CHAPTER (5)
COMPUTATIONAL WORK
RESULTS AND ANALYSIS

In this chapter, all the computational work steps which were done for transformations trials, by using all available data sets which described in chapter (3) and the designed visual basic software package described in chapter (4) were illustrated. The results of those trials were analyzed and discussed.

The practical work includes the following steps:

Step (1): Determining the common points of available data.

Step (2): Data filtering.

Step (3): Unifying the different WGS84-data sets and WGS72-data sets into one WGS84 system.

Step (4): Computing transformation parameters between WGS84 and OED all over Egypt.

Step (5): Transforming all WGS84 coordinates into OED.

Step (6): Transforming all OED coordinates into WGS84.

All the above steps will be explained in the following sections.

5.1 Step (1): Determining the Common Points among the Available Data Sets

Recalling that, the available data sets were collected under three categories:

- The coordinate sets based on the Old Egyptian Datum, (OED).
- The coordinate sets based on the World Geodetic System 1972, (WGS72).
- The coordinate sets based on the World Geodetic System 1984, (WGS84).

5.1.1 Common Points among WGS84 Data Sets

There are twelve data sets defined on WGS84. Description of these data sets is found in chapter (3). Common points among these data sets do not have the same coordinates because of the different specifications concerning:

- The different observation techniques as two or more receivers were used, single or dual frequency receivers and session time.
- One or more reference stations were taken.
- Accuracy of the reference stations, i.e. IGS.
- Kind of software in processing, i.e. commercial or scientific software was used.
- Broadcast or precise ephemeries used.
- Model of atmospheric correction, i.e. standard atmosphere or atmospheric data used.

The constitutes of every WGS84-data set was scanned and examined to define the common points of those WGS84-data sets. The results were as follows:

WGS84-Data Set 1: Is taken to be as reference data set because it has the highest accuracy against all the other data sets. Unifying all the others WGS84-data sets on the same base. WGS84-Data set 1 has been made to meet the specifications of the High Accurate Reference Network (HARN), GPS Zero order 1:10,000,000 were illustrated in Figure (3-6).

WGS84-Data Set 2: It has 8-common points with WGS84-data set 1 (O5, T2, D8, E7, A5, Y4, A6 and G29), 7-common points with WGS84-data set 3 (O5, T2, D8, E7, A5, B3 and A4), 4-common points with WGS84-data set 4 (Y4, Y14, Z95 and Z96), 8-common points with WGS84-data set 5 (E7, A6, A5, T2, A4, G8, G18 and G29), 1-common point (Y5) with WGS84-data set 9 and 6-common points with WGS84-data set 11 (Z64, Z65, Z66, Z69, Z70 and Z71).

WGS84-Data Set 3: It has 7-common points with WGS84-data set 1 (O5, B10, T2, D8, E7, A5 and X8), 7-common points with WGS84-data set 2 (O5, T2, D8, E7, A5, B3 and A4), 8-common points with WGS84-data set 5 (G25, T2, E7, O1, A4, A11, A5 and G22), 2-common points with WGS84-data set 6 (A5 and A3), 1-common point Helwan station (O1) with WGS84-data set 7 and also Helwan station (O1) which exists in WGS84-data set 12.

WGS84-Data Set 4: It has 4-common points with WGS84-data set 2 (Y4, Y14, Z95 and Z96).

WGS84-Data Set 5: It has 5-common points with WGS84-data set 1 (E7, A6, A5, T2 and G29), 8-common points with WGS84-data set 2 (E7, A6, A5, T2, A4, G8, G18 and G29), 8-common points with WGS84-data set 3 (G25, T2, E7, O1, A4, A11, A5 and

G22), 3-common points with WGS84-data set 5 (A4, A5 and A3) and 1-common point with WGS84-data set 7.

WGS84-Data Set 6: It has 1-common point with WGS84-data set 1 (A5), 2-common points with WGS84-data set 3 (A5 and A3) and 3-common points with WGS84-data set 5 (A4, A5 and A3).

WGS84-Data Set 7: It has 1-common point with WGS84-data set 3 and WGS84-data set 5; Helwan station (O1) which was linked with the IGS.

WGS84-Data Set 8: This data set has no reference stations or common points with the other data sets, Chapter (3). But it processed with the observations of some IGS stations using precise ephemeris. The coordinates of this data set are added to file "WGS84 all" as they are in transformation step, to obtain good coverage for the empty area of Sinai.

WGS84-Data Set 9: It has 1-common point (Y5) with WGS84-data set 2.

WGS84-Data Set 10: This data set has no information about the observations, reference stations, or processing but it covers an empty area of the Western Desert.

WGS84-Data Set 11: It has 6-common points with WGS84-data set 2 (Z64, Z65, Z66, Z69, Z70 and Z71).

WGS84-Data Set 12: It has 1-common point Helwan station (O1) which exists in WGS84-data set 3, WGS84-data set 5, and WGS84-data set 7.

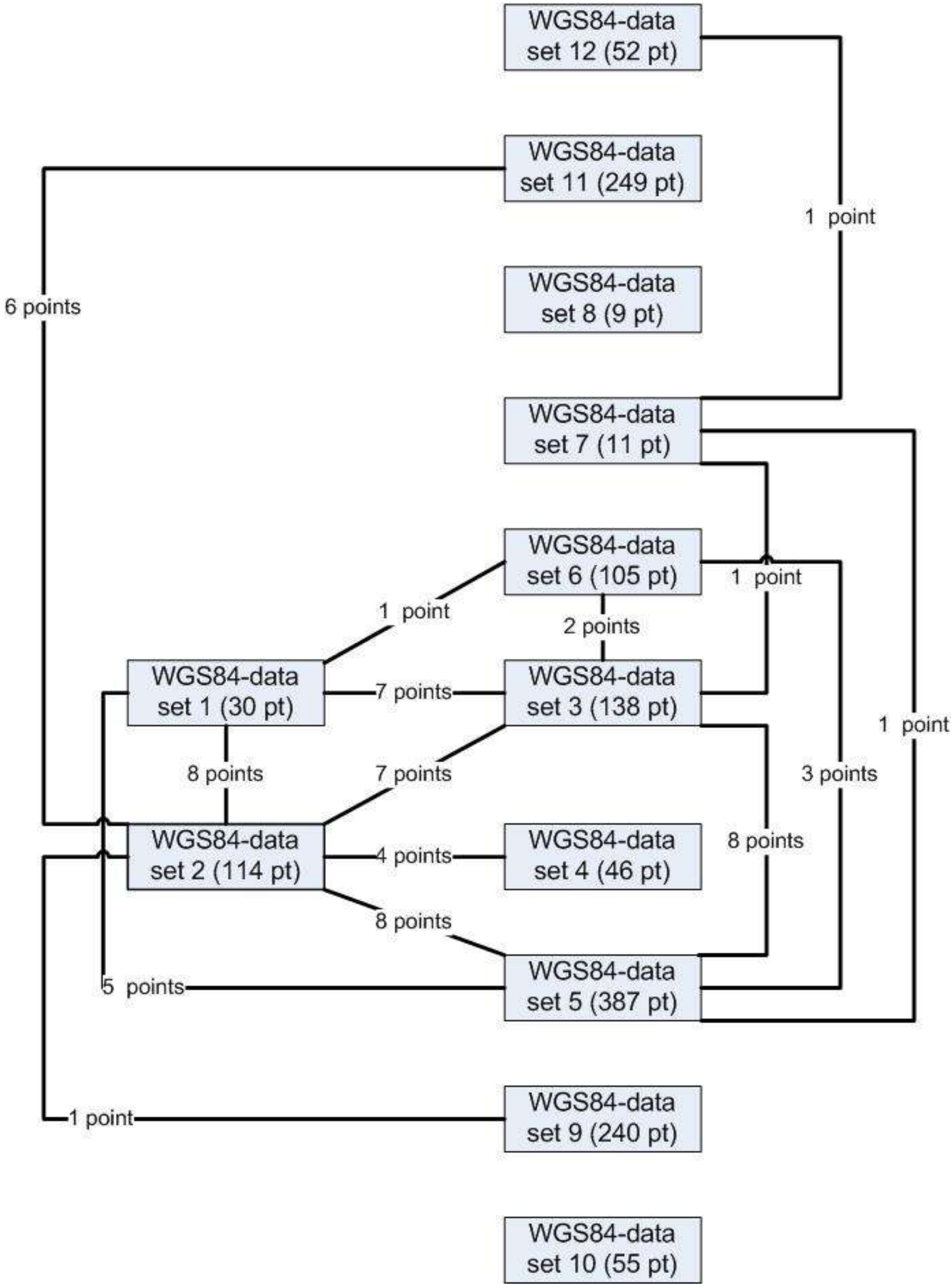

Figure (5-1): Common Points among WGS84-Data Sets

5.1.2 Common Points among WGS72-Data Sets and WGS 84-Data Sets

Recalling that the WGS72-data sets are found in two data sets, they are WGS72-data set 1 and WGS72-data set 2. Description of these data sets is found in chapter (3). The constitutes of the two data sets are scanned and examined to define the common points between those WGS72-data sets and the WGS84-data sets. The results were as follows:

WGS72-Data Set 1: It has 3-common points with WGS84-data set 1 (B19, B20 and A5) and 1-common point (A5) with WGS84-data set 3, WGS84-data set 5, and WGS84-data set 6.

WGS72-Data Set 2: It has 6-common points with WGS84-data set 1 (A5, B19, B20, T2, A6 and E7), 3-common points with WGS84-data set 3 (A5, T2 and E7), 4-common points with WGS84-data set 5 (A5, A6, T2 and E7) and 1-common point (O1) with WGS84-data set 7.

