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Geodetic Infrastructure in India: What is Wrong and What Needs to be Done

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Abstract

Geodetic Infrastructure in India is inadequate. What are shortcomings and what needs to be done, has been discussed and possible solution is suggested in this paper. It appears that, beginning has been made by the National Survey Agency, SURVEY OF INDIA, towards improving the geodetic infrastructure. It will be appropriate, if Survey of India puts on its website, the present status of Geodetic Infrastructure in India and also state as to what are their plans to put in place the adequate geodetic infrastructure along with the time frame.

Keywords: Geodetic Infrastructure in India, Indian Geodetic Datum

1. Introduction

Geodetic Infrastructure in India needs improvement. It needs a fresh look and revision. Indian Geodetic Datum, The Reference Surface, Horizontal Control, The Vertical Datum, Height Control, Indian Geoid and Mean sea level, The Gravity datum, Projection System for Maps, and Indian Grid, are all inadequate or inappropriate for Geodetic monitoring of crustal movements, plate tectonic movements, development and deployment of missiles and many other scientific applications.

2. Indian Geodetic Datum

Indian Geodetic Datum is based on Everest Spheroid as reference surface given by Sir George Everest, then Surveyor General of India in 1830. Kalyanpur in central India was chosen as initial point or origin. Coordinates of initial point and azimuth of a line were obtained by astronomical observations and leveling. The reference surface was however defined at various times from 1825 to 1899, by different observers with improvements. Astronomical observations were carried out at least twice. More precise observations carried out later were accepted. Hence meridional and prime vertical deflection of vertical, were defined at Kalyanpur. Parameters of the datum are given in Table 1.

Table 1: Parameters of the datum defined at Kalyanpur

Initial Point (Origin)	**Kalyanpur**
Latitude of origin	24^0 07′ 11.26″
Longitude of origin	77^0 39' 17.57″
Meridional deflection of vertical	- 0.29″
Prime vertical deflection of vertical	+ 2″.89″
Geoidal undulation	0 meters
Semi major axis	6,377,301.243 meters
Flattening f	1/300.8017

Azimuth to Surantal	190^{0} 27′ 06.39″

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Value of Semi major axis and semi minor axis were given as 20,922,931.80 feet and 20,853,374.58 feet, respectively. These values were converted into meters using different conversion factors resulting in many values of a and b of Everest spheroid. The official conversion factor from feet to meters for India is 0.3047996 and should be accepted.

It is estimated that the center of Everest spheroid is about 1 km away from the center of gravity of the earth; hence it is not a geocentric datum. We therefore conclude that it is inaccurate system and needs redefinition. The present datum is especially not suited for many geodetic, geodynamic, geophysical and defense applications. In absence of redefinition of Indian Geodetic System/Datum, the Survey of India has recommended to use World Geodetic System 1984 (WGS84). Ground check has been done at some points with GPS and Open Series maps have been published. With WGS84 our maps may differ say by 5-10 m in central India but may be by a kilometer in NE India. Ramchandran (2000) mentions that the difference could be up to 1 km. In view of this, a project to redefine Indian Geodetic Datum was taken up in 1989 but nothing much appears to have been done so far. Redefinition project should be taken up and given highest priority. It should be time bound and completed in 2 to 3 years. In USA a similar project was taken up in 1974 by National Geodetic Survey and completed in 1983. It is known as NAD 83 and is used for all applications including Geodynamics and defense (https://www.ngs.noaa.gov › CORS › Articles › WGS84NAD83).

3. Horizontal Control

Horizontal datum in India is Indian Geodetic Datum based on Everest Spheroid as reference surface as mentioned in previous paragraph. Existing horizontal control in India is the result of Great Trigonometrical Survey of India consisting of 5 blocks with 2700 stations and 10 bases. Triangulation series were started from Kalyanpur. The Indian subcontinent was divided into five parts region-wise, four quadrilaterals (NW, NE, SW, SE) and the Southern Trigon. The quadrilaterals could not be adjusted together due to computational limitations at that time. Several corrections viz. for deflection of vertical, skew normal and geodesic also could not be applied. In 1937-38 an attempt was made to readjust the triangulation network but this also suffered from the same limitations. Though densification of control and filling of gaps has been done in addition to observation of more bases and Laplace stations, no fresh adjustment has been carried out. This has resulted in the various series of maps being inconsistent with each other. The horizontal control is therefore burdened with varying degrees of errors; say from a few meters to as much as 100 meters at places. Many stations are however supposed to be of 1st order that is 1 in 50,000 accuracy. Most of the stations of this control are on hills covered by jungles. Many stations have been destroyed and many others are in poor condition, hence not suitable for geodynamic studies and zero/1st order geodetic horizontal control. The need therefore is to provide complete horizontal control of zero and 1st order afresh and adjust it by least squares for the whole country at one go, using available scientific adjustment software. BIGADJUST, the software used by National Geodetic Survey of USA has been obtained by Survey of India to adjust the present control but the same has not been completed and it is not known as to what are their plans regarding this.

