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Predicted Geodetic Reference System for Baghdad City with Aided International Terrestrial Reference Frame (ITRF08)

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Abstract

Historically, the mean Earth ellipsoid is obtained by fitting an ellipsoid of revolution to the geoid. Such an ellipsoid, however, does not necessarily best fit the physical surface of the earth due to the existence of topography outside the geoid. When the distance between geoid and ellipsoid is as low as possible, GPS measurements are accurate because it depends on the measurement on the ellipsoid surface. The ellipsoid is defined as the shape produced by rotating an ellipse about one of its axes, which is a more correct definition mathematically (Deng, X., 2013). An ellipsoid satisfying the condition that the deviations between the geoid and ellipsoid (in a local sense) are minimized. In this paper, presented a purely geometrically defined earth ellipsoid that best fits the physical surface of the Earth so that the resulting geoid undulation (N) attains minimum in Baghdad city. Using orthometric height (H) and ellipsoid height (h), the size, shape, position of such an Earth ellipsoid have been from observation GPS, methods DGPS with (ITRF).

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The establishment of a new geodetic reference frame of Baghdad city based on ITRF system which is compatible with space positioning techniques. One of the fundamental objectives of geodesy is to accurately define positions of points on the surface of the Earth. It is important and necessary to establish an accurate geodetic reference frame for measurements and computations of points on the surface of the earth. Recently, this has seen the advancement of technology of using GPS for determination of a three-dimensional geocentric reference system.

Key words: Earth ellipsoid; Geoid; Best-fitting; Orthometric Height; Ellipsoid height; Geoid Undulation; ITRF; CORS.

1. Introduction

One of the most fundamental tasks of geodesy is to determine the figure of the earth. The shape of the earth is approximated by the mean earth ellipsoid, an ellipsoid of revolution that best fits the global geoid. The geodetic data from State Commission of Survey by the (POLESERVICE) company in 1979. (POLESERVICE) company in Iraq worked a vertical reference system and horizontal reference system in the 1970s. The horizontal reference was based on ellipsoid clark1880. In Iraq, the company worked to bring the elliptical closer to Geoid, establish land control networks. Also reducing N values as low as possible, for accurate coordinates and producing maps. The vertical reference was based on sea level, which was considered the point of Faw zero, in the reference system of Iraq. The production of maps in Iraq was based on Reference system Clarke 1880. Distance N between the geoid and best fitting ellipsoid is called geoid undulation and can be computed from N=h-H. The ellipsoid is as close as possible to the shape of the geoid within the boundaries of the city. It changes the re position of the global ellipsoid WGS84 to fit the city of Baghdad to be a local geodetic reference system for map production and accurate survey works.

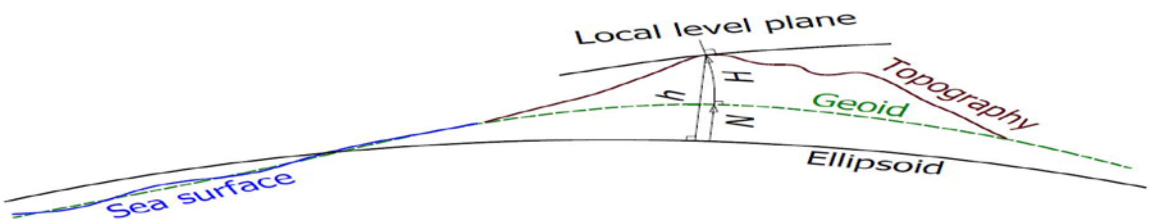

Figure 1: Surfaces, Orthometric Heights, Normal Heights and N values [7].

Ellipsoidal heights (h) are the heights of the location, normal (at right angles) to the reference ellipsoid [5].

Orthometric heights (H) are heights for a given position on the earth's surface above the geoid or MSL following a curved plumb line (Figure 1) [5].

The height difference between the geoid and a specific ellipsoid is known as the geoidal height or the geoid-ellipsoid separation (N). The 'N' value is the ellipsoid height minus the orthometric height (Equations 1 and 2) [5].

$$N = h - H \tag{1}$$

$$H = h - N \tag{2}$$

GNSS natively uses ellipsoidal heights for data processing. These are converted to MSL elevations using an orthometric height from (POLESERVICE) report which computes N values for any given location in Baghdad.