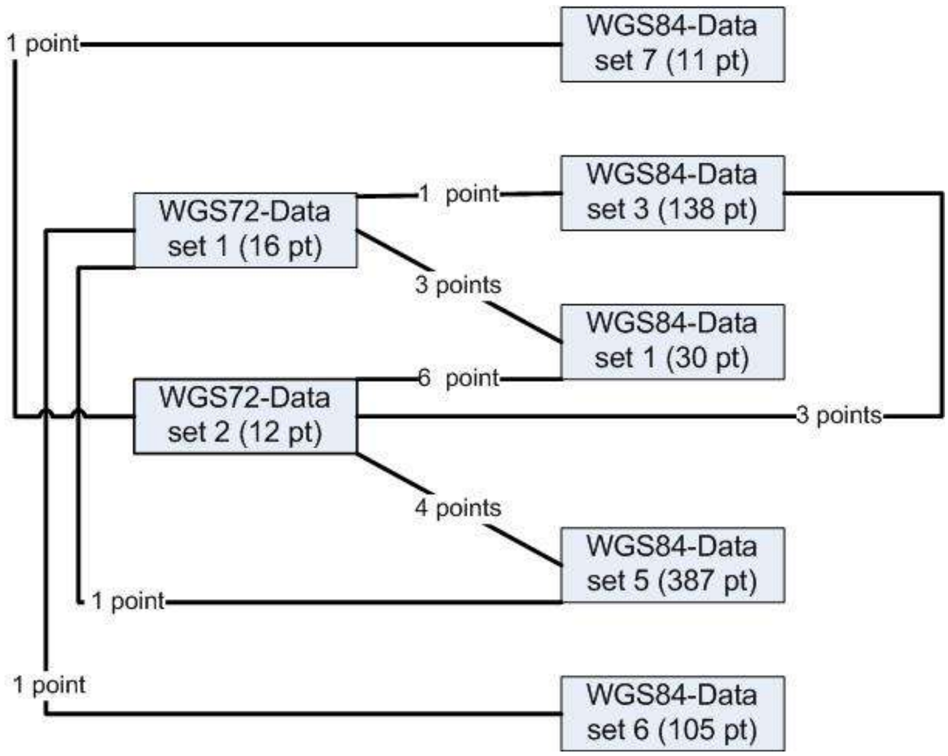

Figure (5-2): Common Points between WGS72-Data Sets and WGS84-Data Sets

5.1.3 Common Points among OED Data and WGS84 Data

The OED-data sets are existed in three data sets; they are OED-data set1, OED-data set2, and OED-data set3. The step of determining the common points between the OED-data sets and the WGS84-data sets was done after the unification process which explained with all details later. After the unification process, all the available coordinates on WGS84-data sets and WGS72-data sets transformed and collected in one file called "WGS84 all" and in the mean time the OED-data sets were collected in one file called "OED all". The constitutes of the two data files were scanned and examined to define the common points between those two data files. At the beginning, there were Sixty four common points found between two files; they were filtered because some of them were repeated in different data sets and others were determined.

5.2 Step (2): Data Filtering

Data filtering is a process made to reject the odd data in common points which are inconsistent with the concerned WGS84-data set1. The differences in (latitude, longitude, and height) were computed at every common point. Those differences were reviewed, studied and it was found that the maximum difference values were: (latitude=4.45 m, longitude=9.47 m, and height=11.89 m) and the minimum difference values were: (latitude=0.0168 m, longitude=0.0009 m, and height=0.18 m). Differences as follows:

Point ID	($\Delta\varphi$) m	($\Delta\lambda$) m	(Δh) m
O5	0.0375	0.0744	0.441
B10	0.045	0.0024	0.208
T2	0.0267	0.0036	0.900
D8	0.0561	0.0108	0.265
E7	0.0489	0.0147	0.284
A5	0.0468	0.0453	0.358
X8	0.0516	0.0141	0.180

Table (5-1): Differences between Common Points on WGS84-Data Set 1, WGS84-Data Set 3

The differences in table (5-1) were insignificant between common points, because the two data sets WGS84-Data Set 1 and WGS84-Data Set 3 observed with the same accuracy and based on the same IGS stations.

Point ID	(Δφ) m	(Δλ) m	(Δh) m
O5	0.0375	0.0744	0.441
T2	0.0267	0.0036	0.900
D8	0.0561	0.0108	0.265
E7	0.0489	0.0147	0.284
A5	0.0468	0.0453	0.358
B3	0.0168	0.0015	0.391
A4	0.0168	0.0009	0.217

Table (5-2): Differences between Common Points on WGS84-Data Set 2, WGS84-Data Set 3

The differences in table (5-2) were very small between common points, because the two data sets WGS84-Data Set 2 and WGS84-Data Set 3 were based on the same system on WGS84-Data Set 1.

Point ID	(Δφ) m	(Δλ) m	(Δh) m
E7	4.1352	8.1609	10.431
A6	4.4403	7.0686	11.808
A5	3.360	9.039	10.741
T2	3.7122	9.2775	10.491
G29	3.8067	7.7028	11.887

Table (5-3): Differences between Common Points on WGS84-Data Set 1, WGS84-Data Set 5

Point ID	(Δφ) m	(Δλ) m	(Δh) m
E7	4.1352	8.1609	10.431
A6	4.4403	7.0686	11.808
A5	3.360	9.039	10.741
T2	3.7122	9.2775	10.491
A4	2.9313	9.3264	10.409
G8	4.3155	7.3803	11.092
G18	3.6477	9.2007	9.535
G29	3.8067	7.7028	11.887

Table (5-4): Differences between Common Points on WGS84-Data Set 2, WGS84-Data Set 5

Point ID	(Δφ) m	(Δλ) m	(Δh) m
A5	0.9453	0.099	0.804

Table (5-5): Differences between one Common Point on WGS84-Data Set 1, WGS84-Data Set 6

Point ID	(Δφ) m	(Δλ) m	(Δh) m
A5	0.9	0.1443	0.448
A3	0.8955	0.1314	0.488

Table (5-6): Differences between Common Points on WGS84-Data Set 3, WGS84-Data Set 6

Point ID	(Δφ) m	(Δλ) m	(Δh) m
G25	3.510	9.4617	11.074
T2	3.687	9.2739	10.841
E7	4.0863	8.1756	10.765
O1	4.2624	7.9986	10.715
A4	2.9145	9.3255	10.626
A11	3.9207	6.9168	12.12
A5	3.3132	9.0858	11.099
G22	3.237	8.7813	11.1830

Table (5-7): Differences between Common Points on WGS84-Data Set 3, WGS84-Data Set 5

Point ID	(Δφ) m	(Δλ) m	(Δh) m
A5	2.4147	8.940	11.547
A4	2.4963	8.3604	10.763
A3	2.3439	8.6499	11.671

Table (5-8): Differences between Common Points on WGS84-Data Set 6, WGS84-Data Set 5

The differences in the above tables (5-3), (5-4), (5-5), (5-6), (5-7), and (5-8) shows very much higher difference values between common points relatively of the difference in tables (5-1) and (5-2), it might be because the low accuracy of observations or not tied to IGS stations or both reasons.

5.3 Step (3): Unifying the Different WGS84-Data Sets and WGS72-Data Sets into One WGS84 System

The available data on WGS84 are found in 12 data sets and those which on WGS72 are found in 2 data sets as mentioned before. This part of this thesis concerns with unifying all those data sets in one system and send them to one data file called "WGS84 all". WGS84-Data set 1 has the highest accuracy among all the other data sets. So it will be taken as reference system for the other data sets. The other data sets concerning the common points with WGS84-Data set 1 are classified into three groups;

- Data sets having common points with WGS84-data set 1, those are WGS84-data set 2, WGS84-data set 3, WGS84-data set 5, and WGS84-data set 6 and WGS72-data set 1 and WGS72-data set 2.
- Data sets having no common points with WGS84-data set 1 but they have common points with the above mentioned others data sets which have common points with WGS84-data set 1, those are WGS84-data set 4, WGS84-data set 7, WGS84-data set 9, WGS84-data set 11, and WGS84-data set 12.
- Data sets having no common points with any other data sets, those are WGS84-data set 8, WGS84-data set 10.

5.3.1 Unifying the Data Sets Having Direct Link with WGS84-Data Set 1

WGS84-data set 2, WGS84-data set 3, WGS84-data set 5, WGS84-data set 6, WGS72-data Set 1 and WGS72-data set 2 having direct link with WGS84-data set 1. Transformation computations trials have been done between those data sets and WGS84-data set 1 using the common points between them. Solutions are made by using the available common points and all possibilities of using them to obtain the best solution. The best solution is the one of smallest standard deviation of the computed parameters and minimum residuals at the used points and the check points. The best solution will be used in transforming the complete data set into WGS84-data set 1. Every time a data set is transformed based on the obtained best parameters and the transformed values are sent to file “WGS84 all”. The following solutions have been done as follows:

WGS84-Data Set 2: It has kept its values because it is based already on reference stations belong to WGS84-data set 1. This data set was sent without change to “WGS84 all”.

WGS84-Data Set 3: It has 5-solutions to be transformed into WGS84-data set 1 according to the number of common points. The five solutions were done by using 7, 6, 5, 4, 3 common points. No significant change of standard deviation for all solution because the common points are on the same base. The best solution was the one using 7-common points. The transformed complete data set values using 7-common points are sent to “WGS84 all” as shown in Table (5-9).

