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Converting Coordinates Between the Local Geodetic Reference and the Global Geodetic Reference for Selective Sites in Babil Province

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ABSTRACT

A geodetic transformation is a mathematical operation that takes coordinates of a point in one coordinate system and returns the same coordinates in another coordinate system. This study aimed to show the compatibility between global positioning system coordinates and the local maps in Iraq; this compatibility will be made for locations in the Babil province. In the study area, fifteen control points have been chosen. GPS measures geographic and projected coordinates depending on the Universal Transverse Mercator projection and the World Geodetic System 1984 datum. In Iraq, the measured geographic coordinates are converted to projected coordinates using a geographic information system based on Clarke 1880 ellipsoid. To facilitate the conversion of the coordinates, both formulas and parameters are provided for any point in the study area between the two systems using a GPS receiver and the ArcGIS software. The present study shows that the differences in easting coordinates are about -287.630 m, while the differences in northing coordinates reach 278.525 m. It was concluded that the various datums might play a significant role in producing maps and updating those maps for engineering works.

Keywords: coordinate transformation, ArcGIS, WGS 1984, Global Positioning System, Clarke 1880.

INTRODUCTION

The spatial data become more and more globalized, so transformation between geodetic datums is necessary and modern techniques of geodetic measurements Global Positioning System (GPS) have been widely adapted for geodetic purposes (Bašić & Bačić, 2015; Ziggah et al., 2019). GPS has become an essential technology for surveying practices at large and has revolutionized data collection. In the case of the GPS data used locally, there is a need to perform coordinate transformation. Applying GPS measurements locally with the least amount of errors possible, which are typically caused by the GPS global datum (geocentric) and the different datum shape, size, and origin between local data (non-geocentric) of countries (Ziggah et al., 2019). Two types of coordinate systems are commonly used: geographic and projected coordinate systems. In most projects, the transformation into projected coordinates usually follows the measuring of geographic coordinates. The coordinate system of the country should be used for measuring any position. Each country has its ellipsoid and datum. Various datum surfaces and ellipsoids are responsible for the occurrence of different coordinate values. The global positioning system was used in this study to measure both geographic and projected coordinates.

WGS84 (World Geodetic System 1984) refers to the global reference frame datum used for GPS positioning. XYZ coordinates or longitude, latitude, and ellipsoid height coordinates can be used to describe WGS84 positions. It is necessary to convert these into the local coordinate system for use in a particular locality (Yakubu, 2015). The Clarke 1880 ellipsoid is the reference ellipsoid utilized in Iraq, because it corresponds to the actual shape and size of the land. The UTM system of map projections was used in conjunction with Karbala 1979 (International Association, 2015).

Local maps in Iraq use the Clarke 1880 ellipsoid as a spatial reference. Its origin point is located in the province of Karbala. The vertical deflection equals to zero at this point. The origin datum is where the ellipsoid surface intersects the geoid, not the ellipsoid center. GPS will use the WGS 1984 datum and ellipsoid. These systems do not identify the local datum or ellipsoid in Iraq. This necessitated the transformation of coordinates between the two datums (Hussain, 2017; Jasim et al., 2018).

Table 1 illustrates the spatial reference properties of the Clarke 1880 and WGS 1984 ellipsoids. For datum transformation, seven parameters must be established. There are three translation parameters, three rotation parameters, and one scale factor included in the parameters. The first step in the GPS process is to obtain geographic coordinates (longitude and latitude). The second step is to use map projection equations to project these coordinates onto the map (northing and easting). The UTM zone 38 north map projection in Iraq is widely used (Al-Saedi et al., 2023; ArcGIS, 2019).

Some government departments in Iraq use the Clarke 1880 ellipsoid as a base map, which must be linked to the WGS 1984 global system. Differences in spatial accuracy may be due to the use of different coordinate systems. Consequently, the study aimed to convert various coordinate systems and investigate the degree of difference that occurs when two ellipsoids and datum surfaces are utilized by employing the ArcGIS software package. In addition, the satellite images of Babylon province were used to achieve the aim of the study.

METHODOLOGY OF RESEARCH

Study area

This study was carried out in the Babil province, which represents a part of central Iraq. It lies between latitude 32 degrees and 33 degrees north and between longitude 44 degrees and 45 degrees east, as shown in Figure 1. The province of Babil is located in the middle of Iraq and shares its internal borders with the governorates of Baghdad, Anbar, Karbala, Najaf, Qadisiyah, and Wasit. Babil intersects with the Euphrates River to split into Hindiya and Hilla. The buildings located south of the Al-Musayyib city, through which a network of irrigation canals passes, supply farms and orchards in the area. To the south, the sloping lands of the Babylon Governorate are 35 meters above sea level.

