



**MODERN GEODETIC 2D AND 3D CADASTRAL MAPPING-A CASE
STUDY OF ARAT KILO CAMPUS**

BY:

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Abstract

This study used satellite Global Positioning System and optical ground-based total station positioning system in an integrated approach to determine a modern geodetic measurement based 2D and 3D cadastral system for Addis Ababa University Science Faculty usually called Arat kilo campus. This provides a parcel-based land and cadastral property spatial and non-spatial registration with a tie to an absolute and global geodetic positioning reference system. Previously, cadastral land property registration was determined traditionally on a paper map using simple architectural drawing that describes the relative location of a particular land parcel and properties on it with respect to a well known locality names (e.g., street name, building name, etc) – the old cadastral system has no spatial component. Now, with the advent of GPS positioning system and optical total station this conventional cadastral system which has been based on non-spatial parcel based registration becomes obsolete.

The modern cadastral registration system has to tie the non-spatial administrative cadastral component to its corresponding spatial component. The new approach uses GPS receiver and optical total station to map the 2D and 3D representations of the cadastral properties. GAMIT/GLOBK was used to eliminate the errors from GPS observations to establish first order cadastral surveying fundamental control points accurate to centimeter level. This provides a unique opportunity to establish a well distributed high accuracy (~ 5cm) second order cadastral surveying control benchmarks using optical total station measurements with a tie to the first order GPS-based survey control points so as to carry out high resolution 2D and 3D cadastral mapping. The combined GPS and Total station surveying techniques have registered the 2D and 3D spatial information of about five cadastral properties occupying an area of 34376 square meters. 26% of the 2D cadastral registration corresponds to buildings, while 1%, 1%, 2%, 1% corresponds to Green area, playground, walkway and asphalt road respectively.

Table of contents

Acknowledgements.....	i
Abstract	ii
Table of contents.....	iii
List of Figures.....	vi
List of Tables	vii
List of Appendices	viii
Acronyms	ix
Chapter One.....	1
1. Introduction.....	1
1.1 Background.....	1
1.2 Thesis Motivation.....	4
1.3 Objective.....	4
1.4 Thesis outline	6
Chapter Two	7
2. Cadastral System	7
2.1 Definition and Concepts of Cadastral System.....	7
2.2 Type of cadastre	7
2.2.1 Fiscal Cadastre.....	7
2.2.2 Legal Cadastre	8
2.2.3 Multipurpose Cadastre	8
2.3 Cadastral Surveying	8
2.3.1 Total station for cadastral surveying.....	9
2.3.2 Global positioning system (GPS) for cadastral surveying	10
2.3.3 Photogrametry for cadastral surveying	12
2.4 The cadastral map	13

2.4.1 Cadastral Map elements/contents	13
Chapter Three	14
3. History of Cadastre in Ethiopia	14
3.1 General	14
3.2 Basic component of cadastre in Ethiopia	19
3.2.1 Right of ownership	19
3.2.2 Right of lease	21
3.2.3 Right of Servitude	22
3.2.4 Joint ownership	23
Chapter Four	24
4. Cadastral data model.....	24
4.1 Introduction.....	24
4.2 Real estate object	25
4.2.1 Land	25
4.2.2 Property.....	25
4.3 Person	25
4.4 Rights, Restrictions, Responsibilities (RRRs) on land.....	25
4.5 Current core data model	26
4.5.1 Legal property object	26
4.5.2 Spatial identifiers	27
4.5.3 Regulating legal property objects using spatial identifiers	28
4.5.3.1 Topological relationship	28
4.5.3.2 Spatial relationship	28
4.5.3.3 General relationship.....	28
4.5.3.4 Vertical relationship	29
4.6 Framework for modeling 2D and 3D cadastral system.....	29

Chapter Five	33
5. Research Methodologies and Design.....	33
5.1 Research Methodologies	33
5.1.1 Planning.....	34
5.1.2 Choice of the Reference ellipsoid.....	34
5.1.3 Method of capturing data by using Total station.....	41
5.2 Research Design.....	44
5.2.1 Reconnaissance.....	44
5.2.2 Establishing control points	44
5.2.3 Detail measurement	45
5.2.4 Data downloading by using Leica geo office	45
5.2.5 Mapping and digitizing data by using ArcGIS software.....	45
Chapter Six	46
6. Result and Discussion.....	46
6.1 Introduction.....	46
6.2 The study area	47
6.3 GPS Data Processing.....	48
6.4 GPS coordinates transformation to local NEU	49
6.5 Establishment of Traverse	50
6.6 Spatial data analysis	53
6.6.1 Data collection.....	53
6.6.2 Spatial analysis	53
6.6.3 Digital map production using ArcMap 2D and 3D map.....	58
Chapter Seven.....	62
7. Conclusions and Recommendations	62
References	63

List of Figures

2.1: Components of Total Station	10
2. 2: GPS segments	11
4. 1: Conceptual model of the cadastral system	24
4. 2: Cadastral Data Model	31
4. 3: Spatial Package in current cadastral data models	32
5. 1: Flow chart showing the scheme for constructing cadastral map	34
5. 2: Three-dimensional transformation	37
5. 3: Cartesian coordinates X, Y, Z and ellipsoidal coordinates ϕ , λ , h (left) and N, the radius of curvature in the prime vertical (right)	38
5. 4: Global and local-level coordinates	40
5. 5: Measurement quantities in the local-level system	41
5. 6: Formula for calculation of coordinate by using total station	42
5. 7: Formula for calculation of height by using total station	43
5. 8: Formula for calculation of building height by using total station	43
6. 1: Map of the study area with relation to Ethiopia	47
6. 2: Traverse on bench mark	51
6. 3: 2D cadastral map of Arat kilo campus	59
6. 4: 3D cadastral map of Arat kilo campus	60

List of Tables

3. 1: Summarized status of the cadastre in the 4 regional capitals as reported in 2006.....	18
5. 1: Transformation parameter to change WGS 84 to adindan	35
6. 1: The estimated NMRS and WRMS on North, East and Up of the continuous IGS stations ..	48
6. 2: The sigma on the new control points	49
6. 3: conversions between different coordinate system on particular datum (WGS84)	50
6. 4: Coordinate of the control points in Adinda	50
6. 5: Shows the adjustment applied to the coordinates of the benchmarks in closed traverse loop.	51
6. 6: Number of bench mark and cadastral measurement	53
6. 7: Lists of cadastral properties surveyed with their name, their height, their area and their perimeter.....	55
6. 8: Spatial area of different cadastral property categories	57

List of Appendices

A: Symbology standard.....	67
B: The Translation of Minilik's Law Granting Security of Tenure	68
C: Shows the detail description of different cadastre instruments and methods use today with the accuracy and the cost.....	71
D: Set-up for GPS for the establishment of control points.....	71
E: Set-up and measurement procedures in Total station for detail measurement and bench mark.	72
F: Data downloading using Leica Geo office	72
G: Mapping the Data Using ArcGIS Software	73
H: Plotted control points by GAMIT software	74
I: Collected data for Arat Kilo campus to produce cadastral map.....	76
J: Working in arc scene	88
K: Sky plot of the continuous IGS station and new point	89

Acronyms

2D	Two Dimensions
3D	Three Dimensions
ASPRS	American Society for Photogrammetry and Remote Sensing
CSA	Central Statistic Agency
DCDB	Digital Cadastral Databases
EMA	Ethiopian Mapping Agency
EPLAUA	Environmental Protection, Land Administration and Use Authority
FIG	Federation of International Geodesists
GAMIT	GPS Analysis at Massachusetts Institute of Technology
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Position System
GTZ	German Technical Support
MCs	Master Control Station
NMRS	Normal Mean Root Square
PPM	Parts Per Million
RMSE	Root Mean Square Errors
RRRs	Rights, Restrictions and Responsibilities
SIDA	Swedish International Development Agency
SNNP	Southern Nation Nationalities of Peoples
UDSS	Urban Development Support Service

USAID United State Agency for International Development

UTM Universal Traverse Mercator projection

WGS84 World Geodetic System 1984

Chapter One

1. Introduction

1.1 Background

A modern geodetic 2D and 3D cadastral mapping has to be based on a land parcel registration system that can potentially provide an up-to-date and accurate land and land related information.

Cadastre is normally a parcel based and up to date land information system that ties a geometric descriptions of land parcels to other records describing the nature of interests, the ownership or control of those interests, and often the value of the parcel and its improvement (FIG, 1995).

Cadastre provides up-to-date information about property location, ownership, value and attributes of land in a given jurisdiction, state or country (Larsson, 1990 (a)). A properly organized and regularly maintained land registration/cadastral system provide security and clarity with respect to the legal status of land.

A well functioning Cadastre/land information system is useful for effective management of land and setting appropriate land related policies, coordination efforts of different agencies. For instance, a matured cadastre system is used for fiscal purpose (e.g. valuation and equitable taxation), legal purposes (conveyance), to assist in the management of the land and land use (e.g. for planning and other administration purposes, and enable sustainable development and environment protection) (FIG, 1995).

According to Pankhrust, the land situation throughout much of the Middle Age in Ethiopia was influenced by the absence of a permanent capital city, a factor that prevented to a greater extent the emergence of urban property in land management until the establishment of Gonder around 1636. Several short-lived capitals such as Lalibela, Debrebrehan, etc. existed only for a few reigns. A real breakthrough came only after the establishment of Addis Ababa as the capital city of the country in 1886 (Pankhrust R. , 1966).

The first recorded land registration and cadastral survey in Ethiopia was initiated in Addis Ababa in 1907. However, there exist early local land measuring indications (e.g. kelad, Gasha, Hudad, Tmad, etc.) that show the existence of traditional land measurement in the early history. But there is no documented record/study to show the outline.

Even though, there was a sporadic effort to establish a cadastral system sometime ago in Addis Ababa, as it is not updated for a long time, it is almost non-existent as a system until very recently. It was Emperor Menilik who issued a decree that brought legislation to initiate the country's first cadastral survey in Addis Ababa in 1909. Thus, landowners were to be given a certificate called “yrist woraqat” or “rist-paper” to be written in Amharic and French, plan/sketch with a map showing the boundaries of land parcels.

The Ethiopian cadastral system has textual and spatial components. Textual Component includes, but not limited to, the description of the land holder, family members, his address, bordering land holders, fertility status of the parcel, encumbrances if any and the like. The spatial component shows a graphical representation of the parcel together with parts of adjacent parcels and unique identifiers. The primary book of holding is issued without any formal plan. The size is described using local measuring units. Location is described by listing the bordering land holders in the east, west, north and south directions. Boundary description at primary book of holding stage can be said very general. For secondary book of holding coordinated digital maps will be attached. Boundaries are fixed. Plan can be produced using ground surveys or photogrammetry remote sensing tools as long as they can meet the accuracy needs of a specific holding type. Taxes are collected based on the information in the register book. The information in the register is also used for valuation which is needed for compensation purposes (Gebeyehu, 2011).

Up-to-now, cadastral mapping in Ethiopia is limited to urban areas. The urban cadastral plans of Ethiopia are not connected to any grid and most of them are still paper based. Where as in the rural areas there are no historical maps that can be used as a base for the new cadastre. The rural cadastre is at development stage. The strategy of the development of the new rural cadastre is to collect digital data from the beginning and to use variety of techniques and technologies to develop cadastral maps suitable for different holding types such as private holdings, communal holdings, state holdings and leased investment lands. The map contains title on the top, north arrow, the plan of the parcel and parts of the adjoining parcel together with major features such as road and foot paths, legend, scale bar, accuracy level, coordinate system and number of the kebele index map. The map also contains information how the right is obtained, the name and signature of the surveyor, the name and signature of who approved the map, the name and

signature of the chairperson of the kebele land administration committee, date area and reference file number (Gebeyehu, 2011).

A modern cadastral system needs to maintain correct and consistent information about the relationships between the owner and land parcel. Practicing of 2D cadastral system can be applied to urban and rural areas which show simple geometry. In essence, a 3D cadastral system is necessary to represent property (building) on the parcel of the land by adding its height. In practice this concept is not explicitly done. It is made implicitly. Hence, with the emerging economic growth of most developing countries and an over increasing population density there is a strong demand to adopt a 3D cadastral system.

According to the Ethiopian Civil Code (1960) (Art. 1211) Ownership of land shall have the right to use his/her lands extend from the center of the earth to the sky. But, Art. 1576 say that the registration and the description of each immovable property in the register of immovable shall be made according to the measurements and indications of the cadastral survey plan. The two dimensions in the legal status of property are made by the establishment and registration of rights and limited rights on the parcels. With a growing interest in using space under and above the surface, the vertical dimension becomes relevant in cadastral registration. To guarantee an efficient, sustainable, and uniform registration in the future using the combination of 2 D and 3D is necessary to establish a modern cadastral system containing all land related information available for the public use.

This thesis seeks to establish an accurate 2D and 3D cadastral conceptual models for Ethiopia where there is a limited practice of modern cadastral system. Practical experimental test is conducted in Arat kilo campus by new geodetic cadastral surveying technology to acquire spatial data for mapping every building, play ground, utilities, and roads in 2D and 3D context. This provides a unique opportunity to establish a unified modern cadastral system that is tied to a common datum or a well distributed geodetic horizontal and vertical position control network. The tasks of establishing such a unified cadastral system revolutionize the way parcel and its related information are communicated with a digital spatial base map allowing a real time access to huge datasets. Currently, there is a real need for the establishment of the modern geodetic 2D and 3D cadastral mapping system for Ethiopia. This will be discussed in detail in the next section (**section 1.2**).

1.2 Thesis Motivation

Due to a rapidly changing pattern of land-use driven by urban economic growth many urban land administrations in Ethiopia have got real challenge in managing land and processing land transactions. This causes inability to increase their revenue base, distortion of urban land market and delays in the implementation of urban development projects. The absence of reliable information regarding land related information is the most crucial impediment for the preparation and implementation of urban plans (Daniel, 2006).

In general, major anticipated problem in most urban infrastructure management system in Ethiopia is the lack of modern cadastre or land registration system. The use of an immature cadastre system will result in the following major problems:

- ✚ The amount of revenue collected from property tax is very low as compared to other sources of revenue.
- ✚ The sales of the houses and application for registration are not treated properly, thus encouraging illegal procedures of transactions.
- ✚ Significant proportions of the inhabitants do not have title or certificate of ownership to their property, which inhibit incentive to urban development.
- ✚ Land disputes do not get quick and legal solution.
- ✚ Squatter settlements or illegal constructions are increasing very alarmingly.
- ✚ Planning and implementing development projects is highly affected by lack of sufficient information and resources especially financial.

This thesis is aimed to develop a modern cadastral conceptual model that can solve the existing problem. Creation of an up-to-date and efficient Cadastral system can solve the above listed problems and other land related problems.

1.3 Objective

The main objective of the thesis is to establish a conceptual modern digital spatial cadastral system based on geodetic coordinate for mapping rural and complex urban land parcels and its associated real state property. It will provide an accurate geometric description of the boundary and location of land parcel and parcel related geo-database reflecting the ownership, property rights and interests. This provide a unique opportunity to create a common cadastral spatial information framework and an automated multipurpose cadastral system that can potentially

utilize legal status and basic opportunity of land development programs including land administrations, land management and environment protection and management.

The main strategy to establishing a digital spatial cadastral system is to provide an easy access to the integrated information system to create a cadastral conceptual model that show the existing legal land management policies in use by the Ethiopian government.

This thesis proposed both 2D and 3D geodetic measurement based on cadastral conceptual model to accurately map the land parcels and its related information. The 2D model is a planar area based representation of land parcels in digital form. It can be accurately used to design rural cadastral system and to map land parcels and building have simple geometry in the context of urban cadastral system. The 3D model is the representation of complex urban building by both area and elevation describing the space above the land parcels. Both 2D and 3D models ties cadastral boundaries and administration component from geodetic coordinate which create unified cadastral spatial information.

This geodetic measurement based cadastral system can be easily applied within a local controlled area to digitally map complex building, infrastructures thereby providing a unique opportunity to solve the real bottlenecked present cadastral practice in Ethiopia. The current practice of using the Global Positioning System coupled with conventional Total station geodetic surveying to develop 2D and 3D concept of a measurement based spatial cadastral system will be explored in depth.

The general objective of the case study is to produce a 2D and 3D cadastral map of Arat kilo campus of Addis Ababa University.

The specific objectives of the case study are:

- To combine GPS and Total Station for preparing a cadastral map referenced to geocentric and local datum.
- For mapping the geographic geometry of physical infrastructures found within Arat kilo campus.
- To register the available infrastructures with their respective current services.
- To know the exact location and property for maintenance.

- For further analysis and use as decision support.
- Preparation of navigation maps that can be used to provide services to the customers.
- Provide data for construction and investigations.

This thesis aims to provide sufficient theoretical and conceptual models that would be efficiently used in the planning and development of urban and rural cadastral system for Ethiopia by providing the following opportunities;

- ✚ Allow update cadastral mapping with the required accuracy and completeness.
- ✚ Provide a common geodetic spatial measurement based digital cadastral system.

1.4 Thesis outline

The thesis consists of seven chapters. The first chapter is an introduction which describes the definition, function and historical background of cadastral in Ethiopia. Also the motivation and the objective of the thesis are included in this chapter.

Chapter two deal about the cadastral system. Specifically it includes the definition, classification, cadastral surveying and cadastral map. Chapter three discuss about the history of cadastre in Ethiopia in detail and the basic component of cadastre in Ethiopia.

Chapter four deal about the cadastral data model used. Chapter five give the detail procedures (methodology) of the research from the beginning to the end.

Chapter six consist the results and discussions of the study. The last chapter (chapter seven) contains the conclusion of the study and some recommendations for the next work.

Chapter Two

2. Cadastral System

2.1 Definition and Concepts of Cadastral System

The word “cadastral” is derived from the French word called “cadastre”. Its actual origin is believed to be Latin word in which it means “capitostrium” or “Cato strum”, meaning “lead to register”. Cadastre is defined as a methodically arranged public land registration system that consists of land parcel description and its associated property information (Osterberg, 1990).

Usually, land parcel based property information contains ownership rights of land, location of parcels, physical description, size, value and record of right, restriction and responsibility on land, etc. Traditionally, a parcel is identified by a unique number and a paper archive in which property information on parcel was recorded (Jantien, 2004). With the advent of Global Navigation Satellite System (GNSS), Geographic Information System (GIS), modern surveying and computing facilities cadastral parcel information is no longer maintained on paper maps. The spatial component representing the exact geometry of land parcel and building on it is spatially linked with the administration part of the cadastral registration (e.g. ownership, rights, interest etc) providing an easy access, query and analysis to relevant and reliable cadastral information.

Many type of cadastral system exist based on country specific cadastral law, policies and management strategies. The next section will briefly explain the classification of cadastral system in use today.

2.2 Type of cadastre

Cadastre can be classified into three categories based on their use, type, quality and quantity of data encapsulated in it. Accordingly, the three types of cadastre are: fiscal, legal and multi-purpose. The purpose of these various types of cadastres vary depending on their specific nature as stated below:

2.2.1 Fiscal Cadastre

Fiscal cadastre is a record of information necessary for levying property taxes, which includes location and value of parcel. Frequently, the occupant of the parcel is identified for tax purpose, and no effort is made to determine the legal owner. Governments need income, which generally

is generated through some sort of taxes. One major resource in a country that can be taxed is land and land related properties. Thus, a fiscal cadastre must include enough information to calculate a value using certain valuation methods.

2.2.2 Legal Cadastre

Legal cadastre is a register identifying the legal owner and precise boundaries of each land parcel. Establishing a legal cadastre requires both fixing parcel boundaries through surveying and mapping, and fixing legal rights, which may involve negotiations among involved parties and a judicial determination of ownership (Adjudication). In other words, the legal cadastre deals with rights to use land.

2.2.3 Multipurpose Cadastre

A relatively new development that incorporates, at one source, the data concerning the legal and fiscal cadastre along with information on land use, infrastructure, buildings, soil and other factors. Each parcel must be assigned a unique identifier, so that all the information can be related to the same plot.

The basic information needed for development planning can be found from the legal or fiscal cadastral systems where they are kept up to date by concerned organizations. Instead of creating special information system for planning purpose it has in many cases proved favorable to develop cadastre into a multipurpose cadastre (Prime.Consultants.P.L.C., 2008).

The use of modern surveying technology has made such activity possible. Therefore, the cadastral surveying technologies used for the implementation of modern cadastral system will be discussed in the next section.

2.3 Cadastral Surveying

Cadastral surveying is a branch of the broader discipline of land surveying that deals with surveying activities relating to property boundary definition and certain associated rights. It involves the physical determination of dimensions, areas and position of rights associated with land properties.

Cadastral surveys are used to subdivide land into parcels for ownership under a land title, and to re-establish the boundaries of previously surveyed properties in order to establish the physical extent of ownership or facilitate the transfer of property title. In conducting a cadastral survey the

surveyor will refer to all relevant survey information, including plans and field notes of previous survey, legislation and legal interpretation and precedence. In the field, the surveyors will seek to use permanent marks and reference marks referred to in any previous surveys.

Proper functioning of cadastral surveying system has great role for land management. That is why; currently cadastral surveying and mapping efforts are taking place across Africa and developing countries at varying degree of success (Eric.c, 2006). In Ethiopia under the existing circumstances modern cadastral surveying methods are rarely utilized compared with other part of Africa like Kenya, Uganda, and Tanzania etc. However, in the last five years some efforts have been made by Governmental and Non-Governmental organization (USAID and SIDA) in some regional states of Ethiopia. (Amanuel, 2009).

2.3.1 Total station for cadastral surveying

Total station instruments can be used for map of cadastral properties effectively. In practice, it is used to establish surveying control benchmarks by traversing so as to make detail spatial measurement easier. Doing so, the total station can capture the spatial information about the size and relative location of geographic objects in a real time by measuring angle and distance to the target.

In addition to measuring distance and angle the total station measures and records the data electronically. The measured data can be directly stored into a computing system so as to make data processing and plotting easier.

In general, total station can perform variety of functions and computations depending on how they are programmed (see **Figure 2.1**). The capabilities vary with different instruments versions, but some standard competition includes:

1. Averaging of a multiple angle and distance observation
2. Correcting electronically observed distance for prism constant, atmospheric pressure, and temperature
3. Making curvature and refraction correction to their horizontal and vertical components
4. Calculating point elevations from the vertical distance components
5. Computing coordinate of surveyed point from horizontal distance and angle component

6. Reducing slope distances to their horizontal and vertical components (Ghilani & R.Wolf, 2008)

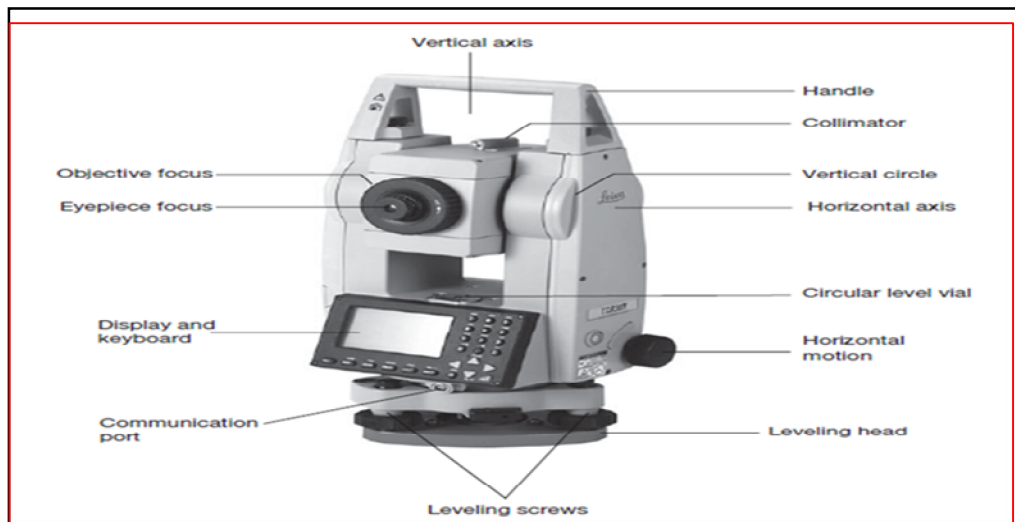


Figure 2.1: Components of Total Station

2.3.2 Global positioning system (GPS) for cadastral surveying

GPS consists of three segments: the space segment, the control segment, and the user segment (see **Figure 2.2**). The space segment consists of 24-satellite constellation. Each GPS satellite transmits a signal, which has a number of components: two sine waves (also known as carrier frequencies), two digital codes and a navigation message. The codes and the navigation message are added to the carriers as binary biphasic modulations. The carriers and the codes are used mainly to determine the distance from the user's receiver to the GPS satellites. The navigation message contains the coordinates (the location) of the satellites as a function of time. The transmitted signals are controlled by highly accurate atomic clocks onboard GPS satellites.

The control segment of the GPS system consists of a worldwide network of tracking stations with a master control station (MCS) located in the United States at Colorado Springs, Colorado. The primary task of the operational control segment is tracking the GPS satellites in order to determine and predict satellite locations, system integrity, behavior of the satellite atomic clocks, atmospheric data, satellite almanac and other considerations. This information is then packed and uploaded into the GPS satellites through the S-band link.

The user segment includes all military and civilian GPS receivers. With a GPS receiver connected to a GPS antenna, a user can receive the GPS signals used to determine his or her position anywhere in the world. GPS is currently available to all users worldwide at no direct charge.

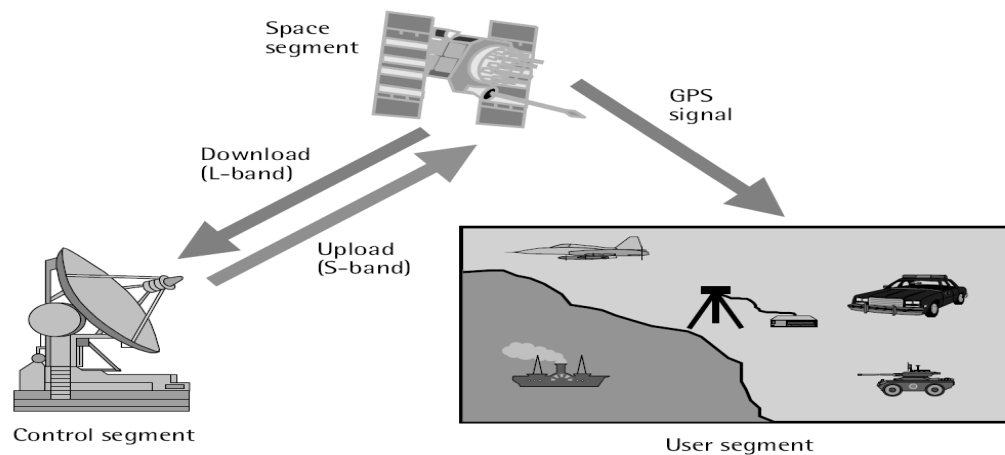


Figure 2. 2: GPS segments

The idea behind GPS is rather simple. If the distances from a point on the Earth (a GPS receiver) to three GPS satellites are known along with the satellite locations, then the location of the point (or receiver) can be determined by simply applying the well-known concept of trilateration.

Theoretically, only three distances to three simultaneously tracked satellites are needed. In this case, the receiver would be located at the intersection of three spheres; each has a radius of one receiver-satellite distance and is centered on that particular satellite. From the practical point of view, however, a fourth satellite is needed to account for the receiver clock offset.

Global Positioning Systems (GPS) have become more and more important for Earth science (e.g. disaster monitoring), geodesy, land surveying, cadastral surveying and maritime surveying, etc (Martin & Jahn, 2000).

