ISTANBUL KULTUR UNIVERSITY
INSTITUTE OF SCIENCES AND ENGINEERING

INTEGRATION OF GPS AND GIS

M.Sc. THESIS BY
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ABSTRACT

Integration of GPS and GIS

Two of most exciting and effective technical developments to emerge in the last tow decade are: the Global Positioning System (GPS) and the Geographic Information System (GIS).

GPS is a powerful tool providing a unique position of a specific feature. It allows you to know where you are by consulting a radio receiver. The accuracies range as good as a few millimeters to somewhere around 100 meters, depending on equipment and procedures applied to the process of data collection.

While GIS is an extremely broad and complex field, concerned with the use of computers to input, store, retrieve, analyze, and display geographic information. Basically GIS programs make a computer think it's a map, a map with wonderful powers to process spatial information, and to tell its users about any part of the world, at almost any level of detail.

Combining the GPS data with GIS allow for greater capabilities than what GPS and GIS can provide individually. With the combination of two technologies one is able to display the "Field/Actual Site" on a PC and make information decisions. There is no need to make specific site visits or review several documents/drawings. Also, anther benefit of the integration is the fact that the data can be shared by unlimited users in various departments for their own specific needs and analysis.

This work has two main objectives; the first objective is to study the integration of GPS and GIS technologies. The second objective is to design and establish a good and up-to-date base for a modern cadastre system for Beyşehir municipality, Turkey, by using the GPS and GIS techniques and other modern surveying instruments.

Table of Contents

Page No.

List of Tables

List of Figures

List of Abbreviations

1-D	One-dimensional
2-D	Two-dimensional
3-D	Three-dimensional
AFB	Air Force Base
A-S	Anti-Spoofing
C/A-code	Coarse /Acquisition code (1.023 MHz)
CAD	Computer Add Design
CCD	Charge-Coupled Device
CLI	Canada Land Inventory
CPU	Central Processing Unit
CRT	Cathode Ray Tube (screen)
CYMK	Cyan, Magenta, Yellow, Black (color spaces)
DBMS	Data Base Management System
DGPS	Differential Global Positioning System
DoD	Department of Defense
DOP	Dilution of Precision
DoT	Department of Transportation
ECEF	Earth Centered Earth Fixed
ED50	European Datum 1950
EER	Enhanced Entity-Relationship (Data modeling)
ER	Entity-Relationship (Data modeling)
ESRI	Environmental System Research Institute
ETA	Estimated Time of Arrival
FOC	Full Operational Capability
GDOP	Geometric Dilution of Precision
GIS	Geographic Information System
GKS	Graphic Kernal System
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRS80	Geodetic Reference System of 1980
GUI	Graphical User Interface

HDOP	Horizontal Dilution of Precision
IAG	International Associated of Geodesy
IERS	International Terrestrial Rotation Service
IGS	International GPS Services
IOC	Initial Operational Capability
ISO	International Standard Organization
ITRF	International Terrestrial Reference Frame
ITRS	International Terrestrial Reference System
IUGG	International Union of Geodesy and Geophysics
JPEG	Joint Photographic Experts Group
JPO	Joint Program Office
LAN	Local Area Network
LIS	Land Information System
LLR	Lunar Laser Ranging
LRF	Laser Range Finders
MHz	Megahertz
MS-DOS	Microsoft Disk Operating System
NAD1927	North American Datum of 1927
NANU	Notice: Advisory to Navigation Users
NASA	National Aeronautic and Space Administration
NATO	North Atlantic Treaty Organization
NAVSTAR	Navigation System with Timing and Ranging
NIS	Navigation Information Service
NMEA	National Maritime Electronics Association
NNSS	Navy Navigation Satellite System (or TRANSIT)
OCS	Operational Control System
PC	Personal Computer
P-code	Precision code (10.23 MHz)
PDOP	Position Dilution of Precision
PPM	Parts Per Million
PRN	Pseudorandom Noise
RAM	Random Access Memory
RF	Radio Frequency
RGB	Red, Green, and Blue (color spaces)

RINEX	Receiver INdependent EXchange (format)
RMS	Root Mean Square
RTCM	Radio Technical Commission for Maritime (Services)
RTK	Real Time Kinematic
SA	Selective Availability
SLR	Satellite Laser Ranging
SPS	Standard Positioning Service
SVN	Space Vehicle Number
TCP/IP	Transmission Control Protocol/Internal Protocol
TDOP	Time Dilution of Precision
TIFF	Tagged Image File Format
UHF	Ultra High Frequency
U.S.	United States
USCG	U.S. Coast Guard
U.S.S.R.	Union of Soviet Socialist Republics
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
VDOP	Vertical Dilution of Precision
VHF	Very High Frequency
VLBI	Very Long Baseline Interferometry
WAN	Wide Area Network
WGS84	World Geodetic System of 1984
Y-code	Encrypted P-code

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Chapter 1

Introduction

The twentieth century gave rise to a great many different technologies, including the computer, wireless and cellular communication services, remote sensing, satellite navigation systems (GPS) and the Internet. The power of the technological innovation is significantly enhanced when it is integrated with other technologies. One such integration seen recently is GPS/GIS integration. GPS/GIS are such an extremely important technology. It is no exaggeration to say that GPS/GIS are revolutionizing aspects of many fields (engineering, geology, urban planning, natural resources, archaeology, agriculture, management, environmental protection, business, and many, many others).

A Geographic Information System (GIS) is a computer based information system that enables capture, modeling, manipulation, retrieval, analysis, and presentation of geographically referenced data. Spatial referenced data is data that is identified according to its geographic location (features). Today's GIS, which are fundamentally a marriage of database management systems with graphics capability, are designed to allow for changes in the processor of individuals and organizations and changes in the data. GIS has caused a revolution in the way we look at geographic and environmental data. Datasets are organized as layers to create a digital representation of an area. Each layer provides some information (sometimes contradictory) about the reality. A layer can be a surface model of the terrain, an aerial image, a street map, or a distribution of population for a given area. Depending upon the application, different layers are combined to provide a composite view. Collecting data and putting them together is just a means to an end, not an end in itself. Therefore, one can see that the focus is now changing towards utilizing this data more intelligently. A large and comprehensive geographic dataset contains a huge wealth of different relationships, both within and between different layers. This is where visualization plays a major role. It is the purpose of visualization to present the data in such a way that relationships and structures contained therein are made apparent.

The Global Positioning System (GPS) is a space-based radio navigation system operated by the United States Federal Government. The technology has been in existence for more than 20 years, and has been used by the U. S. Military and Air Force, but was not of much use at first for civilian users as the accuracy available for civilian applications. The removal of accuracy restrictions on civil users and the innovation of real time carrier phase tracking has opened the doors for a large variety of GPS applications. Given a favorable environment and certain settings it has now become possible to determine three-dimensional position with sub-meter accuracy. There has been a great increase in the number of GPS receiver manufacturers as well as companies devising GPS applications.

Spatial,or geographic, data can obtain from a variety of sources such as existing maps, satellite imagery, and GPS. Once the information collected, a GIS stores it as a collection of layers in the GIS database. The GIS can then be used to analyze the information and decisions can be made efficiently. For example, the decision to build a new road can be made by studying the effect of one feature such as traffic volume. GPS is used to collect the GIS field data efficiently and accurately. With GPS, the data is collected in a digital format in either real time or post-processed mode. A number of GPS/GIS systems that provide centimeter to meter level accuracy are now available on the market. Most of these systems allow the user to enter user defined attributes for each feature.

The growth in GIS is assured because it has been estimated that as much as 80% of all information used by governments and privates are referenced geographically. GIS is a tool that encourages planners, designers, and other decision-makers to study and analyze spatial data along with an enormous amount of attribute data (cultural, social, geographic, economic, resources, environmental, infrastructure, etc.) data that can be tagged to spatial entities.

This project has two main objectives. The first objective is to create a digital cadastral database for rural area in Beyşehir municipality in Turkey, that is tied to the surface of the earth by coordinates, addresses, or other means are collectively called geospatial data. The second objective is to produce maps at different scale ranges for different proposes.

The thesis is organized into five chapters including this introductory chapter.

In the second chapter, necessity for background information and divided to three parts Global positioning system (GPS), Geographic information system (GIS), and GPS/GIS integration.

The third chapter deals with the methodology of the case study and equipments used to produce this work.

The fourth chapter is a case study, the case study was performed with the aim of showing that the research was not only conceptual but in fact was real cadastral project (Beyşehir village's cadastral project, Turkey).

The fifth chapter provides a conclusion and summary of the results found in the previous chapters of this work.

Chapter 2

Background

We begin by presenting a GPS concept and a brief historical background on the GPS followed by a description of the general principle behind the system. We then focus on different error sources with GPS. We then deal with some basic GIS concepts. These include datum, coordinate systems, and map projections. Finally, description of the integration of GPS and GIS.

2.1 Global positioning system (GPS).

2.1.1 GPS Concept.

The NAVSTAR Global Positioning System (GPS) is a passive, all weather, 24-hours global navigation system GNSS designed, financed, deployed, operated, and maintained by the U.S. Department of Defense (DoD). It consists of a nominal constellation of 24 satellites in high altitude orbits. GPS has also demonstrated a significant benefit to the civilian community, who are applying GPS to a rapidly expanding number of applications, (Johan, 2002).

- Relatively high positioning accuracy, from meters down to the millimeter level.
- Capability of determining velocity and time.
- No inter-station visibility is required for high precision positioning.
- Result are obtained with reference to a single, global datum.
- Signals are available to users anywhere on the earth : in the air, on the ground, or at sea.
- No user charges.
- An all weather system, available 24 hours a day.
- Position information is provided in three dimensions (3-D).

2.1.2 Historical background.

History changed on October 4, 1957, a significant technological breakthrough occurred when the Soviet Union successfully launched Sputnik I. The world first artificial satellite was about the size of a basketball, weighted only 183 pounds, and took about 98 minutes to orbit the earth on its elliptical path. That launch ushered in new political, military, technological, and scientific developments. While the Sputnik launch was a single event it marked the start to the space age and the U. S. - U. S. S. R. space race. On November 3, 1957, Sputnik II was launched, carrying a much heavier payload, including a dog named Laika. On January 31, 1958 the tide changed, when the United States successfully launched Explorer I. The GPS is actually the result of the merging of two independent programs that were begun in the early 1960's. The U.S. Navy's TIMATION Program and the U. S. Air Force's 621b Project. Another system similar in basic concept of the current GPS was the Navy Navigation Satellite System (NNSS), also called TRANSIT system, which was also developed in the 1960's. Currently, the entire system in maintained by the U. S. Air Force NAVSTAR GPS Joint Program Office (JPO).

Department of Defense (DoD) initially designed the GPS for military use only, providing sea, air, and ground troops of the United States and members of North Atlantic Treaty Organization (NATO), multi-service type organization that was established in 1973, with unified high-precision, all weather, world wide, real-time positioning system. The first U. S. pronouncement regarding civil use of GPS came in 1983 following the downing of Korean Airlines Flight 007 after it strayed over territory belonging the Soviet Union. As a result of this incident, in 1984, President Reagan announced the Global Positioning System (GPS) would be made available for international civil use once the system became operational. In 1987, DoD formally, requested the Department of Transportation (DoT) to establish and provide an office to respond to civil user's needs and to work closely with the DoD to ensure proper implementation of GPS for civil use. Two years later, the U. S. coast guard became the lead agency for this project. On December 8, 1993 the DoD and DoT formally declared Initial Operational Capability (IOC), meaning that the NAVSTAR GPS was capable of sustaining the Standard Positioning Service (SPS). On April 27, 1995, the U. S. Air Force space command formally declared GPS met the requirements for Full Operational Capability (FOC), meaning that the constellation of 24 operational satellites has successfully completed testing for military capability.

Mandated by Congress, GPS is freely used by both the military and civilian public for real time absolute positioning of ship, aircraft, and land vehicle, as well as highly precise differential point positioning and time transferring.

2.1.3 GPS Segments.

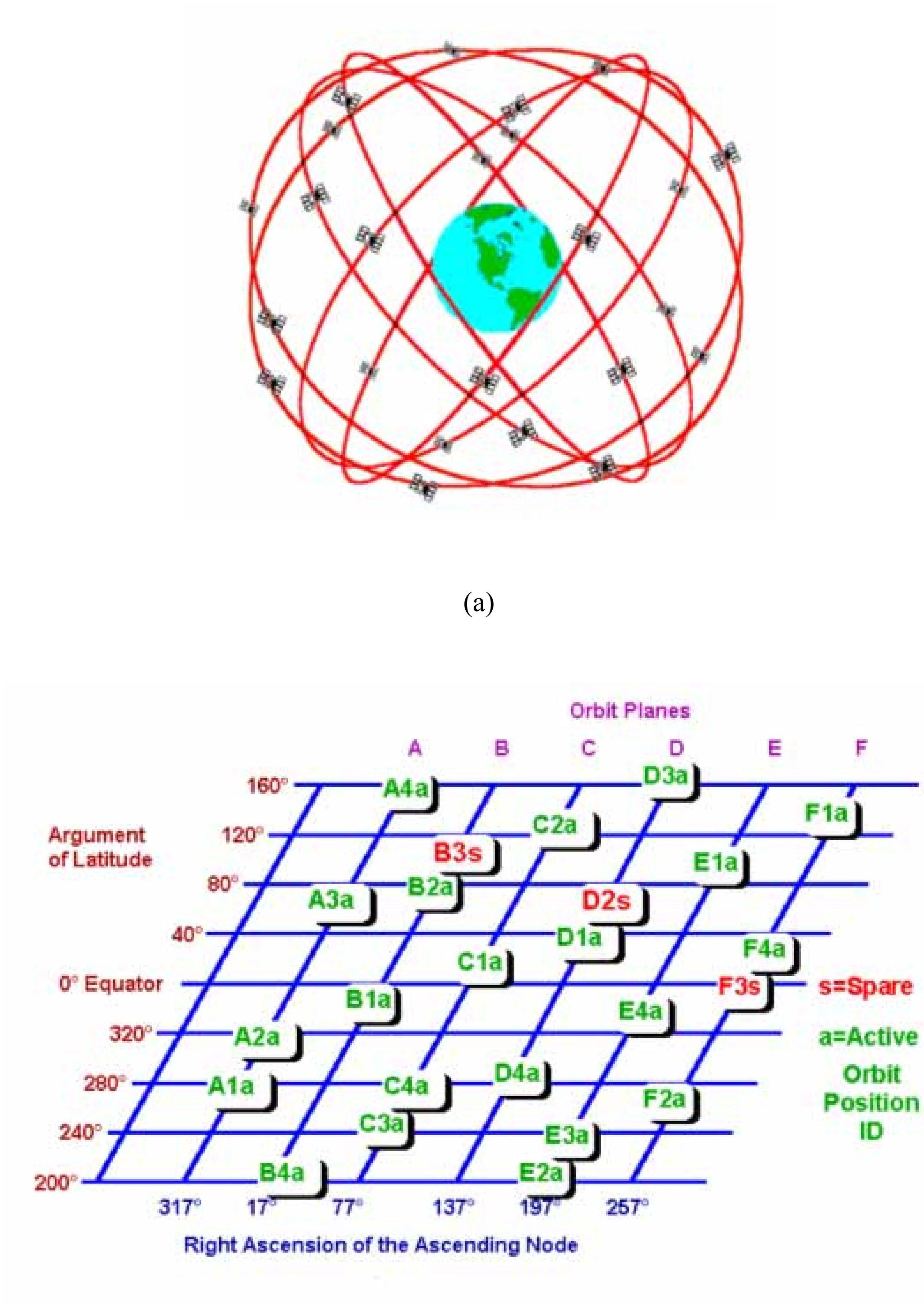
The NAVSTAR GPS consists of three distinct segments: the space segment (satellite which broadcast signals), the control segment steering the whole system (ground tracking and monitoring station), and the user segment including the many type of receivers.

2.1.3.1 Space segment.

- **Constellation.**

The GPS satellites have nearly circular orbital (an elliptical shape with a maximum eccentricity is about 0.01). The initial space segment was designed with four satellites in each of six orbits planes (A to F) with an inclination of about 55 degrees to the equator. The satellites are located at average altitudes of 20,200 km (10,900 nautical miles) above the earth's surface and have 11-hours 58-minutes orbital periods, (Ahmed, 2002). The number of satellites in the GPS constellation has always been more than 24 operational satellites. With the full constellation, the space segment provides global coverage with four to eight simultaneously observable satellites above 15° elevation at any time of day. If the elevation mask is reduced to 10°, occasionally up to 10 satellites will be visible; and if the elevation mask is further reduced to 5°, occasionally 12 satellites will be visible, (Hofmann-Wellenhof, 2001).

Current GPS satellite constellation : The current GPS satellite constellation (as of 31 May 2005) contain five Block II, 18 Block IIA, and six Block IIR satellites (Table 2.1 satellite constellation status report). This makers the total number of GPS



(a)

(b)

Figure 2.1 (a & b), GPS satellites Constellation and planer projection, (Peter, 2003).

satellites in the constellation to be 29, which exceeds the nominal 24 satellites constellation by five satellites. All Block I satellites are no longer operational. As mention above, the GPS satellites are placed in six orbital planes, which are labeled

A through F. Since more satellites are currently available than the nominal 24-satellite constellation, an orbital plane may contain four, five, or six satellites. As in table 2.1, the orbital plane A, B ,and E have four satellites, the orbital plane C has 5 satellites, and orbital planeD and F have six satellites.

Table 2.1 Satellite constellation status report (31 May 2005), (U. S. Coast Guard).

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GPS OPERATIONAL ADVISORY        151
SUBJ: GPS STATUS      31 MAY 2005

