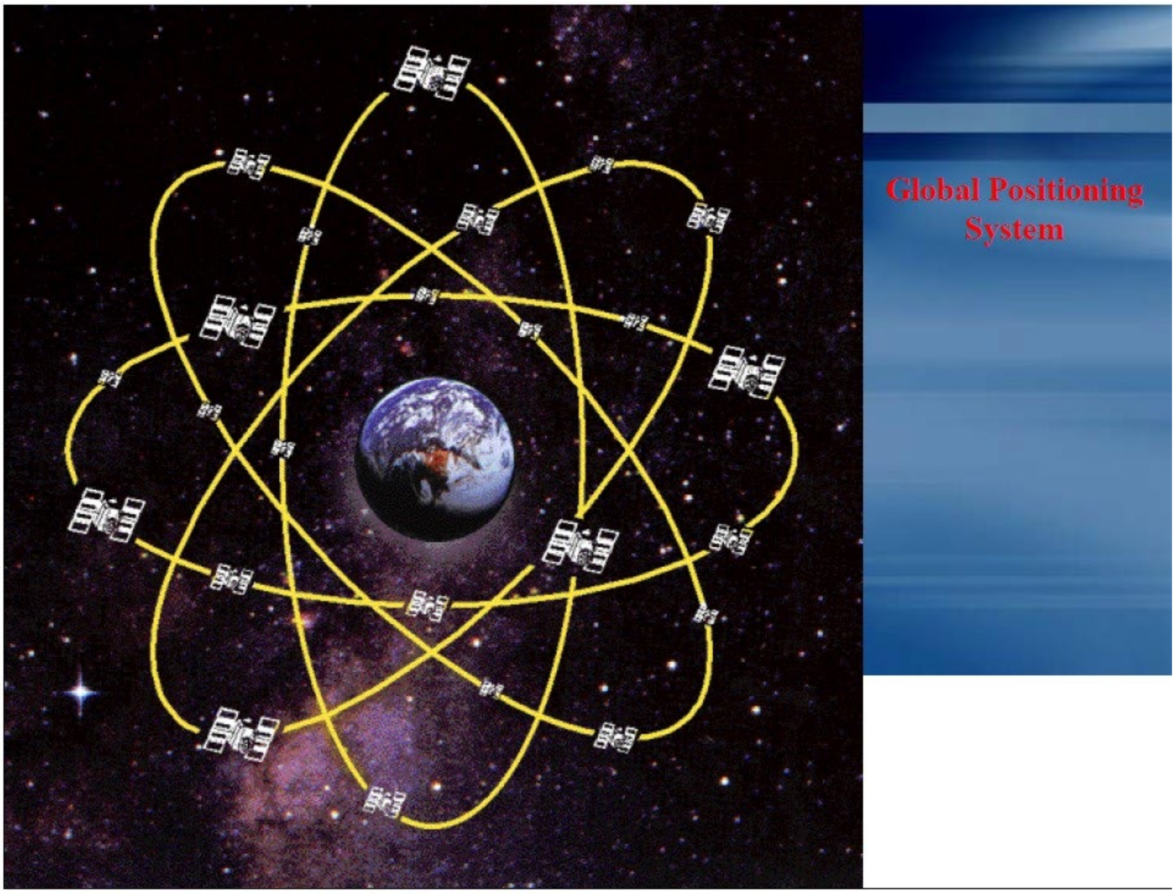
1. INTRODUCTION.

My inherent awe at how science has advanced so much since I graduated an engineer in 1978, gives me great respect for the field of Geodesy. Global positioning using satellite technology gives me precise and accurate measurement of any location on the earth's surface and under the sea. The ability to map the precise location of any spot on the earth's continents despite the movements of the earth's crust from plate tectonics assures me that the simple hand-held GPS has the ability to give me geodetic measurements that is precise and accurate. However, we engineer's have written this technology off, saying that the measurements derived from this equipment is too inaccurate and cannot be used foe anything except "route location". My research paper gave me great pleasure in proving this Hypothesis wrong.



This illustration depicts the relationship of the earth with the space based GPS.

2. THE OBJECTIVE OF MY RESEARCH.

The objective of the study is to test;

Hypothesis 1:

"The derived misclosures using survey data from Hand-Held GPSs may be too large to allow use in producing working drawings and/or use the results to derive BOQ estimates for Conformed contract documents."

