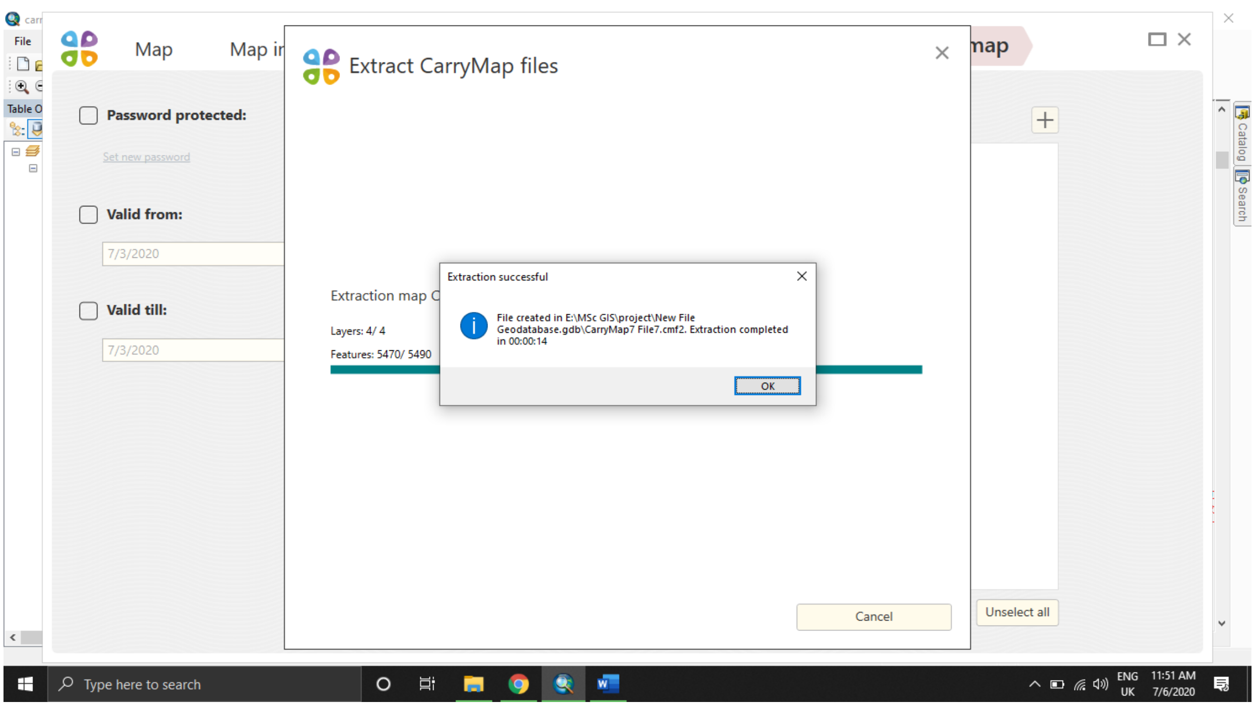


Figure 3.27: CarryMap cmf2 file extraction process successful tab

After the extraction is done a window appear showing the summary of what was extracted, some of what is displayed is a file name which is in CMF2 file format, coordinate system used where in this case Arc_1960 and UTM projection were used. It also shows feature classes that is the layers that are in the file that will be displayed in the CarryMap.

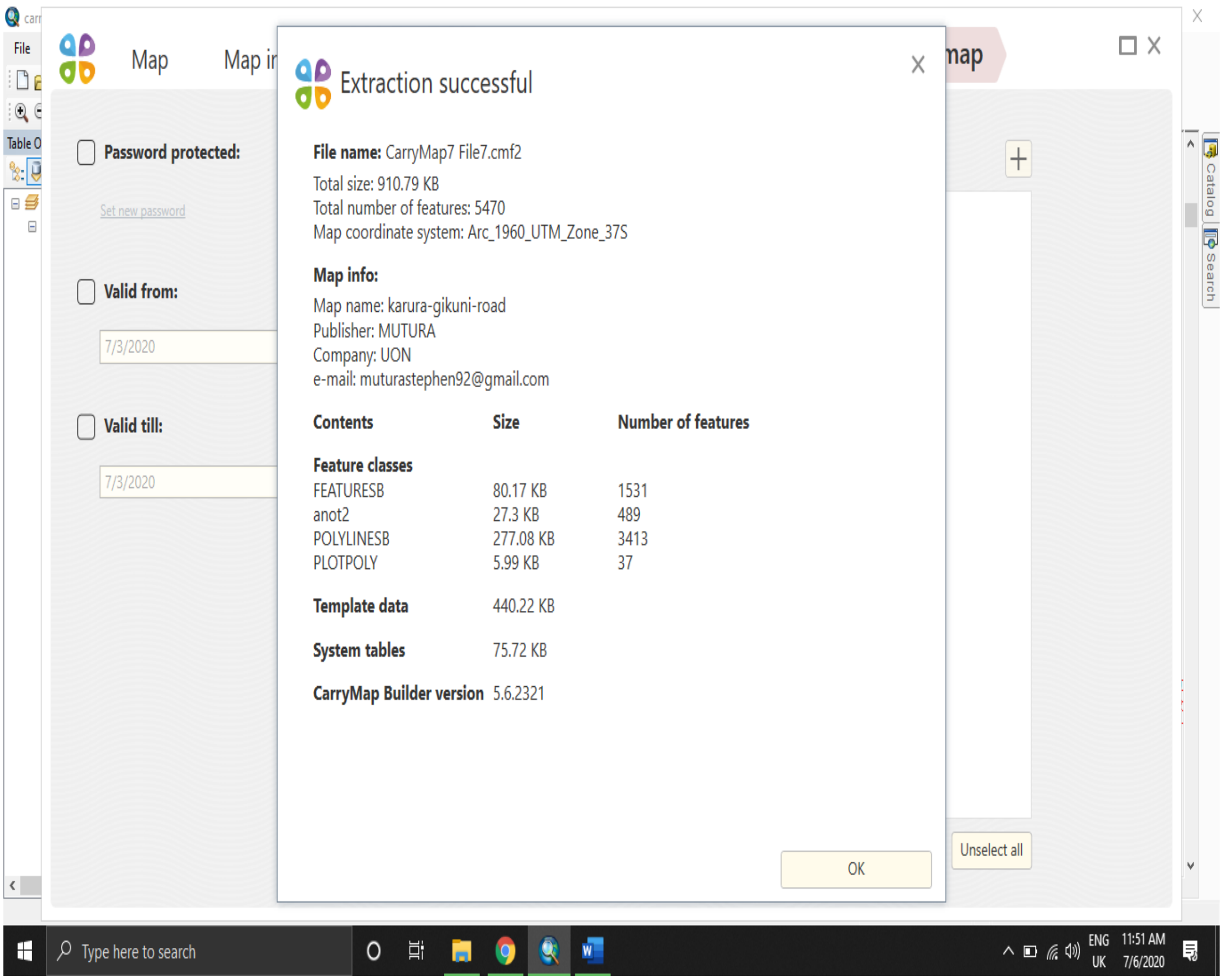


Figure 3.28: Extracted map info after map extraction in CarryMap builder

The file was then transferred to phone then displayed using the CarryMap application and all road information can be viewed by the users

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Results.

In construction of road alignment, there are factors to be considered such as the class and purpose of road, the type of vehicular traffic, horizontal curves, sight distance and many others. This helps in ensures that the desired alignment is done. Since the road is categorized as class E, rural road, its purpose is mainly to provide accessibility of services such as health facilities and connect rural areas to urban centers. This therefore means the vehicular traffic is moderate to low thus speed considered in the design criteria is 80km/hr.

4.2 Road design

According to KERRA road construction manual, roads that are classified as Class E are to be constructed in such a way the road surface achieves a camber. Thus, the road slopes at a specified gradient from the center line to the road edges. This is to ensure that the road surface is not damaged by rain water since it flows to the drainage created. Areas where the road is straight, the road is designed in a camber but areas with curves and bends the road is designed in such a way it achieves super-elevation. Super-elevation is where one side of the road is higher than the other in such a way the road slopes from one side to the other. This is done so as to ensure that the vehicle using the road easily maneuvers the bend at the same speed it was at motion.

In road design factors considered included the road width, number of lanes, the gradient, maximum speed of vehicular traffic. This is done using the super-elevation tool in AutoCAD. The number of lanes specified was two with opposite traffic, the gradient was -2.5% so as to achieve a camber, maximum speed was 80 km/hr. and the road width from the Centre line on each side was 3.5 m thus our total road width was 7m. The road alignment data was used as the input data for the design. The results are as shown in Fig 4.1:

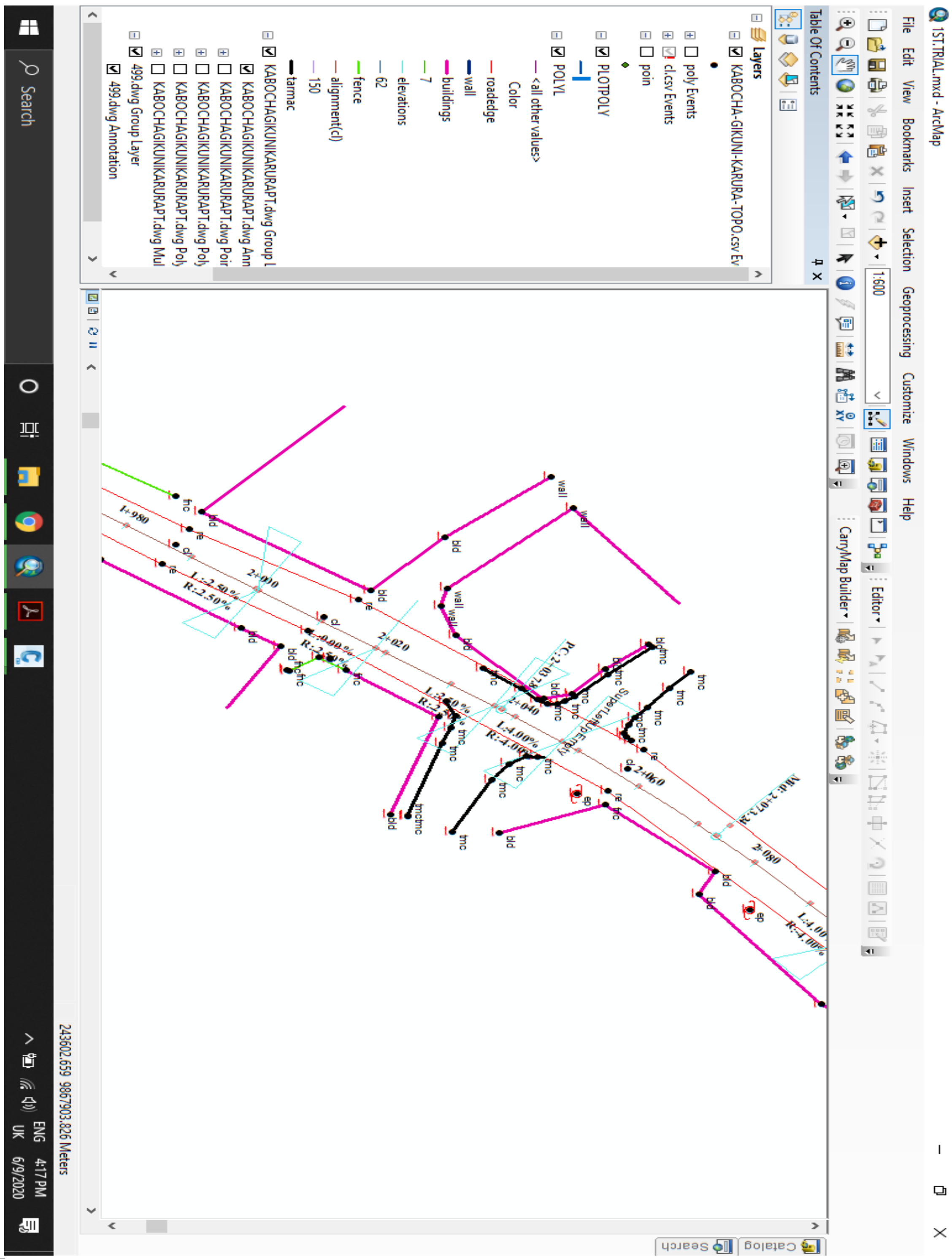


Figure 4.1: Road design and the features

Features such as buildings, electric posts, fence, tarmac, road edge, the centerline and benchmarks were appropriately symbolized in ArcMap as shown:

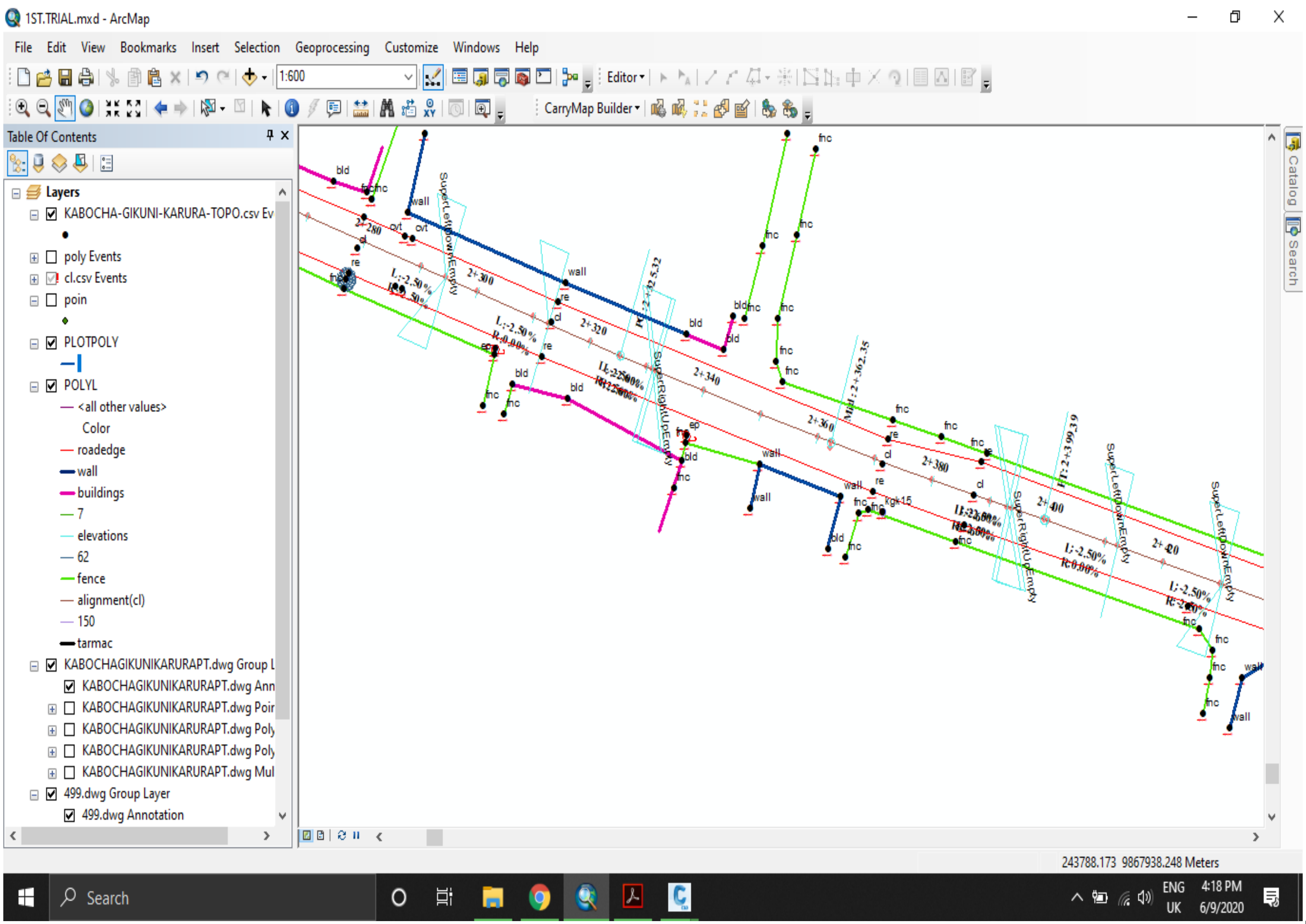


Figure 4.2: Road features and road information

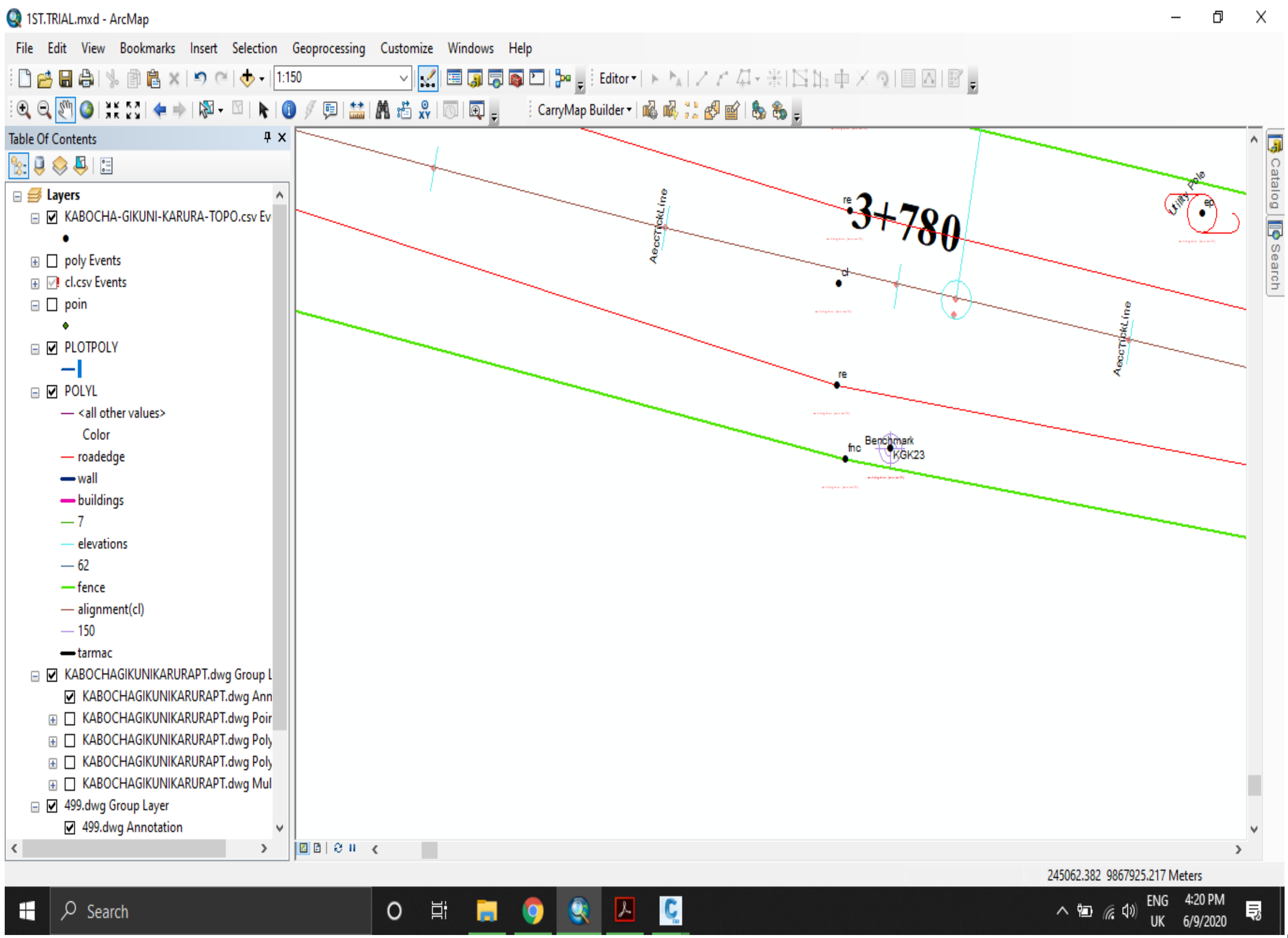


Figure 4.3: Road construction beacons and chainages

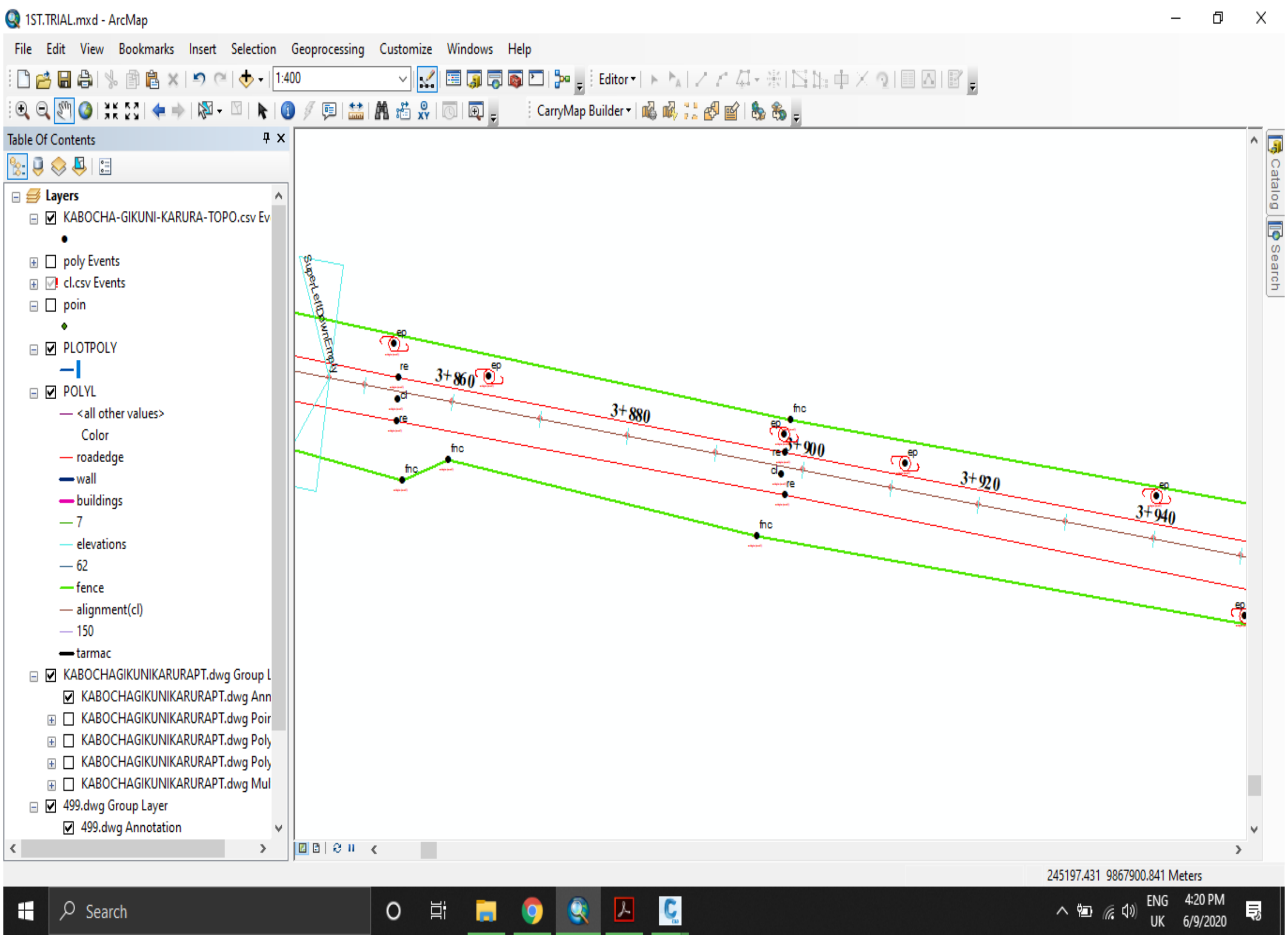


Figure 4.4: Electric posts (ep) along the road reserve

Digitization of abutting land parcels from the cadastral map was done in AutoCAD and imported to our geodatabase. This will aid in identification of encroachment by the land owners along the road reserve and in some instances, enable compensation of land to those whom will be affected by the road construction.

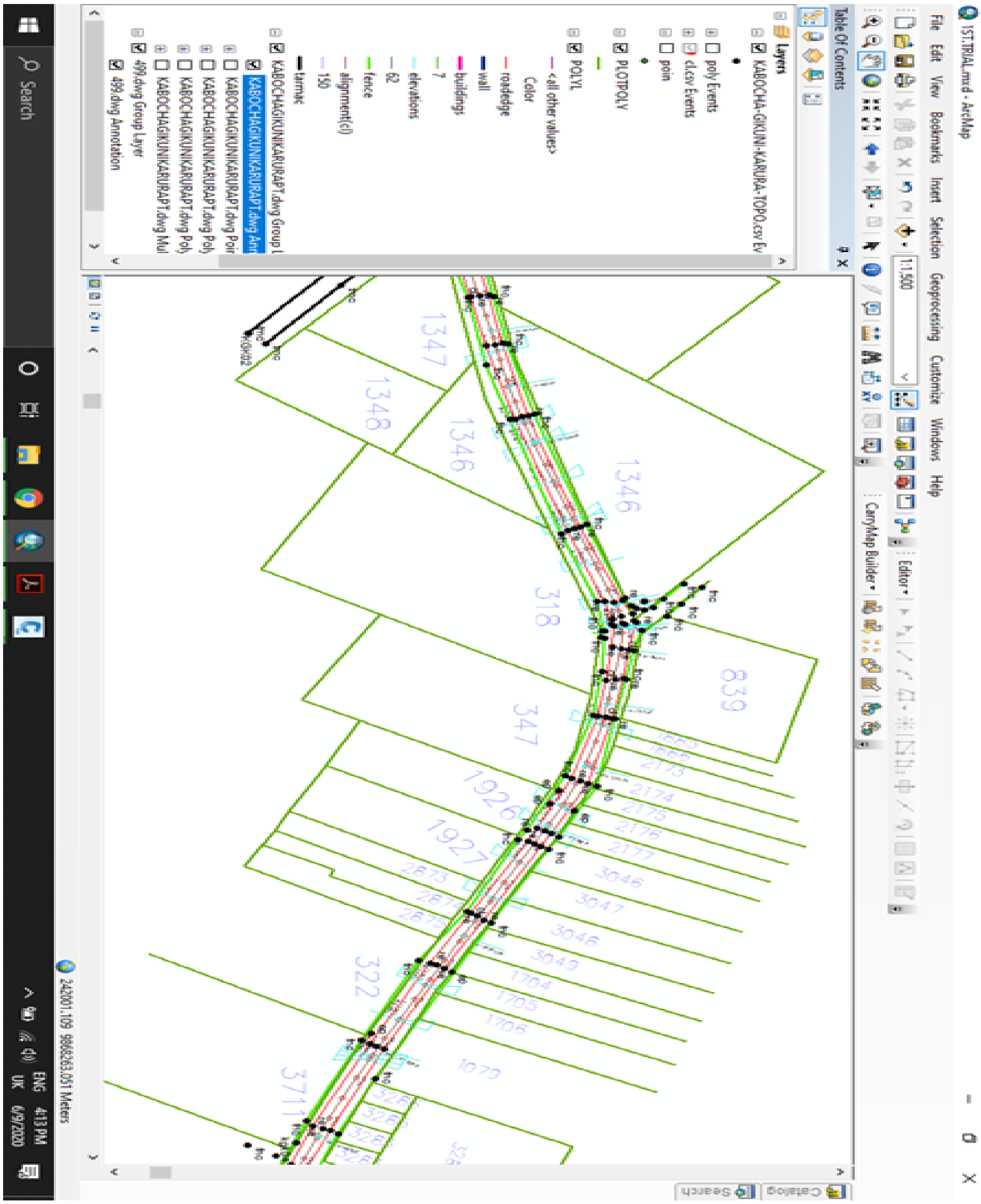


Figure 4.5: Abutting land parcels to the road

4.3. Integrating Road Information to Smart Phone

The extracted map feature which is CarryMap cmf2 file was then transferred to a smart phone. Using the CarryMap mobile application, the extracted map was added and overlaid to the Kenya Classification of Roads and a World Imagery Base Map added. The integration was seamless and accurate.

