1. Introduction:

This report contains the details of theory, procedure, computations, and the results of the estimation of the transformation parameters between Everest and WGS84 ellipsoids for the region, and the coordinate conversion carried out using these transformation parameters.

2. Objectives of the Project:

The objectives of the work are as follows:

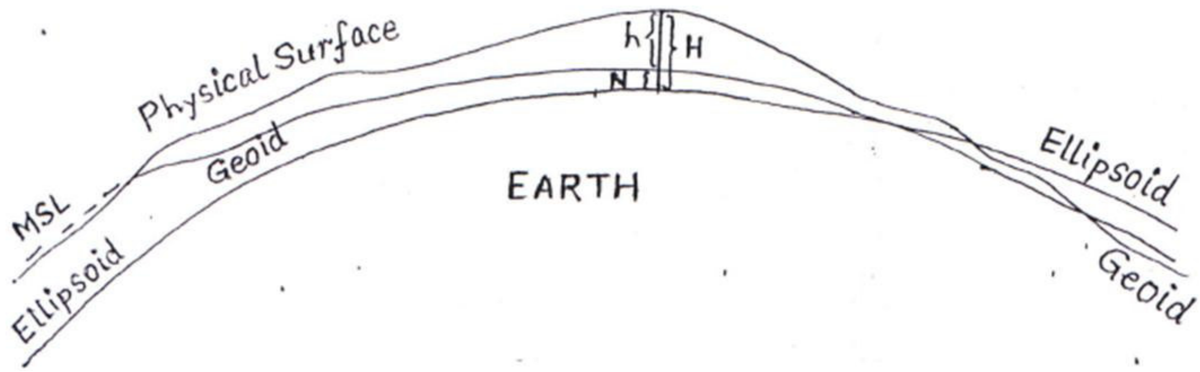
1. To estimate transformation parameters between Indian Geodetic System (Everest ellipsoid) and World Geodetic reference System 1984 (WGS84 ellipsoid) for Cambay region in Gujarat area.
2. To convert the geodetic coordinates of the corner points from Indian datum to WGS84 datum using these transformation parameters.
3. To convert these coordinates to Cartesian Rectangular system (X,Y,Z) and also to Universal Transverse Mercator (UTM) gird system.

3. Theoretical background about Geodetic Datums and Datum Transformations

As the uneven and undulating physical surface of the Earth is not suitable for the mathematical computations of geodetic data reduction, coordinate reference, and also as a map datum, a hypothetical geometrical reference surface called 'Geodetic Datum' must be defined. Traditionally, two different datums are used as reference surfaces for the horizontal and the vertical coordinates: the horizontal datum, which is an ellipsoid of revolution, and the vertical datum, which is Geoid.

A. Geodetic Reference Surfaces (Datums):

The different reference surfaces in Geodesy are shown in Figure 1.



Legend: H: Ellipsoidal height (from GPS), h: Geoidal (MSL) height (from leveling),
N: Geoidal separation (Astro-Gravimetric)

Figure 1: Geodetic reference surfaces

(i) <u>Physical surface of earth</u>: It is the irregular surface of the Earth, on which all geodetic survey observations are taken. However, this can not be mathematically described.

(ii) <u>Geoid</u>: It is an equi-potential (level) surface, taken as the approximate Mean Sea Level (MSL). This is defined by Earth's gravity field, but can not be mathematically described, and is not a regular surface, though it is fairly smooth. This is the reference surface for vertical control: all the (geoidal / MSL) heights are generally referred to this surface.

(iii) <u>Reference ellipsoid</u> : It is an ellipsoid of revolution, which best approximates the physical surface of the Earth. This is an imaginary surface, used as reference datum for horizontal control and mapping. A reference surface is completely defined by:

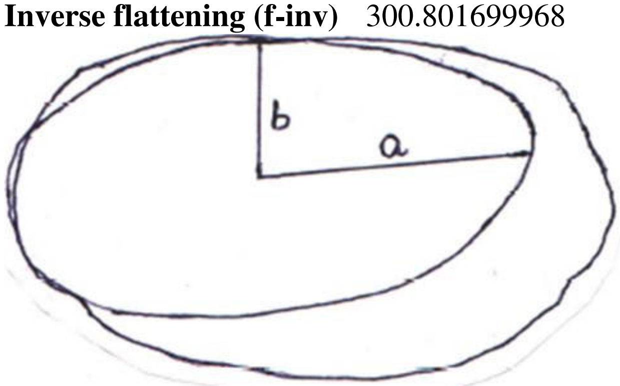
a	semi major axis
f	flattening = (a-b)/a
W	potential of the surface
ϕ_0, λ_0	Origin of the Ellipsoid / Geodetic Datum
ξ_0, η_0	Components of Deflection of Vertical at the Origin