1. SATELLITES, PLANES, AND CLOCKS (CS=CESIUM RB=RUBIDIUM):
A. BLOCK I : NONE
B. BLOCK II: PRNS  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 13, 14, 15
   PLANE   : SLOT F6, D7, C2, D4, B4, C1, C4, A3, A1, E3, D2, F3, F1, D5
   CLOCK   :      CS, RB, CS, RB, CS, RB, RB, CS, CS, CS, RB, RB, RB, CS
   BLOCK II: PRNS 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30
   PLANE   : SLOT B1, E4, C3, E1, D3, E2, F4, D1, A2, F2, A4, B3, F5, B2
   CLOCK   :      RB, RB, RB, RB, RB, RB, RB, CS, CS, RB, RB, RB, RB, RB
   BLOCK II: PRNS 31
   PLANE   : SLOT C5
   CLOCK   :      RB
```

● Satellites.

The satellites have various systems of identification: launch sequence number, assigned pseudorandom noise (PRN) code, space vehicle number (SVN), orbital position number, NASA catalogue number, and international designation. (Hofmann-Wellenhof, 2001). The most popular identification systems within the GPS user community are the SVN and the PRN. Block II / IIA satellites are equipped with four onboard atomic clocks: two cesium (Cs) and two rubidium (Rb). The cesium clock is used as the primary timing source to control the GPS signal. Block IIR satellites, however, use rubidium clocks only, (Ahmed, 2002).

Satellite categories

There are six classes or types of GPS satellites. These are the Block I, Block II, Block IIA, Block IIR, Block IIF, and Block III satellites. GPS satellite constellation buildup started with a series of 11 satellites known as Block I satellites (weighting 845 kg). The first satellite in this series (and in the GPS system) was launched on February 22, 1978; the last was launched on October 9, 1985, from Vandenberg

AFB, California, with Atlas F launch vehicle. All launches were successful. The inclination angle of the orbital planes of these satellites, with respect to the equator, was 63°. Although the design lifetime of Block I satellites were 4.5 years, some remained in service for more than 10 years. The last Block I satellite was taken out of service on November 18, 1995, (Ahmed, 2002). (Today none of the original Block I satellites are in operation).

The second generation of the GPS satellites is known as Block II satellites. The first Block II satellite, costing approximately $50 million and weighing more than 1500 kg, was launched on February 14, 1989, from the Kennedy space center, Cape Canaveral AFB in Florida, using a Delta II Rocket, (Hofmann-Wellenhof, 2001). The orbital plane of Block II satellites are inclined by 55 Degrees with respect to equator. The design lifetime of the Block II satellites is 7.5 years. Individual satellites, however, remained operated more than 10 years. The first Block IIA satellite ('A' denotes advanced) was launched on November 26, 1990. Block IIA is an advanced version of Block II, with an increase in the navigation message data storage capability from 14 days for Block II to 180 days for Block IIA satellites can function continuously, without ground support, for periods of 14 and 180 days respectively. A total of 28 Block II / IIA satellites were launched during the period from February 1989 to November 1997. Of these, 23 are currently in service. To ensure national security, some security features, known as Selective Availability (SA) and Anti-spoofing (A-S), were added to Block II/AII satellites. Today no distinction is made between Block II and Block IIA satellites, (Ahmed, 2002).

The Block IIR satellites ('R' denotes replenishment or replacement) weigh more than 2000 kg and the $ 42 million cost are about the same as for the Block II. The first Block IIR satellite was successfully launched on July 23, 1997 (Hofmann-Wellenhof, 2001). Block IIR consists of 21 satellites with a design life of 10 years. In addition to the expected higher accuracy, Block IIR satellites have the capability of operating autonomously for at least 180 days without ground corrections or accuracy degradation. The autonomous navigation capability of this satellite generation is achieved in part through mutual satellite ranging capabilities. In addition, predicted ephemeris and clock data for a period of 210 days are uploaded by the ground control segment to support the autonomous navigation. As of May 2005, six Block IIR satellites have been successfully launched.

The Block IIF satellites ('F' denotes follow on) will weigh more than 2000 kg and the first Block IIF satellite is scheduled to be launched in 2005 or shortly after that date. Block IIF consisting of 33 satellites, the satellites life span will be 15 years. They will be equipped with improved on-board capabilities (such as internal navigation systems) and an augmented signal structure.

Presently, the DoD undertakes studies for the next generation of GPS satellites, called Block III satellites. These satellites are expected to carry GPS into 2030 and beyond, (Hofmann-Wellenhof, 2001).

2.1.3.2 Control segment.

The Operational Control System (OCS) consists of a master control station, six monitoring stations located throughout the worlds, and three ground control stations. The master Control Station is located at Schriever Air Force Base, Colorado with a backup station in Gaithersburg, Maryland. The information obtained from the monitoring stations that track the satellites is used in controlling the satellites and predicting their orbits. All data from the tracking stations are transmitted to the Master Control Station where it is processed and analyzed. Ephemeredes, clock corrections, and other message data are then transmitted back to the monitoring stations with ground antennas for subsequent transmittal back to the satellites. The Master Control Station is also responsible for the daily management and control of the GPS satellites and the overall control segment, (U.S. army, 2003).

2.1.3.3 User segment.

The user segment represents the ground based GPS receiver units that process the NAVSTAR satellite signals and compute the position and / or velocity of the user. Most GPS receivers perform these functions automatically, in real time, and often provide visual and/or verbal positional guidance information. Users consist of both military and civil activities, for an almost unlimited number of applications in a variety of air, sea, or land based platforms.

2.1.4 GPS signals.

2.1.4.1 Signals structure.

Each NAVSTAR satellite transmits ranging signals on two L-band frequencies, designed as L1 and L2. The L1 carrier frequency is 1575.42 megahertz (MHz) and has a wavelength of approximately 19 cm. The L2carrier frequency is 1227.60 MHz and has a wavelength of approximately 24 cm. The L1 signal is modulated with a 1.023 MHz Coarse/Acquisition Code (C/A-code) and a 10.23 MHz Precision Code (P-code). The L2 signal is modulated with only the 10.23 MHz P-code. Both codes can be used to determine the range between the user and a satellite. The P-code is normally encrypted and is available only to authorized users. When encrypted, it is termed the Y-code, Figure 2.2 summarizes the carrier frequencies and codes. Each satellite carrier's precise atomic clocks to generate the timing information needed for precise positioning. A 50 Hz navigation message is also transmitted on both the P(Y)-code and C/A-code. This message contains satellite clock bias data, satellite ephemeris data, orbital information, ionospheric signal propagation correction data, health and status of satellites, and satellites almanac data for the entire constellation.

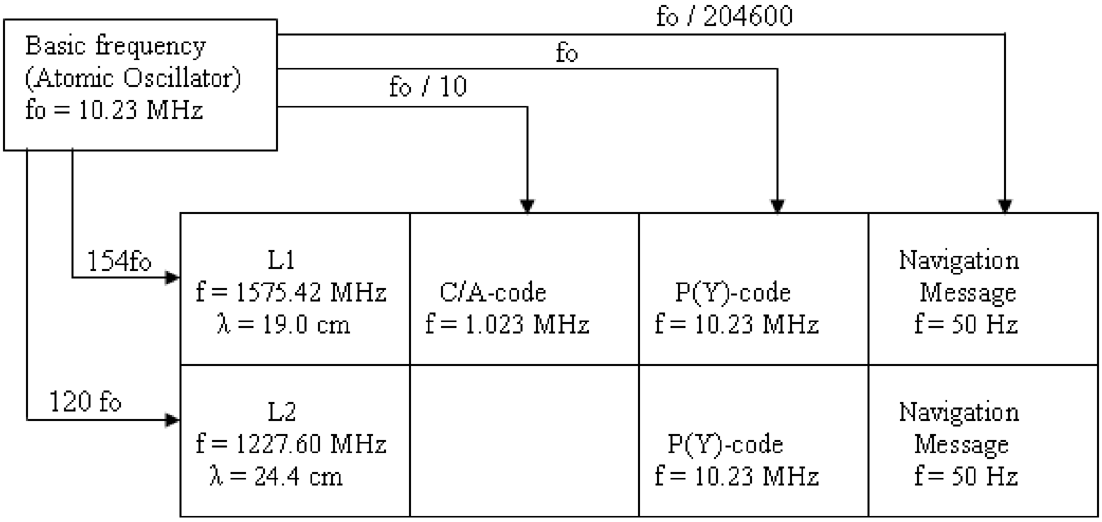


Figure 2.2 Current structure of the GPS L1 and L2 satellite signals, (John, 2001).

2.1.4.2 Pseudorange Measurements.

Pseudorange observations are obtained by measuring the transit time of the signal as it travels from the GPS satellite to the receiving antenna. Due to non-synchronized receiver and satellite clocks, the measured range (pseudorange) is biased. Therefore, the receiver's clock difference with respect to the satellite's GPS time must be taken into account. This leads to a system of equations with four unknown parameters (three coordinates and clock drift); thus at least four satellite observations are necessary for position calculation.

The code observable *P* for a single satellite can be expressed as (Salytcheva, 2004):

$$\mathrm{P} = \rho + d\rho + c(dt - d\mathrm{T}) + d_{ion} + d_{trop} + \varepsilon_p$$

where: ρ is the geometric range between the GPS satellite and receiver antenna (m);

$d\rho$ is the orbital error (m);

dt is the satellite clock error (s);

dT is the receiver clock error (s);

d_{ion} is the ionospheric delay (m);

d_{trop} is the tropospheric delay (m);

ε_p is the code noise (receiver noise + multipath) (m); and

c is the speed of electromagnetic wave in vacuum (m/s).

Orbital, satellite clock, and atmospheric errors can be reduced or even eliminated by differencing pseudorange measurements with a receiver at a known location (DGPS). The receiver clock error is usually included as an unknown parameter in single point and single difference GPS methods. Noise depends on the received signal strength and on the correlation method employed in the receiver, so that it cannot be decreased without access to the hardware. Multipath is caused by multiple reflections of GPS signals interfering with the line-of-sight signal (LOS). It is environmentally dependent and thus cannot be mitigated by DGPS. This error is also difficult to model and therefore to satisfactorily compensate.

2.1.4.3 Carrier phase measurements.

Carrier frequency tracking measures the phase differences between the Doppler shifted satellite and receiver frequencies. Phase measurements are resolved over the relatively short L1 and L2 carrier wavelengths (19 cm and 24cm respectively). This allows phase resolution at the mm level. The phase differences are continuously charging due to changing satellite earth geometry. However, such effects are resolved in the receiver and subsequent data post-processing. When carrier phase measurements are observed and compared between two stations (i.e. relative or differential mode), baseline vector accuracy between the stations below the centimeter level in attainable in three dimensions. Various receiver technologies and processing techniques allow carrier phase measurements to be used in real-time centimeter positioning.

The Doppler, in the case of GPS, is a measurement of the instantaneous phase rate of a tracked satellite's signal; as a result, the velocity of the user with respect to the GPS satellites can be determined. Doppler measurements are also error-corrupted, (Salytcheva, 2004):

$$\dot{\phi} = \dot{\rho} + d\dot{\rho} + c(d\dot{t} - d\dot{T}) - \dot{d}_{ion} + \dot{d}_{trop} + \dot{\varepsilon}_{\phi}$$

where:	$\dot{\phi}$	is the Doppler observable (m/s);
	$\dot{\rho}$	is the geometric range rate (m/s);
	$d\dot{\rho}$	is the orbital error drift (m/s);
	$d\dot{t}$	is the satellite clock drift;
	$d\dot{T}$	is the receiver clock drift;
	$\dot{d}_{ion}$	is the ionospheric delay drift (m/s);
	$\dot{d}_{trop}$	is the tropospheric delay drift (m/s);
	$\dot{\varepsilon}_{\phi}$	is the receiver noise and the rate of change of multipath (m/s).

Similarly to pseudorange errors, the atmospheric effects and satellite clock drift are reduced by DGPS, where the receiver clock drift is considered in the velocity calculation scheme as an unknown parameter, so that a minimum of four Doppler observables is needed to solve for the user's velocity.

2.1.4.4 Signal processing.

The signal emitted from the satellite is represented by the equations (Hofmann-Wellenhof, 2001).

$L_1(t) = a_1 \,.\, P(t).\ W(t).\ D(t) \cos(f_1 \,.\, t) + a_1 \,.\, C/A(t).\ D(t) \sin(f_1 \,.\, t)$

$L_2(t) = a_2 \,.\, P(t).\ W(t).\ D(t) \cos(f_2 \,.\, t)$

Where :	$L_i(t) = a_i \cos(f_i \,.\, t)$	the unmodulated carriers.
	$P(t)$, $C/A(t)$, $W(t)$, and $D(t)$	the state sequences of the P-code, the C/A-code, the W-code, and the Navigation message respectively

.

And contains three components in the symbolic form (L1, C/A, D), (L1, Y, D), and (L2, Y, D). The goal of signal processing by the GPS receiver is the recovery of the signal components, including the reconstruction of the carrier wave and the extraction of the codes for the satellite clock readings and the navigation message. (Hofmann-Wellenhof, 2001). The principle is illustrated in figure 2.3.

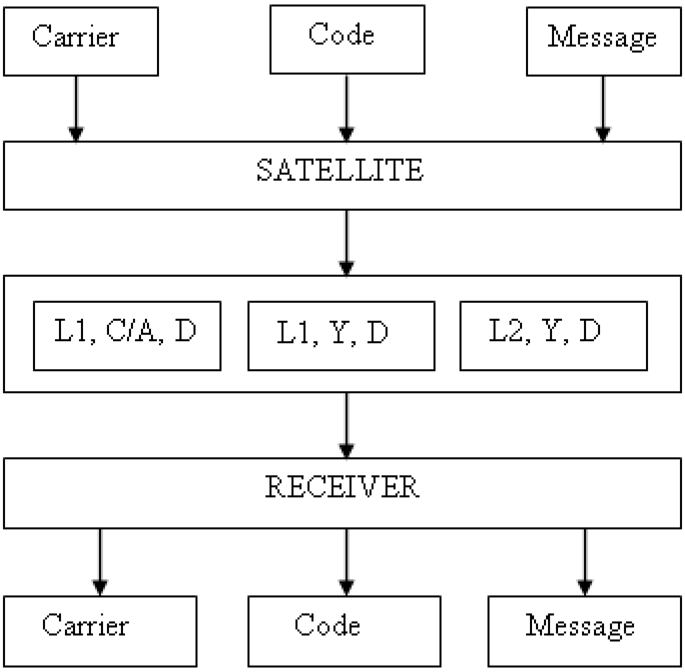


Figure 2.3 Principle of signal processing, (Hofmann-Wellenhof, 2001).

2.1.5 GPS positioning modes.

There are basically two general operating modes from which GPS-derived positions can be obtained: (1) absolute positioning, and (2) differential (or relative) positioning. Within each of these two modes, range measurements to the satellites can be performed by tracking either the phase of the satellite's carrier signal or the pseudo-random noise (PRN) codes modulated on the carrier signal.

2.1.5.1 Absolute point positioning.

Absolute positioning involves the use of only a single passive receiver at the user's location to collect data from multiple satellites in order to determine the user's georeferenced position. GPS determination of a point position on the earth actually user a technique common to terrestrial surveying called trilateration (i.e., electronic distance measurement resection). The user's GPS receiver simply measures the distance (range) between the earth and the NAVSTAR GPS satellites. The user's position is determined by the resected intersection of the observed ranges to the satellites. In actual practice, at least 4 satellite observations are required in order to resolve timing variations. Adding more satellite ranges will provide redundancy (and more accuracy) in the position solution, (US Army, 2003).

2.1.5.2 Differential positioning.

Differential GPS positioning is simply a process of determining the relative differences in coordinates between two receiver points, each of which is simultaneously observing/measuring satellite code ranges and/or carrier phases from the NAVSTAR GPS satellite constellation. These differential observations, in fact, derive a differential baseline vector between the two points, as shown in figure 2.4. This method will position two stations relative to each other, hence the term relative positioning, and can provide the higher accuracies required for project. There are basically two general types of differential positioning:

- Code phase pseudorange tracking.
- Carrier phase tracking.

Both methods, either directly or indirectly, determine the distance, or range, between a NAVSTAR GPS satellite and a ground-based receiver antenna. These measurements are made simultaneously at two different receiver stations. Either the satellite's carrier frequency phase, or the phase of a digital code modulated on the carrier phase, may be tracked depending on the type of receiver. Through various processing techniques, the distance between the satellites and receivers can be resolved, and the relative positions of the two receiver points are derived. From these relative observations, a baseline vector between the points is generated. The resultant accuracy is depending on the tracking method used carrier phase tracking being far more accurate than code phase tracking, (US Army, 2003).

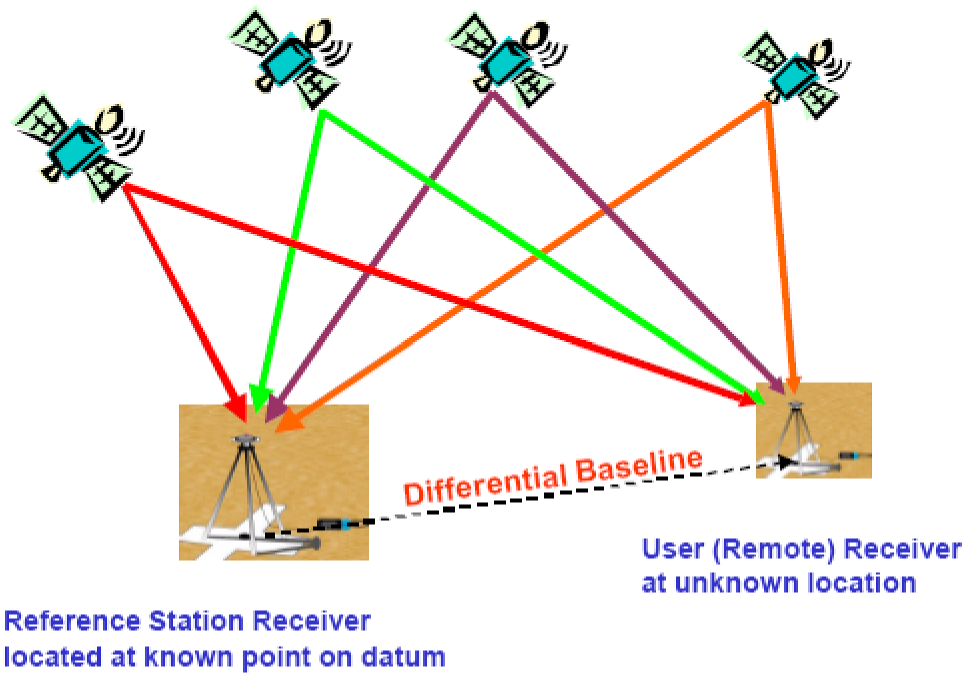


Figure 2.4 Differential or relative GPS positioning, (US Army, 2003).

2.1.5.3 Accuracy versus positioning mode.

The different positioning associated with the different GPS positioning modes, as shown in figure 2.5, (accuracy is quoted as two-sigma values, i.e., 95% confidence level). In all cases, the vertical accuracy is about 2 times worse than the horizontal positioning accuracy. It should be emphasised that GPS was designed to provide accuracies of the order of a dekametre (ten meters) or so in the absolute positioning mode, and is optimised for real-time operations. All other developments to improve this basic accuracy capability must be viewed in this context. As a general axiom of GPS positioning, the higher the accuracy sought, the more effort (in time, instrumentation and processing sophistication) is required, (John, 2001).

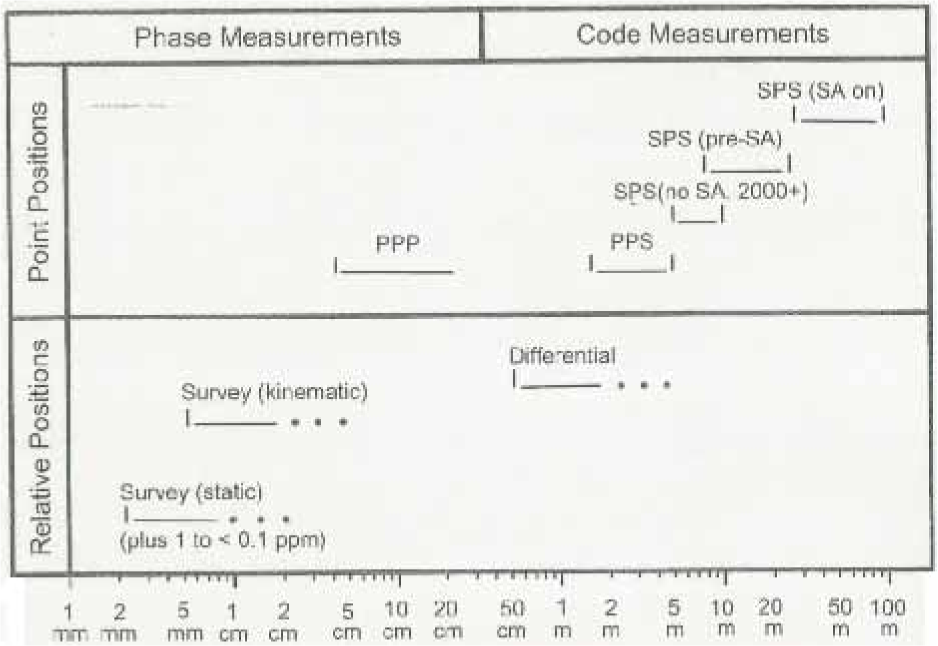


Figure 2.5 GPS Accuracy and positioning modes, (John, 2001).

2.1.6 GPS time system.

Time plays is a very important role in positioning with GPS, the GPS signal is controlled by accurate timing devices, the atomic satellite clock, measuring the ranges (distances) from the receiver to the satellites is based on both the receiver and the satellite clocks. GPS is also a timing system, that is, it can be used for time synchronization. A number of time systems are used worldwide for various purposes; they are based on various periodic processes such as Earth rotation. (Hofmann-Wellenhof, 2001). GPS time is accurately maintained and monitored by the DoD. GPS time is usually maintained within 30 nanoseconds of universal time coordinated (UTC). GPS time is based on a reference 'GPS epoch' of 000 hours (UTC) 6 January 1980, the relationship between GPS time and UTC is following, (US Army, 2003).

GPS time = UTC + number of leap seconds + [GPS-to-UTC bias]

GPS receivers obtain time corrections from the broadcast data messages and can thus output UTC time increments.

2.1.7 Height systems (Orthometric elevation).

Geoidal heights represent the geoid-ellipsoid separation distance measured along the ellipsoid normal and is obtained by taking the difference between ellipsoidal and orthometric height values. Knowledge of the geoid height enable the evaluation of vertical positions either the geodetic (ellipsoid based) or the orthometric height system. The relationship between a WGS84 ellipsoidal height and an orthometric height relative to the geoid can be obtained from the following equation, (US Army, 2003).

$h = H + N$ Where:

h = ellipsoidal height (WGS84).

H = elevation (orthometric–normal to geoid).

N = geoidal undulation above or below the WGS84 ellipsoid.

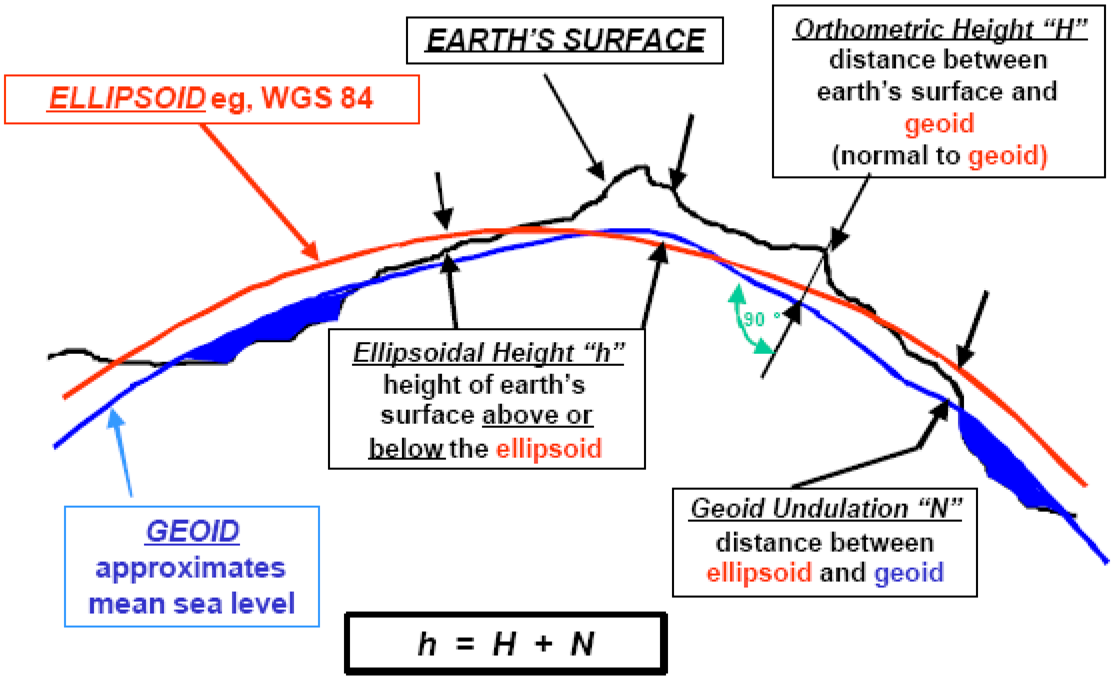


Figure 2.6 Geoid and Ellipsoid relationship, (US Army, 2003).

2.1.8 GPS receivers.

There is a variety of receivers on the market used for different purposes (navigation, surveying, time transfer) and with different features. Despite this variety, all the receivers employ certain common principles.

2.1.8.1 Receiver design.

GPS receiver collects radio waves from various satellites, compares clock times, performs calculations, displays the results on a display device, and stores data in a file for later output. The components must receive, store, display, record, and output data. The receiver structure is shown in figure 2.7, It consist of an antenna, a Radio Frequency (RF) section, processor, control device, storage device, and power supply.

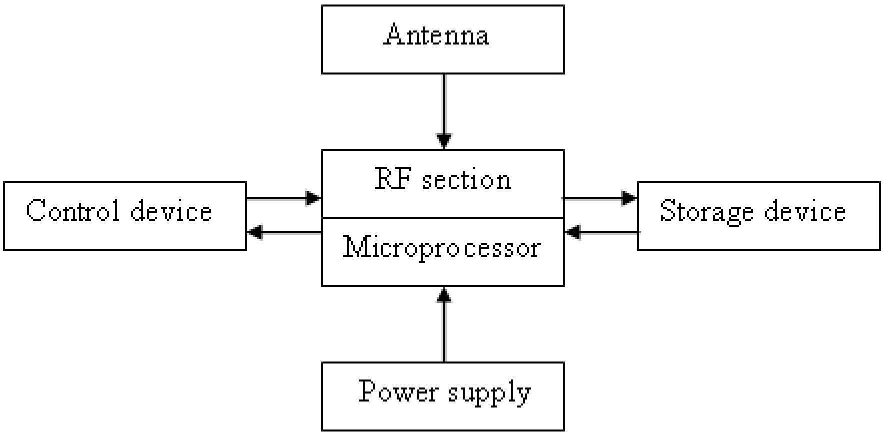


Figure 2.7 Basic concept of a receiver unit, (Hofmann-Wellenhof, 2001).

2.1.8.2 Types of GPS receivers.

In 1980, only one commercial GPS receiver was available on the market, at a price of several hundred thousand U.S. dollars. This, however, has changed considerably as more than 500 different GPS receivers are available in today's market from 58 manufacturers. The current receiver price varies from about $ 200 for the simple handheld units to about $ 35000 for the sophisticated geodetic quality units. Commercial GPS receivers may be divided into four types, according to their receiving capabilities, (Ahmed, 2002). These are:

● The single frequency code receiver: It measures the pseudo-range with the C/A-code only. It is the least expensive and the least accurate receiver type and is mostly used for recreation purposes.

● The single frequency carrier smoothed code receivers: It is also measures the pseudo-ranges with the C/A-code only. The higher resolution carrier frequency is used internally to improve the resolution of the code pseudo-range, which results in high precision pseudo-range measurements.

● The single frequency code and carrier receivers: Output the raw C/A-code pseudo-range, the L1 carrier phase measurements, and the navigation message. In addition, this receiver type is capable of performing the functions of the other receiver types.

● The Dual frequency receivers: They are the most sophisticated and most expensive receiver type. Before the activation of AS, dual frequency receivers were capable of outputting all the GPS signal components (i.e., L1and L2 carriers, C/A-code, P-code on both L1and L2, and the navigation message). However, after the AS activation, the P-code was encrypted to Y-code. This means that the receiver cannot output either the P-code or the L2 carrier using the traditional signal recovering technique. To overcome this problem, GPS receiver manufacturers invented a number of techniques that do not require information of the Y-code. At the present time, most receivers use two techniques known as the Z-tracking and the cross-correlation techniques. Both techniques recover the full L2 carrier, but at a degraded signal strength. The amount of signal strength degradation is higher in the cross-correlation techniques compared with the Z-tracking technique.

GPS receivers can also be categorized according to their number of tracking channels, which varies from 1 to 12 channels. A good GPS receiver would be multi-channel, with each channel dedicated to continuously tracking a particular satellite. Presently, most GPS receivers have 9 to 12 independent (or parallel) channels. Features such as cost, ease of use, power consumption, size and weight, internal and/or external data storage capabilities, interfacing capabilities, and multi-path mitigation (i.e., type of correlator) are to be considered when selecting a GPS receiver.

2.1.9 GPS Errors.

2.1.9.1 Orbital Errors.

Orbital errors occur due to the differences in the actual and modeled positions of the satellites. Three sets of data are available to determine position and velocity vectors of the satellites in a terrestrial reference frame at any instant: almanac data, broadcast ephemerides, and precise ephemerides, (Hofmann-Wellenhof, 2001). Broadcast ephemeredes are available in real time and orbital parameters are uploaded for each interval of two hours. Currently, this type of satellite orbit has an RMS accuracy of about 3 m. More accurate orbit information of about 5 cm can be obtained from the International GPS Service (IGS); however, it is available only from a few days, up to a week, after the observations. Fortunately, orbital errors are correlated for two receivers simultaneously tracking the same satellite and thus can be diminished by differencing observations between the receivers. The remaining errors are generally in the range of much less than 0.5 parts per million (ppm). PPM is the measure of residual errors in GPS measurements, when differential GPS is used. One ppm means that one cm of position error is introduced per ten km baseline, (Salytcheva, 2004).

2.1.9.2 Satellite clock errors.

GPS satellites carry rubidium and cesium time standards that are usually accurate to 1 part in 10^{12} and 1 part in 10^{13}, respectively. Rang error observed by the user as the result of time offset between the satellite and receiver clock is a linear relationship and can be approximated by the following formula, (US Army, 2003).

$$\mathrm{R}_E = \mathrm{T}_0 * \mathrm{c}$$

Where:

R_E = range error due to clock instability.

T_0 = time offset.

c = speed of light.

The calculation of the user equivalent range error as following:

T_0 = 1 microsecond (μs) = 10^{-6} seconds.

c = 299,792,458 m/s.

R_E = (10^{-6} s) * 299,792,458 m/s = 299.79 m = 300 m.

This means that one nanosecond error is equivalent to a range error of about 30 cm. the satellite clock error is about 8.64 to 17.28 ns per day. The corresponding range error is 2.59 m to 5.18 m, (Ahmed, 2002). The amount of drift is calculated and transmitted as a part of the navigation message in the form of three coefficients of a second-degree polynomial. This error can be eliminated by the DGPS.

2.1.9.3 Receiver clock error.

GPS receivers use inexpensive crystal clocks, which are much less accurate than the satellite clocks. This error can range from 200 ns up to a few ms, and changes over time due to the clock drift, (Salytcheva, 2004). It can be removed through differencing between the satellites or it can be treated as an additional unknown parameter in the estimation process.

2.1.9.4 Ionospheric errors.

The ionosphere, extending in various layers from about 50 km to 1000 km above earth, is a dispersive medium with respect to the GPS radio signal, (Hofmann-Wellenhof, 2001). The ionosphere is formed by ultraviolet and X-ray radiations coming from the sun interact with the gas modecules and atoms. These interactions result in gas ionization: a large number of free "negatively charged" electrons and "positively charged" atoms and moleculer, (Ahmed, 2002). The ionosphere bends the GPS radio signal and changes its speed as it passes through the various ionospheric layers to reach a GPS receiver.

The error of ionosphere refraction on the GPS range values is dependent on sunspot activity, time of day, and satellite geometry. Ionospheric delay can vary from 40-60 m during the day and 6-12 m at night. GPS operations conducted during periods of high sunspot activity or with satellites near the horizon produce range results with the most error. GPS operations conducted during periods of low sunspot activity, during the night, or with a satellite near the zenith produce range results with the least amount of ionospheric error, (US Army, 2003).

Resolution of ionospheric refraction can be accomplished by use of a dual-frequency receiver. During a period of uninterrupted observation of L1and L2 signals, these signals can be continuously counted and differenced, and the ionospheric delay uncertainty can be reduced to less than 5 m. The resultant difference reflects the variable effects of the ionosphere delay on the GPS signal, (US Army, 2003).

2.1.9.5 Tropospheric errors.

The troposphere is the electrically neutral atmospheric region that extends up to about 50 km from the surface of the earth. The troposphere is a non-dispersive medium for radio frequencies below 15 GHz. As a result, it delays the GPS carriers and codes identically. The tropospheric delay depends on the temperature, pressure, and humidity along the signal path through the troposphere. Tropospheric delay results in values of about 2.3 m at zenith (satellite directly overhead), about 9.3 m for a 15° elevation angle, and about 20-28 m for a 5° elevation angle, (Ahmed, 2002).

The tropospheric conditions causing refraction of the GPS signal can be modeled by measuring the dry and wet components. The dry component represents about 90% of the delay and can be predicted to a high degree of accuracy using mathematical models, (Ahmed, 2002). The dry component is best approximated by following equation, (US Army, 2003):

$$D_C = (2.27 * 0.001) * P_0$$

Where: Dc = dry term range contribution in zenith direction in meters.
P_0 = surface pressure in millibar (mb).

The average of atmospheric pressure is $P_0 = 1013.243$ mb.

$$D_C = (2.27 * 0.001) * 1013.243 = 2.3 \text{ m}$$

The wet component is considerably more difficult to approximate because its approximation is dependent not just on surface conditions, but also on the atmospheric conditions (water vapor content, temperature, altitude, and angle of the signal path above the horizon) along the entire GPS signal path. As this is the case, there has not been a well correlated model that approximates the wet component, (US Army, 2003).

2.1.9.6 Multipath errors.

This effect is well described by its name: a satellite-emitted signal arrives at the receiver via more than one path. Multipath is mainly caused by reflecting surfaces near the receiver. Secondary effects are reflections at the satellite during signal transmission, (Hofmann-Wellenhof, 2001). Referring to figure 2.8 the satellite signals arrives at the receiver on four different paths, two direct and two indirect.

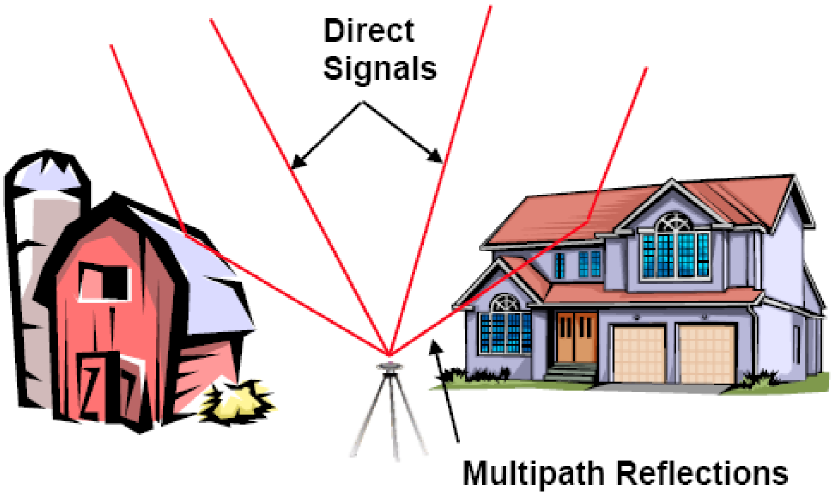


Figure 2.8 Multipath signals impacting GPS observations, (US Army, 2003).

The range errors caused by multipath will vary depending on the relative geometry of the satellites, reflecting surfaces and the GPS antenna, and also the properties and dynamics of the reflecting surfaces, (John, 2001). With the newer receiver and antenna designs, and sound prior mission planning to reduce the possible causes of multipath, the effects of multipath as an error source can be minimized. Averaging of GPS signals over a period of time (i.e., different satellite configurations) can also help to reduce the effects of multipath, (US Army, 2003).

2.1.9.7 Receiver noise.

Receiver noise includes a variety of errors associated with the ability of the GPS receiver to measure a finite time difference. These include signal processing, clock/signal synchronization and correlation methods, receiver resolution, signal noise, and others, (US Army, 2003).

The receiver measurement noise results from limitations of the receiver's electronics. A good GPS system should have a minimum noise level. Two tests can be performed for evaluating a GPS receiver: zero baseline and short baseline tests. (Ahmed, 2001).

A zero baseline test is used to evaluate the receiver performance. The test involves using one antenna/preamplifier followed by a signal splitter that feeds two or more GPS receivers. As one antenna is used, the baseline solution should be zero. In other words, any nonzero value is attributed to the receiver noise. Although the zero baseline test provides useful information on the receiver performance. The contribution of the receiver measurement noise to the range error will depend very much on the quality of the GPS receiver. Typical average value for range error due to the receiver measurement noise is of the order of 0.6 m (1σ-level), (Ahmed, 2001).

To evaluate the actual field performance of a GPS system. This can be done using short baselines of a few meters apart, observed on two consecutive days. In this case, the double difference residuals of one day would contain the system noise and the multipath effect. All other errors would cancel sufficiently. As the multipath signature repeats every sidereal day, differencing the double difference residuals between the two consecutive days eliminates the effect of multipath and leaves only the system noise, (Ahmed, 2001).

2.1.9.8 Selective Availability (SA) and Anti-Spoofing (A-S).

Before May 2000, SA was activated to purposely degrade the satellite signal to create position errors. This is done by dithering the satellite clock and offsetting the satellite orbits, (US Army, 2003). To ensure national security, the U.S. DoD implemented SA on Block II GPS satellites to deny accurate real time autonomous positioning to unauthorized users. SA was officially activated on March 25, 1990. With SA turned on, nominal horizontal and vertical errors can be up to 100 m and 156 m, respectively. SA was turned off on May 1, 2000, (Ahmed, 2001).

A-S is accomplished by the modulo 2 sum of the P-code and an encrypting W-code. The resulting code is denoted as the Y-code, (Hofmann-Wellenhof, 2001). A-S was implemented on 31 January, 1994, The rationale behind this decision was that by keeping the military PRN code secret.

2.1.9.9 Setup errors.

Centering errors can be reduced if the equipment is checked to ensure that the optical plummet is true. High measuring errors can be reduced by utilizing equipment that provides a built-in (or accessory) measuring capability to measure precisely (either directly or indirectly) the antenna height (hi) or by using fixed length tripods and bipods, (Barry, 2003).

2.1.9.10 Dilution of Precision (DOP).

The geometry of the visible satellites is an important factor in achieving high quality results especially for point positioning and kinematic surveying. The geometry changes with time due to the relative motion of the satellites. A measure of the geometry is the Dilution of Precision (DOP) factor, (Hofmann-Wellenhof, 2001). The lower the value of the DOP numbers, the better the geometric strength, and vice versa. Good satellite geometry is obtained when the satellites are spread out in the sky. In general, the more spread out the satellites are in the sky, the better the satellite geometry, and vice versa, as shown in figure 2.9. The Geometry dilution of precision (GDOP) is further classified so as to represent the accuracy of the components of Position and time. These are termed as Position Dilution of Precision (PDOP), Horizontal Dilution of Precision (HDOP), Vertical Dilution of Precision (VDOP), and Time Dilution of Precision (TDOP).

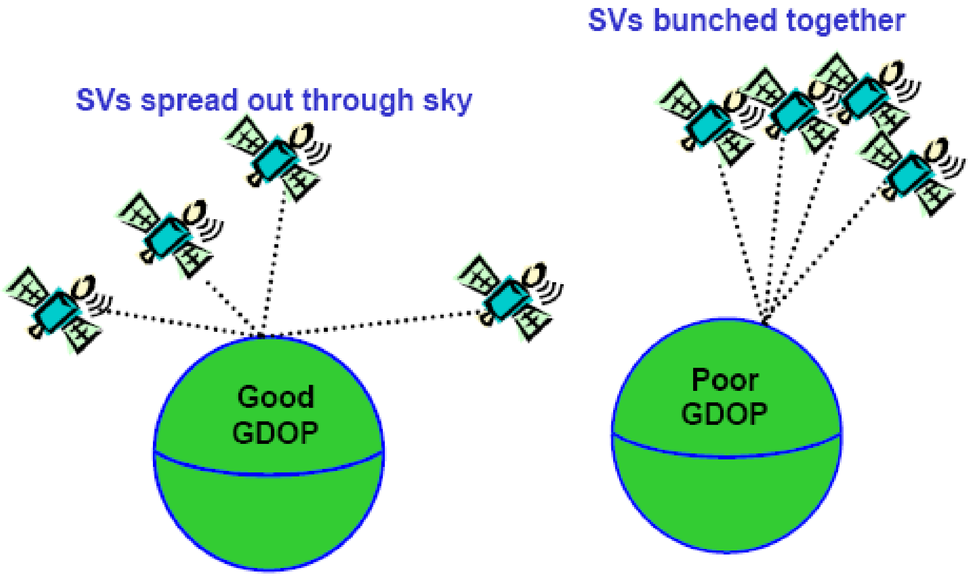


Figure 2.9 Satellite geometry and good & poor configurations, (US Army, 2003).

GDOP is defined to be the square root of the sum of the variances of the position and time error estimates, (US Army, 2003).

$$GDOP = [\sigma_E{}^2 + \sigma_N{}^2 + \sigma_U{}^2 + \sigma_R{}^2 + (c * \delta_T)^2]^{0.5} . [1/\sigma_R]$$

Where:

σ_E = standard deviation in east value, m.

σ_N = standard deviation in north value, m.

σ_U = standard deviation in up direction, m.

c = speed of light (299,729,458 m/s).

δ_T = standard deviation in time, seconds.

σ_R = overall standard deviation in range in meters, at the 1σ (68%) level.

PDOP is a measure of the accuracy in 3-D position, mathematically defined as:

$$PDOP = [\sigma_E{}^2 + \sigma_N{}^2 + \sigma_U{}^2]^{0.5} . [1/\sigma_R]$$

HDOP is a measurement of the accuracy in 2-D horizontal position, mathematically defined as:

$$HDOP = [\sigma_E{}^2 + \sigma_N{}^2]^{0.5} . [1/\sigma_R]$$

VDOP is a measurement of the accuracy in standard deviation in vertical height, mathematically defined as:

$$\text{VDOP} = [\sigma_U] * [1/\sigma_R]$$

In general, GDOP and PDOP values should be less than 6 for a reliable solution. Optimally, they should be less than 5. GPS performance for HDOP is normally in the 2 to 3 range. VDOP is typically around 3 to 4. Increase above these values levels may indicate less accurate positioning. In most cases, VDOP values will closely resemble PDOP values. It is also desirable to have a GDOP/PDOP that changes during the time of GPS survey session. The lower the GDOP/PDOP, the better the instantaneous point position solution is, (US Army, 2003).

2.1.10 Planning a GPS survey.

Planning is important for GPS surveys so that almanac data can be analyzed to obtain optimal time to sets when a geometrically strong array of satellites is available above 15° of elevation (above the horizon) and to identify topographic obstructions that may hinder signal reception. Planning software can graphically display GDOP at each time of the day, as shown in figure 4. The surveyor can use Planning software to help the mission planning process and select not only the optimal days for the survey, but also the hours of the day that will result in the best data.

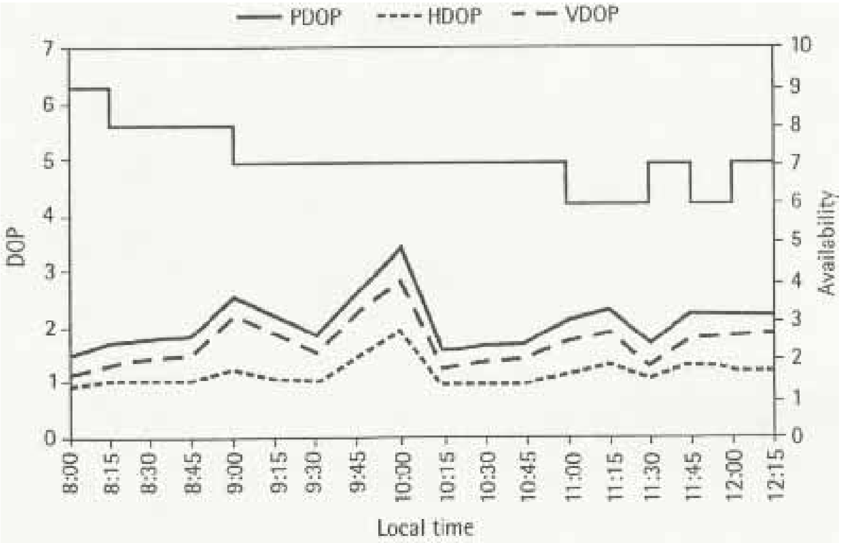
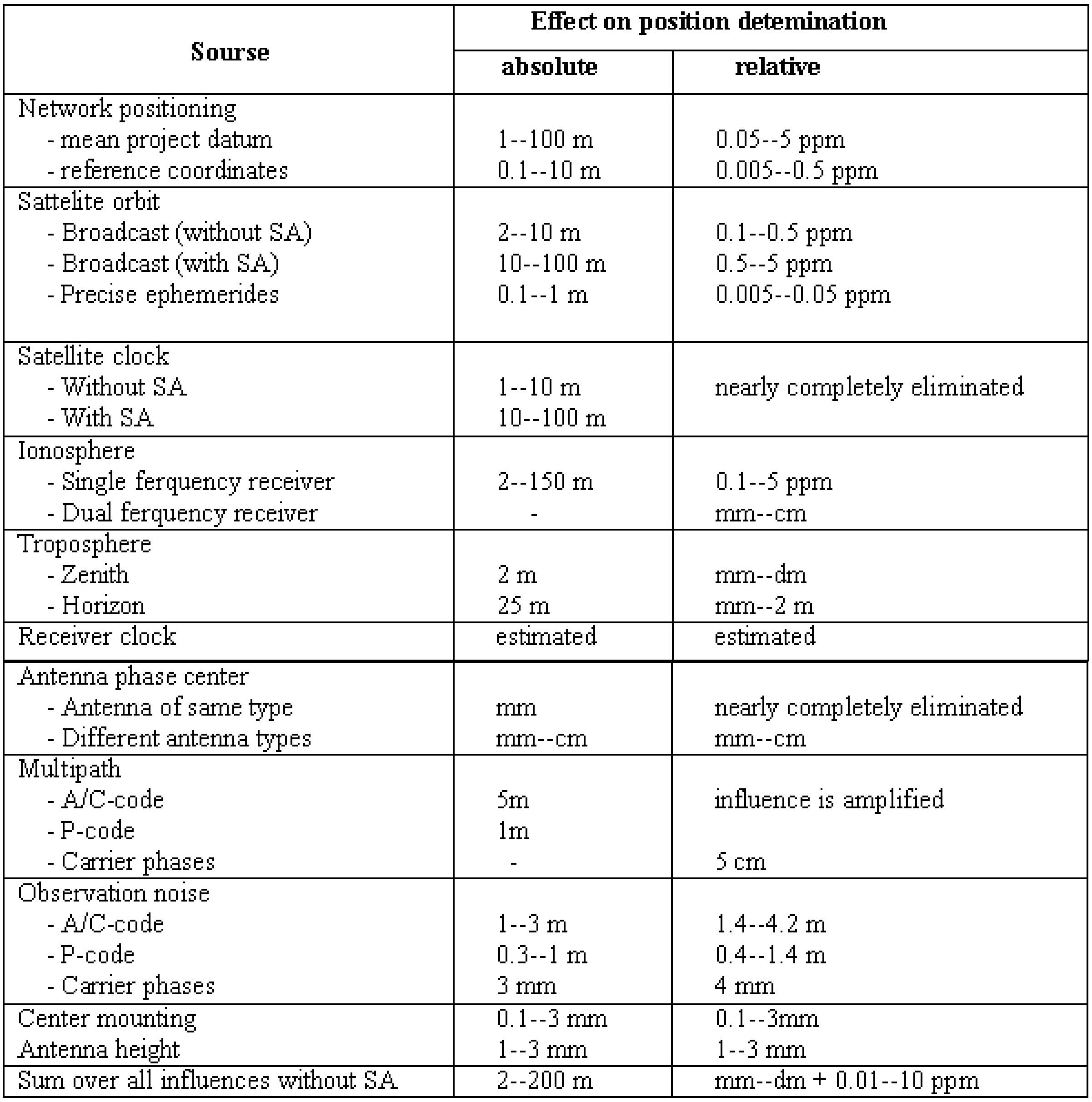


Figure 2.10 Sample of satellite availability and geometry, (Ahmed, 2001).

2.1.11 GPS Error budget.

Table 2.2 gives an overview on the main error sources in GPS positioning.

Table 2.2 Error budget for absolute and relative GPS observations, (Günter, 2000).



Sourse	**Effect on position detemination**	
	absolute	**relative**
Network positioning - mean project datum - reference coordinates	 1--100 m 0.1--10 m	 0.05--5 ppm 0.005--0.5 ppm
Sattelite orbit - Broadcast (without SA) - Broadcast (with SA) - Precise ephemerides	 2--10 m 10--100 m 0.1--1 m	 0.1--0.5 ppm 0.5--5 ppm 0.005--0.05 ppm
Satellite clock - Without SA - With SA	 1--10 m 10--100 m	 nearly completely eliminated
Ionosphere - Single ferquency receiver - Dual ferquency receiver	 2--150 m -	 0.1--5 ppm mm--cm
Troposphere - Zenith - Horizon	 2 m 25 m	 mm--dm mm--2 m
Receiver clock	estimated	estimated
Antenna phase center - Antenna of same type - Different antenna types	 mm mm--cm	 nearly completely eliminated mm--cm
Multipath - A/C-code - P-code - Carrier phases	 5m 1m -	 influence is amplified 5 cm
Observation noise - A/C-code - P-code - Carrier phases	 1--3 m 0.3--1 m 3 mm	 1.4--4.2 m 0.4--1.4 m 4 mm
Center mounting Antenna height	0.1--3 mm 1--3 mm	0.1--3mm 1--3 mm
Sum over all influences without SA	2--200 m	mm--dm + 0.01--10 ppm

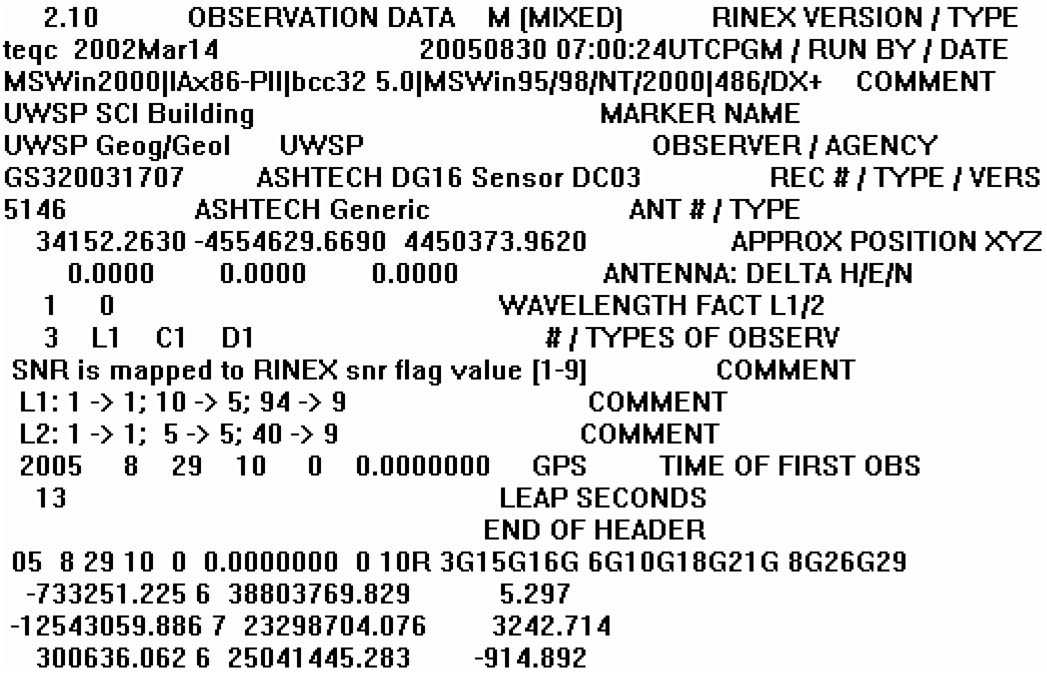
2.1.12 Common Data Exchange formats.

Since individual GPS manufacturers have their own proprietary formats for storing GPS measurements, it can be difficult to combine data from different receivers. A similar problem is encountered when interfacing various devices including the GPS system. To overcome these limitations, a number of research groups have developed standard formats for various user needs.

2.1.12.1 RINEX format.

The Receiver INdependent EXchange (RINEX) format is an ASCII type format that allows a user to combine data from different manufacturer's receivers, (US Army, 2003). The current RINEX version 2.10 defines six different RINEX files; each contains a header and data sections: (1) observation data file, (2) navigation message file, (3) meteorological file, (4) GLONASS navigation message file, (5) geostationary satellites (GPS signal payloads) data file, and (6) satellite and receiver clock data file. Table 2.3 shows sample RINEX V2.10 data file. For the majority of GPS users, the first three files are the most important. The record, or line, length of all RINEX files is restricted to a maximum of 80 characters, (Ahmed, 2001).

Table 2.3 Sample RINEX data file, (Advanced computer lab, 2005).



