CHAPTER- 4

Land Use Land Cover Mapping and Identification of Potential Rechargeable Sites for Study Area

(Part A: Land Use Land Cover Mapping For Study Area)

4.1 Introduction

Irrigation is a vital factor for development of agriculture, especially for India where natural source of water i.e. monsoon, is highly variable in amount and distribution (V.S.Bhrambhatt et al, 2000). In spite of the large investments made in the irrigation sector in India and the phenomenal growth of irrigation potential since the year 1951, the return from the investment, both in terms of crop yeild as well as finance are disappointing (WTC, 1983). The reason for poor performance of canal projects the emphasis on the fact investment of huge money is done behind the development of new irrigation projects rather than putting the existing irrigation projects on high performance level i.e., operation and maintenance part is highly neglected (Palanisami,1984). Hence, regular monitoring of command areas is needed to improve water management practices. There is unique capability of monitoring the command areas with the remote sensing tool. Chari et al (1994) have analyzed multidate satellite data for Bhadra irrigation project of Karnataka, during rabi season prior to and after implementation of National water management project to provide spatial information of irrigated area and paddy productivity right at distributory level. Sahai et al (1985) using multidate, multispectral imagery of pre and post monsoon period for 1972-81 and studied the impact of canal irrigation system on the ecosystem of Ukai Kakrapar command area in Gujarat related to water logging/salinity. Kalubarne et al (1983), (1985) and Mohitkumar and Bhagwat (1989) have also examined the extent of water logging and salinity in Gujarat.


Land use and Land cover can be specifically defined as Land use refers to ‘man’s activities and the various uses which are carried on land’. Land cover refers to
natural vegetation, water bodies, rock/soil, and etc. All though land use is generally inferred based on the cover, yet both the terms are related and interchangeable (NRC-LULC report). Realizing the importance of LULC over a period of time, regional level mapping has been attempted in India using IRS P6 AWiFS data of 56 m spatial resolution to bring out causes, rates, magnitude, patterns and trends in land use/land cover changes. Multi temporal satellite datasets are used as primary inputs for generation of spatial data base on temporally variant LULC classes. This becomes relevant while developing regional and national level databases as LULC classes exhibits varied spatial/temporal characteristics across larger geographical gradients.

The study area is in the command of **Branch Canal 3 of “Sabarmati Right Bank Main Canal”** off suiting from **Dharoi dam in North Gujarat.** The localized study may be concentrated at around Block-6 of branch canal-3 located in Mehasana district, block-6 has the largest irrigation command share of Branch canal 3 of SRBMC i.e. 11652 ha so it is suggested to be evaluated. Mehsana district: Villages:- **Unjha, Visnagar, Vadnagar, Kheralu and part of Sidhpur.**

### 4.2 Review of critical literature

Chari et al 1994 as stated ahead in literature review chapter studied the Bhadra irrigation project of Karnataka; using multidate satellite data prior to and after implementation of National Water Management Project (NWMP). They provided the spatial information on irrigated area and estimated productivity of paddy up to distributory level.

V. S. Brahmbhatt et al 2000 studied the temporal changes (1988-89 to 1997) in land use/land cover using multi temporal, IRS P6, WiFS data having 153 m spatial resolution and 16 days Repetivity satellite data in Mahi Right Bank main canal command area in Kheda district of Gujarat state. They concluded that command area is affected by water logging and salinity. Land use/Land cover change is maximum in a distributory (Lambhvel) situated in highly urbanized zone of Anand city, where built up area increased from 281 ha. to 460 ha. Salt affected area has increased in Chikhaliya command and decreased in Manej command. Water logging is maximum in Pansora command area with 586 ha. of water logged area in 1997.

WIM G.M. Bastiaanssen, 2000 clearly states that supervised classification approach is the most common methodology for forming classes that are similar in spectral reflectances. Settle and Briggs, 1987 assigned classes (training classes) verified on ground at selected areas. This training set represents a small percentage of an entire satellite image and because selection is made by field observers, sampling is often not random and is biased by
few selection procedures. This is because sampling sites may be selected based on conveniences of the sampler. The maximum likelihood classifier is concluded to be a successful criterion that is based on priority based probabilities.

Anita K. Prakash et al 2007 decided alternative sustainable landuse pattern of Ranga Reddy district, Yacharam Mandal of Andhra Pradesh. Land Use Land Cover maps were digitized for the study area and based on various land cover classes sustainable water shed development was suggested by giving priority to agriculture first and also working for soil and water conservation practices, ground water prospects, land capabilities

M.Girish Kumar et al 2008 delineated potential harvesting sites using RS & GIS using the using LISS III data and survey of India (SOI) and other collateral data. Various thematic maps were generated using the principles of thematic class reflectance and potentiality of groundwater depending on it’s water storing capacity. Each class was given the rank and the class or theme was given the weightage and they were reclassified for the suitability of water bearing potential. All reclassified maps were further integrated using GIS and potential ground water potential maps were prepared.

4.3 Scope of present work

In the present study, as a part of performance evaluation of the command area of Branch Canal 3 of “Sabarmati Right Bank Main Canal” off suiting from Dharoi dam in North Gujarat, the Land use/land cover maps are generated using thematic classes reflectances. A standard classification guideline of National remote sensing agency (NRSA), Hyderabad is used for the work and local classification system is developed for the present work as shown in table 4.1. The objectives of doing this exercise are as follows:

1. Systematically study the land use pattern of the command and suggest the refercations.

2. To work out the percentage area occupied by each class within the map over the total command area of considered unit, block 6 of branch canal.

3. To find out weather the command area suffers from salinity and water logging or not.

4. To identify patches of irrigated land predominantly during Rabi or Kharif and those remaining productive or unproductive during both the seasons.

5. Use the generated land use map as thematic layer to exercise on delineation of potential water harvesting zones
The detailed work of study being focused at around Block-6 of branch canal-3 located in Mehasana district, block-6 has the largest irrigation command share of Branch canal 3 of SRBMC i.e. 11652 ha so it is suggested to evaluate command area of 11652 Ha comprising of villages Unjha, Visnagar, Vadnagar, Kheralu and part of Sidhapur. Fig 4.1 clearly depicts the detailed procedure of work.

**FLOW CHART FOR LAND USE LAND COVER MAPPING**

1. Raw data downloading for IRS P6 LISS-III sensor/AWiFS sensor
2. Geometric corrections/Ortho correction of satellite data products
3. Atmospheric correction of satellite data products
4. Sub-setting the data as per SOI toposheet and Taluka boundary maps
5. Preparing base maps using Digital vector, Survey of India toposheet
6. Locating permanent features/AWiFS LULC layer
7. Visual Interpretation of satellite Imageries/
8. Integrate layers to generate land-use classes/feature coding
9. Measure the areas of various classes of land use
10. Land use/Land cover maps

Fig 4.1 FLOW CHART TO DIGITIZE LAND USE LAND COVER MAPS
4.4 Land Use Land Cover classification system

As the rich experience is gained in managing the country natural resource over last two decades by working on the scale 1:20,000 and to some extend to 1:50,000 scale has enhanced our ability to modify the existing system of classification for LULC classes to make it more specific. Exhaustive land use land cover classification was evolved to facilitate as in-depth assessment of all land use/land cover categories. The classes of classification system are hierarchically organized to find it’s applicability in different spatial scales and collapsible for comparison with reported areas; adopted directly by user agencies with refinement at their end.