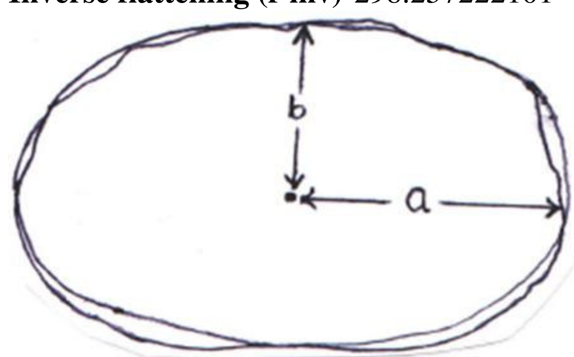
<u>Best fitting ellipsoid</u>: This ellipsoid fits the dimensions and position of the Geoid in the region, in the best possible manner. This is generally adopted as a Geodetic Datum. The accuracy of the geodetic coordinates, computations, and mapping is directly affected by the suitability of the geodetic datum used. The Indian Geodetic Datum adopted in 1880 is the Everest ellipsoid, which is based upon the adjustment of the Great Trigonometrical (G. T.) Triangulation network of India.

The ellipsoid is the geodetic datum, used for all geodetic survey work and for mapping purposes. There are two types of geodetic datums: global datums which fit the entire Earth in the best possible manner, like the World Geodetic System 1984 (WGS84) developed by National Geospatial Intelligence Agency (NGA), USA (used by GPS; for details, see: http://www.nga.mil), and local geodetic datums adopted by different countries to fit the Earth in their region only (e.g. the Everest Ellipsoid used as Indian Geodetic Datum). The details of these two important datums are given in Table 1.

Table 1: Details of Everest and WGS84 ellipsoids

Everest 1880 ellipsoid (Indian Datum)		**WGS84 Ellipsoid (GPS Datum)**	
Datum	INDIAN- India and Nepal	**Datum**	World Geodetic System - 1984 (WGS84)
Semi-major Axis (a)	6377301 m	**Semi-major axis (a)**	6378137 m
Eccentricity (e)	0.081472980	**Eccentricity (e)**	0.081819190
Inverse flattening (f-inv)	300.801699968	**Inverse flattening (f-inv)**	298.257222101



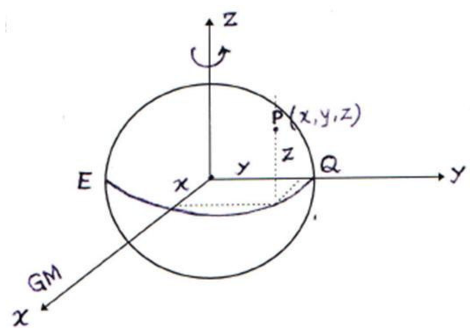
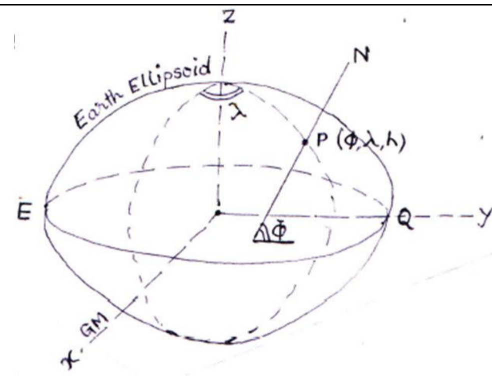
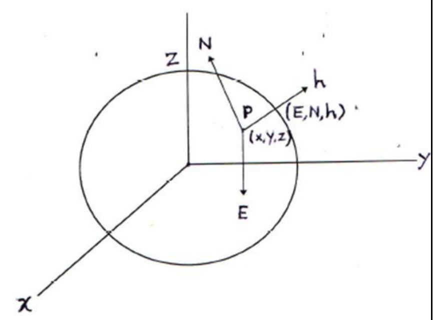


The Global Positioning System (GPS) yields positions of survey points on WGS 84. This geodetic datum is geocentric (ECEF: Earth-centred, Earth-fixed), and defined to a high degree of accuracy by the Defense Mapping Agency, USA (DMA). The Indian topographical maps (topo. sheets), and G. T. coordinates, are based on the Indian Geodetic Datum: Everest, 1880, which is not geocentric.

