Karnataka GIS Spatial Framework

KSRSAC

Karnataka State Remote Sensing Applications Centre
Dept. of IT, BT and S&T, Government of Karnataka

July, 2016

KARNATAKA GIS
SPATIAL FRAMEWORK

ಕರ್ನಾಟಕ ರಾಜ್ಯ ದೂರ ಸಂವೇದಿ ಅನ್ವಯಿಕ ಕೇಂದ್ರ

Karnataka State Remote Sensing Applications Centre

Dept. of IT, BT and S & T, GoK

July, 2016

Contributors:

Mr. MohammedSaleem.I.Shaikh

Mr. PI.K.Namboodri

Mr. B.V.Suresh

Mr. Arun Kumar T D

Dr.S.D.Sujatha

Version Controlled by:

Mr. MohammedSaleem.I.Shaikh

© Karnataka State Remote Sensing Applications Centre

DOCUMENT CONTROL SHEET

Document Number	KSRSAC/K-GIS/DATA CONTENT/01/JULY-2016
Title	K-GIS Spatial Framework
Type of Document	Technical Report
Number of pages	34
Publisher	Karnataka State Remote Sensing Applications Centre
Prepared by	K-GIS Technical Team
Reviewed by	Mission Director, Chairman, Members Technical Committee and Chief Technical Officer
Approved by	K-GIS Technical Committee
Abstract	Spatial framework is a common geographic referenced GIS foundation spatial data on which assembly and maintenance of a seamless coverage of the best available, most current and authoritative, well organized, standardized and quality controlled GIS data. It is frame work of ground control for latitude, longitude and height throughout the state of Karnataka. In this contest a document on to create a spatial frame work for the state of Karnataka consisting of precisely controlled Primary, Secondary, Tertiary, TRPs and CPs to meet the accuracy as defined in the Karnataka Geographical Information System (K- GIS) standards.
Distribution	Unrestricted
Reproduction Rights	This report and its contents are the property of KSRSAC

Contents

Sl.No.	Description	Page No.
1	Introduction	1
2	Elemenents of Spatial Frame work	2
3	Datum and Projection	2
4	Objectives	3
5	Ground Control Points	3
5.1	Primary Control Points (PCPs)	3
5.2	Secondary Control Points (SCPs)	4
5.3	Tertiary Control Points (TCPs)	4
5.4	Terrestrial Reference Points	5
6	Methodology	6
7	Satellite Image Frame	6
7.1	Approaches for Satellite Image Framework	6
7.2	Procedure for preparing image mosaic	7
8	Digital Elevation Model	8
9	Administrative Boundary Frame	8
10	Planning	9
11	Ground Control Survey	10
11.1	Reccee Survey	10
11.2	Observation (SCPs)	11
11.3	Reccee and Observation (TRPs)	12
11.4	Processing Raw Data and Network Adjustment	12
12	Image Georeferencing	12
12.1	Quality Assurance and Quality Control (QA & QC)	13
12.2	GCP Library	13
13	Deliverables	14
14	Instruments	14
15	Phases of Work	15
15.1	Phase - 1	15
15.2	Phase - 2	15
15.3	Phase - 3	16
16	Budget	16
16.1	Budget (Phase-1)	16
16.2	Budget (Phase-2)	16

List of Tables

Table No.	Description	Page No.
1	Accuracy Parameters of Control Points	1
2	UTM Projection Parameters	3
3	Comparative Statement of Errors	13
4	Schedule for Spatial Framework (Phase-1)	17
5	Graphical Representation of Schedule (Phase-1)	17
6	Budget for Collection of TRPs (Phase-1)	18
7	Procurement of Instruments	18
8	Image Georeferencing Cost (Phase-1)	19
9	Total Budgetary Requirement for Spatial Frame Work (Phase-1)	19
10	List of Ground Control Points	19
11	Budget for Collection of SCPs (Phase-2)	20
12	Image Processing Cost (Phase-2)	20
13	Schedule for Spatial Framework (Phase-2)	21
14	Graphical Representation of Schedule (Phase-2)	21
15	Total Budgetary Requirement for Spatial Frame Work (Phase-2)	22

List of Figures

Figure No.	Description	Page No.
1	Network of Primary Control Points (NGCPs)	4
2	Network of Secondary Control Points	4
3	Terrestrial Reference Points	5
4	Cartosat-1 Satellite Image (Path & Row)	7
5	Seamless mosaic Boundary of Karnataka state	7
6	Administrative Boundaries of State	9
7	Reccee Survey of Control Points	11
8	Secondary Control Points Observation Sequence	11

List of Annexures

Annexure No.	Description	Page No.
1	Standard for K-GIS Spatial Framework	23
2	Technical Specifications for GNSS (DGPS) MASTER	27
3	Technical Specifications for GNSS (DGPS) ROVER	30
4	Post Processing Software	33
5	Technical Specification for Digital Level	34

K-GIS SPATIAL FRAMEWORK

1. Introduction

Spatial Framework (SF) is a common geographic referenced GIS foundation spatial data on which assembly and maintenance of a seamless coverage of the best available, most current and authoritative, well organized, standardized and quality controlled GIS data. It is frame work of ground control for latitude, longitude and height throughout the state of Karnataka.

Spatial Framework (SF) is the most critical asset for seamlessness of the spatial database, integration of multi scale spatial data, exchange of geospatial information among government and other organizations of the state. The Spatial Framework consists of datum, projection and bounding limits allows accurate registration, transformation and visualization of the spatial information.

Under K-GIS mission, it is planned to create a spatial frame work for the state of Karnataka consisting of precisely controlled Primary, Secondary, Tertiary, TRPs and CPs to meet the accuracy as defined in the Karnataka Geographical Information System (K- GIS) standards. The Accuracy of Spatial Framework is shown in Table-1 and Frame work Standards are shown in Annexure 1

Table-1: Accuracy Parameters of Control Points

Ground Control Points	Planimetric Accuracy	Height Accuracy
First Order (PCPs)	< 1cm+0.1ppm (< 2 cm)	< 5 cm
Second Order (SCPs)	< 5cm+1ppm (< 10 cm)	< 15 cm
Third Order	< 10cm+1ppm (< 25 cm)	< 25 cm
TRPs / CPs	< 0.4 m	< 0.5 m

The following layers constitute the spatial framework for K - GIS

- Ground Control Library consisting of Primary, Secondary & Tertiary Control Points
- Terrestrial Reference Points & Check Points (TRPs & CPs)
- Administrative Boundaries
- Digital Elevation Model (DEM) layers
- Ortho corrected images

The TRPs can also be used as a reference for higher resolution (sub meter) imagery.

The source for K-GIS database layers shall be from satellite images, maps and ground surveys data using DGPS technologies. It is very much important to spatially reference across these sources, to avoid inconsistency and mismatch in geometry and integration of features. This is ensured by developing a spatial framework and making it available to the users. The Spatial Framework of Karnataka shall be in line with India's Spatial Framework.