The classification scheme is adopted for extracting information for most possible land use/land cover classes in general and all the agricultural seasons in particular and hence enable to repeat the process at regular intervals.

**Land Use Land Cover Classification system developed for Sabarmati Right Bank main canal command area of Branch Canal 3**

**Table 4.1**

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Level-I</th>
<th>Level-II</th>
<th>Level-III</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>Administrative boundaries</td>
<td>District</td>
<td>Taluka boundaries</td>
</tr>
<tr>
<td>2.</td>
<td>Urban-Built-Up land</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3.</td>
<td>Road Network</td>
<td>National Highways</td>
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<tr>
<td></td>
<td></td>
<td>State Highways</td>
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<td></td>
<td></td>
<td>Other roads</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Railway Lines</td>
<td></td>
</tr>
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<td>4.</td>
<td>Water bodies</td>
<td>Reservoirs</td>
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<td></td>
<td></td>
<td>Rivers</td>
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<td></td>
<td></td>
<td>Lakes/ponds</td>
<td></td>
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<td></td>
<td></td>
<td>Canal Networks</td>
<td></td>
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<tr>
<td>5.</td>
<td>Agriculture Land</td>
<td>Crop land</td>
<td>Rabi</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Kharif</td>
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<td>Zaid</td>
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<td>Two season</td>
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<td>Rabi</td>
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<td>Kharif</td>
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<td></td>
<td></td>
<td></td>
<td>Two season</td>
</tr>
<tr>
<td>6.</td>
<td>Wet Lands</td>
<td>Water logged areas</td>
<td>Premonsoon</td>
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<td></td>
<td></td>
<td></td>
<td>Post monsoon</td>
</tr>
</tbody>
</table>
4.5 Methodology

Sabarmati Right Bank Main Canal (SRBMC) Command of Mehasana district is covered by four Survey of India (SOI) toposheet, namely, 46A05, 46A06, 46A09, 46A10 on 1:50,000 scale, For Multi season, Multiyear land use land cover mapping, Various steps followed are as under.

1. Frequent field visits for getting information about land cover classes, crop types crop condition, extent of salinity, water logging etc following standard methodology (Liellesand and Kiefer, 1979).

2. Preparation of base maps on 1:50,000 scale selecting permanent features like railways, major road network, water bodies, settlements and major canal network.

3. Preparation of land use/land cover classification system (table 4.1) by modifying National Remote sensing Authority of India, national level land use land cover classes to take account the local classes present in the command area.

4. Visual interpretation of multi-season multidate AWiFS satellite data was done to locate the areas having Kharif, Rabi and Zaid crops, forest areas, sparse vegetation like alphalpaha.

5. Corrections of interpreted maps were done using field information obtained from Dharoi irrigation circle at Visnagar.

6. Visual interpretation of imageries was carried out for command area in consultation with experienced technicians & classifiers working at BISAG Gandhinagar.

7. The areas covered by various land cover classes were demarcated by drawing polygons and circles.

8. Area occupied by various land classes were calculated using ARC-GIS software.

<table>
<thead>
<tr>
<th>7.</th>
<th>Waste Land</th>
<th>Salt affected Sandy/Stony Land with Pasture</th>
<th>Permanent</th>
</tr>
</thead>
</table>

| 49 |
9. Analysis of maps was done using Geographical information system tool.

4.5.1 NRSA Guidelines to identify Key features of Land use Land Cover Classes by Visual Interpretations of Satellite Imageries

1. Administrative Units

The work of preparing land use land cover maps are to be prepared keeping in view some specific study area. The digital database preparation for GIS and RS work first requires the location of district boundaries and then taluka boundaries which may be followed by village boundaries if necessary. The Survey of India toposheets are superimposed by district and taluka boundaries. The final product with particular latitude and longitude is ready for further process and work.

2. Urban Built –Up land

All places with a municipality, corporation or cantonment or which is notified town areas and all other places which satisfy the criteria of minimum population of 5000, at least 75% of whose male working population is non agricultural and having a density of population at least 400 per Sq.Km are placed under that category. Most of the areas of such agglomerations are seen covered by utility a structure which includes residential, industrial, transportation, power, communication and isolated areas.

3. Rural Built –Up land

These are the land used for human settlement of size comparatively less in size and then the urban settlement, of which 80% of people are involved in the primary activity of agriculture. All the agriculture villages covering 5 hectares area and more are included in this.

4. Transportation

These are the areas under movement of people, goods and material. It is a measure of accessibility and connectivity. It includes railways, roads, airports, ports, waterways etc. The roadways includes major and minor roads, bridges and terminal facilities such as bus and truck terminals. The linear features listed above appear in small in width for roads and narrow in case of railway line, darkbluish green to light
yellowish in most of the cases. They are more prominently seen in plain areas, across water bodies, agricultural lands connecting elements. The permanent linear features for present work are drawn from survey of India toposheets and are verified using satellite imagery. They are more prominently seen in plain areas across water bodies, agricultural lands connecting settlements.

5. Water bodies

This category comprises areas with surface water, either impounded in the form of ponds, lakes and reservoirs or flowing streams, rivers, canals etc. These are seen clearly seen on satellite imagery in light blue to dark blue or cyan colour depending mainly on the depth of water.

A. River, streams are natural course of water flowing on the land surface along a definite channel slope regularly or intermittently towards a sea in most cases or a lake or an inland basin in desert areas or a marsh or other river. They appear in light or dark blue in color, long, narrow to wide depending on the size of river. They normally appear nonlinear and serpentine in nature. Dry rivers can be identified from bright white colour reflectance of sand around them.

B. Canals (Main, Branch and distributaries with field canal) can be identified clearly on satellite imageries with certain clues like they are regularly linear and appear as straight line due to regular cross section. They normally pass through the agglomerations of cultivated fields. The unlined canals need slightly experienced classifiers.

C. Lakes and ponds are accumulation of water in depression of various sizes either natural or saline.

6. Agricultural Crop Land

These are the lands primarily used for farming and for production of food, fiber and other commercial and horticulture crops. It includes land under crops (irrigated and unirrigated fallow, plantations etc.

A. Cropland is the areas with standing crop as on date of satellite overpass. Cropped areas appear bright red to red colour with various shape and size in a contiguous to non-contiguous pattern. They are widely distributed in various terrains;
prominently appear in the irrigated areas irrespective of source of irrigation. The cropping season of India is considered as Kharif (June/July-September/October), Rabi (November/December-February/March) and Zaid crop as (April-May). As crop calendar is region specific the classification must be supported with authentic regional crop calendar and then work on satellite data.

B. Kharif crop areas are synonyms with the crop grown during the period of (June/July-September/October). The season coincides with southwest monsoon season. It is associated with rainfed crops under dry land farming, limited or no irrigation and areas of rainfed paddy and other dry crops.

C. Rabi crops are the crops extending for the period (November/December-February/March). They are areas with assured irrigation. Irrespective of source of irrigation.

D. Two cropped areas are the areas where both the Rabi and Kharif crops are often seen. They are predominantly the areas of irrigated commands. The combinations may be Kharif-Rabi, Kharif-summer where only Kharif and summer crops are cultivated located in isolated pockets of any irrigation command and third combination is Rabi-summer where it was not possible to take Kharif crop due to excessive rainfall or flooding.

Zaid crop are the areas that cropped during summer season with irrigated areas and very fertile soils.

E. Fallow lands are the lands which are taken up for cultivation but are temporarily allowed to rest for season or two, but not less than one year.

