

1. INTRODUCTION

1.1 Hydrology Project

The Hydrology Project (HP) aims at assisting the Central Government and the participating eight state water resources agencies in the development of valid, comprehensive, interactive, easily accessed, and user friendly data bases covering all important aspects of the hydrological and meteorological cycle; and to provide such data to all legitimate users involved in water resources management. The participating States of Andhra Pradesh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, and Tamil Nadu have improved and expanded the observation network, water quality laboratories and computing facilities for collection, compilation, validation and archival of point measurements of hydrometeorological and hydrological parameters.

Subsequent to the Mid Term Review of the project it is now proposed to enhance the component of Geographic Information System (GIS) in HP.

1.2 GIS in Hydrology Project

Building GIS capability in Hydrology project covers

- a) Hardware, GIS modules in surface and ground water data processing software, and stand-alone GIS systems
- b) Generating minimum spatial data sets relevant to SW/GW hydrology
- c) Georeferencing point measurements
- d) Hydrometeorology/ surface water/ ground water measurements referenced to SOI map coordinates and datum
- e) Upgrading skill sets through training for managers and specialists

1.3 Why GIS

GIS will be used in:

Customised mapping

Individual layers or combination, specific area, and as per specified map specification (scale, projection, legend, etc.)

Spatial analysis

Aggregation of point measurements over specified area unit, interpolation and contouring, inputs for models, and theme overlaying

Querying – user specified

By theme, by spatial feature, by time period, and combination of above

1.4 Objective

To generate GIS data sets on select themes for integration in the Surface and Ground Water Data Centres in 8 participating States, and in the National Data Centres

1.5 Scope

- a) State Ground Water agency will have responsibility within each state for generating and distributing spatial data sets to State surface water agency and Central Water Commission and Central Ground Water Board: State level Technical committee will be constituted to support the activity
- b) Surface water and ground water agencies in each state will integrate data in respective Data Centres
- c) Central Water Commission and Central Ground Water Board will integrate data in the National Data Centres
- d) Data to be generated through outsourcing as per standard methodology before March 2001
- e) Spatial data sets will be in 1:50000 scale in 8 states covered by more than 2600 SOI toposheets; Scale will be 1:250000 at national level

1.6 Methodology Overview and Schedule

The approach to generation of spatial data sets is shown in Fig.1.1 along with the proposed time schedule.

1.7 Procurement Process

Five different procurement actions are involved in the generation of spatial datasets under HP (Table 1.1). The manual addresses only fresh generation of satellite derived digital thematic data and digitization of existing thematic maps.

Table 1.1 Different Procurement Processes

Data Set	Procurement Process
Fresh generation of satellite derived thematic digital data	Competitive bidding
Procurement of existing paper maps and digital data	Direct procurement
Procurement of existing digital restricted topomap data	Direct procurement from SOI after clearance from MOD
Digitization of existing paper maps (including SOI unrestricted maps)	Competitive bidding
Digitization of restricted SOI maps	Direct procurement from SOI, after MOD clearance

1.8 Scope and Organization of Manual

It is proposed to procure services from a large number of vendors in the preparation of spatial data sets. The manual provides technical guidelines for preparation of uniform and consistent spatial datasets by multiple vendors, by standardizing the methodology and input and output

products. It is proposed to conduct orientation workshops for successful vendors in understanding the manual and methodology.

The second chapter provides an overview of spatial data sets : selected themes, input data, output data, and generation methodology. This chapter also covers the spatial database organization (including map tiles and TIC mark Ids) and data specifications in regard to scale, map projection, digitization accuracy, and registration accuracy between layers. Theme-wise chapters cover the classification scheme, input data specifications, methodology flowchart, feature and attribute data coding standards, output file naming convention, internal QC and external QA, and specification for deliverable product.

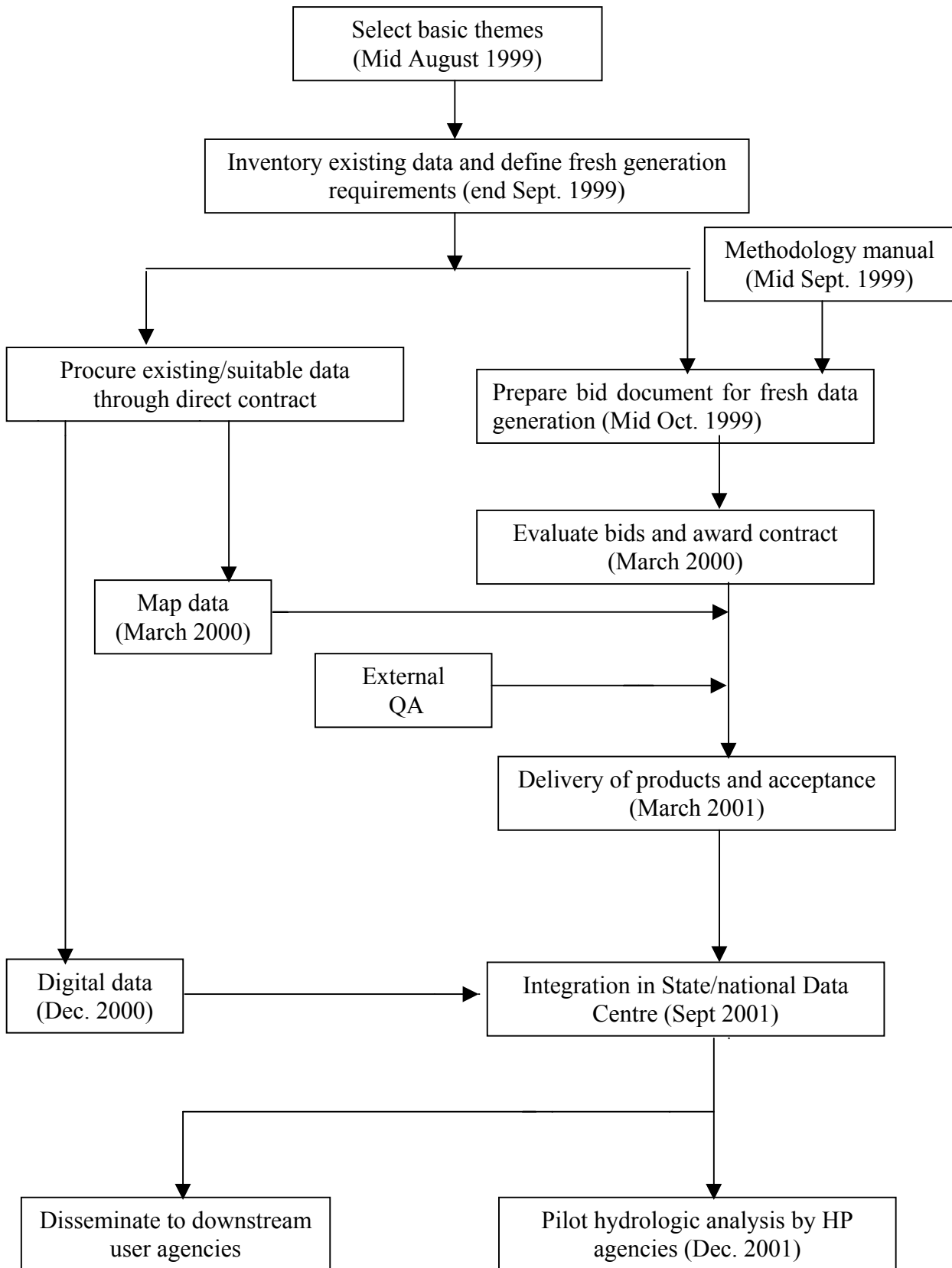
Annexure 1 describes how the classification and map accuracy is estimated.

Annexure 2 describes the standard procedure for digitization.

Annexure 3 describes the internal quality control and external quality audit procedure.

Annexure 4 provide details of the report accompanying each digital map tile including the QC/QA statement (map tile code, generation date, mapping accuracy, thematic accuracy, and digitization accuracy); brief description of input data, generation procedure, and output products; and contact address in vendors office for future follow-up.

Fig. 1.1 Approach to Generation of Spatial Data Sets



2. DIRECTORY OF SPATIAL DATA

2.1 Selection of Minimum Spatial Datasets

The selection of primary themes for minimum GIS data sets will be guided by the relevance and commonality to both surface and ground water component of HP. Surface water analysis requires a minimum set of thematic data on land use, soil, topography and drainage, while GW analysis will additionally require spatial data on geology, geomorphology, structures, lineaments and hydrogeomorphology. General supporting data cover settlements, transport network and administrative boundaries. This only constitutes a minimum spatial data set, considering the time and manpower constraints. For example data on irrigation command areas, canal network and other water use sectors such as industries though useful will be difficult to generate within the balance period of HP. It is envisaged that the minimum data set will be augmented by additional spatial data sets in course of time.

The primary data layers are shown in Fig. 2.1. The last six themes are digitized from existing Survey of India maps (and other maps such as AISLUS National Watershed Atlas and State survey department maps) while the other 5 themes are derived from appropriate satellite data. The directory of spatial data in Table 2.1 lists the themes, input and output data, and generation methodology.

2.2 Inventory of Existing Spatial Data Sets and Fresh Generation Requirements

The extent of fresh data generation requirements will be assessed based on the inventory of existing data sets in map and digital format, generated under national and State programmes (Fig. 2.2). The existing data sets will be reviewed under a set of standard criteria (level of thematic classification, mapping and thematic accuracy, age of data, and availability –Table 2.2) for acceptance in HP. Additional generation of data sets (thematic mapping and digitization, digitization of existing maps and format conversion of existing digital data sets) will be defined for each state. The preparation of these data sets will be as per the standard methodology proposed by HP, to ensure consistency and uniformity amongst the participating States.

Inventory of existing data for possible use in HP will be assisted by technical committees at central and State level. The High Level Technical Group (HLTG) will approve selection of primary themes and classification schemes, methodology manual, bidding procedure and document, and integration of GIS data sets into National and State Data Centres. The State level committee may have representatives from State Ground Water department, Surface Water agency, Central Water Commission, CGWB, Survey of India, GSI and State Remote Sensing Centre. The committee will support the State GWD in conducting inventory of existing GIS data sets, defining fresh data generation requirements, external quality audit of data products, and integration of GIS data sets into the State Data Centre.

2.3 Database Organization

The spatial database for each participating State will be organized with 15 minutes by 15 minutes geographic area, corresponding to a SOI 1:50000 scale map sheet, as the basic map tile. Each map tile will be assigned a unique number, The map tiles covering the state will be precisely identified by superposing the 15 min by 15 min framework on the State map in a suitable scale. Thematic coverage of any specific hydrologic or administrative unit will be generated by digitally mosaicing the map tiles.

Standard and unique TIC Ids will be created for each cross-section of latitude and longitude at 15 minutes interval. All maps will be digitized by taking TIC points at four corners of each 15 minute tile, and the appropriate Id will be assigned. Additional registration points (permanent manmade features) will be digitized to enable co- registration of scanned maps without lat-long details. The registration point Id will be the map tile number followed by a serial number.

All the map sheets (of each theme) in each State will be transformed to the polyconic projection using the central latitude and longitude of projection origin of the State, by using the same *.prj file (text file containing input and output parameters to be used in map projection).

The list and structure of primary data elements are shown in Table 2.3. The code for each primary theme coverage as also the data structure of the Look Up Table (LUT) is listed in respective thematic chapters. Each primary data coverage will be named as for example Landuse54j14 representing the theme and SOI map sheet number, and all associate files will have this identification as the prefix.

