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Development of Methodology for Determining Earth Work Volume Using Combined Static and Kinematic GPS Observations

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ABSTRACT: *Computing earthwork volumes is a necessary activity for nearly all construction projects and is often accomplished as a part of route surveying, especially for roads, Dredging and highways. If the area of the cross section at each station is known, then multiply that average end area by the known horizontal distance between the stations to determine the volume of cut. We present the results of precise static and kinematic point-positioning solutions obtained in post-processing, with a recursive Kalman filter estimator. The observations are dual frequency GPS carrier phase and pseudo-range, treated as two distinct data types, each with its own measurement equations. The receiver data is double differenced between satellites, to eliminate the receiver clock, and processed using precise satellite ephemerides and clock corrections. While estimating receiver coordinates, ionosphere-free carrier phase Lc biases, and tropospheric refraction model errors were treated accordingly. The motivation has been to show the possibility of the application of GPS in Topographical Survey and it associated accuracy. The method is fast, accurate and data was acquired using Trimble 4000SSI GPS Receiver and processed using Trimble Geomatics office.. The results indicate a precision at the level of a few centimeters, for static solutions, and below one decimeter, in kinematic mode.*

KEY WORDS: *Kalman filter, earthwork, GPS, Kinematic, integer ambiguities, Volume*

I. INTRODUCTION

Society recognises the need to move towards sustainable development. Construction has an important role to play within the sustainable development agenda not only because of the contribution to the national economy, but also because the built environment has a major impact on the quality of all of our lives, our comfort and security, our health and wellbeing and our productivity.

Road construction, maintaining and upgrading our existing Road has a potential environmental impact. The challenge today is to deliver road that can stand test of time and enhance the quality of life, while at the same time reducing the suffering encountered while embarking on a journey.

The purpose of the paper is to discuss the Geomatics modern approach used in the construction industries.

Earthwork computations are based on the design cross sections generated in the design process and cut and fill end areas computed and stored by that process.Earthwork computations are based on the design cross sections generated in the design process and cut and fill end areas computed and stored by that process. Additional required and optional data is needed for the earthwork computations. When subsurface data is provided, end areas for each material in cut are computed and is used as a basis for volumes. A compaction factor may be specified for each material, and volumes and mass ordinates will be computed accordingly.The earthwork parameters, such as compaction factors, added quantities, and forced balance stations, are used in computing the earthwork quantities for the designed roadways. These parameters are entered along with the other design data. These parameters are necessary in the compilation of earthwork volumes, mass ordinates and haul computations. Although these data are not strictly design data, they are entered and stored along with design data because the designer may then want to modify volume computation parameters and make new alternate volume computations.

A compaction factor is a characteristic assigned to a specific earth material which indicates how, and to what extent, its volume will change when that material, after having been cut from the original ground, is compacted as fill material. This characteristic is expressed as the ratio of a given volume of this material, in its original ground state, divided by the volume that same material would occupy when compacted as fill. Compaction factors produce an adjusted fill or cut volume to be used in computing earthwork volumes and mass ordinates. The compaction factors are applied when computing volumes. Volumes are computed separately for each roadway, and the appropriate compaction factor is selected and applied. Then these individual roadway volumes are summed to compute the design cross section volume.

II. GLOBAL POSITIONING SYSTEM (GPS)

Navigation and positioning is the art of determining position, speed and orientation of an object. The GPS program me was born in 1972 out of the quest for the US Navy and Air force to develop all weather Global Radio Navigation System. The GPS was designed to be a passive survivable continuous system which will provide any suitably equipped user with three dimensional position (x, y, z) velocity and precise time information.

The principle involves the measurement of distance (or range) to at least three Satellites whose X, Y and Z position is known, in order to define the user's X_p, Y_p and Z_p position. In its simplest form, the satellite transmits a signal on which the time of its departure (tD) from the satellite is modulated. The receiver in turn notes the time of arrival (tA) of this time mark. Then the time which it took the signal to go from satellite to receiver is (tA – tD) = Δt (called the delay time). The measured range R is obtained from (Andrew et.al 2004).

$$R1 = (tA - tD)\, C = \Delta t\, C \qquad (1)$$

where c = the velocity of light.

