Palestine Polytechnic University
College of Engineering
Civil and Architectural Engineering Department
Survey and Geomatics Engineering

Bachelor Thesis
Introduction to graduation project

Defining a Reference Surface for Heights in Hebron District

By
Muhammad Masharqah
Abdulla Sweaty Muhammad Sbitan

Supervisor:
Dr.Ghadi Zakarneh

Hebron
Palestine

January, 2014

Certification

Palestine Polytechnic University

Hebron,Palestine

Defining a Reference Surface for Heights in Hebron District

By

Muhammad Masharqah

Abdulla Sweaty Muhammad Sbitan

By the guidance of our supervisor, and the approval by members of testing committee, this project is delivered to the department of civil and architectural engineering, in the college of engineering to be as partial fulfilment of requirments of the department for the degree of B.Sc in surveying and geomatics engineering.

Supervisor signature	Head of department
Name: Dr. Ghadi Zakarneh	Name; Dr.Ghassan Dweik
Signature:	Signature

committee members' signature

Name:………………………	Name:………………………..	Name:……………………….
Signature:………………......	Signature:……………………	Signature:…………………...

Hebron,Palestine

Date: / /2013

Dedication

To our parents,

To our must-coming Dream!

Acknowledgment

We would like to thank Dr. Ghadi Zakarneh for the continuous guiding and support in our project that we are so grateful for, not forgetting the nice and hard times of work during the last months as the best to be remembered ever.

Our grateful thanks to our teacher Msc.Fayde Shabaneh for instructing and guiding, never forgetting his role of hard efforts in teaching during the last years.

Also we deliver our thanks to all who cooperated with us to accomplish our project, teachers of survey labs on Palestine polytechnic University Eng.Hasan Alrajabi and Eng.Ahmed Herbawi.

Team

Abstract

Defining the height reference surface in Hebron district

Project Team:

Muhammad Masharqah, Muhammad sbitan, Abdulla sweity

Supervisor:

Dr. Ghadi Zakarneh

Getting precise readings in the leveling survey operations of points and getting a height surface as reference is the aim of this project. the modern GNSS technologies measure the heights above the reference ellipsoid, while the precise land surveying leveling operations using differential leveling and trigonometric leveling are related to the mean sea level “approximately the Geoid”. These different types of heights have to be integrated in civil engineering project. For this reason, the ellipsoidal heights have to be transformed to local heights. This can be achieved by computing a height reference surface.

The solution is to be implemented in the Hebron district in Palestine. Common points with both known orthometric and ellipsoidal heights are needed. Here, the original triangulation points are to be used. The orthometric heights are already provided with easting and northing coordinates, while the ellipsoidal heights have to be measured. These heights are measured in a global ITRF (International Terrestrial Reference Frame). This requires the use of GPS/GNSS technologies. Additional data can be provided from the global geoid models. These models are available freely over the internet.

Finally, the common points are used to fit the global model with the local Height Reference Surface (HRS) of Palestine. The final surface with the related accuracy will be introduced.

ملخص المشروع

تعريف سطح مرجعي للارتفاعات في منطقة الخليل

فريق العمل

محمد مشارقة ، محمد سبيتان، عبد الله السويطي

إشراف

د. غادي زكارنة

إن الحصول على قراءات دقيقة في أعمال المساحة للنقاط، وإنتاج سطح مرجعي للارتفاعات هو الهدف الرئيس من المشروع، فالمساحة الحديثة واستخدام تقنيات (GNSS) التي تقوم بقياس الارتفاعات عن سطح الأرض الرياضي الممثل بشكل بيضاوي منتظم (ellipsoid)، فيما يختلف الحال عن العمل المساحي في أعمال التسوية التفاضلية والتسوية المثلثية المستخدمة في الأعمال الهندسية، حيث يتم حساب الارتفاعات بالنسبة لمعدل ارتفاع سطح البحر (ويتم التعامل معه بشكل تقريبي على أنه سطح الجيوئيد). وهذه الارتفاعات المختلفة في هذا المشروع سوف يتم العمل على ربطهما مع بعضهما البعض بواسطة تحويل الارتفاعات المرجعية المقاسة بواسطة GNSS إلى ارتفاعات محلية. وهذا يتحقق عن طريق إيجاد سطح مرجعي للارتفاعات.

سوف يتم تطبيق هذا المشروع في محافظة الخليل /فلسطين، بحيث أن النقاط المستخدمة في ذلك ينبغي الحصول على ارتفاعاتها عن مستوى سطح البحر وعن مستوى سطح الكرة الأرضية الرياضي (ellipsoid)، الارتفاعات للنقاط عن سطح البحر متوفرة بالإضافة إلى إحداثياتها الأفقية، فيما سوف يتم الحصول على ارتفاعاتها عن سطح الأرض الرياضي (ellipsoid) ميدانياً باستخدام تقنية GPS/GNSS . وستكون هذه القيم محسوبة على أساس نظام الإحداثيات ITRF (International Terrestrial Reference Frame). وأية بيانات إضافية أخرى سوف يتم الحصول عليها من النماذج العالمية للسطح المرجعي للارتفاعات الأرضية (الجيوئيد) والمتوافرة عبر الشبكة المعلوماتية.

من خلال النقاط المشتركة والتي تم الحصول عليها وقياسها سوف يتم ربط السطح مرجعي للارتفاعات في فلسطين مع الارتفاعات عن سطح الأرض الرياضي (ellipsoidal heights). في نهاية هذا المشروع سوف يتم عرض السطح المرجعي المحسوب بالإضافة إلى الدقة التي يمكن الحصول عليها.

Table of Contents

Table of Figures

List of Tables

APPINDIX A

Maps Of Geoid Undulations

- Geoid Undulation for Palestine (EGM 96)
- Geoid Undulation for Palestine (EGM2008)
- Geoid Undulation for Palestine (Eigen-5c)
- Geoid Undulation for Hebron District

CHAPTER ONE

Introduction

- Background
- Mission brief
- Objectives
- Previous studies
- Methodology
- Equipment and apparatus
- Study area
- Project schedule and time plan

CHAPTER ONE

Introduction

1.1Background

It becomes crystal clear that the surface of the Earth’s not uniform, topography of the land areas offers large vertical difference between mountains and valleys. This variations make it impossible to approximate the shape of the Earth with any reasonably simple mathematical model. Consequently, two main reference surfaces have been established to approximate the shape of the Earth. One reference surface is called the Geoid, the other reference surface is the ellipsoid.

Geoid is the approximate shape of the Earth if it’s assumed to be fully covered with ocean water and water is subjected to the effect of gravity only, this shape is mathematically sophisticated and it can be represented by the height difference between it and the ellipsoid which is a more uniform shape, the height difference here is called (Geoid undulation) this value varies along the earth surface due to real Earth surface topography, figure (1.1) illustrates the relationship between Geoid, ellipsoid and the real Earth surface.

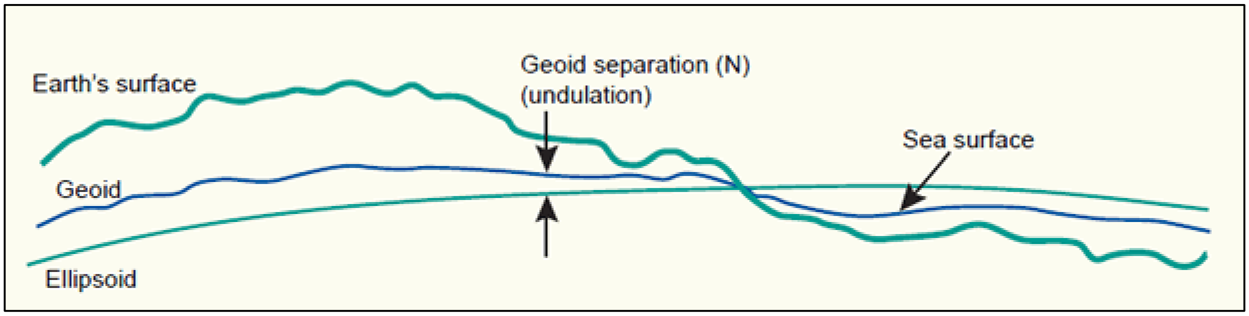


Figure1.1 relationship between Geoid, ellipsoid and the real Earth surface [4]

The high range of geoid undulation among the global geoid surface made it necessary to have a local determination for a vertical reference surface that fits the Earth surface levels in a reasonably small areas of lands, these areas could represent a state or a province. Many methods can be used to achieve such mission, the method that this study interested in is the geometrical method using GNSS/GPS leveling, that is, the modern GNSS technologies measure the heights above the reference ellipsoid, while the precise land surveying leveling operations using differential leveling and trigonometric leveling are related to the mean sea level “approximately the Geoid” moreover, having the precise leveling from the GNSS/GPS usage will give the physical height “H” from equation (1.1)

$$\boldsymbol{H = h - N} \tag{1.1}$$

Where:

$\boldsymbol{h}$ Height above the reference ellipsoid

$\boldsymbol{H}$ Height above the Geoid

$\boldsymbol{N}$ Geoid undulation

The ellipsoidal heights have to be transformed to local heights. This can be achieved by computing a height reference surface.

1.2Mission brief

This project of height reference surface (HRS) determination will be applied on the area of Hebron district in Palestine using a common point of known orthometric heights and coordinates of easting and northing, ellipsoidal heights are to be measured using GNSS technology relative to ITRF ((International Terrestrial Reference Frame).

1.3Objectives

The project will be achieved by following the steps beneath:

1) Data collection of orthometric heights and measurement of ellipsoidal heights, and application of refinements on the readings.

2) Application of surface fitting from the data obtained.

3) Introducing results and parameters of the resulting (HRS) and its accuracy.

1.4 Previous studies

A similar previous study was carries out in 2007, by a team of 3 students in Palestine Polytechnic university, this study was a graduation project supervised by Dr.Ghadi Zakarneh, team worked on making (GPS height integration) on an area 15*15 Km area, benefiting from Visual Basic a program of interpolation was coded and introduced.

1.5 Methodology

Here is a brief description for each chapter that will be included in the introduction of the project:

1) Chapter two, will introduce height surface, Geoid, local height surfaces and methods used in determination of height surfaces.
2) Chapter three, will include an introduction to the use of GNSS technology in various survey works and its role in (HRS) determination.
3) Chapter four, this chapter will include the description of study area, the network of GPS leveling stations, the data collection method (recalled from chapter 3) and measurements.
4) Chapter five, this chapter will include sections that deals with refinement of measurements and data by applying error elimination calculations.

1.6 Equipment and Apparatus

1) Garmin handheld GPS receiver, this receiver will be used just to locate the trigonometric stations on the exploration stage.
2) Trimble 5700 or R8 GNSS devices, this includes the whole components of receivers (base and rover), cables, and planning software to get data for DOP, antenna tripods.
3) Stopwatch.
4) Vehicles for traveling to stations.
5) Field books, and a prepared GNSS data collection sheets.
6) Communication apparatus e.g. wireless push to talk.
7) Camera.
8) Paint sprayer.

1.7 Study area

The area of interest and study is an area within Hebron district in Palestine, figure (1.2) shows the location of study area relative to the occupied West Bank, a ten poins is taken within the city and its surrounding towns.