```
     2.10           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
teqc  2002Mar14                     20050830 07:00:24UTCPGM / RUN BY / DATE
MSWin2000|IAx86-PII|bcc32 5.0|MSWin95/98/NT/2000|486/DX+    COMMENT
UWSP SCI Building                                           MARKER NAME
UWSP Geog/Geol      UWSP                                    OBSERVER / AGENCY
GS320031707         ASHTECH DG16 Sensor DC03                REC # / TYPE / VERS
5146                ASHTECH Generic                         ANT # / TYPE
   34152.2630 -4554629.6690  4450373.9620                   APPROX POSITION XYZ
       0.0000        0.0000        0.0000                   ANTENNA: DELTA H/E/N
     1     0                                                WAVELENGTH FACT L1/2
     3    L1    C1    D1                                    # / TYPES OF OBSERV
 SNR is mapped to RINEX snr flag value [1-9]                COMMENT
  L1: 1 -> 1; 10 -> 5; 94 -> 9                              COMMENT
  L2: 1 -> 1;  5 -> 5; 40 -> 9                              COMMENT
  2005     8    29    10     0    0.0000000     GPS         TIME OF FIRST OBS
    13                                                      LEAP SECONDS
                                                            END OF HEADER
 05  8 29 10  0  0.0000000  0 10R 3G15G16G 6G10G18G21G 8G26G29
  -733251.225 6  38803769.829           5.297
-12543059.886 7  23298704.076        3242.714
   300636.062 6  25041445.283        -914.892
```

2.1.12.2 Real time data transmission formats.

There are two common types of data formats used most often during real time surveying. They are (1) RTCM SC-104 and (2) NMEA.

● Transmission of data between GPS receivers: The Radio Technical Commission for Maritime services (RTCM) is the governing body for transmissions used for maritime services. The RTCM Special Committee 104 (SC-104) has defined the format for transmission of GPS corrections. The RTCM SC-104 standard was specifically developed to address meter-level positioning requirements. The current transmission standard for meter-level DGPS is the RTCM SC-104. This standard enables communications between equipment from various manufacturers. RTCM SC-104 can also be used as the transfer format for centimeter-level DGPS, and will support transmission of raw carrier phase data, raw pseudorange data, and corrections for both, (US Army, 2003). The RTCM SC-104 standards consist of 64 message types.

● Transmission of data between a GPS receiver and a device: The National Maritime Electronics Association (NMEA) standard for interfacing marine electronic devices covers the format for GPS output records. The standard for corrected GPS output records at the remote receiver is found under NMEA 0183, Version 2.xx. NMEA 0183 output records can be used as input to whatever system the GPS remote receiver is interfaced, (US Army, 2003). As shown in figure 2.11, the NMEA 0183 data streams may include information on position, datum, time, fix related data for a GPS receiver, and other variables.

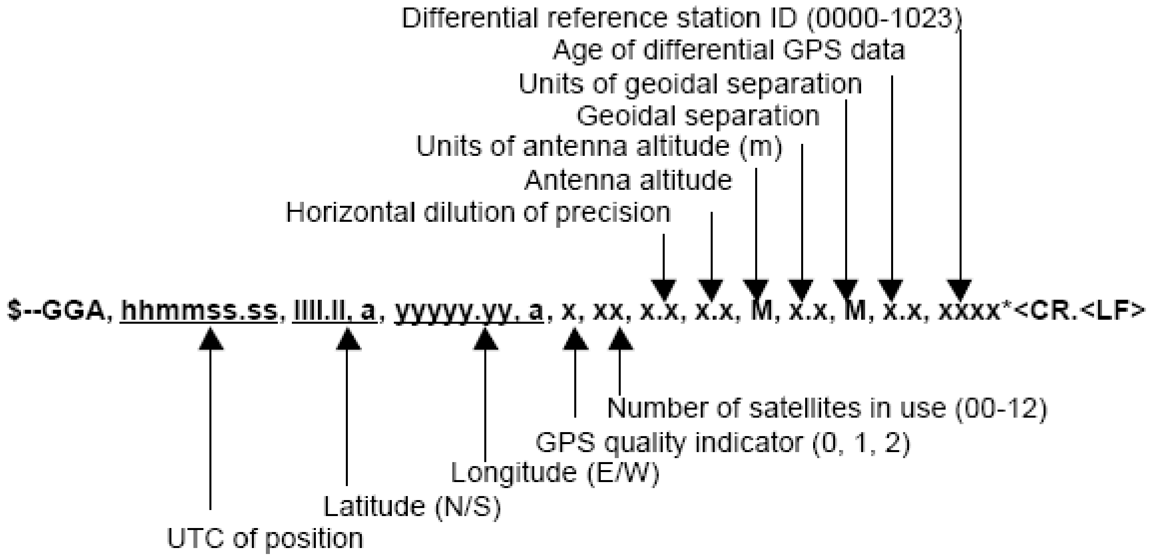


Figure 2.11 GPS fix data (NMEA 0183 format), (US Army, 2003).

2.2 Geographic Information System (GIS).

2.2.1 Historical review.

Geographic Information Systems arose from activities in 4 different fields, (Gottfried, 2003):

- Cartography, which attempted to automate the manually dependent map making process by substituting the drawing work by vector digitisation.
- Computer graphics, which had many applications of digital vector data apart from cartography, particularly in the design of buildings, machines and facilities.
- Data bases, which created a general mathematical structure according to which the problems of computer graphics and computer cartography could be handled.
- Remote sensing, which created immense amounts of digital image data in need of geocoded rectification and analysis. As shown in figure 2.12.

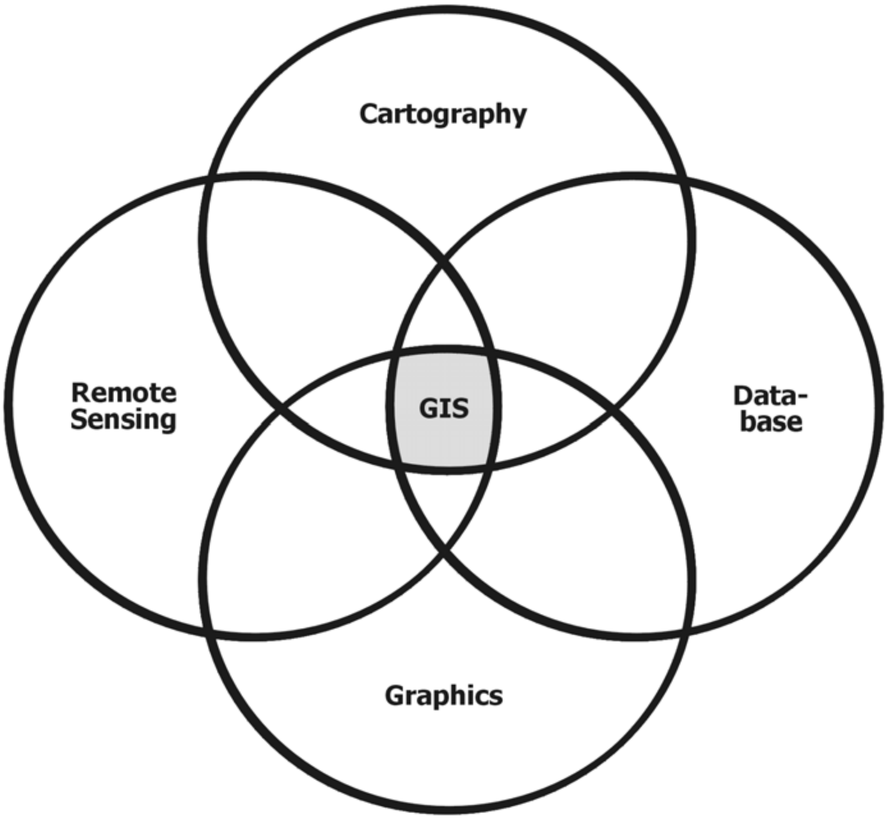


Figure 2.12 Interrelationship between GIS discipline. (Gottfried, 2003).

In the last century, thematic maps came into use. Thematic maps contain information about a specific subject or a theme, such as surface geology, land use, soils, political units and collection areas, as shown in figure 2.13.

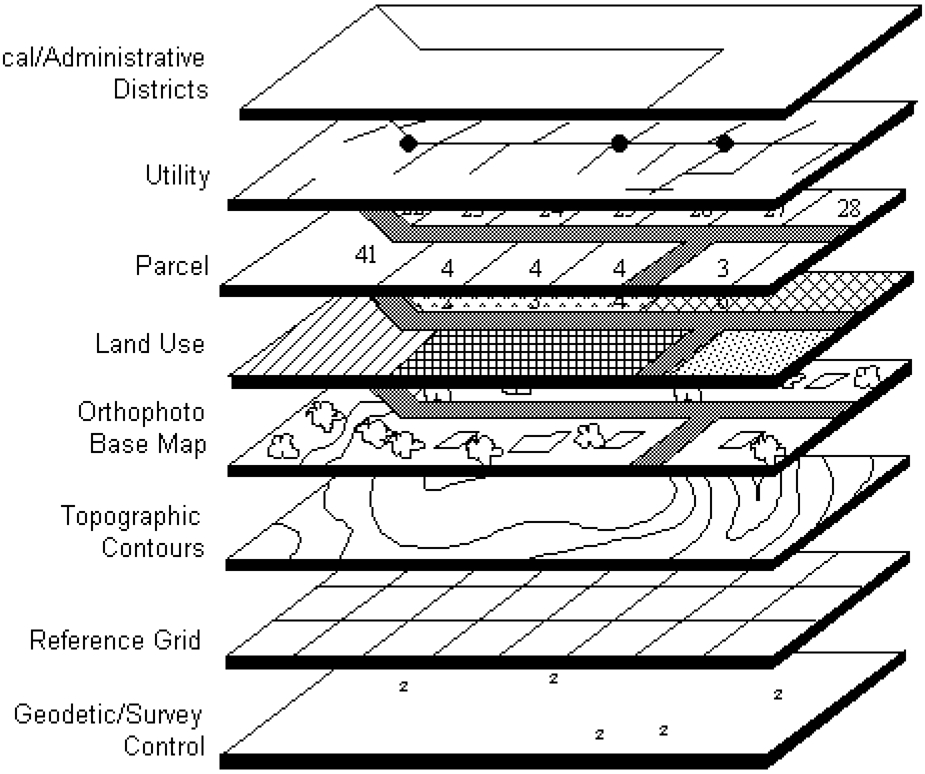


Figure 2.13 Illustration of thematic layers.

The map overlay concept began to exploit thematic maps by extracting data from one map to place it onto another. As an early example, the geographic extent of the German city of Dusseldorf was mapped at different time periods in this way in 1912, and a set of four maps of Billerica, Massachusetts, were prepared as part of a traffic circulation and land-use plan in the same year. By 1922 these concepts had been refined to the extent that a series of regional maps were prepared for Doncaster, England, which showed general land use and included contours or isolines of traffic accessibility . In 1929 “survey of New York and its Environs” clearly shows that overlaying maps on top of each other was an integral part of the analysis, in this case of population and land value, (Keith, 2001).

In 1950, the technique of map overlay was ‘invented’ by Jacqueline Tyrwhitt as presented in Town and country planning Textbook in Britain contained various data themes, including land elevation, surface geology, hydrology/soil drainage, and farmland, were brought together and combined into a single map of “Land characteristics”, (Keith, 2001).

During the 1960s, many new types of thematic maps were becoming available in standardized scales. In this year the term Geographic Information Systems (GIS) first appeared in works by Dr. Tomlinson, a Canadian geographer, who was a major contributor in the vast Canada-wide mapping undertaking – the Canada Land Inventory (CLI), (Barry, 2003).

During the mid and late 1960s, the Harvard University’s Laboratory for Computer Graphics and Spatial Analysis made some major theoretical foundations and developments for successful industrial GIS. In 1964, Harvard Laboratory was responsible for creating the first commercially available computer mapping package, SYMAP, (Syangraphic mapping or “acting together graphically”). The Harvard laboratory , which also developed a vector-based package, called Odessy – that allowed for complex topological data structure – was during the 1970s, (John, 2001).

The 1980s and early 1990s was GIS mature as a technology. As the developments in computers and languages (softwares). The decade of the 1990s saw remarkable growth in the GIS world. Several new factors emerged. First, GIS spread far beyond its origins in the mapping science to encompass developments in new fields. Also, the cost of GIS fell markedly after a series of ‘desktop’ GIS products emmerged. In addition, GIS became fully integrated with the GPS, greatly enhancing the system data capture capability. Finally, the emergence of the Internet and e-commerce has placed GIS onto the world wide web as web-GIS. Many now talk of a new era of g-commerce or g-trade, based on geographically enabled web search capability, rather than simply map display, (Keith, 2001).

In the past the disciplines of geodesy, photogrammetry, and cartography worked in an independent fashion to provide printable maps. In the new concept GPS, remote sensing, digital photogrammetry and GIS are able not only to produce printable maps, but to display raster and vector images on a computer screen and to analyse them in an interdisciplinary manner for the purposes of society, as shown in figure 2.14, (Gottfried, 2003).

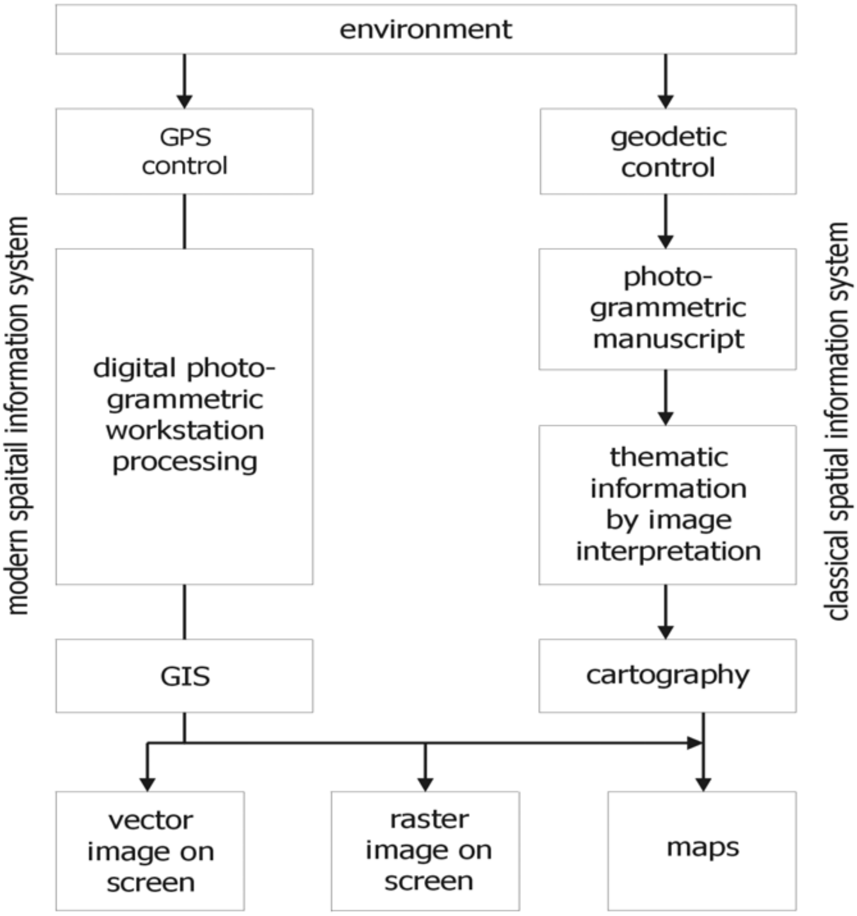


Figure 2.14 Classical and Modern Geospatial Information System, (Gottfried, 2003).

2.2.2 GIS Definition.

In a narrow definition, A geographic information system (GIS) is a computer system for the input, the manipulation, the storage and the output of digital spatial data. Therefore a GIS consists of a system for data input in vector form, in raster form and in alphanumeric form, a CPU containing the programs for data processing, data storage and data analysis and of facilities for visualization and hard copy output of the data, as shown in figure 2.15, (Gottfried, 2003).

In a broad definition, a GIS is a digital system for acquisition, the management, the analysis and the visualization of spatial data for the purposes of planning, administering and monitoring the natural and socio-economic environment. Therefore a GIS includes the data, which are managed by an administration or a unit conducting a project for the purposes of data inventory, data analysis and data presentation for administrative support or for decision support, (Gottfried, 2003).

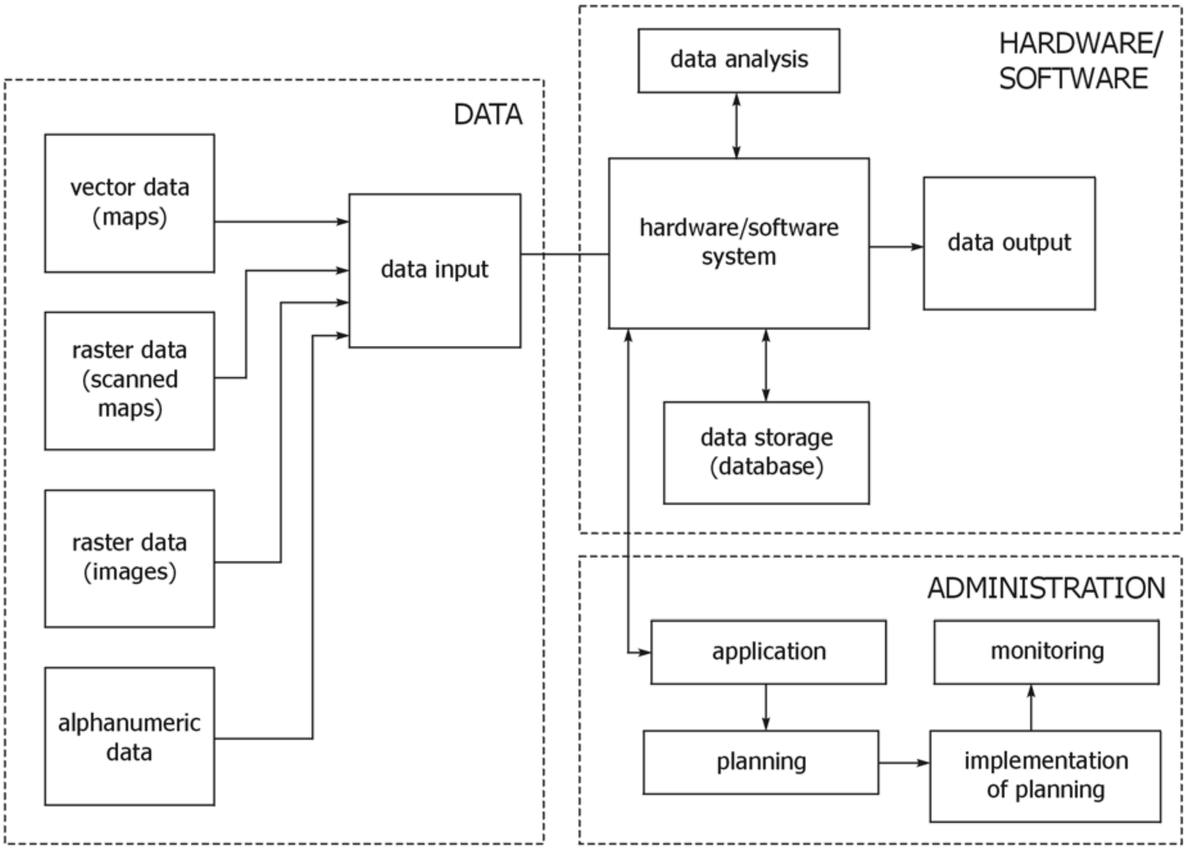


Figure 2.15 Concept of a Geographic Information System, (Gottfried, 2003).

In a GIS, spatial entities have two key characteristics: location and attributes. Location can be given by coordinates, street addresses, etc. and attributes describe some characteristic(s) of the feature being analyzed. GIS has now blossomed into a huge and diverse field of activity. Most activity can be identified as being in one of two broad fields: (1) geographic feature-specific activities such as mapping, engineering, environment, recourses, and agriculture, and (2) cultural/social activities such as marketing research, census, demographics, and social/economic studies. Since GIS is a tool used by engineers, planners, geographers, and other social scientists, it is not surprising that there seems to be as many definitions for GIS as there are fields in which GIS is employed. A definition comes from the University of

Edinborough's GIS faculty, as shown in figure 2.16, GIS is a computerized system for capturing, storing, checking, integrating, manipulating, analyzing, and displaying data related to positions on the earth's surface, (Barry, 2003).

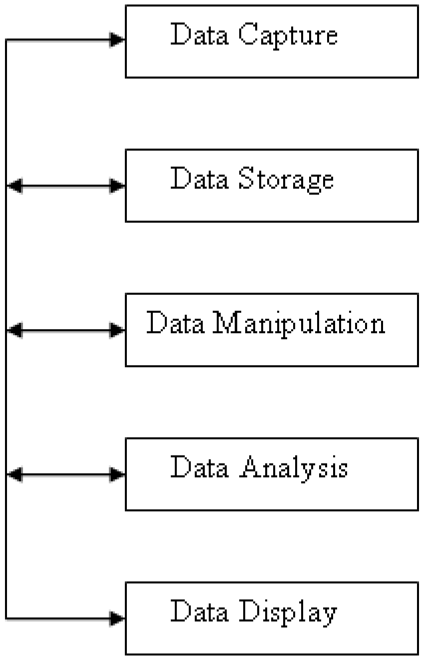


Figure 2.16 The basic five steps associated with GIS applications, (John, 2001).

2.2.3 Sources for GIS data.

It is often remarked that the most expensive part of any GIS is the collection of data. Obviously, if you can obtain suitable data already collected from other sources, the efficiency of the process increases. When importing data from other sources, it is imperative that the accuracy level of the collected data be certified as being appropriate for its intended use, (Barry, 2003). Traditional sources for data collection include:

- Field surveying.
- Remotely sensed images: rectified and digitized aerial photographs (orthophotos) and processed aerial and satellite imagery.
- Existing topographic maps, plans, and photos, via digitizing and/or scanning.
- Census data.

- Electronic transfer of previously digitized data from government agencies or commercial firms.

2.2.4 Hardware components.

The hardware of a GIS is composed of:

- input devices.
- processing and storage devices.
- output devices.

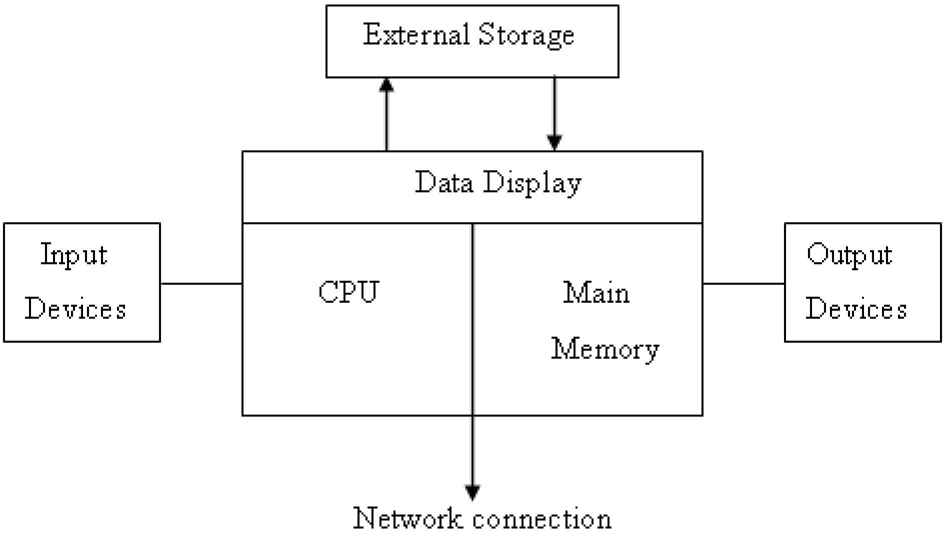


Figure 2.17 Hardware Components, (Gottfried, 2003).

2.2.4.1 Input devices.

Digital data input depends on the type of data to be utilized:

- **Imagery** input is possible from analogue images by the use of image scanners. Digital airborne and space borne systems already use charge-coupled device CCD-sensors to supply the data in digital form. For analogue and for digital images a resolution of 50 lp/mm can be reached, (Gottfried, 2003).

- **Maps** can be manually digitized by 2-D digitizers in vector form. This is possible in a single point mode or by dynamic measurement based on distance or time. The resolution of digitizing is about 0.2 mm. Maps may, however, also be raster scanned using scanners. These are available as drum scanners or as flat-bed scanners with a pixel size of 7 µm and an accuracy of 2 to 4 µm. Scanned raster data may subsequently be converted into vector information with GIS software, (Gottfried, 2003).

● **3-D Vector Data** can be obtained directly by terrestrial survey equipment, such as:

- theodolites.
- electronic tacheometers.
- levelling instruments.
- GPS receivers.
- mobile mapping systems.

3-D information from aerial photographs may be compiled by analogue or analytical plotters or by digital photogrammetric workstations, (Gottfried, 2003).

2.2.4.2. Processing and storage devices.

Processing and storage devices consist of the central processing unit (CPU) and the main memory, the external storage devices and the user interface, as shows in figure 2.18, (Gottfried, 2003).

The CPU executes the program commands. Its arithmetic unit performs algebraic and logical operations for the data. Its control unit regulates the data transfer between arithmetic unit and the main memory. (Gottfried, 2003).

The main memory (random access memory, or RAM) contains the machine programs and accepts data in short access time with caching, if required. The I/O controller communicates with the periphery for hardware ports and for software drivers. The bus system establishes the connections. To speed up the output process additional graphic cards and memory are usually added as interfaces. (Gottfried, 2003).

External Storage Devices are linked to the computer. The User Interface consists of a high resolution CRT screen, which may be adapted for colour viewing and optionally for stereo. It also consists of a mouse and a keyboard, (Gottfried, 2003).

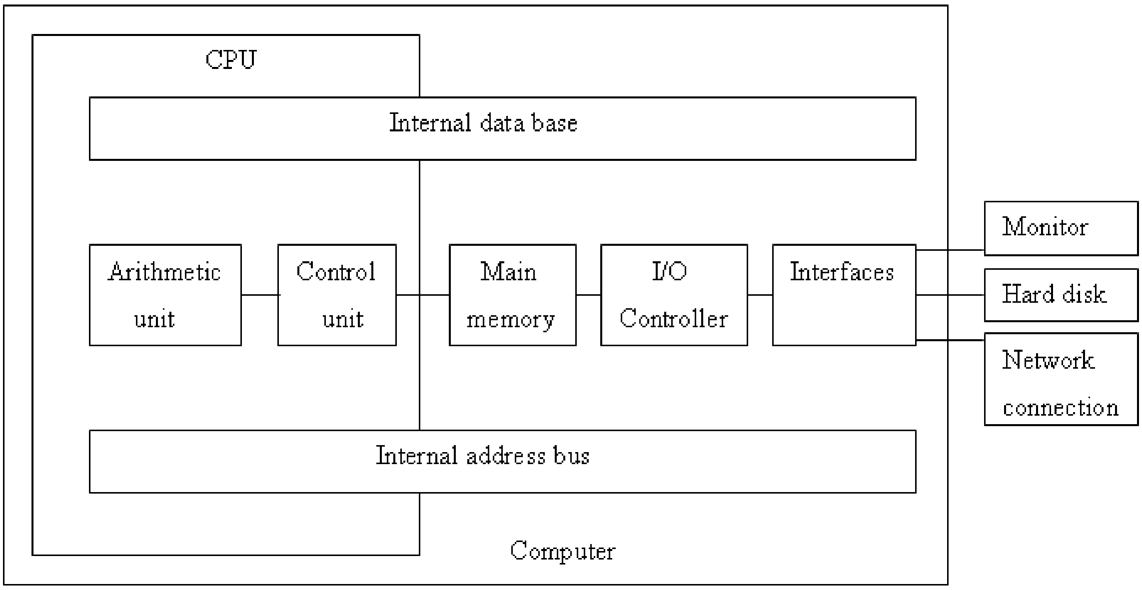


Figure 2.18 CPU and Main Computer Memory, (Gottfried, 2003).

2.2.4.3 Output devices.

Output devices include the ports to printers. Specific to GIS are the graphic output facilities.

Vector Devices are flat-bed plotters and drum plotters. Flatbed plotters have an accuracy of ± 0.05 mm at a speed of < 30 m/min operated with a pen or a light beam. Drum Plotters are less accurate but faster (300-900 m/min). They are used for verification plots.

Raster Devices permit the output halftones in a pixel or a screened manner. They are able to print RGB or CYMK colours in different saturations. They can combine vector and raster data in raster form.

2.2.5 Software components.

2.2.5.1 Operating systems.

The operation of a computer is based on its operating system. It assures that all parts of the computer function in liaison. Most common are Microsoft's operating systems for PC's.

In MS-DOS (Microsoft Disk Operating System) The operation is regulated by text lines. These permit to administer files by name. More modern are Windows operating systems such as Windows 3.1, Windows 95, Windows 98, Windows NT, Windows 2000, Windows ME and Windows XP utilizing graphic symbols (icons). Windows acts as a Graphical User Interface (GUI). Windows is now a network compatible system, (Gottfried, 2003).

An operating system for workstations is UNIX, which has been adapted for the computers of specific manufacturers: HP-UX by Hewlett-Packard, AIX by IBM and Linux, which is generally available. Unix development dates back to the 1960's. It was originally designed for the operation of main frame computers with multi-tasking. It contains a great number of data security features regulating access.

2.2.5.2 Programming languages.

The programming of computers is made possible by programming languages, which translate user formulations into a machine compatible code. For this translation a compiler for the respective programming language is required. Most GIS programmes, based upon a chosen operating system have been programmed in the programming language Fortran (formula translation). More modern languages are C, C+ +, and Visual Basic, (Gottfried, 2003).

2.2.5.3 Networking software.

The communication of computers within a local area network (LAN) and a wide area network (WAN) is assured by International Standards Organization (ISO) standards.

The most common standard is TCP/IP (Transmission Control Protocol/Internet Protocol). TCP/IP separates data transmission into smaller packages transmitted from an identified sender to a receiving computer. The transmission of the packages is checked during the process. (Gottfried, 2003).

2.2.5.4 Graphic Standards.

Graphic Standards have been introduced so that the complex graphic instructions of the computer can be translated into monitor compatible instructions. An internationally-agreed graphic standard is the Graphic Kernel System (GKS). It defines 2-D graphic primitives (position, height, line type, font, colour, and fill). Other standards are X window (X11) and special standards for 3-D graphic cards, (Gottfried, 2003).

2.2.6 Spatial data models.

In GIS, real-world physical features are called entities and are modeled using one or both of the following techniques: vector model or raster model.

2.2.6.1 Vector model.

The modelling of vector geometry depends on local or georeferenced coordinate systems. The advantage of vector systems lies in the possibility of recording and displaying coordinates with full measurement accuracy of ground surveys or of photogrammetric point and line measurements. In general, vector systems also contain less data volume than raster images of the same area. Furthermore, it is easy to attach alphanumeric attributes to the defined elements of a vector system such as:

- points.
- lines.
- areas.
- objects.

A point is defined by its coordinates x,y, and by its node number. A line is defined by the coordinates of its end points x_1,y_1 and x_2y_2 and its line (arc) number. A line string is defined by the coordinates of all points forming the line string: x_1y_1, x_2y_2, … x_ny_n. An area is defined by the coordinates of the line string ending at the initial points: x_1y_1, x_2y_2, … $x_{n-1}y_{n-1}$, x_1y_1. To points, lines and areas, attributes with alphanumeric thematic data may be attached, (Gottfried, 2003).

So far, most GIS systems have been limited to 2-D geometry. Elevations have, however, been included as attributes. The elevation information may be introduced on a case-by-case basis, if a special 3-D query is desired and programmed, (Gottfried, 2003).

2.2.6.2 Raster model.

Raster data consist of a regular 2-D grid of square cells. The grid is characterized by a (geocoded) origin, its (geocoded) orientation and the raster cell size, which for imagery corresponds to a pixel (picture element) size. Other information, such as elevation levels or thematic data may also be arranged by a scheme of regular tessellation. Raster systems may also be arranged in 3-D. The 3-D cell becomes a cube (a voxel). The attribute of the cell describes the thematic information (grey level, elevation level, thematic object content). Raster coverages may be in regular (square, rectangular) or irregular dimensions. Each raster data set constitutes a layer. There may be many layers for the same area.

