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Draft Indian Standard

Guidelines for Aquifer Mapping

Ground Water and Related Investigations Sectional Committee, WRD 03

Last Date for Comment: 18/02/2023

FOREWORD

(*Formal clauses of the foreword will be added later*)

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	Appendix: Colour codes for aquifer maps.

Indian Standard

Guidelines for Aquifer Mapping

Ground Water and Related Investigations Sectional Committee, WRD 03	**Last Date for Comment: 18/02/2023**

1. INTRODUCTION

An aquifer, by definition, is a saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients (Freeze and Cherry, 1979). In the water-well industry the definition of an aquifer also includes that it should be permeable enough to yield economic quantities of water to wells (Freeze and Cherry, 1979).Not just wells, Todd and Mays (2005) defines an aquifer as a formation that has sufficient permeable material to yield significant of water to wells and springs. Furthermore, it is generally understood that an aquifer also includes the unsaturated portion of the permeable unit (Todd and Mays, 2005).

However, in the context of mapping the aquifers, along with aquifers, it is also essential to delineate and characterise the associated rock formations that may not form potential aquifers, but may play significant roles is controlling recharge/discharge of the aquifers, interaction of the aquifers with overlying or underlying formations etc. Aquifer mapping can be defined as a scientific process, wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to i) delineate the horizontal and vertical extents of aquifers ii) characterize the aquifers in terms of their water bearing and transmitting properties, iii) Assess availability and quality of groundwater in aquifers and iv) Estimate status of exploitation of groundwater in the aquifer.

Various development activities over the years have adversely affected the ground water regime in many parts of the world . There is a need for scientific planning in development of ground water under different hydrogeological situations and to evolve effective management practices with involvement of community for better ground water governance.

Taking into consideration the existing groundwater issues and challenges in India, the report of the Working Group (constituted by the erstwhile Planning Commission) for the XIIplan on ‘Sustainable Ground Water Management’ highlighted the need for a comprehensive mapping of India’s aquifers, on a priority, that would form the cornerstone of developing any groundwater management programme. This signifies the importance of aquifer mapping in India and other countries. Systematic aquifer mapping is expected to improve our understanding of the geologic framework of aquifers, their hydrologic characteristics, water levels in the aquifers and how they change over time, and the occurrence of natural and anthropogenic contaminants that affect the usability of groundwater. Such understanding is an essential prerequisite for planning effective development and management strategies. Prior understanding of aquifer extents, properties and resource development status can help reduce time, money and risk involved in taking up development and management activities. Aquifer mapping at the appropriate scale will contribute significantly to prepare, implement and monitor the efficacy of various management interventions aimed at long-term sustainability of ground water resources, which, in turn, will help achieve drinking water security and improved irrigation facilities.

In India, the subject of water resources is being handled by a number of ministries and departments at both national and state levels. In addition, several academic/research institutions, NGOs and private organizations are also working on different aspects of water resources as part of their activities. A huge amount of data on various aspects of water resources has been generated during various activities of these agencies over the years. In this backdrop the present guideline would serve the purpose of providing a common framework for collection, collation, compilation of existing data, generation of additional data and their utilisation for Aquifer Mapping by various agencies.

2. BASICS OF AQUIFER MAPPING

2.1 Scale of Mapping

Aquifer maps are prepared by overlaying information related to aquifers and ground water on a base map containing information on geology, geographical features etc. As such, the scale of the base map should determine the scale of the aquifer map. Based on the intended scale of mapping, density of data points will also vary. Scale of a map is specified using Representative Fraction (RF), where RF is the ratio of distance on the map to the distance on ground. A feature of length 1km on ground will be represented by a line of 2 cm on a map of RF 1:50,000, whereas the same feature of 1 km length will be represented by a line of 10 cm on a map of RF 1:10,000.

2.2 Deliverables of Aquifer Mapping

An aquifer mapping exercise is expected to bring out the following minimum outputs.