2. Best fits ellipsoid and geoid

The spheroid is a very good approximation to the geoid, but there are significant differences. If a spheroid is formed which best fits the geoid. The height of the geoid above the spheroid is known as the geoid-spheroid separation, or often just the separation, and is usually given the symbol N. This may be a positive or a negative quantity. Every country or region that chooses an elliptical is always suitable for it, where the geoid is fits to the ellipsoid. As shown in Figure 2 [1].

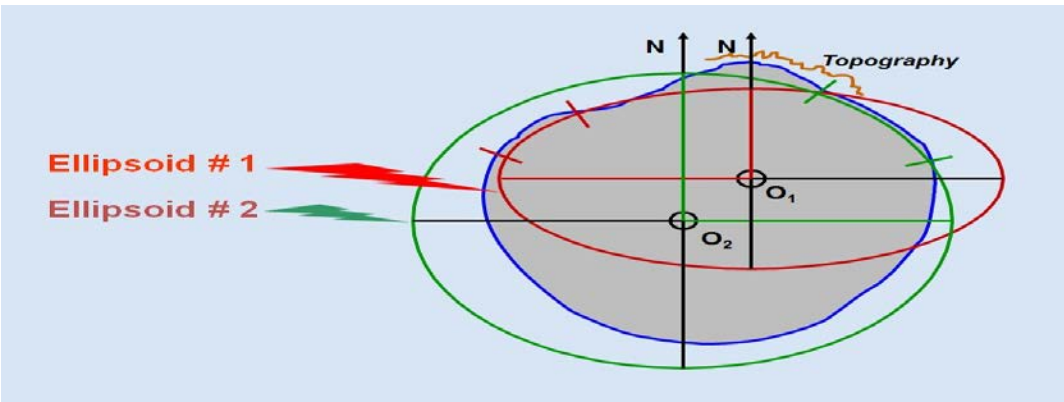

Figure 2: variable two ellipsoid with two zone [1].

3. Experimental Work And Data Collection

The horizontal and vertical measurements for the selected points of the local geodetic network have been taken from the State Commission of Survey and Mayoralty of Baghdad which were previously determined by POLESERVICE company.

These selected points have been observed utilizing GPS (Leica type GR15) by DGPS methods over various time variable as shown table (1).

To conduct a local correction, CORS stations near to the observed points were considered and a GPS LEICA type GR15 was utilized based on LEICA Geo Office program. The calculation of the new three-dimensional coordinates system had been carried out using the WGS84 ellipsoid system and based on Baghdad CORS station. Which adopted on observe the points Baghdad (ISBA) of the CORS stations and may be post-processing the CORS stations as shown figure (4). This can also assure accuracy in computing the ellipsoid height and orthometric height from the difference between the geoid and ellipsoid; this difference is called the geoid undulation (N) (Banerjee, P., G. R 1999). as shown table (2).

These programs can be also used along with Baghdad CORS station to correct the observed points to determine the local geodetic coordinates based on Ellipsoid WGS84. The value of the geoid undulation at all observed points have been computed. In addition, the observed vertical points are with WGS84 coordinates(ϕ, λ,h) and ITRF 2008. Corrected coordinates were based on CORS Baghdad (ISBA); include computed geographic coordinates as shown table (3). The seven unknown parameters (Translation, Rotation, Scale) were then computed between the WGS84 system and the new geodetic system of Baghdad as shown table (4), table 5). Furthermore, the next calculation step included determining the value of the geoid undulation for all the observed points between orthomatric height (from POLESERVICE report) and ellipsoid height (from GPS based on WGS84) as shown in Tables (2). And then developing acomparison between orthomatric height and ellipsoid WGS84 height with local geodetic (new geoid undulation)as shown Table (3) .

4. Research methodology

This study can be conducted through the following steps :

1- Investigate and specify points for this study.

2- Collect data for the geodetic coordinates of the studied area (Baghdad), provided by the ellipsoid (Clarke 1880) of Horizontal and Vertical National Geodetic Network and Iraqi Network, Geospatial Reference System (IGRS).