7. Waste Land

Wasteland is described as degraded land which can be brought under vegetative cover with reasonable effort and which is currently underutilized and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes.

A. Salt affected waste land is generally characterized as land that has adverse effect on growth of more plants due to the action or presence of excess soluble salts(saline) or high exchangeable sodium. These areas are essentially delineated
because of high reflectance; they appear in white or light blue colour depending on moisture content ranging in small to medium sizes. Generally they are irregular in shape and discontinuous.

**B. Gullied/Ravinous Land** are formed due to excessive localized runoff, which affects the unconsolidated material resulting in the formation of perceptible channel causing undulating channels. They appear in light yellow to bluish green in colour depending on surface moisture and depth of fissures caused. They vary in size, shape with irregular broken network pattern. They are also close by with stream courses and sloping grounds.

**C. Scrub Land** is the one which has undergone deterioration due to erosion. Such lands are generally occupying topographically high altitudes excepting high hills and mountainous terrain. They appear light yellow to brown to greenish blue depending on moisture content. They are near foot hills or moderate slopes.

**D. Sandy areas** are the ones having high stabilized accumulation of sand, in coastal, riverine or inland areas that can be either desertic or coastal. They appear white to yellow/bluish depending on moisture content and at times light red when vegetation is associated with the class, vary in size and shape with continuous to linear pattern.

**E. Barren/Rocky/Stony Waste lands** are composed of rock exposures of varying lithology often barren and devoid of soil and vegetation cover. They normally occur in midst of hill forests as openings or as isolated exposures on plateau and plains. Such lands can be easily discriminated from other categories of wastelands because of their characteristic spectral response. They appear greenish blue to brownish in color depending on the rock type.
FLOW CHART FOR MAPPING OF POTENTIAL RECHARGEABLE SITES

Raw data downloading for LANDSAT-7 TM DATA

Geometric corrections/Ortho correction of satellite data products

Atmospheric correction of satellite data products

Sub setting the data as per SOI toposheet and Taluka boundary maps

Preparing base maps using Digital vector, Survey of India toposheet, and location of permanent features

Digitized Soil map and Hydrogeomorphologic al map

Integrating permanent features & AWiFS LULC layer

Visual Interpretation of satellite imageries

Assign weights to all layers as per water holding capacity

Ground truthing input and collateral data input map

Reclassification of all thematic layers as per their assigned weights

Prepare various thematic layers in ARC-GIS

Weighted Overlay Classified maps PWRDS

Fig 4.2 FLOW CHART TO DELINEATE THE POTENTIAL RECHARGEABLE SITES
Part B: Identification of Potential Rechargeable Sites for Study Area

4. 6 Introduction

Remote sensing and GIS are playing vital role in field of subsurface hydrological exploration programe, by providing multi-spectral, multi-temporal and multi-sensor data of the earth’s surface (Choudhury, 1999). The ability of remote sensing to generate the information with spatial and temporal domain, which is very important for successful analysis, prediction, validation and integrated use in hydrological investigations (Saraf, 1999). GIS compliments the remote sensing technology by extending its capacity to handle large amount of complex, spatial and temporal data base with relative ease. In India monsoon is erratic and ingeneral, subsurface and surface water resources are unevenly distributed which gives rise to severe depletion of ground water resource. For the semi arid area like North Gujarat, which has less surface water resources, agricultural sector has greatly overexploited the aquifers, which has worsened the scenerio. The only way to tackle the situation is planning extensive recharge schemes (Choudhury, 1999). Present study has explored the study area, identifying it has overexploited aquifers and have made an attempt to check the competency of command area for developing water harvesting schemes as an integrated part of irrigation scheme. The recharge schemes can also prove to be the solution to acute flourosis problem of North Gujarat region. The satellite remote sensing based ground water inventory can help the hydrologists to select appropriate sites for locating various types of recharge structures.

4.7 Review of critical literature

CGWB (1984) Report of the Groundwater Estimation Committee has put Mehasana district of North Gujarat under grey zone at few places to dark zone at most of the places. Present study locale falls under grey zone. The report also described the detailed methodology to consider the criteria for the selection of water harvesting sites

Integrated Application of Remote Sensing and GIS for Land and Water Resource Management, pp. 64-69. They explained the generation of thematic classes from image interpretation and then discussed their suitability as water bearing strata depending on their hydro geological characteristics.

Chowdhury, A. (2006) Evaluation of groundwater potential in West Medinipur district using remote sensing and GIS. They digitized several thematic layers and ranked each class within each layer according to their water holding capacity and then gave weights to each theme. Then the layers were integrated using GIS environment to locate suitable harvesting sites. Weighted overlay technique was applied.

Anita K. Prakash et al 2007 decided alternative sustainable landuse pattern of Ranga Reddy district, Yacharam Mandal of Andhra Pradesh and also based on integration various thematic maps using GIS identified the ground water prospective zones thereby attaining the goal of developing sustainable water shed development program.

M. Girish Kumar et al 2008 delineated potential harvesting sites using RS & GIS using the using LISS III data and survey of India (SOI) and other collateral data. Various thematic maps were generated using the principles of thematic class reflectance and potentiality of groundwater depending on its water storing capacity. Each class was given the rank and the class or theme was given the weightage and they were reclassified for the suitability of water bearing potential. All reclassified maps were further integrated using GIS and potential ground water potential maps were prepared.

Saumitra Mukherjee et al 2008 revealed in their paper Spatial as well as spectral resolution has a very important role to play in water resource management. They explored the groundwater and rainwater harvesting sites in the Aravalli Quartzite-Granite-Pegmatite Precambrian terrain of Delhi, India. Use of only panchromatic sensor data of IRS-1D satellite with 5.8-meter spatial resolution has the potential to infer lineaments and faults in this hard rock area. It is essential to identify the location of interconnected lineaments below buried pediment plains in the hard rock area for targeting sub-surface water resources. Linear Image Self Scanning sensor data of the same satellite with 23.5-meter resolution when merged with the panchromatic data
has produced very good results in delineation of interconnected lineaments over buried pediment plains as vegetation anomaly.

4.8 Scope of present work

The delineation of potential ground water recharge sites within the study area be benefited in two ways: quickly identify prospective ground water storage zones for further investigations and also for selecting the appropriate sites for the location of recharge structures as a part of command area development program. This chapter summarizes the use of satellite data in digitized format in addition with other collateral field data for generating individual thematic layers on lithology, geomorphology, geological structures and hydrological parameters along with base map details. The generation of thematic layers involves systematic and experienced visual interpretations of satellite imagery with application of thorough knowledge pertaining to spectral signatures of various objects on remote sensing data. These thematic layers are integrated by layer stacking to generate hydrogeomorphic units (having uniform ground water prospects), using GIS environment. The prospective harvesting zones are delineated by weighted overlay technique. The potential sites have been identified based on consideration of selected parameters only. The remote sensing has capability of checking many more influential parameters for suitability of prospective sites, but the study is restricted to most commonly used parameters.