- **Disposition of Water Bearing**

   Formations o Surface outcrops.

   o Subsurface continuity in vertical and horizontal disposition.

   o Overlay of different litho-units to form a group & aquifer system, E.g. - Alluvium - Gravel, sand, silt & clay in different percentage underlain by compact Sandstone,/shale, hard rock etc.
- **Water Bearing Capacity**
   - o Variations with depth
   - o Changes in space and time
   - o Demarcation of runoff zones, recharge zones and discharge zones
   - o Status of ground water abstraction
- **Aquifer (formation water) Quality**
   - o In-situ (depositional)

- Anthropogenic
- Vertical zonation
- Blending/Migration of pollutants in aquifers with time

- **Strategies for Sustainable Management**
  - Quantification of water within different layers (Aquifers- 1,2 3 etc)
  - Quality in each aquifer (group)
  - Demand-Supply analysis
  - Estimation of prevailing Development Status
  - Precise assessment of functional wells for agriculture, industries, drinking water purposes (modified well census as village wise by public participation to be translated into aquifer wise & then administrative unit)
- **Identification of Clusters of Aquifers (layers)**
  - Vertical-horizontal flow of recharged water from source - rainfall, canal, applied irrigation etc.
  - Formation of Aquifer Management Unit (clustering of villages & depth units)
  - Preparation of Aquifer Management Plans for sustainable ground water management. The AMPs need to be prepared in a simplified manner so that they are easily understood and implementable by the stakeholders and ensuring wider acceptability. Sustainability necessarily means the reliability, resilience and the vulnerability of the resource. Reliability is the ability of system to meet demands; resilience is the measure of the ability of the system to recover from failure and vulnerability is the measure of loss/damage incurred because of failure.

3. COLLECTION AND COMPILATION OF AVAILABLE DATA

The occurrence, movement, storage and availability of ground water in an aquifer depend mainly on two factors, viz. the physical framework of the aquifer systems and the recharge and discharge of water to and from the aquifers. The physical framework of the aquifer system is governed mainly by geological and geomorphological characteristics of the area. The recharge and discharge of ground water from and to the aquifers is controlled by the aquifer characteristics as well as several other factors such as soils, climate, cropping pattern, land use, surface water features, agricultural practices etc. A realistic representation of an aquifer and plan for its sustainable management needs to take into account the influence of all these factors on the aquifer system.

Collection of ground water related data available with different agencies in a standard format forms an important pre-requisite for data gap analysis as well as for preparation of aquifer maps and development of aquifer management plans. The major data types and sources are shown in **Table 3.2.**

Table 3.2: Major data types for aquifer mapping and their sources

S. No.	Data Type	Data Sub-type	Data Source	Remarks
1	Maps/ Thematic Layers	Topography	Survey of India	• Shape (.shp) files of Villages, elevationcontours, drainage, roads, water bodies, forest etc. digitized at 1:50,000 scale • Hard copy maps on 1:50,000 scale will also be procured • For identified priority areas, SOI is taking up preparation of 1: 10,000 scale maps which will be also used and efforts will be made to generate more coverage under this project also
		Geomorphology	National Remote Sensing Centre (NRSC)	Satellite data (CARTOSAT, LISS- III, LISS- IV, RESOURCESAT) NRIS codes developed by NRSC may be followed in classification of geomorphological units. GIS layers from 1:50,000 scale available with NRSC will be used as base for updating with more field data
		Geology	Geological Survey of India	Shape files of Geology may be procured from GSI Hard copy maps on the 1: 50,000 scale will also be procured
		Soil	National Bureau of Soil Survey (NBSS)	Maps on 1: 500,000 scale (Available with National Data Centre, CGWB, Faridabad for the entire country)
		Land Use/ Land Cover	National Remote Sensing Centre	To be generated form LISS-III RESOURCESAT
2	Data base of Groundwater monitoring network	Location Details	Central Ground Water Board, State Ground Water Departments	Data available with different agencies to be brought to a standard format and integrated location maps prepared
		Reduced level data, Water Quality data and water level data		Data available with different agencies to be compiled in a standard format
3	Data base of Ground	Location Details	Central	