Differential GPS technique can provide centimeter level accuracy in positioning using the so-called integer ambiguity resolution technique. The basic concept of differential technique is to mitigate the main error sources such as ionospheric and tropospheric delay, orbit errors and satellite clock errors by receiving satellite signals at a well known location. All common errors between base receiver and the rover are cancelled out (Landau, Vollath, Deking, & Palels, 2001).

GPS is very efficient and accurate enough for establishing cadastral survey control points. The use of GPS for detail cadastral surveying is not yet proven because of much satellite signal obstruction. In practice, GPS requires an open area with good satellite visibility in order to determine position of a particular cadastral property at least track four GPS satellites. Building and trees will block GPS radio signal propagation.

Therefore ,GPS provide an alternative to cadastral surveying approaches such as aerial photography or total station techniques, typically adopted in large scale land administration, titling and registration projects (Silayo, 1997).

With GPS it is now possible to obtain precise, timing and positioning information anywhere on the earth with high reliability in low cost .GPS do not require clear lines of sight between survey station. Generally, the objectives of GPS surveys are to locate points on the surface of the earth (Ghilani & R.Wolf, 2008).

Alternatively, electronically surveying techniques have become standard in the more developed world. The advantage of using such equipment includes:

- ✓ Speed with which surveys can be carried out compared with traditional method, thus giving greater level of productivity.
- ✓ The lower level of manipulative skills that are needed to obtain much higher level of precision and accuracy.
- ✓ The lower level of risk of making gross errors in the measurements.

2.3.3 Photogrammetry for cadastral surveying

The identification of land parcel boundaries using photogrammetric methods is considered as an alternative to ground based surveys. It is the fastest and cost effective particularly where a large number of parcel boundaries with good visibility had to be registered. It is highly flexible and can be adopted to meet widely varying requirements for accuracy, cost and type of products.

Generally aerial photos provide more extensive information than ground methods and require less manpower for the production of cadastral map. Photogrammetric methods are offering a form of graphic surveys. This gives accurate information about land from the integrated interpretation of aerial photographs and high accuracy photo control points survey results.

2.4 The cadastral map

Cadastral map is a map which provides detail information about real property within a specific area. For example, cadastral map of a village shows the boundaries of the parcels or lots with in that village. A Cadastral map can also include a number of details including information about tax rates, who owns the land, what kind of structures are present, what the zoning is in that village and so on.

One key features of cadastral map is that it carries detailed information about location. So, people can understand where everything is on the map. Maps are constructed using data acquired by field surveying methods such as total station, GPS and other cadastral surveying methods.

2.4.1 Cadastral Map elements/contents

The map consists of the following elements:

- **Map title:** It should be set a large bold text to stand out from other explanation in the map.
- **Map placement:** The placement of the map should be centered onto the frame of the map.
- **North or south orientation:** The orientation of the map should be north/south with north at the top of the page. If any other orientation is used remember to include a north arrow.
- **Identification of position of mapped:** there should be enough orientation features to ensure that map-readers can see what area has been mapped. Features, which are helpful include towns, roads, railways, rivers, coastline and borders. Grids must be placed on separate layers.
- **Map extent:** should be extended up to the net line of the map.
- **Map sheet size:** the size of the map that shows maximum resolution has to be selected. Some of the standard map sizes are: 75 x75, 80 x 60 cm, A0, A1, A.....A4.
- **Scale:** scale or numerical scale e.g. 1:50000 are essential.
- **Map reference/Ledged:** it has to describe all the spatial layers included to map cadastral properties.
- **Map symbol:** Has to describe the category of geographic objects (see for the detail **Appendix A**).

Chapter Three

3. History of Cadastre in Ethiopia

3.1 General

In previous chapter we looked at the cadastre in a general way and in this chapter we will present the historical development of cadastre system in Ethiopia. Therefore, this chapter introduces when and how the cadastre started in Ethiopia. A detail discussion will be presented on the cadastral practices to the centered on urban land management. A brief report of cadastral practice used for four urban will be presented. This chapter also introduces the stage of the current cadastral system in use by the Ethiopia government today. A 2D and 3D conceptual model will be proposed to better improve the performance of the present cadastral system so as to meet the nation interest.

The first proclamation related to urban lands was published at the regime of Minilik II in 1907. As indicated by Pankhrust (1966), it was Menilek II, who signed the country's first Proclamation related to urban lands at the end of 1907, which brought legislation stating a change in ownership of the city's land. This decree with 32 articles (see for detail **Appendix B**) provided, among others, procedures for the sale and registration of land with all the necessary legal and technical aspects to be fulfilled for the sale and registration of land holdings; procedures of taxation by the government; issuance of a certificate for purchase, fixing transfer tax; system of land purchase by foreigners; etc (Pankhrust R. , 1966).

It was decreed at the same time that on providing the proof/evidence that the land was 'rist' or private property, a contract of acquisition from the former ('rist owner) or a decree of gift from the Emperor or the church, the land owner was to be provided a certificate referred to as "yerist waraqet" or "rist" paper and a sketch showing the boundaries of the land-the rist paper was usually used to be written in Amharic and French. At the beginning, even though the decree ordered everybody to register his land and receive a certificate, the majority did not respond positively. Therefore, by late October 1921, the government issued a notice calling on those who had not registered their lands to do so, otherwise without a certificate they cannot sell, change, and mortgage their lands (Bahru, 1986). As a result in 1935 the registrations have been more or less completed and a total of 45,000 certificates were issued (Bahru, 1986). Among the

incentives to owners of land to register, Pankhurst (1961) cited the policy of the Bank of Abyssinia had given priority of mortgages only for a unit of land that is registered.

During the emperor Haile sellasie era, the existing cadastral registration has been reused to further improve the land registration and administration. During the reign of Haile Selassie I the Ministry of Land Reform and Administration was engaged in registering and measurement of rural land in collaboration with the Ethiopian Mapping Agency, until 1974. The purpose of the registration was to practice cadastral survey, create the system of free hold tenure, register individual title to land, and institute land sale (Hoben, 1973).

Land registration and tax assessment for urban centers in Ethiopia was carried out by the then Ministry of Interior until the creation of the Ministry of Urban Development and Housing after the 1974 Revolution. This sporadic attempt was carried out for the purpose of assessing and collecting land rent and building tax. The registration of land was to be carried out by the concerned municipalities of the urban centers and building tax assessment was done by professionals from the Ministry of Works and Urban Development until the overthrow of the “Derg” government and the establishment of Regional States of Federal arrangement (Pankhurst R. , 1961).

Around 1995 the City Administration of Addis Ababa decided to launch a cadastral project initially intended to register all property owners liable for property taxation and collect data that would enable the city administration to assess a value of a property more realistically. However, latter on the primary objective of establishing “a fiscal cadastre” enhanced and the objective of the project was changed aiming at establishing a “multipurpose cadastre” (Daniel, 2006).

The immature cadastral system is believed to be the general problems which lead to the initiation of the project in Addis Ababa. But, even if lack the of proper land information system is common to most developing countries, the problems associated with it and the reasons to establish an information system may differ from country to country. Accordingly, the four main problems and reasons, which initiated the establishment of the Ethiopia cadastral or land information system apart from the general problems, are:

a) Poor service delivery in land management & administration, especially in services related to :

- ✚ Registration of transactions,
- ✚ Building permits (maintenance & construction),
- ✚ Application for title deed & title book,
- ✚ Resolution of land disputes,
- ✚ Land use change application,
- ✚ Property taxation,
- ✚ Land supply.

b) The alarming increase of squatter settlement or illegal construction.

c) Due to lack of sufficient information it is impossible to plan and implement development projects.

d) Inadequate collection of property tax. As a result of inappropriate cadastral system, the city lacks the technical means to collect revenue from property taxes efficiently.

Even though, a step forward was achieved and some experiences were gained as a result of launching the cadastral project in Addis Ababa, it hasn't yet established a modern cadastral system. The following major problems were identified right from the start and during the project phase.

- ❖ The system lacked a feasibility study of any type, such as technical, economic, social or political and institutional feasibilities,
- ❖ The system lacked clear and updated legal base,
- ❖ No devices are so far set for the updating of the system,
- ❖ Cadastral system is not yet developed,
- ❖ No system is set as to how proper data flow between different organizations engaged in collecting land information has to take place,
- ❖ No system is developed as to how potential users will have access to available data,
- ❖ The effort made to make the public aware of the purpose, benefits and obligatory procedures of the system were not sufficient,

- ❖ The training programs carried out didn't meet the low, middle and high level manpower requirement for the system. Moreover, the training so far given was only limited on training related to some computer software,
- ❖ There is a problem of modern technical devices for different activities of the system,
- ❖ Lack of sufficient qualified manpower.

Thus, it can be concluded that in the city of Addis Ababa still a cadastral system is not yet matured and functional. Still land registration is voluntary for old occupants, while it is obligatory for new acquisitions. The management of registration lacks completeness in terms of spatial coverage, up datedness and accessibility (Daniel, 2006).

In general most cities in developing countries don't have a well established cadastral system. This is also true for most towns and cities found in Ethiopia. Since 1996, the UDSS/GTZ has task an initiative to assist the Ethiopian municipalities in establishing their own cadastral system. As a pilot study the UDSS has selected four towns including Nazareth, Awassa, Bahir Dar and mekele.

UDSS/GTZ played the leading role in promoting cadastre in the four mentioned towns among others, by providing material support, by organizing workshops and trainings, by evaluating the progress of the project in each city, and by giving technical advisory support. Even though, the rational in choosing these regional capitals as pilot areas to a cadastral project was justifiable, until now it was not possible to replicate the system to other urban centers in the country, since the project is still going on for more than 8 years.

The DHV Consultants inception report (2006) show that the cadastral project is still currently operational in Adama and paused due to various reasons in Bahir Dar, mekele and Awassa.

Table 3.1 taken from the same report summarizes the status of the project dated back to 2006.

Table 3. 1: Summarized status of the cadastre in the 4 regional capitals as reported in 2006

City	Start Date	% complete	# Parcels	Status	Remarks
Adama	1999	95%		ongoing due for completion early 2006	Original survey stalled; now being completed by a private contractor
Awassa	1998	75%	20,000	Paused pending reorganization	New project proposal prepared
Bahir Dar	1998	50%		Paused, HR & financial constraints	Some updating with lease subdivisions
Mekelle	1996	90%(spatial) 25% (a spatial)	35,000	Paused; pending new contract	New lease subdivisions being added

According to DHV Consultants (2006) project documents, the major goals of the cadastral projects were:

- a) Preparation of a digital cadastral base map to be updated constantly, and
- b) Establish an efficient land related tax collection system

However, based on the current status of the project one can speculate that these goals are less likely to be achieved due to various reasons that arose right from the inception and during the implementation of the projects. One of the major problems is lack of coordination in an effort to establish a cadastral system by integrating the UDSS experts with experts from local municipalities and stakeholders. This has resulted in a limited technology transfer to local experts consequent of this resulted in the implementation of an ineffective cadastral system.

For instance, Solomon (2002) has observed the following problems related to the implementation of the UDSS proposed cadastral systems.

- ✚ Less or no support from decision makers,
- ✚ Less or no adequate knowledge about cadastre and computers,
- ✚ Institutional and financial problems,
- ✚ Absence or weak central coordination (UDSS/GTZ),

- ✚ All the projects rushed to implementation without any project document,
 - ✚ Absence or lack of appropriate training,
 - ✚ Lack of qualified manpower,
 - ✚ Poor or no quality control mechanism,
 - ✚ Underutilization of modern instruments, and
 - ✚ Lack of capacity or initiative to create awareness at all levels or for all stakeholders
- (Solomon, 2002)

3.2 Basic component of cadastre in Ethiopia

The Ethiopia cadastral system consists of two parts. The first part contains a 2D geometrical description of land parcel and its associated property. It maintain the geometry and topology of the parcel, parcel number, building, building number and street names for reference purpose. With this classical approach it is difficult to generate a digital integrated objects and database that can easily provide reliable cadastral information. Hence, the present cadastral system has to be based on geodetic control points for measurement of land parcel boundaries and property on it using the modern Global Position System and Total station surveying technologies.

The second cadastral component contains legal and other administrative data related to parcels. At a moment, there is no dynamic link between the geometrical and administration components of the Ethiopian cadastral system. Here we proposed conceptual geodetic measurements based cadastral model for Ethiopia that can adequately integrate the two components together. This will create a unique opportunity to access, query, and analyze and edit the cadastral system that can potentially deliver relevant, reliable and up-to-date information to the end users.

It is essential to know what type of rights the people have on 2D or 3D component in legal perspective. These issues will be discussed in detail in the next sections.

3.2.1 Right of ownership

According to the Article 1211 of Book 3 of the Ethiopia Civil Code the right of ownership includes the following:

- Inclusive use of the right of space above the parcel;
- Ownership of the earth layers beneath it;
- Ownership of buildings and constructions forming a permanent part of the land

The most extensive right that a person can have is the use right of ownership in Ethiopian civil code. The ownership to a parcel includes the competence to use the land owned. This includes the space above and under the parcel to a height and depth to which the user has (possible) interest. The use of space above and under the surface is permitted to owner, as long as this is sufficiently high or low, that the owner cannot reasonably object to this use or when this use is regulated by other laws, e.g. by the Law on Air-traffic which prescribes regulations for air-traffic or by the Law on Mining which provides the possibility to extract minerals in the ground of private owners by concession or permit. In principle, the right of ownership of land reaches from the middle of the earth up to the sky. Horizontal division of the volume enclosing the whole parcel column leads to 3D property units, which are bounded spaces to which persons are entitled by means of real rights. Restrictions may be imposed by regional and local land use plans, e.g. no more than five floors per building, be able to also restrict the owner in using his parcel (column). Restrictions according to regional and zoning plans are not registered in the cadastral registration.

Article 1214 of Book 3 of the Ethiopia Civil Code stated that buildings and other works constructed above or below a parcel of land or permanently united therewith may have a distinct owner. Consequently constructions under or above the surface that are permanently fixed to the surface are owned by the owner of the land unless other rights or restrictions have been established on the surface parcel. However, this is not a strict rule. The owner of a construction below or above the surface is not necessarily always the same person as the owner of the land parcel.

With a horizontal accession to real estate a factual horizontal division in ownership takes place. The legal status follows from the factual situation. Consequently, the legal status may change if the factual situation changes. The disadvantage of horizontal accession to real estate is that the legal status of the situation is not registered and therefore not clear in the cadastral registration. The horizontal accession to real estate might conflict with the definition of the right of ownership (vertical accession to real estate). According to the Civil Code the right of ownership contains all constructions that are permanently fixed to the parcel while in case of horizontal accession to real estate the owner of a parcel that intersects with a construction is not the owner of the construction. In principle, vertical accession always gets priority unless horizontal accession can be applied. It should be noted that the horizontal accession to real estate does not justify the

factual situation. For example it is not allowed to build a construction by taking another parcel without permission of the owner of the parcel.

3.2.2 Right of lease

Following the 1994 constitution, Ethiopia has adopted a federal state structure which devolved much of its legislative, juridical and executive powers to the nine semi-autonomous regions. The 1994 constitution clearly states the right to ownership of urban and rural land is vested with the state; citizens occupy land through leases. Leases are established without time limit in the rural sector, and usually limited to 99 years or less in urban areas. The tenure system is evolving differently in the rural and urban sectors, with different federal proclamations governing development and reforms progressing at different speeds in different regions.

Rural land is held by individuals through “lifetime leases”, i.e. these are possession rights which are equivalent to leases without a fixed termination date which can be transferred through inheritance. Recent legislation also allows exchange and sublease, allowing a secondary market to begin to emerge. In practice, the secondary market is yet to emerge in the rural sector and the emphasis is still on the first registration process (first and second level certificates). Land matters are expedited through executing agencies established at the Regional, Zone, Woreda and Kebele levels.

In the urban sector, land is occupied through permits and through leases. Fixed term leases are replacing permits. Leases are held for up to 99 years depending on the type of land occupied (residential, commercial etc). In the urban sector, there is already a strong secondary market established for sales, where properties are sold at “market rates”, accompanied by a transfer of the underlying lease (sub lease). The municipal authorities are responsible by law for maintaining registries of leases and thereby facilitating and regulating land use which include urban cadastres (ORGUT, 2010).

The legal status of constructions below or above the surface can also be established with a right of lease. Right of the lease is a juridical instrument which is sometimes used in 3D situations, however this right is not specifically meant for 3D situations. The right of long lease includes the

surface parcel as well as space below and above the parcel including the buildings that are fixed to the parcel.

Again the geometry of the space to which the right applies is not maintained in the cadastral registration and can only be specified in a drawing attached to the deed. The geometry of the 2D right itself is not known in the cadastral geographical data set, nor, in the administrative database. The only place where information could be found on the factual situation is in the deeds archived in the Public Registers which may be accompanied by scanned and paper drawings.

3.2.3 Right of Servitude

Servitude is a charge encumbering a land, hereinafter called the servient tenement, for the benefit of another land, hereinafter called the dominant tenement. An example of this is when an owner of parcels, “A” can reach the public road easier by crossing the parcel of his neighbor, “B” rather than crossing his own parcel.

Article 1359 of Book 3 of the Ethiopia Civil Code stated that Servitude imposes on the owner of the servient tenement the obligation to submit to the commission of some acts by the owner of the dominant tenement or to refrain from exercising some rights inherent in ownership. Servitude may be created by agreement between the dominant and servient owner.

Servitude shall be of no effect on third parties unless it has been entered in the register of immovables at the place where the servient tenement is situated. The vertical dimension of a right of easement can be relevant, for example when a right of Servitude is established for a bridge above the serving parcel or for a pipeline that crosses a parcel. It is also possible to establish a right of easement for having a building on a serving parcel. In all these cases, the registration would be improved firstly by registering the existence of the Servitude as limited real right in the cadastral database, and secondly by a 3D visualization of the space where the right applies.

3.2.4 Joint ownership

The Ethiopian civil code article 1610 state that where all the joint owners or several of them are interested in the act, the indication "immovable jointly owned" shall be entered in the form, and a reference be made in the complementary and supporting documents to a document establishing the state of joint ownership of the immovable. This is a right to land and/or a construction that can be registered similar to common area as in condominiums. This immoveable thing arises when an immoveable thing is joint owned by the owners of two or more properties and where it is designated by them for the common benefit of those properties by a notary's deed between them.

Joint ownership comprises the obligation of each joint owner to give the other joint owners access to the property held in joint ownership. Property held in joint ownership must be maintained, cleaned and, if necessary, renewed at the expense of all joint owners. A joint owner of a property held in joint ownership may transfer his share in the property to the other joint owners separately from his property. This characteristic is why joint ownership is in some cases favored above registration by means of condominium by which it is not possible to transfer shares separately from the property (apartment unit). A specific cadastral characteristic of joint ownership is only registered on a parcel and not linked to a subject.

Chapter Four

4. Cadastral data model

4.1 Introduction

The development of cadastral information system is based on a specific method of data modeling that aimed to manage interests in land. Identification of the main data elements in land administration subsystem assists to reengineering the existing data models to respond quickly to modern land administration requirements (Simsion, 2005).

The current administrative cadastral data model is based on three key types: real estate object, person (subject) and right or restriction. Real estate objects are parcels and apartment rights. Persons are persons or organizations with rights on parcels. Beside rights, there could be a 'restriction' relationship between a real estate object and a person, since a person is a subject of a restriction.

The core of any cadastral data model is the relationship between real estate objects (e.g. Parcel, apartment or condominium) and persons (sometimes called Subjects) via rights and restrictions. Real estate objects and persons have many-to-many relationships via rights and restrictions (see **Figure 4.1**). A person can have rights related to more than one real estate object (e.g. a person can own three parcels) and one real estate object can be related to more than one person (e.g. one person is bare owner of a parcel and another person has the right of superficies on the parcel) (Oosterom, B. Maessen, & Quak., 10-12 August 2000). Every person in the registration should be associated with at least one real estate object and vice versa; every real estate object should be associated with at least one person.

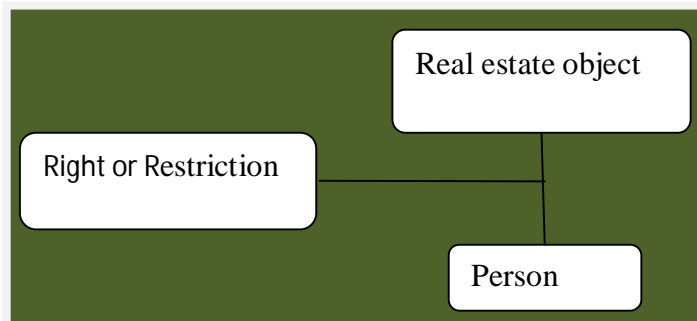


Figure 4. 1: Conceptual model of the cadastral system

4.2 Real estate object

4.2.1 Land

The definition of a parcel varies according to the jurisdiction. For practical purposes, a parcel is a closed polygon on the surface of the Earth (United Nations, 2004). Although the land parcel is identified as the building block of each land administration system, it might have originally been recorded by non-cadastral organizations. So far, cadastral data models relied on land parcels as their foundation. However, land parcels are a fallible organizing tool, lacking sufficient flexibility to incorporate the increasing number and diversity of interests in land.

4.2.2 Property

A property has different meanings in different countries and is often used in conjunction with land parcels (Stuedler, Williamson, & Rajabifard, 2004). In practice, a property is often defined as the building(s) associated with land. A property consists of one or more adjacent or geographically separate land parcels. A parcel can contain several properties. A Land parcel is related to property in a one- to- many, many- to -one or one- to- one relationship. Multiple interests can exist on a property and the attached interests can be shared between two or many holders in separate titles. Properties usually play a greater role in valuation and taxation data models. However, properties, similar to land parcels, are not flexible enough to provide an effective means for organizing interests in land.

4.3 Person

Interests can be held by individuals or groups of individuals, legal persons (organizations such as companies or cooperatives), or by governments (including municipalities). However, historically land registries were involved in registration of private ownership of various interests in land. This trend led most land administration systems to keep separate records of the public and private interests in land. Now, modern land administration requires an integrated and holistic treatment of land including a seamless registration of titles to all public, government and private interests (Bennett, Williamson, & Wallace, 2005).

4.4 Rights, Restrictions, Responsibilities (RRRs) on land

RRRs are intangible concepts that deal with a tangible object such as a piece of land. Land affected by RRRs can be divided into many parts. For instance, the possession of land and a right

of a way over it. The division of land into separate identifiable RRRs can be realized by sharing of the ownership of various rights, occupancy, tenancy or lease. This means the RRRs are broken into smaller parts in which there may be a multiplicity of interested individuals.

RRRs can be presented both spatially and non-spatially. The rights to give, sell or lease land to someone is recorded in non-spatial databases that is linked to individual land parcels. Whereas the rights of land use or right of a way is considered as a spatially physical entity on the surface of the Earth regardless of their configuration in relation to or connection with a specific land parcel-their existence is not necessary subject to any land parcel. Incorporation of RRRs remains an important issue in cadastral data modeling processes.

4.5 Current core data model

Two changes are proposed in order to re-engineer the current core data model. The first change involves the use of legal property objects, not physical land parcels as the basic building blocks of land administration. This facilitates incorporation of a broader range of RRRs and land related commodities into the cadastral fabric. The second is to make the spatial referencing system as a basic component of the cadastral information system by using it to identify property objects. This change promotes interoperability and simplicity in data exchange processes, particularly regarding upgrading and updating cadastral databases.

4.5.1 Legal property object

In the earlier discussion the core of cadastral data model is based on three important data elements: person, land parcel or property and the rights. However, in current thinking and literature on cadastral and land administration issues, usually the rights are replaced by three R's of Rights, Restrictions and Responsibilities (Lemmen, Oosterom, Zevenbergen, Quak, & Molen, 2005). RRRs are a result of cultural, social and political activities in each country and describing the variety of existing rights and restrictions in a common model is difficult (Ottens, 2004). Besides, as a way forward to improve the capacity of land markets, new interests in land and commodities like biota, water and mining, are being recognized.

The introduction of the concept of legal property objects into cadastral system combines an interest and its spatial dimension into an entity: an entity defined by a law or regulation which relates to a physical space on, below or above the earth. This new concept can be applied to a new land related commodity, a land parcel with ownership right, or an interest within a particular

dimension in land. A further instance of this is a tax responsibility (Meyer, 2004). A tax assessment classification usually employs an aggregative method for calculation of dispersed taxable land related commodities. A combination of all taxable land related commodities of a particular person into a single legal property object would facilitate tax assessment process.

4.5.2 Spatial identifiers

Every land parcel or property recorded in a land registry or a cadastral information system must have an identifier (Meyer, 2004). In fact, identifiers are the most important linking data element in the land administration database. There are various ways for referencing of land parcels and property based on historical evolution and geographical location. The most commonly known identifiers are addresses, cadastral maps and coordinates.

One method for identifying a basic property unit is to use the name of the owner in what is sometimes called a grantor/grantee index. The grantor is the person by whom a grant or sale is made, while the grantee is the recipient - as in vendor/vendee or seller/buyer (UnitedNations, 2004).

Another method relies on title numbers, similar to references on letters. Some geographic filtering can be done by providing a regional or municipal name or code number, but essentially the system is designed to support document retrieval.

Traditional identifiers, like grantor/grantee indices, title numbers and volume and folio systems, can all operate without maps or any other spatial connotation apart from an indication of the local administrative area. They are commonly found in land registers and can be applied to both basic property units and parcels. In the cadastre, the focus tends to be specifically on the land parcel (UnitedNations, 2004).

Spatial referencing systems are generally not used as identifiers for matching various databases together. Use of relational or object oriented databases is the common way for integrating various databases, but a spatial referencing system could simplify land administration database management. The new model therefore, requires the coordinates of all legal property objects to be defined in a geocentric datum.

4.5.3 Regulating legal property objects using spatial identifiers

The key to implementing the proposed data model based on its two components of the property object and person is the use of spatial identifiers to regulate relationships among the objects. These relationships allow the possible changes in one legal property object to affect other legal property objects in a cadastral information system.

Four types of relationship exist among the legal property objects in a cadastral information system: topological, spatial, general and vertical.

4.5.3.1 Topological relationship

Topology is a relationship existing among objects (Rigaux, Scholl, & Voisard, 2002). This uses spatial identifiers in a cadastral information system to define the relationships among legal property objects. One advantage of using spatial identifiers is the efficient computation of topological queries. For example, when the dimension of one legal property object, such as an owned land parcel, is changed, the neighboring legal property object will be affected. Another advantage is related to update consistency. Object sharing makes maintenance for consistency and updates easier. The topological relationship can quickly find neighboring legal property objects.

4.5.3.2 Spatial relationship

The spatial relationship can be defined by a set of spatial operations to determine whether one legal property object touches, coincides with, overlaps, is inside or is outside of another legal property object (Worboys & Duckham, 2004). Exploring spatial relationships between legal property objects is a challenging task that requires spatial identifiers in a cadastral information system. For example, one might want to determine which car space footprints fall inside a particular land parcel.

4.5.3.3 General relationship

The general relationship is not physically explicit; for example, the relationship between the owner(s) with an apartment (Zeiler, 1999). In this relationship, spatial identifiers play an important role on defining the people's interest in a particular way in a specific position. The same position may involve complex relationships among persons, each interested in a different way. For example interest of a particular person in as a car space, a water catchment, or as owner of the parcel.

4.5.3.4 Vertical relationship

In addition to these three relationships, a cadastral information system should deliver vertical integrity to be the most successful land administration tool. Vertical integrity is the ability to relate legal property objects from one data set with legal property objects from another. Practical instances include utilities overlaying their facilities (gas lines, water pipes, electricity cable runs, etc) over a property base. When vertical integrity delivers highly accurate spatial identifiers for legal property objects, the replication alignment between the two legal property objects and the maintenance process can be streamlined. For example, automatic realignment of the gas line through its topological link to the property boundary is possible (VGIS, 2003).

