DIGITAL TERRAIN MODELING (DTM) WITH RTK GPS FOR CERTAIN ENGINEERING USES

By

NIK MOHD FAKRUL FIDZRIE BIN NIK MOHD SHUKRI

FINAL PROJECT REPORT

Submitted the Civil Engineering Programme

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in partial fulfillment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(Civil Engineering)

JULY 2008

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CERTIFICATION OF APPROVAL

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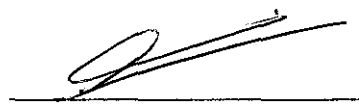
Approved by,



(Assoc Prof. Dr. Abdul Nasir Bin Matori)

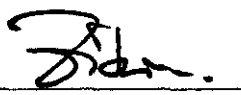
UNIVERSITI TEKNOLOGI PETRONAS

BANDAR SERI ISKANDAR, PERAK

JULY 2008

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.



(Nik Mohd Fakrul Fidzrie Bin Nik Mohd Shukri)

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3. Mr Ahmad Tarmizi Bin Abdul Razak (Survey Department of Inai Kiara Sdn Bhd KT Site)
4. Civil Department Final Year Project Committee

I would like to express my gratitude to my family who constantly gives the outstanding support to me. Next, persons that involved directly and indirectly in this project especially to my fellow colleagues for the assistance and encouragement.

ABSTRACT

Digital terrain modeling is a process to obtain desirable models of the land surface. The objectives of this project are to produce a DTM with RTK GPS as well as getting familiar with RTK GPS usage. This project covers the understanding on dealing with RTK GPS equipment as method for data collection to create DTM. The methodology involved preparing the RTK GPS, preparing the case study area, starting collecting data, processing the collected data, creating the terrain modeling and modeling analyzing. The DTM can be further analyzed to estimate the volume for cut and fill of the area at certain height. RTK GPS method is recommended for survey method straightness, consume less time for collecting data in generating DTM and suitable for all types of surveys.

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CHAPTER 1

INTRODUCTION

1. 1 Background of Study

Digital Terrain Modelling (DTM) is a representation of the earth surface in 3 D. It shows coordinates, altitudes, geographical and natural character in surfaces. Common uses of DTMs include:

- 3D visualizations of the terrain surface
- Cross section area and volume calculation
- extracting terrain parameters
- modelling water flow and mass movement like flood mitigation

Arslanoglu and Ozçelik (2005) pointed out that DTM is the model representing ground surface, having latitude data of irregular scattered critical points.

The procedure of DTM surface construction is called digital terrain modelling. It also known as a process of mathematical modelling in which the terrain is generated by the set of sample points using Triangular Irregular Network (TINs).

Various measurement methods can be used to determine the sample points. One of the methods is RTK GPS. RTK GPS have a broad application in mapping, canal and pipeline projects, road construction application and car trace system.

1.2 Problem Statement

Nowadays, many engineering works requires DTM. DTM can provide a complete and comprehensive system to meet all the construction needs thus DTM become more preferable to represent the terrain surface. There are many ways to obtain the points to generate, either using photogrammetric, Light Detection and Ranging (LIDAR), RTK GPS and Total Station.

LIDAR is a remote sensing system used to collect topographic data. These data are collected with aircraft-mounted lasers capable of recording elevation measurements at a rate of 2,000 to 5,000 pulses per second and have a vertical precision of 15 centimetres (6 inches). Photogrammetric is a remote sensing system in which geometric properties about objects are determined from photographic images.

Comparing the techniques above, photogrammetric and LIDAR are expensive, tedious and slow, compare to RTK GPS method. RTK is one of the GPS surveying method that are stable, fast, accurate and well suited to everyday surveying project.

For this project, there is collaboration with Inai Kiara Sdn Bhd, a marine contractor company that performing reclamation work at Kuala Terengganu, Terengganu. Inai Kiara agreed to collaborate in term of using the RTK GPS equipment, 3D Terramodel Software and reclamation site access.

Figure 1.1 Reclamation site

1.3 Objectives and scope of study

The objectives of this project are listed below:

1. To get familiar with RTK GPS usage.
2. To produce a DTM with RTK GPS
3. To apply the DTM to estimate the volume for cut and fill of the area.
4. To simulate and monitor the reclamation work

The scope for this project will focus at reclamation site at Kuala Terengganu as main study area. The project will utilise the usage of RTK GPS for data collection method, 3D Terramodel Software for modelling part that applying TIN points

1.4 Significance of Project

The significance of this project is that in the future, companies that create DTM using RTK GPS has an advantages in analysis part via the suitable software. Various types of analysis can be done like estimating the cut and fill volume, simulation and monitor of the work, flood mitigation and many more upon the completion of DTM. Besides, companies as well as universities would be able to generate DTM using the data obtained from RTK GPS which is more faster and high accuracy with less time consuming.

CHAPTER 2

LITERATURE REVIEW/THEORY

2.1 Digital Terrain Modeling, DTM

A digital terrain model is a digital model of the earth terrain surface. It uses one or more calculated functions such as interpolation functions to describe the surface according to some specific methods based on set of measured data points. When the process of representation of terrain surface is achieved, it is called surface reconstruction or DTM. The idea of interpolation includes surface reconstruction, extraction of height information, and formation of contours from randomly points.

DTM comprises four major components, that is, data collection, data manipulation and management, computation and modelling, and application.

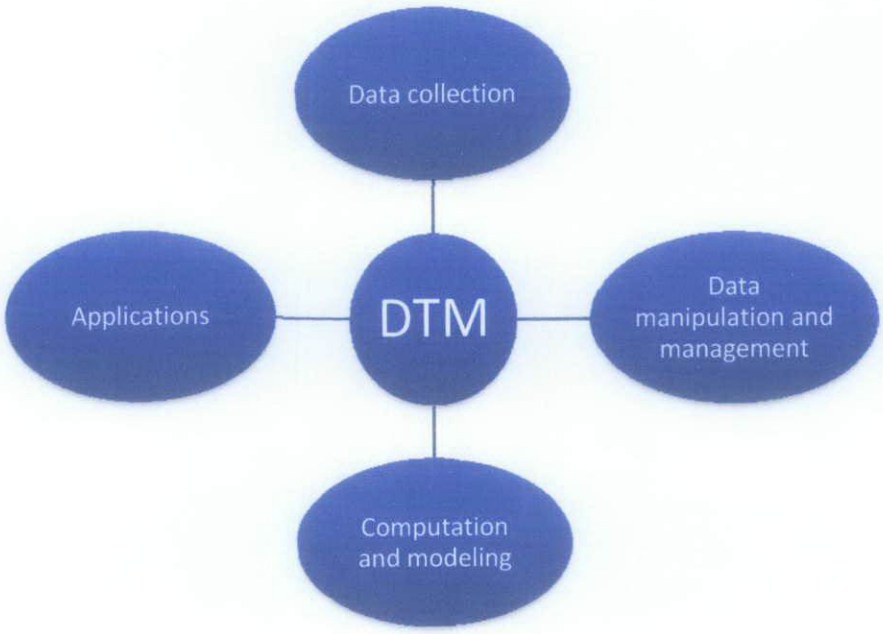


Figure 2.1 Component of DTM

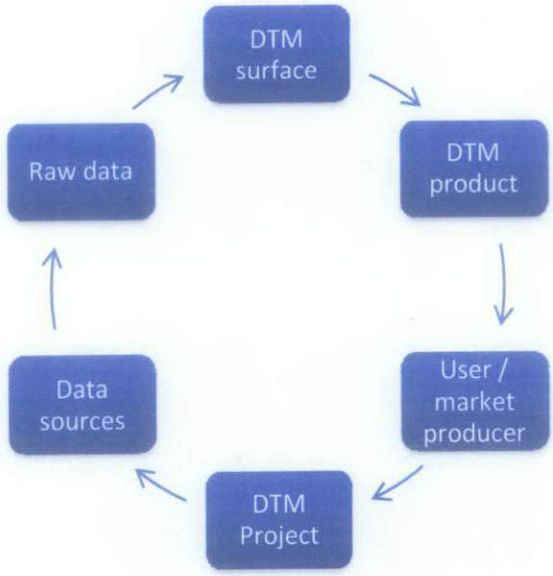


Figure 2.2 The whole process of digital terrain modelling.

In the late1950s, Miller and Laflamme (1958) introduced DTM into civil engineering. Basically, DTM uses regular – grid networks and triangular irregular networks (TINs). A network is a set of structure data used in a unique pattern for surface modelling. It concern with inter – relationship of the data points in the positional. Network differs from DTM surface constructed from network and consist a series of sub – surfaces having or not having continuity in first derivatives.

Originally, terrain models were physical models, made of rubber, plastics, clay, sand, etc. Then, the computer has been introduced and the modelling of terrain been carried out digitally, leading to the current discipline namely digital terrain modelling.

Zhilin Li, Qing Zhu, and C. Gold (2005) added that the advantages of the DTM compared to conventional have the following unique features:

1) A variety of representation forms: In digital forms, various forms of representations can be easily produced, such as topographic maps, vertical and cross sections, and 3-D animation.
2) No accuracy loss of data over time: As time goes by, paper maps may be deformed, but the DTM can keep its precision owing to the use of digital medium.
3) Greater feasibility of automation and real – time processing: DTM can be arranged in different resolutions, corresponding to representations at different scales.

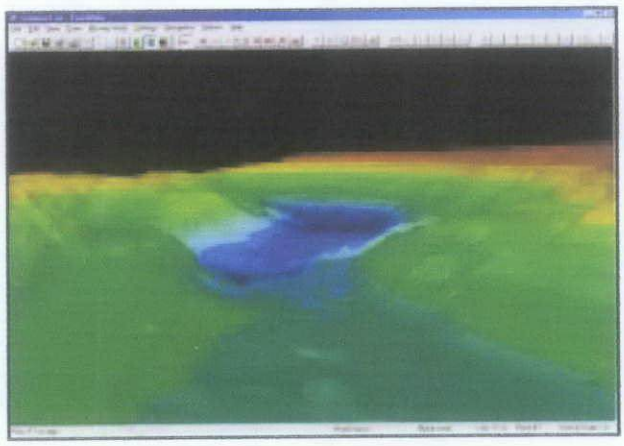


Figure 2.3 Example of DTM generated using TIN model, taken from *Trimble Technical Notes*

2.1.1 Triangular Irregular Network (TIN)

Triangular Irregular Networks (TINs) have been widely used for surface modelling. TIN network is the vector based representation of the physical land surface, made up of irregularly distributed nodes and lines with three dimensional coordinates (x, y, and z) arranged in a network of non overlapping triangles. It is the most basic and can be applied to both regular and irregular located data. The process of forming a triangular network is called triangulation. TIN network can be formed by interpolation from triangulation, which comprises a series of contiguous triangles and irregular size and shape.

Advantage of using a TIN over a DTM:

- The points of a TIN are distributed variably based on an algorithm that determines which points are most necessary to an accurate representation of the terrain.
- Data input is therefore flexible and fewer points need to be stored
- Able to portray terrain in three dimensions.

2.1.1.1 Principle of TIN Formation and Processing

For a set of randomly distributed data, there are many ways to form triangular network, as shown below:

Figure 5.2 Triangular networks with different shapes constructed from the same data set: (a) a set of data; (b) result 1; (c) result 2; and (d) result 3.

Figure 2.4 TIN formation

To form TIN, there are 2 choices:

- Static Delaunay triangulation – consider all data to form an overall network
- Dynamic triangulation – allow addition or removal of points during triangulation process

2.2 Global Positioning System, GPS

GPS is a satellite-based navigation system made up of a network of 24 satellites placed into an orbit by the U.S. Department of Defense. 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.

GPS rely exclusively on the measurement of distances to fix positions. They are measured to satellites orbiting in nearly circular orbits at a nominal altitude of about 20,183 km above the earth.

The range are measured with signals that are broadcast from the GPS satellites to the GPS receivers in the microwave part of the electromagnetic spectrum; called a passive system. GPS is passive in the sense that only the satellites transmit signals; the users receive them. Hence, there is no limitation of GPS receivers that may simultaneously monitor the GPS signals.

Time measurement is essential to GPS surveying in many ways. For example, the determination of ranges like distance measurement in a modern trilateration survey, is done electronically. Distance is a function of the speed of light, electromagnetic signals of stable frequency and elapsed time. The signals from a GPS satellite do not return to the satellite means they travel one way, to the receiver.

2.2.1 How Does GPS Works?

Figure 2.5 The operation of GPS

GPS method is based on range intersection. Three distances from three known points are needed to determine an unknown position in 3 D space. In GPS, the positions of satellites are all known at any time due to constant monitored and controlled by ground station. For example, if someone wants to locate the GPS receiver, he must measure at least three distances from the receiver to three GPS satellites. Hence, the crucial part in GPS is measuring the span from the receiver to the satellites. The distance between GPS receiver and the satellite is:

$$D = c \times t$$

Where D is the distance, t is the travelling time and c is the velocity of light (299,792,458 m/sec).