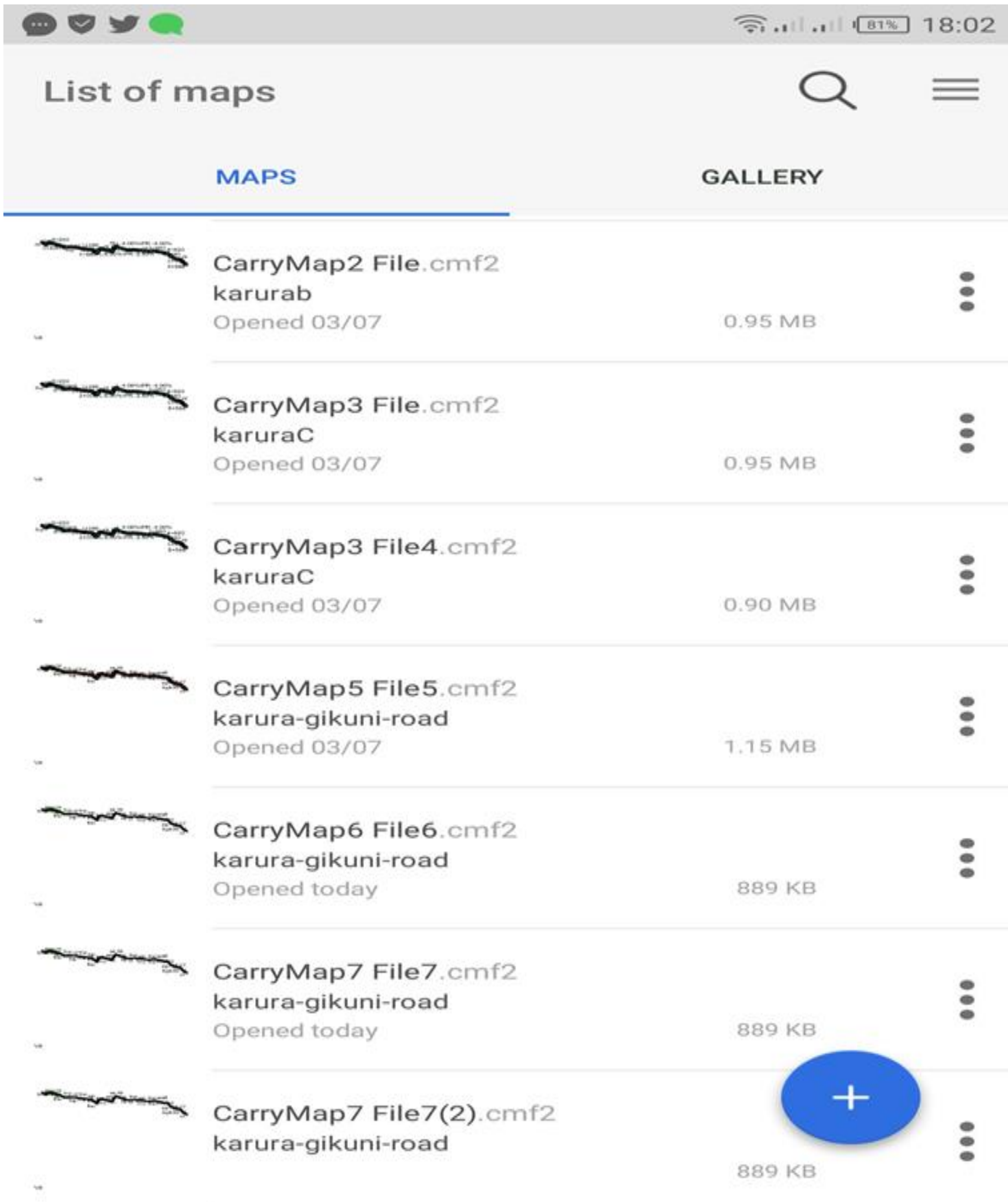


Figure 4.6: Adding the cmf2 file to phone CarryMap application

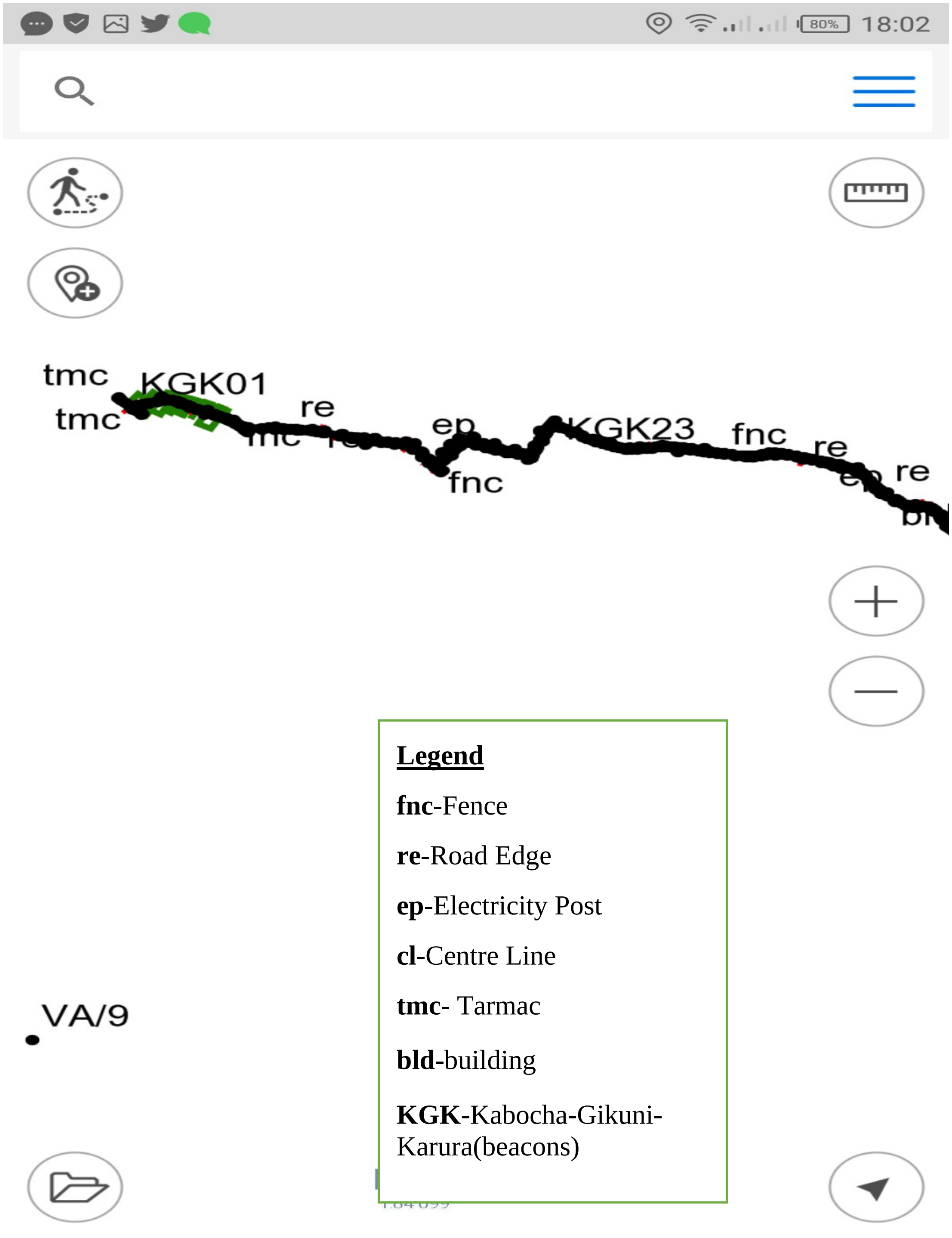
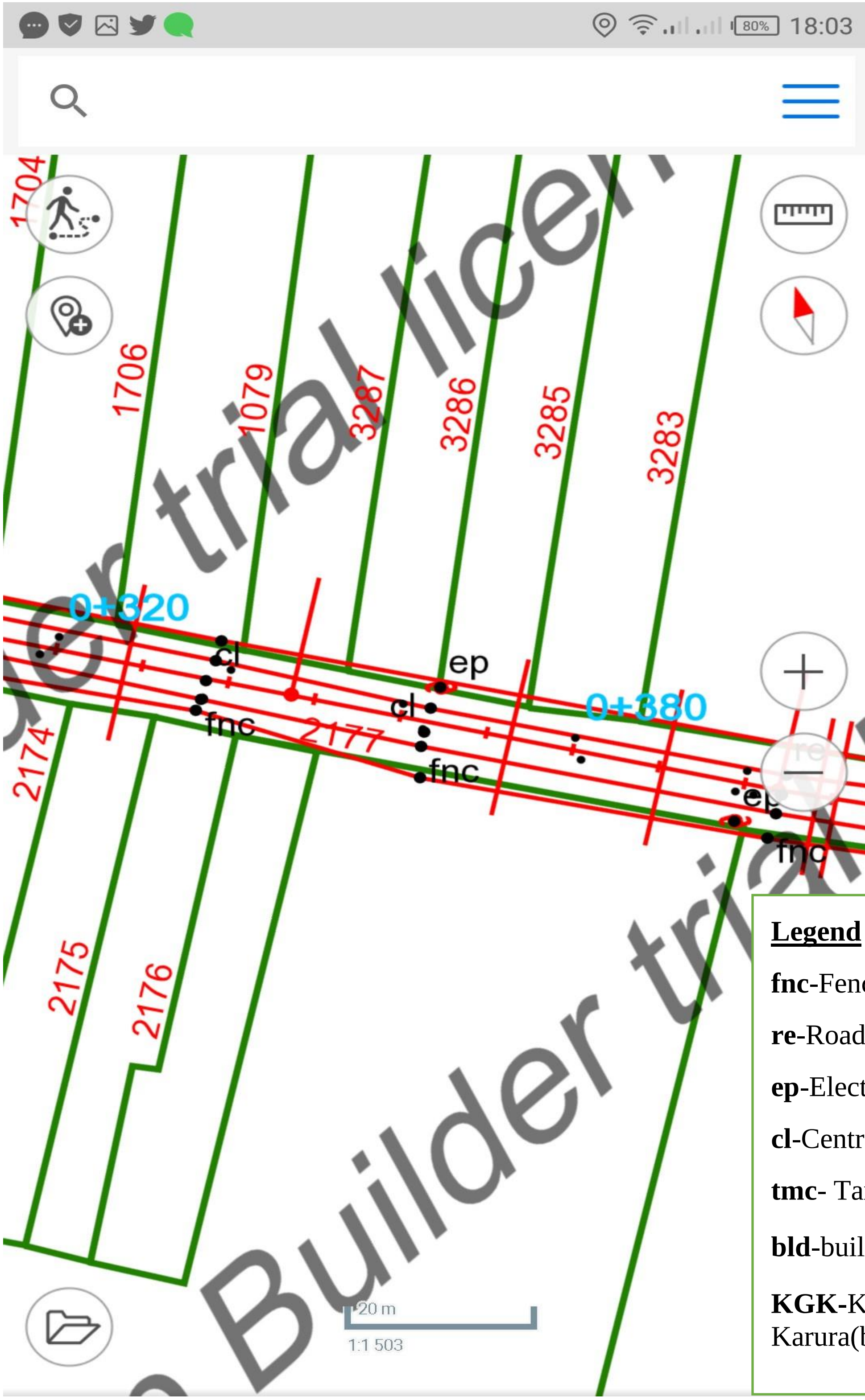


Figure 4.7: Road information displayed in phone CarryMap application



Legend

fnc-Fence

re-Road Edge

ep-Electricity Post

cl-Centre Line

tmc- Tarmac

bld-building

KGK-Kabocha-Gikuni-Karura(beacons)

Figure 4.8: Digitized plots abutting the Road displayed in phone CarryMap application