With four relationships in place, maintenance of a cadastral information system will be straightforward. Spatial identifiers which the key for all the relationships, are needed to be taken into account in all land administration organizations. Having these relationships in cadastral information systems promotes the data interoperability between various organizations. Once the data interoperability becomes uncomplicated, the workflow between organizations will be simpler.

4.6 Framework for modeling 2D and 3D cadastral system

Traditional, cadastral registration was often introduced to assist in land taxation. Today cadastral registration also provides relevant information for land transactions and helps to improve the efficiency of those transactions and security of tenure in land in general. It provides governments at all levels with relevant information for taxation and regulation. Cadastral registration is increasingly used by both private and public sectors in land development, urban and rural planning, land management and environmental monitoring and are no longer related to cadastral surveying and mapping alone (FIG, 1995).

In order to perform these tasks adequately, cadastral registration needs to maintain correct and consistent information, consisting of a complete set of cadastral parcels as well as a record containing interests on the parcels. Moreover cadastral registration has to be organized in such a way that the legal status of real estate becomes clear when querying the cadastral registration.

Individualization of property started originally with subdividing the surface into property units using 2D boundaries. For this reason the basic entity of current cadastral maps is the ‘parcel’,

which makes the cadastral map a 2D map. To ensure completeness and consistency, 2D parcels may not overlap and gaps may not occur (forming a planar partition). Although parcels are represented in 2D, someone with a right to a parcel always has been entitled to a space in 3D, i.e. a right of ownership on a parcel relates to a space in 3D that can be used by the owner and is not limited to just the flat parcel defined in 2D without any height or depth. If the right of ownership only applied to the surface, the use of the property would be impossible. Consequently, from a juridical point of view cadastral registration always has been 3D. The question can be posed if traditional cadastral registration, which is based on the concept of a 2D parcel, is adequate for registering all kinds of situations that occur in the modern world or does cadastral registration need to progress to a 3D approach.

Requirements and developments of 3D cadastre are dependent on the type of cadastre as well as on the historical and juridical background of a specific country. A parcel is the basic registration entity for cadastral registration. This principle of cadastral registration follows the juridical definition of ownership of land. Ownership of land is defined by boundaries on the surface and is not explicitly limited in the vertical dimension. In general, the ownership of land includes all space above and below the parcel, as well as all constructions that are permanently fixed to the land. The consequence is that property to land is very well registered in the cadastral registration by means of 2D parcels, while 3D property units are established and registered by means of limited rights and other restrictions on intersecting parcels.

Pressure on land in urban areas and especially their business centers has led to overlapping and interlocking constructions. Even when the creation of property rights to match these developments is available within existing legislation, describing and depicting them in the cadastral registration poses a challenge. The challenge is how to register overlapping and interlocking constructions when projected on the surface in a cadastral registration that registers information on 2D parcels. Although property has been located on top of each other for many years, it is only recently that the question has been raised as to whether cadastral registration should be extended into the third dimension.

The cadastral map should be able to represent and also provide spatial information related to land rights, restrictions and responsibilities (RRRs) not only in 2D space for land parcels, but also in

3D space for 3D properties. 3D cadastres would assist the management of 3D RRRs. A 3D cadastre should be capable of storing, manipulating, querying, analyzing, updating, and supporting the visualization of 3D land rights, restrictions and responsibilities. 3D cadastral aspects should be considered in any modern system. The legal, institutional and technical aspects of a 3D cadastre provide the framework for its successful development and implementation. However, data modeling is one of the most important elements of a successful 3D cadastre. 3D cadastre data model supports 3D cadastre users to understand the structure or behavior of the system and has a template that guides them to construct and implement the 3D cadastre.

Many jurisdictions have developed their own cadastral data model. The cadastral data models have been developed to support the 3D cadastre. However, most initiatives are based upon the 2D cadastral map. The 2D land parcel object is being used when the model deals with a land parcel, and the building object is being used when a building is being modeled.



Figure 4. 2: Cadastral Data Model

While a few simple RRRs (such as an easement of way) may be represented on 2D (planar) cadastral paper maps, the diversity and complexity of 3D RRRs requires more than a 2D cadastral paper map (where 3D features are often incorporated by accompanying descriptive text). That is, 3D RRRs require more than merely grafting of the 3rd dimension information onto a 2D planar representation. 2D land parcels are not flexible enough to accommodate an increasing number of non-parcel based interests (Bennett, Wallace, & Williamson, 2008) (Kalantari, 2008). Even after recent advances in storage (database) and visualization systems, current cadastral systems do not attempt to represent RRRs in Digital Cadastral Databases (DCDB). Consequently, the DCDB does not contain all RRRs (Oosterom P. v., 2011). User expectations are to establish 3D RRRs to be visualized in a 3D cadastre. However, visualizing 3D RRRs alone would not adequately assist management of 3D RRRs (Aien, 2011c). 3D objects which represent 3D RRRs are not suitable to manage 3D RRRs. The actual construction of the buildings should be visualized in different details for different land administration functions (see **Figure4.3**).

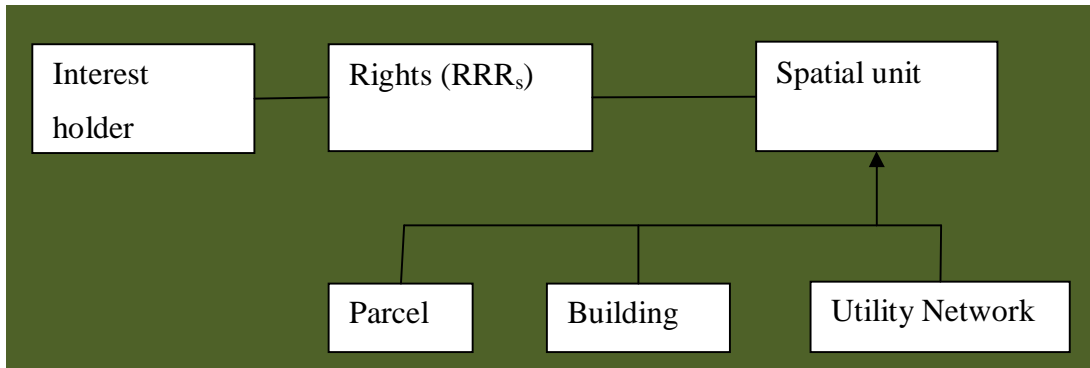


Figure 4. 3: Spatial Package in current cadastral data models

This study uses a combined conceptual model of 2D and 3D RRRs to establish 2D and 3D geodetic measurement based cadastral system (see **Figure 4.3** and **Figure 4.2**). This plot study can be adopted to establish a national cadastral system for Ethiopia.

Chapter Five

5. Research Methodologies and Design

5.1 Research Methodologies

Different surveying techniques can be used to establish a cadastral system. These are broadly classified as field survey methods (steel tape, rope, total station, GPS, etc.) and airborne survey methods (aerial photographs and satellite imagery). The practical implementations of each of the surveying technology are primary based on the accuracy requirement, cost of investment and time. Different countries use different cadastral surveying methodologies, often with varied approaches within a country. For example in Ethiopia different regional states such as Amhara, Oromia, Southern National Nationalities and peoples(SNNP) and Tigray have used different cadastral surveying methodologies when implementing their regional land administration programs. For the First Level Rural Land Certification program, the Oromia and SNNP regional states have deployed simple rope measurements without production of any geo-referenced parcel index maps. For the subsequent Second Level Certification, the Amhara regional state, with the support from the Swedish International Development Agency (SIDA), has used total station and GPS surveying methodologies at pilot level (EMA, 2006).

However, this study proposes the establishment of geodetic measurement based cadastral system. The realization of this modern cadastral system which have both spatial and administrative (non spatial) components can be achieved by using the integrated Global Positioning System (GPS) and Total station surveying techniques. In this modern cadastral surveying approach, GPS and Total station are used to capture the 2D and 3D spatial representation of land parcels and its associated property-this surveying techniques are used in this research due to their high accuracy and low investment cost. The role of the GPS is limited to establish a geocentric coordinate system due to less GPS satellite visibility in Arat Kilo campus, which is used as a case study area for this pilot research. Total station is used to capture 2D and 3D model of each property with a tie to the geocentric absolute GPS station coordinates (See for the detail in **Appendix C**). **Figure 5.1** shows a summary of the planning, surveying and spatial data analysis involved in a 2D and 3D modern cadastral system that has been based on geodetic observation.

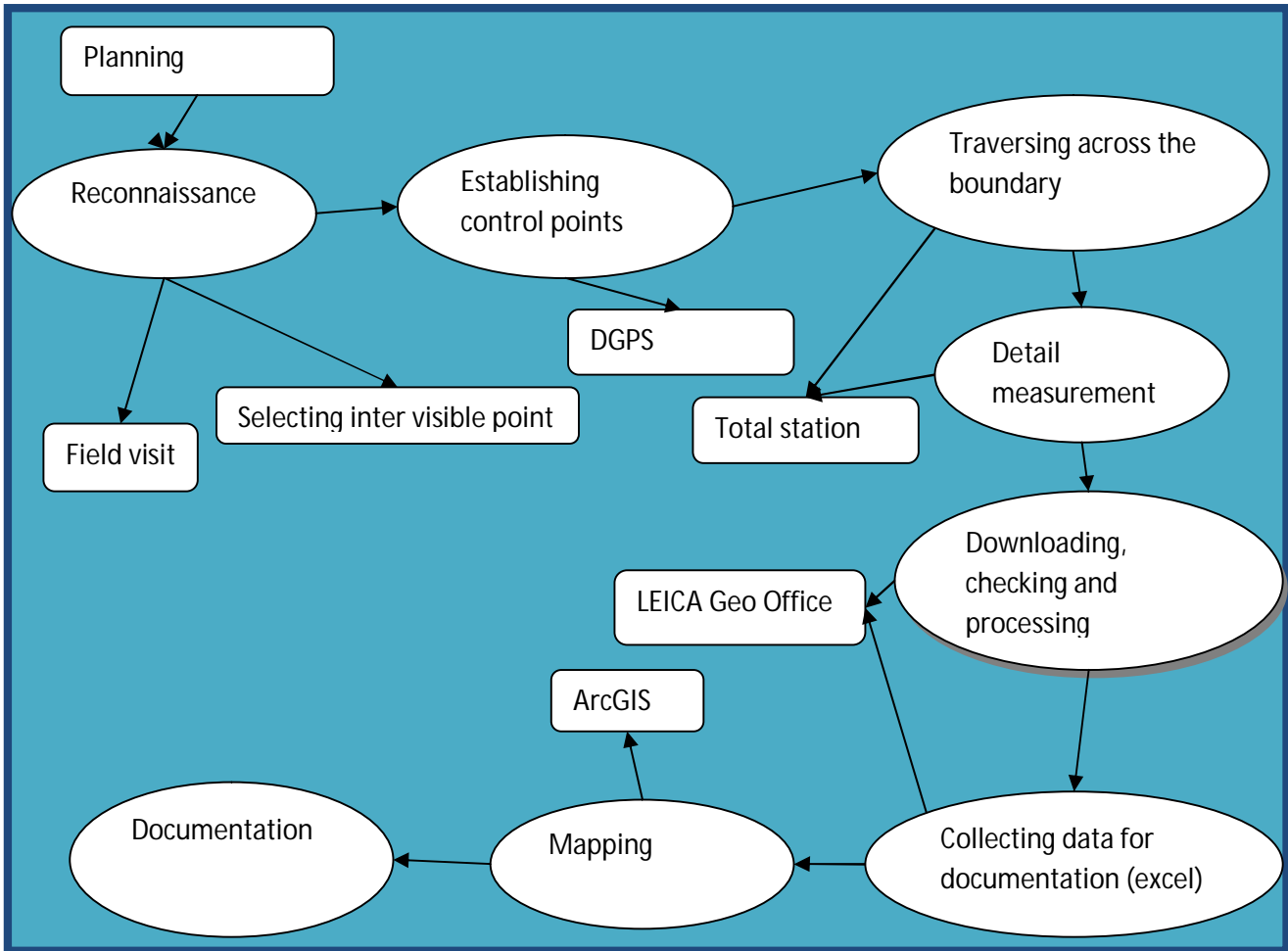


Figure 5. 1: Flow chart showing the scheme for constructing cadastral map

5.1.1 Planning

Planning is done before doing any work. These include the task of choice the reference ellipsoid, selecting the method and the instruments, specify the area etc. The detail of each can be put in the following subsections.

5.1.2 Choice of the Reference ellipsoid

GPS gives us the coordinates that are geometrically tied to the 1984 World Geodetic System (WGS84) datum. However, Ethiopia uses a non-geocentric local ellipsoid commonly called Adindan for most practical surveying and mapping purposes. Most literature argues that there is much confusion on the use of the term Adindan as datum in Ethiopia.

According to coordinate system documentation published in 2003 on the homepage of American Society for Photogrammetry and Remote Sensing (see www.asprs.org), Adindan is only the name of the survey origin, not the datum. Adindan is a survey station now covered by the waters

of Lake Nasser in southern Egypt. This station was used as the origin in the calculation of the survey, which was carried through by a U.S. survey 1958.

Instead, American Society for Photogrammetry and Remote Sensing (ASPRS) state that it should be called the Blue Nile datum. This datum is in use in much of North Africa, and has slightly different parameters for each country composed a globally absolute and geocentric WGS84 which serves as a standard references for GPS positioning. The parameters are important to know especially when GPS technique is used, since every measurement has to be transformed from WGS84 to the local reference ellipsoid. Since the EMA, survey equipment menus and most worldwide literature and documents use the label Adindan for this datum group. The Adindan datums defined for Ethiopia are sometimes called ADI-A (see e.g. www.awe-communications.com) or Adindan 4 (rarely) in listings.

There are different sets of Adindan with different parameters in use in Ethiopia. Normally there should be only one set of parameters in a country to avoid confusion, but for unknown reasons the EMA uses different parameters on different occasions. This study used Adindan UTM37N datum defined in Universal Traverse Mercator projection centered on zone 37N projection as a standard for surveying and mapping (see **Table 5.1**). Because EMA is currently used this datum.

Table 5. 1: Transformation parameter to change WGS 84 to adindan

Parameters	Dx	Dy	Dz	α_1	α_2	α_3	s
Adindan	162m	12m	-206m	0s	0s	0s	0ppm
Adindan Modified 163	163m	12m	-206m	0s	0s	0s	0ppm
Adindan (Ethiopia)	165m	11m	-206m	0s	0s	0s	0ppm

As shown in **Table 5.1** above there is no a rotation or scale factors are used to convert WGS84 based GPS coordinates to Adindan. Rotation parameters are used to adjust the ellipsoid to the geoid (mean sea level) in the selected country, so that the distance between the ellipsoid and the geoid (geoid height) is minimized. Whereas the scale factor is needed to maintain the dimensions/signs of an object during the transformations process the quantities will never zero in reality. A recent measurement and calculation of these parameters have been made in Sudan

2006 at the Karary Academy of Technology (Ahamed et al, 2006). They found the parameters to be ΔX (m) = -146.0 ± 0.89 , $\Delta Y = -33.5 \pm 0.89$, $\Delta Z = 205.3 \pm 0.89$,

S (ppm) = -1.34 ± 1.35 , r_x (10^3 sec) = 1.64 ± 1.87 , $r_y = 2.18 \pm 1.87$, $r_z = -14.8 \pm 2.6$

However, these seven parameters of transformation have not been yet determined for Ethiopia. WGS84 to Adindan transformation in Ethiopia only accounts for the translational shifts between the two systems. This study also considered the translational shift only while transforming the WGS84 based spatial coordinates into Adindan reference system. Our surveying strategy first established an absolute and geocentric horizontal and vertical surveying control points using differential GPS receivers. This GPS stations created within centimeter accuracy at OBS station found within Arat kilo campus very near to Addis Ababa Geophysical observatory. Since practical surveying with Total station requires two points whose coordinates are priori known we have tied the first GPS station to the International GNSS service (IGS) station found at Addis Ababa Geophysical observatory. Doing so, we have tied all the total station measurements to the IGS/ITRF08 which essential best fits to the WGS84 at a centimeter level.

In this study, first the WGS84 Geodetic coordinates of the two GPS stations are converted to geocentric Cartesian coordinates. Secondly, the geocentric Cartesian coordinates are transformed to Adindan Cartesian coordinates that have been defined based on the universal Transverse Mercator projection centered on zone 37N using Helmert's parameters of transformations ($\Delta X = 162\text{m}$, $\Delta Y = 12\text{m}$, $\Delta Z = -206\text{m}$). Finally, Adindan based Cartesian coordinates are converted to topocentric local easting, northing and height (up) coordinates so as to make the spatial data acquisition possible by the Total station. Therefore, the next sections will present coordinate transformations and conversions that have been used in this research to capture the 2D and 3D spatial model of cadastral properties found within Arat kilo campus.

A) Helmert Transformations

The task of transforming the WGS84 based coordinates of the surveying points to Adindan involves the use of the transformation parameters. This thesis used the three translation parameters alone by neglecting the effects of rotation and scale factor. This will cause inaccurate transformation which may cause significant distortion, but we didn't at least able to get one Adindan control point near to the survey area from which we could establish the seven

transformation parameters by performing original survey. In principle, the seven transformation parameters can be accurately determined by using Helmert's approach.

Helmert Considered two sets of three-dimensional Cartesian coordinates forming the vectors W and L (see **Figure 5.2**). In our case a vector L represents adinda coordinates system and a vector W represents WGS84 coordinate system. Helmert transformation between the two sets of coordinate can be formulated by the following relation:

$$W = d + \mu RL, \tag{5.1}$$

Where d is the translation (or shift) vector, μ is a scale factor, and R is a rotation matrix.

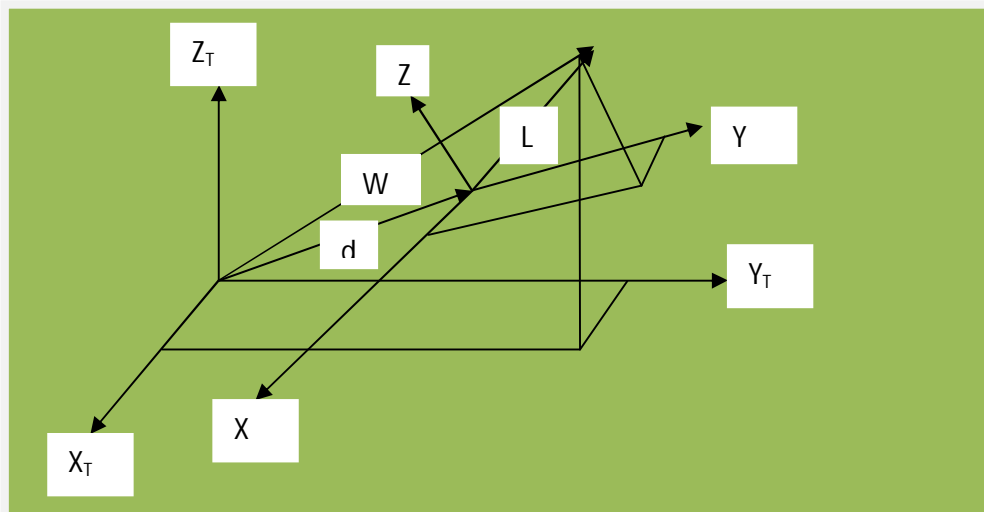


Figure 5. 2: Three-dimensional transformation

The translation vector d defines the shifts in X , Y and Z between WGS and Adindan. The X_T , Y_T and Z_T axes of the WGS84 are not parallel to X , Y and Z of the Adindan respectively. In general, the rotation angle α_1 , α_2 and α_3 represents the angular shift between X_T and X , Y_T and Y , and Z_T and Z axes respectively. The scale factor μ is used to maintain the size and dimensions of objects between the two systems in the transformation process. μ is usually given in ppm (parts per million). (Hofmann-Wellenhof, Lichtenegger, & Wasle, 2008).

B) Geodetic coordinate to Cartesian coordinates and vice versa

Helmert's transformation is only restricted to transformation of coordinates systems between two different datum. Also, the task of transforming one coordinate system to another coordinate system, say for example ellipsoidal to Cartesian or vice versa for a particular datum can be equal important for most practical mapping and surveying. According to Hofmann Wellenhof and

Moritz (2006: p. 195), the relation between the Cartesian coordinates (X, Y, and Z) and the ellipsoidal coordinates (φ , λ , h) is given by;

$$\begin{aligned} x &= (N+h)\cos\varphi\cos\lambda \\ y &= (N+h)\cos\varphi\sin\lambda \\ z &= (N+h)\sin\varphi \end{aligned} \tag{5.2}$$

Where N is the radius of curvature in the prime vertical which is obtained by

$$N = \frac{a}{\sqrt{1 - e^2 \sin^2 \varphi}} \quad e^2 = \frac{a^2 - b^2}{a^2}$$

And a , b are the semi-axes of the ellipsoid and e is eccentricity (See **Figure 5.3** for more graphical illustrations) (Hofmann-Wellenhof, Lichtenegger, & Wasle, 2008).

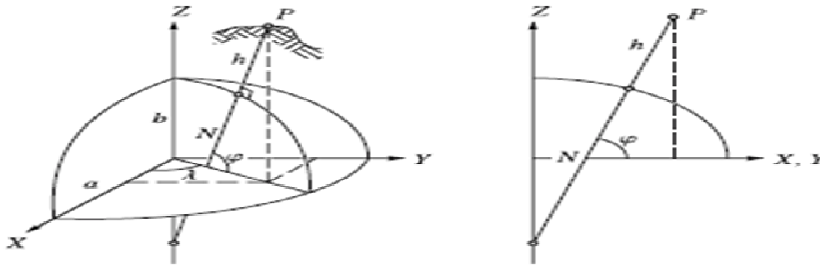


Figure 5. 3: Cartesian coordinates X, Y, Z and ellipsoidal coordinates φ , λ , h (left) and N , the radius of curvature in the prime vertical (right)

The Cartesian coordinates can be directly computed from ellipsoidal coordinates using a closed formula. The task of computing the ellipsoidal coordinate's φ , λ , h from the Cartesian coordinates X , Y , Z usually involves an iterative process. In this iterative process h and φ values have to be solved by an iterative series of back substitutions.

$$x^2 + y^2 + \frac{z^2}{(1 - e^2)^2} = (\rho + h)^2 \left(1 + \frac{2he^2}{(\rho + h)} \sin^2 \varphi + \frac{h^2 e^4}{(\rho + h)^2} \sin^2 \varphi \right)$$

$$\frac{z}{\sqrt{(1-e^2)(x^2+y^2)}} = \tan \varphi \left(1 + \frac{he^2}{(\rho+h)} \right)$$

$$\frac{y}{x} = \tan \lambda$$
(5.3)

Also, the transformation of X, Y, Z into φ , λ , and h can be performed by using an inherent approximation that doesn't require an iterative process. This is given by the following equations.

$$\varphi = \arctan \frac{Z + e'^2 b \sin^3 \theta}{p - e^2 a \cos^3 \theta}$$

$$\lambda = \arctan \frac{y}{x}$$

$$h = \frac{p}{\cos \varphi} - N$$
(5.4)

Where

$$\theta = \arctan \frac{z a}{p b} \quad \text{is an auxiliary quantity and}$$

$$e'^2 = \frac{a^2 - b^2}{b^2} \quad \text{is second numerical eccentricity.}$$

C) Cartesian to Topocentric coordinates

The task of converting the Cartesian coordinates to topocentric local coordinates needs to know Cartesian coordinates for terrestrial point and the Cartesian coordinates of satellites. The vector $X_i(x,y,z)$ represents the Cartesian coordinates of terrestrial point at point P_i (see **Figure 5.4** and **Figure 5.5**). The vector $X_j(x,y,z)$ represent the Cartesian coordinates of the satellite at point P_j . Defining the baseline vector between these two points in the global coordinate system by $X_{ij} = X_j - X_i$, this vector may also be defined in the local-level system referenced to the tangent plane at P_i and introducing the notation x_{ij} .

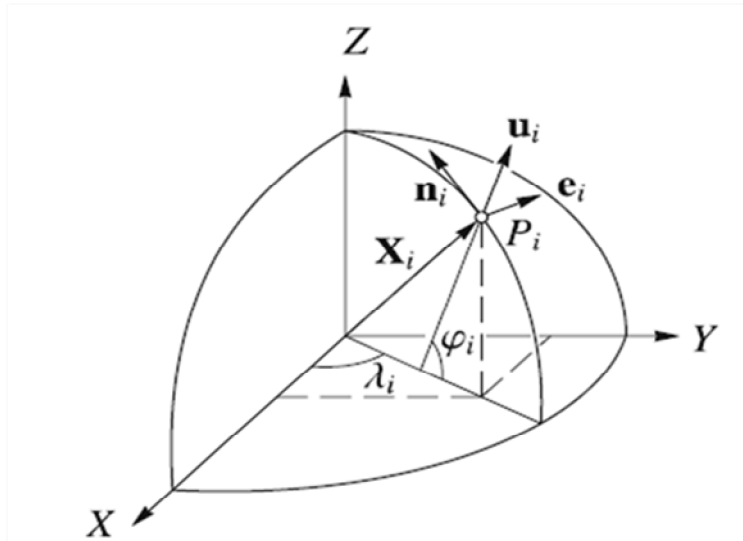


Figure 5. 4: Global and local-level coordinates

Where the axes n_i , e_i , u_i of the local (tangent plane) coordinate system at P_i corresponding to the north, east, up direction.

Where the vectors n_i and e_i span the tangent plane at P_i . The third coordinate the vector u_i , is orthogonal to the tangent plane and coincides with the ellipsoidal normal.

Local topocentric coordinates are calculated by the following formula (Hofmann-Wellenhopf, Lichtenegger, & Wasle, 2008).

$$\begin{pmatrix} N \\ E \\ U \end{pmatrix} local = A^{-1} X_i \quad (5.5)$$

$$A^{-1} = \begin{pmatrix} -\sin\varphi\cos\lambda & -\sin\varphi\sin\lambda & \cos\varphi \\ -\sin\lambda & \cos\lambda & 0 \\ \cos\varphi\cos\lambda & \cos\varphi\sin\lambda & \sin\varphi \end{pmatrix}$$

$$\begin{pmatrix} N \\ E \\ U \end{pmatrix} Global = A \begin{pmatrix} N \\ E \\ U \end{pmatrix} local$$

$$A = \begin{pmatrix} -\sin\varphi\cos\lambda & -\sin\lambda & \cos\varphi\cos\lambda \\ -\sin\varphi\sin\lambda & \cos\lambda & \cos\varphi\sin\lambda \\ \cos\varphi & 0 & \sin\varphi \end{pmatrix}$$

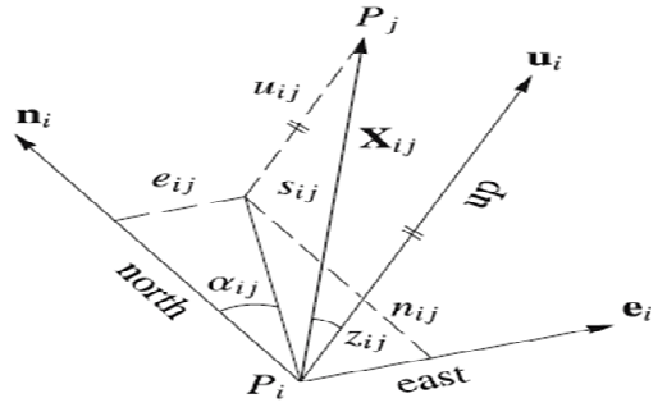


Figure 5. 5: Measurement quantities in the local-level system

The components of x_{ij} may also be expressed by the spatial distance s_{ij} , the azimuth α_{ij} , and the zenith angle z_{ij} , which is assumed to be corrected for refraction (Hofmann-Wellenhof, Lichtenegger, & Wasle, 2008).

$$\alpha_{ij} = \tan^{-1}(Y_{x_{ij}}/X_{x_{ij}})$$

$$z_{ij} = \tan^{-1}\left(\frac{Z_{x_{ij}}}{\sqrt{X_{x_{ij}}^2 + Y_{x_{ij}}^2}}\right)$$

$$s_{ij} = \sqrt{X_{x_{ij}}^2 + Y_{x_{ij}}^2 + Z_{x_{ij}}^2} \quad (5.6)$$

5.1.3 Method of capturing data by using Total station

In principle the distance between the Total station and the reflector is obtained by multiplying the time (the time required for the light to travel from total station to reach the reflector and return back to the total station) with speed of light. In this way the total station gives us the coordinates of another point (e.g. BM1) by using the distance and the azimuth angle (see **Figure 5.5**).