	Water Exploration	Reduced Level	Ground Water Board, State Groundwater Department, Drilling Contractors Industrial Units Farmers	Data available with different agencies to be brought to a standard format and integrated location maps prepared Data available with different agencies to be compiled in a standard format
		Lithological logs		
		Vertical Electrical Sounding (VES) and Well Logging data		
		Parameter Aquifer data (T/K/S/Sy)		
		Aquifer- wise water quality data		
4	Surface Water Data	Rainfall/ Metrological data	Indian Metrological Department/ State Water Resources Organizations/ Agricultural Universities/ Research Institutions	Data to be collected and compiled in a standard format
		Gauge/ Discharge River and Water Quality data	Central Water Commission (CWC), State Water Resources Organizations	Data to be collected and compiled in a standard format
		Spring discharge & Quality	State Water Resources Organizations	Data on location, discharge, quality and other Relevant
		Tanks and Surface water bodies		Details on location, dimensions, storage capacity, number of filling, use, ownership etc. to be collected and compiled in a standard format
		Particular Canal discharges and command area	State Irrigation department/ CADA	Hydraulic particulars, length, no. of days of flow, discharge, designed cropping pattern etc. to be collected and compiled
5	Agriculture	Cropping Pattern	State Agriculture Departments	Data on cropping pattern and reasons for major shifts if any
		Source-wise	State	Data on source-wise irrigation (Surface water,

		irrigation	Irrigation Department	Ground Water, other sources)
		Minor Irrigation	State Minor Irrigation Department	Data on minor irrigation structures, command areas etc.
6	Industries	Location of major industries	State Departments of Industries	Data on use of ground water for industries Mining hydrology Ground Water contamination by industrial effluents
		Location of mines, sand mining areas and abandoned quarries		
		Raw Materials, Products and effluents		
		Water requirement for industries		
		Locations of Effluent Treatment plants		
7	Socio-Economic Date	Population	Census Department	Village- wise population, population density, population growth etc.
		Water supply schemes		Details of drinking water sources & quantum of ground water used for drinking & domestic use

4. DATA GAP ANALYSIS

India is a country with wide variations in hydrogeological, hydrological, geological, topographical conditions;hence a need has been felt to prepare a common and consolidated guideline for aquifer mapping and data gap analysis. The guideline is expected to explain broadly the methodology and data formats for data collection, compilation and data gap analysis so as to ensure uniformity in the analysis and outputs.

It has been attempted to cover entire country broadly under four types of regions viz. Alluvial areas, Hard rock areas, Basaltic/ layered formation areas and Hilly areas. The guideline defines the grid wise and aquifer wise basic requirement for establishing aquifer geometry and characteristics and accordingly the method for data gap analysis to be carried out.

However, due to wide variation in local hydrogeological and geological conditions the filed hydrogeologists involved in mapping may decide on number of aquifers, grids where data generation is required, quality parameters specific to the area etc.

4.1 Methodology

The process of identification of data gap involves the following steps

Aquifer Mapping is a scale dependent activity therefore the data gap analysis must correspond to the scale of mapping. The illustrations in the guideline has been made for 1:50,000 scale which is the most commonly used scale for mapping of natural resources. For a mapping at 1:50,000 scale the grid size would be 5'X5'Accordingly for finer scale mapping eg 1:25,000, the grids size of 2.5'x2.5' would be considered and so on.

- Compilation of the data collected in a common standardized format.
- Identification of data gaps with respect to
  - Thematic layers (Geomorphology, land cover/land use, soils etc.)
  - Sub-surface Data (Litholog, aquifer parameters, water level, water quality, geophysical parameters etc.)
  - Ground water recharge and draft

4.2 Data gaps in thematic layers

After collection of the layer data on various themes from different sources, the data need to be brought to a common platform for examination in respect of correctness and completeness. Gaps in the data depicted in the maps are then to be identified, which are to be filled up using data available with other agencies, sources such as remote sensing imagery, aerial photos etc. or through value addition through data collected in the field.

4.3 Data gaps in sub-surface data

The hydrogeological setup in the Indian sub-continent is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions. Studies carried out over the years have revealed that aquifer groups in alluvial / soft rocks even transcend the surface basin boundaries. Broadly two groups of rock formations have been identified depending on characteristically different hydraulics of ground water, Viz. Porous Formations and Fissured Formations.

Porous formations have been further subdivided into Unconsolidated and Semi – consolidated formations. The areas covered by alluvial sediments of river basins, coastal and deltaic tracts constitute the unconsolidated formations. These are by far the most significant ground water reservoirs for large scale and extensive development. The semi-consolidated formations normally occur in narrow valleys or structurally faulted basins. The Gondwanas, Lathis, Tipams, Cuddalore sandstones and their equivalents are the most extensive productive aquifers in this category. Under favorable situations, these formations give rise to free flowing wells.