Methods

The general methodology involved the following: the first part was selecting the study area and collecting data, which includes (preparing the required surveys and a satellite image of the study area to draw the study area and project the selective points). The second part dealt with the coordinate transformation from the World Geodetic

Table 1. Parameters of the reference ellipsoids used in Iraq (Hussain, 2022)

Geographic coordinate system		
Spheroid	WGS 1984	Clarke 1880 RGS
Datum	WGS 1984	Karbala 1979 Polservice
Semimajor axis (a)	6378137.000 m	6378249.145 m
Semiminor axis (b)	6356752.314 m	6356514.869 m
Inverse flattening (1/f)	298.25722356	293.465
Eccentricity (e2)	0.00669438	0.00680351
Projected Coordinate System		
Projection	UTM of Zone 38 North	Karbala 1979 UTM Zone 38N
False northing	0.0 m	0.0 m
False easting	500000 m	500000 m
Latitude of origin	0°	0°
Central meridian	45°	45°
Scale factor	0.9996	0.9996

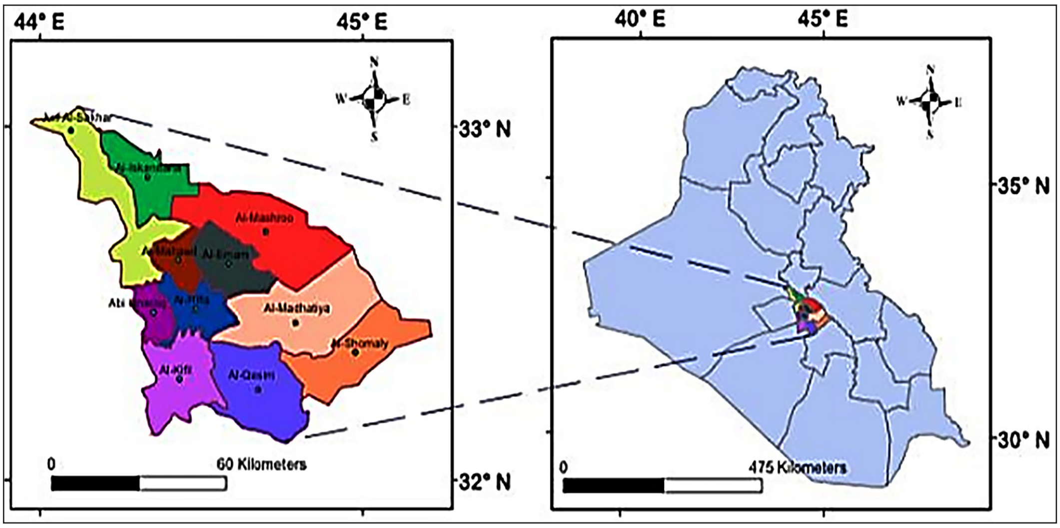

Figure 1. Study area

Reference to the coordinates on the local geodetic reference. The general methodology used in this study is shown in Figure 2.

Data

Data used in this research will be summarized as follows**:**

- Global Positioning System (GPS) technology has been used to measure geographic and map projection coordinates for all 15 selected points within the Babil province using a GPS receiver with visual GPS software, as shown in Table 2. The WGS 1984 datum is used to calculate geographic coordinates (latitudes and longitudes) (Kadhum et al., 2023). The projected coordinates were calculated using the (UTM/UPS) projection.
- Microsoft Excel has been used to prepare the database of the selective points and export them to GIS. Layers are created using these measurements in ArcGIS.