4.9 Methodology

4.9.1 Concept of Occurrence and movement of Ground Water.

The occurrence of ground water is due component of Hydrological cycle of the given area and becomes a dynamic system. The mode of entry as ground water component is broadly the percolation of water deep down by means of infiltration. The percolating water enters the rock formations having different hydro-geological properties. The storage capacity of the rock formations depends on the porosity of the rock. In subsurface hydrology the concept of, water movement is from areas of recharge to area of discharge under the influence of hydraulic gradients depending on hydraulic conductivity or permeability. The occurrence of ground water at any particular site depends on its storage capacity and the rate of transmission. The hydro geological properties of aquifer developed at the time of formation of the rocks with the initial geometrical shape ranging from tabular, lenticular and other cylindrical
shapes undergo changes due to structural and erosional modifications changes the lateral and vertical continuities of fissures. The hydraulic properties of the rock are also altered due to hydrothermal changes, digenesis and mechanical effects. The permeability is altered due to fracturing of the rocks. Thus the transmitting capabilities are altered both in vertical direction and horizontal directions. Ground water prospects in the hydrologic unit depend on the recharge condition which in turn depends on hydrological conditions of site. The ground water regime can be broadly defined as the combination of factors like lithology; landform; structure; recharge conditions. The possible combinations of factors governing the availability are virtually infinite and the ground water conditions at a given sites are unique.

1. Hydrogeomorphological units

The combined units of unique Lithology, landform, structure and recharge conditions are unique are called 'Hydrogeomorphic units'. They are considered as three dimensional homogeneous entities with respect to hydro-geological properties and the recharge condition. In general they are treated as aquifers. The ground water prospect are expected to be uniform in a hydrogeomorphic unit, inventory of the controlling factors i.e., rock type landform, structure, and recharge condition, by which the hydrogeomorphic unit is made up of, has to be done and their hydro-geological characteristics are required to be evaluated.

2. Use of Satellite Data

The hydrogeomorphic unit is evolved from the original rock formation and undergoes further changes due to continued structural, hydrothermal, hydrological and other physical processes. These changes and processes are manifested on the surface. Satellite imagery contains spatial as well as temporal data base for the study of all these parameters available in an integrated environment as well as per original field conditions. The systematic and experienced interpretation of satellite imagery in collaboration with ground truth information, the extraction and mapping of spatial distribution of the rock formations, landforms, structural network and hydrological conditions can be done accurately. They can be studied and interpreted in conjunctive way with respect to each other. The conventional ground survey methods become cumbersome, costly and involve extensive man hours giving unreliable results and conclusions. The water bodies (tanks) which are seen on the imagery as black patches
not only provide irrigation water holding facility but also can act as water recharge structures. Identification of spatially distributed cropland seen as bright red colored patches in False Colour Composites (FCC) of satellite imagery provides the data base for how much ground water is tapped for irrigation and the developmental status ground water resources within the command. Analysing the multispectral high-resolution imageries like LISS IV sensor can provide clear locations of minor lineaments and faults within the area. The source and track of fissures originating from major lineaments and faults passing through water bodies also provides keys to solve local village water supply problems.

4.9.2 Delineation Methodology

The methodology has focus on systematic procedure evolved to prepare ground water prospective maps using satellite data and GIS techniques in compliance with field work for authentification.

1. Creation of thematic layers on lithology, geomorphology, soil texture, hydrology, geological map, drainage density map, and land use classified map, elevation map, along with base map details based on visual interpretations of satellite data.

2. Derivation of hydrogeomorphic units by integration of thematic data.

3. Ground truthing by verification on existing well observations and bore-log of existing wells.

4. Assign rank (1 to 5) to all the classes within the thematic layers as per their water holding capacity.

5. Integrate all reclassified thematic layers by weighted overlay technique, explained in detail ahead, further using Arc-GIS environment integrate all reclassified, thematic layers (as per their water holding capacity), to develop unique ground water prospective map considering all layers.
Fig 4.3 DETAILED FLOW CHART TO DELINEATE THE POTENTIAL WATER HARVESTING SITES
A Interpretation of satellite data

The digital satellite data in digital format as False Colour Composites (FCC) is displayed on to the screen using ENVIS 4.1 remote sensing software. Even GIS software has the capability of creating basic thematic layers, as extracted from survey of India toposheets and all linear features like drainage density, road, rail and urban settlements. The image interpretation techniques are used for feature extractions like rock type, soil characteristics (textural and depth wise), geological, hydrological and elevation layers. The outputs will be in vector format comprising of point, line and polygon features which are supported in GIS environment as well as any remote sensing software based working platform. Ground truthing component must be added to authenticate the work as supported by existing structures.

B Thematic Mapping

The occurrence of ground water and its movement within the aquifers is greatly influenced by lithology, soil structure, geo-morphology, hydrological factors. Each parameter exercises control over the quality and quantity of ground water. Each and every parameter on all individual thematic layers is individually considered with authentification of ground truth check wherever possible. For the present study, it is proposed to complete the generation of data on every parameter based on in all six themes as a separate layer. 1) The Base map for permanent features extracted from Survey of India toposheets (SOI), 2) lithology, 3) soil-structure, 4) geomorphology, 5) hydrology and 6) elevation parameter from Shuttle Radar Topography Mission (SRTM) data.

1) **Base Map Layer**: The base map has four categories of information in which boundary of study area as per latitude longitude and talukas boundaries is there, settlement agglomerations, road net work, railway lines. The settlements are mapped as point coverage, the road network and railway lines as line coverage.

2) **Lithology layer**: All rock formations in the study area are to be mapped in single layer, litho units are annotated and describe as polygon features, but the study area is not a rocky terrain so rock formations are not significant for present study. The most significant part in developing lithology layer is to take reference of existing geological or hydro-geological maps and literature.
Understanding for the general geology of the area and different parent rock type can be better referred. For present work there was no contrasting rock types are encountered in study area and geological map of the scale 1:50,000 scales are available, and same is considered as reference. The available geological maps were modified and updated after incorporating the additional details as viewed in satellite imagery.

3) **Soil-Type layer:** The soils in the study area and its depth also become one of the key factors affecting the recharge and transmittance capacities of the landform. The layer of soil classification is classified according to its textural as well as the type.

4) **Geomorphology Layer:** All land forms/geomorphic units occurring in the study area are inculcated within single layer. They are represented as polygon features in the layers. Each geomorphic groups which are classified as per their type, are given the ranks as per their water holding capacity based on available literature on ground water regime. The reclassified maps are prepared based on their compatibility to hold water. Sometimes single geomorphic units/landforms may exist in one lithologic unit and other way. The geomorphic units which further classified as shallow, moderate and deep categories based on their depth of weathering, thickness of deposited material, etc have to be verified by observing existing river cutting, well bore logs, pits etc.

5) **Hydrology Layer:** There are 5 items which are considered for mapping in hydrology theme. They are a) drainage b) water bodies c) Canals d) Irrigated area e) Wells. The drainage is represented as line as well as polygon features. The water spread area is shown in polygon and river canals as line feature. Wells are represented as point feature. In drainage layer all rivers and streams upto first layer is to be mapped. For present work the drainage delineation has been done with the help of toposheets as well as latest Landsat TM satellite imagery. Mapping water bodies also must be done by putting boundaries of water bodies from SOI toposheets but reference from satellite image must be taken. Canal network upto third order must be mapped taking reference of survey of India toposheet and new canals may be digitized using satellite
imagery. Initially, the extraction of irrigated agriculture area may be done using satellite imagery and visual interpretations. The field visit may be done with help of irrigation officials and local farmers to get information on surface irrigated and ground water irrigated areas. Details of cropping pattern for the area may also be referred and final layer of cropland may be prepared. Before working finally on hydrology layer the information on existing wells, it’s pre-monsoon and post monsoon water table fluctuations, bore log, yield etc must be collected.