2.3 Real Time Kinematic, RTK

Sickle, J.V. (2001) had mentioned that RTK is a process of transmitting the GPS signal corrections in real time from a reference receiver at a known location to one or more remote rover receivers. In practice, RTK systems use a single base station receiver and a number of mobile units. The base station is located at a known surveyed location while mobile units can then produce a highly accurate map by taking fixes relative to that point. The base station re-broadcasts the carrier phase and the mobile units compare their own phase measurements with the ones received from the base station. This allows the units to calculate their *relative* position to millimeters, although their absolute position is accurate only to the same accuracy as the position of the base station.

Using the code phase of GPS signals, as well as the carrier phase, which delivers the most accurate GPS information, RTK provides differential corrections to produce the most precise GPS positioning. The RTK process begins with a preliminary resolving the carrier phase ambiguity. This is a crucial aspect of any kinematic system, particularly in real-time where the velocity of a rover receiver should not degrade either the achievable performance or the system's overall reliability.

Most RTK systems clarify the integer ambiguity, *on-the-fly*. *On-the-fly* refers to a method of resolving the carrier phase ambiguity quickly. This method requires dual-frequency GPS receivers capable of making both carrier phase and precise pseudo range measurements. RTK have an accuracy level at about ± 2 cm in vertical and ± 2 cm horizontal. Today, RTK has become routine in development and engineering surveys where the distance between the base and roving receivers can most often be measured in thousands of feet.

Arslanoglu, M., Ozcelick, M. (2005) assessed that the advantages of RTK GPS to other GPS methods are listed below:

- Free Later calculation
- Coordinate known points make sensitive navigation and application
- In case of determination of well – known points (three points), the other points could be converted simultaneously to local coordinate system

In US, most transmitters connected to RTK GPS surveying equipment operate between 450 – 470 MHz and voice communications also sharing this range. Sickle, J.V. (2001) pointed out that GPS surveyors need to recognize that voice communication have priority over data communication. RTK needs a data rates at about 2400 bps updated every half of a second to make sure the processing data is meeting the expectations.

Utilization of the RTK technique requires at least five satellites for initialization. Tracking five satellites is safer in case of losing one instantly; also add strength to the results. Besides, it is necessary in RTK that every period contains a minimum of four satellites data without cycle slips.

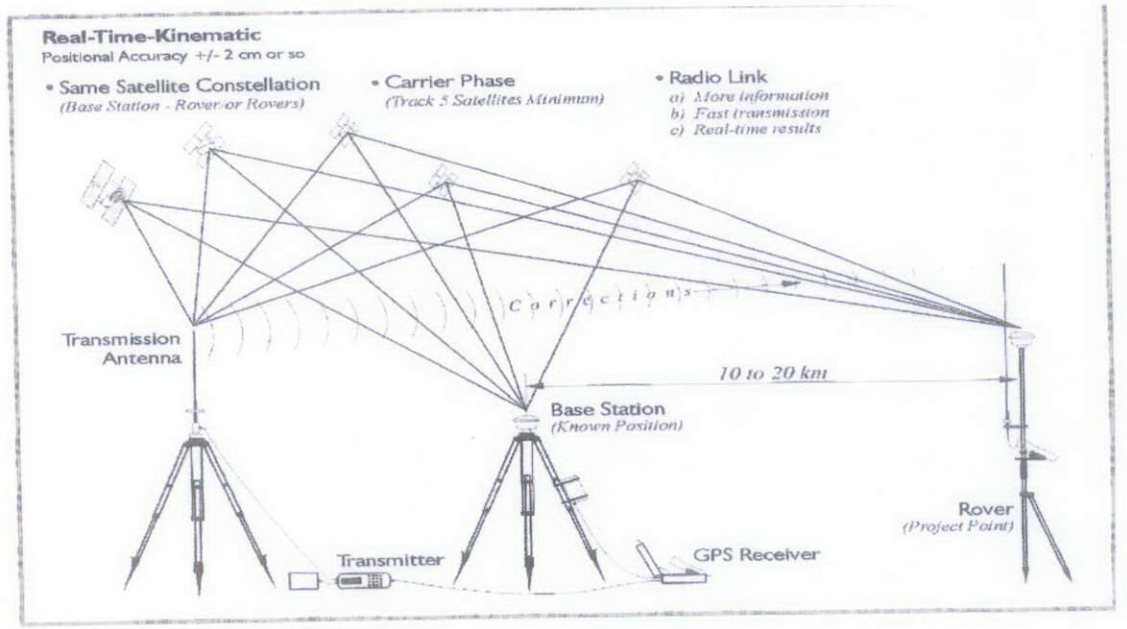


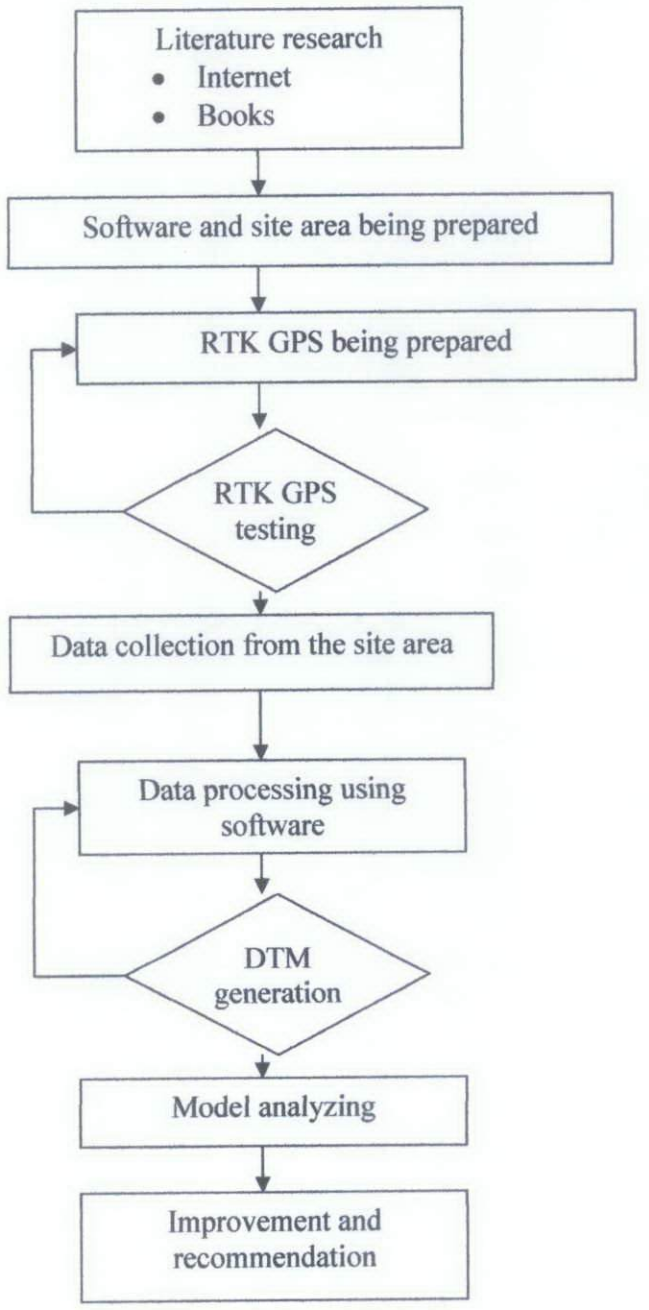
Figure 2.6 Real – Time Kinematics GPS

CHAPTER 3

METHODOLOGY

3.1 Work Flow

Below are the methods that will be implemented on the development of the DTM:



3.2 Preparing RTK GPS

Preparing the RTK involved setting up the base station, rover and controller for RTK survey. It consists of setting up the base station antenna and tripod followed by repeater radio. After setting up the base station, RTK rover needs to be configured including the cables and setting up the rover receiver. After that, set up the independent RTK repeater radio and then creating the new job for the RTK survey. Once the RTK GPS is ready, the RTK survey can be started.

Figure 3.1 Setting the base station located at known location

Figure 3.2 Base station, antenna and lightning conductor

Figure 3.3 Rover

Figure 3.4 RTK controller

3.3 Preparing the case study area

Before any survey work can be done, site preparation must be made like measuring the desired length of area, coordinate of initial control points and marking the temporary control points. GPS static positional practice can be operated to obtain the unknown coordinate of the control points. Equipment like measuring tapes, colour spray, nails, tripod, ruler staff and RTK are required to do the surveying work on site.

3.4 Collecting the data

Figure 3.6 collecting the data at the site

Once the RTK GPS is ready, it can be operated to obtain the data. Data can be in x, y, and z representing the north, east and elevation. To increase the accuracy and better shape of DTM, it was proposed to obtain many data inside the control area and occupying at the point a little bit longer. Once the data are collected, it can be downloaded into the computer and further processing can be done.

3.7 Hazard Analysis

According to U.S. Department of Labour Occupational Safety & Health Administration, hazard is the potential for any harm. A hazard always associated with uncontrolled activity that can cause injury and illness. Canadian Centre for Occupational Health and Safety mentioned that the job hazard analysis is a method to enhance the understanding of hazard in the workplace. This analysis is a procedure which helps integrate accepted safety and health principle and practices into a particular operation.

Hazard analysis can be done in several stages. According to Canadian Centre for Occupational Health and Safety, there are four basic steps involved:

- selecting the job to be analyzed
- breaking the job down into a sequence of steps
- identifying potential hazards
- determining preventive measures to overcome these hazards

Below are the listed potential accidents and preventive measure for my project.

Table 3.1 Potential hazards and preventive measures

Potential hazards	Preventive measure
a) Manual Handling of the instrument	Handling the instrument carefully
b) Adverse Weather condition	Prepare first aid kit around, bring enough drinking water.
c) Dusts	Put on dusts protector
d) Flying Debris	Use safety helmet
e) Being struck by the instrument	Wear PPE equipments, like safety helmet
f) Natural Environmental Hazards- Insects, Ticks, etc	Wear long pant and safety boots

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 Data Collection

Data collection processes were completed after one week of surveying works. There were about744 points recorded inside the designed area. The initial control point for the area is (**590591.491 N, 570512.157 E, 2.974 H**). The length of the site area is about 700 m and width at about 300 m. This survey works are using Malaysia RSO Grid as main grid. The resultant coordinates for the points were summarized below:

4.2 Data Processing

The resultant data from the site will be further analyzed using the Trimble Geomatics Office (TGO) and Terramodel 3D. The figure shows the coordinates in TGO file type. This is the first steps to develop 3 D of the surface. Then, this data file will be converted into *dxf* file so that it can be exported into Terramodel 3D. Details about the process flow are illustrated in Figure 4.1

Figure 4.1 Process flow

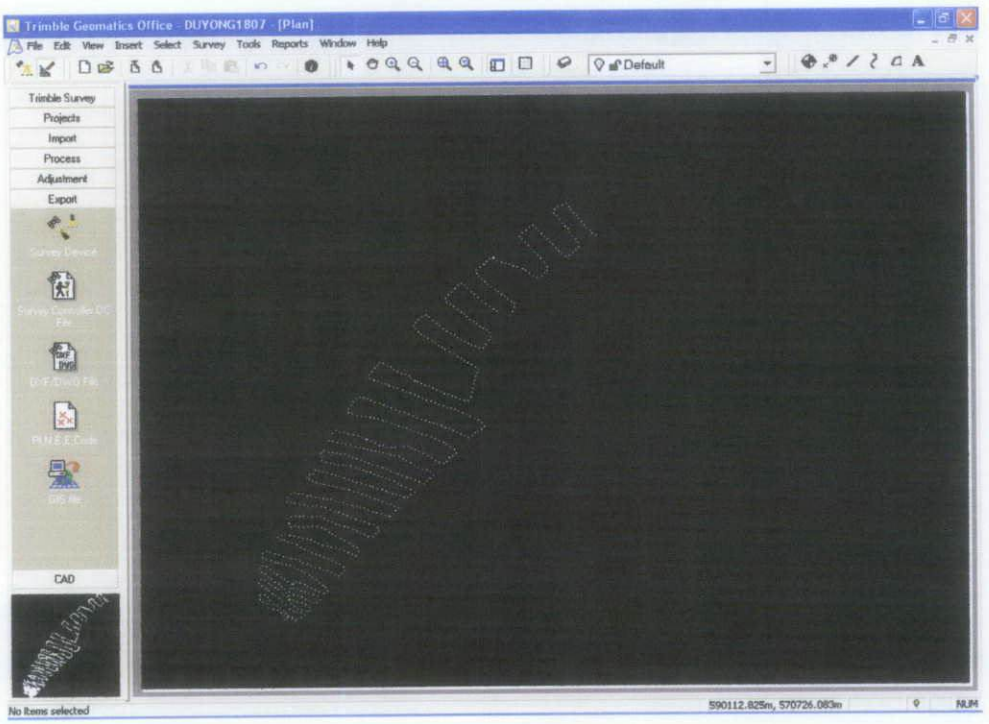


Figure 4.2 Data in Trimble Geomatics Office

4.3 Creation of DTM

These two following figures show the digital model of the reclamation site. From the figures, we can see the colour changes from red to dark green as indicator for the different height at the reclamation site. Besides, the triangular networks that connect the data are clearly shown in the figure. Upon completion of the digital model of this site, cut and fill volume analysis can be carried out to simulate and monitor the reclamation works, either the reclamation process is completed or not.