The consolidated formations occupy almost two-thirds of the country. These formations, except vesicular volcanic rocks have negligible primary porosity. From the hydrogeological point of view, fissured rocks are broadly classified into four type"s viz. Igneous and metamorphic rocks excluding volcanic and carbonate rocks, volcanic rocks, consolidated sedimentary rocks and Carbonate rocks. Density of data requirements will vary based on the type of the terrain. Accordingly the data densities are recommended for two broad terrain types: i) unconsolidated/semi-concolidated formations and ii) consolidated formation

A. Unconsolidated/ semi-consolidated Formations

a. Exploratory Data

Fig.A1: Sample- Exploratory Data required for Two Aquifer group system in Alluvial areas

Exploratory Well		Exploratory Well
	Well Field EW – 2 OW – 2	
Exploratory Well		Exploratory Well

i. It is recommended that 3 to 4 exploratory wells **(EW)** may be constructed in the corner quadrants of each toposheet (or hydrogeologically required areas) at suitable locations to get the lithological information. (Fig-A1). Quadrants for exploratory wells should be changed in adjacent toposheets to avoid clusters of EWs .

ii. In the centre (or any suitable site) of each toposheet a **"Well field"** with exploratory wells (at least 8" dia) and observation well tapping each aquifer is recommended to find out aquifer disposition.

iii. For the first aquifer 4-5 pumping tests are be carried out in the existing dug wells/ if possible in shallow bore wells.

iv. Aquifer performance test shall be conducted in the well field, on EW"s tapping the 2nd/3rd aquifer group to estimate the aquifer wise hydraulic parameters and water quality

v. Assessment of Data Adequacy (Adequacy of available sub -surface information for deciphering aquifer geometry at the desired vertical & horizontal scale) is to be done based on recommended and available information.

b. Geophysical Data

i. It is recommended that 3 Profiling/VES/TEM having 300 meter interpretation depth should be carried out in each of the nine quadrants of the toposheet totaling to 27 nos. in each sheet to decipher aquifer geometry (Fig-A2).

ii. Assessment of Data Adequacy is to be done based on recommended and available information.

Fig-A2

Sample- Geophysical Data required for Two Aquifer group system in Alluvium areas

3 Profiling/ VES/TEM	3 Profiling/ VES/TEM	3 Profiling/ VES/TEM
3 Profiling/ VES/TEM	3 Profiling/ VES/TEM	3 Profiling/ VES/TEM
3 Profiling/ VES/TEM	3 Profiling/ VES/TEM	3 Profiling/ VES/TEM

c. Ground Water Monitoring Data

i. For 1st aquifer (un-confined/Phreatic) two open/dug wells are recommended for each quadrant of a toposheet. (Fig-A3)

ii. For 2nd and 3rd aquifer the well-constructed in the Well field explained above and wells may be used as piezometers for GW monitoring.

iii. Minimum four times monitoring annually is recommended as per the state specific schedule of monitoring.

iv. Assessment of Data Adequacy is to be done based on recommended and available information.

Fig-A3

Sample- GW Monitoring Data required for Two Aquifer group system in Alluvial rock areas

Ist Aq - 2 IInd Aq - 1	Ist Aq - 2	Ist Aq - 2 IInd Aq - 1
Ist Aq - 2	Ist Aq - 2 IInd Aq - 1	Ist Aq - 2
Ist Aq - 2 IInd Aq - 1	Ist Aq - 2	Ist Aq - 2 IInd Aq - 1

d. Ground Water Quality Data

i. For 1st aquifer (un-confined/Phreatic) one sample from open/dug wells are recommended for each quadrant of a toposheet. (Fig-A4)

ii. For 2nd aquifer the sample is to be collected from well-constructed in the Well field explained above and Exploratory wells for GW Quality monitoring.

iii. Minimum two times monitoring initially is recommended.

iv. Assessment of Data Adequacy is to be done based on recommended and available information on quality monitoring stations.