Whilst the above describes the basic principle of range measurement, to achieve it one would require the receiver to have a clock as accurate as the satellite's and perfectly synchronized with it. As this would render the receiver impossibly expensive, a correlation procedure, using the pseudorandom binary codes (P or S), usually 'S', is adopted. The signal from the satellite arrives at the receiver and triggers the receiver to commence generating the S-code. The receiver-generated code is cross-correlated with the satellite code. The ground receiver is then able to determine the time delay (Δt) since it generated the same portion of the code received from the satellite (Abdel –Salem 2005).

However, whilst this eliminates the problem of an expensive receiver clock, it does not eliminate the problem of exact synchronization of the two clocks. Thus, the time difference between the two clocks, termed clock bias, results in an incorrect assessment of Δt. The distances computed are therefore called 'pseudo-ranges'. The effect of clock bias, however, can be eliminated by the use of four satellites rather than three. A line in space is defined by its difference in coordinates in an X, Y and Z system:

$$R = (\Delta X^2 + \Delta Y^2 + \Delta Z^2)^{1/2} \qquad (2)$$

If the error in R, due to clock bias, is (_R) *and* is constant throughout, then:

$$\begin{aligned} R_1 + \_R &= [(X_1 - X_p)^2 + (Y_1 - Y_p)^2 + (Z_1 - Z_p)^2]^{1/2} \\ R_2 + \_R &= [(X_2 - X_p)^2 + (Y_2 - Y_p)^2 + (Z_2 - Z_p)^2]^{1/2} \\ R_3 + \_R &= [(X_3 - X_p)^2 + (Y_3 - Y_p)^2 + (Z_3 - Z_p)^2]^{1/2} \\ R_4 + \_R &= [(X_4 - X_p)^2 + (Y_4 - Y_p)^2 + (Z_4 - Z_p)^2]^{1/2} \end{aligned} \qquad (3)$$

Where X_n, Y_n, Z_n = the coordinates of satellites 1, 2, 3 and 4 (n = 1 to 4)

X_p, Y_p, Z_p = the coordinates required for point P

R_n = the measured ranges to the satellites

Solving the four equations for the four unknowns X_p, Y_p, Z_p and _R eliminates the error due to clock bias. Whilst the use of pseudo-range is sufficient for navigational purposes and constitutes the fundamental approach for which the system was designed, a much more accurate measurement of range is required for positioning in Geodesy. This is done by measuring phase difference by means of the carrier wave in a manner analogous to EDM measurement (Schofield 1993).

III. KINEMATIC POSITIONING ALGORITHM

Kinematic positioning and alignment relies on the relationship of the carrier phase observations to the range observations described in the following equation (Raquet 1998).

$$\begin{aligned} PR_1 &= R + bu_1 + bsv_{PR1} + T + I_1 + {}_{nPR1} \\ PR_2 &= R + bu_2 + bsv_{PR2} + T + I_1 \frac{\lambda_2^2}{\lambda_1^2} + {}_{nPR2} \\ -CPH_1 &= R + bu_{CPH1} + bsv_{CPH1} + T - I_1 + {}_{nCPH1} - N_1\lambda_1 \\ -CPH_2 &= R + bu_{CPH2} + bsv_{CPH2} + T - I_1 \frac{\lambda_2^2}{\lambda_1^2} + {}_{nCPH2} - N_2\lambda_2 \end{aligned} \qquad (4)$$

Where

PR = pseudo-range on L1 or L2 frequencies (meters), CPH = carrier phase on L1 or L2 frequencies, (meters), RT = true range (meters), bu = range equivalent receiver clock offset (meters), bsv = range equivalent satellite clock offset (meters)

T = tropospheric delay (meters), I = ionospheric delay (meters), n = measurement noise (meters), N = CPH integer (cycles), λ = carrier wavelength (meters)

The ionospheric delay is different on the L1 and L2 observations as it is inversely proportional to the frequency squared and so can be removed from the PR by differencing. The DGPS corrections will remove any errors in the navigation solution caused by satellite position and clock offsets. The accuracy of the PR derived DGPS corrected position solution is a function of the pseudo-range noise, which includes receiver noise and multipath errors. The GPS/inertial navigation solution will filter the short-term noise effects, but it cannot correct for correlated noise errors from multipath.