2. Elements of Spatial Framework

The elements of frame work are,

- **Datum and Projection-**The WGS-84 datum will be used with UTM projection.
- **GCPs –** Ground Control Points consists of PCPs, SCPs, TCPs and Bench marks.
- **TRPs-**Reference point for the "anchoring" of each geographical lat/long coordinates to a "precise" location.
- **DEM –** Digital Elevation Model layer
- **Boundary layer–**Administrative boundaries with in the state of Karnataka
- **Seamless satellite image -** Ortho rectified Cartosat-1 image covering the state

3. Datum & Projection

Spheroid / Ellipsoid is defined by either semi major axis **a**, semi minor axis **b** or by semi major axis **a** and flattening **f**, **f** being a small quantity, usually 1/f is considered as a parameter. f= (a-b)/a. All other parameters can be derived from these. The above parameters are known as datum of the spheroid specified.

Projection is the science of converting the spherical earth surface to a plane surface. No projection can do this perfectly. Some distortion will always occur. Properties that distorted are angles, areas, directions, shapes and distances. Each projection distorts one or more of these while maintaining others. In a map, the shape, direction and distance should be maintained as precisely as possible. The state of Karnataka is covered under UTM zones 43N and 44N. The salient projection parameters are given in Table-2.

Table-2 UTM Projection Parameters

Spheroid	WGS 84	
Datum	WGS 84 a=6378137.0 m 1/f=298.257223563 Height in meter above MSL / Ellipsoidal	
Projection	UTM	
Zone	43 N	44 N
False Easting	5,00000 m	5,00000 m
False Northing	0 m	0 m
Central Meridian (Longitude)	75.0 deg	81.0 deg
Latitude Of Origin	0.0 deg	0.0 deg
Scale Factor	0.9996	0.9996

4. Objectives

The objective of K-GIS Spatial Framework (SF) is to create a common geographic referenced GIS foundation spatial data frame work for Karnataka to use as basic layers in GIS application by all departments in the state and prepare a seamless mosaic of Orthorectified and georeferenced Cartosat-1 images.

5. Ground Control Points

Ground control points are reference points marked /established on the ground whose co-ordinates are known. Primary and Secondary Control Points are generally permanent in nature with constructed monuments. Tertiary, TRPs and Check Points are temporary points.

5.1 Primary Control Points (PCPs)

Survey of India (SOI), the National Survey and Mapping Organization has established 21 high precession ground control points which are 100-150 km apart in Karnataka as part of NGCP network. These NGCPs are considered as PCPs. Details of these points will be collected from SOI and be used for establishing a network of Second order of control which are termed as SCPs. PCPs (NGCPs) are shown in Fig. 1

5.2 Secondary Control Points (SCPs)

Secondary Control Points shall be established about 30-50km apart throughout the state with reference to PCPs to provide a closer network of control points. The 131 SCPs established by SOI and 70 points established by DT&CP in 34 towns which are 30 - 50 km apart shall be used as SCPs. In addition to these another 135 SCPs will be established to ensure that a strong network is created with well distributed secondary points. (Refer Fig. 2)

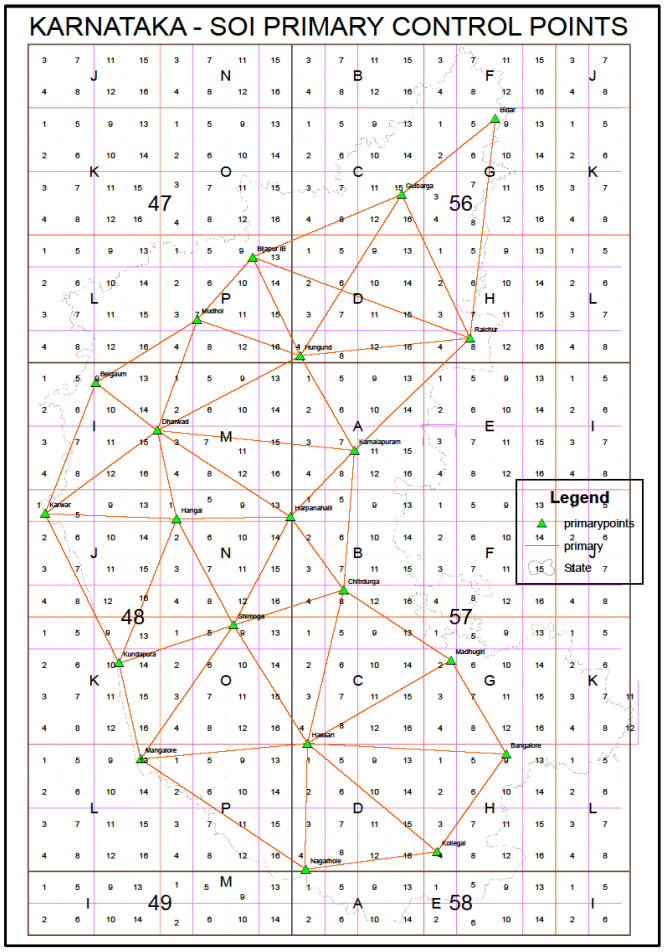

Fig. 1Network of Primary Control Points (NGCPs)

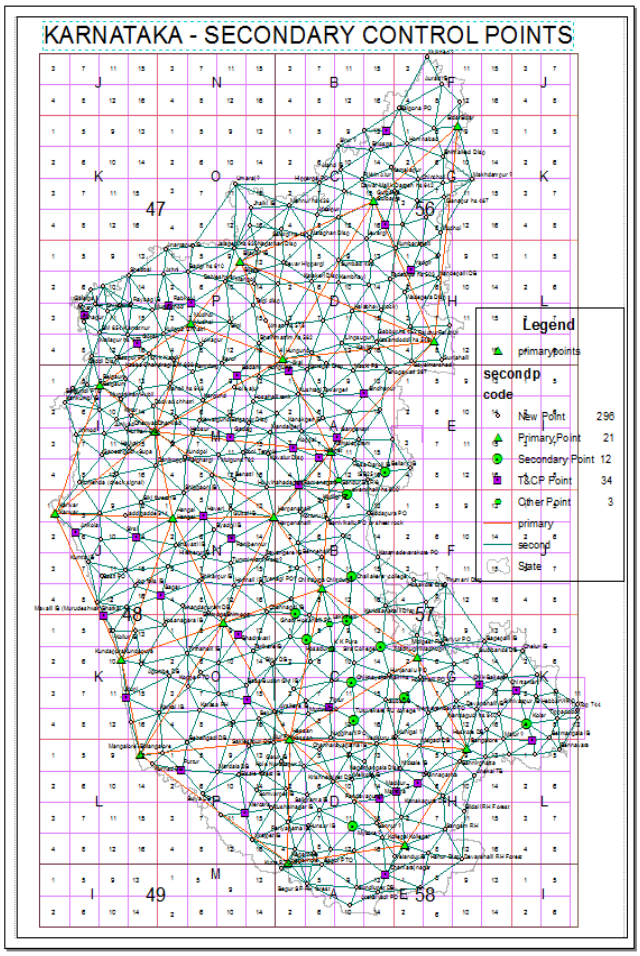

Fig. 2 Network of Secondary Control Points

5.3 Tertiary Control Points (TCPs)

The Tertiary Points generally 5 – 10 km apart, may be established as per the requirement of departments, which may not be permanent in nature. These can be established by K-GIS as and when required, hence not projected at present.