Fig-A4

Sample- GW Quality Data required for Two Aquifer group system in Alluvial rock areas

Ist Aq - 1 IInd Aq - 1	Ist Aq - 1	Ist Aq - 1 IInd Aq - 1
Ist Aq - 1	Ist Aq - 1 IInd Aq - 1	Ist Aq - 1
Ist Aq - 1 IInd Aq - 1	Ist Aq - 1	Ist Aq - 1 IInd Aq - 1

B. Consolidated Formations

a. Exploratory Data

i. In hard rock areas 5 EW‟s and 5 OW‟s should be constructed at suitable locations, preferably one in central quadrant and one each in the four corner quadrants for establishing aquifer geometry and determining aquifer parameters. (Fig-B1). Location of EW/OW in corner quadrants can be changed in adjacent toposheets to insure uniform distribution.

ii. For the first aquifer 4-5 pumping test are be carried out in dug wells/ if possible in shallow bore wells.

iii. Aquifer performance test shall be conducted at all the five EW‟s tapping the fractured aquifer to estimate the aquifer hydraulic parameters and water quality.

iv. Assessment of Data Adequacy (Adequacy of available sub-surface information for deciphering aquifer geometry at the desired vertical & horizontal scale) is to be done based on recommended and available information.

Fig-B1

Sample- Data required for Two Aquifer group system in Hard rock areas (for IInd Aquifer)

EW – 1 OW – 1		EW – 1 OW – 1
	EW – 1 OW – 1	
EW – 1 OW – 1		EW – 1 OW – 1

b. Geophysical Data

i. It is recommended that 2 to 3 Profiling/VES/TEM soundings upto 200 meter interpretation depth should be carried out in each of the nine quadrants of the toposheet totaling to 18 to 27 nos. in each sheet to decipher aquifer geometry (Fig-B2).

ii. Assessment of Data Adequacy is to be done based on recommended and available information.

Fig-B2

Sample- Geophysical Data required for Two Aquifer group system in Hard Rock areas

2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM
2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM
2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM

c. Ground Water Monitoring Data

i. For 1st aquifer (un-confined/Phreatic) one open/dug wells are recommended for each quadrant of a toposheet. (Fig-B3)

ii. For 2nd aquifer (fractured zone) the OW constructed may be used as piezometers for GW monitoring.

iii. Minimum four times monitoring annually is recommended as per the state specific schedule of monitoring.

Fig-B3

Sample- GW Monitoring Data required for Two Aquifer group system in hard rock areas

Ist Aq - 1 IInd Aq - 1	Ist Aq - 1	Ist Aq - 1 IInd Aq - 1
Ist Aq - 1	Ist Aq - 1 IInd Aq - 1	Ist Aq - 1
Ist Aq - 1 IInd Aq - 1	Ist Aq - 1	Ist Aq - 1 IInd Aq - 1

iv. Assessment of Data Adequacy is to be done based on recommended and available information.

d. Ground Water Quality Data

i. For 1st aquifer (un-confined/Phreatic) one sample from open/dug wells is recommended for each quadrant of a toposheet.

ii. For 2nd aquifer (fractured zone) the water sample may be collected from EW constructed for GW quality monitoring.

iii. Minimum two times monitoring initially is recommended for quality monitoring.

iv. Assessment of Data Adequacy is to be done based on recommended and available information.

4.4 Data Gap in Ground Water Recharge and Draft components

Recharge and discharge parameters are vital in assessing the status of ground water resources in the aquifers. Rainfall, recharge from canals, surface water bodies and tanks and recharge from applied irrigation constitute the major sources of recharge, whereas ground water draft for various uses, base flow into streams and evapotranspiration in shallow water table areas constitute the major components of ground water draft.

Data gap in ground water recharge components

As per the guidelines of the Ground Water Estimation Committee of Government of India, data pertaining to aquifer geometry (vertical & lateral), rainfall, ground water levels/piezometric heads, canal command area, cropping pattern, surface water bodies, aquifer parameters (specific yield / storativity) and ground water quality are required for realistic assessment of ground water recharge. Modalities of collection, compilation and processing of data pertaining to all these components have already been elaborated in the previous chapter of this manual. The data gap analysis in respect of recharge components will consist mainly of assessment of inadequacy of data in respect of the components and plans to generate/collect additional data in the data generation phase of the project.