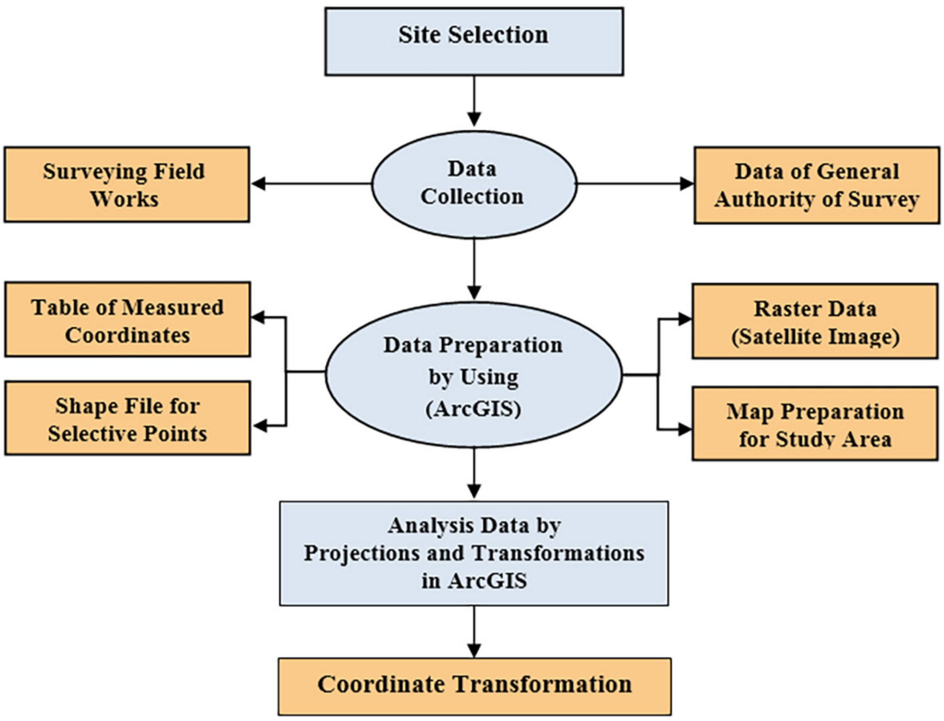

Figure 2. Overall methodology used in this study (Directed by researcher)

- The map for the selective points in the study area is drawn using ArcGIS; the ArcMap program is provided in Figure 3.
- Arc GIS has been used in map preparation for the selective points in the study area and coordinates transformation from Global geodetic ellipsoid (WGS 1984) to local ellipsoid (Clarke 1880), as shown in Figure 4.

TRANSFORMATION OF COORDINATES

Position errors can occur when reference geodetic coordinates are displayed on different datums. The mathematical conversion of a geodetic position between two datum systems is known as transformation. The following are usually used (Dönmez & Tunc, 2016).

Geocentric transformation

Datum transformations based on geocentric coordinates (x,y,z) are three-dimensional similarity transformations. This is illustrated in Figure 5 (Knippers & Hendrikse, 2001). Through three translations, the geocentric translation connects two datum systems. The method involves shifting the centers of the two geocentric coordinate systems. The parameters ΔX, ΔY, and ΔZ define this shift. The equation can be simplified as follows:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{\substack{Global\ Datum \\ WGS\ 1984}} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{\substack{Local\ Datum \\ Clark1880}} \quad (1)$$

Helmert 7-parameter transformation

The Helmert 7-parameter transformation relates two datum systems through a rotation (ω, φ, κ), an origin shift (ΔX, ΔY, ΔZ) and a scale factor (s) (Dönmez & Tunc, 2016):

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{\substack{Global \\ Datum}} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + Scale * R * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{\substack{Local \\ Datum}} \quad (2)$$

RESULTS

After analyzing the data, the results were obtained. By using ArcGIS, the GPS data were analyzed after downloading and post-processing. The WGS 1984 and Clarke 1880 datum ellipsoid parameters were used to compare the processed data.

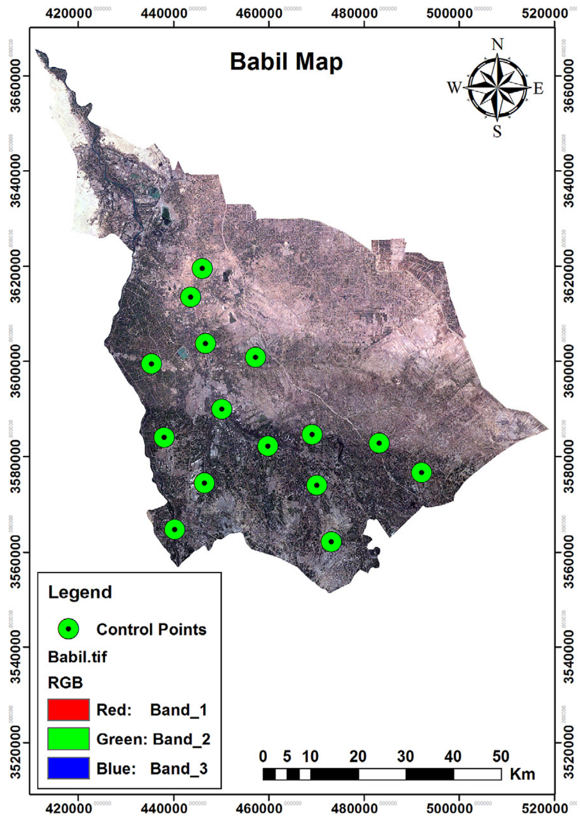

Figure 3. GPS coordinates distribution of selected points in the Babil Province, in WGS84 reference frame