3- Observed the specified points and the nearest one to the CORS stations by of points by DGPS static observation with post-processing the data by (LEICA Geo Office) software program version 8.1 to get the accurate geodetic coordinates with(WGS84) reference.

4- Verity the value N (geoid undulation or geoid separation) for all points between (POLESERVICE) and WGS84.

5- Calculate the rate of geoid undulation and subtract the average value from all points.

6- Verity all points observation with new geoid undulation (N)) between Geoid (POLESERVICE) and new geodetic reference for Baghdad city.

Table 1: Geodetic Coordinates for observed Horizontal and Vertical points National Geodetic Network (Ellipsoid WGS84 /ITRF2008).

No.	Name of point	Latitude(ϕ)	Longitude(λ)	Ellipsoid Height **(m)**
1	20108	33º 14' 8.9474"	44º 29' 23.0654"	55.233
2	20081	33º 22' 23.7309"	44º 31' 21.9874"	58.933
3	20073	33º 24' 14.7503"	44º 17' 52.3269"	39.247
4	20080	33º 20' 14.0360"	44º 23' 31.1269"	84.838
5	527003	33º 21' 53.9122"	44º 15' 0.7972	32.295
6	525504	33º 18' 19.7270"	44º 16' 35.0450"	34.141
7	517301	33º 25' 40.9742"	44º 25' 1.83023"	38.451
8	523002	33º 17' 35.1032"	44º 27' 15.9473"	32.333
9	524001	33° 13' 36.02694"	44° 22' 27.86923"	32.180
10	511701	33º 21' 37.9443"	44º 21' 18.3075"	35.637
11	32/2	33° 22' 39.4728"	44° 19' 05.8638"	36.797