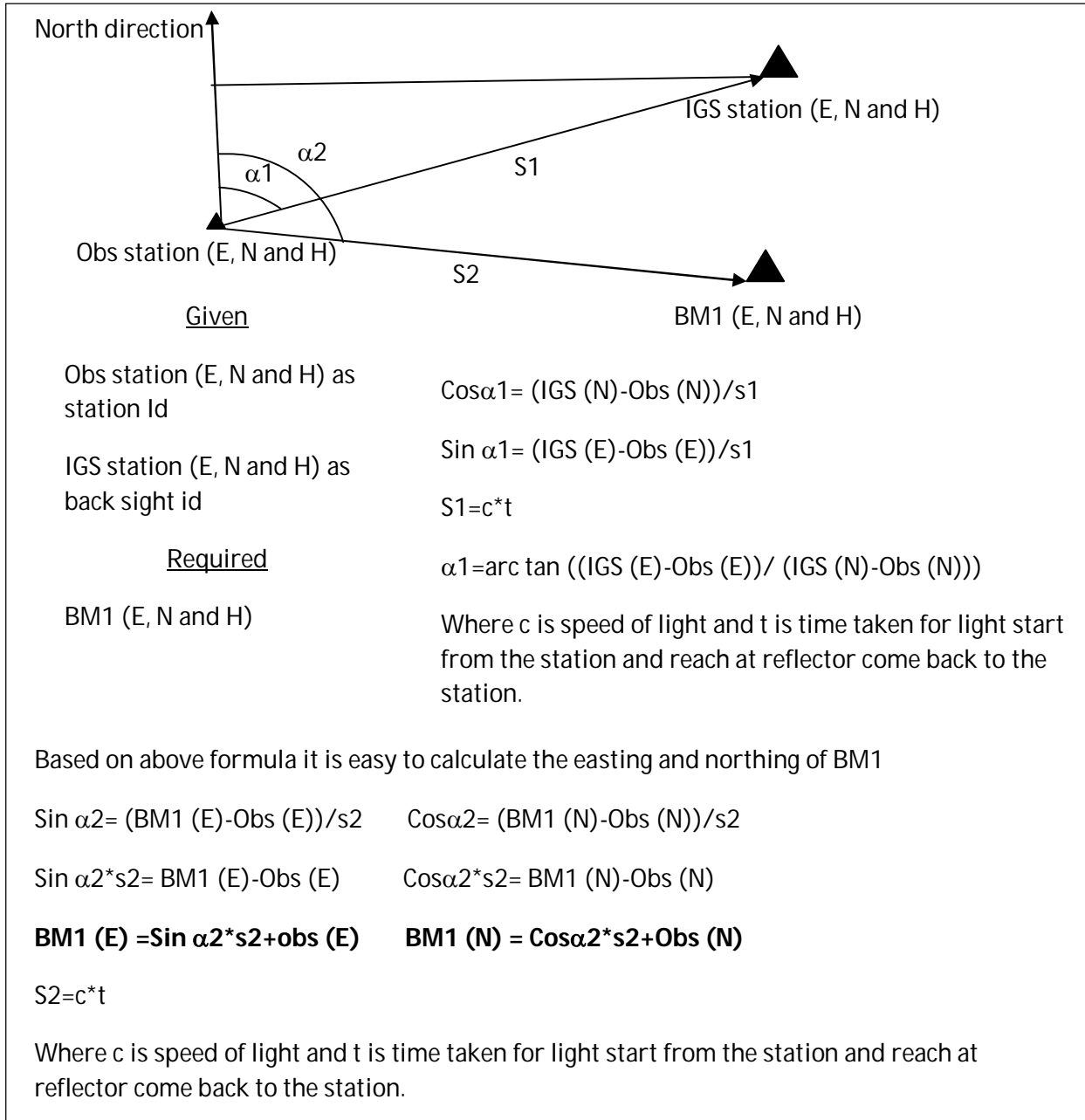


Figure 5. 6: Formula for calculation of coordinate by using total station

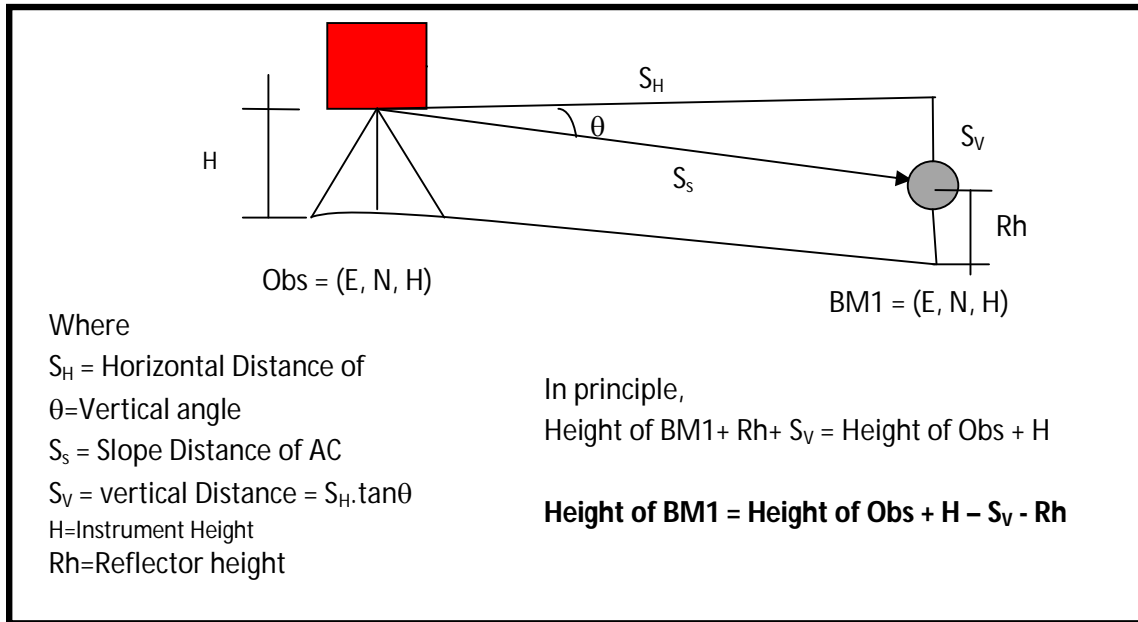


Figure 5. 7: Formula for calculation of height by using total station

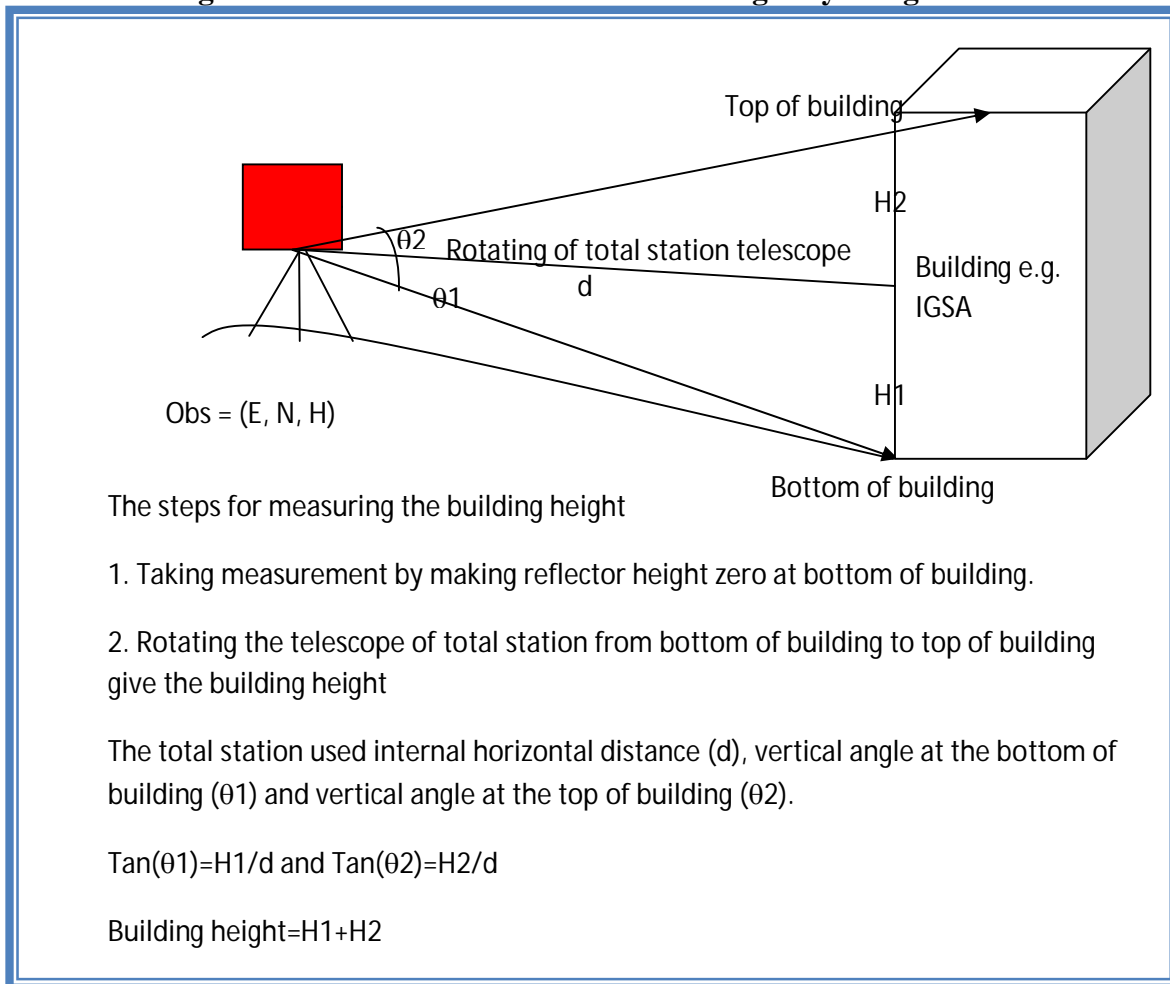


Figure 5. 8: Formula for calculation of building height by using total station

5.2 Research Design

5.2.1 Reconnaissance

Reconnaissance is the first and most important step in the surveying process. So, careful and detailed reconnaissance of Arat kilo campus is the crucial. Because by using the instrument and method to complete the work economically and meet the accuracy specifications (Schofield & Breach, 2007).

Reconnaissance take place in the study area to determine a suitable plan for the work; estimate the personal, materials and time requirements; conceive the most appropriate techniques to execute the survey and thus derive reasonable cost estimates for the survey.

Reconnaissance is an essential part of cadastral survey. In this part the following action take place in study area identify the number of known control points (two control points), making the two consecutive control points inter visible, identifying the place for bench mark in the study area and marking them.

5.2.2 Establishing control points

A control point is the framework of survey stations whose coordinates have been precisely determined and are often considered definitive. For this reason there are two control points in the study area. Those are OBS and ADIS IGS station. Those stations are the reference monuments, to which other survey work (benchmark and detailed measurement) of a lesser quality is related. By its nature, a control survey needs to be precise, complete and reliable and it must be possible to show that these qualities have been achieved. There is an observation which made on OBS for two day. This is done by using GPS equipment. The coordinate of ADIS station is common known (See for the detail **Appendix D**) (Schofield & Breach, 2007).

Making an observation on control points before any other work is made to depend upon it is very important. The practice of using a control points as a basis for further my survey operations is often called 'working from the whole to the part'. Failure to do so will degrade the accuracy of my later work even if the quality of survey observations is maintained.

In this method two control points at selected locations are established by determining their position and elevations. These control points help as guide points in detail survey. The control points can be used total station instrument. The locations of details and elevations of desired points are determined using the established control points in the area.

5.2.3 Detail measurement

Once the traverse points are established the next step is to perform detail surveying measurement. At this stage, the 2D and 3D spatial geometrical representation of cadastral properties such as building corner, road, etc are captured by using Total station.

5.2.4 Data downloading by using Leica geo office







In this stage the detail measured data from the field surveyed are downloading by using Leica Geo office software. The processing of data downloaded using Leica geo-office software is;

- The data copied from instrument (TS or GPS) in to the computer by using serial port or memory redder (file dbx)s
- Import to Leica geo-office
- The data saved as text file
- Import to excel

The detail procedures for set-up the Total station, measurement procedure, Data downloading, Mapping are described in **Appendix E, Appendix F and Appendix G.**

5.2.5 Mapping and digitizing data by using ArcGIS software

The process of mapping data using ArcGIS

-  Opening new ArcGIS
-  The excel data Added to Arc map
-  Specify the field for the 'X'and'Y' coordinates
-  Projection systems(Adindan UTM Zone 37N)
-  Digitizing
-  Export the map

Chapter Six

6. Result and Discussion

6.1 Introduction

This study is aimed to establish a modern cadastral system that has to be based on geodetic measurements. The modern approach of creating a cadastral system requires the technology that can adequately and accuracy capture the 2D and 3D geometrical/spatial representations of all cadastral properties such as land parcels, building, utilities, roads, playground etc. The study uses different modern instruments of surveying for general activity such as total station and GPS.

In practice, we usually establish permanent and temporary survey control points to carry out detail cadastral surveying. Today, in most practical applications Total stations is combined with GPS to create a well defined spatial data of the cadastral properties, but some coordinate system transformation like Helmert's transformation is needed to transform GPS coordinates to Total station compatible local North, East and Up coordinate system (see **section 5.1.1**).

In this modern cadastral surveying technique, differential GPS receivers are used to create control points whose geocentric coordinates are estimated well to millimeter accuracy using GAMIT/GLOBK software. In this study, we have used two first order absolute GPS survey control points called ADIS IGS and OBS to establish cadastral survey. Then, the total station is used to create a well distributed second order survey control benchmarks in the study area with a tie to the GPS first order control points to provide adequate inter station visibility. This creates a unique opportunity to carryout detailed 2D and 3D cadastral mapping. The next sections explore GPS data processing, transformation of WGS84 based GPS coordinates to local NEU(North East and Up), spatial analysis and mapping adopted to create a modern 2D and 3D cadastral database for Arat kilo campus.

6.2 The study area

The study area is located in Arada sub-city of Addis Ababa, Ethiopia. The cadastral study is particularly restricted to the Addis Ababa University science Faculty campus. This particular study area extends from $9^{\circ} 1'47''N$ to $9^{\circ} 2'11''N$ latitudes and $38^{\circ} 45'43''E$ and $38^{\circ} 46'02''E$ longitudes. **Figure 6.1** shows the geographical location of this study area in relation to Ethiopia and Addis Ababa.

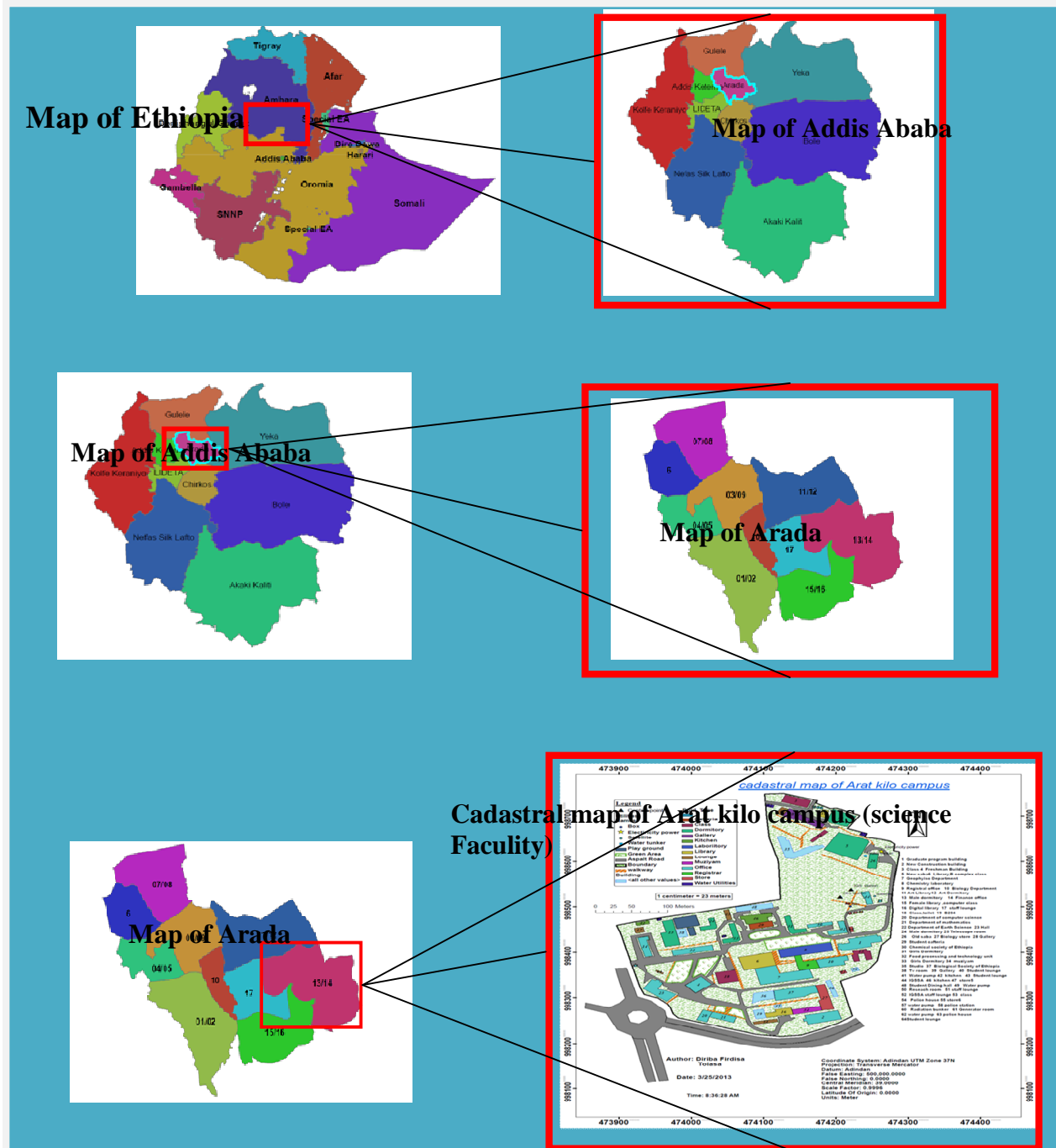


Figure 6. 1: Map of the study area in relation to Ethiopia and Addis Ababa

6.3 GPS Data Processing

GAMIT incorporates a weighted least squares algorithm to estimate the relative positions of a set of stations, orbital and Earth-rotation parameters, zenith delays, and phase ambiguities by fitting to double difference phase observations. Since the functional (mathematical) model relating the observations and parameters is non-linear, GAMIT produces two solutions, the first to obtain coordinates within a few decimeters and the second to obtain the final estimates.

Globk is a Kalman filter whose primary purpose is to combine solutions from the processing of primary data from space-geodetic or terrestrial observations. It accepts data, or "quasi-observations" and associated covariance matrices for station coordinates, earth-rotation parameters, orbital parameters, and source positions generated from analyses of the primary observations. These primary solutions should be performed with loose a priori uncertainties assigned to the global parameters, so that constraints can be applied uniformly in the combined solution (T. A. Herring, 2010).

The availability of high quality reference control station is necessary to achieve the highest order of accuracy in GPS Positioning. **Table 6.1** shows the Normalized Root Mean Square (NRMS) and Weighted Root Mean Square (WRMS) of the continuous IGS stations.

Table 6. 1: The estimated NRMS and WRMS on North, East and Up of the continuous IGS stations

Stations		Coordinates(m)	NRMS(mm)	WRMS(mm)
ADIS	North	1005786.731	0.76	1.1
	East	4261897.822	0.99	1.9
	Up	2439.157	0.32	2.2
MAL2	North	-333519.252	1.13	1.8
	East	4458272.830	0.66	1.3
	Up	-20.893	0.10	0.7
NURK	North	-216466.4	0.15	0.4
	East	3347637.59	1.49	5.0
	Up	1483.82	0.24	2.6

The residual plots of the NRMS in the North, East and Up for these IGS stations as obtained using GAMIT/GLOBK software are presented in **Appendix H**.

Table 6. 2: The sigma on the new control points

Stations	Sigma(m)		
	East	North	Height
ADIS	0.00154	0.00222	0.00723
OBS	0.0036	0.0043	0.0158

This study has computed the primary cadastral surveying control points accurate to centimeter accuracy (see, Table 6.1 and Table 6.2) using GAMIT/GLOBK software. The Sky plot of the continuous IGS station and new point (see **Appendix A**). This level of accuracy is an unprecedented and more than adequate enough to establish a spatial cadastral system as compared to the cadastral surveying standard set by the Ethiopia ministry of urban and construction.

According to ministry of urban and construction in 2011 on urban cadastral standard the level of accuracy required for a cadastral map depends on the sources of data. Cadastral maps prepared from ground surveying technique should be more accurate than aerial photography. Below are accuracy levels that must be achieved from both techniques:

- From ground surveying - positional tolerance shall not be greater than 20mm + 50ppm.
- From aerial photography-
 - Horizontal Accuracy in RMSE must not exceed 250mm in x and y
 - Vertical Accuracy in RMSE must not exceed 250mm for one meter contour interval

Regardless of the method, however, the positional accuracy of the final output should not exceed 250mm (construction, april 2011).

6.4 GPS coordinates transformation to local NEU

Now, GPS technology provides an absolute position coordinates defined either in geodetic coordinates or in Earth Centered Earth Fixed (ECEF) Cartesian coordinates. The GPS data processing using GAMIT/GLOBK can be conceptualized as converting positions between geodetic and geocentric Cartesian coordinate system or vice-versa (see, **Table 6.3**).

Table 6. 3: conversions between different coordinate system on particular datum (WGS84)

Stations	Cartesian coordinates(ECEF)(m)			Ellipsoidal coordinates(m)			Projected coordinates(m)		
	X	Y	Z	Lat	Long	Height	East	North	Height
ADIS	4913652.748	3945922.696	995383.358	9.03513	38.76630	2439.160	4261897.824	1005786.7320	2439.160
OBS	4913663.678	3945910.259	995368.369	9.03500	38.76615	2437.531	4261881.291	1005771.723	2437.531

However, the task of combining Total station with GPS involves the procedure of transforming the GPS-based geocentric Cartesian coordinates system (ECEF) into a local non geocentric ellipsoid reference system. In this case study the transformation from WGS84 to Adindan is needed to tie the total station local measurements to a global GPS coordinates. Only a translational correction ($\Delta X=162m$, $\Delta Y=12m$, $\Delta Z=-206$) has been considered in transforming GPS coordinates into Adindan local NEU using Helmert's transformation because rotation and scale factors are not available for Ethiopia. **Table 6.4** shows the coordinates of control points in Adindan that is the transformation of **Table 6.3**

Table 6. 4: Coordinate of the control points in Adindan

Stations	Cartesian coordinates(local)(m)			Ellipsoidal coordinates(m)			Projected coordinates(m)		
	X	Y	Z	Lat	Long	Height	East	North	Height
Adis station	4913814.748	3945934.696	995177.358	9.0487353	38.90467	2435.4244	474223.4136	998537.8956	2435.4244
Obs station	4913825.678	3945922.259	995162.369	9.045656	39.05634	2433.7967	474206.8759	998522.9993	2433.7967

This Helmert's approach of converting a geocentric coordinates into a local NEU provide a unique opportunity to tie the total station measurement coordinates to a well defined reference ellipsoid and to create a network of inter-station visibility benchmarks closed traverse. This now gives a spatial data at any cadastral property where there is a total station measurement with a tie to Clarke 1880 ellipsoid coordinate system defined in Adindan.

6.5 Establishment of Traverse

In most practical cadastral surveying the task of establishing a closed traverse may be challenging. However, it is recommended to establish adequate closed traverse so as to carry out detailed property mapping accurately. In this study, three closed traverse inter station visibility benchmarks have been created to control the accuracy and quality of the cadastral surveying (see, **Figure 6.2**).

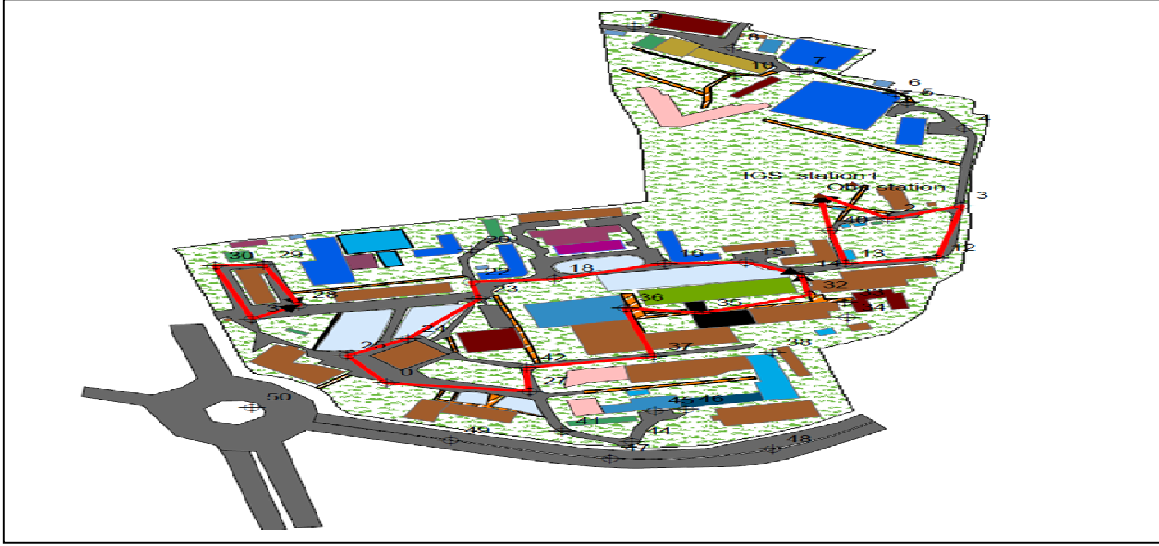


Figure 6. 2: Traverse on bench mark

Table6. 5: Shows the adjustment applied to the coordinates of the benchmarks in closed traverse loop.

