Removal of Inconsistencies Arising from Multiplicity of Transformation Parameters in Nigeria

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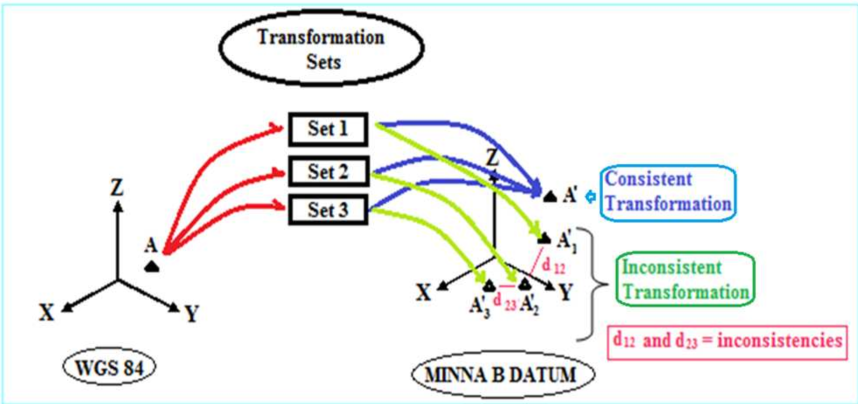
Nigeria

INTRODUCTION

CONSISTENT AND INCONSISTENT TRANSFORMATIONS



THE CHALLENGE OF MULTIPLICITY OF TRANSFORMATION PARAMETERS IN NIGERIA

- In the Nigerian Petroleum industry very many transformation sets are applied by different Companies for transforming WGS84 coordinates to Minna datum .
- Geodetic computations in Nigeria face challenges from this multiplicity of transformation parameters because transformations done for a given point with these different sets differ sometimes by as much as 45 meters.
- This is particularly a major challenge in the Nigerian Petroleum industry because wrongly transformed coordinates can lead to wrong location of an oil-well head, so that, instead of drilling oil, water may be drilled! Or at best, drilling may hit oil, but, at the wrong elevation!
- Another dimension to this challenge is the fact that some of these transformation sets (e.g. DMA parameters) are embedded in the configuration suites of GPS instruments which are used to determine Minna B datum coordinates during field observations. These usually differ from those determined from the transformation sets officially used by other companies.
- This situation exists because the Nigerian Government is still working on an official WGS84/Minna datum transformation set.

GEODETIC NETWORKS IN NIGERIA(1)

- **1. GPS Networks in Nigeria**
  - In 2009/2010 the Federal government of Nigeria established eleven (11) Continuously Operating Reference Stations (CORS) located at strategic positions in the country
  - Many Oil Companies operating in the Niger Delta region of the country had established various GPS control networks to facilitate their oil exploration operations.
  - All these GPS networks are reduced and computed on the World Geodetic System of 1984 (WGS84 – datum) which uses a geocentric ellipsoid with the following dimensions:
    - a = 6378137.0 m
    - f = 1/298.257223563

GEODETIC NETWORKS IN NIGERIA(2)

- **2. The Nigerian (Minna B) Geodetic Network**
  - Nigeria is covered with first-order triangulation chains and traverse control networks.
  - These networks were computed on a local geodetic datum called "Minna B" datum with its origin located at station L40 (the northern terminal of the Minna base of the Nigerian Primary triangulation network).
  - The **Minna B datum** is based on the Clarke 1880 ellipsoid (Semi-major axis, a = 6378249.145m; Flattening, f = 1/293.465).
  - The L40 origin has the following adopted geodetic co-ordinates (Uzodinma and Ezenwere, 1993):
    - Latitude φ = 09° 38′ 09″ N
    - Longitude λ = 06° 30′ 59″ E
    - Height, H = 279.6m above the geoid.