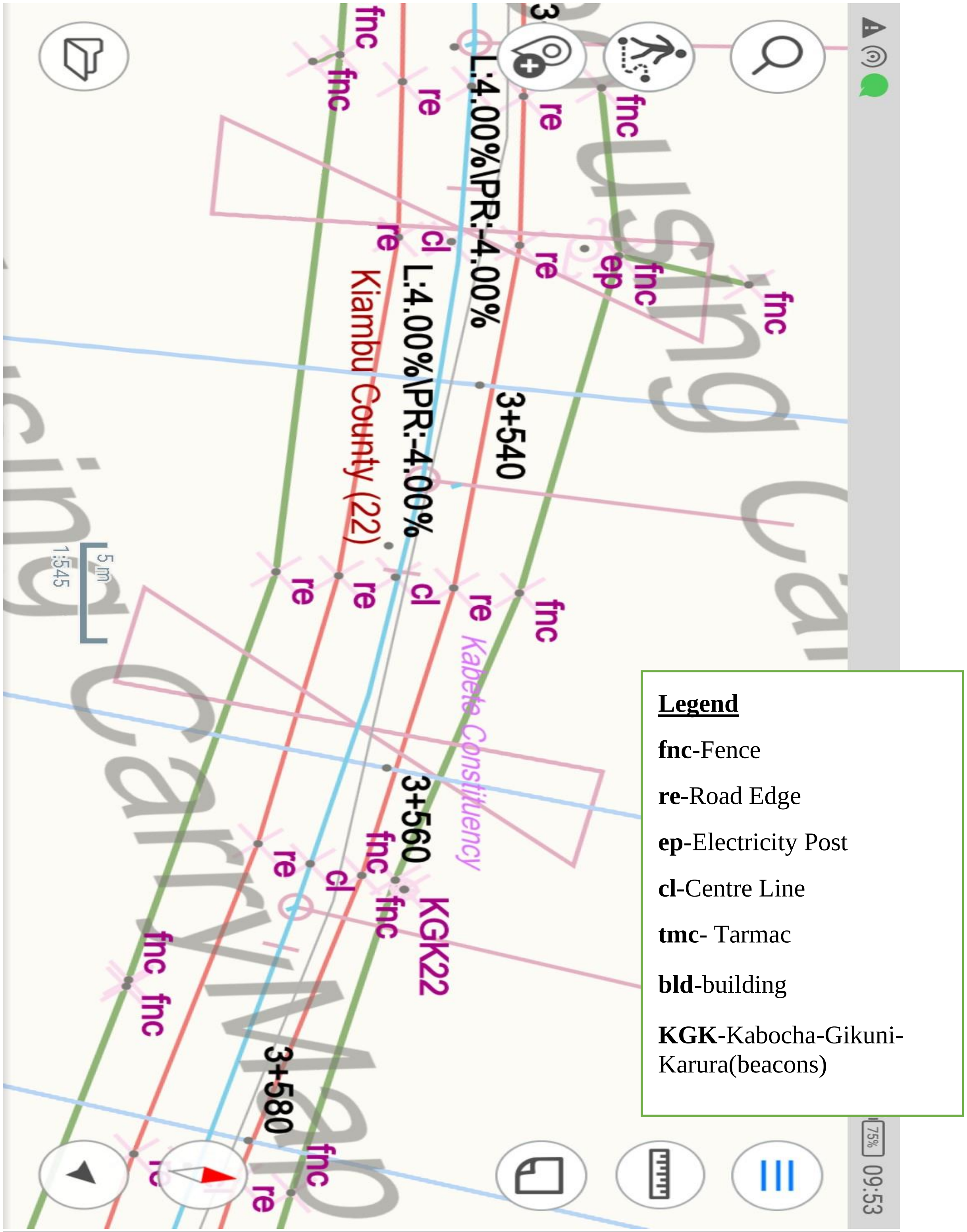


Figure 4.9: Chainages and other Road features displayed in phone CarryMap application

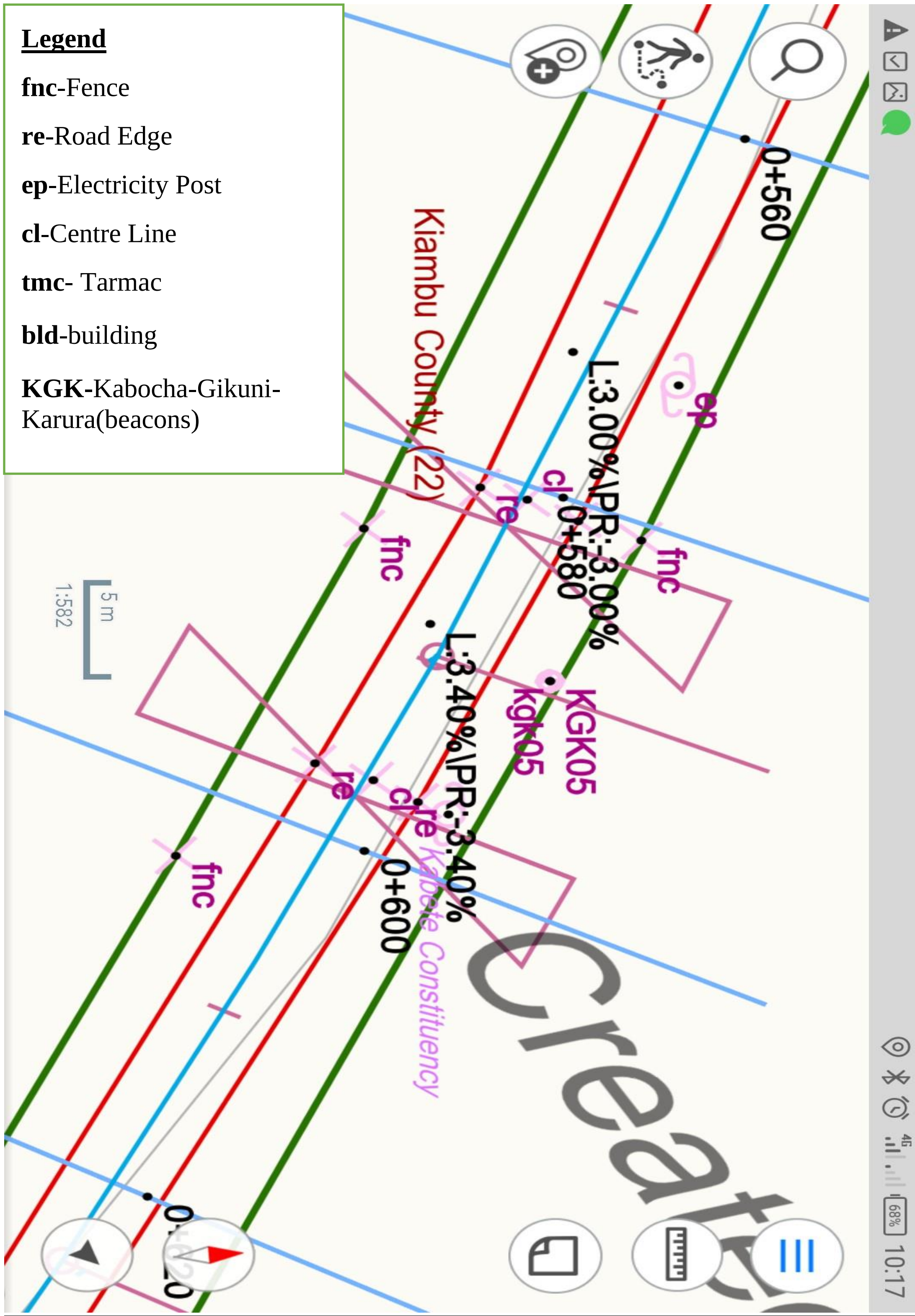


Figure 4.10: Beacon KGK 05 and electricity post (ep) shown in CarryMap application

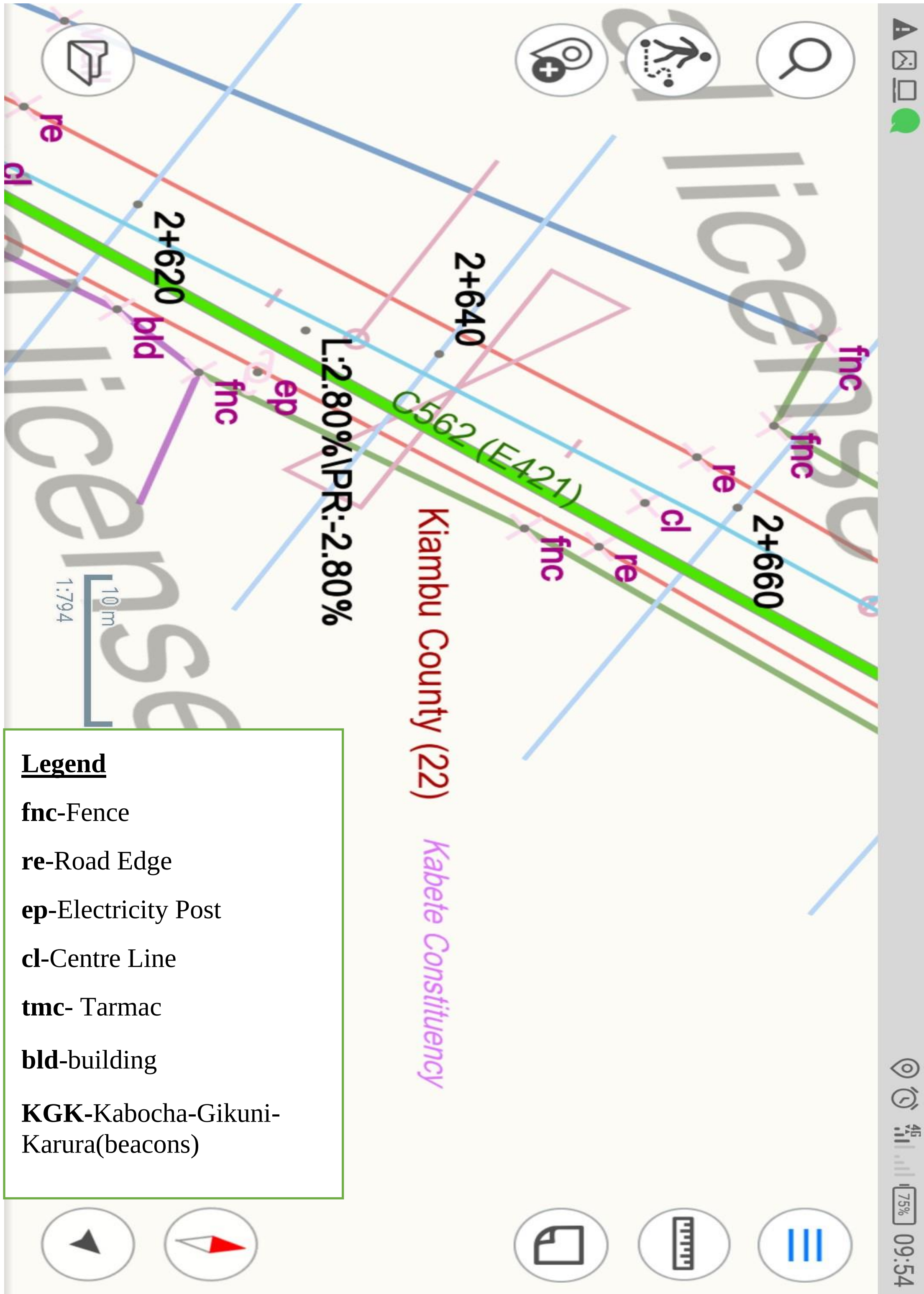


Figure 4.11: Road information integrated with Kenya road classification in CarryMap

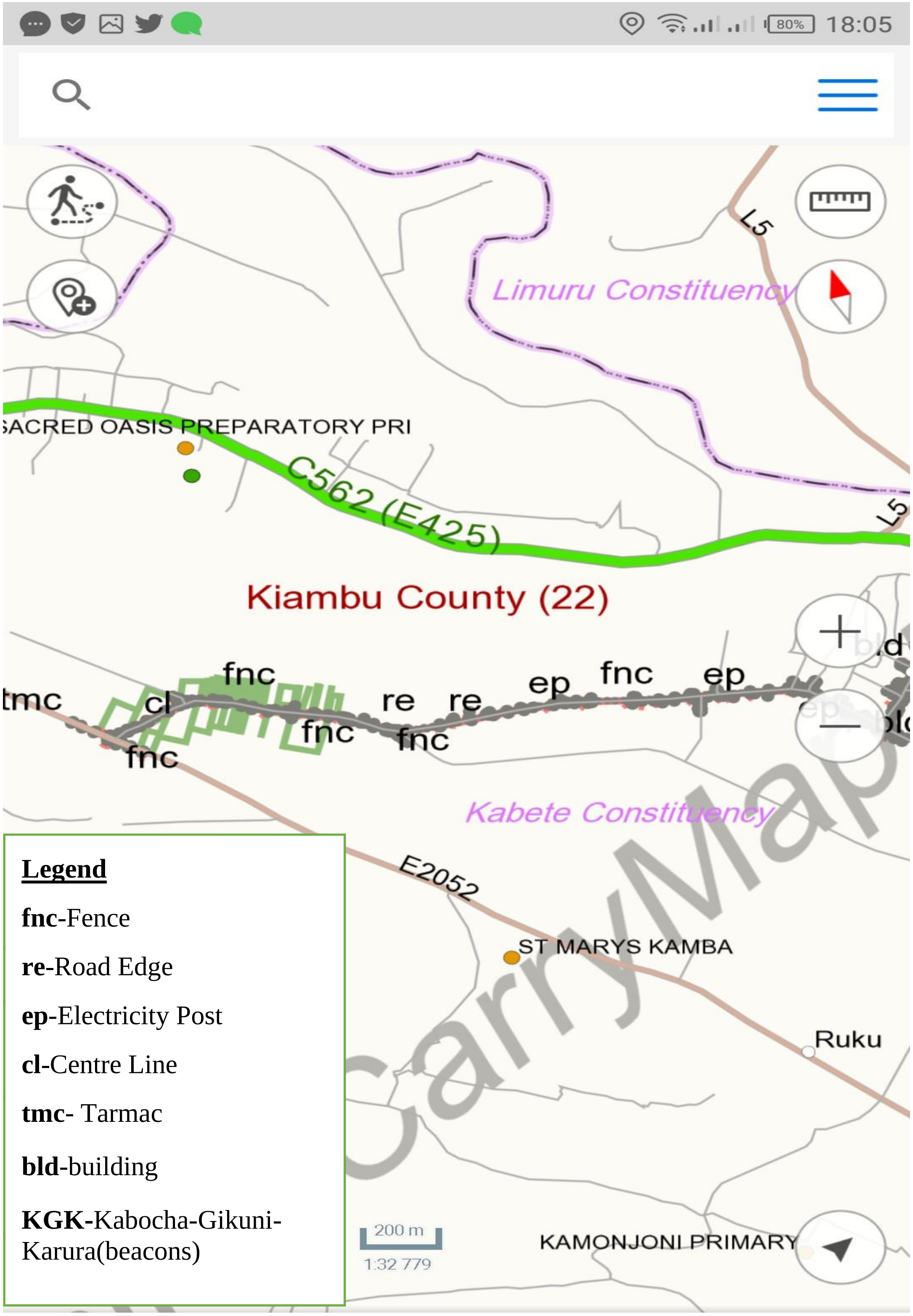


Figure 4.12: Road information integrated with Kenya road classification in CarryMap