Solution Number		Solution Points				Check Points				St. Dev (7-Transformation Parameters)						
		(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	(dx) m	(dy) m	(dz) m	(Rx) sec	(Ry) sec	(Rz) sec	(K) ppm
Sol. (1) using 3 common pts.	**Mean**	0	0	0	0.004	0.002	-0.015	0.028	0.057	0.259	0.315	0.211	0.007	0.008	0.011	0.029
	St.dev	0.019	0.019	0.002	0.023	0.013	0.017	0.051	0.009							
Sol. (2) using 4 common pts.	**Mean**	0	0	0	0.028	-0.001	-0.015	0.002	0.009	0.246	0.3	0.199	0.007	0.007	0.01	0.027
	St.dev	0.016	0.016	0.024	0.008	0.016	0.021	0.056	0.054							
Sol. (3) using 5 common pts.	**Mean**	0	0	0	0.032	0.01	0.005	-0.009	0.056	0.244	0.299	0.195	0.007	0.007	0.01	0.027
	St.dev	0.014	0.022	0.025	0.005	0.012	0.002	0.077	0.010							
Sol. (4) using 6 common pts.	**Mean**	0	0	0	0.035	0.019	0.006	0.041	0.046	0.244	0.291	0.184	0.006	0.007	0.01	0.025
	St.dev	0.013	0.016	0.031	0.008											
Sol. (5) using 7 common pts.	**Mean**	0	0	0	0.035					0.232	0.269	0.173	0.005	0.007	0.01	0.023
	St.dev	0.013	0.015	0.032	0.009											

Table (5-9): Unifying Trials of the WGS84-Data Set 3 Having Direct Link with WGS84-Data Set 1

WGS84-Data Set 5: It has 3-solutions to be transformed into WGS84-data set 1 according to the number of common points. The three solutions were done using 5, 4, 3 common points. The best solution was the one using 5-common points. The transformed complete data set values using 5-common points were sent to "WGS84 all" as shown in Table (5-10).

Solution Number		Solution Points				Check Points				St. Dev (7-Transformation Parameters)						
		(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	(dx) m	(dy) m	(dz) m	(Rx) sec	(Ry) sec	(Rz) sec	(K) ppm
Sol. (1) using 3 common pts.	**Mean**	-0.001	0.002	0	0.055	0.351	0.364	-0.558	1.549	12.649	16.181	6.015	0.241	0.299	0.578	0.78
	St. dev	0.313	0.308	0.014	0.379	1.078	1.719	0.084	0.679							
Sol. (2) using 4 common pts.	**Mean**	-0.002	0.002	0	0.629	-0.429	-1.237	-0.045	1.31	16.216	19.539	7.493	0.239	0.396	0.723	0.739
	St. dev	0.354	0.661	0.2	0.274											
Sol. (3) using 5 common pts.	**Mean**	-0.003	0.003	0	0.729					12.555	14.793	6.753	0.199	0.323	0.547	0.735
	St. dev	0.362	0.745	0.247	0.288											

Table (5-10): Unifying Trials of the WGS84-Data Set 5 Having Direct Link with WGS84-Data Set 1

WGS84-Data set 6: It has only one-solution to be transformed into WGS84-data set 1 because it has only three common points. The transformed complete data set values using 3-common points are sent to "WGS84 all", as shown in Table (5-11).

Solution Number		Solution Points				St. Dev (7-Transformation Parameters)						
		(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	(dx) m	(dy) m	(dz) m	(Rx) sec	(Ry) sec	(Rz) sec	(K) ppm
Sol. (1) using 3 common pts.	**Mean**	0	0	0	0.011	4.928	9.813	9.007	0.282	0.229	0.282	0.716
	St. dev	0.069	0.050	0.001	0.072							

Table (5-11): Unifying the WGS84-Data Set 6 Having Direct Link with WGS84-Data Set1

WGS72-Data set 1: It has only one-solution to be transformed into WGS84-data set 1, because it has only three common points with WGS84-data set 1. The transformed complete data set values using 3-common points are sent to "WGS84 all", as shown in Table (5-12).

Solution Number		Solution Points				St. Dev (7-Transformation Parameters)						
		(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	(dx) m	(dy) m	(dz) m	(Rx) sec	(Ry) sec	(Rz) sec	(K) ppm
Sol. (1) using 3 common pts.	Mean	-0.001	-0.001	0	0.034	7.262	8.168	8.373	0.242	0.261	0.268	0.965
	St. dev	0.174	0.182	0.004	0.209							

Table (5-12): Unifying the WGS72-Data Set 1 Having Direct Link with WGS84-Data Set1

WGS72-Data set 2: It has 3-solutions to be transformed into WGS84-data set 1 according to the number of common points. The three solutions are done using 6, 5, 4 common points. The best solution was the one using 4-common points. The transformed complete data set values using 4-common points are sent to "WGS84 all", as shown in Table (5-13).

Solution Number		Solution Points				Check Points				St. Dev (7-Transformation Parameters)						
		($\Delta\Phi$) m	($\Delta\lambda$) m	(Δh) m	h-resultant m	($\Delta\Phi$) m	($\Delta\lambda$) m	(Δh) m	h-resultant m	(dx) m	(dy) m	(dz) m	(Rx) sec	(Ry) sec	(Rz) sec	(K) ppm
Sol. (1) using 4 common pts.	**Mean**	0.003	0.002	0	0.749	-1.068	-0.211	-1.923	2.349	11.904	12.638	8.789	0.24	0.35	0.467	1.06
	St. dev	0.481	0.37	0.661	0.24	1.329	0.221	0.234	0.776							
Sol. (2) using 5 common pts.	**Mean**	0.003	0.001	0	0.896	-1.956	-0.01	-2.043	2.829	12.355	12.825	9.492	0.255	0.371	0.474	1.14
	St. dev	0.425	0.338	0.93	0.394											
Sol. (3) using 6 common pts.	**Mean**	0.002	0	0	1.098					13.55	13.427	10.247	0.24	0.416	0.511	1.095
	St. dev	0.612	0.456	0.94	0.461											

Table (5-13): Unifying Trials of the WGS72-Data Set 2 Having Direct Link with WGS84-Data Set1

5.3.2 Unifying the Data Sets Having Indirect Link with WGS84-Data Set 1

WGS84-data set 4, WGS84-data set 7, WGS84-data set 9, WGS84-data set 11, and WGS84-data set 12 has no direct link with the reference WGS84-data set 1, those data sets were indirectly linked with WGS84-data set 1. Where the reference stations during the GPS observations have been taken **with the same coordinates values** from other data sets linked with WGS84-data set 1. (The coordinates of these data sets are added as they are to file "WGS84 all"). Their indirect links with WGS84-data set 1 were as follows:

WGS84-Data Set 4: It has 4-common points with WGS84-data set 2 (Y4, Y14, Z95 and Z96).

WGS84-Data Set 7: It has 1-common point with WGS84-data set 3 and WGS84-data set 5 which is Helwan station (O1). Helwan station (O1) is linked with the IGS.

WGS84-Data Set 9: It has 1-common point (Y5) with WGS84-data set 2.

WGS84-Data Set 11: Is has 6-common points with WGS84-data set 2 (Z64, Z65, Z66, Z69, Z70 and Z71).

WGS84-Data Set 12: Is has 1-common point Helwan station (O1) which linked with the IGS and exists in WGS84-data set 3, WGS84-data set 5, and WGS84-data set 7.

5.3.3 Describing and Adding the Data Sets Having No Link with WGS84-Data Set 1

Those data sets have no common points with any other data sets. Those are WGS84-data set 8 and WGS84-data set 10. (The coordinates of these data sets were added as they are to file “WGS84 all”).

WGS84-Data Set 8: This data set has no reference stations or common points with the other data sets, Chapter (3). But it processed with the observations of some IGS stations using precise ephemeris. The coordinates of this data set are added to file “WGS84 all” as they are without transformation as they do not have common points with other data sets that to obtain good coverage for the empty area of Sinai.

WGS84-Data Set 10: This data set has no information about the observations, reference stations, or processing but it covers an empty area in the Western Desert. Therefore, the coordinates of this data set are added to file “WGS84 all” as they are without transformation.

5.4 Step (4): Computing Transformation Parameters between WGS84 and OED all over Egypt

It has been explained in previous sections how the WGS84-data sets and WGS72-data sets were transformed and inserted in one file called "WGS84 all". It contains 1408 points. It is mentioned also that the three OED-data sets were collected in one file called "OED all". This file contains 219 points.

There are 40-common points found between two collected final files. Several transformations trials were made between the two collected files according to the number of common points. In every transformation trial, transformation parameters and their standard deviations as well as the residuals at the used common points were computed. Points with the highest residuals which cause big values for the standard deviations of the computed parameters were rejected and the computations are done once more. Five solutions using 40, 33, 27, 22 common points until using 18 common points give the best solution regarding the best coverage which could be obtained all over the Egyptian territory .

The transformation between WGS84 and the OED were handled here by using:

- **The Three Shift Parameters** and mainly once more using
- **The Seven Transformation Parameters**, the transformation by using the two main methods explained in the following two subsections.