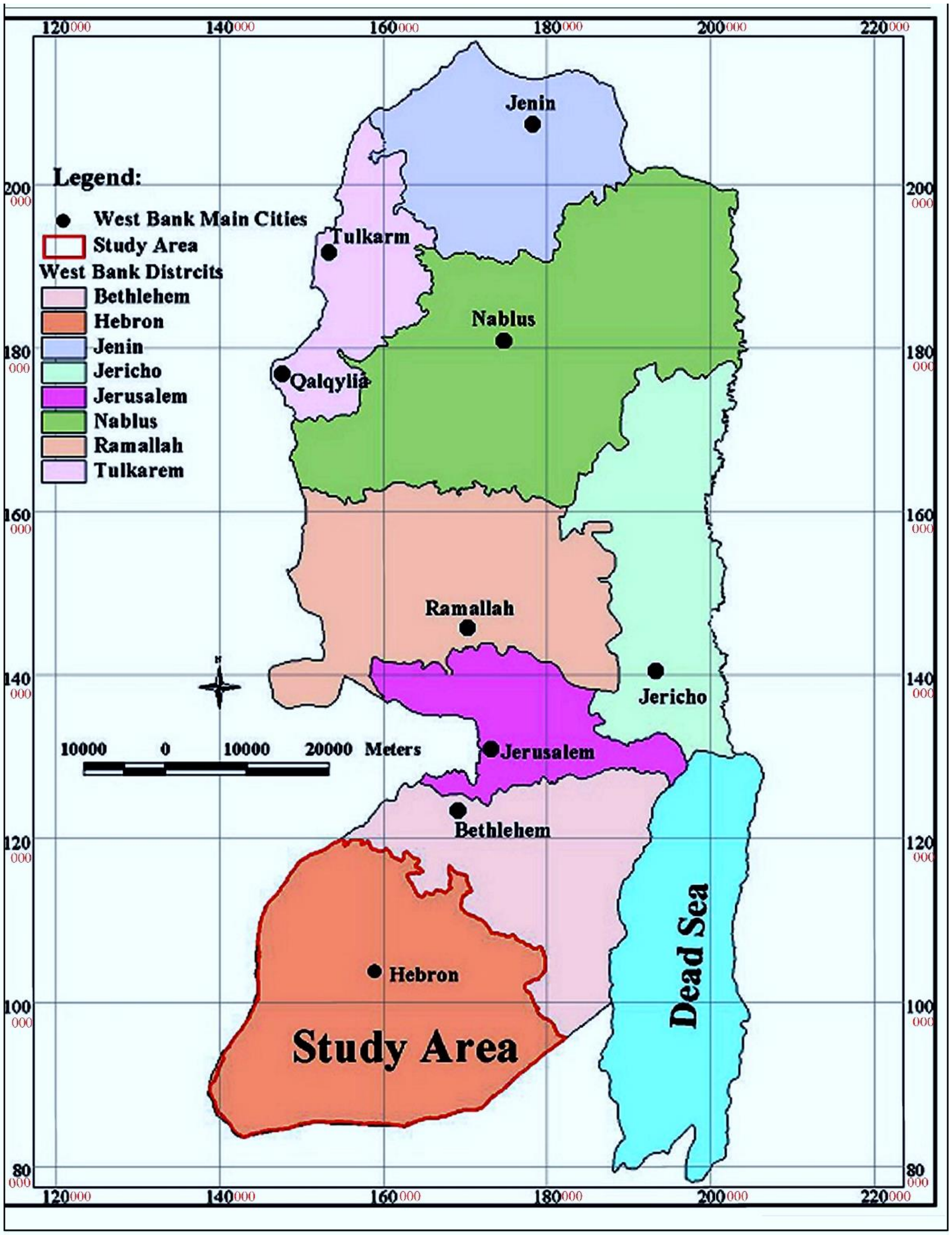


Figure1.2 : Map of study area

1.8 Project schedule and time plan

Table1.1 : Time table

Activities	Time(week)	Starting date (approximate)	Ending date (approximate)	Done (or not)
1-Project idea	2	From week 1	To week 2	Done
2-Project analysis and plane	3	From week 3	To week 5	Done
3-Training on using GNSS devices	3	From week 6	To week 8	Done
4-Selection of points	2	From week 9	To week 10	Done
5-Selection the components of the projects	4	From week 11	To week 14	Done
6- Covering and printing	2	From week 15	To week 16	Done
7-Final report	16	From week 1	To week 16	Done

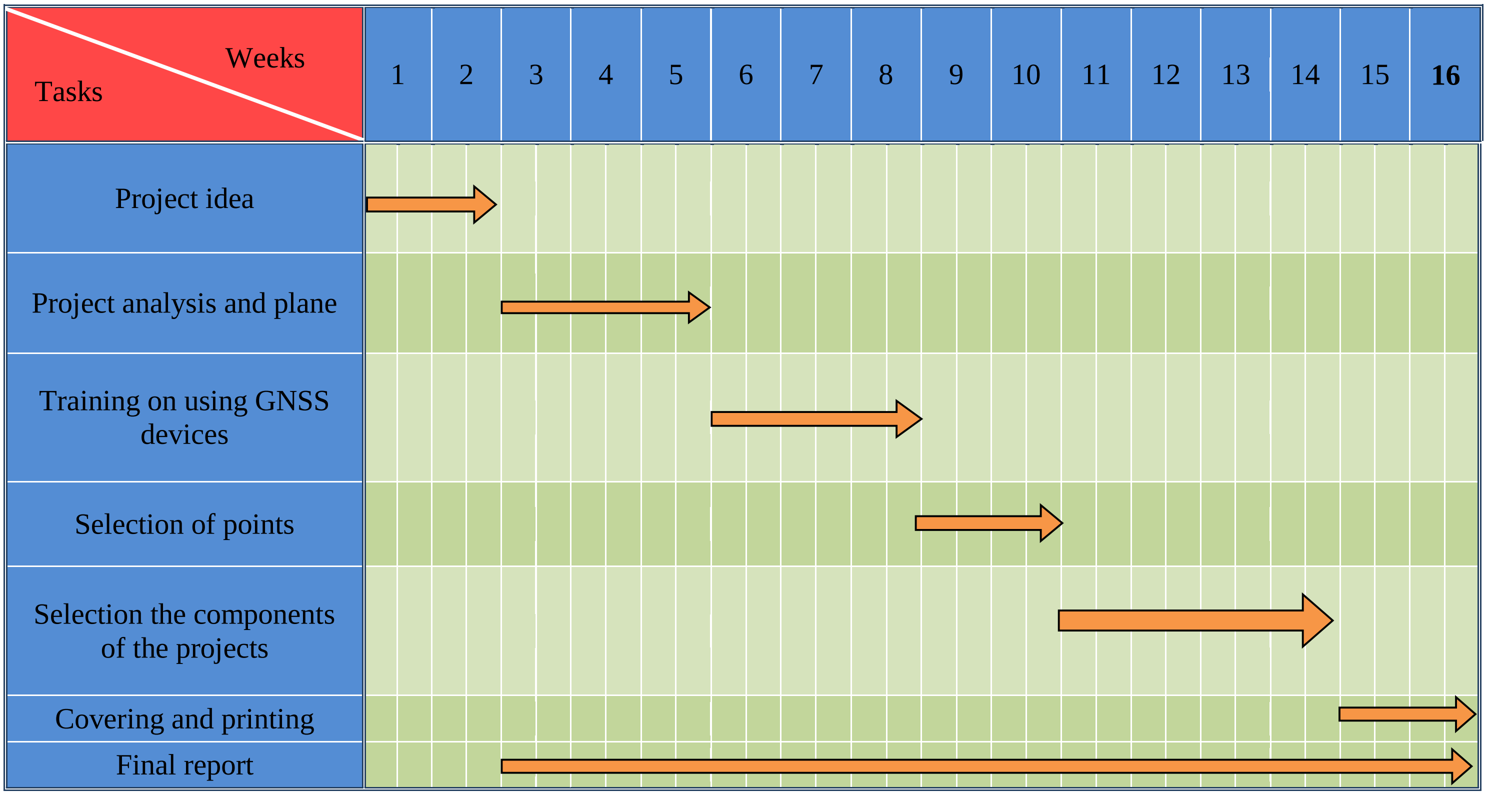


Figure1. 3 Time planning

CHAPTER TWO

Geoid Modeling

- Introduction
- An approach to physical geodesy
- Methods of geoid modeling
- Global geoid models

CHAPTER TWO

Geoid Modeling

2.1 Introduction

Geoid is the approximate shape of the Earth if it’s assumed to be fully covered with ocean water and water is subjected to the effect of gravity only, this shape is mathematically sophisticated and it can be represented by the height difference between it and the ellipsoid which is a more uniform shape, the height difference here is called (Geoid undulation) this value varies along the earth surface due to real Earth surface topography, there are many geoid models developed by various methods, this chapter explains methods of geoid modeling ,shows and illustrates global geoid models.

2.2 An approach to physical geodesy

2.2.1 Geoid in physical geodesy

In physical geodesy, geoid is the surface of constant potential energy that coincides with mean sea level over the oceans. But, mean sea level is not a surface of constant potential, due to dynamic processes within the ocean. For another thing, wherever there are continents, the geoid lies beneath the earth’s surface.

2.2.2 Gravity of Earth and gravity anomaly

As a big mass of non-homogeneous shape and according to Newton law, Earth has an amount of gravity determined by Newton’s general law of attraction, hence and because of the big mass of Earth relative to masses on it, these masses are assumed to be a point mass relative to Earth. Following up with physical properties analysis, this gives a concept that such a gravity possessing mass has an equipotential surfaces around.

Earth reference models in mathematics are either spherical or ellipsoidal, combining the physical properties with the Earth mathematical models, it will be reasonable to consider the difference between geoid gravity potential W and ellipsoid gravity potential U. see figure (2.1)

$$W(x,y,z) = U(x,y,z) + T(x,y,z) \tag{2.1}$$

Where T is the disturbing potential, while gravity disturbance is shown by equation (2.2)

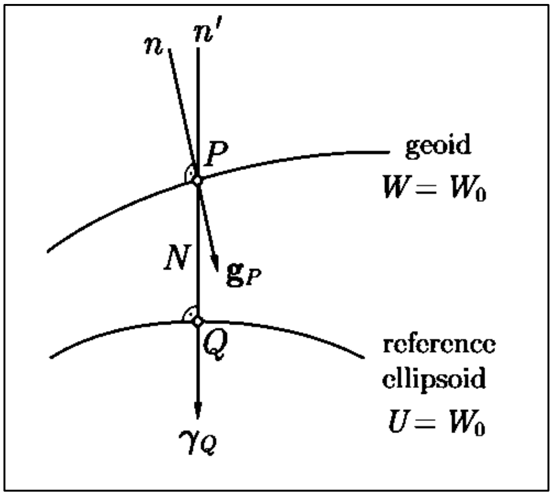


Figure 2. 1 ellipsoid and geoid gravity potentials [9]

$$\partial g_P = g_Q - \gamma_P \tag{2.2}$$

Gravity anomaly between point P and Q is

$$\Delta g_p = g_P - \gamma_Q \tag{2.3}$$

By using Taylor expansion for the expressions above, the equations (2.1, 3.2, and 2.3) becomes:

$$N = \frac{T_p}{\gamma_Q} \tag{2.4}$$

$$\delta g_p = -\frac{\partial T_p}{\partial r} \tag{2.5}$$

$$\Delta g_p = g_p - \gamma_p = -\frac{\partial T_p}{\partial r} - \frac{2}{r} T_p \tag{2.6}$$

The concept of gravity anomaly between point on geoid and ellipsoid can be simplified in mental analogy by saying that it's the correspondent to geoid undulation in equation (1.1).

2.3 Methods of geoid modeling

Geoid modeling can be performed by two – or more – methods, each one has its advantages and its shortcomings, they depend on the accuracy desired and on the cost of measurements, and these methods can be divided into three methods as follows:

2.3.1 Geometric geoid modeling

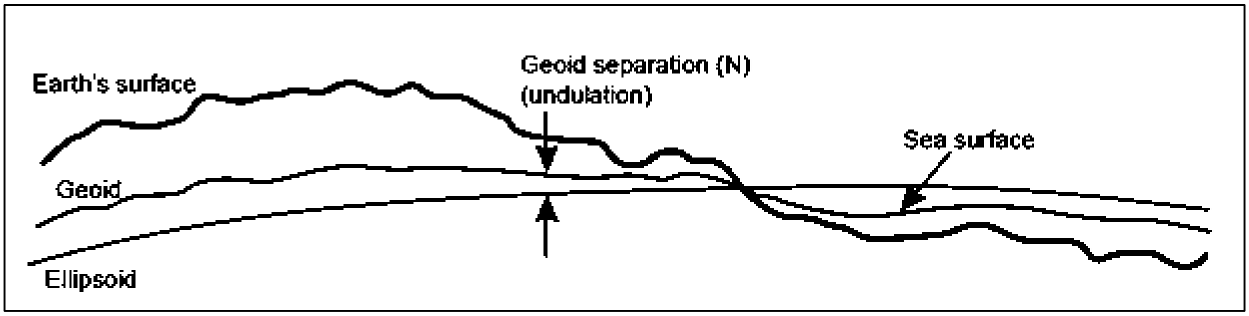


Figure 2. 2 relationship between Geoid, ellipsoid and the real Earth surface [10]

Technology of GNSS that provides a precise values of elevation make it a useful tool to be employed in geoid modeling, a number of bench marks with known and accurate values of orthometric heights are available and ellipsoidal heights are measured by using GNSS\GPS technology following the DGPS technique (will be explained in chapter 3) , the difference between otrhometric height and ellipsoidal height is called geoid undulation, figure 2.2 shows geoid undulation representation with respect to an

$$\boldsymbol{H} = \boldsymbol{h} - \boldsymbol{N} \qquad (2.7)$$

Where:

$\boldsymbol{h}$ Height above the reference ellipsoid

$\boldsymbol{H}$ Height above the Geoid

$\boldsymbol{N}$ Geoid undulation

illustration for the geoid, ellipsoid and natural Earth surface. Equation 2.7 indicates this relationship.

To summarize main concepts, ellipsoidal height of point on the earth is distance between point on the Earth surface and ellipsoid surface at ellipsoidal center direction. Ortometric height of point is distance between point and geoid surface at gravity vector direction.

After GNSS observation and processing, it can be obtained (XYZ) Cartesian or (φ, λ , h) geographic coordinates of point. Determination of ortometric height H of point from ellipsoidal height h depends on determination of geoidal undulation N. in this project, orthometric heights are obtained from Department of land and survey, also it can be get by the observations of GNSS\GPS, since it has a built-in data and transformation software from ellipsoidal to orthometric heights according to global geoids saved in.

There are a lot of techniques for determination of surface models of geoid. Some of these techniques are used direct observation values and the others can be used after adjustment and filtering. Models using determination of geoid surface must be realistic and well-adjusted with structure of surface.