The major problem with static GPS is the time required for an appreciable change in the satellite/receiver geometry so that the initial integer ambiguities can be resolved. However, if the integer ambiguities could be resolved (and constrained in a least squares solution) prior to the survey, then a single epoch of data would be sufficient to obtain relative positioning to sub-centimeter accuracy. This concept is the basis of kinematic surveying. It can be seen from this that, if the integer ambiguities are resolved initially and quickly, it will be necessary to keep lock on these satellites while moving the antenna (Schofield 1993).

IV. RESOLVING THE INTEGER AMBIGUITIES

The process of resolving the integer ambiguities is called 'initialization' and may be done by setting-up both receivers at each end of a baseline whose coordinates are accurately known. In subsequent data processing, the coordinates are held fixed and the integers determined using only a single epoch of data. These values are now held fixed throughout the duration of the survey and coordinates estimated every epoch, provided there are no cycle slips. The initial baseline may comprise points of known coordinates fixed from previous surveys, by static GPS just prior to the survey, or by transformation of points in a local coordinate system to WGS 84 (Abdel – Salam 2005).

An alternative approach is called the 'antenna swap' method. An antenna is placed at each end of a short base (5–10 m) and observations taken over a short period of time. The antennae are interchanged, lock maintained, and observations continued. This results is a massive change in the relative receiver/satellite geometry and, consequently, rapid determination of the integers. The antennae are returned to their original position prior to the surveys. It should be realized that the whole survey will be invalidated if a cycle slip occurs. Thus, reconnaissance of the area is still of vital importance, otherwise re-initialization will be necessary. A further help in this matter is to observe to many more satellites than the minimum four required (Andrew et.al 2004).

IV.1. KALMAN FILTER

The Kalman filter is a digital algorithm that provides current estimates of a system variable such as position coordinates (Schoffield, 1993). The filter uses statistical models to properly weigh each new measurement relative to past information. It also determines up – to – date uncertainties of the estimates for real – time quality assessments (Kaplan 1996).

The Kalman filter is a multiple input multiple – output digital filter that can optimally estimate in real time the states of a system based on its outputs. These states are all the variables needed to completely describe the system behaviour as a function of time such as position and velocity. The Kalman filter filters noisy measurements to estimate the desired signals. The estimates are statistically optimal in the sense that they minimize the mean square estimation error. The Kalman filter contain a dynamic model of the GPS receiver platform motion and outputs a set of user receiver position, velocity and Time (PVT) state estimates as well as associated error variances [6]

The dynamic model can be derived by a Taylor's series expansion about the true position of the receiver. We let u (t) represent the true position of the receiver at a time t. Then at a time t_1 shortly after a time tu the receiver will be at a position (Kaplan 1996).

$$U(t) = U(t_o) + \left.\frac{du(t)}{dt}\right|_{t=t_0} (t - t_0) + \frac{1}{2!}\left.\frac{du^2(t)}{dt^2}\right|_{t=to} (t - t_0)^2 + \frac{1}{3!}\left.\frac{du^3(t)}{dt^3}\right|_{t=to} (t - t_0)^3 \qquad (5)$$

Where

$$\left.\frac{du(t)}{dt}\right|_{t=tv} = Velocity \qquad (5a)$$

$$\frac{1}{2!}\frac{du^2(t)}{dt^2}_{t=t_0} = acceleration \qquad (5b)$$

$$\frac{1}{3!}\frac{du^3(t)}{dt^3}_{t=t_0} = jerk \qquad (5c)$$

The third term in the expansion (Jerk) is regarded as negligible. The non negligible terms depend on the system being modeled and may be estimated for position measurement. Filters designed for PVT determination typically estimate either user states position (x_u, y_u, z_u), velocity $\left(\dot{x}_u, \dot{y}_u, \dot{z}_u\right)$ receiver clock offset (tu) and receiver clock drift $\left(\dot{t}_u\right)$.

IV.2. CODE MEASUREMENT

The GPS code measurement ρ is a linear measurement known as pseudo range in meters. Pseudo Range is a measure of the distance between the satellite and receiver at the time epoch of transmission and reception of the signals.