**C. Delineation of Hydro-geomorphic units**

All the thematic layers generated are integrated using GIS software by superimposing them. Each class within any thematic map is assigned the rank 1 to 5 depending on its water holding capacity and are reclassified for suitability of recharge. The reclassified thematic maps are overlaid by weighted overlay technique.

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**i) Lithology-Landform controlled units**

The integrated lithology-landform units are treated as identical area with respect to hydro geological characteristics. By identifying the sub-surface geological strata the aquifer material is classified into following six categories:

1. Loose Sediments: consisting mainly of unconsolidated sediments represented by Coastal, Deltaic, Aeolin, Alluvial and flood plains.

2. Permeable rock: The semi consolidated sediments and vesicular volcanic rocks having primary porosity and permeability.

3. Weathered rocks: Depth of weathering controls the movement of ground water.

4. Fractured rock: The fractured zones in the hard rocks which are generally act as conduits for movement of ground water.

5. Fissured rocks: The hard rocks like gneisses, schist’s slates, quartzites, limestones etc having jointing, bedding, cleavage and other weak planes which impart limited porosity and permeability.
6. Impervious rock: Granite, Dolerite dykes etc act as barrier for ground water movement.

ii) Structure Control Units

The weak zones such as faults, thrusts, shear zones, fractures etc., and the linear intrusive such as dykes, quartz veins, etc form. Such formations form conduits and barriers for ground water movement.

4.10 Image Interpretation

4.10.1 Image Interpretation Techniques

The task of satellite data interpretation to delineate prospective recharge site, needs the use of systematic visual interpretation techniques. The basis of correct visual interpretation lies on understanding physical spectral reflectances and emittences of any physical object on earth surface. The image classification must take into account the climatic influence on weathering, vegetation cover and mass movements. Digital data processing, enhancements and analysis adds input to spatial database for the work. The overall task of image interpretation involves four basic keys:

1. Identification of image elements based on spectral and temporal signatures.

2. Identification of Geotechnical elements based on guidelines and experience.

3. Correlation of convergence of evidences, their interrelationships and their association with occurrence of ground water.

4. Ground truthing with existing maps or actual field visits or testing bore logs.

A. Identifying image elements from their physical characteristics.

i) Image colour tone: Normally the satellite data product, satellite imageries are in tones of grey and black. Normally rough surfaces, wet surfaces, dense vegetation, high ground water, unbleached basic igneous rocks etc, reflect more especially in Near infra red and red giving lighter shades in grey, ranging from
light grey, medium grey to very light grey. Exceptionally light tones are recorded on satellite imagery as reflectances due to smooth surface, coral sands, snow, ice, fresh vegetation. The lithological changes, permeability changes due to variation is soil porosities are observed by observing irregular patches of colour tones within a satellite imagery. Sometimes the conclusions based on photographic tones in satellite data are deceiving so necessary precautions may be taken. The best example which reveals the use of tone in visual interpretations is that dense vegetation reflects almost all Near infrared radiation (NIR) due to which those patches appear in lighter tones. Moist areas and water bodies absorb NIR and appear dark toned, almost looks black if depth of water body is more.

ii) Image Texture: Texture may be explained as frequency with which the colour tone change is observed in satellite imagery. The texture change is produced due to all aggregate of unit features too small to be clearly discerned individually on the photographs or the aggregate arrangements of minute images as expressed by tone, shape, size and pattern. Texture is function of photoscale. The textural difference due to tonal change is reflected photographic texture. Various terminologies used in describing the texture are Course-Rough, Smooth-Fine, Even-Uneven Banded, Mottled, Speckled, Granular, Linear, Blocky, Matted, and Woolly. The texture may be referred to as some different interpretation for specific fields of data. Wide spacing of drainage pattern may be seen as course texture in a satellite image.

iii) Pattern of image element: The occurrence of orderly and typical spatial arrangements of geological, topographic and vegetation features on the image becomes an important key of identification. A pattern may reflect its genetic origin; it can be naturally formed or manmade. If the features formed becomes too small to be identified as on small scale photographs, they may then be identified from photographic texture. In short pattern may be described as orderly arrangements of stream segments, trees, depressions or other features. Commonly occurring characteristic patterns are as follows.

a) Drainage pattern: It becomes an important element in geological interpretations. Natural drainage pattern depends on following factors:
1. Lithological character of underlying rocks and surface layer deposits. Homogeneous rock type develops a particular type of drainage pattern.

2. Attitude and nature of rock bodies exhibits: Shales exhibits parallel ridge like pattern which makes the streams to rundown dip slopes. They run the steep slopes.

3. Angular and Rectangular drainage pattern is exhibited by virtue of joint controlled arrangement and spacing of weak planes.

4. Surface or subsurface structure: Eroded planes develop over differentially eroded domes.

   b) Vegetation pattern: It reflects the structural condition or Lithological characters of the rock mass type. Following types of patterns are observed.

      1. Blocky pattern reflects uniform outcrops and dip slopes.

      2. Alignments which are narrow in zones, e.g. faults or similar linear features.

   c) Soil pattern: The surface characteristics such as land form, drainage characteristics, vegetation, and landuse pattern giving clues to soil difference pattern. Soil pattern may reveal information of direct use studying engineering geology such as distribution of rock types and geological structure.

   iv) Shape of image element: It means the general form of various types of features. It means general form and geometrical configuration of various terrain elements. Man made elements such as dams, bridges, roads, canals, reservoirs, buildings etc may be identified according to their geometrical shapes. Natural elements may be identified from their typical shape and terrain. The natural forms may be identified as sand dunes, alluvial fans, deltas, cinder cones having specific shapes, landforms, as patterns. The shape may be explained as relief or topographic expression which helps their visual classification. Even the cliff rocks and overlying
rock may be differential clearly due to shape of the element. The surface materials may be distinguished by shape of gully and streams. Folds may involve strata of varying relative resistance to erosion which is reflected in zigzag pattern. Sills may produce trenches along the sides of escarpments or valley walls. Smaller shapes may also convey valuable information. Faults may also be identified according to rectilinear formations.

**v) Size of an image element:** Size of an image element is described as surface or volume dimension of an object. The size of an object can be well identified by relating it to size of known object on the images or by its shadow. Quantitative geomorphology and terrain object identification for geological rock thickness study may be done using size feature. The size of water body may become useful in water related calculations. The types of buildings within the urban area can also be differentiated by size, shape and shadow of element within the image.

**vi) Shadow of an image element:** Shadow may be recognized a feature which is used along with shape and photographic tone. It can identify even tree type e.g. conifers normally have pointed canopy profile due to which it casts slender shadow as compared to broader leaf. The type of tree can give clue to underlying geologic material. The shadow may also prove to be mask for visually identifying shadowed portion at certain instances.

**B. Geotechnical elements**

The visual examination of satellite images for image elements, they are to be analyzed from geotechnical or terrain features point of view. The different features studied in detail are as under:

**i) Landforms:** The analysis of land form and physiographic permits identification of rock type, soils etc. The formation and development of a particular landform is attributed to endogenic process originating in earth surface, androgenic such as constructional or destruction exogenic process. The most familiar endogenic mechanisms are like volcanism, metamorphism, earthquakes, folding, faulting and fracturing. The example of exogenic landform is presence Karsk landforms/features, such as sinkholes indicate calcareous rocks likely soluble
activities. Fluvial deposits are indicated by river terraces, point bars, back swamps, alluvial fans, and paleo channels. Sedimentary rocks having variable erodibility are reflected by structural hills, ridge valley, landscape and hogback.