Fig. 2. 1 Primary Data Layers

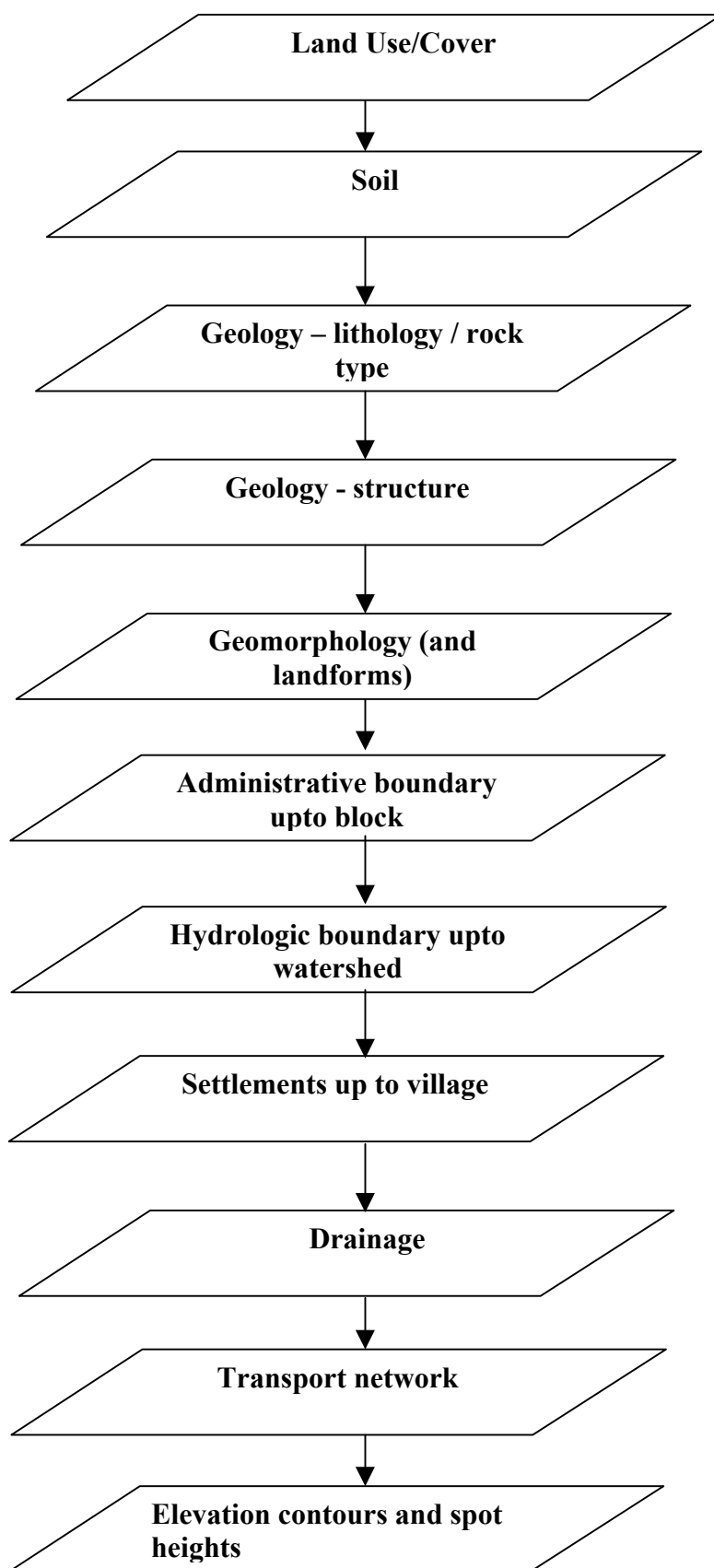


Fig. 2.2 Data Inventory Modality

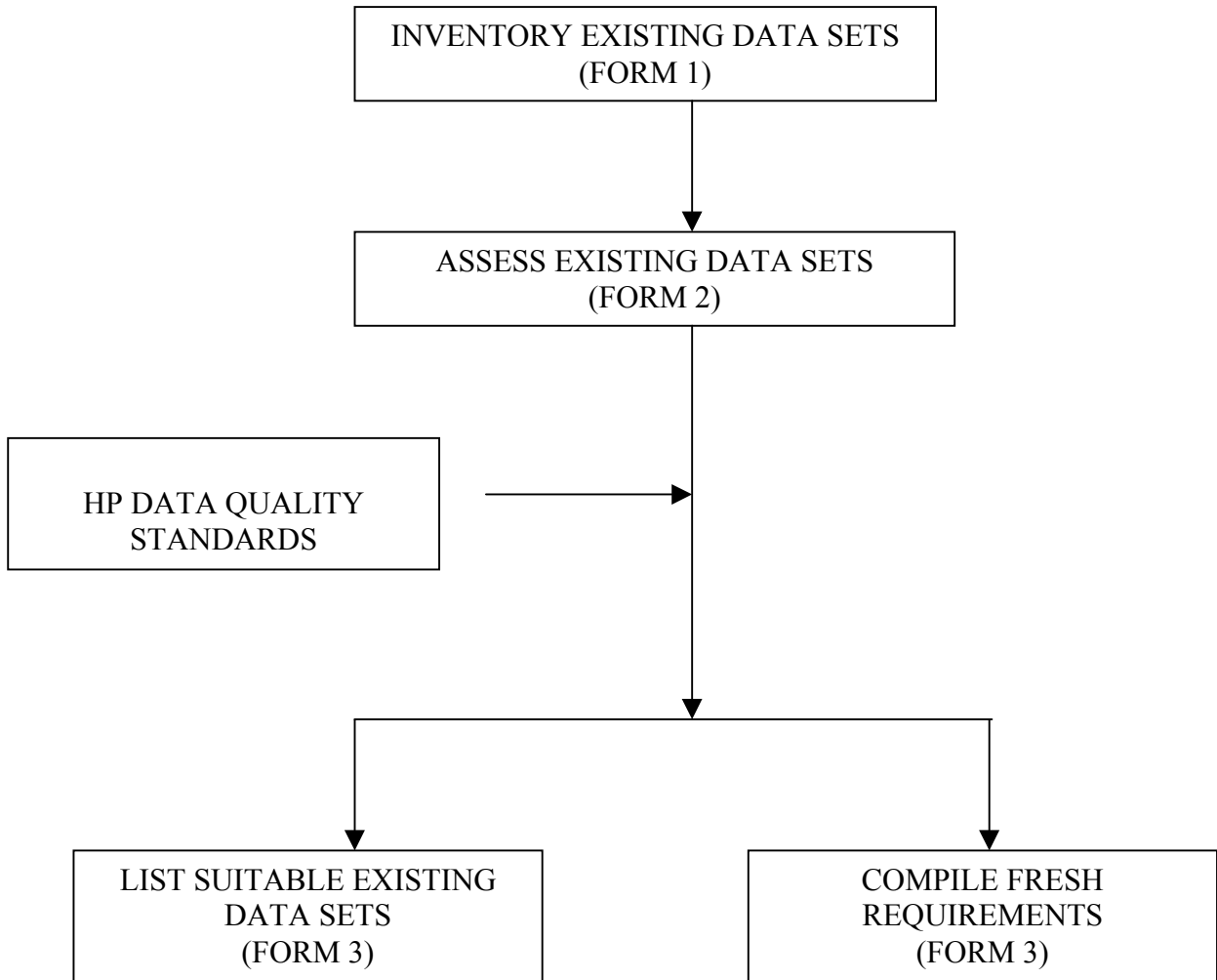


Table 2. 1. Spatial Data Directory

Primary Data	Source of Data	Fresh Generation Process	Output data
1. Land Use/ Cover	IRS Satellite LISS III Sensor	Visual interpretation and digitization	Digital file of spatial data and attribute data upto Level III categories,
2. Soil	IRS Satellite LISS III Sensor	Visual interpretation and digitization	Digital file of spatial data and attribute data of soil categories upto soil series association
3. Geology – lithology	IRS Satellite LISS III Sensor	Visual interpretation and digitization	Digital file of spatial data and attribute data upto lithologic units and local macroscopic features
4. Geology - structure	IRS Satellite LISS III Sensor	Visual interpretation and digitization	Digital file of spatial data and attribute data as per classification
5. Geomorphology	IRS Satellite LISS III Sensor	Visual interpretation and digitization	Digital file of spatial data and attribute data as per classification
6. Administrative boundary	SOI and State survey map	Digitization	Digital file of spatial data and attribute data upto block boundary
7. Hydrologic boundary	Watershed Atlas of India of AISLUS; SOI map in 1:50000 scale	Digitization	Digital file of spatial data and attribute data upto watershed boundary
8. Settlements	SOI 1:50000 scale map	Digitization	Digital file of spatial data and attribute data upto village
9. Drainage	SOI 1:50000 scale map	Digitization	Digital file of spatial data and attribute data of all drainage in SOI map
10. Transport network	SOI 1:50000 scale map	Digitization	Digital file of spatial data and attribute data of all railroad and upto track road
11. Contours and spot heights	1:50000 scale SOI map	Digitization	Digital file of spatial data and attribute data of all 20 m contours and spot heights in SOI map

Table 2.2 . Specifications for Spatial Data in Hydrology Project

Serial No.	Item	Specifications
1	Scale	1:50000
2	Projection	Polyconic
3	<u>Thematic accuracy</u> Minimum spatial unit Classification accuracy	0.01 sq.km 90 percent
4	Mapping accuracy- Planimetric accuracy	25 m
5	<u>Age of thematic map / level of detail</u> Land use (level III) Geology (lithologic units/local macroscopic structures) Geomorphology (landforms) Soil (soil series association) Drainage (as in toposheet) contour (20 m interval) Settlements (upto villages) Transport (upto village /cart roads) Administrative boundaries (upto block) Hydrologic boundaries (upto watershed)	5 years 10 years 10 years 10 years 20 years as in SOI map 5 years (or as in SOI map) 5 years (as in SOI map) Latest (as per State survey Dept) derived from SOI map
6	<u>Digital data specifications</u> Location reference to include lat-long and permanent features Sheet-wise data Coordinate units Pixel resolution Registration accuracy between themes Planimetric accuracy Area Sliver polygon tolerance Weed tolerance Coordinate movement tolerance	 metres 12.5m 1 pixel 2 pixel 0.3 percent 25 sq. m. 12.5 m 12.5 m



Table 2.3 List and Structure of Primary Data Elements

Feature Type	Feature Class	Feature Code	Attribute Table
1. Land Use/ Cover	Poly	LU- Code	LUSE.Lut
2. Soil	Poly	SOIL-Code	SOIL.Lut
3. Geology – lithology	Line	LITH-CODE	LITH.Lut
4. Geology - structure	Poly	STRU-Code	STRU.Lut
5. Geomorphology	Poly	GU-Code	GU.Lut
6. Administrative boundary	Poly	ADMIN-code	ADMIN.LUT
7. Hydrologic boundary	Poly	WS-Code	WS.Lut
8. Settlements Location Extent	Point Poly	SettlP-Code SettlA-Code	SettlP.Lut SettlA.Lut
9. Drainage Minor Streams Major rivers	Line Poly	DRNL-Code DRNP-Code	DRNL.Lut DRNP.Lut
10. Transport network Road/ Rail	Line	TRNPT-Code	TRNPT.Lut
11. Contours	Line	-	-
Spot heights	Point	-	-

3. LAND USE / COVER

3.1 Classification System

The land use / cover map will be prepared as per the classification scheme in Table 3.1. Any category unique to a geographic area and not included in the scheme will be labeled as ‘others – Specific category’.