Several techniques are used for determination of geoid surface and it can be listed as:

1) Interpolation.
2) Finite Elements.
3) Collocation.
4) Numerical differential solution.
5) One dimensional datum transformation.

One of the methods used in geoid modeling, and the method used in this project is the polynomial regression that can be described in equation

$$N = (\varphi, \lambda) = \sum_{i=0}^{n} \sum_{j=0}^{m} a_{ij} \varphi^{i} \lambda^{j} \tag{2.8}$$

Equation 2.8 is a general equation for surface interpolation, degree of polynomial desired is determined according to the desired accuracy and number of parameters to be solved, by choosing the suitable n, equation 3.8 is expanded to variant polynomials that can be classified according to its degree as follows:

1) Simple Planar Surface, this interpolation produces a planar surface with a slope defined by following expression

$$N_0 = a_0 + a_1\varphi + a_2\lambda \tag{2.9}$$

2) Bi-Linear Saddle, this surface is linear with two slopes, equation 3.10 express the surface formula

$$N_0 = a_0 + a_1\varphi + a_2\lambda + a_3\varphi\lambda \tag{2.10}$$

3) Quadratic Surface

$$N_0 = a_0 + a_1\varphi + a_2\lambda + a_3\varphi^2 + a_4\lambda^2 + a_5\varphi\lambda \tag{2.11}$$

4) Cubic Surface

$$N_0 = a_0 + a_1\varphi + a_2\lambda + a_3\varphi^2 + a_4\lambda^2 + a_5\varphi\lambda + a_6\varphi^3 + a_7\lambda^3 + a_8\varphi^2\lambda + a_9\lambda^2\varphi \tag{2.12}$$

Selecting degree of polynomial depends on number of observed points and degree of freedom, degree must be as higher as possible, with testing for variables using statistical tests, having a degree of freedom more than 1 gives us the availability to perform a least squares adjustment to the interpolated surface. Geometric modeling is applicable for small areas, where as it’s hard to be extrapolated, so the area enclosed within the network is applicable for the interpolated surface, generalization for a wider area needs more points.

3.3.2 Gravimetric geoid modeling

Taking advantage from the geophysical concept of gravity anomaly and Stokes equation, geoid can be determined by using an observations of gravity anomalies provided by a specific devices that measure gravity called gravimeters. Stoke's formula determines the geoid undulation N from these measurements of gravity, see equation 2.13, Stoke assumes in his theory that there's no mass outside geoid also assumes that gravity measurements are continuous at the whole surface of the earth.

$$N = \frac{R}{4\pi\gamma}\iint S(\psi)\Delta g \tag{2.13}$$

Where γ is the normal gravity, $S(\psi)$ is called Stoke's function

$$S(\psi) = \sum_{n=2}^{\infty}\frac{2n+1}{n-1}P_n(\cos(\psi)) \tag{2.14}$$

$$S(\psi) = \frac{1}{\sin(\frac{\psi}{2})} - 6\sin\left(\frac{\psi}{2}\right) + 1 - 5\cos(\psi) - 3\cos(\psi)\ln\left(sin\left(\frac{\psi}{2}\right) + sin^2\left(\frac{\psi}{2}\right)\right) \tag{2.15}$$

If $cos(\psi) = t$,then

$$S(t) = \sqrt{\frac{2}{1-t}} - 6\sqrt{\frac{1-t}{2}} + 1 - 5t - 3t * \ln(\sqrt{\frac{1-t}{2}} + \frac{1-t}{2}) \tag{2.16}$$

Where

R: mean radius of the Earth

ψ: spherical distance between point and origin

Gravimetric method provides good spatial coverage over large areas and can provide a detailed description for the geoid, but it also have some disadvantages like its complicated mathematical basis, since it deals with continuous gravimetric observations, any missing areas of gravity values forms a gap in the model of geoid, it’s also influenced by the errors in satellites orbits and locations.

2.3.3 Combined geoid modeling

An integration between the previous methods can be adopted by firstly using the gravimetric method to get the model of geoid, then it can be calibrated and modified from known points of orthometric and ellipsoidal heights, this calibration can be carried out by defining a simple mathematical surface of corrections like simple sloped surface or a more intensive mathematical model when dealing with wide area of modeling, such as a country of a continent.

2.4 Global geoid models

2.4.1 Earth gravitational model 1996 (EGM96)

EGM96 is a geopotential model of the Earth consisting of spherical harmonic coefficients complete to degree and order 360. It is a composite solution, consisting of a combination solution to degree and order 70 and a block diagonal solution from degree 71 to 359 and the quadrature solution at degree 360. This model, just completed, is the result of a collaboration between the National Imagery and Mapping Agency, the NASA Goddard Space Flight Center, and the Ohio State University in 1996. The WGS 84 constants used to define the geometry and the normal field of the reference ellipsoid in the calculation of this geoid height file are the following:

$a = 6378137.0\text{m}$

$f = 1/298.2572235630$

$GM = 0.3986004418 * 10^{15}\, m^3/s^2$

$\Omega = 7292115 * 10^{-11}\, radians/s$

Where

a: semi-major axis of WGS 84 Ellipsoid

f: flattening of WGS 84 Ellipsoid

GM: Earth's Gravitational Constant

Ω: Earth's angular velocity

The geoid undulation values are calculated by applying a correction term that converts a pseudo-height anomaly calculated at a point on the ellipsoid to a geoid undulation value. In addition, a correction term of -0.53 m is added to the prior result to obtain the geoid undulation with respect to the WGS 84 ellipsoid. The value of -0.53 m is based on the geometric features of the WGS84 reference ellipsoid. Figure (2.3) shows a representation for EGM96 geoid model on the whole Earth.

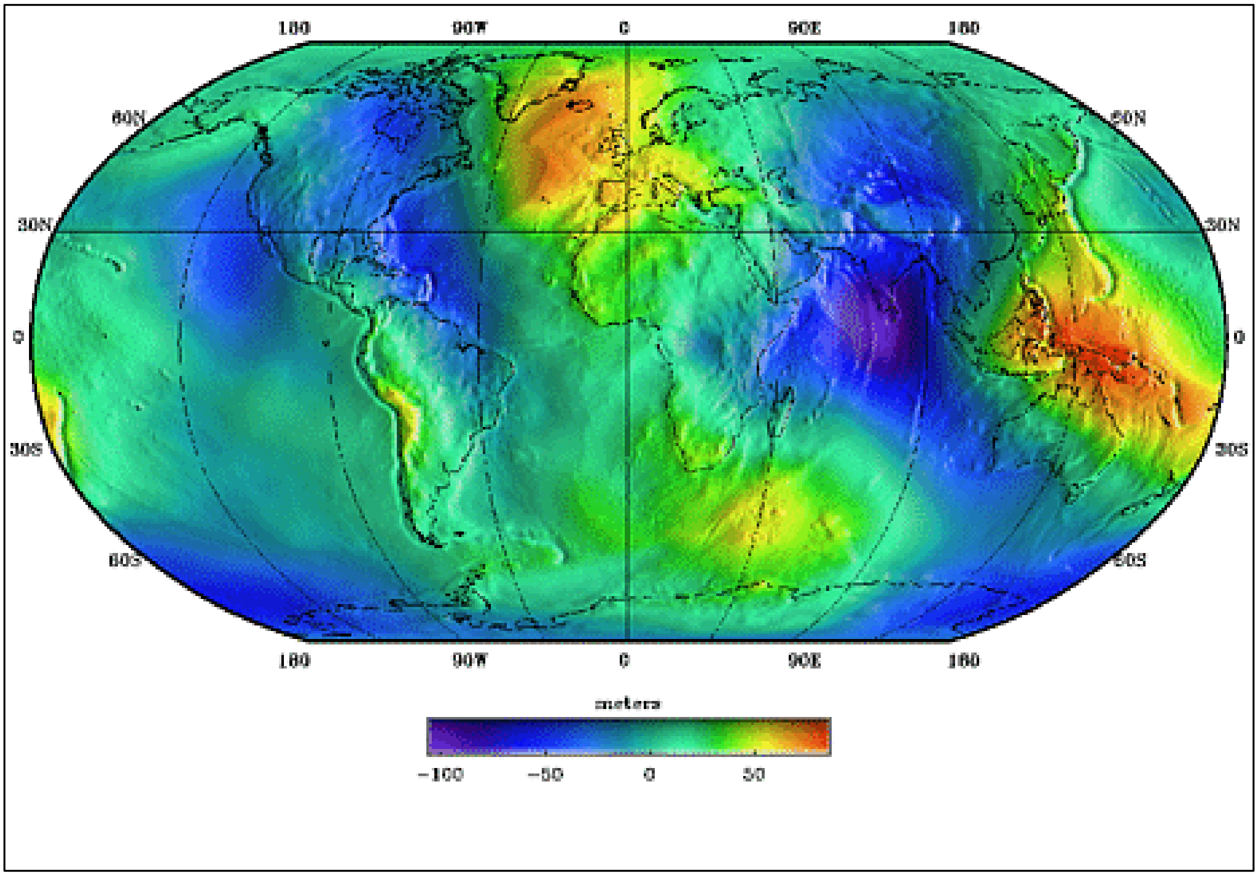


Figure 2.3: A 30'x30' value of the geoid undulations from EGM96 to 360x360 [10]

2.4.2 Earth gravitational model (EGM 2008)

The official Earth Gravitational Model EGM2008 has been publicly released by the national Geospatial-Intelligence Agency (NGA) EGM Development Team. This gravitational model is complete to spherical harmonic degree and order 2159, and contains additional coefficients extending to degree 2190 and order 2159.

The WGS 84 constants used to define the reference ellipsoid, and the associated normal gravity field, to which the geoid undulations are referenced are:

$$a = 6378137.0\text{m}$$

$$f = 1/298.2572235630$$

$$GM = 3.986004418 \text{ x } 10^{14}\, m^3/s^2$$

$$\Omega = 7292115 * 10^{-11}\, radians/s$$

Where

a: Semi-major axis of WGS 84 Ellipsoid

f: Flattening of WGS 84 Ellipsoid

GM: Earth's Gravitational Constant

Ω: Earth's angular velocity

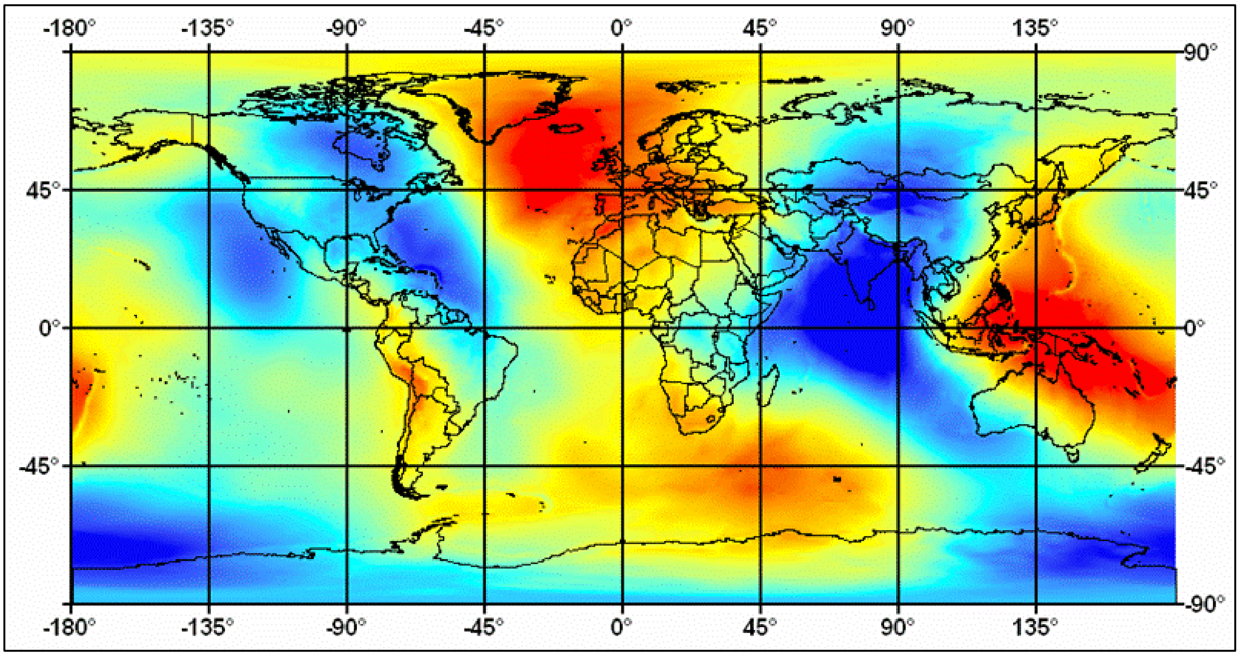


Figure 2.4 value gradient of geoid undulations from EGM2008 [10]

Figure 2.4 shows the distribution of geoid undulations related to EGM2008, data are obtained from the web site of National Geospatial-intelligence Agency (NGA). A GIS raster data are obtained from the web site and a close zoom to Palestine is plotted in figure 2.5