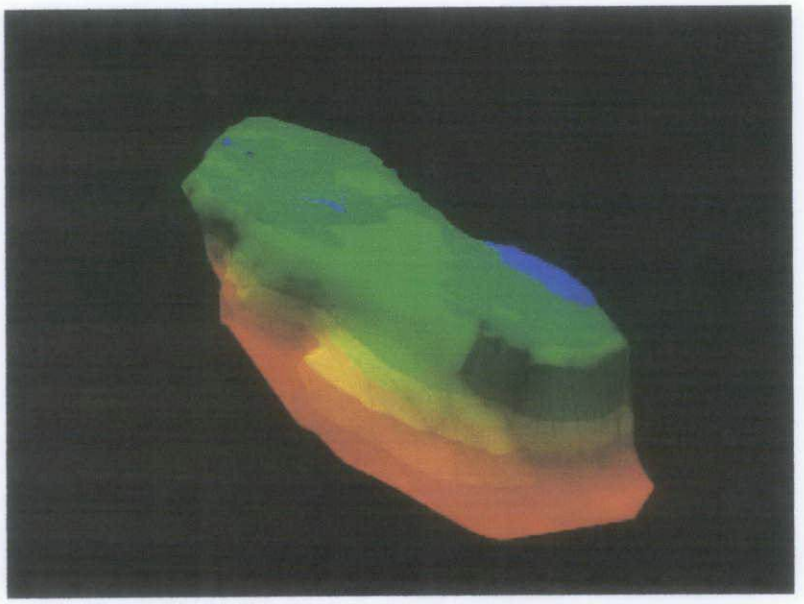


Figure 4.3 Terramodel 3D

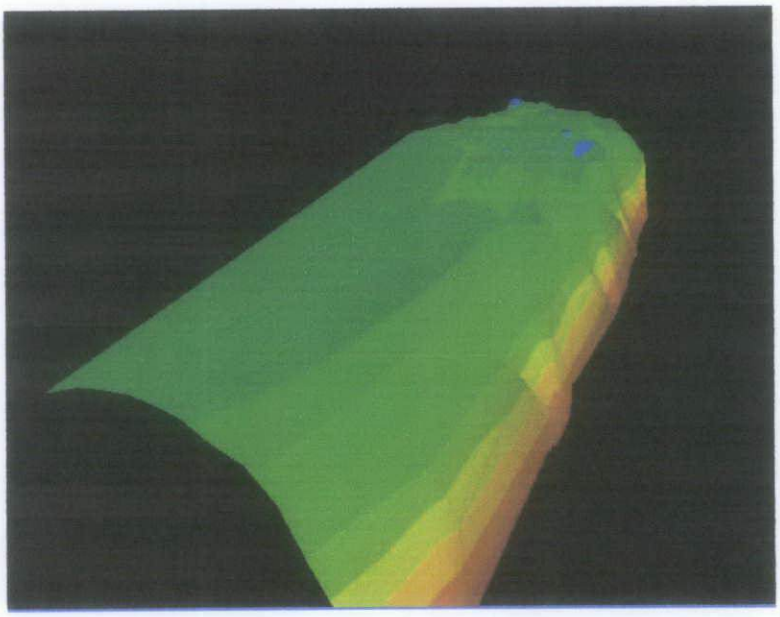


Figure 4.4 Terramodel 3D different angles

4.4 Volume Calculation

There are two main methods to calculate the volume of cut and fill using Terrramodel, which are by cross section and by surface to surface. Volume calculation by cross section is done by calculating the volume form one point to another point, whereas volume calculation by surface to surface is done by overlapping the layers of DTM of the area before reclamation work is done with the DTM of the area after the reclamation work began. Cross section method is suitable for monitoring the work progress since it provide the calculated volume in section

4.4.1 Volume Calculation by Surface to Surface

In this method, two DTMs for the site before and after the reclamation work are needed since the principle of this surface to surface method is about the overlapping the layer of DTMs. From Figure 4.5, the connected green line is the original DTM layer of the site before any reclamation works begins which consists of 7 points, which are all at elevation of 0 m. The white dotted layer is the final DTM layer which consists of 744 points.

So, the cumulative fill volume by this method is **297,378.27 Cu. m**. There is no cut volume during the reclamation process. The shrinkage and swell factors for cut and fill is fixed to 1.000.

Figure 4.5 Volume calculations by Surface to Surface

Table 4.1 Volume calculation of area using surface to surface method

Layer Name	No of Point	Cut Volume (cu. m)	Fill Volume (cu. m)
Original (Green line)	**7**	**0**	**0**
Default (White dotted)	**744**	**0**	**297,378.27**
		Cumulative Fill Volume	**297,378.27**
		Proposed Fill Volume	**295,000.00**

4.5 Monitoring the Work Progress

Work progress of the reclamation in term of volume filled can be monitored consistently on site by using special function called volume calculation by cross section method. To use this method, the reclaimed site need to be fragmented into several segments so that the comparison between volume filled with proposed volume filled of each segment can be carried out.

Specifically, there are 14 sections contain approximately 54 points on each section along the reclamation area. The interval of each section is 50 m and the length of reclaimed site area is about 700 m. The table shows the volume filled at each section, proposed volume to be filled and difference percentages. The total proposed volume and proposed volume to be filled at each section are obtained from the drawing contract provided by Inai Kiara Sdn. Bhd.

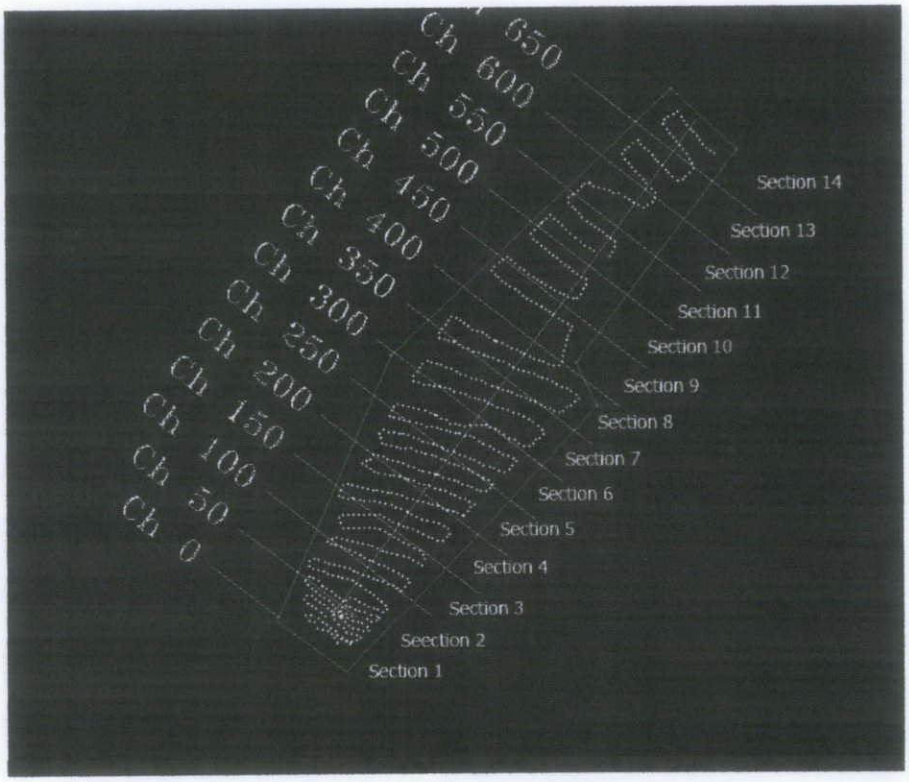


Figure 4.6 Section of the area

The following figures show the development of DTM section by section. This DTM was developed upon the completion of each section to supervise the progress of the work.