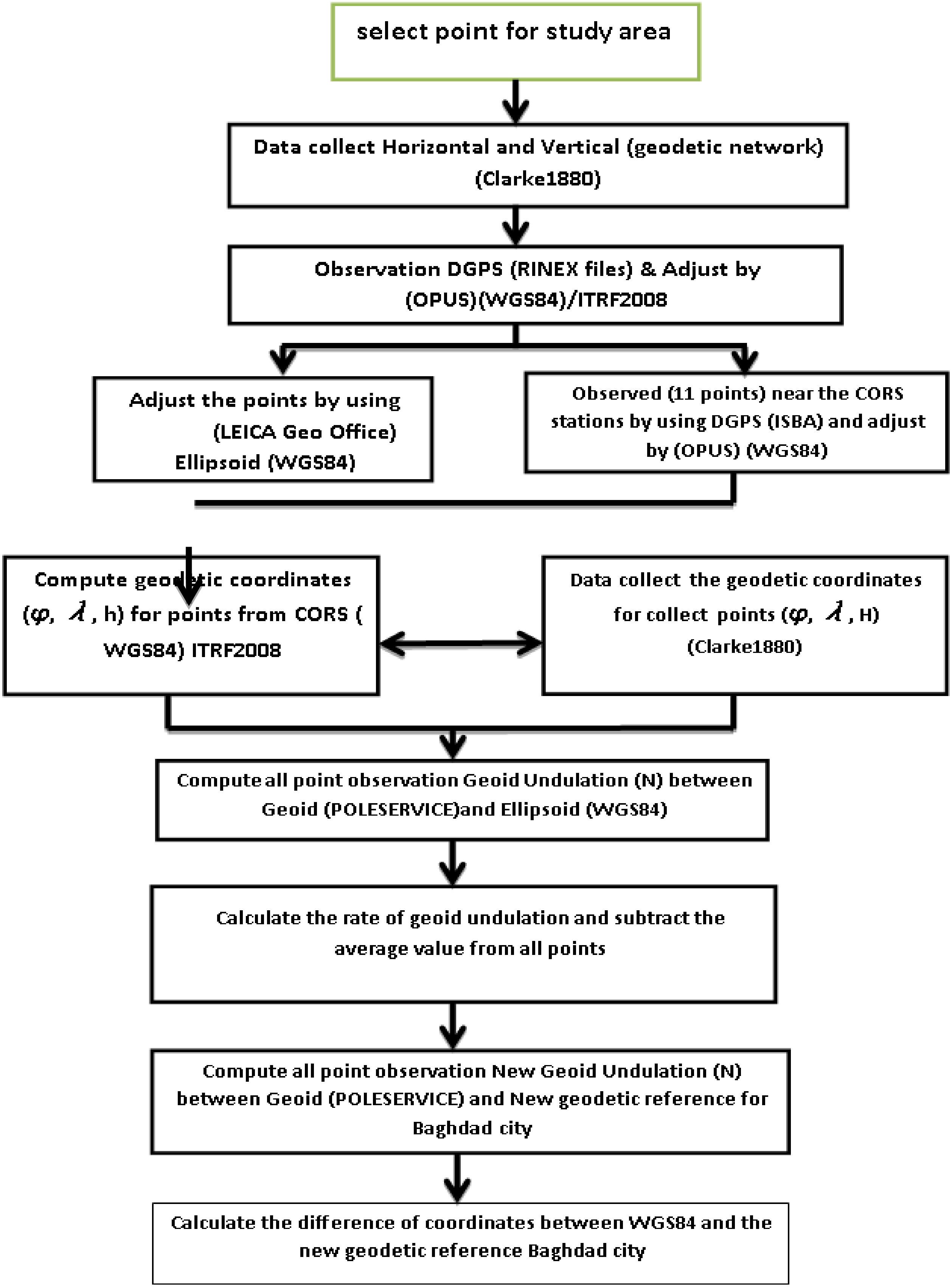

Figure 3: Schematic diagram of the methodology.

Table 2: The Geoid undulation between orthometric height (POLESREVICE) and Ellipsoid height

(WGS84/ITRF2008)

No.	Name of point	Ellipsoid Height (m)	Orthometric Height (m)	Geoid Undulation (m)
1	20108	55.233	57.20	-1.967
2	20081	58.933	60.70	-1.767
3	20073	39.241	40.20	-0.959
4	20080	84.838	85.90	-1.062
5	527003	32.295	33.314	-1.019
6	525504	34.141	35.358	-1.217
7	517301	38.451	40.077	-1.626
8	523002	32.333	33.966	-1.633
9	524001	30.389	32.180	-1.791
10	511701	35.637	36.554	-0.917
11	32/2	35.916	36.797	-0.881
			Average	1.349

Table 3: The Geoid undulation between Orthometric height (POLESREVICE) and New Ellipsoid height (Baghdad city)

No.	Name of point	New Ellipsoid Height (m)	Orthometric ELEV. (m)	New Geoid Undulation (m)
1	20108	55.851	57.2	-0.618
2	20081	59.351	60.7	-0.418
3	20073	38.851	40.2	0.39
4	20080	84.551	85.9	0.287
5	527003	31.965	33.314	0.33
6	525504	34.009	35.358	0.132
7	517301	38.728	40.077	-0.277
8	523002	32.617	33.966	-0.284
9	524001	30.831	32.18	-0.442
10	511701	35.205	36.554	0.432
11	32/2	35.448	36.797	0.468

Table 4: Geographic Coordinates for selected Horizontal and Vertical points Local Observed by (New Geodetic

Reference system).