Hypothesis 2:
"The coordinates derived by hand-held GPS can be "converted" and "calibrated" to PNG94 Datum to give a higher-level accuracy."

3. THE CONCLUSION OF MY RESEARCH.

Hypothesis 1:
"The derived misclosures using survey data from Hand-Held GPSs may be too large to allow use in producing working drawings and/or use the results to derive BOQ estimates for conformed contract documents."

Table 1 below confirms that GPS field measurements **are not accurate** enough to be used for detailed design and construction.

Table 1: Difference between GPS field measurements and converted, calibrated Coordinates and heights to PNG94 Datum.

Name	Easting	Northing	GPS altitude	Google altitude	MSL RL	Variance
PSM 11173-Nubia	261443.7073	9543518.1764	not available	9.9	not available	not available
PSM 11172-Botbot	242448.8531	9546512.7371	not available	13.4	not available	not available
PSM 8522-Angoram	174165.7172	9554360.6980	not available	24.2	22.4880	not available
Waypoint 30-Bunapas Station-Upstream waterfront	243297.5995	9530947.9389	11	8.6	8.053	2.947
Waypoint 31-Starting point of survey	243318.0186	9531549.0721	16	12.5	11.953	4.047
Waypoint 32-Small ridge and rain forest	242571.3473	9531779.1598	35	38.2	37.653	-2.653
Waypoint 33-Small ridge and rain forest	242380.0035	9532007.2177	38	35.3	34.753	3.247
Waypoint 34-Small ridge and rain forest	241033.1668	9532985.9292	21	26.4	25.853	-4.853
Waypoint 35-Small ridge and rain forest	240167.1756	9533488.5333	17	29.4	28.853	-11.853
Waypoint 36-Small ridge and rain forest	239648.1579	9533719.2933	33	30.5	29.953	3.047
Waypoint 37-Small ridge and rain forest	239525.1496	9533995.4964	34	29.3	28.753	5.247
Waypoint 38-Small ridge and rain forest	239349.0880	9534677.1818	37	24.1	23.553	13.447
Waypoint 39-Small ridge and rain forest	239037.4422	9536123.6495	14	29.8	29.253	-15.253
Waypoint 40-Bosmun Ridge	238799.6443	9537638.5643	12	17.8	17.253	-5.253
Waypoint 41-Bur River Bridge Site	238814.3382	9537677.3288	9	18	17.453	-8.453
Waypoint 42-Bosmun Mission School	238802.4691	9537931.7419	31	31.2	30.653	0.347
Waypoint 43/44-Kunai Hilltop Bosmun	238348.1178	9538195.8933	35	30.2	29.653	5.347
Waypoint 45 Taringi Waterfront boat bay	231808.3658	9538495.0511	14	4.8	4.253	9.747
Waypoint 46 Corosie coronous	230893.9111	9541472.0237	51	41.8	41.253	9.747
Waypoint 47 Pilot Track Junction at Korosie	230477.0437	9544599.8955	33	26.7	26.153	6.847
Waypoint 48/49 Karai Village Hilly Terrain	229507.1215	9546333.9302	28	18.3	17.753	10.247
Waypoint 50 Magum Village	227506.5271	9548446.5358	23	17.2	16.653	6.347
Waypoint 51 Ambrongi Kunai	226101.6299	9547081.3803	48	40.8	40.253	7.747
Waypoint 52	228222.8994	9551566.8500	10	8.8	8.253	1.747

Waypoint 53-Gupun Mission	222868.0041	9554500.9375	13	14	13.453	-0.453
Waypoint 54-Julian Hilltop coronous	221677.5425	9553215.6815	82	80.2	79.653	2.347
Waypoint 55-937 m from old pilot track	212397.1653	9549972.2291	53	23.4	22.853	30.147
Waypoint 56-old pilot track Amboringi Village	211467.9540	9549841.9950	53	38.1	37.553	15.447
Waypoint 57-Pankin Village-Jabara Bush camp	210537.4467	9550111.9328	16	16.9	16.353	-0.353
Waypoint 58-Ridge running towards Panion rubber	207554.7302	9550469.2537	41	26.3	25.753	15.247
Waypoint 59-Walking track to Pankin Village Control Point	204496.6955	9551176.6533	15	16.6	16.053	-1.053
Waypoint 60-Pankin Village Waterfront	202781.6030	9550661.9750	24	12.3	11.753	12.247
Waypoint 61-Old Bien Village flood plain ridge	206177.9301	9557561.3851	14	7.9	7.353	6.647
Waypoint 62-Marienberge Waterfront	192418.0680	9561424.3418	15	6	5.453	9.547

Hypothesis 2:

"The coordinates derived by hand-held GPS can be "converted" and "calibrated" to PNG94 Datum to give a higher-level accuracy."