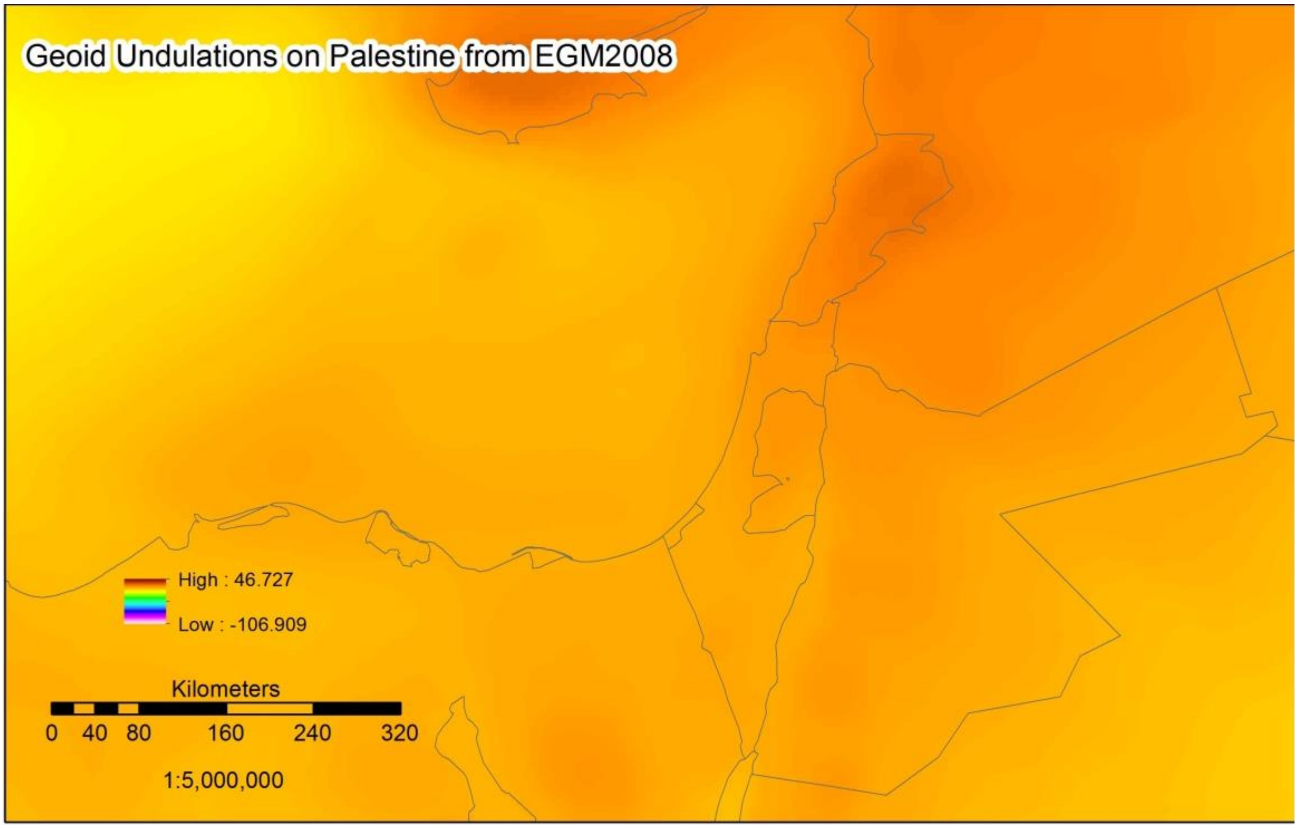


Figure 2.5 Illustration of geoid undulation on Palestine [10]

CHAPTER THREE

Global Navigation Satellite System (GNSS)

CHAPTER THREE

Global Navigation Satellite System (GNSS)

3.1 Introduction

For its necessity in many activities on the earth, defining location is one of the most desires of humankind, this started from a date that is simultaneously ranging around the history of man on the earth, many philosophers, scientists and researchers have been asking the question of location and accuracy since the early historical stages till now, on that along life of discoveries and inventions, it’s noticeable that many achievements in that domain were developed, it can be claimed that surveying came from that big question. One of the most important achievements in that domain is the adoption of Global Positioning System (GPS) in civil applications, since at first phase of using GPS the tool was just used in military uses, but now GPS is used in many civilian applications in survey, land, sea and air navigation and too many other applications. This chapter will deal with how this technology works? And how it could be applied in this project.

3.2 GNSS / GPS working concept

Although originally intended for purely military purposes, the GPS system is now used primarily for civil applications, such as surveying, navigation (air, sea and land), positioning, measuring velocity, determining time, monitoring stationary and moving objects, etc. its basic concept is that a several orbiting satellites constellated on the space in a specified orbits see figure3.1, these satellites receive signals from a number of ground control stations that are responsible for adjusting the highly precise atomic clocks abroad, moreover, these orbiting satellites are with known position, the aim here is to get the position of points on the earth from known positions of four satellites with measured distances between each satellite and the desired point, consequently this become a resection problem.

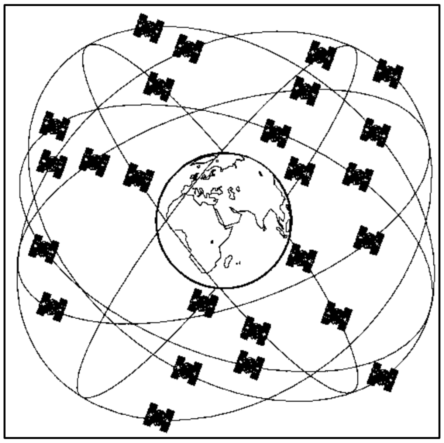


Figure 3. 1: GPS satellites orbit the Earth on 6 orbital planes. [7]

Every nation desiring to have a satellite based positioning system can launch a set of satellites to the space, the first system **was designed** and adopted by U.S. Department of Defense, this's where the name GPS (Global Positioning System) was got, after that, many other nations developed another systems like GLONASS, GALLELIO, APOLLO and other local systems. Recently, a cooperation was made between GPS and GLONASS and named GNSS.

Global Navigation Satellite Systems (GNSS) include constellations of Earth-orbiting satellites that broadcast their locations in space and time, of networks of ground control stations, And of receivers that calculate ground positions by trilateration. GNSS are used in all forms of transportation: space stations, aviation, maritime, rail, road and mass transit. Positioning, Navigation and timing play a critical role in telecommunications, land surveying, law enforcement, emergency response, precision agriculture, mining, finance, scientific research and so on. They are used to control computer networks, air traffic, power grids and more.

3.3 GPS segments

The Global Positioning System consists of three major segments: the Space Segment, the Control Segment, and the User Segment. The space and control segments are operated by the United States Military and administered by the U.S. Space Command of the U.S. Air Force.

Basically, the control segment maintains the integrity of both the satellites and the data that they transmit. The space segment is composed of the constellation of satellites as a whole that are currently in orbit, including operational, backup and inoperable units. The user segment is simply all of the end users who have purchased any one of a variety of commercially available receivers. While the user segment obviously includes military users, this book will concentrate on the civilian uses only. The more deep description of each segment follows in the next sections.

3.3.1 Control segment

The control segment of the Global Positioning System consists of one Master Control Station (MCS) located at Falcon Air Force Base in Colorado Springs, Colorado, and five unmanned monitor stations located strategically around the world. In addition, the Air Force maintains three primary ground antennas, located more or less equidistant around the equator. In the event of some catastrophic failure, there are also two backup Master Control Stations, one located in Sunnyvale, California, and the other in Rockville, Maryland.

The unmanned monitor stations passively track all GPS satellites visible to them at any given moment, collecting signal (ranging) data from each. This information is then passed on to the Master Control Station at Colorado Springs via the secure DSCS (Defense Satellite Communication System) as shown in figure 3.2where the satellite position ("ephemeris") and clock-timing data (more about these later) are estimated and predicted.

The Master Control Station then periodically sends the corrected position and clock-timing data to the appropriate ground antennas which then upload those data to each of the satellites. Finally, the satellites use that corrected information in their data transmissions down to the end user. This sequence of events occurs every few hours for each of the satellites to help insure that any possibility of error creeping into the satellite positions or their clocks is minimized.

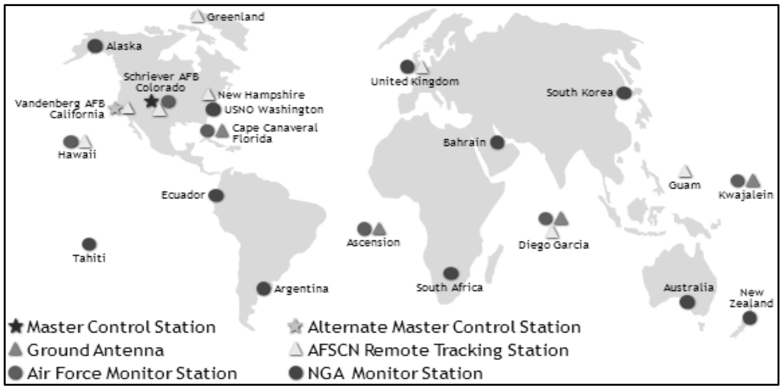


Figure3. 2 distribution of control stations on the earth.[7]

3.3.2 Space segment

The space segment consists of the complete constellation of orbiting Navstar GPS satellites. The current satellites are manufactured by Rockwell International and cost approximately $40 million each. To each satellite must be added the cost of the launch vehicle itself which may be as much as $100 million. To date, the complete system has cost approximately $10 billion.

Each satellite weighs approximately 900 kilograms and is about five meters wide with the solar panels fully extended. There were 11 Block I prototype satellites launched (10 successfully), followed by 24 Block II production units. Currently, only one of the Block I satellites is still operational, while four Block II backups remain in ground storage.

The base size of the constellation includes 21 operational satellites with three orbiting backups, for a total of 24. They are located in six orbits at approximately 20,200 kilometers altitude. Each of the six orbits are inclined 55 degrees up from the equator, and are spaced 60 degrees apart, with four satellites located in each orbit (see diagram on next page). The orbital period is 12 hours, meaning that each satellite completes two full orbits each 24-hour day see table3.1.

Table3. 1 Summary of satellite

Summary of satellites						
Block	Launch Period	Satellite launches				In orbit and healthy
		Success	Failure	In preparation	Planned	
I	1978–1985	10	1	0	0	0
II	1989–1990	9	0	0	0	0
IIA	1990–1997	19	0	0	0	10
IIR	1997–2004	12	1	0	0	12
IIR-M	2005–2009	8	0	0	0	7
IIF	2010–	2	0	10	0	2
IIIA	2014–	0	0	0	12	0
IIIB	Theoretical	0	0	0	8	0
IIIC	Theoretical	0	0	0	16	0
Total		60	2	10	36	31
(update: 24 May 2010)						

3.3.3 User segment

This segment is the ground-based receiver that process the space segment signals and computes the position or velocity of the user. The processing can be done either in real time or it’s needed to apply post processing, post processing is applied for high accuracy needs, such as the construction of control points and baseline in surveying applications. User segments comes in wide variety of manufactured forms according to the usage, they can come in built-in forms in cars, cell phones and other media, or it comes as an independent handheld receiver in a similar form of mobile device, the unique form of user segment is the segment used for survey applications.

3.4 Positioning in GPS

The process and the main concepts of getting the 3D components of location on Earth's surface have depends on a time/distance calculations and these calculations, also procedure of resection appears after having the distances between each satellite and the point to be identified. This process can be explained in details in the following sections.

3.4.1 Signal transit time

Each one of the satellites has up to four atomic clocks on board. Atomic clocks are currently the most precise instruments known, losing a maximum of one second every 30,000 to 1,000,000 years. In order to make them even more accurate, they are regularly adjusted or synchronized from various control points on Earth.

Each satellite transmits its exact position and it's precise on board clock time to Earth at a frequency of 1575.42MHz. These signals are transmitted at the speed of light (300,000 km/s) and therefore require approximately 67.3 ms to reach a position on the Earth's surface located directly below the satellite. The signals require a further 3.33 ms for each excess kilometer of travel. If you wish to establish your position on land (oratseaorintheair), all you require is an accurate clock. By comparing the arrival time of the satellite signal with the on board clock time the moment the signal was emitted, it is possible to determine the transit time of that signal. The distance S to the satellite can be determined by using the known transit time τ by the equation (3.1)

$$\boldsymbol{S = \tau * c} \tag{3.1}$$

Where

S : distance between satellite and receiver

τ : signal transit time

c: speed of light

3.4.2 Determining position in GNSS

Till now it has been assumed that time is measured precisely, but it's an unavoidable case that time can't be measured in a perfectly accurate value and the error of position caused by time has a very noticeable effect. For the receiver to measure time precisely a highly accurate, synchronized clock is needed. If the transit time is out by just 1 μs this produces a positional error of 300m. As the clocks on board all three satellites are synchronized, the transit time in the case of all three measurements is inaccurate by the same amount. Mathematics is the only thing that can help us now. We are reminded when producing calculations that if N variables are unknown, we need at least M independent equations to get an exact solution, more equations are needed to apply least squares solution see figure 3.3.