The geometric accuracy of raster data is limited by the cell resolution. There may exist a mixed-cell problem. Due to limits in resolution, there is a possibility of mixed pixels.

While raster models reflect what is present, vector models more accurately define the whereabouts. Raster topology is defined by the eight neighbouring pixels surrounding a particular pixel. Neighbouring cells carrying the same attribute define a connection component. In this way linear objects may be recognized by the connection components.

2.2.7 Geographic Data (Graphical & Attribute).

We can define a data model as a logical contruct for the storage and retrieval of information. It is the computer's way of memorizing all the GIS data that we need to use. A GIS must have at lesat two data models, and that the two must have a link between them to tie the attributes and the geography together. These are the map data model and the attribute data model, as shown in figure 2.19 and table 2.4.

1. **Spatial data** : is the data pertaining to the locational aspect of geographical features together with their spatial dimensions, (EREN, 2003).

2. **Attribute data** : are the description, measurement and classification of the geographic features. Attribute data has descriptive, quantitative and qualitative aspects, (EREN, 2003).

   - Descriptive : parcel no., owner, vegetation type, etc.
   - Quantitative : area, volume, value, voltage, etc.
   - Qualitative : water, air, sail quality, steepness, etc.

3. **Time** : Geographic information can change over time.

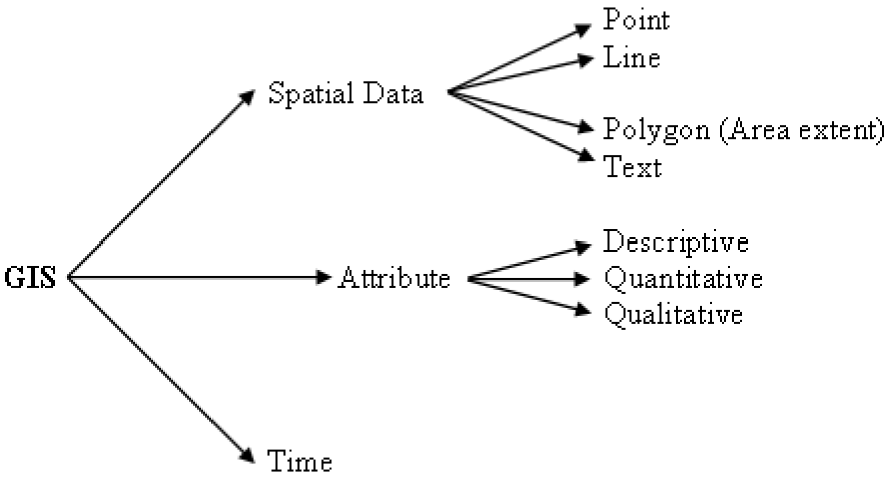
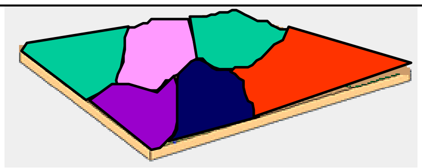
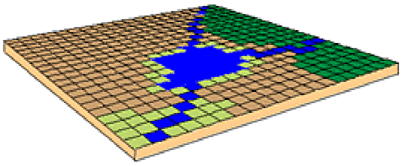
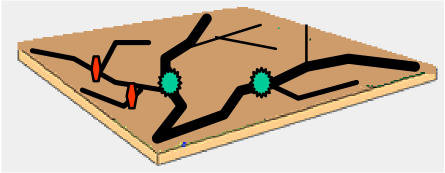
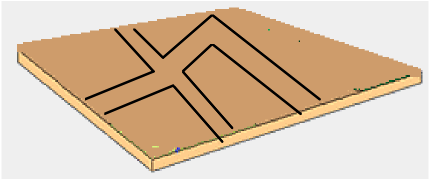
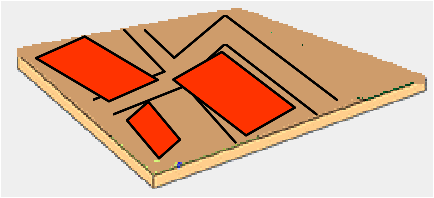
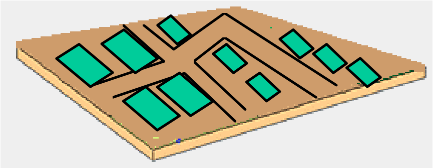
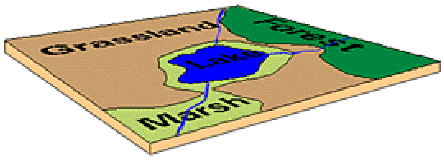
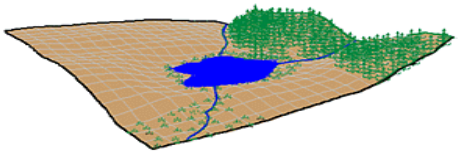
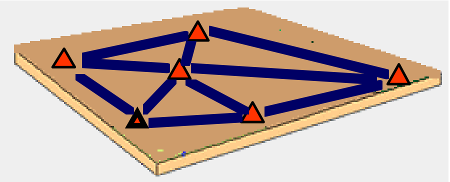


Figure 2.19 GIS basic components, (EREN, 2003).

Table 2.4 Spatial data & Attributes, (EREN, 2003).

SPATIAL DATA MAPS		ATTRIBUTES
Socioeconomic - Political / Administrative Districts - Census district - Security and Military Areas - Demographic areas - Tax rate areas - School districts - Emergency Service Areas - Election management		**Socioeconomic** - Income - Population - Logistics - Classification - Value - Sale restrictions - Responsible agency - Parties
Natural Resources & Environment - Vegetation, landscape, land use - Agriculture, soils - Floodplain, noise level, pollution - Waterbodies, streams - Forestry, parks, gardens		**Natural Res. & Environment** - Vegetation type - Land cover - Date - Volume - Name
Facilities Management (Utilities) - Sewer system - Water system - Electricity - Telecommunications - Natural gas		**Facilities Management (Util.)** - Size - Age - Material - Number of channels - Flow rate
Network Data - Road centerlines and intersections - Street lights and trees - Transportation - Navigation and vehicle tracking - Cleaning network - Fire network - Emergency response, vehicle routing - Road services		**Network Data** - Width - Power - Load - Report - Street name - Building type - Sites - Agency
Land Administration - Easement and right-of-ways - Zoning and planning - Real-Estate and Taxing - Property management - Land use, coding, licensing - Urban redevelopment - Social housing, land development - Tracking development - Facility siting		**Land Administration** - Use - Legal document - Decision maker - Lease - Photograph - Municipality - Tenant - Cost - Dimension
Cadastre - Parcels, lot boundaries - Multi-purpose cadastre		**Cadastre** - Owner - Tax value
Topography - Buildings - Roads, rivers, and other planimetry - Contours		**Topography** - Area - Length - width - Heights
3-D Terrain - 3-D Modelling - Hydrographic modelling - Other 3-D applications		**3-D Terrain** - Angle - Slope - Aspect
Spatial Reference Framework - Control points - GPS Reference Stations		**Spatial Reference Framework** - Date - Organisation

2.2.8 GIS Database.

A database is a self-contained, long-term organization of data for flexible and secure use. It consists of the data and of a data base management system (DBMS), which is the software to manage the data. A database permits the strict separation between data and an application. It has a well-defined interface for application programs. The user of a database is not concerned with the internal data organization, but he can change the data location without changing the application program. The DBMS provides efficient access to the data with security checks, (Gottfried, 2003).

2.2.8.1 Conceptual Database Design.

GIS database elements are considered here. DBMS-independent concepts used to describe data at a high level. A high level data model such as ER or EER model is used during this phase. Entities, relationships, attributes and constraints are defined. All known transactions are specified, (EREN, 2003).

2.2.8.2 Logical Database Design.

Transform (or map) the conceptual schema from the high-level data model into the implementation data model of DBMS chosen. The three most widely used implementation data models – relational, hierarchical and network, (EREN, 2003).

2.2.8.3 Physical Database Design.

It is the actual structure of the GIS database. Choose specific storage structures and file organizations for the database, and map the implementation model schema to internal file structures chosen. Each DBMS will usually have several options available for organizing data such as index selection, security, recovery and so on, (EREN, 2003).

2.2.8.4 Database Implementation.

The question here is that, What Derives GIS Database Design?

● User needs.
● GIS applications data requirements.
● Available data and cost conversion.
● Data conversion schedule.
● Future expansion.
● Maintainability.

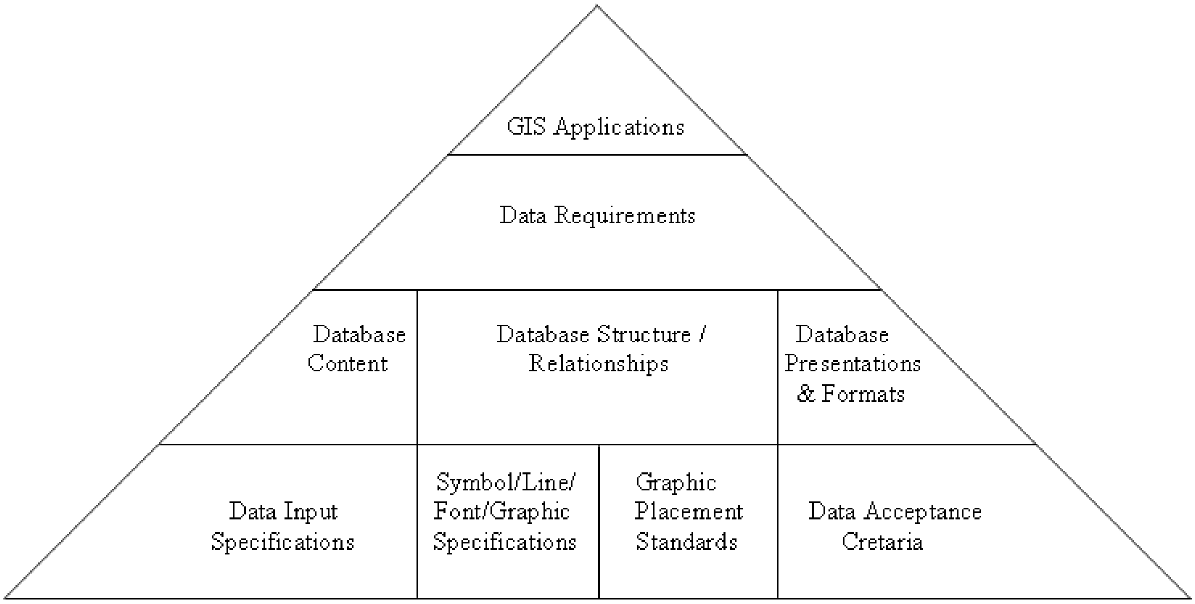


Figure 2.20 Top-down Datadase Design, (EREN, 2003).

GIS data have a ‘direct spatial reference’ via 2-D or 3-D coordinates. To use indirect spatial access data in a GIS geocoded links for these must first be established (e.g. by a parcel no., a building no., or a set of coordinates). In very large databases a coordinate reference is usually added to the data for the purpose of efficient retrieval, (Gottfried, 2003).

2.2.9 GIS systems.

There are a few hundred GIS systems in existence. The big eight packages are ArcInfo (ESRI), ArcView (ESRI), AutoCAD Map (Autodesk Company), GRASS (Baylor university), IDRISI (Clark university), MapInfo (MapInfo corporation), Maptitude (Caliper corporation), Microstation (Intergraph corporation).

There are some significant differences among these “big eight” systems, a factors should be considered when selecting GIS system are cost, upgrades, network configuration support, training needs, ease of installation, maintenance, documentation and manuals, help-line and vendor support, means of marking patches, and work force, (Keith, 2001).

2.2.10 Georeferencing.

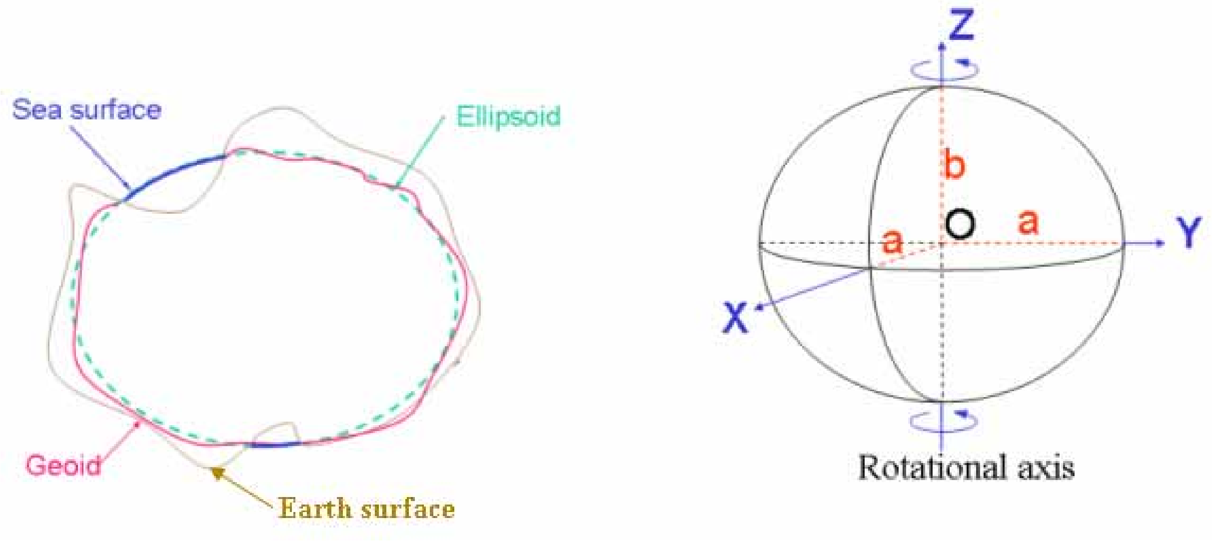
GIS specialists must find some way to relate geospatial data to the surface of the earth. In order to make use of different type of GIS data and GPS position information a common coordinate system is needed in which all the data can be expressed.

2.2.10.1 Datum.

A geodetic datum is a set of constants specifying the coordinate system used for geodetic control, i.e. for calculating coordinates of points on the earth, (John, 2001).

The fact that the topographic surface of the earth is highly irregular makes it difficult for the geodetic calculations. To overcome this problem, geodesists adopted a smooth mathematical surface, called the reference surface, to approximate the irregular shape of the earth (more precisely to approximate the global mean sea level, the geoid). For high accuracy positioning such as GPS positioning, however, the best mathematical surface to approximate the earth and at the same time keep the calculations as simple as possible was found to be the biaxial ellipsoid, as shown in figure 2.21. The biaxial reference ellipsoid can be defined by the semi-major and semi-minor axes (a, b) or the semi-major axis and the flattening (a, f), where the flattening (f) value is $f = 1 - (b/a)$.

An appropriately positioned reference ellipsoid is known as the geodetic datum. In other words, a geodetic datum is a mathematical surface, or a reference ellipsoid, with a well-defined origin (center) and orientation. A geodetic datum is uniquely determined by specifying eight parameters: two parameters to define the dimension of the reference ellipsoid, three parameters to define the position of the origin, and three parameters to define the orientation of the three axes with respect to the earth. Table 2.5 shows some examples of three common reference systems and their associated ellipsoids, (Ahmed, 2001).



(a) (b)

Figure 2.21 (a) Relationship between earth's surface, geoid, and ellipsoid; and (b) ellipsoid parameters, (Philip).

In additional to the geodetic datum, the so-called vertical datum is used in practice as a reference surface to which the heights (elevations) of points are referred. The vertical datum is often selected to be the geoid, the surface that best approximates the mean sea level on a global basis. With modern system such as GPS positioning, it possible to determine the 3-D positions with respect to a 3-D reference system.

Table 2.5 Examples of reference systems and associated ellipsoids.

Reference Systems	Reference Ellipsoid	Semi-major axis (a),m	1/f
WGS 84	WGS 84	6,378,137.0	298.257223563
NAD 83	GRS 80	6,378,137.0	298.257222101
NAD 27	Clarke 1866	6,378,206.4	294.9786982
ITRF	ITRS	6,378,136.49	298.25645

2.2.10.2 Coordinate systems.

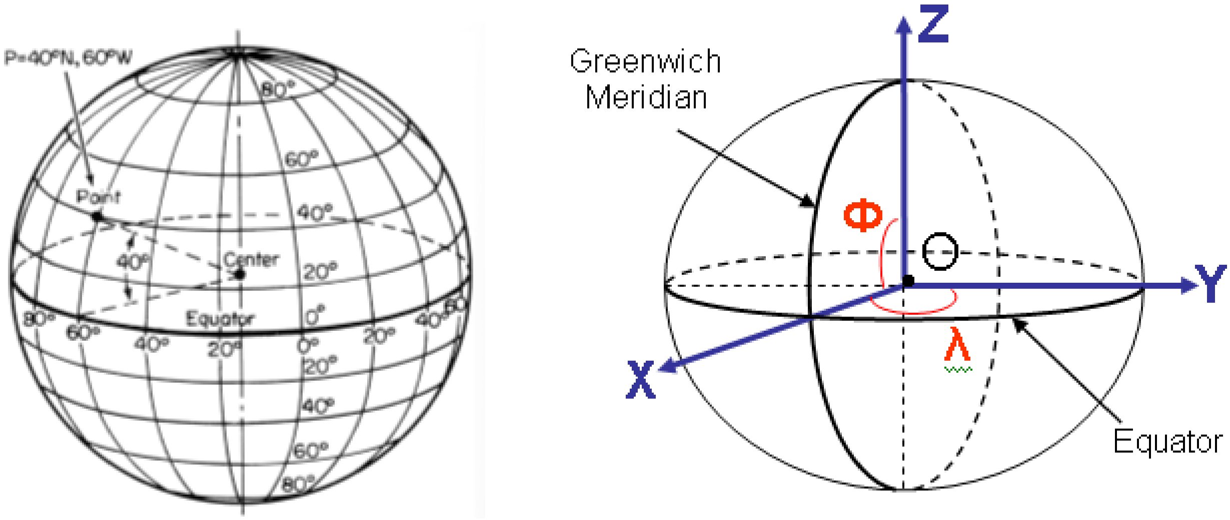
A coordinate system is defined as a set of rules for specifying the locations (also called coordinates) of points on a planar or spherical surface. This usually involves specifying an origin of the coordinates as well as set of reference lines (called axis) with known orientation.

Coordinate systems may be classified as 1-D, 2-D, or 3-D coordinates systems, according to the number of coordinates required to identify the location of a point. Coordinate systems may also be classified as spherical coordinate systems and planar coordinate systems, spherical coordinate systems are associated with the ellipsoidal models of the Earth, while the planar coordinate systems are associated with the map projections of the ellipsoidal models of the Earth. The most common types of map coordinate systems (global systems) used are (A) Spherical coordinate system and (B) Planar coordinate systems.

(A) Spherical coordinate system: The two most commonly used spherical coordinate system are:

(1) Latitude, Longitude and Altitude: The most commonly used coordinate system today is the latitude, longitude, and height (Φ, λ, and h) system. The Prime Meridian and the Equator are the reference planes used to define latitude and longitude. There are several ways to define these terms precisely. The geodetic latitude of a point is the angle between the equatorial plane and a line normal to the reference ellipsoid. The geodetic longitude of a point is the angle between a reference plane and a plane passing through the point, both planes being perpendicular to the equatorial plane. The geodetic height at a point is the distance from the reference ellipsoid to the point in a direction normal to the ellipsoid, (Peter, 2003), as shown in figure 2.22 (a).

(2) ECEF X, Y, Z: Earth Centered Earth Fixed (ECEF) Cartesian coordinates can also be used to define three dimensional positions X, Y, and Z with respect to the center of mass of the reference ellipsoid. The Z-axis points from the center toward the North Pole. The X-axis is the line at the intersection of the plane defined by the prime meridian and the equatorial plane. The Y-axis is defined by the intersection of a plane rotated 90˚ east of the prime meridian and the equatorial plane, (Peter, 2003), as shown in figure 2.22 (b).



(a) (b)

Figure 2.22 Geodetic and Cartesian coordinates, [(a) NOPP, and (b) Philip)].

(B) Planar coordinate system: The most commonly used planar coordinate system is Universal Transverse Mercator (UTM) coordinate system.

- **Universal Transverse Mercator (UTM) coordinates :** The universal transverse mercator (UTM) coordinate system is commonly used in GIS because it has been included since the late 1950s on most topographic maps and provides coordinates on a world wide flat grid for easy computation. UTM system can be used to accurately represent positions, distances, and shapes of features in small geographic areas. The system use a set of geographic zones, with each zone having its own coordinate grid. Grid coordinates are often stated in respect to Easting (relative to a north-south axis) and Northing (relative to a east-west axis).

The UTM system, as shown in figure 2.23, divides the World into 60 zones, each being 6 degrees longitude wide, and extending from 80 degrees south latitude to 84 degrees north latitude. The polar regions are excluded. The first zone starts at the longitude 180 degrees west (or east), at the international date line, and runs east, that is, from 180 degrees west to 174 degrees west. The final zone , zone 60, starts at 174 degrees east and extends east to the date line, (Keith, 2001).

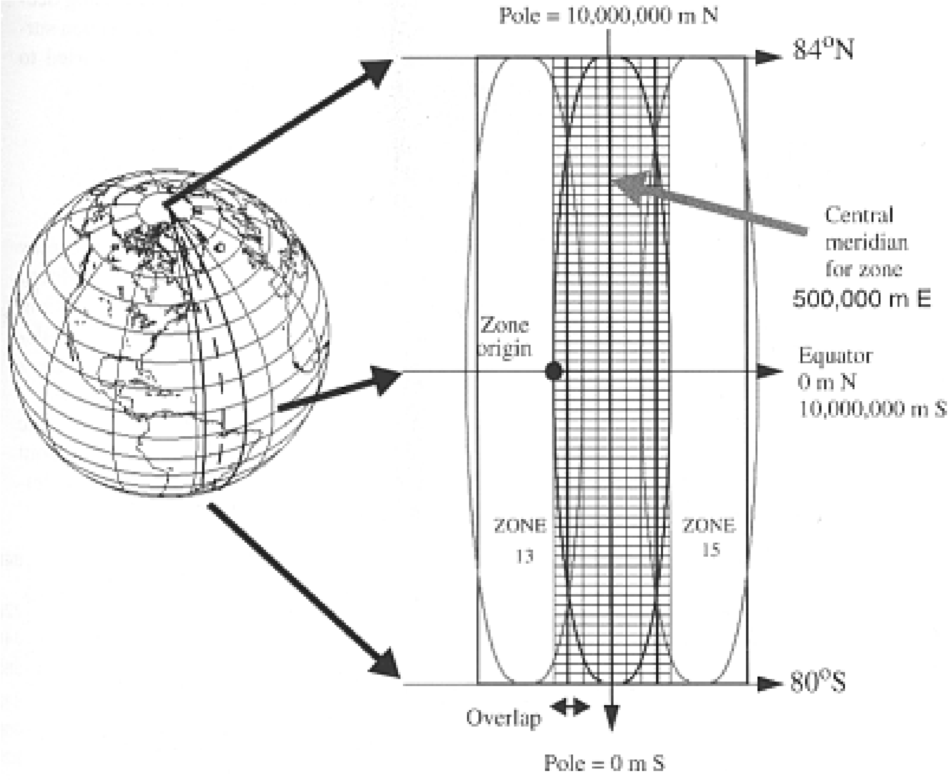


Figure 2.23 The Universal transverse Mercator coordinate system, (Keith, 2001).

2.2.10.3 Map projections.

Map projection is defined as the transformation of the physical features on the curved Earth's surface onto a flat surface called a map, (Ahmed, 2001). The transformation from a round surface to a plane cannot be accomplished without distortion. Some distortions of conformality, distance, direction, scale, and area always result from this process. Some projections minimize distortions in some of these properties at the expense of maximizing errors in others. Some projection are attempts to only moderately distort all of these properties. The characteristics that are normally considered when choosing a map projection can be listed as follows:

● Area: some map projection schemes are designed to be equal area. This means that equal area on map correspond to equal areas on the earth's surface.

● Shape: map projection can be conformal. This means that relative local angles about every point on the map are shown correctly. One important result of conformality is that the local scale in every direction around any point is constant. Since local angle are correct, meridians intersect parallels at right angle on a conformal projection. One should note that no map can be both conformal and equal area.

● Scale: No map projection can show the scale correctly throughout the whole map. Rather, the map projection can be designed in such a way that guarantees uniform scale along one or more lines. Some map projection show true scale along every meridian.

● Direction: Conformal projection gives the relative local directions correctly at any given point. In this type of projection, the direction or azimuths of all points on the map are shown correctly with respect to the center.

● Special characteristics: Some map projections offer special characteristics such as lines of constant directions are shown as straight lines. Some other projections show the shortest distance between the points as straight lines.

Map projections can be classified into three general categories called cylindrical, conic, and azimuthal projections.

(1) Cylinderical projections: These projections result from projecting the Earth onto a cylinder, as shown in figure 2.25. A cylindrical projection can be imagined in its simplest form as a cylinder that has been wrapped around a globe at the equator. If the graticule of latitude and longitude are projected onto the cylinder and the cylinder unwrapped, then a grid-like pattern of straight lines of latitude and longitude would result. The meridians of longitude would be equally spaced and the parallels of latitude would remain parallel but may not appear equally spaced anymore. In reality cylindrical map projections are not so simply constructed. The three aspects of the cylindrical projections:

● Tangent or secant to equator is termed regular, or normal.

- Tangent or secant to a meridian is the transverse aspect.
- Tangent or secant to another point on the globe is called oblique.

The peters, Miller cylindrical, Oblique mercator, Pseudocylindrical, Mollwide, Eckert IV/VI equal area, Robinson, And Transverse mercator projections are examples of Cylindrical projections.

- **Transverse Mercator projection:** Transverse Mercator projection (also known as Gauss-krüger projection) is a conformal map projection invented by Johann Lambert (Germany) in 1772. It's result from projecting the sphere onto a cylinder tangent to a central meridian. Transverse Mercator maps are often used to portray areas with larger north-south than east-west extent. Distortion of scale, distance, direction and area increase away from the central meridian. Many national grid systems are based on the Transverse Mercator projection, (EREN, 2003).

- **Universal Transverse Mercator (UTM) projection**: Universal Transverse Mercator (UTM) projection is a map projection that is based completely on the original transverse mercator. As shown in figure 2.24, with UTM the earth (i.e., the ellipsoid) is divided into 60 zones of the same size, each zone has its own central meridian that is located at exactly the middle of the zone. This means that each zone

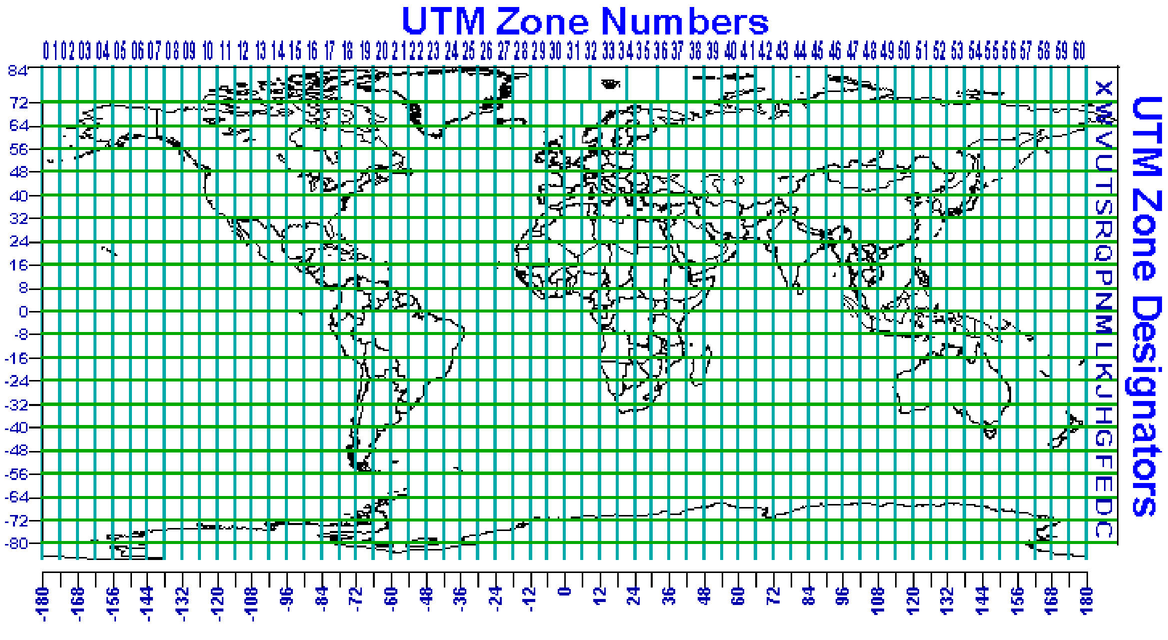


Figure 2.24 Universal Transverse Mercator (UTM) systems, (Peter, 2003).

Cover 6° of longitude, 3° on each side of the zone's central meridian. UTM zone numbers designate 6° longitudinal strips extending from 80 degrees south latitude to 84 degrees north latitude. UTM zone characters designate 8 degree zones extending north and south from the equator, as shown in figure 2.25. Eastings are measured from the central meridian (with a 500 km false easting to insure positive coordinates). Northings are measured from the equator (with a 10,000km false northing for positions south of the equator), (Peter, 2003).