Interconversions between a Global and Local Datum

- The Molodensky-Badekas model is considered the best model for datum transformation between a global (e.g. WGS84) and local datum (e.g. the Minna B datum).
- The model in its matrix-vector form could be written as (Al Marzooqi, Y etal, 2005):

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + \begin{bmatrix} X_M \\ Y_M \\ Z_M \end{bmatrix} + \begin{bmatrix} 1+\Delta L & R_Z & -R_Y \\ -R_Z & 1+\Delta L & R_X \\ R_Y & -R_X & 1+\Delta L \end{bmatrix} \begin{bmatrix} X'-X_M \\ Y'-Y_M \\ Z'-Z_M \end{bmatrix} \quad \ldots\ldots (2)$$

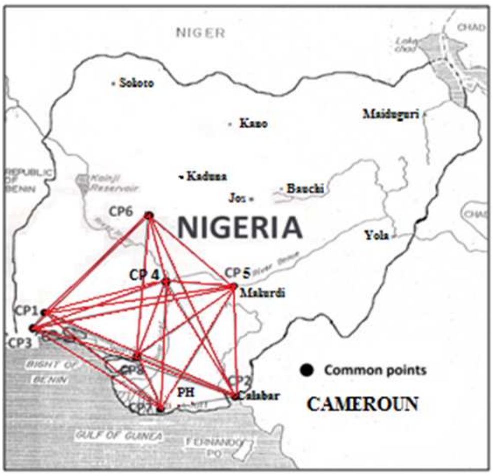
With:

$$X_M = \frac{1}{n}\sum_{i=1}^{n} Xi \; ; \; Y_M = \frac{1}{n}\sum_{i=1}^{n} Yi \; ; \; Z_M = \frac{1}{n}\sum_{i=1}^{n} Zi$$

Where:

n = the number of common points
X_M, Y_M, Z_M = the mean of the Cartesian coordinates of "common" points in the local datum.
X, Y, Z = Cartesian coordinates in the global datum
ΔX, ΔY, ΔZ = the translation parameters
R_X, R_Y, R_Z = the rotation parameters
ΔL = the scale factor
X', Y', Z' = Cartesian coordinates in the local datum

The Study Area



PARAMETER SETS UNDER STUDY

PARAMETER	SPDC	CHEVRON	EXXON-MOBIL	AGIP	DMA	NORTEC	KARIALA	ELF
ΔX	+111.916m±2.3m	+92.968m	+94.031m	+111.916m	92m±3m	+93.200m	+113.936±1.21m	+88.98
ΔY	+88.852m±2.3m	+89.582m	+83.317m	+87.852m	93m±6m	93.310m	+88.918±1.21m	+83.23
ΔZ	-114.499m±2.3m	-116.39m	-116.708m	-114.499m	-122m±5m	-121.156m	-113.701±1.21m	-133.55
Rx	-1.87527±0.33”			-1.87527”		-1.93”	+1.881±0.55”	
Ry	-0.20214±1.61”			-0.20214”		-0.41”	0.204±0.10”	
Rz	-0.21935±0.19”			-0.21935”		+0.14”	+0.222±0.11”	
Scale(ppm)	-0.03245±0.20			-0.03245		-21.2688	-0.017±0.17	

PARAMETER	**FAJEMIROKUN**	**EZEIGBO**	**AGAJELU**
ΔX (m)	-160.4±0.1	-92.9±1.6	-90.1±1.8
ΔY (m)	-67.4±0.0	-116.0±2.3	-107.7±1.8
ΔZ (m)	144.0±0.0	116.4±2.4	116.9±1.8
Rx	00.″4±3.0	00.″33±1.1	00.″08±0.8
Ry	1.“20±4.6	04.“20 ±1.7	-00.“35 ±01.3
Rz	01.”70±3.7	01.”70±1.5	-01.”73±0.8
Scale(ppm)	1 ± 1.4	20± 6	3.43 ± 1.3

Data Used for Study

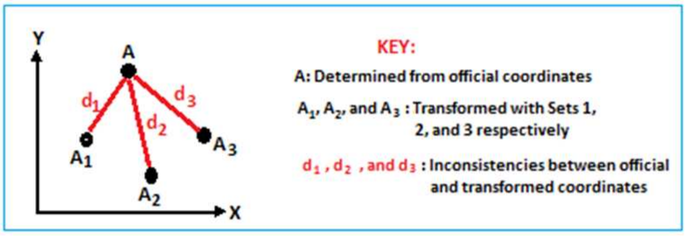
OFFICIAL COORDINATES OF COMMON POINTS (degree decimals)