Table 2 below shows that MSL RLs for the 1st Order Control marks for GS 1495 and PSM 15497 are relatively close to the calculated Orthometric Heights and the extracted Google heights. The difference allows for the "Mean Dynamic Topography" and when adjusted, the calibration provides accurate MSL RLs that can used to generate a Digital Terrain Model (DTM) in Magnet Office Civilcad. This study has used the -0.547 meters offset from the PSM 15497 in Wewak to "calibrate" the google heights observed on the Bunapas-Pankin-Membel survey traverse and derive a DTM (Digital Terrain Model) for the road alignment.

Table 2: PNG94 (ITRF92 at epoch 1994.0) - 1st order control - Adjustment 7th June 2008 - Updated 1st December 2011.

Code	GRS80-UTM South		PNG 1st Order Control		SGS Prime COGO-Survey Pocket Tools Apps: Accuracy Check		Google Pro	Mean Dynamic Topography	
	Location	UTM Zone	PNG 94 Datum		EGM 2008 2.5' Geoid Model			EGM 2008 2.5' Geoid Model	EGM 2008 2.5' Geoid Model
			Ellipsoid Height (m)	MSL RL (PNG 08) (m)	Geoid Height (m)	Orthometric Height (m)	Google Height (m)	Difference: H=h-N (m)	Observed Offsets (m)
GS1495	Madang Airport	55	73.2700	**4.95**	68.2548	**5.0152**	**4**	-0.065	-1.12
PSM 15497	Wewak Airport	54	83.9100	**4.85**	78.5134	**5.3966**	**5**	-0.547	

4. WHY DID I USE GOOGLE EARTH DATA EXTRACTION?

Yinsong Wang et al [1] in their research paper titled "Google Earth data extraction and accuracy assessment for transportation applications" proved and I quote

"The methodology validation results indicate that the proposed extraction method can locate the extracting route accurately, recognize multi-layered roadway section, and segment the extracted route by grade automatically. Overall, it is found that the high accuracy elevation data available from GE provide a reliable data source for various transportation applications."

5. HOW ACCURATE IS GOOGLE EARTH DATA EXTRACTION?

National Oceanic and Atmospheric Administration (NOAA), [2] Coastal Services in their paper titled "Lidar 101: An Introduction to Lidar Technology, Data and Applications, November 2012, says and I quote;

"More sophisticated data discovery tools frequently use a Web map interface (e.g., Google Maps) or a Web GIS interface (e.g., ArcGIS Server, MapServer). Data can often be selected and downloaded from these sites as well."

And;

"Lidar instruments can rapidly measure the Earth's surface, at sampling rates greater than 150 kilohertz (i.e., 150,000 pulses per second). The resulting product is a densely spaced network of highly accurate georeferenced elevation points (Figure 2-2)—often called a point cloud—that can be used to generate three-dimensional representations of the Earth's surface and its features. Many lidar systems operate in the near-infrared region of the electromagnetic spectrum, although some sensors also operate in the green band to penetrate water and detect bottom features. These bathymetric lidar systems can be used in areas with relatively clear water to measure seafloor elevations. Typically, lidar-derived elevations have absolute accuracies of about 6 to 12 inches (15 to 30 centimetres) for older data and 4 to 8 inches (10 to 20 centimetres) for more recent data; relative accuracies (e.g., heights of roofs, hills, banks, and dunes) are even better."

6. WHY DO I TRUST A REAL TIME KINEMATICS (RTK) SURVEY EQUIPMENT TO GIVE ME ACCURATE AND PRECISE SURVEY DATA?

Gigography [3] in their paper titled "Geodetic Datums: NAD 27, NAD 83 and WGS 84" say and I quote;

"It wasn't until the mainstream use of Global Positioning Systems (GPS) until a unified global ellipsoid model was developed. The radio waves transmitted by GPS satellites enable extremely precise Earth measurements across continents and oceans. Global ellipsoid models have been created because of the enhancement of computing capabilities and GPS technology.