### ii) Vegetation Cover

Vegetation is key element to provide help in detection of geologic element. The density and canopy of vegetation is indicative of soil conditions pertaining to fertility, moisture status and at times underlying rocks. Vegetation proves to be a geobotanical factor which helps the mineral exploration. The vegetation also indicates the depth of water table base on subsoil root zone depth studies. The orientation or the slope can also be detected on the basis of type of vegetation. Following are indicative vegetation: Willows are grown where moisture is high. Pine grows more where quartzite rock is present for example Himalayan and Shiwalik ranges. Oak grows more in lime stones. Presence of mango, tamarind and peepal indicates shallow water table.

### iii) Drainage pattern and density

Drainage becomes important clue for visual interpretation of various elements. A drainage pattern generally reflects the characteristics of rock types, soil type, structure or complex natural process. The change in rock or soil type generally is reflected by abrupt change in the drainage pattern. Stream activity and resulting landform becomes vital clue for exercise of visual interpretation of satellite imagery for identifying prospective water harvesting sites. Important drainage pattern from geological point of views are given as below.

1. Dendritic rock is indicated with irregular branching of streams like tree in many directions commonly develops in homogeneous massive rocks.

2. Parallel to sub parallel channels form on slopes of homogenous rocks.

3. Rectangular channels showing right angle bends turns develops generally jointed fractured homogeneous rocks.

4. Trellis indicates presence of folded, faulted or dipping sedimentary rocks of different erosive properties. Trellis means principal
streams are parallel and secondary streams connect them at right angles.

e) Radial channels radiating from central focus indicate volcanic cones or domes.

f) Centripetal streams converging towards centre indicates developed basins.

g) Annular channels follows circular or concentric path; develops dissected domes or basins. Due to high degree of porosity no systematic drainage develops in sand surface, karstic limestone.

h) Stream pattern: The stream pattern, meandering, angular, bended at right angles etc show indication of subsoil geology.

i) Erosive pattern: Under this, the study of cross section of gullies is very important. Granular sandy soil with short and steep gullies with V-cross section.

j) Silt and loess-Rectangular gully cross section with compound gradient- first steep and later flat.

k) Clays and muds – Gullies are long and flat, with flat, curved cross section.

iv) Land Use: It gives information about soil condition. Rugged topography and associated sandy soils developed on sandstone are left as forests. Comparatively level or valley topography and associated clayey soils developed on shale and limestone Flood plain areas silty sand of natural levee are cultivated. Soils are well drained. Orchards develop in well drained areas. Shallow drainage ditches in areas of little relief commonly signify plastic, poorly drained soil. Presences of semicircular to circular pattern of land use with depression in the centre indicate the area of poor internal drainage with plastic nature of clay.

C. Convergence of Evidences/Relationships/Association

The meaning of relationship and association of feature refers to as how on field one object is related to other as seen in the image. This becomes a very
evident and logical tool of visual interpretation. The relation of an object in image must be studied with site location, setting or association. Following points explain the significance of Relationship/Association:

1. Flood plain setting, accurate landforms can be paleo channels, oxbows, point bars.

2. Light toned slightly raised areas are the levees. Whereas associated darker toned smooth textured, landuse depressions are generally filled with back swamps.

3. Piedmont areas, one expects to identify alluvial fans and river terraces.

4. Combination of recognition elements enhances the usefulness and correctness of the mutually supportive elements.

5. An association of tone, topographic expression, site location and texture may permit interpretation of bedding even in areas of subdue topography.

6. Geographical location: The visual interpretation of any satellite image becomes more easy if prior knowledge about the geographical location, climatic condition and other relevant features are known. For e.g. the reflectance of snow glaciers and beach white sand is almost similar but where to expect snow and where to interpret snow can be resolved by prior knowledge in above subject.

4.10.2 Feature extractions

A. Base Map Details

Preparation of base map becomes the first step after the procurement of satellite data. They are prepared by making use of satellite imageries, SOI toposheets, and collateral field data. All the permanent features are digitized like State, Taluka boundaries railway, highways, internal roads, drainages of third order ( in combination with SOI and toposheets). Habitations are also marked which appear in dark bluish green in imagery.
B. Rock formations

Lithological mapping is done with help of image characteristic, prior knowledge of general geological setting of the area, field visits and at times test bore logs if required. The procedure takes in to account tone, colour, landform characteristics combined with relative erodibility, drainage, soil type, land use/land cover classification, many other collateral inputs for correct visual interpretations. e.g the course drainage pattern indicates highly porous and permeable rock formations. Convergence of evidences must be considered by studying all the recognition elements conjunctively. The periodical field checks may provide authenticity to the identification task. There are clues discussed in various literatures pertaining to visual interpretation and object identification, which states that identification, correlation and extrapolation of rock types are based on spectral and morphological characters. Sedimentary areas may yeild more information on lithology and structure compared to igneous and metamorphic rocks. Preferential vegetation also clearly indicates sedimentary rocks. Differential erosion between hard and soft rocks is a clear indication of sedimentary rocks. Sandstone shows medium to light photo tones, course texture, Dendritic, sub parallel, angular joint controlled and trellis drainage. They normally form ridge, scarp, plateau etc landforms. Shales show dart to medium grey tones, smooth texture and fine textured (high density) gulllying drainages. They support good cultivation. Shales occupy valley forming, flat lying areas over lower slopes of scarpes. Lime stones show medium tones and textures, swallow hole or internal drainages. Sink holes, caverns, solutionally enlarged joints etc in humid region. Granite will exhibit medium to light tone, course topographic textures, joint controlled, medium textured angular to dendritic drainages. The metamorphic rocks are exhibiting parent rock photo characters.

C. Geological Structures

The utility of satellite imagery for mapping the geological structures has been emphasized by various workers. The conventional ground mapping methods are incompatible compared to satellite remote sensing due to lack of exposed rock surfaces, soil cover, lack of continuous observations, etc. Folds, Faults and joints can be easily located by their characteristic expressions in satellite imagery.
D. Land forms/Geomorphic units

In the present context, initially, the entire terrain is to be classified into three major zones, Hills and plateaus, Piedmont zones, plains considering physiography and relief as criteria. Then each zone is mapped for specific geomorphic units on the basis of landform characteristics. The geomorphic units classified from satellite imageries needs a ground truth check for criteria like depth of weathering, nature of weathered material, thickness of deposition etc.

C. Hydrological data

Satellite imagery provides excellent information on hydrologic aspects like stream/river, courses, canals major reservoirs, lakes, tanks, springs/seepages, canal commands, ground water irrigated areas, etc. Based on visual interpretation, supported by existing toposheets all the information can be mapped.

4.11 Classification System

Different types of rock formations, land forms, geological structures and recharge conditions exist within the area. They are classified into different types mainly based on the composition, form, origin, or association, etc. Each type is identified and labeled by that particular property based on which it is classified. Porosity and permeability becomes the basic property which is of prime concern for ground water studies.

4.12 Weighted Overlay Technique

To access the ground water prospects of the study area, all different polygons in the thematic maps were labeled separately. Knowledge based weightages are assigned to each thematic features after considering their importance with respect to ground water. All the thematic maps are integrated in GIS environment and polygon have been regrouped into different classes.