First Traverse									
Before Adjustment			Correction applied			After adjustment			
P-id	Easting	Northing	Height	Easting	Northing	Height	Easting	Northing	Height
OBS	474206.909	998523.029	2433.81	0.000	0.000	0.000	474206.9088	998523.029	2433.81
BM40	474211.933	998480.455	2433.954	0.004	0.004	0.005	474211.930	998480.452	2433.949
BM13	474219.622	998440.035	2431.985	0.008	0.007	0.010	474219.614	998440.028	2431.975
BM12	474263.173	998446.715	2430.584	0.012	0.011	0.015	474263.161	998446.704	2430.569
BM3	474275.709	998511.079	2431.442	0.046	0.014	0.020	474275.662	998511.065	2431.422
BM2	474240.464	998495.24	2433.064	0.019	0.018	0.025	474240.445	998495.222	2433.039
NOBS	474206.932	998523.050	2433.840	0.023	0.022	0.030	474206.909	998523.029	2433.810
Errors	0.023	0.022	0.030						
Second Traverse									
Before adjustment			correction applied			After adjustment			
P-id	Easting	Northing	Height	Easting	Northing	Height	Easting	Northing	Height
BM14	474198.535	998427.215	2432.028	0.000	0.000	0.000	474198.535	998427.215	2432.028
BM15	474171.68	998441.804	2433.59	0.003	0.003	-0.002	474171.677	998441.801	2433.592
BM16	474132.294	998440.075	2434.023	0.007	0.006	-0.004	474132.288	998440.069	2434.026
BM18	474079.591	998421.232	2433.862	0.010	0.009	-0.006	474079.582	998421.223	2433.867
BM22	474039.489	998417.58	2432.752	0.013	0.013	-0.007	474039.476	998417.568	2432.759
BM23	474043.484	998396.799	2431.902	0.016	0.016	-0.009	474043.468	998396.783	2431.911
BM24	474009.079	998348.208	2428.79	0.020	0.019	-0.011	474009.059	998348.189	2428.801

BM25	473979.87	998327.887	2428.669	0.023	0.022	-0.013	473979.848	998327.865	2428.682
BM26	473998.542	998294.289	2428.218	0.026	0.025	-0.015	473998.516	998294.264	2428.233
BM27	474067.402	998283.904	2427.493	0.029	0.028	-0.017	474067.372	998283.876	2427.509
BM42	474066.261	998313.007	2428.168	0.033	0.031	-0.018	474066.228	998312.976	2428.187
BM37	474127.193	998326.261	2428.448	0.036	0.035	-0.020	474127.157	998326.226	2428.469
BM36	474113.443	998385.989	2430.06	0.039	0.038	-0.022	474113.404	998385.952	2430.082
BM35	474150.712	998379.734	2430.062	0.042	0.041	-0.024	474150.669	998379.693	2430.086
BM32	474202.112	998401.529	2430.462	0.046	0.044	-0.026	474202.066	998401.485	2430.488
NBM14	474198.584	998427.262	2432.000	0.049	0.047	-0.028	474198.535	998427.215	2432.028
Errors	0.049	0.047	-0.028						
Third Traverse									
Before adjustment			correction applied			After adjustment			
P-id	Easting	Northing	Height	Easting	Northing	Height	Easting	Northing	Height
BM28	473956.679	998389.455	2430.845	0.000	0.000	0.000	473956.679	998389.455	2430.845
BM29	473939.746	998438.637	2432.432	-0.005	-0.008	-0.011	473939.751	998438.645	2432.443
BM30	473916.47	998437.146	2432.428	-0.010	-0.017	-0.023	473916.479	998437.163	2432.450
BM31	473934.324	998372.748	2430.186	-0.014	-0.025	-0.034	473934.338	998372.774	2430.220
NBM28	473956.660	998389.421	2430.800	-0.019	-0.034	-0.045	473956.679	998389.455	2430.845
Errors	-0.019	-0.034	-0.045						

The closure error of the closed traverse inter-station visibility benchmarks provides a unique chance to control the quality and accuracy of the cadastral survey. According to the 2006 draft proclamation and regulation published by the Ethiopian ministry of urban and construction the errors in a closed cadastral traverse shall not exceed the following:

- a) For a survey of urbanized areas of municipalities and other urbanized areas, 50mm, at scale of 1:5,000;
- b) For a survey in Villages and peri-urban areas, 100mm at scale of 1:2,000; and
- c) For a survey in Agricultural, forest and grazing lands and all other areas, 200mm at scale of 1:500

In this research, **Table 6.5** shows that the closure errors in all three closed traverses are determined in centimeter accuracy and errors are within the standards of the Ethiopian ministry of urban and construction.

6.6 Spatial data analysis

6.6.1 Data collection

The main aim of this research is to prepare the modern geodetic 2D and 3D cadastral map for Arat Kilo campus. This research has collected 992 points features. **Table 6.6** shows a summary of the number of control points, benchmark and detail cadastral measurements that have been conducted in the study area.

Table 6. 6: Number of bench mark and cadastral measurement

No	Features	No of point
1	Control points	2
2	Utilities	4
3	Bench mark	45
4	Play ground	9
5	Green area	15
6	Road	566
7	Boundary	49
8	Building	302
	Total	992

The detail information about the easting, northing and height of each bench mark and detail measurements are presented in **Appendix I**.

6.6.2 Spatial analysis

The study used the ArcGIS software to edit, create vector data models, georeference the spatial features, analyze and visualize the spatial data in the form of high standard.

(A) Referencing system

It is most important that all spatial data ArcGIS are referenced with respect to a common frame of reference. In this study, the spatial data are georeferenced to the local Clarke 1880 ellipsoid with Adindan selected as the datum. This involves the task of transforming the GPS-based primary cadastral survey control points from WGS84 to Clarke 1880 ellipsoid defined with Adindan as a datum using Helmert's transformation.

(B) Vector data creation

Vector data provide a way to represent real world features within the GIS environment. A feature is anything you can see on the landscape. A vector feature has its shape represented using geometry. The geometry is made up of one or more interconnected vertices. A vertex describes a position in space using an x, y and optionally z axis. When a feature's geometry consists of only a single vertex, it is referred to as a point feature. Where the geometry consists of two or more vertices and the first and last vertex are not equal, a polyline feature is formed to model a linear geographic object. Where four or more vertices are present, and the last vertex is equal to the first, an enclosed polygon feature is formed to model the geographic object that has at least a 2D extent. Also, vector feature have attributes associated with them to describe information about the particular cadastral properties.

(C) Data editing

The study used ArcMap to edit the collected data features to relate in geometric network. In geodatabase, a geometric network contains special types of network features that enable connectivity tracing, network connection rules, and specialized junction or switch modeling behavior. Geometric networks are useful for modeling networks of building, road, water container etc networks. Networks are built of edge and junction features.

By using the ArcMap snapping environment, the study creates a new edge and junction features on the fly while maintaining network connectivity. The ArcMap snapping functionality will guarantee geometric coincidence when adding new network features along existing network features.

(D) Overlay analysis

The study used the overlay analysis to integrate cadastral point features, linear features and 2D and 3D features together in separable. This is done by combining information from one GIS layer with another GIS layer to establish an integrated cadastral property geodatabase and digital maps.

The spatial analysis used in this study includes the task of determining the area, height and perimeter of each 2D and 3D cadastral object (see, **Table 6.7**). The attribute data has been created for each cadastral object during the spatial data editing stage.

Table 6. 7: Lists of cadastral properties surveyed with their name, their height, their area and their perimeter

	Name	Height(m)	Area(m ²)	Perimeter(m)
1	Graduate program building	35.367	1169	176
2	New construction building	20.256	1013	144
3	Class	17.417	640	110
4	Freshman Building	16.09	663	104
5	New Saba	12.938	2189	186
6	Library,B complex class	12.358	1397	153
7	Geology department	12.358	2018	224
8	Chemistry laboratory	12.358	1408	187
9	Registral office	12.358	665	123
10	Biology Department	12.358	754	123
11	Art library	12.25	140	49
12	Art Dormitory	11.781	906	119
13	Male dormitory	11.649	1026	156
14	Finance office	10.908	490	115
15	Female library,Computer class	9.988	461	131
16	Digital library	9.049	490	108
17	Staff lounge(2)	8.909	144	48
18	Class,toilet	8.682	718	107
19	B204	8.194	281	68
20	Department of computer science	7.569	354	78
21	Department of mathematics	7.569	453	96
22	Department of Earth Science	7.557	680	138
23	Hall	7.54	950	154
24	Male dormitory	7.206	326	94
25	Telescope room	7.182	17	17
26	Old saba	7.17	417	91
27	Biology store	7.115	809	145
28	Gallery	6.975	321	72
29	Student Cafteria	6.931	396	90
30	Girls Dormitory	6.927	471	127

31	Chemical Society of Ethiopia	6.927	255	85
32	Food processing and technology unit	6.702	400	108
33	Girls Dormitory	6.181	493	127
34	Muziyam	6.091	415	101
35	Studio	5.62	1072	209
36	Biological society of Ethiopia	5.355	1216	160
37	-----	5.355	515	99
38	TV room	5.247	243	63
39	Gallery	4.598	468	108
40	Student lounge(3)	4.598	150	50
41	Water pump(4)	4.3	29	22
42	Kitchen(2)	4.3	115	49
43	Student lounge(2)	4.294	161	60
44	IGSSA	4.283	287	79
45	-----	4	64	33
46	Kitchen(1)	3.891	688	124
47	store 5	3.864	23	20
48	Students Dining hall	3.676	518	122
49	Water pump(1)	3.52	23	19
50	Research room	3.462	16	18
51	staff lounge(1)	3.362	203	79
52	IGSSA staff lounge	3.299	18	17
53	Class	3.282	194	76
54	police house(2)	3.223	30	24
55	store6	3.164	16	16
56	-----	3.12	256	88
57	water pump(3)	3.1	58	30
58	police station(3)	3.075	10	13
59	Radiation bunker	3	60	34
60	-----	3	83	37
61	Generator Room	2.5	57	30
62	water pump(2)	2.5	55	31
63	Police House(1)	2.36	13	14
64	Student lounge(1)	2	37	30

The total area of the study is determined to be approximately 116324.19 square meters using ArcGIS software. Out of this, about 34376 square meters corresponds to the area extent occupied by buildings, walkway, green area, playground and asphalt roads (see **Table 6.8 and Chart 6.1**).

Table 6. 8: Spatial area of different cadastral property categories

	Name	Area(m ²)
1	Walkway	2747
2	Playground	922
3	Green area	565
4	Building	30007
5	Asphalt road	1354
6	Remaining	80729.19
	total surveyed	35595
	total area of arat kilo	116324.2

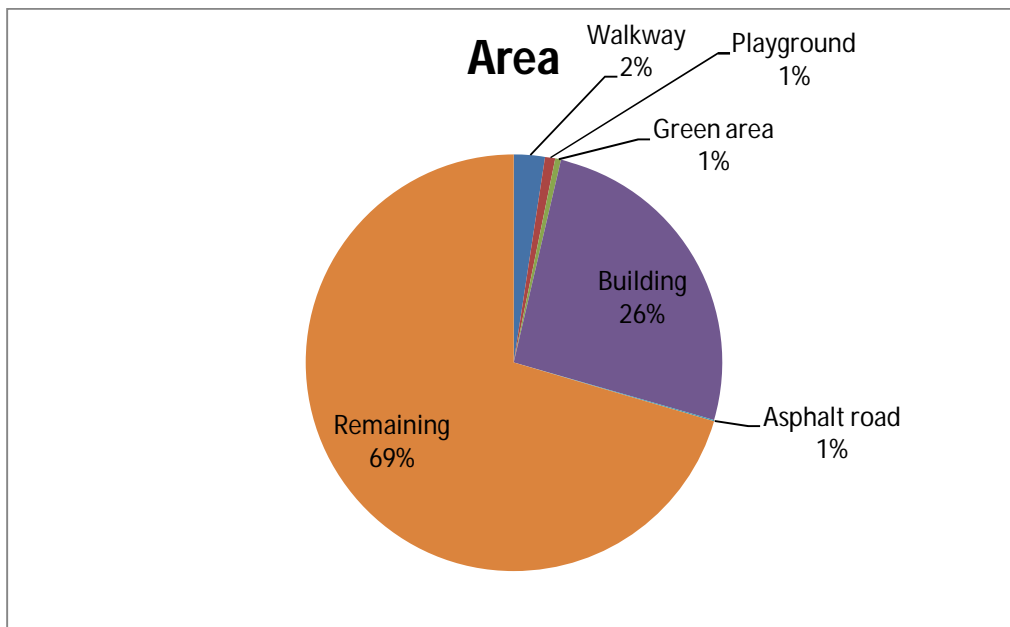


Chart 6. 1: Flow chart of the area in percentage which listed in Table6.8

6.6.3 Digital map production using ArcMap 2D and 3D map

This study has produced 2D and 3D high standard cadastral map of the study area. The standard cartographic map has to include legend, north arrow, scale bar, title, grid, coordinate system, projection type and datum, false northing, false easting, central meridian, scale factor, latitude origin, units and attributes of spatial features.

The 2D map presents the area and perimeter of each cadastral property (see, **Figure 6.3**). However, the complete 3D spatial information of cadastral property such as buildings is shown by producing the 3D map (see, **Figure 6.4**). For more detail about the description of the 3D cadastral map presented in **appendix J**.

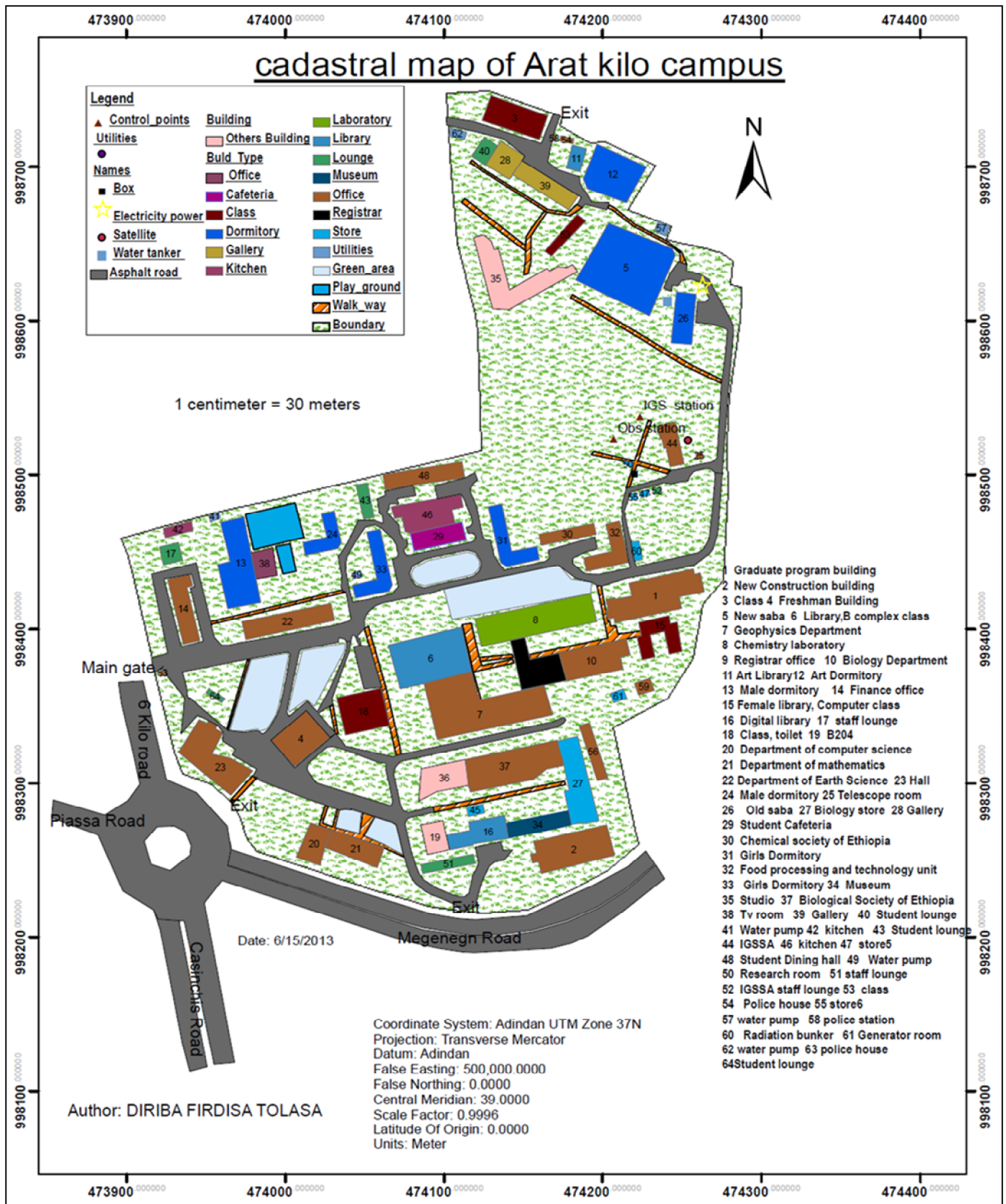


Figure6. 3: 2D cadastral map of Arat kilo campus

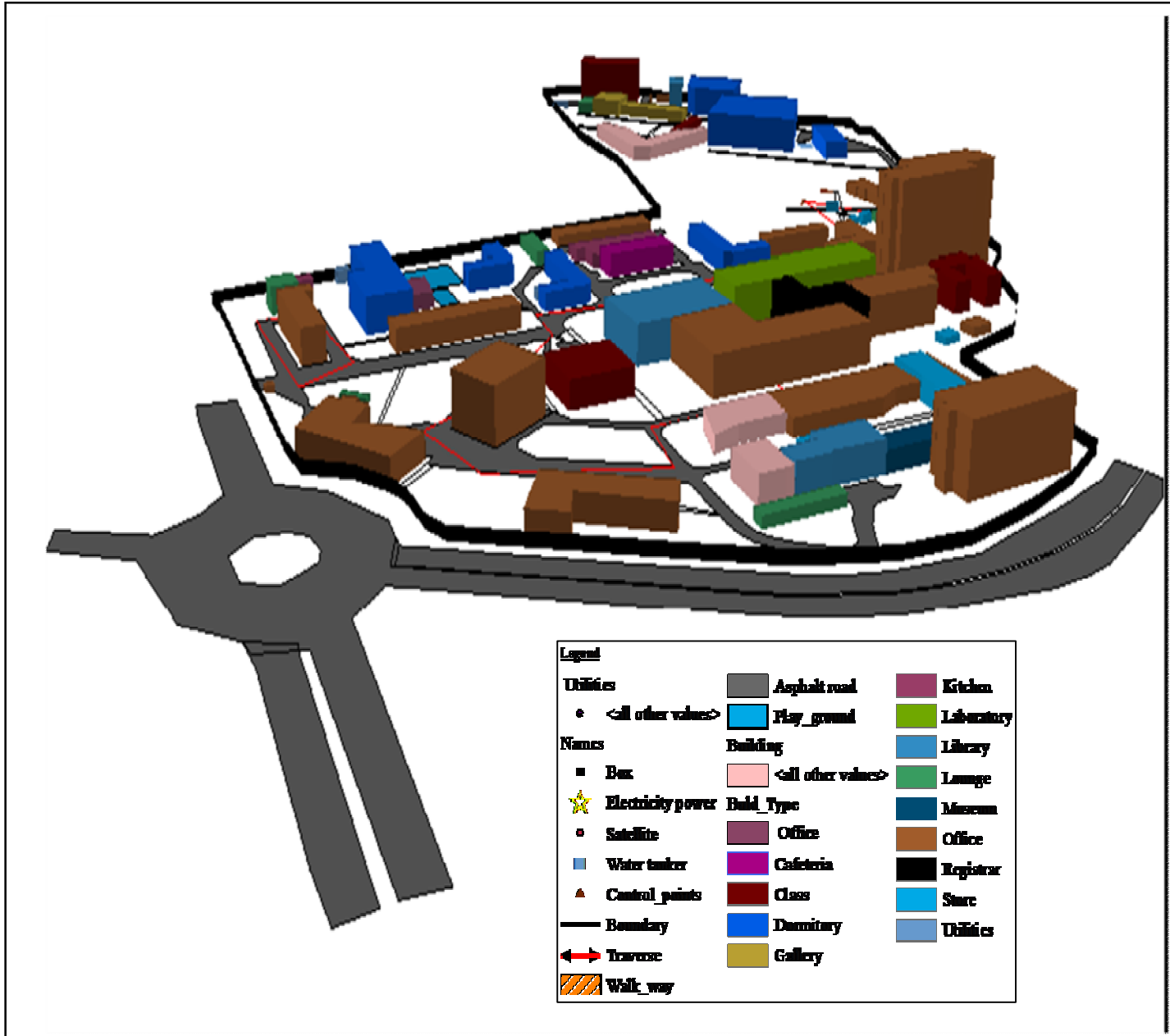


Figure6. 4: 3D cadastral map of Arat kilo campus

After we know the total area of Arat kilo campus using Arc GIS in the study area by using the total area of Addis Ababa it possible to predict the amount of budget, time schedule and the number of human skill power necessary to work the map of Addis Ababa just like the above one

According to Ethiopia Central Statistics Authority (CSA) reports Addis Ababa is occupying a significant area of 529.99 square kilometers and the total area of arat kilo campus is approximate around 116324.19 square meters.

Source: Wikipedia, <http://en.wikipedia.org/wiki/Ethiopia#Geography>

The task of preparing the modern geodetic 2D and 3D cadastral map of Arat kilo campus which occupies 0.11632419 square kilometers, took about 5 months, in term of money it cost about 5,000 birr and the survey involved 3 persons. Therefore, to map the whole Addis Ababa the survey would require huge budget and many experts.

Chapter Seven

7. Conclusions and Recommendations

From the result of this thesis, the following conclusions are drawn:

- ✚ The cadastral survey has been determined at centimeter accuracy (between 2-5 cm). GPS-based primary cadastral survey control points were estimated accurate to centimeter level. The possible sources of centimeter level come from the inter-station visibility cadastral quality controlling closed traverse network.
- ✚ For small area, the combined Differential GPS and Total station surveying technique can adequately and accurate map the 2D and 3D cadastral system.
- ✚ It is possible to represent spatial infrastructure information related to land rights, restrictions and responsibility not only in 2D space for land parcels but also in 3D space for 3D properties by using Arc GIS.

During the thesis work several problems were detected. So, we recommend the following for future cadastral survey.

- Differential GPS observation for long period of time is need to establish the ground based cadastral survey control point accurate to millimeter level.
- Seven Helmert's parameters of transformations are needed to be defined to produce high accuracy cadastral system with minimum map distortion on a local (Adindan) datum for Ethiopia.
- When the errors are out of the tolerance during traverse it is recommended to make repeated closed traverse to come to within tolerance.
- GPS require an open area with good satellite visibility in order to determine position coordinates of particular cadastral property. When there is building or trees it will block the GPS signal. So, we recommend to use other cadastral surveying technique such as total station, photogrammetric method etc in combination with GPS.

References

- Aien, A. R. (2011c). 3D Cadastre in Victoria, Converting Building plans of Subdivision to LandXML. *GIM International*, 25(8), 16-21.
- Amanuel, T. (2009). preparation of coordinate based cadastral map in rural Ethiopia case study in bite ejerse lafoka, Oromia region, and master thesis.
- Bahru, Z. (1986). Early Safrs' of Addis Ababa, Patterns of Evolution, In Proceedings of the centenary of Addis Ababa, Addis Ababa.
- Bennett, R., Kitchingman, A., & Leach, J. (2010). On the nature and utility of natural boundaries for land and marine administration, *Journal of Land Use Policy* 27(3) doi:10.1016/j.landusepol.2009.10.008.
- Bennett, R., Wallace, J., & Williamson, I. P. (2008). A toolbox for mapping and managing new interests over land. *Survey Review*, 40(307), 43-53.
- Bennett, R., Williamson, I., & Wallace, J. (2005). Achieving sustainable land management through better management of rights, restrictions and responsibilities ', Proceedings of Expert group meeting on incorporating sustainable development objectives into I.
- construction, T. m.-o.-d. (april 2011). Urban cadastral standard. netherlands.
- Daniel, T. (2006). Reflection on the situation of urban cadastre in Ethiopia.
- ELTAB. (2007). manual on hand held GPS for cadastral surveying, Addis Ababa Ethiopia .
- EMA. (2006). Ethiopia – Land Tenure and Administration Program (ELTAP) Comparison of Rural Cadastral Surveying Methods.
- Eric.c, W. (2006). experience in cadastral surveying for land registration for Africa.
- FIG. (1995). FIG Statement on the Cadastre. In Retrieved October 3, 2011, from http://www.fig.net/commission7/reports/cadastre/statement_on_cadastre.html.
- FIG. (2010). The Social Tenure Domain Model- A Pro Poor Land Tool, FIG Publication 52, UN-HABITAT, GLTN, Copenhagen, Denmark.
- Gebeyehu, B. S. (2011). Cadastral Template 2010.
- Ghilani, C. D., & R.Wolf, P. (2008). elementary surveying (13th ed.). New Jersey.
- Griffith-Charles, C. (2011). The application of the social tenure domain model (STDM) to family land in Trinidad and Tobago. *Land Use Policy*, 28(3).

- Habtalem, G. (2006). Master thesis on cadastral surveying methods.
- Hoben. (1973). Land Tenure Among the Amhara of Ethiopia, The University of, Chicago and London.
- Hofmann-Wellenhof, B., Lichtenegger, H., & Wasle, E. (2008). GNSS – Global Navigation Satellite Systems ,GPS, GLONASS, Galileo, and more.
- Jantien, E. S. (2004). 3D Cadastre. NCG, Nederlandse Commissie voor Geodesie, Netherlands Geodetic Commission, Delft,.
- Kalantari, M. R. (2008). Spatially referenced legal property objects. Land Use Policy, 25, 173-183.
- Kaufmann, J., & Steudler, D. (2001). Cadastre 2014 : a vision for a future cadastral system. In S.I.International Federation of Surveyors (FIG) (Second edition ed.).
- Landau, H., Vollath, U., Deking, A., & Palels, C. (2001). Virtual reference Station Networks - Recent Innovations by Trimble, Technical Paper, Trimble Terrasat GmbH, November.
- Larsson, G. (1990 (a)). Historical Development of Structure and Function of Different Types of Cadastral and Land Registration System, in Proceedings of Advanced Course in the Development of Cadastral System, Gavle, and Sweden.
- Lemmen, C., Oosterom, P. V., Zevenbergen, J., Quak, W., & Molen, P. V. (2005). Further Progress in the Development of the Core Cadastral Domain Model', Proceedings of FIG Working Week 2005 and GSDI-8, April 16-21, Cairo, Egypt, <<http://www.fig.net/pub/c>.
- Mabogunje, A. (1992). Perspective of Urban Land and Urban Management policies in Sub-Sharan Africa. World Bank Technical Paper No. 196. Washington, D.C.
- Martin, S., & Jahn, C. -H. (2000). Experiences in set-up and usage of a geodetic real-time differential correction network, LETTER, Earth Planet Space,52, 851–855, 2000.
- Meyer. (2004). , GIS and land records, the ArcGIS parcel data model, ESRI, New York, California.
- Oosterom, P. v. (2011). World-wide Inventory of the Status of 3D Cadastres in 2010 and Expectations for 2014. Paper presented at the FIG Working Week 2011.
- Oosterom, P. v., B. Maessen, & Quak., C. (10-12 August 2000). Spatial, thematic and temporal views. In Proceedings of 9th International Symposium on Spatial Data Handling, Beijing, China.
- ORGUT. (2010). the establishment of a harmonized land administration system.

Osterberg, T. (1990). Development of Cadastral System, In Proceedings of Advanced Course in the Development of Cadastral System, Gavle, Sweden.

Ottens, M. (2004). The Cadastral System as a Socio-Technical System', Proceedings of Joint FIG Commission 7 and COST Action G9 Workshop on Standardization in the Cadastral Domain, Bamberg, Germany.

Pankhrust, R. (1961). Introduction to Economic History of Ethiopia, London.

Pankhrust, R. (1966). State and Land in Ethiopian History, The Institute of Ethiopian Studies and The Faculty of Law, Haile Sellassie I University in Association With Oxford university Press, Addis Ababa.

Prime.Consultants.P.L.C. (2008). A manual for the preparation of cadastre for urban center of the ANRS. Amhara National Regional State Prime Consultants PLC Bureau of Works and Urban Development , 7.

Rigaux, P., Scholl, M., & Voisard, A. (2002). Spatial databases with application to GIS, Academic Press.

Schofield, W., & Breach, M. (2007). Engineering Surveying, Sixth Edition, AMSTERDAM.