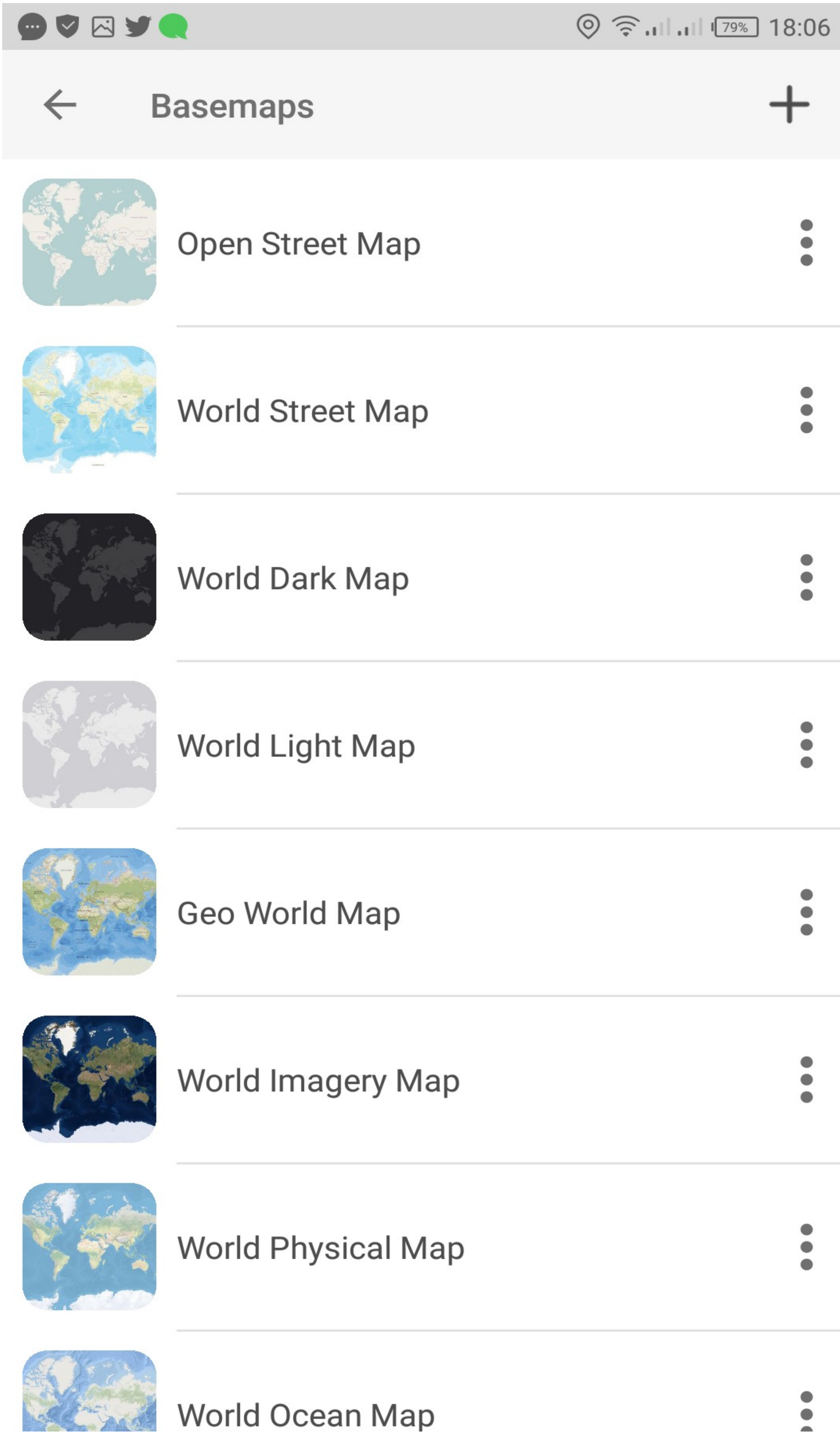


Figure 4.13: Adding the base map (World Imagery Map) to phone CarryMap application

The figure 4.14 below shows between chainage 4+880 and 4+900 there is a curve because the design shows there is a super elevation of -4.00% on Left Hand Side and 4.00% on the Right Hand Side.

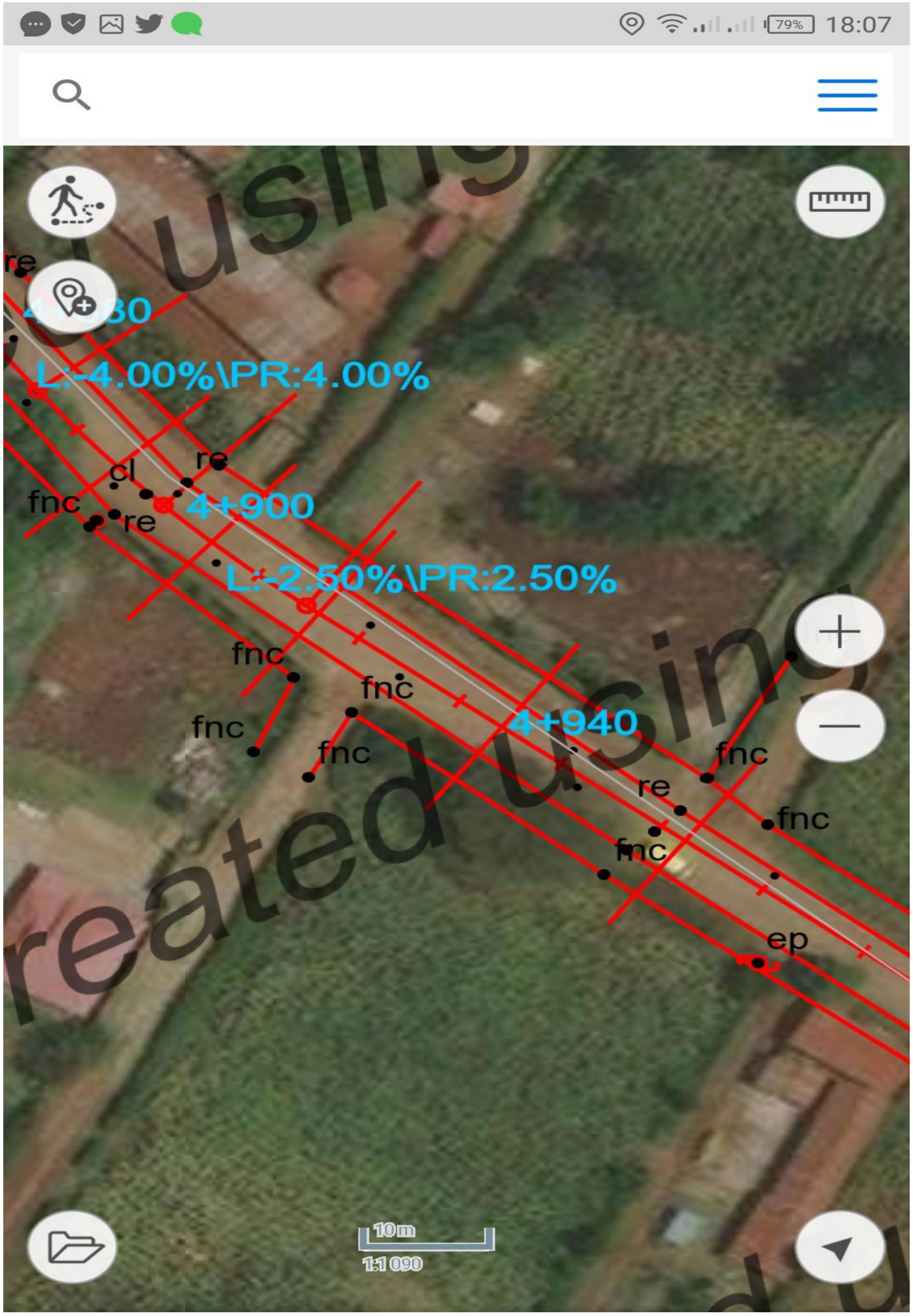


Figure 4.14: Integrating road information with World Imagery Map on phone CarryMap application

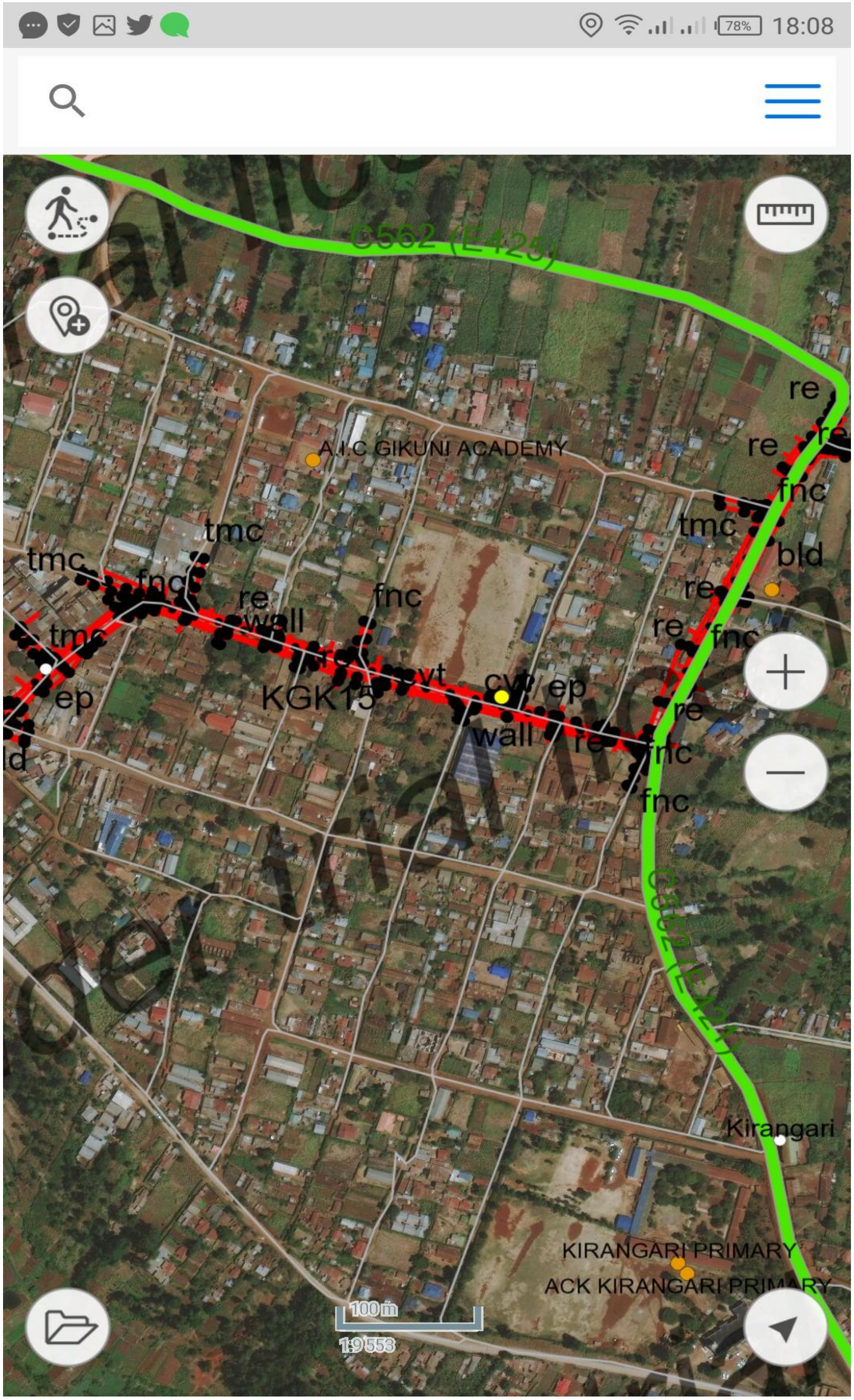


Figure 4.15: Integrating road information with World Imagery Map at Gikuni town Centre

The plot can be seen are on line with fences on the world imagery. The plots were digitized from Registry Index Maps (RIM). Shown below;