It is suggested, that in addition to redefinition of Indian Geodetic Datum a project should be planned to provide horizontal control of zero, 1st and 2nd order throughout India. The following steps are suggested: -

1) Identify places for monuments. Care should be taken to choose places suitable for geodynamic studies also. Rooftops of permanent public buildings can also be chosen in preference to hilltops in many cases, as the control will now be provided using GPS.
2) Design suitable monuments and carry out construction of monument pillars. It should be seen that pillars are fixed to bedrocks to be suitable for future geodynamic studies.
3) Design network and observe all vectors using dual frequency geodetic GPS receivers in relative positioning mode.

4) Process the data using scientific software such as Bernese.

5) Adjust the data by least squares using network adjustment software such as BIGADJUST.
6) Compile the data in a suitable format for use for various purposes and for dissemination to public.

4. Vertical Datum and Height Control

In India, the vertical datum for heights has been chosen as the **mean sea level** at a group of nine tidal observatories situated at various Indian ports. Hourly tidal observations were carried out at these ports for a number of years and averages obtained.

It was assumed that the mean sea level at these ports, belong to the same sea level surface. All these ports served as issue points for the first level net of India. Leveling net in India consists of first level net of moderate precision covering 18,000 miles started in 1858, and second level net of 16,000 miles based on first level net. Second level net was adjusted on to first level net wherever necessary. We can see clearly from the above that assumptions were incorrect. Precision was moderate and adjustment was not carried out properly. Choice of vertical datum was not unique and creates confusion. Gravity observations were not carried out which is necessary for National Level Nets of high precision and 1st order accuracy. The present heights are thus in varying degrees of error and are not of present day standards. These cannot be used as basis for geodynamic studies and many geodetic and geophysical studies where 1st order vertical control is required. It is therefore suggested that a fresh vertical datum be adopted and vertical control of 1st and 2nd order be provided by spirit leveling along with gravity observations. The following steps are suggested: -

1) Select a tidal observatory where hourly tidal observations of 18.6 years cycle of successive nodes of the moon are available. Construct a few permanent benchmarks near the observatory in stable and protected area. Provide heights of these benchmarks by 1st order spirit leveling from the chart datum to the benchmarks. These benchmarks should be taken as issue points for the fresh leveling network of India. The mean sea level obtained here should be the National Mean Sea Level for India at this observatory. Tidal observatory at Mumbai port may be chosen for obtaining the mean sea level. Design the network and construct the benchmarks along the routes selected for leveling in phases. Leveling of 1st order should be carried out along-with gravity observations using relative gravimeters throughout India.
2) Carry out adjustment of the network by least squares at one go and document the heights along with description of benchmarks.
3) Construct a few permanent benchmarks near other tidal observatories also. Find mean sea level at these observatories also and provide heights of the benchmarks constructed near the observatories from the chart datums of such observatories by 1st order leveling. These will represent the local mean sea level in those areas. There will be some difference between the national mean sea level heights and local mean sea level heights. The difference can be applied to heights in that area wherever needed based on sound statistical analysis. Scientific analysis of various mean sea levels and heights may be carried out for geoidal, geodynamic and geophysical studies.
4) All the monuments constructed for zero and 1st order horizontal control, should also be connected by 1st order spirit leveling. Monuments constructed for geodynamic studies should also be similarly connected.

5. Gravity Datum

Presently we do not have a gravity datum in India. The National Base Station of Gravity is at Dehra Dun. The gravity values at the base station were first provided by Lenox Conyngham from Kew reference station using Potsdam pendulums. The value obtained was 979.063 cm/sec^2. The values of Dehra Dun base station were again provided in 1906, 1913, 1924, 1929, 1932, 1939 and 1948. The last value, provided by Woolard and Gulatee by taking absolute gravity value from Washington to Delhi and other places in India using Worden and Frost gravimeter is 979.063 cm/sec^2. Minimum

value is 979.054 of 1924 and maximum 979.085 of 1932. It can be seen from this that the gravity observations were not very reliable even for the National gravity base station. The spread of observations is 31 mgal and it is interesting to note that 1904 and 1948 values are the same. A precise gravity network of 42 stations was established in 1971 by Survey of India covering airports of the country with an uncertainty of + or – 0.05 mgal. These stations served as reference for future gravity surveys in India. This gravity network was adjusted within the framework of International Gravity Standardization Net 1971 (IGSN 71). La-Coste and Romberg model G gravimeters were used for observations.