5.4.1 Transformation Using 3-Shift Parameters

The following table shows the shift parameters at every solution and their standard deviations:

Solution Name	No. of Common Points	Mean			St. Dev		
		(dx) m	(dy) m	(dz) m	δ(dx)m	δ(dy) m	δ(dz) m
Sol (1). 40 Pts.	40	126.996	-109.24	13.857	2.9212	2.9212	2.9212
Sol (2). 33 Pts.	33	130.343	-111.857	14.147	1.6983	1.6983	1.6983
Sol (3). 27 Pts.	27	130.497	-111.428	13.943	2.067	2.067	2.067
Sol (4). 22 Pts.	22	131.414	-110.9	14.514	2.4847	2.4847	2.4847
Sol (5). 18 Pts.	18	131.513	-110.03	14.43	3.0258	3.0258	3.0258
Section 1	2	159.723	-92.102	32.846	26.0219	26.0219	26.0219
Section 2	4	124.854	-112.61	12.597	0.3193	0.3193	0.3193
Section 3	3	127.309	-112.21	14.236	0.5851	0.5851	0.5851
Section 4	3	131.982	-112.45	14.69	0.4355	0.4355	0.4355
Section 5	7	132.313	-116.06	16.058	0.4679	0.4679	0.4679
Section 6	2	127.471	-111.4	10.444	0.7702	0.7702	0.7702
Section 7	2	118.893	-114.4	6.066	2.0254	2.0254	2.0254
Section 8	2	118.893	-114.4	6.066	2.0254	2.0254	2.0254
Section 9	1	110.976	-117.48	2.939	0	0	0
Pts. over section 10	14	131.414	-110.9	14.514	2.4847	2.4847	2.4847

Table (5-14): Three Shift Parameters Trials between WGS84 and OED

1. Five solutions for computing the best three shift parameters between WGS84 and OED depending on number of common points were done, using 40, 33, 27, 22, and 18 as common points.

- Forty common points are used to compute the transformation parameters between WGS84 and the OED using 3 shift parameters method.
- The worst seven stations having the greatest values of residuals in solution 1 were excluded and solution 2 is made by using the remained 33 stations.
- The worst six stations having the greatest values of residuals in solution 2 were excluded and solution 3 is made by using the remained 27 stations.
- The worst five stations having the greatest values of residuals in solution 3 were excluded and solution 4 is made by using the remained 22 stations.
- The worst four stations having the greatest values of residuals in solution 4 were excluded and solution 5 is made by using the remained 18 stations.

2. To assure that the transformation method by the three shift parameter successively work at limited area in short distances only, another eleven solutions were done by using the common points in each section separately, and transformation were made by the three shift parameters method for each section separately to test all available data by this method by every possible ways.

- The results in the above table show that section two have the smallest three shift parameter with mean values dx=124.854m, dy=-112.61m, dz=12.597m and St. Dev values δ(dx)=0.3193m, δ(dy)= 0.3193m, δ(dz)= 0.3193m.

- Also, section two is in center position among the others sections, Figure (5-4).
- The three shift parameters which were computed from the coordinates of the 4-common points of section two are used to test the validity of using the shift parameters against the distance.
- Points around section 2 are divided into 5-groups according to their distances from point (L2) which belong to section 2 and have center position in this section. Then the shift parameters are done at those points.
- The following table shows the residuals at 5-groups:

Group Name	Point ID	(ΔΦ) m	(Δλ) m	(Δh) m	(distance) m	H- resultant	S- resultant	H-resultant/ distance	S-resultant/ distance
Group (1)	**B3**	0.54234	-0.07578	1.8923	102479.757	0.548	1.97	1 : 187140	1 : 52022
	A3	0.50472	-0.468	2.2638	111590.844	0.688	2.366	1 : 162124	1 : 47162
	E7	-2.47857	0.13275	-1.1342	183900.842	2.482	2.729	1 : 74090	1 : 67388
	O1	-2.56848	-0.71649	0.0894	192908.006	2.667	2.668	1 : 72344	1 : 72303
Group (2)	**F1**	-2.71356	-0.57102	0.2247	209520.353	2.773	2.782	1 : 75558	1 : 75311
	F6	-2.789	-0.655	0.163	219430.125	2.865	2.87	1 : 76582	1 : 76458
	N7	-2.907	0.372	-2.869	245554.737	2.931	4.101	1 : 83780	1 : 59874
	M3	0.230	-2.529	4.214	281046.632	2.539	4.92	1 : 110687	1 : 57124
Group (3)	**A6**	-3.639	-0.188	2.63	276955.669	3.644	4.494	1 : 76008	1 : 61631
	B4	-0.65	-3.464	5.684	335015.263	3.525	6.688	1 : 95051	1 : 50089
	A4	-0.626	-3.253	6.241	337892.471	3.312	7.065	1 : 102010	1 : 47824
	D8	-2.672	0.794	-5.125	345865.844	2.787	5.834	1 : 124077	1 : 59289

Group (4)	**P4**	-0.717	-5.225	7.26	496034.755	5.274	8.973	1 : 94054	1 : 55280
	X8	-2.052	1.863	-12.08	501634.964	2.772	12.394	1 : 180960	1 : 40473
	A5	-0.466	-5.403	7.228	501827.41	5.423	9.036	1 : 92535	1 : 55536
	E5	0.014	-6.68	8.088	564446.688	6.68	10.49	1 : 84503	1 : 53809
Group (5)	**L5**	1.654	-7.378	4.391	610885.795	7.561	8.743	1 : 80794	1 : 69868
	Z9	-0.597	1.763	-17.516	634782.119	1.861	17.615	1 : 341060	1 : 36037
	Q5	2.137	-7.775	4.96	658454.31	8.064	9.467	1 : 81656	1 : 69552
	R5	2.214	-7.97	4.707	677363.432	8.272	9.518	1 : 81884	1 : 71170

Table (5-15): The Residuals at the Points of those 5-Groups

- Concerning the horizontal-error component, the results in table (5-15), show that when distance is large the horizontal-error increase.
- Figure (5-3), shows the relation between the Distance in the horizontal axis and the Horizontal-Error in the vertical axis, from the place where the shift parameters were computed.

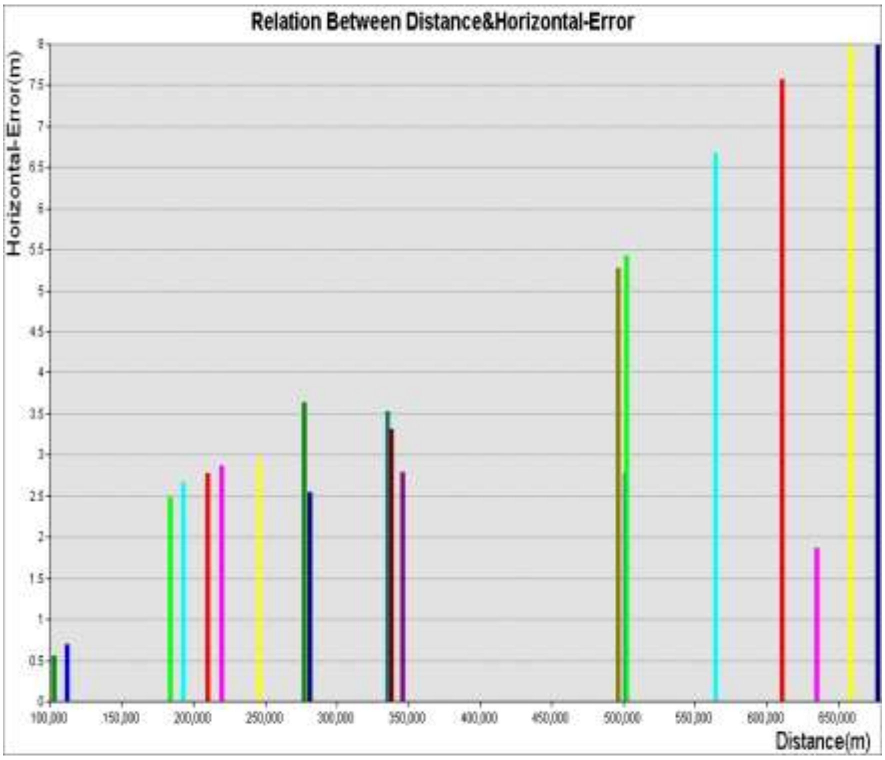

Figure (5-3): The Relation between the Distance and the Horizontal-Errors

- This assures that the transformation using the three shift parameter method work successively at limited distance.
- The above Figure (5-3) shows the relation between the Distance and the Horizontal-Errors component which be worth with the increasing in the distance.

5.4.2 Transformation Using 7-Transformation Parameters

The same five solutions (40, 33, 27, 22, 18) classification for computing the best three transformation parameters between WGS 84 and OED depending on number of common points were done but by the seven transformation parameters method.

In every transformation trial, seven transformation parameters and their standard deviations as well as the residuals at the used common points were computed. Points with the highest residuals which cause big values for the standard deviations of the computed parameters were rejected since the best coverage which could be obtained and the computations were done once more.

Therefore, the five solutions for computing the best seven transformation parameters between WGS84 and OED were done. The distribution of the used common points is shown in figures (5-4), (5-5), (5-6), (5-7), and (5-8). Residuals of latitudes, longitudes, ellipsoidal heights, horizontal resultants, and spatial resultants at the solution points are computed and their statistics are illustrated in tables (5-16), (5-17), (5-18), (5-19), (5-20), (5-21), (5-22), (5-23), (5-24), (5-25) and (5-26). Those statistics were computed once for the residuals and once more for their absolute values. The five solutions for computing the best seven transformation parameters between WGS84 and OED are discussed in separated subsections as follows.

Solution (1): Using 40-Common Points

Forty common points are used to compute the transformation parameters between WGS84 and the OED. The distributions of the used 40-common points are shown in Figure (5-4). The results are in Table (5-16).

