Earthwork Simulation Using RTK GPS

by

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

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September 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MUHAMMAD SYEQAL ALZA BIN ALIAS

ABSTRACT

The earthwork simulation using RTK GPS is a study to simulate earthwork based earth topography that are represented using Digital Terrain Model (DTM) which is in 3 dimensional views that are derived based on the data collected using the RTK GPS surveying method. The research is conducted due to the problem of conventional total station survey which causes nuisances in term of slow survey speed, labours intensive and required intervisibility between the stations. Furthermore, the latest surveying technology of Light Detecting and Ranging (LIDAR) are tedious as the differences between the surface and the terrain are difficult to be differentiated. In addition, the data presentation of the earth topography in 2D plan is not an efficient medium for engineer to estimate for the earthwork. Therefore, this research is conducted covering the data collection using RTK GPS surveying work to cater for the surveying problems and data processing into the earthwork simulation that are represented in 3D view to cater for the inefficient 2D survey plan.

Keywords: Earthwork Simulation, Real Time Kinematic GPS (RTK GPS), Digital Terrain Model (DTM).

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CHAPTER 1: INTRODUCTION

1.1 Background of Study

Earthwork is a common activity in the civil engineering field of work. In conjunction with that, earthwork are intended for various purposes such as slope stability, drainage construction and to establish an even ground for a structure to stand firm on it. On the other hand, before earthwork processes can begin, the earth original ground level has to be determined. Therefore, land surveying will be carried out. Conventionally, total station is implemented. However, this gadget causes nuisances in term of slow speed of survey, the need to have intervisibility between the total stations and labours intensive. On the other hand, the advancement of technology has seen the birth of LIDAR (Light Detecting and Ranging) surveying modus operandi. It uses the theory of light travel in a straight line and are reflected when it encounters an obstacles. In simple words, aeroplane is uses to map out the earth topography by using laser scanning. However, this method required a more processing time since the different between the surface and the terrain are a tedious work. Hence, this is where the RTK GPS surveying method comes into the picture. RTK GPS provide ease in surveying that does not required intervisibility between the stations, relatively faster, less labours are required and the earth original ground level can be obtain directly.

Moreover, the conventional 2 dimensional surveying plan does not provide an effective medium for engineers to study the earth topography. Thus, Digital Terrain Model (DTM) has been introduced that will represented the earth topography in a 3 dimensional view, thus engineers can have a real life interaction with the site surface.

Thus, this paper is a study of the earthwork simulation using RTK GPS that promises an accurate data up to centimetre level and establish simulation in 3 dimensional views that can assist engineers to come out with several alternatives by considering the options that causes minimal damage to the environment, cost effective and resulted in a proper construction project management. GPS.gov (2013) [12] stated that "When used by skilled professionals, GPS provides surveying and mapping data of the highest accuracy. GPS-based data collection is much faster than conventional surveying and mapping techniques, reducing the amount of equipment and labour required. A single surveyor can now accomplish in one day what once took an entire team week to do."

1.2 Problem Statement

a. Problem Identification

The earthwork process is a complex task as the site topography, soil properties, work force and machinery available has to be considered. A set of plan has to be establish in order for the work to be safe, cause minimal disturbance to the nature, and cost effective.
In current practice, the work is done based on the engineer experience and rough estimation that can lead to abuse of nature and not cost effective. Moreover, wrong judgement that delays the earthwork process lead to slow progress of project. On the other hand, surveyour encountered nuisances of collecting terrain data due to slow speed of total station surveying method and the necessity for intervisibility is time consuming.

In short, the main problems is that **the conventional method of earthwork estimation cannot provide engineer with an efficient medium for details assessment of the site and to come out with several alternatives as an optimum options and conventional total station surveying work is a nuisances in term of slow speed surveying and require much man power.**

b. Significant of Project

Nowadays, sustainable development is vital as the government are moving towards 'Go Green' agenda [2]. Furthermore, in construction project management, proper cost planning is crucial. This is associated with the usage of machinery and workforce that required humongous amount of fund allocation. Moreover, human health and safety issue is the main priority highlighted by the Construction Industry Board of Malaysia (CIDB), this proven by the publishing of the Construction Industry Standard or CIS 10: 2008 in November 2008 for the Safety and Health Assessment System in Construction (SHASSIC) [3] .Thus, based on the earthwork simulation produce, engineers can have a 3D view of the site condition that is up to centimetres level of accuracy. Thus, engineers can come out with different set of alternatives by taking consideration of the environmental impact, machinery usage, workforce amount and human health and safety.

At the end of the day, **proper management of earthwork process can be carried out by using the earthwork simulation using RTK GPS as best alternative is produce**

that causes minimal damage to the surrounding environment, effective usage of workforce and machinery and promote good health and safety factors.

1.3 Objective & Scope of Study

1.3.1 Objectives

The main objective of this project is:

a. **To perform earthwork simulation using RTK GPS**.

Through this idea of performing earthwork simulation using RTK GPS can lead to several other objectives such as promoting sustainable development in construction industry and proper construction management in terms of effective fund usage and prioritise the health and safety concern in the construction practices.

1.3.2 Scope of Studies

The scope of studies in this projects is based on several keywords that is Digital Elevation Model (DEM), Global Positioning System (GPS), Real Time Kinematics GPS (RTK GPS), Earthwork and Earthwork Simulation. The following are the scope of studies:

1. Surveying work at site of studies using RTK GPS for data collection.
2. RTK GPS data processing in the Geomatic software laboratory to produce DEM.
3. Data analysis of the DEM for earthwork simulation.
4. Producing earthwork simulation based on analyse data.
5. Study the earthwork 3D simulation for earthwork planning and modus operandi.

1.4 The Relevancy of the Project

The usage of RTK GPS in the construction industry has not being fully implemented. This is due to the lack of awareness to the benefits of implementing earthwork simulation using RTK GPS that can assist project manager in proper management of machinery usage and workforce allocation. Furthermore, sustainable development is the new agenda that the government has been focusing on. In support of this, earthwork simulation using RTK GPS are expected to enhance environmental impacts control due to human activities. Moreover, CIDB has launched the SHASSIC programs to enhance the concern of contractor on health and safety issue in construction industry.

Thus, **the study on Earthwork Simulation of RTK GPS is relevant in support of the government sustainable development agenda and CIDB SHASSIC programmed. At the same time benefits the contractor by promoting better cost management through good construction project management**.

1.5 The Feasilibility of the project within the Scope and Time

1.5.1 Scope Feasibility

- The equipment required for the project and the software use is already available in the Geomatic Laboratory of Civil Engineering Department University of Technology Petronas located at Building 14 level 2.
- The site is picked based on the uneven of the topography to provide a better result and to study based on real site condition which is abundant in the state of Perak.
- The training of using RTK GPS and Simulation software will be assist by the Geomatic Lab Technician and the Postgraduate students as per their agreement and willingness.

1.5.2 Time Feasibility

The project required two types of activities:

- Site surveying at the field
- Data analysis and simulation study in the geomatic laboratory

Thus, to ensure the projects are feasible within time frame, the site of studies is limited to a range of about 10 m by 10 m boundaries.

Furthermore, assistant from the lab technicians and the post graduates students on the data analysis and earthwork simulations will increase the time efficiency.

CHAPTER 2: THEORY & LITERATURE REVIEW

In this section, the Earthwork Simulation using RTK GPS are further discussed by assessing and referred on the research paper, journals and other references that have been published on the subject. The explanations will discuss based on each keywords of DEM, GPS, RTK GPS, Earthwork and the Earthwork Simulation.

2.1 DIGITAL ELEVATION MODEL (DEM)

2.1.1 What is DEM?

Initially, Wikipedia (2013) said that "A digital elevation model is a digital model or 3D representation of a terrain's surface — commonly for a planet (including Earth), moon, or asteroid — created from terrain elevation data."

Thus, in conjunction with the above definition, Softwright (n.d.) added that "Digital Elevation Models are data files that contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the surface of the earth. The intervals between each of the grid points will always be referenced to some geographical coordinate system. This is usually either latitude-longitude or UTM (Universal Transverse Mercator) coordinate systems. The closer together the grid points are located, the more detailed the information will be in the file. The details of the peaks and valleys in the terrain will be better modelled with small grid spacing than when the grid intervals are very large."

Therefore, Satellite Imaging Corporation (2013) explained that "DEM is generally synonymous with a Digital Terrain Model (DTM)."

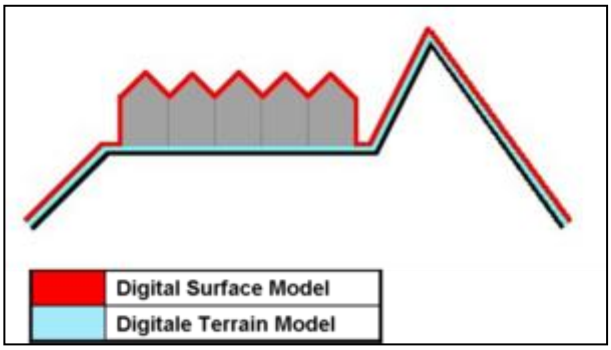


Figure 2.1.1 A. The Digital Surface Model and Digital Terrain Model. (Source: Wikipedia : 2013) .

The Figure 2.1.1 A shows the digital surface model include the objects such as buildings as part of it model. However the digital terrain model shows only the bare ground of the earth that totally depending on the elevation of the bare ground without considering the objects standing on it.

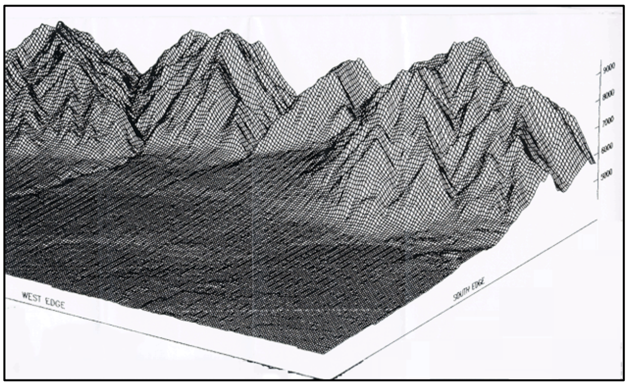


Figure 2.1.1 B. The Digital Elevation Model Example. (Source: USGS : n.d.).

On the other hand, the DEM can be represented as TIN (Triangulated Irregular Network). According to Satellites Imaging Corporation (2013) “TIN's are sets of adjacent, non-overlapping triangles computed from irregularly spaced points with x/y coordinates and z-values. TIN models are used to provide better control over terrain slope, aspect, surface areas, volumetric and cut-fill analysis and generating contours.” Furthermore, “The TIN's vector data structure is based on irregularly-spaced point, line and polygon data interpreted as mass points and breaklines and stores the topological relationship between triangles and their adjacent neighbours.”

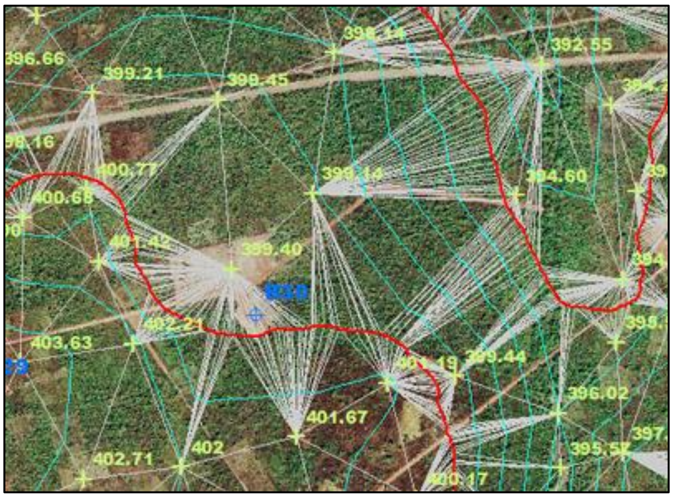


Figure 2.1.1 C. The Digital Elevation Model represented in TIN. (Source: Satellites Imaging Corporation : 2013).

In this project, the DEM focuses it usage on the earthwork process of construction. The DEM is implemented in the simulation stage of the project where the topography of the site will be model out in the software into 3 dimensional models. Furthermore, according to Wikipedia (2013), the elevation data usage in producing the DEM can be obtained from surveying using Real Time Kinematic GPS.