The transmit time of the signals is measured by comparing (correlating) identical Pseudo Random Noise (PRN) codes generated by the satellite and the receiver (Ehiorobo 2009).

$$\rho = R + C\,(dt - dT) + d_{ion} + d\,t_{rop} + d_{mpath.} \qquad (6)$$

where

R = True range between the SV (at transmit time) and receiver (at r receiver time)

C = Speed of light (m/s)

dt = Receiver clock error (sec)

dT = Satellite clock error (sec)

d_{ion} = Ionospheric delay parameter

dt_{rop} = Measurement delay due to troposphere (m)

d_{mpath} = Measurement delay due to multipath

Most DGPS Processing involves generating a nominal "computed" range between the receiver and the satellite which is calculated from the known coordinate of the receiver locations and the satellite [6].

The true range vector **R** is

$$\mathbf{R} = P_{sv} - P_{rec} \qquad (7)$$

Where; P_{sv} – is the computed position of the satellite at transmit time (From ephemeris)

P_{rec} is the nominal position of the receiver at receiver time.

IV.3. CARRIER MEASUREMENT

The constant motion of the GPS satellite constellation in orbit demands that the receiver be capable of taking care of the changing Doppler frequency shift on L_1.

In the case of Dual frequency receivers both L_1 and L_2 are tracked. L_1 wavelength is 19cm and L_2 wavelength is 24cm. The shift in frequency arises due to the relative motion between the satellite and the receivers. Integration of the Doppler frequency offset results in an extremely accurate measurement of the advance in signal carrier phase between time epochs (Gao et.al 2001).

Using Double Differencing Processing DD techniques on C/A or P(Y) – code carrier phase observables removes most of the error sources.

To achieve centimeter level accuracy, it is still necessary to carry out further refinement of the propagation path length measurement using carrier – cycle integer ambiguity resolution.

Once the receiver locks on to a particular satellite, it not only make C/A and or p(Y) code pseudo range measurements on L_1 and L_2 (if L_2 is present) but it also keeps a running count based upon the Doppler frequency shift present on L_1 and L_2 carrier frequencies.

Each epoch for running this cycle count is available for the receiver. It should be noted that the advance in carrier phase during an epoch is determined by integrating the carrier Doppler Frequency offset (fo) over the interval of the epoch. Frequency fo is the time rate of change of the carrier phase, hence integration over an epoch yields, the carrier phase advance during an epoch. At the conclusion of each epoch, a fractional phase measurement is made by the receiver. This measurement is derived from the carrier phase tracking loop of the receiver. Mathematically the relationship is as follows (Abdel – Salam):

$$\phi_{1.1n} = \phi_{1.1n-1} = \int_{I_{n-1}}^{In} f_{0_{1.1}}(r)dr + \phi_{1.10} \quad \text{Where } \phi_{1.10} = 0 \qquad (8)$$

$$\phi_{1.2n} = \phi_{1.2n-1} = \int_{I_{n-1}}^{In} f_{o_{1.2}}(r)dr + \phi_{1.20} \quad \text{Where } \phi_{1.20} = 0$$

Where

ϕ is the accumulated phase at the epoch shown

n and n-1 are the current and immediate past epochs

f_D - is the Doppler frequency as a function of time

ϕ_1 is the fractional phase measured at the epoch shown

IV.4. IONOSPHERIC DELAY

The ionosphere is the part of the upper atmosphere where free electrons occur in sufficient density to have an appreciable influence on the propagation of radio frequency electromagnetic waves. It is a weak ionized plasma extending from approximately 50Km to 1000Km above the surface of the earth and can affect radio wave propagation in various ways (Kaplan 1996).

Ionosphere is a dispersive medium. The refractive index is a function of the operating frequency. The refractive index n of the ionosphere can be expressed as (Schofield 1993).

$$n^2 = 1 - \frac{X}{1 - iZ - \frac{Y_\tau^2}{2(1 - X - iZ)} \pm \left[\frac{Y_\tau^4}{4(1 - X - iZ)^2} + Y_L^2 \right]^{1/2}} \qquad (9)$$

Where

$$X = \frac{N_e e^2}{\varepsilon_n m \omega^2} \quad ; Y_L = f_H \frac{Cos\theta}{f} \quad ; Y_\tau = f_H \frac{\sin\theta}{f}$$

$$Z = \frac{v}{w} \quad ; w = 2\Pi f$$

and

f	-	is frequency of incoming signal in Hz
N_e	-	is the electron density in electron / m^3
e	-	is the electron change = -1.602 X 10^{-19} Coulomb
ε_n	-	is the permeativity of free space = -8.854 X 10^{-12} Farad / m
m	-	is the rest mass of electron = 9.107 X 10^{-31} Kg
θ	-	is the angle of the ray with respect to the earth's magnetic field.
V	-	is the electron – neutron collision frequency and
f_H	-	is the electron gyro frequency typically 1.5MHz