3.2 Input Data

- IRS LISS III geocoded False Colour Imagery (FCC) in 1:50000 scale of two time periods (Kharif and Rabi season)
- SOI map in 1:50000 scale
- Collateral data in the form of maps, area statistics, and reports

3.3 Methodology

The land use/cover categories will be visually interpreted (based on interpretation key developed for the area) into line maps; the mapped categories may vary from map sheet to map sheet depending on ground conditions. The interpretation process will involve reference to collateral data to enable incorporation of features (such as forest boundaries from SOI map and from State Forest department records) and establish consistency with existing maps and statistics (such as existing maps on land use, wastelands and salinity affected lands and 7 fold land classification statistics of State Revenue department). Delineation of Kharif and Rabi crop lands and discrimination of level II and III categories will require interpretation of two season satellite data. All surface waterbodies (reservoirs, lakes, and tanks) will be mapped from SOI map, and updated for recent constructions with reference to recent satellite data. The extent of waterspread will be as in SOI map, and satellite data for new constructions. The classified map will have standard feature codes (Table 3.1).

Field visits will be organized both for collection of ‘ground truth’ to aid and finalize interpretation, and to estimate the classification accuracy. The interpretation process will be continued till the classification conforms to output data accuracy specifications (Table 2.2).

The overall classification accuracy will be estimated through ‘Kappa Coefficient’, which is a measure of agreement between the classified map and ground conditions at a specified number of sample sites (Annexure 1).

The classified map will be scanned and digitized using an appropriate scanner following standard procedure (Annexure 2). The Arc/Info coverage will be created and edited to remove digitization errors, and the topology will be built. The features will be labeled and coded as defined in the LUSE.Lut (Table 3.1 and 3.2). The coverage will then be transformed into polyconic projection and coordinate system in meters. The transformation process will involve geometric rectification through Ground Control Points (GCPs) identified on the input coverage and corresponding SOI map. The HP data specification standards in Table 2.2 need to be conformed. The resulting GIS coverage will be backed up in CD and labeled with corresponding SOI map sheet number, theme, generating agency, and generation date.

Internal quality control and external quality audit will be at different critical stages of mapping and digitization process (Annexure 3).

3.4 Output Products

Five copies of GIS coverage with appropriate file names and format (Annexure 4) in CD and two B/W hardcopies of thematic map will be delivered by the vendor, alongwith a report (Annexure 5) on input data used, interpretation and digitization process, internal QC statement, and contact address for clarifications.

Table 3.1 Land Use /Cover Classification Scheme/ Code (LUSE.LUT)

Level I	Level II	Level III	LU-Code
1. Built-up land			01-00-00
	1.1(towns and cities)		01-01-00
	1.1 Rural settlements - villages		01-02-00
2. Agricultural land	2.1 Crop land	2.1.1 Kharif cropped	02-00-00
		2.1.2 Rabi cropped	02-01-00
		2.1.3 Double cropped	02-01-01
			02-01-02
	2.2 Fallow		02-01-03
	2.3 Plantations (includes tea, coffee, rubber, arecanut and others)		02-02-00
	2.4 Aquaculture		02-03-00
3. Forest	3.1 Evergreen/semievergreen	1.1 Dense	02-04-00
		3.1.2 Open	03-00-00
			03-01-00
	3.2 Deciduous	3.2.1 Dense	03-01-01
		3.2.2 Open	03-01-02
	3.3 Scrub forest		03-02-00
	3.4 Forest blanks		03-02-01
	3.5 Forest plantations		03-02-02
	3.6 Mangrove		03-03-00
	4. Wastelands	4.1 Salt affected	
4.2 Waterlogged			03-05-00
4.3 Marshy/swampy land			03-06-00
4.4 Gullied/ravinous land			04-00-00
4.5 Land with scrub			04-01-00
4.6 Land without scrub			04-02-00
4.7 Sandy area			04-03-00
4.8 Barren rocky/stony waste			04-04-00
4.9 Others			04-05-00
5. Water			04-06-00
			04-07-00
			04-08-00
			04-09-00
			05-00-00

	5.1 River/stream		05-01-00
	5.2 Reservoir/lake/tank		05-02-00
	5.3 Canal		05-03-00
6. Others			06-00-00
	6.1 Inland wetlands		06-01-00
	6.2 Coastal wetlands		06-02-00
	6.3 Grass land/grazing land		06-03-00
	6.4 Salt pans		06-04-00

Table 3.2 Data Structure

Field Name	Field Type	Field Width	Key
LU- Code	I	8	Y
Lev 1	C	30	N
Lev 2	C	30	N
Lev 3	C	30	N

4. SOILS

4.1 Classification Scheme

The soil categories of each SOI map sheet area will be delineated and coded with reference to the Order, sub-order, Great Group, sub-group, family and soil series and /or associations as per Keys to Soil Taxonomy, Sixth Edition, 1994, USDA Soil Conservation Service. The coding scheme will follow NRIS standard developed by the Department of Space¹. The standard classification scheme and code (SOIL.LUT) is shown for two sample soil units at order level, which can be extended to other units and upto series level.

4.2 Input Data

- Geocoded IRS LISS III FCC imagery of summer scene with minimum vegetation cover; when needed Kharif and Rabi season imagery may be used.
- Collateral information such as existing maps on soil, geology, geomorphology and land use, and climatic data
- SOI map in 1:50000 scale

4.3 Methodology

The interpretation key, based on acquired satellite data and in reference to SOI topographic map and existing geological and geomorphologic map and soil map (in any scale), will be prepared. Physiography units will be delineated, and further stratified into possible soil scapes based on variations in geology, landform, parent material, elevation, slope, aspect, natural vegetation, etc.. Sample strips will be selected based on variability in landform, geology and image interpretation elements. Detailed field investigations (soil profile, minipit and auguring) will be conducted in sample strips. Atleast 20 profiles will be examined in a SOI toposheet area. The actual number of profiles will depend on the variability of terrain. Mini- pit and auger bore data will supplement profile investigations. An objective grid based observations may also be made to avoid bias. Typifying pedons are selected and describes as per standard procedures. Horizon-wise soil samples are collected and analyzed for physical and chemical properties for soil classification. Mineralogical class is established using available information. Meteorological data is used in establishing soil temperature, moisture regimes and preparation of ombrothermic diagrams. Locale specific interpretation key is developed between the physiographic unit/ image interpretation and soil categories based on study of sample strips.

Soil units are delineated by drawing boundaries based on interpretation key and auger bore checking. The soil classes are randomly verified in the field. The legend is finalized on completion of classification validation, and appropriate codes (Table 4.1) are assigned.

¹ National (Natural) Resources Information System (NRIS) – Node Design and Standards, Doc. No. SAC/RSA/NRIS-SIP/SD-01/97, Space Applications Centre, Ahmedabad, April 1997

The overall classification accuracy will be estimated through ‘Kappa Coefficient’, which is a measure of agreement between the classified map and ground conditions at a specified number of sample sites (Annexure 1).

The classified map will be scanned and digitized using an appropriate scanner(Annexure 2). The Arc/Info coverage will be created and edited to remove digitization errors, and the topology will be built. The features will be labeled as per codes/symbols defined in Table 4.1 and 4.2.. The coverage will then be projected and transformed into polyconic projection and coordinate system in meters. The transformation process will involve geometric rectification through Ground Control Points (GCPs) identified on the input coverage and corresponding SOI map. The HP data specification standards in Table 2.2 need to be conformed. The resulting GIS coverage will be backed up in CD and labeled with corresponding SOI map sheet number, theme, generating agency, and generation date.

Internal quality control and external quality audit will be at different critical stages of mapping and digitization process (Annexure 3). Additional quality assurance will include ensuring delineation of all physiographic units at the pre-field stage, study of atleast one profile for each prominent soil series, and post-classification validation over atleast 10 percent of the area using auger bore data and road-cuts.

4.4 Output Products

Five copies of GIS coverage with appropriate file names and format (Annexure 4) in CD and two B/W hardcopies of thematic map will be delivered by the vendor, alongwith a report (Annexure 5) on input data used, interpretation and digitization process, internal QC statement, and contact address for clarifications.

Table 4.1 Standard Soil Classification and Code (SOIL.LUT)

Order	Sub Order	Great group	Sub group	Code
Alfisols	Aqualfs	Linthaqualfs	Typic Plithaqualfs	01-01-01-01
		<u>Natraqualfs</u>	Vertic Natraqualfs	01-01-02-01
			Alabic Glossic Natraqualfs	01-01-02-02
			Glossic Natraqualfs	01-01-02-03
			Millic Natraqualfs	01-01-02-04
			Typic Natraqualfs	01-01-02-05
		Duraqualfs	Typic Duraqualfs	01-01-03-01
		Fragiaqualfs	Aeric Fragiaqualfs	01-01-04-01
			Plinthic Fragiaqualfs	01-01-04-02
			Umbric Fragiaqualfs	01-01-04-03
			Typic Fragiaqualfs	01-01-04-04
		Kandiaqualfs	Arenic Kandiaqualfs	01-01-05-01
			Grossarenic Kandiaqualfs	01-01-05-02
			Plinthic Kandiaqualfs	01-01-05-03
			Plinthic Kandiaqualfs	01-01-05-04
			Aeric Umbric Kandiaqualfs	01-01-05-05
			Typic Kandiaqualfs	01-01-05-06
		Glossaqualfs	Arenic Glossaqualfs	01-01-06-01
			Grossarenic Glossaqualfs	01-01-06-02
			Aeric Glossaqualfs	01-01-06-03
			Mollic Glossaqualfs	01-01-06-04
			Typic Glossaqualfs	01-01-06-05
		Albaqualfs	Aeric Vertic Albaqualfs	01-01-07-01
			Chromic Vertic Albaqualfs	01-01-07-02
			Vertic Albaqualfs	01-01-07-03
			Udolic Albaqualfs	01-01-07-04
			Aeric Albaqualfs	01-01-07-05
			Aquandic Albaqualfs	01-01-07-06
			Mollic Albaqualfs	01-01-07-07
			Durinodic Albaqualfs	01-01-07-08
			Typic Albaqualfs	01-01-07-09
		Umbraqualfs	Aquandic Umbraqualfs	01-01-08-01
			Arenic Umbraqualfs	01-01-08-02
			Grossarenic Umbraqualfs	01-01-08-03
			Ferrudalfic Umbraqualfs	01-01-08-04
			Typic Umbraqualfs	01-01-08-05
		Epiaqualfs	Aeric Chromic Vertic Epiaqualfs	01-01-09-01
			Aeric Vertic Epiaqualfs	01-01-09-02
			Chromic Vertic Epiaqualfs	01-01-09-03
			Vertic Epiaqualfs	01-01-09-04
			Aquandic Epiaqualfs	01-01-09-05
			Arenic Epiaqualfs	01-01-09-06
			Grossarenic Epiaqualfs	01-01-09-07