This has led to the development of global ellipsoid models such as WGS72, GRS80, and WGS84 (current). The **World Geodetic System (WGS84)** is the reference coordinate system used by the Global Positioning System.

Never before have we've been able to estimate the ellipsoid with such precision because of the global set of measurements provided by GPS. It's made of a reference ellipsoid, a standard coordinate system, altitude data, and a geoid. Similar to NAD 83, it uses the Earth's center mass as the coordinate origin. The error is believed to be less than 2 centimetres to the center mass."

7. THE PNG 94 DATUM

Richard Stanaway, Quickclose Pty Ltd. for the Association of Papua New Guinea Inc. "Papua New Guinea Vertical Datum" 17th December 2014. [4]

7.1 Papua New Guinea Geodetic Datum 1994 (PNG94). PNG94 is the gazetted national datum for Papua New Guinea (National Gazette of 22 May 1996). EPSG Code 5544 PNG94 is realized by the coordinates of 14 zero order geodetic stations within Papua New Guinea (listed below) related to the International Terrestrial Reference Frame 1992 (ITRF92) at epoch 1994.0 (same as GDA94 in Australia). PNG94 supersedes AGD66 as the national geodetic datum for Papua New Guinea.

7.2 **Reference Ellipsoid:** GRS80
Map Projection: Papua New Guinea Map Grid 1994 (PNGMG94)
Projection type: Universal Transverse Mercator (UTM). The UTM Zones South is the coordinate system *for transformation from different geodetic systems to the PNG 94 datum (added by the author).*

7.3 Vertical Datums.

The predominant height datum in PNG is Mean Sea Level (MSL). Due to the rugged nature of the terrain and inaccessibility of much of the terrain, most of the country has not been connected by conventional leveling networks from a Tide Gauge. Most local realizations of MSL, especially in the Highlands and inland areas have been derived from trigonometric heighting or altimetry. Differences of up to 6 metres between true MSL and local MSL can occur.

The recommended approach for height transfer in PNG is to use GPS or GNSS heighting in conjunction with a suitable geoid model. If GPS/GNSS heighting is used on a project where MSL has already been established then the offset between the geoid model and local MSL should be determined.

7.4 EGM 2008 2.5' geoid model.

The EGM 2008 2.5' geoid model is used widely in PNG, however for coastal engineering and hydrology studies a substantial offset is required to be applied to account for the effects of Mean Dynamic Topography (MDT), which is the elevation of Mean Sea Level (MSL) above the global geoid largely due to thermal expansion of the ocean in warmer equatorial zones………Note that some offsets datums are to fit established MSL height datums, **are not necessarily in agreement** with the MDT model.

Table 3 below provides the ellipsoid height (h) and the Mean Sea Level RL using the PNG2008 Datum. The geoid height (N) is calculated using the Survey Pocket Tools Apps. The Orthometric height (H) is calculated using the formulae;

Local MSL=ITRF Ellipsoid Height (h) – EGM 2008 N Value + Offset.

Table 3: PNG94 (ITRF92 at epoch 1994.0) - 1st order control - Adjustment 7th June 2008 - Updated 1st December 2011.