IV.5. TROPOSPHERIC DELAY

Tropospheric delay occurs as a result of the GPS signals passage through the Earth's lower atmosphere. This region extends to an altitude approximately 10km above the earth's surface. The stratosphere is also considered part of the lower atmosphere. It extends upward from the tropopause to an altitude of approximately 50 kilometers in these two sections of the atmosphere, electromagnetic refraction slows the GPS radio signals causing a delay in its arrival at the receiver [6].

IV.6. RECEIVER NOISE

Receiver noise can be considered as white noise as it is uncorrelated over time. In the case of GPS, it is the error in phase and code measurement due to imperfect tracking of the GPS signals by the phase and delay lock loops. The tracking error is random and is assumed to have a Gaussian distribution. The magnitude of the noise is a function of the measurement type and the signal strength.

The C/A – code measurement can be tracked with a typical accuracy of 1.5 meters but it may vary between 0.2 and 3 meter depending upon the strength of the receiver signal. Typical receiver noise for P(Y) code measurement is 10 – 30cm. Code and carrier phase measurement noise can be smoothed by an estimate of a "zero baseline" test (Kaplan 1996).
The GPS signal is split into two and fed to two separate but same types of receivers. In static application, the predominant error component in carrier phase noise is jitter of the phase lock loop caused by thermal noise. This can be expressed according to; (Schofield 1993).

$$\sigma_n = \sigma_{PLL} = \frac{\lambda}{2\pi}\sqrt{\frac{B_n}{C/\ n_o}\left(1+\frac{\frac{1}{2TC}}{n_o}\right)}\ \ meters \qquad (10)$$

where

B_n	-	carrier loop noise band width in Hz
$\frac{C}{n_{io}}$	-	is the carrier to noise power expressed as $10^{C/No/10}$ with C/No in dB - Hz
T	-	is the predetections integration time in seconds
λ	-	is carrier wavelength

IV.7. SATELLITE ORBIT ERRORS

Satellite orbit errors result from the uncertainty in orbital information. To compute the satellite position, we either use broadcast ephemeris or precise ephemeris. Although precise ephemeris information is much more accurate than those of broadcast information. The satellite positions are computed from a set of Keplerian orbit and perturbation parameters with clock parameters which are predicted states for the satellite orbit and are updated every two hours (Raquet 1998).

IV.8. MULTI PATH

Multi path refers to the existence of signals reflected from objects in the vicinity of a receiver's antenna that corrupt the direct line-of-sight signals from the GPS satellites, thus degrading the accuracy of both code-based and carrier phase-based measurements. The object may be tall buildings, television and Telephone masks, etc

IV.9. GEOMETRIC DILUTION OF PRECISION

In GPS observations, the position of the satellite affects the three dimensional angles of intersection between the satellite and the users position. When the satellites are close together or in a straight line, a low accuracy fix is obtained. When they are wide apart almost forming a square, a high accuracy is obtained (Abdel-Salam, 2005)

Thus, the dilution of precision is used to measure user position accuracy. The satellite configuration geometry with respect to the ground station is called the GDOP the geometric dilution of precision defined as (Ehioro 2008);

$$\text{GDOP} = \frac{1}{\sigma}\sqrt{\sigma_x^{\ 2} + \sigma_y^{\ 2} + \sigma_z^{\ 2} + \sigma_b^{\ 2}} \qquad (11)$$

Where; σ is the mean square error of the pseudo range, which has a zero mean
$\sigma_x\ \sigma_y\ \sigma_z$ – measured r ms errors of the users position in the xyz direction and
σ_b is measured rms user clock error expressed in distance.
Other DOP parameters include
VDOP – vertical Dilution of Precision – One dimensional (1-D)
HDOP – Horizontal Dilution of Precision – Two dimensional (2-D)
PDOP – Position Dilution of Precision – Three dimensional (3-D)
The position dilution of precision is defined as

$$\text{PDOP} = \frac{1}{\sigma}\sqrt{\sigma_x^{\ 2} + \sigma_y^{\ 2} + \sigma_z^{\ 2}} \qquad (12)$$