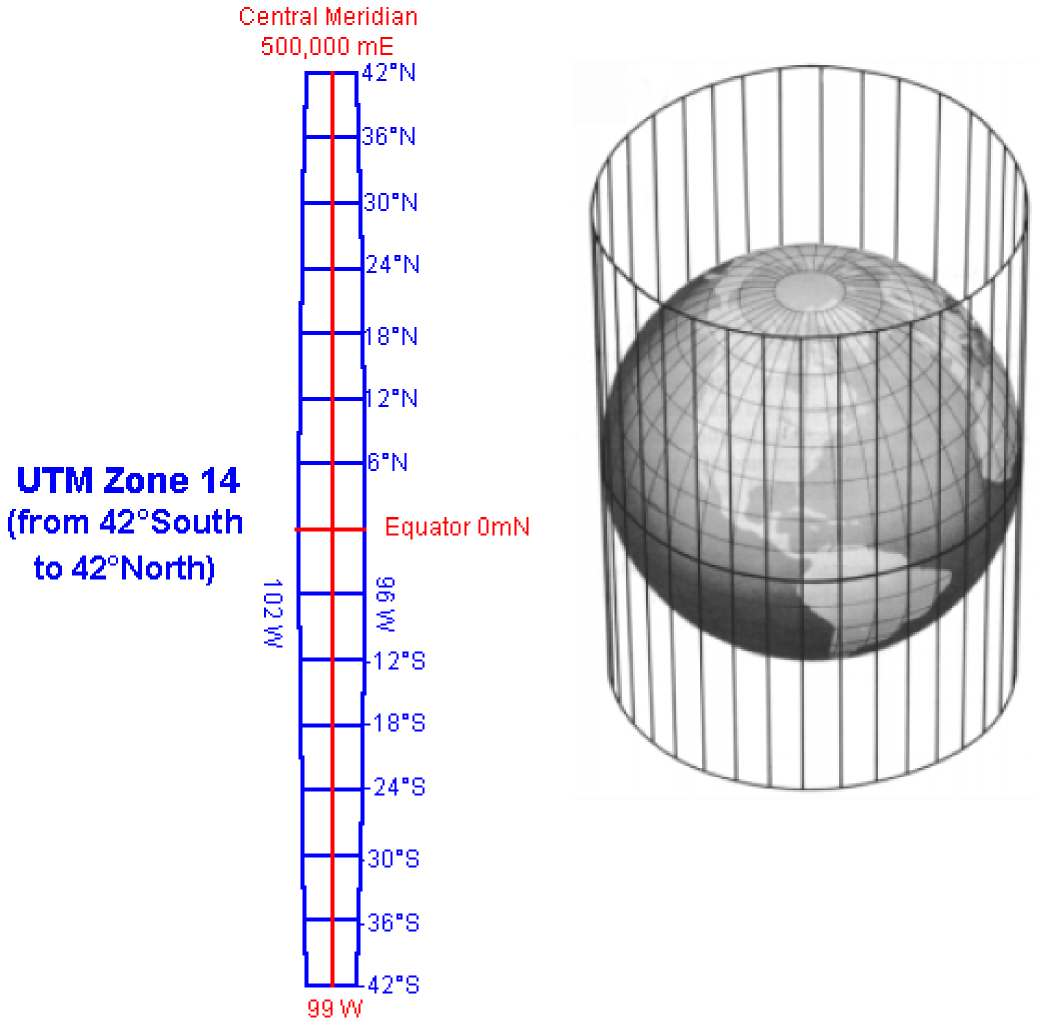


Figure 2.25 Simple Cylindrical projections and UTM zone 14, (Peter, 2003).

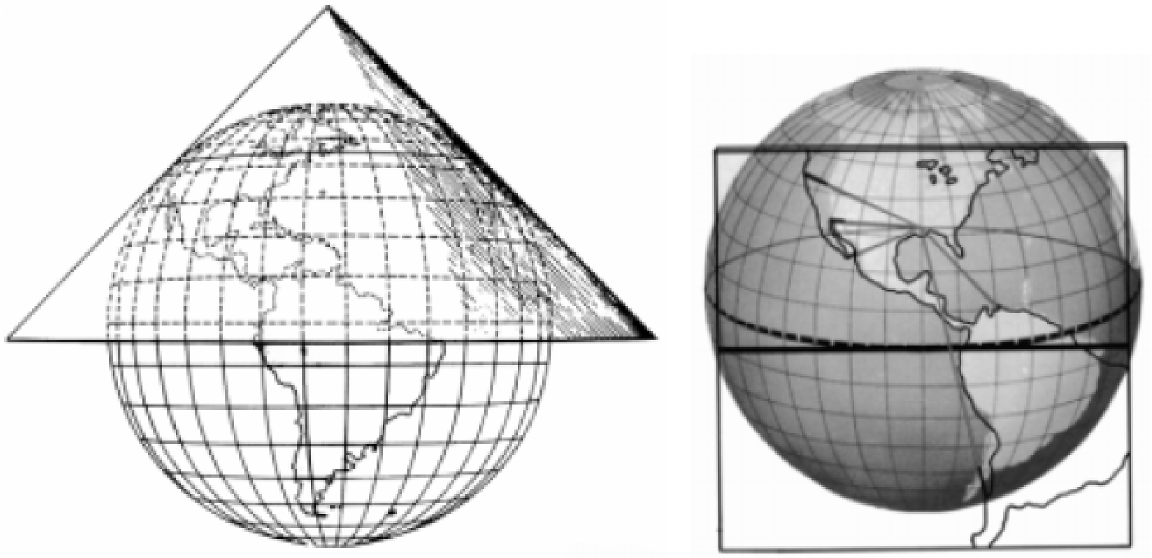
(2) Conic projection: These projections result from projecting the Earth onto a cone, as shown in figure 2.26 (a). Conic projections have as distinctive features:

- meridians are straight equidistant lines, converging at a point which may or not be a pole. Compared with the sphere, angular distance between meridians is always reduced by a fixed factor, the cone constant.

● parallels are arcs of circle, concentric in the point of convergence of meridians. As a consequence, parallels cross all meridians at right angles. Distortion is constant along each parallel.

Albers Equal Area Conic, Lambert Conformal Conic (LCC), and Polyconic projections are examples of conic projection.

(3) Azimuthal projections: Azimuthal projections are projections to a plane placed tangent to the globe at a point, figure 2.26 (b). In normal (or polar) aspect, the point of tangency is either the north or south pole and meridians of longitude are represented as radial straight lines through the pole while parallels of latitude appear as concentric circles. Distortion in the map increases with distance from the point of tangency. Since distortion is minimal near the point of tangency, azimuthal projections are useful for representing areas having approximately equal extents in the north-south and east-west directions. Azimuthal Equidistant, Lambert Azimuthal Equal Area, and Orthographic projections are examples of azimuthal projections.



(a) (b)

Figure 2.26 (a) Conic projection, and (b) Azimuthal projection, (Nathantel, 2002).

2.3 GPS and GIS Integration.

GPS has long been considered a technology that compliments GIS operations. The integration of GPS technology into GIS activities can be achieved through a variety of means. These range from the transfer of data from GPS systems, for the building of new database, though to the complete integration of GPS technology into existing GIS systems, to conduct spatial analysis directly in the field, (Andrew, 2000). Here we cover the numerous ways that GPS can be integrated with GIS.

2.3.1 GPS/GIS Integration Techniques.

There are three basic ways that GPS technology can interact with or be integrated into GIS. The level of integration associated with these vary from a 'disparate' connection, whereby data is transferred between a GPS system and a GIS system, through to a very 'tight' level of integration, whereby GPS technology is totally embedded directly within GIS application software. GIS/GPS integration can be categorized into the following three categories:

- Data-focused integration.
- Position-focused integration.
- Technology-focused integration

The appropriateness of each method is dependent upon the requirements that a user has for field-based operations, the level of dependence the user has on GPS and, to a large extent, the availability of a complete system to meet the specific needs that the user has for a system, (Andrew, 2000).

2.3.1.1 Data-focused integration.

To date, the most common method of integrating GPS into GIS has been through a data-focused method of integration. Data-focused integration, as shown in Figure 2.27, utilizes a complete, self-contained GPS system that has data collection and storage capability for use in the field. Data that is collected in the field is later transferred to an office PC for processing and eventual export to an enterprise GIS that resides within an organization. Historically, data-focused systems have concentrated on a one-way data flow whereby data is transferred from the GPS product to the GIS database. GPS field products are now emerging, however, that allow data from the GIS to be uploaded as well, so existing data can be taken easily back to the field for data update and maintenance purposes, (Andrew, 2000).

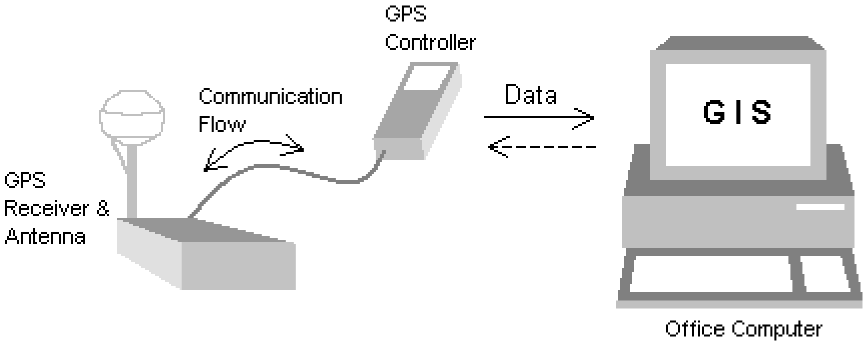


Figure 2.27 Conceptual view of data-focused integration, (Andrew, 2000).

The system consists of a GPS receiver, GPS antenna and a controlling device with data storage capability. Units can be either modular fully integrated into one housing or a combination of the two. The primary advantage of utilizing a data-focused approach to GIS/GPS integration is that an end-user can operate the GPS system "out of the box" with little or no need for customization. For many GPS users, an off-the-shelf system will cater for most, if not all, of their needs for data collection and maintenance. An example of a data-focused solution is Trimble Navigation's Geo-Explorer, for data collection and update, with GPS Pathfinder Office, for data transfer and processing, and ESRI's ArcInfo or ArcView products, for spatial analysis, query and archive, (Andrew, 2000).

2.3.1.2 Position-focused integration.

Position-focused integration is, historically, the most common approach to GPS integration. As shown in Figures 2.28 and 2.29, position-focused integration generally consists of a complete GPS system supplying a separate field application with GPS derived data that is related solely to the computation of positions. Data from the GPS is commonly transmitted to the field device using the NMEA-0183 protocol. Data from the field device may be transferred to and from the enterprise GIS. This is not imperative however, as the field application may be a self contained GIS in its own right, (Andrew, 2000).

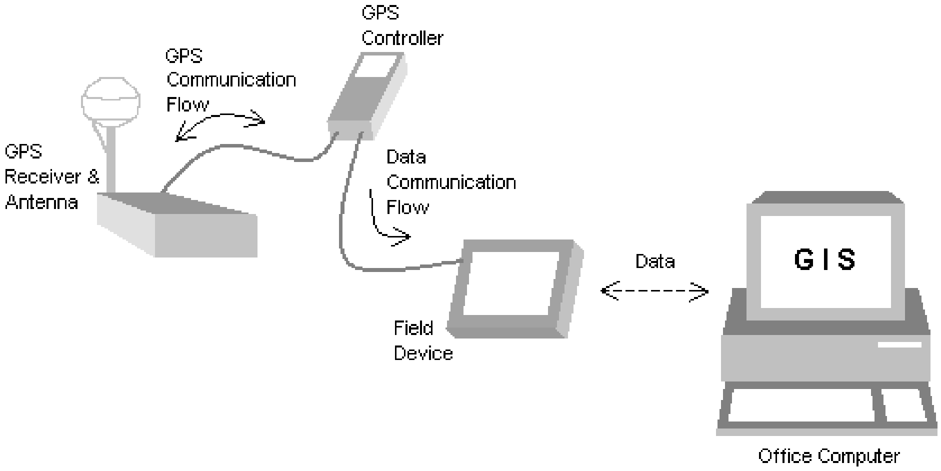


Figure 2.28 Conceptual representation of position-focused integration using two field device, (Andrew, 2000).

Figure 2.28 presents a good perspective on the components associated with position-focused integration. Position-focused integration essentially uses a GPS system, which could be the same as that used in data-focused integration, to provide data directly into an application running on the field device. In effect, the GPS system is treated as an external sensor by the application on the field device. The field device will usually provide data storage, (Andrew, 2000).

With the advances in handheld field devices, it is becoming more common to find both the GPS control application and the field device application operating on the same device, as shown in Figure 2.29. It’s important to note though that the applications will be operated totally separate to one another. In general, one application is used to configure the GPS receiver and control the provision of position related data, while another application is used to store and use the data that is being sent to it. It's important to note that the data storage application has little or no control over the operation of the GPS equipment, (Andrew, 2000).

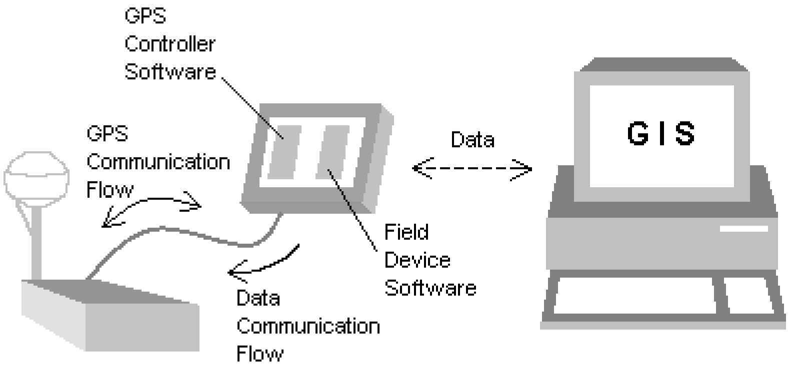


Figure 2.29 Conceptual representation of position-focused integration using a single field device, (Andrew, 2000).

While systems that make use of position-focused integration can become cumbersome, from an equipment and ease of use perspective, and expensive they are very useful when GPS positioning is required on an infrequent basis. The ability to utilize the GPS system when GPS is useful makes good economic sense. The downside of losing a tight integration with the GPS receiver or carrying a cumbersome system may be an acceptable alternative to the expense required to fully customize a system.

An example of position-focused integration is seen through the use of Trimble Navigation's GPS Pathfinder Controller software to setup a GPS Pathfinder XRS receiver for use with ESRI’s ArcPad field-GIS product. While ArcPad is actually able to power on and connect to a GPS Pathfinder XRS receiver directly, it has not been designed to configure the GPS receiver directly. The Pathfinder Controller software acts as the controlling device for the GPS receiver, while ArcPad provides an interface that is designed well for image display and spatial query.

2.3.1.3 Technology-focused integration.

Technology-focused integration is a refinement of position-focused integration. As shown in Figure 2.30, control of the GPS hardware is achieved directly from a third party application, thus eliminating the need for a separate application or device to control the GPS receiver. Communication between the application and the GPS receiver has a two-way communication flow - as compared to the one-way flow associated with the secondary application and the GPS system in the position focused approach. As with position-focused integration, it is optional for data to be transferred between the field device and the enterprise GIS. The transfer of data is dependant on the capabilities of the application on the field device, (Andrew, 2000).

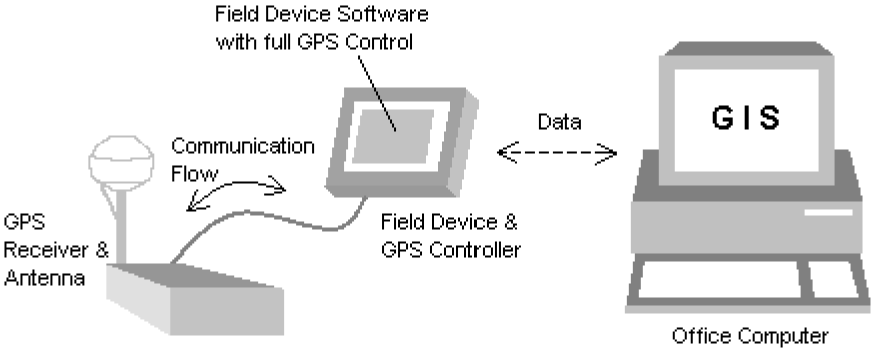


Figure 2.30 Conceptual representation of technology-focused integration, (Andrew, 2000).

This ability for a customized application to communicate directly with the GPS receiver enables GPS and GIS technologies to truly be integrated together in a seamless manner. In fact, the GPS technology is able to be totally embedded within a GIS application system to an extent that an end-user of the system will think that technologies from two different organizations actually came from one single source. Thus making a technology-focused application very similar to a data-focused system. The advantage though is that the full power of the GIS can also be taken directly into the field. The user-interface and functionality of the application can be totally designed around the needs of the user-resulting in powerful spatial analysis systems that are familiar and easy to use for the person who is going to use it most, (Andrew, 2000).

The reason that GPS receivers can be so tightly integrated is not new, but the current state of software technology has made a technology-focused integration approach more readily accessible to more people.

Now, however, through the use of component technologies (such as ActiveX components), it's significantly easier to integrate GIS and GPS components within the same programming code - or application.

The most significant advantage of a technology-focused integration approach is the flexibility it offers for both end-users and application developers alike. technology-focused integration is best suited to very simple applications or applications that are complex in nature and cannot be catered for by an off-the-shelf system. For the majority of GIS professionals who make use of GPS, therefore, a data-focused integration approach often provides the most economical solution, (Andrew, 2000).

An example of technology-focused integration is the use of Trimble Navigation's Pathfinder Tool software development kit to integrate a GPS Pathfinder XRS receiver within a customized application that uses ESRI's MapObjects product to visually display a map and carry out spatial analysis directly on a pen-based field computer.

Chapter 3

Case Study Methodology and Equipments

In many developing countries, there are many factors ranging from political, legal, financial, social, and cultural situations that are affecting in developing, operating and maintaining cadastre and land registration namely Land Information System (LIS). In this case study, we are aim to creating, updating, converting and integrating land parcel maps and related text information from paper to digital format for Beyşehir municipality rural area. This information (GIS data) can be assembled from existing data bases, digitized or scanned from existing maps and plans, and collected using surveying techniques and methods. GPS receivers, Total stations, and Digital levels were used for data collection.

The chapter deals with case study methodology, GIS software used, and information about instruments that we have used.

3.1 Methodology of the case study.

To design and establish a good, and up-to-date base for a modern cadastre system for Beyşehir municipality, we using the recent techniques and technologies in surveying and computer science. Parcel-based land information systems, or cadastres, form a subset of spatial information systems, in which the fundamental structure for collecting, storing, and retrieving information, is the cadastral parcel. Their primary objective is to provide a complete, up-to-date record of ownership of land, value, and land use in graphical and textual format.

A large percentage of rural areas (agriculture and new land areas) in Turkey, are not yet covered by new cadastral maps. In this project, there are two major stages of the work plan, which must be curried out one after the other. These two stages are, namely: collecting spatial and non-spatial cadastreal data, and building the cadastral system database. The methodology plan shows in figuur 3.1.

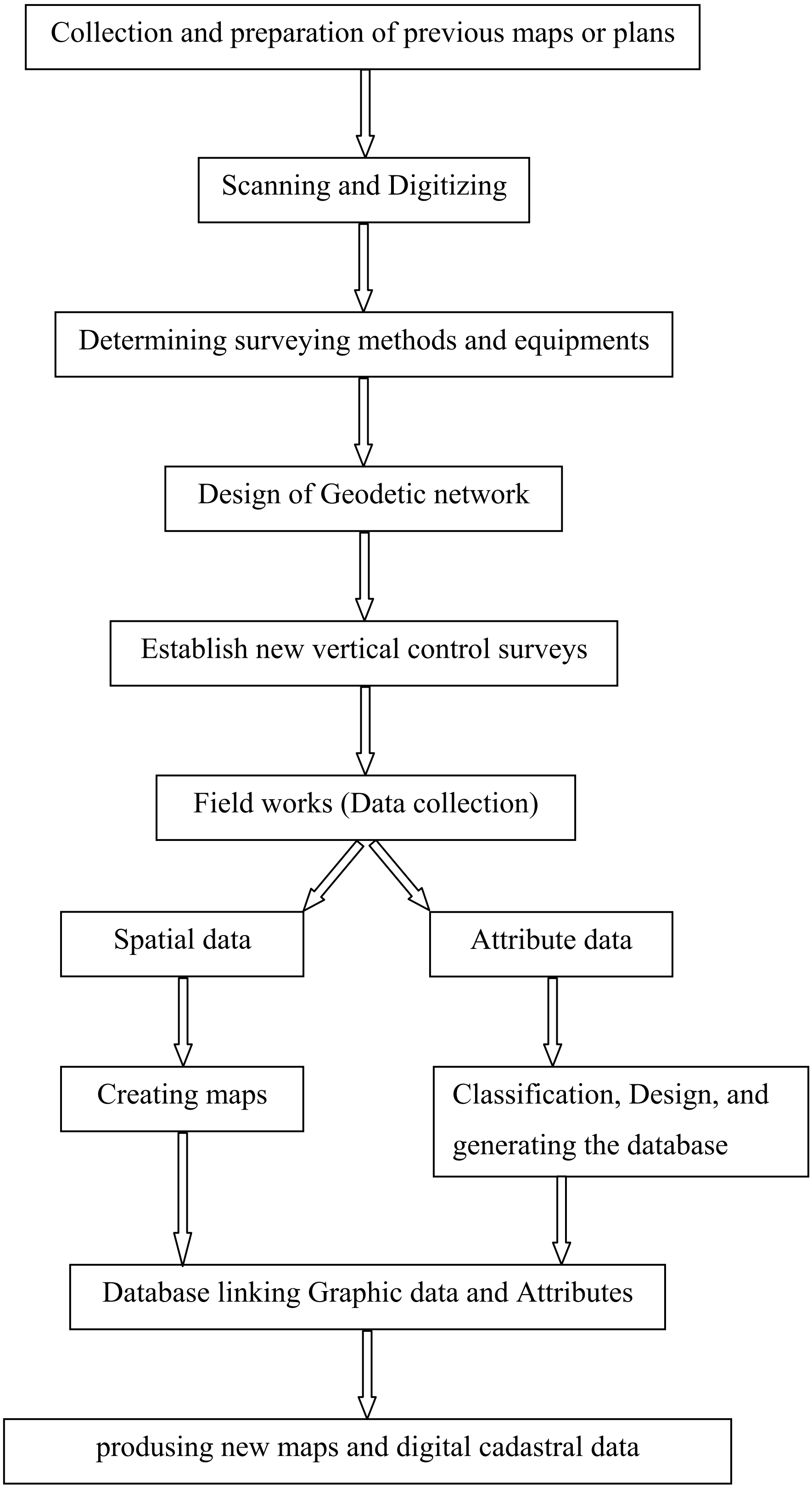


Figure 3.1 Methodology of the case study.

In the first stage, the main target will be the data capture, in both its spatial and attribute format. The spatial data may be in digital form, or as a hard copy form, which should be in turn digitized. The attributes or descriptive data will include, for example parcel number, parcel owner, area, land use type, … etc. The second stage, which is building the cadastre system database, is achieved by two steps,namely: designing the database, and creating the database. At this point, we are establishing the relationships between tables, and between tables and maps.

3.2 GIS technology used.

GIS technologies as a tool for information integration. In most part, people are still using it only to make maps but GIS can do much more. Thus, using GIS technology for analysis, we can find out what things are related, where and how. GIS analyses are very important for people to mapping density, finding what's nearby, mapping changes, finding some places to accommodation in a city, finding a street or a objective to visit, keep a strictly evidence of a agricultural lands, forest, evaluation for a land and many more, things which is impossible or very hard to made without a computer and some data collected as we know about. NetCAD 4.0 GIS software we have used in this project.

3.2.1 NetCAD 4.0 GIS.

NetCAD 4.0 GIS software is the only national (Turkey) software that has international standards. NetCAD was started to develop in 1987, and since then it has been the software package including several business and engineering solutions. NetCAD also has integrated GIS solutions for the purposes of analyzing datas, querying, classifying and creating new types of maps and data types.

3.2.2 Geographic referencing.

Accurate referencing of geographic location is fundamental to GIS. If the maps are not georeferenced, no other information can be displayed over or positioned under the map coverage. the systems of locational reference used in this project is UTM, ED50, ITRF96, and GRS80.

3.2.2.1 International Terrestrial Reference Frame 1996 (ITRF-96).

The International Earth Rotation Service (IERS) has defined a civil International Terrestrial Reference System (ITRS), in agreement with and more accurate than the U.S. military WGS 84 system. The ITRS was adopted by the International Union of Geodesy and Geophysics (IUGG) in 1991. The realization of the ITRS is a network of more than 200 sites throughout the world, called the "International Terrestrial Reference Frame" (ITRF). This network is constructed from the combination of sets of station coordinates and velocities derived from observations of space geodetic techniques such as very long baseline interferometry (VLBI), satellite laser ranging (SLR), lunar laser ranging (LLR), and GPS . The co-ordinates of sites slowly change (by up to 10 centimeters per year) due to the motion of tectonic plates; ITRF coordinates are given in relation to the year (ITRFyy for the year 19yy) and associated velocity is obtained by differencing combined coordinates at two epochs, (EPSG, 2002). In this project we were used ITRF96.

3.2.2.2 Geodetic Reference System 1980 (GRS80).

GRS80 Adopted by the International Union of Geodesy and Geophysics in 1979 as a standard set of measurements for the earth's size and shape. GRS80 is a geodetic reference system consisting of a global reference ellipsoid and a gravity field model. The reference ellipsoid is defined by the semimajor axis is a = 6,378,137.0 m, and Flattening is 1/f = 1/298.257222101.

3.2.2.3 European Datum 1950 (ED50).

ED50 is a geodetic datum which was defined after the 2nd world war for the international connection of geodetic network. It was based on the international Ellipsoid of Hayford 1909 (International 1924) the radius of the earth's equator a = 6378.388 km, and flattening 1/f = 1/297. It widely used all over the world up to the eighties, when GRS80 and WGS84 were established. Many national coordinate system of Gauss-Krüger are defined by ED50 and oriented by means of Geodetic Astronomy.

The geodetic datum of ED50 is centered at the Frauenkirche of Muncih in Southern Germany, where the approximately center of the Western Europe national networks was situated in the years of the Cold war. ED50 was also part of the fundamentals of the NATO coordinates (Gauss krüger and UTM) up to the Eighties.

3.3 GPS Positioning Methods.

A variety of GPS field data acquisition methods may be used for Cadastral Measurements and Cadastral Project Control. Some of the observing techniques being used in GPS surveying include Static, Rapid Static, Post-Processed Kinematic (PPK) Positioning and Real-time Kinematic (RTK) Positioning. In this case study, we will focus on Static positioning and Real-time Kinematic (RTK).

3.3.1 Static Positioning.

Static positioning typically uses a network or multiple baseline approach for positioning. It may consist of multiple receivers, multiple baselines, multiple observational redundancies and multiple sessions. A least squares adjustment of the observations is required. This method provides the highest accuracy achievable and requires the longest observation times. Static positioning is primarily used for ties to the National Spatial Reference System (NSRS) when observing Cadastral Project Control. This method may also be used for the Cadastral Measurement portion of a cadastral survey.