S/NO	STATION ID	MINNA DATUM COORDINATES			WGS 84 (ITRF 2008) COORDINATES		
		LATITUDE	LONGITUDE	HEIGHT(Mean Sea Level) m	LATITUDE	LONGITUDE	HEIGHT (Ellipsoidal) m
1.	CP1	07 12 14.635	03 20 44.397	195.378	07 12 15.833	03 20 41.619	198.168
2.	CP2	05 07 17.371	08 20 22.008	111.265	05 07 19.304	08 20 19.778	105.584
3.	CP3	06 37 35.451	03 19 26.009	68.256	06 37 36.847	03 19 23.227	70.634
4.	CP4	07 48 26.201	06 42 49.262	438.934	07 48 27.462	06 42 46.824	437.548
5.	CP5	07 27 44.488	08 36 13.662	366.022	07 27 45.803	08 36 11.535	362.025
6.	CP6	09 38 19.885	06 33 33.980	471.012	09 38 20.581	06 33 31.311	470.679
7.	CP7	04 50 50.575	07 02 54.441	39.941	04 50 52.685	07 02 52.134	35.590
8.	CP8	05 32 19.445	05 44 18.970	25.970	05 32 21.410	05 44 16.472	23.590

INTERPOLATION METHODS APPLIED

- **1. Kriging Interpolation Method**
  - It measures the relationships between all of the sample points and then applies sophisticated statistical methods to predict the value of an unknown cell.
- **2: Inverse Distance Weighted Interpolation Method**
  - The Inverse Distance Weighted (IDW) interpolation method assumes that the nearer a sample point is to the cell whose value is to be estimated, the more closely the cell's value will resemble the sample point's value.

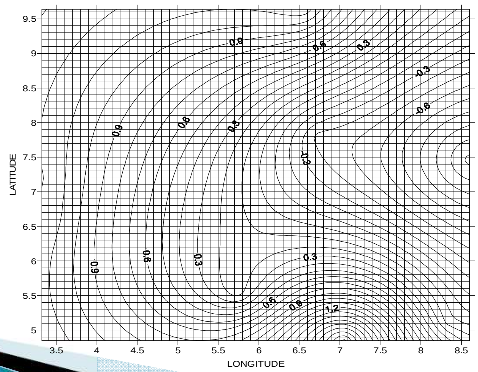
Estimation of Inconsistencies



- Magnitudes of the inconsistencies (dx, dy, and dz) were determined by computing the difference between the official Minna datum coordinates (X_O) of a point (obtained from OSGoF) and the corresponding Minna datum coordinates (X_T) transformed from WGS 84 datum using a Transformation set.
  - $dx = X_o - X_T$
  - $dy = Y_o - Y_T$
  - $dz = Z_o - Z_T$

REMOVAL OF INCONSISTENCIES (1)

- Two Steps Adopted:
  1. Inconsistencies determined at 8 common points were used to estimate the corresponding inconsistencies at the nodes of 90 grid cells using Kriging interpolation method.



REMOVAL OF INCONSISTENCIES (2)

2. The IDW (Inverse Distance Weighted) interpolation method uses the inconsistencies at the grid nodes to estimate the correction (dX_{cor}) for inconsistencies at any given point as follows:

$$X_I = X_T + dX_{cor}$$
$$Y_I = Y_T + dY_{cor}$$
$$Z_I = Z_T + dZ_{cor}$$

Where,

X_I = improved X coordinate

X_T = transformed X coordinate

Modified Approach

- One disadvantage of the approach shown so far is that a different set of Kriging charts has to be prepared for each transformation set.
- In order to have one set of charts for ALL the transformation sets, we made some modifications.
- In the modified approach:
  - instead of computing the inconsistencies (dx) at each grid node, the improved coordinates (X_I) of the grid node are determined.
  - For any transformation set, the transformed coordinates (X_T) (of a grid node) are compared with its corresponding X_I to yield the correction (dX_{cor}) at the node:

    $dX_{cor} = X_I - X_T$.

    - Note: the magnitude of dX_{cor} at a point will vary according to the set used.
  - The IDW (Inverse Distance Weighted) interpolation method then uses the dXcor at the grid nodes to estimate the correction (dX_{cor}) at any given point (as shown earlier).