			Aeric Umbric Epiaqualfs	01-01-09-08
			Udollic Epiaqualfs	01-01-09-09
			Aeric Epiaqualfs	01-01-09-10
			Mollic Epiaqualfs	01-01-09-11
			Umbric Epiaqualfs	01-01-09-12
			Typic Epiaqualfs	01-01-09-13
		Endoaqualfs	Aquandic Endoaqualfs	01-01-10-01
			Arenic Endoaqualfs	01-01-10-02
			Gossarenic Endoaqualfs	01-01-10-03
			Udollic Endoaqualfs	01-01-10-04
			Aeric Endoaqualfs	01-01-10-05
			Molic Endoaqualfs	01-01-10-06
			Umbric Endoaqualfs	01-01-10-07
			Typic Endoaqualfs	01-01-10-08
	Boralfs	Paleboralfs	Antic Paleboralfs	01-02-01-01
			Vitrandic Paleboralfs	01-02-01-02
			Aquic Paleboralfs	01-02-01-03
			Oxyaquic Paleboralfs	01-02-01-04
			Abruptic Paleboralfs	01-02-01-05
			Mollic Paleboralfs	01-02-01-06
			Typic Paleboralfs	01-02-01-07
		Fragiboralfs	Andic Fragiboralfs	01-02-02-01
			Vitrandic Frgiboralfs	01-02-02-02
			Aquic Frgiboralfs	01-02-02-03
			Oxyquic Frgiboralfs	01-02-02-04
			Typic Fragiboralfs	01-02-02-05
		Natriboralfs	Typic Natriboralfs	01-02-03-01
		Cryoboralfs	Lithic Mollic Cryoboralfs	01-02-04-01
			Lithic Cryoboralfs	01-02-04-02
			Vertic Cryoboralfs	01-02-04-03
			Aquic Cryoboralfs	01-02-04-04
			Oxyaquic Cryoboralfs	01-02-04-05
			Psammentic Cryoboralfs	01-02-04-06
			Mollic Cryoboralfs	01-02-04-07
			Glossic Cryoboralfs	01-02-04-08
			Typic Cryoboralfs	01-02-04-09
		Eutroboralfs	Lithic Eutroboralfs	01-02-05-01
			Vertic Eutroboralfs	01-02-05-02
			Andic Eutroboralfs	01-02-05-03
			Vitrandic Eutroboralfs	01-02-05-04
			Aquic Arenic Eutroboralfs	01-02-05-05
			Glossaquic Eutroboralfs	01-02-05-06
			Aquic Arenic Eutroboralfs	01-02-05-07
			Oxyaquic Eutroboralfs	01-02-05-08
			Pasmmentic Eutroboralfs	01-02-05-09
			Arenic Eutroboralfs	01-02-05-10
			Mollic Eutroboralfs	01-02-05-11

			Glossic Eutroboralfs	01-02-05-12
			Typic Eutroboralfs	01-02-05-13
		Glossoboralfs	Lithic Glossoboralfs	01-02-06-01
			Andic Glossoboralfs	01-02-06-02
			Vitrandic Glossoboralfs	01-02-06-03
			Aquic Glossoboralfs	01-02-06-04
			Oxyaquic Glossoboralfs	01-02-06-05
			Pasammentic Glossoboralfs	01-02-06-06
			Eutric Glossoboralfs	01-02-06-07
			Typic Glossoboralfs	01-02-06-08
	Ustalfs	Durustalfs	Typic Durustalfs	01-03-01-01
		Plinthustalfs	Typic Plinthustalfs	01-03-02-01
		Natrustalfs	Vertic Natrustalfs	01-03-03-01
			Grossarenic Natrustalfs	01-03-03-02
			Aquic Arenic Natrustalfs	01-03-03-03
			Aquic Natrustalfs	01-03-03-04
			Arenic Natrustalfs	01-03-03-05
			Petrocalcic Natrustalfs	01-03-03-06
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			Aquic Kandiustalfs	01-03-04-04
			Arenic Aridic Kandiustalfs	01-03-04-05
			Arenic Kandiustalfs	01-03-04-06
			Aridic Kandiustalfs	01-03-04-07
			Udic Kandiustalfs	01-03-04-08
			Rhodic Kandiustalfs	01-03-04-09
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			Aquic Kanhaplustalfs	01-03-05-02
			Aridic Kanhaplustalfs	01-03-05-03
			Udic Kanhaplustalfs	01-03-05-04
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			Oxaquic Vertic aleustalfs	01-03-06-02
			Udertic Pleustalfs	01-03-06-03
			Vertif Paleustalfs	01-03-06-04
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			Grossarenic Paleustalfs	01-03-06-06
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			Plinthic Paleustalfs	01-03-06-08
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			Petrocalcic Paleustalfs	01-03-06-11
			Arenic Aridic Paleustalfs	01-03-06-12
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			Kanhaplic Rhodustalfs	01-03-07-02
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			Aquertic Haplustalfs	01-03-08-02
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			Udertic Haplustalfs	01-03-08-04
			Vertic Haplustalfs	01-03-08-05
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			Aquilitic Haplustalfs	01-03-08-07
			Aquic Haplustalfs	01-03-08-08
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			Abruptic Haplic Durixeralfs	01-04-01-04
			Abruptic Durixeralfs	01-04-01-05
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			Aquic Natrixeralfs	01-04-02-02
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			Hydric Hapludands	02-07-06-14
			Eutric Thaptic Hapludands	02-07-06-15
			Thaptic Hapludands	02-07-06-16
			Eutric Hapludands	02-07-06-17

			Oxic Hapludands	02-07-06-18
			Ultic Hapludands	02-07-06-19
			Alfic Hapludands	02-07-06-20
			Typic Hapludands	02-07-06-21

The coding scheme will be extended to series level using the following table.

Soil Unit	Order	Sub-order	Great Group	Sub-group	Family	Series
Code	AA	BB	CC	DD	EE	FF

Table 4.2 Structure of Data

Field Name	Field Type	Field Width	Key
SOIL-Code	I	8	Y
Order	C	15	N
Sub-order	C	15	N
Great Group	C	30	N
Sub-group	C	50	N
Family	C	50	N
Series	C	50	N

5. GEOLOGY - LITHOLOGY

5.1 Classification Scheme

The standard classification scheme for lithology unit and rock type (and code) is shown in Table 5.1 while the structure of data is described in Table 5.2. Only those units present in the map area will be classified, and any other unit present in the area and not covered by the scheme will be mapped and provided appropriate code.

5.2 Input Data

- Geocoded IRS LISS III FCC imagery in 1:50000 scale of summer season (with minimum vegetation cover); where necessary Kharif or Rabi season data will be additionally used
- Existing geological and hydrogeological maps and literature

5.3 Methodology

Classification and mapping of lithologic units/rock types is performed through visual interpretation of image characteristics and terrain information, supported by the *a priori* knowledge of general geologic setting of the area. The description of rock types / lithologic units is provided in Table 5.3.

The tone (colour) and landform characteristics, and relative erodibility, drainage, soil type, land use/cover and other contextual information are used in classification. Acidic and arenaceous rocks are lighter in tone compared to basic/ argillaceous rocks. Coarse grained rocks with higher porosity and permeability appear brighter as compared to fine grained rocks with higher moisture retaining capacity. Highly resistant rock formations occur as different hill types depending on their texture and internal structure, while the easily erodible rocks occur as different types of plains and valleys. Dendritic drainage indicates homogeneous rocks, while trellis, rectangular and parallel drainage patterns indicate structural and lithologic controls. Coarse drainage texture indicates highly porous and permeable rock formations, while fine drainage texture is present in less pervious formations. Coarse textured and light coloured soils indicate acidic/ arenaceous rocks rich in quartz and feldspars, while fine textured and dark coloured soils indicate basic/ argillaceous rocks. Convergence of evidence from different interpretation elements will be followed for reliable classification. The contacts of identified rock types will be extended over large areas based on tonal contrast or landform on satellite imagery. Inferred boundaries (where the contrast is not adequate) is marked by different symbol. The rock types are mapped and labeled as per classification scheme (Table 5.1).

After preliminary interpretation field visit is conducted for proper identification and classification of rock types.

The overall classification accuracy will be estimated through 'Kappa Coefficient', which is a measure of agreement between the classified map and ground conditions at a specified number of sample sites (Annexure 1).

The classified map will be scanned and digitized using an appropriate scanner (Annexure 2). The Arc/Info coverage will be created and edited to remove digitization errors, and the topology will be built. The features will be labeled as per codes/symbols defined in Table 5.1 and 5.2.. The coverage will then be projected and transformed into polyconic projection and coordinate system in meters. The transformation process will involve geometric rectification through Ground Control Points (GCPs) identified on the input coverage and corresponding SOI map. The HP data specification standards in Table 2.2 need to be conformed. The resulting GIS coverage will be backed up in CD and labeled with corresponding SOI map sheet number, theme, generating agency, and generation date.

Internal quality control and external quality audit will be at different critical stages of mapping and digitization process (Annexure 3).

5.4 Output Products

Five copies of GIS coverage with appropriate file names and format (Annexure 4) in CD and two B/W hardcopies of thematic map will be delivered by the vendor, alongwith a report (Annexure 5) on input data used, interpretation and digitization process, internal QC statement, and contact address for clarifications.

Table 5.1 Rock Groups and Rock Type/ Lithologic Unit Classification (LITH-LUT)
(proposed by NRSA in RGDWMTM mapping project)

Rock Group	Rock Type/ Lithologic Unit	LITH-Code
Unconsolidated Sediments		01-00
	Gravel	01-01
	Sand & silt	01-02
	Clayey sand & silt	01-03
	Sandy clay	01-04
	Clay	01-05
	Alternating sequence of sand/silt & clay	01-06
	Colluvium	01-07
Residual cappings		02-00
	Laterite	02-01
	Bauxite	02-02
	Kankar	02-03
	Chert	02-04
	Detrital Laterite	02-05
Deccan Traps and Intertrappeans		03-00
	Inter & intra- trappean sand/clay bed	03-01
	Tuffaceous Basalt	03-02
	Vesicular Basalt	03-03
	Amygdaloidal Basalt	03-04
	Massive Basalt	03-05
	Red /Green Bole	03-06
Older Volcanics / Metavocanics		04-00
	Basalt	04-01
	Rhyolite	04-02
	Dacite	04-03
	Andesite	04-04
Semi-consolidated Sediments		05-00
	Sandstone & conglomerate	05-01
	Shaly sandstone	05-02
	Sandstone with shale /coal partings	05-03
	Shell Limestone/ Limestone	05-04
	Sandy Shale	05-05
	Shale with sandstone partings	05-06
	Shale/ Coal/ Lignite	05-07
Consolidated sediments		06-00
	Thin bedded Sandstone / Quartzite	06-01
	Thin bedded Limestone / Dolomite	06-02
	Thick bedded / Massive Limestone/	06-03

	Dolomite	
	Thick bedded Sandstone/ Quartzite	06-04
	Shaly Limestone	06-05
	Conglomerate	06-06
	Shale with Limestone/ sandstone Bands/ Lenses	06-07
	Shale	06-08
Plutonic rocks		07-00
	Granitic/ Acidic rocks	07-01
	Alkaline rocks	07-02
	Basic rocks	07-03
	Ultrabasic rocks	07-04
	Quartz reef	07-05
	Pegmatite/ Aptite/Quartz vein	07-06

Note: Rock type and stratigraphy to be assigned on case by case basis as per GSI classification

Table 5.2 Structure of Data

Field Name	Field Type	Field Width	Key
LITH-Code	I	4	Y
Rock Group	C	30	N
Lithologic Unit	C	50	N
Rock Type	C	50	N
Stratigraphy	C	50	N

