# Challenges of Current National Reference Frame (NRF) and Map Sheet Layout in Nepal Cadastral Mapping

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## KEYWORDS

*Cadastral Survey, National Reference Frame, Projection System, Transformation Parameter*

## ABSTRACT

*Systematic Cadastral mapping in Nepal used to be carried out using local coordinates. Later National Reference Frame (NRF) and a map sheet layout is being used to improve the situation. Current trend of use of GNSS in establishing control points demands a set of transformation parameters. The coordinates in NRF which are obtained by transforming the GNSS results, does not give expected accuracy to be used for large scale mapping. In addition, map sheet layout is being used not in line with the guidelines due to complications at the margins of projection zones. The conclusion is the current NRF and map sheet layout is not appropriate to use further for large scale mapping – which demands improvements in reference frame as well as projection system.*

## 1. BACKGROUND

Systematic cadastral surveying and mapping in Nepal started in year 1964/65 (Dhakal, 2021) after enactment of Land (Survey Measurement) Act, 1963. During those periods, mapping was based on so called "Local Reference Frame", in which base lines were established locally. These maps are termed as "Island Maps". Use of National Reference Frame (NRF) was not in place. The basis for integration of these maps are the common objects in adjoining maps and their shapes at the map boundaries. This job is not possible in the areas where accumulation of error is considerably high or mapping of neighboring area is absent. In summary, due to absence of geometric basis for georeferencing, integrating such maps is cumbersome task and sometimes impossible.

For overcoming such issues, mapping in the remaining areas has been initiated using coordinates in NRF. An institution was established for establishing nationwide control network of NRF and develop geographic information base, initially with the name "Trigonometrical Survey Branch" in 25 September 1970. Later, name was changed to "Geodetic Survey Division". The division is under the national mapping organization (NMO) of Nepal – "Survey Department".

Details of establishment of control points in NRF and use of map sheet layout for mapping at different scales have been specified in Triangulation Instruction Book (DOS, 1976) as described below in sections 2 and 3 respectively.

This study tries to identify - how the NRF and map sheet layout is being currently implemented and what are the challenges present in actual practices. The study has been limited to limitation of map sheet layout design (specifically in the zone margins) and NRF.

## 2. NATIONAL REFERENCE FRAME

For surveying and mapping, NRF and a set of square grid map sheet layout have been adopted. For this purpose, Everest 1830 ellipsoid was used with semi-major axis a = 6, 377, 276.345 m., semi-minor axis b = 6, 356, 075.413 m. and inverse flattening 1/f = 300.8017. The NRF is adopted based on Transverse Mercator (TM) Projection with zones of 3° longitudinal widths (Krakiwsky, 1973). Three such zones have been considered for covering whole area of the Nepal. The central meridians of those zones are 81° E, 84° E and 87° E (Figure 1) with extents of 79°30’ - 82°30’ E, 82°30’ - 85°30’ E and 85°30’ - 88°30’ E; and zone numbering as 44.0, 44.5 and 45.0 respectively. The scale factor at each of the central meridians is 0.9999.

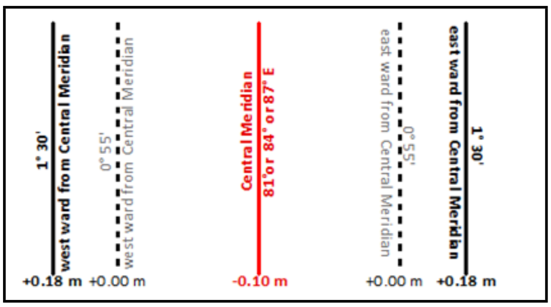


*Figure 1: Transverse Mercator Zones.*

In each of the zones, distortions per kilometer at the central meridian, at the meridians where the projecting cylinder intersects with the ellipsoid (which are at 0°55’ apart eastward and westward from central meridian), and at the edges (which are at 1°30’ apart eastward and westward from central meridian) are taken as the values -0.10 m., 0.00 m. and +0.18 m. respectively. Since wider zone consist larger distortion, the modified version of the UTM system (MUTM) with three zones was adopted.

## 3. MAP SHEET LAYOUT

Coordinate extents of each of the zones is between 350000-650000 m. in easting and 2900000-3400000 m. in northing, each of which spaces has been divided into square grids of 50 km. X 50 km. wide. This resulted in forming 10 rows and 6 columns for each zone. Numbers from 001 to 060, 061 to 120 and 121 to 180 have been assigned to respective grids of the zones starting at north west corner and ending at south east corner (Figure 2).