Silayo, E. (1997). cadastral surveying practice in Tanzania, Daresalam University pres, Daresalam.

Simsion, G. C. (2005). Data modelling essentials, third edn, Elsevier Inc, San Farnscisco.

Solomon, G. (2002). Urban Land Issues and Policies in Ethiopia, In the Proceedings of the Second Workshop of the Land Tenure Project, ed. by Dessalegn Rahameto, Working Papers in Ethiopian Development No. 8.

Stuedler, D., Williamson, I., & Rajabifard, A. (2004). A world wide comparison of cadastral systems, cadastral template' GIM International, <www.sli.unimelb.edu.au/research/SDI_research/publications/files/CAD_CT_GIM2004.pdf>.

Stoter, J., & and Salzmann, M. (2003). Towards a 3D cadastre: where do cadastral needs and technical possibilities meet?, Computers, Environment and Urban Systems (Vol. 27).

T. A. Herring, R. W. (2010). Introduction to GAMIT/GLOBK, Department of Earth, Atmospheric, and Planetary Sciences Massachusetts Institute of Technology .

Thomas, D. (2009). Survey manual for EPLAUA.

UnitedNations. (2004). Guidelines on real property units and identifiers, New York and Geneva, <www.unece.org/env/documents/2005/wpla/Guidelines_On_Real_Property_Identifiers.pdf>.

Van Oosterom, P., Lemmen, C., Ingvarsson, T., van der Molen, P., Ploeger, H., Quak, W., et al. (2006). The core cadastral domain model, *Computers, Environment and Urban Systems* (Vols. 30, 5).

VGIS. (2003). *Geospatial Information Spatial Accuracy*, DSE, Melbourne, <<http://www.land.vic.gov.au/land> >.









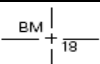
Worboys, M., & Duckham, M. (2004). *GIS, A computing Perspective*, 2 edn, CRC Press.

Zeiler, M. (1999). *Modeling our world*, ESRI, California.

Zhu, J. (1993). Exact conversion of earth-centered, earth-fixed coordinates to geodetic coordinates.

Appendix B: Symbology standard

Elevation Point	Transportation	Land Cover
TP	Asphalt	Sand
Spot Height	All Weather	Grassland
Services/Facilities	Dry Weather	Swamp
School	Gravel	Forest
Police Station	Trail	waterbody
Clinic	Hydrography	Land Use
Christian Cemetery	Wide	Horticulture
Hospital	Main	Cropland
Resturant	Intermittent	Park
Fuel Station	Disappearing	Industrial
Telephone	Ditch	Cemetery
Zoo	Height/Elevation	Commercial Neighbourhood
Airport	Index	Recreational Park
Spring	Normal	Waste Disposal Site
Factory	Suplimentary	Others
Reservoir	Utilities	Public Owned
Place of Worship	High Tension Power Line	Potential Flood Area
Church	Telephone Line	Military Training Area
Mosque	Boundary	
Others	Regional	
Tree	Zonal	
Gojjo	Were da	
Bridge	Town	
	Kebele	

No.	Feature	Symbol			
			6	Electric pole	
1	FOOT PATH	7	Parcel	
2	FENCE		8	BUILDING/HOUSE	
3	WATER TANK		9	NORTH ARROW	
4	TRIGONOMETRIC POINT		10	SCALE BAR	
5	BENCH MARK				

Appendix C: The Translation of Minilik's Law Granting Security of Tenure

Article I

I, Minilik II, Emperor of Ethiopia, have authorized my countrymen and foreigners, for whom I have given a special law, to buy land in the town of Addis Ababa, but they must not transgress this law.

Article II

The Government shall assess the amount of money to be paid for a certain area of Government land depending on its value.

Article III

Individual holders may sell their holdings in accordance with the provision of this law.

Article IV

All measurements of land shall be square meters. A square meter shall mean an area of land one-meter long by meter wide.

Article V

Any person purchasing land shall have its size and value assessed by the Government representative (Meslene) and mapped by an engineer.

Article VI

A copy of this map is to be given to the Government to be included in the Addis Ababa map, and shall be called the cadastre of Addis Ababa.

Article VII

The delimitation of borders, the determination of prices, and the measurement of a piece of land shall be done by two engineers, one of whom, and preferably both, must be employees of the Government. They shall survey the land and have it registered. The remuneration of such engineers shall be met by the Government.

Article VIII

If Government land is bought, the purchaser shall cover the expenses of the engineer; in other cases the parties must agree as to who should meet these costs.

Article IX

The Government representative is given the power to determine the value of the land in order to facilitate its sale. The Government has also given permission to the buyers to pay their debts in installments, but has the right to fix a closing date for such payments. If by that date payment is not completed, the Government may confiscate the land, paying back the owner without interest the money received from him.

Article X

The Government shall issue a certificate of purchase to persons who have bought land so that they may make use of it in accordance with the provision of this law. They cannot, however, obtain such a certificate until they have completed their payment and unless they abide by the provision of this law.

Article XI

A copy of the certificate issued by the Government is to be kept in the register, with the following particulars: 1) Its number 2) The name of the seller of the land 3) The name of the buyer of the land 4) The size of the land and information of any kind of property on it 5) The boundaries of the land 6) The name or names of neighbors 7) The name of the locality 8) The price of the land 9) the date of sale.

Article XII

The certificate shall bear the seal of the Government. The fee for this seal is \$ 10.00 and 1% of the land is also to be paid

Article XIII

When individuals sell or buy land, it shall be done in the presence of a government representative and two witnesses who must sign on the certificate.

Article XIV

When individual sale land to each other, the sale shall be recorded in Government registers and shall bear the official seal. In accordance with Article XII the fee shall be fixed at \$10.00 plus 1% of the price.

Article XV

If the seller and the buyer agree between themselves to state a false price in order to deprive the Government of its share the buyer shall be liable to pay four times the amount initially due to the Government. The seller and witness shall be the buyer's guarantors. No one may be penalized, if the crime is not discovered within two years.

Article XVI

Foreigners and foreign companies may buy land in accordance with the law, but such land may not exceed 10 hectares though the Government has the right to increase this if it so wishes. Any person who violates this law will be heavily penalized. The Government can confiscate the land, merely by refunding the purchase price.

Article XVII

If within 25 years an individual sells at a profit, land purchased from the Government he shall give the latter one third of the profit. Any one violating this Article shall be liable to the penalties specified in Article XV of this decree

Article XVIII

If land purchase from the Government is sold before completion of payment the buyer and seller shall notify the Government who shall complete the payment. Such agreement shall be recorded in the Government register.

Article XIX

Liabilities to the Government in respect of land i.e. purchase money and taxes have priority over any other payments.

Article XX

If the purchase of the land has paid the full amount of money and has fulfilled the requirements for a certificate, he can do whatever he wills with the land. He may sell it, in whole or in part, transfer it or use it as guarantee to borrow money. If he sells land in a city, the area of the land sold shall not be less than 400 square meter.

Article XXI

The size of present holdings of land shall continue as they are, but henceforth land should not be divided except in accordance with the provision of this law.

Article XXII

If a person dies before completing his monetary obligations, his successors shall pay the remaining amount or make alternative arrangements with the Government. If they fail to do so the Government shall take the land in accordance with article

IX. If a house has been built on the land, both the house and the land shall be sold and after paying the debt, the remaining amount shall be paid to the heirs.

Article XXIII

If the heirs find it necessary to share the land they may do so, but they must obtain the Government permission to reduce their shares to less than 400 sq. meters.

Article XXIV

Heirs shall pay to the Government 2% of the value of land they inherit

Article XXV

The Government may dispossess an individual of his holdings if the land is found to be essential for the orderly development of a city, and in such cases compensation as determine by Government experts shall be paid.

Article XXVI

If the size of land require is small, less than 2 meters wide, the Government shall pay the original price of the land. If however, the land has been wanted by the individual for more than 10 years, the value of the land shall be as estimated by experts.

Article XXVII

If there are buildings on the land, the Government shall pay the price of the land, or may agree to give the owner on equivalent holding elsewhere.

Article XXVIII

If a foreign owner dies and has neither successor not a consulate to represent him, the Government shall take the land and rent it. If and when at any time an heir comes the Government shall deduct the following:

1. Any debt of the deceased to the Government
2. Any amount spent by the Government on improving the land

3. A tax of 2% on the value of the land in accordance with Article XXIV

Article XXIX

After 30 years if no heir appears the Government shall take over the land and no subsequent claims can be countenanced.

Article XXX

If the deceased has no heirs, his land shall become the property of Government

Article XXXI

If disputes arise about land, the judge shall rule the dispute in accordance with the accepted laws of the country; if such laws are insufficient the judge shall apply the Napoleonic code.

Article XXXII

This law shall be written and posted in convenient places in the city. Written on 20th of 'teqemt' 1900, in the city of Addis Ababa. (Pankhrust, PP. 156-162, 1966)

Appendix D: Shows the detail description of different cadastre instruments and methods use today with the accuracy and the cost.

Ethiopia – Land Tenure and Administration Program (ELTAP) Comparison of Rural Cadastral Surveying Methods

No.	Method	Accuracy	Cost in Birr/ha	Application
1	Rope	----	13.12	Most rural areas
2	Rope & Handheld GPS centroid reading	----	15.71	Most rural areas
3	Hand-Held (HH) GPS on corners	5-15m	82.95	Most rural areas
4	Compass/Tape*		292.38	inappropriate for all areas
5	Total Station	0-1m	119.95	High Potential areas: -peri urban, irrigation -resettlement, compensation; -commercial farming -investment purposes, etc.
6	IKONS High resolution Satellite Data**	1-?m	229.87	Applicable for all areas if cost contained
7	DGPS (not in EMA study)	0-1m		High potential areas as in Total Station

(EMA, 2006)

The field-testing was undertaken in “Hordofi Got” of Bolle Kebele Administration (KA), West Shoa Administrative Zone.

Appendix E: Set-up for GPS for the establishment of control points

Create a job and configure for static measurement on the base and rover. Set the GPS in base and rover points with leveling and centering. Click Survey. After creating a job and configure the setting and choosing the antenna type, press F1 (Continue). Insert the Point ID and Press Occupy to start the observation. To stop the measurement, Press stop and store the data.

Appendix F: Set-up and measurement procedures in Total station for detail measurement and bench mark.

It is very important to level and centre the total station before starting measurement. The bubble on tribach should be leveled and the centre of the instrument should be on the centre of point over the ground. Some instruments use the laser plummet for centering. After we finish the above activity we start to do the following activity.

1. New job creation.

Go to **Management** (i.e. 3) → select jobs then Enter → Click new (press F2) → Enter the name (to change letter to number or number to letter press F6) then Enter and Click Store (press F1) → Click Cont (means continue) (Press F1) to finish the job creation.

OR

Go to **Survey** (i.e. 1) → Press Enter → Click new (press F2) → Enter the name (to change letter to number or number to letter press F6) then Enter and Click Store (press F1) → Click Cont (means continue) (Press F1) to finish the job creation.

2. Configuration setting

Go to **Management** (i.e. 3) → Select Configuration Sets then Enter → Click new (press F2) → Enter the name (to change letter to number or number to letter press F6) then Enter and Click Store (press F1) → Click Cont (Press F1) and Follow the Wizard to create your own settings.

Some of the main settings include:

Angle and distance units: make degree-minute-second format and meters (use 4 decimal)

EDM and ATR settings: Usually EDM type is reflector, the EDM mode is standard, and the reflector type is **leica circle prism with prism constant 0.00 mm**

If the Target Check is on, you should insert the position tolerance.

3. Measurement Procedure

Go to **Survey** (i.e. 1) → Press Enter → Click on the Job (i.e. Press Enter) → Select the job created before → go to the Config set and select the configuration setting name created before. → Go down to the reflector and choose the right type of reflector.

After that go to **SETUP** (Press F3) Select the method of measurement (use **Known BS Point**)

Station Coord: Select Frm fixed point Job

Station ID : Press enter → Select New (F2) → Give the point ID and East, North and Height coordinates of the station (you can give also in x, y, and z OR lat, long and height format by pressing COORD (F2)) → Press Store (F1) → Press Cont (F1)

Measure the instrument height and enter the result

Fix point job: you must select the one you created before.

Then Press Cont (F1) → Press Enter as the back sight ID selected and Press New (F2) → Give the back sight point ID and its East, North and Height coordinates → Press Store (F1) → Press Cont (F1)

Set the Reflector Height 2.00 m → then **SET THE TOTAL STATION AT THE BACK SIGHT POINT** → Press SET (F1) → then it says 'Station and orientation has been set' → Click OK (F4)

Then after these steps, you can start to take detail measurement. But you have to always check the Reflector height!

Then to take detail measurement: Focus on the reflector → Press DIST (distance) (F2) → then REC (Record) OR you can press ALL (F1) to do the two processes at once. The Total Station changes the point ID by itself for further detail measurement. At this step you have to record and sketch your detail points on your field notes.

Appendix G: Data downloading using Leica Geo office

1. Importing the data to the Computer

Insert the memory card to the memory card reader → then you can open the data on the memory card like Flash Disk (i.e. go to My Computer → Open Removable Disk) → Open 'DBX' Folder → then copy the files with your job name → Create a new folder in your computer and open it → then paste the data in to this folder.

2. Importing data to Leica Geo Office

Open Leica Geo Office Software → Click Import → Click Raw Data → Browse your project data on your computer (make sure the **file type** is **System 1200**) → Click Import → Right Click and Click New Project → Give file name for your project and Click Assign and Close.

Go to  **View/Edit** to view and edit your data and Go to  **Points** to export the data in to Note Pad.

3. Exporting the Data as Text File


While you are at **Points**, Press **Ctrl + A** to select all (the Data we need here are **Only** Point ID, East, North, and Ellipsoidal height. Right click on the selected points → Click **Save As** → on **Save as type** select **Text**, choose the directory where you want to store the data, write the file name and click **Save**.


4. Importing the Data to Excel

Open Excel → Click Data → Click from Text → Browse the text file and follow the wizard by clicking **next**. At this step the Point ID, East, North, and Height are imported to the Excel.

Appendix H: Mapping the Data Using ArcGIS Software

1. Importing the Data to ArcGIS


Open ArcGIS → Click Ok as the New empty map is selected → Click Arc Catalog  → Browse the folder you want to import the data to ArcGIS (You can first create new folder for this step) → Right click on the **Contents view** and Click on New → Click dBASE Table → Rename the file Name → the Close the Arc Catalog Window.

Then on ArcMap window click add data button  and add the table you created before. You will see the table on the table of content. Right Click the Table and Click Open. You will get a table with two columns with names **OID** and **Field1**. On the lower right corner of the window click **Options** → Click **Add Field ...** → write the name as **Point ID** and type **short integer**. Click **Options** again → Click **Add Field ...** → write the name as **East** and type **double**. Do the same for North and Height Columns.

To import the data into Data View click Tools on the Menu. Click Add XY Data → Choose X and Y Field as East and North → Click OK → the data will come as point data on the data view. Convert the event file into shape file. To do this right click the event point data → click data → Click Export Data → Write the file name with appropriate directory and Click Ok. Again Click OK to add the exported data to Arc Map. It is this data that you are going to digitize to different features (details).


2. Digitizing


According to your sketch, start digitizing the different features such as Trees, Roads, Bridges, forest boundaries, Building. But first you need to create new files on Arc Catalog.


Click Arc Catalog  → Browse the folder you want to store the data → Right click on the **Contents view** and Click on New → Click Shape file → Write the Name as for example Tree and choose feature type **Point**. Do the above steps to create file for **Roads (Polyline or polygon)**, **Forest Boundaries (Polygon)**, **Building (Polygon)**, **Electric Pole (point)** and etc.

Add the new files to ArcMaP by clicking  and browse the file where the above files are stored.

To digitize the features, Click Editor → Click Start Editing → Select the Target **Road** to digitize road feature.

Click  and start digitizing (in this case connecting points by lines) by snapping to the point. To snap to the point right click on the point and click **Snap to Feature** → Click **Vertex**. Repeat this until you finish digitizing the feature.

When finish the road feature, change the Target to electricity. But in this case since electricity is represented by a point, you do not need connect one point to the other. To digitize electricity, click  and start digitizing by snapping to the point.

To digitize Buildings, click  and start digitizing (in this case connecting building corners to form polygon) by snapping to the point. Similarly do the above steps for other features or details.

3. Exporting the Map

Now change the data view to layout view.



Insert Title of the Map: go to **Insert** click **Title** and name it like ‘Cadastral Map of ___’

Insert Legend: go to **Insert** and click **Legend** and follow the wizard to show the features by symbols

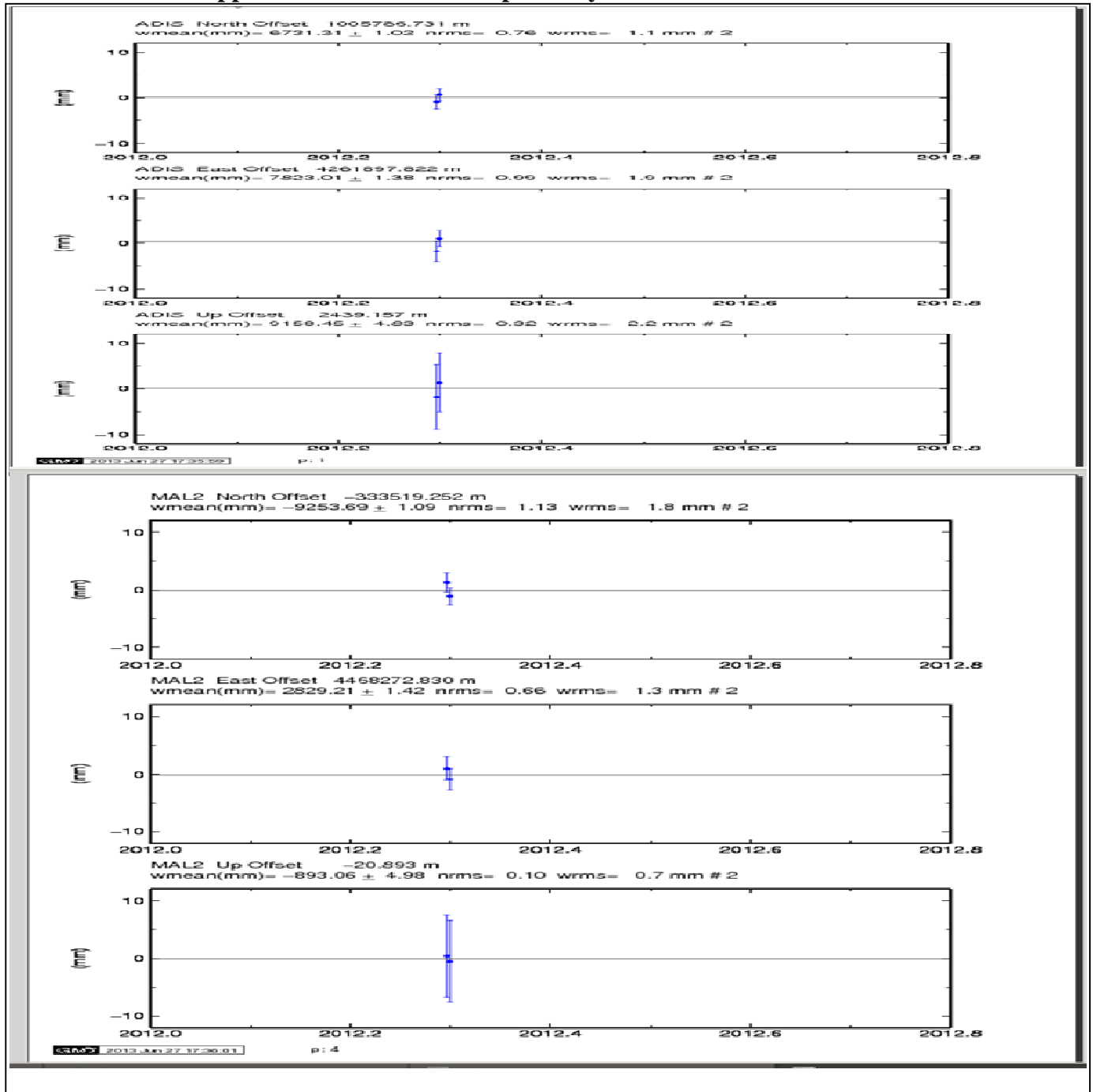
Insert Scale: go to **Insert** and click **Scale Bar**

Insert North Arrow: go to **Insert** and Click **North Arrow**

Finally insert Title Box at right lower part of your paper which includes the title of the project and the name.

To Export the map go to File → click Export Map → give the file name, make the save as type JPG, chose the directory where to save and click OK.

Appendix I: Plotted control points by GAMIT software



Appendix J: Collected data for Arat Kilo campus to produce cadastral map

No	p-id	Total	Easting	Northing	Height	No	p-id	Total	Easting	Northing	Height
1	b1	1	474212.7596	998506.8484	2434.4555	84	r198	500	474067.1801	998445.5595	2434.6395
2	b10	2	474218.1473	998483.1934	2434.2441	85	r199	501	474070.9381	998427.5551	2433.8754
3	b100	3	474196.2599	998404.8204	2429.9832	86	R2	502	474071.202	998480.897	2433.987
4	b101	4	474192.2253	998423.2672	2430.1044	87	r200	503	474069.3043	998425.767	2433.8737
5	b102	5	474119.4209	998407.0093	2430.0978	88	r201	504	474068.0249	998423.8548	2433.8088
6	b11	6	474220.8795	998488.3588	2434.2491	89	r202	505	474067.3354	998423.0565	2433.7346
7	b115	7	474187.8236	998446.3436	2432.5633	90	r203	506	474042.3636	998417.5494	2432.7414
8	b116	8	474195.7055	998461.3035	2433.6182	91	r204	507	474041.7367	998419.6365	2432.8475
9	b117	9	474161.2227	998454.0111	2433.6898	92	r205	508	474038.8973	998418.8999	2432.8274
10	b118	10	474158.3646	998453.3431	2434.4045	93	r206	509	474040.1471	998412.4041	2432.5547
11	b119	11	474139.4251	998440.6499	2434.2105	94	r207	510	474057.9635	998415.8618	2432.948
12	b12	12	474201.9028	998467.9272	2436.1093	95	r208	511	474059.8444	998416.587	2433.0857
13	b120	13	474159.9649	998445.2211	2434.2299	96	r209	512	474072.609	998419.3671	2433.7744
14	b13	14	474210.4176	998469.7652	2433.2668	97	r210	513	474092.8696	998423.6347	2433.8672
15	b131	15	474135.4954	998443.2109	2434.3905	98	r211	514	474095.1669	998423.0883	2433.9293
16	b132	16	474139.3835	998440.6686	2434.4061	99	r212	515	474098.0148	998423.6584	2433.9919
17	b133	17	474127.7499	998479.2017	2433.5831	100	r213	516	474097.8286	998425.3422	2433.9553
18	b134	18	474113.8939	998457.7592	2434.7931	101	r225	517	474028.6821	998402.1716	2431.9184
19	b135	19	474111.266	998469.0497	2435.8791	102	r226	518	474035.4694	998403.9691	2432.1078
20	b14	20	474216.3085	998443.4177	2432.2679	103	r227	519	474040.3371	998405.4175	2432.2576
21	b15	21	474236.4249	998491.7492	2433.0915	104	r228	520	474041.2157	998407.3489	2432.3666
22	b16	22	474231.3627	998490.6159	2433.5471	105	r229	521	474037.8302	998423.991	2432.9518
23	b17	23	474237.1304	998488.2305	2432.8923	106	r23	522	474214.681	998491.24	2433.8709
24	b18	24	474228.9163	998490.351	2433.2583	107	r230	523	474035.3615	998434.89	2433.3414
25	b19	25	474223.0458	998488.7573	2433.6184	108	r231	524	474034.6181	998438.1521	2433.5242
26	b2	26	474216.1852	998509.1997	2434.4577	109	r232	525	474034.1625	998440.2182	2433.6827
27	b20	27	474218.5995	998504.9037	2434.3914	110	r233	526	474034.8385	998449.4303	2433.9406
28	b214	28	474081.0596	998450.606	2434.2435	111	r234	527	474033.1263	998447.1898	2433.9933
29	b215	29	474078.6645	998462.1097	2434.054	112	r235	528	474038.7803	998455.4182	2434.1741
30	b216	30	474059.6402	998464.4703	2434.5646	113	r236	529	474038.6228	998446.8839	2433.8896
31	b217	31	474065.0943	998424.6466	2433.6714	114	r237	530	474037.8814	998443.4544	2433.7029
32	b218	32	474067.294	998428.6477	2434.5805	115	r238	531	474037.9567	998437.8968	2433.4394
33	b219	33	474044.1408	998419.9929	2432.6738	116	r239	532	474039.8335	998428.2324	2433.1102
34	b220	34	474042.1965	998428.4981	2433.4199	117	r24	533	474214.8514	998491.1506	2433.8636
35	b221	35	474041.7595	998436.3872	2433.7036	118	r240	534	474042.3981	998417.4591	2432.7276
36	b222	36	474042.6075	998432.5171	2433.5502	119	r241	535	474050.6767	998419.1884	2433.0368
37	b223	37	474031.0032	998405.5138	2432.1328	120	r242	536	474062.78	998421.8256	2433.5816
38	b224	38	474028.5228	998416.8556	2432.134	121	r243	537	474063.7569	998417.5235	2433.6255