N	Description	Latitude (ϕ)	Longitude (λ)	New Geoid Undulation(m)	Δ Latitude	Δ Longitude
1	20108	33º 14' 08.9474"N	44º 29' 23.06540"E	-0.618	0º 0' 0.02"N	0º 0' 0.01"E
2	20081	33º 22' 23.7309"N	44º 31' 21.98741"E	-0.418	0º 0' 0.02"N	0º 0' 0.01"E
3	20073	33º 24' 14.7503"N	44º 17' 52.32691"E	0.39	0º 0' 0.01"N	0º 0' 0.01"E
4	20080	33º 20' 14.0360"N	44º 23' 31.12691"E	0.287	0º 0' 0.01"N	0º 0' 0.01"E
5	527003	33° 21' 53.89554" N	44° 15' 00.78797"E	0.33	0º 0' 0.01"N	0º 0' 0.01"E
6	525504	33° 18' 19.71011" N	44° 16' 35.03610"E	0.132	0º 0' 0.01"N	0º 0' 0.01"E
7	517301	33° 25' 40.93261" N	44° 25' 01.82503" E	-0.277	0º 0' 0.01"N	0º 0' 0.01"E
8	523002	33° 17' 35.08228" N	44° 27' 15.94200" E	-0.284	0º 0' 0.02"N	0º 0' 0.01"E
9	524001	33° 13' 36.02694" N	44° 22' 27.86923" E	-0.442	0º 0' 0.01"N	0º 0' 0.01"E
10	511701	33° 21' 37.93224" N	44° 21' 18.29184" E	0.432	0º 0' 0.01"N	0º 0' 0.02"E
11	32/2	33° 22' 39.47279" N	44° 19' 05.86379" E	0.468	0º 0' 0.01"N	0º 0' 0.01"E

Figure 5: Location of the study area (Baghdad city) [9].