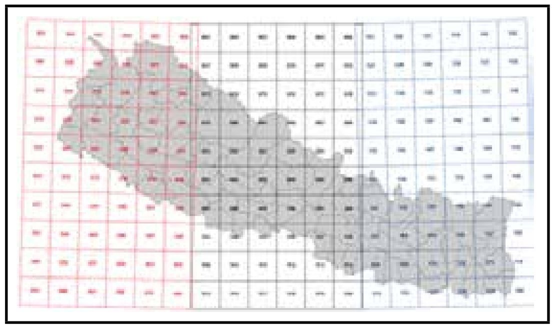

*Figure 2: Grids of 50 Km X 50 Km.*

Large scale maps are defined to be from 1:2,500 to 1:500. One of the grids of 50 km X 50 km is divided into 40X40 grids to form total 1600 grids of 1,250 m X 1,250 m sheets for mapping at a scale of 1:2,500 (Figure 3). Assignment of number for these sheets started from 0001 at the north-west corner to 1600 at the south-east corner assigning the map sheet number for first grid as 102-0001 and for last as 102-1600.

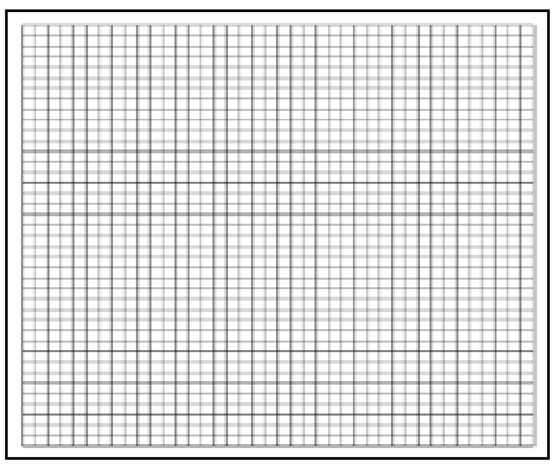

*Figure 3: Grids for mapping in scale 1:2500*

One of the sheets of 1,250 m. X 1,250 m. is divided into 4 sheets of 625 m X 625 m for mapping at a scale of 1: 1,250. Assignment of number for these grids starts from 1 at the north-west corner and ends at 4 in the south-east corner (Figure 4) assigning the map sheet number for first grid as 102-0001-1 and for last as 102-0001-4.

| | |
|---|---|
| 1 | 2 |
| 3 | 4 |

*Figure 4: Grids for mapping in scale 1:1250*

In the similar manner, same sheet of 1,250 m X 1,250 m is divided into 25 grids of 250 m X 250 m for mapping at a scale of 1:500. Assignment of number for these grids starts from 01 at the north-west corner and ends at 25 in the south-east corner (Figure 5) assigning the map sheet number for first grid as 102-0001-01 and for last as 102-0001-25.

| | | | | |
|---|---|---|---|---|
| 01 | 02 | 03 | 04 | 05 |
| 06 | 07 | 08 | 09 | 10 |
| 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 |

*Figure 5: Grids for mapping in scale 1:500.*

Map sheet numbering system has been designed in such a way that, for any map whose sheet number (identifier) is known, then its scale, the grid number to which it belongs and the subsequent map sheet can also be identified. For example, if a map has an identification number 085-0254 then the scale of the map is 1: 2,500 and its source grid is 085. If a map identification number is 085-0254-3 then its scale is 1:1,250, its source grid is 085 and its source map sheet at scale 1: 2,500 is 0254. In a similar manner, if a map identification number is 085-0254-13 then its scale is 1:500, it belongs to grid 085 and source map sheet at scale 1: 2,500 of 0254. Apart from this, the location coordinate of a specific map sheet can also be calculated.

## 4. CONTROL POINTS, COORDINATES AND TRANSFORMATION PARAMETER

For mapping an area, a network of control points has to be established and accurate coordinates of those are needed. During previous periods, traditional technologies such as triangulation, trilateration, traversing were used for such purpose. Recent trend is to use modern technology like GNSS to establish control networks. From the accuracy, economy and time perspective, this technology is efficient which is based on WGS84 Spheroid (with parameter values a = 6, 378, 137.000 m., b = 6, 356 752.314 m. and 1/f = 298.2572). From the use of GNSS technology we can expect relatively higher level of accuracy.

As the ellipsoids of current NRF and GNSS system are different, a set of transformation parameters are needed for transforming coordinates between the two systems. Based on the observation on existing control network, a set of computed transformation parameters to transform coordinates from WGS84 to Everest 1830 has been calculated using Bursa-Wolf method (Manandhar, 2015) as shown in table 1.