5.4 Terrestrial Reference Points (TRPs)

A Terrestrial Reference Points provides a set of coordinates of some points located on the Earth's surface.

The geographical area of Karnataka State is 1, 91,791 sq.km and is covered by 460 scenes of Cartosat-1 satellite images. 9 – 10 unambiguous sharp, clearly visible as well as easily identifiable on the ground and well distributed points are planned on Cartosat-1 image. The TRPs are spaced on the ground at 13 - 15km interval. Thus, a total of 3200 points including check points (CPs) are planned for establishment of the TRPs. Refer Fig 3.

TRPs /CPs are the identifiable points on the earth's surface and also on satellite image like road intersection & similar locations. The guideline for selecting locations on the earth's surface for good TRPs are:

- Intersection of parcel boundaries / field bunds
- Intersections of river/stream banks with parcel boundary
- Intersection of roads and canals
- Any other sharp points which are visible both on the image as well as on the ground.

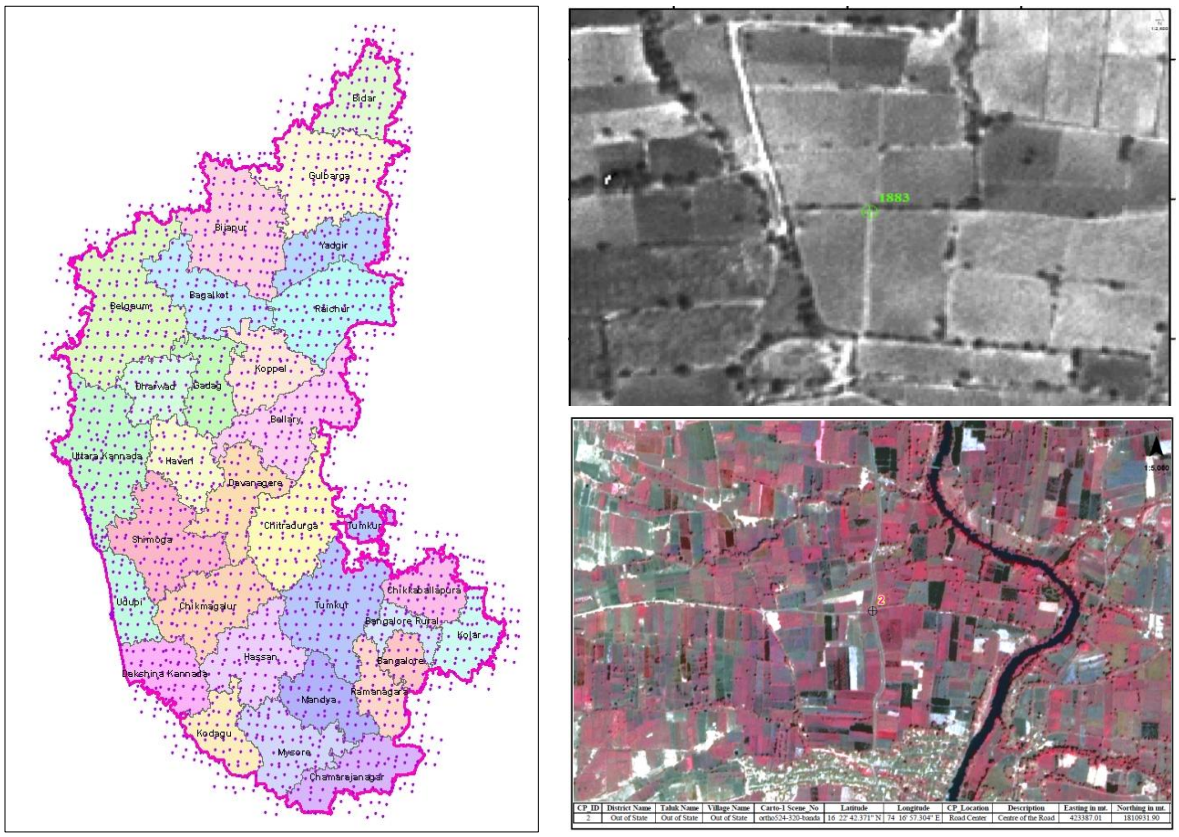

Fig. 3 Terrestrial Reference Points

6. Methodology

21 NGCPs points established by SOI will be used as reference points (PCPs) in K-GIS spatial framework. Sufficient Secondary Control Points (SCPs) shall be planned along with Primary Control Points to build a triangular network in Karnataka. Each base will be observed in static mode of DGPS technologies. Duration of observations shall be decided by considering the distance of baselines. The observed data will be processed using an appropriated software.

Primary Control Points (PCPs) will be used as references / base stations using GSM /GPRS RTK mode. TRPs/CPs will be observed within 100 km from base stations. Using of RTK mode, have the following benefits:

- Corrected results are achieved immediately without post processing
- Solid, reliable communication between base and rover
- Directly connecting from PCPs to TRPs
- Requires less time for observation, hence faster the work
- Real-time locating system
- Eliminate establishment of densified control points

7. Satellite Image Frame

Imagery is derived from sensor technologies used to detect, locate, classify and record objects relative to the surface of the Earth. Raw data collected from a satellite is processed and ortho rectified to remove tilt, terrain, atmospheric and other image distortions.

The primary objective of preparing Satellite Image Frame is to generate, archive and disseminate seamless Ortho-images in usable units. (Typically, Tiles with 3”45’x 3”45’ extent). Cartosat-1 stereo imagery will be used to prepare state wide mosaiced ortho images to serve as a spatial frame work image layer for Phase 1. Refer Fig.4 & 5

7.1 Approaches for Satellite Image Framework

- Ortho-rectified Cartosat-1 satellite imagery, 2.5m resolution, shall be georeferenced with TRPs and shall be mosaiced to create the state wide frame work layer for Phase-

1. High resolution satellite images will be used for phase -2 with sub meter spatial resolution. K - GIS will procure satellite images and update periodically.

- The fusion of imagery with additional datasets is a significant component of its value, creates a detailed mosaic of information to be exploited and allow identification of key features of interest. Imagery data forms a fundamental input for assessing land cover and land use mapping, along with assessing environmental and land use changes.
- Imagery will be 'stacked' in time sequences, which will improve the ability of users to analyze the effects of land degradation, flood damage, deforestation across time.