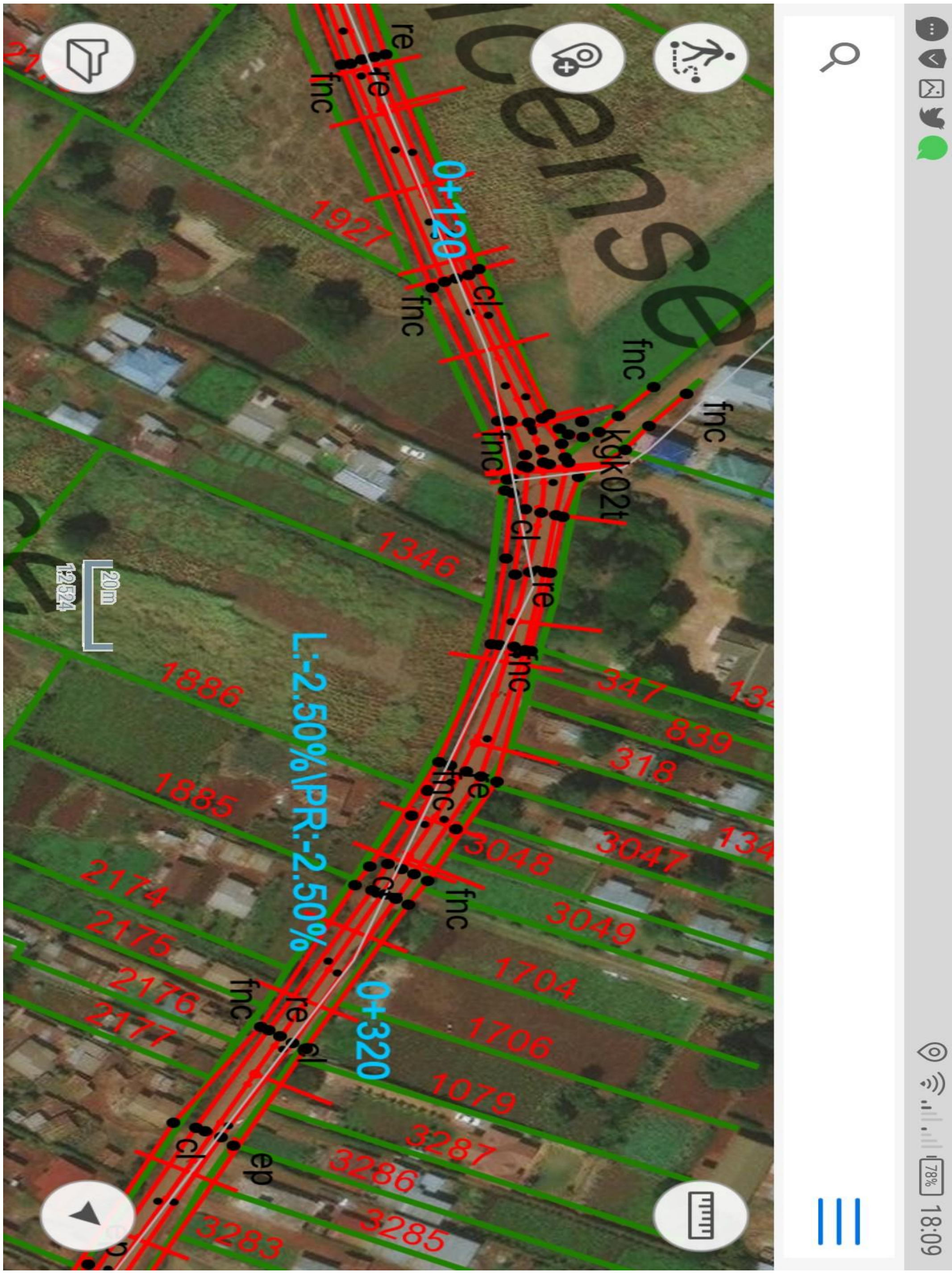


Figure 4.16: Integrating abutting plots with World Imagery Map on phone CarryMap application

When the road was selected it show the road classification as shown below.

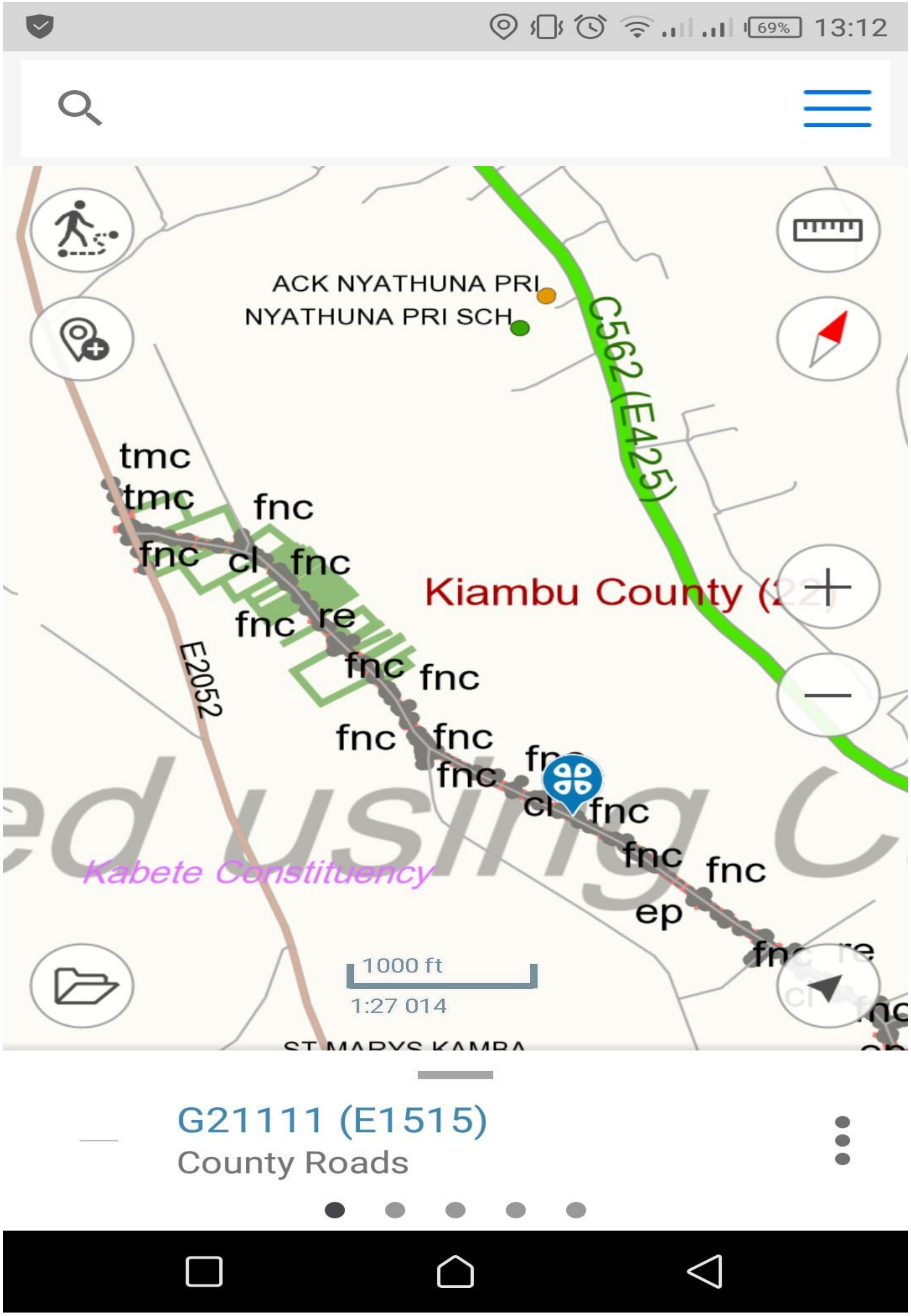


Figure 4.17: The study road classification (G21111) on phone CarryMap application

The figure 4.18 bellow shows my location pushpin on the road where you can be able to tell at which chainage you are and what features of the road design are at that exact location. For example, the location pushpin shows the surveyor was between chainage KM 5+420 and 5+440, it also shows that there is a road beacon KGK32 and on right hand side of the road there is a wall.