2.2 GLOBAL POSITIONING SYSTEM (GPS)

2.2.1 What is GPS?

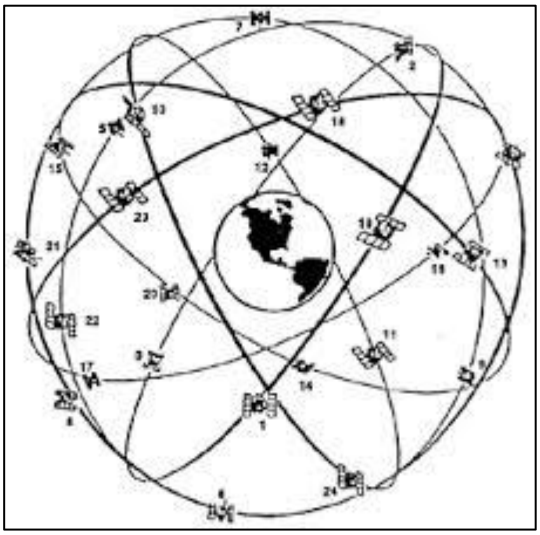


Figure 2.2.1 A. The Satellite Constellation in the Earth Orbit. (Source: Partrick's Webpage:2007).

Garmin (2013) stated that "The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or setup charges to use GPS".

Furthermore, to go deeper into the subject, GPS.gov (2013) document that "The Global Positioning System (GPS) is a U.S.-owned utility that provides users with positioning, navigation, and timing (PNT) services. This system consists of three segments: the space segment, the control segment, and the user segment. The U.S. Air Force develops, maintains, and operates the space and control segments."

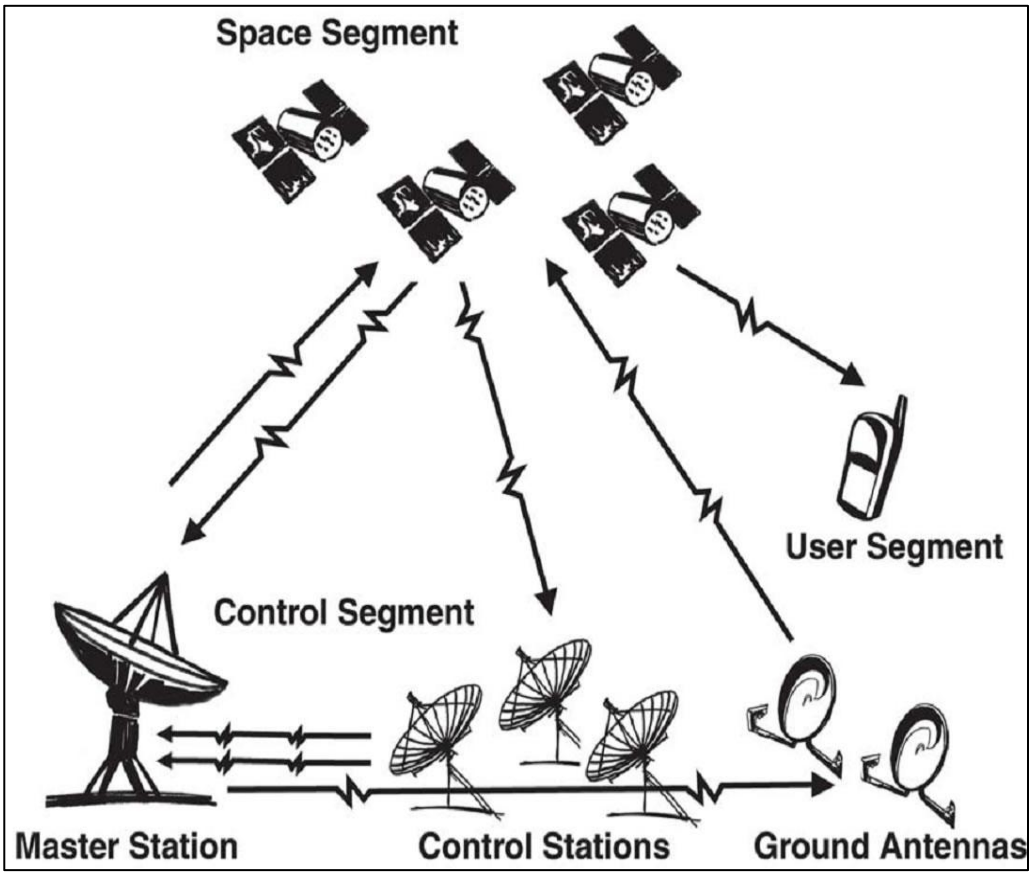


Figure 2.2.1 B. Segment of the GPS System. (Source: Navigation and Flight Control :2012) .

Based on the above theory, Patrick's Webpage (2007) added that:

The GPS space segment uses a total of 24 satellites in a constellation of six orbiting planes. This configuration provides for at least four equally spaced satellites within each of the six orbital planes. The orbital planes have an inclination of 55° relative to the earth's equator. At 20,200km, GPS satellites are able to complete one orbit around the earth every 11 hours and 58 minutes. Since the earth is rotating under the satellites, the satellites trace a track over the earth's surface, which repeats every 23 hours 56 minutes. A user at a fixed location on the ground will observe the same satellite each day passing through the same track in the sky, but the satellite will rise and set four minutes earlier each day, due to the four minute difference between the rotational period of the earth and two orbital periods of a satellite. The satellites are positioned in orbital planes so that four or more satellites, with a good geometric relationship for positioning, will normally be observable at every location on earth.

Thus, based on the literature review above, the GPS is a technology originating from the army advance navigational and positioning technology development. GPS technology has been introduced to the world as early as 1980’s and the technology is constantly developing and upgrade from time to time. GPS are widely use in army for navigating submarine, missiles and locating enemy position. Nowadays, according to GPS.gov (2013), “GPS are use by civilian for navigation while driving and up until today, GPS have been developed to fit various activities such as agriculture, aviation, marine, environment, public safety and disaster relief, rail, recreation, road and highways, space exploration, timing and surveying and mapping.”

2.2.2 The GPS Datum

GPS uses Earth Centred Earth Fixed (ECEF) coordinate system WGS’84. NCHRP Synthesis 258 (1995) stated that “There are three surfaces to consider when making measurement on the earth,as shown in Figure 2.1.2:

1. The topography – the physical surface of the earth
2. The geoid – the equipotential (gravity) surface that best approximates mean sea level; and
3. The ellipsoid- a mathematical reference surface that approximates the shape and size of the earth.

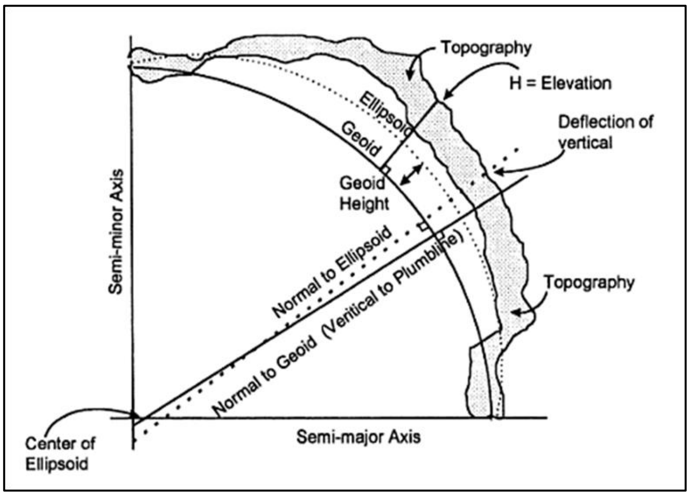


Figure 2.2.2. Measurement Surfaces of the Earth. (Source: NCHRP Synthesis 258 :1995) .

Furthermore, NCHRP Synthesis 258 (1995) also stated that "GPS measurement, on the other hand, is referred to an ellipsoid, a mathematical surface centered at the mass center of the earth."

Thus, the datum of the measurement made using GPS is taking the centre of the earth as the datum that is the (x,y,z) is (0,0,0). Therefore, any measurement made will be referred to the earth centred earth fixed (ECEF) coordinate system of WGS'84.

2.2.3 How it works?

Garmin (2013) defined that "GPS satellites transmit two low power radio signals, designated L1 and L2. Civilian GPS uses the L1 frequency of 1575.42 MHz in the UHF band."

In order to understand the GPS satellites signals, Garmin (2013) also stated that "A GPS signal contains three different bits of information - a pseudorandom code, ephemeris data and almanac data. The pseudorandom code is simply an I.D. code that identifies which satellite is transmitting information. You can view this number on your Garmin GPS unit's satellite page, as it identifies which satellites it's receiving. Ephemeris data, which is constantly transmitted by each satellite, contains important information about the status of the satellite (healthy or unhealthy), current date and time. This part of the signal is essential for determining a position. The almanac data tells the GPS receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits almanac data showing the orbital information for that satellite and for every other satellite in the system."

Thus, based on the data received, the location of the GPS receiver can be determined by using triangular method as the Ephemeris data and Almanac data will spot the location of the satellite in the orbit at the exact time as in the earth. This calculation is based on a fundamental concept of distance equal to velocity multiply the time taken as shown below:

$$Distance\ (m) = Velocity\ \left(\frac{m}{s}\right) x\ Time(s) \quad \text{...(1)}$$

To support this idea, Navigating at the Speed of Satellites (n.d.) stated that "Navigation satellites are like orbiting landmarks. Rather than seeing these landmarks with our eyes, we "hear" them using radio signals." Thus, Wikipedia (2013) stated that "Radio waves are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light. Radio waves have frequencies from 300 GHz to as low as 3 kHz, and corresponding wavelengths ranging from 1 millimeter (0.039 in) to 100 kilometers (62 mi). Like all other electromagnetic waves, they travel at the speed of light."

To explain on the speed of light, Wikipedia (2013) specify that "The speed of light in vacuum, commonly denoted *c*, is a universal physical constant important in many areas of physics. Its value is exactly 299,792,458 metres per second, a figure that is exact because the length of the metre is defined from this constant and the international standard for time."

Therefore, the velocity is considered as the speed of light. The time is measured from when the signal is transmitted from the satellites until it reaches the receiver. Thus, the distances obtained can be use as radius with the satellites as the centre point producing a circle that locate the possible location of the receiver along it circumferences.

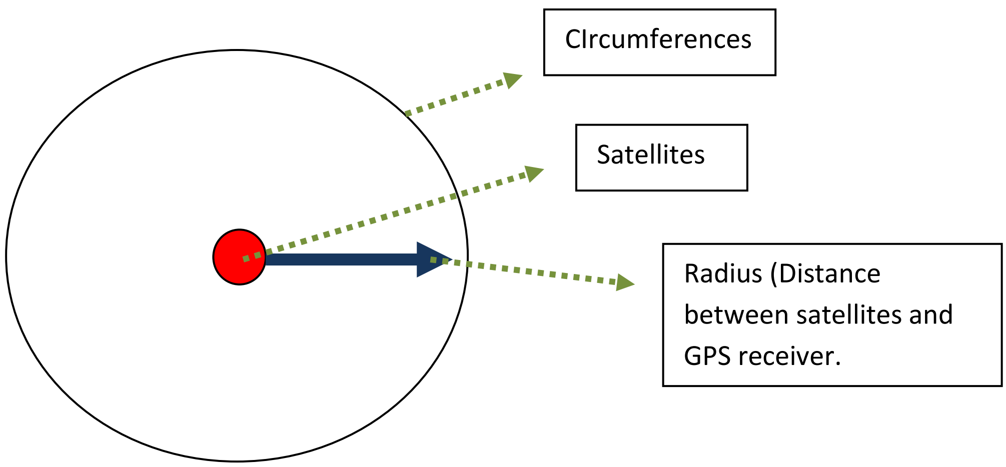


Figure 2.2.3 A. The circle locating possible location of GPS receiver.

In short, based on the simple explanation above, the process are repeated using 3 others satellites that will eventually pin point the location of the GPS receiver at the surface of the earth. The process are shown in Figure 2.2.3 B, the radius for satellites number one is 12, 000 miles, second satellites is 11, 000 miles and the third satellites is 11,500 miles.

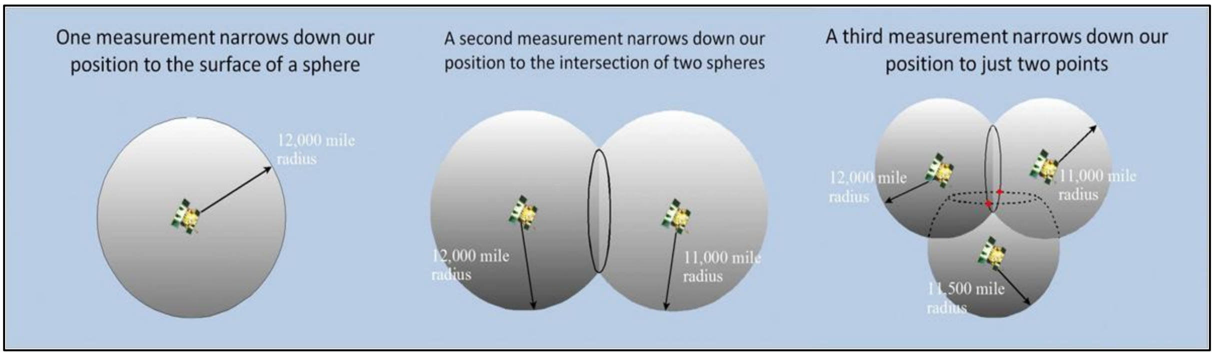


Figure 2.2.3 B. The process of locating the GPS receiver. (Source: Ocean Adventure Rowing and Education :2013) .