39	b262	39	474049.2902	998471.0967	2435.074	122	r244	538	474059.4309	998416.4102	2433.4211
40	b263	40	474055.7738	998472.4701	2435.4159	123	r245	539	474055.8258	998414.6117	2433.1694
41	b264	41	474044.282	998493.3271	2437.2636	124	r246	540	474051.7537	998410.7047	2432.8067
42	b267	42	474030.7475	998476.3472	2435.1607	125	r247	541	474049.5382	998406.5312	2432.5132
43	b268	43	474051.1398	998462.7978	2434.5756	126	r248	542	474049.7986	998402.7555	2432.307
44	b269	44	474057.1448	998432.2827	2433.4188	127	r249	543	474049.7102	998400.3087	2432.0794
45	b279	45	474047.2561	998438.0293	2433.5328	128	r25	544	474229.4798	998495.6503	2433.3437
46	b284	46	474012.4974	998447.8483	2435.1257	129	r250	545	474047.3926	998391.0945	2431.5616
47	b285	47	474010.6314	998455.8971	2436.2707	130	r251	546	474046.7676	998393.4173	2431.6915
48	b286	48	473972.4227	998404.9079	2430.2203	131	r252	547	474045.1408	998395.2684	2431.8176
49	b287	49	473974.943	998393.2817	2431.1061	132	r253	548	474043.6543	998395.9534	2431.8536
50	b295	50	473935.7666	998390.0892	2430.6981	133	r254	549	474041.9189	998395.6664	2431.8794
51	b296	51	473946.0692	998392.6435	2431.3885	134	r255	550	474041.3066	998392.5369	2431.6838
52	b297	52	473937.9515	998427.1741	2430.7111	135	r256	551	474039.8666	998384.449	2431.4144
53	b298	53	473941.5161	998428.1392	2432.2499	136	r257	552	474046.4262	998389.3961	2431.4499
54	b299	54	473939.7583	998435.4827	2432.3749	137	r258	553	474042.8081	998388.4872	2431.4798
55	b3	55	474219.3908	998507.3987	2434.3898	138	r259	554	474033.1411	998391.3159	2431.1952
56	b317	56	473963.507	998413.299	2431.0612	139	r26	555	474239.6478	998498.6866	2433.1451
57	b318	57	473984.462	998417.426	2431.7919	140	r260	556	474033.5044	998394.4728	2431.1892
58	b319	58	998451.399	473976.524	2434.6523	141	r261	557	474037.3936	998393.3927	2431.0606
59	b320	59	998453.304	473984.462	2434.6458	142	r27	558	474240.7027	998500.3953	2433.1504
60	b325	60	473959.1499	998468.8135	2435.9765	143	r270	559	474040.1302	998449.7538	2434.086
61	b326	61	473965.0484	998444.0342	2434.198	144	r271	560	474046.1996	998460.1601	2434.5558
62	b327	62	473957.1844	998442.0326	2433.0792	145	r272	561	474050.4211	998466.1789	2435.0052
63	b328	63	473935.336	998444.7473	2432.3593	146	r273	562	474055.9772	998467.313	2435.2627
64	b329	64	473932.6981	998455.9449	2432.6734	147	r274	563	474061.1439	998468.5202	2435.552
65	b330	65	473925.7216	998432.2283	2432.3844	148	r275	564	474061.3022	998473.7154	2435.8693
66	b335	66	473923.1665	998441.7907	2432.2923	149	r276	565	474049.3776	998471.0242	2435.0892
67	b336	67	473920.7019	998453.0074	2432.5167	150	r277	566	474045.8598	998470.4133	2435.0031
68	b337	68	473921.2173	998450.2186	2432.4783	151	r278	567	474043.9838	998466.5679	2434.738
69	b338	69	473922.2457	998445.2765	2432.3682	152	r28	568	474242.8636	998502.995	2433.1613
70	b339	70	473925.9391	998442.4274	2432.469	153	r288	569	473959.789	998389.7119	2430.6628
71	b346	71	473924.0746	998373.4031	2429.9893	154	r289	570	473961.8798	998389.5444	2430.678
72	b347	72	473924.8345	998370.0562	2429.928	155	r29	571	474252.8855	998504.9285	2433.064
73	b357	73	473932.7307	998319.7557	2427.2597	156	r290	572	473964.1686	998389.7095	2430.707
74	b358	74	473945.5471	998341.0517	2429.8355	157	r291	573	473992.185	998394.9096	2430.9339
75	b359	75	473950.32	998338.2935	2429.847	158	r292	574	474023.8368	998401.2796	2431.4913
76	b360	76	473951.5221	998340.3094	2429.8413	159	r293	575	474033.2042	998391.3872	2431.643
77	b361	77	473957.1157	998337.3602	2428.8155	160	r294	576	474009.7435	998386.5861	2432.296
78	b362	78	473949.8884	998358.5248	2429.27	161	R3	577	474065.858	998481.041	2435.414
79	b363	79	473951.5417	998361.0583	2429.3463	162	r30	578	474260.326	998506.6509	2432.3642

80	b364	80	473959.886	998352.0923	2429.5049	163	r300	579	473940.7318	998435.7892	2432.3485
81	b365	81	473955.909	998335.0729	2429.8327	164	r301	580	473942.7401	998427.6271	2432.1557
82	b366	82	473960.6198	998332.3802	2429.8344	165	r302	581	473939.9907	998426.8196	2432.1251
83	b367	83	473953.6021	998318.775	2427.2382	166	r303	582	473948.1138	998392.195	2430.7581
84	b368	84	473965.185	998316.0995	2427.0962	167	r304	583	473934.2416	998388.7118	2431.4156
85	b369	85	473979.2252	998308.0561	2427.4369	168	r305	584	473945.1192	998436.561	2432.4182
86	b370	86	473991.0724	998327.734	2428.8497	169	r306	585	473952.8147	998404.801	2431.168
87	b371	87	474005.7345	998310.6443	2428.8497	170	r307	586	473953.1932	998402.9486	2431.1195
88	b372	88	474013.0053	998346.8526	2428.8757	171	r308	587	473955.0579	998394.7226	2430.6371
89	b4	89	474234.1951	998532.1626	2433.7471	172	r309	588	473961.898	998389.4042	2430.9331
90	b40	90	474251.2441	998506.9759	2433.1802	173	r31	589	474264.2498	998504.0923	2432.5539
91	b41	91	474259.0208	998510.0752	2432.2555	174	r310	590	473972.0681	998391.3921	2430.6347
92	b415	92	474029.2405	998354.7742	2429.6823	175	r311	591	474001.4538	998385.0439	2431.966
93	b416	93	474032.2184	998355.2426	2430.0749	176	r312	592	473977.6281	998380.6767	2431.0807
94	b417	94	474060.4015	998361.647	2429.8912	177	r313	593	473975.9792	998380.4088	2431.0419
95	b42	95	474245.6215	998534.5189	2433.8839	178	r314	594	473935.1634	998371.9754	2431.3253
96	b424	96	474037.7441	998330.9858	2429.2982	179	r315	595	474034.984	998427.533	2432.8599
97	b429	97	473965.5993	998292.287	2426.8517	180	r316	596	474035.778	998425.549	2432.6727
98	b430	98	474028.0066	998329.39	2428.8656	181	r32	597	474256.8434	998501.9045	2432.7082
99	b450	99	474015.7467	998274.1027	2425.8707	182	r321	598	473922.8536	998375.8178	2431.8266
100	b451	100	474029.3074	998269.5318	2426.1289	183	r322	599	473937.8214	998356.6007	2434.615
101	b452	101	474031.8224	998268.6988	2425.1346	184	r323	600	473936.2326	998355.3435	2434.6201
102	b453	102	474062.1872	998258.1103	2425.5684	185	r324	601	473921.2761	998374.3521	2431.8688
103	b48	103	474262.4453	998515.0011	2432	186	r33	602	474254.5372	998498.8709	2433.3928
104	b481	104	474085.1678	998272.9624	2426.8113	187	r331	603	473943.7115	998443.0934	2432.7122
105	b482	105	474057.9491	998245.1668	2426.0233	188	r332	604	473915.6182	998435.7726	2432.4866
106	b499	106	474218.4472	998421.8038	2431.9213	189	r333	605	473923.4452	998432.6447	2432.3355
107	b5	107	474236.0654	998523.0897	2433.8563	190	r334	606	473940.4753	998436.6882	2432.1432
108	b500	108	474216.5704	998430.0467	2432.1986	191	r34	607	474253.5893	998496.1642	2432.7214
109	b501	109	474207.9073	998420.5268	2431.8749	192	r340	608	473915.4426	998381.1028	2429.8674
110	b502	110	474202.1175	998419.1571	2431.5319	193	r341	609	473915.7516	998378.956	2429.775
111	b503	111	474203.635	998412.6648	2431.0782	194	r342	610	473916.8468	998374.4852	2429.9484
112	b504	112	474202.0081	998412.2977	2431.0216	195	r343	611	473925.7223	998384.1914	2430.2452
113	b505	113	474203.3399	998406.6233	2430.6994	196	r344	612	473916.1361	998432.6896	2432.3598
114	b506	114	474249.7116	998413.6885	2430.2042	197	r345	613	473923.3684	998432.6421	2430.6604
115	b508	115	474241.7857	998408.8084	2429.8749	198	r348	614	473924.833	998369.9817	2429.9374
116	b509	116	474207.0307	998407.3797	2432.2046	199	r349	615	473934.119	998331.6402	2428.7147
117	b510	117	474207.7369	998404.204	2430.5225	200	r35	616	474248.6404	998495.174	2432.2186
118	b511	118	474222.4305	998404.2533	2430.1015	201	r350	617	473944.4945	998343.8984	2428.2061
119	b512	119	474224.3541	998395.8205	2429.8549	202	r351	618	473940.6876	998353.8901	2428.7622
120	b513	120	474221.3837	998395.0415	2429.3307	203	r352	619	473939.1472	998355.1518	2428.8309

121	b514	121	474214.8231	998393.6045	2430.9914	204	r353	620	473938.0635	998359.4634	2429.0428
122	b515	122	474154.1773	998380.1776	2430.0766	205	r354	621	473937.6242	998362.0068	2429.5976
123	b516	123	474151.0662	998394.8461	2430.2614	206	r36	622	474242.9346	998493.995	2432.8028
124	b517	124	474196.3123	998404.6796	2430.1342	207	r37	623	474238.0132	998494.7881	2433.1552
125	b518	125	474192.319	998423.1843	2431.3705	208	r373	624	473983.6468	998330.398	2428.2675
126	b539	126	474224.7918	998379.9648	2430.0109	209	r374	625	473985.3335	998331.6312	2428.2989
127	b540	127	474232.8478	998381.7156	2429.9915	210	r375	626	473963.8794	998333.9158	2428.7536
128	b541	128	474241.8339	998383.6472	2429.9335	211	r376	627	473960.2505	998327.2122	2428.5249
129	b542	129	474249.8597	998385.3945	2429.7942	212	r377	628	473968.2341	998321.7398	2428.4979
130	b543	130	474217.0959	998383.1486	2430.0524	213	r378	629	473966.3338	998318.0153	2428.3987
131	b544	131	474212.807	998373.8731	2430.041	214	r379	630	473981.8254	998309.0037	2428.3271
132	b545	132	474219.9705	998364.8145	2429.8582	215	r38	631	474227.3026	998491.5656	2433.5023
133	b546	133	474229.6512	998368.0156	2429.7103	216	r380	632	473979.179	998304.7021	2427.9563
134	b547	134	474212.7188	998361.2219	2429.9194	217	r381	633	474012.3178	998290.2238	2427.4424
135	b548	135	474204.6868	998358.152	2429.95	218	r382	634	473940.5133	998353.8093	2429.2833
136	b549	136	474148.8916	998360.3128	2430.0326	219	r383	635	473973.7886	998332.6666	2428.787
137	b558	137	474141.6204	998392.5445	2430.0683	220	r384	636	474005.5653	998309.8971	2428.8137
138	b559	138	474123.3597	998388.4971	2430.1014	221	r385	637	473990.6873	998327.6238	2428.8289
139	b560	139	474119.152	998406.9566	2429.7593	222	r386	638	474013.141	998347.5302	2428.862
140	b561	140	474110.9261	998401.2276	2429.9741	223	r387	639	474013.6125	998352.6847	2428.6278
141	b562	141	474121.4956	998353.7322	2430.045	224	r388	640	474002.1433	998343.0304	2428.7424
142	b576	142	474183.868	998330.145	2428.3338	225	r389	641	473981.8883	998333.9096	2428.3566
143	b577	143	474168.4447	998344.1123	2431.23	226	r39	642	474217.5016	998488.6252	2433.8811
144	b578	144	474196.6292	998301.6835	2427.9129	227	r390	643	473983.2467	998333.1139	2428.3524
145	b579	145	474185.141	998336.8271	2427.9853	228	r391	644	474001.6254	998344.1242	2428.5702
146	b580	146	474085.613	998309.2099	2429.4575	229	r392	645	474000.9615	998345.9368	2428.6288
147	b581	147	474095.6936	998328.1902	2429.7385	230	r393	646	474001.3264	998349.6375	2428.7998
148	b582	148	474065.7343	998337.1781	2429.6798	231	r394	647	474008.7566	998385.6539	2431.2114
149	b583	149	474037.8245	998330.9019	2429.9331	232	r395	648	474002.8757	998383.284	2431.0399
150	b6	150	474237.2432	998523.1669	2433.8965	233	r396	649	474000.37	998368.0629	2429.9434
151	b601	151	474087.3263	998364.4725	2430.1236	234	r397	650	473996.8131	998350.7527	2429.0591
152	b602	152	474072.2964	998361.1209	2430.0683	235	r398	651	473994.8801	998344.4626	2428.5176
153	b606	153	474259.2317	998510.1188	2432.2479	236	r399	652	473989.2305	998334.6841	2428.6507
154	b607	154	474263.2771	998511.0385	2431.5485	237	R4	653	474064.685	998477.454	2435.061
155	b608	155	474262.4225	998515.0392	2432.0272	238	r400	654	473986.2813	998332.3036	2428.5733
156	b634	156	474255.8656	998584.616	2435.4054	239	r401	655	474013.6503	998353.1075	2428.644
157	b635	157	474258.7846	998617.3213	2437.1312	240	r402	656	474018.3901	998348.0037	2428.5755
158	b646	158	474246.4051	998618.628	2436.7665	241	r403	657	474037.578	998384.5976	2431.45
159	b647	159	474229.2806	998603.0644	2436.385	242	r404	658	474038.4765	998388.0834	2431.4793
160	b648	160	474245.6325	998642.3594	2437.8455	243	r405	659	474038.1894	998391.787	2431.6829
161	b649	161	474243.5274	998647.4037	2437.8901	244	r406	660	474041.7481	998395.2844	2431.8171

162	b658	162	474239.5845	998655.0394	2439.6429	245	r407	661	474039	998382.2645	2431.3103
163	b659	163	474232.2463	998658.1436	2437.7204	246	r408	662	474029.8515	998350.9702	2429.9523
164	b660	164	474203.7189	998663.5364	2438.1209	247	r409	663	474027.9861	998361.3714	2429.9691
165	b661	165	474234.8911	998664.8145	2438.8949	248	r410	664	474021.1849	998348.6135	2429.0518
166	b663	166	474214.906	998676.537	2440.6013	249	r411	665	474019.7865	998346.2707	2428.6938
167	b664	167	474190.4321	998685.5911	2439.9447	250	r412	666	474031.6649	998331.9715	2428.5629
168	b665	168	474184.5178	998681.3599	2440.4732	251	r413	667	474032.6343	998333.796	2429.3789
169	b666	169	474178.5404	998672.0371	2440.609	252	r414	668	474028.1212	998349.9144	2429.81
170	b667	170	474183.9222	998669.2969	2438.7678	253	r418	669	474058.4036	998363.7084	2429.9034
171	b668	171	474188.8497	998664.959	2440.3806	254	r419	670	474049.3701	998360.9152	2429.8577
172	b684	172	474187.5966	998692.0747	2440.1204	255	r420	671	474047.467	998369.0793	2430.5929
173	b685	173	474196.2783	998714.841	2439.7383	256	r421	672	474047.2582	998389.4467	2431.5614
174	b686	174	474185.5449	998697.0439	2440.8694	257	r422	673	474052.8556	998388.7758	2431.4882
175	b687	175	474189.7245	998711.7874	2440.8108	258	r423	674	474042.8713	998388.3674	2431.2575
176	b688	176	474176.9321	998699.3797	2441.0333	259	r425	675	473983.806	998301.8238	2426.1869
177	b690	177	474180.7835	998714.3594	2440.8367	260	r426	676	473982.0919	998303.6899	2426.202
178	b691	178	474181.0239	998714.9224	2440.8743	261	r427	677	473966.6895	998287.0801	2426.3264
179	b692	179	474172.845	998716.778	2441.0734	262	r428	678	473965.0677	998288.7186	2427.192
180	b693	180	474173.5267	998720.2858	2441.8797	263	r43	679	474267.9958	998508.3657	2431.6608
181	b694	181	474170.2293	998716.3992	2441.1577	264	r431	680	474030.069	998323.3795	2428.0941
182	b695	182	474168.0161	998716.9516	2441.2715	265	r432	681	474028.8007	998323.3588	2428.4764
183	b696	183	474168.7539	998721.2335	2441.0664	266	r433	682	474025.9383	998323.0491	2428.8054
184	b7	184	474238.5379	998517.2318	2433.7187	267	r434	683	474014.2615	998312.7607	2428.0563
185	b704	185	474148.9443	998704.1742	2441.0653	268	r435	684	474013.5973	998309.391	2427.9238
186	b705	186	474150.7433	998707.0652	2441.011	269	r436	685	474014.1958	998307.6261	2427.8348
187	b706	187	474165.3823	998733.2735	2442.8256	270	r437	686	474019.1749	998300.5235	2427.7555
188	b707	188	474159.936	998717.7251	2442.9729	271	r438	687	474066.4506	998285.3438	2427.5579
189	b708	189	474123.9403	998730.2255	2443.8345	272	r439	688	474025.1348	998285.7612	2427.3304
190	b710	190	474135.6532	998716.6738	2441.4988	273	r44	689	474265.6967	998503.8644	2431.4092
191	b711	191	474133.9208	998713.8075	2441.6612	274	r440	690	474022.3979	998276.9187	2426.0483
192	b712	192	474125.0608	998719.4718	2441.6887	275	r441	691	474031.2864	998271.2589	2424.509
193	b713	193	474112.7734	998717.799	2442.3911	276	r442	692	474033.8999	998282.6846	2427.018
194	b714	194	474114.26	998722.6576	2442.3915	277	r443	693	474037.503	998283.298	2426.8465
195	b715	195	474104.0993	998725.7899	2442.8228	278	r444	694	474041.7998	998283.1728	2426.6226
196	b724	196	474142.9795	998694.9049	2441.6168	279	r445	695	474048.1685	998281.1408	2426.5499
197	b725	197	474141.23	998691.9653	2441.3418	280	r446	696	474046.7863	998267.1122	2425.63
198	b726	198	474117.3518	998707.2394	2441.4622	281	r447	697	474049.1593	998265.8403	2425.5105
199	b727	199	474163.3712	998645.171	2439.9607	282	r448	698	474048.7086	998280.7731	2426.5579
200	b737	200	474118.5275	998654.0751	2439.7883	283	r45	699	474262.0921	998503.323	2431.8623
201	b738	201	474124.965	998655.7888	2439.7449	284	r454	700	474062.8107	998276.0998	2427.1713
202	b739	202	474129.8394	998651.819	2439.7654	285	r455	701	474066.6547	998275.1326	2427.2304

203	b740	203	474131.4191	998646.1933	2439.7922	286	r456	702	474069.5855	998273.2073	2426.4899
204	b741	204	474134.1945	998646.7809	2439.6828	287	r457	703	474074.3805	998253.5839	2425.8805
205	b742	205	474139.5256	998626.5904	2439.6144	288	r458	704	474074.8565	998251.9478	2425.8626
206	b743	206	474141.1555	998620.0105	2438.4359	289	r459	705	474074.8465	998251.9342	2425.857
207	b744	207	474164.7265	998634.0753	2439.0824	290	r46	706	474259.1227	998502.7923	2431.9422
208	b745	208	474166.6336	998632.3311	2439.1207	291	r460	707	474076.2598	998246.2311	2425.7376
209	b746	209	474171.3774	998634.892	2439.0864	292	r461	708	474078.3067	998240.3496	2425.7501
210	b747	210	474177.4889	998634.5548	2438.9549	293	r462	709	474081.5733	998234.9056	2425.7198
211	b748	211	474184.2127	998632.0569	2439.8016	294	r463	710	474087.9385	998229.5326	2425.5862
212	b78	212	474257.0417	998439.1379	2431.0933	295	r464	711	474091.7038	998227.5702	2425.5065
213	b79	213	474257.8059	998435.7366	2431.1624	296	r465	712	474086.8592	998237.3842	2425.2981
214	b8	214	474242.321	998505.2152	2433.384	297	r466	713	474084.3297	998240.7827	2425.4253
215	b80	215	474261.4476	998436.7847	2431.0484	298	r467	714	474079.6857	998253.9384	2425.8641
216	b81	216	474263.9938	998424.3839	2430.7545	299	r468	715	474075.3222	998273.5652	2427.2144
217	b82	217	474215.3922	998429.769	2432.1906	300	r469	716	474075.884	998275.5958	2426.5796
218	b83	218	474202.109	998419.2728	2431.6932	301	r470	717	474076.8821	998276.888	2426.6497
219	b84	219	474220.2667	998444.2779	2432.9792	302	r471	718	474078.3398	998277.6046	2426.6914
220	b85	220	474217.7002	998456.2154	2432.7252	303	r472	719	474093.6696	998281.0326	2427.5667
221	b86	221	474224.9368	998445.2274	2433.1249	304	r473	720	474090.3553	998284.1021	2427.0872
222	b87	222	474189.6039	998437.7504	2432.9847	305	r474	721	474077.5577	998281.2098	2426.8176
223	b9	223	474216.9725	998487.0304	2434.2728	306	r475	722	474074.0098	998282.4712	2426.8328
224	b97	224	474216.6821	998422.3306	2431.8696	307	r476	723	474072.4143	998285.9912	2426.9834
225	b98	225	474203.6417	998412.6969	2431.0769	308	r477	724	474068.138	998306.7935	2428.0956
226	b99	226	474201.933	998412.2608	2430.9985	309	r478	725	474063.2116	998308.6141	2428.1328
227	BBD1	227	474197.669	998275.789	2427.68	310	r479	726	474067.3461	998288.3771	2426.9533
228	BBD2	228	474186.875	998273.786	2427.263	311	r480	727	474089.2247	998253.8047	2426.1365
229	BBD3	229	474186.662	998274.446	2427.327	312	r488	728	474107.5397	998220.6569	2425.2957
230	BBD4	230	474168.736	998269.928	2427.244	313	r489	729	474098.0665	998225.0541	2425.4228
231	bbM1	231	474062.1	998258.152	2426.28	314	r49	730	474278.2342	998593.2162	2434.3003
232	bbM1	232	474012.688	998447.871	2435.555	315	r490	731	474091.6396	998227.6703	2425.4144
233	bbM10	233	473981.639	998450.319	2435.042	316	r491	732	474095.7054	998231.5494	2425.3981
234	bbM11	234	473973.758	998472.727	2435.195	317	r492	733	474099.204	998230.0997	2425.3649
235	bbM12	235	473958.922	998471.916	2435.264	318	r493	734	474105.1964	998227.6099	2425.3883
236	bbM13	236	473957.878	998476.015	2436.178	319	r494	735	474109.9301	998226.2249	2425.1563
237	bbM2	237	474010.815	998456.114	2435.561	320	r495	736	474087.4888	998236.8293	2425.3831
238	bbm265	238	474035.3394	998455.8509	2435.0949	321	r496	737	474084.1696	998241.0053	2425.5241
239	bbm266	239	474032.9113	998452.1783	2435.0803	322	r497	738	474082.0211	998246.4	2425.6797
240	bbM3	240	473994.886	998434.945	2435.124	323	r498	739	474080.0897	998252.8586	2425.9586
241	bbM4	241	473992.029	998452.535	2435.525	324	R5	740	474063.792	998475.663	2434.954
242	bbM5	242	473993.431	998440.734	2435.187	325	r50	741	474277.0728	998577.8169	2433.5256
243	bbM6	243	474025.982	998459.398	2437.615	326	r51	742	474275.7488	998561.6655	2432.8166

244	bbM7	244	474022.643	998474.214	2435.642	327	r52	743	474271.9354	998512.4623	2431.5038
245	bbM8	245	474030.761	998476.405	2436.065	328	r527	744	474196.1858	998428.4704	2431.694
246	bbM9	246	474044.692	998493.421	2437.771	329	r528	745	474202.9661	998395.0466	2430.0315
247	bbN1	247	474161.2	998241.393	2428.008	330	r529	746	474199.1264	998428.1844	2431.6043
248	bbN2	248	474155.715	998248.102	2427.068	331	r53	747	474271.5902	998511.0593	2431.4803
249	bbN3	249	474154.474	998253.785	2427.036	332	r530	748	474203.1697	998405.007	2430.5777
250	bbN4	250	474158.156	998254.800	2427.348	333	r531	749	474204.0878	998405.1751	2430.6035
251	bbN5	251	474156.401	998262.135	2427.721	334	r532	750	474204.946	998401.6987	2430.3217
252	bbN6	252	474202.337	998273.060	2427.331	335	r533	751	474208.1671	998402.4047	2430.4701
253	BBS1	253	474178.234	998282.371	2427.451	336	r534	752	474209.3832	998396.633	2430.1518
254	bBS1	254	474084.041	998288.716	2427.542	337	r535	753	474223.6559	998398.6376	2429.5168
255	BBS2	255	474175.816	998294.843	2427.48	338	r536	754	474224.2093	998395.7886	2429.6324
256	bBS2	256	474095.259	998294.658	2427.618	339	r537	755	474153.718	998383.2209	2430.2083
257	BBS3	257	474178.702	998295.529	2427.489	340	r538	756	474154.3202	998380.2098	2430.2481
258	bBS3	258	474115.375	998298.711	2427.231	341	r54	757	474270.4651	998509.5145	2431.5048
259	bBS4	259	474116.669	998294.258	2427.791	342	r55	758	474278.8369	998551.1034	2432.5065
260	bBS5	260	474156.22	998302.469	2425.646	343	r550	759	474143.1563	998380.4011	2430.0534
261	bBS6	261	474175.541	998311.401	2427.136	344	r551	760	474143.8283	998377.9306	2430.0361
262	bBS7	262	474164.418	998309.117	2427.711	345	r552	761	474117.655	998374.734	2430.026
263	bbw650	263	474240.7559	998612.4596	2436.9655	346	r553	762	474118.1393	998372.1851	2430.0492
264	bbw651	264	474246.9089	998622.5884	2437.4733	347	r554	763	474122.9095	998378.8404	2429.5407
265	bbw652	265	474243.5017	998622.7563	2437.6087	348	r555	764	474117.4764	998375.6688	2430.0121
266	bbw653	266	474243.1757	998619.1049	2437.6886	349	r556	765	474143.6728	998381.4377	2429.501
267	bbw654	267	474238.2295	998621.1232	2437.7285	350	r557	766	474142.7114	998383.5891	2429.5468
268	bbw655	268	474242.1059	998630.6256	2437.7923	351	r56	767	474276.7569	998523.6482	2431.7264
269	bbw656	269	474243.9641	998629.9505	2437.702	352	r563	768	474117.5548	998375.6265	2429.9408
270	bbw657	270	474247.4429	998638.3715	2437.7677	353	r564	769	474122.0386	998381.5638	2428.3525
271	bCB1	271	474021.675	998246.600	2426.28	354	r565	770	474117.1325	998403.8018	2430.1706
272	bCB2	272	474024.694	998258.405	2426.423	355	r566	771	474111.3647	998402.8321	2430.0565
273	bCI1	273	473941.806	998463.699	2434.503	356	r567	772	474069.7483	998317.6789	2428.086
274	bCI2	274	473952.728	998469.220	2435.341	357	r568	773	474072.7534	998318.4016	2428.0211
275	bCI3	275	473924.306	998459.070	2432.736	358	r569	774	474072.866	998314.0374	2428.065
276	bCI4	276	473922.851	998465.248	2435.225	359	r57	775	474276.2917	998516.1569	2431.5594
277	bDL1	277	474099.216	998275.731	2427.662	360	r570	776	474171.1413	998336.1269	2428.7283
278	bDL2	278	474101.341	998266.251	2428.586	361	r571	777	474174.8453	998338.497	2428.7417
279	bDL3	279	474115.42	998274.768	2427.155	362	r572	778	474176.7305	998340.8171	2428.8232
280	bIDL1	280	474115.126	998278.267	2427.157	363	r573	779	474171.4267	998340.9808	2427.1864
281	bIDL2	281	474113.882	998284.133	2427.208	364	r574	780	474168.9797	998339.8873	2428.6933
282	bIDL3	282	474124.285	998286.483	2427.144	365	r58	781	474272.5464	998465.603	2430.1327
283	bIL1	283	474089.102	998253.814	2424.881	366	r584	782	474030.417	998323.2115	2428.8471
284	bIL2	284	474099.954	998255.939	2426.69	367	r585	783	474036.5499	998321.5678	2428.7686