This technique of relative GPS positioning places one base receiver antenna (Dual frequency) over a point of known coordinates (X, Y, Z) on a tripod. While other antennas are placed, also on tripods. Over permanent stations to be positioned. Observation times are 1 hour or more (perhaps days), depending on the receiver, accuracy requirements, the satellite's geometric configuration, the length of line, and atmospheric conditions. Dual frequency receivers shall be used on baselines longer than 20 kilometers in geodetic control. All points shall be measured by two independent baselines as to provide enough redundancy to perform a least squares adjustment, also a mask angle of 10 degrees above the horizon shall be used.

3.3.2 Real Time Kinematic (RTK) Positioning.

A RTK GPS survey consist of a data transfer link and at least one GPS receiver over a known point usually a Control Survey Marker, that has been surveyed by a static survey, which remains stationary and a rover which moves from point to point. RTK requires a base station to measure the satellite signals, to process baseline corrections, and then to broadcast the corrections to any number of roving receivers via radio transmission. Depending on conditions, terrain, vegetation, radio strength, .. etc. The roving receiver can use this data to help resolve ambiguities and to solve for changes in coordinate differences between the reference and the roving receivers. Occupation times for the rover are generally a few seconds to a few minutes. A mask angle of 10 degrees or higher above the horizon shall be used. RTK can be used over distances of up to 10 km with an accuracy of between 2 and 10cm. Corrections are applied in real-time and no post processing is required. This method is used extensively for land sub-division and cadastral connections.

3.4 GPS equipments.

The GPS equipment that we have used for data collecion are the Magellan SporTrak GPS Receiver, and Topcon HiPer XT System.

3.4.1 Magellan SporTrak GPS receiver.

We have used the Magellan SporTrak GPS receiver, as shown in figure 3.2, manufactured by Thales. It is has a good Performance 12 parallel-channel technology, tracks up to 12 satellites to compute and update information with quadrifilar antenna. Power is supplied to the receiver from either 2 AA alkaline batteries or 9-18 VDC with power cable and battery life up to 15 hours. According to the specifications, Magellan SporTrak provides positional accuracy of 7 meters (95% 2D RMS) and with WAAS technology, the SporTrak is accurate to within 3 meters (95% 2D RMS) or better. The velocity accuracy is 0.1 knots. It is a dual frequency receiver. We can Store up to 20 routes, 500 way points and 2,000 track-points to easily find your way back again and again. Also it is including full featured navigation as nine large customizable graphic navigation displays show a map, compass, speedometer, and text readouts of heading, bearing, speed, direction, ETA, and more. Choose from 12 built-in coordinate systems and 76 datums including Latitude/Longitude, Universal Transverse Mercator, and Military Grid Reference System. The receiver can be used for navigation and to store position and attribute information, (THALES corporation).

Figure 3.2 Magellan SporTrak GPS receiver (THALES corp.).

3.4.2 Topcon HiPer GPS receiver.

We use Topcon HiPer dual frequency receivers manufactured by Topcon positioning systems, Inc.. Topcon's HiPer GPS survey system is used for several purposes. We use it for establish project control points (static method) and boundary surveys (RTK). Our HiPer system includes GPS antenna, GPS receiver, communication (UHF radio) and battery (Li-ion, 3000 mAh , 7.4V), all on-board with a total weight of 1.65 kg (less than 3.7 lb). HiPer leading dual-constellation (GPS+GLONASS) tracking technology which provides 40% more satellite coverage than GPS alone. This added advantage virtually eliminates downtime due to poor satellite coverage or in difficult environments where satellite obstructions knock out GPS only systems. According to its specification, it provides positional accuracy as shown in table 3.1.

Table 3.1 Topcon HiPer GPS receiver accuracy, (Topcon).

Survey method	Ferquency	Accuracy	
		Horizontal	Vertical
Static & Fast Static	Dual	3 mm + 1 ppm * D	5 mm + 1 ppm * D
	Single	5 mm + 1.5 ppm * D	6 mm + 1.5ppm * D
Kinematic	Dual	10 mm + 1.5 ppm * D	20 mm + 1.5 ppm * D
	Single	15 mm + 1.5 ppm * D	30 mm + 1.5 ppm * D
RTK	Dual	10 mm + 1.5 ppm * D	20 mm + 1.5 ppm * D
	Single	15 mm + 1.5 ppm * D	30 mm + 1.5 ppm * D

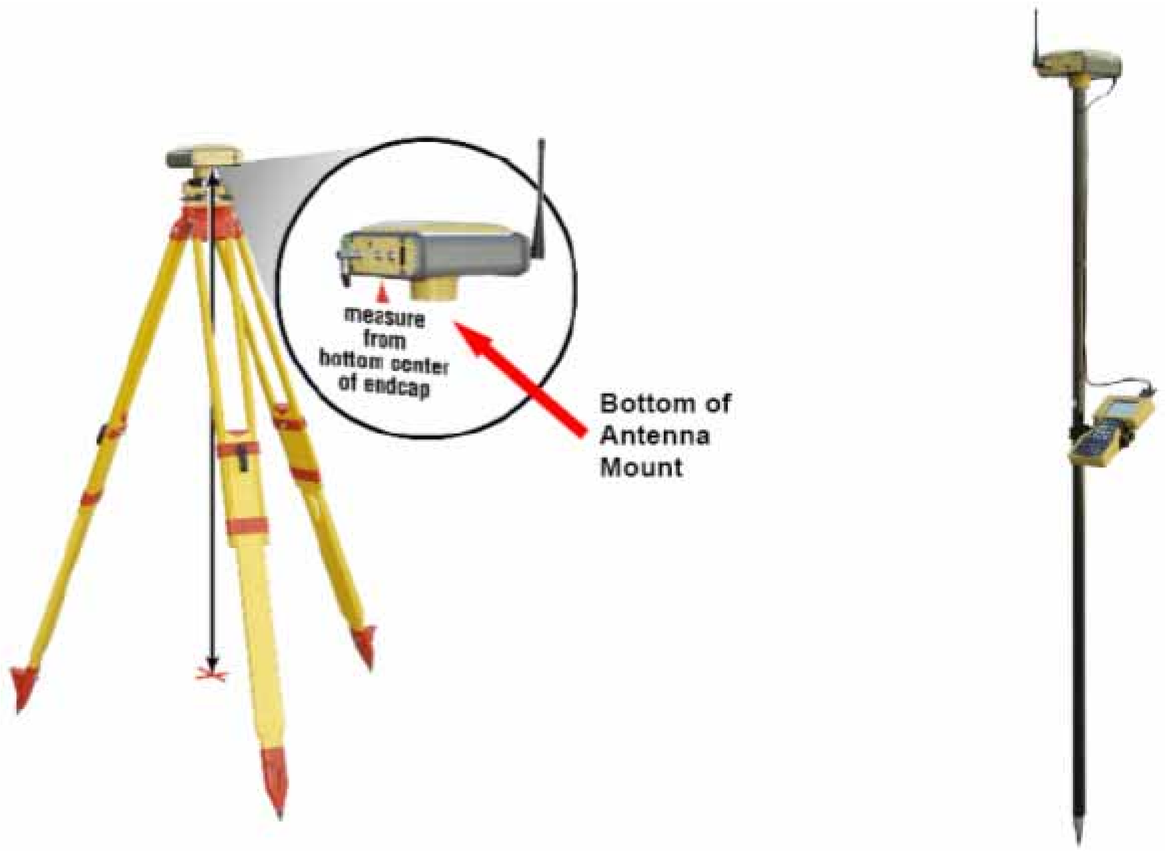


Figure 3.3 Topcon HiPer GPS receiver base and rover (Topcon).

3.4.3 Ashtech software.

Ashtech Solutions is a comprehensive software package containing all of the tools required to successfully process GPS and GPS+GLONASS survey data. It presenting survey data in graphical and tabular form makes processing, adjusting, analyzing, and exporting data. Ashtech Solutions includes advanced blunder detection and quality analysis tools to ensure accurate and reliable solutions. Blunder detection and quality analysis tools such as loop closures, automatic repeat observation analysis, automatic control analysis, and least-squares adjustments are integral components of Ashtech Solutions. All survey data collection are supported including Static, Rapid Static, Pseudo-Kinematic, Stop and Go Kinematic and Continuous Kinematic. In addition, Ashtech Solutions supports processing of RINEX data format.

3.5 Modern surveying instruments.

In line with our goals to develop systems for digitally recording, we using total station and digital level that we need to produce accurate work quickly and economically.

3.5.1 Topcon GTS-225 Total station.

Total station can read and record horizontal and vertical angles together with slope distances. The microprocessors in the total stations can perform various mathematical operations, for example, averaging multiple angle measurements, averaging multiple distance measurements, determining horizontal and vertical distances, determining X, Y, and Z coordinates, remote object elevations, and distance between remote points, and making atmospheric and instrumental corrections. The data collector built into the instrument.

Figure 3.4 shows a Topcon GTS-225 total station, this instrument has angle accuracy 5 seconds (1.5 mgon), distance range (one prism) from 3,000 m to 3,500 m, distance accuracy ±(2mm + 2ppm * D), dual-axis Compensation, and the internal memory store up to 8,000 points for data collection, or up to 16,000 points for layout work. The data can be transferred directly to the computer from total station via cable.

Figure 3.4 Topcon GTS-225 Total station (Topcon).

3.5.2 Topcon DL-102 Digital level.

The latest in auto level technology is the automatic digital level. Figure 3.5 shows a Topcon DL-102 digital level and bar-code rod.

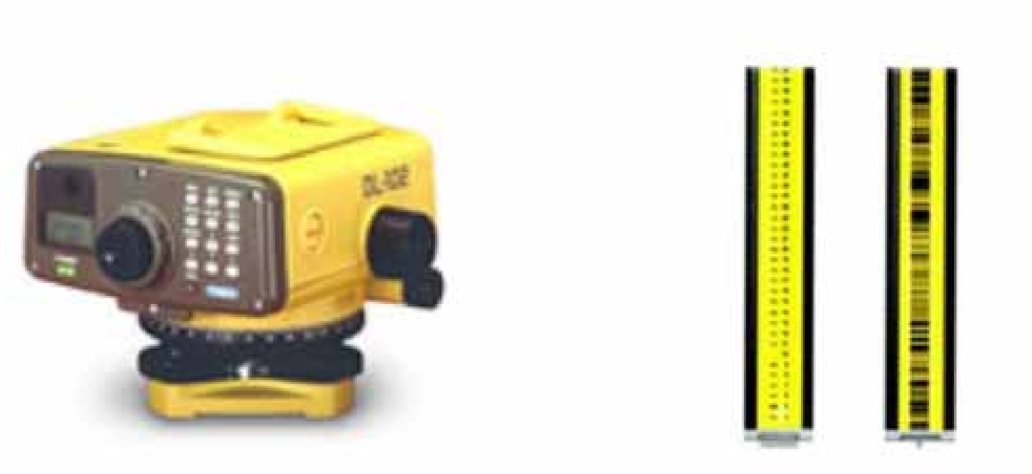


Figure 3.5 Topcon DL-102 digital level (Topcon).

This level features digital, electronic image processing for determining heights and distances, with the automatic recording of data for later transfer to the computer, which means that the processed leveling data can be transferred directly to the computer data base. The bar code can be read in the range of 2 to 100 m (Fiberglass staff 3 m length and Aluminum staff 5 m length) and from 2 to 60 m (Invar staff 3 m length) away from the instrument, optically the rod can be read as close as 1.5 mm. Distance measurement accuracy is 1 to 5 cm, whereas leveling accuracy is stated as having a standard deviation for 1 km double run levelling of 1.0 mm for electronic measurement and 1.5 mm for optical measurement.

Chapter 4

Case Study

4.1 Introduction.

In Turkey, various projects have been undertakeing for implementatiıon of cadastral activities in digital environment. The general objective of cadastral project is to establish the Turkish cadastral information system throughout the country. In this case study the Beyşehir cadastral project will enable anyone to access current rights, interests and boundary information involving real property. The Beyşehir cadastral project will build partnership for the collection, management, standardization, and sharing of Beyşehir's land parcel information to improve business processes and support decision making. Our vision in this case study to create a system for sharing accessible, accurate, consistent, and integrated land parcel information. This project may serve as a source of valuable information that can be used for the development of the country.

4.1.1 Objective of the case study.

The case study main objective are to:

- The development, maintenance and update of a cadaster in Beyşehir municipality.
- The geodetic and mapping coverage of Beyşehir rural area.
- The creation of a land and environment data bank.
- create new maps by modeling or re-interpreting existing data.
- Use the stored data to prepare maps at different scales, for a wide range of purpose.

4.1.2 study area.

The Beyşehir municipality is located in a rural mountainous area in Konya region (Turkey), Beyşehir is locating at the cross point of latitude 37.69 and longitude 31.73

lines. It is located 75 km west of Konya city. The project area covered 5 villages, as in table 4.1, about 25800 Donum (2850 hecters) in Beyşehir municipality. As shown in figure 4.1 Beyşehir is located in section 3C and figure 4.2 shows Beyşehir city satellite image.

Table 4.1 Details of study area.

Village	Sector	Area (Donum)	Parcel
Y. KAYALAR	FATIH	4000	2500
	MEYDAN	3000	1000
	YENİ	3500	1500
AKÇABELEN	SELIMIYE	3500	1750
	MEYDAN	3500	1750
ASAGIKAYALAR	ÇIFTLIK	2000	1000
ADAKÖY		6500	3500
DUMANLI		2500	800
Total		**28500**	**13800**

Figure 4.1 Map of turkey (Tapu Kadastro).

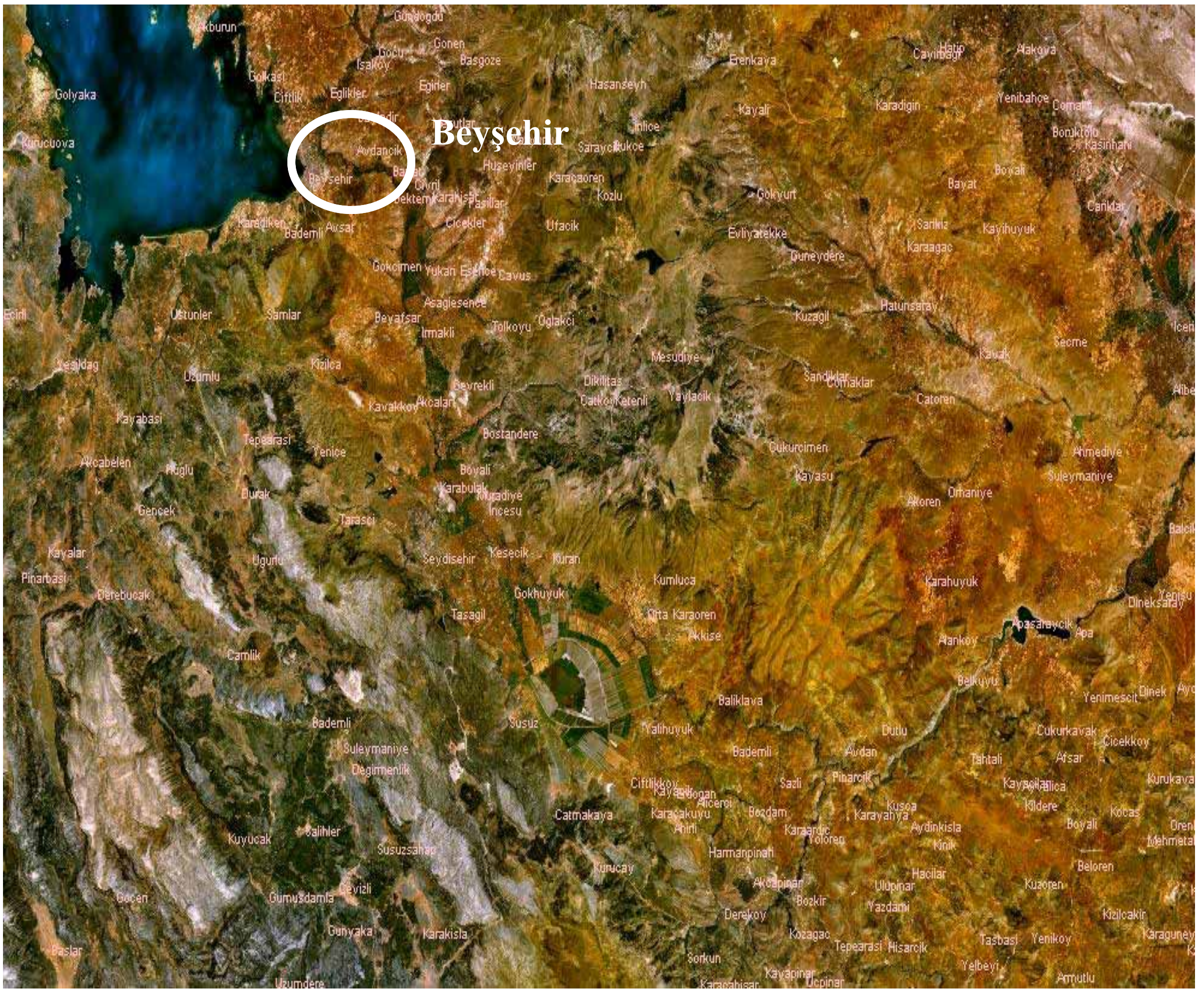


Figure 4.2 Beyşehir city satellite image (Seydişehir kadastro).

4.2 Exsiting maps and Data provided by General directorate of land registry and cadastre.

We find and receive three types of maps (data):

4.2.1 Photogrammetric maps.

General directorate of land registry and cadastre delivers Photogrammetric maps have been producted in 1990’s in scale 1:5000 paper maps, figure 4.3 show as sample of Photogrammtric maps.

Figure 4.3 Sample of photogrammetric map (sheet) for rural area.

4.2.2 Turkish national fundamental GPS network (TUTGA).

Turkish National Fundamental GPS Network (TUTGA) has been established to remove the problem of National Geodetic Network, to provide reliable and robust geodetic network infrastructure for current and future geo-based data collection technologies, distribution of TUTGA points shown in Figure 4.4 . TUTGA were established between 1997 and 1999 and it has been realised based on an agreement among General Directorate of Land Registry and Cadastre and General Commander of Mapping. The total number stations are about 600 and it has been designed as four dimensional (4-D). Positional accuracy of the stations is about 1-3 cm whereas the relative accuracies are in the range of 0.01 ppm. Designing concept is sufficient for all type of small scale, low resolution digital mapping and data collection applications.

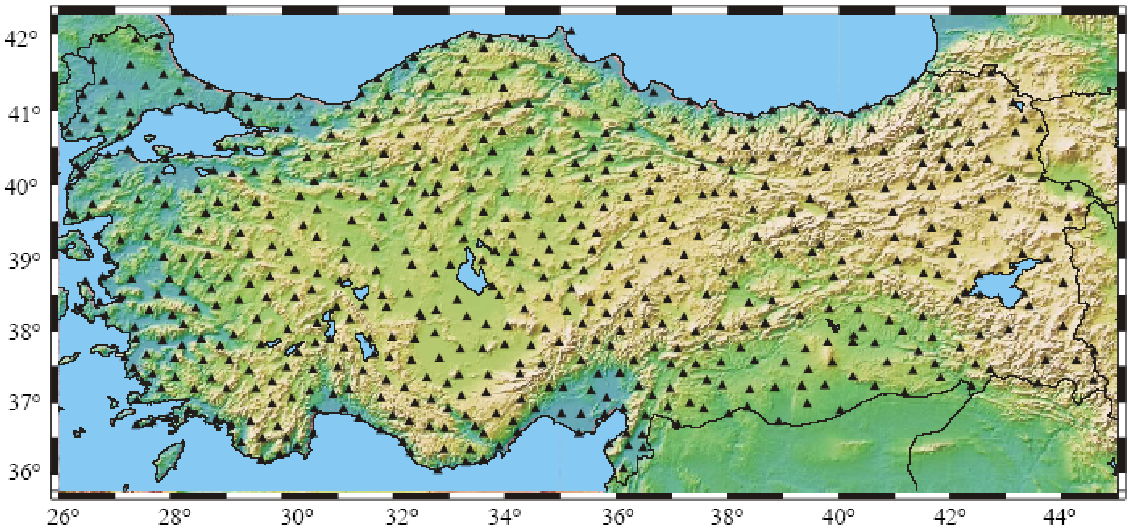
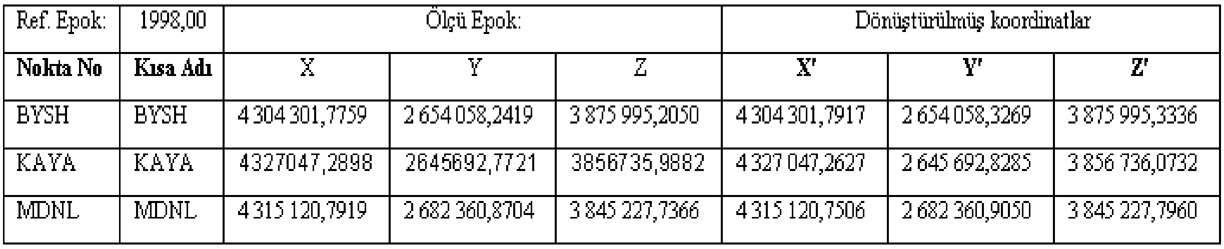


Figure 4.4 Distribution of TUTGA stations (Harita genel komutanlığı).

After investigated our work area, we have only 3 TUTGA points around our area, these points coordinates as shown in table 4.2. A point (x,y,z) moved by a distance of (dx, dy, dz) by simply adding the values pairwise, so we get a new point (x+dx, y+dy, z+dz), the new coordinates are X′, Y′, and Z′.

Table 4.2 TUTGA points coordinates in work area.



Ref. Epok:	1998,00	Ölçü Epok:			Dönüştürülmüş koordinatlar		
Nokta No	**Kısa Adı**	X	Y	Z	**X'**	**Y'**	**Z'**
BYSH	BYSH	4 304 301,7759	2 654 058,2419	3 875 995,2050	4 304 301,7917	2 654 058,3269	3 875 995,3336
KAYA	KAYA	4327047,2898	2645692,7721	3856735,9882	4 327 047,2627	2 645 692,8285	3 856 736,0732
MDNL	MDNL	4 315 120,7919	2 682 360,8704	3 845 227,7366	4 315 120,7506	2 682 360,9050	3 845 227,7960

4.2.3 Turkish National Vertical Control Network (TUDKA).

Turkish National Vertical Control Network (TUDKA-99) was established with the adjustment of 243 lines of 25680 points with total length of 29316 km. This network, as shown in figure 4.5, includes 151 first and 41 second order lines measured between 1970 and 1993, and 7 first and 44 second order lines measured before 1970. Vertical datum for TUDKA-99 is defined with arithmetic mean of instantaneous sea level measurements recorded at Antalya tide gauge between 1936 and 1971. The adjustment results in precision of point heights varying from 0.3 cm to 9 cm depending on the distance from the datum point. Differences between TUDKA-99 orthometric heights and currently used Normal orthometric heights were found to be between –14 cm and +36.9 cm and mean value of it was found as +9.5 cm with standard deviation of ±8.4 cm. Correction value between two height systems at any point given with position can be calculated.

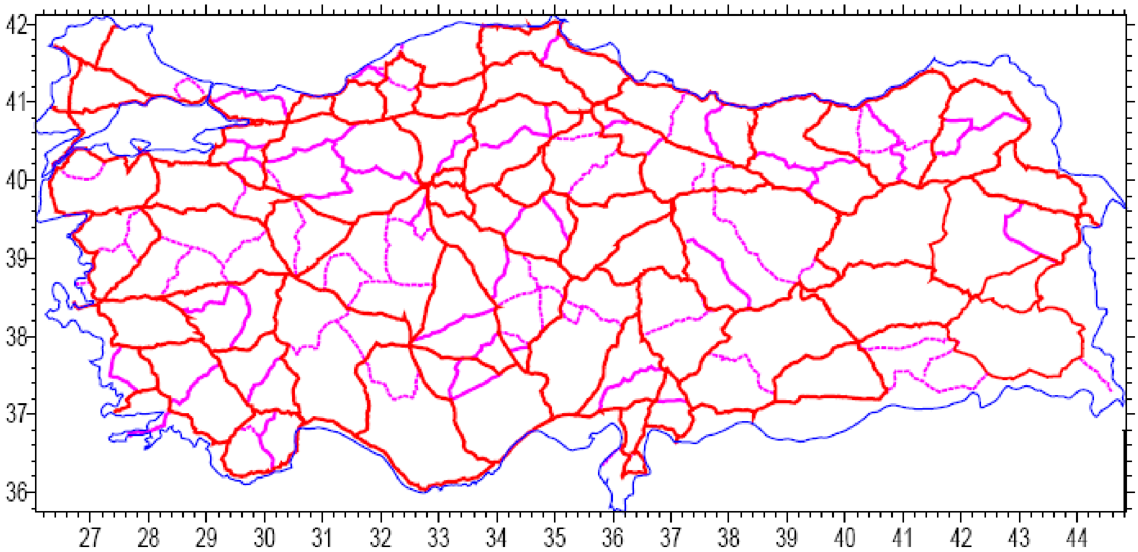


Figure 4.5 Turkish National Vertical Control Network-1999 (TUDKA-99).

4.3 Scanning and digitizing.

Digitizing refers to the process whereby an analog (or paper) map is converted into a digital format. This data conversion process is also known as geocoding. Digitizing is one of the key ways in which data can be input and stored in a GIS. Here we will focus on the process of converting a papaer map into usable GIS data using on-screen digitizing methods in NetCAD.

4.3.1 Scanning.

The first step in the conversion process is scanning. Map can be scanned into a rasterized digital format like JPEG or TIFF using a flatbed scanner also known as desktop scanner. We have been taken to transfer photogrammetric maps to a digital device, figure 4.6 shows photogrammetic map scanned in NetCAD.

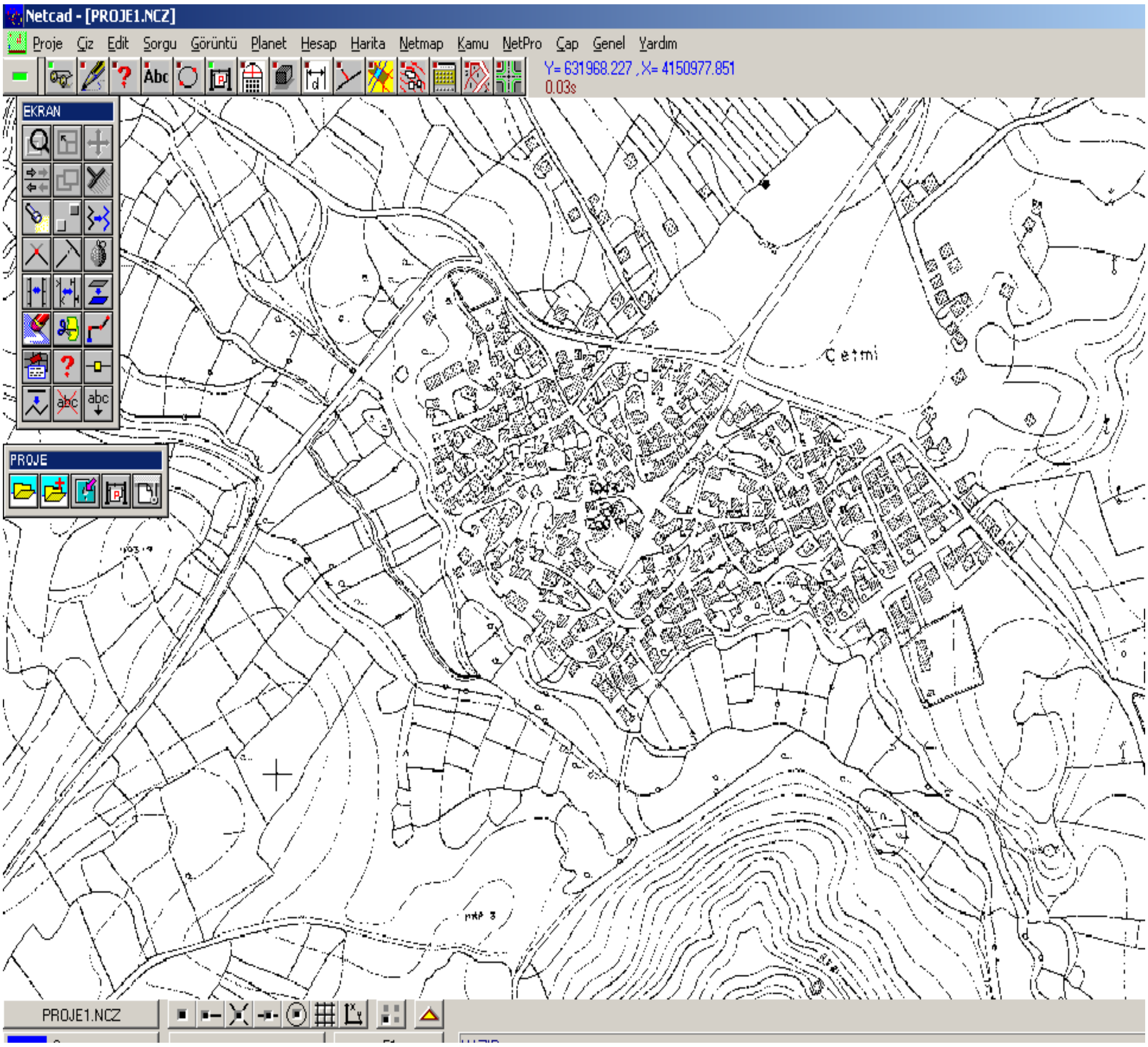


Figure 4.6 Sample of scanning the map (sheet) in NetCAD.

4.3.2 Registration.

Typically the next step in the process is georeferencing, converting the scanned image or map from pixel units to real-world coordinates. This enable the map to be used with other data layers covering the area of interest. To georeference a map you must identify the datum (WGS84) and projection (UTM), as shown in figure 4.7.

Mevcut Sistem
Dilim Orta Boylamı: 33
Dilim: ○ 3° ● 6°

Yeni Sistem
Dilim Orta Boylamı: 30
Dilim: ● 3° ○ 6°

☐ Coğrafi ve Konvergens Değerlerini Rapora Ekle

Mevcut Sistem
Dilim Orta Boylamı: 33
Dilim: ● 3° ○ 6°

Yeni Sistem

Figure 4.7 Georeferencing.

We now have a map that has been georeferenced to real-world coordinates and is ready for digitizing.

4.3.3 On-screen digitizing.

On-screen (or heads-up) digitizing involves bringing a scanned map into the GIS software and tracing the features using a mouse. The first step in on-screen digitizing is to create new shapefiles or geodatabase feature classes to store the map feature you plan to trace. There are lot of specialized editing tools in NetCAD that can be used to create new features or edit existing features. Digitized map shows in figure 4.8.

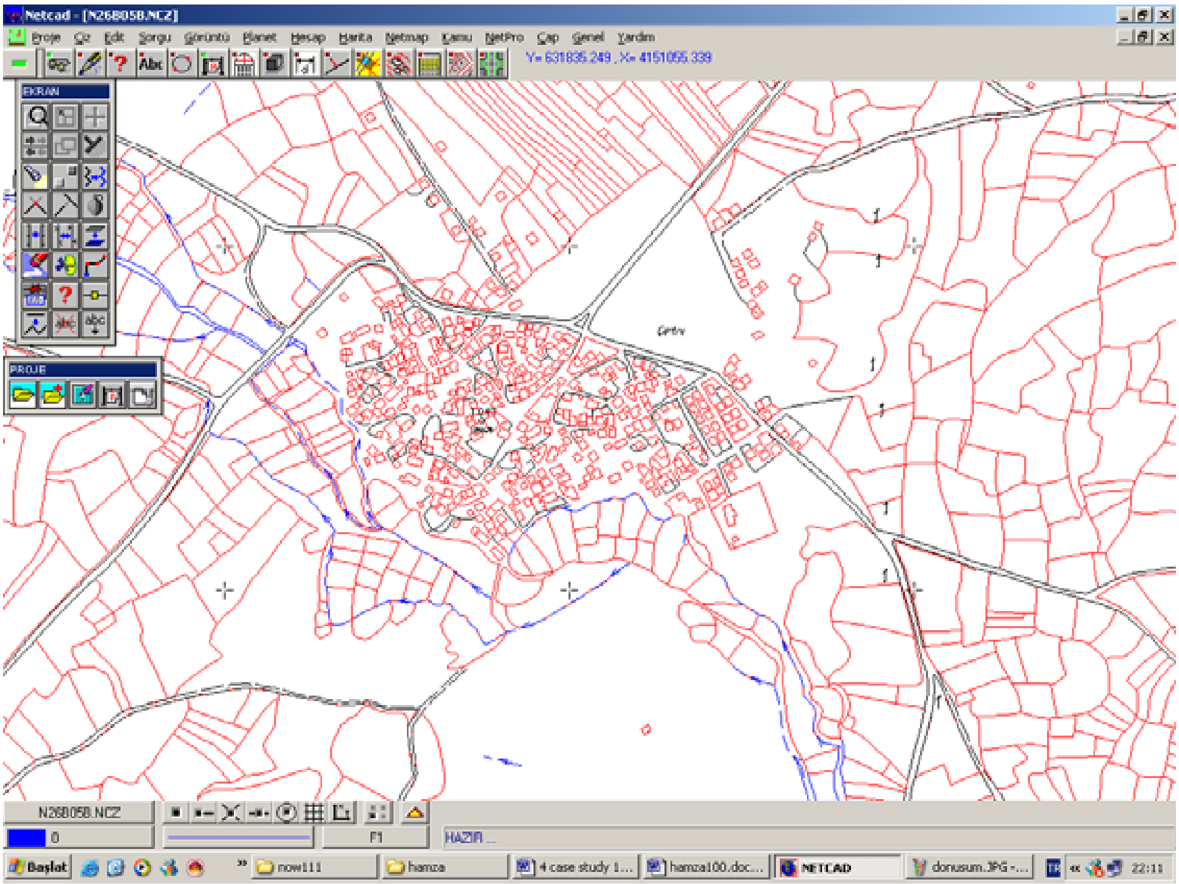


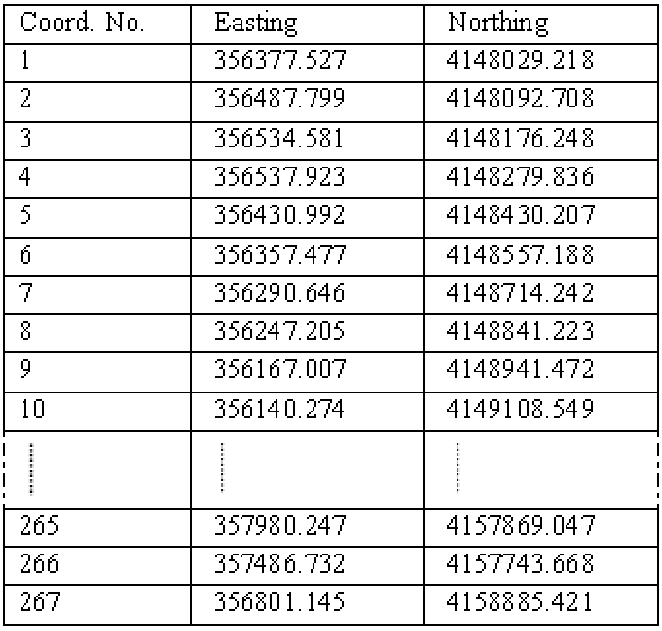
Figure 4.8 Sample of map digitized.

4.4 Work area boundaries (Village or quarter boundary).

Part of the study was to demarcate boundary (digitally). Before starting this work it is necessary to inform the local authorities (village committee member). For this task we was used Magellan handheld GPS receiver and maps in the field.

- Locating the coordinates using Magellan SporTrak GPS Receiver: As we began our search we had to wait a few moments for the GPS Receiver to locate a satellite signal. We started located first point and By walking away registred second point and so on. After finish we have a table that contains X and Y coordinates for each location. We knew that the exact location of points and the location the handheld GPS Receiver may be off by several meters. GPS data can be downloaded from the field collection unit into PC, the table of coordinates for village boundary as shown in table 4.3. The data will be transferring into the NetCAD software.

Table 4.3 Sample of village boundary coordinates collected by handheld GPS.



Coord. No.	Easting	Northing
1	356377.527	4148029.218
2	356487.799	4148092.708
3	356534.581	4148176.248
4	356537.923	4148279.836
5	356430.992	4148430.207
6	356357.477	4148557.188
7	356290.646	4148714.242
8	356247.205	4148841.223
9	356167.007	4148941.472
10	356140.274	4149108.549
⋮	⋮	⋮
265	357980.247	4157869.047
266	357486.732	4157743.668
267	356801.145	4158885.421

● Draw village boundary: By Using NetCAD software and coordinates collected before, we can draw village boundary map, As shwon in Figure 4.9 & 4.10.

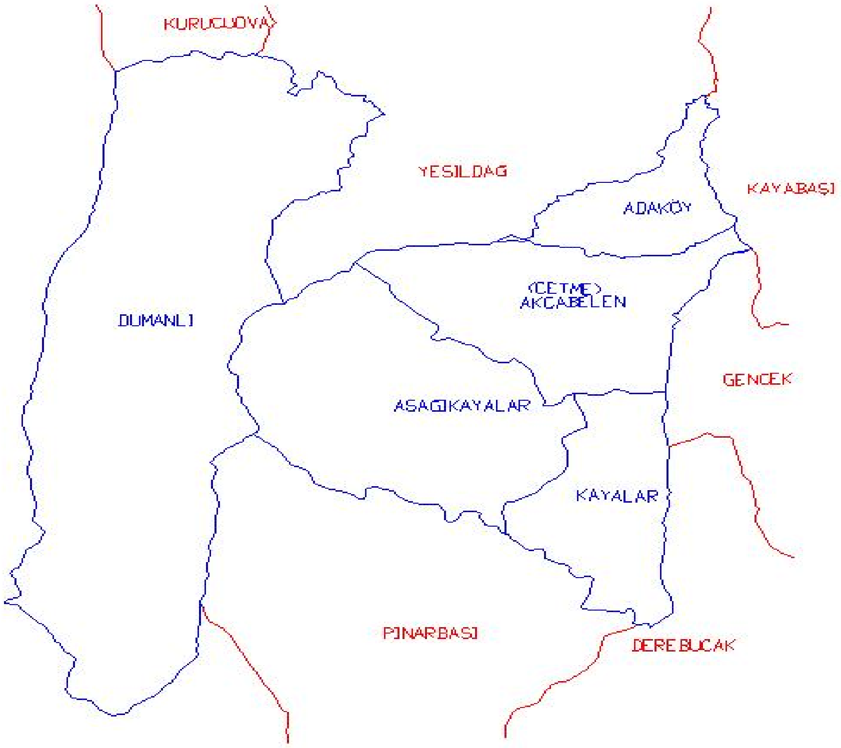


Figure 4.9 All work area boundaries.

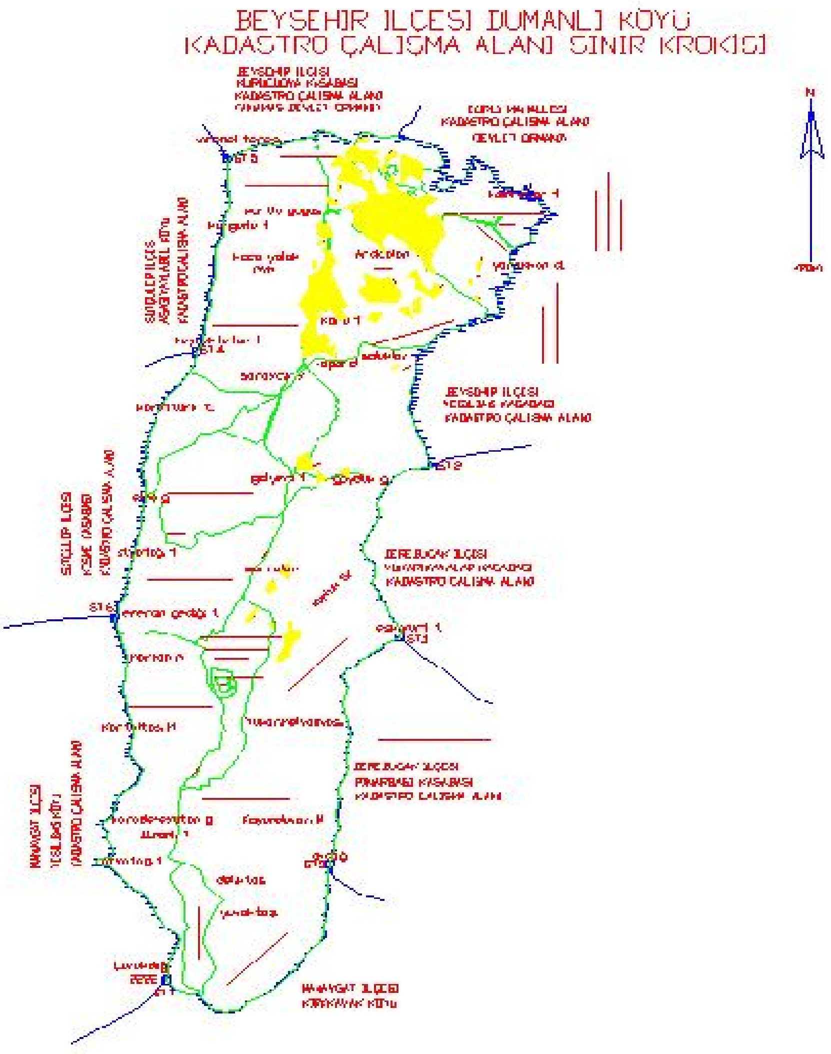


Figure 4.10 Sample of village boundary (Dumanlı köyü).

4.5 Geodetic Work (Geodetic control network).

The goal of geodetic measurements in the Beyşehir villages is to make highly accurate maps. The control network points in the Beyşehir consist of 3 points, this network Turkey's national coordinate system, namely "Turkish National Fundamental GPS Network (TUTGA)", a TUTGA point nearby the Beyşehir was used as reference point. Thus, TUTGA coordinates were known.

4.5.1 Network design in office.

Preliminary network design on map according design criteria and priority area. The network consists of three fixed (known x-y-z) control points (TUTGA) as base station. On the map of Beyşehir we choose three 1st order points (C1), four 2nd order points (C2), and seventeen 3rd order points (C3), as shown in figure 4.11, and Table 4.4 shows us the average distance between points.

Table 4.4 Average distance between geodetic network points.

From point	To point	Distance (km)
TUTGA	TUTGA	15-70
C1	C1	25-35
C2	C2	10-30
C3	C3	4-15

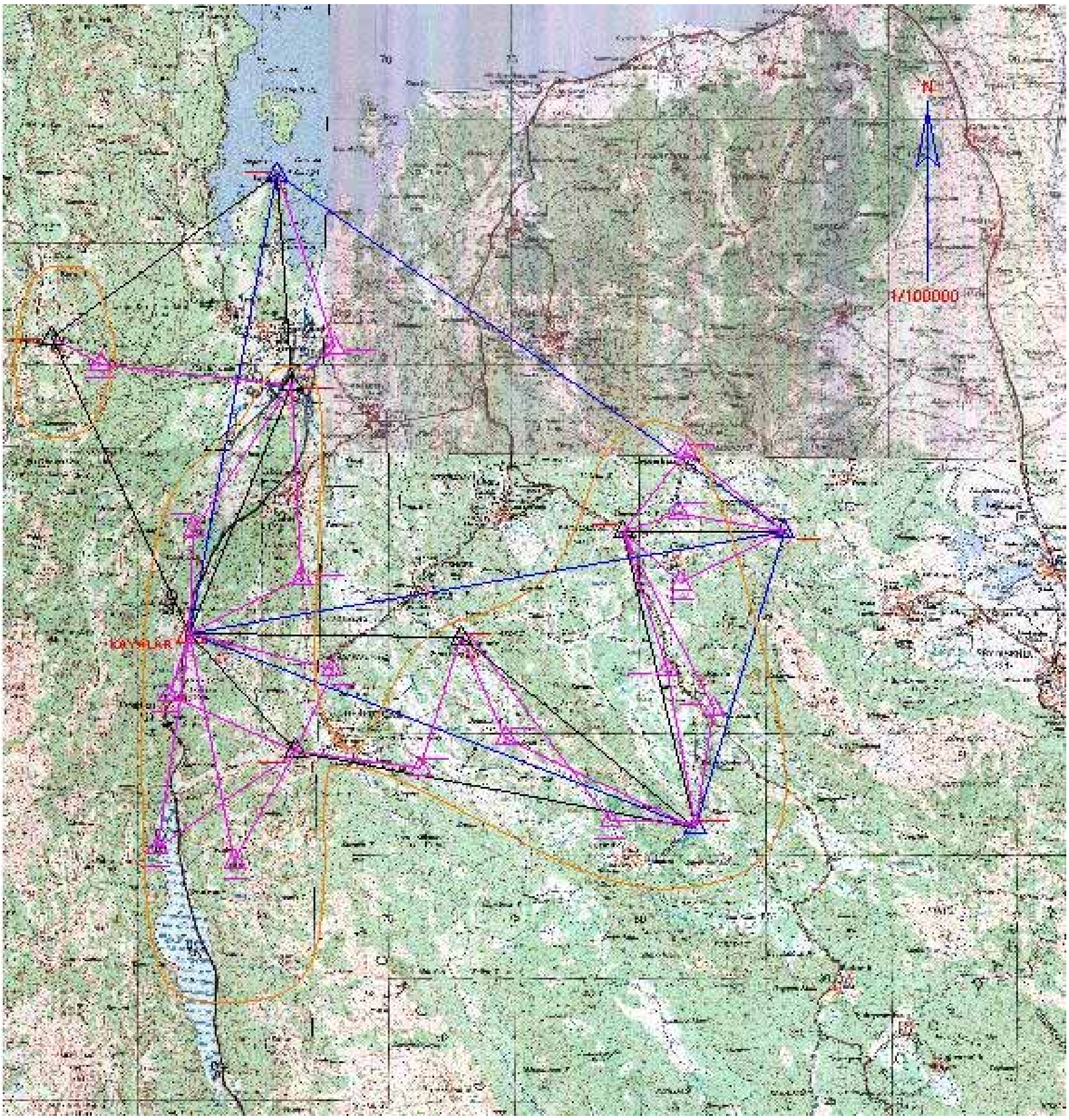
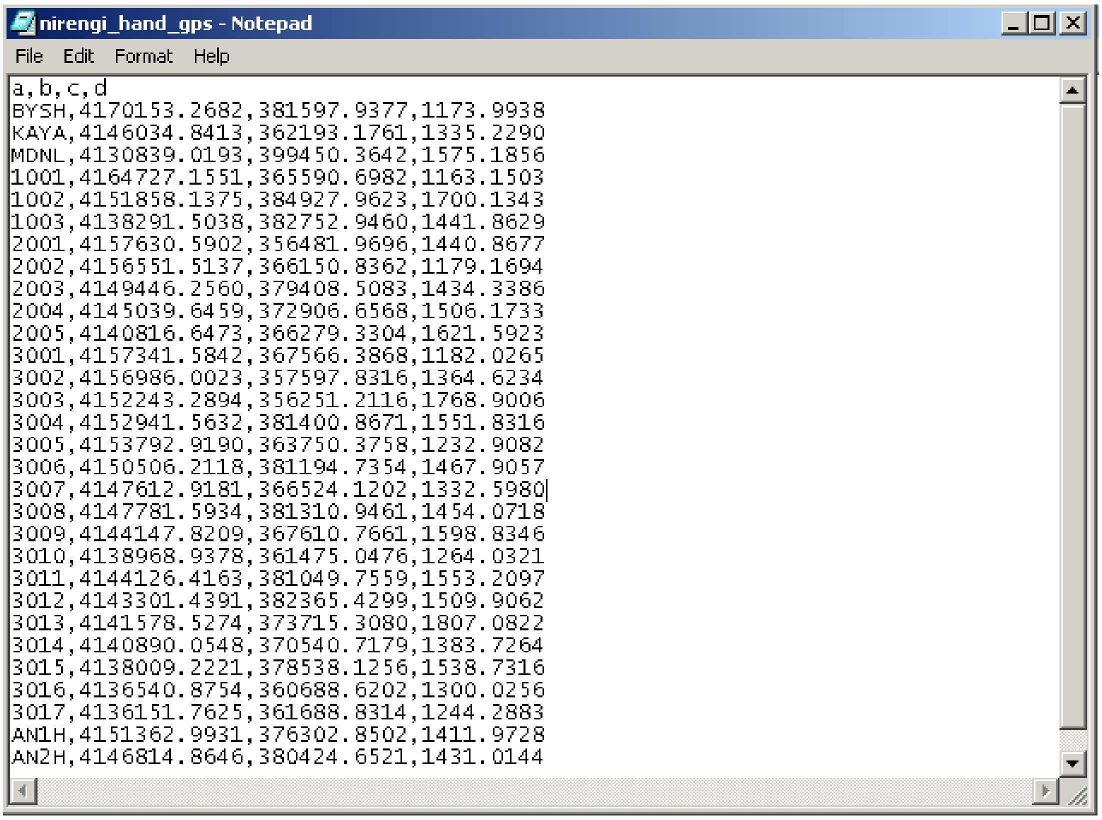


Figure 4.11 Preliminary network design over Beyşehir map.

4.5.2 Establish preliminary geodetic control network.

In the field, we have used topographic map that signed by TUTGA, C1, C2, and C3 points (figure 4.11), and Magellan Spor Trak GPS receiver to establish the primary position of network points in field. These points recorded by names (ID), and coordinates. At the same time, we signed the points positioning by surveying marks. The primary geodetic control network may be changed depending on environments obstructed in the work area. After finish our work and downloaded data into PC, we have text file coordinates of control points as shown in figure 4.12.