RESULTS(1)

Table 4: Discrepancies from different transformation sets

STN	COMPONENTS	DISCREPANCIES										
		SPDC	CHEVRON	EXXON-MOBIL	AGIP	DMA	NORTEC	KARIALA	ELF	FAJEMIROKUN	EZEIGBO	AGAJELU
CP1	dx	1.344	20.400	19.337	1.344	21.368	22.414	-0.457	24.388	275.026	202.330	200.754
	dy	0.644	2.421	8.686	1.644	-0.997	-11.177	5.596	8.773	160.842	215.985	200.421
	dz	8.228	6.885	7.203	8.228	12.495	9.390	0.948	24.045	-254.320	-222.552	-225.509
CP2	dx	2.939	21.184	20.121	2.939	22.152	22.603	-0.493	25.172	269.960	194.537	206.666
	dy	-7.363	-3.555	2.71	-6.363	-6.973	-7.575	1.663	2.797	154.496	199.071	192.906
	dz	2.093	5.808	6.126	2.093	11.418	-1.786	4.941	22.968	-253.913	-217.519	-225.640
CP3	dx	1.475	20.470	19.407	1.475	21.438	22.775	-0.448	24.458	274.736	200.971	200.888
	dy	0.243	2.606	8.871	1.243	-0.813	-11.623	6.366	8.958	161.215	216.373	200.572
	dz	7.943	6.577	6.895	7.943	12.187	7.766	0.615	23.737	-254.614	-221.751	-225.587
CP4	dx	2.832	21.561	20.498	2.832	22.529	22.319	0.372	25.549	273.567	202.613	205.042
	dy	-2.006	-0.886	5.379	-1.006	-4.304	-6.034	1.635	5.466	156.699	204.844	196.165
	dz	-2.420	-0.365	-0.047	-2.420	5.245	0.008	-2.893	16.795	-260.681	-229.699	-232.912
CP5	dx	3.616	22.088	21.025	3.616	23.056	22.295	0.639	26.075	272.188	201.118	207.451
	dy	-7.643	-6.21	0.055	-6.643	-9.628	-7.317	-3.373	0.142	151.053	195.244	190.336
	dz	-2.293	1.671	1.989	-2.293	7.281	-0.746	1.057	18.831	-258.073	-226.110	-230.705
CP6	dx	0.84	19.788	18.725	0.840	20.756	19.556	-1.180	23.776	273.156	205.656	202.856
	dy	6.397	5.667	11.932	7.397	2.249	1.939	6.331	12.019	162.649	211.249	202.949
	dz	-4.761	-2.87	-2.552	-4.761	2.740	1.896	-5.559	14.290	-263.260	-235.660	-236.160
CP7	dx	1.011	19.377	18.314	1.011	20.345	21.413	-2.178	23.365	269.121	192.847	203.648
	dy	-8.921	-4.811	1.454	-7.921	-8.229	-12.109	0.709	1.541	153.619	200.873	191.965
	dz	-0.168	2.241	2.559	-0.168	7.851	-4.628	0.062	19.401	-257.851	-221.151	-229.122
CP8	dx	2.759	21.354	20.291	2.759	22.322	23.534	0.030	25.342	272.728	197.384	204.247
	dy	-4.253	-0.821	5.444	-3.253	-4.239	-10.486	4.017	5.531	157.683	207.720	196.346
	dz	-0.701	0.377	0.695	-0.701	5.987	-3.497	-3.135	17.537	-260.126	-224.959	-231.288

RESULTS(2)