The formula (1) can further developed to cater for the 3 Dimension element of x,y and z that is needed to suit for the real life situation. Partick's Webpage (2007) stated that:

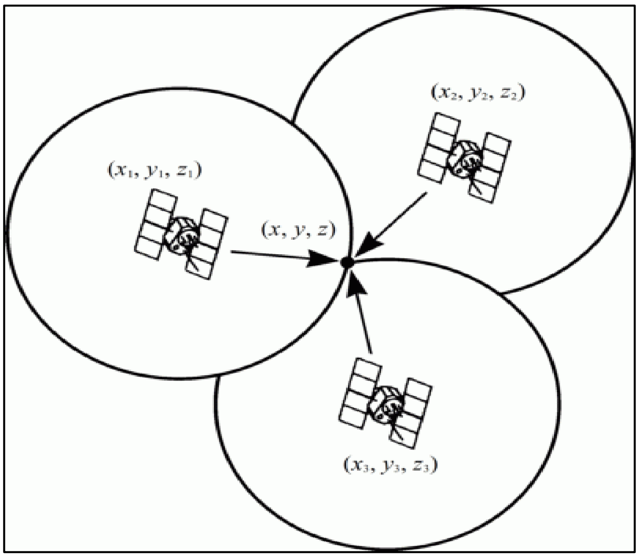


Figure 2.2.3 C. The three satellites and the GPS receiver coordinate. (Source: Partrick's Webpage :2007) .

For the 3D case, three satellites are required. The pseudoranges yield spheres of position (Figure 2.2.3 C). Clearly, a unique receiver position (x, y, z) of the receiver can be determined by solving the following equations:

$$p_1 = (\sqrt{(x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2}$$

$$p_2 = (\sqrt{(x - x_2)^2 + (y - y_2)^2 + (z - z_2)^2}$$

$$p_3 = (\sqrt{(x - x_3)^2 + (y - y_3)^2 + (z - z_3)^2} \quad \text{...(2)}$$

where (x_1, y_1, z_1), (x_2, y_2, z_2), and (x_3, y_3, z_3) are the known positions of the satellites, and p_1, p_2 and p_3 are the measured pseudoranges.

Since the receiver clock used to measure the signal propagation times is not synchronized to GPS time, the clock offset between receiver time and GPS time must be determined. This parameter can be calculated by adding a fourth satellite. By design, all of the satellite clocks are synchronized using very precise atomic clocks. The cheap crystal oscillators used in the receivers introduce a time offset (clock bias) between the receiver and the GPS clocks so one must consider their effects in the computation. The receiver clock bias is the time offset of the receiver, and it is the same for each satellite. Thus both the receiver position and clock offset can be derived from the following equations:

$$p_1 = (\sqrt{(x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 + c(dt - dT_1)}$$

$$p_2 = (\sqrt{(x - x_2)^2 + (y - y_2)^2 + (z - z_2)^2 + c(dt - dT_2)}$$

$$p_3 = (\sqrt{(x - x_3)^2 + (y - y_3)^2 + (z - z_3)^2 + c(dt - dT_3)}$$

$$p_4 = (\sqrt{(x - x_4)^2 + (y - y_4)^2 + (z - z_4)^2 + c(dt - dT_4)} \quad \text{............................(3)}$$

where (x_1, y_1, z_1), (x_2, y_2, z_2), and (x_3, y_3, z_3), and (x_4, y_4, z_4) are the known satellite positions, p_1, p_2, p_3, and p_4 are measured pseudoranges, c is the speed of light, dT_1, dT_2, dT_3, and dT_4 are the known satellite clock bias terms from GPS time, and dt is the unknown receiver clock offset from GPS time. The satellite clock bias terms are calculated by the receiver from the broadcast navigation message.

The time differences are corrected by the control segment on earth which is at a known position and has time exactly the same as the time at the GPS satellites. The process is described in Figure 2.2.3 D.

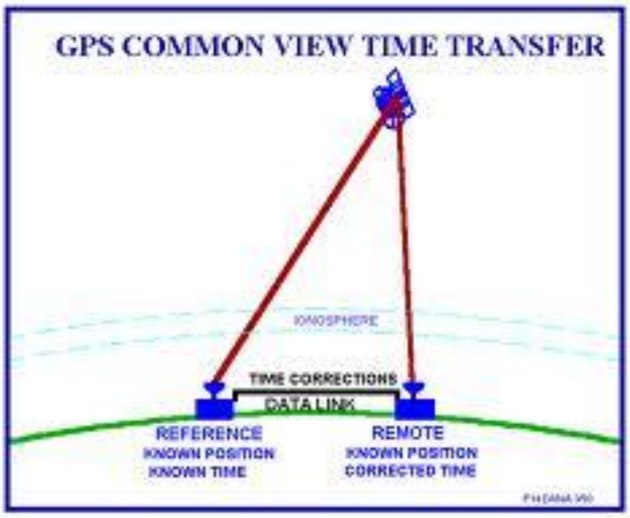


Figure 2.2.3 D. The GPS time correction. (Source: PDF Online :n.d.) .

2.2.4 GPS Limitation and errors

Before using GPS, several limitations and errors of usin GPS needed to be understood to avoid data error. Therefore, Garmin (2013) stated that:

Factors that can degrade the GPS signal and thus affect accuracy include the following:

1. Ionosphere and troposphere delays - The satellite signal slows as it passes through the atmosphere. The GPS system uses a built-in model that calculates an average amount of delay to partially correct for this type of error.
2. Signal multipath - This occurs when the GPS signal is reflected off objects such as tall buildings or large rock surfaces before it reaches the receiver. This increases the travel time of the signal, thereby causing errors.

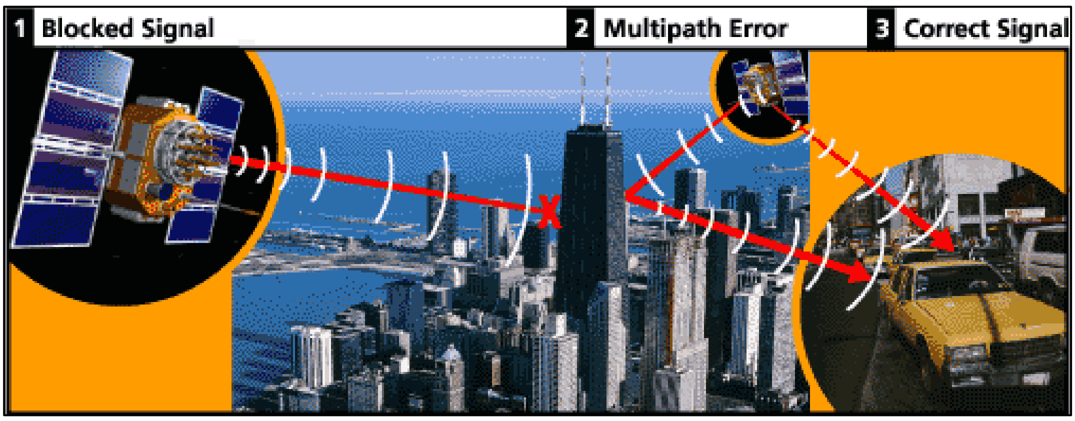


Figure 2.2.4 A. The GPS signal blocked by tall building and corrected by another satellites. (Source: Garmin :2013)

3. Receiver clock errors - A receiver's built-in clock is not as accurate as the atomic clocks onboard the GPS satellites. Therefore, it may have very slight timing errors.
4. Orbital errors - Also known as ephemeris errors, these are inaccuracies of the satellite's reported location.
5. Number of satellites visible - The more satellites a GPS receiver can "see," the better the accuracy. Buildings, terrain, electronic interference, or sometimes even dense foliage can block signal reception, causing position errors or possibly no position reading at all. GPS units typically will not work indoors, underwater or underground.
6. Satellite geometry/shading - This refers to the relative position of the satellites at any given time. Ideal satellite geometry exists when the satellites are located at wide angles relative to each other. Poor geometry results when the satellites are located in a line or in a tight grouping.
7. Intentional degradation of the satellite signal - Selective Availability (SA) is an intentional degradation of the signal once imposed by the U.S. Department of Defense. SA was intended to prevent military adversaries from using the highly accurate GPS signals. The government turned off SA in May 2000, which significantly improved the accuracy of civilian GPS receivers.

Thus, based on the literature review above, the surveying cannot be done under the canopy of trees or a roof that can block the signal from the satellites. This is based on the limitation number 2 and number 5. Furthermore, the limitation stated in number 1 and number 2 are fixed by using advanced RTK GPS which is implemented in this research. The limitation number 4 and 6 is out of the researcher reach, but the control segment operated by the US department of defence have establish a strict control of the satellites operations. Moreover, How Stuff Works (n.d.) stated that “The Global Positioning System (GPS) is actually a constellation of 27 Earth-orbiting satellites (24 in operation and three extras in case one fails).”

2.3 RTK GPS

2.3.1 What is RTK GPS?

Wikipedia (2013) defined that "Real Time Kinematic (RTK) satellite navigation is a technique used to enhance the precision of position data derived from satellite-based positioning systems, being usable in conjunction with GPS, GLONASS and/or Galileo. It uses measurements of the phase of the signal′s carrier wave, rather than the information content of the signal, and relies on a single reference station to provide real-time corrections, providing up to centimetre-level accuracy. With reference to GPS in particular, the system is commonly referred to as Carrier-Phase Enhancement, or CPGPS. It has application in land survey and in hydrographic survey."

Furthermore, Althos (2009) stated that "Real time kinematic GPS is a position location process whereby signals received from a reference device (such as a GPS receiver) can be compared using carrier phase corrections transmitted from a reference station to the user's roving receiver. Using the correction information, RTK systems can provide real time accuracy below 5 cm."

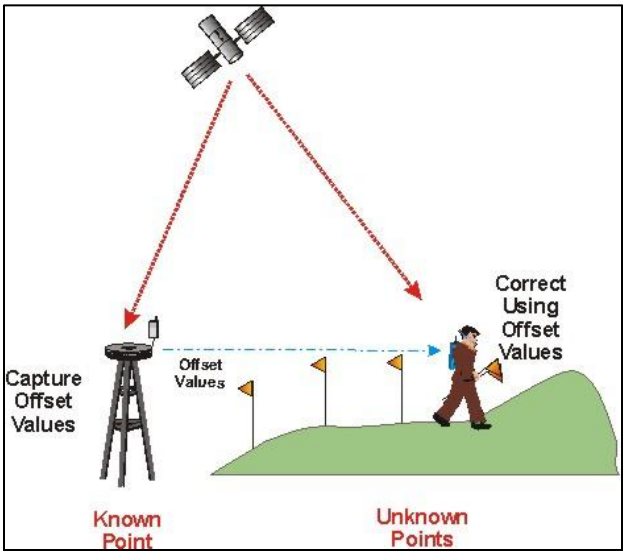


Figure 2.3.1. The RTK GPS system. (Source: Althos :2009)

Figure 2.3.1 shows how a RTK GPS system uses a base GPS receiver to gather and transfer information to a GPS rover receiver. The data from the base receiver can be used by the roaming receiver to calculate more accurate position information in real time (or near real time) (Althos, 2009).

2.3.2 How Does RTK GPS works?

GPS AgSystems (2010) elaborated that "With RTK, you need a base station placed on a known, surveyed point, and one or more mobile receivers within a ten kilometre range of your base station. The base station transmits corrections via radio to the mobile receivers in the field. A typical radio link required for RTK is in the UHF, VHF, or spread spectrum radio band. Radios operate best within line of sight or with a repeater."

Furthermore, Natural Resources Canada (2012) added that "RTK performs Real Time Phase Differential and computes the 3D vector (D X, DY, DZ) between the rover and base antennas. Base Station coordinates and both antenna heights need to be entered to compute ground coordinates at the Rover."