```
a,b,c,d
BYSH,4170153.2682,381597.9377,1173.9938
KAYA,4146034.8413,362193.1761,1335.2290
MDNL,4130839.0193,399450.3642,1575.1856
1001,4164727.1551,365590.6982,1163.1503
1002,4151858.1375,384927.9623,1700.1343
1003,4138291.5038,382752.9460,1441.8629
2001,4157630.5902,356481.9696,1440.8677
2002,4156551.5137,366150.8362,1179.1694
2003,4149446.2560,379408.5083,1434.3386
2004,4145039.6459,372906.6568,1506.1733
2005,4140816.6473,366279.3304,1621.5923
3001,4157341.5842,367566.3868,1182.0265
3002,4156986.0023,357597.8316,1364.6234
3003,4152243.2894,356251.2116,1768.9006
3004,4152941.5632,381400.8671,1551.8316
3005,4153792.9190,363750.3758,1232.9082
3006,4150506.2118,381194.7354,1467.9057
3007,4147612.9181,366524.1202,1332.5980
3008,4147781.5934,381310.9461,1454.0718
3009,4144147.8209,367610.7661,1598.8346
3010,4138968.9378,361475.0476,1264.0321
3011,4144126.4163,381049.7559,1553.2097
3012,4143301.4391,382365.4299,1509.9062
3013,4141578.5274,373715.3080,1807.0822
3014,4140890.0548,370540.7179,1383.7264
3015,4138009.2221,378538.1256,1538.7316
3016,4136540.8754,360688.6202,1300.0256
3017,4136151.7625,361688.8314,1244.2883
AN1H,4151362.9931,376302.8502,1411.9728
AN2H,4146814.8646,380424.6521,1431.0144
```

Figure 4.12 Sample output text file coordinates.

We rearrangement the point coordinates as shown in table 4.5. Also By using NetCAD software, we were drawing the positioning of our control points (C1, C2, and C3) depending on their coordinates. Figure 4.13 shows, all our control points, TUTGA points (red), C1 points (green), C2 points (cyan), and C3 points (blue). At this moment, we were returning to the field to building the surveying concrete marks for all control points.

Table 4.5 Preliminary coordinates of GPS Geodetic network.

Name of point	Point No.	Easting (m)	Northing (m)	Height (m)
TUTGA	BYSH	4170153.2682	381597.9377	1173.9938
TUTGA	KAYA	4146034.8413	362193.1761	1335.2290
TUTGA	MDNL	4130839.0193	399450.3642	1575.1856
C1	1001	4164727.1551	365590.6982	1163.1503
C1	1002	4151858.1375	384927.9623	1700.1343
C1	1003	4138291.5038	382752.9460	1441.8629
C2	2001	4157630.5902	356481.9696	1440.8677
C2	2002	4156551.5137	366150.8362	1179.1694
C2	2003	4149446.2560	379408.5083	1434.3386
C2	2004	4145039.6459	372906.6568	1506.1733
C2	2005	4140816.6473	366279.3304	1621.5923
C3	3001	4157341.5842	367566.3868	1182.0265
C3	3002	4156986.0023	357597.8316	1364.6234
C3	3003	4152243.2894	356251.2116	1768.9006
C3	3004	4152941.5632	381400.8671	1551.8316
C3	3005	4153792.9190	363750.3758	1232.9082
C3	3006	4150506.2118	381194.7354	1467.9057
C3	3007	4147612.9181	366524.1202	1332.5980
C3	3008	4147781.5934	381310.9461	1454.0718
C3	3009	4144147.8209	367610.7661	1598.8346
C3	3010	4138968.9378	361475.0476	1264.0321
C3	3011	4144126.4163	381049.7559	1553.2097
C3	3012	4143301.4391	382365.4299	1509.9062
C3	3013	4141578.5274	373715.3080	1807.0822
C3	3014	4140890.0548	370540.7179	1383.7264
C3	3015	4138009.2221	378538.1256	1538.7316
C3	3016	4136540.8754	360688.6202	1300.0256
C3	3017	4136151.7625	361688.8314	1244.2883
C3	AN1H	4151362.9931	376302.8502	1411.9728
C3	AN2H	4146814.8646	380424.6521	1431.0144

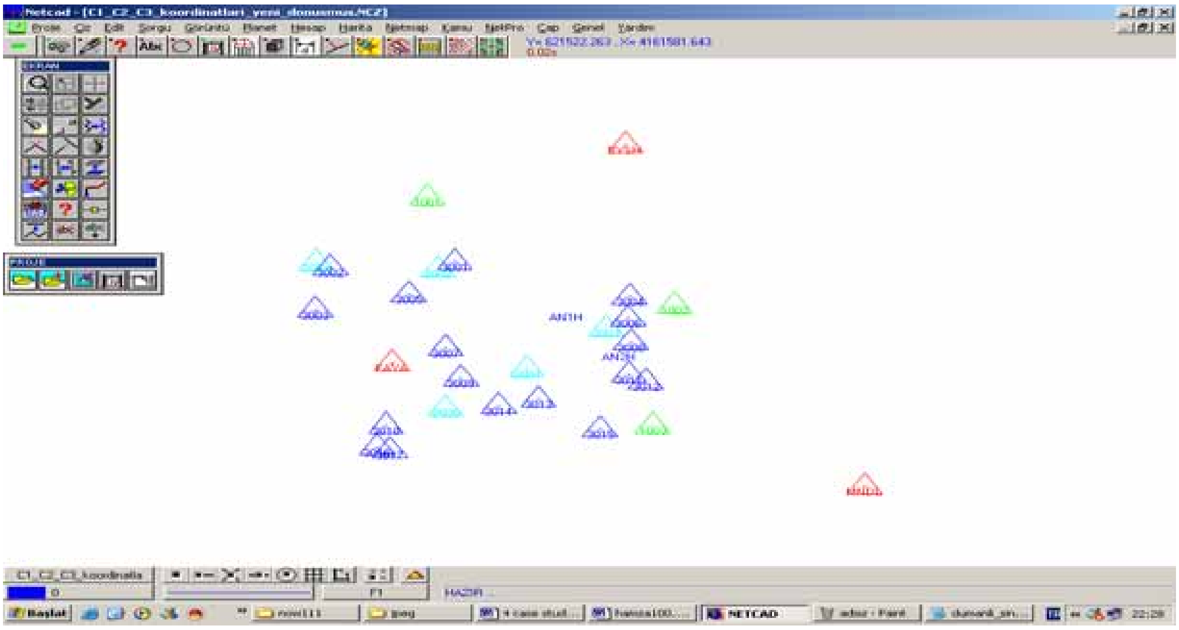
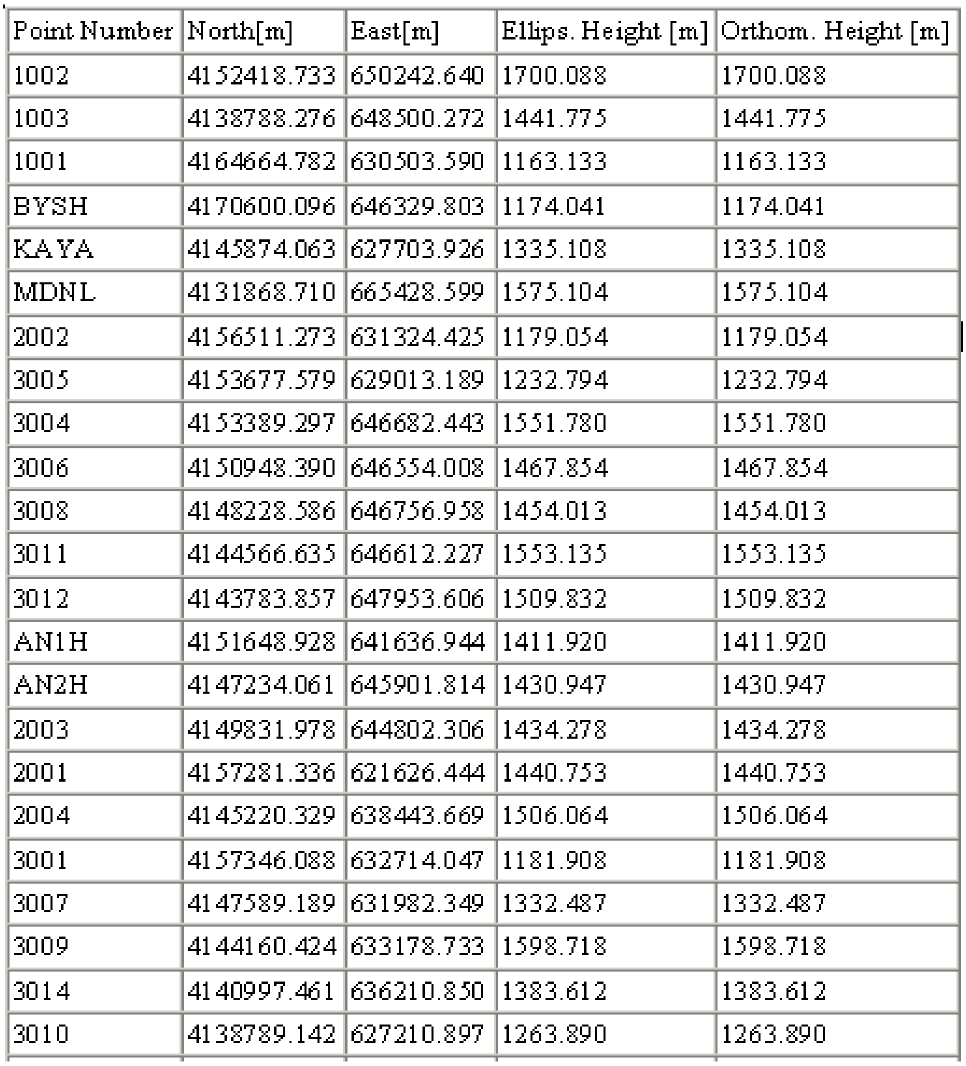


Figure 4.13 Draw preliminary coordiinates location by NetCAD.

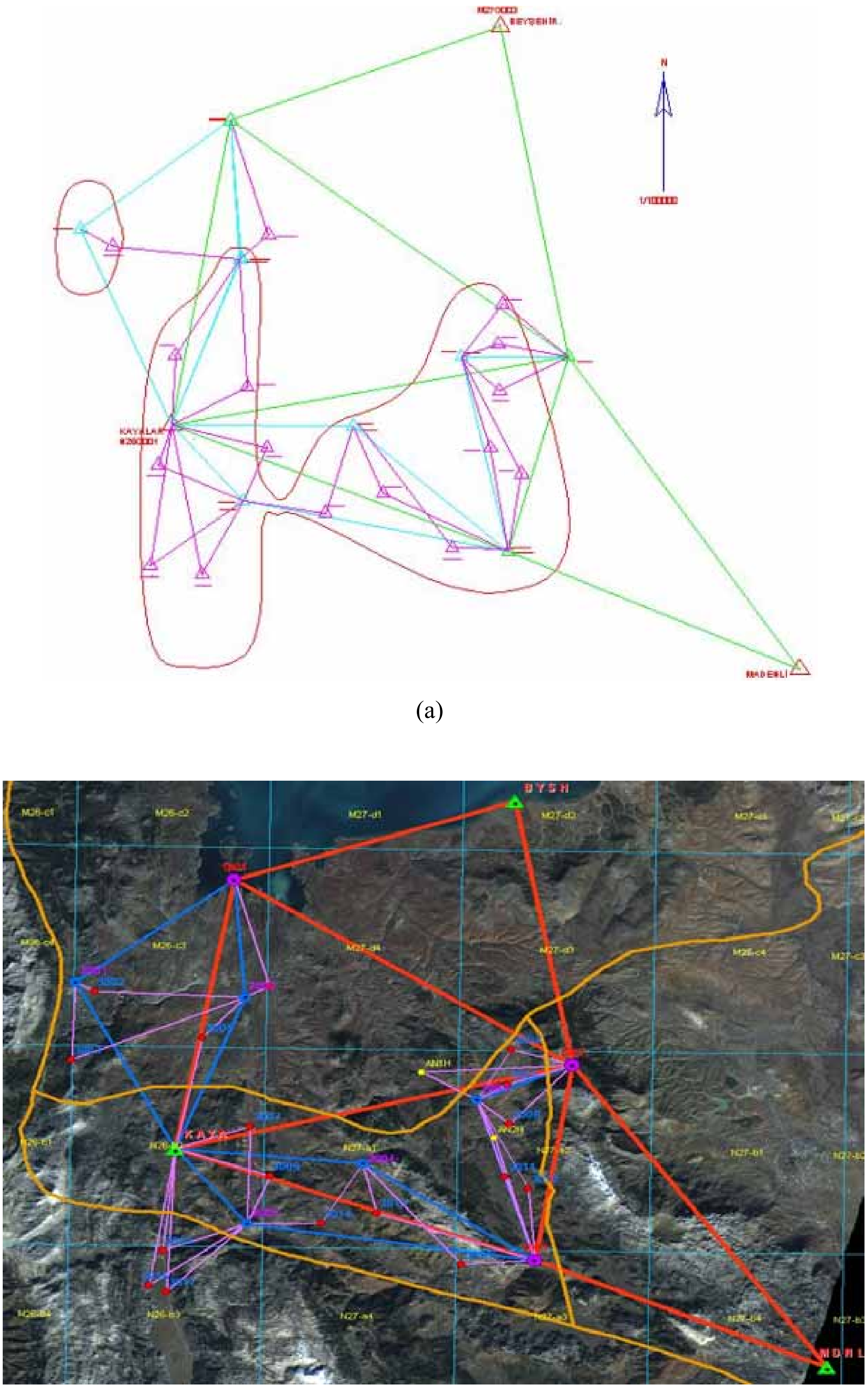
4.5.3 Final network points coordinates.

Now we are planning to measurement the actual coordinates for C1, C2, and C3 by GPS equipments using static surveying method (GPS relative positioning). In this case, we used six Topcon GPS receivers two of them must be setup on TUTGA points as base station and four receivers as rover. After finished we came to office to transfer data collection into PC, and make post-processing using Ashtech solution software. At this moment, we have distance (vector) and approximatly coordinates. By using adjustment computation software and existing data (TUTGA, vectors, and approximatly coordinates), we get actual coordinates for all points as shown in table 4.6 and final network control points as shown in figure 4.14.

Table 4.6 Geodetic network coordinates adjustment.



Point Number	North[m]	East[m]	Ellips. Height [m]	Orthom. Height [m]
1002	4152418.733	650242.640	1700.088	1700.088
1003	4138788.276	648500.272	1441.775	1441.775
1001	4164664.782	630503.590	1163.133	1163.133
BYSH	4170600.096	646329.803	1174.041	1174.041
KAYA	4145874.063	627703.926	1335.108	1335.108
MDNL	4131868.710	665428.599	1575.104	1575.104
2002	4156511.273	631324.425	1179.054	1179.054
3005	4153677.579	629013.189	1232.794	1232.794
3004	4153389.297	646682.443	1551.780	1551.780
3006	4150948.390	646554.008	1467.854	1467.854
3008	4148228.586	646756.958	1454.013	1454.013
3011	4144566.635	646612.227	1553.135	1553.135
3012	4143783.857	647953.606	1509.832	1509.832
AN1H	4151648.928	641636.944	1411.920	1411.920
AN2H	4147234.061	645901.814	1430.947	1430.947
2003	4149831.978	644802.306	1434.278	1434.278
2001	4157281.336	621626.444	1440.753	1440.753
2004	4145220.329	638443.669	1506.064	1506.064
3001	4157346.088	632714.047	1181.908	1181.908
3007	4147589.189	631982.349	1332.487	1332.487
3009	4144160.424	633178.733	1598.718	1598.718
3014	4140997.461	636210.850	1383.612	1383.612
3010	4138789.142	627210.897	1263.890	1263.890



(a)

(b)

Figure 4.14 (a) & (b) final geodetic network.

Total number, as shown in figure 4.15, of the control stations in the networks:

- TUTGA Zero order GPS network - 3 points
- First order GPS network (C1) - 3 points.
- Second order GPS network (C2) - 5 points
- Third order GPS network (C3) - 17 points.

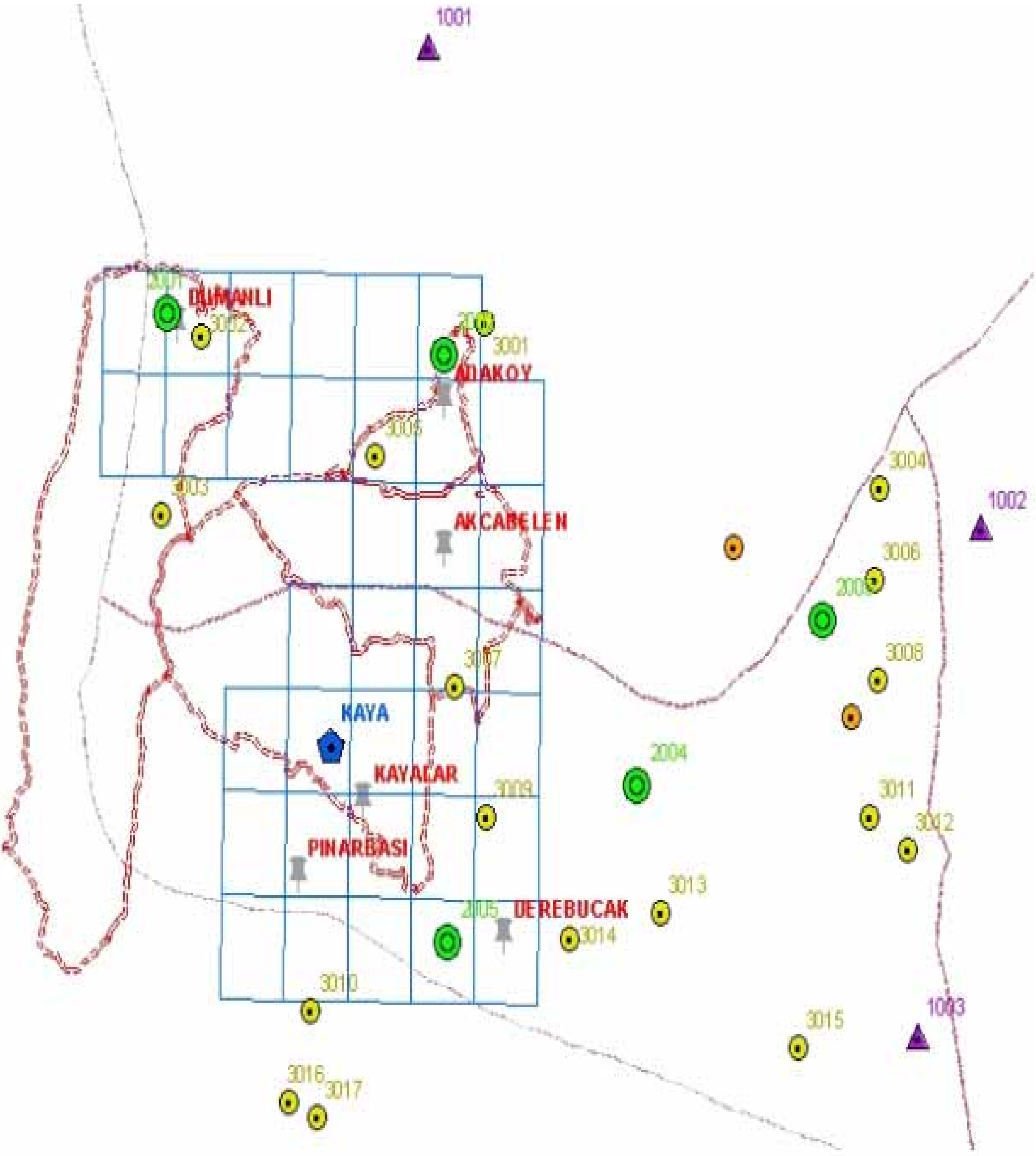


Figure 4.15 Total number of control points and work area boundary.

4.6 Data collection.

Data collected in the field consist typically of graphic and nongraphic data. The data are observed and recorded through standard field surveying procedures. The data may be non-digital (recorded in notebooks), or digital (recorded on some sort of GPS or total station) In the latter case the data will be transferred to office computers through specialized software.

4.6.1 Field survey.

An increasing amount of data for this project comes from a combination of field data and existing data. Field data are collected using standard surveying methods and equipments, Field conditions require many different techniques for surveying, these modern surveying instruments will be more effective and will result to a better quality of the cadastral index map.

In this project, the observation data is collected from several surveying instruments (modern equipments) depending on the selected site and type of work.

4.6.1.1 RTK GPS.

The use of real-time kinematic Global Position System (RTK GPS) can integrate the field measurements with the real-time computation into a uniform positioning system, which can significantly improve the productivity and efficiency of the whole system. Before doing any field work, it is necessary to have done good planning in order to obtain the desired accuracy. It is wise to check out the number of visible satellites, where the satellites will travel, and the PDOP (Position Dillusion of Precision) of the day.

In outside the villages, farms, we have used Topcon GPS receivers (using the RTK process) to collection the coordinates of farms boundaries. The coordinates obtained will be used to draw better maps after downloaded into PC and using NetCAD software. The sample of results as shown in table 4.7 and figure 4.16.

Table 4.7 Sample of coordinates collected by RTK GPS.

Point No.	X	Y	Z
136/403	4153042.779	632192.430	1232.906
136/407	4153030.749	632186.320	1232.030
136/410	4153020.056	632182.883	1232.402
136/411	4153012.079	632181.663	1231.902
136/413	4152988.010	632179.194	1231.500
136/415	4152981.896	632178.741	1232.021
136/416	4152974.915	632176.497	1232.502
136/418	4152968.433	632172.757	1231.854
136/427	4152952.477	632159.045	1231.802
136/431	4153056.146	632155.958	1231.204
136/432	4152997.473	632154.713	1230.902
136/433	4152990.479	632154.507	1230.933
136/436	4152983.690	632150.804	1230.943
136/439	4153019.897	632147.513	1230.845
136/443	4152971.141	632140.724	1231.099
136/445	4152928.116	632138.010	1231.107
136/446	4153064.739	632137.245	1231.122
136/449	4152954.478	632128.586	1231.400
136/452	4153074.308	632122.203	1231.354
136/453	4152938.226	632119.535	1231.104
136/454	4153071.133	632117.440	1230.745
136/457	4153069.545	632111.443	1230.844
136/459	4152942.340	632110.689	1231.021
136/462	4153063.900	632105.798	1231.121

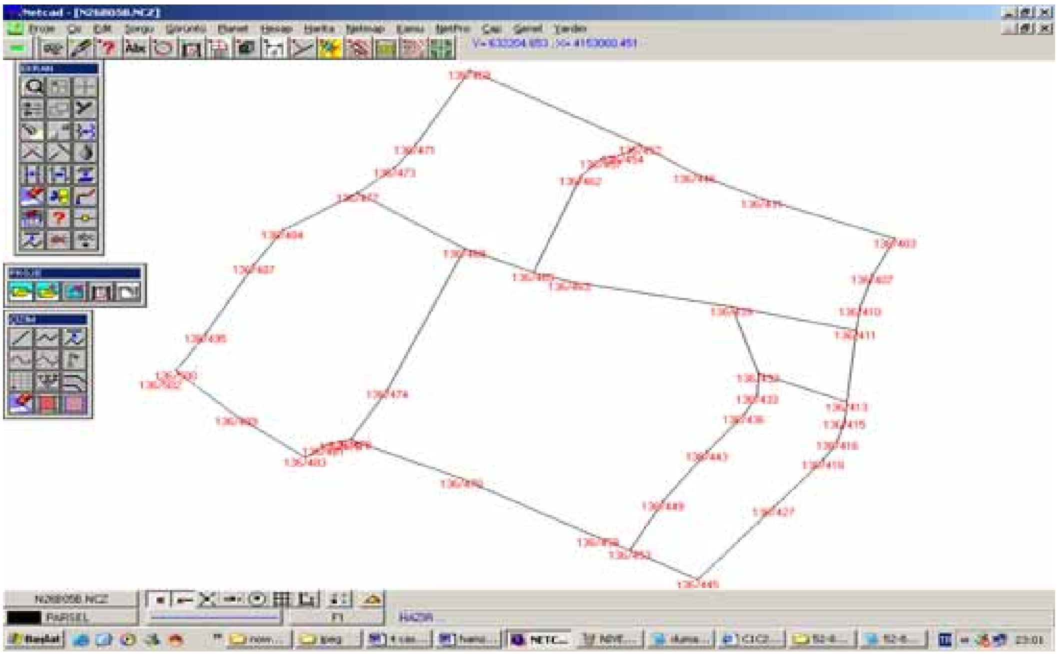


Figure 4.16 NetCAD is used for drawing farms (parcels).

4.6.1.2 Total station.

A total station is helpful for collecting data inside villages in a variety of situations. The field equipment includes a Topcon GTS-225 total station and two prism reflectors. After setup of the Total Station we started operations and collecting data. At the same time, one of the field surveyors makes a hand drawing (sketch) of the work area, noting the surveyed point number, and any other relevant information, as shown in figur 4.17. The field survey data is transfer from total station to a PC, as shown in figure 4.18. The results, coordnates, are shown in the table 4.8. By using NetCAD software and data collected by total station, we are drawing parcels on screen as shown in figure 4.19.

Figure 4.17 Sample of sketch draw in field.