Table 5: Corrections to dx, dy, dz estimated by IDW

STN	COMPONENTS	CORRECTIONS										
		SPDC	CHEVRON	EXXON-MOBIL	AGIP	DMA	NORTEC	KARIALA	ELF	FAJEMIROKUN	EZEIGBO	AGAJELU
CP1	dx	-1.344	-20.399	-19.336	-1.344	-21.367	-22.411	0.459	-24.387	-275.021	-202.315	-200.752
	dy	-0.693	-2.479	-8.744	-1.693	0.939	11.134	-5.661	-8.831	-160.900	-216.047	-200.481
	dz	-8.200	-6.856	-7.174	-8.200	-12.466	-9.343	-0.917	-24.016	254.348	222.559	225.535
CP2	dx	-2.918	-21.160	-20.0974	-2.918	-22.128	-22.568	0.520	-25.148	-269.912	-194.490	-206.666
	dy	7.372	3.560	-2.705	6.372	6.978	7.532	-1.663	-2.792	-154.485	-199.012	-192.897
	dz	-2.043	-5.7818	-6.100	-2.043	-11.392	1.849	-4.939	-22.942	253.931	217.519	225.664
CP3	dx	-1.485	-20.478	-19.415	-1.485	-21.446	-22.775	0.442	-24.466	-274.726	-200.966	-200.915
	dy	-0.092	-2.454	-8.719	-1.092	0.964	11.730	-6.215	-8.806	-161.058	-216.177	-200.415
	dz	-7.956	-6.610	-6.928	-7.956	-12.220	-7.778	-0.668	-23.770	254.575	221.708	225.553
CP4	dx	-3.018	-21.747	-20.684	-3.018	-22.715	-22.495	-0.559	-25.735	-273.757	-202.812	-205.227
	dy	2.005	0.885	-5.380	1.005	4.303	6.041	-1.635	-5.467	-156.696	-204.846	-196.171
	dz	2.417	0.364	0.047	2.417	-5.246	-0.010	2.895	-16.796	260.678	229.687	232.912
CP5	dx	-3.614	-22.096	-21.033	-3.614	-23.064	-22.318	-0.657	-26.084	-272.267	-201.207	-207.390
	dy	7.620	6.199	-0.066	6.620	9.617	7.456	3.374	-0.153	-151.073	-195.411	-190.367
	dz	2.147	-1.747	-2.065	2.147	-7.357	0.567	-1.063	-18.907	258.016	226.086	230.636
CP6	dx	-0.858	-19.800	-18.737	-0.858	-20.768	-19.607	1.174	-23.788	-273.136	-205.500	-202.864
	dy	-6.248	-5.591	-11.856	-7.248	-2.173	-1.752	-6.329	-11.943	-162.599	-211.230	-202.874
	dz	4.732	2.858	2.540	4.732	-2.752	-1.757	5.564	-14.302	263.249	235.512	236.120
CP7	dx	-0.993	-19.367	-18.304	-0.993	-20.335	-21.373	2.179	-23.355	-269.166	-193.023	-203.621
	dy	8.769	4.734	-1.531	7.769	8.152	11.972	-0.710	-1.618	-153.675	-200.945	-192.047
	dz	0.152	-2.251	-2.569	0.152	-7.861	4.440	-0.066	-19.411	257.846	221.291	229.141
CP8	dx	-2.749	-21.348	-20.285	-2.749	-22.316	-23.532	-0.031	-25.336	-272.763	-197.439	-204.206
	dy	4.227	0.809	-5.456	3.227	4.227	10.543	-4.016	-5.543	-157.698	-207.809	-196.369
	dz	0.632	-0.410	-0.728	0.632	-6.020	3.395	3.138	-17.570	260.103	224.965	231.261

RESULTS(3)

Table 6: Discrepancies after applying corrections (dx, dy, dz)