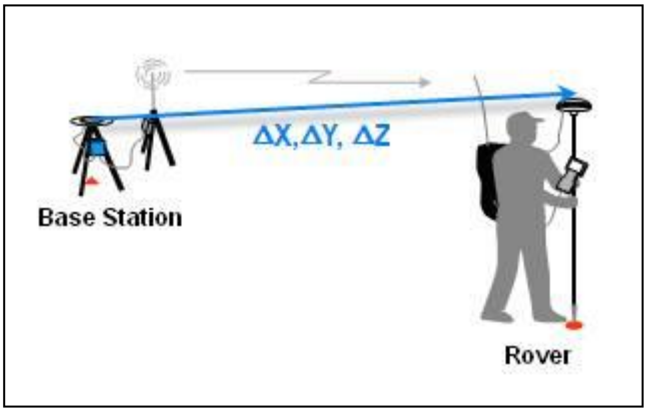


Figure 2.3.2. The RTK GPS base station and rover. (Source: Natural Resources Canada :2012)

Data from the Base Station (either raw GPS data or RTK corrections; there are different RTK approaches) is sent in real time via radio to the Rover. With a sufficient number of common satellites visible at both GPS antennas, a "FIXED" solution of centimeter-level precision can be calculated. If there are insufficient common satellites, a "FLOAT" solution of lower precision (a few decimetres) is calculated. You can try waiting for a "FIXED" solution or re-initializing the system (consult your manual) but these may not be successful as most often the FLOAT solution is due to poor satellite visibility at the Rover. RTK systems are available in dual-frequency and single-frequency versions. Dual-frequency systems deliver greater precision, faster and over longer baselines than single-frequency systems.

Your choice in equipment will ultimately depend on your budget, expected baseline lengths and precision needs. (Natural Resources Canda, 2012).

The typical horizontal precisions (RMS) according to the baseline lengths are as follows:

Table 2.3.2. The RTK GPS horizontal precisions based on baseline length. (Source: Natural Resources Canada :2012)

Baseline Length	**1 km**	**10 km**	**30 km**
Dual-Frequency	~ 1 cm	~ 2 cm	~ 4 cm
Single-Frequency	~ 2 cm	~ 4 cm	Too long

Thus, based on the literature review above, the RTK GPS will enhance the accuracy of the surveying up to a centimeter level as the base station of known (fixed) location and time will fix the time bias on the rover as the surveying process is carried out. Furthermore, to increase the accuracy in surveying, the base station has to be located at optimum radius lengths of 10 km from the rover. Moreover, dual frequency system will provide greater precisions of the data collected.

2.4 EARTHWORK & EARTHWORK SIMULATION

2.4.1 What is Earthwork?

Martinez and Tech (n.d.) stated that "Earthwork operations involve the excavation, transportation and placement or disposal of materials. They typically involve repetitive work cycles, expensive fleets and large volumes of work. Consequently, even small improvements in planning result in substantial cost and time savings. It is for these reasons that earthwork operations improvement has been the focus of so many studies. The work is performed outdoors under conditions that are highly variable and that affect the performance of the different pieces of equipment. Factors that affect performance include weather (i.e., trucks cannot travel as fast on wet, muddy haul roads), haul road maintenance (i.e., a well-maintained road reduces rolling resistance), operator experience, ground conditions, load and dump area layouts, and the material being excavated."

Furthermore, Petronas Technical Standard (2003) explained:

Earthworks are required to establish the general shape of the site on which the facility is to be constructed. They comprise the formation of on-plot and off-plot areas, road alignments, flood protection bunds and drainage channels. Where suitable material is not available on site, material shall be imported. Unsuitable material arising from site works shall either be stored at a designated location on site, or shall be disposed of in a responsible manner in accordance with all applicable local and national laws and regulations. In some area, the final grade or level may not be formed as finishing work may be scheduled at a later date. To minimise the import and export of material to and from a site, materials identified in the site investigation shall be considered for re-use. The approximate quantities of materials shall be determined and laboratory testing shall be carried out to determine the engineering properties and mineralogical composition of potential sources of fill. Site construction trials shall be carried out to satisfactorily demonstrate that the proposed equipment, compaction methods and compliance testing programme fulfill the design requirements.BS 6031 extensively describes the design of cuttings, excavations, embankments and general fill, execution of excavation, filling and compaction. Also, the design and construction of trenches and pits is covered in this standard. Earthworks shall therefore be designed, planned and executed in accordance with BS 6031.

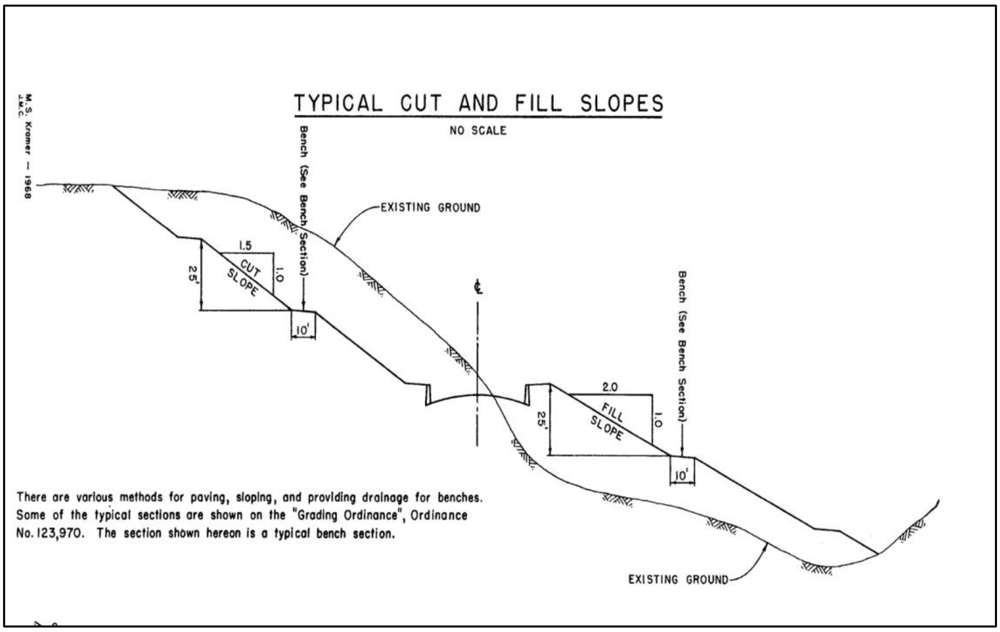


Figure 2.4.1. The Earthwork Cut and Fill at Slopes. (Source: .docstoc : 2011)

Figure 2.4.1 shows the example of cut and fill diagram at a slopes. The best ways of the cut and fill is to reuse back the earth cut to fill the required portions at the same site. Thus, reducing the earth's required from others site that can cause increase in operation cost due to vehicles diesel charges.

2.4.2 The Process and Method of Earthwork Estimation

The following earthwork planning is based on (HDRE CORP, n.d.).

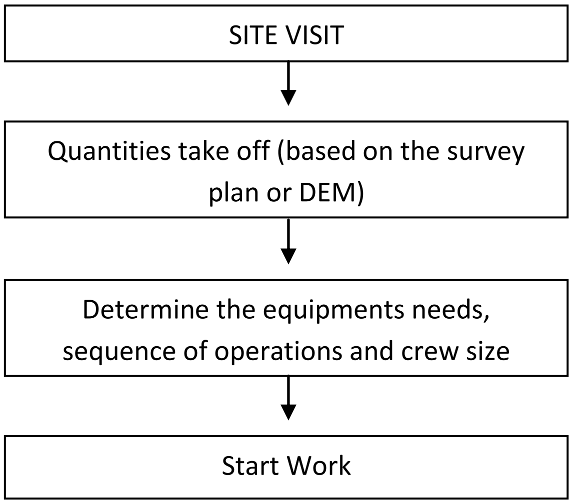


Figure 2.4.2. The Typical Earthwork Planning.

According to Construction Administration (n.d.) "To determine the amount of soil to be moved, the estimator needs to have a plot plan or topographic survey. This drawing is developed by plotting the readings (elevations) obtained from a topographic field survey usually performed by a licensed land surveyor. The different contour lines represent changes in elevation. The dashed lines usually indicate existing elevations; the solid lines represent proposed or finish elevations."

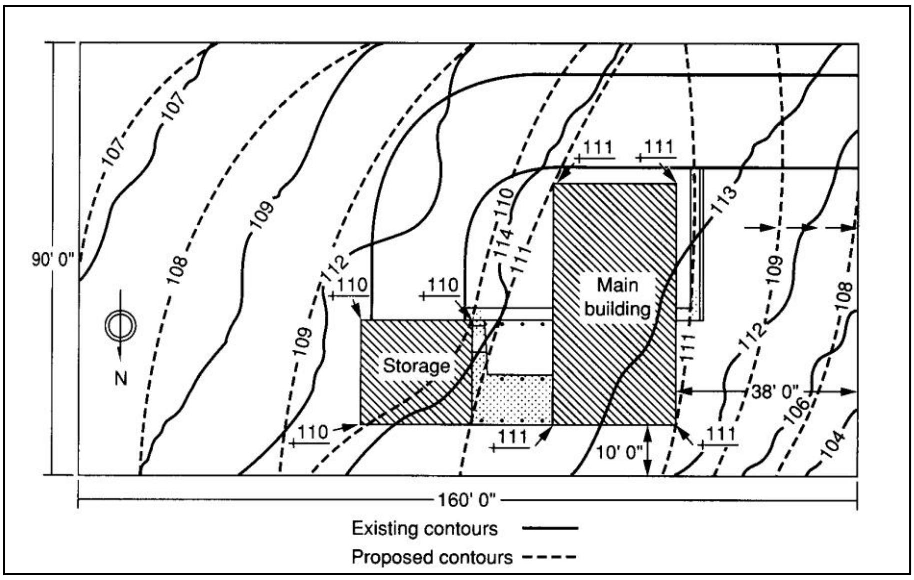


Figure 2.4.2.B The Site Topography Plan. (Source: Construction Administration : n.d.)

Moreover, Construction Administration (n.d.) stated "Before the excavations can begin the site will have to be cleared of unwanted trees and underbrush. It will be necessary for the estimator to visit the site to determine the extent of clearing and grubbing. By visiting the site and using the drawings, the estimator can determine how much land needs to be cleared. Two methods are used to calculate the quantity of earth to be moved on a site. The area average end method is normally used for heavy and highway work, and the grid method is usually used for building construction."

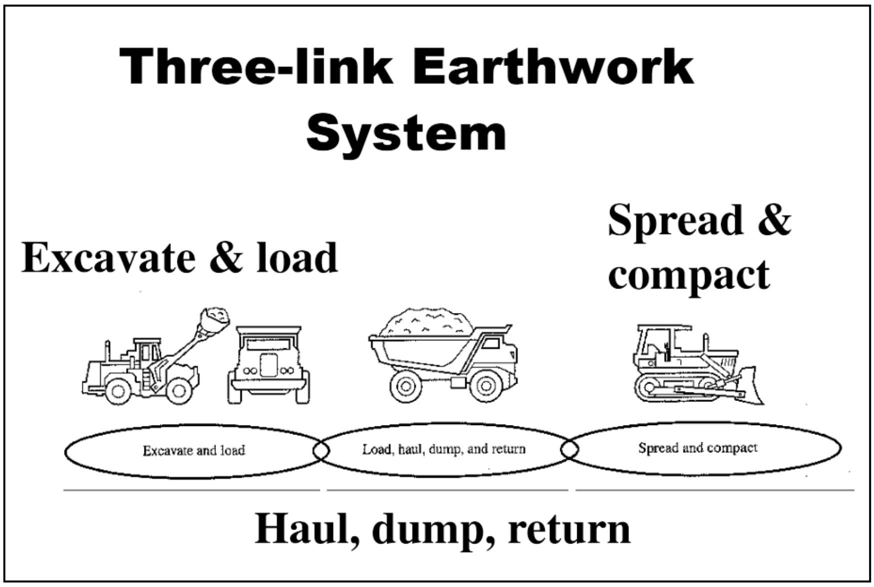


Figure 2.4.2.C The Three Link Earthwork System. (Source: HDRE CORP : n.d.)

2.4.3 The Need for Earthwork Simulation

Financially, earthwork is one of the most risky phases in the construction of a project because of the multitude of unknowns. Weather and subsurface conditions such as rock, underground water, and soil type add to the uncertainties. These variables not only affect labor productivity but also equipment selection and production. Measuring site work and excavation work is different from measuring most other work of a construction project because tender drawings usually provide very little detail about the specific requirements of site work operations. The drawings will give details of the new construction required for the project, but information about what is currently to be found at the site of the proposed work may not be provided. Furthermore, the size and depth of foundations may be defined in detail on the drawings, but there is typically nothing disclosed about the dimensions and shape of the excavations required to accommodate these constructions. (Construction Administration, n.d.).

Thus, according to Lee, Pyeon, & Kim (n.d.) “Scheduling simulation is an effective management tool that supports responses to real challenges in sites and plans optimum solutions in terms of product schedule and cost by testing different construction scenarios with a variety of factors in advance.”

Furthermore, in schedule control, simulation can be an effective tool that can produce optimum schedule beyond the capabilities of that Bar-Chart, PERT, CPM, etc. for civil construction where huge volume of work is performed in iterative process and it is obviously a useful tool that can minimize project risks by testing scenarios against a variety of conditions. Notably, earthwork which is one of the most important work disciplines in apartment complex construction project involves massive work volume that consists of iterative processes involving excavation, dirt loading, spoil transportation and filling, as spoil is cut or filled and is known to be the most effective model for scheduling simulation. Estimation of earthwork equipment efficiency estimation and determination of mobilization conditions are based on standard estimation system in public construction projects around the nation, which results in significant gap when it is applied actually in sites. Therefore, selecting a combination of equipment to be mobilized based on realistic simulation model can enable huge saving of time and cost in overall earthwork process. (Lee, Pyeon, & Kim , n.d.)