The Horizontal Dilution of precision is defined as

$$\text{HDOP} = \frac{1}{\sigma}\sqrt{\sigma_x^{\ 2} + \sigma_y^{\ 2}} \qquad (13)$$

The Vertical Dilution of precision

$$\text{VDOP} = \frac{\sigma_z}{\sigma} \tag{14}$$

The time dilution of precision

$$\text{TDOP} = \frac{\sigma_b}{\sigma} \tag{15}$$

The smallest dilution of precision DOP value means the best satellite geometry for calculating user position. The observation is at the base of the tetrahedron. Under this condition, the DOP values are (Raquet 1998)

GDOP = $\sqrt{3} \approx 1.73$

PDOP = $2\sqrt{2/3} \approx 1.63$

HDOP = VDOP = $2/\sqrt{3} \approx 1.15$

And finally TDOP = $1/\sqrt{3} \approx 0.58$

V. CYCLE SLIPS

A cycle slip is a break in continuous satellite tracking. The wave fronts that the receiver counts during continuous tracking are also referred to as cycles. Therefore, when the receiver loses count because of an interruption in satellite tracking, the cycle or wave counting slips.

V.1 RESULTS OF ADJUSTMENTS OF OBSERVATIONS

The qualities to be obtained after field measurements and adjustment in a GPS network include baseline vector components and their covariance.

The final outcomes of baseline adjustment are the adjusted baseline vectors, estimated points coordinates and their covariance matrices. We present below results of adjustment using Trimble Geomatics office.

Table 1 - Baseline Processing Summary

Processing Summary

Baseline Summary B120 (3842 to AE000091)

Processed:	Thursday, Jul 21, 2011 07:44:35PM
Solution type:	L1 fix
Solution acceptability:	Multiple
Ephemeris used:	Broadcast
Met Data:	Standard
Baseline slope distance:	2538.933m
Elevation mask:	13 degrees
Variance ratio:	0.0
Reference variance:	11.688
RMS:	0.008m
Horizontal Precision 1-sigma (scaled):	0.030m
Vertical Precision 1-sigma (scaled):	0.068m

Table 2 - Baseline Components (Mark to Mark)

From:	3842				
Grid		**Local**		**WGS 84**	
Northing	367124.091m	**Latitude**	7°19'01.50193"N	**Latitude**	7°19'02.82741"N
Easting	436929.511m	**Longitude**	6°22'02.87020"E	**Longitude**	6°22'00.44966"E
Elevation	365.672m	**Height**	365.672m	**Height**	366.558m

To:	AE000091				
Grid		**Local**		**WGS 84**	
Northing	368263.699m	**Latitude**	7°19'38.89654"N	**Latitude**	7°19'40.21925"N
Easting	434660.811m	**Longitude**	6°20'49.07818"E	**Longitude**	6°20'46.65650"E
Elevation	308.438m	**Height**	308.438m	**Height**	309.357m

Baseline:					
□ **Northing**	1139.607m	**NS Fwd Azimuth**	296°54'33"	□ **X**	48.700m
□ **Easting**	-2268.701m	**Ell. Distance**	2538.153m	□ **Y**	-2272.047m
□ **Elevation**	-57.235m	□ **Height**	-57.201m	□ **Z**	1132.082m

Table 3 - Standard Errors

Baseline Errors:					
□ ◫ **Northing**	0.005m	□ **NS Fwd Azimuth**	0.517 seconds	□ ◫ **X**	0.020m
□ ◫ **Easting**	0.009m	□ **Ell.Distance**	0.008m	□ ◫ **Y**	0.008m
□ ◫ **Elevation**	0.020m	□ ◫ **Height**	0.020m	□ ◫ **Z**	0.005m

Table 4 - Occupations

		From	**To**
Point Name:		3842	AE000091
Data file:		38420790.DAT	30760790.DAT
Receiver Type:		4000SSi	4000SSi
Receiver Serial Number:		13842	13076
Antenna type:		Compact L1/L2	Compact L1/L2
Measured To:		Bottom of antenna	Bottom of antenna
Antenna height	**Measured**	1.270m	1.630m
	APC	1.332m	1.692m

Table 5 – Adjusted 3D Coordinate

Statistical Summary

Successful Adjustment in 1 iteration(s)
Network Reference Factor : 1.00
Chi Square Test (□ =95%) : PASS
Degrees of Freedom : 90.00
GPS Observation Statistics

Errors are reported using 1.96□ .