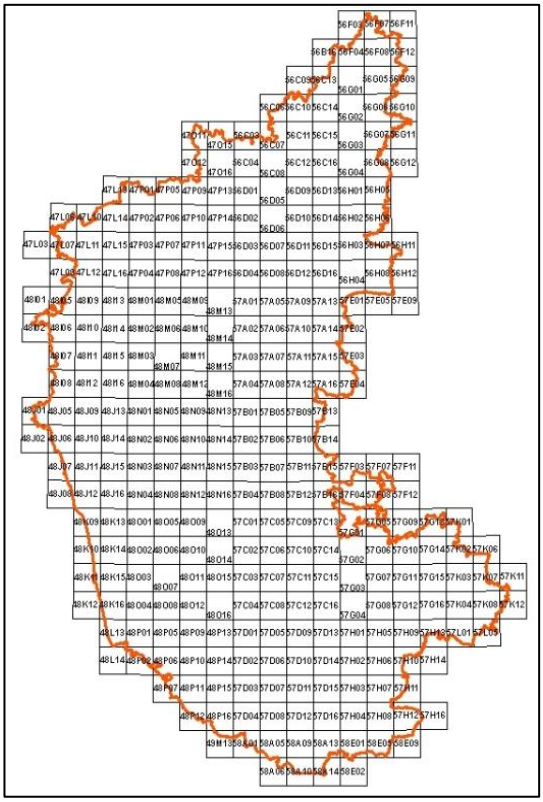

Fig 4 Cartosat-1 Satellite Image (Path & Row)

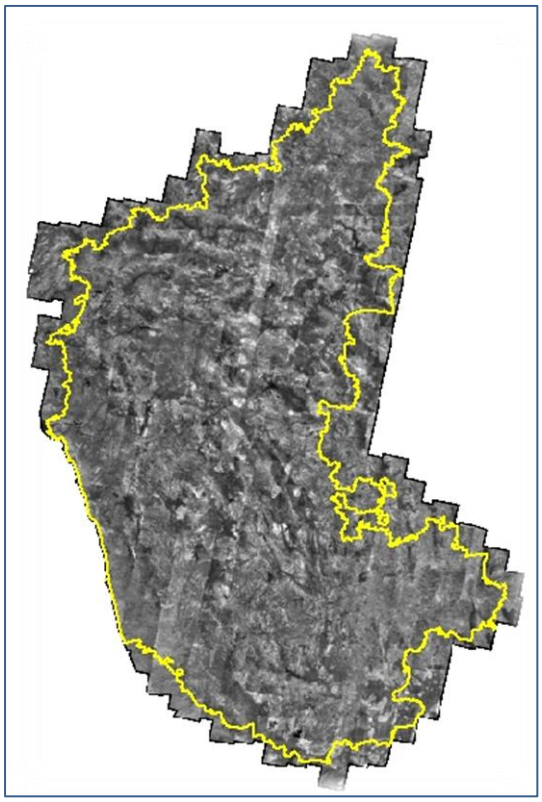

Fig. 5 Seamless mosaic Boundary of Karnataka State

7.2 Procedure for preparing image mosaic

The following steps will be carried out for preparing Mosaicked Cartosat-1 images

- Organizing of ortho rectified Cartosat-1 images of Karnataka
- Image Georeferencing

- Quality Assurance & Quality Check,
- Create a seamless mosaic of the image for the state of Karnataka.

8. Digital Elevation Model

Digital elevation models (DEMs) are a 3D representation of the Earth's surface, devoid of all natural and vegetation and man-made features above ground surface. DEM provides an authoritative digital representation of the Earth's surface enabling evidence-based decision-making, policy development and an essential reference to other datasets. Key uses of DEM data include flood risk management, safe hydrographic, aeronautical and road navigation, climate science, emergency management and natural hazard risk assessment, defense and national security operations, natural resource exploration, exploitation and conservation and agriculture and precision farming. A 10m spaced DEM data is included in the spatial frame work.

9. Administrative Boundary Frame

The Boundary layers helps to determine link of the repository to administrative limits and allow integration of large amount of administrative GIS databases that are available for the state. All the layers available in K-GIS data base shall be registered to administrative boundaries and help the users, to limit their mapping activities to their administrative zones.

Boundaries are un demarcated on the ground. However the administrative boundaries of the State, Districts and Taluks are available at 1:1Mile in Dept. of SSLR. These will be obtained from SSLR and used in creating the administrative boundary frame.

The administrative boundaries of the State, Districts and Taluks are also available at 1:50k in the Survey of India (SOI) open series topographic maps with WGS84 datum and UTM projection.

From the digital data obtained, seamless mosaic of administrative boundaries of State, Districts & Taluks will be prepared by K - GIS as separate layers of SSLR and SOI. Refer Fig.6.

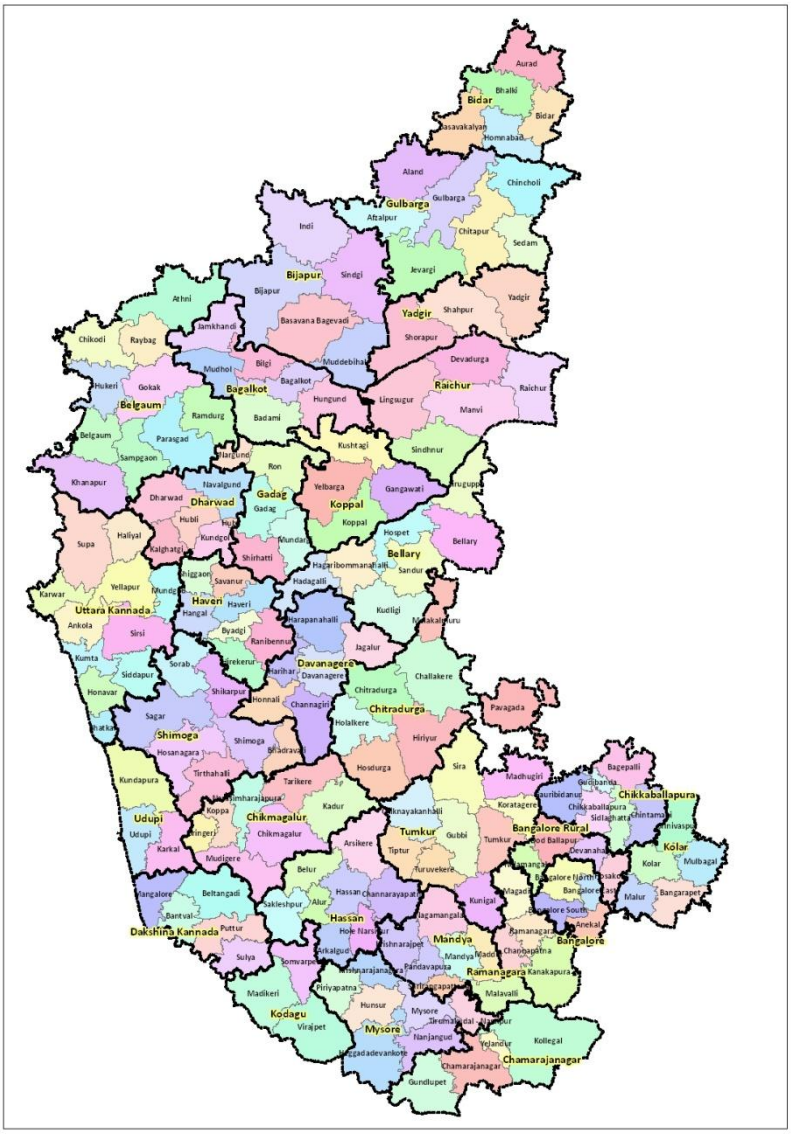

Fig.6 Administrative Boundaries of State

10. Planning

The following steps are involved in planning:

- Collection of data of NGCPs established by SOI (Co-ordinates and Descriptions)
- Collection of SCPs established by SOI (Co-ordinates and Descriptions)
- Collection of Bench Marks established by SOI and also from DT&CP
- Collection of Control points from other Dept.'s (KFD, SSLR, DTCP Etc.)
- Planning of new SCPs wherever required
- Reccee of existing and PCPs and SCPs (existing and new)
- Preparation of Observation Schedule

- Collection of Cartosat-1 satellite images
- Procurement of High Resolution (sub meter) Satellite images
- Selection of TRPs and CPs
- Prepare Enlarged print for post pointing of TRPs and CPs
- Workout requirements of instruments and its availability

The available NGCPs (PCPs), SCPs and control points collected from other department will be plotted. State boundary will be superimposed. Additional points where necessary will be selected to have a better network adjustment that connects all PCPs and SCPs. Available Bench Marks shall also be connected to the series.