2.5 RESEARCH PAPER REVIEW

2.5.1 SITE OF STUDY

To ensure that the DEM is significant to conduct earthwork, the site of studies must consist of an uneven earth topography that has a clear variation of height. This is to make sure that the earthwork simulation is logic.

Furthermore, according to Atunggal, D., Cahyono, B.K., & Nassir,A. (2007) [30], it stated that:

1. Applying RTK GPS for data collection tool on area with average sky of view of above 60% can produce a good quality of DTM with height errors ranging from millimeters to a few centimeters, and volumetric accuracy of approximately 0.5%.
2. Less quality of DTM was generated for area with average sky of view between 60% and 50% where height errors reached almost a decimeter and volumetric error reached approximately 1%.
3. Applying RTK GPS for data collection tool on area with sky of view less than 50% is not recommended since the resulting DTM might be unreliable.

Thus, based on this statement, the site of study shall be chosen of a sky of view greater than 50% in order to ensure that the data and DEM generated is reliable.

Figure 2.5.1. The Sky of View. (Source: Atunggal, D., Cahyono, B.K., & Nassir,A. : 2007 [30])

Moreover, according to Nassir, A., & Hidzir, H. (2010) [28], "Before conducting data collection, suitable terrain area is chosen based on the following criterias:"

a. Strategic location (easier for the transportation and movement of equipment)
b. Suitable topography to perform surveying by total station and GPS.
c. Open space with less obstruction.
d. Must have terrains with major change in the shape of the terrain surface (to produce visible shape on the DTM)

2.5.2 RTK GPS TECHNIQUE & DATA COLLECTION

According to Nassir, A., & Hidzir, H. (2010) [28]:

Higher density of data is required at the area with major change in shape. However, optimizations of data need to be achieved by determining the type of the terrain. Terrain with little variations in height requires less density of data compared to the terrain with more variations in height. Time and energy can be saved through optimization of data sampling. Proper procedures in performing the data acquisition process are important in obtaining better representation of DTM with less error. Better planning of data sampling is needed to be done to achieve optimization and better representation of DTM.

Furthermore, Nassir, A., & Hidzir, H. (2010) [28] stated that:

The sampling method used in collecting terrain data is composite method of the following methods:

1. Random sampling, to acquire data points for the topography purposes.
2. Progression sampling, to acquire more points at the area where curve shape is required and fewer points are collected at the area with straight line features.
3. Selected sampling, to describe the boundaries of man-made objects (such as road divider, drainage, pathway and stairs).

RTK GPS depends on a single base point as the point of references during the data collection. Furthermore, according to Yilmaz, I., Tiryakioglu, I., Taktak,F., & Uysal, M. (n.d.) [29], "Advantage of RTK GPS than classical measurements in obtaining height data is that facing rover station to base station is unnecessary. But this situation is limited with radio broadcasting used in RTK GPS. To solve this problem base station should be founded in higher point be should be far from anti signal effects".

Moreover, as the RTK GPS system depends on a single base point, the base point coordinate and location has to be identified to be implemented in my studies. In conjunction with that Fauzi, M., & Nassir, M. (2012) [31] stated that "the communication signal between base point and rover is well works within 2 km range". Thus, the base point has to be establish in range radius of 2km.

2.5.3 DATA PROCESSING & DATA ANALYSIS

The data collected by the RTK GPS survey has to be process into digital elevation model (DEM) and based on the DEM generated, earthwork simulation has to be study and analyze to produce the earthwork simulation.

Based on Nassir, A., & Hidzir, H. (2010) [28], a breaklines has to be establish by connecting the collected coordinates to establish the features of rivers, road, pathways and stairs. This can view in Figure 2.5.3 A.

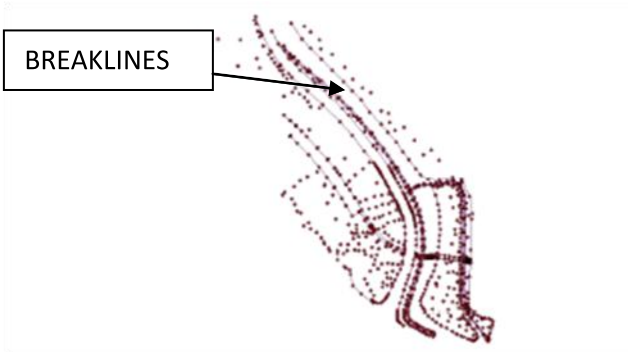


Figure 2.5.3 A. The Breaklines. (Source: Nassir, A., & Hidzir, H. : 2010 [28])

According to Atunggal, D., Cahyono, B.K., & Nassir,A. (2007) [30], the Digital Elevation Model can be produce by using triangular irregular network. This is done by connecting the coordinated into a series of triangular network as shown in Figure 2.5.3 B.

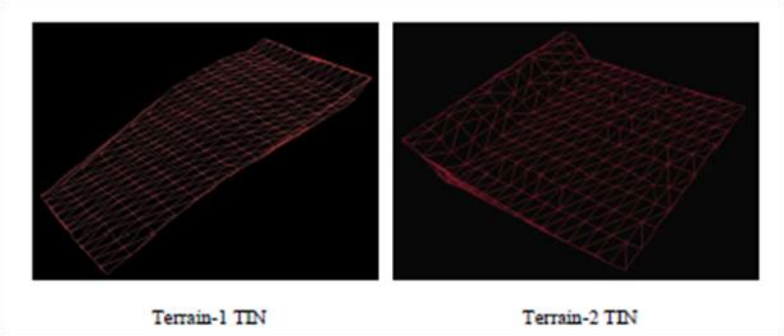


Figure 2.5.3 B. The Tin of DEM. (Source: Atunggal, D., Cahyono, B.K., & Nassir,A. : 2007 [30])

Atunggal, D., Cahyono, B.K., & Nassir,A. (2007) [30] added that for triangular prism which has edges perpendicular to the base triangle, the volume was calculated as follow;

V = area (T1', T2', T3')*(T1T1', T2T2', T3T3')/3

While, for area which edges not perpendicular to the base triangle, the volume was calculated as follow;

V = area (T1", T2", T3")*(T1T1', T2T2', T3T3')/3

Where T1", T2"and T3" denote any perpendicular section of the prism.

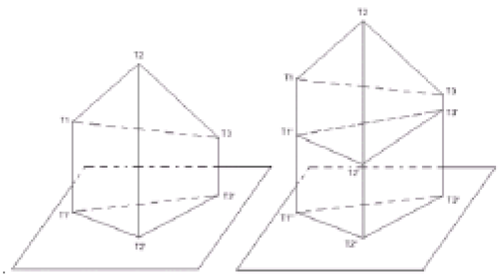


Figure 2.5.3 C. The Triangular Prism Basis for Calculation. (Source: Atunggal, D., Cahyono, B.K., & Nassir,A. : 2007 [30])

2.5.4 RESEARCH PAPER CRITICAL ANALYSIS SUMMARY

Table 2.5.4. The Research Paper Critical Analysis Table.

Research Topic	Author	Date	Findings	Similarities	Differences	Implementation
Digital Terrain Model by Real Time Kinematic GPS	Dedi Atunggal, SP Bambang Kun Cahyono Abdul Nasir Matori	2007	Applying RTK GPS for data collection tool on area with sky of view less than 50% is not recommended since the resulting DTM might be unreliable.	**Data Collection:** Usage of RTK GPS **Data processing:** Generation of DEM	**Data analysis:** Quality of DEM	**Data Collection:** Site of study SOV > 50% **Data Processing:** DEM generation by TIN method
Low Cost DTM for Certain Engineering Purposes	Abd Nasir MATORI Hazwani HIDZIR	2010	Higher density of data is required at the area with major change in shape. However, optimizations of data need to be achieved by determining the type of the terrain. Terrain with little variations in height requires less density of data compared to the terrain with more variations in height. Time and energy can be saved through optimization of data sampling.	**Data processing:** Generation of DEM **Data analysis:** Earthwork Cut & Fill	**Data Collection:** Total Station	**Data Collection:** Using DATA SAMPLING technique **Data analysis:** Breaklines implementation

Using RTK GPS method in creation of DTM	Ibrahim Yılmaz, Ibrahim Tiryakioglu, Fatih Taktak, Murat Uysal	n.d.	Advantage of RTK GPS than classical measurements in obtaining height data is that facing rover station to base station is unnecessary. But this situation is limited with radio broadcasting used in RTK GPS. To solve this problem base station should be founded in higher point be should be far from anti signal effects	**Data Collection:** Usage of RTK GPS **Data processing:** Generation of DEM	**Data analysis:** Quality of DEM	**Data Collection:** Base station located at a high ground
Assessment of Real Time Kinematic Global Positioning System (RTK GPS) Application for Simulation of Building Monitoring	Fauzi, M., & Nassir, M.	2012	The communication signal between base point and rover is well works within 2 km range	**Data Collection:** Usage of RTK GPS	**Data processing:** Network and Baseline between rover and base station **Data analysis:** Quality of signals and precision of single base point rtk gps and capability to detect small and large building movement	**Data Collection:** Base station located at a known point in pocket C parking of UTP 485282.229 (N) and 330054.789 (N).

CHAPTER 3: METHODOLOGY

The methodology section will explain the following items:

- Project Activities
  A. Studied Area
  B. Data Collection
  C. Data Processing & Analysis
- Key Milestone
- Gantt Chart
- Tools

3.1 Project Activities

The flow chart below shows the sequence of the activities and the highlighted text is the current stage of work.

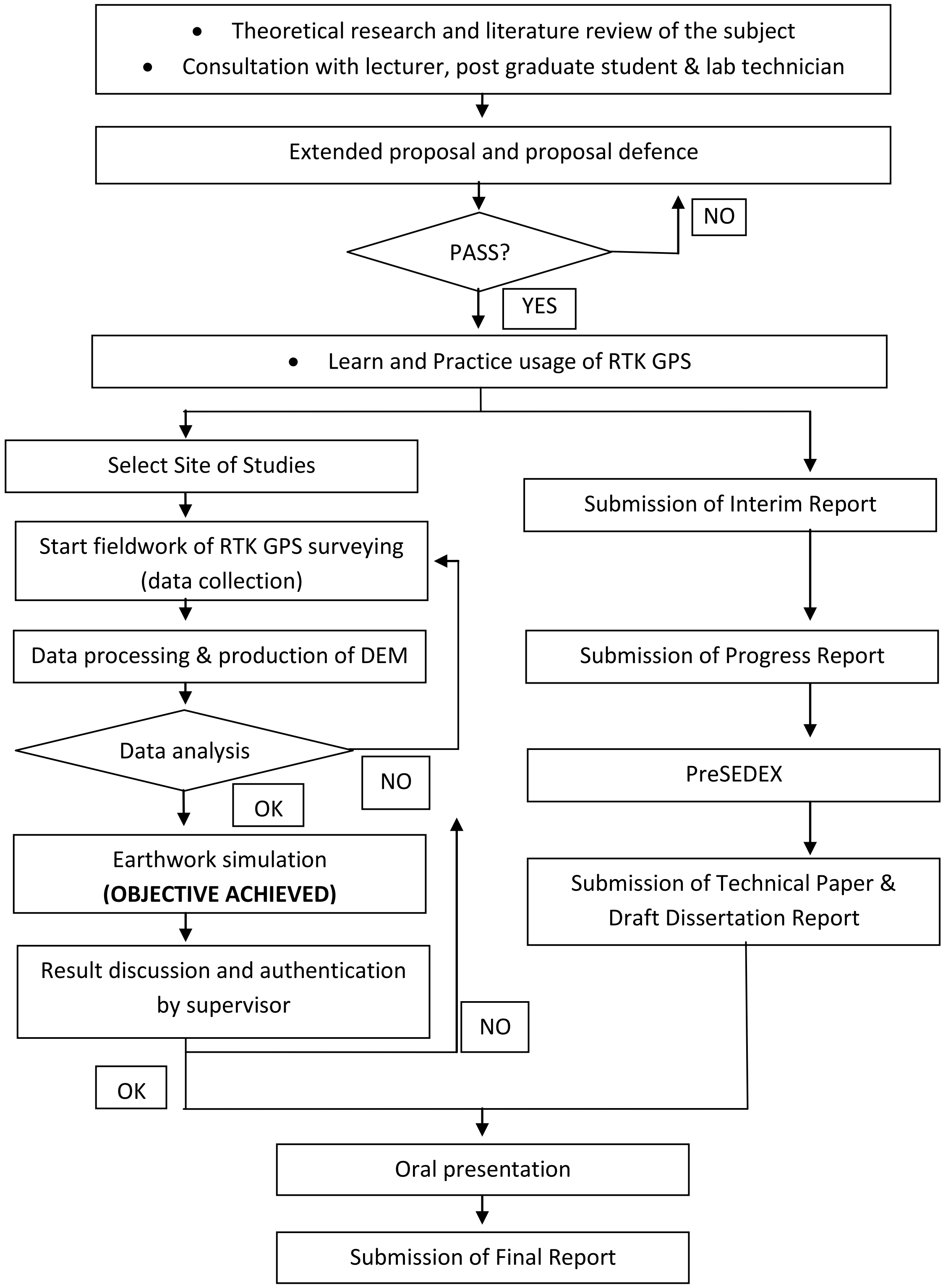


Figure 3.1. The Project Activities Flow Chart.