*Table 1:Transformation parameters.*

| | | |
|---|---|---|
| *Translation* | | |
| *dx=124.3813* | *dy=-521.6700* | *dz=-764.5137* |
| *Rotation* | | |
| *X=-17.1488"* | *Y=8.1154* | *Z=-11.1842* |
| *Scale factor=2.1105 ppm* | | |

*(Source: Manandhar, 2015)*

Manandhar (2015) identified the difference between the existing and computed values of coordinates as 0.77912 m. (minimum), 2.7737 m. (maximum) and 0.872848 m. (average) and also, suggested that these parameters are well enough to map at the scale of 1: 3,500 and smaller, and a need of further improvement of the parameters.

Other sets of parameters are from ESRI which is published and used in its software system. 3 sets of parameters for converting coordinates between the above-mentioned systems are defined (ESRI, 2012) as shown in table 2.

*Table 2: Transformation parameters from ESRI.*

| | | |
|---|---|---|
| *WGS_1984_To_Nepal_Nagarkot _1_EPSG (Method: Geocentric Translation)* | | |
| *dx=-293.17 m* | *dy=726.18 m* | *dz=-245.36 m* |
| *WGS_1984 _To_ Nepal_Nagarkot_1 (Method: Geocentric Translation)* | | |
| *dx=-296.00 m* | *dy=732.00* | *dz=-273.00 m* |
| *WGS_1984 _To_ Nepal_Nagarkot_2 (Method: Geocentric Translation)* | | |
| *dx=-296.207 m* | *dy=731.245 m* | *dz=-273.001 m* |

ESRI also has published the list of accuracies of these parameters as: 0.30 m, 10 m and 5 m respectively.

## 5. SHEETS AT THE EDGES OF TWO ZONES

The cadastral map sheets at the margins of two projection zones with central meridians 81° E and 84° E covering the part of Rolpa District (Figure 6) is considered for this study. Black line is the boundary between zones. Coverage of this district is the limits of grids 030, 036, 085 and 091. The grids 030 and 036 are in the zone with central meridian 81° E. and the grids 085 and 091 are in that with central meridian 84° E. Between these two zones, almost 5 map sheets of 1: 2,500 scale are overlapped to each other. As the map is in the projection system with central meridian of 84° E, grids those lying in this zone is aligned with the coordinate system where as grids in neighboring zone is not aligned with coordinate system (map is prepared by taking TM projection with 84° E. as central meridian).

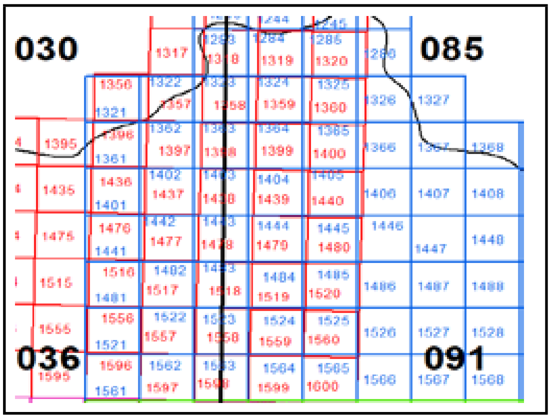


*Figure 6: Sheet lying at the edges of two zones.*

## 6. IMPLEMENTATION OF SHEET LAYOUT

Cadastral maps of Rolpa district are prepared in the scale of 1: 2,500. Figure 7 is the map sheet layout used for cadastral surveying in Rolpa District. This implementation of sheet system has been taken as the key example in current study for analysis.

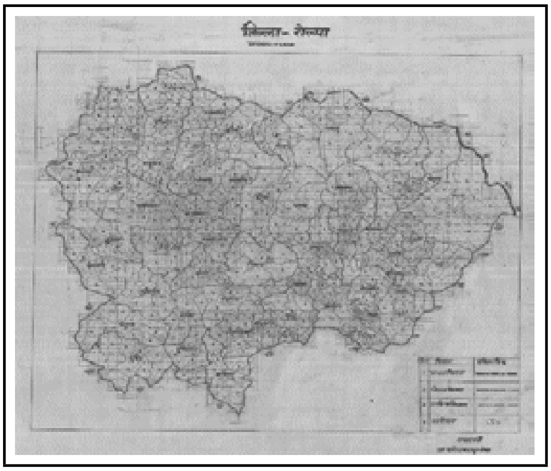

*Figure 7: Sheet layout of cadastral map of Rolpa.*

*(Source: Survey Office, Rolpa)*