Point Name	Latitude	Longitude	Height	Northing	Easting
BM_5	7°19'02.77547"N	6°22'00.45644"E	345.315m	367122.496m	436929.726m
AE0001__	7°19'20.68657"N	6°21'11.59110"E	315.061m	367666.655m	435428.264m
AE000002	7°19'20.68709"N	6°21'11.59047"E	315.062m	367666.671m	435428.244m
AE000003	7°19'20.39312"N	6°21'11.91540"E	314.984m	367657.679m	435438.250m
AE000004	7°19'19.83339"N	6°21'11.34336"E	312.618m	367640.407m	435420.771m
AE000005	7°19'18.96313"N	6°21'10.67891"E	310.233m	367613.581m	435400.497m
AE000006	7°19'17.86287"N	6°21'09.61401"E	309.004m	367579.638m	435367.966m
AE000007	7°19'17.36933"N	6°21'07.72061"E	314.694m	367564.232m	435309.940m
AE000008	7°19'17.78599"N	6°21'06.86673"E	312.349m	367576.927m	435283.690m
AE000009	7°19'20.04550"N	6°21'04.33317"E	307.704m	367646.036m	435205.675m
AE000010	7°19'21.79386"N	6°21'05.17316"E	307.674m	367699.866m	435231.224m
AE000011	7°19'22.34130"N	6°21'04.59310"E	307.730m	367716.615m	435213.359m
AE000012	7°19'22.59900"N	6°21'03.57478"E	308.978m	367724.404m	435182.084m
AE000013	7°19'23.90880"N	6°21'00.67533"E	305.055m	367764.285m	435092.965m
AE000014	7°19'25.53640"N	6°20'58.39906"E	308.067m	367814.010m	435022.923m
AE000015	7°19'26.33917"N	6°20'58.24238"E	306.304m	367838.657m	435018.015m
AE000016	7°19'27.27521"N	6°20'57.19865"E	303.496m	367867.288m	434985.875m
AE000017	7°19'28.10378"N	6°20'55.42582"E	302.408m	367892.524m	434931.381m
AE000018	7°19'28.04179"N	6°20'52.51781"E	302.460m	367890.251m	434842.173m
AE000019	7°19'28.36471"N	6°20'50.60862"E	302.719m	367899.932m	434783.560m
AE000020	7°19'29.17996"N	6°20'49.09372"E	302.824m	367924.792m	434736.980m
AE000021	7°19'30.54718"N	6°20'48.80818"E	300.627m	367966.768m	434728.047m
AE000022	7°19'31.80050"N	6°20'47.82717"E	288.209m	368005.156m	434697.792m
AE000023	7°19'33.41452"N	6°20'48.26109"E	293.172m	368054.806m	434710.900m

AE000024	7°19'34.79316"N	6°20'48.74330"E	290.426m	368097.230m	434725.519m
AE000025	7°19'36.66374"N	6°20'46.95549"E	273.746m	368154.483m	434670.434m
AE000026	7°19'37.96679"N	6°20'47.67879"E	255.774m	368194.614m	434692.459m