Table 5.3 Description of rock types/ lithologic units

Rock Type/ Lithologic Unit	Description
Unconsolidated Sediments	Quaternary sediments associated with alluvial, deltaic, coastal, eolian, flood plains, valley fills, etc. Based on their composition, 7 litho-units are identified in this group as shown below
<u>Gravel</u>	Comprising of granular sediments of 2-4 mm size
Sand & Silt	Comprising of granular sediments of 2-1/256 mm size
Clayey Sand / Silt	Comprising of dominantly granular sediments with significant clay content
Sandy Clay	Comprising of dominantly non-granular sediments with significant sand content.
Clay	Comprising of dominantly non-granular sediments having <256 mm particle size
Alternating Sequence of Sand/Silt and Clay	Interbedded granular (sand / silt) and non-granular sediments (clay in different proportions)
Colluvium	Assorted mixture of cobbles, pebbles, sand, silt and clay
Residual Cappings	Duricrusts associated with remnants of planar surfaces. Occur as plateaus, mesas, buttes, etc. 4 litho-units are identified in this group as shown below.
Laterite (Ferricrete)	Hard and pisolitic oxidised crust at surface underlain by soft lithomargic clays formed by deep chemical weathering and enrichment of iron oxides by leaching.
Bauxite (Alcrete)	Same as above, but formed due to enrichment of aluminium oxide.
Kankar (Calcrete)	Produced by the formation of calcium carbonate nodules.
Chert (Silcrete)	Cryptocrystalline silica; occur as bands or layers of nodules
Detrital Laterite	Formed by deposition of laterite / ferruginous detritus as valley fills.
Deccan Traps & Intertrappeans	Upper Cretaceous to Palaeocene volcanic flows like Deccan basalts and their equivalents. Based on their aquifer characteristics, 6 litho-units are identified in this group as shown below-
Inter-/Infra-trappean Sand/Clay bed	Thin beds of semi-consolidated sediments occurring between different lava flows and also at the base of Deccan traps.
Tuffaceous Basalt	Soft, friable and porous basalt formed mainly by volcanic tuff.
Vesicular Basalt	Hard and vesicular basalt with limited porosity.
Amygdaloidal Basalt	Vesicular basalt filled with amygdales.
Massive Basalt	Hard and massive basalt. Fracturing and weathering lead to the development of secondary porosity and permeability.
Red / Green Bole	Red / Green clay beds of 0.5-5 m thickness occur between different lava flows.
Older Volcanics /	Volcanic rocks of different composition of Precambrian

Metavolcanics	age.
Besalt	Hard and massive basalts
Rhyolite	Hard and massive rhyolites
Dacite	Hard and massive dacites
Andesite	Hard and massive andesites
Semi-consolidated Sediments	Upper Carboniferous to Pliocene sediments comprising of mainly Gondwanas, Rajamundry Sandstone, Nari, Gaj series, Cretaceous beds to Trichy etc, which are partially consolidated, soft and friable having significant intergranular pore spaces. Based on their composition in this group as shown below -
Sandstone & Conglomerate	Comprising of dominantly granular sediments with insignificant shale / clay content.
Shaly Sandstone	Comprising of dominantly granular sediments with significant shale / clay content.
Sandstone with Shale / Coal partings	Dominantly granular sediments, interbedded with shale, clay or coal partings.
Shell Limestone / Limestone	Mainly formed by cementation of shell fragments and oolites.
Sandy Shale	Comprising of dominantly non-granular sediments with significant sand content.
Shale with Sandstone Partings	Mainly shale/clay, coal, lignite formations with thin sandstone partings.
Shale / Coal / Lignite	Comprising of dominantly non-granular sediments with insignificant sand content.
Consolidated Sediments	Mainly Precambrian to Cambrian sedimentaries of Cuddapah, Delhi, Vindhyan Groups and their equivalents, comprising of fully consolidated sediments without any intergranular pore spaces (except the bedding planes). Based on their aquifer characteristics, 8 litho-units are identified in this group as shown below-
Thin Bedded Sandstone/Quartzite	Hard and indurated sandstone / quartzite with a non. of well defined bedding planes.
Thin Bedded Limestone/Dolomite	Thin bedded, flaggy limestone / dolomite with a no. of defined bedding planes.
Thick Bedded / massive Limestone / Dolomite	Hard and massive limestone / dolomite with very few bedding planes.
Thick Bedded Sandstone/Quartzite	Hard and massive sandstone / quartzite, without any intergranular pore spaces.
Shaly Limestone	Dominantly limestone with significant shale content as impurity or with shale intercalations.
Conglomerate	Hard & massive conglomerate without significant intergranular pore spaces
Shale with Limestone/Sandstone Bands / Lenses	Mainly shale sequence with bands and lenses of limestone / sandstone
Shale	Hard and compact shale / claystone
Plutonic Rocks	Include a variety of hard and massive plutonic igneous

	rocks with no primary porosity.
Granitic / Acidic Rocks	Hard and massive plutonic rocks of granitic / acidic composition.
Alkaline Rocks	Hard and massive plutonic rocks of alkaline composition.
Basic Rocks	Hard and massive plutonic rocks of basic composition.
Ultrabasic Rocks	Hard and massive igneous rocks of ultrabasic composition.
Quartz Reef	Hard and brittle quartz reefs.
Pegmatite / Aplite / Quartz Vein	Hard and brittle veins of Pegmatite / Aplite / Quartz
Granite & Gneissic Complexes / Migmatitic Complexes	Include Peninsular gneissic complex and equivalents with granitic intrusions, and migmatitic complexes.
Granite & Gneissic Complex	Comprising of gneisses and granites in roughly same proportion.
Grantic Gneiss	Mainly comprising of gneisses with granitic lenses.
Migmatitic Complex	Hard and massive migmatities.
Migmatite with Granite Lenses	Hard and massive migmatites with lenses of granite.
Metamorphics	Include, a variety of metamorphosed igneous, sedimentary and volcanic rocks.
Gneiss	Gneisses of different mineral composition with crude to well developed foliations.
Schist	Crudely foliated schists of different composition.
Quartzite	Hard and brittle quartzites.
Slate	Slates with well developed slaty cleavage.
Phyllite	Crudely foliated phyllites.
Calc Gneiss	Calcareous gneisses with crudely to well-developed foliations.
Calc Schist	Crudely foliated calcareous schists.
Limestone / Marble	Hard and brittle limesone / marble.

6. GEOLOGY – STRUCTURES

6.1 Classification Scheme

The geological structures will be mapped as per the classification scheme in Table 6.1. Only those units present in the map area will be classified, and any other unit present in the area and not covered by the scheme will be mapped and provided appropriate code.

6.2 Input Data

- Geocoded IRS LISS III FCC imagery in 1:50000 scale of summer season (with minimum vegetation cover); where necessary Kharif or Rabi season data will be additionally used
- Existing geological and hydrogeological maps and literature

6.3 Methodology

Different types of primary and secondary geological structures (attitude of beds, schistosity / foliation, folds, lineaments, circular features, etc..) can be visually interpreted by studying the landforms, slope asymmetry, outcrop pattern, drainage pattern, and stream/ river courses. Lineaments (faults, fractures, shear zones, and thrusts.) appear as linear and curvilinear lines on the satellite imagery, and are often indicated by the presence of moisture, alignment of vegetation, straight drainage courses, alignment of tanks / ponds, etc.. Lineaments are further sub-divided based on image characteristics and geological evidence.

The attitude of beds (strike and dip) are estimated by studying the slope asymmetry, landform, drainage characteristics, etc.. For instance horizontal to sub-horizontal beds show mesa / butte type of landform, dendritic drainage pattern and tonal / colour banding parallel to the contour lines; inclined beds show triangular dip facets, cuestas, homoclines and hogbacks. The Schistosity / foliation of the rocks are shown as numerous thin, wavy and discontinuous trend lines. Non-plunging and plunging folds are mapped from the marker horizons. Non-plunging folds produce outcropping in parallel belts, and plunging folds produce V or U shaped outcrop pattern. Doubly plunging folds are indicated by oval shaped outcrops. Further classification into anticline or syncline can be made on the basis of dip direction of beds. Circular features, representing structural domes/ basins, sub-surface igneous intrusions, salt domes, etc. show circular to quasi-circular outcrops and trend lines with radial/ annular drainage pattern. Reference to existing literature can support confirmation of interpreted details. The geological structures will be mapped with standard symbols.

The pre-field structural map will be checked in the field and validated.

The overall classification accuracy will be estimated through ‘Kappa Coefficient’, which is a measure of agreement between the classified map and ground conditions at a specified number of sample sites (Annexure 1).

The classified map will be scanned and digitized using an appropriate scanner (Annexure 2). The Arc/Info coverage will be created and edited to remove digitization errors, and the topology will be built. The features will be labeled as per codes/symbols defined in Table 6.1

and 6.2.. The coverage will then be projected and transformed into polyconic projection and coordinate system in meters. The transformation process will involve geometric rectification through Ground Control Points (GCPs) identified on the input coverage and corresponding SOI map. The HP data specification standards in Table 2.2 need to be conformed. The resulting GIS coverage will be backed up in CD and labeled with corresponding SOI map sheet number, theme, generating agency, and generation date.

Internal quality control and external quality audit will be at different critical stages of mapping and digitization process (Annexure 3).

6.4 Output Products

Five copies of GIS coverage with appropriate file names and format (Annexure 4) in CD and two B/W hardcopies of thematic map will be delivered by the vendor, alongwith a report (Annexure 5) on input data used, interpretation and digitization process, internal QC statement, and contact address for clarifications.

Table 6.1 Geologic Structure Classification and Code (STRU-LUT)
(proposed by NRSA in RGDWTM mapping project)

Structure	Sub- categories	STRU-Code
Bedding	Horizontal (dip angle between 0 and 5 degrees)	01-00
	Gentle (dip angle between 5 and 15 degrees)	01-01
	Moderate (dip angle between 15 and 45 degrees)	01-02
	Steep(dip angle between 45 and 80 degrees)	01-03
	Vertical to sub-vertical(dip angle greater than 80 degrees)	01-04
	Overturned (beds are overturned)	01-05
		01-06
Schistosity / Foliation		02-00
	Moderate (dip angle less than 45 degrees)	02-01
	Steep(dip angle between 45 and 80 degrees)	02-02
	Vertical to sub-vertical (dip angle greater than 80 degrees)	02-03
	Overturned (Schistosity / foliation overturned)	02-04
Faults/ Fractures/ Lineaments/Shear zones/ Thrusts		03-00
	Confirmed	03-01
	Inferred	03-02
Folds		04-00
	Anticline/ Antiform	04-01
	Syncline/Synform	04-02
	Folds to be classified as non-plunging, plunging, doubly plunging and overturned	04-03
Circular features		05-00
	Structural dome	05-01
	Structural basin	05-02
Trend lines		06-00
Escarpment		07-00

Table 6.2 Structure of Data

Field Name	Field Type	Field Width	Key
Stru-Code	I	4	Y
Structure	C	30	N
Sub-Structure	C	100	N

7. GEOMORPHOLOGY

7.1 Classification Scheme

Geomorphic units/ different landforms will be mapped as per the classification scheme (and code) in Table 7.1, and the structure of data is described in Table 7.2. While the scheme is comprehensive only those units present in the area to be mapped will be classified, and any other unit present in the area and not listed in Table 7.1 will be classified and appropriate code/ symbol used.

7.2 Input Data

- Geocoded IRS LISS III FCC imagery in 1:50000 scale of summer season (with minimum vegetation cover); where necessary Kharif or Rabi season data will be additionally used
- Existing geological and hydrogeological maps and literature

7.3 Methodology

The geomorphic units/ landforms in the classification scheme are described in Table 7.3. The satellite imagery will be visually interpreted into geomorphic units/ landforms based on image elements such as tone, texture, shape, size, location and association, physiography, genesis of landforms, nature of rocks/ sediments, and associated geological structures. The topographic information in SOI topomaps aids in interpreting satellite imagery. Three major geomorphic units – hills and plateaus, piedmont zones, and plains- based on physiography and relief. Within each zone different geomorphic units will be mapped based on landform characteristics, their areal extent, depth of weathering, thickness of deposition, etc.

The interpreted geomorphic units/landforms will be verified through field visits, in which the depth of weathering, nature of weathered material, thickness of deposition, nature of deposited material, etc. are examined at nala and stream cuttings, existing wells, lithologs of wells drilled, etc..

The overall classification accuracy will be estimated through ‘Kappa Coefficient’, which is a measure of agreement between the classified map and ground conditions at a specified number of sample sites (Annexure 1).