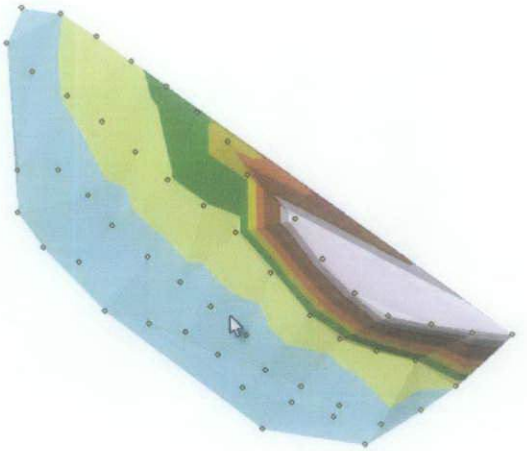


Figure 4.7 DTM for section 1

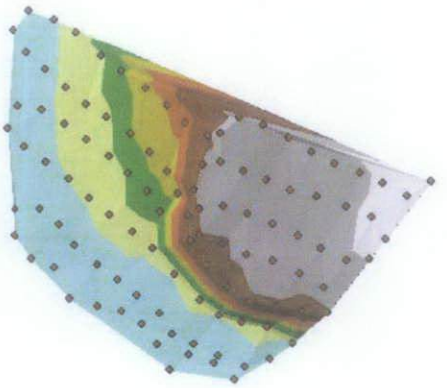


Figure 4.8 DTM from section 1 to section 2

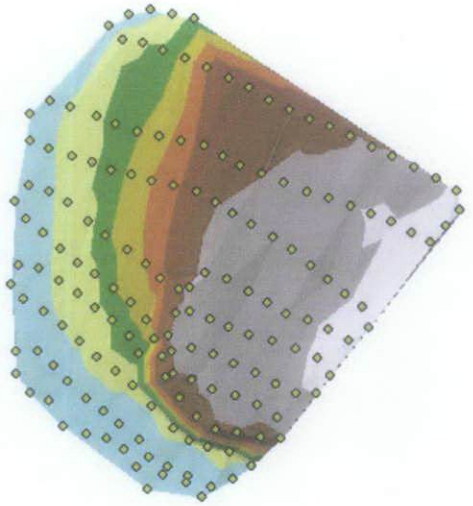


Figure 4.9 DTM from section 1 to section 3

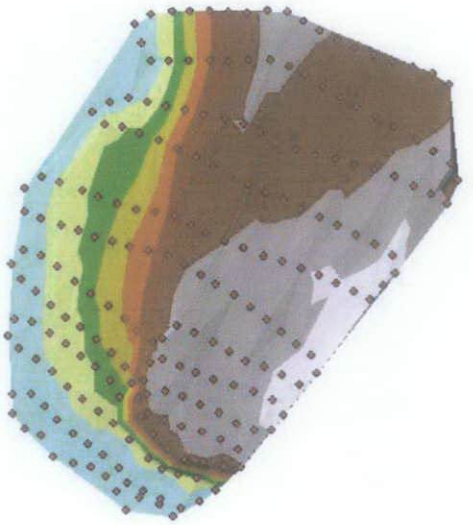


Figure 4.10 DTM from section 1 to section 4

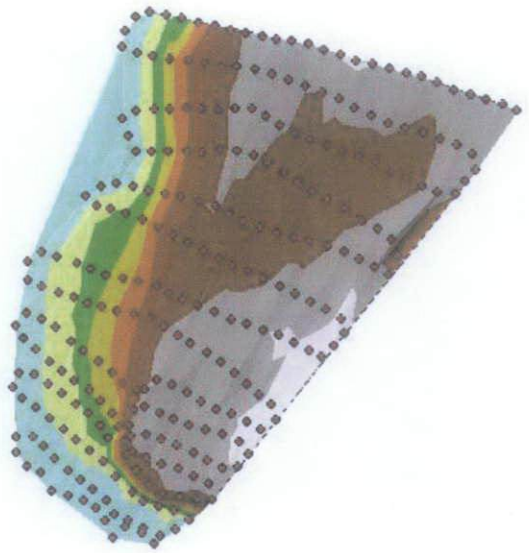


Figure 4.11 DTM from section 1 to section 5

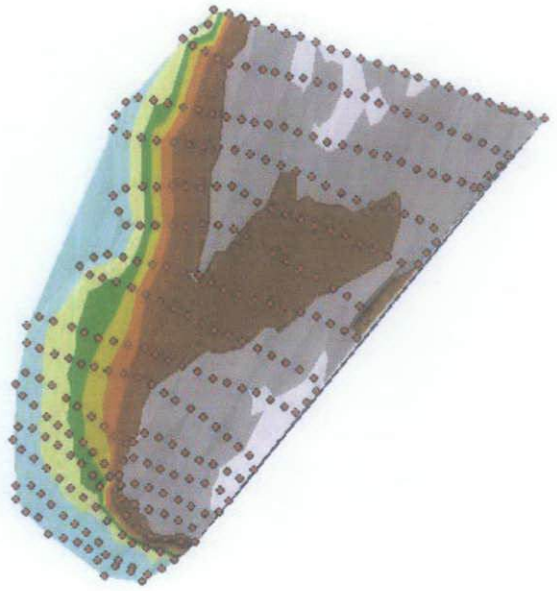


Figure 4.12 DTM from section 1 to section 6

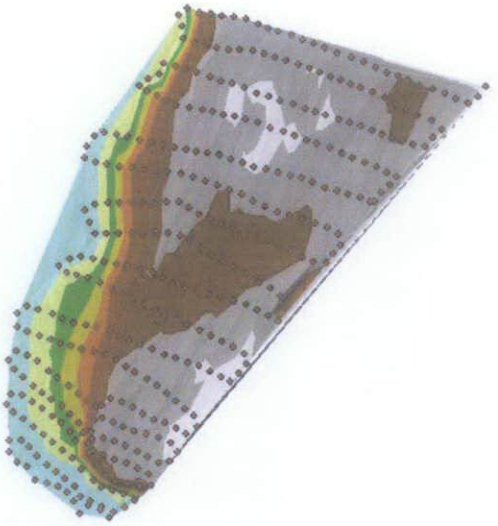


Figure 4.13 DTM from section 1 to section 7

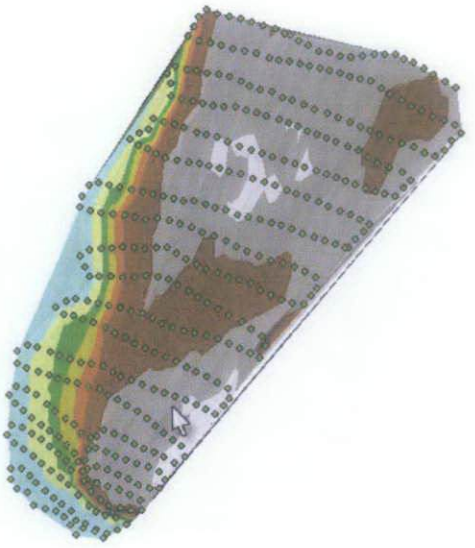


Figure 4.14 DTM from section 1 to section 8

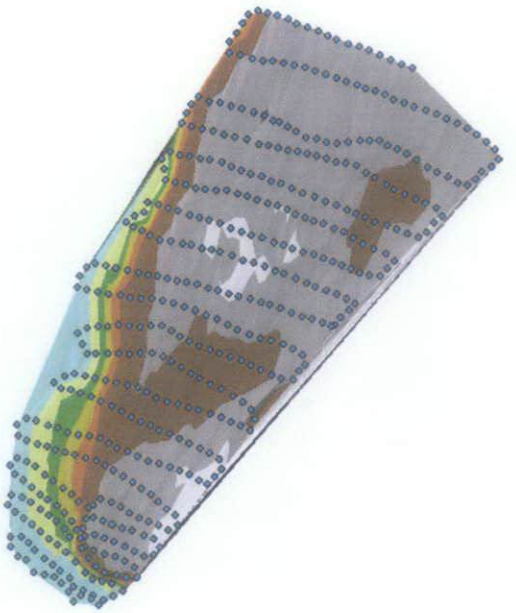


Figure 4.15 DTM from section 1 to section 9

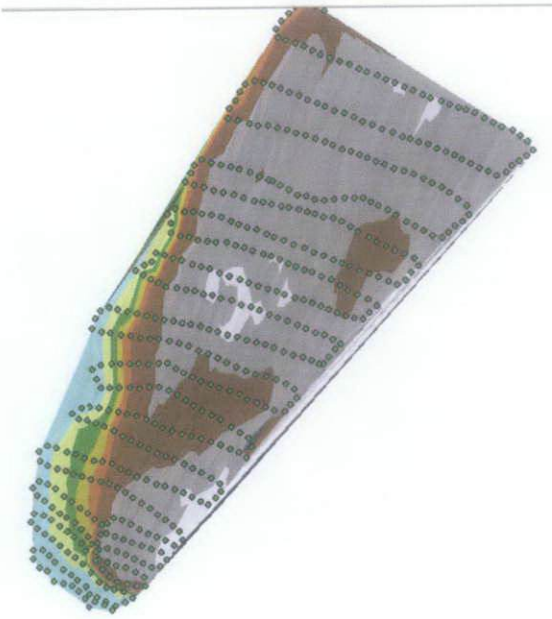


Figure 4.16 DTM from section 1 to section 10

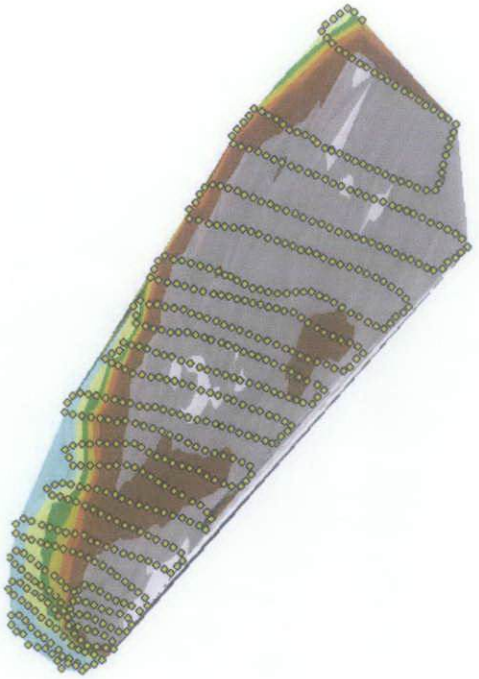


Figure 4.17 DTM from section 1 to section 11

Figure 4.18 DTM from section 1 to section 12

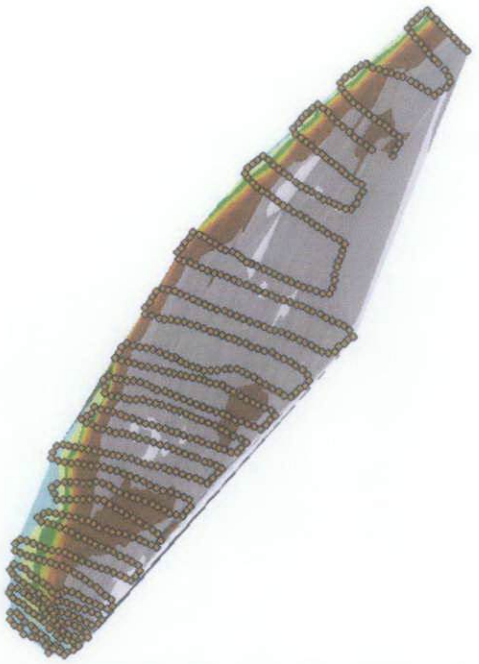


Figure 4.19 DTM from section 1 to section 13

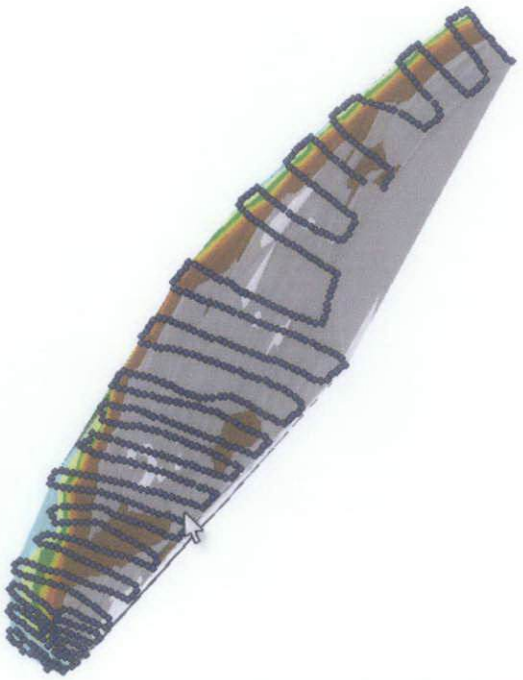


Figure 4.20 DTM for the whole area of reclamation

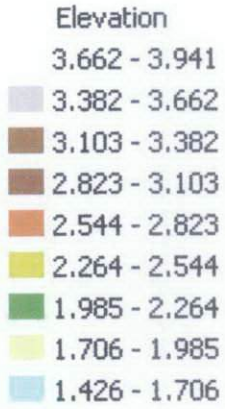


Table 4.2 Table Amount of sand being filled at each section

Section	Point Number	Volume filled (cu. m)	Proposed volume to be filled (cu. m)	% differences
1	1 to 54	6877.95	7000.00	0.174
2	55 to 109	15757.44	15000.00	0.050
3	110 to 164	19449.10	20000.00	0.028
4	165 to 219	22676.06	20000.00	0.134
5	220 to 274	25509.67	25000.00	0.020
6	275 to 329	28036.67	30000.00	0.065
7	330 to 384	30631.64	30000.00	0.021
8	385 to 439	31364.27	30000.00	0.046
9	440 to 494	28068.16	30000.00	0.064
10	495 to 549	24277.39	25000.00	0.029
11	550 to 604	22156.44	20000.00	0.108
12	605 to 659	19577.10	20000.00	0.021
13	660 to 714	16021.41	13000.00	0.234
14	714 to 744	8081.17	10000.00	0.192
	Total Volume	298484.47	295000.00	0.012

From the table, we can figure out that the difference between proposed volume and volume filled at each section is significantly in small value, ranging around just 0.02% to 0.2 %. This indicates that the accuracy of the software's volume calculation application is good and it is acceptable. Generally, it is proven that the monitoring work of reclamation work can actually be done digitally onsite.

4.5.1 Picture of Site Monitoring Work

Figure 4.21 Sand being pumped out from the dredger

Figure 4.22 Sand being discharged at designated area

Figure 4.23 Excavator being used to level the sand

Figure 4.24 Ongoing levelling works

Figure 4.25 Excavator being used to level the sand

Figure 4.26 Completed reclamation area

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The demand of digital terrain modelling especially in construction industry nowadays is rapidly increasing due to its beneficial and widely useful applications. It can provide a better platform in analyzing stages with improved accuracy and less time consumed in construction. In my project, it is concluded that the digital model of the terrain surface is found to be successfully generated using the data collected with RTK GPS as main data collection tools.

Basically, this project successfully fulfils the objectives where DTM for the reclamation area is successfully generated using data obtained using RTK GPS. Figure 4.3 and 4.4 clearly shows the DTM of the area.

Secondly, the volume calculation of the area is successfully calculated using the Terramodel Software, as shown in Table 4.1 by using the method of surface to surface.

Next, the progress of reclamation work can be monitored digitally. This can be done by monitoring the work in section, like in Figure 4.6 where the area is divided into 14 sections. So, the volume calculation comparison of each section can be done later to achieve this monitoring purposes.

5.2 Recommendations

To increase the level of accuracy of the points collected, it is suggested that we should occupy on the point a little bit longer around five to ten minutes. This is to allow for more connections between the rover and the satellites and also to the base station.

To increase the accuracy of the outcome result, it is suggested that we should take more points inside designated area. For my project, I had collected 744 points inside the area and it is possible to obtain more points up to thousand points. In construction scope, it depends on the needs of the owner of the project whether they need the high accuracy in their project. If high accuracy of the project is the main criteria for the owner, the contractor should collect more data inside the area to produce highly accurate outcome.

Next, civil student in UTP should undergo a learning course in operating RTK GPS during taking Geomatics course. In my experience during doing my final year project, this surveying tool is very beneficial but then only few people in UTP managed to use this tool properly. The learning course should cover basic understanding on the operation of RTK GPS and onsite operation to prepare the students on handling this tool later.

Purchasing Terramodel Software should be a good step since this modelling software is very beneficial and effective that would benefit the student in learning surveying works. Many analyzing tools are inside this software like cut and fill volume calculation, drainage flow and many more.