3.1.1 Selection of study area

Suitable terrain area is chosen based on the following criteria:

a. Suitable Topography
   To emphasis on the cut and fill since significant elevation differences provided a better and clearer result. In conjunction with that, major changes in shape of terrain provide more visible DTM.

b. Open Space with less obstruction (to avoid signal errors)
   To optimize the capabilities of RTK GPS since it is subjected to signal multipath error and satellite visibility error [8]. Signal multipath error occur when GPS signal is reflected off objects such as tall building before it reaches the receiver. Therefore, increase the travel time of the signal, thereby causing errors. In addition, signal reception can be block by building, terrain and electronic interferences. Thus lead to position error or possibly no position reading at all [8].

Based on the above criteria, a site of study is chosen as illustrated in Figure3.1.1. The site is located 6.8 km for known landmark of Universiti Teknologi Petronas (UTP).

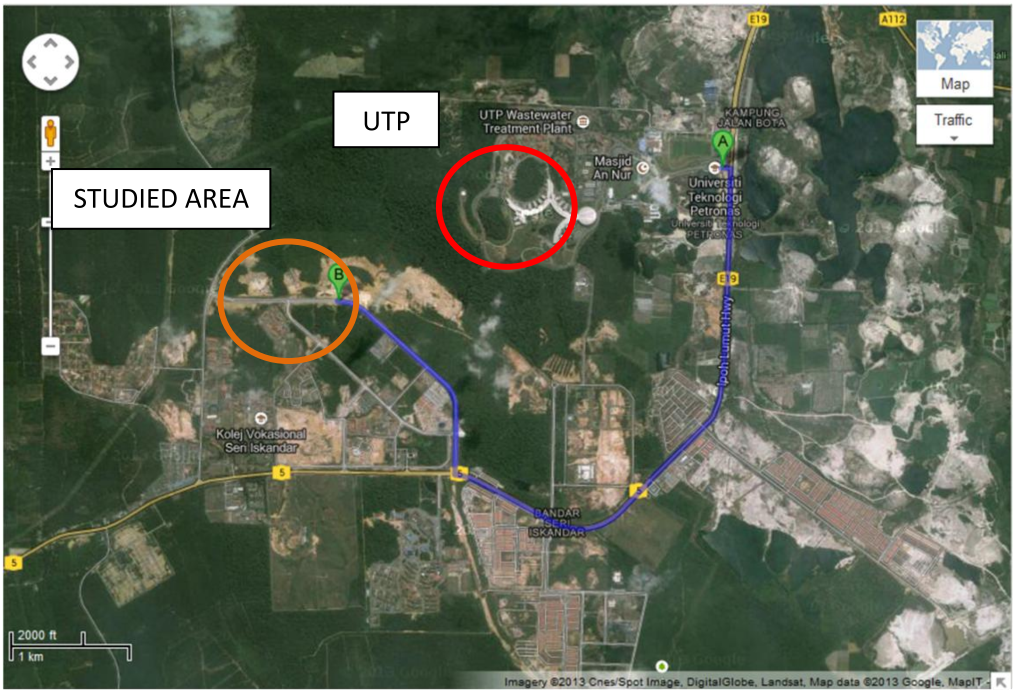


Figure 3.1.1 Site Location of the study area.

3.1.2 Data Collection

Figure 3.1.2(a) Data Collection Flow Chart.

The flow chart above show the flow of the data collection work, initially the control station has to be established. Then, the base has to be setup according to a specific step documented in the TOPCON Real Time Kinematic GPS setup manual that has been provided by the supplier. Next, once the base is ready, rover is setup according to the same manual [33].

Figure 3.1.2 (b) Author Setting Up Base Station at Site.

A. Data Acquisition Technique

Throughout the data collection session, the rover must be positioned so that it is vertically pointed upwards. Next, the rover have to be at a fixed positioned for a few seconds until the FC 250 (hand held interface gadget) shows at least 4 satellites are in range and the position type is fixed. Thus, once the rover is in fixed positions, the coordinate of the point are automatically recorded.

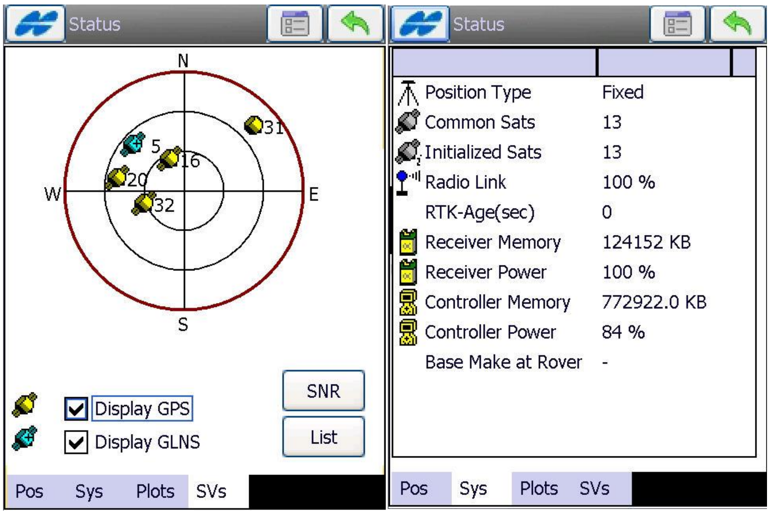


Figure 3.1.2 (c) Satellites at the Rover Range and the Status of the Rover.

The data collection techniques are as follows:

1. Random Collection: To acquire topography data
2. Progression Sampling: To acquire more points difficult area (Curve area required more points compared to straight line).

Figure 3.1.2 (d) Author during one of the Data Collection Processes.

3.1.3 **Data Processing**

The collected data are then transferred into computer. Topcon Tools V.8 software is used to export the data into file format of (tp3) that is the use in Topcon Office 3D to process the raw data collected into Triangulated Irregular Network as shown in Figure below.

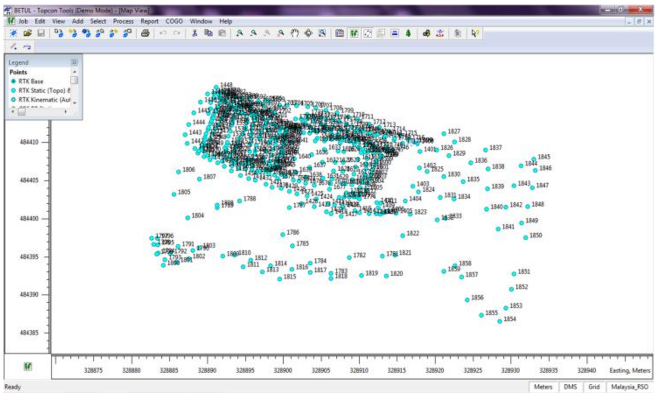


Figure 3.1.3 (a) Raw Data in Map View.

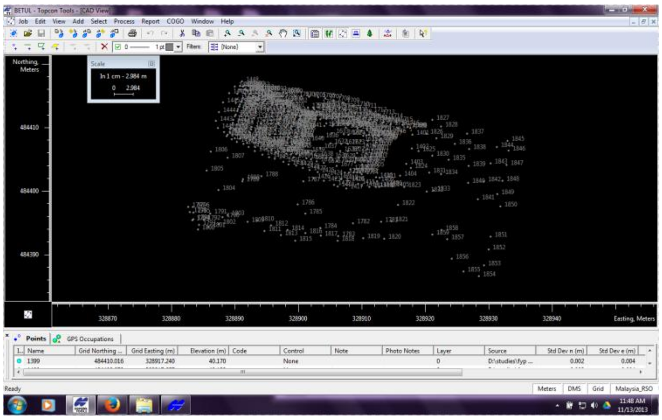


Figure 3.1.3 (b) Raw Data in CAD View.

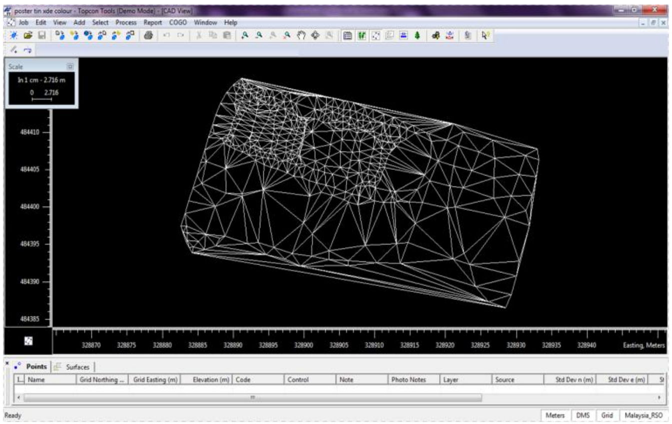


Figure 3.1.3 (c) Data Processed into Triangulated Irregular Network (TIN).

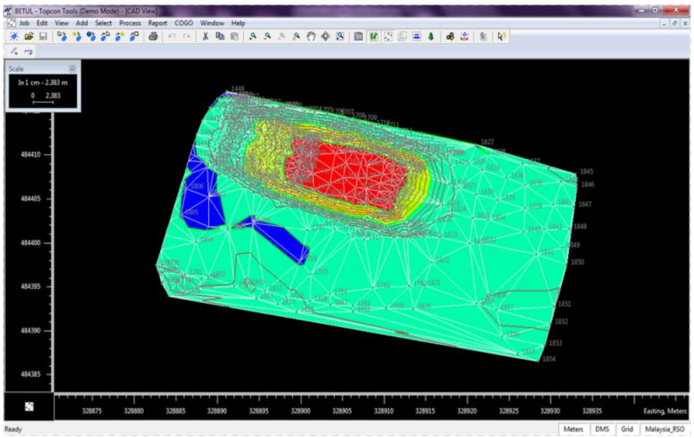


Figure 3.1.3 (d) Data Processed into TIN with contours

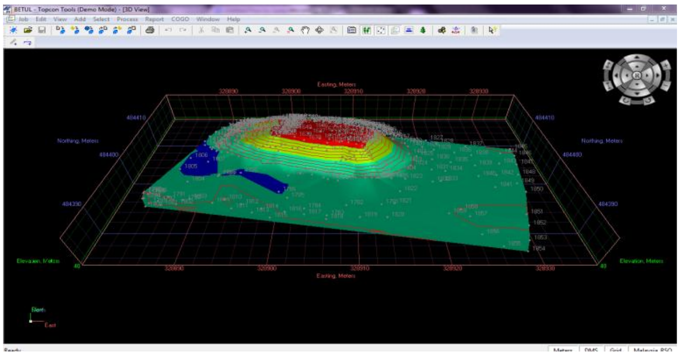
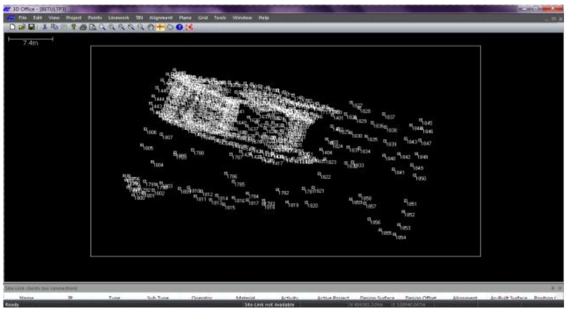


Figure 3.1.3 (e) Data Processed into 3D model.

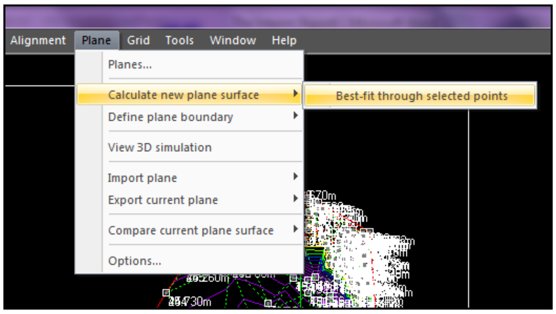
3.1.4 Data Analysis

The Digital Terrain Model (DTM) is then study to generate the cut and fill. The workflows are as shown in Figure 3.1.4.