B. Coordinate Systems:

Different co-ordinate systems used in Geodesy are tabulated in **Table 2**

Table 2: Coordinate systems in Geodesy

<table>
<tr><th>Cartesian rectangular coordinates</th><th>Geodetic coordinate system</th><th>Local coordinate system</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Origin: Center of Earth
Z axis: Axis of rotation of Earth
X axis: Zero (Greenwich) meridian
Y axis: Forms right handed system</td><td>Latitude, Longitude, Height (φ,λ,h)</td><td>h: along normal to ellipsoid at point P (height)
N: at 90^0 to E in North direction (Northing)
E: at 90^0 to N, in East Direction(Easting)</td></tr>
</table>

C. Transformation of Coordinates between Global Datum and Local Datum

In order to convert the coordinates obtained by using GPS, on WGS84 datum, to the coordinates of the points on the Indian Geodetic Datum, which is used for all Indian topographical maps, and the reverse transformation, the relationship between the WGS 84 and Indian map datum must be defined precisely. The transformation of coordinates involves seven transformation parameters - the three translations due to shift of origin, three rotations due to change in orientation (which are theoretically zero due to the axes being parallel) and a scale factor due to the different dimensions of the two reference ellipsoids (see Table 1). As the three rotational parameters are theoretically zero, and the scale factor is absorbed in the translations, for a small region, three parameter approach can be adopted to calculate the transformation parameters locally. These transformation parameters must be estimated, using coordinates of several well-distributed stations in both the systems, in order to obtain the geodetic coordinates in local reference system. The estimated parameters can only be considered to be valid in that region, and not for the entire ellipsoid.

D. GPS Heights and Mean Sea Level Heights

The height deduced from GPS observations is the ellipsoidal height - height of the observation point above the reference ellipsoid. The geodetic height of a point is the geoidal height - height above the geoid, commonly termed as Mean Sea Level (MSL) height. These two are related by the simple equation:

MSL Height (h) = Ellipsoidal Height (H) - Geoidal Undulation (N)

4. Estimation of the Transformation Parameters for Cambay Region, Gujarat

In order to estimate the transformation parameters for conversion of coordinates from Indian Geodetic Datum to the WGS84 Geodetic Datum, few high precision geodetic stations of the G.T. triangulation network (GT), situated in the region were used. Their precise geodetic coordinates in Indian system were obtained from Survey of India (SOI), and coordinates in WGS84 system were obtained from high precision geodetic GPS data, earlier collected over these stations for another project. International GPS/GNSS Service (IGS- official web site: http://igscb.jpl.nasa.gov/) stations---LHAS and BAHR and IITB GPS reference station data was also used, and the precise coordinates of these GT stations were calculated

The observed WGS84 coordinates and Everest coordinates were used in Equation 1 to find out the transformation parameters. The three translation transformation parameters Δx, Δy, and Δz were calculated for some of the GT stations. Average value of the computed Δx, Δy, and Δz for the three stations was calculated and considered as transformation parameters. Using these parameters, coordinates of other GT stations were calculated and were compared to those supplied by SOI, to estimate the accuracy of the computed transformation parameters.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS84} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{Everest} + \begin{bmatrix} \Delta x \\ \Delta y \\ \Delta z \end{bmatrix}_{Everest \to WGS84} \quad (1)$$

In the four parameter approach, the scale factor (*SF*) was used in addition to the three translation transformation parameters $\Delta x, \ \Delta y, \ and \ \Delta z$ as in Equation 2. The scale factor was calculated as ratio of the semi-major axis of the two ellipsoids --- Everest ellipsoid and WGS84 ellipsoid, as given in Equation 3. Details of these ellipsoids are given in Table 1.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS84} = SF \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{Everest} + \begin{bmatrix} \Delta x \\ \Delta y \\ \Delta z \end{bmatrix}_{Everest \to WGS84} \quad (2)$$

$$SF = \frac{a_{everest}}{a_{WGS84}} \quad (3)$$

Since the results obtained for the GT stations using the above two methods were consistent, the three-parameter approach was preferred, and the coordinates calculated in the first method were used for determining the transformation parameters. The parameters are listed in Table 3.