Different results were yielded from these two datum definitions. Using Clarke 1880 and WGS 1984 datum ellipsoid parameters allowed for detecting a positional change on fifteen points. The magnitude of the differences between the two sets of coordinates (WGS 1984 and Clarke 1880 coordinates) for each point was calculated, as shown in Table 3. ΔE stands for the changes in Eastings coordinates, and ΔN stands for the changes in Northings coordinates. The easting coordinate differences reach -287.630 m, while the northing coordinate differences are about 278.525 m. Figures 6, 7, and 8 illustrate the differences in northing and easting coordinates, respectively. The maximum and minimum of easting differences are (-287.584 and -287.661 m), respectively, while the maximum and minimum of northing differences are (278.553 and 278.485 m). Equations 3 and 4 give an approximate local coordinate transformation.

$$E\ (CLARCK\ 1880) = E\ (WGS\ 1984) - DE\ (Mean) \quad (3)$$

$$N\ (CLARCK\ 1880) = N\ (WGS\ 1984) - DN\ (Mean) \quad (4)$$

Table 2. Measuring both geographic and map projection coordinates for all 15 selected points based on WGS 1984

Point	(WGS 1984 SPHEROID)		(WGS 1984 SPHEROID)	
	Easting (m)	Northing (m)	Longitude (DMS)	Latitude (DMS)
1	459854.927	3582244.137	44° 34' 23.637"	32° 22' 35.236"
2	473160.126	3562125.432	44° 42' 54.868"	32° 11' 43.286"
3	438061.800	3584054.921	44° 20' 29.220"	32° 23' 30.451"
4	446034.186	3619555.142	44° 25' 27.013"	32° 42' 44.779"
5	435356.295	3599531.087	44° 18' 41.849"	32° 31' 52.469"
6	483247.463	3582801.135	44° 49' 18.834"	32° 22' 55.473"
7	446469.862	3574477.487	44° 25' 52.983"	32° 18' 20.990"
8	450148.222	3589970.810	44° 28' 10.703"	32° 26' 44.751"
9	446706.440	3603761.708	44° 25' 56.078"	32° 34' 12.027"
10	443602.321	3613534.574	44° 23' 54.913 "	32° 39' 28.833 "
11	457277.401	3600853.001	44° 32' 41.961 "	32° 32' 39.217 "
12	470106.806	3573983.229	44° 40' 56.910 "	32° 18' 8.111 "
13	469123.378	3584645.135	44° 40' 18.055 "	32° 23' 54.273 "
14	492143.922	3576685.850	44° 54' 59.508 "	32° 19' 37.222 "
15	440229.460	3564725.379	44° 21' 56.563 "	32° 13' 3.151 "