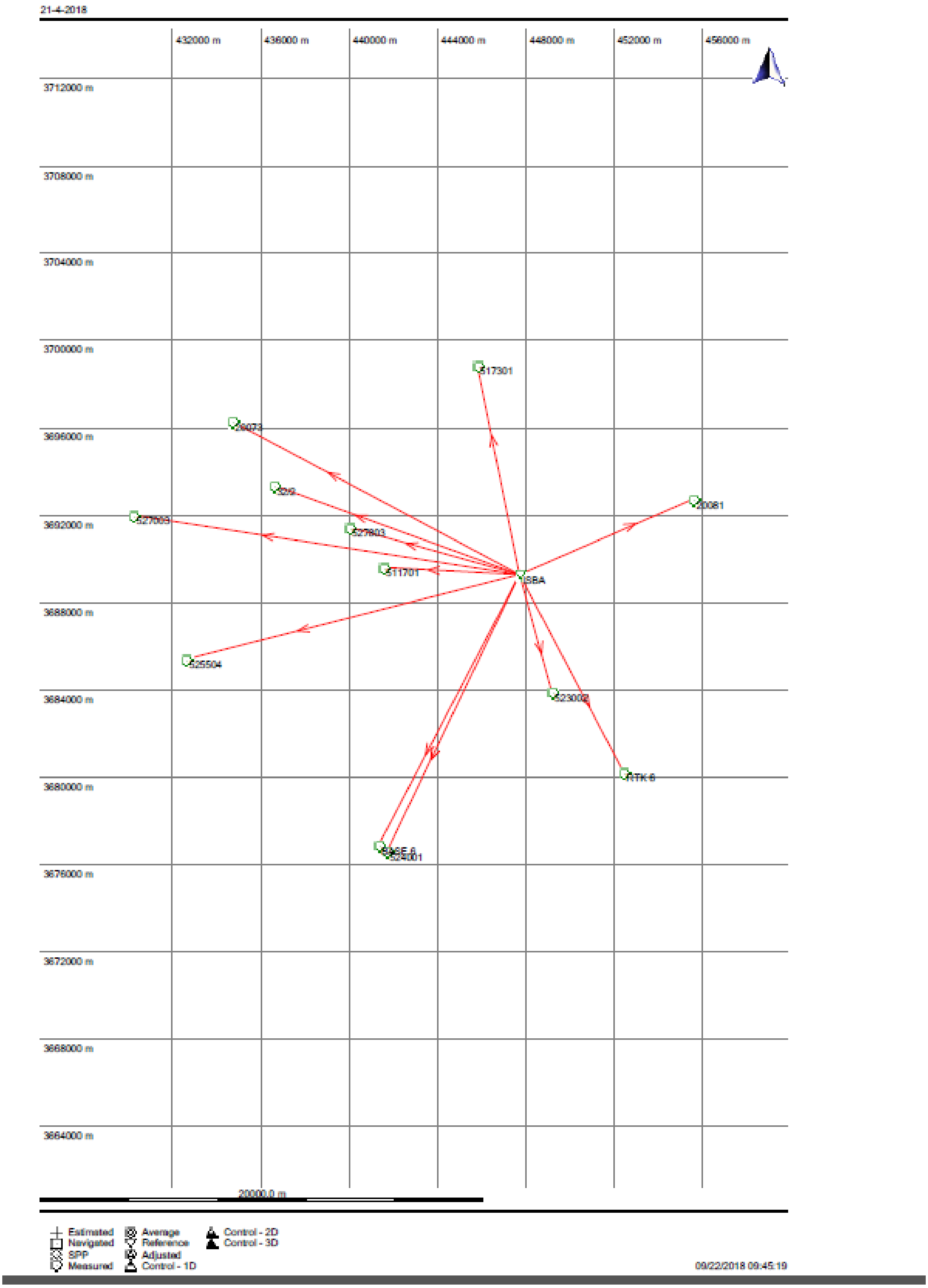

Figure 4: point correction with CORS Baghdad.

Table 5: Geographic coordinate WGS84 and coordinate new geodetic reference system and difference between two systems.

		WGS84/ITRF2008			New geodetic reference system Baghdad city				
N	Description	Latitude	Longitude	h	Latitude	Longitude	h	Δ Latitude	Δ Longitude
1	20108	33° 14' 8.9674"N	44° 29' 23.07154"E	-1.967	33° 14' 08.9474"N	44° 29' 23.06540"E	-0.618	0° 0' 0.02"N	0° 0' 0.01"E
2	20081	33° 22' 23.71115"N	44° 31' 21.99846"E	-1.767	33° 22' 23.7309"N	44° 31' 21.98741"E	-0.418	0° 0' 0.02"N	0° 0' 0.01"E
3	20073	33° 24' 14.76191"N	44° 17' 52.33808"E	-0.959	33° 24' 14.7503"N	44° 17' 52.32691"E	0.39	0° 0' 0.01"N	0° 0' 0.01"E
4	20080	33° 20' 14.03710"N	44° 23' 31.1369"E	-1.062	33° 20' 14.0360"N	44° 23' 31.12691"E	0.287	0° 0' 0.01"N	0° 0' 0.01"E
5	527003	33° 21' 53.9122"N	44° 15' 0.7972"E	-1.019	33° 21' 53.87554" N	44° 15' 00.78797"E	0.33	0° 0' 0.04"N	0° 0' 0.01"E
6	525504	33° 18' 19.7270"N	44° 16' 35.0450"E	-1.217	33° 18' 19.69011" N	44° 16' 35.03610"E	0.132	0° 0' 0.04"N	0° 0' 0.01"E
7	517301	33° 25' 40.9742"N	44° 25' 1.83023"E	-1.626	33° 25' 40.93261" N	44° 25' 01.82503" E	-0.277	0° 0' 0.04"N	0° 0' 0.01"E
8	523002	33° 17' 35.1032"N	44° 27' 15.9473"E	-1.633	33° 17' 35.06228" N	44° 27' 15.94200" E	-0.284	0° 0' 0.04"N	0° 0' 0.01"E
9	524001	33° 13' 36.03786"N	44° 22' 27.87714" E	-1.791	33° 13' 36.02694" N	44° 22' 27.86923" E	-0.442	0° 0' 0.01"N	0° 0' 0.01"E
10	511701	33° 21' 37.9443"N	44° 21' 18.3075"E	-0.917	33° 21' 37.93224" N	44° 21' 18.29184" E	0.432	0° 0' 0.01"N	0° 0' 0.02"E
11	32/2	33° 22' 39.4728"N	44° 19' 05.8638"E	-0.881	33° 22' 39.47279" N	44° 19' 05.86379" E	0.468	0° 0' 0.01"N	0° 0' 0.01"E

5. Conclusions

- Geodetic surveying specialists often adopt a national or local geodetic reference system for a country or a specific region. Producing geographic maps based on this reference can lead to consistent and accurate results especially when the adopted reference surface simulates as much as possible the shape of the earth in the region.

In the works of geodesy, the size of the area needs to be surveyed should be carefully selected such that the distances among the geodetic points do not exceed 35 Km. The reason is to minimize the errors in the survey computations and map productions[9].