	(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	s-resultant m	(ΔΦ)abs m	(Δλ)abs m	(Δh)abs m
Min	-3.538	-10.084	-4.925	0.419	0.469	0	0.014	0.034
Max	4.752	7.814	11.489	10.088	14.338	4.752	10.084	11.489
Range	8.29	17.898	16.414	9.669	13.869	4.752	10.07	11.455
Mean	0.013	-0.255	-0.123	2.579	4.002	1.277	1.933	2.756
St.Dev	1.713	3.127	3.87	2.441	3.368	1.124	2.452	2.684

Table (5-16): Statistic of Coordinates Residuals for Sol. No (1). Based on (40-C.P)

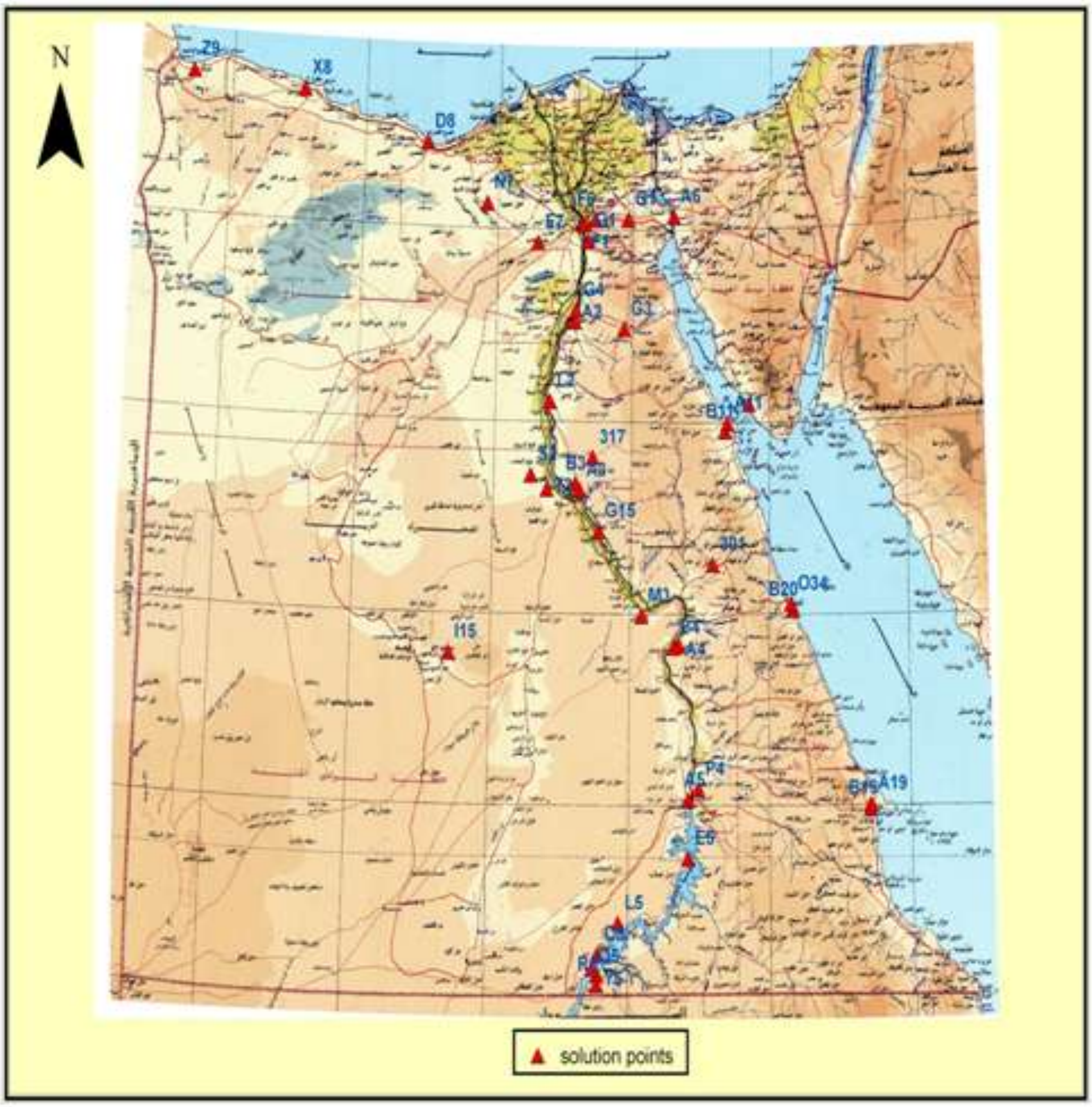

Figure (5-4): Distribution of Common Points Used in Sol. No (1). Based on (40-C.P)

Solution (2): Using 33-Common Points

The worst seven stations having the greatest values of residuals in solution (1) were excluded and solution (2) is made by using the remained 33-stations. The distribution of the used 33-common points is shown in Figure (5-5). Statistics of the results are in Table (5-17).

	(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	s-resultant m	$(\Delta\Phi)_{abs}$ m	$(\Delta\lambda)_{abs}$ m	$(\Delta h)_{abs}$ m
Min	-2.144	-2.681	-1.855	0.316	0.503	0.08	0.029	0.117
Max	2.163	2.27	5.777	2.996	5.791	2.163	2.681	5.777
Range	4.307	4.952	7.632	2.68	5.289	2.083	2.653	5.66
Mean	0.008	-0.009	0	1.48	1.909	0.743	1.147	0.954
St.Dev	0.992	1.391	1.442	0.813	1.114	0.644	0.76	1.068

Table (5-17): Statistic of Coordinates Residuals for Sol. No (2) Based on (33-C.P)

Figure (5-5): Distribution of Common Points Used in Sol. No (2) Based on (33-C.P)

Solution (3): Using 27-Common Points

The worst six stations having the greatest values of residuals in solution (2) were excluded and solution (3) was made by using the remained 27-stations. The distribution of the used 27-common points is shown in Figure (5-6). The excluded six points are used as check points. Statistics of the results are in Table (5-18).

	(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	s-resultant m	$(\Delta\Phi)_{abs}$ m	$(\Delta\lambda)_{abs}$ m	$(\Delta h)_{abs}$ m
Min	-1.663	-2.743	-1.436	0.314	0.528	0.007	0.033	0.199
Max	1.748	2.391	5.59	2.883	5.6	1.748	2.743	5.59
Range	3.412	5.134	7.025	2.568	5.072	1.741	2.71	5.391
Mean	0.009	-0.008	0	1.301	1.843	0.664	1.023	1.072
St.Dev	0.878	1.312	1.524	0.858	1.136	0.56	0.797	1.063

Table (5-18): Statistic of Coordinates Residuals for Sol. No (3) Based on (27-C.P)

The results at the check points and their statistics are tabulated in Table (5-19) and Table (5-20) respectively.

Point No.	Point ID	(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	s-resultant m	$(\Delta\Phi)_{abs}$ m	$(\Delta\lambda)_{abs}$ m	$(\Delta h)_{abs}$ m
1	**A3**	0.136	-0.933	-0.323	0.943	0.996	0.136	0.933	0.323
2	**A4**	0.404	-0.806	0.163	0.901	0.916	0.404	0.806	0.163
3	**R5**	0.121	0.478	-0.075	0.493	0.499	0.121	0.478	0.075
4	**S2**	0.588	-1.006	0.339	1.165	1.214	0.588	1.006	0.339
5	**Y5**	0.15	0.462	-0.006	0.485	0.485	0.15	0.462	0.006
6	**B11**	-1.425	1.765	-0.098	2.268	2.27	1.425	1.765	0.098

Table (5-19): Coordinates Residuals for Check Points for Sol. No (3) Based on (27-C.P)

	$(\Delta\Phi)$ m	$(\Delta\lambda)$ m	(Δh) m	h-resultant m	s-resultant m	$(\Delta\Phi)_{abs}$ m	$(\Delta\lambda)_{abs}$ m	$(\Delta h)_{abs}$ m
Min	-1.425	-1.006	-0.323	0.485	0.485	0.121	0.462	0.006
Max	0.588	1.765	0.339	2.268	2.27	1.425	1.765	0.339
Range	2.013	2.771	0.662	1.783	1.785	1.304	1.303	0.333
Mean	-0.004	-0.007	0	1.043	1.063	0.471	0.908	0.167
St.Dev	0.720	1.103	0.228	0.657	0.657	0.503	0.477	0.136

Table (5-20): Statistic of Coordinates Residuals for Check Points for Sol. No (3) Based on (27-C.P)