4.13 Weight Assignment

Thematic layers viz, Landuse layer, geology, geomorphology, soil type, drainage density, slope (elevation layer), road, railway, village location map layers have been considered for suitability of place as potential water harvesting site. Based available knowledge from experts and authentic published literature on role of each of these parameters in controlling the occurrence, storage and
distribution of ground water, weightage 10, 30, 15, 25, 20, uniform weightage is assigned to landuse layer, geology, soil type, hydro geomorphology, drainage density layer respectively. The uniform weightage is assumed throughout the site for slope layer as the slope is almost uniform. Road, rail and public utility places are considered straight way as non suitable site for water harvesting purpose. Also all the layers are further classified into different classes based on their rank. The classes have ranks ranging from 1 to 5, such that 5 has highest potential suitability for recharge and 1 has minimum suitability for storing and transmitting the ground water. Finally, the scores have been calculated as the product of the weightage and rank e.g. under the geology layer having weight 30, channel fill (Varahi formation) have the rank 5 giving it’s final score as 30 * 5 = 150. The table below shows the scores of different classes within different thematic layers. The reclassified thematic layers were generated after scoring each class within individual layers and then all reclassified maps were integrated using G.I.S software Arch Map 9.1. The weighted aggregation overlay method was adopted for the integration work and final map showing the suitability of each pixel for its suitability as recharge site was developed based on considered criteria. The table 4.2 below shows the weight assigned to each thematic class and ranks of classes within a thematic map.
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Thematic Map/Classes</th>
<th>Weight of Theme/Rank Assigned to classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LAND USE MAP</td>
<td>10</td>
</tr>
<tr>
<td>A)</td>
<td>Built Up Kiln</td>
<td>2</td>
</tr>
<tr>
<td>B)</td>
<td>Built Up</td>
<td>1</td>
</tr>
<tr>
<td>C)</td>
<td>Cultivated Land</td>
<td>4</td>
</tr>
<tr>
<td>D)</td>
<td>Current Fallow</td>
<td>3</td>
</tr>
<tr>
<td>E)</td>
<td>Open Land</td>
<td>3</td>
</tr>
<tr>
<td>F)</td>
<td>River Land</td>
<td>5</td>
</tr>
<tr>
<td>G)</td>
<td>Scrub Land</td>
<td>3</td>
</tr>
<tr>
<td>H)</td>
<td>Vegetation</td>
<td>5</td>
</tr>
<tr>
<td>I)</td>
<td>Wasteland</td>
<td>2</td>
</tr>
<tr>
<td>J)</td>
<td>Water Body</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>GEOLOGY</td>
<td>30</td>
</tr>
<tr>
<td>A)</td>
<td>Channel Fill deposits (Varahi formation)</td>
<td>5</td>
</tr>
<tr>
<td>B)</td>
<td>Flood Plain Deposit (Kapfur formation)</td>
<td>4</td>
</tr>
<tr>
<td>C)</td>
<td>Flood Plain Deposit (Varahi formation)</td>
<td>4</td>
</tr>
<tr>
<td>D)</td>
<td>Granite, Quartz Vein</td>
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</tr>
<tr>
<td>E)</td>
<td>Levee Deposit (Kapfur formation)</td>
<td>3</td>
</tr>
<tr>
<td>F)</td>
<td>Sand Dune (Akhaj formation)</td>
<td>3</td>
</tr>
<tr>
<td>G)</td>
<td>Sand Dune (Jatral formation)</td>
<td>5</td>
</tr>
<tr>
<td>H)</td>
<td>Sand Sheet (Akhaj formation)</td>
<td>3</td>
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<tr>
<td>I)</td>
<td>Sand Sheet (Jatral formation)</td>
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<td>J)</td>
<td>Variegated Clay, Siltstone Marl</td>
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<tr>
<td>3</td>
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<td>Coarse Loamy, Calcareous Typic Ustochrept</td>
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</tr>
<tr>
<td>B)</td>
<td>Coarse Loamy, Typic Ustochrept</td>
<td>3</td>
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<tr>
<td>C)</td>
<td>Coarse loamy, Calcareous, Typic Ustiluents</td>
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</tr>
<tr>
<td>D)</td>
<td>Fine Loamy, Typic Ustochrept</td>
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<tr>
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<td>Mixed, calcareous, Typic Ustipsamments</td>
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<tr>
<td>H)</td>
<td>Ro</td>
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<tr>
<td>C)</td>
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<tr>
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<td>Eroded Land</td>
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<td>DRAINAGE</td>
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<td>Continuous Dense Network</td>
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</tr>
<tr>
<td>B)</td>
<td>Discontinuous and Paleo Channels</td>
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</tr>
<tr>
<td>6</td>
<td>SLOPE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Uniform so no weight is assigned</td>
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</tr>
</tbody>
</table>
4.14 Results and Conclusions

Landuse land cover mapping of the study area clearly concludes as under:

**Agriculture land:** The study area is predominantly agricultural area and covers around 80% of the land cover classes of the area. Out of 80% cultivable land the 90% of the area is under Rabi cultivation and only 60% of area is cultivated during Kharif which clearly shows that 10% of cultivable land, during Rabi and 40% land during Kharif remains as cultivable fallows.

The above situation is attributed to poor irrigation water availability during Rabi season and almost nil during Kharif season. Almost all the Kharif cultivation depends on ground water resource for their irrigation requirement. Also 10% of total 80% shows perennial cultivation, which is classified as Alphalpaha and vegetables. For the water scarce region like North Gujarat the cultivation of Alphalpaha which requires very high amount of water proves to be wrong.

In Rabi cultivation the predominantly major crop is found to be wheat and Raydo, the above results were derived for two consecutive Rabi season from multi temporal satellite data source i.e. for Rabi 2007-08 and Rabi 2008-09, which was further ground truthed with crop calendars having records of crop yield in section office of block 6 of irrigation command of branch canal no.3 of SRBMC.

**Water bodies:** The water bodies comprising of rivers, streams, canal networks right from branch canals to field distributaries, ponds, reservoirs and other water storing bodies occupied of about 6% of total study area. The canals are normally found to be lined on at branch canal level the distributaries’ and minors are appearing in dark black colour which shows they are unlined canals. There are two major non perennial rivers bounding the study area Puspavati and Rupen river. There are no continuous drainage connections within the command. Many paleo channels are reflected in satellite imagery visual interpretation which shows that they have been buried due to scarcity of flowing water.

**Waste Lands:** Under this category two classes are considered, 1) Salt affected and 2) Water logged area. There is no salt affected area seen in the
command and no water logging is also reflected. The result also shows that the area is not having any wet lands on sandy deposits. Most of the areas falling under the category of uncultivated land is seen to cultivable fallows. Strategic and conjunctive (surface and ground) irrigation water management can convert all area into cultivated lands.

The command area, thus does not suffer from water logging and salinity but the water samples of the existing tube well (ground truth details) showed the traces of unsafe ranges of fluorine content (>1.5 mg/l).

The landuse proves to be highly potential site for water harvesting area as per the Land use classification category, being the agriculturally predominant area.

**Road & Rail network:** The study area is well connected with the road network right from national highways to well constructed village road networks. The Unjha railway junction is connecting the area with all major places in India.

The integrated studies have been carried out on at the study area, using remote sensing data, collateral primary and secondary data like well log data, ground truth field data, they have been processed as per their remotely sensed spectral signatures to prepare thematic layers. All thematic layers are integrated using the ARC-GIS software. The suitability of the command area for developing recharge structures have been tested.