Code	GRS80-UTM South		PNG 1st Order Control		SGS Prime COGO-Survey Pocket Tools Apps: Accuracy Check		Google Pro	Mean Dynamic Topography	
	Location	UTM Zone	PNG 94 Datum		EGM 2008 2.5' Geoid Model			EGM 2008 2.5' Geoid Model	EGM 2008 2.5' Geoid Model
			Ellipsoid Height (m)	MSL RL (PNG 08) (m)	Geoid Height (m)	Orthometric Height (m)	Google Height (m)	Difference: MSLRL-H (m)	Observed Offsets (m)
GS1495	Madang Airport	55	73.27	4.95	68.3	5.02	4	-0.065	-1.12
PSM 15497	Wewak Airport	54	83.91	4.85	78.5	5.4	5	-0.547	
PSM 3507	Mendi Airport	54	1815	1732	81.7	1733	1736	-1.304	
PSM 9833	Goroka Airport	55	1665	1585	79.9	1585	1581	0.131	
PSM 9513	Kavieng Airport	56	78.81	2.85	74.3	4.47	6	-1.623	
PSM 9799	UNITECH Sports	55	130.3	57.4	71.8	58.5	64	-1.148	
PSM 19471	Finschafen	55	74.24	7.42	74.7	-0.4	13	6.989	
AA 583	Louisa	56	85.16	5.61	74.3	7.63	12	-2.019	
PSM 9538	Alotau Gurney Airport	56	94.87	16.4	77.9	17.1	19	-0.681	
PSM 9522	Lombrum secor	55	129.8	50.8	77.9	51.9	23	-1.146	
PSM 4871	Buka Airport	56	73.25	2.87	65.9	7.36	9	-4.494	
PSM 23342	Kenebot Lands Base	56	136.7	63.1	73.6	63.1	56	0.053	
RVO	Rabaul RVO Base	56	266.2	191	74	192	170	-0.805	
PSM 31927	Port Moresby NMB Base	55	123	47.2	75.7	47.3	46	-0.153	-0.93
Kumul 34	Kumul Oil Export Platform	55	103.3	28.2	74.3	29	-3	-0.785	
PSM 31703	Kerema Catholic Mission	55	97.57	21.3	75.1	22.5	14	-1.186	-0.93
PSM 5583	Kikori Airport	55	88.93	12.4	76	12.9	17	-0.536	

AA 440/A	Daru Airport	54	80.28	5.28	74.2	6.05	9	-0.774	
PSM 32685	Kiunga Airport	54	112.5	37.5	73.9	38.5	34	-1.022	
PSM 32695	Tabubil Airport	54	559.8	479	81.4	478	477	0.109	
PSM 32629	Bulolo-Unitech WS	55	802.1	723	78.4	724	728	-0.795	
PSM 15262	Gobe Airport	54	129.2	51	78.8	50.4	56	0.572	
PSM 17442	Moro	54	917.9	838	80.3	838	901	0.1	
PSM 3419	Mt. Hagen Airport	55	1710	1627	81.5	1629	1631	-2.101	
ST 31024	Nadzab Airport	55	148.8	76.1	77.1	77.1	73	-0.997	

8. THE SURVEY CONTROLS FOR DESIGN AND CONSTRUCTION.

The Project Survey, Design and Construction Controls are provided in Table 4 below.

Table 4: PNG94 (ITRF92 at epoch 1994.0) - 1st order control - Adjustment 7th June 2008 - Updated 1st December 2011 for the Project.

PNG94 (ITRF92 at epoch 1994.0) - 1st order control - Adjustment 7th June 2008 - Updated 1st December 2011																	
Station location			PNG94 Ellipsoidal Coordinates							PNGMG94 Grid Coordinates			MSL RL (PNG08)	ITRF Site		PNG94	
Location	GPS ID	NMB Number	Latitude			Longitude			Ellipsoid Height	Zone	Easting	Northing		E m/yr	N m/yr	Latitude Decimal	Longitude Decimal
Madang -	MAD1	GS 1549	-5	12	41.2891	145	46	56.1940	73.27	55	365044.17	9423829.87	4.95	0.023	0.039	-5.21146919	145.78227611
Wewak	WEWK	PSM 1549	-3	35	2.5848	143	40	0.1481	83.91	54	796268.18	9603418.22	4.85	0.017	0.053	-3.58405133	143.66670781
Nubi	not	PSM	-4	7	37.0160	144	51	4.0350	not given	55	261442.85	9543516.00	not	not	not	not given	not given
Botb	not	PSM	-4	5	57.8320	144	40	48.6750	not given	55	242447.92	9546511.19	not	not	not	not given	not given
Ang	not	PSM	-4	1	35.2864	144	3	57.2101	not given	55	174164.54	9554359.16	22.49	not	not	not given	not given

REFRENCES:

1. Yinsong Wang at all, "Google Earth data extraction and accuracy assessment for transportation applications", PLoS One 2017; 12(4): e0175756, published on line 2017 April 26. Doi: 10.1371/journal.phone.0175756.
2. National Oceanic and Atmospheric Administration (NOAA), Coastal Services in their paper titled "Lidar 101: An Introduction to Lidar Technology, Data and Applications, November 2012.
3. Gigography in their paper titled "Geodetic Datums: NAD 27, NAD 83 and WGS 84"
4. Richard Stanaway, Quickclose Pty Ltd. for the Association of Papua New Guinea Inc. "Papua New Guinea Vertical Datum" 17th December 2014.