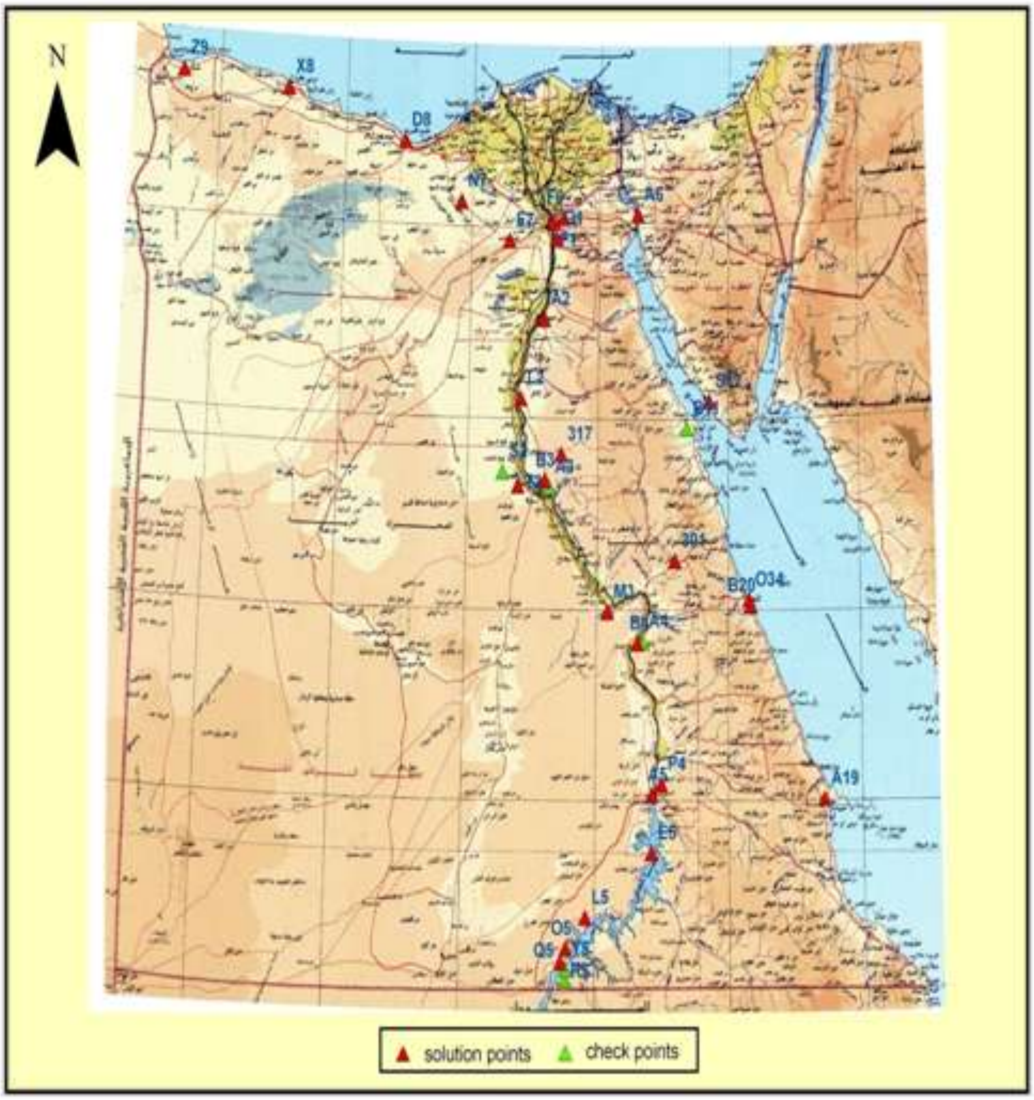

Figure (5-6): Distribution of Common Points and Check Points Used in Sol. No (3) Based on (27-C.P)

Solution (4): Using 22-Common Points

The worst five stations having the greatest values of residuals in solution (3) were excluded and solution (4) was made by using the remained 22 stations. The distribution of the used 22 common points is shown in Figure (5-7). The excluded five points were used as check points. Statistics of the results are in Table (5-21).

	(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	s-resultant m	$(\Delta\Phi)_{abs}$ m	$(\Delta\lambda)_{abs}$ m	$(\Delta h)_{abs}$ m
Min	-1.585	-2.019	-1.228	0.31	0.329	0.001	0.096	0.054
Max	1.609	2.29	2.327	2.567	3.421	1.609	2.29	2.327
Range	3.194	4.309	3.555	2.257	3.092	1.608	2.193	2.273
Mean	0.008	-0.007	0	1.241	1.475	0.62	0.973	0.611
St.Dev	0.837	1.238	0.865	0.786	0.837	0.546	0.734	0.597

Table (5-21): Statistic of Coordinates Residuals for Sol. No (4) Based on (22-C.P)

The results at the check points and their statistics are tabulated in Table (5-22) and Table (5-23) respectively.

Point No.	Point ID	(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	s-resultant m	$(\Delta\Phi)_{abs}$ m	$(\Delta\lambda)_{abs}$ m	$(\Delta h)_{abs}$ m
1	**E5**	-0.067	1.498	-0.58	1.499	1.608	0.067	1.498	0.58
2	**L2**	-1.497	-1.247	-2.086	1.948	2.854	1.497	1.247	2.086
3	**X8**	1.322	1.314	0.828	1.864	2.04	1.322	1.314	0.828
4	**301**	-0.332	0.368	3.515	0.495	3.549	0.332	0.368	3.515
5	**S12**	0.631	-1.988	-1.677	2.086	2.676	0.631	1.988	1.677

Table (5-22): Coordinates Residuals for Check Points for Sol. No (4) Based on (22-C.P)

	$(\Delta\Phi)$ m	$(\Delta\lambda)$ m	(Δh) m	h-resultant m	s-resultant m	$(\Delta\Phi)_{abs}$ m	$(\Delta\lambda)_{abs}$ m	$(\Delta h)_{abs}$ m
Min	-1.497	-1.988	-2.086	0.495	1.608	0.067	0.368	0.58
Max	1.322	1.498	3.515	2.086	3.549	1.497	1.988	3.515
Range	2.819	3.486	5.6	1.591	1.942	1.43	1.621	2.934
Mean	0.011	-0.011	0	1.579	2.545	0.77	1.283	1.737
St.Dev	1.061	1.550	2.266	0.643	0.751	0.62	0.588	1.167

Table (5-23): Statistic of Coordinates Residuals for Check Points for Sol. No (4) Based on (22-C.P)

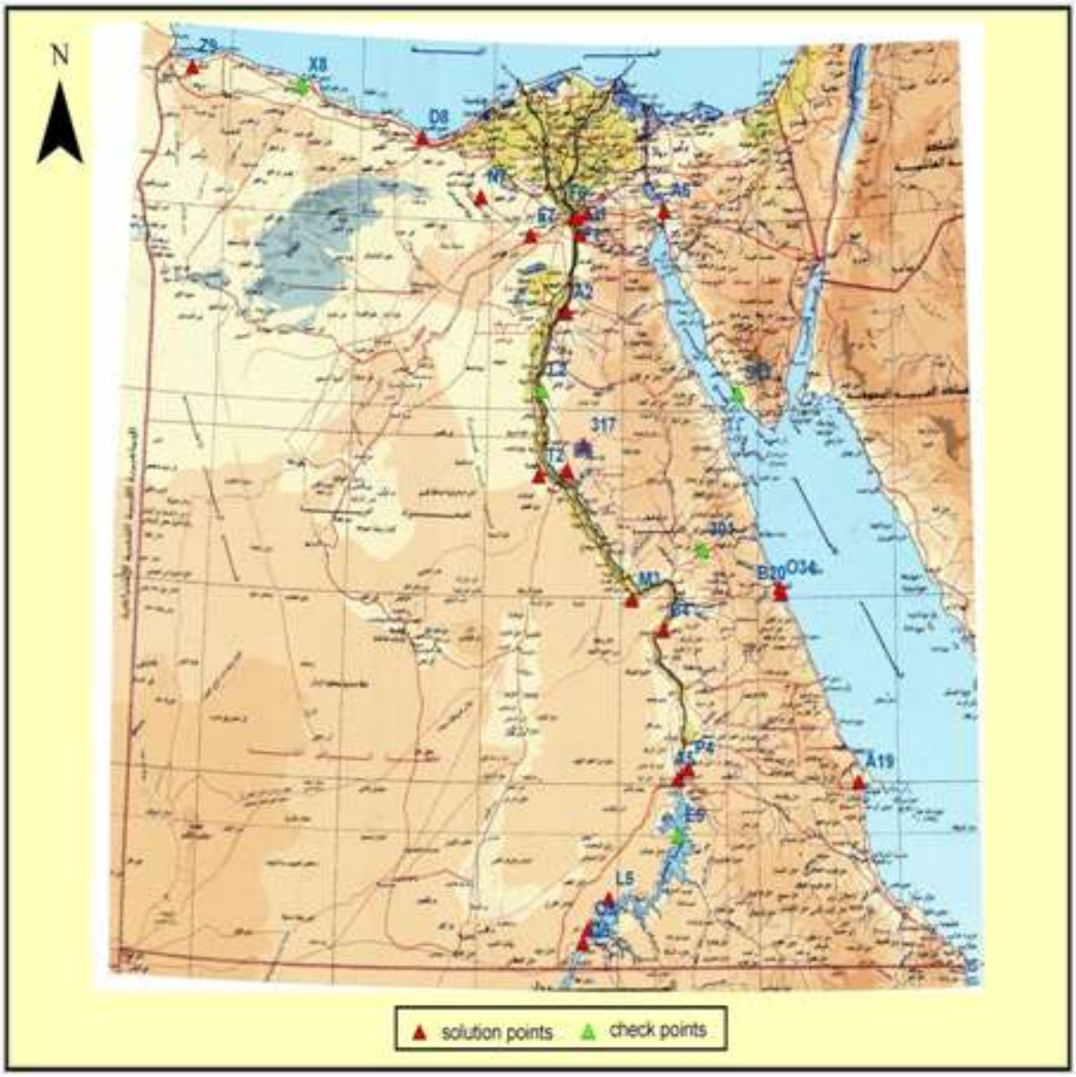

Figure (5-7): Distribution of Common Points and Check Points Used in Sol. No (4) Based on (22-C.P)

Solution (5): Using 18-Common Points

The worst four stations having the greatest values of residuals in solution (4) were excluded and solution (5) was made by using the remained 18 stations. The distribution of the used 18 common points is shown in Figure (5-8). The excluded four points were used as check points. Statistics of the results are in Table (5-24).

	(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	s-resultant m	$(\Delta\Phi)_{abs}$ m	$(\Delta\lambda)_{abs}$ m	$(\Delta h)_{abs}$ m
Min	-1.711	-1.803	-1.147	0.272	0.275	0.022	0.117	0.046
Max	1.099	2.576	2.252	2.607	2.992	1.711	2.576	2.252
Range	2.809	4.379	3.398	2.336	2.717	1.689	2.458	2.206
Mean	0.005	-0.002	0	1.093	1.322	0.656	0.782	0.603
St.Dev	0.861	1.075	0.842	0.794	0.869	0.534	0.712	0.569

Table (5-24): Statistic of Coordinates Residuals for Sol. No (5) Based on (18-C.P)

The results at the check points and their statistics are tabulated in Table (5-25) and Table (5-26) respectively.