This exercise is part of command area development practice which can be implemented to increase the performance of the command. The development of recharge schemes and inter basin connections can be practiced to solve the scarcity of irrigation water.

It has been concluded from the exercise that the study area falls in the category of excellent to good recharge potential area. The area is having the mild slope of about 3% which is towards natural drainage areas which retains runoff and recharge can be induced.

The geology of the area is also recharge inductive as it falls under the category of silty loam and alluvial deposits as per the map no.
The drainage pattern is discontinuous but well connected giving better prospects of water transfer. This is also excellent factor for practicing water recharge schemes.

The geological layer shows mainly sand sheet, sand dune of Jantral formation which gives excellent and good recharge capability, other predominant geological feature is flood plain which gives moderate recharge ability.

Hydro-Geomorphologic units of the study area, having identical water bearing and transmitting capabilities, shows the presence of alluvial plains which has excellent water bearing and transmitting capacity giving the area high potential for developing recharge areas.

The rivers within the command are of non-perennial nature which does not give them potential to work as source for recharge activity. The sources of water recharge must be developed as induced, injection wells.

The area shows very good to excellent potential for recharge as per different parameters for water storage and transmittance. The source of water for recharge becomes the thrust area of concern so Intra basin transfer practice is strongly recommended as a command area development program for recharge activities.
FIG NO 4.4 LANDUSE/LAND COVER MAP FOR TOPOSHEET GRID NO 46A05
(DATA USED IRS P6 LISS III)
FIG NO 4.5 LANDUSE/LAND COVER MAP FOR TOPOSHEET GRID NO 46A06
(DATA USED IRS P6 LISS III)
FIG NO 4.6  LANDUSE/LAND COVER MAP FOR TOPOSHEET GRID NO 46A08

(DATA USED IRS P6 LISS III)
FIG NO 4.7 LANDUSE/LAND COVER MAP FOR TOPOSHEET GRID NO 46A09

(DATA USED IRS P6 LISS III)
FIG NO 4.8  LANDUSE/LAND COVER MAP FOR TOPO SHEET GRID NO 46A10

(DATA USED IRS P6 LISS III)
FIG NO 4.9  LANDUSE/LAND COVER MAP FOR TOPOSHEET GRID NO 46A05, 46A06, 46A08, 46A09, 46A09 OVERLAPPED BY TALUKA BOUNDARIES OF STUDY AREA (DATA USED IRS P6 LISS III & AWIFS SENSOR)

FIG NO 4.10  LANDUSE/LAND COVER MAP FOR TOPOSHEET GRID NO 46A05, 46A06, 46A08, 46A09, 46A09 OVERLAPPED BY TALUKA BOUNDARIES OF STUDY AREA (DATA USED IRS P6 LISS III & AWIFS SENSOR- LAYER SHOWING RABI, KHRIF AND ZAID CROP)
FIG NO 4.11  LANDUSE/LAND COVER MAP FOR TOPOSSHEET GRID NO 46A05, 46A06, 46A08, 46A09, 46A09 OVERLAPPED BY TALUKA BOUNDRIES OF STUDY AREA

(DATA USED IRS P6 LISS III & AWIFS SENSOR - LAYER SHOWING URBAN SETTLEMENT, WATER LOGGING, SALT INTRUSION STATUS, SANDY PLAINS & TALUKA BOUNDRY)
FIG NO 4.12 IMAGE MAP FOR TOPOSHEET GRID NO 46A06, 46A08, 46A09, 46A09 OVERLAPPED BY TALUKA BOUNDRIES OF STUDY AREA (DATA USED LANDSAT – 7, THEMATIC MAPPER)
FIG NO 4.13 DRAINAGE MAP FOR TOPOSHEET GRID NO 46A06, 46A08, 46A09, 46A09 OVERLAPPED BY TALUKA BOUNDRIES OF STUDY AREA (DATA USED LANDSAT – 7, THEMATIC MAPPER)
FIG NO 4.14 SOIL CLASSIFICATION MAP FOR TOPOSHEET GRID NO 46A06, 46A08, 46A09, 46A09 OVERLAPPED BY TALUKA BOUNDRIES OF STUDY AREA (DATA USED LANDSAT – 7, THEMATIC MAPPER)
FIG NO 4.15 GEOLOGICAL CLASSIFICATION MAP FOR TOPOSHEET GRID NO 46A06, 46A08, 46A09, 46A09 OVERLAPPED BY TALUKA BOUNDARIES OF STUDY AREA (DATA USED LANDSAT – 7, THEMATIC MAPPER)
FIG NO 4.16 GEOMORPHOLOGICAL CLASSIFICATION MAP FOR TOPOSHEET GRID NO
46A06, 46A08, 46A09, 46A09 OVERLAPPED BY TALUKA BOUNDRIES OF STUDY AREA
(DATA USED LANDSAT – 7, THEMATIC MAPPER)
FIG NO 4.17 ELEVATION MAP FOR TOPOSHEET GRID NO 46A06, 46A08, 46A09, 46A09 OVERLAPPED BY TALUKA BOUNDRIES OF STUDY AREA (DATA USED LANDSAT – 7, THEMATIC MAPPER & SHUTTLE RADAR TOPOGRAPHY MISSION)
FIG NO 4.18 RECLASSIFIED DRAINAGE MAP FOR RECHARGE SUITABILITY FOR
TOPOSHEET GRID NO 46A06, 46A08, 46A09, 46A09
(DATA USED LANDSAT – 7, THEMATIC MAPPER)
FIG NO 4.19 RECLASSIFIED GEOLOGICAL MAP FOR RECHARGE SUITABILITY FOR TOPOSHEET GRID NO 46A06, 46A08, 46A09, 46A09 (DATA USED LANDSAT – 7, THEMATIC MAPPER)
FIG NO 4.20 RECLASSIFIED GEOMORPHOLOGICAL MAP FOR RECHARGE
SUITABILITY FOR TOPOSHEET GRID NO 46A06, 46A08, 46A09, 46A09
(DATA USED LANDSAT – 7, THEMATIC MAPPER)
FIG NO 4.21 RECLASSIFIED SOIL MAP FOR RECHARGE SUITABILITY FOR TOPOSHEET GRID NO 46A06, 46A08, 46A09, 46A09
(DATA USED LANDSAT – 7, THEMATIC MAPPER)
FIG NO 4.22   LANDUSE/LAND COVER MAP FOR TOPOSHEET GRID NO 46A05, 46A06, 46A08, 46A09, 46A09 OVERLAPPED BY TALUKA BOUNDARIES OF STUDY AREA (DATA USED LANDSAT – 7, THEMATIC MAPPER & SHUTTLE RADAR TOPOGRAPHY MISSION)
FIG NO 4.23 RECLASSIFIED LANDUSE/LAND COVER MAP FOR RECHARGE
SUITABILITY FOR TOPOSHEET GRID NO 46A06, 46A08, 46A09, 46A09
(DATA USED LANDSAT – 7, THEMATIC MAPER & SHUTTLE RADAR TOPOGRAPHY
MISSION)
FIG NO 4.24 WEIGHTED OVERLAY MAP FOR RECHARGE SUITABILITY OF STUDY AREA CONSIDERING ALL LAYERS FOR TOPOHEET GRID NO 46A06, 46A08, 46A09, 46A09

(DATA USED LANDSAT – 7, THEMATIC MAPPER & SHUTTLE RADAR TOPOGRAPHY MISSION)