Schedule is shown in Table-3 and Graphical Representation of schedule is shown in Table- 4 for Phase 1. Schedule is shown in Table-12 and Graphical Representation of schedule is shown in Table- 13 for Phase 2.

11. Ground Control Survey

Control survey broadly covers Reccee, Observation and Processing of raw data and Network Adjustment

11.1 Reccee Survey

- The purposes of doing reconnaissance survey is to:
- Identify the PCPs (NGCPs) / selected SCPs on the ground with help of description
- Identify a best access to the point
- Check the suitability for DGPS observation and clear the obstacles, if any
- Establish / Construct new monuments for control points/mark on ground as suitable
- Prepare proper sketches and mark the exact position on image with name / numbers
- Make Cairon or heap of stones for future identification / protection
- Prepare a field report and description of the station

All the PCPs (NGCPs) will be visited on the ground for identification and to verify its existence. Existing SCPs shall be verified & new ones shall be constructed. Refer fig. 7

Fig.7 Reccee Survey of Control Points

11.2 Observation (SCPs)

Observations are planned for 2 – 4 hrs. at each station connecting as a network of triangles. The schedule of observations by individual receivers will be prepared after reccee. This will help the observers to move in the field without confusion. A complete diagrammatic representation is shown in fig. 8.

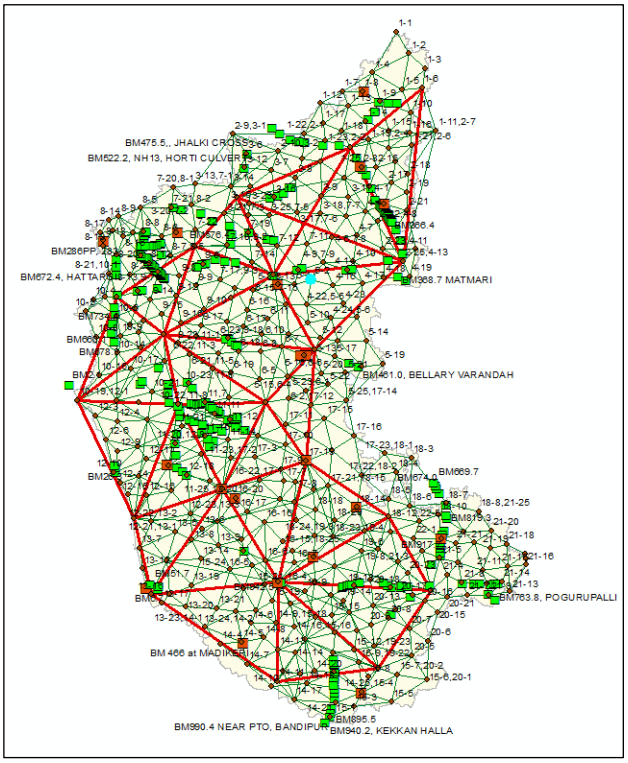

Fig.8. Secondary Control Points Observation Schedule

11.3 Reccee and Observation (TRPs)

Simultaneous Reccee and observations in RTK mode are planned for TRPs / CPs with reference PCPs. The position of the point shown on the image for TRPs shall be identified on the ground and temporary mark will be made with nail and washer before starting the observation. Necessary measurements to the landmarks in the close vicinity of the point also shall be recorded. Proper sketch will be prepared for each point.

11.4 Processing of Raw Data and Network Adjustment

DGPS observations at PCPs and SCPs will be processed and network adjusted using available DGPS data processing software. Observed data will be downloaded from the DGPS receivers and loaded in the project file. Raw data shall be rectified for multipath disturbance etc. and base line processing shall be done with “fixed” solution. Precise orbit data of satellites (.sp3 files which will be available after 15 days on internet) will be downloaded from the internet and the base lines shall be recomputed using these data. Loop closure checks will be carried out. Free Network adjustments (without control points) shall be carried out before carrying out final constrained least square network adjustments. All observed PCPs will be considered as fixed stations in the final adjustment.

Though there is no need to re-compute and adjust the co-ordinates of TRPs/CPs, DGPS observations of TRPs/CPs can be computed and adjusted using data processing software for a check.

12 Image Georeferencing

It is the process of assigning spatial coordinates to data that is spatial in nature, but has no explicit geographic coordinate system. Individual scenes will be georeferenced and create seamless mosaic of the entire state using TRPs by Image processing software.

Terrestrial Reference Points (TRPs) are particularly important for geometric correction of high resolution satellite images. The high resolution satellite image can be geometrically corrected using the Terrestrial Reference Points (TRPs).

The TRPs helps in modeling the precise relationship between the images and ground. TRPs are identifiable features located on the earth's surface and satellite imagery whose ground coordinates i.e., X, Y and Z are derived by DGPS observation w.r.t. the PCPs.

12.1 Quality Assurance and Quality Control (QA & QC)

The internal accuracy of ortho rectified and mosaicked cartosat-1 imagery shall be checked before using as Spatial Framework element in K - GIS. Well distributed 900 check points shall be made available as part of TRPs collections for checking the internal accuracy. All the check points collected from the field will be properly tabulated with planimetric co-ordinates. These will be plotted and superimposed over the images where the points are already marked. The difference of points already marked on the image and the points plotted in the field shall also be tabulated. From the above data, errors and error pattern can be determined. A comparative statement of errors are shown in Table-3.

Table-3 Comparative Statement of Errors

Sl.no	Point ID	Field co-ordinates		Image co-ordinates		Difference		Remarks
		CP X	CPY	I X	IY	DX(CPX- IX)	DY (CPY-IY)	
1	CP1							
2	CP2							
3	CP3							
4	CP4							
5	CP5							
6	CP6							
7	CP7							
8	CP8							
9	CP9							
10	CP10							

12.2 GCP Library

The major objective of the K - GIS project is to populate the database with coordinates of the GCPs along with associated information. Each GCP/ TRPs record in the database consists of GCP/TRPs metadata information like ground coordinates its accuracy, description, zone, nearby features and image information in the form of field sketch, topo map, field photographs and satellite image chips which can be used for future reference.

- The GCP Libraries mainly consist of the following in soft and hard copies
  - Primary Control Points (PCPs)
  - Secondary Control Points (SCPs)
  - Tertiary Control Points (TCPs)
  - Terrestrial Reference Points (TRPs)
  - Check Points (CPs)
- Each GCPs consists of the following
  - Field sketch of the Location
  - Co - ordinates (spherical and grid coordinates)
  - Image chips
  - Field photographs

13. Deliverables

After completion of the project, the following shall be submitted to K - GIS mission:

- GCP Library - (Phase 2)
- QA/QC report – (Phase 1)
- Adjustment report – (Phase 2)
- Rectified and mosaiced image with 3”45’ X 3”45’ tiles – (Phase 1)
- Administrative boundary layers containing State, Districts and Taluks boundaries – (Phase 1 & 2)
- GCP & TRP layers – Geodatabase / Shape file – (Phase 1 & 2)

14. Instruments

K-GIS have planned to establish spatial framework using DGPS with RTK Technologies. To speed up and complete the entire task in a stipulated time, it is proposed to procure 5 Master and 20 Rover receivers. The technical specifications are given in Annexures 2, 3, 4 & 5.