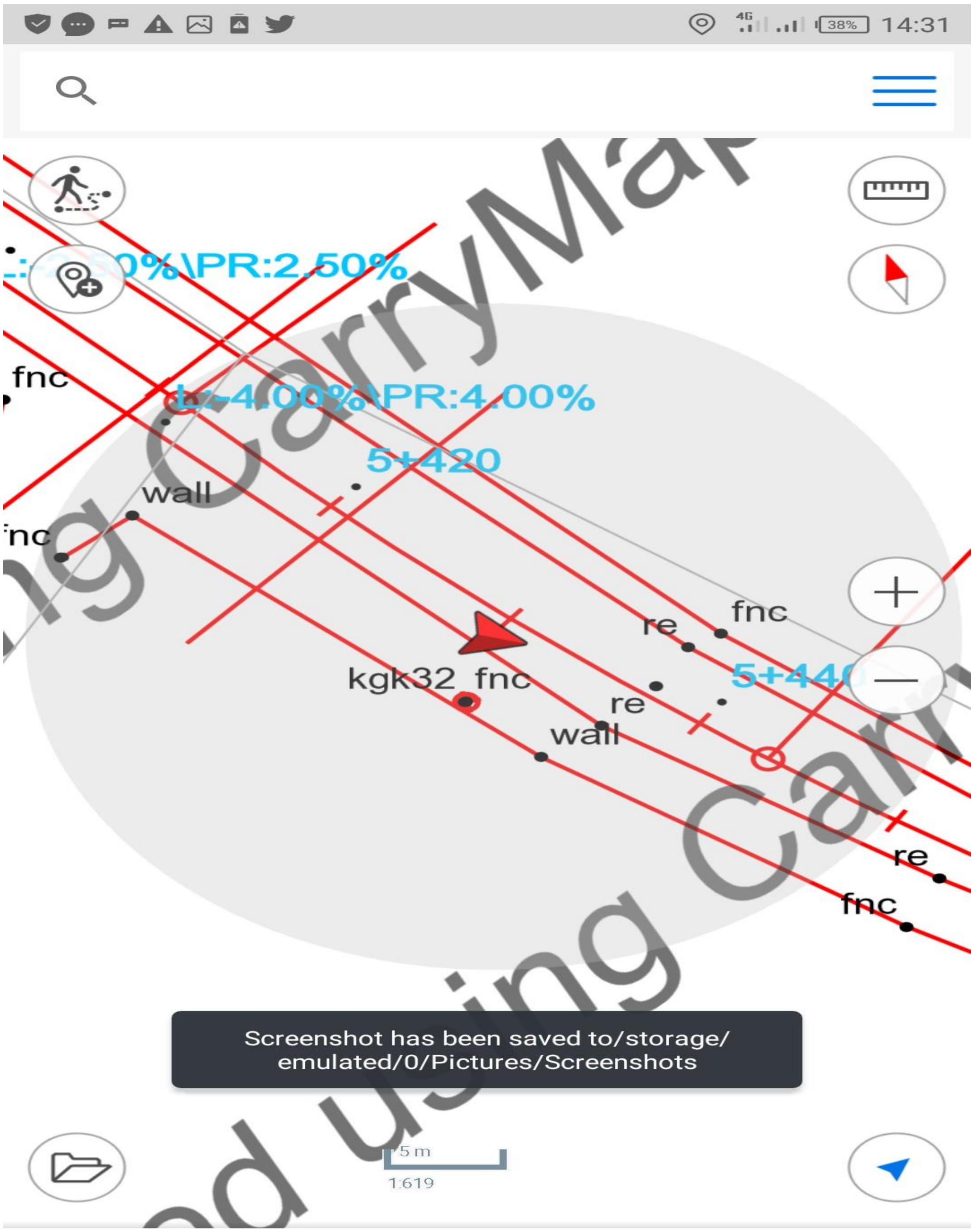


Figure 4.18: The pushpin location on phone CarryMap application

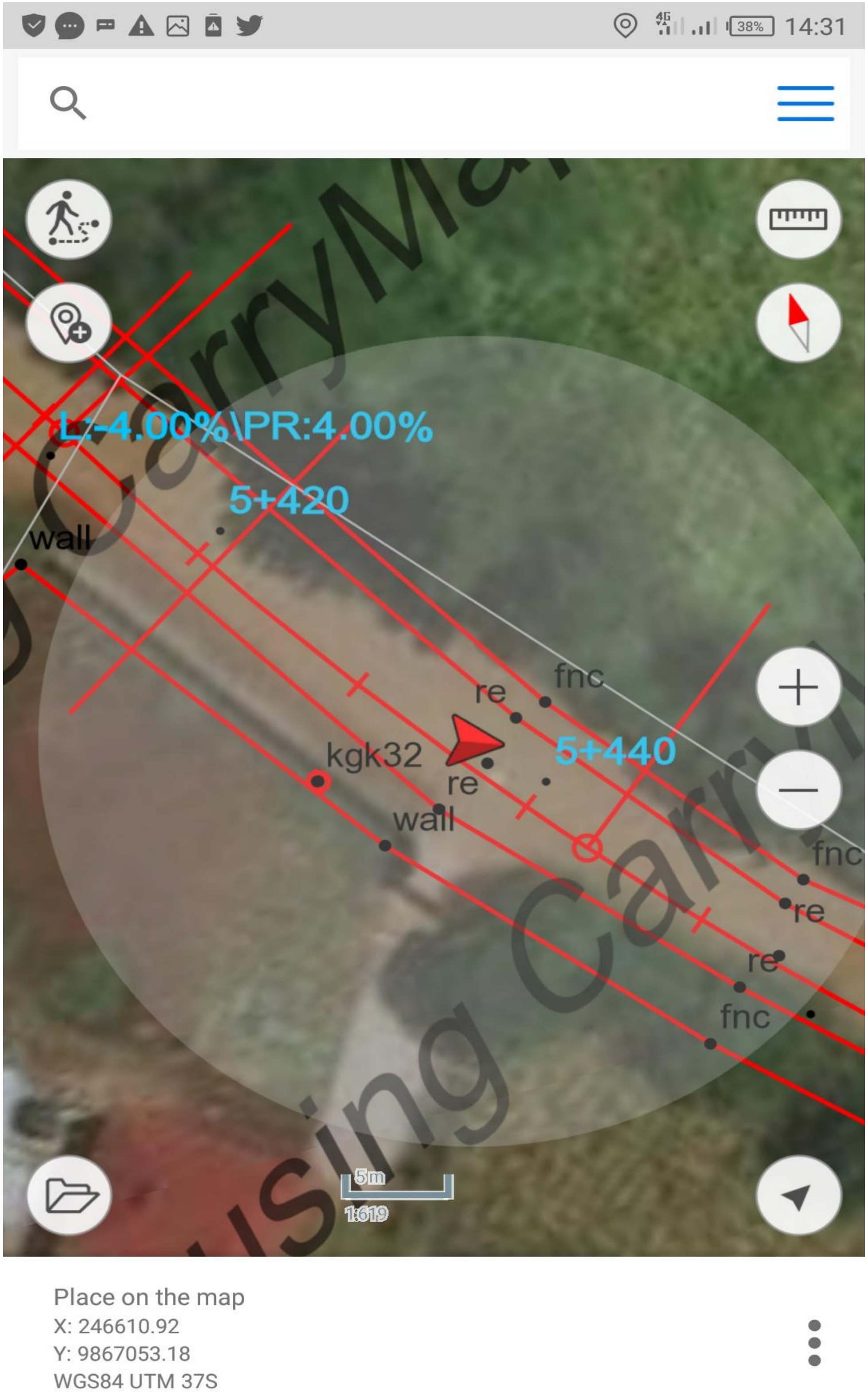


Figure 4.19: The location pushpin on World Imagery Map integrated with road information

4.4. Discussion

Along the road corridor, there were areas that needed the fences to be aligned with the land parcel boundary while in some areas there were minor encroachments on the road reserves. There was no existing case of encroachment to the road reserve by the owners. Facilities such as electric posts however some were located on the road reserve thus the need to be removed by the managing authorities that is Kenya Power Company, either before or during the road construction.

Navigation using the application was easy since the application makes use of the device's GPS system and the navigation tool on the application. Distances from one station to the next or in between features could be measured. This allows for estimation of distances to be covered to the problematic area. A push pin is used to mark area of interest on the map. This allows for easier navigation to the problem identified on the project.

There are various users of road data that need this kind of a map to be readily available to them upon visiting the site. This data can be made available through the web and on the users' mobiles devices by just downloading the application and be granted access to the data by the data administrator. The interoperability of various datasets adds value to the data and makes work easier. This will reduce on costs and users time is bound to be saved by development of this system.

It is evident that adding road design and road features to CarryMap add value to the users from road agencies they can now view road designs in the mobile phone rather than just using CarryMap to view only road classification and measure distances.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This project achieved its major objective of integrating the road design information with Kenya Roads Classification Map in CarryMap. The road design alignment in AutoCAD was successfully done through development of the road chainages and elevation data which include both camber and super elevation. Mapping of existing road reserve was successfully done and it was noted that encroachment of road reserves was very minimal (see Figure 4.8) with majority of the areas having fences that needed to be aligned with the road reserve boundary. Few electric posts have to be moved and no existing structure is to be destroyed during construction.

Georeferencing the cadastral maps and digitizing with existing road reserve was successfully done and the results were displayed in the CarryMap. All road information was then integrated with CarryMap and Kenya New Roads Classification map and were displayed in mobile phones and tablets.

To conclude, before the integration of road information efforts, only CAD users could access the majority of detailed information about a construction project. With CAD data now integrated into GIS, Users can more easily access project information and compare it to known information on the ground. The surveyors can also quickly create maps for customers who seek more information about a construction site and its surroundings. Minimizing fieldwork reduces travelling and accommodation expenses. When a worker does not have to travel to a job site because she or he can answer a question using integrated CAD and GIS data, the savings are apparent. Besides, when CAD data are accessible in a GIS environment, it allows stakeholders to identify potential issues with transportation projects earlier in the design process. Individuals who experience these and other benefits will likely share the use of new technologies or strategies with colleagues.

5.2. Recommendations

1. The Ministry of Roads should adopt to this technological improvements' road information representation on smart phones or tablets instead of using hard copy maps and designs. This road information can be easily be shared among all road agencies and interested individuals. The Road agencies individuals for example KeRRA engineers and Surveyors will be able to communicate with exactness of the linear location and features along the road they are interested in.
2. The Kenya Power Company are also recommended to use this initiative because it gives the exact coordinates of the electricity pole where they need to be relocated, there will be no need to waste time and resources to go to the filed to do an inventory they will be just be given a CarryMap file with all road information. This road information will show them where the pole is located, is it within the road reserve or outside and they will make a decision based on the information provided.

3. The road agencies and the Ministry of Transport, Infrastructure, Housing, Urban Development and Public Works should educate or teach individuals on how to use the application while they visit the site. The road agencies should buy CarryMap builder licences for all road projects in Kenya and train site surveyors on how to use it. Road agencies in conjunction with the Ministry of Roads should encourage the use of the application by educating staff and various stakeholders on the importance of using CarryMap application during site visits and assessment of works and buying of licences for all road projects in Kenya.

4. There are other phone applications that can be used such as; locus GIS offline Geodata collecting/SHP edits, Landgrid Map and Survey Property, LandGlide etc. but use of CarryMap should be recommended because is very user friendly and very convenient.

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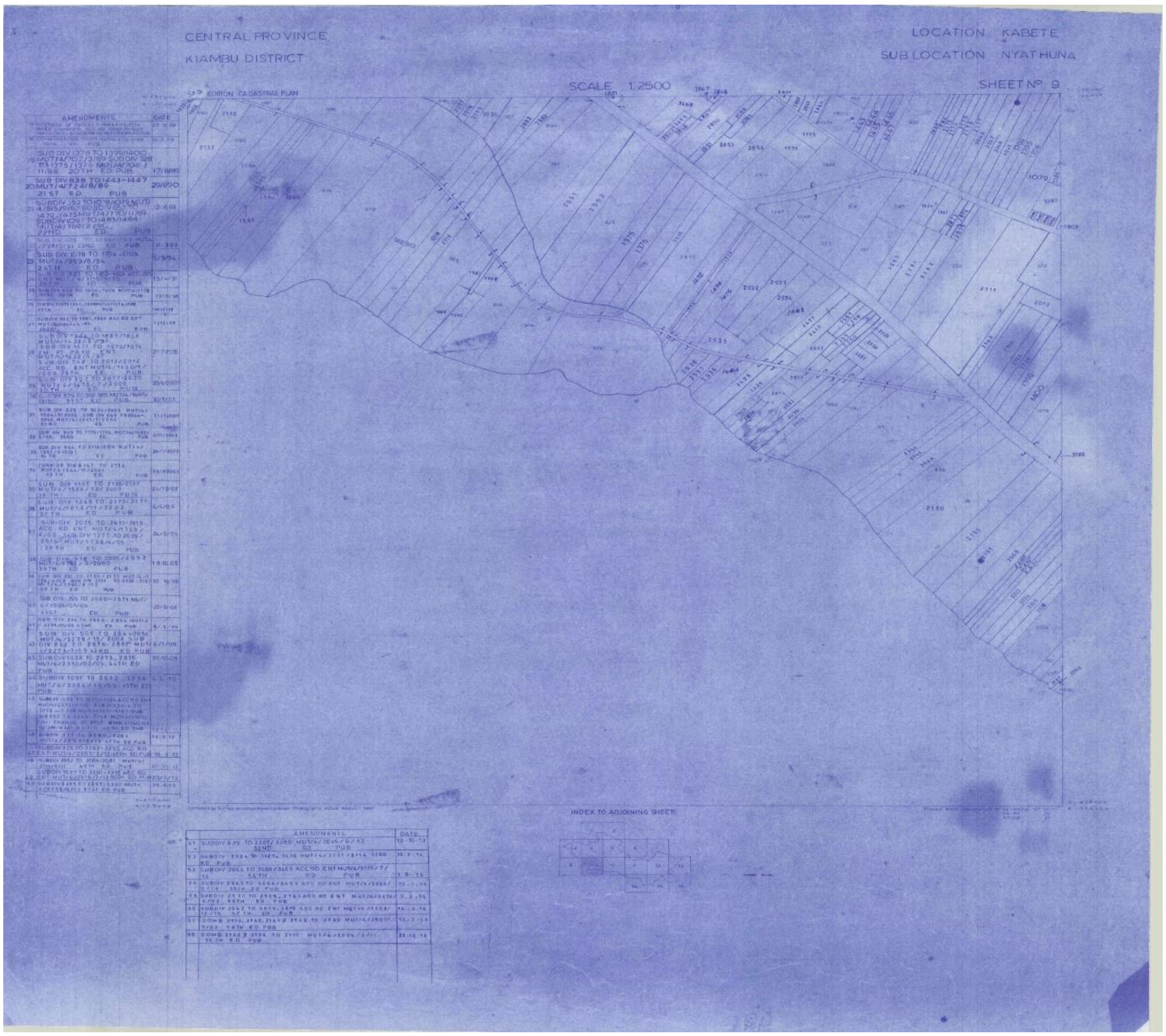
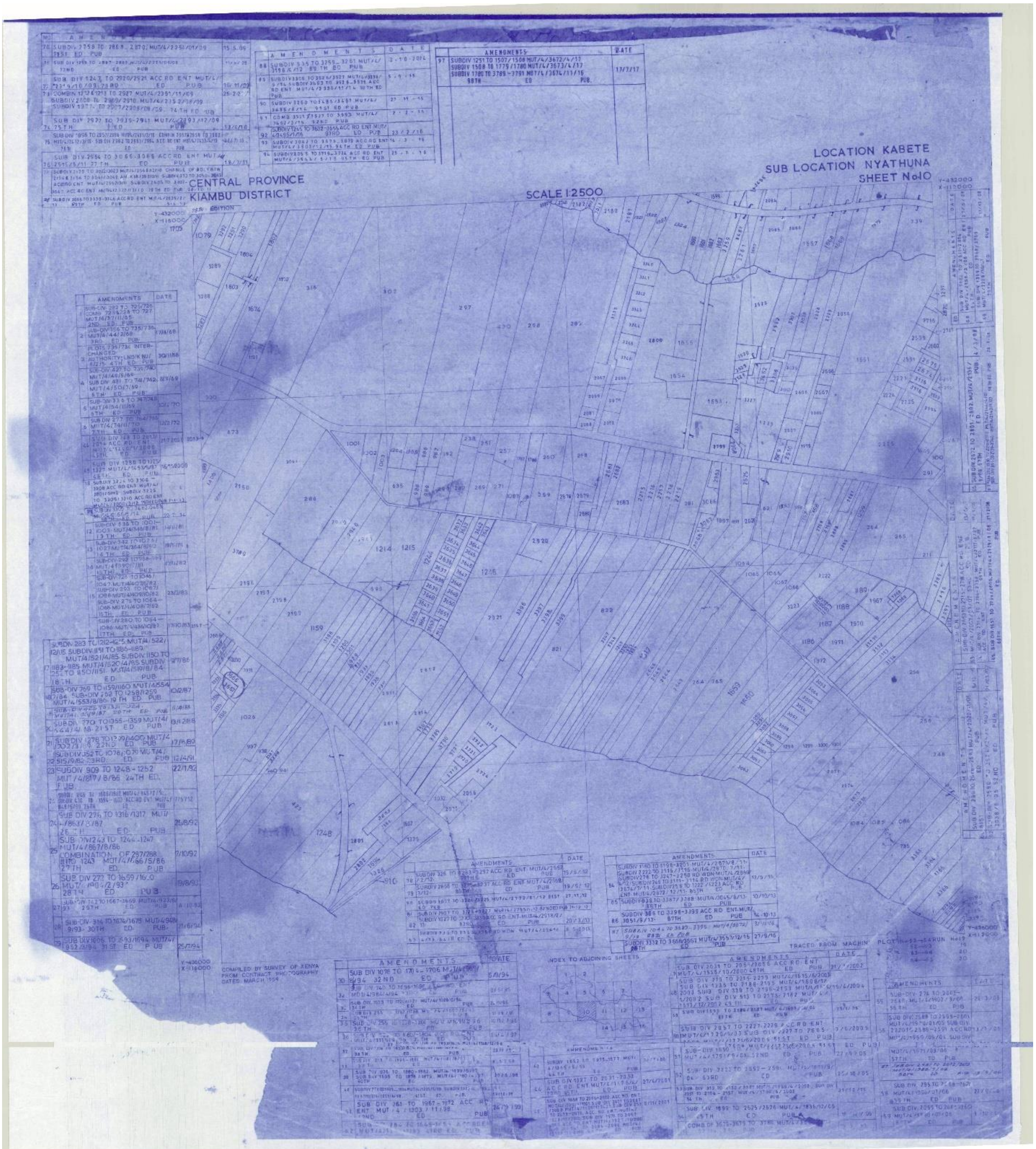
APPENDICES

Considering the length of the road data used that is Cadastral maps (RIMs), Topographical survey data and_Alignment Incremental Station Report were many for all to be put in the appendix. However, for the purpose of this research project appendix will contain two Cadastral maps sheets, four pages of topographical raw data and Alignment Incremental Station Report from KM 0+000-2+000.