In calculating position of point in GNSS, the unknowns are position in X, position in Y, position in Z and error of time Δt, hence, four satellites are needed in order to get these four variables, this is why the number of satellites in the space are distributed in order to have at least 4 satellites in each point observation anywhere on the globe. This's the simple way in getting positions by an accuracy within 5 to 10 meters. Further more accurate modes to be explained in the coming sections.

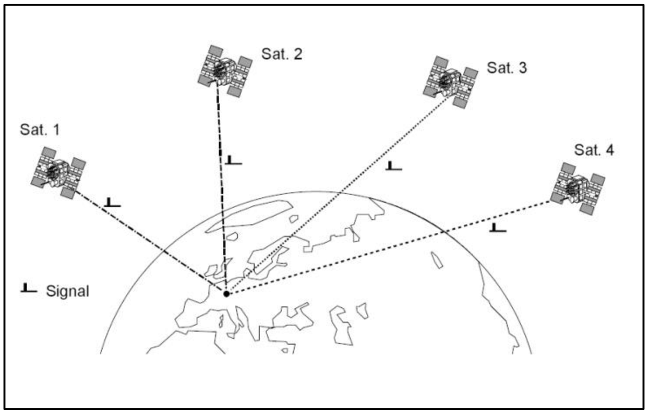


Figure3. 3 positioning of a point in GNSS. [7]

3.5 GNSS/GPS signals

When a satellite transmits a signal, it is in the form of a simple sine wave that has a particular frequency (the number of “peak to peak” on the sine wave that pass a fixed point per unit of time usually given as Hertz, or times per second), wavelength (the distance between “peak to peak” or any matching successive point on the sine wave), and amplitude (the “height” of the “peak-wave”) Radio wavelengths can range from tens of kilometers down to fractions of micrometer. Frequencies, intrinsically linked to wavelengths, also have wide ranges, from only a few per hour (Low frequency) to billions per second (high frequency).

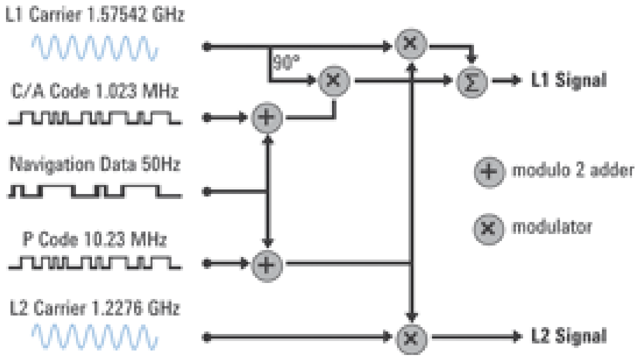


Figure4. 4 structure of GPS signals. [2]

Waves are used to carry data on, this method of loading data on the wave is called modulation, modulation can be done by many methods; first is to change its amplitude and it’s called Amplitude Modulation (AM), or by changing its frequency, this’s called frequency modulation (FM), the previous types are used in radio transmission stations in a variant areas of broadcast.

Finally, the phase which is the phase is the relative up/down position of the sine waves can be modulated by regularly reversing the ups and downs. This is how GPS transmits data on its two carriers.The 1575.42 MHz L1 carrier wave (top of the diagram) carries the C/A-code as shown in figure 3.4, the P-code, and the navigation message. The 1227.6 MHz L2 carrier wave (bottom of the diagram) only carries the P-code and the NAV-msg. Therefore, while the P-code is available on both Ll and L2 frequencies, the C/A-code is only available on the Ll. The navigation message is transmitted on both carriers.

3.6 Position Calculations

As shown in figure 3.5, receiver should receive four time signals from four variant satellites in order to calculate signal transit times, calculations are effected in a Cartesian, three-dimensional coordinate system with a geocentric origin. The ranges of the user from the four satellites R1, R2, R3 and R4 can be determined with the help of signal transit times Δt_1, Δt_2, Δt_3 and Δt_4 between the four satellites and the user. As the locations X_{Sat}, Y_{Sat} and Z_{Sat} of the four satellites are known, the user coordinates can be calculated.

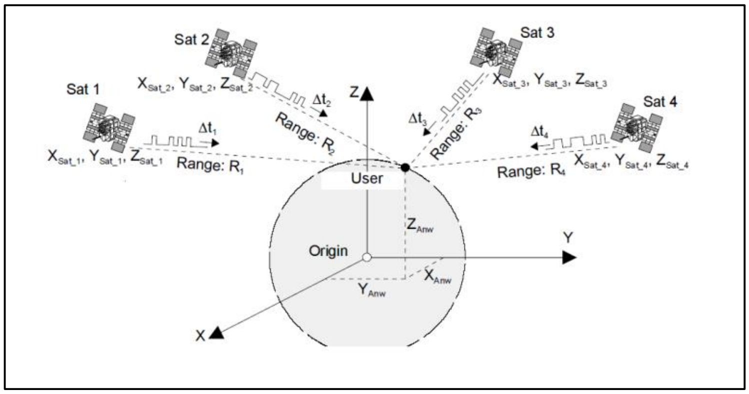


Figure3. 5 positioning in three dimensional coordinate system. [2]

Due to the atomic clocks on board of the satellites, the time at which the satellite signal is transmitted is known very precisely. All satellite clocks are adjusted or synchronized with each another and universal time coordinated. In contrast, the receiver clock is not synchronized to UTC and is therefore slow or fast by Δt0. The sign Δt0 is positive when the user clock is fast. The resultant time error Δt_0 causes inaccuracies in the measurement of signal transit time and the distance R. As a result, an incorrect distance is measured that is known as pseudo distance or pseudo-range.

$$-\Delta t_{measured} = \Delta t + \Delta t_0 \tag{3.2}$$

$$PSR = (\Delta t_{measured} \cdot c) \tag{3.3}$$

$$PSR = R + (\Delta t_0 . c) \tag{3.4}$$

$$R = \sqrt{(x_{sat} - x_{user})^2 + (y_{sat} - y_{user})^2 + (z_{sat} - z_{user})^2} \tag{3.5}$$

Where:

R: true range of the satellite from the user

c: speed of light

Δt: signal transit time from the satellite to the user

Δt0: difference between the satellite clock and the user clock

PSR: pseudo range

$(\mathrm{x}, \mathrm{y}, \mathrm{z})_{\mathrm{user}}$: position of the reciver

$(\mathrm{x}, \mathrm{y}, \mathrm{z})_{\mathrm{sat}}$: position of the satellite

By Sub of (3.5) in (3.4)

$$PSR = \sqrt{(x_{sat} - x_{user})^2 + (y_{sat} - y_{user})^2 + (z_{sat} - z_{user})^2} + (\Delta t_0 . c) \qquad (3.6)$$

For each satellite for variables $(\Delta t_0, x_{user}, y_{user}\ and\ z_{user})$ are exist and expressed by equation (3.6), so at least four satellites are necessary for having an exact solution for the position of the receiver, further equation means more visible satellites in the space and means a least squares solution for the position.

3.7 Errors in GNSS/GPS observations

There are, in fact, several sources of error that severely degrade the accuracy of all forms of GNSS/GPS positioning. They include satellite clock timing error, satellite position error (ephemeris error) these errors are monitored by control stations and corrections are provided to the system of navigating satellites by the control stations, another error sources are ionospheric and tropospheric refraction, receiver noise, multipath, and Selective Availability, or SA. Finally, the sum of the errors is multiplied by a factor of 1 to 6, a figure that represents the Dilution of Precision, or DOP.

3.7.1 Ionospheric and tropospheric refraction

Another problem area is the atmosphere itself, through which the satellite signals must pass. Assuming that waves always travels in the speed of light That’s not strictly true. It is true in the perfect vacuum of space. Unfortunately, the signal has to travel through some 300 kilometers of the Earth’s atmosphere to reach us. The two most troublesome components of the atmosphere are the ionosphere and the troposphere as shown in figure 3.6. The ionosphere is a layer of electrically charged particles between around 50 and 200 kilometers altitude. The troposphere is simply what we usually think of as the atmosphere, extending from the surface up to between eight and 16 kilometers altitude. Each of these literally “drag” radio waves down, causing them to bend a tiny, but significant, amount. This “bending” of radio waves is called refraction

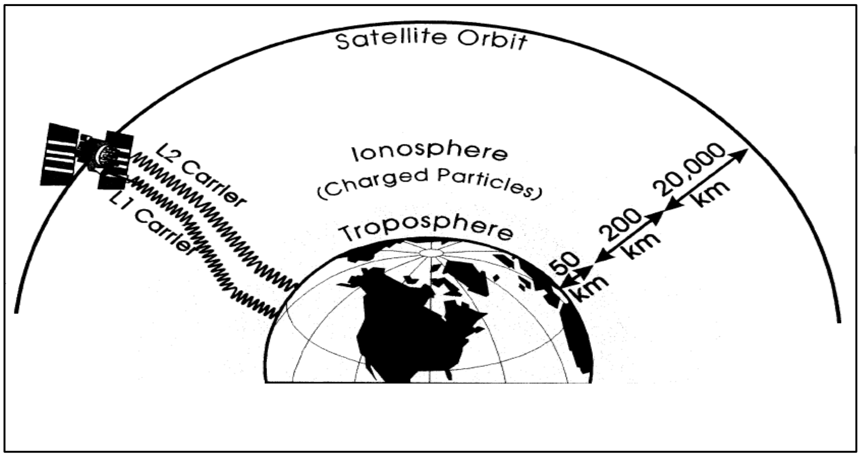


Figure3. 6 effect of Ionospheric and tropospheric media on GPS signals. [2]

Further complicating the problem is the fact that the ionosphere and troposphere each refract differently. The problem with the ionosphere is the electrically charged particles that “drag” on the incoming signal. In the troposphere, the problem is with the water vapor content which does the same thing, just at a different rate.

There are a couple of ways to deal with refraction. First, the satellite’s navigation message includes an atmospheric refraction model that compensates for as much as 50-70% of the error. A more effective method for ionospheric refraction is to use a dual-frequency receiver which simultaneously collects the signals on both the Ll and L2 carriers. Because the amount of refraction that a radio wave experiences is inversely proportional to its frequency, using two different frequencies transmitted through the same atmosphere at the same time makes it relatively easy to compute the amount of refraction taking place and compensate for it. Unfortunately, tropospheric refraction is not frequency-dependent and so cannot be corrected by this method.

The ionospheric propagation delay from p-code and c/a- code can be calculated from these equation .

$$P_{RL1}=\rho+L_{1\,iono}+C\tau_{RX1}+C\tau_{GD} \quad (3.7)$$

$$P_{RL2}=\rho+\frac{L_{1iono}}{(\frac{F_{L2}}{F_{L1}})^2}+C\tau_{RX2}+C\frac{\tau_{GD}}{(\frac{F_{L2}}{F_{L1}})^2} \quad (3.8)$$

Where $P_{RL1}=L_1$ pseudorange .

$P_{RL2}=L_2$ pseudorange.

ρ= geometric distance between GPS satellite transmitter and GPS receiver ,including nondispersive contributions such as tropospheric refraction and clock drift .

$F_{L1}=L_1$ frequency=1575.42 MHZ.

$F_{L2}=L_2$ frequency=1227.6 MHZ.

τ_{RX1}=receiver noise as manifested in code (receiver and calibration biases) at L_1 (ns).

τ_{RX2}= receiver noise as manifested in code (receiver and calibration biases) at L_2 (ns).

τ_{GD}=satellite group delay (inter frequency bias)

C=speed of light =0.299792458 m/ns.

A further method to eliminate ionospheric refraction is that nearly all GPS receivers, inexpensive or expensive, have a “Mask Angle” setting. This means that the receiver can be set to ignore any satellite signals that come from below a user-definable angle above the horizon, or “mask” them out. The most typical mask angle is usually somewhere between 10 and 15 degrees.

3.7.2 Multi-path error

The error here comes from that receiver gets reflected signal, whereas receiver should collect a direct signal from the satellite, having a reflected signal causes an error of determining pseudo rang and carrier phase resulting an error in position determining.

Since the reflected multi-path signal has traveled a longer path, it will arrive a fraction of a second later, and a fraction weaker than the direct signal. By recognizing that there are two signals, one right after another, and that one is slightly weaker than the other, the receiver can reject the later, weaker signal, minimizing the problem. This ability is referred to as the receiver’s multi-path rejection capability.

3.7.3 Selective availability

The selective availability is a military-wise procedure that the US Department of Defense applies, that will decrease that accuracy of positioning to more than 100 meters, this procedure affects the civilian applications of positioning, but not the use DGPS techniques.

3.7.4 Dilution of Precision

The cumulative UERE (User Equivalent Range Error) totals are multiplied by a factor of usually 1 to 6, which represents a value of the Dilution of Precision, or DOP. The DOP is, in turn, a measure of the geometry of the visible satellite constellation.

A low numeric Dilution of Precision value represents a good satellite configuration, as shown in figure 3.7, whereas a higher value represents a poor satellite configuration. The DOP at any given moment will change with time as the satellites move along their orbit. GDOP can be determined using equation (3.9)

$$\mathrm{GDOP} = \frac{1}{\sigma}\sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 + \sigma_b^2} \tag{3.9}$$

Where

σ Is the measured rms error of the pseudorange, which has a zero mean.