15. Phases of Work

Full control work in Karnataka will take much time to complete. This will delay the availability of spatial framework image layer to other tasks which shall cause the delay in completion of the project. To speed up the work and to make the image layer available early, it is decided to carry out the work in two phases.

15.1 Phase - 1

In phase-1 the following activities will be taken up to deliver the image frame early:

- Procurement of PCPs (NGCPs)
- Procurement of Instruments
- Recce of PCPs (NGCPs)
- Planning of TRPs & CPs
- Reccee and Observation of TRPs & CPs
- Processing of Raw Data and Adjustment
- Creation of TRPS & CPs Library
- Image Georeferencing
- Administrative Boundary layers of SOI
- Submission of Deliverables

15.2 Phase - 2

At present, GSM/GPRS RTK mode technology is used to establish TRPs with sub meter positional accuracy from PCPs as base stations (100 – 150 km apart). The Primary Control Points can be further densified with Secondary and Tertiary Control Points as the requirement of other departments. Virtual Reference Stations or Real Time Differential (RTD) stations can also be established at a suitable interval apart (say 60 or 100km) which can be utilized by Revenue, Forest, Town and Country Planning, Municipal Administration and other departments efficiently.

In Phase-2 the following activities shall be taken up:

- Procurement of SCPs
- Recce and Monumentation of SCPs

- Planning of new SCPs
- Observation of SCPs
- Processing of Raw Data and Network Adjustment
- Image Processing (High resolution)
- Creation GCP Library
- Administrative Boundary layers from Dept. of SSLR
- Submission of Deliverables
- Proposal for setting up of VRS/RTD stations in Karnataka

15.3 Phase-3

Establishment of Tertiary Control Points (TCPs) as per the requirement of the department

16. Budget

The ground control work will be carried out in two phases. Hence the budget is also shown in two parts

16.1 Budget (Phase-1)

- The budget for TRPs is shown in Table-6
- The budget for procurement of instruments is shown in Table-7
- The budget for image process is shown in Table-8
- The Overall budget for Spatial Framework which includes establishing of TRPs, Procurement of Satellite Image & Procurement of Instruments is shown in Table-9

16.2 Budget (Phase-2)

- The Budget for collection of SCPs is shown in Table-11
- Image Processing cost are shown in Table – 12
- Schedule for Spatial Frame work is shown in Table-13
- Graphical Representation of Schedule is shown in Table-14
- Total Budget requirement is shown in Table-15

Annexure-1

STANDARD FOR K - GIS SPATIAL FRAME WORK

Standard defines frameworks for specifying and classifying the accuracy of coordinates and the spatial relationships between them. Accuracy is a measure of the difference between data and its standard or accepted value. The purpose of this standard is to specify an accuracy classification framework for coordinates and spatial relationships that can be used by other KGIS standards to ensure the consistent specification and reporting of the accuracy of different geospatial datasets.

This standard specifies accuracies for horizontal, vertical and for both. Error is the difference between an observed or calculated value of a quantity and its accepted value or true value.

Network accuracy is a value that represents the uncertainty of a coordinate relative to a datum. Local accuracy is a value that represents the uncertainty of a coordinate relative to other coordinates nearby.

The network accuracy of a coordinate must be quantified at the 95% confidence level.

$$HE_{95} = \frac{2.45}{\overline{2}} \quad \overline{\sigma x^2 + \sigma y^2} \text{ at the 95 \% confidence level}$$

Where:

σx, σy are the standard deviations of a horizontal coordinate in the *X* and *Y* Dimensions.

$$VE_{95} = 1.96\ \sigma x \text{ at the 95 \% confidence level}$$

where:

σx is the standard deviation of a vertical coordinate in the *X* dimension.

For linear adjustment of levelling, maximum permissible errors are calculated as below:

Double Tertiary Levelling: 12 $\overline{k}$ mm

Single Tertiary Levelling: 24 $\overline{k}$ mm

Where 'k' is distance in kilometres.

The three-dimensional network accuracy of a point must be calculated using:

$$SE_{95} = \frac{2.80}{\overline{3}} \quad \overline{\sigma x^2 + \sigma y^2 + \sigma z^2} \quad \text{at the 95 \% confidence level}$$

Where:

σx, σy, σz are the standard deviations of a three-dimensional coordinate in the *X, Y* and *Z* dimensions.

The local accuracy threshold between coordinates in a class must be specified using:

$LE_{95} = \sqrt{c^2 + (Dp)^2}$

where:
c is a constant term, expressed in metres,
d is the distance between the two coordinates being evaluated, expressed in metres and
p is a distance dependent term, expressed in ppm.

Category is a categorisation of a coordinate's network accuracy.
Class is a categorisation of a coordinate's local accuracy.
Order is a combined categorisation of a coordinate's local and network accuracy.

Table: CATEGORY

Category	**Accuracy(m)**
A	0.05
B	0.10
C	0.15
D	0.20
E	0.25
F	0.35
G	0.50
H	0.75
I	1
J	2
K	5
L	10
M	20
N	50

Table: CLASS

Class	**Constant term (c)** (m)	**Distance dependent term (p)** (m)	**Distance (d)** (km)
I	0.003	$1x10^{-7}$	100 - 150
II	0.003	$3x10^{-7}$	30 - 50
III	0.010	$1x10^{-6}$	30 - 50
IV	0.010	$3x10^{-6}$	30 - 50
V	0.050	$1x10^{-5}$	5 - 10
VI	0.050	$2x10^{-5}$	5 - 10
VII	0.050	$3x10^{-5}$	5 - 10
VIII	0.100	$1x10^{-4}$	1 - 5
IX	0.100	$2x10^{-4}$	1 - 5
X	0.100	$3x10^{-4}$	1 - 5
XI	0.500	$1x10^{-3}$	1 - 5
XII	0.500	$2x10^{-3}$	1 - 5
XIII	0.500	$3x10^{-3}$	1 - 5
XIV	1.0	$4x10^{-3}$	1 - 5
XV	1.0	$5x10^{-3}$	1 - 5
XVI	1.0	$1x10^{-2}$	1 - 5

Table: ORDER

Order	Purpose	Horizontal category	Horizontal class	Vertical category	Vertical class
1	National reference frame - PCP	A	I	A	III
2	Regional -	B	III	B	III
3	Regional/cadastral - SCP	C	III	C	V
4	Local/cadastral/BP	D	IV	E	VI
5	Local/cadastral – TCP/BP	E	VI	F	VII
6		F	VII	G	VIII
7	TRP/CHP (High)	F	VIII	G	VIII
8	TRP/CHP (Cartosat-1)	G	VIII	G	VIII
9		H	VIII	H	IX
10		I	IX	I	X
11		J	X	J	XI
12a		-	-	-	-
VERTICAL – ORTHOMORPHIC/MSL					
M1	National height control – GTS BM	-	-	B	III
M2	Local – DT BM	-	-	C	IV
M3	Local – ST BM	-	-	E	VI
M4	Local – PWD/Canal BM	-	-	F	VII
M5	Local – Others BM	-	-	F	VIII
M6b		-	-	-	-

a Order 12 includes all coordinates that do not achieve the order 11 requirements
b Order M6 includes all coordinates that do not achieve the order M5 requirements

Assigning Rules

1. Each Category must be defined by an accuracy threshold and unique identifier.
2. Each Class must be defined by an accuracy threshold and unique identifier.
3. When assigning a coordinate to a class, local accuracy must be assessed against all other coordinates of the same or higher class within a specified radius.
4. A coordinate may only be assigned to a class if all local accuracy assessments are numerically smaller than the threshold for that class.
5. A coordinate must only be assigned to an order if it achieves both the category and class standards for that order.