- The value of N, which represents the difference between the geoid production by (POLESERVICE) and the ellipsoid (WGS84) reference surfaces, ranges from -1 m to -2 m in the city of Baghdad. This difference is relatively large for the city of Baghdad.

This difference can negatively affects the accuracy of ground points coordinates and hence their real locations on the ground. Consequently, it can lead to significant inaccuracy in surveying applications such as the production of maps and the construction of infrastructure projects.

- The difference between geoid and ellipsoid (WGS84) was reduced by suggesting a new coordinate system in order to obtain a higher precision.

The new coordinates were linked to the satellite coordinates for the purpose of updating the maps based on adopted on an reference stations such as Baghdad station or any other stations in the country. That is because it depends on the global reference WGS84 where the center of WGS84 is the same center of gravity (geoid).

- In accordance with the development of the Geodesy, each area should be based on a base maps. In Iraq, the universal reference system Clarke 1880 was modified in the 1980s of the last century to be the Iraqi system that is nationally adopted in all surveying works – it was referred to as Karbala79. Regarding the vertical reference, the mean sea level (geoid) is still adopted [9].

6. Recommendations

The establishment of a geodetic reference to be utilized for assuring precise surveys requires at first the identification and determination of reference points that are approved by governmental institutions.

- Furthermore, the establishment of a geodetic reference should be complemented with adopting a proper vertical reference. It is important that this vertical system be continuously updated to match real earth (geoid). Several factors could contribute in changing the shape of the earth over the years including the tide effects, most of the countries updating their systems every ten years.
- In this research, due to the absence of an updating vertical reference, the vertical reference previously proposed by POLESERVICE in 1979 was adopted[9].
- On the other side, the correction of the coordinates of the observed points is highly recommended to be based on reference stations that are as much as possible close to these observed points; that is in order to ensure high accuracy.
- Furthermore, modern software that are compatible with GPS observations should be used in the process of coordinates correction. The exact paths of the satellites have to uploaded and entered in order to coordinates with high accuracy.
- Another important aspects that are relevant to the accuracy of observation process, includes the avoidance of high building, the selection of adequate time, and also the examining of operation status of the nearby CORS station.
- Finally yet importantly, it is recommended that the methodology proposed in this research is nationally adopted and implemented to create new Iraqi reference system.

7. Discussion

In the 1970s a completely new geodetic network covering all of Iraq was established by the Polish State Enterprise for Geodesy and Cartography GEOKART, operating as part of a larger foreign aid organization named Polservice. This was a traditional astro-geodetic control network consisting of 2778 points with an average inter-point distance of 15 km. The horizontal network was supplemented by a new spirit-levelled vertical network, tied to two tide gauges at the port of Al-Faw. Gravity observations were made along all precise levelling lines. The Fundamental Point of the horizontal network was moved from Nahrwan to Karbala. The change

in coordinates of any point in Iraq is significant: in the Baghdad area the apparent ‘shift’ between Nahrwan and Karbala 1979 coordinates exceeds 400 metres. Although most of the documentation is still available, many of the control point monuments have been damaged.

Karbala 1979 was used in conjunction with the UTM system of map projections, as well as with a dedicated TM projection, known as the Iraq National Grid whose area of use is all of onshore Iraq.

The geodetic positioning is important for precise approximation of terrestrial and inertial reference system required to define local horizontal geodetic datum. Although the large number of the available local horizontal geodetic datums, which exceeds several hundreds, the number of the local horizontal datums for any selected area are significantly in decrease continuously. In order to accepted and implement a global geodetic datum, within a specified area, it is required to transform it between the geodetic datums.

The Iraqi national reference system, known as karbala-1979, was set by Geokart–Poland company in the late1970s. The system is a Clark1880 ellipsoid that is transformed to fit Iraq.

To accomplish the conversion from global to regional, the local geodetic datum and The World Geodetic System 1984 (WGS84) coordinates are both required at one or more sites within the local selected study area, so that the shift between the two datums can be computed. Satellite stations positioned within WGS84, for known local geodetic datum coordinates, are the basic components to convert between any local geodetic datum and the WGS 84 datum [7].

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