$\sigma_x \sigma_y \sigma_z$ Are the measured rms errors of the user position in the xyz directions.

σ_b Is the measured rms user clock error expressed in distance.

The position dilution of precision is defined as

$$\mathrm{PDOP} = \frac{1}{\sigma}\sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2} \tag{3.10}$$

The horizontal dilution of precision is defined as

$$\text{HDOP} = \frac{1}{\sigma}\sqrt{\sigma_x^2 + \sigma_y^2} \tag{3.11}$$

The vertical dilution of precision is

$$\text{VDOP} = \frac{\sigma_z}{\sigma} \tag{3.12}$$

The time dilution of precision is

$$\text{TDOP} = \frac{\sigma_b}{\sigma} \tag{3.13}$$

There are a number of Dilution of Precision components. The overall GDOP, or Geometric Dilution of Precision includes:

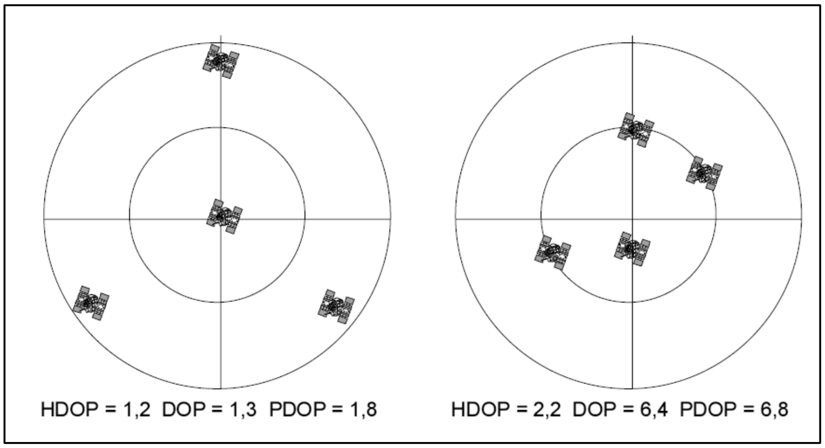


Figure3. 7 Effect of constellation on DOP value. [7]

PDOP, or Precision Dilution of Precision, probably the most commonly used, which is the dilution of precision in three dimensions. Sometimes called the Spherical DOP.

HDOP, or Horizontal Dilution of Precision, is the dilution of precision in two dimensions horizontally. This value is often lower (meaning “better”) than the PDOP because it ignores the vertical dimension.

VDOP, or Vertical Dilution of Precision, is the dilution of precision in one dimension, the vertical.

TDOP, or Time Dilution of Precision, is the dilution of precision with respect to time.

A DOP value of less than 2 is considered excellent-about as good as it gets, but it doesn't happen often, usually requiring a clear view of the sky all the way to the horizon. DOP values of 2 to 3 are considered as very good. DOP values of 4 or below are frequently specified when equipment accuracy capabilities are given.

DOP values of 4 to 5 are considered as fairly good and would normally be acceptable for all but the highest levels of survey precision requirements. A DOP value of 6 would be acceptable only in low precision conditions, such as in coarse positioning and navigation. Position data generally should not be recorded when the DOP value exceeds 6.

3.8 differential (relative) GPS concepts

The absolute (point) positioning discussed through section (3.2-3.6) can't provide the desired accuracy for applications of mapping and control projects due to errors involved and discussed before. DGPS is a process of determining the relative differences in coordinates between two receiver points as shown in figure 3.8, one as a reference station (base) with precisely known coordinates, and another receiver (rover). This method provides data for either (post-processing) or (real time processing). Most projects of high need to accurate position values uses DGPS.

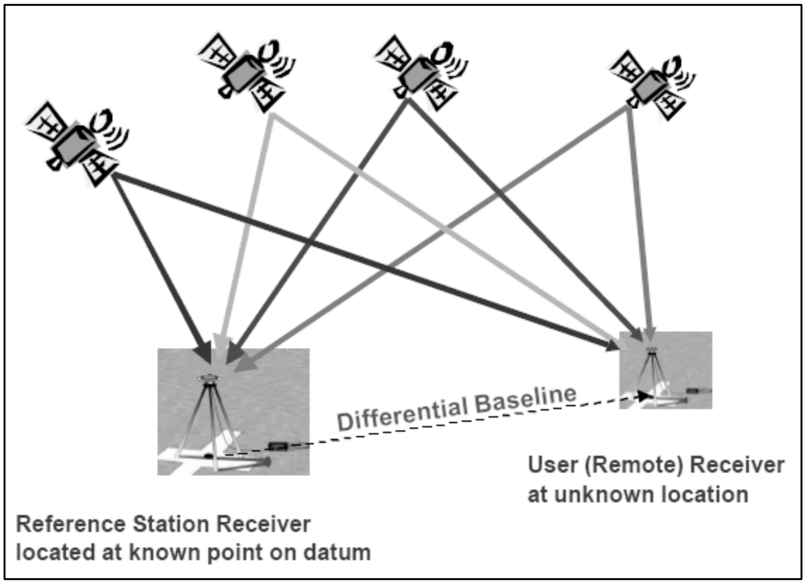


Figure3. 8 Relative (differentia) GPS positioning. [2]

3.8.1 Code phase pseudo range tracking

code phase pseudo range tracking is the most widely used DGPS, it has an accuracy that reaches to “meter level” ranges between (0.5m to 5m), it’s used in many applications that needs to track navigation and to observe movements in land or marine navigation, it’s mathematically applied similar to position calculation in absolute ranging described in section (3.6) but having two simultaneous observations for base and rover provides much more minimization of clock error and atmospheric uncertainties.

3.8.2 Carrier phase tracking

Differential positioning using carrier phase tracking uses a formulation that also can be applied with working on absolute GPS positioning. The process in DGPS is more complex since the carrier signals are tracked such that range changes are measured by phase resolution. The modulated codes are removed from carrier, and a phase tracking process is used to measure the Differences in phase of the receiver satellite signals between the reference receiver (base) and the user receiver (rover) at unknown point. The transmitted satellite signals is shifted due to Doppler Effect. The phase is phase isn’t changed. GPS receivers measure what is termed the carrier phase, usually symbolized by (Φ). This observable represents the frequency difference between the satellite carrier and the generated in receiver, or “beat” phase reference. This phase measurement observation can be shown in equation for the carrier phase observable

$$\emptyset_{\boldsymbol{k}}^{\boldsymbol{p}}(\boldsymbol{t}) = \emptyset_k^p(t_0) - \emptyset^p(t) + N_k^P + S_k + f\tau_k + f\tau_p - \beta_{iono} + \delta_{tropo} \qquad (3.14)$$

Where:

$\emptyset_{\boldsymbol{k}}^{\boldsymbol{p}}(\boldsymbol{t})$: Length of propogation path between satellite “p” and receiver “k” (cycles)

$\emptyset_k^p(t_0)$: received phase of satellite “p” at receiver “k” at time t_0

$\emptyset^p(t)$: transmitted phase of satellite “p”

N_k^P: integer ambiguity

S_k: measurement noise

f: carrier frequency (Hz)

$\tau_{p,}\tau_k$: satellite, receiver clock bias

β_{iono}: ionospheric advance

δ_{tropo} : tropospheric delay

3.8.3 Carrier phase surveying techniques

There are several techniques that use the carrier phase in order to determine the position of a remote receiver. These generally break down to static and kinematic methods however, both sides have Similar observation and initialization requirements, and differ mainly in their initialization procedures and whether the positional computations are performed in real-time or post-proceed. The basic concepts of some of the most common survey techniques are explained below.

1) Static. Static survey is the most widely used differential technique for precise control and geodetic surveying. It involves long observation times (30 minutes to more than 6 hours, depending on the number of visible satellites, base line length, accuracy) in order to resolve the integer ambiguities between satellite and receiver. Accuracies in the sub-centimeter range can be obtained using this method.

2) Rapid Static. It’s used to measure baselines and determine positions ate the centimeter level with short, static observation times (5 to 25 minutes). The observation time is dependent on the length of the baseline and number of visible satellites. Loss of lock, when moving from one station to another, can also occur since each baseline is processed independent of each other. Unlike Pseudo Kinematic, stations are occupied only once. Dual-frequency receivers are required.

3) Kinematic. Kinematic surveying is a GPS carrier phase surveying that allows the user to rapidly and accurately measure baseline while moving from point to another. Stopping only briefly at the unknown points, or in dynamic motion. A reference base is set up at a known station and a rover traverse between the unknown points to be positioned. It needs some form of initialization to resolve the carrier ambiguities. This can be done by performing “antenna swap” procedure between two receivers.

4) Stop and Go Kinematic. It involves collecting static data for several minutes at each station after a period of initialization to gain the integers. This technique doesn't allow for loss of satellite lock during survey. If loss of satellite lock does occur, a new period of initialization must take place, this method can be performed by having two known stations.

5) Real-time Kinematic (RTK). This method is widely used for constructions and engineering works, construction stake outs. This method determines the integer number of carrier wavelengths between the GPS antenna to the GPs satellite while the rover receiver is in motion and doesn't need initialization, since it uses an " on the fly" integer initialization where no static initialization is needed.

CHAPTER FOUR

Field Work

- Introduction
- Getting familiar into using GNSS devices Methods of geoid modeling
- Points Selection
- Methodology of points selection
- List of points

CHAPTER FOUR

Field work

4.1 Introduction

As mentioned in the project timeline, a field work is to be performed in order to get a precise GNSS point readings, this work is divided into many stages; exploration of points on the area specified is to be done before the observation of points, also these points are located on some areas of personal property or it may be doesn't existing due to the early time of 1932 when the point where installed.

4.2 Getting familiar into using GNSS devices

Figure 4.1: components of GPS Trimble 5700[5]

Using GNSS based devices is roughly known for any researcher or a student of survey, hence, the use of GNSS static method that was described before is to be practiced in order to master the task needed to get the necessary data.

The initial stages of GNSS practical training on the devices is performed uing two brands of GNSS apparatus which are:

1) Trimble R8
2) Trimble 5700

Ultimately, the main structure of the devices are familiar, also using them became familiar and team is ready for the stage of point observations.

4.3 points Selection

Points that are needed is ones of known and briefly precise 3-dimensional coordinates, these are the trigonometric points fixed during the British mandate on Palestine.

The actual preparations for setting up a triangulation system commenced only in February 1921 after the Survey Department moved to its new home in Jaffa; the survey began in May 1921The first step was for the survey parties to lay out geodetic points throughout the entire country, to measure their values, and to provide mathematical bases for the survey nets. The geodetic points required for mapping are classed in three categories:

1) Fixed points, or trigonometric stations, are determined by trigonometric methods and must be in sight of each other for the surveying observations. These imaginary lines form the sides of the triangles of the observation net. The data obtained are the position of the points in planimetric coordinates. The elevation of the points is determined in relation to the datum (reference) level, which is the mean sea level (MSL).
2) Spot heights are determined by precise levelling and not necessarily in relation to the trigonometric net. The topographic heights are measured in relation to the MSL along fixed runs in the field.
3) Gravimetric points, for the determination of the figure of the Earth.

As the points of trigonometric stations are mostly available with their names and position values, so the points of project network is chosen from these points, a suitable coverage of an area within Hebron district is chosen according to the availability of points and ease of accessibility to them. Figure 5.2 illustrates the distribution of these points within the area of study. Table 5.1 also shows the information about points’ names and coordinates also it provides the location of the point according to the nearest town or city.