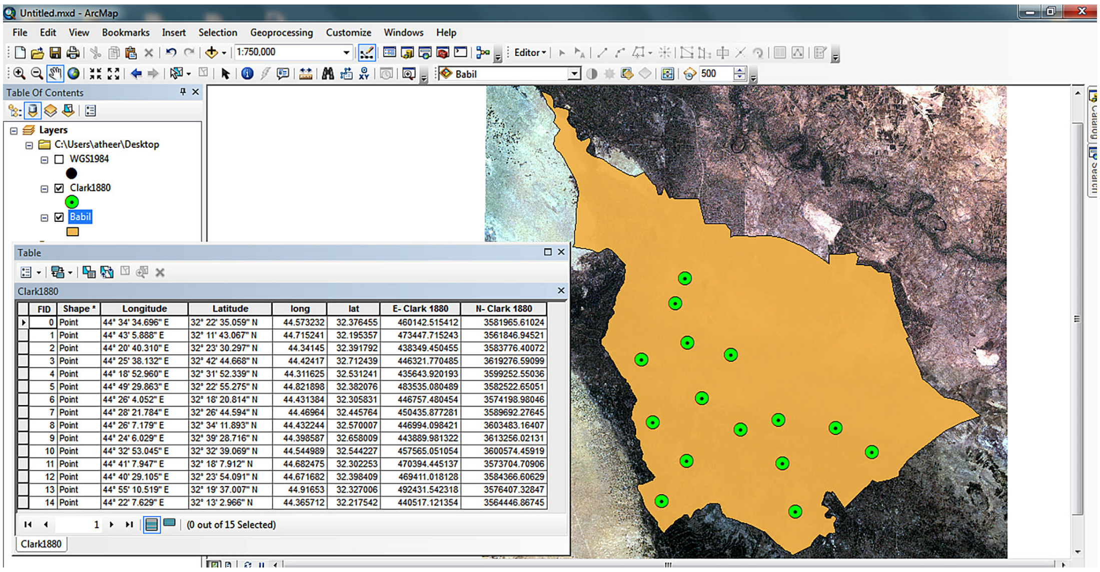

Figure 4. Implementation of Transformation in ArcMap, ArcGIS

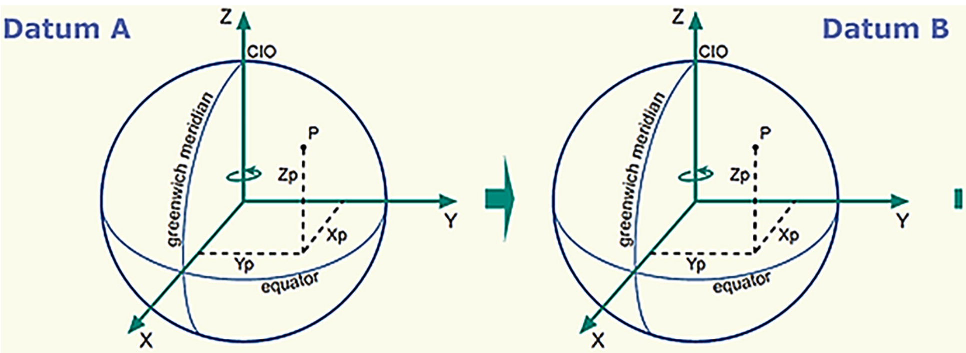

Figure 5. The principle of transform between two datum systems using geocentric coordinates (Knippers & Hendrikse, 2001)

Table 3. UTM coordinate differences between WGS84 and Clarke 1880

Point	(WGS 1984 SPHEROID)		(CLARCK1880 SPHEROID)		Calculated differences	
	E (m)	N (m)	E (m)	N (m)	DE (m)	DN (m)
1	459854.927	3582244.137	460142.515	3581965.610	-287.588	278.527
2	473160.126	3562125.432	473447.715	3561846.945	-287.589	278.487
3	438061.800	3584054.921	438349.450	3583776.400	-287.650	278.521
4	446034.186	3619555.142	446321.770	3619276.590	-287.584	278.552
5	435356.295	3599531.087	435643.920	3599252.550	-287.625	278.537
6	483247.463	3582801.135	483535.080	3582522.650	-287.617	278.485
7	446469.862	3574477.487	446757.480	3574198.980	-287.618	278.507
8	450148.222	3589970.810	450435.877	3589692.276	-287.655	278.533
9	446706.440	3603761.708	446994.098	3603483.164	-287.658	278.545
10	443602.321	3613534.574	443889.981	3613256.021	-287.661	278.553
11	457277.401	3600853.001	457565.051	3600574.459	-287.649	278.542
12	470106.806	3573983.229	470394.445	3573704.709	-287.639	278.520
13	469123.378	3584645.135	469411.018	3584366.606	-287.640	278.529
14	492143.922	3576685.850	492431.542	3576407.328	-287.621	278.522
15	440229.460	3564725.379	440517.121	3564446.867	-287.661	278.512

Note: DE (mean) = -287.630 m, DN (Mean) = 278.525 m.