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APPENDICES

Appendix A: Resultant Coordinates

No	Northing (m)	Easting (m)	Elevation (m)
1	590591.491	570512.157	2.974
2	590595.790	570508.934	2.508
3	590600.268	570505.056	1.529
4	590598.220	570500.207	1.517
5	590595.229	570494.691	1.597
6	590592.480	570490.077	1.535
7	590575.184	570525.569	4.058
8	590563.121	570536.175	4.155
9	590571.154	570528.843	4.124
10	590567.050	570532.335	4.164
11	590559.225	570539.856	4.116
12	590556.389	570544.220	4.040
13	590582.980	570518.715	3.772
14	590587.045	570515.333	3.481
15	590578.973	570522.132	3.879
16	590587.496	570489.437	2.437
17	590583.019	570493.104	3.113
18	590578.456	570496.768	3.444
19	590573.821	570500.363	3.681
20	590565.196	570507.715	4.258
21	590560.990	570511.112	4.108
22	590556.145	570514.296	4.303
23	590569.340	570503.951	3.943
24	590562.876	570469.521	3.141
25	590559.190	570473.365	3.457
26	590555.332	570477.097	3.640
27	590570.793	570461.538	1.737
28	590566.898	570465.560	2.846
29	590567.797	570456.481	1.662

30	590564.441	570452.616	1.635
31	590551.551	570517.453	4.224
32	590546.983	570520.876	4.241
33	590540.952	570522.062	4.181
34	590536.758	570517.491	4.181
35	590544.095	570487.868	4.339
36	590540.078	570491.914	4.286
37	590536.336	570495.447	4.293
38	590533.147	570513.690	4.231
39	590529.540	570509.737	4.196
40	590532.220	570499.697	4.239
41	590528.418	570504.263	4.249
42	590551.617	570480.467	3.979
43	590547.898	570484.101	4.272
44	590547.501	570452.189	3.140
45	590534.469	570463.612	4.038
46	590538.842	570459.483	3.717
47	590543.161	570455.786	3.405
48	590526.237	570471.255	4.246
49	590520.252	570476.477	4.189
50	590529.942	570467.879	4.124
51	590561.031	570448.588	1.584
52	590556.342	570444.606	1.875
53	590551.726	570448.107	2.805
54	590515.986	570435.660	4.165
55	590517.820	570430.480	4.147
56	590519.485	570425.458	3.671
57	590521.270	570420.259	3.182
58	590523.263	570414.281	2.864
59	590526.426	570410.177	2.225
60	590526.229	570409.933	2.197
61	590526.694	570409.127	1.957
62	590525.539	570404.255	1.572

63	590522.130	570400.520	1.559
64	590518.372	570396.246	1.544
65	590514.988	570480.367	4.187
66	590509.881	570480.861	4.309
67	590506.364	570477.218	4.355
68	590502.442	570472.596	4.215
69	590505.653	570456.880	4.230
70	590509.146	570452.078	4.179
71	590502.330	570461.538	4.174
72	590499.486	570467.250	4.166
73	590512.034	570447.602	4.185
74	590514.989	570440.899	4.066
75	590483.398	570411.491	4.021
76	590480.203	570415.860	3.927
77	590498.123	570394.478	3.474
78	590514.579	570391.606	1.513
79	590510.897	570386.963	1.509
80	590505.736	570387.529	2.263
81	590501.803	570391.036	3.138
82	590486.574	570407.180	3.953
83	590490.640	570401.878	4.011
84	590494.101	570398.105	3.926
85	590485.488	570376.142	3.308
86	590481.108	570380.154	3.620
87	590467.634	570432.879	3.963
88	590464.345	570436.864	3.936
89	590458.988	570436.696	3.884
90	590473.974	570424.342	3.890
91	590470.840	570428.610	3.911
92	590476.960	570420.165	3.918
93	590453.792	570433.937	3.838
94	590448.507	570431.092	4.007
95	590454.101	570413.913	4.026

96	590468.323	570394.524	3.933
97	590460.499	570403.869	3.893
98	590464.306	570399.177	4.061
99	590473.116	570388.974	4.026
100	590476.945	570384.633	4.040
101	590457.237	570409.038	3.914
102	590440.407	570382.808	4.190
103	590443.658	570378.656	4.227
104	590447.064	570374.647	4.239
105	590492.619	570367.421	1.616
106	590489.120	570371.968	2.953
107	590489.308	570363.073	1.546
108	590486.172	570359.034	1.514
109	590485.017	570357.811	1.553
110	590481.211	570354.165	1.562
111	590460.620	570356.926	3.555
112	590476.970	570350.427	1.579
113	590472.468	570346.394	1.469
114	590467.607	570348.491	2.292
115	590464.048	570352.636	3.241
116	590453.426	570366.336	4.328
117	590450.336	570370.451	4.314
118	590457.263	570361.850	3.685
119	590449.624	570320.379	1.568
120	590442.069	570329.500	2.698
121	590446.777	570324.862	2.163
122	590446.564	570315.787	1.591
123	590442.883	570311.213	1.586
124	590439.393	570306.449	1.529
125	590430.600	570396.015	3.941
126	590424.722	570404.775	4.069
127	590427.721	570400.518	4.188
128	590437.048	570387.194	4.088

129	590433.735	570391.600	4.041
130	590419.490	570405.266	4.111
131	590414.791	570402.789	4.117
132	590409.705	570399.846	4.018
133	590405.177	570396.079	4.096
134	590410.854	570376.517	4.212
135	590406.786	570385.747	4.366
136	590405.071	570390.878	4.246
137	590408.642	570381.040	4.364
138	590384.389	570375.411	4.034
139	590378.539	570385.061	4.032
140	590375.289	570389.650	4.016
141	590381.500	570380.440	4.136
142	590370.249	570387.963	3.971
143	590365.614	570386.023	4.006
144	590421.508	570357.526	4.218
145	590434.806	570338.094	4.217
146	590431.184	570343.008	4.342
147	590427.658	570348.065	4.455
148	590424.180	570353.076	4.238
149	590415.714	570367.148	4.359
150	590413.044	570371.499	4.303
151	590418.814	570361.851	4.362
152	590402.774	570345.999	4.182
153	590408.024	570337.252	4.316
154	590405.337	570341.522	4.138
155	590438.135	570333.908	3.443
156	590420.488	570318.939	3.824
157	590431.115	570307.239	2.366
158	590434.906	570303.924	1.812
159	590427.530	570310.810	2.949
160	590423.497	570314.895	3.350
161	590411.460	570332.394	4.426

162	590414.392	570328.185	4.378
163	590417.787	570323.189	4.192
164	590396.527	570357.133	4.056
165	590393.693	570361.297	4.104
166	590387.392	570370.437	4.036
167	590390.259	570366.266	4.075
168	590399.722	570351.408	4.089
169	590367.175	570297.957	4.051
170	590363.971	570300.741	4.103
171	590360.706	570384.435	3.976
172	590355.789	570382.720	3.971
173	590349.703	570381.376	3.963
174	590344.577	570380.504	3.927
175	590338.523	570379.067	4.001
176	590333.609	570376.181	4.126
177	590306.512	570388.760	4.220
178	590309.546	570384.287	4.182
179	590311.639	570378.565	4.116
180	590314.077	570373.315	4.211
181	590303.376	570393.588	4.158
182	590298.278	570396.716	4.366
183	590295.044	570392.545	4.260
184	590291.712	570388.628	4.262
185	590289.590	570384.046	4.245
186	590343.939	570344.185	4.246
187	590346.392	570339.198	4.202
188	590335.797	570364.919	4.224
189	590339.460	570354.177	4.291
190	590337.848	570359.148	4.316
191	590333.929	570370.471	4.149
192	590341.781	570349.184	4.322
193	590324.848	570348.077	4.117
194	590326.805	570342.555	4.357

195	590328.724	570336.756	4.349
196	590354.709	570319.886	4.265
197	590348.527	570334.234	4.291
198	590350.825	570329.547	4.210
199	590352.864	570324.689	4.297
200	590359.681	570309.635	4.405
201	590359.681	570309.613	4.407
202	590359.617	570309.657	4.408
203	590359.630	570309.588	4.399
204	590359.621	570309.538	4.398
205	590359.599	570309.487	4.390
206	590357.584	570314.789	4.311
207	590361.276	570305.461	4.339
208	590343.983	570299.392	4.179
209	590335.082	570321.108	4.340
210	590337.631	570315.522	4.345
211	590330.276	570331.791	4.172
212	590332.889	570326.532	4.229
213	590339.338	570310.790	4.323
214	590341.856	570305.187	4.288
215	590316.900	570368.070	4.157
216	590321.520	570357.657	4.239
217	590319.508	570362.378	4.233
218	590323.111	570352.854	4.200
219	590288.180	570365.191	3.996
220	590292.982	570355.128	4.016
221	590290.686	570360.192	4.044
222	590297.514	570345.115	4.126
223	590301.838	570334.963	4.202
224	590299.498	570340.211	4.084
225	590295.525	570350.105	4.138
226	590306.734	570319.747	4.296
227	590315.624	570296.829	4.046

228	590311.019	570308.296	4.201
229	590308.755	570314.055	4.233
230	590313.349	570302.591	4.053
231	590303.385	570329.586	4.282
232	590305.027	570324.460	4.320
233	590286.715	570320.696	4.122
234	590288.376	570314.848	4.070
235	590290.416	570309.341	4.065
236	590292.722	570303.934	4.168
237	590294.725	570299.122	4.192
238	590285.297	570380.516	4.257
239	590283.987	570375.042	4.280
240	590285.910	570370.151	4.207
241	590277.502	570342.754	4.059
242	590279.870	570337.325	4.061
243	590274.014	570347.452	4.030
244	590270.405	570352.320	4.208
245	590266.517	570357.062	4.225
246	590261.533	570358.819	4.264
247	590257.803	570354.982	4.279
248	590255.337	570350.302	4.179
249	590251.131	570346.740	4.063
250	590248.233	570342.541	4.155
251	590249.609	570337.149	4.269
252	590282.342	570331.979	4.152
253	590284.924	570326.425	4.115
254	590267.414	570305.707	4.070
255	590271.619	570296.400	4.258
256	590269.207	570301.005	4.155
257	590257.979	570321.640	4.047
258	590261.584	570315.671	3.934
259	590255.373	570326.957	4.045
260	590252.458	570332.069	4.178

261	590264.811	570310.912	4.011
262	590249.029	570299.752	3.842
263	590239.144	570320.590	3.914
264	590236.747	570326.067	4.181
265	590232.657	570329.143	4.275
266	590243.608	570309.710	3.713
267	590241.109	570314.971	3.784
268	590246.418	570304.090	3.836
269	590228.877	570324.573	4.412
270	590224.391	570321.046	4.411
271	590221.477	570316.354	4.188
272	590223.263	570310.883	4.035
273	590225.980	570305.396	4.033
274	590227.985	570299.765	3.977
275	590213.550	570299.434	3.996
276	590209.573	570303.949	4.143
277	590205.604	570299.827	4.086
278	590381.798	570269.261	3.599
279	590384.522	570264.773	3.009
280	590386.305	570259.883	2.621
281	590373.005	570282.556	4.045
282	590376.053	570278.101	3.913
283	590369.538	570293.189	4.015
284	590371.301	570287.948	4.070
285	590379.293	570273.916	3.815
286	590381.782	570256.881	2.985
287	590377.949	570253.157	2.989
288	590373.303	570249.152	2.979
289	590369.318	570245.924	2.968
290	590364.174	570246.645	3.334
291	590345.934	570294.780	4.143
292	590348.053	570288.805	4.068
293	590350.251	570283.249	4.017

294	590352.240	570277.618	3.928
295	590354.191	570272.116	4.024
296	590358.908	570262.002	4.051
297	590356.516	570267.136	4.070
298	590326.102	570269.722	4.117
299	590330.695	570258.987	3.977
300	590328.259	570264.322	3.983
301	590360.575	570256.805	4.106
302	590362.429	570251.645	3.793
303	590335.121	570248.532	4.145
304	590336.836	570243.239	4.160
305	590332.576	570253.480	4.098
306	590339.209	570233.156	3.310
307	590338.316	570238.339	3.931
308	590337.574	570227.729	2.754
309	590333.177	570224.716	2.724
310	590328.190	570221.844	2.863
311	590318.122	570291.319	4.060
312	590320.220	570286.106	4.108
313	590321.885	570280.267	4.053
314	590324.016	570274.360	4.158
315	590305.593	570268.605	4.029
316	590307.558	570262.762	4.005
317	590296.635	570294.431	4.217
318	590298.061	570289.554	4.182
319	590301.724	570278.980	4.154
320	590299.804	570284.620	4.091
321	590303.628	570274.212	4.115
322	590310.999	570252.041	4.052
323	590309.294	570257.492	4.087
324	590312.230	570246.457	4.150
325	590313.124	570240.726	4.204
326	590314.893	570230.029	4.202

327	590316.677	570223.238	3.954
328	590313.661	570235.245	4.181
329	590286.538	570230.213	4.004
330	590288.493	570224.153	4.093
331	590323.553	570217.928	3.066
332	590317.889	570217.764	3.374
333	590291.548	570212.810	4.172
334	590290.023	570218.552	4.205
335	590292.679	570207.171	4.014
336	590294.717	570201.577	3.400
337	590291.450	570197.378	3.062
338	590286.717	570195.059	2.849
339	590271.577	570291.277	4.252
340	590271.456	570285.950	4.215
341	590271.024	570279.715	4.097
342	590270.343	570273.964	4.200
343	590271.239	570268.413	4.243
344	590273.021	570263.219	4.238
345	590258.683	570284.110	4.156
346	590259.996	590259.996	4.265
347	590255.099	570289.155	4.019
348	590252.31	570293.690	3.896
349	590262.497	570268.394	4.221
350	590260.969	570273.377	4.184
351	590263.780	570263.528	4.171
352	590265.056	570258.517	4.226
353	590281.582	570243.483	4.137
354	590282.576	570240.680	4.047
355	590279.092	570248.147	4.107
356	590273.681	570257.944	4.199
357	590276.703	570252.913	4.116
358	590267.450	570248.266	4.212
359	590268.563	570243.008	4.152

360	590284.563	570235.946	3.919
361	590269.606	570237.831	4.183
362	590270.275	570232.826	4.209
363	590272.601	570226.408	4.046
364	590274.164	570220.512	4.055
365	590266.437	570253.221	4.147
366	590249.774	570244.386	4.155
367	590251.186	570239.577	4.211
368	590253.665	570234.222	4.233
369	590255.280	570228.270	4.176
370	590256.802	570223.249	4.139
371	590229.675	570293.885	3.899
372	590232.186	570288.423	3.937
373	590234.232	570283.747	3.961
374	590235.998	570278.868	4.034
375	590240.805	570267.671	3.980
376	590242.941	570261.984	4.073
377	590238.546	570273.399	4.036
378	590230.661	570261.633	4.090
379	590224.528	570277.549	3.960
380	590221.491	570282.591	3.930
381	590216.178	570292.920	3.960
382	590218.575	570287.361	3.882
383	590226.787	570272.035	4.086
384	590228.958	570266.343	4.067
385	590211.374	570266.430	4.042
386	590213.136	570261.424	4.178
387	590245.282	570255.722	4.094
388	590247.584	570250.031	4.110
389	590234.434	570252.167	4.285
390	590232.592	570256.939	4.182
391	590236.591	570247.256	4.339
392	590238.502	570242.470	4.335