```
115-15_ ?+00007220m1031954+2722352g+
00007210m+55-30102_*_,1.500_+
```

Figure 4.18 Data transfers from total station to PC.

Table 4.8 Sample of data collected by total station.

Point No.	X	Y
1	4149541.816	366391.341
2	4149533.131	366378.750
3	4149547.613	366388.878
4	4149546.697	366385.791
5	4149546.050	366385.903
6	4149555.074	366383.598
7	4149545.339	366383.103
8	4149542.149	366383.982
9	4149540.909	366379.437
10	4149543.822	366378.091
11	4149543.215	366375.820
13	4149552.008	366372.184
14	4149552.926	366374.364
15	4149552.094	366374.765
16	4149552.697	366376.228
17	4149551.664	366376.860
18	4149560.626	366376.983
19	4149551.896	366369.084
20	4149551.145	366365.923
21	4149547.566	366366.610
22	4149546.667	366367.679
23	4149548.241	366369.871
24	4149558.926	366355.015
25	4149562.362	366352.228
26	4149565.205	366351.297
27	4149559.807	366347.276

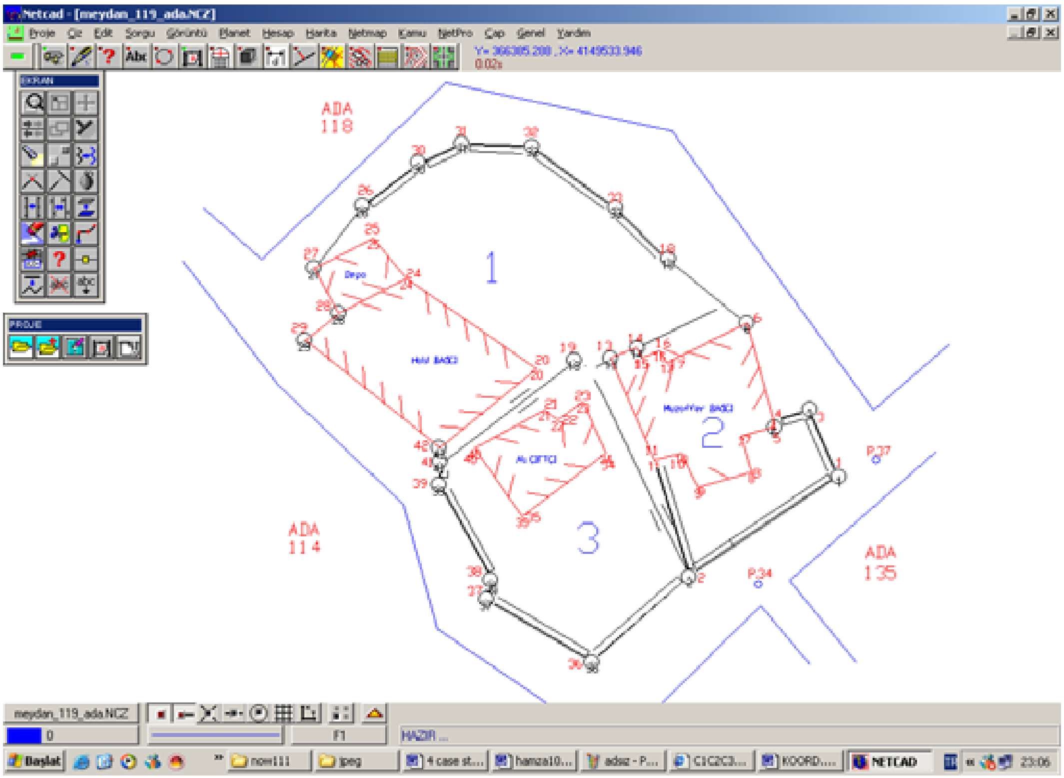


Figure 4.19 Sample of map draw depending on total station data collection.

The point over which the Total Station is set up is called a Polygon point. Figure 4.20 shows sample of distributed of Polygon points in an inside the village.

Figure 4.20 Sample of Polygon points location.

4.6.1.3 Digital level.

We employed digital level when a system of benchmarks is to be established in our work area. Here we have used TUDKA-99 points as benchmark, Topcon DL-102 digital level was used for this work; data collection will be dawnlaoded into PC. NetCAD software used to drawing the leveling network lines depending on data collected by DL-102 as shown in figure 4.21.

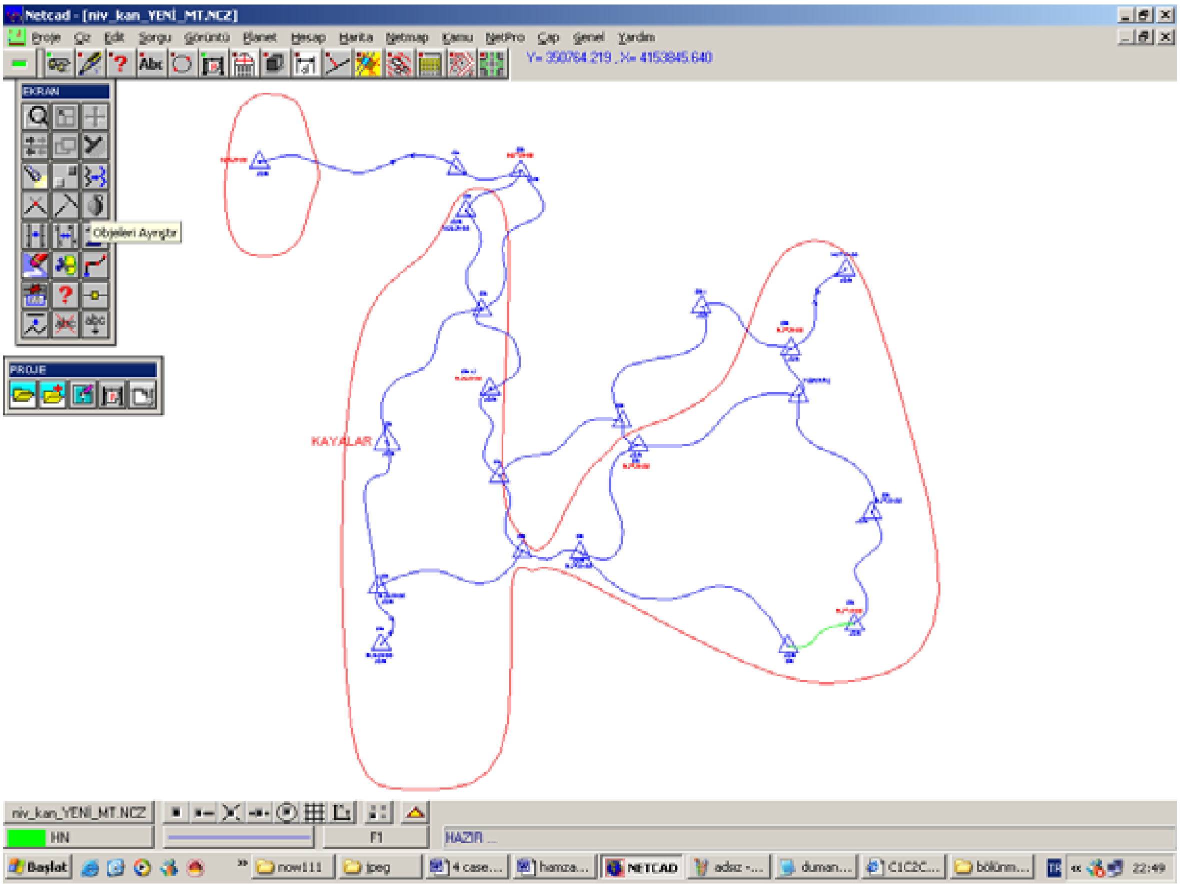


Figure 4.21 Digital level way in our work area.

4.6.2 Attribute Data.

The attribute data was collected at the same time when we have taked surveying observations. Attributes are the characteristics of a graphic map feature that are described by alphanumeric characters which are typically stored in a tabular format. Attribute (tabular) data is what we know about a feature. Examples of attributes of a property parcel might include: address, area, ownership, size, zoning, value, etc., as in table 4.9. Figure 4.22 shows attribute data enter into the form.

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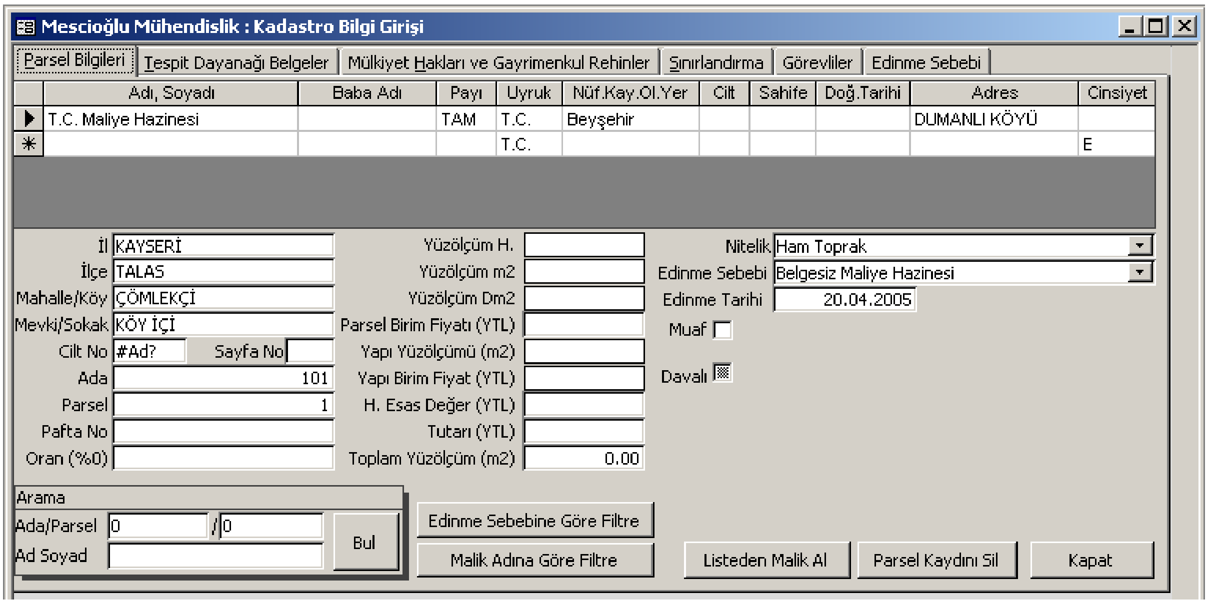


	Adı, Soyadı	Baba Adı	Payı	Uyruk	Nüf.Kay.Ol.Yer	Cilt	Sahife	Doğ.Tarihi	Adres	Cinsiyet
▶	T.C. Maliye Hazinesi		TAM	T.C.	Beyşehir				DUMANLI KÖYÜ	
*				T.C.						E

İl: KAYSERİ
İlçe: TALAS
Mahalle/Köy: ÇÖMLEKÇİ
Mevki/Sokak: KÖY İÇİ
Cilt No: #Ad?
Sayfa No:
Ada: 101
Parsel: 1
Pafta No:
Oran (%0):
Yüzölçüm H.:
Yüzölçüm m2:
Yüzölçüm Dm2:
Parsel Birim Fiyatı (YTL):
Yapı Yüzölçümü (m2):
Yapı Birim Fiyat (YTL):
H. Esas Değer (YTL):
Tutarı (YTL):
Toplam Yüzölçüm (m2): 0.00
Nitelik: Ham Toprak
Edinme Sebebi: Belgesiz Maliye Hazinesi
Edinme Tarihi: 20.04.2005
Muaf ☐
Davalı ▨
Arama
Ada/Parsel: 0 / 0
Ad Soyad:

Figure 4.22 Enter the attribute information into the form.

Table 4.9 An attribute table organized.

ID	Code	Owner_name	Type	Shape	Area_m2	Village_code	Municipality_code	Title_type	Land use type
1	5565	Ali mustfa	1	polygon	2500	25	32	ownership	farming
2	5550	Ahmed tark	2	polygon	3000	25	32	ownership	farming
3	5560	Akin abdallah	2	polygon	621	25	32	ownership	building
4	5555	Mustfa nadim	4	polygon	463	25	32	ownership	building
5	5540	Orhan kaled	2	polygon	300	25	32	ownership	building
6	5535	Hakmet ali	3	polygon	4000	25	32	ownership	farming
7	5545	Jamhor hamza	3	polygon	3322	25	32	ownership	farming
8	5575	Kamal adel	3	polygon	5425	24	32	ownership	farming

4.7 Update (new maps).

Over time parcels have changed, when land is to be subdivided or property boundaries changed. We updating cadastral maps by use land holding information and surveying observations for process digital cadastral map, finally we produce new digital cadastral map including all existing data at the present time, figure 4.23.

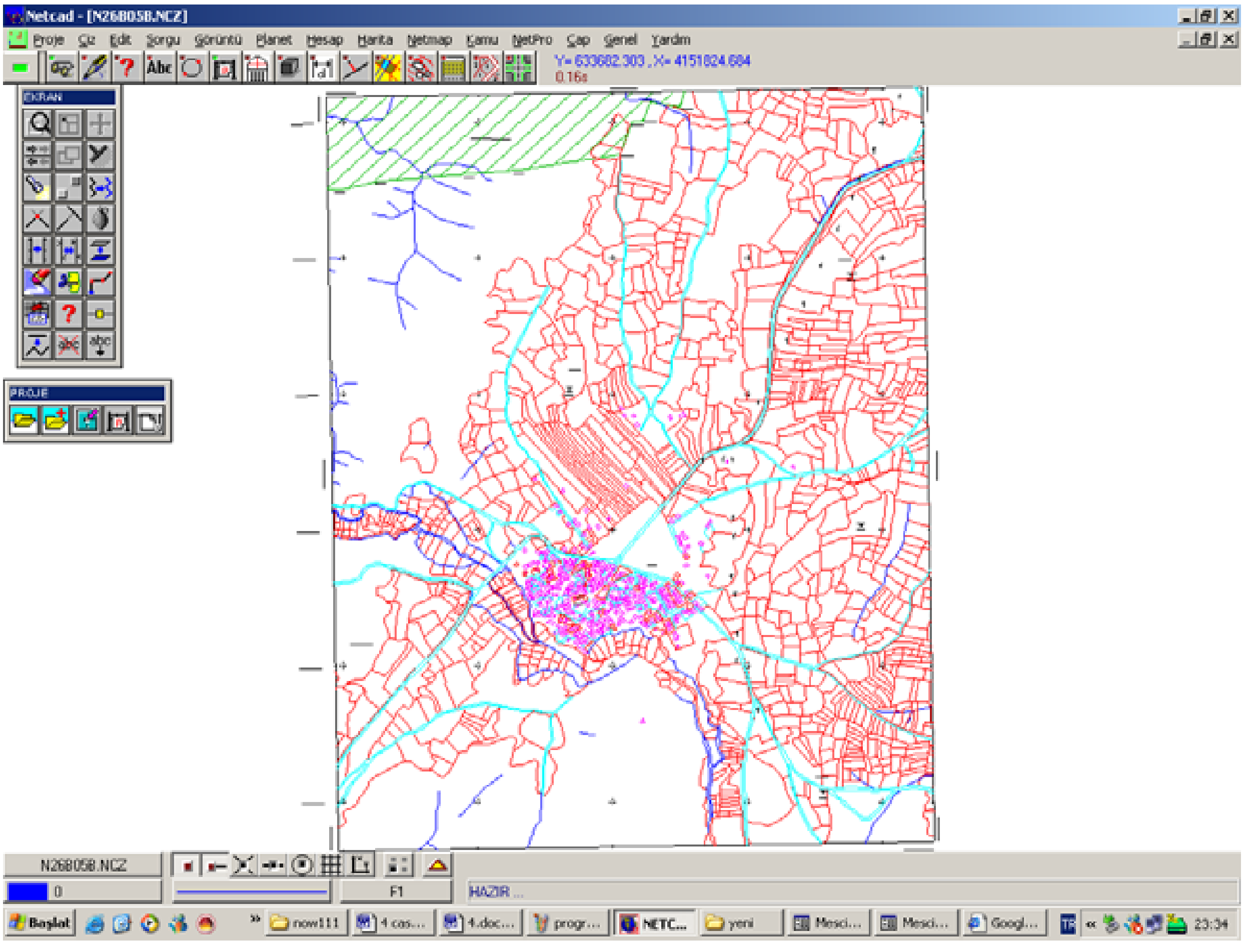


Figure 4.23 Sample of new map (map updated).

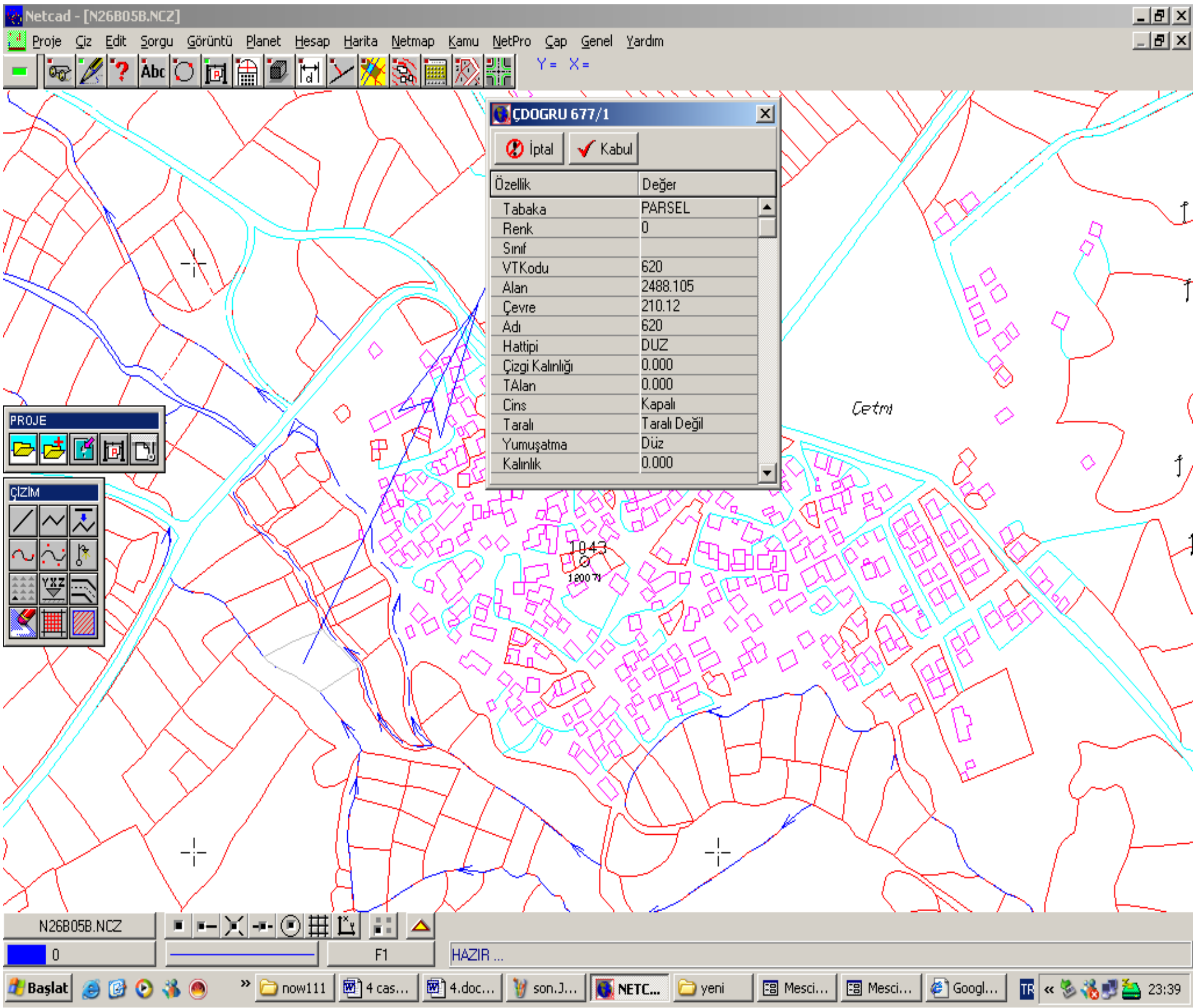
4.8 Data Base Management.

There is a need to manage data and information efficiently. As we know there is spatial and attribute data, which provide information on individual cases, people, places, features etc. Data must be organized so that information about entities and their attributes may be accessed by rapid computerized search and retrieval techniques. In GIS, There can be several classes of records in a database. Database creation involves several stages: input of the spatial data, input of the attribute data, and linking spatial and attribute data.

4.8.1 Linking spatial and attribute data.

The link between graphically-based locational data and the more descriptive, non-spatial data elements stored in tables is one of the most powerful concepts in applying the analytical capabilities of a GIS. Linking spatial and attribute data allows the user to analyze the relationships between the location of features and their attributes. Attribute data linked to the graphic map feature by a user assigned identifier. For example, attributes of a property parcel might include: area, ownership, zoning, or value and might be linked to the property parcel graphics by a parcel identification number (PIN).

The most common manifestation of cadastral data is an ownership or parcel map. Cadastral data is both information in a graphic form about parcels, most commonly referred to as a parcel map, and tabular database information tied to the parcel map via a PIN. Figure 4.24 shows sample of linking between attribute and graphic data.



Özellik	Değer
Tabaka	PARSEL
Renk	0
Sınıf	
VTKodu	620
Alan	2488.105
Çevre	210.12
Adı	620
Hattipi	DUZ
Çizgi Kalınlığı	0.000
TAlan	0.000
Cins	Kapalı
Taralı	Taralı Değil
Yumuşatma	Düz
Kalınlık	0.000

Figure 4.24 Graphic data and Tabular data integration.

Chapter 5

Conclusion

There are numerous ways that GIS and GPS technology can (and already do) work well together. From complete off-the-shelf data collection and data maintenance systems, to help with the management of spatial features and attribute data, through to very flexible software development kits, to assist in the creation of unique and sophisticated field applications. The use of GPS within a GIS environment has already been well accepted and proven - especially for data collection and now data maintenance. The manner in which GPS is used with GIS is now wide and varied allowing users to determine the way GIS and GPS are used together to best meet their needs.

The integration of GPS with GIS brings the real world to the desktop. What could take days to visit a specific site and analyze can now be performed on your desktop. The power of GPS / GIS is immense and application are unlimited and varied in all areas such as agriculture, environmental, defense, natural resources, health, business etc.. As the price of hardware and software comes down, I see the potential of this integration to grow tremendously in the world.

GPS is used to collect the field data efficiently and accurately. With GPS, the data is collected in a digital format in either real-time or postprocessed mode. A number of GPS/GIS systems that provide centimeter- to meter-level accuracy are now available on the market. Most of these systems allow the user to enter user-defined attributes for each feature.

The current form of cadastral system in rural area is faced with many troubles and powerless capabilities in providing information related to land and its uses, such as: landowner, boundaries, ownership and the roots of this ownership, relation between owners and user of the parcel, purchase and mortgage matters, etc. So, considerable time is needed in order to access, locate, and retrieve this information, which in turn lead to a significant wastage of public and private money, and effort.

To solve these problems, the study used modern technology for data collection (GPS, Total station, and Digital level) from field surveying, and GIS for data processing, management, data storage, displaying, and analyzing. Also, the GIS software packages, that are used in cadastre systems, can utilizing the capabilities of designed relational database (spatial and nonspatial data), and accessing into it, and exploring, locating, retrieving, and processing its data, with an efficient manner, which leads to save the public and private money, time, and effort.

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