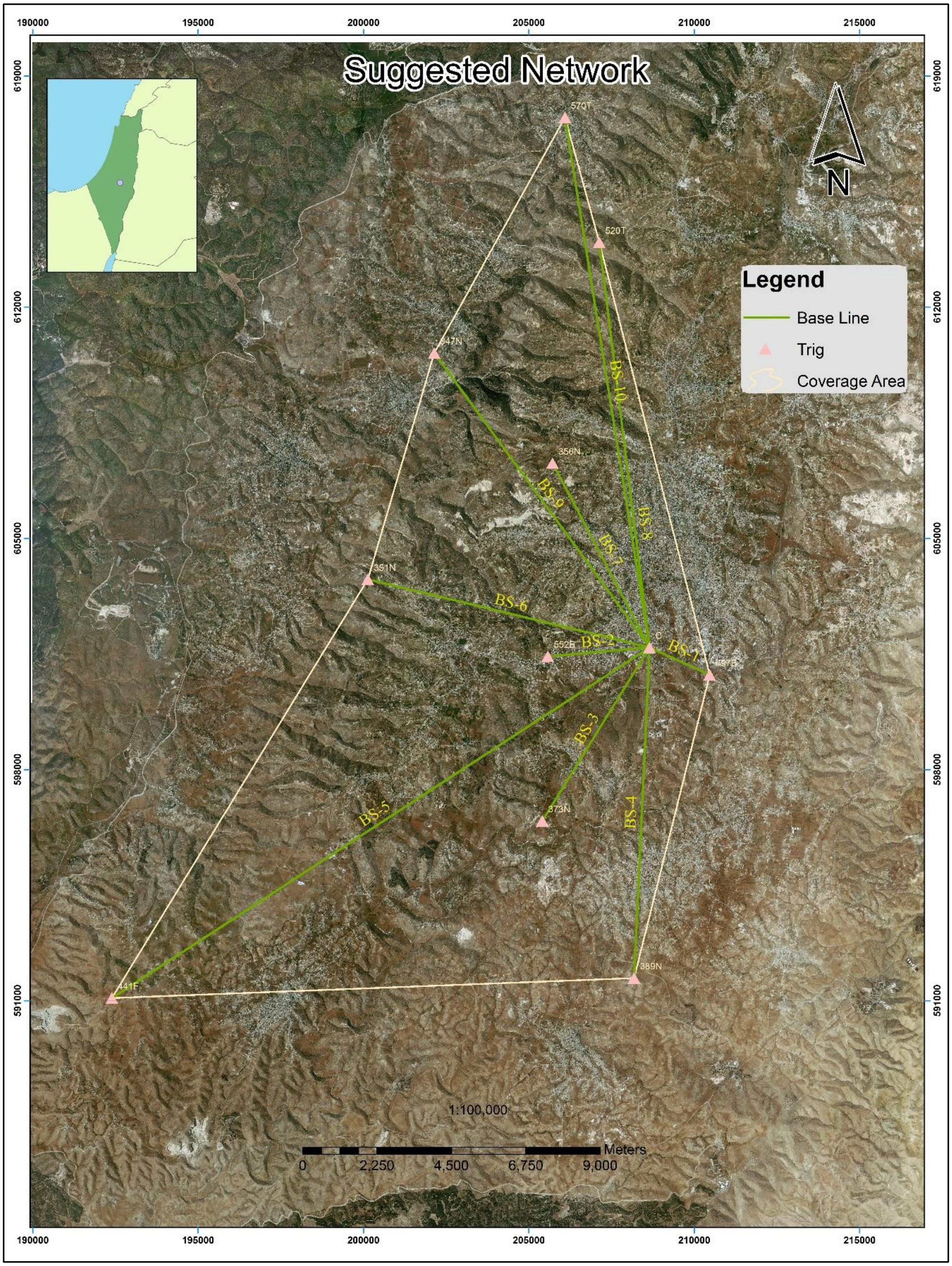


Figure 4. 2 : distribution of points within study area in Hebron district [11]

4.4 Methodology of point's selection

1. List of points and their coordinates are obtained from the Palestinian department of land and survey.
2. Benefiting from an orthophoto of the West Bank, and by conversion of the txt file of trigs into a shapefile in ArcMap. The location of points can be located.
3. The availability of points are not determined by a theoretical database, so exploration of the points is the only way to get into points.
4. By using of Garmin handheld GPS, the application of GOTO is used to explore the points and to reach them.
5. A resulting set of 10 points are available and explored, so they are just ready to be observed.

4.5 List of network points

Each point of network is described either by coordinates and aerial photos are listed

Table 4. 1: List of network points

Point name	Easting (m)	Northing (m)	Elevation (m)	Location
552B	155580.17	101424.37	913.81	Dura (Sinjer)
356N	155722.87	107271.25	875.47	Hebron (Looza)
441F	142397.9	91081.11	643.29	Aldahriyeh (Ramadeen)
520T	157133.47	113959.94	849.42	Halhoul (Jala)
351N	150135.28	103756.06	730.17	Dura (Homsa)
597B	160474.73	100867.46	902.79	Hebron (Qilqis mt.)
373N	155409.64	96442.86	739.5	Yatta (beit Emra)
389N	158184.65	91685.62	752.37	Yatta (Sosya)
347N	152144.28	110606.8	567.75	Beit Oula
570T	156096.76	117739.33	588.94	Sourif

Figure 4. 3 : Point 552B [11]

Figure 4.4: Point 356N [11]

Figure 4.5: Point 351N [11]

Figure 4.6: Point 389N [11]

Figure 4.7: Point 441F [11]

Figure 4.8 Point 347N [11]

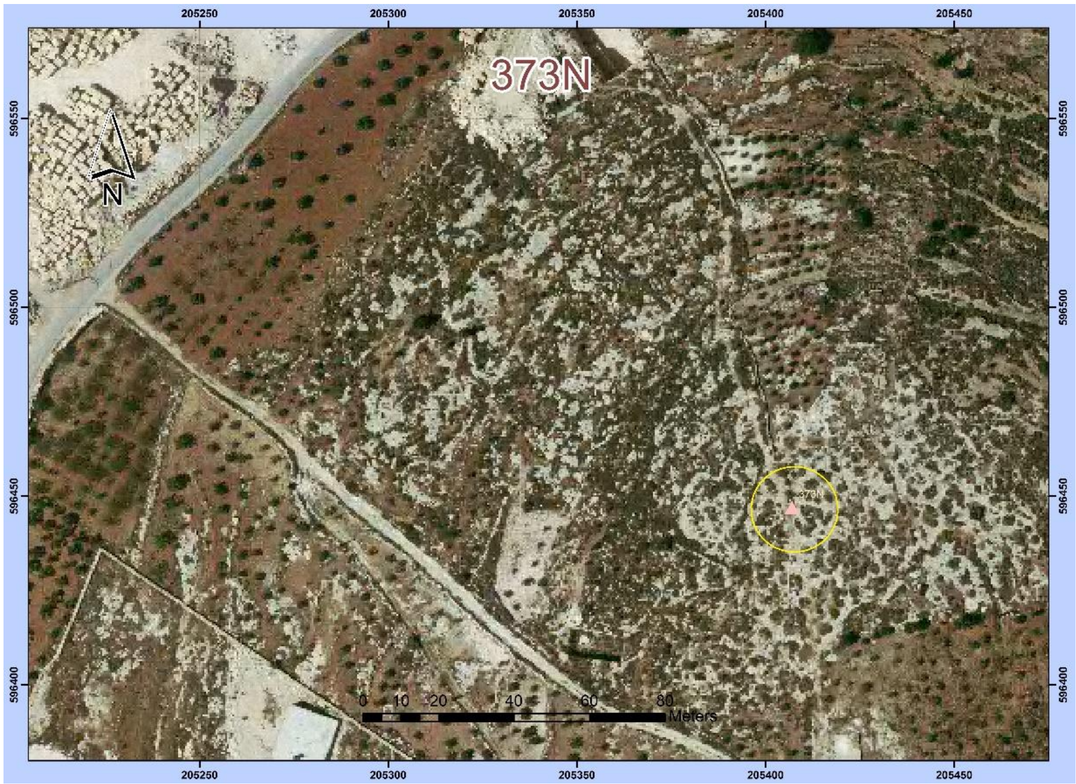


Figure 4.9 Point 373N [11]

Figure 4.10: Point 520T [11]

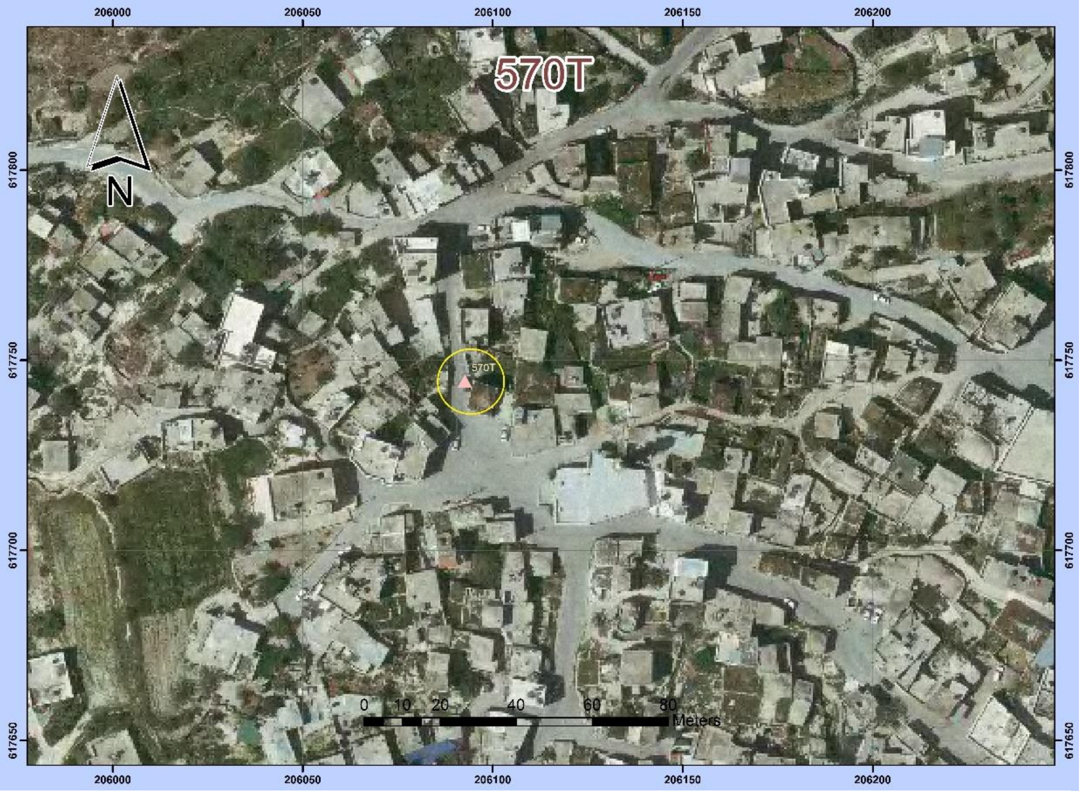


Figure 4.11 Point 570T [11]

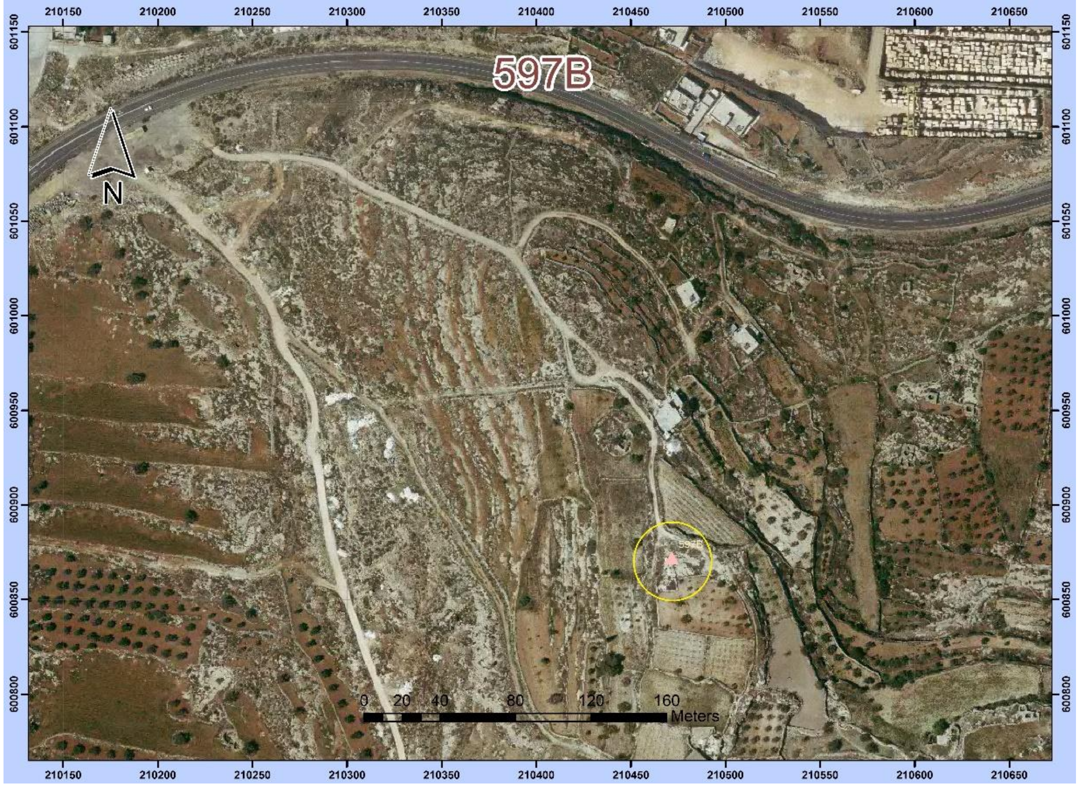


Figure 4.12: Point 597B [11]

1) Point 522B: this point is located at the hill of Sinjer neighborhood in Dura, it's located on a rock at the uphill. Figure (4.3) shows an orthophoto for the point mentioned.
2) Point 356N: this point is located at the hill in Looza neighborhood in Hebron, it's located on a rock at the uphill under Oak tree. Figure (4.4) shows an orthophoto for the point mentioned
3) Point 351N: this point is located on Humsa Dura, it's located on a vacant land. Figure (4.5) shows an orthophoto for the point mentioned
4) Point 389N: this point is located on Yatta and it's located on a rock on uphill of Sosya neighborhood. Figure (4.6) shows an orthophoto for the point mentioned
5) Point 441F: this point is located on Aldahreyeh and it's located on a rock on uphill near Alramadeen neighborhood. Figure (4.7) shows an orthophoto for the point mentioned.
6) Point 347N: this point is located on beat-Oula, it's located between two properties. Figure (4.8) shows an orthophoto for the point mentioned
7) Point 373N: this point is located on Yatta and it's located on a rock on Beietemra Figure (4.9) shows an orthophoto for the point mentioned.
8) Point 520T: this point is located on Halhul near Jala street, Figure (4.10) shows an orthophoto for the point mentioned.
9) Point 570T: this point is located on center of Sourif town on the center of a cross vault of a house near the main mosque, Figure (4.11) shows an orthophoto for the point mentioned.
10) Point 597T: this point is located on Hebron city at the top of Qilqis mount south to city center, Figure (5.11) shows an orthophoto for the point mentioned.