Instrument Specifications

- DGPS Master with RTK
- DGPS Rover with RTK
- Processing Software
- Digital Leveler

Annexure-2

Technical Specifications for GNSS (DGPS) MASTER

Sl No	Characteristics	Specifications
1	**Measurements**	
	Satellite tracking	Should be capable for tracking GPS L1C/A, L1,L2 Full cycle carrier, L2C,L5; GLONASS L1,L2,L3; al GALELIO; BEIDOU; SBAS; (GAGAN) Preferably also IRNSS
	No of channels	200 or more, capable of tracking more than 60 satellites simultaneously
	Measuring mode	Static, PPK, Real time kinematic, stop and go
	Measurement technology	High precision multiple co relater for GNSS measurement for low noise, low multipath error. Receiver should be capable to log the data without controller in internal removable memory of GNSS receiver
	Sampling rate	1 to 60 seconds or better, selectable
	Masking angle	Any angle, selectable
	Initialisation time	< 10 seconds
2	**Accuracy**	
	High precision static	
	Horizontal	3mm +0.1ppm or better
	Vertical	3.5mm +0.4ppm or better
	PPK + RTK	
	Horizontal	10mm +1ppm or better
	Vertical	20mm +1ppm or better
	Code	
	Horizontal	0.25m +1ppm or better
3	**Antenna (geodetic accuracy)**	Multi frequency, high gain integrated / external antenna with sub mm phase centre repeatability
4	**General & Accessories**	
	Power port	Minimum 1 number for external power supply with input voltage/polarity protection Automatic swapping between internal and external power sources without affecting data recording
	Other ports	RS232, USB, data, blue tooth, GSM slot,
	Network and Wireless	GSM/GPRS/EDGE

	connectivity	CDMA Wi-Fi Bluetooth
	Real Time correction protocol	RTCM 2x, RTCM3x, CMR, CMR+
	Internal Batteries	Needs to supply required number of batteries for each receiver to last for 10 hours field operation or more
	Operating Temperature	-40 degree C to +60degree C
	Storage Temperature	-40 degree C to +70 degree C
	Humidity	100% condensing and IP 68
	Drop	With stands pole drop on to concrete/stone up to 1m
	Positioning rate	20 Hz or better
	NMEA	Needs to support
	Internal memory	Minimum 4Gb + SD or micro sd slot(up to 32GB) or better
	Battery charger	External charger must be able to fully charge all batteries in overnight
	RTK compatibility	Should have both integrated UHF and GSM for RTK
	VRS compatibility	Should support VRS
	Blue tooth	Integrated blue tooth to communicate between GPS and controller
	Cables	All necessary connecting cables to be supplied such as a) Antenna to GPS receiver 15m, 5m b) Data cable c) charging unit & cables d) External battery cable
	Stand/tripod	Wooden stand with centering devices (plumbob) and tightening screw Robust adjustable range pole (minimum 2.5m long) quick release operation and robust bipod
	Tribrach & Adaptor	Tribrach with optical plummet, levelling screws and circular bubble. Appropriate adaptor to attach antenna to Tribrach
	Covers/bag	Heavy duty canvas bags constructed such that they can be closed to protect the top of the tripod with a reinforced solid base and reinforced opening, same type to pole also
	GNSS	Can be used as master or rover as per the requirement in field
	GPRS RTK Kit	RTK using GSM/GPRS for multiple rovers from single/

		multiple bases should be possible. Should have integrated GSM (3.5G or better)/GPRS support for real time correction on field, mail or other internet services. Fully integrated RTK kit complete with all necessary accessories, fittings, cables software etc., for RTK operations using GSM/GPRS or CDMA connectivity Should be provided. Rover station should have the provision to indicate the connectivity with base station. Capable of "on the fly "initialisation. Ability to continue logging data when GSM/GPRS or CDMA connectivity is not available for post processing.
5	Controller	External or integrated
	OS	MS Windows mobile latest version/Android
	Display	4.2" Colour graphical or better, daylight readable, touch screen with back light illumination
	Key board/pad	Full alphanumeric keypad
	Functionality	• Full operator control of receiver functions • Field input of file name, antenna height and type, point ID etc. • Display of battery strength in percentage • Display of date, time and day number • Display of files in memory and available memory • Display of antenna position and PDOP • Display of satellite health, rise and set time • Display of satellite elevation, azimuth and signal to noise ratio (signal strength) • Display position co-ordinates in spherical and grid
	Controller on board software	Should support for survey style configuration, multitasking, co-ordinate system manager, colour graphical, COGO, stakeout, back ground map, transfer data between field and office, data storage and user friendly menu driven.
		Each GNSS set includes receiver, antenna, GSM/GPRS RTK Kit, controller, all accessories, soft-wares, manuals etc.
6	Technical evaluation	Instrument precision and accuracy of the result shall be checked against the standard base lines
7	Warranty and Maintenance agreement	Minimum 5 years warranty is required In case of supplier fails to rectify the system within 7 days from the date of filing the complaint, alternative similar/compatible system should be provided as a stand by the supplier during the warranty period at free of cost
8	Training	Training of officers at customers site for a required period (decided by mutually)

Annexure-3

Technical Specifications for GNSS (DGPS) ROVER

Sl No	Characteristics	Specifications
1	**Measurements**	
	Satellite tracking	Should be capable for tracking GPS L1C/A, L1,L2 Full cycle carrier, L2C,L5; GLONASS L1,L2,L3; al GALELIO; BEIDOU; SBAS; (GAGON) Preferably also IRNSS
	No of channels	200 or more, capable of tracking more than 60 satellites simultaneously
	Measuring mode	Static, PPK, Real time kinematic, stop and go
	Measurement technology	High precision multiple co relater for GNSS measurement for low noise, low multipath error. Receiver should be capable to log the data without controller in internal removable memory of GNSS receiver
	Sampling rate	1 to 60 seconds or better, selectable
	Masking angle	Any angle, selectable
	Initialisation time	< 10 seconds
2	**Accuracy**	
	High precision static	
	Horizontal	3mm +0.1ppm or better
	Vertical	3.5mm +0.4ppm or better
	PPK + RTK	
	Horizontal	10mm +1ppm or better
	Vertical	20mm +1ppm or better
	Code	
	Horizontal	0.25m +1ppm or better
3	**Antenna (geodetic accuracy)**	Multi frequency, high gain integrated, external antenna with sub mm phase centre repeatability
4	**General & Accessories**	
	Power port	Minimum 1 number for external power supply with input voltage/polarity protection Automatic swapping between internal and external power sources without affecting data recording
	Other ports	RS232, USB, data, blue tooth, GSM slot