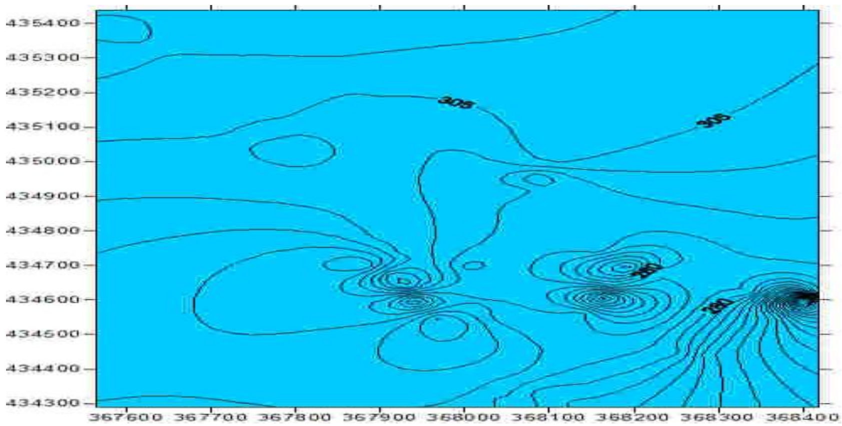

Figure 1 – Contour of the Site

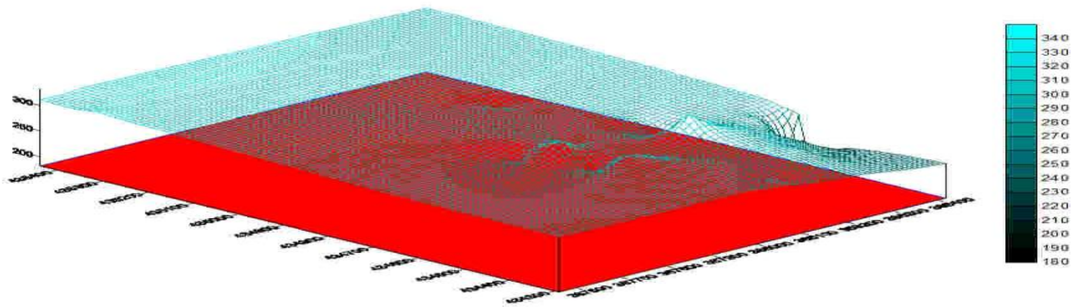

Figure 2 – 3D model of the Site

V.2 Grid Volume Computations

Volume calculations are made using the average end area method and distances along each roadway alignment. For a particular baseline, volume computations may be done for individual roadways, combinations of roadways, or the entire design, and may extend through any baseline station limits. Each volume calculation request generates volume calculations through the limits specified by the user by accessing the appropriate baseline cross section file to get the end area per station (established during the design process) and then determining the volume using the volume parameters entered with the design data. A mass ordinate file is created as the volumes are calculated. Any design exceptions in the stationing are taken into account in the volume calculations. Corrections for horizontal curvature may be applied to the volume computation as desired.

The determination of earthwork quantities is based upon field crosssections taken in a specified manner before and after excavation. Crosssections are vertical profiles taken at right angles to the survey centerline. Every section is an area formed by the subgrade, the sideslopes, and the original ground surface.

Volumes are computed from cross-section measurements by the average end area method.

Volume (metric) (m3) = $$\frac{\left[L \times \left(A1 + A2\right)\right]}{2} \quad (16)$$

Where L is in meters A1 and A2 are in square meters

Specifications require this calculation. All the plans and bidding for the formula for average end areas is accurate only when the end areas are equal. For other cases, the formula generally gives volumes slightly larger than their true values. If applied to a pyramid, for example, the error would be the maximum and would be equal to 50 % of the correct volume.

From fig 2, the minimum upper surface in term of (XYZ) coordinate are (367564.24mN, 434290.11mE, 182.542m), while the maximum is (368418.331mN, 435438.297mE, 332.052m) at an interval of 12m spacing. The grid size is 100 rows by 75 columns. The lower surface is defined by Z value of 165m.

Using Trapezoidal Rule, the total volume of the surface was found to be 128594444.07633m^3. Using Simpson's Rule, the total volume was found to be 128591558.2169m^3. The positive volume (cut) was found to be 128594039.74377m^3, while the net Volume (cut – Fill) was found to be 128594039.74377m^3. The total planar area was found to be 980656.18301705m^2, while the positive Surface Area (cut) was found to be 996019.8002409m^2.

VI. DISCUSSION AND CONCLUSION

Our approach present baseline Static and kinematic GPS positioning by using standard Kalman filter process model. Table 1 is the baseline processed results. Table 2 is the result of the adjusted 3D coordinate of the site investigated. Figure 1 is the contour showing the nature of the terrain. Figure 2 is the presented Digital Terrain Model (DTM). The DTM reveal the area the will needed to be filled and cut. The quantity of material needed was also computed. The contour, 3D model, the area and Volume was derived using SUFFER 8.0 software.

Performance assessment of the measurement system carried during the data acquisition involved the use of three receivers, one control for static model and two rovers for Kinematic model both acquiring data at 5 seconds interval. From the results obtained it can be concluded that GPS observation by combining static and kinematic models gives very high accuracy for 3-D Survey.

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