4.5 Obstacles of field work

Many obstacles in executing the project can appear, and many of them are already facing the process of work, some of these obstacles are related to the availability of the GNSS devices since the proposed devices to be used in this project are the same used in Palestine Polytechnic University (PPU) in the Department of Civil Engineering of architecture. Also weather conditions can affect the schedule of work.

4.6 Mission planning

In planning to go for using GNSS observation, it's important to choose a suitable time that provides a good results and precise work. Since GNSS depends on the constellation of the satellites that affects the DOP, consequently, that affects the quality and accuracy of observation got, it’s important to be in the suitable time and place to measure points.

Many of tasks should be accomplished before heading with apparatus to the field, and planning for GNSS/GPS working session should be performed before getting involved in the field, this can be performed following several useful and important tips

1) Firstly, the scope of the region to be measured should be determined, in order to decide which points can be reached and in same case that satellite signals can reach it without interruption or loss due the nature of the region (may be congested area, high rise buildings around etc.).
2) Checking for the satellite constellation during surveying, since that will highly affect the measurements. Recently, GNSS/GPS receivers manufacturers distribute software that provide information about the available visible satellites at specific points to be measured, it’s presented as a sky plot for the area to be worked on with the available satellites and values of DOPs that can make it clear for the surveyor to determine the best time of best constellation, more satellites and least DOP
3) Checking for the weather forecast just before going to field so as to decide whether is it appropriate to work under certain circumstances.

4.6 Data Collection

Heading to field to get data from GNSS observation needs an arrangement for data, RINEX files that are stored in the memory of the receiver is used, also an arrangement for the data observed is to be documented using a data collection sheet as follows on the next page

GNSS Point Measurement Sheet

Point ID.______________

Team: Masharqah, Sbeitan, Sweity.	**Date: / / 2013**
Instrument:	**Output File:**
GNSS Type ∆ Base ∆ Rover	
Antenna Height	
Measurement Start Time	
Measurement Finish Time	
Description of location	
Point Ties	**Point shot**

Chapter 5

Data processing, calculations and results

5.1 Introduction

Points that were described and identified in the previous chapter are observed using GNSS static method of observation, and the resulted raw data are subjected to many mathematical operations in order to get its accuracy, and then to get the desired results of the heights reference surface.

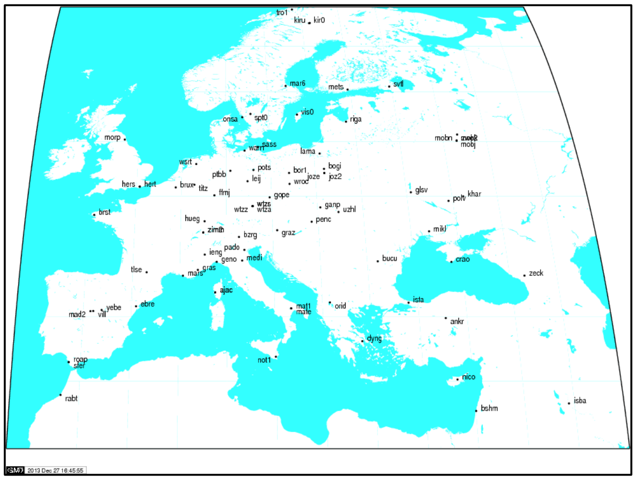
5.2 Data processing

Static observation method is classified as a post-processing observation method, and the method used here to process data is by benefiting from AUSPOS online service to get the 3D position of each point observed

5.2.1 AUSPOS online service

AUSPOS is a free online GPS data processing facility provided by Geoscience Australia, and it's a free available online tool that works with any static data collected on the earth in a more than one hour observations. Data observed by static method are submitted and uploaded online, after while the processing results could be received containing values of geodetic and Cartesian coordinates value with their accuracy values in a form of SINEX files (available on appendix (B)).

Figure5. 1 Available IGS Stations in Europe and Mediterranean at a specific time[]



This service takes benefit from the IGS (international GNSS service) tracking network, which is a set of ground stations of world-wide spread network that are provided with hourly updated position values, figure (5.1) shows the IGS stations in the area around the Mediterranean sea and Europe at a specific time.

The results received by AUSPOS are summarized on table (5.1) that shows geodetic position values of the observed points.

Table 5.1 Values of Coordinates and accuracy of observed points

Point	Position Geodetic coordinates (WGS84/GRS80) (Degrees)(Meters for H)					
	Lat	*Long*	*h*	*σLat*	*σLong*	*σh*
347N	31.58762638	35.02204579	587.4169	0.0933	0.0898	0.2058
351N	31.52580931	35.00101277	748.9729	0.0162	0.0238	0.0287
356N	31.55759318	35.05979802	895.2368	0.0148	0.0633	0.0421
373N	31.45993032	35.05665236	758.4460	0.0223	0.0344	0.0381
441F	31.41134169	34.91989644	663.4462	0.0099	0.0180	0.0366
520T	31.61793341	35.07456802	868.8533	0.0197	0.0401	0.0378
597B	31.49988480	35.10990263	921.6776	0.0114	0.0227	0.0243
570T	31.65200666	35.06359326	609.6782	0.0088	0.0126	0.0317
ST1	31.50486002	35.05837632	933.5242	0.0084	0.0132	0.0300

The values of N (geoid undulations) are calculated for each point by applying the equation (1.1), table (5.2) below indicates the value of N for each point.

Table 5.2 Calculations of Geoid Undulations

Point	*Ellipsoidal Height (h)*	*Orthometric Height (H)*	*Geoid Undulation (N = h – H)*
347N	587.4169	567.75	19.667
351N	748.9729	730.17	18.803
356N	895.2368	875.47	19.767
373N	758.4460	739.50	18.946
441F	663.4462	643.29	20.156
520T	868.8533	849.42	19.433
597B	921.6776	902.79	18.888
570T	609.6782	588.94	20.738
ST1	933.5242	913.81	19.714

5.3 Surface Interpolation

Getting the values of Geoid undulations for each point enables to apply an interpolation for these values to get a graphical surface representation for the area covered by this area, the method used is the inverse distance weighted (IDW) interpolation. Inverse distance weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance with a specific power of inverse distance. The power of the inverse distance provides that far points affect less on the value of the unknown point than near ones.

By defining a higher power value, more emphasis can be put on the nearest points. Thus, nearby data will have the most influence, and the surface will have more detail (be less smooth). As the power increases, the interpolated values begin to approach the value of the nearest sample point. Specifying a lower value for power will give more influence to surrounding points that are farther away, resulting in a smoother surface.

Since the (IDW) formula is not linked to any real physical process, there is no way to determine that a particular power value is too large. As a general guideline, a power of 30 would be considered extremely large and thus of questionable use. Also keep in mind that if the distances or the power value are large, the results may be incorrect.

A simple form of (IDW) formula is described in equation (5.1)

$$F(X,Y)=\sum_{i=1}^{n} w_i f_i \tag{5.1}$$

Where

$n : The\ number\ of\ scatter\ points\ (knowns)$

$f\ : The\ function\ of\ origional\ (known) points\ [N\ in\ this\ project]$

$w\ : weight\ functions\ assigned\ for\ each\ point\ [see\ equation\ 5.2\ ]$

$$w_i = \frac{h_i^{-p}}{\sum_{j=1}^{n} h_j^{-p}} \tag{5.2}$$

Where

p : $Power\ parameter\ [typicaly\ p = 2]$

h_i : *The distance from the scatter point to the interpolation point*

Equation (5.1) is also called Shepard's method [(8)] depending on the name of its innovator, this equation is the basic formula in how graphical interpolation softwares and applications are working on, points on this chapter are subjected to (IDW) interpolation using application of Esri® ArcGIS® and the resulting graphical representations are availiable on Appendix (A).

In addition to the produced surface, an EGM2008 geoid model values are extracted for the study area, and an error surface is produced by applying raster calculations on both the produced surface and the EGM2008 surface depending on equation (5.3)

$$P(x_i, y_j)_{Diff} = P(x_i, y_j)_{EGM2008} - P(x_i, y_j)_{Produced} \tag{5.3}$$

Where

$P(x_i, y_j)_{diff}$: $Pixel\ value\ at\ any\ point\ for\ diffrence\ surface$

$P(x_i, y_j)_{EGM2008}$: $Pixel\ value\ at\ any\ point\ for\ EGM2008\ surface$

$P\left(x_i, y_j\right)_{Produced}$ :: $Pixel\ value\ at\ any\ point\ for\ the\ produced\ surface$

5.4 Results

Table 5.3 Difference between produced model and EGM2008

Point	*Geoid Undulation (N = h – H)*	*Geoid Undulation (EGM2008)*	Difference m
347N	19.667	19.981249	0.314257
351N	18.803	19.705931	0.902931
356N	19.767	19.925194	0.158194
373N	18.946	19.450581	0.504581
441F	20.156	19.157467	-0.99853
520T	19.433	20.141239	0.708239
597B	18.888	19.514969	0.626969
570T	20.738	20.210653	-0.52735
ST1	19.714	19.653257	-0.06074

For discrete 9 observed points' difference between EGM2008 model and the points can be tabulated and difference can be expressed numerically as follows in table (5.3), the table shows the difference between the observed points and the EGM2008 model, this difference ranges between (0.060) to (0.998533) meters, this range provides that point (441F) has the greater difference, from the location and geometry of the point, which is the farthest one, and lies on a sharp far edge of the corner of the observed point network, that may explain the abnormality of the result, moreover, the other data ranges around each other. The average of difference is (0.533533) m and this values complies with the published accuracy of EGM as $(\pm 0.5m)$.

Additional maps are available in appendix () that shows the model and points with geoid undulations.

Chapter 6

Conclusions and recommendations

6.1 Conclusions

In this project a network of trig points sets are observed in a static GNSS technique which provided a high accuracy in readings and gives a reference values for their coordinates either horizontal or vertical values. The test was performed on the difference between calculated EGM2008 and the values calculated from observed points and available orthometric heights expressed an average value of about 0.5 m, but it’s highly recommended to take in mind that the available orthometric heights used are not accurate and the only available source of them doesn’t indicate the method observed, this may be the main source of errors in the project.

A graphical representation of the reference surface is not recommended for the whole area of Hebron district, since the available reachable trig points can’t cover the whole area in a uniform spreading, the problem of reaching the eastern points of the district is related to the dangerous military areas and settlements that are classified as C areas (Occupied lands)

6.2 Recommendations

The process preformed and its results recommends that the orthometric heights of the trigs in the district are to be observed, calculated and corrected. The observed points on this project can be used as a precise bench marks for surveyors and future scholars on the domain, also an extended time for observations for the same points can give a better accuracy for these who wants to study the reference surface again.

For future studies on the same district for having a full district surface, points are to be observed in the eastern region that are strict areas.

CHAPTER FIVE

Data processing, calculations and results

- Introduction
- Data processing
- Surface Interpolation
- Results

CHAPTER SIX

Conclusions and recommendations

- Conclusions
- Recommendations

References

Books

[1] Bossler, J. D. (2002). *Manual of Geospatial Science and Technology.* London: Taylor & Francis.

[2] French, G. T. (1996). *Understanding The GPS.* Chicago: GeoResearch.Inc.

[3] Gavish, D. (2005). *A Survey Of Palestine Under The British Mandate.* London: RoutledgeCurzon.

[4] Moritz, D. H. (2005). *Physical Geodesy.* Veina: Springer-Verlag Wien.

[5] R.Well, L. (2001). *Global Positioning System,Inertial Navigation and Integration.* NY: John Wiley and sons.

[6] Wahr, J. (1996). *Geodesy and Gravity.* Colorado: Samizdat.

[7] Zogg, J.-M. (2002). *GPS basicis.* Zuercherstrasse: Ublox.

Thesis

[8] M.Talahmeh and F.Najajreh and F.Tarayreh,*GPS height Integration,Bachalor,* Palestine Polytechnic University PPU,2007

[9] A.Abdallah, *Determination of a Gravimetric Geoid Model of Sudan Using the KTH Method*, MA, Royal Institute of Technology of Stockholm,2009

Websites

[10] National Geospatial-intelligence Agency, Raster data of EGM 2008, available at htttps://www.nga.net/data/Egm2008toWGS84

Map Resources and aerial photos

[11] Ortho photo for the West Bank,2011