The classified map will be scanned and digitized using an appropriate scanner (Annexure 2). The Arc/Info coverage will be created and edited to remove digitization errors, and the topology will be built. The features will be labeled as per codes/symbols defined in Table 7.1 and 7.2. The coverage will then be projected and transformed into polyconic projection and coordinate system in meters. The transformation process will involve geometric rectification through Ground Control Points (GCPs) identified on the input coverage and corresponding SOI map. The HP data specification standards in Table 2.2 need to be conformed. The resulting GIS coverage will be backed up in CD and labeled with corresponding SOI map sheet number, theme, generating agency, and generation date.

Internal quality control and external quality audit will be at different critical stages of mapping and digitization process (Annexure 3).

6.4 Output Products

Five copies of GIS coverage with appropriate file names and format (Annexure 4) in CD and two B/W hardcopies of thematic map will be delivered by the vendor, alongwith a report (Annexure 5) on input data used, interpretation and digitization process, internal QC statement, and contact address for clarifications.

Table 7.1 Geomorphic Classification Scheme and Code (GU-LUT)
(proposed by NRSA in RGDWTM mapping project)

Zone	Geomorphic Unit	Sub- categories	Landforms	GU-Code	
Hills and Plateaus	Structural hills			01-01-00-00-00	
	Denudational hills			01-02-00-00-00	
	Plateaus	Upper	Undissected		01-03-00-00-00
			Moderately dissected		01-03-01-00-00
			Highly dissected		01-03-01-01-00
		Middle	Undissected		01-03-01-02-00
			Moderately dissected		01-03-01-03-00
			Highly dissected		01-03-02-00-00
		Lower	Undissected		01-03-02-01-00
			Moderately dissected		01-03-02-02-00
			Highly dissected		01-03-02-03-00
	Valleys	Structural valley			01-03-03-00-00
					01-03-03-01-00
					01-03-03-02-00
		Intermontane valley			01-03-03-03-00
					01-04-00-00-00
				01-04-01-00-00	
				01-04-02-00-00	
	Linear/Curvilinear ridge		01-00-00-00-01		
	Cuesta		01-00-00-00-02		
	Mesa		01-00-00-00-03		
	Butte		01-00-00-00-04		
	Dome (Structural)		01-00-00-00-05		
	Dome (massive)		01-00-00-00-06		
	Inselberg		01-00-00-00-07		

Piedmont Zone	Pediment.	Buried pediment Dissected pediment Pediment-Inselberg complex		02-01-00-00-00 02-01-01-00-00 02-01-02-00-00 02-01-03-00-00
	Piedmont slope			02-02-00-00-00
	Piedmont alluvium	Shallow Moderate Deep		02-03-00-00-00 02-03-01-00-00 02-03-02-00-00 02-03-03-00-00
	Bajada	Shallow Moderate Deep	Linear/Curvilinear ridge Cuesta Mesa Butte Dome (Structural) Dome (massive) Inselberg	02-04-00-00-00 02-04-01-00-00 02-04-02-00-00 02-04-03-00-00 02-00-00-00-01 02-00-00-00-02 02-00-00-00-03 02-00-00-00-04 02-00-00-00-05 02-00-00-00-06 02-00-00-00-07

Plains	Pediplain	Weathered	Shallow	03-01-00-00-00		
			Moderate	03-01-01-00-00		
			Deep	03-01-01-01-00		
		Buried	Shallow	03-01-01-02-00		
			Moderate	03-01-01-03-00		
			Deep	03-01-02-00-00		
		Linear/Curvilinear ridge			Shallow	03-01-02-01-00
					Moderate	03-01-02-02-00
					Deep	03-01-02-03-00
					Cuesta	03-01-00-00-01
					Mesa	03-01-00-00-02
					Butte	03-01-00-00-03
					Dome (Structural)	03-01-00-00-04
					Dome (massive)	03-01-00-00-05
Inselberg	03-01-00-00-06					
Valleyfill-Shallow	03-01-00-00-07					
Valleyfill-Moderate	03-01-00-00-08					
Valleyfill-Deep	03-01-00-00-09					
			03-01-00-00-10			

	Etch plain	Shallow weathered Moderately weathered Deeply weathered	Linear/Curvilinear ridge Cuesta Mesa Butte Dome (Structural) Dome (massive) Inselberg Valleyfill-Shallow Valleyfill-Moderate Valleyfill-Deep	03-02-00-00-00 03-02-01-00-00 03-02-02-00-00 03-02-03-00-00 03-02-00-00-01 03-02-00-00-02 03-02-00-00-03 03-02-00-00-04 03-02-00-00-05 03-02-00-00-06 03-02-00-00-07 03-02-00-00-08 03-02-00-00-09 03-02-00-00-10
	Stripped plain	Shallow basement Moderate basement Deep basement	Linear/Curvilinear ridge Cuesta Mesa Butte Dome (Structural) Dome (massive) Inselberg Valleyfill-Shallow Valleyfill-Moderate Valleyfill-Deep	03-03-00-00-00 03-03-01-00-00 03-03-02-00-00 03-03-03-00-00 03-03-00-00-01 03-03-00-00-02 03-03-00-00-03 03-03-00-00-04 03-03-00-00-05 03-03-00-00-06 03-03-00-00-07 03-03-00-00-08 03-03-00-00-09 03-03-00-00-10
	Flood plain	Older/Upper Shallow Moderate		03-04-00-00-00 03-04-01-00-00 03-04-01-01-00 03-04-01-02-00

		<p>Deep Younger/ Lower Shallow Moderate Deep</p>	<p>Channel bar Point bar River terrace Natural levee Backswamp Cut-off meander Abandoned channel Ox-bow lake Paleochannel Buried channel</p>	<p>03-04-01-03-00 03-04-02-00-00 03-04-02-01-00 03-04-02-02-00 03-04-02-03-00 03-04-00-00-01 03-04-00-00-02 03-04-00-00-03 03-04-00-00-04 03-04-00-00-05 03-04-00-00-06 03-03-00-00-07 03-04-00-00-08 03-04-00-00-09 03-04-00-00-10</p>
	Alluvial plain	<p>Older/Upper Shallow Moderate Deep Younger/ Lower Shallow Moderate Deep</p>	<p>Channel bar Point bar River terrace Natural levee Backswamp Cut-off meander Abandoned channel Ox-bow lake</p>	<p>03-05-00-00-00 03-05-01-00-00 03-05-01-01-00 03-05-01-02-00 03-05-01-03-00 03-05-02-00-00 03-05-02-01-00 03-05-02-02-00 03-05-02-03-00 03-05-00-00-01 03-05-00-00-02 03-05-00-00-03 03-05-00-00-04 03-05-00-00-05 03-05-00-00-06 03-05-00-00-07 03-05-00-00-08</p>

			Paleochannel Buried channel	03-05-00-00-09 03-05-00-00-10
	Deltaic plain	Older/Upper Shallow Moderate Deep Younger/ Lower Shallow Moderate Deep	Channel bar Point bar River terrace Natural levee Backswamp Cut-off meander Abandoned channel Ox-bow lake Paleochannel Buried channel	03-06-00-00-00 03-06-01-00-00 03-06-01-01-00 03-06-01-02-00 03-06-01-03-00 03-06-02-00-00 03-06-02-01-00 03-06-14-02-02 03-06-00-02-03 03-06-00-00-01 03-06-00-00-02 03-06-00-00-03 03-06-00-00-04 03-06-00-00-05 03-06-00-00-06 03-06-00-00-07 03-06-00-00-08 03-06-00-00-09 03-06-00-00-10
	Coastal plain	Older/Upper Shallow Moderate Deep Younger/ Lower Shallow Moderate Deep	Beach Beach ridge	03-07-00-00-00 03-07-01-00-00 03-07-01-01-00 03-07-01-02-00 03-07-01-03-00 03-07-02-00-00 03-07-02-01-00 03-07-02-02-00 03-07-02-03-00 03-07-00-00-01 -3-07-00-00-02

			Beach ridge & Swale complex Swale Off-shore bar Spit Mud flat Salt flat Tidal flat Lagoon Sand dune Channel island Paleochannel Buried Channel	03-07-00-00-03 03-07-00-00-04 03-07-00-00-05 03-07-00-00-06 03-07-00-00-07 03-07-00-00-08 03-07-00-00-09 03-07-00-00-10 03-07-00-00-11 03-07-00-00-12 03-07-00-00-13 03-07-00-00-14
	Eolian plain	Shallow Moderate Deep	Sand dune Stabilised dune Dune complex Interdunal depression Interdunal flat Playa Desert Pavement Loess Paleochannel Buried Channel	03-08-00-00-00 03-08-01-00-00 03-08-02-00-00 03-08-03-00-00 03-08-00-00-01 03-08-00-00-02 03-08-00-00-03 03-08-00-00-04 03-08-00-00-05 03-08-00-00-06 03-08-00-00-07 03-08-00-00-08 03-08-00-00-09 03-08-00-00-10

Table 7.2 Structure of Data

Field Name	Field Type	Field Width	Key
GU-Code	I	10	Y
Descr-Level 1	C	50	N
Descr-Level 2	C	50	N
Descr-Level 3	C	50	N
Descr-Level 4	C	50	N
Descr-Landform	C	50	N

Table 7.3 Description of Geomorphic units and Landforms

Geomorphic Unit/ Landform	Description
Structural Hills	Linear to arcuate hills showing definite structural trends.
Denudational Hills	Hills formed due to differential erosion and weathering, so that a more resistant formation or intrusion stand as mountains / hills.
Plateaus	Elevated flat uplands occupying fairly large area (greater than 5 km x 5 km) and bound by escarpments / steep slopes on all sides. Based on their geomorphic position, they are classified into 3 categories – 1) Upper, 2) Middle and 3) Lower. Further based on dissection, these Upper, Middle and Lower Plateaus have been further classified into undissected, moderately dissected and highly dissected categories.
- Undissected	A plateau (upper / middle / lower) which is fully preserved in its original form and has not been dissected.
- Moderately Dissected	A plateau (upper / middle / lower) dissected by deep valleys/gullies changing the original form considerably.
- Highly Dissected	A plateau (upper / middle / lower) more frequently dissected by deep valleys separating into individual mesas / buttes.
Valleys	Low lying depressions and negative landforms of varying size and shape occurring within the hills associated with stream / nala courses.
Structural Valleys	Narrow linear valleys formed along the structurally weak planes like faults, fractures, lithological-contacts etc.
Intermontane Valley	Small valleys occurring within the structural / denudational hills.
Linear / Curvilinear Ridge	A narrow linear / curvilinear resistant ridge formed by dolerite dyke, quartz reef, quartzite bed, etc.
Cuesta	An isolated hill formed by gently dipping (5-10o) sedimentary beds having escarpment / steep slopes on one side and gentle dip slopes on the other side.
Mesa	Flat-topped hills having width 2 km to 250 m.