285	bIL3	285	474117.897	998260.467	2426.718	368	r586	784	474063.0395	998308.6704	2428.1776
286	bIL4	286	474118.182	998259.790	2426.989	369	r587	785	474065.0302	998299.7198	2427.9823
287	BL1	287	474111.462	998469.039	2435.878	370	r588	786	474033.8696	998324.0097	2428.873
288	BL10	288	474073.291	998472.454	2436.154	371	r589	787	474037.24	998324.8287	2428.9281
289	BL11	289	474068.719	998471.441	2436.157	372	r59	788	474266.925	998458.7206	2430.4311
290	BL12	290	474066.602	998479.239	2435.109	373	r590	789	474037.4141	998323.9531	2428.871
291	BL13	291	474063.015	998489.888	2435.607	374	r591	790	474058.0091	998313.3126	2428.3473
292	BL2	292	474106.828	998468.438	2435.922	375	r592	791	474063.2228	998312.6207	2428.2178
293	BL3	293	474104.818	998477.361	2436.251	376	r593	792	474067.642	998316.9144	2428.2395
294	BL4	294	474112.03	998479.039	2436.283	377	r594	793	474072.0258	998313.3019	2428.1737
295	BL5	295	474110.38	998487.054	2436.601	378	r595	794	474069.5858	998310.9959	2428.1391
296	BL6	296	474113.006	998498.207	2437.113	379	r596	795	474068.6748	998309.0816	2428.128
297	BL7	297	474111.29	998508.488	2437.444	380	r597	796	474068.1753	998305.8202	2428.1007
298	BL8	298	474070.976	998462.275	2434.988	381	r598	797	474072.0865	998323.4489	2429.8433
299	BL9	299	474075.305	998463.142	2435.106	382	r599	798	474065.6862	998351.6597	2430.0646
300	bLO1	300	474086.451	998241.221	2426.093	383	R6	799	474059.157	998474.860	2434.937
301	bLO2	301	474085.229	998247.100	2426.099	384	r60	800	474268.8864	998476.9847	2430.5851
302	bLO3	302	474118.179	998253.997	2426.082	385	r600	801	474065.9914	998336.0474	2430.0793
1	BM1	303	474222.8763	998534.0728	2435.1107	386	r603	802	474061.6057	998356.0345	2430.1594
2	BM10	304	474166.8789	998669.8405	2440.6853	387	r604	803	474060.6105	998362.136	2430.1228
3	BM12	305	474263.1727	998446.7149	2430.584	388	r605	804	474063.2852	998362.5827	2430.068
4	BM13	306	474219.6217	998440.0352	2431.9853	389	r609	805	474275.5744	998559.4108	2432.7338
5	BM14	307	474198.535	998427.2149	2432.0277	390	r61	806	474270.6441	998498.7847	2431.1508
6	BM15	308	474171.6803	998441.8042	2433.59	391	r610	807	474275.8195	998562.6331	2432.8454
7	BM16	309	474132.2944	998440.0749	2434.0225	392	r611	808	474274.3773	998558.058	2432.6634
8	BM18	310	474079.5914	998421.232	2433.8616	393	r613	809	474250.4656	998571.5325	2434.7058
9	BM19	311	474063.8019	998472.0469	2435.8148	394	r614	810	474256.3467	998571.2174	2434.4187
10	BM2	312	474240.4639	998495.2404	2433.0642	395	r615	811	474282.4074	998593.1739	2433.7758
11	BM20	313	474039.6537	998456.701	2434.2344	396	r616	812	474281.9789	998596.8614	2434.3159
12	BM22	314	474039.4888	998417.5804	2432.7516	397	r617	813	474280.8185	998600.045	2434.4945
13	BM23	315	474043.484	998396.7987	2431.9017	398	r618	814	474267.1848	998626.0683	2436.424
14	BM24	316	474009.0788	998348.2077	2428.7903	399	r619	815	474262.1325	998629.8697	2436.8159
15	BM25	317	473979.8704	998327.887	2428.6694	400	r62	816	474270.3702	998501.3746	2431.2164
16	BM26	318	473998.5419	998294.2889	2428.2183	401	r620	817	474252.2186	998632.3547	2437.4607
17	BM27	319	474067.4018	998283.9038	2427.4925	402	r621	818	474252.8152	998636.1768	2437.673
18	BM28	320	473956.679	998389.4549	2430.8453	403	r622	819	474277.8177	998594.3636	2434.2259
19	BM29	321	473939.7463	998438.6365	2432.4321	404	r623	820	474276.3186	998599.5633	2434.4887
20	BM3	322	474275.7085	998511.0791	2431.4417	405	r624	821	474272.856	998601.7179	2434.8432
21	BM30	323	473916.4697	998437.1462	2432.4275	406	r625	822	474270.2189	998597.5053	2434.4591
22	BM31	324	473934.3238	998372.7482	2430.1861	407	r626	823	474258.3277	998598.559	2435.424
23	BM32	325	474202.1117	998401.5294	2430.4619	408	r627	824	474259.4054	998612.2938	2435.4854

24	BM33	326	474219.2329	998392.4545	2430.1661	409	r628	825	474264.4375	998612.1851	2435.4673
25	BM34	327	474220.5472	998374.1663	2429.9718	410	r629	826	474266.8201	998614.0332	2435.5177
26	BM35	328	474150.7115	998379.7342	2430.0616	411	r63	827	474268.4301	998503.2991	2431.4534
27	BM36	329	474113.4433	998385.9892	2430.0597	412	r630	828	474263.7079	998624.0167	2436.4066
28	BM37	330	474127.1927	998326.2605	2428.4482	413	r631	829	474255.5075	998626.9779	2437.1087
29	BM38	331	474184.7035	998331.2902	2428.1649	414	r632	830	474249.9162	998626.1209	2437.3064
30	BM4	332	474276.8487	998605.1878	2434.9617	415	r669	831	474203.6173	998675.3375	2439.4454
31	BM40	333	474211.9334	998480.4553	2433.9544	416	r670	832	474202.3936	998672.1759	2439.7347
32	BM41	334	474083.2004	998234.9146	2426.0352	417	r671	833	474192.844	998677.2877	2440.1837
33	BM42	335	474066.2605	998313.0074	2428.1683	418	r672	834	474188.7481	998675.5171	2440.4822
34	BM44	336	474116.966	998222.468	2425.833	419	r673	835	474187.168	998673.5353	2440.5392
35	BM45	337	474127.715	998259.856	2426.977	420	r674	836	474183.6451	998675.5635	2440.5694
36	BM46	338	474142.383	998261.974	2428.478	421	r675	837	474186.328	998680.2317	2440.4648
37	BM47	339	474106.384	998201.805	2425.766	422	r676	838	474184.7866	998681.3431	2440.5148
38	BM48	340	474184.607	998213.367	2426.31	423	r677	839	474165.1451	998703.2197	2440.7632
39	BM49	341	474029.721	998223.95	2425.197	424	r678	840	474171.6582	998698.3243	2440.4495
40	BM5	342	474249.156	998636.7835	2437.686	425	r679	841	474185.3815	998693.7363	2440.0659
41	BM50	343	473934.309	998263.987	2424.59	426	r68	842	474266.7451	998458.1478	2430.4413
42	BM6	344	474243.8469	998648.5406	2437.7397	427	r680	843	474185.5938	998689.7854	2440.1043
43	BM7	345	474197.2914	998674.7494	2439.9982	428	r681	844	474187.3541	998685.7324	2440.0157
44	BM8	346	474165.5365	998703.6143	2440.9172	429	r682	845	474189.0381	998684.0468	2439.9118
45	BM9	347	474118.0398	998729.4766	2442.1752	430	r683	846	474203.9024	998676.7924	2439.2901
	box21	348	474222.7302	998498.2135	2433.7672	431	r69	847	474272.2565	998461.346	2430.3436
	box22	349	474220.0301	998500.9474	2433.9171	432	r698	848	474163.6954	998722.5351	2441.1691
1	ADIS	350	474223.4136	998537.8956	2435.4244	433	r699	849	474161.0403	998715.2487	2440.9399
2	OBS	351	474206.8759	998522.9993	2433.7967	434	r6K1	850	473899.761	998288.731	2424.796
	e633	352	474262.9106	998622.7512	2435.9564	435	r6K2	851	473908.202	998299.509	2425.659
1	F1	353	473992.922	998484.762	2436.676	436	r6K3	852	473902.872	998324.514	2426.88
2	F2	354	473964.884	998478.204	2436.513	437	r6K4	853	473896.646	998351.590	2428.208
3	f355	355	473917.7027	998371.9477	2430.7581	438	r6K5	854	473909.714	998366.308	2428.822
4	f356	356	473929.536	998320.664	2427.5644	439	r6K6	855	473925.037	998302.696	2425.658
5	F4	357	473922.207	998467.213	2435.302	440	r6K7	856	473943.393	998293.967	2425.271
6	f483	358	474057.1494	998230.5368	2425.3288	441	r6K8	857	473963.107	998272.185	2424.85
7	f484	359	474077.8575	998224.1582	2425.4288	442	R7	858	474057.848	998484.464	2435.277
8	f485	360	474097.9754	998218.9068	2425.2275	443	r70	859	474263.3093	998451.8723	2430.495
9	F5	361	473900.212	998447.626	2433.25	444	r700	860	474118.2483	998729.6843	2442.1779
10	f507	362	474262.2772	998416.4999	2430.6814	445	r701	861	474103.9505	998732.021	2442.2529
11	f575	363	474185.0305	998336.8179	2428.3185	446	r702	862	474136.7287	998718.4877	2441.4543
12	F6	364	473903.944	998431.639	2432.737	447	r703	863	474151.5187	998708.7306	2440.9666
13	f612	365	474250.5683	998569.3965	2434.5685	448	r71	864	474260.1444	998449.4609	2430.6366
14	f636	366	474278.316	998541.1125	2432.1589	449	r716	865	474101.4793	998727.1944	2442.7841

15	f637	367	474287.0369	998614.8444	2434.537	450	r717	866	474101.2669	998732.2934	2442.7449
16	f638	368	474285.7107	998600.7632	2434.5868	451	r718	867	474122.9962	998722.2303	2441.9551
17	f639	369	474287.1156	998621.979	2437.5009	452	r719	868	474125.7783	998721.2859	2441.822
18	f64	370	474270.7998	998512.2262	2431.5467	453	r72	869	474205.9179	998437.3692	2432.3412
19	f640	371	474279.9444	998623.623	2435.7781	454	r720	870	474134.9198	998718.9137	2441.551
20	f641	372	474281.0732	998638.6882	2436.4127	455	r721	871	474111.0552	998724.8777	2442.3987
21	f642	373	474274.6193	998644.1577	2435.2754	456	r728	872	474124.4322	998698.7435	2440.6838
22	f643	374	474261.9058	998648.0997	2437.8425	457	r729	873	474123.8907	998697.3815	2440.6838
23	f644	375	474244.1663	998652.0575	2438.1995	458	r73	874	474269.448	998451.8536	2430.3213
24	f645	376	474239.3682	998653.1507	2438.074	459	r730	875	474164.7287	998670.5584	2440.6716
25	f65	377	474274.5559	998557.895	2432.8047	460	r731	876	474165.3779	998672.2238	2440.6652
26	f66	378	474277.572	998515.8738	2431.5233	461	r74	877	474267.2749	998449.1643	2430.4334
27	f662	379	474215.4401	998672.1867	2439.7037	462	r75	878	474257.71	998441.5871	2430.8486
28	f67	380	474278.3999	998491.1453	2431.1379	463	r76	879	474244.6679	998438.6552	2431.1055
29	f689	381	474191.9171	998715.916	2441.1472	464	r77	880	474215.0625	998433.1285	2431.9114
30	f6K1	382	473974.941	998264.836	2425.001	465	R8	881	474062.976	998486.863	2435.343
31	f6K2	383	473970.66	998279.490	2425.141	466	r88	882	474211.7288	998471.609	2433.6239
32	f6K3	384	473952.851	998299.796	2425.354	467	r89	883	474212.1158	998481.9381	2433.4295
33	f6K4	385	473934.739	998307.043	2425.747	468	R9	884	474062.426	998489.093	2435.482
34	f709	386	474168.7597	998734.6858	2442.4126	469	r90	885	474211.7086	998477.2865	2433.2905
35	f722	387	474101.6194	998726.1062	2442.8657	470	r91	886	474212.1229	998474.0296	2433.1615
36	f723	388	474103.9739	998695.8437	2441.9154	471	r92	887	474213.5086	998476.4972	2433.1905
37	f736	389	474107.4667	998651.2726	2440.7251	472	r93	888	474214.0768	998473.2938	2433.0868
38	fd486	390	474110.2859	998217.4817	2425.2938	473	r94	889	474215.0592	998467.7041	2432.6311
39	fd487	391	474115.3436	998217.8196	2425.2849	474	r95	890	474216.986	998459.1775	2432.2716
40	fd697	392	474164.9657	998722.3275	2441.0931	475	r96	891	474219.6832	998444.9798	2431.7378
41	fM1	393	474125.045	998215.673	2425.65	476	RD1	892	474119.544	998220.046	2425.862
42	FM10	394	474089.233	998220.245	2425.405	477	RD10	893	474131.81	998248.834	2426.745
43	FM11	395	474037.127	998237.364	2425.07	478	RD11	894	474138.185	998250.442	2426.914
44	FM12	396	473981.369	998256.381	2424.768	479	RD12	895	474143.151	998256.768	2427.042
45	fM2	397	474151.585	998218.632	2425.73	480	RD13	896	474136.986	998256.422	2427.029
46	fM3	398	474179.628	998230.739	2425.901	481	RD14	897	474135.615	998262.061	2427.084
47	fM4	399	474202.632	998244.209	2426.179	482	RD15	898	474119.61	998258.483	2426.995
48	fM5	400	474222.236	998260.624	2426.661	483	RD16	899	474121.391	998248.226	2426.398
49	FM9	401	474122.675	998215.746	2425.619	484	RD2	900	474122.279	998230.853	2426.107
1	g103	402	474211.098	998423.2526	2431.7692	485	RD3	901	474124.126	998237.074	2426.294
2	g104	403	474200.2161	998421.0274	2431.6363	486	RD4	902	474119.753	998243.198	2425.85
3	g105	404	474199.6885	998428.656	2432.0703	487	RD5	903	474118.073	998240.446	2426.567
4	g519	405	474155.6175	998384.923	2430.0431	488	RD6	904	474115.376	998228.366	2426.066
5	g520	406	474153.6428	998394.5322	2430.0231	489	RD7	905	474112.971	998226.327	2425.935
6	g521	407	474198.6245	998404.8243	2430.116	490	RD8	906	474109.744	998226.034	2425.918

7	g522	408	474200.999	998394.7126	2430.0086	491	RD9	907	474128.626	998246.424	2426.63
8	g523	409	474220.7516	998399.3006	2429.5213	492	RK1	908	473948.654	998222.318	2423.296
9	g524	410	474219.5896	998404.665	2430.1614	493	RK10	909	473897.438	998229.506	2423.405
10	g525	411	474208.4713	998402.3917	2430.4692	494	RK11	910	473881.969	998266.548	2423.788
11	g526	412	474209.5486	998396.573	2429.9579	495	RK12	911	473852.634	998277.875	2423.816
12	g732	413	474128.6886	998698.493	2440.7114	496	RK13	912	473853.607	998289.592	2423.911
13	g733	414	474117.0583	998681.138	2441.077	497	RK14	913	473885.867	998279.537	2423.978
14	g734	415	474154.4583	998659.1337	2440.3714	498	RK2	914	473968.062	998118.923	2419.988
15	g735	416	474167.8962	998675.8254	2440.7964	499	RK3	915	473955.16	998117.396	2419.967
1	R1	417	474070.17	998484.255	2435.51	500	RK4	916	473950.664	998116.417	2419.85
2	R10	418	474080.347	998493.159	2435.55	501	RK5	917	473935.157	998129.668	2420.255
3	r106	419	474192.9452	998430.4569	2432.3006	502	RK6	918	473919.439	998211.285	2422.631
4	r107	420	474182.6603	998433.1201	2432.9071	503	RK7	919	473932.911	998209.894	2422.632
5	r108	421	474172.1559	998441.476	2433.5363	504	RK8	920	473936.936	998210.870	2422.643
6	r109	422	474169.4228	998441.2301	2433.3535	505	RK9	921	473916.661	998217.774	2422.946
7	r110	423	474197.1983	998435.6217	2432.4548	506	rM1	922	474115.445	998201.366	2425.66
8	r111	424	474188.1655	998436.3618	2432.7361	507	rM10	923	474120.234	998211.268	2425.327
9	r112	425	474191.6585	998435.7336	2432.5515	508	rM11	924	474095.687	998192.707	2425.909
10	r113	426	474180.9363	998442.7967	2433.355	509	rM12	925	474110.593	998190.713	2426.061
11	r114	427	474180.841	998445.4748	2434.2129	510	rM13	926	474166.897	998192.279	2426.537
12	r121	428	474181.3447	998446.2426	2433.3986	511	rM14	927	474189.429	998200.131	2426.7
13	r122	429	474189.0028	998449.9372	2433.0376	512	rM15	928	474226.946	998255.908	2426.198
14	r123	430	474196.3299	998451.9136	2432.9482	513	rM16	929	474215.824	998245.877	2426.173
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19	r128	435	474137.3965	998438.4222	2433.9599	518	rM20	934	474197.188	998218.953	2426.275
20	r129	436	474161.6985	998439.5853	2433.8705	519	rM21	935	474213.291	998230.474	2426.391
21	r130	437	474124.156	998431.6601	2433.4561	520	rM22	936	474213.847	998229.694	2426.398
22	r136	438	474111.3622	998486.7211	2435.9129	521	rM23	937	474232.735	998247.551	2426.382
23	r137	439	474117.0192	998472.5217	2435.2838	522	rM24	938	474233.456	998246.806	2426.391
24	r138	440	474117.7468	998468.5904	2435.1751	523	rM25	939	474238.853	998238.081	2426.423
25	r139	441	474116.266	998466.4336	2435.0737	524	RM25	940	474108.683	998212.086	2425.232
26	r140	442	474113.685	998465.9263	2435.0975	525	rM26	941	474210.74	998215.444	2426.725
27	r141	443	474115.2408	998461.8392	2435.0738	526	RM26	942	474091.509	998215.185	2425.161
28	r142	444	474118.3119	998461.9623	2434.8807	527	rM27	943	474191.417	998200.956	2426.753
29	r143	445	474119.7128	998460.0858	2434.693	528	RM27	944	474073.272	998209.801	2425.34
30	r144	446	474119.5132	998457.9748	2434.549	529	rM28	945	474179.448	998196.218	2426.63
31	r145	447	474117.4723	998456.4465	2434.502	530	RM28	946	474072.991	998208.927	2425.357
32	r146	448	474106.2621	998453.9374	2434.714	531	RM29	947	474086.735	998204.873	2425.473

33	r147	449	474095.328	998451.4807	2434.8568	532	rM3	948	474135.498	998201.616	2425.803
34	r148	450	474088.9307	998450.262	2434.2169	533	RM30	949	474086.961	998205.922	2425.468
35	r149	451	474100.6669	998448.2041	2434.2127	534	RM31	950	474118.159	998201.211	2425.645
36	r150	452	474107.0499	998449.6445	2434.6065	535	RM32	951	474118.06	998200.194	2425.709
37	r151	453	474114.6272	998451.0674	2434.4567	536	RM33	952	474127.425	998200.137	2425.774
38	r152	454	474119.7395	998449.5614	2434.3283	537	RM34	953	474127.431	998201.071	2425.739
39	r153	455	474123.0969	998444.3405	2434.1475	538	RM35	954	474117.915	998190.096	2426.119
40	r154	456	474123.0739	998439.8212	2433.9914	539	RM36	955	474110.257	998190.590	2426.025
41	r155	457	474121.4649	998437.1981	2433.9217	540	RM37	956	474077.623	998196.650	2425.658
42	r156	458	474118.4928	998434.6392	2433.8938	541	RM38	957	474066.32	998200.284	2425.554
43	r157	459	474116.0534	998433.6783	2433.8274	542	RM39	958	474037.935	998232.291	2424.861
44	r158	460	474099.5337	998429.9282	2433.1631	543	rM4	959	474135.525	998200.558	2425.86
45	r159	461	474097.9039	998425.7556	2433.7965	544	RM40	960	473965.793	998257.041	2424.581
46	r160	462	474118.4583	998430.4521	2433.809	545	RM41	961	473963.752	998246.875	2424.606
47	r161	463	474142.135	998435.3762	2433.9233	546	RM42	962	473963.501	998246.257	2424.59
48	r162	464	474131.3885	998447.4216	2434.1353	547	RM43	963	473960.188	998236.490	2424.212
49	r163	465	474129.1039	998457.7331	2434.6607	548	rM5	964	474155.701	998204.422	2425.944
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53	r167	469	474120.5159	998479.1591	2435.3314	552	rM9	968	474152.099	998213.956	2425.554
54	r168	470	474116.6754	998488.2503	2435.7706	553	RO1	969	473936.662	998268.084	2424.644
55	r169	471	474116.4205	998490.7541	2435.8961	554	RO2	970	473929.99	998272.360	2424.779
56	r170	472	474118.3263	998494.2371	2436.1892	555	RO3	971	473918.705	998271.249	2424.67
57	r171	473	474120.9978	998496.8002	2436.4121	556	RO4	972	473911.194	998261.542	2424.0225
58	r172	474	474119.1757	998501.4996	2436.6125	557	RO5	973	473915.223	998247.598	2424.008
59	r173	475	474113.207	998498.169	2436.3221	558	RO6	974	473927.039	998243.347	2423.983
60	r174	476	474093.851	998493.0468	2436.0896	559	RO7	975	473939.515	998252.986	2424.487
61	r175	477	474095.6938	998484.3967	2436.4713	560	RO8	976	473940.395	998259.208	2424.569
62	r176	478	474110.2742	998487.3445	2435.7269	561	rWW1	977	474102.128	998285.937	2427.263
63	r177	479	474112.6805	998483.6849	2435.5228	562	rWW2	978	474102.404	998283.054	2427.189
64	r178	480	474087.5472	998427.0697	2433.9503	563	rWW3	979	474153.353	998296.974	2427.156
65	r179	481	474082.2414	998428.5839	2433.9946	564	rWW4	980	474152.741	998294.037	2427.103
66	r180	482	474079.2876	998432.042	2434.1218	565	rWW5	981	474175.783	998301.578	2429.37
67	r181	483	474078.1145	998436.3283	2433.9014	566	rWW6	982	474176.459	998299.124	2429.22
68	r182	484	474079.9716	998440.8095	2433.8321		sate47	983	474253.7667	998522.2662	2433.0482
69	r183	485	474088.8721	998445.644	2434.4885	1	V1	984	473974.696	998474.125	2435.167
70	r184	486	474080.052	998448.2663	2434.1307	2	V2	985	473979.981	998451.274	2435.022
71	r185	487	474076.2966	998447.8422	2434.087	3	v280	986	473998.2791	998435.7693	2434.6813
72	r186	488	474074.6249	998450.4033	2434.5341	4	v281	987	474006.7929	998437.6267	2434.6105
73	r187	489	474074.9718	998452.2031	2434.6269	5	v282	988	473993.8531	998453.3017	2434.6774

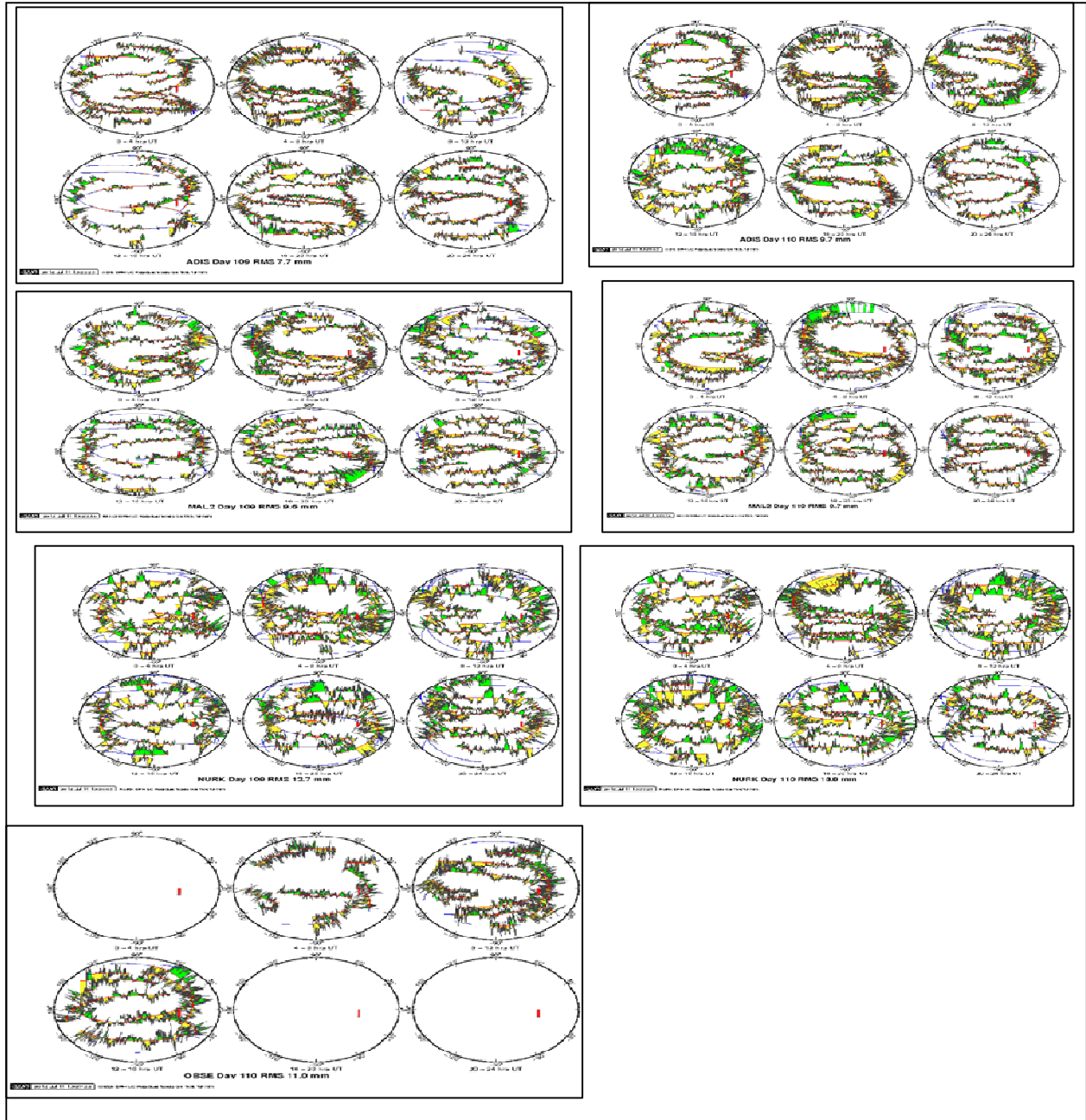
74	r188	490	474076.8526	998453.2836	2434.339	6	v283	989	474003.034	998455.2882	2433.978
75	r189	491	474076.435	998457.9329	2434.4093	7	V3	990	474011.616	998459.286	2435.173
76	r190	492	474074.312	998458.0115	2434.4372	8	V4	991	474006.117	998481.956	2435.269
77	r191	493	474072.5209	998461.1828	2434.603	9	V5	992	473976.323	998462.134	2435.118
78	r192	494	474071.4751	998467.3311	2434.8886						
79	r193	495	474067.4723	998464.4615	2435.3042						
80	r194	496	474069.6454	998454.4598	2435.0716						
81	r195	497	474070.7927	998449.2934	2434.8475						
82	r196	498	474070.4173	998446.906	2434.7344						
83	r197	499	474068.7056	998445.9085	2434.7078						

Appendix K: Working in arc scene

Opening arc scene → copy the layer from Arc map and paste at arc scene → Right click on the layer name in the table of contents and click on **Properties** — then select the **'Extrusion'** tab.

There are two options. 1. Making all the features the same height by putting a number in the extrusion box.
 2. When the buildings to be different heights, then you need to use, or create a column in the attribute table with height information.

Appendix L: Sky plot of the continuous IGS station and new point



Declaration

I declare that this thesis is my own work and that it has not been submitted anywhere for any award and I have acknowledged other sources of information where used.

SUBMITTED BY:

Diriba Firdisa Tolasa

Signature

Date

CONFIRMATION:

Dr. Tulu Besha Bedada
Advisor

Signature

Date