STN	COMPONENTS	NEW DISCREPANCIES										
		SPDC	CHEVRON	EXXON-MOBIL	AGIP	DMA	NORTEC	KARIALA	ELF	FAJEMIROKUN	EZEIGBO	AGAJELU
CP1	dx	0	0.001	0.001	0	0.001	0.003	-0.065	-0.058	0.005	-0.062	-0.06
	dy	-0.049	-0.058	-0.058	-0.049	-0.058	-0.043	0.031	0.029	-0.058	0.007	0.026
	dz	0.028	0.029	0.029	0.028	0.029	0.047	0.027	0.024	0.028	0.047	0
CP2	dx	0.021	0.024	0.0236	0.021	0.024	0.035	0	0.005	0.048	0.059	0.009
	dy	0.009	0.005	0.005	0.009	0.005	-0.043	0.002	0.026	0.011	0	0.024
	dz	0.05	0.0262	0.026	0.05	0.026	0.063	-0.006	-0.008	0.018	0.005	-0.027
CP3	dx	-0.01	-0.008	-0.008	-0.01	-0.008	0	0.151	0.152	0.01	0.196	0.157
	dy	0.151	0.152	0.152	0.151	0.151	0.107	-0.053	-0.033	0.157	-0.043	-0.034
	dz	-0.013	-0.033	-0.033	-0.013	-0.033	-0.012	-0.187	-0.186	-0.039	-0.199	-0.185
CP4	dx	-0.186	-0.186	-0.186	-0.186	-0.186	-0.176	0	-0.001	-0.19	-0.002	-0.006
	dy	-0.001	-0.001	-0.001	-0.001	-0.001	0.007	0.002	-0.001	0.003	-0.012	0
	dz	-0.003	-0.001	0	-0.003	-0.001	-0.002	-0.018	-0.009	-0.003	-0.089	0.061
CP5	dx	0.002	-0.008	-0.008	0.002	-0.008	-0.023	0.001	-0.011	-0.079	-0.167	-0.031
	dy	-0.023	-0.011	-0.011	-0.023	-0.011	0.139	-0.006	-0.076	-0.02	-0.024	-0.069
	dz	-0.146	-0.076	-0.076	-0.146	-0.076	-0.179	-0.006	-0.012	-0.057	0.156	-0.008
CP6	dx	-0.018	-0.012	-0.012	-0.018	-0.012	-0.051	0.002	0.076	0.02	0.019	0.075
	dy	0.149	0.076	0.076	0.149	0.076	0.187	0.005	-0.012	0.05	-0.148	-0.04
	dz	-0.029	-0.012	-0.012	-0.029	-0.012	0.139	0.001	0.01	-0.011	-0.176	0.027
CP7	dx	0.018	0.01	0.01	0.018	0.01	0.04	-0.001	-0.077	-0.045	-0.072	-0.082
	dy	-0.152	-0.077	-0.077	-0.152	-0.077	-0.137	-0.004	-0.01	-0.056	0.14	0.019
	dz	-0.016	-0.01	-0.01	-0.016	-0.01	-0.188	-0.001	0.006	-0.005	-0.055	0.041
CP8	dx	0.01	0.006	0.006	0.01	0.006	0.002	0.001	-0.012	-0.035	-0.089	-0.023
	dy	-0.026	-0.012	-0.012	-0.026	-0.012	0.057	0.003	-0.033	-0.015	0.006	-0.027
	dz	-0.069	-0.033	-0.033	-0.069	-0.033	-0.102	-0.065	-0.058	-0.023	-0.062	-0.06

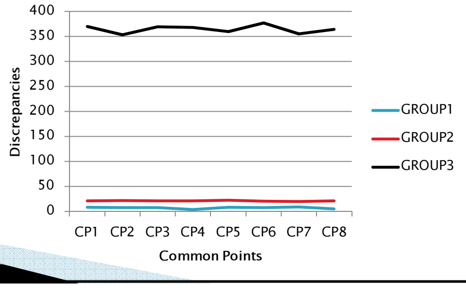
RESULTS(4)

Table 7: 3-D discrepancies before and after applying corrections ("OLD" and "NEW" respectively)

STN	DISCREPANCIES (m)	TRANSFORMATION SETS										
		SPDC	CHEVRON	EXXON-MOBIL	AGIP	DMA	NORTEC	KARIALA	ELF	FAJEMIROKUN	EZEIGBO	AGAJELU
CP1	OLD	8.362	21.666	22.389	8.498	24.773	26.749	5.694	35.354	407.662	370.292	362.388
	NEW	0.056	0.064	0.065	0.056	0.065	0.064	0.077	0.069	0.065	0.078	0.065
CP2	OLD	8.200	22.252	21.207	7.315	25.879	23.905	5.237	34.190	401.521	353.254	361.714
	NEW	0.055	0.036	0.035	0.055	0.036	0.084	0.006	0.028	0.052	0.059	0.037
CP3	OLD	8.082	21.658	22.425	8.174	24.673	26.723	6.411	35.240	407.797	369.297	362.594
	NEW	0.152	0.156	0.156	0.152	0.155	0.108	0.246	0.242	0.162	0.283	0.245
CP4	OLD	4.231	21.582	21.192	3.859	23.528	23.120	3.344	31.060	409.082	368.476	367.112
	NEW	0.186	0.186	0.186	0.186	0.186	0.176	0.018	0.009	0.190	0.090	0.061
CP5	OLD	8.761	23.005	21.119	7.903	26.025	23.477	3.592	32.164	404.358	360.131	363.990
	NEW	0.148	0.077	0.077	0.148	0.077	0.228	0.009	0.078	0.099	0.230	0.076
CP6	OLD	8.018	20.783	22.350	8.837	21.057	19.743	8.507	30.232	412.765	377.434	371.632
	NEW	0.153	0.078	0.078	0.153	0.078	0.239	0.005	0.078	0.055	0.231	0.089
CP7	OLD	8.980	20.091	18.549	7.987	23.308	25.031	2.291	30.409	403.128	355.595	361.690
	NEW	0.154	0.078	0.078	0.154	0.078	0.236	0.004	0.078	0.072	0.167	0.094
CP8	OLD	5.118	21.373	21.020	4.323	23.496	26.001	5.096	31.311	408.546	364.3	365.736
	NEW	0.074	0.036	0.036	0.074	0.036	0.117	0.065	0.068	0.044	0.109	0.070
Mean Value	**OLD**	**7.469**	**21.551**	**21.281**	**7.112**	**24.092**	**24.344**	**5.022**	**32.495**	**406.857**	**364.847**	**364.607**
	NEW	**0.122**	**0.089**	**0.089**	**0.122**	**0.089**	**0.157**	**0.054**	**0.081**	**0.092**	**0.156**	**0.092**
										Overall Mean, (m)	**OLD**	**116.334**
											NEW	**0.104**