Butte	Flat-topped hills having width <250 m.
Dome (Structural)	Dome shaped hills of structural origin.
Dome (Massive)	Dome shaped hills formed by exfoliation and sheeting of plutonic rocks.
Inselberg	An Isolated hill of massive type abruptly rising above surrounding plains.
Pediment	Gently undulating plain dotted with rock outcrops with or without thin veneer of soil cover.
Buried Pediment	Same as above, but buried under unconsolidated sediments.
<u>Dissected pediment</u>	Same as pediment, but dissected.
Pediment-Inselberg Complex	Pediment dotted with a number of inselbergs which cannot be separated and mapped as individual units.
Piedmont Slope	Slope formed by bajada and pediment together.
Piedmont Alluvium - Shallow - Moderate - Deep	Alluvium deposited along foot hill zone due to sudden loss of gradient by rivers / streams in humid and sub-humid climate. Based on the thickness, it is divided into 3 categories – 1) Shallow (0-10 m), 2) Moderate (10-20m), and 3) Deep (more than 20 m).
Bajada - Shallow - Moderate - Deep	Detrital alluvial out-wash of varying grain size deposited along the foot hill zone in arid and semi-arid climate. Based on the thickness, it is divided into 3 categories – 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (>20 m).
Alluvial Fan	A fan shaped mass of sediment deposited at a point along a river where there is a decrease in gradient.
Talus Cone	A cone shaped deposit of coarse debris at the foot of hills / cliffs adopting the angle of repose.
Pediplain-Weathered - Shallow Weathered - Mod. Weathered - Deeply Weathered	Gently undulating plain of large areal extent often dotted with inselbergs formed by the coalescence of several pediments. Based on the depth of weathering, weathered pediplains are classified into 3 categories – 1) Shallow (0-10 m), 2) Moderate (10-20 m), and 3) Deep (more than 20 m)
Pediplain-Buried - Shallow - Moderate - Deep	Same as above, but buried under transported material. Based on the total thickness of transported material and depth of weathering, buried pediplains are classified into 3 categories – 1) Shallow (0-10m), 2) Moderate (10-20 m), and 3) Deep (more than 20 m).
Etch Plain - Shallow Weathered - Mod. Weathered - Deeply Weathered	A plain formed by deep chemical weathering and stripping. Based on the depth of weathering, etch plains are classified into 3 categories – 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).

Stripped Plain - Shallow Basement - Mod. Basement - Deep Basement	Gently undulating plain formed by partial stripping (erosion) of older pediplains. The presence of rock outcrops along valleys and deeply weathered zones along inter-stream divides indicate the stripped plains. Based on depth to basement, it is classified into 3 categories – 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).
Valley Fill - Shallow - Moderate - Deep	Valleys of different shapes and sizes occupied by valley fill material (partly detrital and partly weathered material). They are classified into 3 categories - 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).
Flood Plain	Alluvium deposited along the river / stream courses due to repeated flooding. It is classified into 2 categories –1) Older / Upper and 2) Younger / Lower.
Flood Plain-Older/Upper - Shallow - Moderate - Deep	Same as above. Older refers to earlier cycle of deposition and upper refers to higher elevation ⁸ . Based on the thickness of alluvium, it is classified into 3 categories - 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).
Flood Plain-Younger/ Lower - Shallow - Moderate - Deep	Same as above. Younger refers to late cycle of deposition and lower refers to lower elevation. Based on the thickness of alluvium, it is classified into 3 categories - 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).
Alluvial Plain	Nearly level plain formed by the deposition of alluvium by major rivers. It is further classified into 2 categories – 1) Older / Upper and 2) Younger / Lower.
Alluvial Plain-Older / Upper - Shallow - Moderate - Deep	Same as above. Older refers to earlier cycle of deposition and upper refers to higher elevation ⁸ . Based on the thickness of alluvium, it is classified into 3 categories - 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).
Alluvial Plan-Younger / Lower - Shallow - Moderate - Deep	Same as above. Younger refers to late cycle of deposition and lower refers to lower elevation. Based on the thickness of alluvium, it is classified into 3 categories - 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).
Deltaic Plain	Alluvial plain formed by the distributary network of the rivers / streams at their confluence with sea, it is further classified into 2 categories – 1) Older / Upper and 2) Younger / Lower.
Deltaic Plain-Older / Upper - Shallow - Moderate - Deep	Same as above. Older refers to earlier cycle of deposition and upper refers to higher elevation. Based on the thickness of alluvium, it is classified into 3 categories - 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).
Deltain Plain – Younger /	Same as above. Younger refers to late cycle of

Lower - Shallow - Moderate - Deep	deposition and lower refers to lower elevation. Based on the thickness of alluvium, it is classified into 3 categories - 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).
Channel Bar	Sand bar formed in the braided river course due to vertical accretion of the sediments.
Point Bar	Sand bar formed at the convex side of meandering river by lateral accretion of sediment.
River Terrace	Flat upland adjoining the river course, occurring at different levels and occupied by river-borne alluvium. It indicates the former valley floor.
Natural Levee	Natural embankment formed by deposition of alluvium on river bank due to flooding.
Back Swamp	Depressions formed adjacent to natural levees in the flood plains of major streams / rivers. Occupied by clay & silt with or without water.
Cut-off Meander	Meander loop of a matured river, cut-off from the main stream / river, filled with river-borne sediments.
Abandoned Channel	An old river bed cut-off from the main stream, occupied by channel-lag / channel-fill material.
Ox-bow Lake	A lunate shaped lake located in an abandoned meandering channel.
Coastal Plain	Nearly level plain formed by marine action along the coast, mainly containing brackish water sediments. It is further classified into 2 categories – 1) Older / Upper and 2) Younger / Lower.
Coastal Plain- Younger / Upper - Shallow - Moderate - Deep	Same as above. Older refers to earlier cycle of deposition and upper refers to higher elevation. Based on the thickness of alluvium, it is classified into 3 categories - 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).
Coastal Plain – Younger / Lower - Shallow - Moderate - Deep	Same as above. Younger refers to late cycle of deposition and lower refers to lower elevation. Based on the thickness of alluvium, it is classified into 3 categories - 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).
Beach	Narrow stretch of unconsolidated sand / silt deposited by tidal waves along the shore line.
Beach Ridge	A linear ridge of unconsolidated sand / silt parallel to the shore line.
Beach Ridge & Swale Complex	A group of beach ridges and swales occurring together.
Swale	Linear depression occurring between two beach ridges.
Offshore Bar	Embankments of sand and gravel formed on the sea floor by waves and currents, occurring parallel to the coast line.
Spit	Off-shore bar attached to the land at one end and terminating in open water at the other.

Mud Flat	Mud deposited in the back swamps and along tidal creeks.
Salt Flat	Flat lands along the coast comprising of salt encrustations.
Tidal Flat	Flat surface formed by tides comprising of mostly mud and fine sand.
Lagoon	An elongated body of water lying parallel to the coast line and separated from the open sea by barrier islands.
Channel island	An island formed in the braided river course.
Eolian Plain - Shallow - Moderate - Deep	A plain formed by the deposition of wind blown sand dotted with a number of sand dunes. Based on the thickness of sand sheet and dissection, it is classified into 3 categories - 1) Shallow (0-10 m), 2) Moderate (10-20 m) and 3) Deep (more than 20 m).
Sand Dune	Heaps of sand of different shapes and sizes formed by wind action in the desertic terrain.
Stabilized Dune	Same as above, but stabilised.
Dune Complex	Group of sand dunes occurring together which cannot be mapped separately.
Interdunal Depression	Depression occurring between sand dunes.
Interdunal Flat	Flat land occurring between sand dunes.
Playa	Dry lake in an interior desert basin.
Desert Pavement	Flat or gently sloping surfaces, developed on fans, bajadas and desert flats formed by concentration of pebbles after removal of finer material by wind action.
Loess	Deposit of wind-blow silt.
Palaeochannel	An earlier river course filled with channel lag or channel fill sediments.
Buried Channel	Old river course filled with channel lag or channel fill deposits, buried by recent alluvium / soil cover.

6. ADMINISTRATIVE UNITS

8.1 Classification Scheme

The primary layers of administrative units upto Block will be created. The code is created to account also for future expansion of database to States outside HP.

Table 8.1 Classification Scheme and Code for Administrative Units (ADMIN.LUT)

Administrative Unit	State	District	Tahsil	Block
Code	AA	AA	AA	AA

8.2 Input Data

- Most recent SOI map in 1:50000 scale
- Latest map from State Survey Department in comparable scale, and list of administrative unit names

8.3 Methodology

The list of administrative units with names will be obtained from State Revenue Department, and the information on boundaries from most recent SOI map will be updated with the help of State Survey department map. It will be desirable to prepare a fresh cartographic product of such boundaries on clean polyester film for scanning and digitization.

The administrative unit map will be scanned and digitized using an appropriate scanner (Annexure 2). The Arc/Info coverage will be created and edited to remove digitization errors, and the topology will be built. The features will be labeled as per codes/symbols defined in Table 8.1. The coverage will then be projected and transformed into polyconic projection and coordinate system in meters. Since the State survey department maps may not have accuracy similar to SOI map, the transformation process will involve geometric rectification through Ground Control Points (GCPs) identified on the input coverage and corresponding SOI map. The HP data specification standards in Table 2.2 need to be conformed. The resulting GIS coverage will be backed up in CD and labeled with corresponding SOI map sheet number, theme, generating agency, and generation date.

Internal quality control and external quality audit will be at different critical stages of mapping and digitization process (Annexure 3).

8.4 Output Products

Five copies of GIS coverage with appropriate file names and format (Annexure 4) in CD and two B/W hardcopies of thematic map will be delivered by the vendor, alongwith a report (Annexure 5) on input data used, interpretation and digitization process, internal QC statement, and contact address for clarifications.

9. HYDROLOGIC UNITS

9.1 Classification Scheme

The primary layers of hydrologic units upto watershed will be created. The classification scheme follows the hierarchical system of watershed delineation developed by AISLUS.

Table 8.2 Classification Scheme and Code for Hydrologic Units (WS-LUT)

Hydrologic Unit	Region	Basin	Catchment	Sub-Catchment	Watershed
WS-Code	A	B	CC	DD	EE

9.2 Input Data

- SOI map in 1:50000 scale
- Watershed Atlas of India from All India Soil and Land Use Survey (AISLUS) in 1:1 million scale

9.3 Methodology

The hydrologic boundary upto watershed in AISLUS Atlas is drawn from 1:250000 scale SOI maps (and further into sub-watershed using 1:50000 scale SOI maps) but shown in 1:1 million scale map. The boundary delineation of hydrologic units at different hierarchical level in AISLUS classification is also based on keeping the unit size relevant to river valley project and flood prone river management. Thus the hydrologic boundaries need to be updated using 1:50000 scale SOI map, generally following the stream order (rather than point of interception such as dam, barrage, etc.). The six water resources regions are as suggested by Dr. Khosla in 1949. Each water resources region is delineated into basins, drained by a single major river or a group of small rivers or a major distributary of a major river. Each basin is subdivided into catchments, drained by a single major river or a group of small rivers or a major tributary of a major river such as Cauvery. Each catchment is divided into sub-catchments, drained by a single river or a group of small rivers or a major distributary of a major river like Vaigai. Each sub-catchment is divided into watersheds, drained by a single river or group of small rivers or a tributary of a major river.

The hydrologic unit map will be scanned and digitized using an appropriate scanner (Annexure 2). The Arc/Info coverage will be created and edited to remove digitization errors, and the topology will be built. The features will be labeled as per codes/symbols defined in Table 9.1. The coverage will then be projected and transformed into polyconic projection and coordinate system in meters. The HP data specification standards in Table 2.2 need to be conformed. The resulting GIS coverage will be backed up in CD and labeled with corresponding SOI map sheet number, theme, generating agency, and generation date.

Internal quality control and external quality audit will be at different critical stages of mapping and digitization process (Annexure 3).

9.4 Output Products

Five copies of GIS coverage with appropriate file names and format (Annexure 4) in CD and two B/W hardcopies of thematic map will be delivered by the vendor, alongwith a report (Annexure 5) on input data used, interpretation and digitization process, internal QC statement, and contact address for clarifications.

10. SETTLEMENTS

10.1 Classification Scheme

All urban settlements (towns) and rural settlements (villages) will be mapped as per the coding scheme below:

The code (SettlP.LUT and SettlA.LUT) will be State –AA; District – BB; Taluq – CC; Block-DD; Town/City – EE; and Village- FFF.

It is not proposed to categorize the settlements by size, which can be performed in the GIS by attaching population data.