393	590240.093	570237.564	4.295
394	590242.103	570231.586	4.212
395	590243.815	570226.587	4.264
396	590245.270	570221.305	4.248
397	590219.932	570240.408	4.127
398	590214.734	570256.061	4.308
399	590216.632	570250.029	4.369
400	590218.482	570245.369	4.291
401	590221.929	570234.531	4.259
402	590225.390	570223.609	4.358
403	590223.656	570228.658	4.315
404	590211.148	570224.165	4.397
405	590277.004	570208.836	4.065
406	590278.505	570203.117	3.984
407	590275.469	570214.514	4.073
408	590281.493	570192.374	2.701
409	590279.616	570197.248	3.325
410	590259.244	570218.640	4.141
411	590261.691	570213.121	4.204
412	590262.540	570207.337	4.132
413	590263.404	570201.845	4.099
414	590264.445	570196.397	3.857
415	590265.007	570191.421	3.269
416	590266.854	570185.860	2.297
417	590258.355	570183.098	1.834
418	590248.479	570199.345	4.127
419	590249.873	570194.289	3.813
420	590251.070	570188.754	3.430
421	590252.768	570183.410	2.205
422	590263.605	570181.713	1.821
423	590246.876	570215.995	4.114
424	590246.944	570210.125	4.109
425	590247.339	570204.648	4.101

426	590229.551	570211.878	4.319
427	590231.653	570206.203	4.337
428	590232.890	570201.200	4.219
429	590234.530	570196.123	4.239
430	590236.676	570189.932	4.191
431	590238.341	570184.857	3.643
432	590227.261	570217.625	4.351
433	590214.973	570212.412	4.270
434	590213.403	570218.467	4.239
435	590216.429	570207.580	4.361
436	590217.422	570202.453	4.334
437	590219.580	570192.237	4.209
438	590220.878	570186.272	4.220
439	590218.945	570197.214	4.171
440	590239.837	570179.813	3.015
441	590241.498	570174.431	1.887
442	590236.384	570171.984	1.708
443	590234.208	570167.261	1.754
444	590231.306	570162.634	1.804
445	590221.856	570180.205	3.986
446	590224.018	570175.684	3.617
447	590226.345	570171.229	3.080
448	590228.516	570166.722	2.625
449	590210.159	570146.545	1.672
450	590201.854	570296.143	4.072
451	590202.655	570290.646	4.024
452	590205.921	570281.024	3.923
453	590204.135	570285.724	3.937
454	590207.619	570276.032	4.038
455	590209.332	570271.272	4.010
456	590192.897	570273.402	4.171
457	590194.727	570267.898	4.227
458	590197.171	570262.250	4.086

459	590188.309	570283.004	4.183
460	590190.409	570278.432	4.260
461	590184.745	570279.791	4.279
462	590180.803	570275.670	4.212
463	590177.005	570272.304	4.093
464	590176.826	570270.272	4.162
465	590178.687	570265.587	4.135
466	590180.450	570260.294	4.028
467	590201.454	570251.720	4.143
468	590205.441	570241.134	4.288
469	590203.575	570245.873	4.276
470	590199.103	570257.475	4.009
471	590207.472	570235.471	4.370
472	590209.436	570229.972	4.330
473	590190.901	570227.785	4.265
474	590192.266	570221.878	4.310
475	590181.961	570254.816	4.044
476	590183.656	570249.160	4.067
477	590186.000	570243.604	4.043
478	590187.979	570238.160	4.189
479	590189.464	570233.373	4.235
480	590172.930	570226.978	4.064
481	590175.363	570221.251	4.046
482	590162.319	570255.368	4.118
483	590165.343	570250.334	4.066
484	590167.578	570244.691	3.983
485	590157.325	570256.503	4.082
486	590153.610	570253.051	4.039
487	590169.492	570238.780	3.897
488	590171.047	570232.860	3.955
489	590154.431	570233.118	3.815
490	590159.890	570222.967	3.752
491	590156.777	570227.921	3.723

492	590149.613	570249.842	3.951
493	590150.052	570243.634	4.128
494	590151.871	570238.384	3.948
495	590134.256	570228.142	4.262
496	590137.797	570223.258	4.073
497	590193.623	570216.228	4.387
498	590195.54	570210.754	4.340
499	590197.140	570205.453	4.192
500	590200.715	570189.420	4.153
501	590201.741	570184.469	4.018
502	590198.916	570200.229	4.104
503	590200.298	570194.645	4.181
504	590183.137	570204.568	3.954
505	590178.089	570215.801	4.079
506	590180.775	570210.456	4.044
507	590187.385	570193.319	4.055
508	590185.206	570198.899	3.965
509	590189.201	570187.565	4.114
510	590172.087	570190.480	3.998
511	590175.090	570185.891	4.054
512	590202.933	570178.934	3.991
513	590203.981	570173.95	3.892
514	590205.399	570168.788	3.679
515	590206.458	570163.114	2.963
516	590191.900	570175.858	3.948
517	590191.715	570170.397	3.904
518	590192.742	570164.859	3.713
519	590207.902	570157.188	2.189
520	590208.995	570151.871	2.053
521	590194.029	570159.353	3.363
522	590194.426	570153.300	2.785
523	590195.440	570147.549	2.181
524	590190.752	570181.841	4.116

525	590177.723	570181.123	4.136
526	590177.989	570175.542	3.996
527	590177.495	570169.647	3.920
528	590177.748	570163.990	3.654
529	590178.249	570158.494	3.186
530	590177.963	570152.890	2.771
531	590177.980	570147.710	2.159
532	590163.387	570211.486	3.779
533	590165.346	570206.183	3.804
534	590161.767	570217.25	3.699
535	590167.347	570200.653	3.897
536	590169.523	570195.536	3.913
537	590153.423	570196.213	3.952
538	590156.425	570191.423	3.899
539	590159.796	570186.374	3.852
540	590144.890	570211.867	3.827
541	590150.410	570200.998	3.737
542	590147.639	570206.479	3.795
543	590140.874	570218.297	3.942
544	590134.352	570200.298	3.822
545	590135.726	570194.723	3.773
546	590138.643	570183.532	3.615
547	590137.124	570189.046	3.801
548	590162.349	570181.422	4.019
549	590163.929	570176.043	4.022
550	590164.211	570169.920	3.914
551	590163.558	570164.139	3.667
552	590163.984	570158.607	3.246
553	590164.036	570152.421	2.612
554	590164.109	570146.608	1.960
555	590143.469	570173.142	3.869
556	590145.980	570168.327	3.987
557	590140.491	570177.883	3.763

558	590148.719	570156.861	3.546
559	590147.331	570162.762	3.943
560	590150.012	570151.430	2.959
561	590151.167	570145.917	2.315
562	590133.994	570159.403	3.753
563	590136.490	570154.251	3.809
564	590139.211	570149.160	3.263
565	590129.471	570230.109	3.529
566	590125.880	570222.413	4.192
567	590123.166	570227.053	4.008
568	590130.609	570211.970	4.109
569	590128.189	570217.231	4.233
570	590132.620	570206.207	3.947
571	590117.002	570195.318	4.075
572	590119.487	570190.232	4.126
573	590122.001	570184.822	3.914
574	590108.636	570210.891	4.427
575	590111.788	570205.950	4.186
576	590103.752	570211.998	4.372
577	590099.942	570208.489	4.562
578	590096.121	570204.373	4.586
579	590114.401	570200.660	4.221
580	590105.155	570184.568	4.292
581	590101.053	570194.815	4.333
582	590098.384	570199.881	4.456
583	590103.210	570189.889	4.356
584	590124.349	570179.457	3.854
585	590126.385	570174.457	3.871
586	590131.173	570164.409	3.838
587	590128.729	570169.577	3.962
588	590115.134	570157.311	3.829
589	590120.207	570148.164	3.426
590	590117.478	570152.725	3.746

591	590107.049	570179.071	4.200
592	590108.561	570173.659	4.109
593	590110.955	570167.989	4.069
594	590097.718	570165.235	4.114
595	590113.035	570162.612	3.960
596	590106.376	570150.869	3.934
597	590108.913	570146.168	3.675
598	590100.988	570159.895	4.037
599	590103.653	570155.393	4.068
600	590083.812	570183.199	4.270
601	590080.543	570187.304	4.437
602	590075.472	570188.884	4.682
603	590072.594	570183.827	4.656
604	590090.890	570174.588	4.269
605	590087.371	570178.729	4.134
606	590094.453	570169.956	4.173
607	590077.470	570173.727	4.250
608	590081.688	570163.578	4.043
609	590079.225	570168.530	4.204
610	590087.427	570153.610	4.144
611	590089.062	570148.407	4.192
612	590084.677	570158.916	3.958
613	590085.860	570144.472	4.220
614	590078.091	570149.212	4.248
615	590079.955	570144.373	4.077
616	590075.204	570178.789	4.404
617	590068.391	570176.337	4.462
618	590072.590	570164.876	4.079
619	590070.585	570170.860	4.206
620	590063.947	570179.230	4.569
621	590059.875	570175.829	4.331
622	590059.598	570170.794	4.278
623	590061.855	570165.680	4.070

624	590074.113	570159.254	4.084
625	590076.115	570154.200	4.129
626	590066.953	570155.299	4.073
627	590069.305	570150.120	4.103
628	590070.893	570144.919	4.128
629	590064.68	570160.715	4.033
630	590059.453	570155.542	4.112
631	590062.995	570144.678	3.917
632	590061.020	570149.910	4.077
633	590208.538	570141.806	1.425
634	590203.682	570138.158	1.423
635	590196.627	570142.080	1.702
636	590198.354	570136.766	1.577
637	590177.368	570141.688	1.684
638	590174.583	570136.814	1.431
639	590169.002	570139.089	1.529
640	590164.010	570141.602	1.441
641	590153.633	570134.843	1.647
642	590152.438	570140.411	1.857
643	590143.615	570138.266	2.225
644	590152.55	570129.729	1.508
645	590145.332	570133.143	2.127
646	590146.165	570128.106	2.101
647	590141.611	570143.644	2.675
648	590149.675	570124.456	1.504
649	590125.696	570126.237	2.268
650	590121.393	570142.387	2.986
651	590122.391	570137.006	2.776
652	590123.763	570131.413	2.477
653	590127.538	570121.314	2.078
654	590129.831	570114.954	1.857
655	590131.269	570109.714	1.632
656	590116.407	570120.382	2.083

657	590117.856	570115.131	1.955
658	590119.697	570109.574	1.751
659	590110.435	570140.626	3.148
660	590111.848	570135.160	2.895
661	590113.316	570130.029	2.641
662	590114.311	570125.035	2.333
663	590106.469	570114.149	1.959
664	590109.215	570109.429	1.731
665	590101.866	570119.261	2.053
666	590098.634	570123.586	2.466
667	590099.105	570107.732	1.673
668	590128.202	570104.783	1.482
669	590121.935	570104.884	1.534
670	590111.075	570104.259	1.609
671	590107.020	570100.711	1.476
672	590102.656	570103.560	1.542
673	590087.925	570136.977	3.025
674	590091.674	570133.297	2.889
675	590095.077	570128.793	2.743
676	590085.137	570141.776	3.870
677	590079.306	570140.783	4.028
678	590082.024	570129.513	2.585
679	590085.859	570125.446	2.503
680	590077.917	570133.313	2.596
681	590077.847	570124.994	2.180
682	590091.931	570116.287	1.921
683	590089.067	570120.510	2.066
684	590095.332	570111.992	1.885
685	590090.851	570106.903	1.705
686	590087.792	570111.615	1.843
687	590084.545	570116.287	1.948
688	590081.186	570120.856	2.047
689	590076.756	570112.346	1.792

690	590080.063	570107.687	1.728
691	590074.161	570138.886	3.967
692	590073.331	570135.315	2.608
693	590070.263	570139.823	3.986
694	590068.932	570137.541	3.727
695	590074.009	570129.040	2.410
696	590069.645	570131.725	2.295
697	590064.899	570139.940	3.944
698	590063.842	570137.984	3.886
699	590058.731	570141.665	3.807
700	590062.202	570130.081	1.850
701	590065.666	570125.742	1.949
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703	590069.113	570121.035	1.956
704	590067.236	570110.371	1.630
705	590070.445	570106.377	1.573
706	590059.082	570118.262	1.570
707	590063.163	570113.590	1.561
708	590058.564	570109.110	1.426
709	590091.646	570101.672	1.563
710	590086.997	570099.570	1.645
711	590083.257	570103.000	1.616
712	590070.429	570100.986	1.496
713	590065.020	570100.918	1.520
714	590060.481	570104.312	1.426
715	590054.015	570166.138	4.061
716	590048.871	570166.950	3.941
717	590057.023	570160.948	4.089
718	590049.053	570161.631	3.835
719	590050.210	570156.124	3.927
720	590054.278	570145.942	3.726
721	590051.319	570150.392	3.918
722	590048.402	570143.954	1.807

723	590045.589	570154.054	1.948
724	590042.124	570159.349	1.731
725	590039.112	570154.666	1.525
726	590046.817	570148.761	1.851
727	590039.775	570143.747	1.548
728	590037.314	570149.298	1.620
729	590034.671	570147.168	1.583
730	590056.953	570134.688	1.816
731	590051.433	570139.938	1.914
732	590052.700	570126.688	1.635
733	590048.915	570131.485	1.588
734	590042.299	570138.695	1.464
735	590040.174	570137.433	1.523
736	590044.457	570133.958	1.517
737	590046.429	570127.604	1.506
738	590042.123	570130.911	1.559
739	590055.851	570122.630	1.610
740	590049.337	570123.333	1.546
741	590050.517	570118.396	1.470
742	590052.223	570112.464	1.521
743	590038.291	570143.000	1.565
744	590036.795	570133.470	1.427

Appendix B: Terramodel Complete 3D Civil/Survey Office Software

The Trimble Terramodel™ software is a powerful software package for the Surveyor, Civil Engineer and Contractor, who requires a CAD and Design package with integrated support for raw survey data.