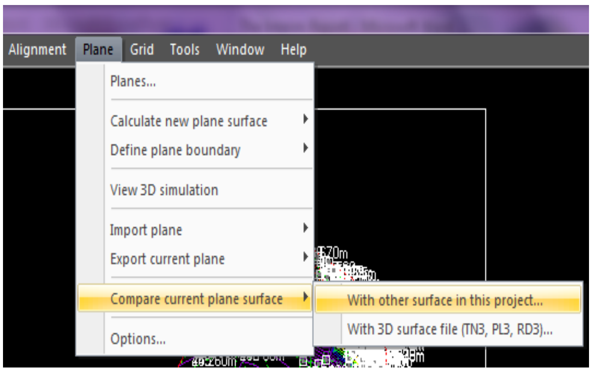
Step 1: Select all point



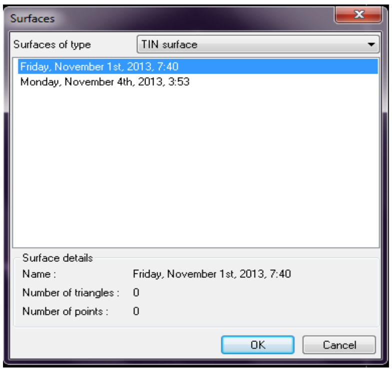
Step 2: Calculate new plane surface



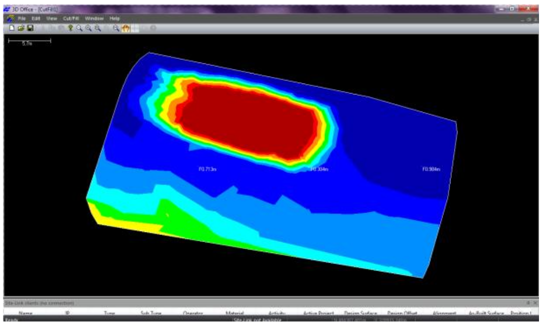
Step 3: Compare current plane surface



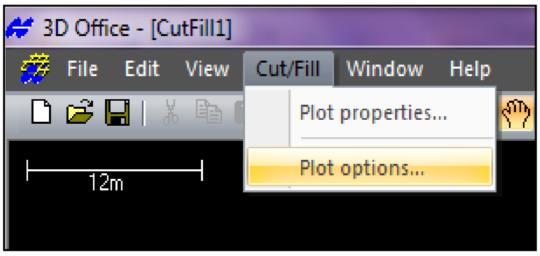
Step 4: Select the surface desired



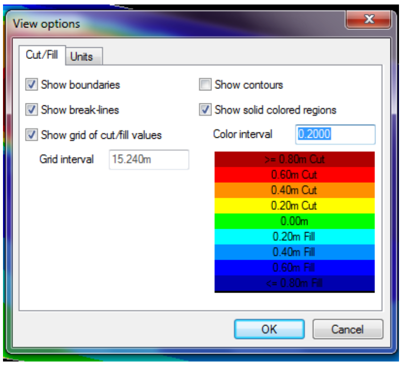
Step 5: Initial Cut & Fill result



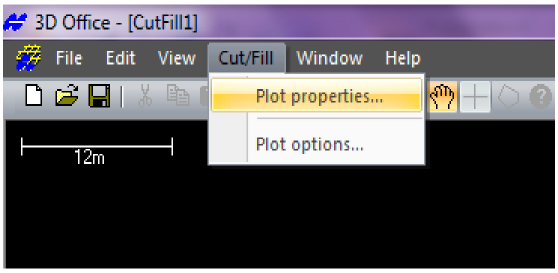
Step 6: Click on Plot options to render the Cut /Fill



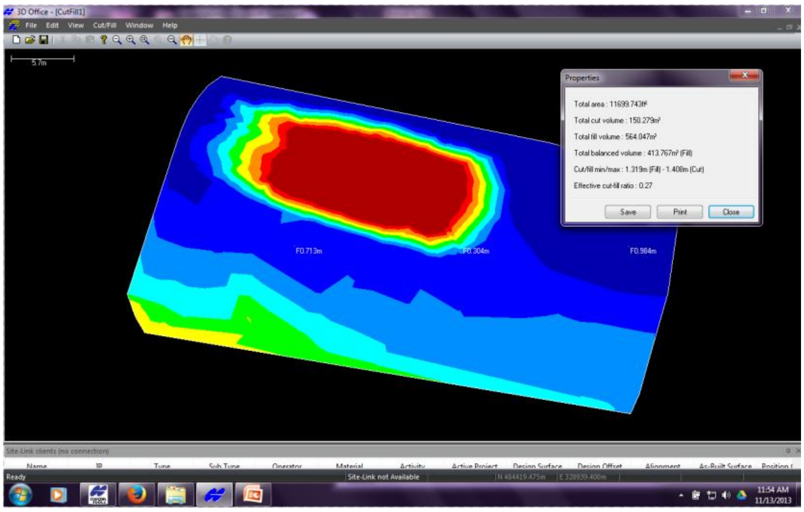
Step 7: Change legend and properties of cut/fill to desired quantities



Step 8: Select on Plot Properties to get the result of cut/fill



Step 9: The result obtained



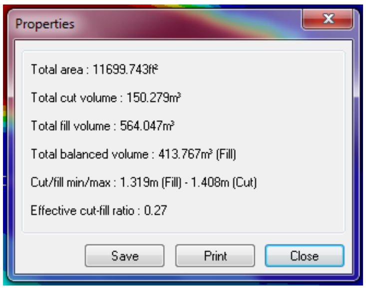


Figure 3.1.4 The Process of Data Analysis of Cut & Fill.

3.2 Key Milestone

3.2.1 Semester 1

Table 3.2.1. Key milestone for FYP I.

Subject	Target Date	Description	Status	Personnel
Selection of Project Title	Week 2	Author confirms the chosen topic that is relevant and significant to the civil engineering field of study.	Done	-Author - Supervisor
Theoretical Research	Week 9	Author studies the theoretical information regarding the research topic and list out all the details such as limitation of the research and the required item during the research.	Done	-Author - Supervisor
Extended proposal	Week 6	Author submits a report that specifies the literature review of the project and the proposed methodology to the supervisor for review and authentication of method.	Done	-Author - Supervisor
Proposal Defense	Week 10	Author presents the research proposal to the supervisor and the internal examiner (lecturer) for comment and to specify the things that author should look into before the actual work are done.	Done	-Author - Supervisor - Internal Examiner
Learn & Practice Session of RTK GPS & Software	Week 2 (Sem Break)	Author will undergo practice session on the data collection and data processing using RTK GPS. This is to ensure that the real field work are carried out correctly and accordance to the specifications.	Done	-Author - Lab Technician - FYP 2 student - PG student
Interim Report	Week 14	Author will submit a report that specifies the current progress and the details of methodology, expected result and problem encountered.	Done	-Author - Supervisor - Internal Examiner

3.2.2 Semester 2

Table 3.2.2. Key milestone for FYP II.

Subject	Target Date	Description	Status	Personnel
Selection of Site & Carry out Dummy Work on site	Week 2	Author will confirms the site of studies and carry out dummy work to ensure that the site conditions are fit to the research purposes.	Done	-Author
Real Work a. Data Collection b. Data Processing	Week 8	Author will carry out real data collection & data processing at the selected site of studies. At this stage, the **OBJECTIVE IS ACHIVED**.	Done	-Author
Progress Report & Result Authentication	Week 8	Author submits a report that specifies the work progress and result obtain for the supervisor to review and authenticated that the data and result obtained are sufficient and valid.	Done	-Author - Supervisor
Pre SEDEX	Week 11	Author will present the research finding and related information to the internal examiner for him to be qualified to enter SEDEX.	Done	-Author - Supervisor - Internal Examiner
Oral Presentation	Week 14	Author will conduct an oral presentation to attend by the supervisor and the external examiner. This oral presentation will present the research work and the findings.	On track	-Author - Supervisor - External Examiner
Dissertation Report & Technical Report	Week 15	Author will submit a report that concludes all the research work from day 1 until the end of the research for records.	On track	-Author - Supervisor

3.3 Gantt chart

A careful planning of the final year project has been established covering the whole two semesters. The planning consists of comprehensive breakdown of the project work and activities. Furthermore, the documentation and presentation of findings are also incorporated in the schedule as it represent the whole purposes of the research that is to compile all the work activities, problems encountered, methodology and findings for references.

The entire task has been assigned and chained with a targeted date and a key milestone in order to keep track with the progress and performance of the project work.

Legend is created to assist author in marking the targeted date, completed event date and the revised date. Furthermore, the key milestones of the projects are also marked in the chart. This is to ensure that the essential requirement of the coursework of final year projects is not being left out. The legends are as shown below:

(blue)	Target date
(green)	Completed event
(red)	Revised target date

X	Key Milestone
E	End
(light blue)	Semester Break

Figure 3.3. The Earthwork Simulation using RTK GPS Gantt Chart Legend.

3.4 Tools

This study requires specific usage of hardware tools as well as software. The required tools that are implemented in this study are as follows:

a. HARDWARE TOOLS

1. TOPCON RTK GPS

   The TOPCON RTK GPS are implemented in this study as a tools or medium to records the coordinate that will be use to create the Digital Elevation Model (DEM). It consists of the base and rover.

Figure 3.4.1. The RTK GPS Hardware Equipments.

Table 3.4.1. The RTK GPS Hardware Equipments List.

ROVER	BASE
• HiPerII Receiver (Rover)	• HiPerII Receiver (Base)
• Radio Antenna	• Radio Antenna
• Litepole	• Spacer
• Pole Bracket for FC-250	• Tribrach with adapter
• FC-250 w/ TopSURV	• Tripod
• Bipod	

2. Measuring Tape

   The measuring tape is use to elevation of the base during the base setup.

b. Software Tools

1. Topcon Tools V.8 (Static and Kinematic Software)

   The software is use to configure and process the raw data collected from a point to an established Digital Terrain Model with triangulated irregular network system. Therefore, the site topography can be view in a 3 Dimensions manners with the contours of different color tone.

2. The 3D simulation software

   The software is use for data analysis that is to generate the cut and fill properties of the study area. With proper utilization the cut and fill of the study area can be obtain in a nick of time. Furthermore, the plot properties enable user to simulate earthwork according to the scale and desired specifications.

CHAPTER 4: RESULT AND DISCUSSION

The results are discussed into two stages:

a. Data Collection
b. Digital Terrain Model Integrity
c. Cut and Fill analysis

4.1 DATA COLLECTION

859 data was collected as per attached in Appendices 2. Based on the processed done, author discovered and proven the abilities of RTK GPS surveying method as listed below:

a. Enable ease in mapping difficult slope

The base station is located at one point that is literally not visible from the opposite site of the small hill. Therefore, enhancing the abilities and distinguish the unique of RTK GPS surveying that does not require intervisibility as compared to the conventional total station.

b. Shorten surveying work duration

Duration of 4 hours is taken for 859 data to be collected. In addition, a clear sky with no obstruction will only take 5 seconds for one data collection at one point. Thus, implicate that the RTK GPS surveying technique is fast despite of the weather condition.

4.2 DTM INTEGRITY

There is two main software used for data processing and analysis that is the Topcon Tool Version 8 and Topcon Office 3D.