For some years NGRI, Hyderabad has been operating absolute gravity meter for scientific research. We have to plan establishment of absolute gravity datum in India and connect existing gravity stations to the absolute gravity station/stations as we can see from the above paragraph that gravity values in India are not so reliable. It is hoped that NGRI will take leading part in this project. All first order horizontal control monuments and 1st order leveling bench marks should be connected to gravity network so as to have 1st order gravity values. This will facilitate precise repeat gravity observations for geodynamic applications such as 1) Detection and interpretation of vertical ground motion for earthquake precursor study. 2) Monitoring and interpretation of post earthquake motion. 3) Postglacial rebound studies. 4) Monitoring of movement of magma in volcanic areas along with leveling. 5) Reservoir depletion studies of all kinds. 6) Tectonic motions and crustal warping studies.

6. Indian Geoid

Presently no satisfactory Indian geoid is available. To obtain heights above MSL with GPS we need a geoid, which can give geoidal undulation accuracy of about 25 to 50 cm or better. It is therefore necessary that a project should be taken up to determine Indian geoid by gravimetric as well as by astro-geodetic methods.

7. Projection for Maps

All topographical maps in India are on polyconic projection. Assumptions and approximations applied to it make it a mockery if we say that a projection has been adopted. The sheets on 1:25,000; 1:50,000; and 1:250,000 topographical sheets are individually projected assuming that distortion along meridians can be neglected. There is no distortion along parallels. Besides these, the meridians and parallels are joined by straight lines. This means that it is not a projection. It amounts to assuming that the earth is flat in respect of individual sheets. It has created a lot of problems in integration of different maps, compilation of maps, digitization and hence in GIS. National Map Policy has since been adopted; Open series maps are to be on Universal Transverse Mercator (UTM) projection on WGS 84 datum.

USA has adopted NAD 83 and not WGS 84. Likewise many other countries have adopted their own datum. It is not proper to adopt UTM projection for India, as all six degree zones covering India have origins on equator and not in our own country. Northing values in these zones become very high which is not desirable. We should design suitable zones in Transverse Mercator or Lambert Conformal Conic or both as in USA and have origins of zones in India. In place of WGS 84 accepted in the Map Policy, we should define our own Indian datum and adopt it for mapping. Further, It is also recommended that each state in India or combination of two are three small states be designed and adopted so that each state has only one coordinate system for all mapping in that state specially for cadastral maps.

In case UTM is adopted for states as in Andhra Pradesh we may have as many as three UTM zones resulting in three coordinate systems in one state which will present difficulties and will be nightmare for all those dealing with these coordinates and maps.

8. Indian Grid

Grids are superimposed on maps for easy reading of distance and angles. Indian grid was designed during British days dividing India into 9 zones in Lambert Conformal Projection. The grid is not satisfactory as scale error for grid zero is 1 in 650 but 1 in 850 for other grids. Distortion is considered high. We should aim for 1 in 2500 but should not be more than 1 in 1000. Restriction of the grid is also irrational as parameters and all information about it is available to everyone anywhere in the world except in India. There is therefore an urgent need to design grids afresh. We should adopt either Lambert Conformal Conic or Transverse Mercator depending upon whether the area to be projected is greater in E-W extent or N-S extent. The present grid on maps of border areas with hostile neighbours is a security risk. We should immediately adopt a new grid immediately in such areas for our maps. Further it will be appropriate if a separate grid is adopted by each state of India. Some such grids have already been designed e.g. for Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra etc. by the author.

Concluding Remarks

Geodetic Infrastructure in India is the same as provided prior to independence. All further work is based on this infrastructure, which is thoroughly inadequate for mapping requirements to support rapid development, growth, defense and scientific research viz. geodynamical studies, crustal movements, plate tectonics and earthquake prediction research.
In view of what is stated above, the following recommendations are made:

1. Transverse Mercator or Lambert Conformal Conic projection should be adopted.
2. Construction of appropriate monuments for horizontal control. The monuments could be at every 50 km of zero order (maximum error of 1 in 2,50,000), every 20 km of 1st order (1 in 50,000), every 10 km of 2nd order (1 in 20,000), every 5 km of 3rd order (1 in 5,000), and every 2 km of 4th order (1 in 2,000).
3. In place of WGS 84 accepted in the Map Policy, we should define our own Indian datum and adopt it for mapping with desired accuracy.
4. A national Committee of experts be formed to examine the above issues and come out with recommendations within a specified time-frame.
5. National Geodetic Institute be established at the earliest to supplement the geodetic activities of Survey of India.

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