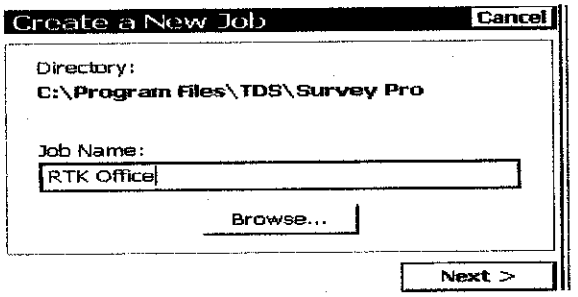
Using Terramodel software you can import data collected using the Trimble conventional instrument product line, as well as from the Trimble TSCe™ Controller running the Trimble Survey Controller™ software. The software allows you to do all the necessary COGO calculations, quickly and easily produce roadway designs, generate contours, and calculate volumes. With the integrated 3D Visualizer, you can view your project as an interactive 3D model, which makes the design and quality control process extremely efficient. And with the powerful CAD functions available, you are able to perform survey, engineering and CAD tasks all in one package! With the convenience of a number of modules, Terramodel software can be configured to provide the features needed.

Additionally road data can be exported from Terramodel software to the RoadLink module of the Trimble Geomatics Office software using the TRMBROAD macro. Terramodel macros (TML) for these features are included on the Trimble Geomatics Office v1.6 CD. DTM data can be shared using a 3D faces file.

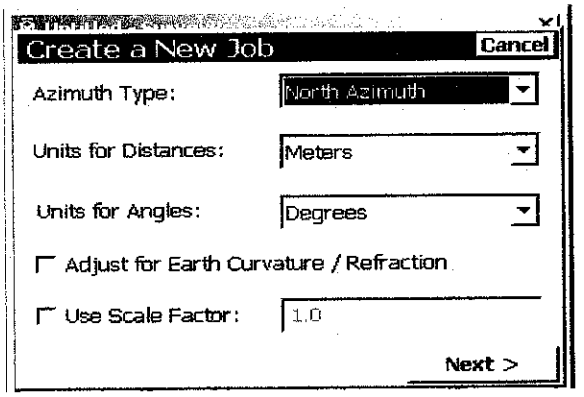
The Terramodel software is ideal for surveyors who require an integrated Survey, CAD, drafting and surface modeling tool.

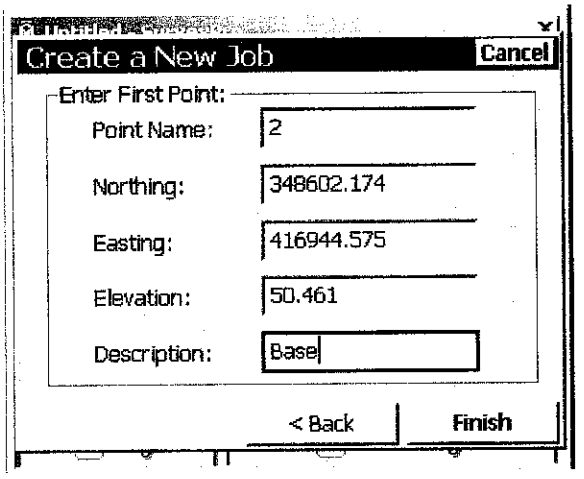
Appendix B RTK Survey with Mapping Plane (RSO)

Create New Job, click Next

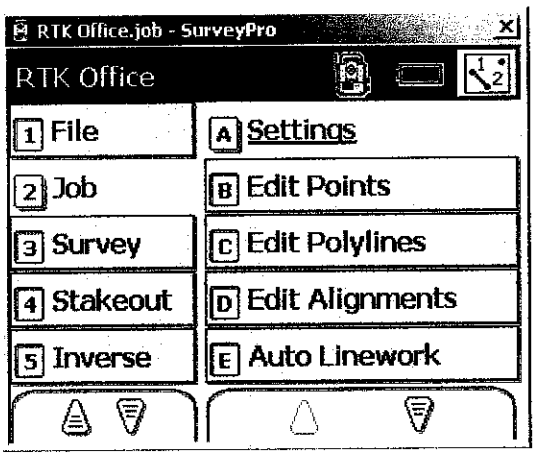


Enter the Point info for Base Stn, then click Finish

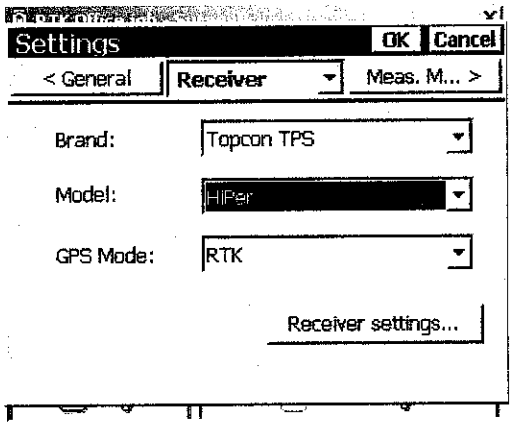




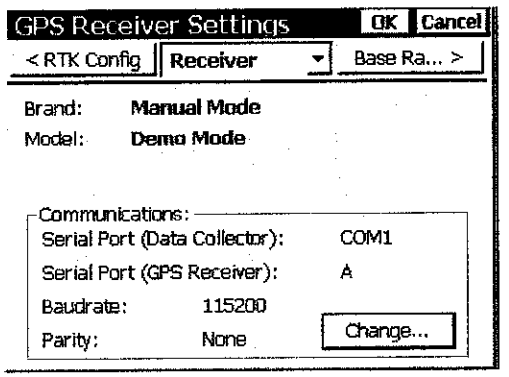
Check Receiver Setting by doing JOB------Setting----Receiver



Confirm the Brand as TOPCON TPS, Model can be Hiper or Legacy E depending which model is connected to. Make sure GPS Mode is set to RTK

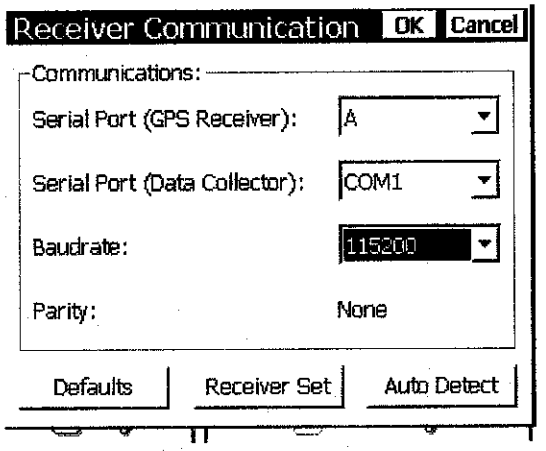


Check and Set the Receiver Setting by tapping the Receiver Setting Button.

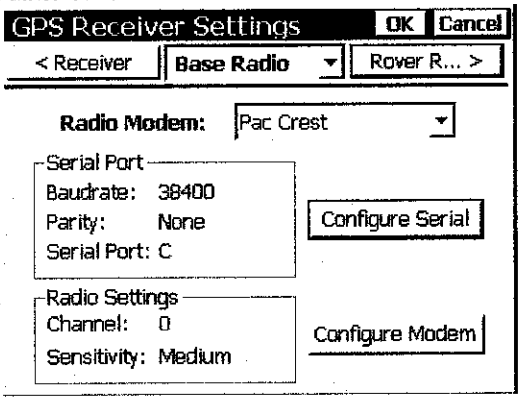


Set the Receiver Setting by Tapping the Change Button

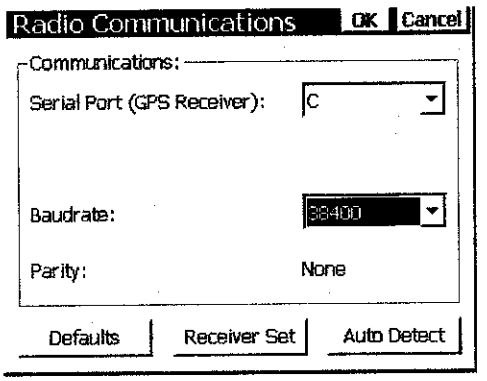
Make sure that the Serial Port GPS is connected to A
Serial Port for Data Collector is connected to COM1
Baud Rate could be at 9600 or 115200 depending on the Auto Detect Setting
TAP Auto Detect Button to detect the Baud Rate between the Receiver and Data Collector
Click Receiver Set to confirm the parameter
Click OK to exit the Receiver Communication screen



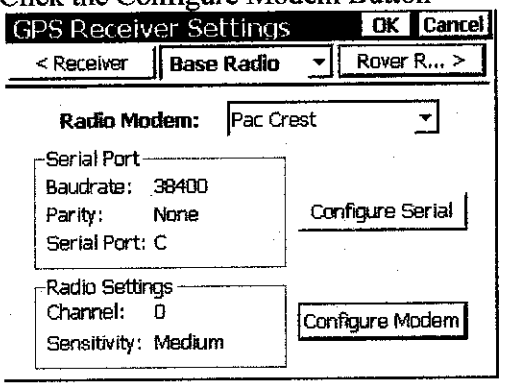
Do the Base Radio Setting by Tapping on Base Radio Button
Make sure the Radio Modem is set to Pac Crest



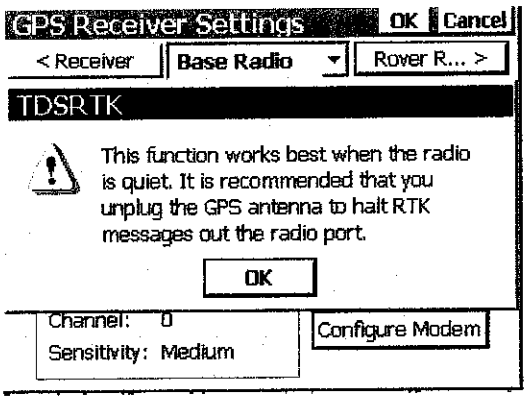
Configure the Serial Port of the Base Radio
Make sure that the Serial Port of GPS is connected to C
Baud Rate is 38400 (You could not do Auto Detect for Radio Communication)
Parity is None
Set the Receiver by clicking on the Receiver Set Button



Configure the Radio Modem
Click the Configure Modem Button



You will be prompted by the following screen to unplug GPS antenna to halt RTK messages out from the Radio. This is to ensure that the Radio is quiet to Configure Modem. So, do so as being advised.



Channel Setting: 0/1/2/3 You can set the Radio Channel to transmit radio using Channel 0/1/2/3 only.
Normally you can start with Channel 0, and if you are getting problem like Tx Light of the Base Radio is not blinking or Rx light is blinking instead, then try to change to different channel.
There is a possibility that some Radio interference is around the area you are working.
Sensitivity: Must be set to Low for Base Radio

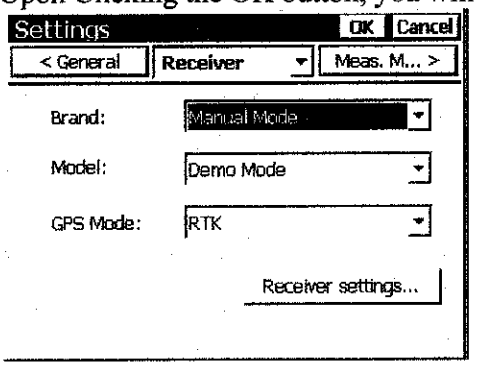
The program might ask you to toggle the power on and off if you had not switch on the Radio Power. Do so by following the instruction.

At this point of time, you should be able to notice on the Base Radio that the Channel display is set to C, and when you toggle the power on again, the require Channel Setting will be detected with together with the sensitivity(LOW)(Must Be). Click the OK button if the radio channel is set or detected with the LOW sensitivity.