	Network and Wireless connectivity	GSM/GPRS/EDGE CDMA Wi-Fi, Bluetooth
	Real Time correction protocol	RTCM 2x, RTCM3x, CMR, CMR+
	Internal Batteries	Needs to supply required number of batteries for each receiver to last for 10 hours field operation or more
	Operating Temperature	-40 degree C to +60degree C
	Storage Temperature	-40 degree C to +70 degree C
	Humidity	100% condensing and IP 68
	Drop	With stands pole drop on to concrete/stone up to 1m
	Positioning rate	20 Hz or better
	NMEA	Needs to support
	Internal memory	Minimum 4Gb + SD or micro SD slot(up to 32GB) or better
	Battery charger	External charger must be able to fully charge all batteries in overnight
	RTK compatibility	Should have both integrated UHF and GSM for RTK
	VRS compatibility	Should support VRS
	Blue tooth	Integrated blue tooth to communicate between GPS and controller
	Cables	All necessary connecting cables to be supplied such as a) Antenna to GPS receiver 15m, 5m b) Data cable c) charging unit & cables d) External battery cable
	Pole/Bipod	Robust adjustable range pole (minimum 2.5m long) quick release operation and robust bipod
	Covers/bag	Heavy duty canvas bags constructed such that they can be closed to protect the top of the bipod with a reinforced solid base and reinforced opening, same type to pole also
	Receiver	Dual frequency geodetic real time RTK receiver combined antenna, receiver and display.
	GPRS RTK Kit	RTK using GPRS for multiple rovers from single/ multiple bases should be possible. Should have integrated GSM/GPRS support for real time correction on field, mail or other internet services. Fully integrated RTK kit complete with all necessary accessories, fittings, cables software etc., for RTK

		operations using GSM(3.5G or better)/GPRS or CDMA connectivity should be provided. Rover station should have the provision to indicate the connectivity with base station. Capable of “on the fly “initialisation. Ability to continue logging data when GSM/GPRS or CDMA connectivity is not available for post processing.
5	Controller	External or integrated
	OS	MS Windows mobile latest version /Android
	Display	4.2” Colour graphical or better, daylight readable, touch screen with back light illumination
	Key board/pad	Full alphanumeric keypad
	Functionality	• Full operator control of receiver functions • Field input of file name, antenna height and type, point ID etc. • Display of battery strength in percentage • Display of date, time and day number • Display of files in memory and available memory • Display of antenna position and PDOP • Display of satellite health, rise and set time • Display of satellite elevation, azimuth and signal to noise ratio (signal strength) • Display position co-ordinates in spherical and grid
	Controller on board software	Should support for survey style configuration, multitasking, co-ordinate system manager, colour graphical, COGO, stakeout, back ground map, transfer data between field and office, data storage and user friendly menu driven
		Each ROVER set includes receiver, antenna, GSM/GPRS RTK Kit, controller, all accessories, soft-wares, manuals etc.
6	Technical evaluation	Instrument precision and accuracy of the result shall be checked against the standard base lines
7	Warranty and Maintenance agreement	Minimum 5 years warranty is required In case of supplier fails to rectify the system within 7 days from the date of filing the complaint, alternative similar/compatible system should be provided as a stand by the supplier during the warranty period at free of cost
8	Training	Training of officers at customers site for a required period (decided by mutually)

Annexure-4

Post Processing Software

Sl No.	Characteristics	Description
1	**Post Processing Software**	• One complete set of original software to be supplied with each receiver • Observation configuration software with precision time snapping tool during the observation supporting on all version of windows • Data down loading, conversion software must be compatible on all versions of windows • Capable of importing and exporting RINEX and CAD format data • Facility for creation and application of user defined ellipsoid • Capable for transferring the data from one datum to another for given set of common points with or without the knowledge of datum • Processing software should have the capability to process raw data of different sampling time interval • Processing software should have the capability of merging raw/converted data before processing if desired • Appropriate baseline processing software sufficient to achieve the desired accuracy from different types of satellite data such as GPS, GLONAS etc • Software must be capable of processing all type of satellite data in dual frequency mode • Software must be capable for network adjustment on least square principle • Automatic data processing on different measuring modes i.e. static/fast or rapid, static, kinematic, stop and go, kinematic continuous, PPK • Output all statistical data with result to enable analysis of data quality • Software should have report generation facility • Software should be interactive • Software needs to support feature coding • Software should have COGO functionality • The software should be capable of surface modelling, 3D visualisation and quick contouring • Must have full mission planning software to provide full information on, and plots of satellite visibility, PDOP, GDOP, azimuth and elevation etc • One set of original software on cd/dvd • Full set of software manuals • Upgrades/upgrade/new version to be supported free of cost throughout the service life of the instrument

Annexure-5

Technical Specification for Digital Level

Sl No	Characteristics	Specification
1	Measurement Accuracy per km	±1mm or better with standard staff
	Distance accuracy	±25mm or better for 20m
2	Range	2 to 100m or better
3	Measuring resolution for height	0.1mm or better
4	Measurement Programmes	All standard programmes like line levelling with intermediate sights, stakeout, line adjustment, single measurement with and without stationery etc
5	Methods	All standard methods of levelling should be supported
6	Horizontal circle graduation	400g and 360d interval of one unit with estimation of 0.1 unit or better
7	Telescope	Magnification 25X, aperture 40mm, field view 2m or better
8	Compensator	Inclination range ±15”; setting accuracy <±0.5” or better
9	Circular level	Normal (8½mm) with illumination
10	Memory	1. internal – support recording more than 30,000 data lines 2. External – 16GB usb flash drive/sd card or better
11	Data transfer	USB interface to transfer data from digital level to pc or vice versa
12	Display	Graphical 240 X 160 pixels or better, monochrome/colour with illumination
13	Key Pad	Alphanumeric with special keys as required to operate the instrument
14	Real time clock and Temp.sensor	Record temperature and time for each observation
15	Power supply	Suitable rechargeable power supply with charger and battery, supporting about 3 days observations per charge
16	Operating temperature	-20 to +50 deg C or better
17	Dust and water proofing	IP55 standard
18	Weight	<4kg
19	Levelling staff	Standard staves with pads and appropriate level for positioning vertical
20	Accessories	Any other accessories required
21	Software	Working on windows OS 7 or higher versions, capable line adjustment, network adjustment using least square principles, report generation, export to cad or any other formats

Karnataka State Remote Sensing Applications Centre

Dept. of IT, BT and S&T, Government of Karnataka

"Doora Samvedi Bhavana", Major Sandeep Unnikrishnan Road
Vidyaranyapura Post, Bengaluru -560 097

Tel: 080 29720557/58, Fax: 080 29720556
Email: ksrsac_gok@yahoo.co.in
Website: www.karnataka.gov.in/ksrsac