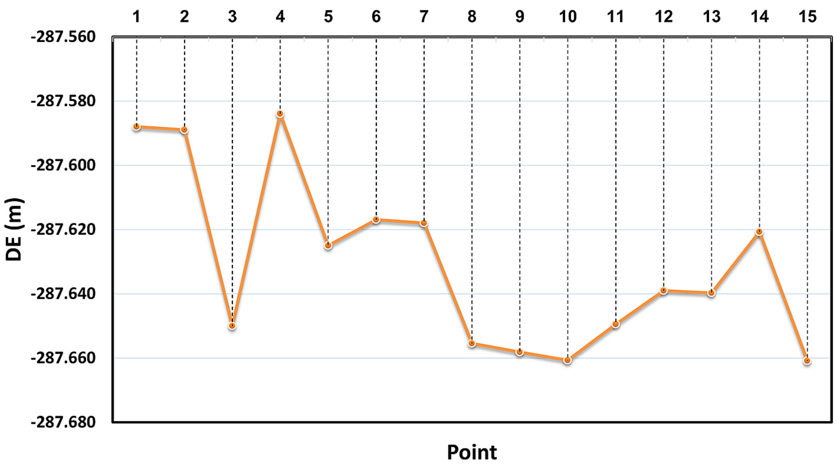

Figure 6. Chart shows the easting differences

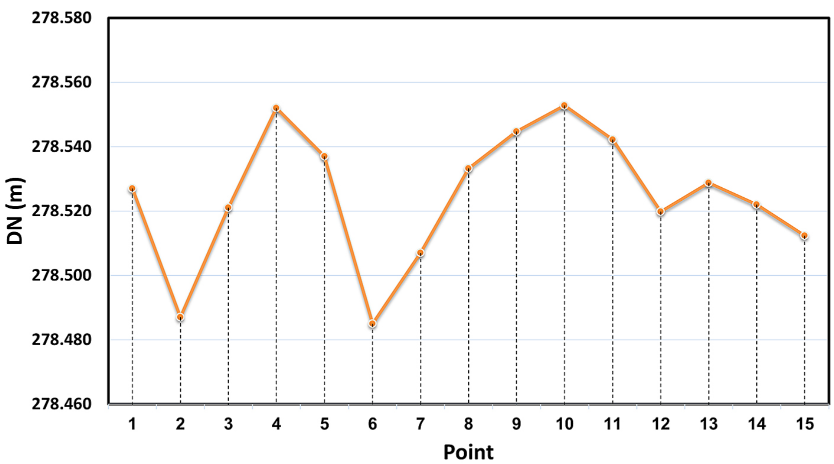

Figure 7. Chart of the northing differences

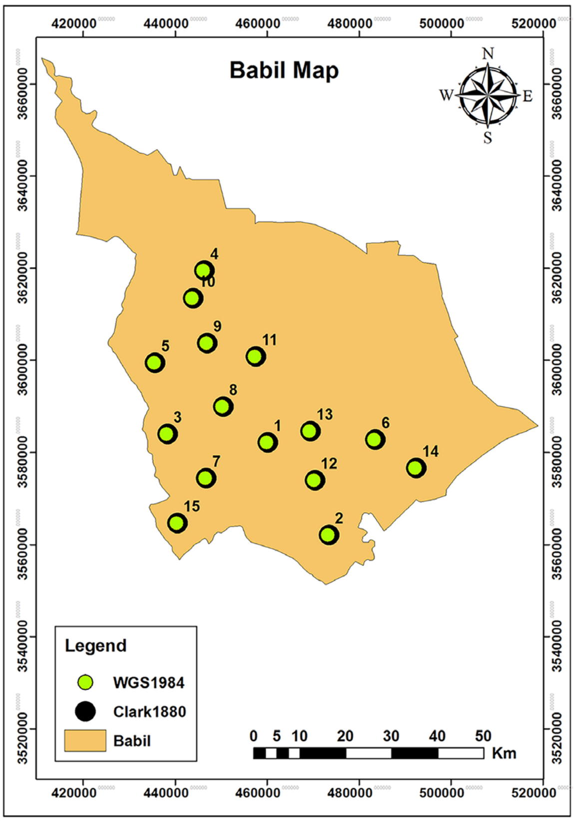

Figure 8. UTM Coordinates difference between WGS1984 and Clark1880 reference ellipsoid

CONCLUSIONS

Since GPS receivers and their associated software applications have different datum options, before measuring coordinates, the user should choose a local datum and an ellipsoid. In Iraq, GPS does not support local datum. Using the ArcGIS programs, the coordinates are measured concerning the WGS 1984 spatial reference and then transformed to the Clarke 1880 ellipsoid and Karbala datum. The use of local Clarke 1880 and WGS84 datums to compare the coordinate transformation was essential during this study. As a result, the different datums may play a significant role in the production of the different planes that differ in shape and area.

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