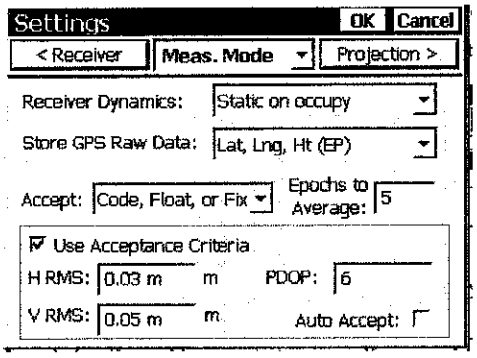
If you are still not able to change or check the radio channel, please try the steps listed below.

- You attempt to change or check the radio channel and the radio does not go into command mode after you toggle the power
  - Older versions of the radio firmware do not behave well at faster bauds. Set the data collector to receiver baud rate to 9600 and try again.
  - If this still does not work, try leaving the radio unplugged for five seconds before plugging it back in.

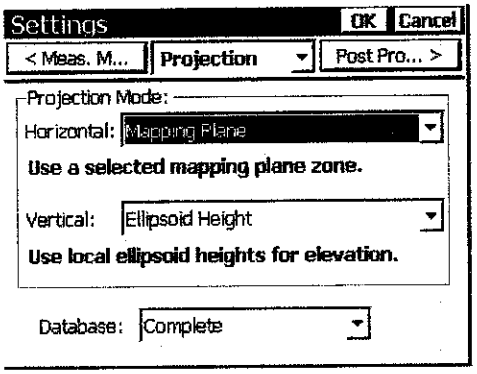
Upon Clicking the OK button, you will be bring back to the Receiver Setting screen again.



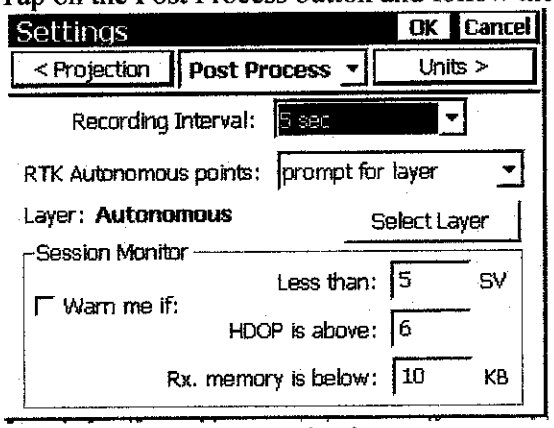
Tab the Meas. Mode Button. Check and follow the setting below.



Tap on the Projection Button to set the projection setting. Follow the setting below.

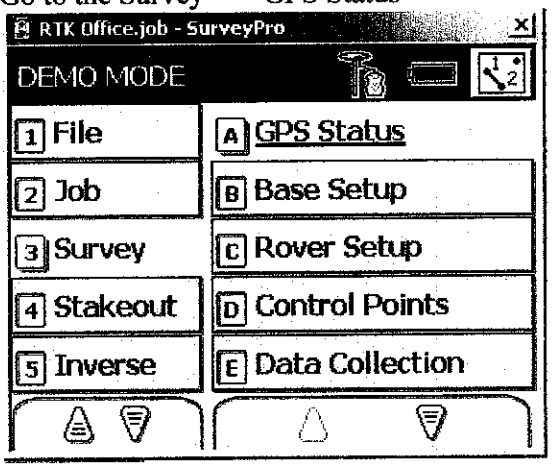


Tap on the Post Process button and follow the setting below.

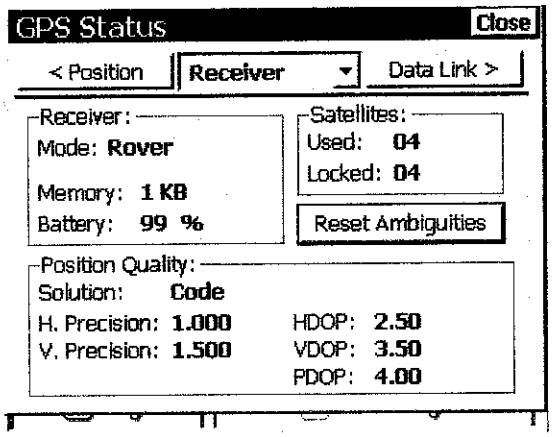


Check Receiver communication

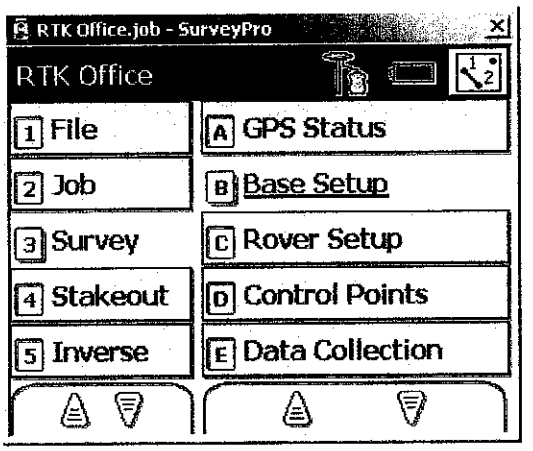
Go to the Survey -----GPS Status



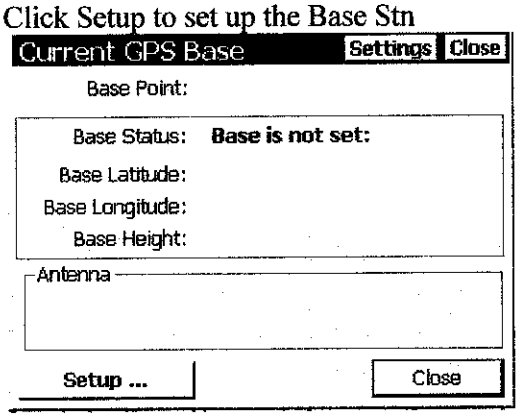
Make sure you are locking to satellites and HDOP is good, below 2.



Setup the Base Receiver by going to Survey---Base Setup

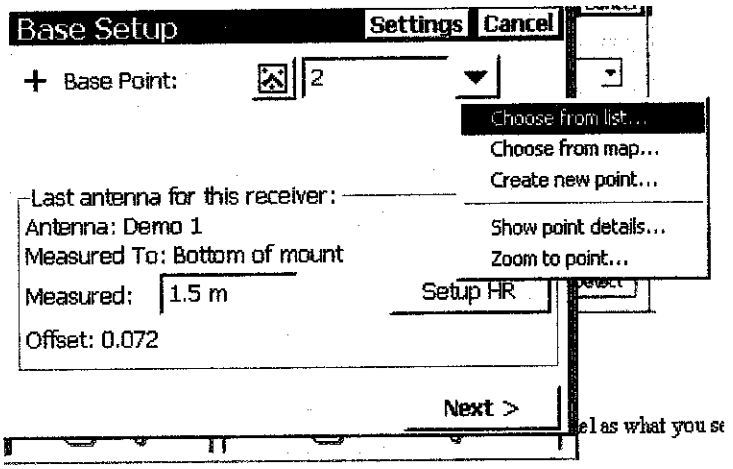


Click Setup to set up the Base Stn



You will be prompted to select a mapping plane. Select Malaysia RSO Projection.

Pick the Base Point and Key in the Anttena Height.

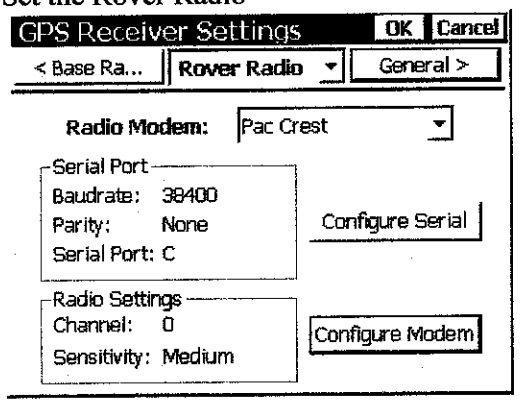


Start the survey, and you should see Tx Light on the Base Radio is blinking at a standard interval to indicate it is sending the Base Stn data out.

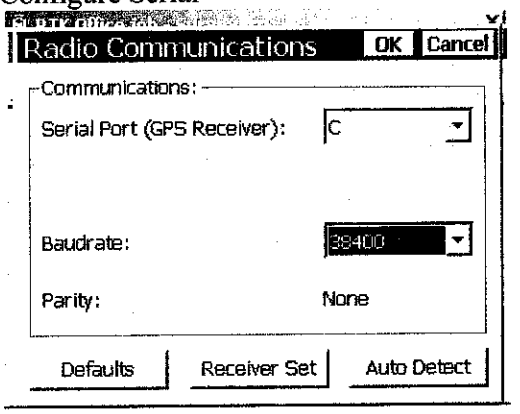
Setup the Rover. Connect the Data Collector to the Rover unit and repeat the above setting.

21..0 Go to Job---Setting---Receiver-----Receiver Setting----Change---Auto Detect

Set the Rover Radio



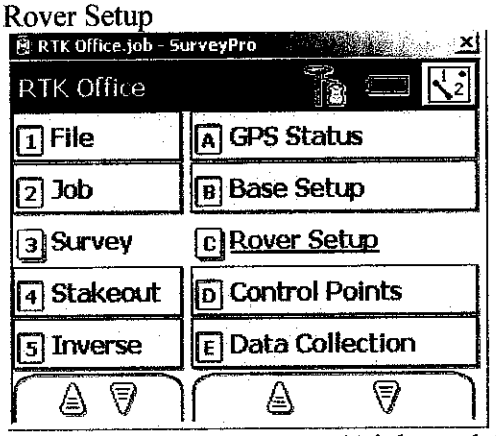
Configure Serial



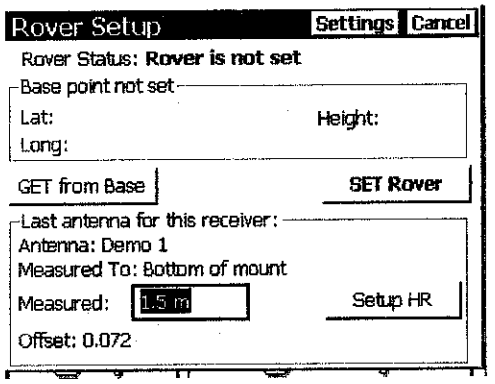
Click Ok button

Configure Modem
Make sure you set the same Radio Channel as what you set on the Base Radio. Both the receiving and Transmitting channel must be same.
Make sure sensitivity is set to Medium or High for Rover Radio.

Rover Setup



Key in the Antenna Height, and then Tap the Set Rover Button



Check the GPS Status before you Start Data Collection. You should see the following message.

Position Quality: Fix or Coarse
If you are having Autonomous Position Quality,
Check that you are locking to at least 4 satellites.
If you are not tracking to satellites,
Check Antenna Cable is firmly connected
Redo the Receiver to Data Communication Setting by doing the Auto Detect Button
If you are not able to Auto Detect the communication setting
Check the following

Hardware Configuration

- You attempt to auto detect and the program fails to find the baud rate of the receiver.
  - Check to make sure you selected the correct brand and model.
  - The port you are connected to may be 'broken' or temporarily unavailable. Plug into another port and try again.
  - If you cannot detect the baud from any of the ports, toggle the power on the receiver and try again.
  - If you still cannot connect, do a soft reset of your receiver hardware.
  - If you still cannot connect, do a hard reset of your receiver hardware.

Check the Data Link
Make sure you have 100% Radio Quality
Signal Latency is 1 sec
If you are having 0% Radio Quality,
Check the following,

- You set up the rover and the Rx. Light on the rover radio is not blinking.
  - Make sure the radio serial cable is connected.
  - Make sure the radio antenna is connected.
  - Make sure the rover radio COM port and baud rate is correct.
  - Make sure the base and rover radios are on the same channel.

- You set up the rover and the Rx. light is blinking sporadically.
  - The radio is receiving interfering signals on this channel. Switch the base and rover radios to a different channel

- You set up the rover and the Rx. light is blinking but the Data Link card on the GPS Status screen says No Data from Radio.
  - Make sure the radio serial cable is connected.
  - Make sure the rover radio COM port and baud rate is correct.

How to Clear NVRAM

It is possible to clear NVRAM using only MINTER. To do that:

1. Turn the receiver OFF.
2. Press and hold FN button.
3. Press and release PWR button to turn the receiver ON.
4. Wait until both LEDs will light green.
5. Wait around five seconds, until both LEDs will blink yellow.
6. Release FN button.

Note that LEDs will blink yellow only during next five seconds, and to clear NVRAM it is essential to release FN button when they blink yellow.

How to Set the Receiver Baud Rate to 9600

Some of the order version of Radio firmeware could not support baud rate at Baud Rate 115200. Try change to lower baud rate, 9600

Holding the FN key for more than 5 and less than 8 seconds will turn baud rate of the serial port A to 9600. After about 5 seconds of holding the FN button the REC LED becomes red, and you need to release FN button while REC LED is red (during next 3 seconds).

Holding the FN key for more than 8 seconds has no impact.