Point No.	Point ID	(ΔΦ) m	(Δλ) m	(Δh) m	h-resultant m	s-resultant m	$(\Delta\Phi)_{abs}$ m	$(\Delta\lambda)_{abs}$ m	$(\Delta h)_{abs}$ m
1	**O5**	-0.03	0.37	0.32	0.371	0.49	0.03	0.37	0.32
2	**Q5**	0.048	0.457	-0.312	0.459	0.555	0.048	0.457	0.312
3	**317**	1.131	-0.11	0.051	1.136	1.137	1.131	0.11	0.051
4	**B20**	-1.136	-0.769	-0.059	1.372	1.373	1.136	0.769	0.059

Table (5-25): Coordinates Residuals for Check Points For Sol. No (5) Based on (18-C.P)

	$(\Delta\Phi)$ m	$(\Delta\lambda)$ m	(Δh) m	h-resultant m	s-resultant m	$(\Delta\Phi)_{abs}$ m	$(\Delta\lambda)_{abs}$ m	$(\Delta h)_{abs}$ m
Min	-1.136	-0.769	-0.312	0.371	0.49	0.03	0.11	0.051
Max	1.131	0.457	0.32	1.372	1.373	1.136	0.769	0.32
Range	2.267	1.226	0.632	1.001	0.883	1.106	0.66	0.269
Mean	0.003	-0.013	0	0.835	0.889	0.586	0.426	0.186
St.Dev	0.926	0.562	0.262	0.495	0.435	0.632	0.272	0.151

Table (5-26): Statistic of Coordinates Residuals for Check Points For Sol. No (5) Based on (18-C.P)

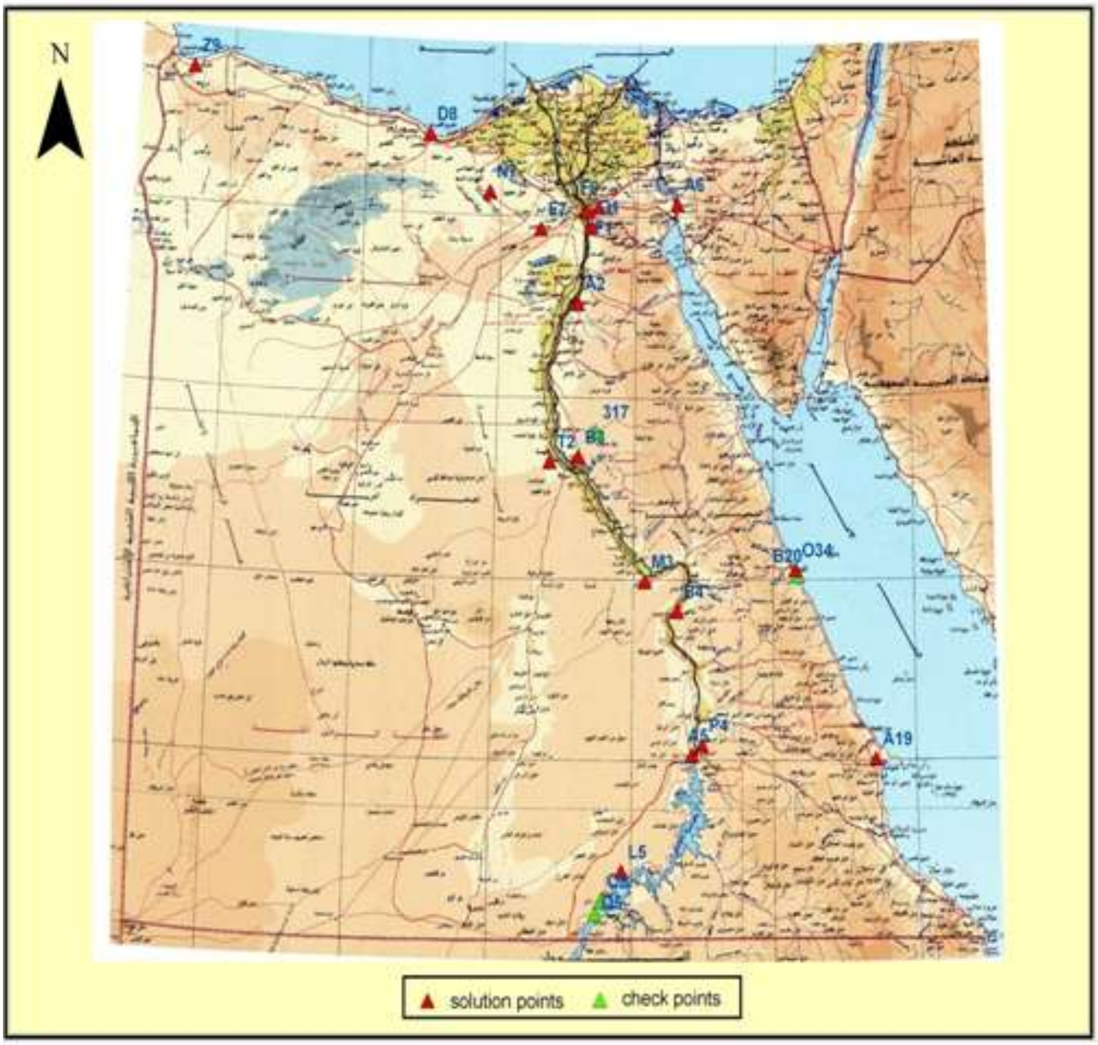

Figure (5-8): Distribution of Common Points and Check Points Used in Sol. No (5) Based on (18-C.P)

5.4.3 Comparing the Results of the Five Solutions

For the easiness of choosing the best transformation set among the above five solutions in seven transformation parameters method, the previous results were re-tabulated as follow:

- **Latitude Residuals Comparison**

(ΔΦ) m	SOL1	SOL2	SOL3	SOL4	SOL5
Min	-3.538	-2.14	-1.66	-1.59	-1.711
Max	4.752	2.163	1.75	1.609	1.099
Range	8.29	4.307	3.41	3.194	2.809
Mean	0.013	0.008	0.01	0.008	0.005
St. Dev	1.713	0.992	0.88	0.837	0.861

Table (5-27): Statistic of Latitude Coordinates Residuals as a Comparison between 5-Solutions

From the above table considering the greatest and smallest values of the standard deviation for latitude (max=1.713 and min= 0.837) so solution no (4) is the best one.

- **Longitude Residuals Comparison**

(Δλ) m	SOL1	SOL2	SOL3	SOL4	SOL5
Min	-10.08	-2.68	-2.74	-2.02	-1.803
Max	7.814	2.27	2.39	2.29	2.576
Range	17.9	4.952	5.13	4.309	4.379
Mean	-0.255	-0.01	-0.01	-0.01	-0.002
St. Dev	3.127	1.391	1.31	1.238	1.075

Table (5-28): Statistic of Longitude Coordinates Residuals as a Comparison between 5-Solutions

From the above table considering the greatest and smallest values of the standard deviation for longitude (max=3.127 and min= 1.075) so solution no (5) is the best one.

- **Ellipsoidal Height Residuals Comparison**

(Δh) m	SOL1	SOL2	SOL3	SOL4	SOL5
Min	-4.925	-1.86	-1.44	-1.23	-1.147
Max	11.49	5.777	5.59	2.327	2.252
Range	16.41	7.632	7.03	3.555	3.398
Mean	-0.123	0	0	0	0
St. Dev	3.87	1.442	1.52	0.865	0.842

Table (5-29): Statistic of Height Coordinates Residuals as a Comparison between 5-Solutions

From the above table considering the greatest and smallest values of the standard deviation for ellipsoidal height (max=3.87 and min= 0.842) so solution no (5) is the best one.

- **Horizontal-Resultant Residuals Comparison**

h-resultant(m)	*SOL1*	*SOL2*	*SOL3*	*SOL4*	*SOL5*
Min	*0.419*	*0.316*	*0.31*	*0.31*	*0.272*
Max	10.09	2.996	2.88	2.567	2.607
Range	9.669	2.68	2.57	2.257	2.336
Mean	2.579	1.48	1.3	1.241	1.093
St. Dev	2.441	0.813	0.86	0.786	0.794

Table (5-30): Statistic of HI-Resultant as a Comparison between 5 -Solutions

The horizontal resultant residual is the resultant of latitude and longitude residuals. From the above table considering the greatest and smallest values of the standard deviation for the horizontal-resultant (max=2.441 and min= 0.786) so solution no (4) is the best one.

- **Spatial-Resultant Residuals Comparison**

  Spatial resultant residuals are the resultants of latitude, longitude, and ellipsoidal heights residuals.

s-resultant (m)	SOL1	SOL2	SOL3	SOL4	SOL5
Min	0.469	0.503	0.51	0.329	0.275
Max	14.34	5.791	5.6	3.421	2.992
Range	13.87	5.289	5.07	3.092	2.717
Mean	4.002	1.909	1.84	1.475	1.322
St. Dev	3.368	1.114	1.14	0.837	0.869

Table (5-31): Statistic of S-Resultant as a Comparison between 5-Solutions

From the above table considering the greatest and smallest values of the standard deviation for spatial resultant (max=3.368 and min= 0.837) so solution no (4) is the best one.