DISCUSSIONS OF RESULTS(1)

- From the discrepancies shown in Tables 4 and 7, it can be noticed that the transformation sets can be categorized into three in accordance with the magnitudes of their discrepancies as follows:
  - GROUP 1: Kariala, Agip, and SPDC transformation sets which gave mean discrepancies within the range 5m to 7.5metres.
  - GROUP 2: Exxon-Mobil, Chevron, DMA, Nortec, and ELF where mean discrepancies are within the range 21.3m - 32.5m.
  - GROUP 3: Agajelu, Ezeigbo, and Fajemirokun where the range of mean discrepancies is 364.6-406.9m.



DISCUSSIONS OF RESULTS(2)

- Table 2 shows:
  - the Group1 transformation sets were derived from coordinates obtained from GPS re-observation of some National primary triangulation points sponsored by the SPDC[Fubara, 2011];
  - the Group2 sets comprise mainly of 3-parameter transformation sets (except for Nortec).
  - The Group3 sets are suspected to have been derived from Transit (Doppler) satellite data captured in the ADOS (African Doppler Survey) project which was computed on the WGS 72 datum and later transformed to WGS84 (Ezeigbo, 2004; Jackson, 2011).
    - This third category was deliberately included in this study to show the power of our method in improving results obtained from transformation sets derived from heterogeneous data.

DISCUSSIONS OF RESULTS(3)

- Tables 5, 6 and 7 show the capability of our method to reduce the absolute discrepancies from 35m to a mean value of 0.104 metres (10.4 cm) for all the transformation sets (shows 2nd-order improvement) (Fig 4).

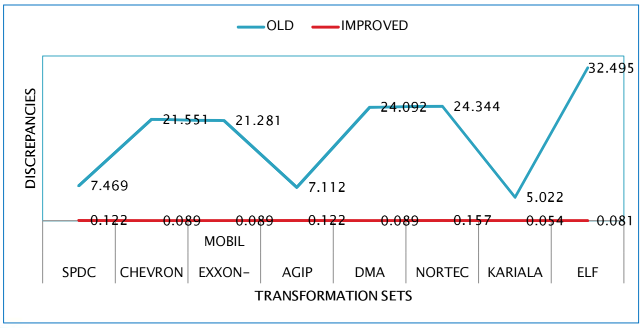


Fig. 4

CONCLUSION AND RECOMMENDATIONS

- From the discussions above, the following conclusions can be drawn:
- Our method was able to reduce the inconsistencies between the different transformation set studied from the level of 35metres to 0.104metres (10.4cm). The method can therefore use any of the transformation sets to transform the WGS84 coordinates of any given point into the Minna datum (and vice-versa) with mean accuracy of 0.104m (10.4cm).
- With our method it is possible to transform the Minna datum curvilinear coordinates (ϕ, λ, H) of existing primary triangulation points in Nigeria to the WGS84 datum (and consequently to the African geodetic Reference Frame, AFREF) with accuracy better than 0.104m (10.4cm).
- The method is therefore recommended for the reduction of the inconsistencies arising from the multiplicity of transformation sets currently used by the various petroleum exploration companies in Nigeria to the level of 10.4cm.

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THANK YOU