APPENDIX A: Cadastral Map sheets



Kabete/Nyathuna Sheet 9



Kabete/Nyathuna Sheet 10

APPENDIX B: Topographical Survey Data

TOPOGRAPHICAL SURVEY DATA				
POINT	**EASTINGS**	**NORTHINGS**	**ELEVATION**	**DESCRIPTION**
1328	246608	9867222	1887.718	re
1327	246613.2	9867227	1887.783	re
244	246611	9867225	1887.787	cl
1326	246592.5	9867242	1887.965	re
1107	246598.4	9867239	1888.051	re
659	246591.8	9867232	1888.167	fnc
1108	246594.6	9867235	1888.195	re
144	246596.5	9867236	1888.254	cl
925	246594.3	9867245	1888.291	fnc
1325	246589	9867239	1888.299	re
243	246591.3	9867241	1888.353	cl
658	246599.6	9867240	1888.36	fnc
1106	246575.3	9867258	1888.389	re
1105	246571.1	9867253	1888.422	re
657	246576.1	9867258	1888.618	fnc
382	246586	9867239	1888.618	ep
143	246573.8	9867256	1888.637	cl
1324	246557.1	9867266	1888.675	re
37	246570.4	9867252	1888.707	bld
67	246587.1	9867236	1888.746	bld
1323	246560.1	9867270	1888.879	re
923	246560.9	9867273	1888.91	fnc
242	246558.7	9867268	1888.968	cl
656	246569.4	9867252	1888.973	fnc
924	246555.7	9867263	1889.087	fnc
1104	246540.7	9867286	1889.125	re

TOPOGRAPHICAL SURVEY DATA				
POINT	**EASTINGS**	**NORTHINGS**	**ELEVATION**	**DESCRIPTION**
1103	246537	9867282	1889.262	re
654	246534.5	9867281	1889.302	fnc
655	246541.4	9867287	1889.452	fnc
142	246538.3	9867284	1889.47	cl
329	246535	9867281	1889.49	ep
1102	246518	9867306	1889.7	re
1101	246514.4	9867303	1889.704	re
381	246517	9867297	1889.894	ep
141	246515.8	9867304	1889.934	cl
1321	246500.8	9867316	1890.012	re
653	246519.3	9867308	1890.017	fnc
1322	246504	9867320	1890.114	re
1320	246494.5	9867332	1890.172	re
652	246511.9	9867301	1890.174	fnc
241	246503	9867317	1890.179	cl
1319	246489.7	9867329	1890.181	re
240	246492.6	9867330	1890.304	cl
921	246498.7	9867314	1890.46	fnc
1531	246486.8	9867328	1890.615	wall
922	246505.2	9867321	1890.815	fnc
649	246470.9	9867354	1891.032	fnc
1445	246484.6	9867332	1891.039	KGK 32
1474	246484.6	9867332	1891.041	kgk32
920	246484.6	9867332	1891.045	fnc
1318	246464.8	9867370	1891.053	re
1495	246474.3	9867346	1891.071	wall
919	246496	9867333	1891.186	fnc
1317	246469.8	9867372	1891.235	re

TOPOGRAPHICAL SURVEY DATA				
POINT	**EASTINGS**	**NORTHINGS**	**ELEVATION**	**DESCRIPTION**
917	246471.3	9867374	1891.459	fnc
239	246467.5	9867371	1891.475	cl
918	246462.3	9867368	1891.583	fnc
1315	246452.8	9867391	1891.622	re
1316	246456.9	9867393	1891.776	re
916	246458.1	9867394	1891.778	fnc
651	246470.7	9867345	1891.786	fnc
238	246454.8	9867392	1891.795	cl
650	246467.3	9867346	1891.811	fnc
915	246449	9867390	1892.247	fnc
1100	246437.4	9867427	1892.469	re
1099	246432.9	9867425	1892.51	re
140	246435	9867426	1892.532	cl
1314	246422.6	9867441	1892.796	re
1313	246426.6	9867443	1892.941	re
647	246429.6	9867423	1892.98	fnc
237	246424.7	9867442	1893.02	cl
648	246438.5	9867427	1893.127	fnc
1098	246402.9	9867463	1893.175	re
1473	246432.4	9867437	1893.231	kgk31
1444	246432.5	9867437	1893.232	KGK 31
914	246419.9	9867439	1893.571	fnc
913	246427.5	9867444	1893.589	fnc
1312	246400.7	9867472	1893.628	re
1097	246406.4	9867467	1893.638	re
139	246404.9	9867465	1893.711	cl
1311	246397.3	9867469	1893.802	re
236	246399.1	9867471	1893.975	cl

TOPOGRAPHICAL SURVEY DATA				
POINT	**EASTINGS**	**NORTHINGS**	**ELEVATION**	**DESCRIPTION**
646	246408.6	9867453	1894.057	fnc
910	246389.9	9867458	1894.08	fnc
645	246407.1	9867469	1894.16	fnc
1310	246381.7	9867480	1894.27	re
911	246393.8	9867466	1894.302	fnc
912	246401.7	9867474	1894.325	fnc
1309	246385.1	9867484	1894.408	re
1308	246371.6	9867487	1894.491	re
235	246384	9867482	1894.54	cl
909	246379.2	9867478	1894.632	fnc
234	246372.1	9867490	1894.758	cl
1307	246373.3	9867492	1894.782	re
1096	246359.2	9867493	1894.806	re
907	246369.8	9867484	1895.003	fnc
908	246386.5	9867486	1895.023	fnc
1095	246360.4	9867498	1895.044	re
138	246360.2	9867495	1895.06	cl
1094	246348.6	9867496	1895.07	re
1093	246349.8	9867501	1895.103	re
137	246349.1	9867498	1895.241	cl
644	246357.4	9867489	1895.293	fnc
906	246374.2	9867494	1895.452	fnc
1472	246369.6	9867496	1895.507	kgk30
1443	246369.6	9867496	1895.533	KGK 30

APPENDIX C: Chainages Coordinates

Alignment Incremental Station Report

Prepared by:
Client: Mutura
Date: 06/11/2020 08:42:08
Alignment Name: kabocha-gikuni-karura-cl
Description: chainages coordinates
Station Range: Start: 0+000.00, End: 5+588.11
Station Increment: 20.00

Station	Northing (M)	Easting (M)	Tangential Direction
0+000.00	9868282.73	241725.77	N56° 44' 20"E
0+020.00	9868290.09	241744.23	N76° 50' 17"E
0+040.00	9868294.64	241763.70	N76° 50' 17"E
0+060.00	9868299.05	241783.21	N79° 07' 47"E
0+080.00	9868303.38	241802.73	N75° 49' 49"E
0+100.00	9868308.83	241821.97	N72° 31' 52"E
0+120.00	9868315.25	241840.91	N70° 54' 19"E
0+140.00	9868321.79	241859.81	N70° 54' 19"E
0+160.00	9868328.33	241878.71	N70° 54' 19"E
0+180.00	9868334.88	241897.61	N70° 54' 19"E
0+200.00	9868339.36	241916.98	N89° 34' 26"E
0+220.00	9868336.65	241936.77	S80° 30' 12"E
0+240.00	9868333.25	241956.48	S78° 26' 43"E
0+260.00	9868328.12	241975.80	S71° 51' 39"E
0+280.00	9868320.82	241994.41	S65° 16' 36"E
0+300.00	9868311.74	242012.23	S62° 23' 42"E
0+320.00	9868302.47	242029.95	S62° 20' 12"E
0+340.00	9868293.17	242047.65	S62° 16' 43"E
0+360.00	9868283.86	242065.35	S62° 13' 13"E
0+380.00	9868274.53	242083.04	S62° 09' 44"E
0+400.00	9868265.18	242100.73	S62° 06' 15"E
0+420.00	9868256.34	242118.66	S64° 41' 06"E
0+440.00	9868247.99	242136.84	S65° 59' 16"E
0+460.00	9868240.06	242155.20	S67° 17' 27"E
0+480.00	9868232.55	242173.73	S68° 35' 37"E
0+500.00	9868225.44	242192.43	S69° 13' 33"E
0+520.00	9868218.10	242211.03	S67° 41' 45"E
0+540.00	9868210.26	242229.43	S66° 09' 56"E
0+560.00	9868201.94	242247.61	S64° 38' 07"E
CHAINAGES COORDINATES			
Station	**Northing (M)**	**Easting (M)**	**Tangential Direction**

0+580.00	9868193.13	242265.57	S63° 06' 19"E
0+600.00	9868183.66	242283.18	S60° 15' 21"E
0+620.00	9868173.43	242300.37	S58° 15' 26"E
0+640.00	9868162.62	242317.19	S56° 15' 31"E
0+660.00	9868151.19	242333.60	S50° 13' 16"E
0+680.00	9868138.77	242349.28	S52° 59' 40"E
0+700.00	9868127.34	242365.67	S59° 59' 39"E
0+720.00	9868119.66	242384.08	S74° 44' 30"E
0+740.00	9868116.76	242403.83	S85° 37' 49"E
0+760.00	9868115.24	242423.77	S85° 37' 49"E
0+780.00	9868113.71	242443.71	S85° 37' 49"E
0+800.00	9868112.19	242463.65	S85° 37' 49"E
0+820.00	9868110.71	242483.60	S86° 48' 56"E
0+840.00	9868110.12	242503.59	S88° 21' 44"E
0+860.00	9868109.55	242523.58	S88° 21' 44"E
0+880.00	9868108.97	242543.57	S88° 21' 44"E
0+900.00	9868108.40	242563.56	S88° 21' 44"E
0+920.00	9868107.83	242583.56	S88° 21' 44"E
0+940.00	9868107.26	242603.55	S88° 21' 44"E
0+960.00	9868106.69	242623.54	S88° 21' 44"E
0+980.00	9868105.94	242643.53	S87° 15' 01"E
1+000.00	9868104.91	242663.50	S86° 51' 14"E
1+020.00	9868103.74	242683.46	S86° 27' 28"E
1+040.00	9868102.44	242703.42	S85° 42' 03"E
1+060.00	9868100.94	242723.37	S85° 42' 03"E
1+080.00	9868099.44	242743.31	S85° 42' 03"E
1+100.00	9868097.94	242763.25	S85° 42' 03"E
1+120.00	9868096.00	242783.16	S82° 50' 00"E
1+140.00	9868092.94	242802.92	S79° 33' 34"E
1+160.00	9868088.76	242822.47	S76° 17' 08"E
1+180.00	9868083.96	242841.89	S76° 08' 13"E
1+200.00	9868079.17	242861.31	S76° 08' 13"E
1+220.00	9868074.38	242880.72	S76° 08' 13"E
1+240.00	9868069.58	242900.14	S76° 08' 13"E
1+260.00	9868064.79	242919.56	S76° 08' 13"E
1+280.00	9868060.00	242938.98	S76° 08' 13"E
1+300.00	9868055.21	242958.39	S76° 08' 13"E
1+320.00	9868050.42	242977.81	S76° 08' 13"E
1+340.00	9868045.62	242997.23	S76° 08' 13"E
1+360.00	9868040.89	243016.66	S77° 09' 49"E
1+380.00	9868036.92	243036.26	S79° 54' 18"E
CHAINAGES COORDINATES			
Station	**Northing (M)**	**Easting (M)**	**Tangential Direction**

1+400.00	9868033.88	243056.03	S82° 38' 48"E
1+420.00	9868031.24	243075.85	S81° 24' 48"E
1+440.00	9868028.02	243095.59	S80° 04' 10"E
1+460.00	9868024.43	243115.26	S79° 43' 24"E
1+480.00	9868020.86	243134.94	S79° 43' 24"E
1+500.00	9868017.29	243154.62	S79° 43' 24"E
1+520.00	9868013.72	243174.30	S79° 43' 24"E
1+540.00	9868010.15	243193.98	S79° 43' 24"E
1+560.00	9868006.59	243213.66	S79° 43' 24"E
1+580.00	9868003.02	243233.34	S79° 43' 24"E
1+600.00	9867999.45	243253.02	S79° 43' 24"E
1+620.00	9867995.88	243272.69	S79° 43' 24"E
1+640.00	9867992.31	243292.37	S79° 43' 24"E
1+660.00	9867988.75	243312.05	S79° 43' 24"E
1+680.00	9867982.62	243331.02	S63° 56' 00"E
1+700.00	9867971.41	243347.51	S47° 40' 16"E
1+720.00	9867956.91	243361.27	S42° 52' 00"E
1+740.00	9867942.25	243374.88	S42° 52' 00"E
1+760.00	9867927.60	243388.48	S42° 52' 00"E
1+780.00	9867912.94	243402.09	S42° 52' 00"E
1+800.00	9867898.28	243415.69	S42° 52' 00"E
1+820.00	9867883.62	243429.30	S42° 52' 00"E
1+840.00	9867868.96	243442.91	S42° 52' 00"E
1+860.00	9867854.30	243456.51	S42° 52' 00"E
1+880.00	9867839.64	243470.12	S42° 52' 00"E
1+900.00	9867824.98	243483.72	S42° 52' 00"E
1+920.00	9867818.32	243500.75	N64° 57' 01"E
1+940.00	9867833.81	243513.03	N33° 31' 26"E
1+960.00	9867850.48	243524.07	N33° 31' 26"E
1+980.00	9867867.15	243535.12	N33° 31' 26"E
2+000.00	9867883.83	243546.16	N33° 31' 26"E