- **Transformation Parameters Comparison**

  For choosing the best seven transformation parameters set, standard deviations for the seven transformation parameters are computed and collected together to determined which is the best set among the five solutions.

St.Dev	SOL1	SOL2	SOL3	SOL4	SOL5	Dim
Shift dx	0.463	0.245	0.22	0.223	0.213	**m**
Shift dy	0.463	0.245	0.22	0.223	0.213	**m**
Shift dz	0.463	0.245	0.22	0.223	0.213	**m**
Rotation about x	0.292	0.144	0.14	0.133	0.127	**sec**
Rotation about y	0.425	0.246	0.23	0.202	0.198	**sec**
Rotation about z	0.556	0.287	0.28	0.267	0.255	**sec**
Scale factor	1.293	0.652	0.61	0.609	0.567	**ppm**

Table (5-32): Statistic of ST.DV of Seven Transformation Parameters as a Comparison between 5-Solutions

- From the above table considering the greatest and smallest values of the standard deviation for seven transformation parameters (max values for Shift dx=0.463 m, Shift dy= 0.463 m, Shift dz=0.463 m, Rotation about x=0.292′, Rotation about y=0.425′, Rotation about z=0.556′ and Scale factor=1.293 ppm) and (min values for Shift dx=0.213 m, Shift dy=0.213 m, Shift dz=0.213 m, Rotation about x=0.127′, Rotation about y=0.198′, Rotation about z=0.255′ and Scale factor=0.567 ppm) so solution no (5) is the best one.
- The above figures and tables assure that the transformation method using the seven transformation parameters work successively at large area.
- Set of the seven transformation parameters resulted from solution (5) will be used in the next two sections in transforming collected data file which called "WGS84 all" which includes 1408 points into the OED as a reference datum.
- Those parameters will be also used in transforming the 219 collected data file which called "OED all" into WGS84 as a reference datum.

5.5 Step (5): Transforming all WGS84 Coordinates into OED

In the previous step, the best seven transformation parameters set using the available common points all over the Egyptian territory were computed. The transformation parameters set resulted from using 18 common points was the best one. Using the best set of parameters, all WGS84 coordinates which are collected in file "WGS84 all", 1408 stations, were transformed into the Old Egyptian Datum (OED). Therefore, 1408 transformed stations were added to the OED to cover new empty areas in Egypt. Those stations could be added to the 219 OED stations, to be totally 1627 stations having coordinates on the Old Egyptian Datum (OED) covers most area in Egypt.

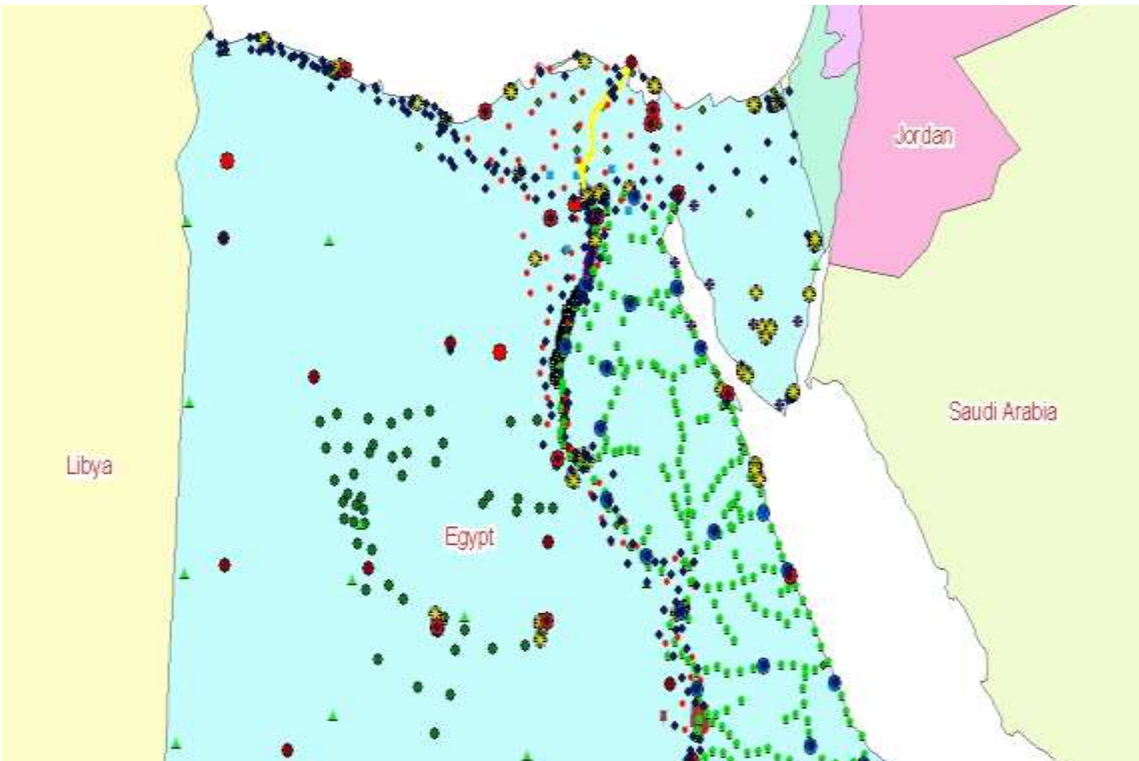

Figure (5-9): Distribution of 1627 OED Points

5.6 Step (6): Transforming all OED Coordinates into WGS84

Using the best set of parameters as mentioned before, all OED coordinates which are collected in file "OED all", 219 stations, were transformed into WGS84. So, 219 transformed stations, first order network (I) mainly, are added to file "WGS84 all" and could be used as GPS reference stations covers empty places of GPS reference stations. So, 1627 stations defined on WGS84 are now available all over the Egyptian territory.

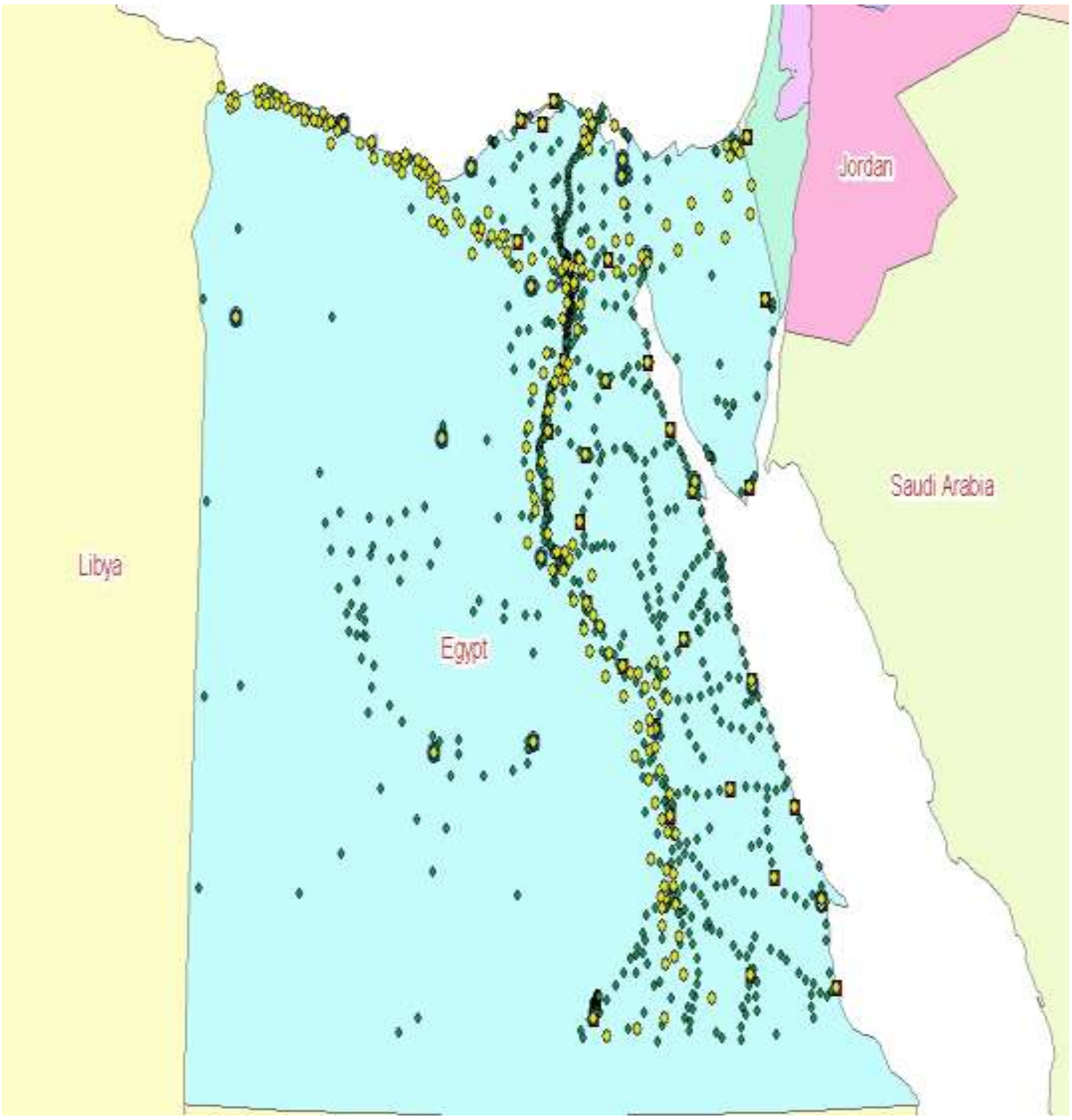

Figure (5-10): Distribution of 1627 WGS84 Points