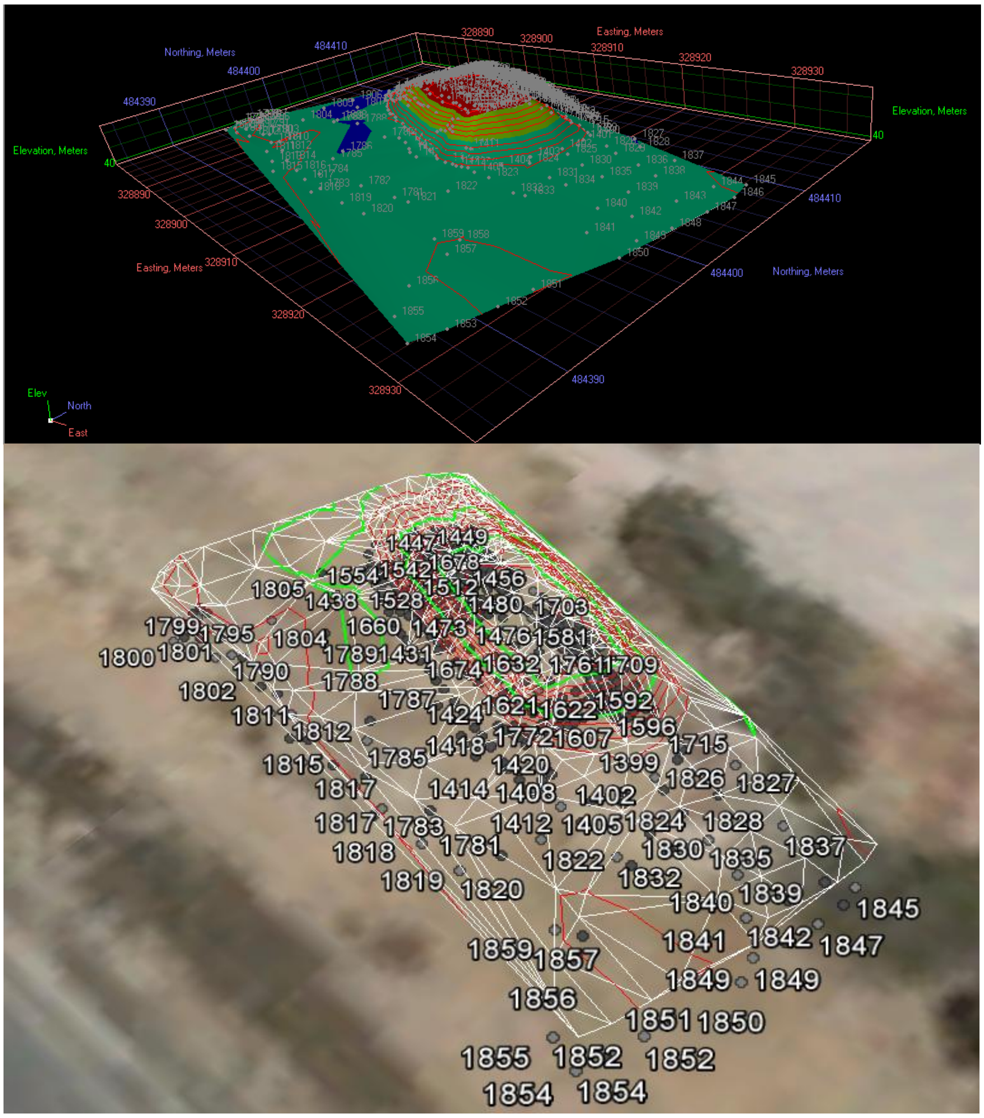


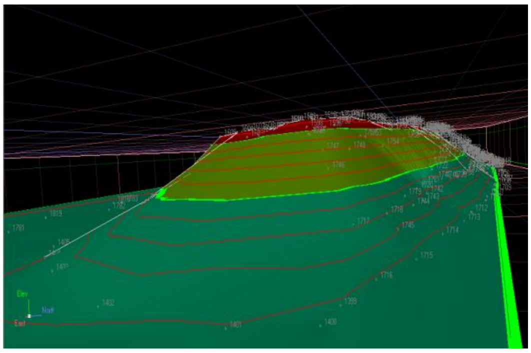
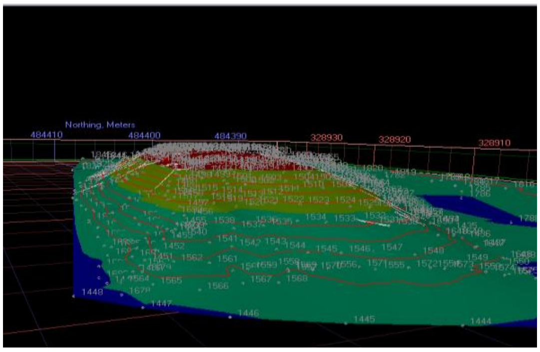
Figure 4.2(a) Overall Studied Area Views from DTM (top) and from Google Earth (bottom).

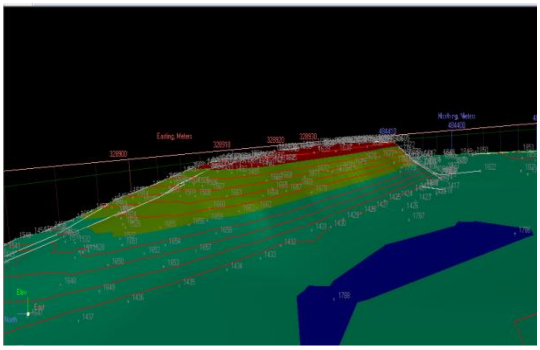
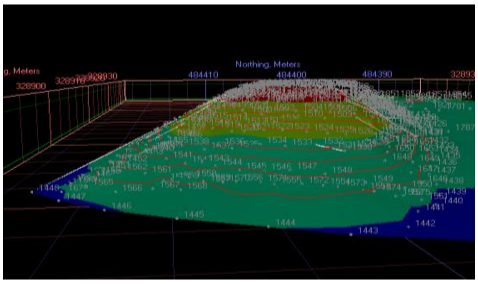
Overall view of the site DTM are compared with the photo of the site area taken from Google Earth software. In comparison, the DTM is in 3D view with different colour legend to distinguish the elevation level of the terrain.

In addition, to test for DTM integrity, closer look are done by comparing the real site topography with generated DTM. This is as illustrated in Table 4.2. The DTM yield the same shape as the real site topography based on the comparison. The accurate result is due to correct selection of study area that provides clear sky view to promote full access to satellites signal and no signal interferences. Satellites available at site during surveying work are as shown in Figure 4.2(b).

Figure 4.2(b) Satellites Availability during Surveying Work.

Table 4.2 Comparison of Real Site Topography with Generated DTM.

Real Image	Digital Terrain Model
	
	

In addition, the good result is due to good data acquisition technique and modus operandi. That is to acquire more point at curve area to ensure details and accurate terrain model. The location of denser data acquisition is as illustrated in Figure 4.2 (c). In conjunction with that, since RTK GPS are designed for data accuracy below 5 cm, thus the result obtains is as expected to be accurate.

Figure 4.2(c) Denser Data Collection at Sloping Area. (red circle).

Based on figure 4.2 (c), it is concluded that the proper data acquisition technique that is to collect more terrain data at area with significant height variation will result in more accurate and consistent DTM. Next, it is recorded that the more data collected at an area the better it is the representation of the area topography in DTM.

4.3 CUT AND FILL ANALYSIS

The study area was once a track for motocross activities. However, the place has been abandoned for few years. Furthermore, there is no proposed development to be constructed at the area. Thus, author can only assume the finish ground level for the study area so as to simulate the required cut and fill work.

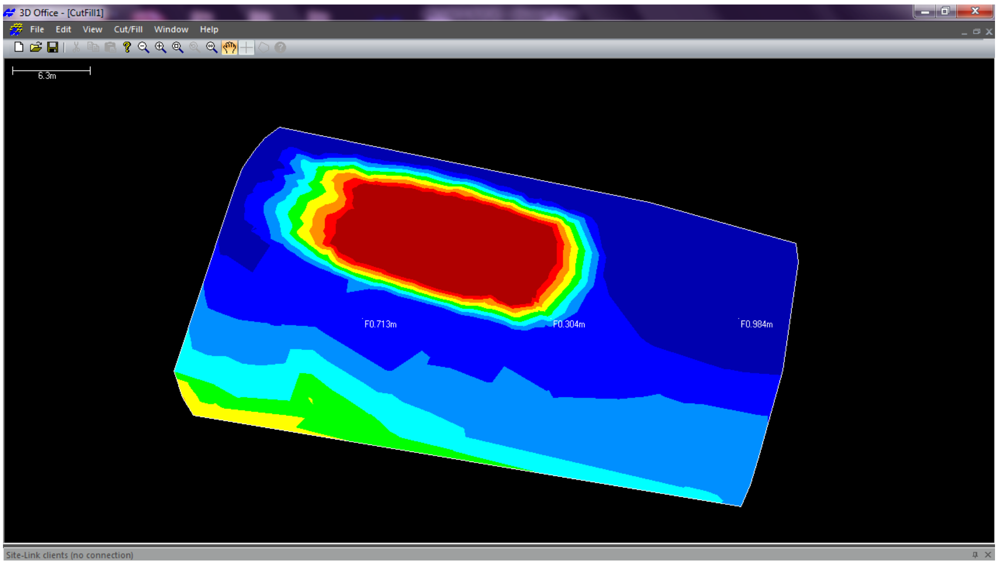


Figure 4.3 (a) Earthwork Simulations of Cut and Fill.

The simulated cut and fill is as shown in Figure 4.3 (a). Based on Figure 4.3 (a), the ground zero (datum) is referred as colour green. The legends of elevation for cut or fill is as shown in Figure 4.3 (b).

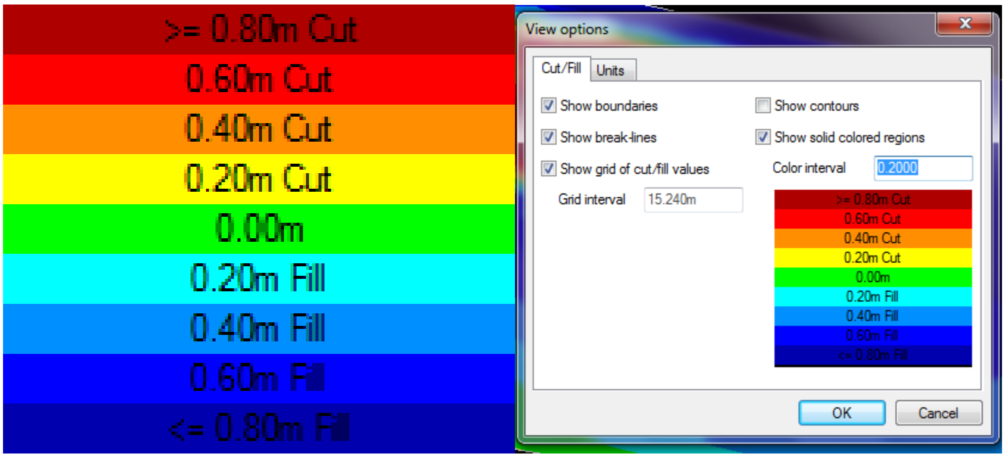


Figure 4.3 (b) Cut and Fill Properties

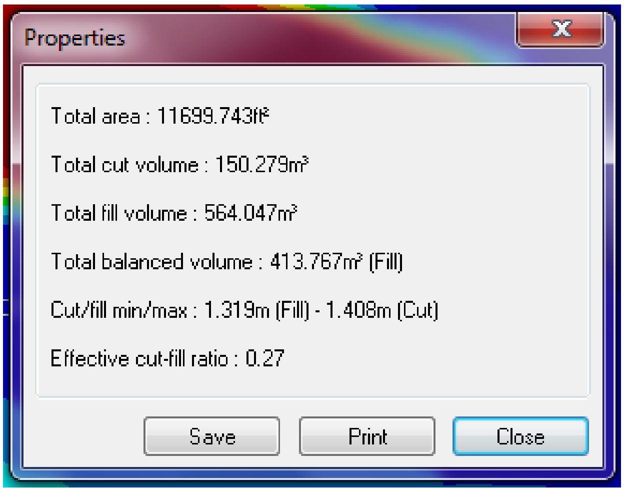


Figure 4.3 (c) Cut and Fill Result

Next, the cut and fill result are as per Figure 4.3 (c). However, in term of gross volume of cut and fill the result is accurate. But, earthwork process is complex as it has to consider the geotechnical aspect of the soil properties. For instance, water content of the soil that significantly influence the weight and volume of the soil.

Clay soil will have much water content and is susceptible to shrinking when it is cut or fill. Thus, the result obtains from earthwork simulation need to take into account the soil properties in order to cater for variability of soil characteristic.

CHAPTER 5: CONCLUSION

In conclusions, the result shown that the objective of performing earthwork simulation using RTK GPS is achieved. The digital terrain model generated show the same shape and pattern as the actual topography of the site. This is obtained with the proper technique of data acquisition that is to do a proper data sampling. Progressive data collection are implemented where higher density of data is collected at the difficult area such as curve and less data is collected on a straight line features. In addition, the flexibility of RTK GPS surveying has given author ease in time and energy conducting the survey work. Difficult terrain can be surveyed and the data collected are easily transferred into computer.

With proper software utilisation, the earthwork simulation of cut and fill can be easily obtained. This is feasible as the generation of Digital Terrain Model that provide a 3 dimensional view of the site topography. In addition, with the implementation of Topcon Tools Version 8 that is the software compatible for Topcon RTK GPS equipment, the data collected can be easily view on Google Earth with embedded Google Earth Plug-In in the software. Furthermore, with the 3D view option, surveyor can have a better initial understanding of the earth topography. In conjunction with that, Topcon Office 3D provide good interface as the cut and fill or the site study can easily be analyse based on the DTM generated using Triangulated Irregular Network module.

In short, the utilisation of Topcon RTK GPS equipment that is equipped with Topcon Tools V.8 and Topcon Office 3D software can generate a Digital Terrain Model that is capable of simulating the cut and fill for earthwork activities.

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APPENDIX 1

Earthwork Simulation using RTK GPS Gantt Chart

APPENDIX 2

Data Collected at Studied Area