Table 3: Estimated Transformation Parameters with their accuracy

(Everest Datum to WGS84 Datum, for Cambay Region)

	ΔX m	ΔY m	ΔZ m
Trans. Parameter:	**296.26**	**737.79**	**254.74**
Estimated Max. Error:	**1.21**	**-0.37**	**-2.99**

5. Conversion of Coordinates of the Corner Points to WGS84 System, and to Cartesian Rectangular and UTM Grid Coordinates

The two-dimensional (horizontal) coordinates of the six corner points of the block were supplied in Geodetic terms (Latitude and Longitude) in Indian Geodetic System (Everest Datum). These were converted to Cartesian Rectangular Coordinates (X, Y, Z) and Universal Transverse Mercator (UTM) grid coordinates (Easting and Northing) using the software developed by the GPS Research group at IIT Bombay (details available at: http://www.civil.iitb.ac.in/~kulkarni): Datum and Coordinate Conversion System (DCCS). These coordinates, in Indian Geodetic System, are listed in Table 4.

Using the transformation parameters computed, these coordinates were converted to WGS84 system, and to X,Y,Z and UTM coordinates, on WGS84. The results are listed in Table 5.

Table 4: Coordinates of Corner Points in Indian Geodetic System (Everest Ellipsoid)

Geodetic Coordinates (given)		**Cartesian Coordinates**			**UTM Coordinates (Zone 43 N)**	
Latitude	Longitude	X	Y	Z	E	N
A. 22deg 25' 00"	72 deg 32' 53"	1768919	5626745	2416940	247633	2480813
B. 22deg 17' 51"	72 deg 32' 53"	1770424	5631533	2404737	247418	2467615
C. 22deg 17' 51"	72 deg 35' 42"	1765809	5632982	2404737	252256	2467537
D. 22deg 18' 56"	72 deg 35' 42"	1765582	5632258	2406586	252288	2469537
E. 22deg 18' 56"	72 deg 40' 50"	1757170	5634888	2406586	261104	2469399
F. 22deg 25' 00"	72 deg 40' 50"	1755902	5630821	2416940	261276	2480596

Table 5: Coordinates of Corner Points in WGS84 System (WGS84 Ellipsoid)

Geodetic Coordinates			Cartesian Coordinates			UTM Coordinates (Zone 43 N)	
	Latitude	Longitude	X	Y	Z	E	N
A.	22deg 25' 02.1"	72 deg 32' 50.9"	1769215	5627483	2417195	247539	2481072
B.	22deg 17' 53.1"	72 deg 32' 50.9"	1770720	5632271	2404992	247324	2467874
C.	22deg 17' 53.1"	72 deg 35' 39.9"	1766105	5633720	2404992	252163	2467796
D.	22deg 18' 58.1"	72 deg 35' 39.9"	1765878	5632996	2406841	252194	2469795
E.	22deg 18' 58.1"	72 deg 40' 47.8"	1757466	5635626	2406841	261010	2469657
F.	22deg 25' 02.1"	72 deg 40' 47.8"	1756198	5631559	2417195	261182	2480855

6. Summary

1. Based on these results it can be concluded that the transformation parameters between Indian Geodetic Datum (Everest Ellipsoid) and WGS84 Datum estimated using the available data of GT stations in the region, and the observed GPS data on these stations, can be used for the conversion of coordinates of other points lying in the Cambay region. These parameters, with their estimated & tested maximum errors, are as listed in Table 3. This estimated precision of the parameters (approx. 0.1 second of arc in Latitude / Longitude), is about one order of magnitude (10 times) more than the precision of the coordinates provided (one arc second).

2. The geodetic coordinates (Latitude, Longitude) of the corner points of the block, given in Indian Geodetic Datum, are converted to Cartesian Rectangular coordinates (X,Y,Z), and Universal Transverse Mercator (UTM) coordinates, using software DCCS, developed by the IIT Bombay GPS research group. These are given in Table 4.

3. Using the transformation parameters estimated, as explained in (1) above, these geodetic coordinates are converted from the Indian Geodetic Datum to WGS84 system, and then to Cartesian Rectangular coordinates (X,Y,Z), and Universal Transverse Mercator (UTM) coordinates, using software DCCS. These are given in Table 5.