Data gap in ground water draft components

Ground water draft from the aquifers is generally for irrigation, domestic and industrial uses. Irrigation sector is the major user of ground water from aquifers in the major part of the country. Season-wise unit draft and the number of ground water abstraction structures in each aquifer zone used for irrigation are vital for realistic assessment of ground water draft. Data pertaining to crop-water requirements and prevailing cropping pattern in the area are often used to cross check the estimated ground water draft. Data pertaining to population, per-capita water requirement, number of industrial units, their water requirements and the number and types of abstraction structures used for ground water extraction are required to assess the domestic and industrial ground water draft. As mentioned in the case of recharge components, the data gap analysis in ground water draft components will also consist mainly of assessing the inadequacy of the components mentioned and plans for additional data generation to facilitate realistic ground water draft assessment.

5.0 GENERATION OF ADDITIONAL DATA

Data generation consists of generation/collection of additional data to fill up the identified data gaps in respect of thematic layers, subsurface data and ground water recharge/draft components. Data generation may often require tailor-made field investigations aimed at generating data pertaining to one or more aquifer zones in standard formats developed for the purpose.

The activities for data generation can broadly be classified into the following groups:

- Hydrological and hydrogeological investigations
- Exploratory drilling
- Geophysical investigations
- Ground water levels and water quality monitoring
- Hydrochemical investigations and analyses
- Isotope studies / Carbon dating
- Techno-economic studies.

Details of data to be generated from these activities are summarized in **Table 5.1**

Table 5.1: Activities for data generation for Aquifer Mapping.

Sl.No	Activity/study	Sub-activity	Data to be generated
1	Hydrological	Soil infiltration studies	Soil infiltration rates Rainfall infiltration factor
		Determination of Recharge / Draft Parameters (Through sample surveys)	Recharge parameters (Recharge through canals, surface water/ground water irrigation, water bodies etc.) Draft parameters (Season-wise unit draft)
2	Hydrogeological	Well inventory	Subsurface geological information Thickness of weathered zone Fracture density Basement topography
		Pumping tests/Slug tests	Aquifer parameters (Sy,K,T,S)
		Ground water draft estimation	Unit drafts of ground water abstraction structures for various uses.

		Determination of Specific yield through dry season water balance studies	Specific yields of various litho-units in the phreatic zone
		Ground water level/ piezometric heads monitoring	Depth to water levels/ Piezometric Heads, Seasonal fluctuations, Ground water flow directions
3	Exploratory drilling & Pump tests.	Exploratory drilling	Sub-surface lithology
		Slug tests	Aquifer parameters
		Aquifer performance tests	
4	Geophysical	Vertical Electrical sounding	Subsurface Hydrologic information to supplement data collected from exploratory drilling and to provide sub- surface data in areas not feasible for exploratory drilling
		Borehole logging	
		Profiling	
		Resistivity imaging	
		Ground/Heli-borne TEM	
		Seismic/Gravity/Magnetic surveys	
5	Hydrochemical	Collection of water samples (both surface & groundwater)	Spatial and temporal variations in ground water quality and Ground water contamination issues
6	Techno- economic studies	Sample survey of investment & returns in ground water irrigation	Economic aspects of ground water use in the aquifer

AQUIFER MAP PREPARATION

6.1 Introduction

Once the collection, compilation, data gap analysis and additional data generation to fill the identified data gap are completed, the final and most important step is the preparation of the aquifer map, which brings together various aspects of the aquifers and their ground water resources in the form of a map, which can then be used by the stakeholders to plan their sustainable development and management. Aquifer map preparation essentially involves the following activities

- Digitization of aquifer map and preparing aquifer GIS Data sets.
- Preparation of GIS datasets of aquifer thickness, depth of occurrences of water bearing zones, their water bearing and transmission properties, etc.
- Digitization of the Maps and preparing GIS Datasets depicting geophysical parameters.
- Digitization of the Maps and preparing GIS Datasets depicting water quality parameters
- Digitization of the Maps and preparing GIS Datasets depicting status of ground water resources.
- Preparation of conceptual model of the area and visualization of the aquifer units in three dimension including fence and cross section preparation.