10.2 Input Data

- most recent SOI map in 1:50000 scale
- Census data and maps
- most recent IRS LISS III FCC geocoded imagery in 1:50000 scale

10.3 Methodology

The location of towns and villages will be mapped from SOI map, and updated with reference to Census map and satellite data.

The settlement boundary will be taken from SOI map (and village boundary from revenue or census map), and updated with reference to satellite imagery. In case of sparse distribution of settlement, only the main part of settlement will be shown.

The settlement location and spread map will be scanned and digitized using an appropriate scanner (Annexure 2). The Arc/Info coverage will be created and edited to remove digitization errors, and the topology will be built. The features will be labeled as per codes/symbols defined in Section 10.1. The coverage will then be projected and transformed into polyconic projection and coordinate system in meters. The HP data specification standards in Table 2.2 need to be conformed. The resulting GIS coverage will be backed up in CD and labeled with corresponding SOI map sheet number, theme, generating agency, and generation date.

Internal quality control and external quality audit will be at different critical stages of mapping and digitization process (Annexure 3).

10.4 Output Products

Five copies of GIS coverage with appropriate file names and format (Annexure 4) in CD and two B/W hardcopies of thematic map will be delivered by the vendor, alongwith a report (Annexure 5) on input data used, interpretation and digitization process, internal QC statement, and contact address for clarifications.

11. TRANSPORT NETWORK

11.1 Classification Scheme

The classification scheme for roads and rail is shown in Table 11.1

Table 11.1 Road Classification Scheme and Code (TRNPT.LUT)

Type	Sub-category	TRNPT-Code
Metalled Road	National highway	01-00
	State highway	01-01
	District road	01-02
	District road	01-03
	Village road	01-04
Un- Mettaled Road	National highway	02-00
	State highway	02-01
	District road	02-02
	District road	02-03
	Village road	02-04
Tracks		03-00
Rail		04-00

Table 11.2 Structure of Data

Field Name	Field Type	Field Width	Key
TRNPT-Code	I	4	Y
Type	C	30	N
Sub-category	C	30	N

11.2 Input Data

- most recent SOI map in 1:50000 scale
- maps from State Transport department

11.3 Methodology

The road and rail alignments from SOI map will be mapped and symbolized. All roads will be classified into specified categories, while all rail tracks will be shown as single category.

The road and rail map will be scanned and digitized using an appropriate scanner (Annexure 2). The Arc/Info coverage will be created and edited to remove digitization errors, and the topology will be built. The features will be labeled as per codes/symbols defined in Section 11.1. The coverage will then be projected and transformed into polyconic projection and coordinate system in meters. The HP data specification standards in Table 2.2 need to be conformed. The resulting GIS coverage will be backed up in CD and labeled with corresponding SOI map sheet number, theme, generating agency, and generation date.

Internal quality control and external quality audit will be at different critical stages of mapping and digitization process (Annexure 3).

11.4 Output Products

Five copies of GIS coverage with appropriate file names and format (Annexure 4) in CD and two B/W hardcopies of thematic map will be delivered by the vendor, alongwith a report (Annexure 5) on input data used, interpretation and digitization process, internal QC statement, and contact address for clarifications.

12. DRAINAGE

12.1 Classification Scheme

The classification will cover perennial, seasonal and peripheral categories. Minor streams and rivers will be represented by line, while the major rivers with edges in the SOI map will be represented by polygon.

Table 12.2 Drainage Classification Scheme and Code (DRNL.LUT and DRNP.LUT)

Drainage Type	Code
Perennial Stream/River	01
Seasonal Stream/River	02
Ephemeral Stream/River	03

Table 12.2 Structure of Data

Field Name	Field Type	Field Width	Key
DRNL-Code/ DRNP-Code	I	2	Y
Description	C	30	N

12.2 Input Data

- Most recent SOI map in 1:50000 scale
- Flow data from State Water Resources Department

12.3 Methodology

The drainage details will be digitized from SOI map in 1:50000 scale. Where necessary flow data from the State Water Resources Department and kharif and rabi season satellite imagery may be used to support further classification into perennial, seasonal and ephemeral streams/rivers. Major rivers with defined water edge will be represented by polygons while minor streams will be shown as lines.

The road and rail map will be scanned and digitized using an appropriate scanner (Annexure 2). The Arc/Info coverage will be created and edited to remove digitization errors, and the topology will be built. The features will be labeled as per codes/symbols defined in Section 12.1. The coverage will then be projected and transformed into polyconic projection and coordinate system in meters. The HP data specification standards in Table 2.2 need to be conformed. The resulting GIS coverage will be backed up in CD and labeled with corresponding SOI map sheet number, theme, generating agency, and generation date.

Internal quality control and external quality audit will be at different critical stages of mapping and digitization process (Annexure 3).

12.4 Output Products

Five copies of GIS coverage with appropriate file names and format (Annexure 4) in CD and two B/W hardcopies of thematic map will be delivered by the vendor, alongwith a report (Annexure 5) on input data used, interpretation and digitization process, internal QC statement, and contact address for clarifications.

13. CONTOURS AND SPOT HEIGHTS

13.1 Classification Scheme

All contours of 20 m interval in SOI map in 1:50000 scale will be represented as lines and spot heights will be shown as points. The contour will be coded as integer by its value (ContL.LUT), and spot heights will be coded as 58J14S1, where the first five alphanumeric characters represent the SOI map number, and the next two characters represent the sequential number of spot heights within the sheet (ContP.LUT).

13.2 Input Data

- SOI map in 1:50000 scale

13.3 Methodology

The contours and spot heights from SOI map will be scanned and digitized. The Arc/Info coverage will be created and edited to remove digitization errors, and the topology will be built. The features will be labeled as per codes/symbols defined in Section 13.1. The coverage will then be projected and transformed into polyconic projection and coordinate system in meters. The HP data specification standards in Table 2.2 need to be conformed. The resulting GIS coverage will be backed up in CD and labeled with corresponding SOI map sheet number, theme, generating agency, and generation date.

Internal quality control and external quality audit will be at different critical stages of mapping and digitization process (Annexure 3).

13.4 Output Products

Five copies of GIS coverage with appropriate file names and format (Annexure 4) in CD and two B/W hardcopies of thematic map will be delivered by the vendor, alongwith a report (Annexure 5) on input data used, interpretation and digitization process, internal QC statement, and contact address for clarifications.

Annexure 1. Classification and Mapping Accuracy

1. Classification Accuracy

The thematic classification accuracy is evaluated through Kappa coefficient², which is a measure of agreement between classification and truth as obtained from ground verification. This is determined from the error matrix, which provides the number of correctly classified units but also the errors of commission (classifying some other category as the target category) and omission (wrongly classifying target category as some other class).

Kappa statistic is defined as follows

$$K = (\theta_1 - \theta_2) \div (1 - \theta_2)$$

Where,

$$\theta_1 = \sum x_{ii} / N$$

$$\theta_2 = \sum x_{i+} * x_{+i} / N^2$$

Where i = 1 to r

r = no. of rows in the error matrix

x_{ii} ith diagonal element

x_{i+} marginal total of row i

x_{+i} marginal total of column i

N no. of observations

Large sample variance of the kappa estimate is given as;

$$\text{Var}(k) = (\theta_1 * (1 - \theta_1)) \div (1 - \theta_2)^2 + [2 * (1 - \theta_2)^2 * (2 * (1 - \theta_1) * (2\theta_1 * \theta_2 - \theta_3) \div (1 - \theta_2)^3) + [(1 - \theta_1)^2 * (\theta_4 - 4 * \theta_2^2) \div (1 - \theta_2)^4]$$

$$\text{Where } \theta_3 = \sum_{i=1 \text{ to } r} x_{ii} * (x_{i+} + x_{+i}) \div N^2$$

$$\theta_4 = \sum x_{ij} * (x_{j+} + x_{+i})^2 \div N^3$$

The kappa coefficient of .9 means that the classification is 90 % accurate.

Using the variance value, confidence interval is estimated. For example, kappa coefficient can be 90% +/- (plus or minus) 5 % at 90 % confidence level and so on..

Individual class accuracy or conditional kappa coefficient is calculated as

$$K[i] = (N * x_{ii} - (x_{i+} * x_{+i})) \div (N * x_{i+} - (x_{i+} * x_{+i}))$$

² Congalton G.R. 1991. A review of assessing the accuracy of classifications of remotely sensed data, Remote Sensing of Environment, 37, (35-46)

$\sigma^2(k(i)) = 1 \div N * [A * (B+C)]$ where

$$A = P_{i+} - P_{ii} \div P_{i+}^3 * (1 - P_{+i})^3$$

$$B = (P_{i+} - P_{ii}) * (P_{i+} * P_{+i} - P_{ii})$$

$$C = P_{ii} * (1 - P_{i+} - P_{+i} - P_{ii})$$

$$P_{ii} = x_{ii} \div N$$

$$P_{i+} = x_{i+} \div N$$

$$P_{+i} = x_{+i} \div N$$

Minimum sample size is determined as under

$$n = (W^h p^h q^h) Z_{\alpha}^2 / e^2$$

$W^h = N_h / N$ is the stratum weight

N = total no. of units

p^h is the expected accuracy level of the category

e allowable/permissible error

$Z_{\alpha} = 1.96$ for 95 % conf. Level

An ideal sampling scheme requires lesser number of sample points for field checking, producing yet reliable statistics. Cost, time and other logistic considerations in operational remote sensing projects do not allow for field checking of large number of points for accuracy evaluation. It is suggested that for 90 per cent accuracy at least 30 points are needed per stratum.

2. Mapping (planimetric) Accuracy

The thematic maps derived from geocoded satellite imagery after digitization is transformed to polyconic projection (and rubber sheeting as required). The input coverage Tics are compared to those in output coverage, and the Root Mean Square (RMS) error is reported. The RMS error describes the deviation between the locations in the input coverage and those in the output coverage. In case of high RMS error repeat the transformation process till acceptable accuracy is achieved.

It may be easier to transform the scanned raster image of thematic map to real world coordinates through an image processing software such as ERDAS or EASI/PACE than in the GIS environment.

Annexure 2. Standard Procedure for Digitization

1. Prepare each input thematic map on separate tracing paper, with cartography done using Rotring or any other similar pen of preferably 0.2 number on clean polyester film.
2. Scan the map and store data in 'tif' format for use by any raster to vector conversion software.
3. Raster to Vector conversion using either Arc/Info GIS or CAD software.
4. Add Tic points (map sheet corner lat-long coordinates or any other known coordinate points) for easy transformation and map jointing at a later stage.
5. Edit to remove digitization errors, and clean and build topology.
6. Label features as per standard code / symbols in Look Up Tables.
7. Transform each coverage using same projection parameters (central meridian, standard parallels, and false easting and northing etc.) for the State.
8. Check edgematching and map joining errors, and error in co-registration of different layers.

Annexure 3 Internal Quality Assessment and External Quality Audit

Generation of standard and consistent data sets by multiple vendors in different locations require that rigorous quality control is exercised internally and through independent external audit. Internal Quality Assurance procedures will cover different critical stages in data set generation, starting from appropriate satellite and other map input data selection, thematic interpretation and validation, and final map validation. The stages in digitization process will cover scanning and digitization, labeling and attribute tables, and product labeling and reporting. Quality assessment will involve both visual inspection and measurements. The vendor will develop a comprehensive QA procedure and report compliance. While internal QA will cover each data product, external QA will be on sampling basis.

A check list of parameters to be assessed at each stage will be prepared and completed and attached to the report accompanying the product. For example the data selection assessment will involve the parameters of year and seasons of satellite data, sensor, and area coverage corresponding to specified SOI map.

The QC report will also be accessible to the external QA team during visit to the vendor site.

1.