The GIS data created and data obtained from various statistical analyses would be integrated in GIS environment with the derived aquifer information to generate composite maps in respect of aquifers. These maps would provide area and location specific information for judicious management of ground water resources in them in a user-friendly manner. These maps can grouped in three categories namely, aquifer maps, aquifer properties & vulnerability maps and aquifer management option maps.

- The aquifer maps may depict the aquifer extents, bed rock configuration etc. along with the locational features. 2D and 3D diagrams can be presented on the aquifer map as insets.
- Derivative maps depict aquifer properties such as hydraulic properties, water quality, water resources availability, water stressed and contaminated area.

6.2 Map Composition and Printing

Lay-out and design

As discussed in the previous paragraphs,all map data for the maps will be generated in GIS environment. Since these data will consist of point, line or polygon features and hence difficult to be clearly understood by the stakeholders, they will have to be color coded and annotated with standard labels for easy understanding.

Since these maps will be used as the base for formulation and implementation of various scientific interventions for the management of ground water resources, they have to be presented on a suitable scale, preferably on 1:50,000 scale having standard 15 minutes by 15 minutes coverage. The hard copy format will be available in the form of A0 size map (1 / 1.2-meter paper print). Maps will have important geographical features such as village locations, roads, railway lines, administrative boundaries etc.to help the users locate their areas of interest.

The map title, fonts, styles, color scheme, annotation styles etc. should be the same as used in Survey of India toposheets. The recommended color-coding scheme and symbology for aquifer maps is given in Appendix -1.

Map legend

Legend is the key to the map and help in reading the map information. The number of themes, their color schemes and font give richness to the map and help in understanding it in a user friendly manner. The international legend style will be used in preparation of aquifer maps. The fonts, styles, color scheme, annotation styles etc. of the legends should be adopted from the Survey of India toposheets and aquifer Atlas of India. The map should preferably have the following information:

- Map Title
- Method followed in preparing the Map
- Map Scale
- Map number - Survey of India 1:50,000 scale toposheet index number
- Administrative area covered by the map
- Geographical directions of the map area
- Copyright information
- Input data used for preparing the map
- Organization which has prepared the map
- Index for Aquifer Map - Fixed part of the legend
- Index for hydrological Information - Fixed part of the legend
- Index for base map Information - Fixed part of the legend
- Body of the map
- Main Legend of the map - Dynamic part of the legend describes body of the map taking
- Location map - index

Appendix – I

Aquifer classification and colour codes as per the Aquifer Atlas of India (CGWB, 2012)

Sr. No.	Aquifers	Code	Red	Green	Blue
1	Alluvium (AL)	AL 01	224	255	176
2		AL 02	255	208	64
3		AL 03	255	255	208
4		AL 04	255	255	0
5		AL 05	255	255	165
6		AL 06	255	254	64
7		AL 07	230	200	0
8	Laterite (LT)	LT 01	255	158	48
9	Basalt (BS)	BS 01	208	255	232
10		BS 02	112	112	0
11	Sandstone (ST)	ST 01	160	160	255
12		ST 02	176	255	176
13		ST 03	176	255	255
14		ST 04	128	255	255
15		ST 05	80	255	255
16		ST 06	0	208	208
17	Shale (SH)	SH 01	255	128	128
18		SH 02	255	176	176
19		SH 03	255	220	208
20		SH 04	255	216	176
21		SH 05	255	192	128
22		SH 06	255	112	64
23	Limestone (LS)	LS 01	255	0	128
24		LS 02	255	96	176
25		LS 03	255	208	64
26		LS 04	255	160	208
27		LS 05	255	208	232
28	Granite (GR)	GR 01	112	160	255
29		GR 02	160	190	255
30	Schist (SC)	SC 01	222	224	0
31		SC 02	112	255	112
32		SC 03	160	255	160
33	Quartzite (QZ)	QZ 01	128	0	255
34		QZ 02	200	144	255
35	Charnockite (CK)	CK 01	255	208	255
36	Khondalite	KH 01	125	208	0
37	BGC (BG)	BG 01	255	216	176
38	Gneiss (GN)	GN 01	208	208	255
39		GN 02	208	240	255

40		GN 03	172	230	255
41	Intrusives (IN)	IN 01	96	203	255
42		IN 02	208	208	208